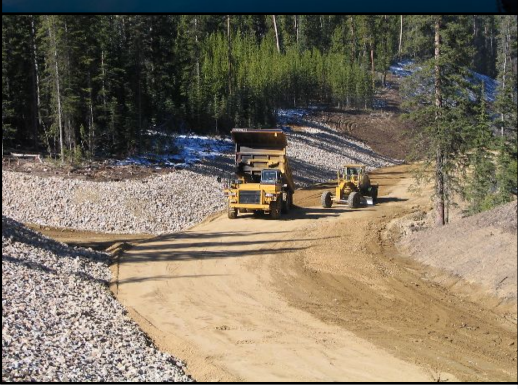
Idaho Catalog of Storm Water Best Management Practices



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Abbreviations, Acronyms, and Symbols

AMC	antecedent moisture condition
API	American Petroleum Institute
ASTM	American Society for Testing and Materials
BMP	best management practice
CEC	Cation exchange capacity
CESQG	conditionally exempt small quantity generator
CFR	Code of Federal Regulations
CGP	construction general permit
CN	curve number
CP	coalescing plate (separator)
CWA	Clean Water Act
DCIA	directly connected impervious areas
DEQ	Idaho Department of Environmental Quality
EPA	United States Environmental Protection Agency
FERC	Federal Energy Regulatory Commission
FIRM	flood insurance rate maps
GIS	geographic information system
HEC-HMS	Hydrologic Engineering Center Hydrologic Modeling System
IDAPA	Numbering designation for administrative rules in Idaho promulgated in accordance with the Idaho Administrative Procedures Act.
IDF	intensity duration frequency
IDWR	Idaho Department of Water Resources
ITD	Idaho Transportation Department
LID	low-impact development
MS4	Municipal Separate Storm Sewer System
MSDS	material safety data sheet
MSE	mechanically stabilized earth
MSGP	Multi-Sector General Permit
NED	National Elevation Dataset
NOI	notice of intent
NPDES	National Pollutant Discharge Elimination System

NRCS	Natural Resources Conservation Service
O&M	operation and maintenance
OSHA	Occupational Safety and Health Administration
PVC	polyvinyl chloride
RV	recreational vehicle
SPCC	spill prevention control and countermeasures
SSURGO	Soil Survey Geographic Database
SWMM	Storm Water Management Model
SWPPP	Storm Water Pollution Prevention Plan
TMDL	total maximum daily load
TSS	total suspended sediment
USDA	United States Department of Agriculture
USFS	United States Forest Service
USGS	United States Geological Survey

1 Introduction

The *Idaho Catalog of Storm Water Best Management Practices* provides technical guidance for construction site design and selecting storm water best management practices (BMPs) as well as information on permitting requirements for storm water discharges in Idaho. A BMP is a physical, chemical, structural, or managerial practice that prevents, reduces, or treats storm water contamination or prevents or reduces soil erosion. This catalog contains voluntary controls that could be formally adopted by a jurisdiction to establish standards. The measures described and other recognized equivalents should be used to manage the quantity and quality of storm water runoff from land development.

Technical guidance regarding storm water management is necessary for several reasons:

- Idaho's fast growing population has led to expanded land development, which is a recognized source of nonpoint source pollution called *polluted runoff*. This catalog includes structural and nonstructural BMPs to prevent discharge of pollutants from developing areas, both during the construction phase and for the life of the development. BMPs can also be used to reduce polluted runoff from existing land uses.
- Many water bodies throughout the state are not in compliance with state water quality standards. Beneficial uses such as domestic water supply, fishing, swimming, boating, and agricultural water supply may be impaired due to excessive pollutants such as those that come from storm water runoff. The catalog identifies various controls to reduce *conventional* pollutants with special consideration for phosphorus and sediment, both common pollutants in Idaho.
- The National Pollutant Discharge Elimination System (NPDES) storm water regulations mandate that some communities develop and implement storm water management programs to ensure that pollutants in storm water runoff are controlled to the maximum extent practicable. Because polluted runoff can potentially contribute to the degradation of receiving waters, improved implementation of storm water management programs at the local level is important for attaining and maintaining high water quality standards.

1.1 Goals and Objectives

The goal of the catalog is to provide general information on the design of a storm water management plan, selection of storm water BMPs, and technical information on the design, installation, and maintenance of BMPs. This information is primarily intended for design professionals (e.g., landscape architects, geologists, engineers, and soil scientists), landowners, developers, and construction contractors.

The catalog can also be used by local public officials or staff members who are responsible for reviewing and approving development applications and it could be formally adopted by a jurisdiction to establish BMP and storm water standards. However, it is not all-inclusive and should be used with other reference sources published by other agencies as appropriate based on local conditions and policies. Specific conditions, alternative practices, or local regulations may also require modifications to the recommended BMPs.

1.2 Catalog Updates

This 2020 BMP catalog provides updated information on storm water regulations and provides additional technical information on selected BMPs. The catalog focuses on how to design a storm water management plan and organizes BMPs under the broad categories of construction BMPs (temporary in nature and used during project construction) and permanent BMPs (those that remain on the landscape after development completion). The catalog is created for design professionals preparing storm water management plans for their clients and for others who are tasked with developing their own plan.

The practice of storm water management evolves quickly. Design information for various BMPs is expected to change as more people apply the practices and learn from their experience. To accommodate these changes, the catalog will be periodically updated and posted on the *Idaho Department of Environmental Quality (DEQ) website*.

2 Storm Water Management Objectives

Traditionally, the objective of storm water management has been to transport runoff efficiently through the drainage system to prevent flooding and protect lives and property. Referred to as flood or quantity control, the most important goals are public health and safety, but other objectives should be met as well:

- Manage runoff quantities and flow to mimic predevelopment conditions and minimize damage to property and natural resources.
- Manage development sites to minimize the amount of sediment and other contaminants in runoff.
- Manage development to preserve the stability and integrity of drainage ways and stream corridors.

Balancing flood prevention with habitat protection objectives can be achieved by pursuing regional solutions, such as effective land use planning to minimize impervious areas and preserve native vegetation especially within riparian areas along streams and lakes. Local ordinances and codes can reduce impervious areas and increase vegetation by limiting the extent to which a site can be developed. Quantity and quality goals can also be met at the local level through proper site planning and design that carefully considers the impact of development and applies appropriate BMPs.

The following sections discuss how development affects the hydrologic cycle and the quantity and quality of storm water runoff.

2.1.1 Quantity Impacts

The quantity or volume of storm water runoff from urban and suburban land uses depends on several factors: intensity and duration of a given storm event; basin slope; amount and type of vegetation retained; and, most importantly, amount of impervious area such as asphalt, concrete, building rooftops, and compacted soils. Urbanization increases the quantity of runoff, which has a serious impact on receiving waters. Figure 1 shows how the natural water balance is disrupted when an area is developed. Paved surfaces and buildings replace vegetation that once intercepted

the rain, allowed it to soak into the ground, and returned water to the air through evapotranspiration. Heavily compacted surfaces act much the same as pavement in preventing water from seeping into the ground. Snowmelt, especially when accelerated by rain, also increases the chance of flooding. As the volume and flow rate of the runoff increases, water reaches streams and lakes more quickly, and typically there is less recharge to ground water which contributes baseflow to streams. The higher runoff volumes and rates lead to overland erosion, scouring or undercutting of streambanks, flooding, and loss of riparian habitat.

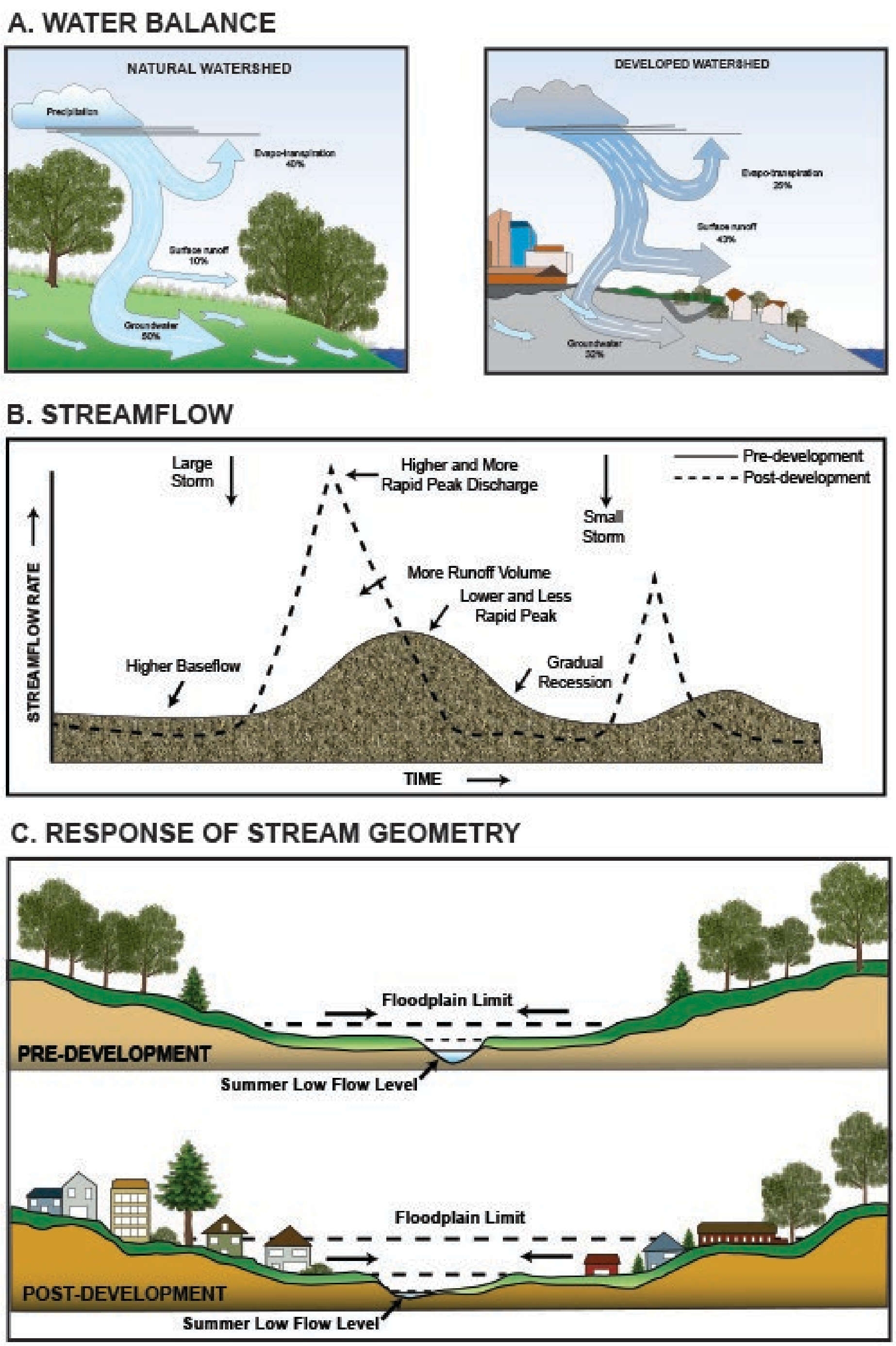


Figure 1. Impact of urbanization on watershed hydrology (UNHSC 2010).

2.1.2 Quality Impacts

Urbanization adversely affects the temperature and quality of storm water runoff, which in turn has a serious impact on receiving waters. In addition, runoff collects and transports pollutants from impervious surfaces:

- Sediment carries other pollutants that can smother fish eggs.
- Organic debris and fertilizer contains nutrients such as phosphorus and nitrogen.
- Bacteria and viruses from humans and animals.
- Organic chemicals contain pesticides, oil, and antifreeze.
- Heavy metals such as lead, copper, zinc, and cadmium from roof runoff, worn tires, and automobiles.
- Oxygen-demanding substances.
- Floatables, such as litter.

2.1.2.1 Sediment

The most common pollutant found in urban runoff is sediment. Sediment consists of tiny soil particles that are washed or blown into nearby waterways. Sediment can fill up river channels, lakes, wetlands, and reservoirs, creating potential flooding problems. Sediment smothers aquatic life, such as phytoplankton, fish, and invertebrates, and makes feeding or reproducing difficult for aquatic life. Sediment can also carry pollutants, such as nutrients, toxic chemicals, and heavy metals. These pollutants can affect water quality and potentially contaminate drinking water supplies. Sediment is associated with the following:

- Construction site runoff
- Streambank erosion
- Road maintenance
- Yard and garden landscaping

2.1.2.2 Nutrients

Nutrients found in urban runoff are nitrogen and phosphorus. Excessive levels of nutrients encourage undesirable algal blooms and aquatic weed growth in surface waters. When the nutrients are used up, this growth dies and uses oxygen as it decays. As a result, the lake, river, or other receiving waterway has less dissolved oxygen, creating an unfavorable environment for fish and other aquatic life. Nutrients are associated with the following:

- Fertilizers
- Lawn clippings and leaves
- Animal wastes

2.1.2.3 Bacteria and Viruses

Two of the most common bacteria and viruses found in urban runoff are fecal coliform and enterococcus. If high levels of bacteria and viruses in storm water flow into a nearby waterway, human health could be jeopardized. Bacteria and viruses are associated with the following:

- Sanitary sewer infiltration into the storm drain system
- Failing septic tanks
- Pet wastes

2.1.2.4 Petroleum-Derived Substances

Oil and grease are petroleum-derived substances found in urban runoff. Petroleum-derived substances contain hydrocarbons. Hydrocarbons are toxic to sensitive animal and aquatic life species. Hydrocarbons degrade fish habitat and can accumulate in the food chain. Petroleum-derived substances are associated with the following:

- Parking lots and roads
- Automobile service stations
- Waste oil storage
- Illegal dumping or improper disposal of petroleum-derived substances

2.1.2.5 Toxic Chemicals

Toxic chemicals found in urban runoff include organic compounds, such as pesticides, paints, solvents, adhesives, or other similar products. Improper disposal or storage, illegal discharges, or unnecessary application of toxic chemicals can harm aquatic life. In addition, toxic chemicals can accumulate in the food chain and potentially contaminate drinking water supplies. Toxic chemicals are associated with the following:

- Automobile emissions
- Gasoline and oil additives
- Household cleaners
- Toxic chemical storage
- Illegal dumping or improper disposal of toxic chemicals
- Pesticides
- Lawn and golf course maintenance

2.1.2.6 Heavy Metals

Common heavy metals found in urban runoff are lead, copper, cadmium, and zinc. Nickel and chromium are also frequently present in urban runoff. As these metals corrode, dissolve, or settle out, wind or water deposits them in surface water. Heavy metals can degrade water quality, are toxic to aquatic life, can accumulate in the food chain, and can contaminate drinking water supplies. Heavy metals are associated with the following:

- Automobile emissions
- Automobile brake and tire wear
- Galvanizing agents
- Batteries
- Paints and wood preservatives
- Metal rooftops and pipes

2.1.2.7 Oxygen-Demanding Substances

Organic matter is found in urban runoff and reduces the available oxygen in water. When microorganisms decompose organic matter, dissolved oxygen levels become depleted, and if these levels become too low in water, the stressed aquatic life can die. Oxygen demanding substances are associated with the following:

- Leaves and lawn clippings
- Small wood products (sawdust, wood chips, and bark)
- Animal wastes
- Food wastes from leaking garbage dumpsters
- Street litter

2.1.2.8 Floatable Materials

Floatable materials found in urban runoff are street litter and industrial yard waste. Floatable materials can contain significant amounts of pollutants such as heavy metals, toxic chemicals, and bacteria. Floatable materials can also cause waterways or permanent storm water control features, such as detention basins, to become unsightly.

2.2 Clean Water Act Requirements

Not only is storm water management important for mitigating the environmental impacts of development, it is required by law. The Federal Water Pollution Control Act (33 USC §1251 et seq. 1972), known as the Clean Water Act (CWA), establishes the structure for regulating discharges into waters of the United States and establishes surface water quality standards. Under the authority of the CWA, the National Pollutant Discharge Elimination System (NPDES) permit program was created to regulate point source discharge into waters of the United States. These federal regulations require that some communities, industries, institutions, and construction contractors obtain NPDES permits and develop and implement storm water management programs to ensure that pollutants in storm water runoff are controlled to the maximum extent practicable. The 1987 CWA amendments prohibit the discharge of any pollutant to waters of the United States from nonagricultural sources unless authorized by an NPDES permit.

The NPDES storm water permit program covers discharges from three sources, including municipal separate storm sewer systems (MS4s), construction activities, and industrial activities, and is implemented in two phases. Phase I (1990) requires operators of medium and large MS4s (defined as an incorporated place or county with a population of 100,000 or more) to obtain NPDES permit coverage for their storm water discharges. Phase I also applies to 11 industrial categories including construction sites disturbing 5 acres of land or more. Phase II (1999) requires operators of regulated small MS4s in urbanized areas to obtain NDPES permit coverage for their storm water discharges. A regulated small MS4 is located in an *urbanized area*, as defined by the US Census Bureau, and includes small MS4s located outside of an urbanized area that are designated to be included by NPDES permitting authorities. Phase II also applies to construction activities that result in land disturbance of greater than or equal to 1 acre of land.

2.2.1 Responsible Authorities

Government agencies, industries, businesses, construction contractors, and individual landowners collectively share the responsibility of managing storm water to help preserve surface water quality in Idaho. Persons wishing to discharge storm water runoff into a drainage channel or water body should contact the appropriate agency or special district identified in the following sections about conditions or permitting requirements that may apply.

2.2.1.1 Federal Government

At the federal level, the United States Environmental Protection Agency (EPA) is responsible for developing, implementing, and enforcing the requirements of CWA through the NPDES permit program. EPA has delegated NPDES authority to many states, and in July 2018, the Idaho Pollutant Discharge Elimination System (IPDES) received authorized permitting authority from EPA to address water pollution by regulating point sources that discharge pollutants to waters of the United States.

2.2.1.2 State Government

DEQ's IPDES Program will administer the discharge of pollutants into waters of the United States in Idaho. These discharges include municipal effluent, industrial effluent, storm water, pretreatment controls for certain discharges to publicly owned treatment works (POTWs), and the municipal sewage sludge (biosolids) management program. DEQ is approved to administer the IPDES Program through the CWA and the "Rules Regulating the Idaho Pollutant Discharge Elimination System Program" (IDAPA 58.01.25).

DEQ provides technical assistance and support to cities, counties, and watershed advisory groups for controlling surface water and ground water pollution from nonpoint sources. Nonpoint source pollution management includes using BMPs designed, implemented, and maintained to provide full protection or maintenance of beneficial uses (IDAPA 58.01.02.350.02).

DEQ adopts water quality standards to protect public health and welfare, enhance the quality of water, and serve the purposes of the CWA. Any project that requires a federal permit or license under CWA, such as an NPDES permit, §404 dredge and fill permit, or Federal Energy Regulatory Commission (FERC) license, requires a §401 water quality certification. The certification ensures that the project or permitted discharge will not cause or contribute to a violation of state water quality standards.

In addition to surface water quality protection, DEQ is also responsible for protecting the quality of ground water in Idaho and relies on a combination of programs to protect ground water from pollution, clean up degraded ground water, and monitor and assess ground water quality. DEQ's authority for nonpoint source control of ground water pollution includes the Idaho Environmental Protection and Health Act (Idaho Code §39-120–127), *Idaho Ground Water Quality Plan* (DEQ 1996), and "Ground Water Quality Rule" (IDAPA 58.01.11). Discharges from constructed wetlands to waters of the state (including discharges to natural wetlands) are regulated under Idaho's "Water Quality Standards" (IDAPA 58.01.02).

Idaho Department of Water Resources (IDWR) has authority to regulate stream channel alterations under the Alteration of Channels of Streams (Idaho Code §42-38) and to regulate the

safety of most impoundment structures under the dam safety statutes (Idaho Code §42-1717). Idaho Code §42-38 requires that stream channels and their environment be protected against alteration to protect fish and wildlife habitat, aquatic life, recreation, aesthetic beauty, and water quality. IDWR must approve in advance any work being completed within the bed and banks of a continuously flowing stream. IDWR regulates dams 10 feet or higher or which store more than 50 acre-feet of water.

IDWR also regulates wastewater disposal by injection wells. An injection well is "Any feature that is operated to allow injection which also meets at least one (1) of the following criteria: (a) A bored, drilled or driven shaft whose depth is greater than the largest surface dimension; (b) A dug hole whose depth is greater than the largest surface dimension; (c) An improved sinkhole; or (d) a subsurface fluid distribution system. Provided however, that injection well does not mean or include any well used for oil, gas or geothermal production activities" (Idaho Code §42-3902). Design professionals considering using injection wells for storm water runoff disposal should contact IDWR for information on proper disposal methods.

The Idaho Transportation Department (ITD) is responsible for maintaining the drainage systems (roadside ditches and stream, canal, and river crossings) associated with state roads. If a development project has the potential to affect a state highway project, design professionals should contact the appropriate ITD regional office.

2.2.1.3 Local Government

County and city building and planning departments are responsible for reviewing and issuing building permits within their jurisdictions and some building departments may require storm water BMPs based on specific types of development. Local jurisdictions that are part of the National Flood Insurance Program are also responsible for managing floodplains, and they should be contacted for information on floodplain development permits and any other requirements.

Local highway jurisdictions are responsible for maintaining roads in the unincorporated areas of a county, including all drainage contained in the road right-of-way. For the most part, the drainage system associated with county roads consists of natural drainages (e.g., streams), irrigation canals, and roadside ditches.

Irrigation districts, ditch companies, and individual farmers operate irrigation systems primarily throughout the southern half of the state. Land development projects must seek approval from a ditch or canal company or district to discharge storm water from pending development sites to such conveyances.

Idaho's public health districts, through their septic system permit, work closely with county landowners outside of areas connected to sewer systems. Seven health districts monitor public health-related water quality parameters, support the local sewer districts, and track performance of on-site systems. For centralized sewer systems, DEQ assumes the responsibility for review and approval.

2.2.1.4 Individuals

Landowners are principally responsible for storm water runoff from their property. In subdivisions with a storm water facility (e.g., detention pond) that collects runoff from the entire development, the developer or local homeowner's association may assume responsibility for maintenance. Alternatively, the facility could have an easement to allow for maintenance by the city, county, or local highway jurisdiction. The local agency may charge the developer or homeowner's association for the cost of such maintenance.

2.2.2 NPDES/IPDES Permits

An NPDES or IPDES permit contains limits on what can be discharged and other provisions to ensure that the discharge does not harm water quality or public health.

2.2.2.1 MS4 Permits

Operators of Phase I and Phase II regulated MS4s are required to obtain permit coverage and develop, implement, and enforce a storm water management program designed to reduce pollutant discharge to the *maximum extent practicable* to protect water quality and satisfy the CWA requirements. See *EPA's MS4* for more information.

Beginning in July 2021, permitting authority for municipal storm water activities will be transferred to DEQ. DEQ will maintain the current permits until they expire and then will draft, publish, and issue the next permit.

2.2.2.2 Construction General Permit for Construction Activities

While EPA is the permitting authority in Idaho, EPA's Construction General Permit (CGP) requirements must be met. Construction activities that disturb an area of 1 acre or more or that are part of a larger common plan of development (e.g., lots in subdivisions created since 1987) are required to obtain coverage under the CGP by submitting a Notice of Intent (NOI) to EPA and by preparing and implementing a Storm Water Pollution Prevention Plan (SWPPP). These permit requirements are in addition to local regulations. See *EPA's CGP* for more information.

Beginning in July 2021, permitting authority for construction storm water activities will be transferred to DEQ. DEQ will maintain the current CGP until it expires and then will draft, publish, and issue the next CGP.

2.2.2.3 Multi-Sector General Permit for Industrial Activities

While EPA is the permitting authority in Idaho, EPA's Multi-Sector General Permit (MSGP) requirements must be met. Additional permit conditions related to Idaho's antidegradation policy, which provides three levels of protection to Idaho water bodies, must be met as well. *Twenty-nine sectors of industrial activities* have been identified by EPA as needing an NPDES industrial storm water permit. Industrial facilities that fall under at least one of these categories must obtain coverage under MSGP if they discharge storm water either directly to surface waters or indirectly through separate municipal storm drains.

Beginning in July 2021, permitting authority for industrial storm water activities will be transferred to DEQ. DEQ will maintain the current MSGP until it expires and then will draft, publish, and issue the next MSGP.

3 Storm Water Management Plan

This section provides step-by-step guidance for preparing a storm water management plan for a project site both during and after construction. Although many of the BMPs included in this catalog can be used by municipalities and industrial activities to comply with MS4 and MSGP permits, this section focuses on storm water management plans for new developments and the CGP permit.

Consideration of storm water management should occur as early as possible during the project development process to ensure cost-effective and efficient designs. In addition to the guidance provided here, it is important to comply with local, state, and federal regulations as applicable.

3.1 Evaluate Site Conditions

The first step when preparing the design of a new or redeveloped project is to evaluate the existing site conditions, including physical features and legal considerations.

3.1.1 Topography

Topography—the shape, gradient, and stability of slopes—of the project site should be evaluated. The potential for erosion increases exponentially with increased slope length and gradient due to storm water runoff traveling faster with more erosive energy. Higher velocity runoff forms rills and gullies that concentrate erosive flows and energy further. Slopes can be grouped by gradient and degree of potential erosion hazard as shown in Table 1.

Table 1. Erosion hazard based on slope gradient and length.

Erosion Hazard	Slope Gradient (%)	Maximum Length (feet)
Low	0–7	300
Moderate	7–15	150
High	>15	75

Areas with little topographic relief pose the least risk of erosion due to terrain. However, a slope with a low erosion hazard may still require soil erosion control measures because of length, the erosive nature of the soil, the size of the drainage area, or the lack of vegetative protection. The relative erodibility of various soils can be determined from soil maps and soil descriptions.

When evaluating site topography, identify areas that can be used to reduce the risk of turbid water discharges. Closed depressions, flat areas, or gently-sloped and heavily-vegetated areas can often be used to treat, infiltrate, or contain runoff.

Natural drainage patterns that exist on the site should be identified as critical areas where water will concentrate. Where possible, natural drainage ways should be used to convey runoff over and off the site to avoid the expense and challenges of constructing artificial drainage systems.

Man-made ditches, diversions, and waterways can become part of the erosion and flooding problem if they are not properly constructed and stabilized. Consideration should be given to the entire watershed in which the project is located to properly evaluate the site hydrology, downstream and upstream hydrology, and the impact of the site on the entire watershed.

Sources of Information—Topography can be evaluated using slope and contour maps produced from digital elevation models and/or 7.5-minute, United States Geological Survey (USGS) topographic quadrangles. Digital elevation model data are available through the USGS National Elevation Dataset (NED), which is a seamless dataset with the best available raster elevation data of the conterminous United States, Alaska, Hawaii, and territorial islands. *NED data* are available at resolutions ranging from 1 arc-second (about 60 meters) to 1/9 arc-second (about 3 meters). NED data can be obtained through the *National Map Viewer*. USGS NED data may not be accurate enough for sites with complicated drainage and/or steeper slopes. If NED data do not provide the required accuracy, contours should be generated using a topographic ground survey or an aerial survey.

3.1.2 Soils

Geotechnical soils information is essential to adequately evaluate all project sites. The design and effectiveness of both temporary and permanent BMPs depend on soils information, and it should be factored in early in the planning stage. Soil types of primary concern include highly erodible soils and hydric (wetland) soils. Important soil characteristics include soil texture, soil depth, infiltrative capacity, particle size distribution, and hydrometer settling times.

Soil texture is determined by the proportion of sand, silt, and clay particles in the soil. Soil texture affects the erodibility of the soil, how quickly soil particles will settle out of runoff, soil infiltration potential, and runoff volumes. Soil erodibility is greater in the case of silts and fine sands than clays or soils with substantial gravel or organic content. The infiltration potential is greater for coarsely textured, highly porous soils. Finely textured silt and clay soils permit almost no infiltration, generating large runoff volumes. Finely textured soils also take longer to dry between storm events and may remain unworkable for long periods of time.

Highly erodible soils can create a wide range of problems for many types of development and construction. Problems include water quality degradation, fish and wildlife habitat impairment, instability of slopes and structures, and aesthetic impairment. Soil infiltration capacity largely determines the effectiveness of storm water BMPs (e.g., infiltration trenches and ponds).

Hydric or wetland soils are important to identify if they are present on the project site. Many restrictions limit construction in wetland areas, and many storm water BMPs are ineffective or impossible to implement in saturated soils. In glaciated terrain, soil depth can vary widely, and soils tend to be relatively underdeveloped and shallow.

Sources of Information—Several methods exist to determine the potential for erosion and sediment transport problems associated with the soils, including geotechnical reports, published countywide soil surveys, jar testing, and hand texturing.

Site-specific geotechnical reports prepared by geotechnical engineers evaluate the structural properties of soils for construction purposes and also include information on soil erodibility, infiltration rates, and ground water levels. The reports often provide specific recommendations to

prevent erosion, such as specifying the maximum allowable slope angles or where retaining walls are required. Jar testing and hand texturing are some evaluation tools used in preparing a geotechnical report for a site.

Countywide soil surveys have been published by the United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS). These surveys are available from local NRCS or Soil and Water Conservation District field offices or the *Web Soil Survey*. Soil surveys contain general soil maps, soil descriptions, soil properties, and soil classifications. In addition, the NRCS has published a list of hydric soils in select, surveyed counties, which includes where hydric soils are most likely to occur and whether all major components of a soil unit are hydric. Consult the local NRCS office for a list of highly erodible soils, including slope ratings.

NRCS also maintains the detailed Soil Survey Geographic Database (SSURGO). SSURGO data are also available through the NRCS Web Soil Survey. *Soils erosion sensitivity* maps can be developed from this database if it has been digitized. The United States Forest Service (USFS) has developed *soil severity* ratings for soils in recently burned areas of national forests. In some cases, soil borings and tests may be necessary to determine soil groups and depth, especially in transitional landscape areas.

3.1.3 Precipitation

Precipitation characteristics, such as frequency, intensity, and duration, directly influence the amount of runoff that occurs and the potential for erosion on a site, particularly when the precipitation is in the form of rainfall. As the frequency of rainfall increases, the soil may remain saturated for long periods of time, and the volume of runoff may be greater. Higher intensity storms produce runoff with higher velocities, generating more erosion. Longer storm events also increase erosion potential due to their duration. Seasonal variation in precipitation affects erosion potential as do seasonal temperature variations. Frozen soils are relatively erosion resistant but can result in high runoff.

Although weather cannot be controlled during a construction project, builders can minimize erosion through proper timing, phasing, and BMP selection based on general weather patterns. Average monthly precipitation gives a good starting point to determine how projects should be phased and at what time during the year the site should be most heavily protected. Extreme events, not average events, are responsible for severe erosion problems. The probability of extreme events can be evaluated to assess the likelihood of a given rainfall amount over a given time period.

Sources of Information—Weather data are readily available on the internet. The *Western Regional Climate Center* provides statistical information on precipitation, temperature, as well as tabular and graphical information and interactive probability graphing capabilities.

3.1.4 Land Use and Landownership

Land use and zoning information is essential to determine site design and BMP placement. Zoning regulations may limit the type of structural BMPs that can be used and permitted. Landownership is important to know when considering BMP implementation to ensure all legal

considerations are taken into account, access issues are resolved, and BMP maintenance is arranged. Availability of land for placement of large structural BMPs (e.g., detention facilities) must also be ascertained in some situations.

Sources of Information—Current and projected land use data and restrictions can be obtained from the municipality or county. To ensure proper compliance with current planning department regulations, contact the local planning departments. A county assessor's office and/or geographic information systems (GIS) office generally has ownership records for specific sites.

3.1.5 Critical Areas and Vegetation

Critical areas include features such as wetlands, protected and endangered species habitat areas, and floodplains. Ground cover and vegetation can indicate critical areas and can influence the ability to construct and implement storm water BMPs.

Vegetation offers a number of important benefits that prevent erosion, including reducing raindrop impact, slowing runoff velocity, absorbing water, and holding soil in place. Eliminating vegetation effectively decreases the soil's ability to hold and process water and may result in a decrease in ground water recharge. Limiting and phasing the removal of existing vegetation to decrease the area and duration of soil exposure can significantly reduce soil erosion and sediment transport.

Sources of Information—Wetlands mapped for the *National Wetlands Inventory* are available at a local NRCS field office. NRCS also has site-specific information and/or wetland delineations for some counties, as do the local municipalities and health district offices. Protected and endangered species information is available from the *United States Fish and Wildlife Service* or from the Idaho Department of Fish and Game. Floodplain information can be obtained from IDWR, cities, and counties. IDWR hosts an interactive map showing digital *Flood Insurance Rate Maps* (FIRMs) and scanned FIRMs for most Idaho counties. Ground cover and vegetation can be identified for large areas from aerial photos, or detailed vegetation surveys can be conducted for specific sites.

3.1.6 Culturally Significant Sites

Culturally significant sites include Native American tribal sites, archaeological sites, and historic buildings and areas designated in the National Historic Register. Cultural sites must be identified and protected during construction. If cultural relics are found during construction, construction must cease immediately until the relics can be protected, and the extent of the archaeological find and its significance can be determined.

Sources of Information—The *State Historic Preservation Office* is an excellent source of information for historical structures and sites.

3.1.7 Utilities and Infrastructure

Utilities and infrastructure can influence BMP construction. Before construction, locate the utilities, including wastewater, water, gas, electricity, telephone, and transportation (roads, railroads, and airports). Construction near infrastructure must be coordinated with future infrastructure development plans and easements.

Sources of Information—Utility and infrastructure information can be obtained from local building, public works, and planning departments; local sewer and water districts; domestic water suppliers; local transportation providers; ITD; local utility companies; and utility locator services such as *Idaho DIG Line*.

3.1.8 Water Resources

Water resource considerations that influence the ability to construct and implement BMPs include hydrography of tributaries, lakes, and reservoirs; ground water levels and water table depth; well locations; and irrigation diversions and canals. Understanding the watershed and impact of upgradient water sources on the site is critical to determine run-on control needs and design effective erosion control BMPs.

Sources of Information—Hydrography information can be obtained from USGS 7.5-minute quadrangles. IDWR can provide information on *ground water levels and water table depth* for permitted wells, monitoring wells, and irrigation diversions and canals. Local irrigation districts also have information on irrigation diversions and canals, and DEQ has information on the boundaries of the *Rathdrum Prairie Aquifer.*

3.1.9 Boundaries

Watershed, political, irrigation district, water district, and sewer district boundaries should be determined for legal reasons and to coordinate BMP activities with the neighboring entities. Boundaries should be ascertained to determine which immediate receiving water body will be affected by the BMPs under consideration and to be aware of and coordinate with other activities within the watershed. The watershed features, both physical and biological, greatly affect which BMPs will be effective for storm water management. All management features should be designed and engineered with the entire watershed in mind.

Sources of Information—Boundary information is available from the *DEQ GIS database*, or contact the individual municipality, irrigation district, sewer district, or water district.

3.1.10 Other Flood Reduction and Water Quality Improvement Projects

Coordination with other water quality related projects could be leveraged to obtain greater water quality benefits than stand-alone storm water BMPs.

Sources of Information—Information on flood reduction and water quality improvement projects can be obtained from flood control districts and *DEQ's water quality webpage*.

3.2 Identify Performance Goals and Regulatory Considerations for the Site

Storm water management performance goals and objectives should be identified for the development site. These goals and objectives are based on applicable regulatory requirements for quantity control (flood and drainage), peak flow reduction, and any special local area needs, such as protection of fisheries, water supplies, and ground water.

While selecting the appropriate level of control is usually a local mandate, in some cases the downstream receiving waters will influence the regulatory requirements. It is important to identify the storm drain system or waterway where site runoff will drain to determine what requirements apply. The agency managing the receiving drainage system may have special restrictions or permitting requirements. Examples include total maximum daily load (TMDL) requirements, compliance with IDAPA 58.01.02, maintenance of the maximum carrying capacity of the receiving system, endangered species protection, and/or federal storm water regulations and associated NPDES storm water permits conditions.

The regulatory requirements of the local jurisdiction must be considered when selecting BMPs. Many jurisdictions have requirements to control the rate of discharge (or peak runoff rate) from new developments or redeveloped sites to prevent increased flooding, provide channel protection, and/or maintain water quality. For example, developments may be required to match postdevelopment and predevelopment peak flow rates and runoff volumes for one or more design storms. Other performance goals and objectives may include specific pollutant guidelines, multiparameter controls (including ground water recharge and channel protection), and habitat protection strategies. Although pollutant removal has become a main objective for using BMPs, no single value exists for percent pollutant removal for a particular BMP because pollutant removal efficiency is site specific and highly variable between storm events and influent loads.

Contact the local permitting authority to obtain the permit application forms, design standards, and any other applicable requirements for the project site area. These requirements could include planning and building codes, flood control and water quality design standards, and seasonal restrictions for earthmoving and grading. Local requirements may change periodically, so check with the agencies for each new construction project.

3.3 Characterize Storm Water Flows (Run-on and Runoff)

Evaluate the characteristics of the run-on that enters the site from adjacent and upstream properties, as well as the runoff that will be discharged from the site following development or redevelopment. Consider the following, which will potentially influence the quantity (volume), peak flow, and quality of run-on to and runoff from the site:

- Upstream activities currently affecting the site
- Planned upstream land use likely to affect the site in the future
- Type and capacity of the downstream receiving water or drainage system
- Amount of impervious area planned for the site
- Activities that will take place on the site (e.g., industrial and commercial activities may generate different pollutants and require different BMPs than residential activities)

Investigate the site carefully for evidence of ephemeral streams, natural swales, snow melt conveyances, seeps, and other signs of seasonally wet conditions. The investigation might require skills in botany and hydrology or local knowledge to learn about the existence of these flow paths.

3.4 Develop a Site Plan and Map

The site plan developed should consider the site conditions, storm water run on and runoff characterization, and storm water performance goals. Ideally storm water management should be integrated into the site's design during the early design stages.

3.4.1 Natural Drainage System Design

Conventional storm water management focuses on concentrating flow to quickly carry water away from the site and relies heavily on curbs, pipes, inlets, dams, riprap, detention basins, and other *hard* engineering solutions. In contrast, the natural drainage system approach manages storm water on site to the greatest extent possible and uses practices that infiltrate and evapotranspirate storm water to return it to the natural water cycle. This approach treats storm water as closely as possible to the source of runoff generation using simple, nonstructural practices that mimic the natural functions of soil, vegetation, and landforms.

With an informed understanding of the site, this distributed *at-the-source* control strategy reduces drainage system costs by eliminating the need for pipe and inlet conveyances and/or engineered mitigation or proprietary treatment structures. The site design process presents opportunities to achieve both environmental quality protection and cost savings by avoiding single-purpose structures and infrastructure.

3.4.2 Green Infrastructure and Low-Impact Development

The term, green infrastructure, is used differently by various organizations. According to the Green Infrastructure Center, green infrastructure is "the interconnected network of waterways, wetlands, woodlands, wildlife habitats, and other natural areas; greenways, parks, and other conservation lands; working farms, ranches and forests; and wilderness and other open spaces that support native species, maintain natural ecological processes, sustain air and water resources and contribute to health and quality of life." EPA uses green infrastructure to refer to systems and practices that use or mimic natural water flow processes and retain storm water or runoff on the site where it is generated. Green infrastructure includes systems and tools supporting low-impact development (LID) principles.

LID is a natural drainage system storm water management approach based on managing rainfall at the source by using uniformly distributed decentralized microscale controls. The goal of LID is to mimic a site's predevelopment hydrology by using design solutions that infiltrate, filter, store, evaporate, and detain runoff close to its source.

In the 1990s, the Department of Environmental Resources of Prince George's County, Maryland, pioneered LID by developing and using bioretention cells. In 1998, Prince George's County produced the first municipal LID manual, which was nationally distributed in 2000. Many US municipalities have embraced LID due to its holistic approach to design. LID fundamentals include the following:

- Use hydrology as the integrating framework.
- Think micromanagement.
- Control storm water at the source.

- Use simple, nonstructural methods.
- Create a multifunctional landscape.

Both landscape features and the built environment are the building blocks of the LID approach. Every urban landscape or infrastructure feature (roof, street, parking, sidewalk, and green space) offers the opportunity to store, convey, filter, retain, and reuse runoff. LID is a versatile approach that can be applied equally well to new developments, urban retrofits, and redevelopment and revitalization projects.

3.4.2.1 Site Design

Existing drainage pathways should inform the overall site design. LID achieves storm water management by applying natural watershed hydrologic functions (discharge, frequency, recharge, and volume), minimizing impacts, providing on-site detention and retention, and designing flow routing to mimic natural hydrologic conditions.

3.4.2.2 Minimize Impacts

Development impacts storm water, and these impacts should be minimized to the extent practicable by conserving natural resources and ecosystems; maintaining natural drainage courses; minimizing clearing and grading; and reducing imperviousness. Certain techniques reduce impervious surfaces, such as using narrower residential streets, using less impervious sidewalk area, using porous pavement or replacing existing pavement with pervious materials, using clustered development layouts, and creating concave medians and landscaped traffic-calming features. Innovative architectural designs, such as incorporating rooftop or basement parking, can also reduce impervious areas. Techniques that conserve existing site resources and functions include preserving vegetation and trees, site fingerprinting (minimal disturbance), using on-site water reuse facilities, preserving soils with high infiltration rates, locating BMPs on high-infiltration soils, and constructing impervious features on soils with low infiltration rates. The following BMPs minimize development impacts through site planning:

- BMP 1: Minimize Land Disturbance
- BMP 2: Provide Natural Buffers
- BMP 3: Minimize Disturbance of Steep Slopes
- BMP 4: Manage Impervious Surfaces—Disconnect and Reduce
- BMP 5: Reduce Roadway and Sidewalk Surface Areas
- BMP 6: Green Streets and Parking

Planting or maintaining existing vegetation is a cost-effective way to reduce the impact of development and improve water quality. Integrating storm water controls within the landscape saves money and reduces pollutants such as sediment and nutrients in storm water runoff. Controls such as vegetated swales (BMP 9) and vegetated filter strips (BMP 11) can be integrated into the landscape with minimal construction cost.

Consider preserving existing vegetation (BMP 38) or planting native vegetation in disturbed areas (BMP 8). Shrubs and coniferous trees without leaf litter are particularly desirable from a water quality standpoint. Using native plants reduces water requirements, as well as pesticide,

herbicide, and fertilizer use. Using native plants in storm water BMPs will also ensure proper plant establishment and long-term BMP performance from sustainable plant growth.

Properly selecting plants and preparing the site are crucial to successful plant establishment. Plant during favorable planting and seeding seasons. Irrigation, mulching, and weed and pest control may be necessary to encourage proper plant growth. See the *Storm Water Plant Materials* guide for plant selection and establishment information.

3.4.2.3 On-Site Detention and Retention

Dispersed detention and retention storage should be created throughout a site by using open swales (BMP 9), gradual slopes, rain gardens (bioretention) (BMP 18), rainwater capture and reuse (cisterns and rain barrels) (BMP 27), and subsurface storage (BMP 26). Other storage techniques are available that can be integrated into the site planning and design process for a LID site. These techniques include swales with check dams (BMP 60), wide low-gradient swales (BMP 9); green roofs (BMP 20); wet ponds (BMP 22); and shallow parking lot storage. These detention practices can easily be integrated into the site design features, especially if the space allocation requirements are identified early in the design stages.

3.4.2.4 Flow Routing

The predevelopment time of concentration (T_c) should be maintained by strategically routing flows to maintain the same travel time after development. The following site planning techniques can be used for this purpose. Maintain the predevelopment flow path length by dispersing and redirecting flows using open swales and natural or vegetated drainage patterns. Increase surface roughness by preserving existing vegetation or creating vegetated swales. Detain flows in open swales and rain gardens, minimize disturbances by minimizing compaction and changes to existing vegetation, and flatten grades in impacted areas. Disconnect impervious areas (BMP 4) by eliminating curb and gutter and redirecting downspouts to connect pervious and vegetated areas.

3.5 Select the Right BMPs

BMP selection should be based on the identified performance goals and physical characteristics of the development site. Physical site conditions that should be considered during BMP selection include soil characteristics, topography, existing drainage ways, precipitation, water table depth, bedrock depth, and watershed size. Determine geotechnical properties of the soils on site to ensure that BMPs are appropriately selected and designed for the soil particle sizes present and the infiltrative capacity of the subsurface. In many instances, individual BMPs may be modified to account for site constraints, while in other cases site constraints may eliminate an individual BMP as an option.

BMPs can be categorized by function, physical characteristics, or how and when they are typically employed. BMP functions include erosion, sediment, source, and treatment controls. Physically, BMPs are either structural or nonstructural. Some BMPs are applied during the site design phases, while others are applied during construction. Permanent BMPs are present postconstruction and remain for the life of the project. Temporary BMPs applied during

construction can be converted to permanent BMPs. BMPs should be selected so that multiple functions are addressed throughout the life of the project.

3.5.1 Site Design BMPs

A number of land development and site design tools can prevent degradation of streams, lakes, and other water bodies. BMPs used during site design are comprehensive in nature and should be tailored to a specific context and a specific set of problems. BMPs that promote a natural drainage system approach with land development have been grouped into the following categories:

- Programming and predesign
- Runoff minimization
- Rainwater capture
- Infiltration and landscaping
- Conveyance

All BMP fact sheets are included in section 4 and present applications and limitation information as well as design parameters, construction guidelines, and operation and maintenance recommendations.

3.5.1.1 Programming and Predesign

Surface forms, soils, and plants are critical functional components of a landscape. Each plays a role in the flow and processing of water through a site by providing pathways, retention, detention, treatment, and disposal. These site elements can be protected during the design and construction process.

Areas that are conserved in their natural state retain their natural hydrology and are not exposed to erosion during construction. Natural drainage systems should be preserved and maintained to allow discharges from the site to occur at the natural location. Naturally vegetated buffers along streams should not be disturbed, unless the vegetated buffer is part of the water quality treatment facility.

BMPs for the site programming and predesign phase are as follows:

- BMP 1: Minimize Land Disturbance
- BMP 2: Provide Natural Buffers

3.5.1.2 Runoff Minimization

Impervious areas directly connected to the storm drain system are the greatest contributor of nonpoint source pollution in storm water runoff. Streets and other transport-related structures typically comprise between 60% and 70% of total impervious area, and unlike rooftops, streets are almost always directly connected to a storm water system. Literature on the impacts of development indicates that the level of imperviousness (or directly connected imperviousness) in a watershed is a factor that negatively influences the structural integrity of a stream or the health of its aquatic species.

Methods for minimizing runoff include disconnecting impervious surfaces and using permeable pavements when a stabilized surface is needed to minimize the impact. Development plans can optimize positive attributes of the site such as soil groups, vegetation, and landform. Open space design, conservation development, and cluster development refer to site-planning techniques that concentrate development on one or more portions of a site, and conversely preserve more of the site as open space. Reconfigured development forms offer an attractive alternative to conventional subdivision design and are applicable to most forms of residential development, with special opportunities in rapidly growing rural settings and within suburban fringes of growing communities.

BMPs that help minimize runoff are as follows:

- BMP 3: Minimize Disturbance of Steep Slopes
- BMP 4: Manage Impervious Surfaces—Disconnect and Reduce
- BMP 5: Reduce Roadway and Sidewalk Surface Areas
- BMP 6: Green Streets and Parking
- BMP 19: Porous Pavement

3.5.1.3 Rainwater Capture

Rain and snow fall as naturally distilled water that can be collected on site and consumed as a resource for many beneficial uses such as irrigation, water for recreational lakes, ground water recharge, industrial cooling and process water, and other nonpotable domestic uses.

Water harvesting collects, captures, and stores rainwater from roofs, paved surfaces, and landscaped areas. Water harvesting uses tanks, cisterns, or sealed wells to collect storm water runoff that can be used for irrigation or other nonpotable domestic uses. The result is a reduction in the total volume of runoff from the site because the impervious surface from the roof no longer generates runoff.

Green roofs are another tool for capturing storm water and mimicking a variety of hydrologic processes normally associated with open space. Plants in green roofs capture rainwater on their foliage and absorb it in their root zone, encouraging evapotranspiration and reducing the amount of storm water runoff. Storm water can also be captured and infiltrated into subsurface storage associated with green space on the site.

BMPs that focus on rainwater capture and reuse are as follows:

- BMP 20: Vegetated Roofs
- BMP 21: Storm Water Planters
- BMP 27: Rainwater Harvesting and Reuse

3.5.1.4 Infiltration and Landscaping

While the foremost objective of storm water site design should be to minimize the total disturbance of the site, there are instances where grading can be used to create forms that provide hydrologic functions. If carefully fitted to topography and soil, subtle and inexpensive landform alterations, such as swales, berms, and depressions, can guide or slow the water flow. Other techniques for new developments that perform hydrologic functions include constructed

wetlands on larger sites, bioretention areas, and storm water planters. Functionality can also be provided in the built environment by using minimally sized, green parking lots that have LID features.

If grading or excavation has removed soil from the site, healthy soil may need to be re-created. Methods that rebuild the soil on site are more sustainable than importing topsoil. Only on rare occasions should soil materials be imported in quantity and never at the expense of another site.

Site revegetation should create sustainable landscapes and conservation landscaping, which means using regionally appropriate vegetation, controlling invasive species, and planting based on patterns of plant growth that occur naturally in the region. On a larger scale, urban forestry programs can restore natural functions.

Facilities such as infiltration trenches and basins could be approved if the developer demonstrates that the site can handle infiltration. Site-specific testing is required to determine the infiltration rate at the site. An acceptable infiltration rate should be greater than 0.4 inches per hour.

BMPs that retain or improve water infiltration and reduce runoff are as follows:

- BMP 6: Green Streets and Parking
- BMP 9: Vegetated (Biofiltration) Swale
- BMP 10: Bioinfiltration Swale
- BMP 17: Infiltration Trench
- BMP 18: Bioretention Basin
- BMP 21: Storm Water Planters
- BMP 24: Constructed Wetlands
- BMP 38: Preserve Topsoil and Vegetation

3.5.1.5 Conveyance

Certain conveyance techniques can provide hydrologic functions by dispersing and redirecting flows. Open swales and shallow channels slow runoff, provide filtration, and promote infiltration into the ground. As a result, runoff volumes are smaller, peak discharge rates are lower, and runoff is cleaner. Vegetated swales can replace curb and gutter systems as well as storm sewer pipe conveyances. Swales can function as conveyances in association with alternative street layouts and when traditional curb and gutter are eliminated. They can also be used to provide parking lot and street storage. Other conveyance practices such as furrows and trenches mimic natural drainage patterns and work to disperse runoff.

BMPs that include conveyance techniques are as follows:

- BMP 6: Green Streets and Parking
- BMP 9: Vegetated (Biofiltration) Swale
- BMP 10: Bioinfiltration Swale
- BMP 24: Constructed Wetlands
- BMP 28: Conveyance Furrows for Roof Runoff
- BMP 29: Dispersal Trench for Roof Runoff

3.5.2 Construction BMPs

BMPs are designed to control storm water pollution during a project's construction phase. This BMP category includes contractor awareness and education, general construction site guidelines, housekeeping, slope protection, storm drain and channel protection, sediment collection, and permanent stabilization. Each BMP fact sheet (section 4), presents application and limitations information as well as design parameters, construction guidelines, and maintenance tips. Pollutant removal effectiveness is also included. Contact the local permitting authority for additional requirements or restrictions that may apply to any of the BMPs.

3.5.2.1 Erosion Control

BMPs that prevent soil erosion should be used as a first line of defense against off-site damage caused by storm water runoff. Erosion prevention BMPs protect exposed soil surfaces from rain-generated splash erosion and can slow flows across a disturbed area. Erosion control BMPs decrease energy in erosion-causing flows so that they cause less damage as they proceed down a slope.

Soil erosion control BMPs are often used during construction, and their selection should be based on the type of erosion that could occur on a construction site, physical features of the site, and types of activities that will be performed on site.

The following are different types of erosion that may be encountered.

Raindrop erosion is the first effect of a rainstorm on the soil. Raindrop impact dislodges soil particles and splashes them into the air. These detached particles are then vulnerable to sheet erosion.

Sheet erosion is caused by a shallow sheet of water as it runs over the land. These very shallow, moving sheets of water are seldom the detaching agent, but the flow transports soil particles that are already detached by raindrop erosion. The shallow surface flow rarely moves as a uniform sheet for more than a few feet on land surfaces before concentrating in surface irregularities. Preserving existing vegetation where possible and stabilizing soil reduces raindrop and sheet erosion. However, if allowed to start, sheet erosion can lead to rill erosion.

Rill erosion develops as the shallow surface flow begins to concentrate in the low spots of the landscape surface. As the water flow changes from shallow sheet flow to deeper flow in these low areas, the velocity and turbulence of flow increase. The energy of this concentrated flow detaches and transports soil particles. This action begins to cut tiny channels of its own. Rills are small but well-defined channels that are, at the most, only a few inches deep. The rills are easily obliterated by harrowing or other surface treatments and have a cross-sectional area of no more than 1 square foot.

Gully erosion occurs when the flow in individual rills combines to create larger channels. The major difference between gully and rill erosion is size. Gullies are too large to be repaired with conventional tillage equipment and usually require heavy equipment and special techniques for stabilization.

Channel erosion is created by the volume and velocity of flow causing movement of the streambed and bank materials.

Exposed soil surfaces should be minimized at all times and, whenever possible, natural vegetation on the site should be preserved. If exposed soil surfaces are unavoidable, it is essential to apply erosion and sedimentation control BMPs to reduce sediment discharge off site to storm drainage systems and nearby streams.

The following BMPs can be implemented during the construction phase to control erosion during and/or after construction:

- BMP 42: Erosion Prevention on Construction Roads
- BMP 43: Dust Control
- BMP 44: Stockpile Management
- BMP 52: Mulching
- BMP 53: Geotextile
- BMP 54: Matting
- BMP 55: Soil Binders
- BMP 56: Riprap Slop Protection
- BMP 57: Pipe Slope Drain
- BMP 58: Slope Roughening
- BMP 59: Gradient Terracing
- BMP 60: Check Dams
- BMP 61: Channel Liners

3.5.2.2 Sediment Control

BMPs that control sediment should be used as a second line of defense against off-site damage due to storm water runoff. While erosion control practices are designed to prevent soil particles from being detached, sediment control uses practices that prevent the detached soil particles, or sediment, from leaving the disturbed area and reaching the receiving waterways. It is better to minimize erosion than to rely solely on sedimentation removal from construction site runoff. To accomplish sediment control, reduce the capacity of surface runoff to transport sediment by slowing the flow of water through spreading, ponding, or filtering and containing the sediment on site. Sediment control BMPs protect storm drains and channels, collect sediment, or divert runoff or run on. The following are sediment control BMPs:

- BMP 40: Vehicle Sediment Control
- BMP 41: Stabilized Construction Roads and Staging Areas
- BMP 63: Biofilter Bags
- BMP 64: Fiber Rolls
- BMP 65: Silt Fence
- BMP 66: Sediment Basins and Traps
- BMP 67: Portable Sediment Tank
- BMP 71: Turbidity Curtains
- BMP 72: Flocculation
- BMP 74: Inlet Protection

Storm Drain and Channel Protection—It is important to protect storm drains during construction activities so that sediment and debris are not allowed to enter the storm water drainage system. Protection of natural channels and earth ditches is critical to prevent scouring and undercutting. BMPs for storm drain and channel protection are as follows:

- BMP 35: Energy Dissipation Devices
- BMP 60: Check Dams
- BMP 61: Channel Liners
- BMP 62: Temporary Stream Crossing
- BMP 74: Inlet Protection

Runoff Diversion—The following BMPs include construction site measures to divert run on from entering the site, keep runoff from leaving the site, or divert runoff away from sensitive areas or certain site activities:

- BMP 68: Temporary Swale
- BMP 69: Diversion Dike
- BMP 70: Temporary Berms
- BMP 73: Dewatering

3.5.2.3 General Construction Site Guidelines and Housekeeping

General construction site guidelines and good housekeeping BMPs include practices that are nonstructural, as well as temporary structural erosion and sediment controls. For example, effective construction scheduling (phasing and sequencing) minimizes the duration of exposed soils. Protection of existing vegetation also minimizes exposed areas and can reduce the cost of final site stabilization. Stabilized construction entrances (vehicle-tracking controls) and street sweeping are critical source control measures to minimize the amount of sediment that leaves a site. Additionally, several miscellaneous activities must be carefully conducted to protect water quality, such as dewatering operations, temporary batch plants, temporary stream crossings, and other practices.

BMPs that provide general guidelines for construction site activities and good housekeeping are as follows:

- BMP 36: Construction Timing
- BMP 37: Staging Areas
- BMP 38: Preserve Topsoil and Vegetation
- BMP 39: Clearing Limits
- BMP 40: Vehicle Sediment Control
- BMP 41: Stabilized Construction Roads and Staging Areas
- BMP 42: Erosion Prevention on Construction Roads
- BMP 43: Dust Control
- BMP 44: Stockpile Management
- BMP 45: Minimize Soil Compaction
- BMP 46: Spill Prevention and Control
- BMP 47: Construction Equipment Washing and Maintenance
- BMP 49: Concrete Waste Management

- BMP 50: Sanitary and Septic Waste Management
- BMP 51: Solid Waste Storage and Disposal

3.5.3 Postconstruction BMPs

This section presents an overview of permanent BMPs for continued control of storm water pollution after construction is complete. Postconstruction BMPs include treatment controls, such as storm water filters, infiltration, detention, and other structural facilities, as well as source controls that apply to municipal, commercial, industrial, and residential sites. The BMP fact sheets in section 4 present applications and limitation information as well as design parameters, construction guidelines, and operation and maintenance recommendations. The most important requirements for successful performance of treatment control postconstruction facilities are proper sizing and regular inspection and maintenance. The local permitting authority should be contacted for additional requirements or restrictions that may apply to any of these BMPs.

3.5.3.1 Treatment Controls

Treatment control BMPs are designed to treat runoff and remove pollutants that have already entered runoff and/or drainage conveyances on site. Most treatment control BMPs are structural and can be more expensive to implement than source control BMPs. Some treatment controls are less costly to install during new construction than to retrofit afterwards. Design professionals should consider what potential pollutants may originate from the site throughout the life span of the facility, not just during construction. Structural treatment control measures will reduce pollutant loads in postconstruction site runoff if the facilities are properly designed, installed, and maintained. Examples of treatment controls include storm water filters, infiltration facilities, detention facilities, and other structural controls.

Storm Water Filters—Storm water filters are designed to filter pollutants out of runoff. The primary removal mechanisms employed by these facilities are straining and settling, which allow capture of coarse-to-fine sediments with the pollutants adhered to them. Vegetated filters, such as bioswales, offer limited nutrient uptake in plants as well as sorption in underlying soils. *Biofiltration* is the process of filtration, infiltration, adsorption, and biological uptake of pollutants in storm water that takes place when runoff flows over and through vegetated treatment facilities.

In vegetated systems, the degree to which the biofilter operates will vary considerably depending upon many factors, such as the depth and condition of the vegetation, velocity of the water, slope of the ground, and texture of the underlying soil. However, the most important design criterion is the residence time of the storm water in the biofilter, provided an adequate stand of vegetation exists and the underlying soil is of moderate texture. To be effective, the biofilter should be designed so that the residence time is sufficient to permit most, if not all, of the particulates and at least some of the dissolved pollutants to be removed from the storm water.

Storm water filters can be used for a variety of land uses. They may not be suitable where runoff contains high sediment loads over long periods, unless the facility is inspected and maintained frequently. Vegetated filters may also be unsuitable for direct runoff from commercial and industrial sites with a greater-than-average potential for toxic pollutants or where infiltration of

these pollutants to ground water could be of concern. In such cases, the use of liners should be considered if the design meets the approval of the local permitting authority.

Vegetated filters can be less expensive than piped systems for conveying storm water runoff and are typically more economical than separators, vaults, or other structural controls. As part of the on-site landscaping, vegetated filters can reduce peak flows and be aesthetically pleasing.

BMPs that provide storm water filtration are as follows:

- BMP 9: Vegetated (Biofiltration) Swale
- BMP 10: Bioinfiltration Swale
- BMP 11: Vegetated Filter Strip
- BMP 13: Catch Bain Insert
- BMP 14: Media Filters

***Infiltration Facilities*—**Infiltration facilities are designed to intercept and reduce direct site surface runoff. They hold or retain runoff long enough to allow it to enter the underlying soil. These devices can include layers of coarse gravel, sand, or other media that filter the runoff before it infiltrates the soil. Infiltration BMPs remove pollutants by settling, percolation and filtering, soil sorption, and degradation. These BMPs can effectively remove sediments and nutrients such as phosphorus, heavy metals, toxic materials, floatable materials, oxygen-demanding substances, oil and grease, and bacteria and viruses.

Infiltration cannot be applied everywhere and depends on the soil and water table conditions at the site. Site-specific testing should be conducted to demonstrate site infiltration rates of at least 0.4 inches per hour. Good design and maintenance of infiltration BMPs are critical to ensure that they do not clog and seal up after a year or two of operation. To prevent clogging, pretreatment should be provided whenever possible, and observation wells should be installed to facilitate maintenance.

Subsurface disposal systems, including dry and injection wells, are not recommended in areas with poorly drained soil conditions and/or a high water table. If dry or injection wells are constructed, they should be permitted by IDWR. Facilities such as infiltration trenches and basins could be approved if the developer demonstrates that the site can handle infiltration. This demonstration requires site-specific testing to determine the infiltration rate at the site.

BMPs that provide storm water infiltration are as follows:

- BMP 17: Infiltration Trench
- BMP 18: Bioretention Basin
- BMP 19: Porous Pavement
- BMP 20: Vegetated Roofs
- BMP 21: Storm Water Planters

Detention Facilities—Detention facilities capture storm water runoff and provide pollutant removal primarily through settling, and if they include vegetation, biological uptake. Biological uptake of dissolved pollutants is an important mechanism for controlling nutrients. Detention BMPs can be used to handle runoff from a variety of land uses. When used in areas with high dissolved concentrations of heavy metals or toxic organic chemical loads in the runoff (e.g.,

industrial sites), they should be lined to prevent ground water contamination. These facilities can reduce streambank erosion and flooding by temporarily detaining runoff before releasing it at flow rates and frequencies similar to those occurring under natural hydrologic conditions. These BMPs can be aesthetically designed and enhance wildlife habitat.

Detention BMPs may be either *wet* or *dry* and either aboveground (ponds) or belowground (tanks or vaults). A wet pond, as the name implies, maintains a permanent pool of water (dead storage) for run-off treatment purposes. In contrast, a dry facility does not contain this dead storage (except for a few inches for sediment storage) and is designed to dry out between storms.

A typical detention BMP configuration maintains a permanent pool of water as a dead storage area for treatment and a live storage area above the permanent pool to temporarily detain runoff for streambank erosion control. Wet detention BMPs that use a permanent pool of water are considered the most effective treatment BMPs. The permanent pond improves the removal efficiency for particulate pollutants in the following ways:

- Dissipating the inflow energy of the storm water as it enters the basin
- Preventing scour of material settled to the bottom
- Allowing exchange of incoming storm water with previously captured water, providing additional time between storms to settle pollutants

Wet detention BMPs that establish vegetation within the permanent pool volume can provide additional pollutant removal. The vegetation in shallow wetland (marsh) areas serves as a filtration medium for removing particulate pollutants. Aquatic plants in the permanent pool can assimilate dissolved pollutants. Biological uptake and/or transformation of pollutants and nutrients into less toxic materials can be an important means of pollutant removal.

Extended detention facilities can be used in cases where a permanent pool cannot be established and the pollutant removal efficiency of detention facilities can be improved by extending the detention period of the runoff from smaller, more frequent storms.

Sediments accumulating over long periods in a detention facility may contain high levels of toxic organic chemicals and require expensive disposal methods. To avoid this problem, regular inspection and maintenance should be scheduled. Testing may be done periodically after construction to verify that the maintenance schedule is working effectively.

Table 2 shows a comparative ability of 10 different pond and wetland systems.

BMPs that detain storm water runoff are as follows:

- BMP 18: Bioretention Basin
- BMP 22: Wet Pond
- BMP 23: Extended Detention Basin
- BMP 24: Constructed Wetlands
- BMP 25: Presettling/Sedimentation Basin
- BMP 26: Underground Detention Facilities

Other Structural Controls—Oil/water separators and other structural controls are installed as part of the piped storm water drainage system. These controls slow flows and allow both settling of particulates and separation of floatable materials and oil/grease. These controls can be used

for urbanized or industrial sites where land availability is low or for pretreatment preceding other types of storm water BMPs. Regular cleaning is essential to ensure effectiveness. This BMP works best when designed as an off-line device allowing high flows from large storm events to bypass the device without resuspending previously settled materials. These facilities have low pollutant removal capabilities and high maintenance requirements.

BMPs with oil/water separators and other structural controls are as follows:

- BMP 15: Oil and Water Separators
- BMP 16: Centrifugal or Vortex-Separation Structures
- BMP 30: Level Spreader

Table 2. Comparative ability of different pond and wetland systems.

Pond/Wetland Alternative	Minimum Drainage Area[a]	Space Index[b]	Water Balance	Clogging Risk	Sediment Cleanout (years)	Waters of United States (§404)	Stream Warming	Safety Risk
Conventional dry ponds	5	0.5	No restrictions	Moderate	Basin (10–20)	No	Low	Low
Dry ED ponds	10	1.0	No restrictions	High	Basin (10–20)	Yes	Moderate	Low
Micropool dry ED ponds	15	1.0	May require base flow	Low	Forebay (2–5)	Yes	Moderate	Low
Wet ponds	25+	1.0	Climate	Low	Forebay (2–5)	Yes	High	High
Wet ED ponds	25+	1.0	Climate	Low	Forebay (2–5)	Yes	High	High
Shallow marsh systems	25+	2.5	Climate, base flow	Low	Forebay (2–5)	Yes	High	Moderate
ED wetlands	10+	1.5	Climate, base flow	Low	Forebay (2–5)	Yes	High	Moderate
Pocket wetlands	1–5	2.0	Climate, ground water	Moderate	Basin (5–10)	No	Moderate	Moderate
Pocket ponds	1–5	1.0	Climate, ground water	Moderate	Basin (5–10)	No	Moderate	Moderate
Pond/marsh systems	25+	1.5	Climate, base flow	Low	Pool (10–15)	Yes	High	High

a. Maximum of 400 acres in most cases.
b. Space consumption index (1 = space required for wet pond).
Notes: Extended detention (ED)

3.5.3.2 Source Controls

Source control BMPs focus on minimizing or eliminating the source of the pollution so that pollutants, such as sediment, heavy metals, oil and grease, and toxic chemicals, are prevented from contacting runoff or entering the drainage system. Source controls are a cost-effective way to control storm water pollution on site so it is important to incorporate source controls into the site design. A source control BMP can be a structural component of a planned site (e.g., a covered area for material storage) or a procedural BMP. This BMP category applies to

municipal, commercial, industrial, and residential operations and activities. Some examples of source controls BMPs follow.

Municipal Operations—Communities regulated under Phase I or II of the NPDES program are required to conduct the following:

- Prevent or reduce the amount of polluted storm water generated by municipal operations.
- Educate employees to incorporate pollution prevention and good housekeeping practices into municipal operations.
- Identify BMPs and measurable goals to prevent or reduce the amount of polluted storm water that is generated by municipal operations.

Municipalities should develop and implement a good housekeeping program that is specific to the community. BMPs commonly applied to municipal operations include the following:

- BMP 75: Street Sweeping
- BMP 76: Storm Water System Cleaning
- BMP 80: Building and Grounds Maintenance
- BMP 84: Vehicle and Equipment Cleaning, Maintenance, and Repair
- BMP 86: Nonstorm Water Discharges to Drains
- BMP 91: Employee Training

Commercial Operations—Source controls for commercial operations focus on reducing the exposure of materials to rainfall and runoff and preventing hazardous materials from entering storm drainage systems. Commercial BMPs focus on good housekeeping, preventative maintenance, properly storing and handling materials, waste management, and employee training. BMPs commonly applied to commercial operations are as follows:

- BMP 50: Sanitary and Septic Waste Management
- BMP 51: Solid Waste Storage and Disposal
- BMP 77: Outdoor Storage
- BMP 80: Building and Grounds Maintenance
- BMP 83: Vehicle and Equipment Re-Fueling
- BMP 84: Vehicle and Equipment Cleaning, Maintenance, and Repair
- BMP 91: Employee Training
- BMP 92: Restaurant Control Practices
- BMP 93: Marinas

Industrial Controls—Industrial control BMPs are specific design features to consider when designing industrial facilities. Industrial sites can have more toxic pollutants on site compared to commercial or residential sites. Pollutants such as heavy metals, oil and grease, and toxic chemicals can be significant components of industrial storm water. Consequently, the BMPs used on an industrial site will be different from those used on a commercial or residential site. Source controls that reduce or remove toxic pollutants before they can enter runoff are especially important and most effective on industrial sites. Treatment controls are also important to remove pollution that is not completely prevented by source controls. BMPs in this category are not all inclusive but provide a starting point for planning. These BMPs should be used with best professional judgment and sound engineering practices. BMPs commonly applied to industrial controls include the following:

- BMP 46: Spill Prevention and Control
- BMP 48: Hazardous Materials Management
- BMP 50: Sanitary and Septic Waste Management
- BMP 51: Solid Waste Storage and Disposal
- BMP 77: Outdoor Storage
- BMP 80: Building and Grounds Maintenance
- BMP 81: Loading Dock Design Features
- BMP 82: Equipment Yard Design Features
- BMP 84: Vehicle and Equipment Cleaning, Maintenance, and Repair
- BMP 86: Nonstorm Water Discharges to Drains
- BMP 87: Outdoor Loading and Unloading of Materials
- BMP 88: Outdoor Process Equipment
- BMP 89: Contaminated Soil Management
- BMP 90: Building Repair, Remodeling, and Construction
- BMP 91: Employee Training

Residential Controls—Daily actions in and around homes have a profound effect on storm water quality. Small amounts of pollution from many different sources can significantly affect waterways and storm water systems. Yard maintenance, waste storage, car washing and maintenance, and pool cleaning are activities that can adversely impact water quality. BMPs applicable to residential activities are as follows:

- BMP 48: Hazardous Materials Management
- BMP 51: Solid Waste Storage and Disposal
- BMP 80: Building and Grounds Maintenance
- BMP 84: Vehicle and Equipment Cleaning, Maintenance, and Repair
- BMP 90: Building Repair, Remodeling, and Construction
- BMP 94: Swimming Pool and Spa Maintenance

3.5.3.3 Treatment Train

The goal in watershed management should be to reduce the pollutant load either through source control, which is the most effective, or through multistage treatment called a *treatment train*. Although individual BMPs may be less effective on a percent basis when part of a treatment train, if they cumulatively result in a lower effluent concentration (or load), they benefit the watershed. When planning source control and treatment control BMPs for a site, consider how the controls can be used together.

Multistage, combination, or treatment train facilities (i.e., several facilities in a row or series) can remove pollutants more effectively than individual source and treatment control BMPs. These BMPs can be designed so that upfront facilities pretreat the runoff, allowing the main device to function optimally. This concept also allows different mechanisms to clean different portions of the pollutant load. For example, sedimentation ponds are good at removing coarse and fine particulates if adequate detention time is provided, but they are not effective with dissolved pollutants. Multiple systems can provide additional secondary benefits such as controlling floods, enhancing fish and wildlife habitats, providing aesthetics and recreation, and complying with landscaping requirements.

Many treatment train options exist, but generally smaller BMPs are used as pretreatment and/or conveyance to larger BMPs. Using smaller BMPs as pretreatment adds the benefit of extending the maintenance intervals and useful life of the primary BMP. Examples of treatment train BMPs are as follows:

- Vegetated filter strips—sand filter or infiltration basin
- Grassed swales—dry extended detention pond, wet pond, or wetland
- Bioretention—dry extended detention pond or infiltration basins
- Manufactured products for storm water inlets or catch basins and catch basin inserts—dry extended detention ponds or infiltration basins

Structural control BMPs in treatment trains can improve both the water quality as well as total effluent volume, minimizing the effects on receiving waters. The most effective combinations are made between BMPs with different dominant pollutant removal mechanisms, such as integration of a sand filter (filtration) with a wet retention pond (sedimentation). Combining strong water quantity control BMPs (e.g., dry detention ponds) with strong water quality control BMPs (e.g., sand filters) also make effective treatment trains.

With some land uses, more than one treatment method may be needed. For example, if storm water runoff is expected to contain high oil concentrations, it may be necessary to use an oil/water separator to pretreat the water before it enters other treatment devices. Many jurisdictions require pretreatment in the form of solids removal or spill control by providing catch basins or gravity oil/water separators. These pretreatment measures are often used with detention and water quality treatment devices.

3.5.4 Mountainous Terrain and Cold Weather Climates

With 80 recognized mountain ranges, Idaho's vast areas are extremely rugged and experience very cold weather. The state can be divided geographically into three major land regions: Rocky Mountains, Columbia Plateau, and Basin and Ridge regions (Figure 2). The northern two-thirds of the state make up the Rocky Mountain region and consist of a mountain massif broken only by valleys carved by rivers, streams, and three prairies. The Columbia Plateau follows the Snake River across southern Idaho, and the Basin and Ridge region includes the land area in southeastern Idaho. Idaho's highest peak is Borah Peak at 12,662 feet and its lowest elevation is near the seaport of Lewiston at 710 feet. The mean elevation in Idaho is 5,000 feet above sea level.

Idaho's climate is equally diverse with plant hardiness zones ranging from 7A to 2B (Figure 2) with average annual minimum winter temperatures ranging from 5 to -45°F. In general, the northern portion of the state has greater precipitation than either southwestern or southeastern Idaho. For example, the annual mean precipitation in Coeur d'Alene located in the Idaho Panhandle is 25.7 inches whereas the annual mean precipitation in Twin Falls in southcentral Idaho is less than half that amount at 10.5 inches.

The following sections summarize modifications or adjustments that can be made to the design of BMPs to improve their effectiveness in Idaho's mountainous terrain and cold climate areas.

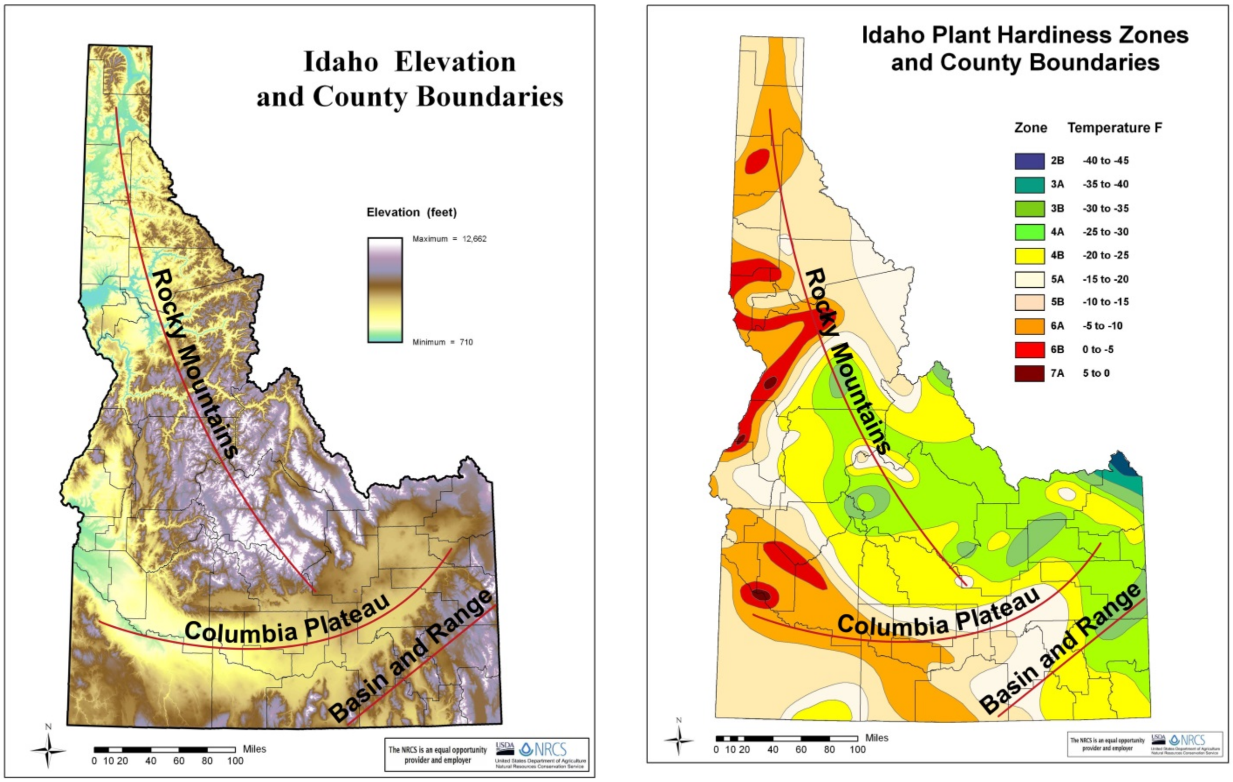


Figure 2. Idaho elevations (left) and plant hardiness zones (right) (NRCS 2017).

3.5.4.1 Mountainous Terrain BMPs

Mountainous terrain, as defined for this BMP, are locations where elevation is sufficient to affect temperature, precipitation, and species of vegetation present and has a compounding factor of steep slopes (greater than 3:1). The combination of these factors creates challenges for development, such as a shorter growing season, reduced selection of vegetation adapted to these conditions, significant differences in climate, often increased snow pack, snowmelt flowing down steep slopes, increased frost depths, significant seasonal subsurface flows, springs, unstable slopes after vegetation removal, and access challenges for equipment and materials due to switchback roads.

Steep slopes in particular can eliminate the use of many BMPs and reduce the effectiveness of others. Some BMPs can only be used on essentially level terrain (e.g., sedimentation basins, detention and wet ponds, and constructed wetlands). Steep slopes combined with erosion-prone soils can contribute to high rates of erosion and sedimentation when soils are disturbed, such as during new construction activities. Steep slopes require more complex engineering and the recommended BMPs are structural in nature, requiring less land space than facilities on flat sites.

For sites with steep slopes, include slope protection and vegetative controls on site to reduce erosion and sediment in site runoff. Investigate upstream conditions and eliminate any off-site sources of sediment from neighboring properties. After applying these measures, if high sediment loads are still unavoidable, select a detention facility that will initially treat the storm water through settling. Use storm water filters and vegetated detention only after pretreatment

settling has been applied to reduce the sediment load. Otherwise, excessive sediment may clog the infiltration facilities and damage vegetation.

Mountainous terrain is highly susceptible to erosion caused by storm water runoff. Removing trees and other vegetation combined with new impervious surfaces accelerates the rate of erosion. Accelerated erosion and improper surface water drainage can leave slopes susceptible to significant erosion or slope failure, endangering people and property. These areas are sensitive to development, so measures should be taken to control storm water runoff and erosion:

- Preserve 65% of a site in a forested or native condition for land development projects with steep slope zones. Ensure the effective impervious land surface draining into the native vegetation is less than 10% of the entire site.
- Due to the steepness of slopes, focus on infiltration BMPs rather than those requiring conveyance. Ensure that the infiltration area can accept the additional water without creating a slope failure. Consult a geotechnical engineer if construction could create a high risk situation to life, property, or the environment.
- Maintain native vegetation in a mountainous terrain to the maximum extent practicable (BMP 38) with limited disturbance for building foundations, driveways, and other impervious surfaces. Minimize site grading and the disturbance of steep slopes (BMP 3) to ensure predevelopment conditions are maintained. Preserve natural formations, existing trees, and grades to the maximum extent practicable (BMP 1). Vegetation types can reveal locations where subsurface flows, springs, or other sources of moisture are located. Protect native vegetation on these areas as much as possible to minimize erosion and preserve slope stability. Introduced vegetation species may not use as much water as the native species or may use water during the same times as the native species (BMP 8).
- Preserve natural channels and drainage waterways to the maximum extent practicable. Obtain permits for altering streams and filling wetlands. This step ensures the work will be done without impacting downstream users, culverts are properly sized, and the improvement is a sustainable feature.
- Do not alter or obstruct the natural flow of surface or subsurface water with grade changes that may adversely affect adjacent property by pooling or collecting water or by concentrating or intensifying surface water discharge.
- Perform and stabilize all land disturbance activities in mountainous terrain in the shortest practical period of time. Remove all excess excavated materials from the steep slope zone. Temporary or permanent storage of material within the steep slope zone can endanger life and property without sufficient engineering controls.
- Grading, construction, or storage of materials and equipment should be contained within the limits of construction activity (BMP 39).

Grading recommendations for mountainous terrain sites include the following:

- In place of silt fence, use stabilized earthen berms (BMP 70) reseeded on the downhill side or appropriately sized wattles/sediment tubes in steep slope zones.
- Establish interception ditches or diversion dikes (BMP 69) outside of a steep slope zone so soil is not saturated and the intercepted water is conveyed to the bottom of a slope to minimize erosion.
- Stabilize natural drainage ways by landscape integration, stone, rolled erosion control products, or other means consistent with professional engineering practice (BMP 61).

Ensure this stabilization continues below drainage and culvert discharge points to convey the discharge while minimizing channel erosion by using energy dissipation devices (BMP 35).

- Use retaining walls (BMP 34) to preserve natural grade and site features, to prevent unnatural grading that does not mimic the natural landscape, and to prevent erosion. Taller retaining wall heights may require using smaller stepped walls that provide the height needed to match surrounding slopes and to create planting terraces. Retaining walls have a maximum height of 8 feet. Two or more terraced walls not exceeding 10 feet in height combined may also be used (Greenville County 2013).

3.5.4.2 Cold Weather Climate Modifications

The impact of cold weather climates should also be considered when selecting BMPs for a development or redevelopment project (Table 3). Low temperatures, deep frost penetration, short growing seasons, and significant snowfall can negatively impact the BMP's effectiveness due to pipe freezing, ice cover on ponds, reduced biological activity, reduced settling velocities, reduced infiltration in frozen soil, high runoff, high pollutant loads, and reduced storage volumes. Many cold weather challenges can be overcome with appropriate BMP design modifications and proper installation and maintenance. Scheduling construction around predictable runoff events and during the warmer and dryer seasons is an important consideration for storm water management of development projects in cold weather climates.

Table 3. Challenges to the design of runoff management practices in cold climates (Caraco and Claytor 1997).

Climatic Condition	BMP Design Challenge
Cold temperatures	Pipe freezing Permanent pool ice covered Reduced biological activity Reduced oxygen levels during ice cover Reduced settling velocities
Deep frost line	Frost heaving Reduced soil infiltration Pipe freezing
Short growing season	Short time period to establish vegetation Different plant species appropriate to cold climates than moderate climates
Significant snowfall	High runoff volumes during snowmelt and rain-on-snow High pollutant loads during spring melt Other impacts of road salt/deicers Snow management may affect BMP storage

BMPs, such as infiltration trenches (BMP 17), bioinfiltration swales (BMP 10), and permeable pavements (BMP 19), can be successful in cold climates if they are designed, installed, and maintained properly. BMPs, such as rain gardens or bioretention basins (BMP 18) and storm water planters (BMP 21), improve water quality primarily during the growing season, which can be short in cold weather climates but can still provide sump areas for snow storage and infiltration during spring melt. Plants appropriate for the growing season and climate at the site should be considered for all BMPs that include landscaping. Consider the growing season when timing seeding in cold climates.

Filtering BMPs—All filtering BMPs rely on the ability of water to flow through a filtering medium. In frozen conditions, system efficiency is reduced, particularly for surface filters. Seasonal performance evaluations indicate that filtration BMPs designed and maintained properly differ minimally from summer to winter (Roseen et al. 2009). The following general guidelines determine BMP feasibility:

- Surface sand filters (BMP 12) will not provide treatment during the winter season in areas with long, cold winters.
- Underground filters may not be effective during the winter season unless the filter bed is placed below the frost line. In regions with very deep frost lines (i.e., deeper than 6 feet), this may not be practical.
- Media filters (BMP 14) are ineffective during the winter in cold climates. These filters retain water and can freeze solid, becoming completely impervious during the winter.

The following modifications are recommended for conveyance systems used in cold climates to prevent freezing of the system and filter:

- Minimum underdrain diameter of 8 inches except for submerged gravel wetlands; by increasing the diameter of the underdrain, freezing is less likely. The larger diameter pipe also increases the drain capacity, prevents the filtering media from becoming saturated, and decreases the impact of freezing.
- Underdrain slope greater than 1%—Increases the velocity of flow passing through the underdrain system and reduces the risk of freezing and clogging.
- Minimum of 18 inches gravel base—Prevents standing water in the system and is less susceptible to frost heaving than finer grained media.
- Inflow pipes at least 2% slope and 12 inches in diameter.
- Replace standpipes with weirs—For filters placed above the freeze line, standpipes are more susceptible to freezing than weirs. Weirs also provide retention storage.

These design modifications encourage rapid draining of the filter media to retain storage and filtering capacity, prevent damage from freezing, and prevent frost damage.

Infiltration BMPs—Porous pavement (BMP 19), infiltration trenches (BMP 17), and bioretention basins (BMP 18) pose challenges in cold climates due to potential for frozen underlying soils or porous media and maintenance and contamination concerns with winter sanding and salting. However, infiltration systems are effective under cold climate conditions if adequately maintained to ensure their effective performance (MCPA 2015).

Design modifications for infiltration systems include the following:

- Porous pavement should not be sanded, and a maintenance agreement should be in place that includes vacuum sweeping and inspection in the spring to prevent clogging.
- Infiltration trenches and basins should not be used in regions with permafrost and should not be used to infiltrate road or parking lot snowmelt due to potential chloride contamination of ground water from salt application. If an infiltration practice is used, design infiltration rate requirements should be increased.

Ponds and Basins—Pond systems (BMPs 22, 23, and 25) can perform well in cold climates because many modification options are available to increase their effectiveness in frigid and snowy conditions. Inlets, outlet structures, and outfall protection for pond systems require

modifications to function well in cold climates. Most of these modifications address the problems associated with pipe freezing.

Modifications to inlets include the following guidelines:

- Bury inlets below the frost line to prevent frost heave and pipe freezing.
- Use pipe slope greater than 1 to prevents standing water in the pipe and reduce the potential for ice formation.
- Use a minimum diameter of 15 inches or 18 inches for low relief areas to reduce the likelihood of ice blocking the pipe and provide a larger flow area if icing occurs.
- Overexcavate and backfill with gravel or sand to protect against frost heaving.
- Avoid submerged inlet pipes to prevent upstream flooding if permanent water storage in submerged pipes freezes.
- Use insulation to prevent freezing pipes and frost heaving by creating a temperature barrier between the pipes and frozen ground.
- Use pretreatment for *online ponds* that receive flows from all storms and baseflow events to create continuous movement of the baseflow through a pond system and discourage ice build-up.

Modifications to outlets include the following guidelines:

- Perforated riser pipes should have a minimum orifice diameter of 0.5 inches with a minimum pipe diameter of 6 inches.
- Solid riser pipes shall be a minimum of 18 inches in diameter and be placed within the embankment.
- Concrete riser low flow outlet pipes shall have a 6-inch minimum diameter to prevent freezing. Concrete risers shall be placed in the embankment to prevent frost heave and to protect pipes within the riser from freezing.
- Outlet pipes shall be buried below the frost line if practicable.

Constructed Wetlands—Many of the cold climate modifications are similar to those of ponds and basins, and modifications in this section are additions. For pretreatment purposes, the forebay to a constructed wetland (BMP 24) should be increased by 0.25 inches per impervious acre. A weir system to separate the forebay from the wetland further enhances the performance of the forebay.

To enhance treatment in cold climate areas, the following modifications may be made to constructed wetlands:

- Design with extended detention storage for a minimum of 25% of the total storage volume.
- Ensure at least 50% of storage is in deep pool areas, which allows the wetland to retain much of its permanent pool during the winter, while the shallow marsh may be completely filled with ice.

3.5.5 Mosquito Control

This section discusses storm water management measures designed to eradicate or control mosquito habitat and prevent the spread of diseases carried by mosquitoes. Concerns have been

raised about disease vectors associated with structural storm water BMPs. The mosquito is known to be a potential carrier of the West Nile virus. Various studies have found that some structural water quality BMPs can support mosquito populations. The significance of these BMPs as a risk of West Nile virus is debatable, and many municipalities determined that further action is not required. However, if a municipality determines that further efforts to control mosquito production in structural BMPs are needed, certain measures can be taken while still maintaining compliance with the requirements of federal storm water regulations.

For mosquitoes to breed, specific conditions must be present. A mosquito's life cycle consists of four stages: egg, larvae, pupa, and adult. Mosquitoes must lay their eggs in stagnant water, or on damp soil that will soon be flooded with water. Mosquitoes need water to breed as all mosquitoes spend their larval and pupal states in water. Most mosquitoes breed in temporary standing waters that are less than 1 foot deep where nutrients are available for feeding, and the water temperature is acceptable. It will take 24–48 hours for the eggs to hatch into larvae. The larvae and pupa must have standing water to survive, and this stage typically takes 5 to 18 days before maturation into an adult mosquito (Floore 2002).

To prevent mosquitoes, most sources indicate that water should not remain stagnant for over 48 hours, which is a conservative estimate. When a new storm water BMP is installed, a design that does not rely on extended retention of storm water without flushing (exceeding 48 hours) should be considered. Many options for structural control BMPs can meet these criteria, including grass swales, porous pavement, landscape detention, extended detention basins, sand filters, and reducing directly connected impervious areas. Proper design and maintenance ensure that BMPs continue to operate as intended to prevent stagnant water being available for mosquito production. Designing BMPs with the proper slope, using easily accessed forebays to allow for removal of accumulated materials, and adequately inspecting and maintaining basins are some key practices to consider.

For existing basins with storm water retention sufficient to promote mosquito production, these designs could be retrofitted for complete drainage over a shorter time period. However, the first step is to determine if the BMP in its current state is promoting mosquito production.

For wet detention basins or wetlands where retrofitting is not an option, stocking BMPs with a population of minnows is recommended. A healthy population of minnows will feed on the mosquito larvae and prevent them from reaching the hatching stage. Only native minnow species should be used. Contact the Idaho Department of Fish and Game for stocking and species information. Other natural predators of mosquitoes include birds, dragonflies, bats, aquatic insects, fish, and spiders.

3.5.5.1 BMP Design for Mosquito Control

New storm water management structures that may foster mosquito propagation include the vegetative fringe encircling ponds where mosquitoes breed and avoid predators; shallow or semipermanent ponds such as catch basins and riprap settling basins; structures that take longer to drain than they are designed to; and pools of water in storm drains. These areas can create stagnant water without a resident predator population to keep mosquitoes under control naturally. In site design, take site-specific conditions into account so storm water runoff does not pool and stagnate on the site.

Permanent Pool Design—When designing a permanent pool, two methods are used to reduce mosquito propagation: minimizing shallow depths (1 foot or less) and increasing circulation in ponds. Deep pools of water are preferable to shallow ones for mosquito control. Wet ponds and man-made wetlands should be designed to support continuous water flow to prevent stagnation and vegetative growth. Prevent shallow water by steeply grading both banks of the pond and impoundment. Include mechanical aerators in wet ponds, such as a fountain in the middle of a pond, which makes the site more attractive, deters the growth of unwanted vegetation, and improves the habitat for predators of mosquitoes. The principal outlet, such as a weir or riser, should have positive drainage, such as a 0.1-foot vertical drop from the low flow inlet to the outlet barrel. *Inlet shaping* should be used in risers and junctions. The inlet shaping (or sweep) construction method installs concrete at a curve at the junctions of drop inlets or risers and storm sewer pipe to maintain hydraulic efficiency of the risers and pipes and prevent stagnant pools of water.

Temporary Impoundments—Take special care for ponds that temporarily impound water. Some storm water management measures, such as dry ponds and man-made wetlands, pond water for an extended period. These facilities must drain completely within 30 hours of the storm event to prevent mosquito propagation. The bottoms of the ponds must have positive drainage and be free of depressions. Avoid placing dry ponds and underground structures in areas where they are likely to remain wet (i.e., high water tables). Ensure that pond bottoms have a low flow channel and a minimum of 1% to 2% bottom slope to prevent stagnation. If water quality orifices are required in the principal outlet structure, ensure that the minimum size is greater than 2 to 3 inches to prevent clogging and stagnant pools of water ponding at the outlet structure. Manufactured methods are available to prevent the primary water quality outlet from clogging without restricting the hydraulic capacity of the outlet control orifices, including installation of trash racks.

3.5.6 BMP Selection Matrix

Table 4 shows site selection criteria and restrictions for each BMP. Use this table to get a sense of the BMPs that could be appropriate for your site. The table also shows which BMPs should be eliminated from further consideration due to restrictive site-specific conditions. The table indicates the expected pollutant removal effectiveness for typical pollutants of concern in urban storm water runoff such as sediment, phosphorus, trace metals (e.g., lead, copper, and cadmium), bacteria, and petroleum hydrocarbons (e.g., gasoline, oil, and grease). Estimated values are provided for phosphorus and sediment removal for most of the permanent BMPs, based on available data from other areas. For the other pollutants, a more qualitative estimate is provided.

The following describes the information presented in Table 4:

- Targeted pollutants——A full circle on the table indicates that the BMP is very effective at controlling the pollutant (70% or greater of the pollutants may be removed). A half-filled circle represents moderate effectiveness (greater than or equal to 30% and less than 70% of the pollutants may be removed). An empty circle indicates little or no effectiveness (less than 30% of the pollutants may be removed).
- Drainage area—The maximum contributing drainage area for the BMP.
- Maximum slope—The maximum allowable site slope for placing the BMP.

- Minimum depth to bedrock—The minimum allowable depth to bedrock for placing a BMP on a site.
- Depth to high water table—The minimum allowable depth to the high water table for locating a BMP on a site.
- NRCS soil group—Soil group is classified as A, B, C or D. Group A has the best infiltration rate (e.g., sands), while Group D allows little or no infiltration (e.g., clays). The BMP is best suited for the soil groups given on the table.
- Use with freeze/thaw cycle—BMP performance during the winter and spring freeze/thaw cycles are indicated as good, fair, or poor.
- Drainage/flood control—A checkmark in this column of the table indicates that the BMP can be used to provide drainage and flood control as well as water quality control.
- Expected life—The expected life span of the BMP. The numbers shown represent industry guidelines; the actual life expectancy depends on proper design, placement, and maintenance of BMPs.

Table 4. BMP selection matrix.

BMP Number	BMP Description	BMP Function	BMP Control	Targeted Pollutants[a]							Physical Constraints						
				Sediment	**Nitrogen**	**Phosphorus**	**Metals**	**Bacteria**	**Hydro-carbons**	**Litter**	**Maximum Tributary Drainage Area (acres)**	**Maximum Upstream Slope (%)**	**Minimum Bedrock Separation (feet)**	**Minimum Ground Water Separation (feet)**	**NRCS Soil Type[b]**	**Freeze/ Thaw Resistance**	**Filtration/ Infiltration**
1	Minimize land disturbance	☒ Construction ☒ Permanent ☐ Structural ☐ Nonstructural	☒ Erosion ☐ Sediment ☐ Source ☐ Flood	●	NA	◖	◖	○	○	○	NA	NA	NA	NA	ABCD	Good	—
2	Provide natural buffers	☒ Construction ☒ Permanent ☐ Structural ☐ Nonstructural	☒ Erosion ☒ Sediment ☐ Source ☐ Flood	●	NA	◖	○	○	○	○	NA	25	NA	NA	ABCD	Good	Filtration
3	Minimize disturbance of steep slopes	☒ Construction ☒ Permanent ☐ Structural ☐ Nonstructural	☒ Erosion ☐ Sediment ☐ Source ☐ Flood	●	NA	◖	◖	○	○	○	NA	NA	NA	NA	ABCD	Good	—
4	Manage impervious surfaces–disconnect and reduce	☐ Construction ☒ Permanent ☐ Structural ☐ Nonstructural	☒ Erosion ☐ Sediment ☐ Source ☐ Flood	●	NA	◖	◖	○	○	○	NA	NA	NA	NA	ABCD	Good	Infiltration
5	Reduce roadway/ sidewalk surface areas	☐ Construction ☒ Permanent ☐ Structural ☐ Nonstructural	☒ Erosion ☐ Sediment ☐ Source ☐ Flood	●	NA	◖	◖	○	○	○	NA	NA	NA	NA	ABCD	Good	Infiltration
6	Green streets and parking	☐ Construction ☒ Permanent ☐ Structural ☐ Nonstructural	☒ Erosion ☒ Sediment ☐ Source ☐ Flood	●	NA	◖	◖	○	○	○	NA	NA	NA	NA	ABCD	Good	Both
7	Soil restoration/ enhancement	☐ Construction ☒ Permanent ☐ Structural ☐ Nonstructural	☒ Erosion ☐ Sediment ☐ Source ☐ Flood	●	NA	●	◖	◖	◖	○	5	30	6	3	ABCD	Good	Both

BMP Number	BMP Description	BMP Function	BMP Control	Targeted Pollutants[a]							Physical Constraints						
				Sediment	Nitrogen	Phosphorus	Metals	Bacteria	Hydro-carbons	Litter	Maximum Tributary Drainage Area (acres)	Maximum Upstream Slope (%)	Minimum Bedrock Separation (feet)	Minimum Ground Water Separation (feet)	NRCS Soil Type[b]	Freeze/ Thaw Resistance	Filtration/ Infiltration
8	Vegetation restoration	☒ Construction ☒ Permanent ☐ Structural ☐ Nonstructural	☒ Erosion ☒ Sediment ☐ Source ☒ Flood	●	○	○	○	○	○	○	NA	NA	NA	NA	ABC	NA	Infiltration
9	Vegetated (biofiltration) swale	☐ Construction ☒ Permanent ☐ Structural ☐ Nonstructural	☐ Erosion ☒ Sediment ☐ Source ☐ Flood	◐	NA	○	◐	○	◐	○	15	6	3	3	BC	Fair	Filtration
10	Bioinfiltration swale	☐ Construction ☒ Permanent ☐ Structural ☐ Nonstructural	☐ Erosion ☒ Sediment ☐ Source ☒ Flood	●	NA	◐	◐	◐	◐	◐	5	4	6	3	AB	Fair	Both
11	Vegetated filter strip	☐ Construction ☒ Permanent ☐ Structural ☐ Nonstructural	☐ Erosion ☒ Sediment ☐ Source ☐ Flood	◐	NA	◐	◐	○	◐	◐	5	6	5	3	ABC	Good	Filtration
12	Sand filter	☒ Construction ☒ Permanent ☐ Structural ☐ Nonstructural	☐ Erosion ☒ Sediment ☐ Source ☐ Flood	●	○	◐	●	◐	●	●	5–50	10	3	3	NA	Fair	Both
13	Catch-basin insert	☒ Construction ☒ Permanent ☐ Structural ☐ Nonstructural	☐ Erosion ☒ Sediment ☐ Source ☐ Flood	●	○	○	◐	○	◐	●	0.1	NA	NA	NA	NA	Good	Filtration
14	Media filters	☐ Construction ☒ Permanent ☐ Structural ☐ Nonstructural	☐ Erosion ☒ Sediment ☐ Source ☐ Flood	●	NA	◐	◐	◐	◐	○	1	NA	NA	NA	NA	Fair	Filtration
15	Oil and water separators	☐ Construction ☒ Permanent ☐ Structural ☐ Nonstructural	☐ Erosion ☒ Sediment ☒ Source ☐ Flood	○	○	○	◐	○	●	◐	12	15	8	8	ABC	Fair	Filtration

BMP Number	BMP Description	BMP Function	BMP Control	Targeted Pollutants[a]							Physical Constraints						
				Sediment	Nitrogen	Phosphorus	Metals	Bacteria	Hydro-carbons	Litter	Maximum Tributary Drainage Area (acres)	Maximum Upstream Slope (%)	Minimum Bedrock Separation (feet)	Minimum Ground Water Separation (feet)	NRCS Soil Type[b]	Freeze/ Thaw Resistance	Filtration/ Infiltration
16	Centrifugal or vortex-separation structures	☐ Construction ☒ Permanent ☐ Structural ☐ Nonstructural	☐ Erosion ☒ Sediment ☒ Source ☐ Flood	●	NA	○	◖	○	●	●	Varies	NA	NA	NA	ABCD	Fair	Filtration
17	Infiltration trench	☐ Construction ☒ Permanent ☐ Structural ☐ Nonstructural	☐ Erosion ☒ Sediment ☐ Source ☐ Flood	●	NA	◖	●	●	○	○	5	20	4	3	AB	Fair	Infiltration
18	Bioretention basin	☐ Construction ☒ Permanent ☐ Structural ☐ Nonstructural	☐ Erosion ☒ Sediment ☐ Source ☒ Flood	●	NA	●	◖	◖	◖	○	5	25	6	3	ABCD	Fair	Infiltration
19	Porous pavement	☐ Construction ☒ Permanent ☐ Structural ☐ Nonstructural	☐ Erosion ☐ Sediment ☒ Source ☒ Flood	●	○	●	●	Unknown	●	○	Unlimited	10	NA	2	ABCD	Fair	Both
20	Vegetated roofs	☐ Construction ☒ Permanent ☐ Structural ☐ Nonstructural	☐ Erosion ☐ Sediment ☒ Source ☐ Flood	○	○	○	○	○	○	○	NA	25	NA	NA	NA	Good	Filtration
21	Storm water planters	☐ Construction ☒ Permanent ☐ Structural ☐ Nonstructural	☐ Erosion ☒ Sediment ☒ Source ☒ Flood	●	○	○	◖	◖	●	○	<1	8	5	5	ABCD	Fair	Both
22	Wet pond	☐ Construction ☒ Permanent ☐ Structural ☐ Nonstructural	☐ Erosion ☒ Sediment ☐ Source ☐ Flood	●	NA	◖	◖	◖	◖	○	400	15	3	3	CD	Fair	—
23	Extended detention basin	☐ Construction ☒ Permanent ☐ Structural ☐ Nonstructural	☐ Erosion ☒ Sediment ☐ Source ☒ Flood	●	NA	○	◖	○	◖	○	400	15	3	3	ABCD	Good	—

BMP Number	BMP Description	BMP Function	BMP Control	Targeted Pollutants[a]							Physical Constraints						
				Sediment	**Nitrogen**	**Phosphorus**	**Metals**	**Bacteria**	**Hydro-carbons**	**Litter**	**Maximum Tributary Drainage Area (acres)**	**Maximum Upstream Slope (%)**	**Minimum Bedrock Separation (feet)**	**Minimum Ground Water Separation (feet)**	**NRCS Soil Type[b]**	**Freeze/ Thaw Resistance**	**Filtration/ Infiltration**
24	Constructed wetlands	☐ Construction ☒ Permanent ☐ Structural ☐ Nonstructural	☐ Erosion ☒ Sediment ☐ Source ☒ Flood	●	NA	◖	◖	○	◖	○	50	15	3	3	CD	Fair	—
25	Presettling/ sedimentation basin	☐ Construction ☒ Permanent ☐ Structural ☐ Nonstructural	☐ Erosion ☒ Sediment ☐ Source ☐ Flood	◖	NA	○	◖	○	○	◖	10	15	3	3	ABCD	Good	—
26	Underground detention facilities	☐ Construction ☒ Permanent ☐ Structural ☐ Nonstructural	☐ Erosion ☒ Sediment ☐ Source ☒ Flood	●	NA	◖	◖	○	○	○	5	15	2	2	ABC	Fair	—
27	Rainwater harvesting and reuse	☐ Construction ☒ Permanent ☐ Structural ☐ Nonstructural	☐ Erosion ☐ Sediment ☐ Source ☒ Flood	◖	NA	◖	◖	◖	◖	○	NA	NA	NA	NA	NA	Fair	—
28	Conveyance furrows for roof runoff	☐ Construction ☒ Permanent ☐ Structural ☐ Nonstructural	☒ Erosion ☒ Sediment ☐ Source ☐ Flood	●	NA	◖	◖	○	○	○	<10,000 ft^2	25	6	3	ABCD	Good	Both
29	Dispersal trench for roof runoff	☐ Construction ☒ Permanent ☐ Structural ☐ Nonstructural	☒ Erosion ☐ Sediment ☒ Source ☒ Flood	○	○	○	○	○	○	○	7,500 ft^2	20	3	3	ABC	Fair	Infiltration
30	Level spreader	☐ Construction ☒ Permanent ☐ Structural ☐ Nonstructural	☒ Erosion ☐ Sediment ☐ Source ☐ Flood	○	○	○	○	○	○	○	5	1	NA	NA	BCD	Fair	—
31	Topsoiling	☐ Construction ☒ Permanent ☐ Structural ☐ Nonstructural	☒ Erosion ☐ Sediment ☐ Source ☐ Flood	◖	○	○	○	○	○	○	Unlimited	50	2	3	ABCD	Fair	—

BMP Number	BMP Description	BMP Function	BMP Control	Targeted Pollutants[a]							Physical Constraints						
				Sediment	Nitrogen	Phosphorus	Metals	Bacteria	Hydro-carbons	Litter	Maximum Tributary Drainage Area (acres)	Maximum Upstream Slope (%)	Minimum Bedrock Separation (feet)	Minimum Ground Water Separation (feet)	NRCS Soil Type[b]	Freeze/ Thaw Resistance	Filtration/ Infiltration
32	Landscaping	☒ Construction ☒ Permanent ☐ Structural ☐ Nonstructural	☒ Erosion ☒ Sediment ☐ Source ☐ Flood	◖	○	◖	◖	○	○	○	Unlimited	Varies	3	3	ABCD	Good	Filtration
33	Gabions	☐ Construction ☒ Permanent ☐ Structural ☐ Nonstructural	☒ Erosion ☐ Sediment ☐ Source ☐ Flood	◖	○	○	○	○	○	○	Unlimited	40	NA	2	ABCD	Good	—
34	Retaining walls	☐ Construction ☒ Permanent ☐ Structural ☐ Nonstructural	☒ Erosion ☐ Sediment ☐ Source ☐ Flood	◖	○	○	○	○	○	○	Unlimited	67	NA	3	ABCD	Fair	—
35	Energy dissipation devices	☒ Construction ☒ Permanent ☐ Structural ☐ Nonstructural	☒ Erosion ☐ Sediment ☐ Source ☐ Flood	◖	○	○	○	○	○	○	5	10	NA	NA	ABCD	Good	—
36	Construction timing	☒ Construction ☐ Permanent ☐ Structural ☐ Nonstructural	☒ Erosion ☒ Sediment ☐ Source ☐ Flood	●	NA	●	◖	○	○	○	NA	NA	NA	NA	ABCD	NA	—
37	Staging areas	☒ Construction ☐ Permanent ☐ Structural ☐ Nonstructural	☐ Erosion ☒ Sediment ☒ Source ☐ Flood	●	NA	◖	◖	◖	◖	◖	NA	NA	NA	NA	ABCD	Good	—
38	Preserve topsoil and vegetation	☒ Construction ☐ Permanent ☐ Structural ☐ Nonstructural	☒ Erosion ☐ Sediment ☐ Source ☐ Flood	●	NA	○	○	○	○	○	NA	NA	NA	NA	ABCD	Good	—
39	Clearing limits	☒ Construction ☐ Permanent ☐ Structural ☐ Nonstructural	☒ Erosion ☐ Sediment ☐ Source ☐ Flood	●	NA	◖	◖	○	○	◖	NA	NA	NA	NA	ABCD	Good	—

				Targeted Pollutants[a]							**Physical Constraints**						
BMP Number	**BMP Description**	**BMP Function**	**BMP Control**	**Sediment**	**Nitrogen**	**Phosphorus**	**Metals**	**Bacteria**	**Hydro-carbons**	**Litter**	**Maximum Tributary Drainage Area (acres)**	**Maximum Upstream Slope (%)**	**Minimum Bedrock Separation (feet)**	**Minimum Ground Water Separation (feet)**	**NRCS Soil Type**[b]	**Freeze/ Thaw Resistance**	**Filtration/ Infiltration**
40	Vehicle sediment control	☒ Construction ☐ Permanent ☐ Structural ☐ Nonstructural	☐ Erosion ☒ Sediment ☐ Source ☐ Flood	●	NA	○	○	○	○	○	NA	15	NA	NA	ABCD	Good	—
41	Stabilized construction roads and staging areas	☒ Construction ☐ Permanent ☐ Structural ☐ Nonstructural	☒ Erosion ☒ Sediment ☐ Source ☐ Flood	●	NA	○	○	○	○	○	NA	15	3	NA	ABCD	Good	—
42	Erosion prevention on construction roads	☒ Construction ☐ Permanent ☐ Structural ☐ Nonstructural	☒ Erosion ☒ Sediment ☐ Source ☐ Flood	●	NA	○	○	○	○	○	5	15	3	NA	ABCD	Good	—
43	Dust control	☒ Construction ☐ Permanent ☐ Structural ☐ Nonstructural	☒ Erosion ☐ Sediment ☐ Source ☐ Flood	●	NA	○	◐	○	◐	○	NA	NA	NA	NA	ABCD	Good	—
44	Stockpile management	☒ Construction ☐ Permanent ☐ Structural ☐ Nonstructural	☒ Erosion ☐ Sediment ☒ Source ☐ Flood	●	NA	◐	◐	○	○	◐	NA	NA	NA	NA	ABCD	Good	—
45	Minimize soil compaction	☒ Construction ☐ Permanent ☐ Structural ☐ Nonstructural	☐ Erosion ☐ Sediment ☐ Source ☐ Flood	○	NA	○	○	○	○	○	NA	NA	NA	NA	ABCD	Good	Infiltration
46	Spill prevention and control	☒ Construction ☐ Permanent ☐ Structural ☐ Nonstructural	☐ Erosion ☐ Sediment ☒ Source ☐ Flood	○	NA	○	●	○	●	○	NA	NA	NA	NA	NA	Good	—
47	Construction equipment washing and maintenance	☒ Construction ☐ Permanent ☐ Structural ☐ Nonstructural	☐ Erosion ☒ Sediment ☐ Source ☐ Flood	●	NA	●	◐	○	◐	○	NA	5	NA	NA	ABCD	Good	—

BMP Number	BMP Description	BMP Function	BMP Control	Targeted Pollutants[a]							Physical Constraints						
				Sediment	Nitrogen	Phosphorus	Metals	Bacteria	Hydro-carbons	Litter	Maximum Tributary Drainage Area (acres)	Maximum Upstream Slope (%)	Minimum Bedrock Separation (feet)	Minimum Ground Water Separation (feet)	NRCS Soil Type[b]	Freeze/ Thaw Resistance	Filtration/ Infiltration
48	Hazardous materials management	☒ Construction ☒ Permanent ☐ Structural ☐ Nonstructural	☐ Erosion ☐ Sediment ☒ Source ☐ Flood	○	NA	◐	◐	◐	●	◐	NA	NA	NA	NA	ABCD	NA	—
49	Concrete waste management	☒ Construction ☐ Permanent ☐ Structural ☐ Nonstructural	☐ Erosion ☐ Sediment ☒ Source ☐ Flood	○	NA	○	●	○	○	○	NA	NA	NA	3	ABCD	Good	—
50	Sanitary and septic waste management	☒ Construction ☐ Permanent ☐ Structural ☐ Nonstructural	☐ Erosion ☐ Sediment ☒ Source ☐ Flood	○	NA	○	○	●	○	●	NA	NA	NA	NA	NA	NA	—
51	Solid waste storage and disposal	☒ Construction ☒ Permanent ☐ Structural ☐ Nonstructural	☐ Erosion ☐ Sediment ☒ Source ☐ Flood	○	NA	○	○	●	○	●	NA	NA	NA	NA	ABCD	NA	—
52	Mulching	☒ Construction ☐ Permanent ☐ Structural ☐ Nonstructural	☒ Erosion ☒ Sediment ☐ Source ☐ Flood	◐	NA	◐	○	○	○	○	2	50 (conventional) 15 (hydromulch)	NA	NA	ABCD	Good	—
53	Geotextile	☒ Construction ☒ Permanent ☐ Structural ☐ Nonstructural	☒ Erosion ☐ Sediment ☐ Source ☐ Flood	●	○	○	◐	○	○	○	100	50	NA	NA	ABCD	Good	—
54	Matting	☒ Construction ☐ Permanent ☐ Structural ☐ Nonstructural	☒ Erosion ☐ Sediment ☐ Source ☐ Flood	●	NA	○	◐	○	◐	○	100	100	2	NA	ABCD	Good	—
55	Soil binders	☒ Construction ☐ Permanent ☐ Structural ☐ Nonstructural	☒ Erosion ☐ Sediment ☐ Source ☐ Flood	◐	○	○	○	○	○	○	Unlimited	NA	NA	NA	ABCD	Fair	—

BMP Number	BMP Description	BMP Function	BMP Control	Targeted Pollutants[a]							Physical Constraints						
				Sediment	Nitrogen	Phosphorus	Metals	Bacteria	Hydro-carbons	Litter	Maximum Tributary Drainage Area (acres)	Maximum Upstream Slope (%)	Minimum Bedrock Separation (feet)	Minimum Ground Water Separation (feet)	NRCS Soil Type[b]	Freeze/ Thaw Resistance	Filtration/ Infiltration
56	Riprap slope protection	☐ Construction ☒ Permanent ☐ Structural ☐ Nonstructural	☒ Erosion ☐ Sediment ☐ Source ☐ Flood	◐	○	○	○	○	○	◐	5	40	NA	NA	ABCD	Good	—
57	Pipe slope drain	☒ Construction ☒ Permanent ☐ Structural ☐ Nonstructural	☒ Erosion ☐ Sediment ☐ Source ☐ Flood	◐	○	○	○	○	○	○	10	5	5	2	ABCD	Good	—
58	Slope roughening	☒ Construction ☐ Permanent ☐ Structural ☐ Nonstructural	☒ Erosion ☐ Sediment ☐ Source ☐ Flood	◐	○	○	○	○	○	○	1	20	3	5	BCD	Good	—
59	Gradient terracing	☐ Construction ☒ Permanent ☐ Structural ☐ Nonstructural	☒ Erosion ☒ Sediment ☐ Source ☒ Flood	◐	○	○	○	○	○	○	10	5	6	8	BCD	Good	—
60	Check dams	☒ Construction ☒ Permanent ☐ Structural ☐ Nonstructural	☐ Erosion ☒ Sediment ☐ Source ☒ Flood	●	NA	○	◐	○	◐	○	4	50	2	NA	ABCD	Good	—
61	Channel liners	☒ Construction ☒ Permanent ☐ Structural ☐ Nonstructural	☒ Erosion ☐ Sediment ☐ Source ☐ Flood	●	NA	○	○	○	○	○	Varies	Varies	NA	NA	NA	Good	—
62	Temporary stream crossing	☒ Construction ☐ Permanent ☐ Structural ☐ Nonstructural	☐ Erosion ☒ Sediment ☐ Source ☒ Flood	●	NA	○	◐	○	◐	○	5	25	6	NA	ABCD	Good	—
63	Biofilter bags	☒ Construction ☐ Permanent ☐ Structural ☐ Nonstructural	☒ Erosion ☒ Sediment ☐ Source ☐ Flood	◐	○	○	○	○	○	◐	NA	10	NA	NA	ABCD	Fair	Filtration

BMP Number	BMP Description	BMP Function	BMP Control	Targeted Pollutants[a]							Physical Constraints						
				Sediment	Nitrogen	Phosphorus	Metals	Bacteria	Hydro-carbons	Litter	Maximum Tributary Drainage Area (acres)	Maximum Upstream Slope (%)	Minimum Bedrock Separation (feet)	Minimum Ground Water Separation (feet)	NRCS Soil Type[b]	Freeze/ Thaw Resistance	Filtration/ Infiltration
64	Fiber rolls	☒ Construction ☐ Permanent ☐ Structural ☐ Nonstructural	☒ Erosion ☒ Sediment ☐ Source ☐ Flood	●	NA	○	○	○	○	○	NA	Varies	NA	NA	ABCD	Good	—
65	Silt fence	☒ Construction ☐ Permanent ☐ Structural ☐ Nonstructural	☒ Erosion ☒ Sediment ☐ Source ☐ Flood	●	NA	○	◖	○	○	◖	0.25 acres/ 100 lineal feet	33	2	2	ABCD	Good	—
66	Sediment basins and traps	☒ Construction ☐ Permanent ☐ Structural ☐ Nonstructural	☐ Erosion ☒ Sediment ☐ Source ☒ Flood	●	NA	○	◖	○	◖	◖	100	25	6	3	ABCD	Fair	—
67	Portable sediment tank	☒ Construction ☐ Permanent ☐ Structural ☐ Nonstructural	☐ Erosion ☒ Sediment ☐ Source ☐ Flood	◖	○	○	◖	○	○	○	Unlimited	NA	NA	NA	NA	Poor	—
68	Temporary swale	☒ Construction ☐ Permanent ☐ Structural ☐ Nonstructural	☒ Erosion ☒ Sediment ☐ Source ☐ Flood	●	○	○	◖	○	◖	○	10	14	5	3	BCD	Fair	—
69	Diversion dike	☒ Construction ☐ Permanent ☐ Structural ☐ Nonstructural	☒ Erosion ☒ Sediment ☐ Source ☐ Flood	◖	NA	○	○	○	○	○	10	10	5	5	BCD	Fair	—
70	Temporary berms	☒ Construction ☐ Permanent ☐ Structural ☐ Nonstructural	☒ Erosion ☒ Sediment ☐ Source ☐ Flood	◖	○	○	○	○	○	◖	5	50	NA	NA	ABCD	Good	—
71	Turbidity curtains	☒ Construction ☐ Permanent ☐ Structural ☐ Nonstructural	☐ Erosion ☒ Sediment ☐ Source ☐ Flood	●	NA	○	○	○	○	◖	NA	NA	NA	NA	NA	Fair	—

BMP Number	BMP Description	BMP Function	BMP Control	Targeted Pollutants[a]							Physical Constraints						
				Sediment	Nitrogen	Phosphorus	Metals	Bacteria	Hydro-carbons	Litter	Maximum Tributary Drainage Area (acres)	Maximum Upstream Slope (%)	Minimum Bedrock Separation (feet)	Minimum Ground Water Separation (feet)	NRCS Soil Type[b]	Freeze/ Thaw Resistance	Filtration/ Infiltration
72	Flocculation	☒ Construction ☐ Permanent ☐ Structural ☐ Nonstructural	☐ Erosion ☒ Sediment ☐ Source ☐ Flood	●	NA	◐	◐	○	○	○	NA	NA	NA	NA	ABCD	Good	—
73	Dewatering	☒ Construction ☐ Permanent ☐ Structural ☐ Nonstructural	☒ Erosion ☒ Sediment ☐ Source ☐ Flood	●	NA	○	○	○	○	○	NA	NA	NA	NA	NA	NA	—
74	Inlet protection	☒ Construction ☐ Permanent ☐ Structural ☐ Nonstructural	☒ Erosion ☒ Sediment ☐ Source ☐ Flood	●	NA	○	○	○	○	◐	1	5	2	2	ABCD	Good	Filtration
75	Street sweeping	☐ Construction ☒ Permanent ☐ Structural ☐ Nonstructural	☐ Erosion ☒ Sediment ☒ Source ☐ Flood	●	NA	○	◐	○	○	●	NA	NA	NA	NA	NA	Good	—
76	Storm water system cleaning	☐ Construction ☒ Permanent ☐ Structural ☐ Nonstructural	☐ Erosion ☒ Sediment ☒ Source ☐ Flood	●	NA	○	◐	○	◐	●	5	25	6	3	ABCD	Good	—
77	Outdoor storage	☒ Construction ☐ Permanent ☐ Structural ☐ Nonstructural	☐ Erosion ☐ Sediment ☒ Source ☐ Flood	○	NA	○	◐	○	◐	○	NA	NA	NA	NA	NA	NA	—
78	Fertilizer management	☒ Construction ☒ Permanent ☐ Structural ☐ Nonstructural	☐ Erosion ☐ Sediment ☒ Source ☐ Flood	○	●	●	○	○	○	○	NA	NA	NA	NA	NA	NA	—
79	Pesticide management	☒ Construction ☒ Permanent ☐ Structural ☐ Nonstructural	☐ Erosion ☐ Sediment ☒ Source ☐ Flood	○	●	●	○	○	○	○	NA	NA	NA	NA	NA	NA	—

BMP Number	BMP Description	BMP Function	BMP Control	Targeted Pollutants[a]							Physical Constraints						
				Sediment	Nitrogen	Phosphorus	Metals	Bacteria	Hydro-carbons	Litter	Maximum Tributary Drainage Area (acres)	Maximum Upstream Slope (%)	Minimum Bedrock Separation (feet)	Minimum Ground Water Separation (feet)	NRCS Soil Type[b]	Freeze/ Thaw Resistance	Filtration/ Infiltration
80	Building and grounds maintenance	☒ Construction ☒ Permanent ☐ Structural ☐ Nonstructural	☐ Erosion ☐ Sediment ☒ Source ☐ Flood	○	●	●	○	○	○	○	NA	NA	NA	NA	NA	NA	—
81	Loading dock design features	☐ Construction ☒ Permanent ☐ Structural ☐ Nonstructural	☐ Erosion ☐ Sediment ☒ Source ☐ Flood	○	NA	○	○	○	◖	◖	NA	NA	NA	NA	ABCD	Good	—
82	Equipment yard design features	☒ Construction ☒ Permanent ☐ Structural ☐ Nonstructural	☐ Erosion ☐ Sediment ☒ Source ☐ Flood	●	NA	○	◖	○	◖	○	NA	NA	NA	NA	NA	NA	—
83	Vehicle and equipment refueling	☒ Construction ☒ Permanent ☐ Structural ☐ Nonstructural	☐ Erosion ☐ Sediment ☒ Source ☐ Flood	○	NA	○	◖	○	●	○	NA	NA	NA	NA	NA	NA	—
84	Vehicle and equipment cleaning, maintenance, and repair	☒ Construction ☒ Permanent ☐ Structural ☐ Nonstructural	☐ Erosion ☐ Sediment ☒ Source ☐ Flood	●	NA	○	◖	○	◖	○	NA	NA	NA	NA	NA	NA	—
85	Remote access roads and rail corridors	☒ Construction ☒ Permanent ☐ Structural ☐ Nonstructural	☒ Erosion ☐ Sediment ☒ Source ☐ Flood	●	NA	◖	◖	◖	●	○	NA	NA	NA	NA	NA	NA	—
86	Nonstorm water discharges to drains	☒ Construction ☒ Permanent ☐ Structural ☐ Nonstructural	☐ Erosion ☐ Sediment ☒ Source ☐ Flood	●	NA	◖	◖	○	◖	◖	NA	NA	NA	NA	NA	NA	—
87	Outdoor loading and unloading of materials	☒ Construction ☒ Permanent ☐ Structural ☐ Nonstructural	☐ Erosion ☐ Sediment ☒ Source ☐ Flood	○	NA	○	◖	○	◖	◖	NA	NA	NA	NA	ABCD	NA	—

BMP Number	BMP Description	BMP Function	BMP Control	Targeted Pollutants[a]							Physical Constraints						
				Sediment	Nitrogen	Phosphorus	Metals	Bacteria	Hydro-carbons	Litter	Maximum Tributary Drainage Area (acres)	Maximum Upstream Slope (%)	Minimum Bedrock Separation (feet)	Minimum Ground Water Separation (feet)	NRCS Soil Type[b]	Freeze/ Thaw Resistance	Filtration/ Infiltration
88	Outdoor process equipment	☐ Construction ☒ Permanent ☐ Structural ☐ Nonstructural	☐ Erosion ☐ Sediment ☒ Source ☐ Flood	◖	NA	○	◖	○	◖	○	NA	NA	NA	NA	ABCD	NA	—
89	Contaminated soil management	☒ Construction ☐ Permanent ☐ Structural ☐ Nonstructural	☐ Erosion ☒ Sediment ☒ Source ☐ Flood	●	NA	◖	◖	○	◖	○	NA	NA	NA	NA	ABCD	NA	—
90	Building, repair, remodeling, and construction	☒ Construction ☐ Permanent ☐ Structural ☐ Nonstructural	☐ Erosion ☒ Sediment ☒ Source ☐ Flood	●	NA	○	◖	○	◖	◖	NA	NA	NA	NA	NA	NA	—
91	Employee training	☒ Construction ☒ Permanent ☐ Structural ☐ Nonstructural	☐ Erosion ☐ Sediment ☒ Source ☐ Flood	◖	NA	◖	◖	◖	◖	◖	NA	NA	NA	NA	NA	NA	—
92	Restaurant control practices	☐ Construction ☒ Permanent ☐ Structural ☐ Nonstructural	☐ Erosion ☐ Sediment ☒ Source ☐ Flood	○	NA	●	◖	◖	○	○	NA	NA	NA	NA	NA	NA	—
93	Marinas	☒ Construction ☒ Permanent ☐ Structural ☐ Nonstructural	☒ Erosion ☒ Sediment ☒ Source ☐ Flood	○	◖	◖	◖	◖	●	●	NA	NA	NA	NA	NA	NA	—
94	Swimming pool and spa maintenance	☐ Construction ☒ Permanent ☐ Structural ☒ Nonstructural	☐ Erosion ☐ Sediment ☒ Source ☐ Flood	○	NA	○	◖	◖	◖	○	NA	NA	NA	NA	NA	NA	—

a. The pollutant removal efficiencies are for planning purposes only. Actual removal rates depend on specific site characteristics, maintenance, and other factors. The following sources were used to determine the most likely average removal rate for conditions prevalent in Idaho: Camp, Dresser & McKee, and Larry Walker Associates 1993; Debo and Reese 1995; CBIC 1995; Maine DEP 1995; MPCA 2000 ; Idaho Panhandle Health District 1996; Brown and Caldwell1991; and EPA 1995.
b. Natural Resources Conservation Service soil types (A, B, C, D) range from A = high infiltration to D = little or no infiltration.
Notes:
● = Very effective, removes > 70% of pollutant; ◖ = Moderately effective, removes ≥30%–<70% of pollutant; ○ = least effective, removes < 30% of pollutant
— = No data; NA = Not applicable
Portland 1991 and EPA 1995.

3.6 Perform Engineering Calculations and Design for Storm Water Management

After the conceptual site design and BMP selection is completed, perform hydrologic calculations for both the predevelopment and postdevelopment conditions, with upstream and downstream conditions in mind. Use local design standards for flood control and water quality control. If local design standards are not available, Table 5 provides a summary of design storm frequencies and their corresponding benefits. Calculate the required volume and peak flow of the discharge and determine the amount of runoff to be detained and/or treated on site. Check with the performance goals and adjust the site design and BMP selection and design as necessary until performance goals are met.

Table 5. Design storm frequencies and assumed benefits (EPA 2005).

Design Storm	Assumed Benefits	Comments
1/2 to <1-inch rainfall	Intended to capture 70%–80% of annual runoff volume in an attempt to improve water quality.	Used by many municipalities. Some studies have shown that capturing the first 1/2 inch of runoff will control 70% of the annual runoff.
1-inch rainfall	Intended to capture 90% of annual runoff volume in an attempt to improve water quality.	Replacing 1/2 inch as basis for water quality control. Some studies have shown that capturing the first 1 inch of runoff will control 90% of the annual runoff.
1 year	Intended to capture sufficient runoff volume to improve water quality and provide downstream channel protection.	Used by some municipalities for water quality management and is based on the supposition that the channel-forming event is the annual storm.
2 year	Intended to provide protection from accelerated channel erosion and for habitat protection.	Used by many municipalities. Limited field monitoring indicates that the strategy is flawed, as increased volume in postdevelopment runoff results in pond discharges at flow rates near the peak discharge for much longer times than in the predevelopment state. This results in more erosion over the storm duration, which subsequently results in wider and deeper channels than in the predevelopment state although the peak flow rates for pre- and postdevelopment are equal.
10 year	Intended to provide flood protection from intermediate-sized storm events by matching postdisturbed peaks to predisturbed peaks.	When used for on-site detention, flood control benefits are provided primarily to local areas with limited protection of larger downstream channels. In some cases, potential for downstream flooding is increased due to timing of runoff events.
100 year	Used for flood control protection from major storms; also used to maintain 100-year floodplain limits.	When used for on-site detention, flood control benefits are provided primarily to local areas with limited protection of larger downstream channels. In some cases, potential for downstream flooding is increased due to timing of runoff events.

3.6.1 Design for Flood Control Facilities

While the most frequently used design for flood control and channel protection are the 2-, 10-, and 100-year storms, local design standards for sizing storm water facilities for flood control may vary. New development and redevelopment projects are typically required to produce peak discharges less than or equal to predevelopment levels.

Although peak discharge control is a widely used method for mitigating the impacts of land development on storm water runoff, it does have limitations and drawbacks when it is the only approach used. Depending on the location and hydrologic timing of a project site, on-site detention could increase the peak flow in the receiving water when it is combined with other tributaries depending on timing. Peak discharge control also does not address issues associated with increased frequency, duration, and volume of storm water discharges, which can cause increased erosion and bank instability in the receiving channels. Water quality degradation, insufficient low flows, and reduction in ground water recharge due to development are also not addressed by detention alone. Evaluate the impact on the watershed as a whole, and combine peak discharge control BMPs with BMPs that can mitigate for water quality and attempt to replicate the natural hydrologic systems before development.

3.6.2 Design for Water Quality Facilities

Design for water quality control is focused on smaller, more frequent storms, and criteria are typically expressed as either treatment of a specified rainfall depth or removal of a specified percentage of a pollutant.

Treatment of a specified rainfall depth is intended to capture the *first flush* of runoff from the initial portion of the storm event. As pollutants accumulate between events, the first flush of runoff has the tendency to carry a high concentration of pollutants, such as sediment, litter, and automotive discharges, from the surface of paved areas. The potential for pollution from the first flush is determined by such storm characteristics as the duration between events, size of the subwatershed, and partitioning characteristics of the pollutants of concern. Nationally, many jurisdictions specify a treatment volume, referred to as the water quality volume, designed to capture the first flush component of the storm water runoff. This is achieved by specifying a rainfall amount (e.g., first 1/2-inch, 1-inch, or other rainfall depth over impervious areas) or by specifying the capture of a storm water runoff volume that correlates to a design storm (such as the 6-month, 1-year, or 2-year frequency storm). Ideally, several decades of storm volume and intensity information for a given county would be analyzed to determine rainfall volumes for the various design storms. ITD has completed the analysis but only for 2-year storms and larger.

Another water quality control approach is to require that a specified amount of the pollutant of concern be removed from the storm water runoff before it is discharged from the site. This reduction is commonly specified as a percentage reduction of the pollutant of concern, and the compliance point may be determined by the MS4 requirements, TMDL of a specific receiving water body, or final storm water discharge location in the watershed. For example, the federal coastal zone guidance specifies that urban runoff from new and stabilized development sites must have 80% of suspended solids removed before it is discharged from the site. Implementing pollution reduction strategies requires knowledge of the preconstruction and postdevelopment average mass of pollutants. This strategy is effective if the regulating municipality selects an achievable pollutant reduction amount and ensures that the storm water controls are properly selected, designed, constructed, operated, and maintained.

3.6.3 Calculate Peak Discharge Rates and Volumes

Hydrologic models are either single event models or continuous simulation models. Single event models estimate peak discharges and volumes for a single rainfall event, referred to as the design

storm. These models assume the watershed characteristics remain constant during a rainfall event and the return period of the peak discharge is the same as the return period of the design rainfall event. Continuous simulation models analyze rainfall and predict the resulting runoff and loading on a daily basis. Typically, 25 to 100 years of simulation is conducted, and the return period analysis is completed using the predicted values.

Benefits and drawbacks exist for each modeling method. In general, continuous simulation is best for water quality analysis, and a single event design storm is best for flood analysis. Several computer models are available for performing continuous simulation analysis, including the Hydrological Simulation Program—Fortran (*HSPF*), Hydrologic Engineering Center Hydrologic Modeling System (*HEC-HMS*), and Storm Water Management Model (SWMM). EPA's *National Stormwater Calculator*, released in 2012, uses the SWMM modeling engine combined with an interactive map that seamlessly integrates with soil and meteorological databases to estimate runoff and evaluate the effectiveness of different BMP types. HEC-HMS and SWMM computer models can perform single event simulations in addition to continuous simulations. The rational method and *NRCS Technical Release-55* (TR-55) method are simple and widely used for performing single event design storm analysis.

3.6.3.1 Rational Method

The rational method is simplified for estimating the peak rate and total volume of runoff for a single drainage basin during a single storm event. This method is commonly used to compute peak runoff rates for flow-based runoff treatment BMPs such as biofiltration swales and oil/water separators. It is also commonly applied to infiltration trench and conveyance system design.

The rational method assumes that rainfall is distributed uniformly over the entire basin area and the rainfall intensity is constant during the storm. The standard rational method only produces one point on the runoff hydrograph. Due to the assumptions and limitations of the rational method, it is recommended for developed areas smaller than 100 acres with large areas of impervious surface (e.g., pavement and roof tops).

Peak runoff rates may be estimated by the rational formula (Equation 1):

$$Q_P = CIA$$

Equation 1. Rational formula for peak discharge.

Where

Q_p = peak discharge (cubic feet per second)

C = dimensionless runoff coefficient

I = average rainfall intensity (inches per hour) for a duration equal to the time of concentration and for the recurrence interval chosen for design

A = drainage area (acres)

The total volume of runoff may be estimated by the rational formula for volume (Equation 2):

$$V_r = CIAT$$ **Equation 2. Rational formula for total runoff volume.**

Where

V_r = volume of runoff (cubic feet)

C = dimensionless runoff coefficient

I = average rainfall intensity for a duration equal to the time of concentration and for the recurrence interval chosen for design (inches per hour)

A = drainage area (acres)

T = storm duration (seconds)

The runoff coefficient, C, represents the ratio of rainfall to runoff and reflects the cumulative effect of infiltration, evaporation, retention, and interception, which depends on the imperviousness, slope, and ponding characteristics of the surface. Soil factors including antecedent moisture content, degree of compaction, porosity of the subsoil, and proximity of the water table also affect runoff volumes. Suggested C values can be obtained from Table 6 and Table 7. For mixed surfaces within a basin, an area-weighted composite runoff coefficient can be calculated using the following formula (Equation 3):

$$C = \frac{\sum_{j=1}^{n} C_j A_j}{A}$$ **Equation 3. Composite runoff coefficient.**

Where

C = composite runoff coefficient

n = total number of subbasins

C_j = estimated runoff coefficient for a given subbasin

A_j = drainage area for a given subbasin

Table 6. Recommended C coefficients (modified from Lindeburg 2009).

Description of Runoff Area	Runoff Coefficients
Business	
Central business areas	0.70–0.95
District and local areas	0.50–0.70
Residential	
Single family	0.35–0.45
Multifamily, detached	0.40–0.60
Multifamily, attached	0.60–0.75
Residential 0.5 acre lots or larger	0.25–0.40
Industrial and commercial	
Light areas	0.50–0.80
Heavy areas	0.60–0.90
Parks, cemeteries	0.10–0.25
Playgrounds	0.20–0.35
Unimproved areas	0.10–0.30
Landscaped areas	0.20
Streets (asphalt, concrete), drives and walks, roofs	0.90–0.95

Table 7. Recommended C coefficients for pervious surfaces.

Slope	Runoff Coefficient			
	A soils	B soils	C soils	D soil
Flat 0%–2%	0.04	0.07	0.11	0.15
Average 2%–6%	0.09	0.12	0.15	0.20
Steep >6%	0.13	0.18	0.23	0.28

The time of concentration is the time it takes a drop of water to travel from the most hydraulically remote point in the basin to the basin outlet. Time of concentration is often calculated by adding the estimated travel times for each segment along the flow path including sheet flow, shallow concentrated flow, and open channel flow. Details are found in the NRCS *National Engineering Handbook,* Chapter 15 "Time of Concentration" (NRCS 2010).

Rainfall intensity-duration frequency (IDF) curves can be used to acquire storm duration and intensity for use in the rational method. IDF curves for Idaho have been developed by ITD and are found in the *Roadway Design Manual, Appendix B.*

NRCS TR-55 presents a single event hydrograph method that uses a dimensionless unit hydrograph with drainage area characteristics to determine flow volume and peak discharge. Runoff flows and volumes are estimated using an empirically derived *runoff curve number* (CN). The CN is similar to the "C" value used in the rational method. The CN depends on hydrolic soil group, vegetation, imperviousness, interception, and surface storage. CNs range from 30 to 100. Lower numbers indicate low runoff potential while larger numbers indicate high runoff potential.

CN values were developed from 20 years of studies of the rainfall-runoff relationship for small, rural, agricultural-based watersheds. The TR-55 method assumes that rainfall is uniformly distributed over a watershed over a specified time distribution. The method is limited to NRCS type distributions, 24-hour duration rainfall, and concentration times between 0.1 hour and 10-hours. Additionally, since CNs were originally developed from annual flood flows from experimental watersheds, their application to low flows or small flood peak flows is not recommended. For example, the minimum 24-hour design rainfall depth for a CN of 65 ranges between 2.47 and 2.99 inches, depending on the reference source (NRCS 1986; Hawkins et al. 1985). Thus, the applicability of the curve number approach is limited to flood events most likely larger than the water quality design storm.

CN runoff is shown in (Equation 4):

$$Q = \frac{(P - I_a)^2}{(P - I_a) + S}$$

Equation 4. CN runoff.

Where

Q = runoff (inches)

P = rainfall depth (inches)

S = potential maximum retention after runoff begins (inches)

I_a = initial abstraction (inches)

The initial abstraction can be approximated by the following empirical Equation 5:

$$I_a = 0.2S$$ **Equation 5. Initial abstraction.**

The potential maximum retention after runoff begins, S, is related to the soil and cover conditions with the CN (Equation 6):

$$S = \frac{1000}{CN} - 10$$ **Equation 6. Potential maximum retention.**

Runoff CNs for urban areas based on hydrologic soil group and an average runoff condition are shown in Table 8. These values assume that pervious urban areas are equivalent to pasture in good hydrologic condition, impervious areas have a CN of 98 and are directly connected to the drainage system, and the cover types listed have assumed percentages of impervious area as shown in Table 8. Additional information on calculating composite CNs and CNs for agricultural and forest lands is included in the NRCS National Engineering Handbook, Chapter 10 "Estimation of Direct Runoff from Storm Rainfall" (NRCS 2004).

Table 8. Runoff curve numbers for urban areas (NRCS 2004).

Cover description cover type and hydrologic condition	Average percent impervious area 2/	-- CN for hydrologic soil group -- A	B	C	D
Fully developed urban areas (vegetation established)					
Open space (lawns, parks, golf courses, cemeteries, etc.) 3/					
Poor condition (grass cover < 50%)		68	79	86	89
Fair condition (grass cover 50% to 75%)		49	69	79	84
Good condition (grass cover > 75%)		39	61	74	80
Impervious areas:					
Paved parking lots, roofs, driveways, etc. (excluding right-of-way)		98	98	98	98
Streets and roads:					
Paved; curbs and storm sewers (excluding right-of-way)		98	98	98	98
Paved; open ditches (including right-of-way)		83	89	92	93
Gravel (including right-of-way)		76	85	89	91
Dirt (including right-of-way)		72	82	87	89
Western desert urban areas:					
Natural desert landscaping (pervious areas only) 4/		63	77	85	88
Artificial desert landscaping (impervious weed barrier, desert shrub with 1- to 2-inch sand or gravel mulch and basin borders)		96	96	96	96
Urban districts:					
Commercial and business	85	89	92	94	95
Industrial	72	81	88	91	93
Residential districts by average lot size:					
1/8 acre or less (town houses)	65	77	85	90	92
1/4 acre	38	61	75	83	87
1/3 acre	30	57	72	81	86
1/2 acre	25	54	70	80	85
1 acre	20	51	68	79	84
2 acres	12	46	65	77	82
Developing urban areas					
Newly graded areas (pervious areas only, no vegetation)		77	86	91	94

1/ Average runoff condition, and $I_a = 0.2S$.

2/ The average percent impervious area shown was used to develop the composite CNs. Other assumptions are as follows: impervious areas are directly connected to the drainage system, impervious areas have a CN of 98, and pervious areas are considered equivalent to open space in good hydrologic condition.

3/ CNs shown are equivalent to those of pasture. Composite CNs may be computed for other combinations of open space type.

4/ Composite CNs for natural desert landscaping should be computed using figures 9–3 or 9–4 based on the impervious area percentage (CN=98) and the pervious area CN. The pervious area CNs are assumed equivalent to desert shrub in poor hydrologic condition.

Runoff rates can be calculated using either the graphical peak discharge method to determine peak discharge or the tabular hydrograph method to determine a partial composite flood hydrograph. Input data required include 24-hour rainfall depth (inches), appropriate rainfall distribution (Type I, IA, II, or III), CN, T_c (hours), and drainage area (mi^2). Information on rainfall distributions and rainfall depth for specific storm frequencies are available from the National Oceanic and Atmospheric Administration's *National Weather Service*.

Other computer programs that use TR-55 features include *WinTR-55* and *HydroCAD.*

3.6.3.2 Estimating Runoff During Snowmelt

Most storm water facilities are designed for events assumed to consist of precipitation entirely in the form of rain. In most parts of the country, the largest storms are intense summer thunderstorms. In the Pacific Northwest, the largest rainfall volumes occur in less intense but prolonged winter storms. A different type of event that often contributes to flooding is snowmelt, especially during a rainstorm. One characteristic that makes snowmelt so damaging is that due to the saturated and frozen ground, the heavy flows are reduced by infiltration. Because of the large amount of water contained in snowpack, snowmelt can cause significant capacity and erosion problems. The problem worsens if a significant rain event occurs during snowmelt, and the ground is still frozen.

Three factors must be considered to estimate flows during snowmelt. First, the storm parameters should be derived from IDF curves in the same manner as the regular design storm. IDF curves represent the greatest intensity expected during a given time period, which usually occurs during summer thunderstorms. The assumption that this storm intensity occurs during a time of snowmelt is conservative.

Second, the CN number should be adjusted. The CN numbers given for the various land uses in the TR-55 documentation are for an antecedent moisture condition (AMC) of II, which is defined as average conditions. Using Table 9, AMC II numbers are converted to AMC III, which is defined as heavy rainfall, or light rainfall and low temperatures occurring within the last 5 days, leading to saturated soils.

Third, the water contributed from the snowmelt itself needs to be computed. The degree-day method outlined in the *National Engineering Handbook* (NRCS 2004) can be used for clear weather melt in forested watersheds. For rain-on-snow events, an energy balance approach using a computer model such as HEC-HMS is recommended.

The degree-day method is based on Equation 7:

$$M = C_M(T_a - T_b)$$

Equation 7. Snowmelt using degree-day method.

Where:

M = snowmelt (inches/day)

T_a = mean daily air temperature (°F)

T_b = base temperature or temperature at which snow melts (°F)

C_M = degree day coefficient (inches/degree-day F)

The coefficient, C_M, varies with location and seasons, and typical values range from 0.035 to 0.13 inches per degree-day Fahrenheit. Often a value of 0.06 is used when information is not available for the site. For example, a sudden thaw of 40 degrees occurs, and the snowmelt equals 0.06 (40–32) or 0.48 inches per day. This occurrence should be added to the rainfall from the storm and used with the adjusted CN from Table 9.

Table 9. Converting AMC II to AMC III.

CN for AMC Condition II	CN for AMC Condition III	CN for AMC Condition II	CN for AMC Condition III
100	100	62	79
99	100	61	78
98	99	60	78
97	99	59	77
96	99	58	76
95	98	57	75
94	98	56	75
93	98	55	74
92	97	54	73
91	97	53	72
90	96	52	71
89	96	51	70
88	95	50	70
87	95	49	69
86	94	48	68
85	94	47	67
84	93	46	66
83	93	45	65
82	92	44	64
81	92	43	63
80	91	42	62
79	91	41	61
78	90	40	60
77	89	39	59
76	89	38	58
75	88	37	57
74	88	36	56
73	87	35	55
72	86	34	54
71	86	33	53
70	85	32	52
69	84	31	51
68	84	30	50
67	83	25	43
66	82	20	37
65	82	15	30
64	81	10	22
63	80	5	13

3.7 Complete Project Plans and Maps

Once the site has been designed and the supporting calculations are complete, prepare the project construction plans for submittal to the approving agencies. In addition to the site civil and architectural plans required for development (e.g., building plans, grading plans, utility plans, and landscape plans), the final design package should include the following storm water-related plans:

- SWPPP to include a report and site map
- Drainage plan with size, design, and location of permanent storm water BMPs
- Maintenance plan for BMPs and vegetation both during and after construction (section 3.10).

3.7.1 Storm Water Pollution Prevention Plan

A SWPPP is required in order to obtain permit coverage under CGP for construction activities that disturb an area of 1 acre or more. The SWPPP identifies potential sources of storm water pollution and clearly establishes control measures intended to prevent storm water pollution and off-site pollutant discharge. Measures should include erosion and sediment control, good housekeeping, conservation techniques, and infiltration practices (where appropriate). The SWPPP should interpret approved construction documents based on specifications and sequences of construction that are stated on the erosion and sediment control plans. The SWPPP should also demonstrate what best practices will be used to achieve compliance with water quality regulations.

The SWPPP must be completed before submitting an NOI to EPA to obtain coverage under CGP; should be completed before the project goes to bid so that all potential contractors know what will be expected; and the SWPPP should be part of the general construction contract. EPA's website provides specific information on *SWPPP submittal and posting requirements*.

3.7.1.1 SWPPP Report

Templates are available from EPA to assist in preparing the *SWPPP report*. The SWPPP report should be typed on 8.5- x 11-inch paper and bound in a sturdy binder. Maps, diagrams, and figures should be clearly labeled and folded to fit within the binder. The SWPPP should indicate the title on the outside of the binder and include a title sheet, table of contents, list of figures and tables, and the narrative or body, in that order.

Refer to the current CGP for required components of the SWPPP. In general, the SWPPP should contain the following:

- Contact information and responsible parties (i.e., operators and subcontractors)
- Site evaluation, assessment, and planning
  - Project and site information
  - Discharge information
  - Nature of the construction activity
  - Sequence and estimated dates of construction activities
  - Allowable nonstorm water discharges
  - Site maps

- Documentation of compliance with other federal requirements
  - Endangered species protection
  - Historic preservation
  - Safe Drinking Water Act underground injection control requirements
- Erosion and sediment controls
  - Provide natural buffers or equivalent sediment controls
  - Install perimeter controls
  - Minimize sediment track-out
  - Control discharges from stockpiled sediment or soil
  - Minimize dust
  - Minimize the disturbance of steep slopes
  - Preserve topsoil
  - Minimize soil compaction
  - Protect storm drain inlets
  - Other storm water controls, as applicable
    - Constructed storm water conveyance channels
    - Sediment basins
    - Chemical treatment
    - Dewatering practices
- Site stabilization
- Pollution prevention standards
  - Potential sources of pollution
  - Spill prevention and response
  - Fueling and maintenance of equipment or vehicles
  - Washing equipment and vehicles
  - Storage, handling, and disposing of construction products and materials
  - Washing applicators and containers used for pain, concrete, or other materials
  - Fertilizers
  - Other pollution prevention practices
- Inspection and corrective actions
  - Inspection personnel and procedures
  - Delegation of authority
- Training
- Certification and notification

3.7.1.2 SWPPP Site Map

SWPPP site maps and engineering plans illustrate and specify the project's location, existing and modified site conditions, and BMPs. Include the following information in the site plan map:

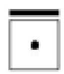
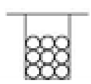
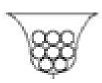
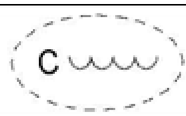
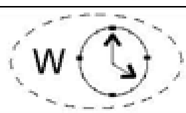
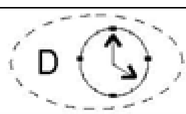
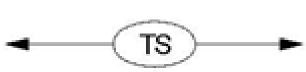
- Location of the proposed construction site in relation to the surrounding area
- Property boundaries and lot lines
- North arrow, scale, and date
- Location of proposed structures and impervious features, including roadways and utilities
- Location of water conveyance systems and new or modified drainage systems (including system dimensions)

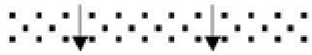
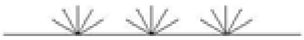
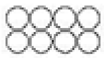
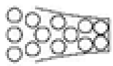
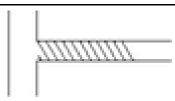
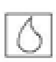
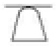
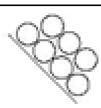
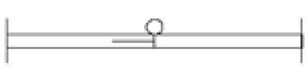
- Existing topography and drainage patterns
- Approximate slopes after grading (2-foot intervals)
- Existing vegetation and areas of clearing
- Areas of soil disturbance
- Location of critical areas, such as water bodies and wetlands
- Location of major structural controls and areas where stabilization practices will occur.
- Geology or geotechnical engineering reports, if this information was used for design purposes. (An engineering geology or geotechnical report providing recommendations for erosion control may need to be submitted upon a determination that additional information is required.)

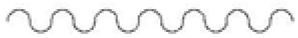
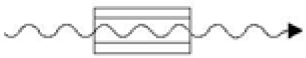
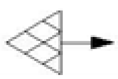
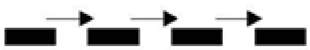
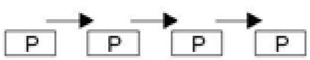
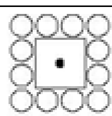
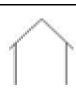
Show all temporary and permanent erosion control features on the plan sheets. Table 10 provides the symbols recommended for use on SWPPP maps to indicate locations of proposed BMPs. In addition to the BMPs, the SWPPP site map should show the clearing and grubbing limits, cut and fill slope lines, topography, impervious features, drainage features, environmentally sensitive areas and associated buffer zones, receiving water, and storm water treatment areas.

The SWPPP site maps will be used by the contractor for construction and by the regulators to evaluate the site for compliance. The SWPPP should include details and notes that correspond to erosion and sediment controls on each plan view. In addition to instructions on installation and maintenance, the SWPPP should indicate when to remove controls that are no longer needed.

Table 10. Symbols recommended for use on SWPPP maps to indicate locations of proposed BMPs.

Symbol	Best Management Practice	Description
	BMP 2	Natural vegetated buffers
	BMP 9	Vegetated swale
	BMP 11	Vegetative filter strip
	BMP 12	Sand filter
	BMP 13	Catch-basin insert
	BMP 14	Compost storm water filter
	BMP 15	Oil and water separators
	BMP 17	Infiltration trench
	BMP 18	Bioretention basin
	BMP 22	Wet pond (conventional control)
	BMP 22	Wet pond (nutrient control)
	BMP 23	Wet extended detention pond
	BMP 23	Dry extended detention pond
	BMP 25	Presettling/sedimentation basin
	BMP 26	Wet vault or tank
	BMP 31	Topsoiling

Symbol	Best Management Practice	Description
	BMP 32	Seeding
	BMP 32	Sodding
	BMP 32	Planting
	BMP 33	Gabions
	BMP 34	Retaining wall
	BMP 35	Riprap outlet protection
	BMP 38	Preservation of existing vegetation
	BMP 39	Clearing limits
	BMP 41	Stabilization of construction entrance, roads, and driveways
	BMP 42	Erosion prevention on construction roads
	BMP 43	Dust control
	BMP 46	Spill prevention and control
	BMP 47	Construction equipment washing and maintenance
	BMP 52	Mulching
	BMP 52	Hydromulching
	BMP 53	Geotextile
	BMP 54	Matting
	BMP 56	Riprap slope protection
	BMP 57	Pipe slope drain

Symbol	Best Management Practice	Description
	BMP 69	Earth dike
	BMP 58	Slope roughening
	BMP 59	Gradient terracing
	BMP 60	Check dams
	BMP 62	Temporary stream crossing
	BMP 63	Biofilter bags
	BMP 65	Silt fence
	BMP 66	Sediment basins and traps
	BMP 67	Portable sediment tank
	BMP 68	Temporary swale
	BMP 69	Perimeter dike/swale
	BMP 70	Temporary berms (sandbags)
	BMP 70	Temporary storm drain diversion
	BMP 74	Inlet protection
	BMP 82	Cover for materials and equipment

3.8 Submit Final Plan and Obtain Permits

If possible, present the preliminary project design, storm water site plan, and preliminary landscape plan to the local permitting authority for approval before proceeding to final design. This step can save time and money later in the process.

Once the final design is completed, submit the final documents, including design calculations, to the appropriate agencies for final approval and permitting. For construction projects, this will include, at a minimum, approvals from the local municipality and/or local highway jurisdictions,

preparing the SWPPP, and filing an NOI with the EPA for coverage under the CGP if the construction site is 1-acre or more or part of a larger plan of development. See EPA's website for more information on *CGP requirements*.

3.9 BMP Implementation

Once permits are obtained, it is important that BMPs are properly installed according to the SWPPP. To ensure effective communication between the designer and contractor, a preconstruction meeting with the prime contractor, subcontractors, designer, and owner is recommended to review the approved SWPPP, answer questions, and discuss potential issues. Contractors must understand why BMPs are needed, and the responsible person (as designated by the pollution prevention team) should see that the SWPPP is implemented correctly.

If changes must be made to the SWPPP due to field conditions, the SWPPP should be amended. Significant changes should be resubmitted for approval to local jurisdictions before implementation. Note approved changes and the associated formal documentation in the SWPPP.

3.9.1 Contractor Awareness and Education

As noted above, contractors must understand why BMPs are needed, and one of the best and most cost-effective measures for controlling storm water pollution at new construction sites is for the general contractor to encourage pollution awareness and prevention among crew leaders or, on smaller jobs, individual workers. General contractors must be responsible for educating and informing all subcontractors. Education may include the following:

- Provide copies of the construction BMP plan and applicable BMP fact sheets to the crew leaders.
- Point out and label sensitive areas that should not be disturbed during project construction.
- Clearly tag trees and other vegetation that should be removed and instruct crew leaders not to remove or disturb any other vegetation without prior approval.
- Discuss techniques and answer questions about erosion and pollution control at regular site safety meetings.
- Demonstrate proper housekeeping methods, including proper use and application of water for dust control.
- Inform the crew leaders of actions to take in the event of a spill of toxic materials (e.g., used oil, hydraulic fluid, pesticides, or herbicides).
- Post signs throughout the site at key locations reminding crew leaders how to properly store construction materials, handle and dispose of toxic or solid wastes, dispose of washwater, and similar instructions.
- Remind the crew leader of fines and penalties that may be levied against the contractor by the permitting agencies if pollution is not properly controlled.

3.9.2 Scheduling

Scheduling and construction timing (BMP 36) are important in implementing the SWPPP. Strategic scheduling can facilitate construction, as well as minimize impacts on storm water. Timing can be especially important in high elevation areas because of the limited duration of the

construction season. Careful planning is needed to minimize the potential impact of projects that require revegetation during short growing seasons and include construction near streams and shorelines.

Keep the following points in mind when establishing the construction schedule:

- Comply with seasonal restrictions for earthmoving and exposed soil established by the local permitting authority or as practical given local climate.
- Schedule installation of BMPs. Some temporary BMPs should be installed before earthmoving activities begin.
- Implement housekeeping BMPs (e.g., covering stockpiles) as soon as possible after the project breaks ground.
- Schedule regular inspections of the site and the storm water BMPs throughout the construction process and repair or replace BMPs as needed.
- Maintain the BMPs as specified in the maintenance plan.
- Schedule removal of temporary BMPs (or retrofit them for permanent use) at the end of the construction project.

3.10 Operation and Maintenance

Storm water systems that are properly operated and maintained function better, reduce cost, and reduce potential liability problems. This section provides information on properly operating, inspecting, and maintaining storm water systems for residential, commercial, or industrial developments. Use this information with best professional judgment and sound engineering principles.

Templates are available from EPA to assist in *preparing inspection reports and corrective action reports*. Include these forms, or their equivalent, in the site's operation and maintenance (O&M) plan and/or SWPPP.

3.10.1 Conduct Proper Maintenance

Every storm water system must be properly maintained to reduce or eliminate costly repair problems and to properly treat storm water. The lack of proper maintenance is the most common cause of storm water system failure.

Properly maintaining a storm water system reduces the risk of flooding due to system failure. For example, detention systems (such as detention ponds) are designed to detain sediments and still function properly. Remove sediments in the sediment-trapping area regularly to reduce excessive sediment buildup. If the sediments accumulate beyond what the system is designed for, the system could fail and cause storm water to backup, or overflow, and flood an area.

Properly maintaining a storm water system improves the level in which pollutants are effectively removed. For example, a vegetated swale is designed to remove sediment, oil, grease, and toxic chemicals by filtering out these pollutants. Storm water flows slowly through the swale filtering through the grass and infiltrating into the underground sand and rock layers. But, if the swale lacks a grass cover or the swale has severely eroded, the storm water will flow too quickly through the swale and the rate at which these pollutants are removed is significantly reduced.

Properly maintaining a storm water system reduces the likelihood that sediment or other debris need to be disposed of as hazardous waste. High vehicle-use areas or industrial sites can produce heavy metals and toxic chemicals that can end up in a storm water system. If the storm water system is not maintained regularly, the debris may be characterized as hazardous waste due to hazardous compounds accumulating to a hazardous level, but regular maintenance may prevent this characterization. Hazardous waste disposal can be costly while regularly removing sediment or other debris is typically not as costly.

Properly maintaining a storm water system reduces safety hazards on the site. A poorly functioning infiltration system may cause storm water runoff to pond. This runoff can freeze in the winter and become a safety hazard to site employees or the public. Keeping good inspection and maintenance records helps the owner or operator with liability issues if safety problems arise. In addition, regularly inspecting the storm water system alerts the operator if hazardous materials (which may have been illegally dumped into the system) are present.

Properly maintaining a storm water system improves its visual appeal and preserves its value as a neighborhood amenity. A well-maintained natural area can act as a storm water collection area and neighborhood park. Because these storm water systems may be considered amenities, the value of homes located near these systems can be higher than the value of home located in other parts of a subdivision.

Properly maintaining a storm water system ensures that nuisance situations do not develop into bigger problems. Mosquitoes can be controlled near ponds or constructed wetlands by installing inexpensive predacious bird and bat boxes and encouraging these wildlife species to live near the site. More information about mosquito control is found in section 3.5.5. Similarly, regularly removing a few nuisance weeds is more time and cost-efficient than controlling the weeds after they have invaded the entire area.

Some mosquito habitats may be fostered by a lack of maintenance of storm water management facilities (e.g., temporary erosion and sediment control structures, permanent storm water management ponds, storm sewers, and storm water ditches). Vegetative overgrowth including floating algae, sediment, trash, dead grass, emergent aquatic grasses, weeds, and cattails provide hiding places and a nutrient-rich environment for mosquitoes. Clogged outlets that temporarily have pond water provide good mosquito breeding habitats. Small temporary water bodies do not support the predator populations that keep mosquito populations in check. Inadequate drainage in constructed wetlands and dry ponds causes small puddles to remain at the base, especially adjacent to the outflow pipe. Corrugations in storm sewers may cause standing water.

3.10.2 Develop an Operation and Maintenance Plan

This section describes the guidelines that should be followed to develop a customized O&M plan for new or existing storm water systems. An O&M plan helps to coordinate inspection and maintenance activities for a system, track problems, and make the system more cost-effective. The plan should outline the scope of activities, schedule, and responsible parties for inspecting and maintaining each BMP.

Vegetation, sediment management, access, and safety are primary issues to address in any maintenance plan. It is important to schedule maintenance activities around sensitive wildlife and

vegetation seasons. Most industrial site facilities will generally require more frequent maintenance than facilities on commercial or residential sites. The BMP fact sheets located in section 4 provide specific information on operation and maintenance for each BMP.

The O&M plan should consist of the following items:

- Site plans, landscape design plans, design plans, and material specifications for the storm water system
- Facility access
- Sediment management
- Inspection frequency information
- Inspection and maintenance forms
- Safety information
- Scope of work, responsible personnel, waste disposal, and maintenance budget, if known
- Source control BMPs

Facility access should be provided for inspection, operation, and maintenance activities. All storm water control facilities should be located in designated and reserved storm water easements. Easements should be located to provide access for routine inspection and sized for access of construction equipment and activities that may be needed for maintenance and repair work.

In cases when sediment is suspected to contain a high level of pollutants, include provisions in the maintenance plan for testing the sediment. For example, if the site is located in an area with a history of upstream industrial spills that are not being controlled by adequate source control BMPs, testing could include parameters for detecting oil and grease, metals, or nutrients. Store and dispose of sediments removed from storm water BMPs according to applicable local, state, and federal regulations.

3.10.2.1 New Systems

For new systems, an O&M plan should be prepared at the time the system is being designed when information about the new system is readily available. Ideally, the person responsible for executing the O&M plan should work with the design professional to develop the plan. Maintenance procedures, material specifications, and operation practices should be specified for each individual system. System operators should discuss any design problems encountered while inspecting or maintaining the system with the design professional. These comments will help the design professional modify the design so that the same problem will not occur in the future.

3.10.2.2 Existing Systems

Preparing an O&M plan for existing storm water systems is also recommended. Although the information may be harder to find, the extra steps taken to develop an O&M plan for an existing system will make long-term operation and maintenance easier and more effective. To prepare an O&M plan for an existing system, available design plans and past maintenance information should be collected if possible from the owner or design professional.

3.10.3 Inspect the Storm Water System

Frequent, thorough, and consistent inspections are the key to the successful operation and maintenance of a storm water system. Inspections reveal the operational status of the system, identify needed maintenance actions, and provide information to update the O&M plan. Inspect storm water systems at least twice annually after construction and after any rainstorm event that produces more rainfall the 25-year, 24 hour storm event using the Western Regional Climate Center Precipitation Frequency Map.

Regular inspections should be performed until the system's routine maintenance requirements have been identified. The time interval in which subsequent inspections will be performed should be determined by actual maintenance requirements or as specified in the system's NPDES permit (if applicable). This section addresses inspection frequency, conducting inspections safely, and using the inspection and corrective action forms.

During construction, check the reporting requirements for inspections and corrective actions in your permit and ensure that these are met. EPA developed two templates for inspection and corrective action reports, one for field use and one for electronic use (EPA website).

3.10.3.1 Inspection Frequency

The frequency in which a storm water system should be inspected depends on the type of system, seasonal weather conditions, the characteristics of the drainage area, and the conditions in system's NPDES permit (if applicable). A vegetated swale should be inspected frequently to ensure that the grass cover is thriving and sediment and debris are not accumulating in the swale; whereas, a retention pond, once constructed, may only have to be inspected once or twice per year.

Seasonal weather conditions can also determine the inspection schedule. Because of their intensity, summer storms may cause more problems for a system than storms that occur at other times of the year. Therefore, a storm water system should be inspected before and after the summer months when the system can experience its greatest use. Inspect detention and evaporation ponds at least once each time the pond is empty. Inspections may need to be completed more frequently if rainfall is above average.

The type of drainage area and the activities that occur in the drainage area will affect inspection frequency. A storm water system may require more frequent inspections in drainage areas where construction is taking place and creating a large amount of sediment. Likewise, storm water systems located in the Boise foothills may require more frequent inspections because the combination of vast open areas and steeper slopes increases the potential for sediment to accumulate more quickly in a storm water system. Sites that may generate more waste, such as industrial and high vehicle-use areas, should be inspected more frequently.

3.10.3.2 Inspect Storm Water Systems Safely

Individuals who are responsible for inspecting storm water systems should always consider safety as the first priority. The inspector should have the proper safety equipment (e.g., heavy-duty gloves, boots, and first-aid kits) and training before conducting any inspections. Although the safety precautions listed here are common sense, they should not be disregarded. Neglecting

to follow even the simplest safety precaution can potentially cause serious injury. If the storm water system inspection reveals a safety problem, site activities may have to be modified to reduce or eliminate the safety risk. The following is a list of safety precautions an inspector should be aware of when conducting storm water system inspections:

- Never enter a confined space unless you have proper Occupational Health and Safety Administration (OSHA) training. Do not enter any confined space unless the atmosphere has been checked and proper safety equipment is worn and/or erected. Avoid entering pipes or conduits without another individual present. If the structural strength of a pipe or conduit is questionable, do not enter the pipe or conduit at all.
- Check the ventilation in the storm water system before using any type of ignitable materials (e.g., lighters, matches, and cigarettes). Some storm water systems may be sealed and have poor ventilation, posing a safety risk to the inspector if flammable vapors come in contact with an open flame. Allow the storm water system to vent for a period of time if a peculiar odor is present.
- Wear gloves if any mechanical parts or structural components are going to be handled. Wearing gloves reduces the risk of getting cuts and abrasions and also reduces the exposure of pollutants to the skin.
- Lift manhole covers or other structural covers (e.g., trash racks and access covers) carefully. These items can be heavy and slippery if wet. Learn the correct way to lift heavy items to avoid back injury.
- Check the water depth of the system before taking a step in the water. The water may be deeper than it appears, or there may be steep slopes below the water line.
- Be aware that nails, broken glass, or other sharp debris may be in the storm water system. Wearing the proper safety clothing will reduce the safety risk associated with these objects.
- Check for poison ivy, poison oak, or other poisonous plants when inspecting ponds or other large storm water systems. Inform the individual who will perform maintenance on the system that these plants are present.
- Look where you walk. Rodent holes may be present around ponds or constructed wetlands. Some holes may be partially covered and not easily seen at first glance.
- Check for spiders and other biting or stinging insects.

3.10.3.3 Using the Inspection and Corrective Action Forms

To use the inspection and corrective action forms, identify the system components that compose your storm water system. Photocopy the applicable inspection and corrective action forms and the *Inspection Cover Sheet*. Inspect each system design feature to determine if any of the conditions are present. If the current condition of the feature matches the description on the inspection and corrective action form, place a checkmark in the appropriate box. The system design features that have been checked will need to be maintained or repaired if it is determined that a problem exists.

3.10.4 Perform Maintenance on a System

Implement a thorough maintenance program before, during, and after development is completed. Inspect all BMPs and additional safeguards to determine that they are working properly and to

ensure that problems are corrected as soon as they develop. The maintenance schedule should be based on site conditions, design safeguards, construction sequence, and anticipated weather conditions.

A storm water system may require either routine or nonroutine maintenance. Routine maintenance of a storm water system is performed by an individual to ensure that the storm water system is functioning as designed and that the system aesthetics are well maintained. Nonroutine maintenance would be performed by an individual in the event of a catastrophic event, such as a hazardous chemical spill. This section discusses routine and nonroutine maintenance, performing maintenance safely, and completing the *corrective action report* form if needed.

3.10.4.1 Routine Maintenance

The type and frequency of maintenance for a specific storm water system is determined by inspection results, the maintenance schedule in the O&M plan, or NPDES permit requirements (if applicable). Performing timely maintenance is important in preventing system failure and will be less expensive in the long-term. Prepare an annual maintenance budget to ensure the necessary resources are available to perform maintenance adequately.

If required, the following permits may be obtained from federal, state, or local agencies to conduct storm water maintenance activities:

- §404 (dredge and the legal definition of a jurisdictional wetland)—The United States Army Corps of Engineers requires a §404 permit to place fill in any water body considered "waters of the United States." Most commercial storm water ponds are not considered wetlands or waters of the United States.
- If dewatering a storm water system is needed as part of maintenance operations, pumping uncontaminated ground water or storm water into the storm sewer system may be acceptable with permission. These activities may require a permit. Contact the local municipality or highway jurisdiction.
- If storm water will be discharged from storm water ponds to surface water, obtain an NPDES permit prior to discharge.
- If storm water will be discharged from a storm water dewatering system to land, obtain a land application permit from DEQ.

3.10.4.2 Perform Maintenance Safely

The individuals performing maintenance on the storm water system should always consider safety as the first priority. All maintenance work should be done according to OSHA regulations. Maintenance personnel should have the proper safety equipment (e.g., heavy duty gloves, steel-toed boots, and first-aid kits) and training before performing any maintenance on a storm water system. Include relevant safety information in the O&M plan. The following list provides safety precautions maintenance personnel should be aware of when performing maintenance on storm water systems:

- Operate equipment safely and according to manufacturers' specifications.
- Equipment operators should be aware of site personnel at all times to avoid causing injury to others.

- Contact utility companies before excavating a site. Underground utility wires may be present. Cover or clearly mark excavated areas that cannot be filled by the end of the day to alert site employees of the potential risk. Be aware of overhead electrical wires that could come in contact with maintenance equipment.
- Identify where removed sediment or wastes will be disposed before cleaning the storm water system. Use shovels, trowels, or a high-suction vacuum to remove wastes. Do not clean out sediment or waste with bare hands. The sediment or waste may be hazardous or contain medical wastes such as needles. Place the sediment or waste in an area where it will not wash into a storm drain, water body, or waterway.
- Wear gloves if any mechanical parts or structural components are going to be handled. Wearing gloves reduces the risk of getting cuts and abrasions and also reduces skin exposure to pollutants.
- Use caution when mowing detention ponds, retention ponds, or other storm water systems with steep slopes.

3.10.4.3 Nonroutine Maintenance

In addition to routine maintenance, situations may occur that require nonroutine maintenance, such as illegal dumping into the system, accidental spills, or massive sediment and debris inflows from major storm events. For illegal dumping or sediment and debris inflow, determine if it has caused a problem in the storm water system.

If an accidental spill occurs, isolate the spill to keep it from reaching other water bodies (including ground water). Storm water system flow-control points, such as gates, valves, orifices, and outlet pipes, should be checked to ensure that those points are closed to isolate the spill. Spill kits should be purchased, kept on site, and placed in areas that are easily accessible by maintenance personnel. If the spill consists of flammable or hazardous materials, call 911 for assistance.

The storm water system owner is responsible for cleaning the spill and disposing of the waste properly. If the spill contains hazardous materials, a qualified environmental consultant who specializes in spill containment may be called to assist in clean up and disposal.

3.10.4.4 Maintenance Report

After a storm water system has been maintained, a maintenance report form should be completed. In the report, describe the maintenance activities, including the type of work, completion dates, contractors used, time needed, and costs. Documenting the maintenance performed on a storm water system will be useful in planning future maintenance activities.

3.10.5 Properly Dispose of Wastes

Most storm water system wastes consist of trash, leaves, grass, and sediment. For many system owners, maintaining a storm water system is not difficult because the quantity of wastes is small or the wastes may not be hazardous. For others, however, disposing of storm water system wastes may be more complex because the quantity of wastes is large and/or the wastes are hazardous. This section provides information on how to properly and legally dispose of both hazardous and nonhazardous wastes.

Sediment and debris removed from storm water systems located in residential and commercial areas generally do not contain pollutants that would characterize the sediment or debris as hazardous waste. Storm water systems located in industrial facilities or vehicle-related, high-use areas have the greatest potential for sediment and debris to be characterized as hazardous waste.

If a facility uses hazardous materials or generates hazardous waste as part of daily operations (e.g., automotive repair shops or fueling stations), determine whether storm water system waste is considered hazardous waste under federal and state law, regardless of where the storm water system is located on the site. Before disposing of the sediment or debris, determine whether the material is hazardous by using either process knowledge or analytical testing.

3.10.5.1 Process Knowledge

Process knowledge is "the understanding of the processes and activities conducted at a site and the waste resulting from those activities." In most cases, process knowledge can be used to show that hazardous materials or wastes are not stored, handled, or used in a process within an area that discharges to a storm water collection system. It may also be possible to show that access to the storm water system is controlled so that unauthorized activity or illegal dumping will not occur.

In some cases process knowledge may not be adequate to determine if a waste is hazardous:

- The access to the storm water system is uncontrolled.
- The storm water system is located in an area where hazardous chemicals or materials are used.
- The storm water system is located in an area where oil or antifreeze is handled or stored.
- The storm water system is located in an area where engine washing and steam cleaning or other degreasing processes are conducted.

If any of these situations exist, the process-knowledge method of determining if the maintenance waste is hazardous cannot be used. The analytical testing method must be used to determine if the waste is hazardous.

3.10.5.2 Analytical Testing

Analytical testing requires that a sample is taken from the sediment and/or liquids and tested to determine if any of these categories of physical properties or associated chemical analyses are within an acceptable range:

- Flash point (to determine ignitability)
- pH (to determine corrosivity)
- Toxicity characteristic leaching procedure (to determine toxicity)

A pesticide screening analysis may also be required if a facility handles or uses pesticides. If samples are taken without the assistance of an expert, the following procedures should be followed:

- Choose an analytical laboratory that conducts hazardous waste analysis. Some laboratories limit their services to construction-related testing and cannot provide the necessary analysis.

- Explain to the laboratory representative how to characterize the storm water system waste. The laboratory personnel will provide the appropriate sampling bottles, explain how the samples should be taken, demonstrate how to fill out the associated paper work, and provide the appropriate container for transporting the samples back to the laboratory for analysis.
- Collect the results from the laboratory and interpret the analysis. A laboratory representative or DEQ technical staff can provide assistance in interpreting the results. Analytical results, whether they indicate a hazardous waste characteristic or not, should be kept on file for a minimum of 3 years at the facility where the samples were taken. Idaho regulatory agencies strongly urge facilities to keep sampling results on file indefinitely.

3.10.5.3 Sampling Frequency

The following sampling frequencies are recommended:

- If no changes occur in the types of activities or processes and access to the storm water system is controlled with oversight, it may be possible to characterize the storm water system sediment and liquid only once.
- If the facility restricts access to the storm water system and site activities could result in the release of a hazardous substance, it may be necessary to test on a yearly basis.
- If access to the system is unrestricted, or site activities could result in the release of a hazardous substance to the storm water system, system sediments must be tested each time prior to removal and disposal.

3.10.6 Nonhazardous and Hazardous Waste Disposal

The following section discusses how to properly dispose of maintenance waste once it has been determined whether it is nonhazardous or hazardous.

3.10.6.1 Nonhazardous Waste Disposal

Nonhazardous sediment and debris can be routinely disposed of at the local landfill, according to Idaho and local solid waste regulations. Solid waste regulations require that the sediment or debris does not contain any liquid. The liquid must be removed from the sediment and returned to the storm water system. To remove residual liquid, sediment or debris should be spread out on the ground (away from storm drains, gutters, or waterways) and dried in the sun before disposing of the material with the facility's solid waste.

The solid waste contractor should be provided with documentation that the facility's storm water system sediment is nonhazardous waste. For questions concerning the disposal of sediment with solid waste, contact the site's solid waste contractor.

Another way to dispose of nonhazardous sediment is to incorporate the sediment into landscape areas, such as shrub beds. Remove any litter or nonbiodegradable material from the sediment, and incorporate the sediment in areas where it is unlikely to wash back into the storm water system.

Yard wastes (such as leaves or grass) can be used as mulch around flowers, shrubs, and trees. Apply the mulch 3 to 4 inches deep or use the mulch as a soil amendment by mixing it into the surrounding soils. Shredded leaves and grass may also be spread thinly over established turf. Mulching adds valuable nutrients to the soils, retains moisture, and protects plant roots during the cold weather months.

3.10.6.2 Hazardous Waste Disposal

If sampling results indicate the sediment in a facility's storm water system is classified as a hazardous waste, dispose of the sediment as hazardous waste according to federal and state regulations. Two general disposal options are available, and the option chosen depends on the facility's hazardous waste generator status. Under federal and state regulations, the amount of hazardous waste generated by the facility in a calendar month determines the generator status category:

- A conditionally exempt small quantity generator (CESQG) generates less than 220 pounds of hazardous waste in a calendar month.
- A small quantity generator (SQG) generates between 220 and 2,200 pounds of hazardous waste in a calendar month.
- A large quantity generator (LQG) generates 2,200 pounds or more of hazardous waste in a calendar month.

To calculate the generator status, add together all hazardous wastes generated by the facility and show the total number in units of pounds. The exceptions to this include the following:

- Used motor oil that is recycled or collected for fuel blending
- Antifreeze that is recycled on site or sent to a recycling facility, or
- Automotive batteries that are returned to the distributor for recycling

If serviced parts washers or other solvent-based cleaning systems are on site, include the amount of spent solvent removed from the facility during servicing in the generator status calculations. If no serviced parts washers are on site (either in-house or by contractor), convert the number of gallons of spent solvent to pounds. Most servicing companies will provide the conversion factor and may assist in converting and calculating the facility's generator status.

If you do not know the generator status or do not have a servicing contractor's assistance, DEQ may be called to request technical assistance from a hazardous materials/waste specialist. Based on the facility's generator status, disposal options for sediment that is characterized as hazardous waste are as follows:

- If your generator status is CESQG, you may qualify for a hazardous waste disposal program in some counties. To participate, wastes should be preregistered with the program, and the CESQG facility manager should be called for an appointment to turn in the wastes. A disposal fee must be paid; however, the fee will be less than the cost to hire a disposal contractor.
- If the site is determined to be a small or large quantity generator, the facility's hazardous waste should be disposed of through a qualified hazardous waste management firm.

3.10.7 Construction Disposal Alternatives

Construction sites can generate many other pollutants, in addition to sediment, through paving operations, handling and storage of various materials, spills, and waste handling. These pollutants can include petroleum products, solvents, paints, sanding dusts, pesticides, and fertilizers. The potential exists for runoff contamination from sources that produce these pollutants. Solid waste can also be a problem at construction sites, and a trash receptacle should be used on every construction site.

Properly dispose of materials used during construction to minimize the potential for hazardous materials and other solids from entering storm water runoff and compromising erosion and sediment control BMPs. Table 11 provides disposal options based on the type of construction activity and discharge.

Table 11. Disposal options for pollutants and wastes created during construction.

General Construction, Painting, and Maintenance	
Discharge/Activity	**Disposal Techniques**
Excess oil-based paint	Recycle/reuse; donate to nonprofit organization Dispose of as hazardous waste
Excess water-based paint	Recycle/reuse; donate to nonprofit organization For small quantities, let the paint residue dry in the can; remove lid; dispose of in trash For large quantities, solidify with cat litter, air dry, and dispose of in trash
Oil-based paint cleanup	Wipe paint out of brushes Filter and reuse thinners and solvents Donate to nonprofit organization or dispose of as hazardous waste
Water-based paint cleanup	Wipe paint out of brushes; rinse to sanitary sewer; dispose of in trash
Empty paint cans (dry)	Remove lids; dispose of lids and cans in trash
Paint-stripping substances (with solvent)	Dispose of as hazardous waste
Exterior cleaning of buildings (high-pressure water)	Prevent entry into storm drain and remove off site Wash onto soil-covered area and spade in Mop up washwater and discharge to sanitary sewer
Exterior cleaning of buildings (mercury, chromium, or other hazardous materials in paints)	Use dry cleaning methods (e.g., sandblasting) Mop up washwater; reduce volume by evaporating liquid mixture Dispose of as hazardous waste
Exterior cleaning of buildings (paint contains lead)	Dispose of as hazardous waste For assistance, contact EPA 1-800-LEAD-FYI
Construction and demolition debris (no hazardous materials in debris)	Reduce/reuse concrete, wood, or other construction materials Transport to landfill as construction and demolition waste
Construction and demolition debris (hazardous materials such as asbestos in debris)	Follow landfill packaging requirements; transport to landfill as asbestos waste or other hazardous waste
Paint scraping/sandblasting (no hazardous materials in paints)	Dry sweep; dispose of in trash
Building and Property Management/Maintenance	
Discharge/Activity	**Disposal Techniques**
Leaking garbage dumpsters	Collect and contain leaking material Repair leak; return dumpster for repair
Washwater from cleaning garbage dumpsters	Filter washwater through grease interceptor; contact wastewater treatment plant staff before discharging to sanitary sewer
Cleaning driveways, paved areas	Sweep and dispose of in trash. For vehicle leaks:

General Construction, Painting, and Maintenance

Discharge/Activity	Disposal Techniques
	Clean up leaks with rags or absorbents Sweep using granular absorbent material (e.g., cat litter) Mop and dispose of mop water in sanitary sewer
Cleaning sidewalks, paved areas	Clean up leaks with rags or absorbents Sweep using granular absorbent material (e.g., cat litter) Either mop and dispose of mop water in sanitary sewer or collect all water from cleaning and pump to sanitary sewer.

Vehicle Maintenance—Industrial/Commercial

Discharge/Activity	Disposal Techniques
Used motor oil	Use secondary containment while storing; send to recycler
Antifreeze	Use secondary containment while storing; send to recycler
Other vehicle fluids and solvents	Dispose of as hazardous waste
Vehicle washing	Recycle washwater Contact local wastewater treatment plant before discharging to oil and water separator connected to sanitary sewer
Mobile vehicle washing	Recycle washwater Contact local wastewater treatment plant before discharging to oil and water separator connected to sanitary sewer
Rinse (new car fleets)	Contact local wastewater treatment plant before discharging to oil and water separator connected to sanitary sewer Contact operator of storm drain system regarding approval to discharge, if rinse water is free of detergents or other cleaners.
Vehicle leaks (auto repair shops)	Sweep up leaks using granular, absorbent material (e.g., cat litter) Mop and dispose of mop water to oil and water separator connected to sanitary sewer
Automobile batteries	Send to auto battery recycler

Vehicle Maintenance—Residential

Discharge/Activity	Disposal Techniques
Used motor oil	Use curbside recycling, where available, or Return to retail outlet for recycling, or Recycle through local Household Hazardous Waste Collection events/facilities
Antifreeze	Dispose of through local Household Hazardous Waste Collection events/facilities
Other vehicle fluids and solvents	Dispose of through local Household Hazardous Waste Collection events/facilities
Automobile batteries	Send to auto battery recycler

Landscape/Garden Maintenance

Discharge/Activity	Disposal Techniques
Pesticides	Use up, rinse containers, use rinse water as product Dispose of rinsed containers in trash Dispose of unused pesticide as hazardous waste
Garden clippings	Compost or take to landfill
Tree trimmings	Chip, if necessary, before composting, or take to landfill
Swimming pool, spa, or fountain water	Avoid using metal-based algaecides (copper sulfate) Determine when chlorine residual is 0, wait 24 hours, then use for irrigation water
Swimming pool, spa filter backwash	Reuse for irrigation water Dispose of on dirt area Contact local wastewater treatment plant before discharging to sanitary sewer

Other Wastes

Discharge/Activity	Disposal Techniques
Carpet cleaning discharge	Contact wastewater treatment plant before discharging to sanitary sewer
Kitchen grease	Provide secondary containment; collect and send to recycler

General Construction, Painting, and Maintenance	
Discharge/Activity	**Disposal Techniques**
Exhaust hood filter cleaning	Discharge washwater through a grease interceptor, then to sanitary sewer
Clean up wastewater from sewer backup	Block storm drain, contain, collect and return material to the sanitary sewer Block storm drain, rinse remaining material to collection point and pump to sanitary sewer (no rinse water may flow to storm drain)
Contaminated pumped ground water, infiltration/foundation drainage	Treat as necessary; with prior approval from wastewater treatment plant, discharge to sanitary sewer

3.10.8 Record Keeping

Proper record keeping provides a useful record of past operation and maintenance practices and also documents that the storm water system has been properly operated and maintained. In addition, proper record keeping provides the following advantages:

- Provides a new system owner or operator with needed information on routine operation and maintenance procedures, frequencies, and associated costs.
- Contains information that may be useful in updating the O&M plan.
- Provides a central source of information to any federal, state, or local agency that may request information on the storm water system.

Include the following information in your records: O&M plan, maintenance reports, invoices for materials or work contracted, copies of permits, and laboratory analysis results that characterize clean-out wastes.

4 BMP Fact Sheets

This section includes fact sheets for site design, construction, and postconstruction BMPs, including treatment and source controls. Each fact sheet includes a description and photo of the BMP, information on where and when the BMP is most applicable, what limitations may affect its use, and design, construction, and maintenance guidance. The fact sheets include a *quick reference* box, as shown below, with the following information.

4.1 Primary BMP Functions and Controls

Construction—Most applicable during the construction phase of a development.

Permanent—Postconstruction or permanent BMP that remains in place throughout the life of the development.

Erosion Control—Retains soil particles in place and prevents mobilization.

Sediment Control—Contains or prevents mobilized soil particles or other pollutants from leaving the site.

Source Control—Minimizes or eliminates sediment, heavy metals, oil, grease, toxic chemicals, or other pollutants so they are prevented from contacting runoff and entering the drainage system.

Flood Control—Detains, retains, or provides significant infiltrative capacity to attenuate peak flood flows and/or runoff volumes.

Filtration—Mechanically filters pollutants from storm water runoff.

Infiltration—Provides significant opportunity to infiltrate storm water runoff into the subsurface.

Primary BMP Functions and Controls

☒ Construction	☒ Permanent
☒ Erosion Control	☐ Sediment Control
☐ Source Control	☐ Flood Control
☐ Filtration	☐ Infiltration

Typical Effectiveness for Targeted Pollutants

●	Sediment
◖	Phosphorus
◖	Metals
○	Bacteria
○	Hydrocarbons
○	Litter

Other BMP Considerations

Relative Cost	$
Maintenance Requirements	Easy
Ease of Installation	Medium
Freeze/Thaw Resistance	Good
Max. Tributary Drainage Area	5 acres
Max. Slope	10%
NRCS Soil Group	ABCD
Min. Ground Water Separation	3 feet
Min. Bedrock Separation	3 feet

4.2 Typical Effectiveness for Targeted Pollutants

The pollutants of concern are described in section 2.1.2. The following symbols indicate the effectiveness of BMPs for each pollutant.

● = BMP is very effective at removing the targeted pollutant. Generally, ≥70% of the pollutant may be removed.

◖ = BMP is moderately effective at removing the targeted pollutant. Generally, 30% to 70% of the pollutant may be removed.

○ = BMP has little or no effectiveness at removing the targeted pollutant. Generally, <30% of the pollutant may be removed.

4.3 Other BMP Considerations

Relative Cost—Rating ranges from minimal costs represented by a dollar sign ($) and costs increase as additional dollar signs are added, which reflects the initial capital cost for installation of the BMP relative to other BMPs.

Maintenance Requirements—Rating ranges from High, Medium, to Low and reflects the cost and difficulty of ongoing maintenance relative to other BMPs. A high maintenance rating may indicate frequent maintenance that requires specialized training to perform. A low maintenance rating may only require a limited amount of maintenance that could be performed by a property owner.

Ease of Installation—Rating ranges from Hard, Medium, to Easy and reflects the difficulty and amount of specialized expertise or training needed to install the BMP. An easy installation could be performed by most homeowners or contractors. A hard installation requires specialized training or certifications to install the BMP properly.

Freeze/Thaw Resistance—Rating ranges from Good, Fair, to Poor depending on how the BMP performs during seasonal freeze/thaw cycles. Good indicates the BMP is not affected, fair indicates the BMP is somewhat affected, and poor indicates the BMP is very affected and may not be functional.

Max. Tributary Drainage Area—Maximum recommended area to drain to the BMP.

Max. Slope—Maximum recommended slope that either the BMP can be constructed on or can be found upstream of the BMP.

NRCS Soil Classification—Soil group best suited for the BMP. Soil group is classified as A, B, C, or D. Group A has the best infiltration rate (e.g., sands), while Group D allows little or no infiltration (e.g., clays).

Min. Ground Water Separation—Minimum recommended separation from the bottom of the BMP to the high ground water table.

Min. Bedrock Separation—Minimum recommended separation from the bottom of the BMP to bedrock.

BMP 1: Minimize Land Disturbance

Description

While land disturbance is unavoidable during site development, it should be minimized to limit environmental impacts on the site. Where grading is required, follow natural landforms and design to guide and slow the flow of runoff (Figure 3).

Figure 3. Disturb only the area needed and clearly define the construction area with fencing.

Applicability

This BMP applies wherever undisturbed areas must be impacted during site preparation, construction, and development.

Limitations

Site constraints such as property boundaries, natural features, legal agreements, and rights of way may affect where land disturbances take place.

Design Basis

When planning a development project, disturb the smallest possible area to minimize hydrologic impacts. Use conservation design techniques to plan developments around natural features and cluster development on the least sensitive areas of the site. Identify sites with environmentally, hydrologically, or socially important features to preserve such as the following:

- Streams and stream buffers
- Floodplains
- Riparian areas
- Existing vegetation
- Forest conservation areas
- Wetlands, springs, and seeps
- Highly erodible soils
- Steep slopes
- Storm water infiltration areas
- Designated open space areas
- Natural corridors and greenways
- Historically significant areas

Primary BMP Functions and Controls

☒ Construction	☒ Permanent
☒ Erosion Control	☐ Sediment Control
☐ Source Control	☐ Flood Control
☐ Filtration	☐ Infiltration

Typical Effectiveness for Targeted Pollutants

●	Sediment
◖	Phosphorus
◖	Metals
○	Bacteria
○	Hydrocarbons
○	Litter

Other BMP Considerations

Relative Cost	$
Maintenance Requirements	Easy
Ease of Installation	Easy
Freeze/Thaw Resistance	Good
Max. Tributary Drainage Area	N/A
Max. Upstream Slope	N/A
NRCS Soil Group	ABCD
Min. Ground Water Separation	N/A
Min. Bedrock Separation	N/A

After preservation areas are identified, locate applicable building setbacks or other building restrictions based on local zoning code and subdivision regulations (Figure 4).

The remaining portion of the site is then identified as the development envelope. The proposed development including buildings, access roads, utilities, and other structures should be located only within the development envelope, taking into consideration buildability, accessibility, visual obtrusiveness, and distance from adjacent buildings. Avoid or mitigate the impact of high water tables and shallow bedrock when planning a development.

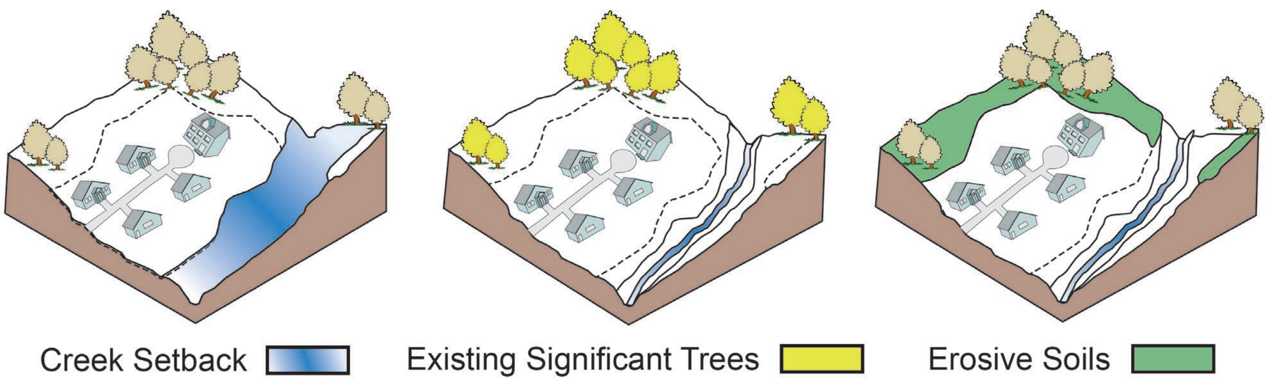


Figure 4. Identify preservation areas and cluster development on the remaining portion of the site.

Construction Guidelines

Minimize the amount of land disturbance required for grading by fitting the development to the natural gradient within the development envelope. For example, orient the major axis of the building parallel to existing contours and stagger floor levels to fit the natural grade.

In locations where site grading is necessary, the proposed grading should mimic the surrounding natural features and landforms and include slopes with a diversity of concave, convex, shaded, sunny, exposed, and sheltered habitats where applicable. This diversity decreases erosion and mass wasting while respecting the geomorphologic processes of natural slopes. Consider natural drop lines to minimize drainage gradients.

To ensure that land disturbance is minimized during construction, include a *limits of disturbance* plan that delineates the boundary between disturbed and protected areas in the construction drawings (Figure 5). This boundary should also be clearly marked in the field with signage, staking, flagging, or fencing. Limit disturbance to the smallest area possible and minimize the area needed to build lots, allow access, and provide necessary utilities based on construction techniques, equipment needs, and physical site constraints. If possible, land disturbance should occur in phases with each phase stabilized and revegetated before proceeding to the next construction phase.

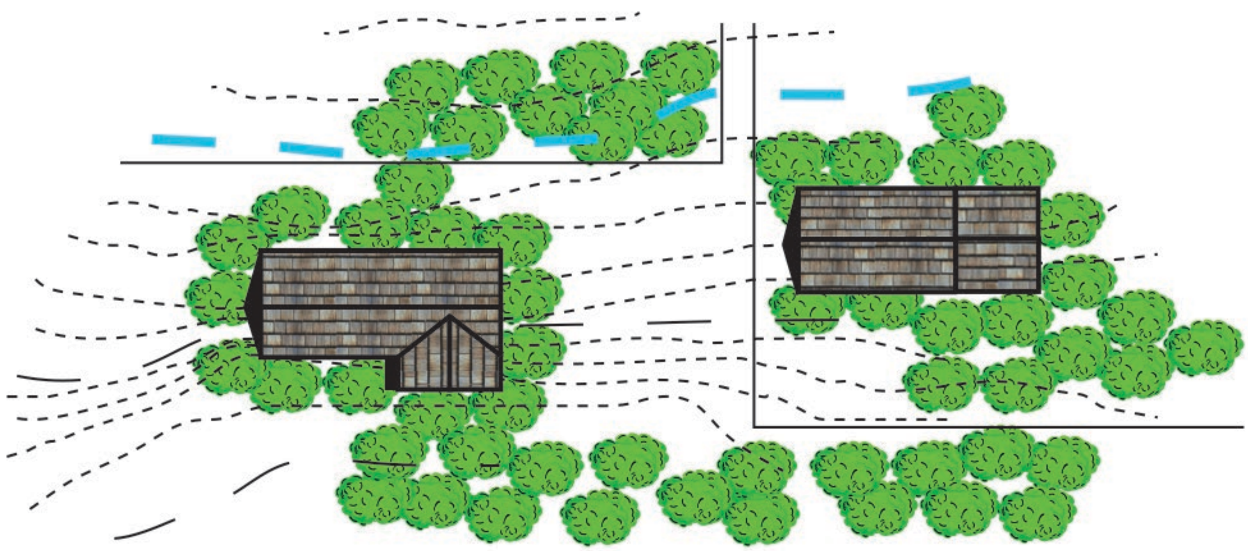


Figure 5. Illustration depicting minimal disturbance areas to be cleared and graded with shading (Corish 1995).

Maintenance

Not applicable

Additional Resources

Arendt, R.G. 1996. *Conservation Design for Subdivisions: A Practical Guide to Creating Open Space Networks.* Washington, DC: Island Press.

Dramstad, W.E., J.D. Olson, and R.T.T. Forman. 1996. *Landscape Ecology Principles in Landscape Architecture and Land-use Planning.* Washington, DC: Harvard University Graduate School of Design, Island Press, and the American Society of Landscape Architects.

Forman, R.T. 1995. *Land Mosaics: The Ecology of Landscapes and Regions*. Cambridge University Press, UK.

Forman, R.T. et al. 2002. *Road Ecology: Science and Solutions.* Washington, DC: Island Press.

Johnson, B.R. and K. Hill, eds. 2001. *Ecology and Design: Frameworks for Learning.* Washington, DC: Island Press.

Little, C.E. 1995. *Greenways for America*. Baltimore, MD: The Johns Hopkins University Press.

Puget Sound Action Team. 2003. *Natural Approaches to Stormwater Management.* Seattle, WA: Puget Sound Action Team. *http://www.napawatersheds.org/files/managed/Document/3004/lid_natural_approaches.pdf*.

Smith, D.S. and P. Cawood Hellmund, eds.1993. *Ecology of Greenways.* Minneapolis, MN: University of Minnesota Press.

BMP 2: Minimize Disturbance of Steep Slopes

Description

Minimize disturbance to steep slopes caused by land development activities. Steep slopes are defined as those 15% or greater in grade, unless the term *steep slope* has been otherwise defined by a state, tribe, local government, or industry technical manual. Disturbance includes removing vegetation, excavation, fill, building, regrading, or removing soil.

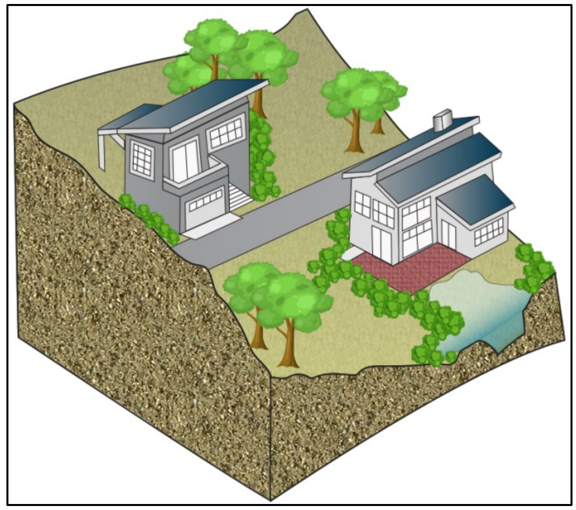


Figure 6. Example of fitting development to natural gradient.

Applicability

Steps to minimize disturbance of steep slopes should be taken during the site design and construction phases of any project on a site with steep slopes. By minimizing disturbance, soil erosion, sedimentation, and pollutant discharge is also minimized.

Design Basis

During the site design phase, locate buildings and roads outside of steep slope areas and relocate development on the portion of the site least likely to impact the natural landforms, geologic features, and vegetation (Figure 6). Conservation design methods can be used to fit development to the natural features of the site. Roads and driveways should follow the natural topography to the greatest extent possible to minimize the amount of grading required.

When it is not possible to locate buildings outside of steep slope areas, they should be located to fit into the hillside instead of altering the hillside to fit the building. For example, orient the major axis of the building along the existing contours and step down the floor levels with the grade changes or reduce the footprint of the building to minimize grading. For slopes greater than 40%, a geotechnical analysis is recommended to ensure that development is not proposed on highly erodible and landslide-prone areas.

If regrading is necessary, blend it in with the natural contours and undulations of the land, with cuts and fills rounded off to eliminate sharp angles on the top, bottom and sides of regraded slopes. The angle of cut

Primary BMP Functions and Controls

☒ Construction	☒ Permanent
☒ Erosion Control	☐ Sediment Control
☐ Source Control	☐ Flood Control
☐ Filtration	☐ Infiltration

Typical Effectiveness for Targeted Pollutants

●	Sediment
◖	Phosphorus
◖	Metals
○	Bacteria
○	Hydrocarbons
○	Litter

Other BMP Considerations

Relative Cost	$
Maintenance Requirements	Easy
Ease of Installation	Easy
Freeze/Thaw Resistance	Good
Max. Tributary Drainage Area	N/A
Max. Upstream Slope	N/A
NRCS Soil Group	ABCD
Min. Ground Water Separation	N/A
Min. Bedrock Separation	N/A

and fill slopes should not exceed the natural angle of repose of the soil or rock material, unless structural stabilization is used. Generally, the slope should be not steeper than two horizontal to one vertical (2:1).

Construction Guidelines

If all development is located outside of steep slope areas, these areas should be delineated with fencing, flagging, or other markers and designated as preservation areas that should not be disturbed during construction.

If unavoidable during construction, minimize disturbance to steep slopes to the greatest extent possible. Use erosion and sediment control practices, such as phasing land-disturbing activities, and use control measures designed for steep grades. Phase construction so that the amount of land disturbed at one time and the duration of exposure is limited. Construction BMPs appropriate on or around steep slopes include biofilter bags (BMP 63), fiber rolls (BMP 64), matting (BMP 54), pipe slope drains (BMP 57), and gradient terracing (BMP 59). Permanently stabilize the slope as soon as possible using mulch (BMP 52), landscaping (BMP 32), or channel liners (BMP 61).

Maintenance

If steep slopes are not disturbed, slope maintenance is not required. For any steep slopes that are disturbed and stabilized, maintenance activities associated with the BMP used to stabilize the slope are required.

Additional Resources

EPA (US Environmental Protection Agency). 2012. *EPA Construction General Permit*. National Pollutant Discharge Elimination System Stormwater Program. *https://www.epa.gov/npdes/epas-2017-construction-general-permit-cgp-and-related-documents*

Land of Sky Regional Council. 2008. *Mountain Ridge and Steep Slope Protection Strategies*. North Carolina.

Thompson, J.W. and K. Sorvig, 2000. *Sustainable Landscape Construction: A Guide to Green Building Outdoors.* Washington, DC: Island Press.

Town of Somers, NY. 2002. "Chapter 148: Steep Slope Protection." *Code of the Town of Somers.* New York. *http://ecode360.com/11112788.*

BMP 3: Provide Natural Buffers

Description

Natural buffers are areas along surface waters that are undisturbed and where development and land-disturbing activities are prohibited. Ideally, the natural buffer contains existing vegetation. If the natural buffer is not vegetated, native plants can be established to provide storm water management benefits (Figure 7).

Figure 7. Example of a natural buffer along the Boise River.

Applicability

Natural vegetative buffers are best for intercepting sheet flow from disturbed sites, pervious surfaces or other sediment source areas, and filtering storm water runoff before entering a stream, creek, canal, wetland, or other surface water. Buffers reduce the velocity of surface runoff, promote infiltration, and reduce pollutant discharge by capturing and holding sediments and other pollutants carried in the runoff water. These buffers are best suited for areas where the soils are well drained or moderately well drained and where the bedrock and water table are well below the surface.

Construction sites with earth disturbances located within 50 feet of surface water should ensure the storm water runoff from the site to the surface water is treated by a 50-foot natural buffer and/or erosion and sediment controls that achieve a sediment load reduction equivalent to a 50-foot natural buffer.

Natural buffers established and maintained during construction can become a permanent part of the development, providing habitat for wildlife and acting as a natural barrier for noise and views between the development and surface waters.

Primary BMP Functions and Controls

☒ Construction	☒ Permanent
☒ Erosion Control	☒ Sediment Control
☐ Source Control	☐ Flood Control
☒ Filtration	☐ Infiltration

Typical Effectiveness for Targeted Pollutants

●	Sediment
◖	Phosphorus
○	Metals
○	Bacteria
○	Hydrocarbons
○	Litter

Other BMP Considerations

Relative Cost	$
Maintenance Requirements	Easy
Ease of Installation	Easy
Freeze/Thaw Resistance	Good
Max. Tributary Drainage Area	N/A
Max. Upstream Slope	25%
NRCS Soil Group	ABCD
Min. Ground Water Separation	N/A
Min. Bedrock Separation	N/A

Limitations

Buffers can require significant land space; thick, established vegetative cover is best for sediment removal. Planted or seeded areas cannot be used as buffers for sediment trapping until the vegetation is well established.

Pollutant removal performance is best for buffers with slopes less than 5% within the buffer and contributing flow lengths less than 150 feet. Consider incorporating other BMPs measures in addition to using natural buffers if slopes within the buffer exceed 15%.

Design Basis

The effectiveness of natural buffers for sediment removal depends on buffer width, vegetation density and type, slope, soil group and infiltration rate.

Width

The recommended minimum width of a natural buffer is 50 feet measured perpendicularly from the ordinary high water mark or the edge of bank, bluff, or cliff of the water body (Figure 8 and Figure 9). The high water mark is indicated by clear natural line impressed on the bank, shelving, changes in the character of the soil, destruction of terrestrial vegetation, and/or the presence of litter/debris. Buffers should be provided on both sides of the surface water if development and land-disturbing activities are occurring on both sides. Take the width measurement at regular intervals along the stream if its flow path changes frequently.

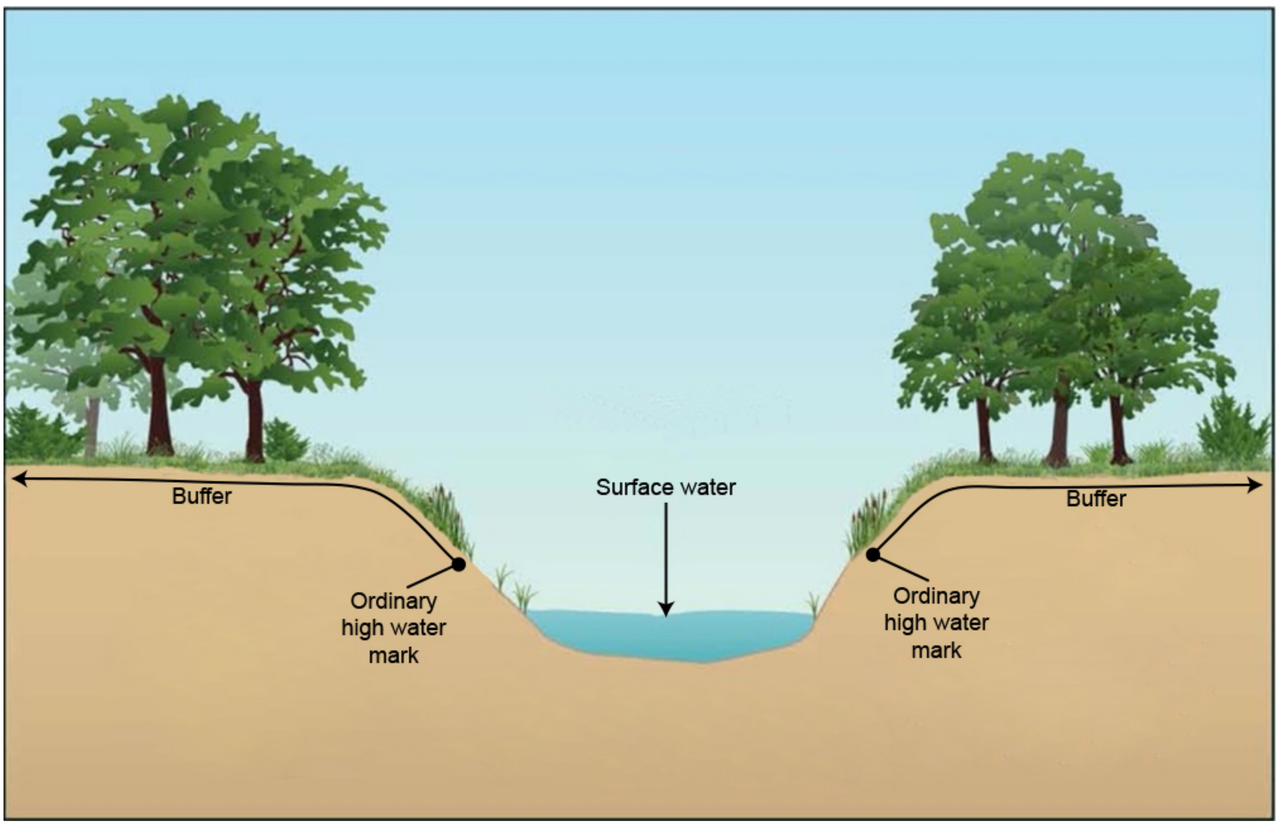


Figure 8. Buffer measurement from ordinary high water mark (EPA 2012a).

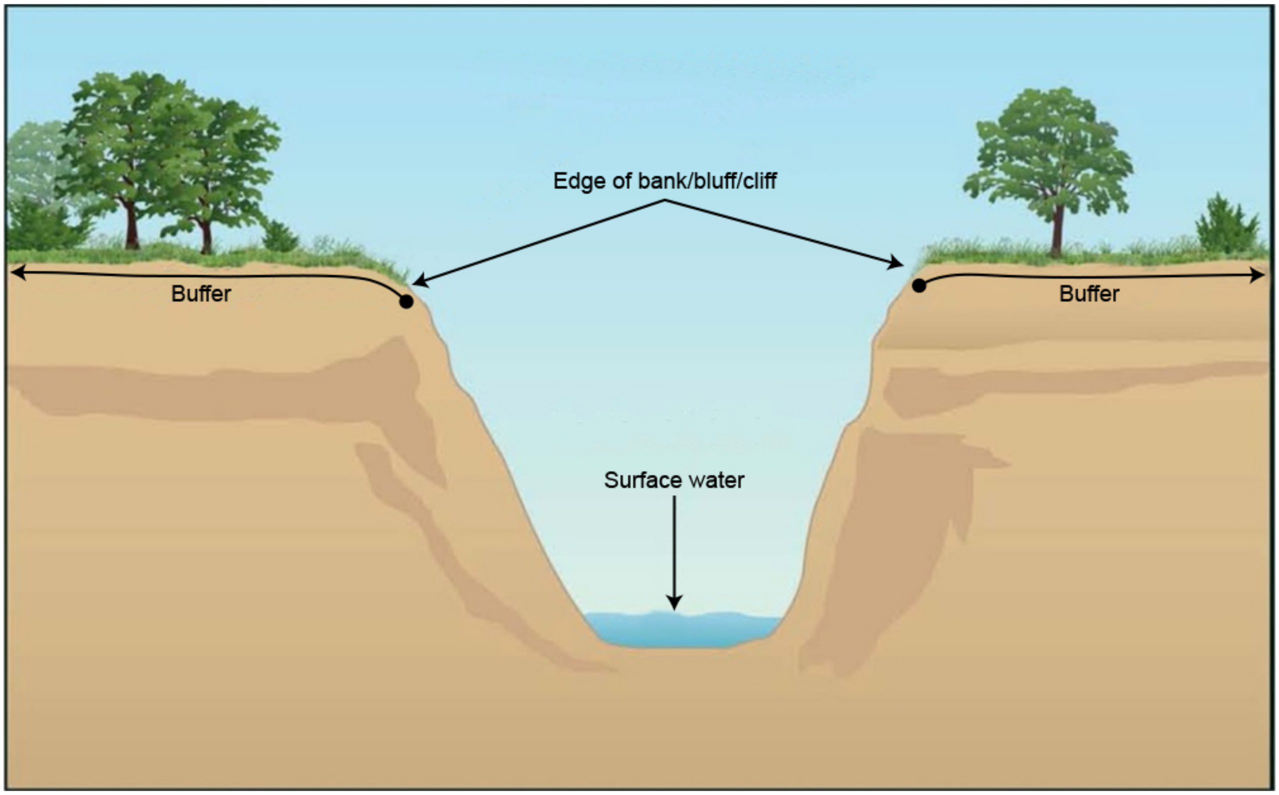


Figure 9. Buffer measurement from the edge of bank, bluff, or cliff (EPA 2012a).

Increasing the buffer width increases sediment removal (Liu and Zhang 2008). If it is feasible, a vegetative buffer with a width of at least 100 feet consisting of three zones should be maintained as a permanent BMP, especially adjacent to sensitive water bodies and wetlands. The three zones shown in Figure 10 include inner Zone 1, middle Zone 2, and outer Zone 3 and are distinguished by function, width, vegetation, and allowable uses. Use progresses from no or low impact (floodplain function and footpaths) within Zone 1, to higher impact (recreational bike paths and storm water BMPs) in Zone 2 to highest impact (lawns, gardens, and grazing) within Zone 3.

Zone 1 serves to protect the physical and ecological integrity of the surface water and has a minimum width of 25 feet plus wetland and critical habitats. Zone 2 provides distance between upland development and Zone 1 to allow for velocity reduction and sediment settling of storm water runoff. The width of Zone 2 is typically 50 to 100 feet, depending on soil type, pollutant source area, and slope and on site-specific factors such as the location and size of the 100-year floodplain. Zone 3 functions to prevent encroachment, filter sediment, and provide space necessary to convert concentrated flow to uniform shallow sheet flow. The minimum width of Zone 3 is 25 feet.

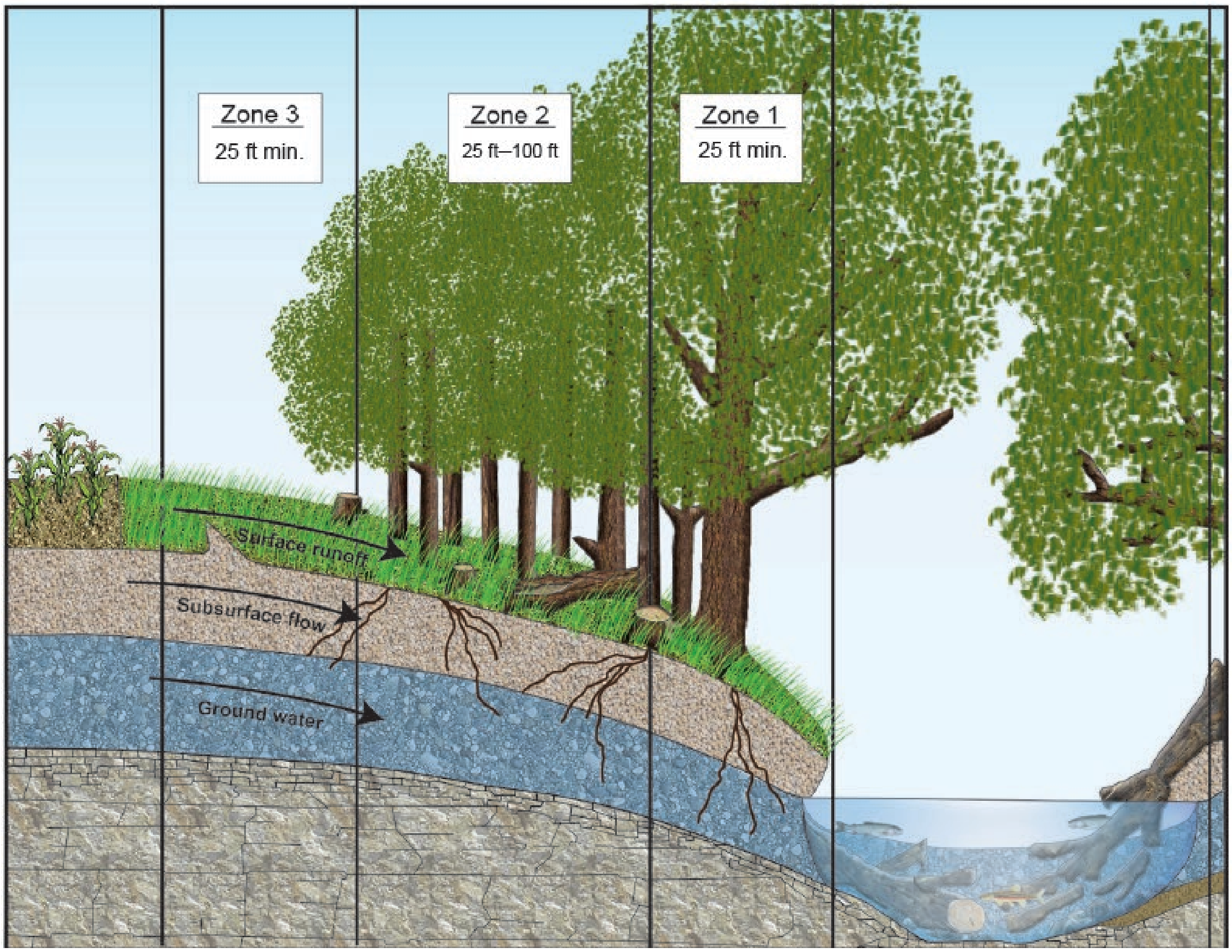


Figure 10. Three zone riparian/forest buffer (Welsch 1991).

The following additional criteria can be used to establish the total width of a three zone buffer (Welsch 1991):

Streamside Buffers

- Hydrologic Soil Group—Increase the width of Zone 2 to occupy any D and C soils subject to frequent flooding. If A or B soils are adjacent to the stream, the minimum combined width of Zone 1 and 2 is 75 feet.
- Area—The width of Zone 2 should be increased to provide a combined width of Zones 1 and 2 equal to one-third of the slope distance from the streambank to the top of the pollutant source area. The effect creates a buffer strip between the development and stream that occupies approximately one-third of the source area.

Pond and Lake-Side Buffers

- Area—The buffer should be at least one-fifth of the drainage area within the source area and is determined by creating a uniform width buffer of the required area between the source area and pond.

Vegetation

Forested buffers are preferred to vegetated strips, and existing vegetation is preferred to planted vegetation, especially near a water body where bank stabilization is desired. Tall, dense stands of grass form good sediment traps, as do willows and alder. A mix of vegetation types including grasses, deciduous and evergreen shrubs, and understory and overstory trees is also effective.

Vegetative cover throughout the buffer should be at least 75% of the total area to ensure adequate sediment removal. In areas where limited vegetation exists, consider enhancing the buffer with targeted plantings. Any planted species should be deep rooted and able to adjust to low oxygen levels. When choosing a planted species, consider site factors such as climatic, hydrologic, and soil conditions, and chose native plants that will adapt.

Other BMPs

In many cases, a vegetative buffer strip will not effectively control runoff and retain sediments unless employed with other control measures. Where heavy runoff or large volumes of sediment are expected, provide diversions or filtering measures above the buffer strip. Other BMPs that can be used with natural buffers include level spreaders or diversion measures such as diversion dikes (BMP 69) and slope drains (BMP 57).

If a 50-foot natural buffer cannot be provided on site, other control measures can be installed to provide equivalent sediment removal. These measures could include a sediment pond, additional perimeter controls, or other BMPs upgradient of the buffer.

Construction Guidelines

Before construction, the buffer boundary should be clearly marked with fencing, flagging, or other marking devices. The most effective delineation device for sensitive areas is steel construction fencing. All equipment, construction debris, and extra soil should be kept out of the natural buffer zone, and soil should not be compacted. Any planted vegetation should be well established before using the buffer for filtering runoff.

Maintenance

Buffers should be inspected at least four times a year and after large storm events exceeding 1 inch. Remove trash and repair any damage to the boundary markers. Any problem sediment accumulation should be removed. Erosion, scouring, or ponding due to channelization or high flows should be repaired with seeding, planting and/or regrading.

Keep vegetation healthy, and avoid excessive use of fertilizers, pesticides, or other chemicals. Naturally deposited leaves, woody debris, and other biomass should remain as they help retain water and filter pollutants. In Zone 3, vegetation may be mowed with clippings left in place.

Additional Resources

EPA (US Environmental Protection Agency). No date. *Riparian/Forested Buffer.* *https://enviroatlas.epa.gov/enviroatlas/DataFactSheets/pdf/ESN/PercentForestandWoodyWetlandsinStreamBuffer.pdf*.

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BMP 4: Manage Impervious Surfaces—Disconnect and Reduce

Description

Directly connected impervious areas (DCIA) are impervious surfaces that drain into a catch basin, area drain, or other impervious conveyance structure and are contributors to nonpoint source pollution. Impervious surfaces that can be disconnected vary from small surfaces such as sidewalks to large surfaces such as roofs and driveways. Disconnecting impervious surface areas by directing storm water runoff to pervious surfaces increases opportunities for infiltration, decreases runoff velocities, and reduces the negative impact that impervious surfaces have on storm water runoff rates and volumes (Figure 11).

Figure 11. Impervious sidewalk and parking leading to a pervious gravel surface.

Primary BMP Functions and Controls

☐ Construction	☒ Permanent
☒ Erosion Control	☐ Sediment Control
☐ Source Control	☐ Flood Control
☐ Filtration	☒ Infiltration

Typical Effectiveness for Targeted Pollutants

●	Sediment
◖	Phosphorus
◖	Metals
○	Bacteria
○	Hydrocarbons
○	Litter

Other BMP Considerations

Relative Cost	$
Maintenance Requirements	Easy
Ease of Installation	Easy
Freeze/Thaw Resistance	Good
Max. Tributary Drainage Area	N/A
Max. Upstream Slope	N/A
NRCS Soil Group	ABCD
Min. Ground Water Separation	N/A
Min. Bedrock Separation	N/A

Applicability

This BMP applies wherever pervious surfaces and well drained soils may be used to disconnect runoff from a storm water conveyance system.

Limitations

In dense and highly urban areas, pervious surfaces may not be present for use as a point of disconnection.

In certain cases, soil types, such as tight clays, may not support subsurface recharge and will be considered unsuitable for disconnecting impervious surfaces.

Design Basis

Impervious areas should be designed so that storm water runoff is not collected and conveyed to one discharge point but rather dispersed in several directions and discharged into adjacent pervious areas with appropriate soils for infiltration. Maximizing overland sheet flow path helps to decrease runoff velocity and minimize erosion. Pervious surfaces include areas of existing vegetation, landscaped areas, lawns, retention areas, drainage swales, or pervious pavements.

Strategies to disconnect impervious areas include the following:

- Disconnect roof drains from storm sewers and direct flow to stabilized vegetated areas.
- Design roads and driveways without curbs to direct runoff via sheet flow to roadside swales, bioretention areas, and vegetated buffers.
- Design roads with periodic curb cuts or slotted curbing to direct runoff to storm water bioretention areas, vegetated swales, and filter strips within traffic islands.
- Use pervious materials for the shoulder of roads in place of curb and gutter.
- Break up large parking areas with landscaped *infiltration islands* that intercept storm water runoff.
- Break up flow directions by locating roads on ridgelines, allowing water to drain naturally downhill.
- Use retention grading to create slightly sunken and bermed lawn areas to hold rainwater from roofs, driveways, and sidewalks until it can percolate into the ground.

Construction Guidelines

Not applicable

Maintenance

Not applicable

Additional Resources

BASMAA (Bay Area Stormwater Management Agencies Association). 1999. *Start at the Source: Design Guidance Manual for Stormwater Quality Protection*. San Francisco, CA: BASMAA.

DNREC and Brandywine. (Delaware Department of Natural Resources and Environmental Control and Brandywine Conservancy.) 1997. *Conservation Design for Storm water Management: A Design Approach to Reduce Stormwater Impacts from Land Development and Achieve Multiple Objectives Related to Land Use*. Dover, DE: DNREC.

BMP 5: Reduce Roadway and Sidewalk Surface Areas

Description

Reduce the amount of impervious roadway and sidewalk surfaces to decrease storm water runoff volume. Reducing roadway and sidewalk surfaces also provides more room for landscaped areas that allow storm water infiltration, improve water quality, and add visual appeal (Figure 12).

Figure 12. Planter bed used at merging intersection to reduce impervious surface area.

Applicability

Reductions to impervious cover should be incorporated into new and redevelopment whenever possible.

Limitations

Local regulations and ordinances may limit certain types of compact development.

Design Basis

Options to reduce the amount of roadway and sidewalk surfaces during the site design phase include lot roadway and driveway configurations that limit impervious surfaces. Techniques include the following:

- Cluster lots and reduce lot size to reduce roadways length and preserve natural open space areas.
- Use *loops and lollipops* instead of gridded street layouts to reduce roadway length.
- Minimize the radius of cul-de-sacs and include a landscape island in the center to accept runoff from the surrounding pavement (Figure 13 and Figure 14).
- Use a T-shaped *hammerhead* turnaround in place of cul-de-sacs (Figure 14).
- Minimize the setback distance between buildings and the roadway to reduce driveway length.
- Use shared driveways to reduce the amount of impervious surface.

Primary BMP Functions and Controls

☐ Construction	☒ Permanent
☒ Erosion Control	☐ Sediment Control
☐ Source Control	☐ Flood Control
☐ Filtration	☒ Infiltration

Typical Effectiveness for Targeted Pollutants

●	Sediment
◖	Phosphorus
◖	Metals
○	Bacteria
○	Hydrocarbons
○	Litter

Other BMP Considerations

Relative Cost	$
Maintenance Requirements	Easy
Ease of Installation	Easy
Freeze/Thaw Resistance	Good
Max. Tributary Drainage Area	N/A
Max. Upstream Slope	N/A
NRCS Soil Group	ABCD
Min. Ground Water Separation	N/A
Min. Bedrock Separation	N/A

- Use concrete paving only under wheel areas of driveways.
- Use a single driveway lane for access to the street and flare the driveway at multicar garages.

Design streets using the minimum width necessary to support traffic volume, on-street parking, and emergency service vehicles. Minimize the width and length of sidewalks where possible. If it is practical, place sidewalks on only one side of the street, or eliminate them completely if a consolidated walkway is provided in another location that adequately connects neighborhoods, schools, and shops.

If local subdivision ordinances do not allow for clustered development or minimizing lot sizes and setbacks and roadways, work closely with the local officials to obtain variances or changes to the regulations. Guidance on changing development regulations is provided in *Better Site Design: A Handbook for Changing Development Rules in Your Community* (CWP 1998).

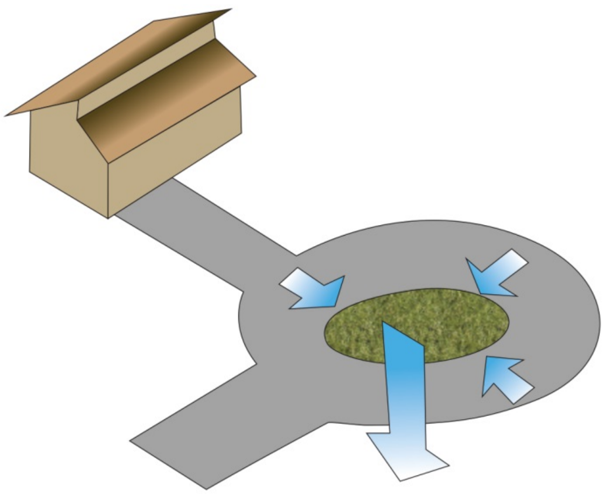

Figure 13. Landscape island in center of cul-de-sac.

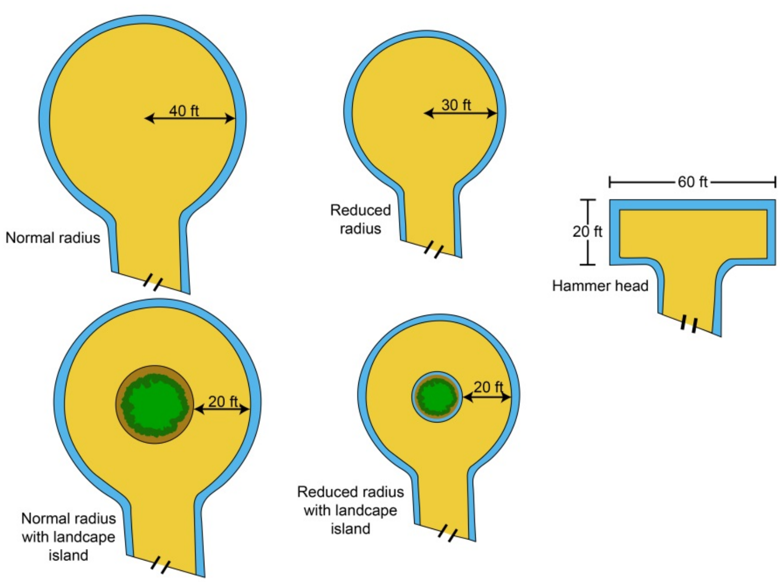

Figure 14. Alternative cul-de-sac and turnaround configurations.

Construction Guidelines

Not applicable

Maintenance

Not applicable

Additional Resources

Arendt, R.G. 1996. *Conservation Design for Subdivisions: A Practical Guide to Creating Open Space Networks.* Washington, DC: Island Press.

BASMAA (Bay Area Stormwater Management Agencies Association). 1999. *Start at the Source: Design Guidance Manual for Stormwater Quality Protection*. San Francisco, CA: BASMAA.

Coffman, L. 2000. *Low-Impact Development Design Strategies, an Integrated Design Approach*. Prince George's County, MD: Department of Environmental Resources, Programs and Planning Division. EPA 841-B-00-003.

CWP (Center for Watershed Protection). 1998. *Better Site Design: A Handbook for Changing Development Rules in Your Community.* Ellicott City, MD.

DEQ (Idaho Department of Environmental Quality) 1997. *Environmental Planning Tools and Techniques*. Boise, ID: DEQ.

Forman, R.T. et al. 2002. *Road Ecology: Science and Solutions.* Washington, DC: Island Press.

Little, C.E. 1995. *Greenways for America*. Baltimore, MD: The Johns Hopkins University Press.

BMP 6: Green Streets and Parking

Description

Trees, shrubs, and other vegetation located within urban settings have numerous benefits; they help break up the landscape of impervious cover, reduce storm water runoff volume, provide storm water management functions, and improve water quality. The *greening* of the urban landscape can be as small as a single tree located within a landscape island in a parking lot, or as large as an entire forest that is preserved or created within a city (Figure 15).

Figure 15. Green street in Portland, Oregon (City of Portland 2014).

Applicability

This BMP applies to all new and redeveloped streets, parking, and driving areas.

Limitations

Local regulations and ordinances may limit certain types of greening activities such as reduced parking stall sizes, reduced number of parking stalls and subsurface drainage below parking lots (in cold climates).

Primary BMP Functions and Controls

☐ Construction	☒ Permanent
☒ Erosion Control	☒ Sediment Control
☐ Source Control	☐ Flood Control
☒ Filtration	☒ Infiltration

Typical Effectiveness for Targeted Pollutants

●	Sediment
◖	Phosphorus
◖	Metals
○	Bacteria
○	Hydrocarbons
○	Litter

Other BMP Considerations

Relative Cost	$
Maintenance Requirements	Medium
Ease of Installation	Easy
Freeze/Thaw Resistance	Good
Max. Tributary Drainage Area	N/A
Max. Upstream Slope	N/A
NRCS Soil Group	ABCD
Min. Ground Water Separation	N/A
Min. Bedrock Separation	N/A

Design Basis

To create green streets and parking, it is important to reduce the amount of impervious surface and use the space saved to integrate functional landscaping and better storm water treatment. Methods to reduce the amount of street surface are included in BMP 5, and some techniques are described below:

- Reduce the number of parking spaces.
  - Use average parking standards instead of single peak day projections
  - Implement shared parking arrangements (day versus evening uses)
  - Reduce spaces if mass transit is available
- Shrink parking stall sizes
- Narrow drive aisles
- Use grid pavers for spillover parking

Functional landscaping integrated into the streetscape and parking areas provides both aesthetic and storm water management benefits. Locations for functional landscaping include traffic islands or medians within the street, the area between the street and sidewalk, landscape islands within parking lots, designated open space areas, and any other area not occupied by hardscape or buildings. Functional landscaping includes bioretention basins (BMP 18), vegetated (bioinfiltration) swales (BMP 9), and vegetated filter strips (BMP 11). These areas should be designed as a concave surface slightly depressed below the pavement so that water is directed from the impervious surface to the landscape area.

To direct runoff from street and parking areas to landscape areas, replace traditional curb and gutter with flat concrete curb. While curb and gutter is often considered the *standard* in road design, it increases storm water volume and velocity and prevents infiltration and ground water recharge. Where curb and gutter are necessary, design it with multiple openings or curb cuts so runoff can drain into adjacent landscape areas.

On sensitive sites, it may be appropriate to scatter parking (Thompson 2000). Scattered parking requires more detailed siting and construction, but facilitates using natural drainage systems by breaking up parking lots into smaller units so that each parking area can drain to an adjacent vegetated area. Green parking lots can also be created by designing a parking grove that uses a grid of trees and bollards to delineate parking stalls and create a shady environment (BASMAA 1999).

Construction Guidelines

Not applicable

Maintenance

When using the suggested BMPs for the functional landscaping and greening of areas, the suggested maintenance activities for that BMP should be followed.

If alternative functional landscapes are used, manufacturer or designer guidelines should be followed for ongoing maintenance and upkeep.

Additional Resources

BASMAA (Bay Area Stormwater Management Agencies Association). 1999. *Start at the Source: Design Guidance Manual for Stormwater Quality Protection*. San Francisco, CA: BASMAA.

Coffman, L. 2000. *Low-Impact Development Design Strategies, an Integrated Design Approach*. Prince George’s County, MD: Department of Environmental Resources, Programs and Planning Division. EPA 841-B-00-003.

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EPA (US Environmental Protection Agency). 2014. “Green Parking.” *What is Green Infrastructure?* Water: Green Infrastructure: *http://water.epa.gov/infrastructure/greeninfrastructure/gi_what.cfm#parking*

EPA (US Environmental Protection Agency). 2014. *Eliminating Curbs and Gutters*. Water: Best Management Practices Fact Sheet: *https://www.epa.gov/npdes/national-menu-best-management-practices-bmps-stormwater#edu*

EPA (US Environmental Protection Agency). 2014. *Urban Forestry*. Water: Best Management Practices Fact Sheet: *https://www.epa.gov/sites/production/files/2014-04/documents/stormwater-best-management-practices.pdf*

Metro. 1997. *Green Streets, Innovative Solutions for Stormwater and Stream Crossings, Portland, Oregon*. *http://www.oregonmetro.gov/tools-partners*

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Utah Association of Conservation Districts. 2001. *North Logan Low Impact Development Roadway Design Standards*. *https://www.cachecounty.org/assets/department/publicworks/roads/RoadManual.pdf*

Zielinski, J. 2000. “The Benefits of Better Site Design in Commercial Development.” *Watershed Protection Techniques* 3(2): 647–656.

BMP 7: Soil Restoration and Enhancement

Description

Soil restoration and enhancement improves compacted or low organic content soils to increase infiltration capacity, biological characteristics, and the ability of the soil to support vegetation. Improving soil integrity protects air and water quality and ensures human and animal health. Soil offers critical pollutant removal functions through filtration, biological processing by microbial action, and chemical processing (Figure 16).

Figure 16. Straw added to the soil as mulch.

Soil enhancement can restore soil porosity through mechanical loosening (e.g., tilling) and/or adding soil amendments. Soil amendments, like soil conditioners and fertilizers, make the soil more suitable for plant growth and increase water retention capabilities. Examples include biochar, bone meal, peat, coffee grounds, compost, coir, manure, straw, vermiculite, sulfur, lime, meal, compost tea, hydroabsorbent polymers, and sphagnum moss.

Primary BMP Functions and Controls

☐ Construction	☒ Permanent
☒ Erosion Control	☐ Sediment Control
☐ Source Control	☐ Flood Control
☒ Filtration	☒ Infiltration

Typical Effectiveness for Targeted Pollutants

●	Sediment
●	Phosphorus
◖	Metals
◖	Bacteria
◖	Hydrocarbons
○	Litter

Other BMP Considerations

Relative Cost	$$
Maintenance Requirements	Easy
Ease of Installation	Medium
Freeze/Thaw Resistance	Good
Max. Tributary Drainage Area	5 acres
Max. Slope	30%
NRCS Soil Group	ABCD
Min. Ground Water Separation	3 feet
Min. Bedrock Separation	6 feet

Applicability

Soil restoration and enhancements apply to sites where the soil is suffering from compaction, low organic content, or lack of soil organisms and where topsoil material is lacking or unsuitable to support vegetation. Urban sites often have highly compacted soils that do not allow adequate storm water infiltration. These soils can be further compacted by site preparation, backfill methods, and heavy machinery used in final demolition.

For structural storm water controls using vegetation and relying on infiltration and subsurface recharge, soil enhancement is especially important. Encouraging vegetation and reducing the effects of compaction, soil enhancement may improve the performance of vegetated (biofiltration) swales (BMP 9), bioinfiltration swales (BMP 10), and vegetated filter strips (BMP 11).

Soil enhancement and amendments may also be needed on sites where soil has been stockpiled for extended periods of time; stockpiling disrupts soil health and results in the partial or total loss of microorganisms. Limiting the time stockpiles sit and mixing the top foot of stockpiled topsoil with the remaining soil before final placement will ensure uniform distribution of living organisms.

Limitations

Soil restoration and enhancement may be needed to improve native soils to adequately support proposed landscaping. Depending on the amount of enhancement needed, it can add significant cost. However, improving the soil can ensure that the landscaping will be sustainable over the long term.

Design Basis

Upon completing restoration and enhancement efforts, soils should be of equivalent, or better, quality than local soils and exhibit increased infiltration capacity, healthy biological characteristics, ability to support vegetation, proper soil texture, and adequate resistance to erosion.

Specific improvements may be required for select BMP use. For BMPs where rapid vegetation growth is essential, soil nutrient levels may be adjusted accordingly. Other infiltration BMPs may require enhanced drainage above and beyond that of local soils. For both general and specific soil needs, consult a local cooperative extension office or landscape professional.

Two methods have been shown to restore some soil properties damaged by compaction: (1) adding soil amendments and (2) tilling. Soil amendments, such as fertilizers and conditioners, improve the organic and microbial content and nutrients in the soil so that it can adequately support vegetation. Tilling improves soil's physical characteristics and increases available airspace and permeability. The combination of tilling and soil amendments is often the most effective strategy.

Soil Amendment

For challenging soil amendment needs, such as amending steep slopes, high erodible soils, long project durations, large project areas, or proximity to surface waters, consult a soil scientist to develop a soil amendment specification appropriate to your site. For less complicated soil amendment needs, use the guidelines provided in this BMP and in the fact sheet, *Choosing a Soil Amendment* (Davis and Whiting 2013).

Consider the following factors when selecting a soil amendment:

- How long the amendment will last in the soil
- Soil texture
- Soil salinity and plant sensitivity to salts
- Salt content and pH of the amendment
- Permeability and water retention characteristics of the soil

The properties of a healthy soil include available nutrients, high water-holding capacity, porosity, bulk density, and structure. Nutrients such as nitrogen, phosphorus, and potassium are usually lacking from the soil as plants use large amounts for their growth and survival. The proper nutrient ratio should be determined based on anticipated soil needs. Physical characteristics affect the

spaces between solid particles where water, air, and soil organisms can move (Figure 17). Soil compaction occurs when weight on the soil surface collapses these spaces, creating a hard, solid mass. Water, air, and roots may be completely unable to penetrate compacted soil, reducing or destroying its capacity to sustain life. In general, compaction problems occur when airspace is reduced to 10%–15% of the total soil volume.

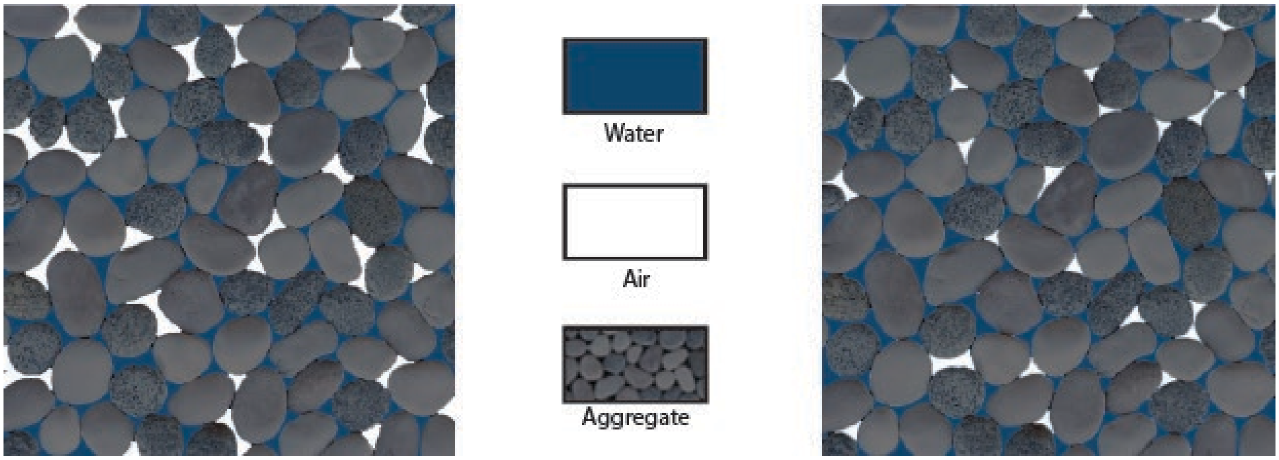

Figure 17. Healthy soil (left) versus compacted soil (right) (Pennsylvania DEP 2006).

To reduce the need for soil restoration, strip topsoil from all parts of the site that will be disturbed and stockpile on site for reuse. In addition to stockpiling existing topsoil in construction areas, soils in other areas should be managed to minimize compaction (BMP 45: Minimize Soil Compaction and BMP 38: Preserve Topsoil and Vegetation). The need for soil restoration can also be reduced by grouping plants that require high soil fertility together and planting native vegetation on the remainder of the site with unamended soils and no long-term irrigation. Short-term or periodic irrigation may be required if planting occurs during a dry season or on sandy soils. Species dependent, watering may also be necessary up to 2 years after planting and during periods of drought or intense heat.

If a site does not contain adequate topsoil, soils should be amended before revegetating. It is preferable to amend existing soils rather than to import large quantities of topsoil as purchasing and transporting clean fill is a high-cost approach. However, in certain instances importing fill may be needed based on vegetation requirements. The use of soil amendments with organic matter that has a low bulk density reduces compaction. The potential hydrologic benefits of compost-amended soils include increasing the soil's permeability and water-holding capacity, which delays and often reduces the peak storm water runoff flow rate (reduces the chance of erosion), and decreases irrigation water, fertilizer, and pesticide requirements. Materials such as compost, leaf mold, partially rotted manure, or composted sewage sludge are excellent, inexpensive sources found commercially. In addition to compost, soil conditioners, amendments, and fertilizers may be appropriate for use where the existing soil is badly damaged.

A list of advantages and disadvantages for a variety of soil amendments is shown in Table 12.

Table 12. Types of soil amendments (EPA 2007).

Amendment	Uses	Advantages	Disadvantages
Biosolids	Nutrient and organic matter source; sorbent properties	Multipurpose, multibenefit soil amendment; highly cost effective; EPA regulated; well characterized, consistent quality	Public concern/perceptions; high nutrient loadings in some settings; some sources have high moisture content.
Manures	Nutrient and organic matter source	Widely and readily available	Not consistently regulated; variable quality; not routinely treated for pathogen reduction; generally uncharacterized.
Compost	Nutrient and organic matter source	Readily accepted; stable product; used in or near water	High cost; limited availability; N quantity usually significantly lower than noncomposted materials.
Digestates	Nutrient and organic matter source	—	New enough to be regulated; variable quality; not routinely treated for pathogen reduction; generally uncharacterized.
Pulp sludges	Organic matter source; slope stabilizer	High C content; large volumes; locally available	Highly variable quality; may contain other residuals (e.g., fly ash, waste lime, clay) that can be a benefit or detriment for intended use. Total C may not reflect available C. Very low nutrient value.
Yard/wood waste	Organic matter source; can be high in C; use for bulking and structure	May be used to control erosion; variable sizes available	Large category; high variability; may be hard to obtain; can contain herbicides.
Ethanol production byproducts	Nutrient and organic matter source	—	New, not regulated; variable quality; not routinely treated for pathogen reduction; generally uncharacterized.
Lime	Increase pH; increase Ca	Regulated; well characterized; very uniform; soil aggregation	Agricultural limestone has low solubility and can become coated and ineffective at severely acidic sites. Can be a source of fugitive dust.
Wood ash	Increase pH; source of mineral nutrients, Ca, Mg, K; use for odor control	Acceptance; cost; multipurpose; limits odor of organic soil amendments	Highly variable; lime equivalent will vary by burn temperature and age of material; dioxins should not be a problem, but tests should be conducted to verify.
Coal combustion products	Increase pH; source of mineral nutrients (e.g., Ca)	Regulated; well characterized; soil aggregation; light color reduces surface temperature for seedlings; increases moisture-holding capacity; reduces odor of organic soil amendments	Varies plant to plant; can be high in B and salts; can leach Se and As.
Sugar beet lime	Increase pH	More reactive than agricultural limestone	Potential fugitive dust.
Cement kiln; lime kiln	Increase pH; high Ca	Highly soluble and reactive	Potential fugitive dust; highly caustic; variable content; may contain contaminants.
Red mud	Increase pH; sorbent	Demonstrated effective in limited testing in Australia and other sites at moderating pH and sorbing metals	Potentially costly; high salt content; variable CCE.
Lime-stabilized biosolids	Increase pH; nutrient and organic matter source; potential sorbent	—	Can have high odor; lower N content than conventional biosolids, variable lime content.
Foundry sand	Modifies texture; sorbent	Good filter; sand replacement	Can have trace metals; significant Na; only Fe and steel sands currently acceptable.
Steel slag	CCE; sorbent; Mn fertilizer	Combination of CCE and sorbent, including Mn	May volatilize ammonia.
Dredged material	Modifies texture; top soil substitute for covering sites	Top soil substitute; ideal for blending with other residuals	Needs dewatering; can have a wide range of contaminants; can have Na.
Gypsum	Good for sodic soil, low pH soil, and soil structure	Improves aggregation; offsets aluminum toxicity	Different sources of waste gypsum and wide range of potential contaminants, many of which are regulated.
Water treatment residuals (WTR)	Good for binding P; potential sorbent	Moderates P availability when mixed with high P soil amendments	Different materials have variable reactivities; may contain As and radioactive isotopes.
Coal combustion products (CCPs)	Sorbent; improve water-holding capacity; excellent mix for biosolids; compost to create cover soil	May have CCE value; large volumes available	Large quantities generally necessary to achieve benefits; can have contaminants. including Se, B, As, and metals

Tilling

Tilling mechanically loosens the soil by aeration, digging, scraping, mixing, subsoiling, or ripping the soil to circulate air into the soil mantle in various layers. Tilling exposes compacted soil devoid of oxygen to air and recreates temporary air space.

Whenever possible, perform tilling and subsoiling when the soil is mostly dry and friable to produce better results. If the soil is too wet, the subsoiler shanks slide through the ground without breaking up the soil, and the shank can actually glaze the soil and compact it more. If the soil is extremely dry, getting the subsoiler into the ground can be difficult, requiring larger, more powerful tractors to pull the shanks through compacted areas. Two passes at an angle to each other may be required to completely fracture compacted soil (Figure 18).

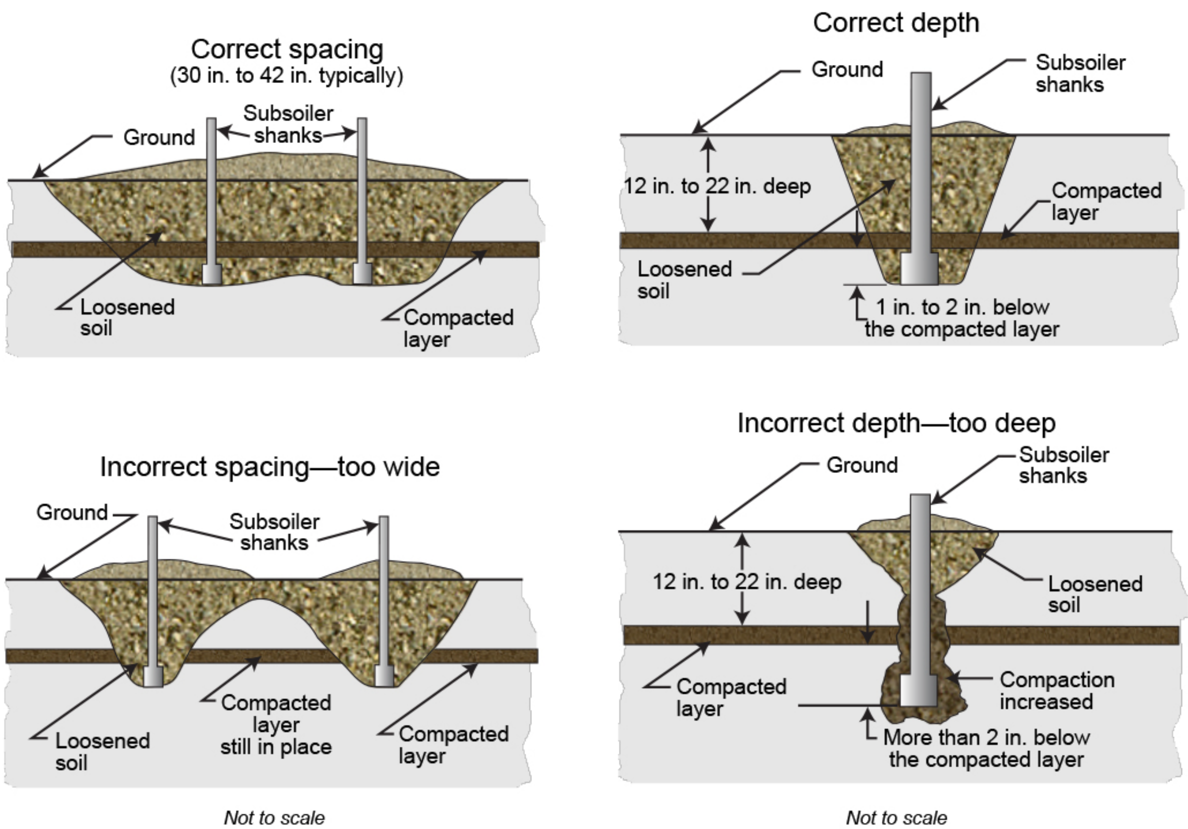

Figure 18. Effect of spacing and depth of subsoiler shanks (USDA 2008).

Other physical methods for addressing compaction include deep-water jetting and air injection, in which compressed air or water is injected to fracture the compressed soil; the fractures are then backfilled with some dry material such as vermiculite.

Determine the depth and thickness of compacted layers before deciding on the soil tilling specifications. Dig a test hole 24 to 30 inches deep and probe the sides with a knife or hand-held soil penetrometer. Soil compacted to depths of 12 to 22 inches will require ripping or subsoiling with properly spaced shanks that run 1 to 2 inches below the compacted layer.

Construction Guidelines

Add soil enhancements and amendments after grading is completed and before landscaping, seeding, or sodding.

Maintenance

After construction, monitor vegetation and adjust the use of further soil enhancements, microbial inoculants, irrigation, fertilizers, pesticides, and herbicides as necessary.

Additional Resources

Craul, P.J. 1992. *Urban Soil in Landscape Design.* Hoboken, NJ: John Wiley & Sons, Inc.

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Thompson, J.W. and K. Sorvig. 2000. *Sustainable Landscape Construction: A Guide to Green Building Outdoors*. Washington, DC: Island Press.

USDA (US Department of Agriculture, Forest Service). 2008. *Using Subsoiling to Reduce Soil Compaction*. Missoula, MT: USDA Forest Service, Technology and Development Program. 0834–2828–MTDC.

WDOE (Washington Department of Environmental Quality). 2009. "Building Soil—Guidelines and Resources for Implementing Soil Quality and Depth BMP T5.1" *WDOE Stormwater Management Manual for Western Washington*. *https://ecology.wa.gov/DOE/files/45/4569b90a-217a-40d2-a997-49adb8db5d86.pdf*

BMP 8: Vegetation Restoration

Description

Restoring vegetated areas that have been disturbed or eroded decreases the amount and rate of storm water runoff through increased infiltration and evapotranspiration. Vegetated areas also improve water quality through filtering and can stabilize soil and streambanks (Figure 19).

To develop a vegetation restoration plan, conduct a thorough site evaluation, select a holistic range of native and regionally appropriate vegetation, and control any existing invasive species.

Figure 19. Streambank restoration along Lane's Creek, Caribou County, Idaho.

Applicability

Vegetation restoration focuses on replacing native vegetation that has been disturbed or eroded and should be part of a comprehensive restoration plan. BMP 32: Landscaping provides information on adding vegetation to newly developed areas using seeding, sodding, and planting.

Sustainability is the most important consideration in vegetation restoration. Nonnative sod grass lawns, or managed turf, are unsustainable due to their relatively high irrigation, fertilizer, pesticide, and mowing needs when compared to native species, which are well adapted to Idaho's climate. These grasses should be limited to use in areas where high quantities of sod grass, such as Kentucky bluegrass or perennial ryegrass, are already widely used. Alternative ground covers are available that require less maintenance and also decrease the potential for pollutants to leave the site in runoff.

A vegetation restoration plan may also be used with additional storm water and construction needs such as stabilizing stream and riverbanks and a planting plan for LID BMPs, which mimic natural drainage patterns. The goal of LID is to replicate a site's predevelopment hydrology by using design solutions that infiltrate, filter, store, evaporate, and detain runoff close to where rainfall lands.

Primary BMP Functions and Controls

☒ Construction	☒ Permanent
☒ Erosion Control	☒ Sediment Control
☐ Source Control	☒ Flood Control
☐ Filtration	☒ Infiltration

Typical Effectiveness for Targeted Pollutants

●	Sediment
○	Nitrogen
○	Phosphorus
○	Metals
○	Bacteria
○	Hydrocarbons
○	Litter

Other BMP Considerations

Relative Cost	$
Maintenance Requirements	Low
Ease of Installation	Easy
Freeze/Thaw Resistance	NA
Max. Tributary Drainage Area	NA
Max. Upstream Slope	NA
NRCS Soil Group	ABC
Min. Ground Water Separation	NA
Min. Bedrock Separation	NA

For more information on LID practices, see Section 3.4 "Develop a Site Plan and Map" on the *EPA LID website*.

Limitations

Permanent revegetation may take several years before sufficient establishment is achieved.

Design Basis

Whenever possible, the need for revegetation should be minimized by adopting practices such as those in BMP 38: Preserve Topsoil and Vegetation. If preserving existing vegetation is not possible, replant with native plants or regionally adapted plants. These plants require less water, fertilizer, and pesticides than introduced species. Additionally, plants native to a region are usually more resistant to insects and diseases than other plants.

Native plant restoration usually involves managing communities rather than individual plants. Plants grow in communities, and understanding the importance of this pattern is essential to creating self-sustaining landscapes. Contact your local cooperative extension office to obtain native plant lists appropriate for the restoration site, or visit one of the resources below:

- *Idaho Master Gardener at the University of Idaho Extension*
- *Lawns at the University of Idaho Extension*
- *Native Plants for Idaho Roadside Restoration and Revegetation Programs*
- *North Idaho Native and Beneficial Plant List*

Base plantings on patterns of plant growth that naturally occur in the region. Field sketch the local growth patterns of regional trees and shrubs and create maps of these patterns on graph paper as roughly scaled plans of the major plants. Similar to a designer's planting plan but derived from naturally occurring patterns, these plant patterns can then be used as models to base designed and constructed plantings.

Divide the site's landscape into zones when designing the planting to take advantage of the varying conditions or microclimates that exist in every landscape and to ensure that vegetation remains healthy while requiring minimal care. These microclimate zones are based on a number of factors: the amount of water required for the vegetation present to flourish, soil group, daily sun light and shading conditions, and possible human and/or animal influences.

Revegetation is not just about replanting appropriate species but also controlling and removing ecologically inappropriate plants. Site restoration requires attention to altered soil, grading, and drainage patterns that may have allowed weeds to become established. Correcting these problems is essential to restoring a healthy plant community. For instance, changing soil conditions to favor native plants can eliminate some invasive species. Invasive plant removal may also be necessary and require grubbing, forking the soil to remove roots or tubers, and/or the selective use of herbicides through low-volume, targeted application (BMP 79: Pesticide Management).

Maintenance

Compared with nonnative lawns consisting of turf, shrub, and perennial plantings, landscapes planted with native species require less maintenance. Native species require minimal watering after

establishment unlike many nonnative species that require watering throughout their lifecycle. Native species also need little to no chemical fertilizers or pesticides. The following are characteristics of native plants that reduce maintenance:

- Species may live for many decades.
- Plants are appealing most of the year as opposed to only in certain seasons.
- Plants can tolerate a wide range of light and moisture conditions.
- Species grow into dense groupings, which reduce and eliminate unwanted weeds.

While native species require reduced maintenance requirements, they still require on-going care and attention:

- Native species cannot compete with invasive species. Mulching with a weed-free material (e.g., clean straw) will keep the weeds and introduction of invasive species at a minimum.
- Cut, rather than pull, weeds. Pulling weeds may damage the roots of young native plants. Pulling also disturbs the soil, encouraging weed growth and invasive species introduction.
- Many native species have adapted to fire-dominated ecosystems. While performing controlled burns is an option, it should only be performed by certified professionals. Cutting and removing the debris from the area mimics the natural fire cycle, is a safe alternative to controlled burns, and exposes soil to the sun's warmth, encouraging growth.

Additional Resources

American Forests. 2015. *CITYgreen*. *http://www.sustainable.org/economy/forestry-a-wood-products/366-american-forests-citygreen*

Idaho Native Plant Society. *https://idahonativeplants.org/*

EPA (US Environmental Protection Agency). 2012. *Landscaping with Native Plants*. *https://www.epa.gov/watersense/what-plant*

EPA (US Environmental Protection Agency). 2014. *Urban Forestry*. Water: Best Management Practices Fact Sheet: *https://www.epa.gov/npdes/national-menu-best-management-practices-bmps-stormwater#edu*

State of Idaho Department of Agriculture. *Idaho's 67 Noxious Weeds*. *http://www.agri.state.id.us/Categories/PlantsInsects/NoxiousWeeds/watchlist.php*

Thompson, J.W. and K. Sorvig. 2000. *Sustainable Landscape Construction: A Guide to Green Building Outdoors*. Washington, DC: Island Press.

USDA (US Department of Agriculture). 2015. *Resource Library: Invasive Species Lists*. *http://www.invasivespeciesinfo.gov/resources/lists.shtml*

BMP 9: Vegetated (Biofiltration) Swale

Description

Biofiltration swales, commonly called grass or vegetated swales, are densely vegetated open channels designed to convey storm water runoff slowly to facilitate particle settling, filtration, adsorption, and some biological uptake of pollutants. They have mild longitudinal slopes and are wider and shallower than standard storm drain channels to maximize flow residence time (Figure 20).

Figure 20. Vegetated swale (Virginia DCR 2011).

Applicability

Biofiltration swales apply in areas with low-to-moderate slopes (less than 6%), although drop structures can be integrated into the design so that they can be used on steeper sites. Swales are linear in nature, so they are well suited for treating runoff from roadways and can be used to replace traditional curb and gutter systems. They are also useful for providing conveyance to and from other BMPs as part of a treatment train within an integrated storm water management plan. For example, placing a sedimentation basin (BMP 25) upstream of a biofiltration swale will help protect the swale from excessive siltation and decrease erosion potential. Low flow vegetated swales can also be placed within retention or detention ponds (BMPs 22 and 23).

Biofiltration swales can provide runoff treatment of conventional pollutants, such as suspended solids, metals, oil and grease, and petroleum hydrocarbons, but are less effective with nutrients. Vegetated swales, when used as a primary treatment measure, should be located off-line from the primary conveyance/ detention system to enhance effectiveness. When a facility is off-line, it is not located within the primary flow path, and runoff is diverted from the primary conveyance to the facility. Swales can also be made smaller when they are located off-line.

Primary BMP Functions and Controls

☐ Construction	☒ Permanent
☐ Erosion Control	☒ Sediment Control
☐ Source Control	☐ Flood Control
☐ Infiltration	☒ Filtration

Typical Effectiveness for Targeted Pollutants

◖	Sediment
○	Phosphorus
◖	Metals
○	Bacteria
◖	Hydrocarbons
○	Litter

Other BMP Considerations

Relative Cost	$
Maintenance Requirements	Medium
Ease of Installation	Easy
Freeze/Thaw Resistance	Fair
Max. Tributary Drainage Area	15 acres
Max. Slope	6%
NRCS Soil Group	BC
Min. Ground Water Separation	3 feet
Min. Bedrock Separation	3 feet

Limitations

The presence of dense vegetation is the key to the effectiveness of biofiltration swales. Sites that are arid or semiarid should weigh the value of the swale against irrigation needs of the vegetation, although using native vegetation can reduce or eliminate the need for irrigation. Also, vegetated swales are not appropriate for storm water hotspots with highly contaminated runoff due to the variability in their performance between storms (Washington State Department of Ecology 2012).

For a vegetated swale, the minimum channel length is 100 feet for adequate pollution removal.

Biofilters should be protected from siltation by a presettling basin (BMP 25) when the erosion potential is high; otherwise, presettling is not generally needed for normal operation. However, a series arrangement of a retention/detention pond and biofilter can offer extra protection to sensitive receiving waters, due to the complementary pollutant removal mechanisms that can operate in the two devices. Equipping both sides of the swale with vegetative buffers or filter strips will also help reduce loading and decrease swale maintenance.

Design Basis

The design for biofiltration swales focuses on providing adequate conveyance through dense vegetation at a slow rate and shallow depth to facilitate sediment removal and infiltration. The following steps and criteria outline the design procedure for vegetated swales.

Design Discharge

Determine the peak flow to be conveyed by the swale for the water quality design storm under fully developed conditions. The swale should also have capacity to safely pass the major storm (10 year, 25 year, or 100 year depending on specifications of the local agency). Use hydrologic procedures presented in section 3.6 to determine peak flows.

Longitudinal Slope

Establish the horizontal location of the swale and determine the longitudinal slope. Minimally, the channel slope should be between 1% and 5% but ideally between 2% and 4% if grasses are used to vegetate the swale. Swales with slopes less than 2% should include underdrains placed beneath the channel to ensure positive drainage, or they should be planted with vegetation that can withstand periods of ponding water. For slopes greater than 4%, log or rock check dams (BMP 60) or drop structures can be used approximately every 50 feet so that a maximum 4% slope can be maintained between structures. Energy dissipation measures should be used downstream of each drop structure.

Flow Depth

Select a flow depth based on the vegetation to be used in the swale. To be effective, the depth of flow for the water quality design storm should not exceed the height of the vegetation. The maximum depth of flow is approximately 2 inches for mowed vegetation, 4 inches for infrequently mowed vegetation, and 6 inches for unmowed vegetation, depending on species.

Geometry

Determine the geometry of the swale based on the longitudinal slope, flow rate, and flow depth. Use either a trapezoidal or triangular shape with side slopes no steeper than 3:1 (horizontal: vertical). For ease of construction and maintenance, the recommended geometry is a trapezoidal shape with a minimum bottom width of 2 feet and 4:1 side slopes. The maximum bottom width should be 10 feet unless a divider is used (Figure 21).

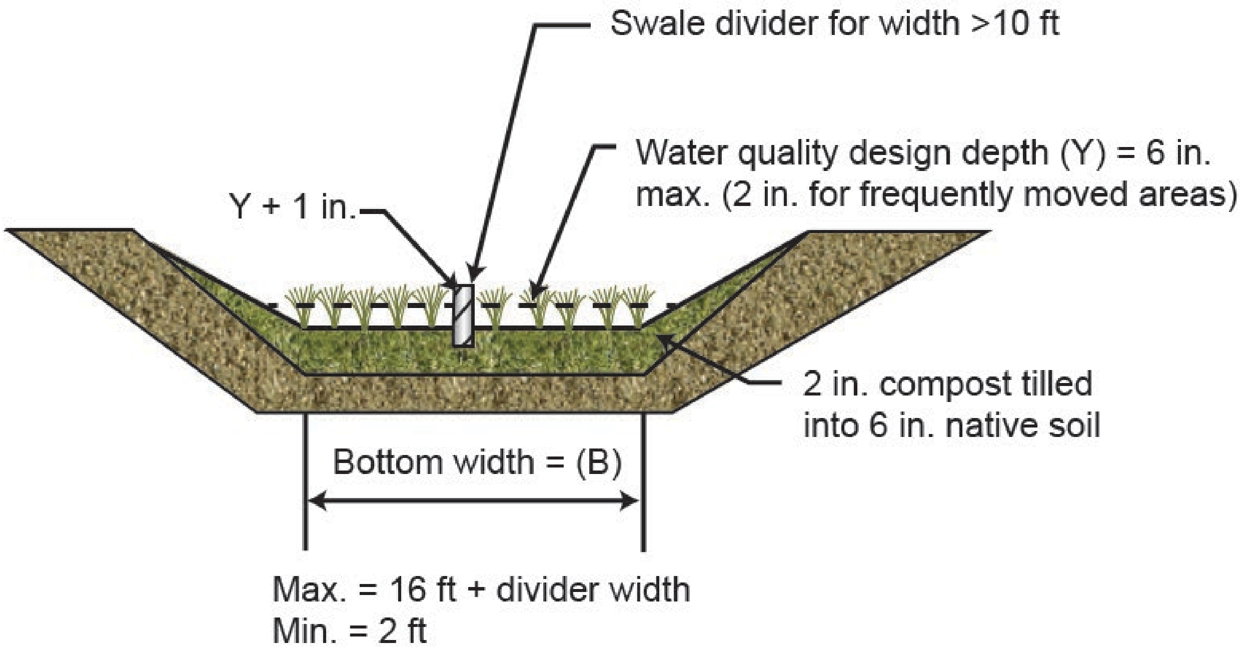


Figure 21. Typical biofiltration swale cross section (adapted from King County 2009).

Manning's equation for open channel flow can be used to size the swale. Select a value for the Manning's roughness coefficient, n, based on the vegetation to be used (generally n = 0.2 to 0.3 for grass or other dense vegetation that is not submerged by the very shallow flow depth). For a trapezoidal channel with shallow flow, the hydraulic radius can be approximated to the depth of flow and Manning's equation can be expressed as follows (Equation 8):

$$B = \frac{Q * n}{1.49\, y^{\frac{5}{3}} S^{\frac{1}{2}}} - Zy$$

Equation 8. Swale bottom width.

Where:

B = bottom width of swale (feet)
y = depth of flow (feet)
S = longitudinal slope of swale (feet per feet)
Z = side slope of the swale in the form Z:1 (H:V)
Q = design flow rate (cubic feet per second)

Velocity

Use the calculated bottom width and swale geometry to check the velocity within the swale. The velocity can be calculated using Equation 9:

$$V = \frac{Q}{A}$$

Equation 9. Channel velocity.

Where:

V = velocity (feet per second)
A = cross-sectional area of flow (square feet) = $By + Zy^2$
Q = flow (cubic feet per second)

The velocity of the water should not exceed 1 foot per second during the water quality design storm and should not exceed 3 feet per second during the major storm. If the velocity exceeds the maximums, adjust the swale design until the conditions are met. This adjustment may entail changing the bottom width, reducing the flow by installing a flow divider, or changing the vegetation type to increase the allowable depth.

Hydraulic Residence Time

For biofiltration, maximize water contact with vegetation and the soil surface. A minimum hydraulic residence time of 9 minutes is required to provide adequate pollutant removal. In no case should residence time be less than 5 minutes. For better pollutant removal, a longer residence time is recommended.

Compute the hydraulic residence time using Equation 10:

$$t = \frac{L}{V * 60}$$

Equation 10. Hydraulic residence time.

Where

t = hydraulic residence time (minutes)
L = length of the swale (feet)
V = flow velocity (feet per second)

If the hydraulic residence time is less than 9 minutes, reconfigure the swale to increase the length. It may be necessary to use a wide-radius curved path, where land is not adequate for a linear swale (avoid sharp bends to reduce erosion or provide for erosion protection).

Check the surface area of the swale compared to the tributary drainage area. As a general rule, the total surface area of the swale should be approximately 1% of the total drainage area.

High Flows

High flows during a major storm should either be conveyed safely by the swale or bypass the swale through a parallel pipe with a flow-regulating device inside the inlet structure. If the swale is to convey high flows, consider channel erosion control and vegetation destruction, and perform a stability analysis. The swale should provide at least 1 foot of freeboard over the water quality storm and safely pass the major storm with a maximum velocity of 3 feet per second.

Slopes

For swales with longitudinal slopes less than 2%, install an underdrain under the channel if grasses are desired. The underdrain should be installed within an 8-inch aggregate layer. Use either a 4- or 6-inch diameter perforated high-density polyethylene pipe for the underdrain and include cleanouts every 150 feet. A filter sock around the pipe should not be used as it can cause the pipe perforations to clog. The underdrain can daylight to either a storm water inlet or through the face of a grade control structure at the end of the swale.

Alternatively, emergent wetland plant species can be used when some period of soil saturation is expected or where particular pollutant uptake characteristics are desired.

Soils

The soils within the swale should support a dense growth of vegetation, which can eliminate very heavy clay soils. Soils in hydrologic soil groups A, B, and C with good infiltration qualities and lower runoff potentials are preferred.

Below the design water depth, install an erosion control blanket, at least 4 inches of topsoil, and the selected biofiltration seed mix. Above the design water line, use an erosion control seed mix with straw mulch or sod.

Vegetation

Select vegetation based on pollution control objectives and according to what will best establish and survive in the site conditions. Select close-growing, water-resistant grasses with a height of 6 inches or less. Grasses over 6 inches tend to flatten down when water is flowing over them, which prevents settling of sediment.

In swales next to roadways where deicer is regularly used, salt-tolerant species should be used. Selecting different, low-growing ground covers for the swale's side slopes can lessen the amount of mowing required.

Construction Guidelines

The success of biofiltration swales depends more on proper construction and maintenance than any other factor. Construction guidelines include the following:

- Avoid compaction during construction and protect the area from construction activities.
- Use netting to protect plants from predation during establishment.
- Provide irrigation as necessary.
- Perform fine grading, soil amendment, and seeding after stabilizing upgradient surfaces.

Maintenance

Inspect and maintain biofiltration swales to ensure the vegetation remains healthy and rills or gullies are repaired. The following measure should be taken:

- Inspect swales at least every 6 months, preferably during and after storm events. Check for uniform vegetative cover and traffic impacts. Spot replace vegetation as necessary.

- Mow grasses if needed for good growth. Mowing requirements vary for different grass species. Remove clippings to maintain the performance capacity of the swale.
- Remove sediment as needed near culverts and the channel to maintain flow capacity.
- Remove leaves, litter, and oily materials. Clean curb cuts and level spreaders as needed.
- Control weeds as needed. Mechanical weed control by pulling or mowing is preferred to chemical herbicides.
- Irrigate if necessary to establish and maintain vegetation.
- Fertilizing is often unnecessary because runoff from lawns and other areas provides enough nutrients. If needed, use only biodegradable, nontoxic fertilizers and apply at a rate and formula compatible with plant uptake and soil group. Soil tests may be necessary to determine existing soil fertility and proper application rate.
- Perform public education for residents living near biofilter swales; describe their purpose and the importance of keeping them free of debris.

Additional Resources

EPA (US Environmental Protection Agency). No date. *Grassed Swales*. Water: Best Management Practices Fact Sheet. *https://www.swbmp.vwrrc.vt.edu/wp-content/uploads/BMP_Spec_No_10_DRY_SWALE.pdf*

Goldberg, J. 1993. *Dayton Avenue Swale Biofiltration Study*. Seattle Engineering Department, Seattle, WA.

Schueler, T. 1997. "Comparative Pollutant Removal Capability of Urban BMPs: A Reanalysis." *Watershed Protection Techniques* 2(2): 379–383.

Virginia DCR (Virginia Department of Conservation and Recreation). 2011. *Dry Swales*. Ver. 1.8. Stormwater Design Specification No. 10. *http://vwrrc.vt.edu/swc/april_22_2010_update/DCR_BMP_Spec_No_10_DRY_SWALE_Final_Draft_v1-8_04132010.htm*

Washington State Department of Ecology. 2012. *Stormwater Management Manual for Western Washington*. Lacey, WA. Publ. 12-10-030. *http://www.ecy.wa.gov/programs/wq/stormwater/manual.html*

BMP 10: Bioinfiltration Swale

Description

Bioinfiltration swales combine grasses (or other vegetation) and soils to remove storm water pollutants by percolation into the ground. The swales pollutant removal mechanisms include filtration, soil sorption, and uptake by vegetated root zones. Bioinfiltration swales have been used over the Rathdrum Prairie Aquifer located in northern Idaho for many years to treat urban storm water and recharge the ground water (Figure 22).

Figure 22. Grassy biofiltration swale (DEQ and Kootenai County 2018).

Bioinfiltration swales treat storm water runoff from roofs, roads, and parking lots. For flow control, flows greater than the water quality design flows (as specified by local regulations) are typically overflowed to the subsurface through an appropriate conveyance facility such as a dry well, or to surface water through an overflow channel. Although Underground Injection Control regulations do not apply to the swales in these facilities, the regulations do apply to any dry well used in connection with the swale.

Primary BMP Functions and Controls

☐ Construction	☒ Permanent
☐ Erosion Control	☒ Sediment Control
☐ Source Control	☒ Flood Control
☒ Filtration	☒ Infiltration

Typical Effectiveness for Targeted Pollutants

●	Sediment
◖	Phosphorus
◖	Metals
◖	Bacteria
◖	Hydrocarbons
◖	Litter

Other BMP Considerations

Relative Cost	$
Maintenance Requirements	Medium
Ease of Installation	Medium
Freeze/Thaw Resistance	Fair
Max. Tributary Drainage Area	5 acres
Max. Slope	4%
NRCS Soil Group	AB
Min. Ground Water Separation	3 feet
Min. Bedrock Separation	6 feet

Applicability

An open basin bioinfiltration swale at the ground surface can be used where sufficient open space is available. This use takes advantage of existing natural surface depressions and swales on site where a berm or a low dam could create the needed area. Alternatively, the landscape can be designed to include a depressed area to place the bioinfiltration swale. Road ditch areas are suited for bioinfiltration swales given the proper soil conditions.

Limitations

The appropriate soil conditions for infiltration and ground water protection are the most important considerations limiting the use of this BMP. Soils should be permeable enough to infiltrate runoff but should also contain enough fine soils and organic material to remove pollutants and promote the growth of deep-rooted, healthy vegetation. Planting soils should be at least loamy, with a clay content of less than 15%.

The soil should contain 3%–5% organic material and have a pH of 5.5 to 6.5 (in Idaho, the Garrison, Avonville, and McGuire soil groups are appropriate on the Rathdrum Prairie).

Because soils can vary tremendously over short distances, site-specific evaluation may be required to determine if the minimum infiltration rate is attainable. If the tested infiltration rate cannot meet minimum values, import more permeable material and modify the soil profile to allow these swales to properly function.

As with any type of infiltration facility, bioinfiltration swales should not be used in areas with shallow aquifers. An official inventory form for shallow injection wells, used with the swales, should be submitted to the IDWR or, in some cases, the local health district. Contact the closest IDWR regional office for further information.

Design Basis

Bioinfiltration swales may be sized using several different design methods. The county or municipality where the facility is located should provide the design storm for the facility and any minimum sizing requirements. The local jurisdiction may direct the designer to use a particular method. Do not confuse the requirements for storm water treatment with the need to control and dispose of design storm flows.

The following method determines the volume necessary for treating the first 0.5 inch of runoff (Equation 11). This method applies only in certain climates. The bioinfiltration swale design should determine if this method is geographically appropriate.

$$V = \frac{A_i \, 0.5 \, in.}{12 \, in./ft}$$

Equation 11. Volume of bioinfiltration swale.

Where

V = volume of bioinfiltration swale (cubic feet)

Ai = impervious area needing treatment that drains to the bioinfiltration swale (square feet)

This methodology uses the first 0.5 inch of runoff from pollutant-generating impervious surfaces that are hydraulically connected to the treatment facility to size the bioinfiltration swale. This method does not require treating permeable surfaces and does not give credit for infiltration through the bottom of the swale. The treatment soil depth is typically 6 inches. A maximum treatment depth of 8 inches is allowed if cation exchange capacity (CEC) testing indicates that CEC is 15 milliequivalents (meq)/100 grams or greater. CEC testing can be completed postconstruction or a soil amendment that meets the CEC requirements can be specified on the construction drawings. The swale is sized to store the required runoff volume generated by the contributing basin. The sizing uses the entire swale depth, typically no deeper than 1 foot, with a subsurface infiltration facility such as a dry well. If water in the swale is deeper than this, the additional head may increase the infiltration rate beyond the design rate and reduce pollutant removal effectiveness.

Soil Infiltration

Because of potentially heterogeneous soil conditions, multiple infiltration tests should be performed within the area of the basin. The number of tests necessary will depend on the area of the basin and variability of soil conditions. The larger the basin and more variable the soil conditions, the more tests will be required. Different methods are available for measuring infiltration rates. The recommended test methods are the double-ring infiltrometer (ASTM D 3385-03) and large-scale pilot infiltration test (pit) method (*Stormwater Management Manual for Western Washington* [Washington State Department of Ecology 2019]). The two tests measure infiltration rates, but the double-ring infiltrometer test provides a measure of the vertical infiltration rate of the test area and the large-scale pilot infiltration test method provides a measure of both vertical and lateral infiltration rates of the test area. Consult a storm water design professional to determine the method and number of tests required to adequately characterize basin infiltration rates and any additional analysis that maybe necessary.

Soil infiltration capacity should be a minimum of 0.5 inches per hour for the life of the swale. The maximum infiltration rate should be 2.4 inches per hour. A higher maximum infiltration rate may be acceptable if an adequate vegetative cover can be maintained without excessive irrigation. If the swale does not meet the minimum infiltration rate of 0.5 inches per hour, more permeable material should be brought in and incorporated, and infiltration tested again. If the soil cannot be treated to reach the minimum infiltration rate, make an alternative design. Prolonged ponding around the dry well intake indicates infiltration rates are too low, and maintenance is needed.

Dry Well Rim Height and Placement

Infiltration swales should be designed to infiltrate the design flow before reaching the dry well rim. Local jurisdictions will determine the minimum dry well rim height, but the rim should be elevated above the lowest point of the swale. The dry well should be placed as far as possible from any points of inflow. None of the first 0.5 inch of storm water should enter the dry well for the design to be acceptable (Figure 23 and Figure 24).

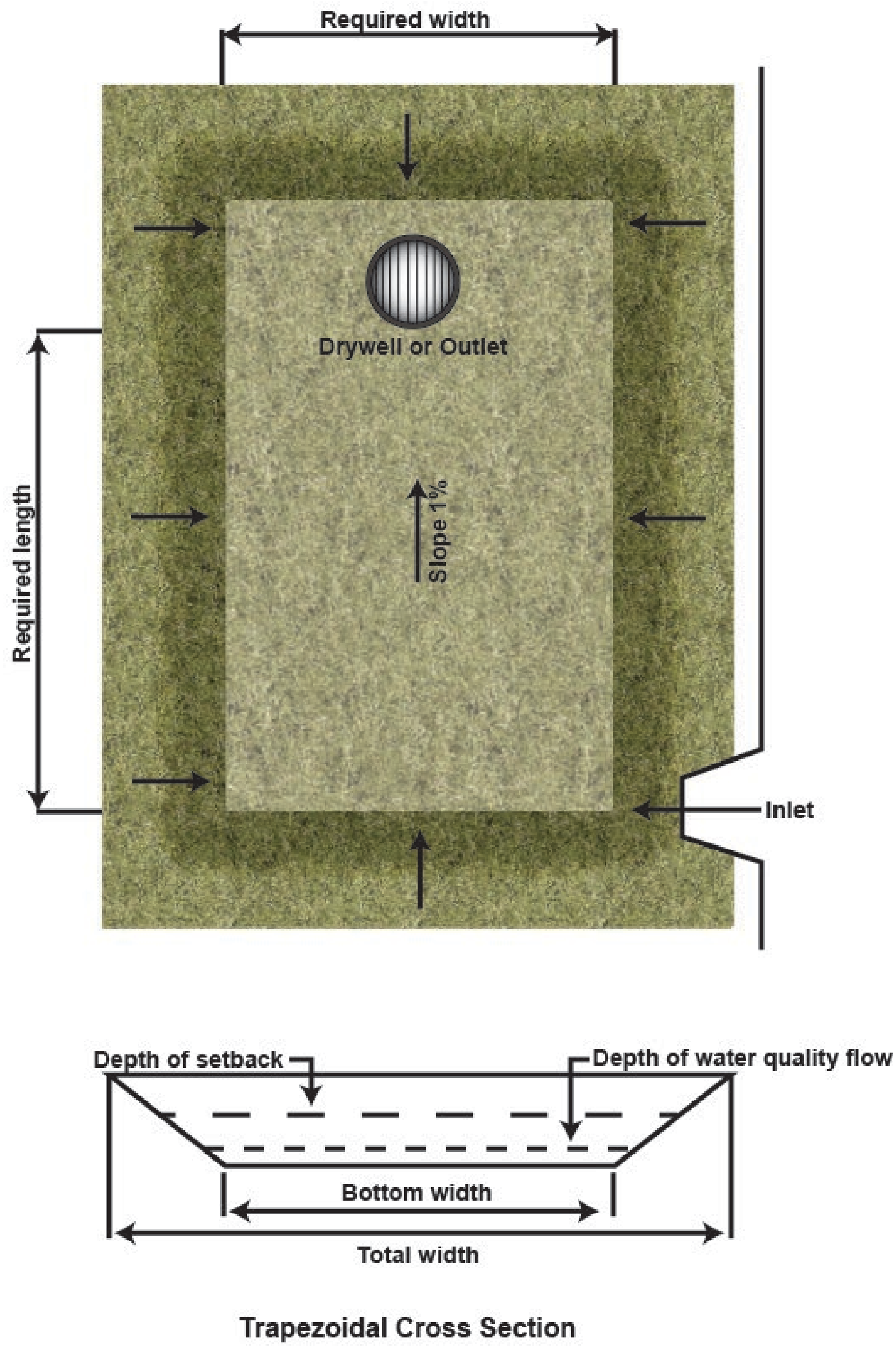


Figure 23. Bioinfiltration swale with dry well.

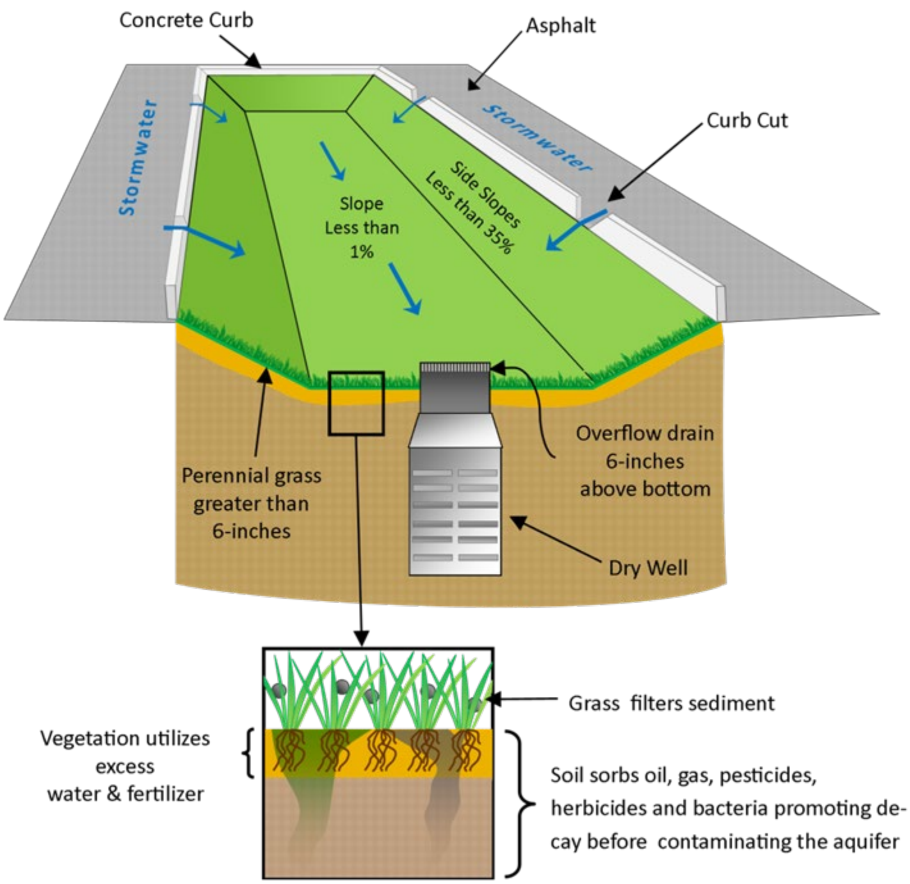


Figure 24. Bioinfiltration swale with dry well (DEQ and Kootenai County 2018).

Additional Design Criteria for Bioinfiltration Swales

- The maximum drawdown time for the flooded depth should be within 72 hours after flow ceases.
- A concrete or riprap apron shall be provided at the curb opening to prevent vegetation from blocking the inlet.
- Curb cuts should be at an elevation lower than the contributing runoff area.
- Curb cuts require regular maintenance to prevent vegetation from blocking flow from the curb cut into the swale.
- To prevent piping around the rim of the dry well, ensure fill placed above the dry well weep holes matches or is less than the infiltration rate of surrounding soils. Otherwise water will not pond in the swale, and its pollutant removal effectiveness will be lost.
- The swale bottom should be flat with a longitudinal slope less than 1%.
- The maximum flood depth of swale should be 6 inches before overflow to a dry well or other infiltrative or overflow facility.
- The volume contained by the swale must be sufficient for the water quality volume to be treated before overflow or infiltration.
- The treatment soil should be at least 6 inches thick with a CEC of at least 5 meq/100 grams dry soil, organic content of at least 1%, and sufficient target pollutant-load capacity (City of Tacoma 2012).

- Other combinations of treatment soil thickness, CEC, and organic content design factors can be considered if it is demonstrated that the soil and vegetation will provide a target pollutant-load capacity and performance level acceptable to the local jurisdiction.
- The treatment zone depth of 6 inches or more should contain sufficient organics and texture to ensure good growth of the vegetation.
- The average infiltration rate of the 6-inch thick layer of treatment soil should not exceed 1-inch per hour for a system relying on the root zone to enhance pollutant removal. A maximum infiltration rate of 2.4 inches per hour is recommended if certain site suitability guidelines are applied. These guidelines include setbacks or avoiding sensitive areas such as water wells, slopes, foundations, and saturated conditions.
- Pretreatment, such as a sedimentation chamber or oil and water separator, may be used to prevent clogging the treatment soil and/or vegetation by debris, total suspended sediment (TSS), and oil and grease.

Vegetation

Native grasses or adapted grasses with significant root mass should be used. Grasses should be drought tolerant, or irrigation should be provided in sufficient amounts to prevent dormancy. Actively growing grass uses nutrients in the storm water. The minimum grass height should be at least 4 inches; however, taller grass heights will minimize erosion. Mow grass if needed for good growth and reseed bare spots. Fertilizing a bioinfiltration swale should be avoided in any application where nutrient control is an objective, such as over the Rathdrum Prairie Aquifer. Test the soil for nitrogen, phosphorous, and potassium, and consult with a landscape professional about the need for fertilizer in relation to soil nutrition and vegetation requirements. If fertilizer use cannot be avoided, use a slow-release fertilizer formulation in the least amount needed.

Construction Guidelines

Basin construction should be coordinated with the overall project construction schedule. Early rough excavation of the swale will allow use of the fill in other areas. A partially excavated basin (not down to design depth) may serve as a temporary sediment trap or pond to assist in erosion and sediment control during construction. However, swales near the final stages of excavation should never be used prematurely for runoff disposal. Drainage from untreated, freshly constructed slopes within the watershed area could load the newly formed basin with a heavy concentration of fine sediment. This sediment could seriously impair the natural infiltration characteristics of the swale floor and plug the dry well.

In the final phase of excavation, remove all accumulated sediment. Light, tracked equipment is recommended for this operation to avoid compacting the swale floor. Use of the swale should be postponed until vegetation is established. Soils imported for landscape development must be properly incorporated into existing soils, which includes tilling the soils to 6 inches deep for optimal blending.

Maintenance

To ensure that the bioinfiltration swale operates as designed, provide enough access space for maintenance activities and check with local permitting authority to determine if a dedicated maintenance easement is required.

After bioinfiltration swales are placed into use, inspect on a monthly basis and after large storm events. Once it is determined that the basin is functioning in a satisfactory manner and no potential sediment problems exist, inspections can be reduced to a semiannual basis with additional inspections following the occurrence of a large storm. Inspectors should check for functional inlet, erosion, condition of vegetation, ponded water, improper disposal of other waste in the swale or dry well, piping around the dry well rim, and general conformance with the original design.

Grass bottoms in bioinfiltration swales seldom need replacement because grass serves as a good filter material. If silty water is allowed to trickle through the turf, most of the suspended material is strained out within a few yards of surface travel. Well-established turf on a swale floor will grow up through sediment deposits forming a porous turf and preventing the formation of an impenetrable layer. Grass planted on swale side slopes prevents erosion.

When designing, consider the leading causes of failure for bioinfiltration swales:

1. Presilting during construction—Occurs after the contractor has roughed in the swales during the excavation phase of construction. Loose soil from the development is washed from the streets and off of building sites into the swales. This fine soil lowers the permeability to the point of swale failure although the original soil permeability was adequate.
2. Overcompacting soils during construction—Equipment operated improperly in the swale will decrease swale permeability and may cause failure.
3. Improperly incorporating imported soils—Soils (e.g., topsoil and compost) imported for landscape development must be properly incorporated into existing soils.
4. Excessively irrigating grass—Vegetation in the swale is irrigated excessively to the point where the soil is constantly saturated, and when a rainfall event does occur the infiltration rate is not adequate.

Additional Resources

Chow, V.T. 1959. *Open Channel Hydraulics*. Tokyo, Japan: McGraw-Hill Book Company, Inc.

Washington State University. 2009. "Stormwater Biofiltration Swale Project by Spokane County and WSU Spokane Extension." *Washington State Magazine*. Spokane, WA. *http://wsm.wsu.edu/s/index.php?id=750*

BMP 11: Vegetated Filter Strip

Description

A vegetative filter strip is a vegetated surface designed to treat sheet flow from adjacent impervious surfaces by reducing runoff velocities, filtering sediments, and allowing time for infiltration (Figure 25). A successfully functioning filter strip uses dense vegetation (typically grass), allows only overland sheet flow to cross the strip, and avoids concentrated flows. Vegetative filter strips are engineered runoff treatment measures and should not be confused with natural buffers (BMP 2), which are natural undisturbed areas used to protect streams, creeks, canals, wetlands, and other surface waters.

Figure 25. Filter strip (ITD 2018).

Primary BMP Functions and Controls

☐ Construction ☒ Permanent
☐ Erosion Control ☒ Sediment Control
☐ Source Control ☐ Flood Control
☒ Filtration ☐ Infiltration

Typical Effectiveness for Targeted Pollutants

◖ Sediment
◖ Phosphorus
◖ Metals
○ Bacteria
◖ Hydrocarbons
◖ Litter

Other BMP Considerations

Relative Cost	$
Maintenance Requirements	Medium
Ease of Installation	Easy
Freeze/Thaw Resistance	Good
Max. Tributary Drainage Area	5 acres
Max. Slope	6%
NRCS Soil Group	ABC
Min. Ground Water Separation	3 feet
Min. Bedrock Separation	5 feet

Applicability

Use vegetative filter strips to treat sheet flow runoff from parking lots, roadways, roofs, or other small impervious surfaces. The filter strips are effective at pretreating runoff to protect filtration BMPs from siltation or serve as an *outer zone* of a natural buffer. The strips are especially applicable as part of a storm water treatment train of BMPs.

Figure 26 shows how a vegetative filter can be used with a vegetative swale and natural buffer along a roadway. Filter strips may also be a viable treatment measure for small, less intensely developed sites and on shallow slopes with low runoff velocities.

Vegetative filter strips can help disconnect impervious areas (BMP 4) and are an important component of LID design. If the design requirements listed below cannot be met due to space constraints, vegetative filters can provide some pollutant removal and volume reduction benefits.

Limitations

The prime limitation of vegetated filter strips is their inability to handle concentrated flows due their

decreased effectiveness and potential for erosion, which could cause the filter strips to become a source of pollution. Unlike swales, a vegetative filter strip should not be used for conveyance of major storms because of the need to maintain sheet flow conditions. Vegetative filter strips should not be used on slopes greater than 6% because of the difficulty in maintaining sheet-flow conditions on steep slopes.

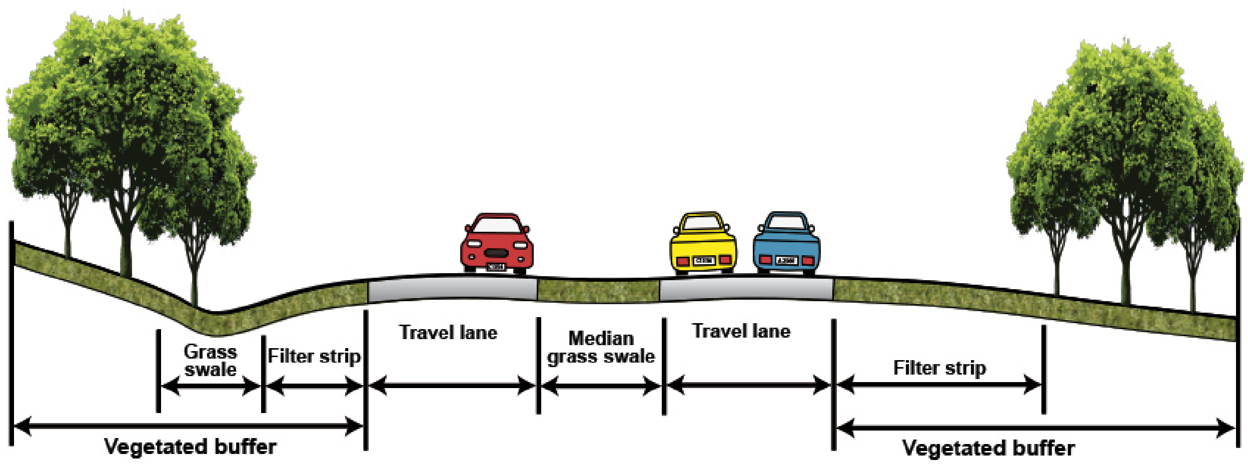


Figure 26. Application of vegetated filter strip with swale and buffer BMPs (Storey 2009).

Similar to vegetated swales (BMP 9), vegetated filters are not appropriate for storm water hotspots with highly contaminated runoff due to their questionable performance in reliably removing pollutants (EPA 2018).

Vegetated filters should not be used in soil with high clay content because of their reliance on some infiltration for treatment. This filter cannot be used where limited land area is available as they can require approximately the same amount of infiltration area as the area being treated.

Design Basis

Filter strip design is based on providing adequate length to treat runoff and ensuring sheet-flow conditions (Figure 27).

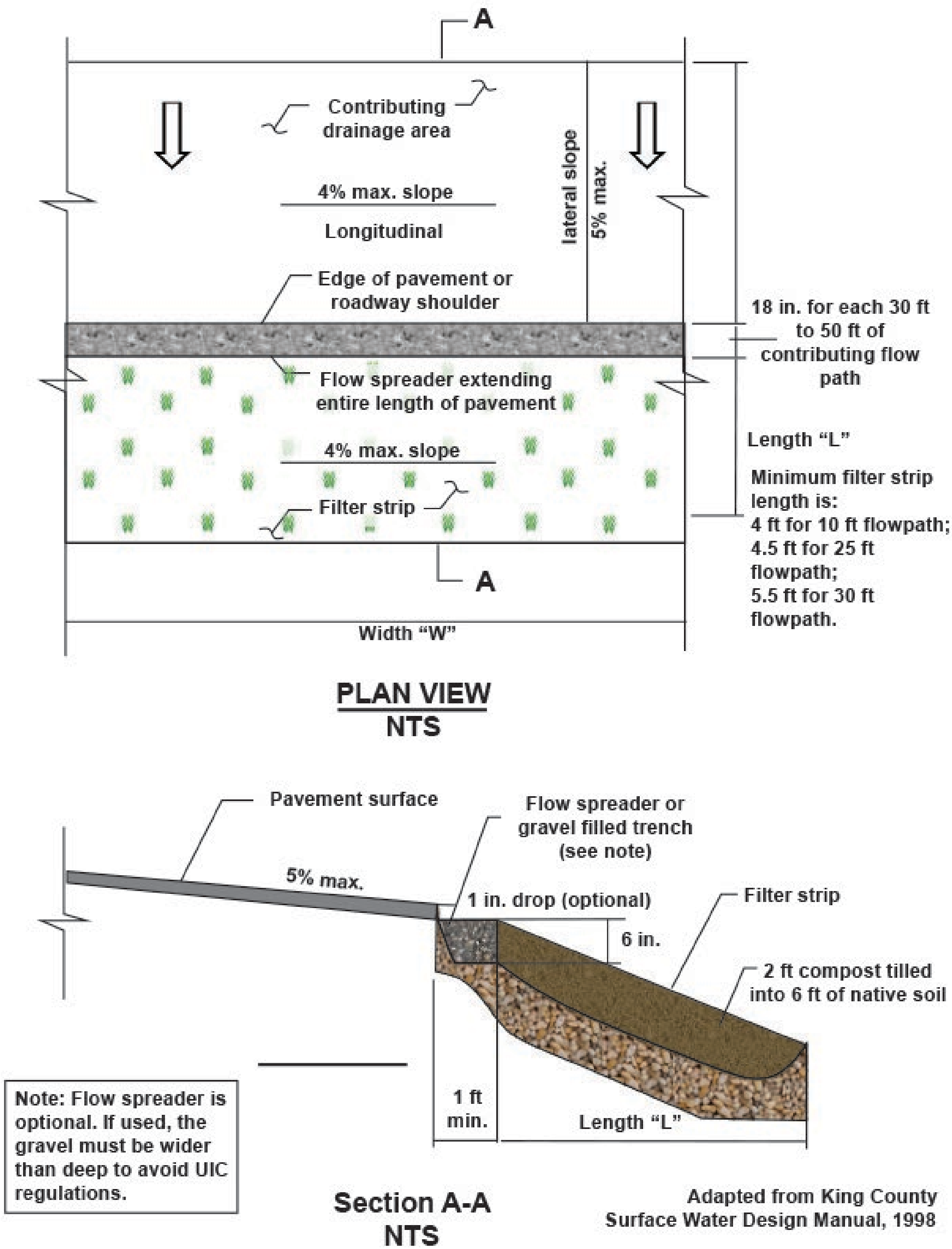


Figure 27. Plan and section view of a typical vegetated filter strip (adapted from King County 1998).

Drainage Area

Although the maximum recommended drainage area for a vegetative filter strip is 5 acres, the limiting design factor is often the flow path length leading up to the strip because flows tend to concentrate after traveling a certain distance. Sheet flows concentrate within a maximum of 75 feet for impervious surfaces and 150 feet for pervious surfaces (Caraco and Claytor 1997). Unless a flow spreader is used, a filter strip length of 580 feet is needed to treat 1 acre of impervious surface.

Design Discharge

Determine the peak flow to be conveyed to the filter strip for the water quality design storm under fully developed conditions. Use hydrologic procedures presented in section 3.6 to determine peak flows.

Flow Depth

Set the width of the filter strip perpendicular to flow equal to the width of the contributing area. Determine the resulting depth of flow needed to convey the design discharge. The design flow depth is limited to 0.5 to 1 inch to maintain sheet flow over the strip. Due to the shallow flow depth, a hydraulic radius approximately equal to the design flow depth can be assumed and Manning's equation for open channel flow can be expressed (Equation 12):

$$y = \left(\frac{Qn}{1.49WS^{\frac{1}{2}}}\right)^{0.6}$$

Equation 12. Design flow depth for vegetative filter.

Where

y = depth of flow (feet)
Q = flow rate (cubic feet per second)
n = Manning's roughness coefficient
W = width of filter perpendicular to flow (feet)
S = longitudinal slope (feet per feet)

Select a value for the Manning's roughness coefficient, n, based on the vegetation to be used (generally n = 0.35). Calculate velocity through the filter strip using Equation 13:

$$V = \frac{Q}{Wy}$$

Equation 13. Velocity through a vegetative filter.

Where

V = velocity (feet per second)
y = depth of flow (feet)
Q = flow rate (cubic feet per second)
W = width of filter perpendicular to flow (feet)

If the required depth is greater than 1 inch or the velocity is greater than 0.5 feet per second, the design should be modified to either accept a smaller drainage area, or a flow spreader can be used to distribute runoff over a greater width.

Length

Calculate the necessary length (parallel to flow) to produce a hydraulic residence time of at least 9 minutes. The minimum length should be 25 feet as most pollutant removal occurs within this distance (Storey 2009).

The length can be calculated using Equation 14:

$$L = t\,V = 540\,V$$

Equation 14. Length of vegetative filter.

Where
L = length of filter (feet)
t = hydraulic residence time
= 540 seconds (9 minutes)
V = velocity (feet per second)

Slope

Vegetative filter strips should be designed with a longitudinal slope of 2% to 6% and should not be used for slopes in excess of 10%. Slopes less than 2% tend to pond water on the surface unless very sandy or gravelly soils are used. Sheet-flow conditions are difficult to maintain on slopes greater than 10%. The top and toe of the filter strip slope should be as flat as possible to encourage sheet flow and prevent erosion.

Flow Distribution

Install a shallow stone trench across the top of the strip to serve as a level spreader (BMP 30). The stone trench should have a minimum depth of 6 inches, minimum width of 12 inches, and should be located 1 inch below the impervious surface to allow for sediment to be accommodated in the filter without blocking flow onto the strip. Make provisions to avoid flow bypassing the filter strip. The stone trench will also act as a pretreatment facility to settle out sediment. Use flush curbing to spread flows across the stone trench.

Soil

Soil conditions enhance infiltration and ensure the long-term health of the vegetation. If possible, stockpile and reuse on-site topsoil. If adequate topsoil is not available on site, import topsoil to provide a minimum topsoil depth of 4 inches on the filter strip or amend the existing soil with compost tilled 6 inches deep. Conduct soil tests to determine the required soil amendments.

Vegetation

Vegetation for filter strips should be durable, dense, and tolerant of both wet and dry periods. Turf or mat-forming grasses are often selected for these reasons although small herbaceous shrubs, which provide root penetration into the subsoils and enhance infiltration, can also be used. Vegetative cover of at least 80% is required and at least 90% is preferred for best pollutant removal. For filter strips next to roadways where deicer is regularly used, salt-tolerant species should be selected.

Depending on the plant species selected, irrigation may be required for plant establishment and for ongoing maintenance. Native species will require little or no irrigation after established so they are preferred over species with high water requirements.

Construction Guidelines

Proper construction of vegetative filter strips is important for good performance. Construction guidelines include the following:

- Avoid compaction during construction and protect the area from construction activities to preserve infiltration capacities.
- If the filter area has been compacted, till and/or amend the soil with compost before installing the filter strip.
- Protect plants from predation during establishment by installing netting or fencing.
- Provide irrigation as necessary for plant establishment.
- Perform fine grading, soil amendment, and seeding after upgradient surfaces have been stabilized and any utility work across the filter area has been completed.
- Properly grade the strip to avoid low spots and ponding.
- If necessary, fence the area during and after construction to keep vehicles, pedestrians, and animals out.
- If the filter is being vegetated with sod, stagger the ends of the sod tiles to prevent the formation of channels along the joints. Use a roller on the sod to remove air pockets between the soil and sod.

Maintenance

Maintenance for vegetated filter strips is similar to other vegetative BMP practices and is aimed at keeping the vegetation healthy:

- Inspect filter strips every 3 months for the first 2 years after installation and then every 6 months thereafter. Preferably, inspect filter strips after storm events.
- Check for uniform vegetative cover and inspect for rills and gullies. Spot replace vegetation as necessary.
- Mow grasses if needed for good growth. Mowing requirements vary for different grass species.
- Leave grass clippings and mulched leaves in place. Do not blow them onto impervious areas as they can be washed into the stream and cause problems with oxygen depletion.
- Remove sediment as needed from the stone trench to prevent clogging. Remove sediment buildup within the bottom when it has accumulated to 25% of the original capacity.

- Remove leaves, litter, and oily materials. Clean curb cuts and level spreaders as needed.
- Check for pools of water and regrade to prevent ponding if necessary.
- Control weeds as needed. Mechanical weed control by pulling or mowing is preferred to chemical herbicides.
- Irrigate if moisture is inadequate during summer drought.
  Fertilizing is often unnecessary because runoff from lawns and other areas provides enough nutrients. If fertilizers are needed, use biodegradable nontoxic fertilizers only at an application rate and formula compatible with plant uptake and soil group. Conduct soil tests as needed to determine existing soil fertility and proper application rate.

Additional Resources

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

EPA (US Environmental Protection Agency). 2018. *Vegetated Filter Strip*. Water: Best Management Practices. *https://www.epa.gov/npdes/national-menu-best-management-practices-bmps-stormwater#edu*

Storey, B.J., et al. 2009. *Stormwater Treatment with Vegetated Buffers*. Texas College Station, TX: Transportation Institute.

BMP 12: Sand Filter

Description

Sand filters are devices that filter and infiltrate storm water runoff through a sand layer to provide physical and chemical filtration of storm water. The filtration system consists of an inlet structure, sedimentation chamber, sand bed with optional underdrain piping, and impermeable liners as required.

Sand filter variations are a sand filtration trench (or a sand filter inlet) and a sand filtration basin (Figure 28).

Figure 28. Sand filters (UNHSC 2010).

Applicability

Sand filters take up little space and can be used in urbanized areas and on sites with slopes up to 10%. Sand filters rely on physical straining, settling, and adsorption to remove pollutants. The filters are effective at removing TSS, with moderate removal efficiency for TP. Sand filters can also be designed for existing sites and used as pretreatment BMPs before a wet pond (BMP 22) or infiltration systems such as a bioinfiltration swale (BMP 10) and infiltration trench (BMP 17).

Applications and general recommendations for sand filters include the following:

- Sand filtration trenches are often used as drainage areas of less than 5 acres, such as along the perimeter of a parking lot.
- Depending on local requirements, sand filtration may be substituted for oil and water separators (BMP 15) to remove oil from runoff.
- The filters can be used during construction, especially for construction projects with longer durations.

Primary BMP Functions and Controls

☒ Construction	☒ Permanent
☐ Erosion Control	☒ Sediment Control
☐ Source Control	☐ Flood Control
☒ Filtration	☒ Infiltration

Typical Effectiveness for Targeted Pollutants

●	Sediment
○	Nitrogen
◖	Phosphorus
●	Metals
◖	Bacteria
●	Hydrocarbons
●	Litter

Other BMP Considerations

Relative Cost	$$
Maintenance Requirements	Low
Ease of Installation	Fair
Freeze/Thaw Resistance	Fair
Max. Tributary Drainage Area	5–50 acres
Max. Upstream Slope	10%
NRCS Soil Group	NA
Min. Ground Water Separation	3 feet
Min. Bedrock Separation	3 feet

Limitations

Sand filters are not recommended in areas with high sediment load (i.e., disturbed areas, unvegetated areas, and along roadways that receive cold weather sanding) without proper pretreatment as fine

sediments clog and reduce the removal efficiency of the system. Because of potential clogging, sand filtration BMPs should never be used as sediment basins (BMP 66) during construction.

Sand filters, especially online filters, have a limited life span and require frequent maintenance such as the periodic replacement of media to ensure proper functioning.

In cold climates, surface sand filter units may lose their effectiveness when the upper layers of filter media freeze and become effectively impervious. Special consideration should be taken when expecting cold weather flows, including an oversized underdrain that encourages rapid infiltration.

Design Basis

Online and off-line BMPs are the predominant types of structural storm water controls available (Figure 29). Online BMPs provide storm water treatment and control within the runoff conveyance channel. Because of this, online facilities must be able to handle the entire range of design storm discharges. Off-line BMPs provide storm water treatment outside of the runoff conveyance channel and are typically designed to receive only a specified discharge rate or volume. After the design runoff flow has been treated and/or controlled, it is returned to the conveyance system.

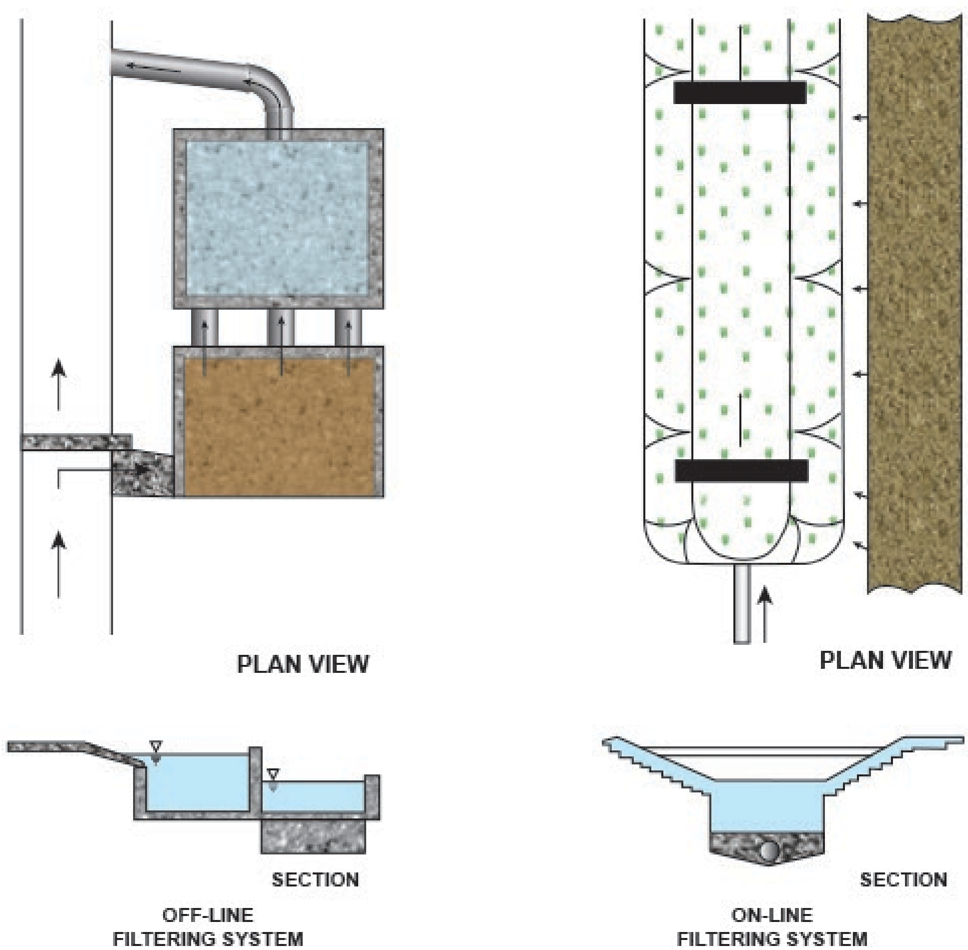


Figure 29. Online and off-line storm water treatment systems (CWP 1996).

Online Sand Filtration BMPs

Avoid placing an online sand filter upgradient of subsequent BMPs that may be adversely affected by soil media transported during high flows.

Proper overflow design is paramount for online systems and should include a primary overflow, secondary overflow, and an emergency spillway. The overflow should be placed at the ponding design depth for the sand filter.

Off-Line Isolation/Diversion Structure

Locate sand filtration systems off-line from the primary conveyance/detention system to maintain the long-term effectiveness of the treatment system. Off-line systems are designed to capture and treat the locally specified design storm, which is typically achieved by using isolation/diversion baffles and weirs. A typical approach for achieving isolation of the water quality volume is to construct an isolation/diversion weir in the storm water channel so the height of the weir equals the maximum height of water in the filtration basin during the water quality design storm. When additional runoff greater than the water quality storm enters the storm water channel, it will spill over the isolation/diversion weir; mixing with the already isolated water quality volume will be minimal.

Sizing Sand Filtration BMPs

As shown in Equation 15, Darcy's law is one method for sizing sand filtration BMPs:

$$Q = fiA_s$$

Equation 15. Darcy's law applied to flow through a sand filter.

Where

Q= flow rate into the sand filter

f= infiltration rate of sand

i= hydraulic gradient

A_s= surface area of the filtration bed

Conservative values of the infiltration rate of the sand, f, should be used. For infiltration BMPs, a safety factor of two should be applied to the infiltration rate determined from the textural analysis; then, the design infiltration rate will be labeled f_d where $f_d = 0.5 * f$. While the infiltration rate will likely be closer to f upon installation, the safety factor of f_d will account for any flaws in the textural analysis and the accumulation of fines over time. A design infiltration rate that is half of the theoretical infiltration rate is recommended. For sand infiltration BMPs, a f_d value of about 2 inches per hour is recommended for design purposes. This value appears to be a low but reflects actual rates achieved by operating sand infiltration systems that treat urban runoff; the lower rates reflect the effects of suspended solids and sediment on the sand's permeability. The hydraulic gradient is given by Equation 16:

$$i = \frac{h + L}{L}$$

Equation 16. Hydraulic gradient.

Where

i = hydraulic gradient

h = height of water column over the top of the sand

L = thickness of the sand bed (typically 18 inches)

Drawdown Time (Basins)

Design sand filtration basins to completely empty within 24 to 72 hours. In many areas, preventing mosquito breeding habitat or standing water must be taken into account during design.

Inlet Structure

The inlet structure to the sand filter should spread the flow uniformly across the surface of the filter media. Flow spreaders, weirs, or multiple-orifice openings are recommended. Install stone riprap or other dissipation devices to prevent gouging of the sand media and promote uniform flow.

Sand Bed

The final sand bed depth varies and depends on the hydraulic head acting on the filter. For example, if the hydraulic head varies between 2 and 8 inches on the surface of the bed, a design depth may vary between 18 and 24 inches. Keep in mind that consolidation of the sand is likely during construction. Sand should meet the size gradation (by weight) given in Table 13.

Table 13. Sand medium specification (Washington State Department of Ecology 2012).

US Sieve Number	Percent Passing
4	95–100
8	70–100
16	40–90
30	25–75
50	2–25
100	<4
200	<2

Two sand bed configurations can be selected: (1) with a gravel layer and (2) a trench design that uses drainage matting as a substitute for the gravel layer. The top surface layer should be level so that equal distribution of runoff will be achieved in the basin. Design guidelines for each type are provided below.

Sand Bed with Gravel Layer

A sand bed with a gravel layer is a multilayer design constructed as follows: the top layer is a minimum of 18 inches of 0.02–0.04-inch diameter sand (smaller sand size is acceptable). Under

the sand is a layer of 0.5–2-inch diameter gravel that provides a minimum of 2 inches of cover over the top of any underdrain lateral pipes. No gravel is required under the lateral pipes. In some cases, sand and gravel should be separated by a layer of geotextile fabric (Figure 30).

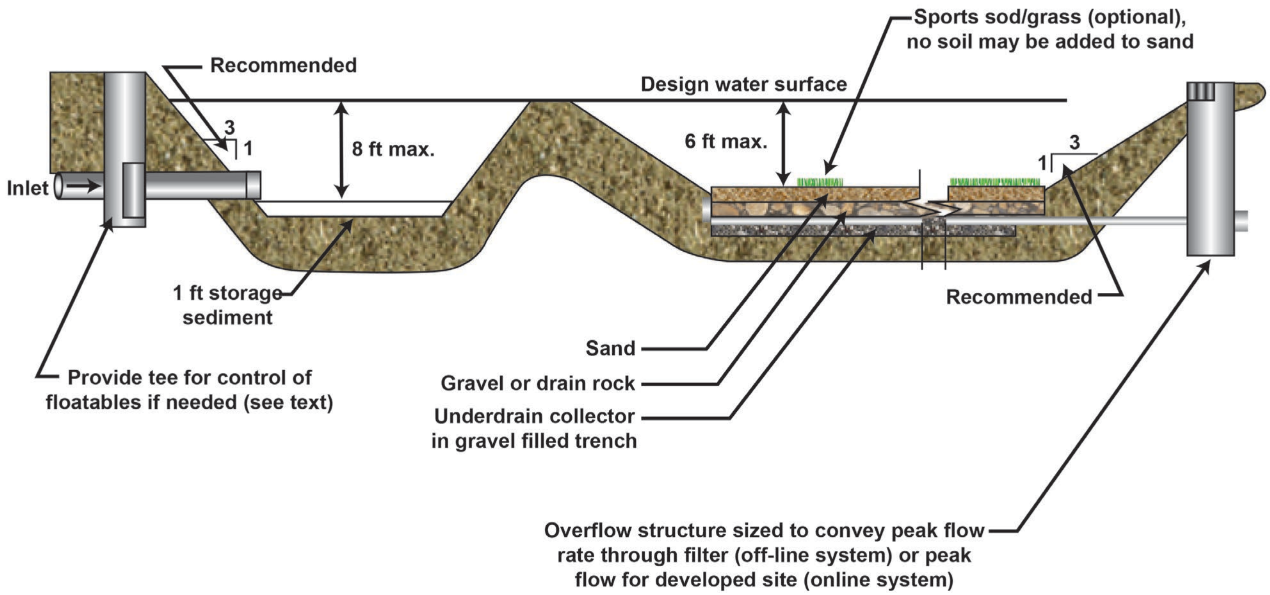


Figure 30. Sand bed with gravel layer.

Sand Bed with Trench Design

This multilayer design is constructed for use on flatter sites where using the sand bed with gravel layer design is restricted. The top layer should be 12 to 18 inches of 0.02–0.04-inch diameter sand (smaller sand size is acceptable). Place laterals in trenches with a covering of 0.5- to 2-inch gravel and geotextile fabric. The lateral pipes should be underlain by a layer of drainage matting. The geotextile fabric prevents the filter media from infiltrating into the lateral piping. The drainage matting provides adequate hydraulic conductivity to the laterals.

Sand Filtration Liners

Liners for sand filters are recommended when infiltration to ground water through the sand filter is not desired. Impermeable liners may be concrete, geomembrane, or equivalent impermeable material. If a geomembrane liner is used, it should be ultraviolet resistant and thick enough to avoid tears during construction. The geomembrane should be protected from puncture, tearing, and abrasion by installing geotextile fabric on the top and bottom of the geomembrane. The local permitting authority may consider equivalent methods for protecting the geomembrane liner (see geotextile materials in BMP 53).

Concrete liners may also be used for sedimentation chambers and sedimentation and filtration basins. Concrete should be 5 inches thick, Class A or better, and reinforced by steel wire mesh. Adding fiberglass fibers to the mix (3 pounds per cubic yard) will decrease risk of cracking. The steel wire mesh should be 6-gauge wire or larger and 6- x 6-inch mesh or smaller. An *ordinary surface finish* is required. When the underlying soil is clay or has an unconfined compressive

strength of 0.25 tons per square foot or less, the concrete should have a minimum 6-inch compacted aggregate base consisting of coarse sand and river stone, crushed stone, or equivalent with diameter of 0.75 to 1 inch. Where visible, the concrete should be inspected annually and all cracks should be sealed.

Underdrain Piping

The underdrain piping consists of the main collector pipes and perforated lateral branch pipes. Reinforce the piping to withstand the overburden weight. Internal diameters of lateral branch pipes should be 4 inches or greater and perforations should be 3/8 inch. For all piping, use schedule 40 polyvinyl chloride (PVC) or greater strength. A maximum spacing of 10 feet between laterals is recommended. The maximum spacing between rows of perforations should not exceed 6 inches.

The minimum grade of piping should be 1/8 inch per foot (1% slope). Place geotextile fabric above the underdrain piping to prevent clogging. Provide access for cleaning all underdrain piping by installing cleanout ports that tee into the underdrain system and surface above the top of the sand filtration media.

Pretreatment for Sand Filters

A presettling basin (BMP 25), vegetated swale (BMP 9), or both are recommended to pretreat runoff discharging to the sand filter. If a presettling basin is used for pretreatment, give careful attention to designing the inlet and outlet structures. The presettling basin consists of an inlet structure, outlet structure, and basin liner if permeable soils underlay the basin. The presettling basin design should maximize the distance between the locations where the heavier sediment is deposited near the inlet to where the finer sediments are deposited at the outlet structure location. This approach maximizes the flow path to increase detention time, improves basin performance, reduces maintenance requirements, and minimizes the potential for flow to short-circuit the filter.

Inlet Structure

The inlet structure design should be adequate for isolating the water quality volume from design storms larger than the 2-year storm and to convey the peak flows for these storms past the basin. The water quality volume should be discharged uniformly and at low velocity into the presettling basin to maintain conditions necessary for effective treatment. It is desirable for larger suspended material to drop out near the front of the basin; a drop inlet structure is recommended to facilitate sediment removal and maintenance. Energy dissipation devices may be necessary to reduce inlet velocities exceeding 3 feet per second.

Outlet Structure

Outlet structures convey water quality volumes from the presettling basin to the filtration basin and from the filtration basin to the discharge point. The outlet structure to the presettling basin should be designed to provide for a residence time of 24 hours for the 6-month, 24-hour storm. Achieve residence time by installing a throttle plate or other flow control device at the end of the riser pipe (discharges through the perforations should not be used for drawdown time design purposes). The outlet structure to the discharge point should be designed to provide treatment and control for, at minimum, the 2-year, 24-hour design storm.

A trash rack should be provided for the outlet. Openings in the rack should not exceed one-half the diameter of the vertical riser pipe. The rack should be made of durable material, resistant to rust and ultraviolet rays. The bottom rows of perforations of the riser pipe should be protected from clogging. To prevent clogging of the bottom perforations, wrap geotextile over the pipe's bottom rows and place a cone of 1- to 3-inch diameter gravel around the pipe. If a geotextile fabric wrap is not used, then the gravel cone should not include any gravel small enough to enter the riser pipe perforations.

The inlet and outlet should be placed to prevent short-circuiting the basin, and the inlet and outlet configuration should encourage full use of the basin for presettling by maximizing detention time.

Basin Liner

The pretreatment BMP may need to have a basin liner to prevent runoff from being lost to soil infiltration before treatment by the filtration basin.

Observation Well

An observation well should be installed every 50 feet of BMP length. The observation well serves two primary functions: (1) indicates how quickly the trench dewaters following a storm, and (2) indicates how quickly the trench fills up with sediment.

The observation well should consist of perforated PVC pipe, 2 to 4 inches in diameter. The well should be located in the center of the structure and constructed flush with the ground elevation of the trench. Cap the top of the well to discourage vandalism and tampering. Obtain specific construction information from IDWR or DEQ.

Sand Filters for Oil Removal

If a sand filtration basin is used as a substitute for an American Petroleum Institute (API) or coalescing plate (CP) oil and water separator (BMP 15), pretreatment may not be necessary if the contributing drainage area is small and completely impervious (restrictions that apply to oil and water separators also apply to sand filtration basins in this case) (Figure 31 and Figure 32).

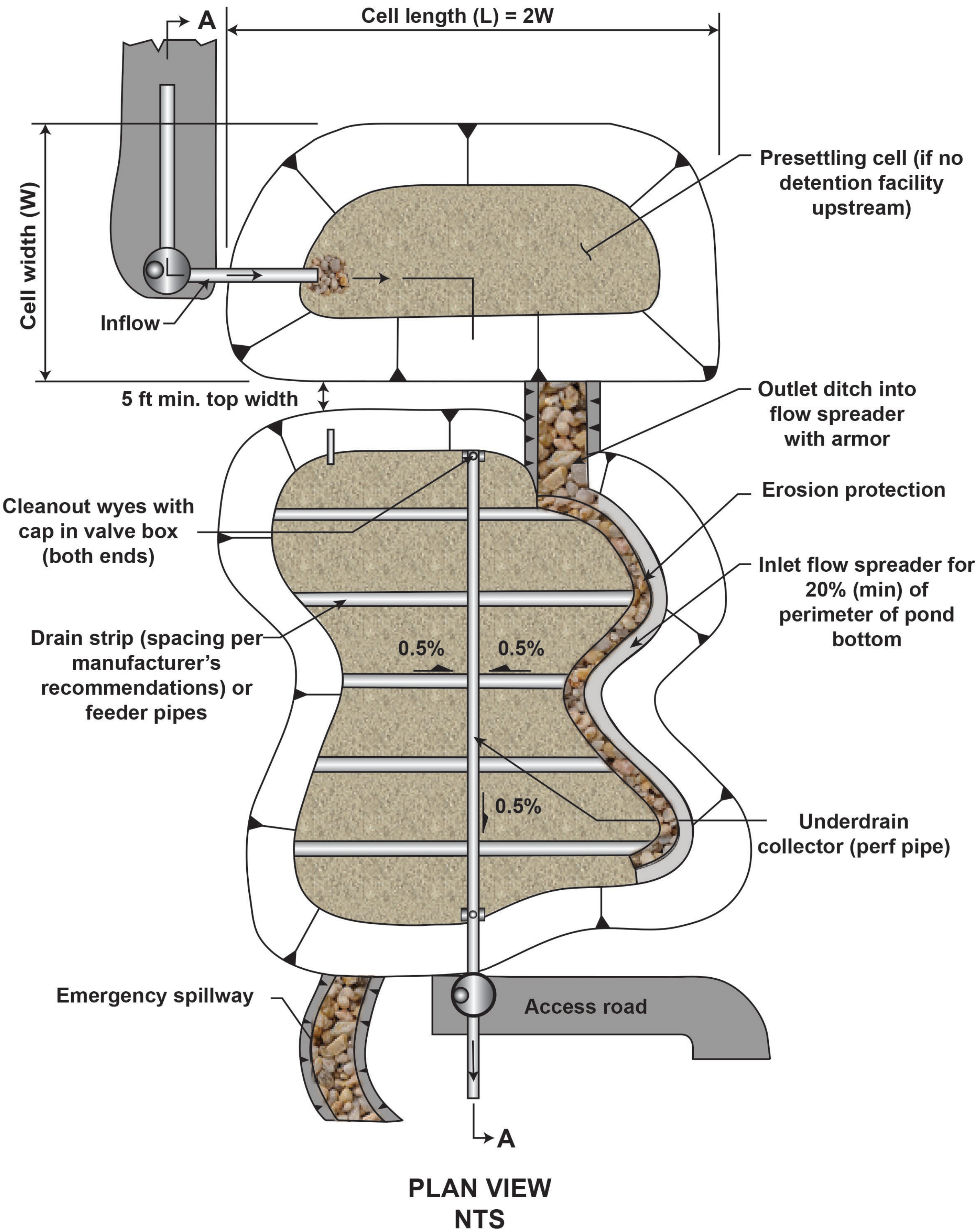


Figure 31. Sand filter with pretreatment cell (Washington State Department of Ecology 2012).

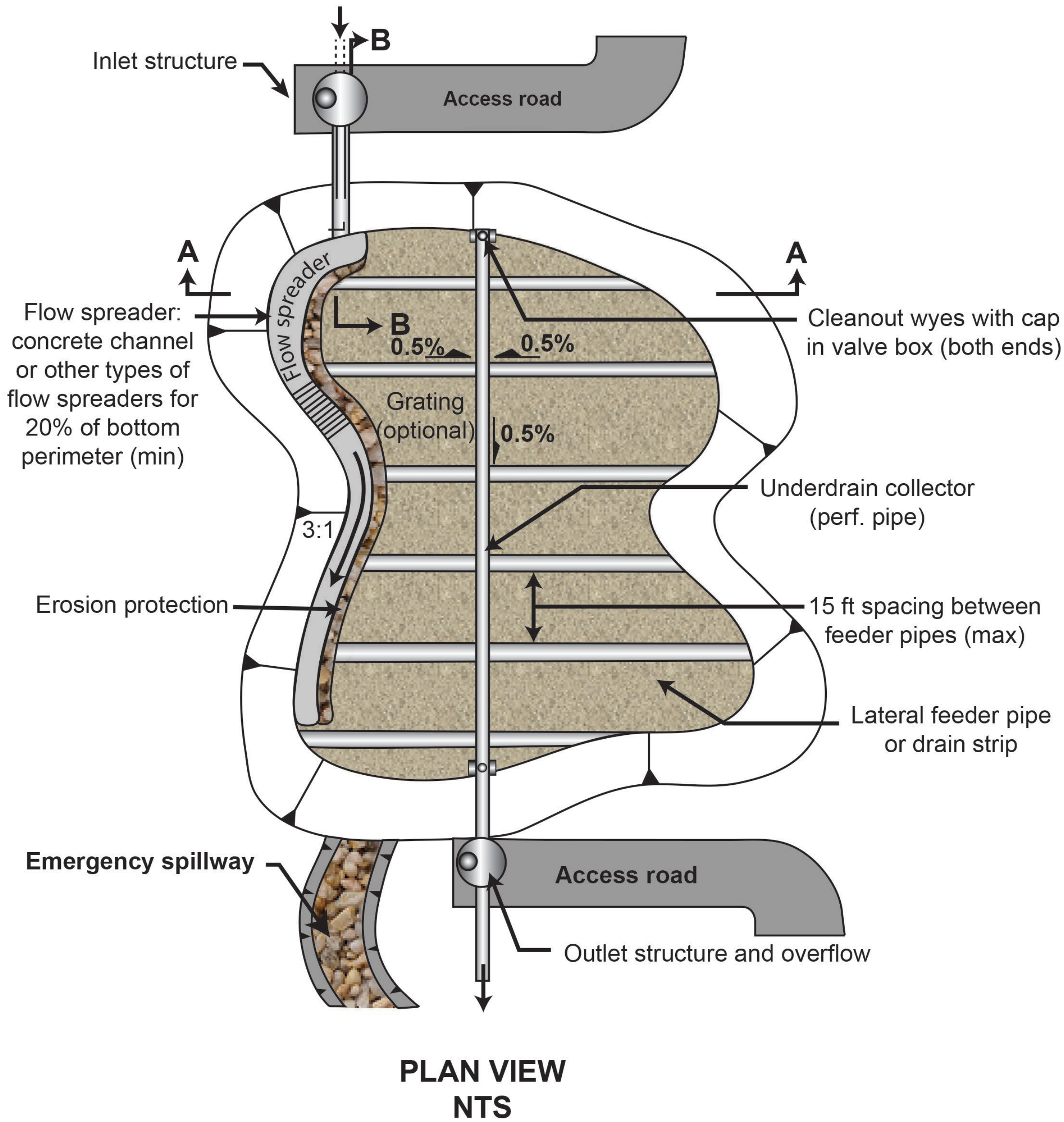


Figure 31 continued. Sand filter with pretreatment cell (Washington State Department of Ecology 2012).

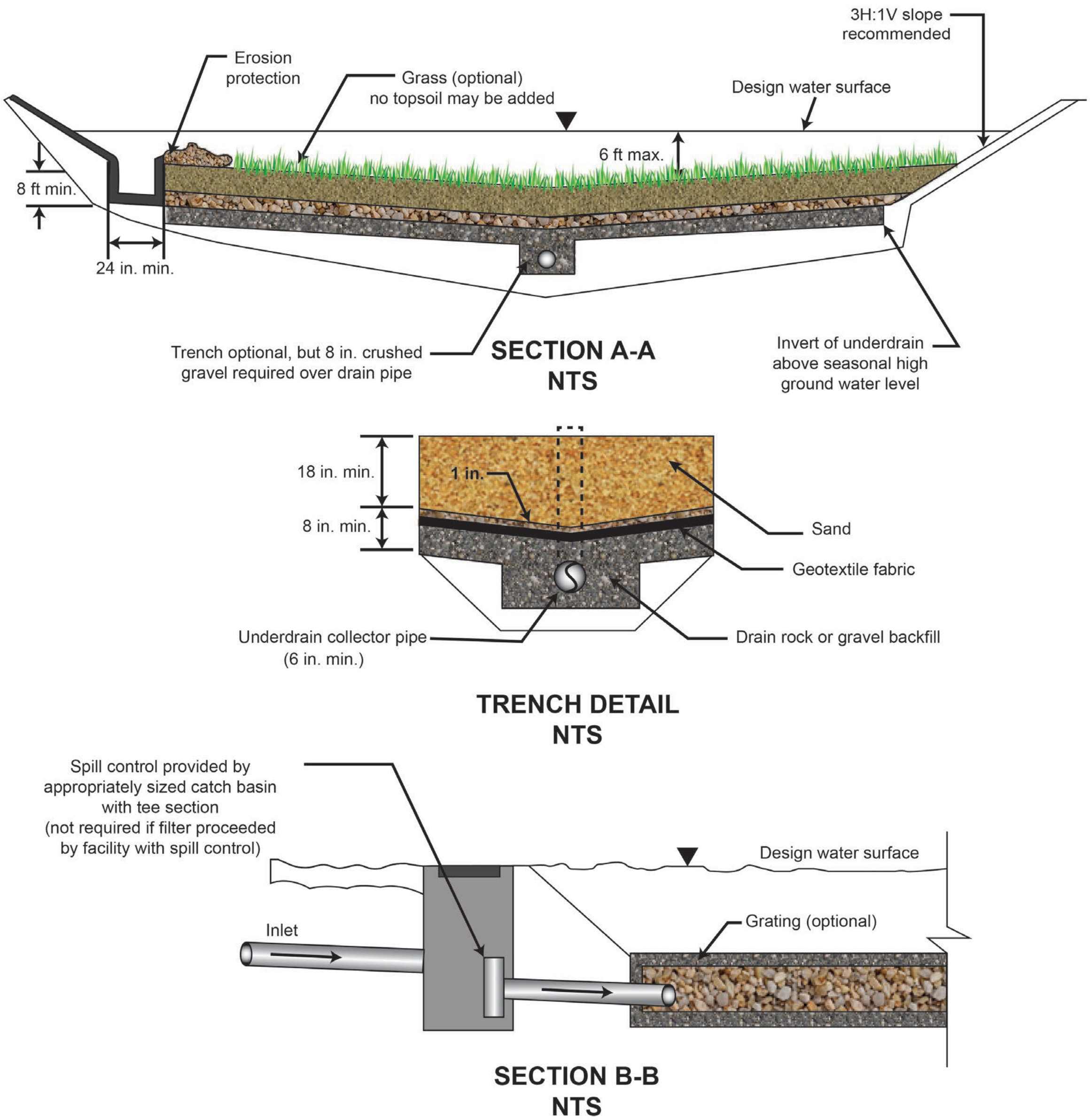


Figure 32. Sand filter with level spreader (Washington State Department of Ecology 2012).

Construction Guidelines

The following criteria are recommended for constructing a surface sand filter system.

- The final sand bed depth should be 18 inches; take into account that the sand will consolidate during installation. Periodically wet the sand, allow it to consolidate, and add extra sand. Repeat this procedure until the bed depth has stabilized at 18 inches.
- Provide access to the basin for maintenance purposes. A maintenance vehicle access ramp is necessary. The slope of the ramp should not exceed 4:1.
- The design should minimize susceptibility to vandalism by using strong materials for exposed piping and accessories.
- Side slopes for earthen embankments should not exceed 3:1 to facilitate mowing.

- No runoff should enter the sand filtration basin before completing construction and site revegetation (BMP 8).
- Outfalls from sand filtration units should not be directed into surface waters without additional treatment from nutrient-reducing BMPs including BMP 9: Vegetated (Biofiltration) Swale, BMP 10: Bioinfiltration Swale, BMP 18: Bioretention Basin, BMP 22: Wet Pond, BMP 23: Extended Detention Basin, and BMP 24: Constructed Wetlands.

Maintenance

Follow the guidelines below for inspection and maintenance of sand filters.

Inspection Schedule

Inspect the sand filters at 6-month intervals for sediment and debris removal. Inspections should take place both before and after the wet seasons. If required as part of an NPDES permit or adjacent to impaired water bodies such as those on the §303(d) list, the observation well in a filtration trench may be monitored for water quality periodically or if triggered by a visual inspection (i.e., excessive turbidity, noticeable odors, or a visible sheen). For the first year after completing construction, monitor the well after every large storm (greater than 1 inch in 24 hours), and during October 1 to March 31, conduct inspections monthly. From April 1 through September 30, the facility should be monitored on a quarterly basis. A logbook should be maintained by the responsible person designated by the local government to indicate the rate at which the facility dewaters after large storms and the depth of the well for each observation. Once the performance characteristics of the structure have been verified, the monitoring schedule can be reduced to an annual basis unless the performance data indicate that a more frequent schedule is required.

Sediment and Debris Removal

Sediment buildup in the top foot of stone aggregate or the surface inlet should be monitored on the same schedule as the observation well. A monitoring well in the top foot of stone aggregate should be required when the trench has a stone surface. Do not allow sediment deposits to buildup to the point where they will reduce the rate of infiltration into the device. As a rule of thumb, remove silt when accumulation exceeds 0.5 inch. Remove accumulated paper, trash, and debris every 6 months, both before and after the wet seasons.

Sand Media Rehabilitation and Replacement

Over time, a layer of sediment will build up on top of the filtration media that can inhibit the percolation of runoff. During dry periods, this sediment can be easily scraped off with steel rakes or other devices. Once sediment is removed, the design permeability of the filtration media can typically be restored by striating the surface layer of the media. Eventually, however, finer sediments that have penetrated deeper into the filtration media will reduce the permeability to unacceptable levels, requiring replacement of some or all of the sand. The frequency in which the sand media should be replaced depends on where the basin is located relative to external influences and will depend on the suspended solids levels entering the system. Drainage areas that have disturbed areas containing clay soils will likely need more frequent replacement. Properly designed and maintained sand filtration BMPs in arid climates that have functioned effectively, without

completely replacing the sand media for at least 5 years should have design lives of 10 to 20 years. In areas with specific contaminants of concern, more frequent replacement of the sand media may be desired to ensure the permanent removal of trapped contaminants.

Additional Resources

Colorado Urban Drainage and Flood Control District. 2010. *Urban Storm Drainage, Criteria Manual, Volume 3 Best Management Practices.* Denver, CO.

EPA (US Environmental Protection Agency). 2015. *Stormwater Technology Fact Sheet: Sand Filters*. Washington, DC: Office of Water. *http://water.epa.gov/scitech/wastetech/upload/2002_06_28_mtb_sandfltr.pdf; https://www.epa.gov/npdes/industrial-stormwater-fact-sheet-series*

EPA (US Environmental Protection Agency). 2014 *Sand and Organic Filters*. Water: Best Management Practices. *http://water.epa.gov/polwaste/npdes/swbmp/Sand-and-Organic-Filters.cfm*; *https://www.epa.gov/npdes/industrial-stormwater-fact-sheet-series*

VDOT (Virginia Department of Transportation). 2013. *BMP Design Manual of Practice*. Richmond: VA. *http://www.virginiadot.org/business/locdes/bmp_designmanual.asp*

Washington State Department of Ecology. 2012. *Stormwater Management Manual for Western Washington*. Lacey, WA. Publ. 12-10-030. *http://www.ecy.wa.gov/programs/wq/stormwater/manual.html*

BMP 13: Catch-Basin Insert

Description

Catch-basin inserts are devices installed under storm-drain grates to provide water quality treatment through filtration, settling, or adsorption. Catch-basin inserts are generally configured to remove one or more of the following contaminants: coarse sediment, oil and grease, and/or litter and debris (Figure 33).

Figure 33. Basket-type catch-basin insert (VDOT 2013).

Primary BMP Functions and Controls

☒ Construction	☒ Permanent
☐ Erosion Control	☒ Sediment Control
☐ Source Control	☐ Flood Control
☒ Filtration	☐ Infiltration

Typical Effectiveness for Targeted Pollutants

●	Sediment
○	Nitrogen
○	Phosphorus
◖	Metals
○	Bacteria
◖	Hydrocarbons
●	Litter

Other BMP Considerations

Relative Cost	$
Maintenance Requirements	High
Ease of Installation	Easy
Freeze/Thaw Resistance	Good
Max. Tributary Drainage Area	0.1 acre
Max. Upstream Slope	NA
NRCS Soil Group	NA
Min. Ground Water Separation	NA
Min. Bedrock Separation	NA

Applicability

Catch-basin inserts can be used during construction and for new development and as retrofits in locations where available land area is limited. They are well suited for locations where storm water runoff travels from an impervious surface directly to a storm water conveyance system.

Possible locations for catch-basin inserts include, but are not limited to, parking lots, gas stations, golf courses, streets, driveways, and industrial or commercial facilities.

Limitations

Catch-basin inserts have limited usefulness as a primary treatment approach and are better suited as a pretreatment device installed ahead of other storm water BMPs. The inserts cannot effectively remove soluble pollutants or very fine particles.

Existing catch-basin dimensions limit the treatment capabilities for catch-basin inserts. Limited sizing, tendency for sediments to clog the filter media, and the fluctuating nature of the flow cause these devices to be maintenance intensive. Maintenance issues for catch-basin inserts may be further compounded by conflicting practices, such as street sanding.

Unless frequently maintained, catch-basin inserts may become a source of pollution through resuspension and washouts of captured pollutants. As proper maintenance is important for the functioning

of this BMP, ensure the maintenance requirements for these systems are dedicated before design and installation.

Design Basis

Types of catch-basin inserts include the following:

- Tray type
- Bag
- Basket
- Hooded

The location and size of catch basins should be determined based on the tributary drainage area and land uses within the drainage catchment. In general, the total maximum tributary area to a catch basin with an insert should be 5,000 square feet (+5%) per unit for new development projects and 7,000 feet per unit for redevelopment projects. Locate the catch-basin insert so it is accessible for maintenance and not limited by continuous vehicle parking. While no pretreatment is required with a catch-basin insert, the use of source control BMPs will decrease maintenance needs.

Tray, bag, and basket-type inserts should fit inside a standard grate, and if the insert is installed in an existing catch basin, the insert should fit properly so that a positive seal is achieved around the grate preventing low-flow bypass. The maximum height of the grate above the top of the frame, with the insert installed, should not exceed 3/16 inch, and the grate should be nonrocking.

Tray Type

A tray placed under the grate and around the perimeter of the inlet captures and passes storm water runoff through a filter media. During higher flows, storm water bypasses the tray over a weir directly into the catch basin.

Acceptable filter media include, but are not limited to, whole fibrous moss (not necessarily sphagnum moss), Petrolok, and general purpose absorbent (i.e., wood fiber). The bottom of the filter media (oil absorbent/absorbent material) should be above the level of normal low flows. If the media is above the crown of the outlet pipe, it is assumed to be above the normal low flows. An alternative method to demonstrate that the media is above the normal low flow is to show (by backwater analysis method) that the bottom of the media is above the water surface elevation corresponding to the water quality design flow (Figure 34).

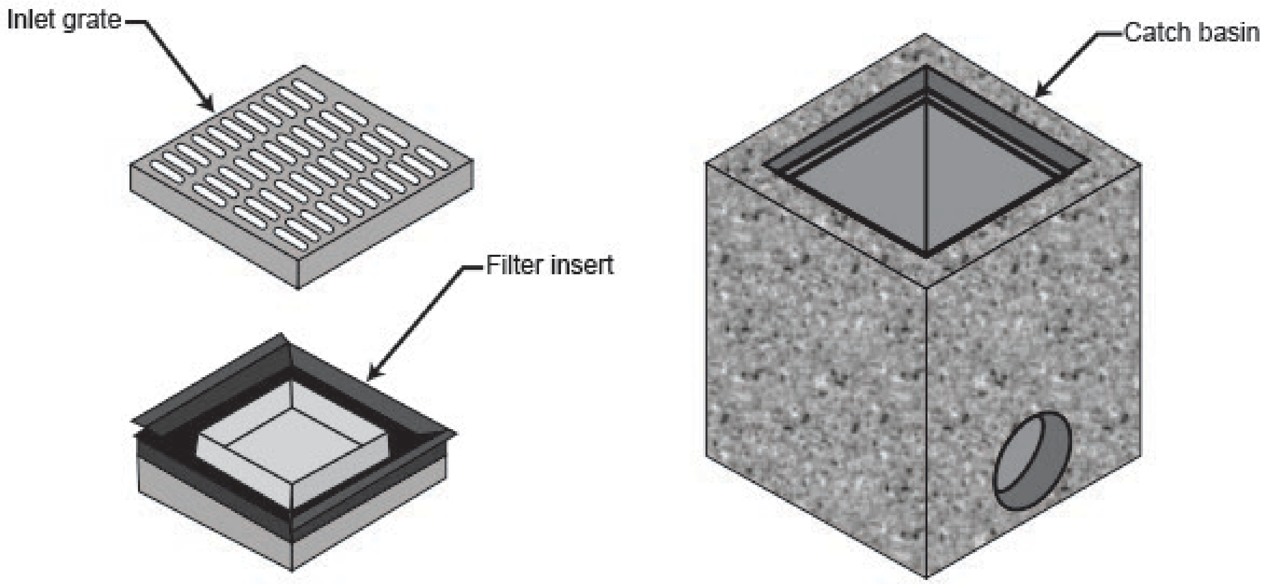


Figure 34. Diagram of tray-type catch-basin insert (VDOT 2013).

Bag Type

Bag-type inserts, such as a *witch's hat*, are often used on existing inlets during construction. Bag-type inserts consist of filter fabric that is placed around the perimeter of the catch basin grate with a bag below the grate that filters storm water through the bag before entering the catch basin. Bag-type inserts are often designed with overflow holes to prevent clogging and backwater flooding conditions, and they can include special fabrics to capture heavy metals (Figure 35).

Figure 35. Witch's hat bag insert (*GEI Works*).

Basket Type

Basket inserts, similar to bag inserts, are designed to be easily removed and installed for frequent maintenance. Basket inserts do not use a filter fabric and are traditionally used to capture large litter and debris (Figure 36).

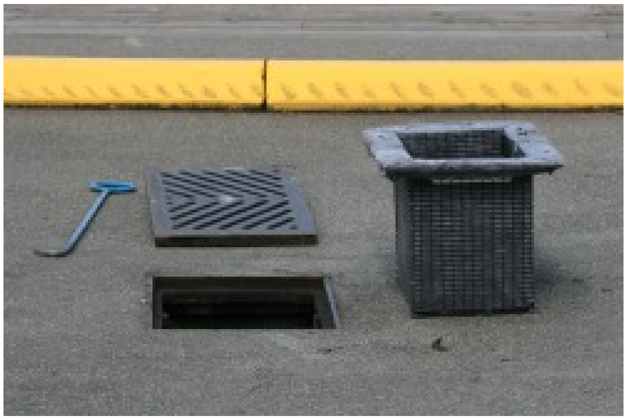


Figure 36. Basket-type insert in Twin Falls, Idaho.

Hooded Inserts

Hooded catch basins are designed to trap hydrocarbons and floating debris on the water surface forcing storm water to exit through a submerged outlet. Hooded inserts are often affixed permanently around the outlet pipe creating a standing water level above the submerged outlet. These inserts vary from the tray, bag, and basket-type systems as they are placed within the catch basin around the outlet pipe as opposed to directly below the catch-basin grate (Figure 37).

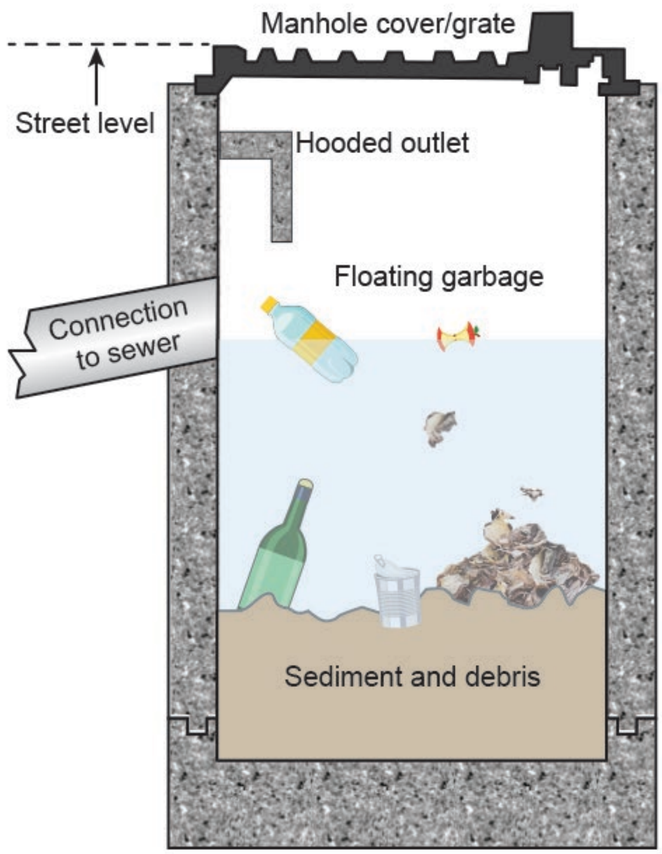


Figure 37. Diagram of hooded insert for catch-basin outlet (*Sanitrol Services*).

Construction Guidelines

Following the manufacturer's recommended procedures, install the catch-basin insert in the catch basin after the site has been paved or stabilized (for new development) or after completing construction (for a redevelopment site that is already paved).

Maintenance

Ensure that maintenance requirements for these systems will be dedicated before design and installation. Inserts should be routinely cleaned and emptied to achieve maximum removal efficiency. The inserts need to be cleaned frequently following runoff-producing events, during the wet season, and during leaf fall. When used for sediment control, inspect the insert weekly and maintain as needed.

Catch-basin inserts fitted with oil-absorbent material and sediment filter media should be inspected monthly and changed before the insert is saturated with water or oil and no longer has the capacity to absorb.

Additional Resources

EPA (US Environmental Protection Agency). 2014. *Catch Basin Inserts*. Water: Best Management Practices. *https://www.epa.gov/trash-free-waters/clean-water-act-and-trash-free-waters*

VDOT (Virginia Department of Transportation). 2013. *BMP Design Manual of Practice*. Richmond: VA. *http://www.virginiadot.org/business/locdes/bmp_designmanual.asp*

Walche, M. 2004. *Delaware's Pollution Control Strategy: Tributary Times-Evaluation of the Performance of Catch Basin Inserts*. Delaware Department of Transportation NPDES Program.

BMP 14: Media Filters

Description

Alternative media filters use filtration media other than sand, such as peat, compost, activated alumina, activated charcoal, pleated fabric, perlite, or zeolite to filter out particles and particle-bound constituents in storm water. Storm water pollutants can be removed through mechanical filtration to remove fine sediments; ion exchange to remove solubilized ionic pollutants such as metals; molecular absorption to remove organics; and microbial degradation to removed organic compounds such as oil and grease (Figure 38).

Figure 38. Peat sand filter.

Media filters are often constructed within precast concrete vaults that are installed underground. The vault includes a sedimentation chamber forebay to reduce sediment load and limit filter clogging. The media, which may be encapsulated within cartridges, is housed within the filtering chamber. Several specialty storm water filtration systems are available, and some systems are configured to include manholes or catch basins, which provide flexibility for locating them on site. Check with the local jurisdiction before implementing a specialty system to ensure it is accepted by their engineering department.

Primary BMP Functions* and Controls

☐ Construction ☒ Permanent
☐ Erosion Control ☒ Sediment Control
☐ Source Control ☐ Flood Control
☒ Filtration ☐ Infiltration

Typical Effectiveness for Targeted Pollutants*

● Sediment
◖ Phosphorus
◖ Metals
◖ Bacteria
◖ Hydrocarbons
○ Litter

Other BMP Considerations*

Relative Cost	$$
Maintenance Requirements	Medium
Ease of Installation	Hard
Freeze/Thaw Resistance	Fair
Max. Tributary Drainage Area	1 acre
Max. Upstream Slope	N/A
NRCS Soil Group	N/A
Min. Ground Water Separation	N/A
Min. Bedrock Separation	N/A

* Information varies according to manufacturer.

Applicability

Media filters are used solely for water quality enhancement and are not intended for use as storm water detention systems. They are useful in urban and ultra-urban settings where surface BMPs are not feasible and in applications where removing dissolved constituents such as metals, nutrients, and trace organics (of which sand filters do not remove particularly well) is needed. Media filters may be designed as online systems located within the main conveyance system for small drainage areas, or as off-line systems located off of the main conveyance system.

Media filters are preferred over infiltration practices when contamination of ground water with

conventional pollutants is a concern. This usually occurs in areas where underlying soils alone cannot treat runoff adequately, soils may already be contaminated, or ground water tables are high. In the case of high ground water levels, the media vault should be designed to be impermeable, and buoyancy effects should be considered.

Limitations

Pretreatment is recommended for runoff that contains high TSS and/or hydrocarbon loadings and debris, such as from parking lots or high traffic roads, that could cause the filter media to clog and prematurely fail. Media filtrations, such as amended sand, should be considered for some metals treatment applications to remove soluble metals and soluble phosphates.

Design Basis

Vault Design

Media filter vaults vary in size according to the media used and the volume needed to treat the water quality capture volume. Most require a minimum horizontal distance between the elevation inverts of the inlet and outlet pipes and a minimum hydraulic head of 2.5 to 4 feet to operate properly. Vaults can be specified with traffic-bearing lids to enable them to be installed directly into a paved traffic area.

Designs that do not allow for a permanent pool of standing water will help prevent mosquito breeding and vector control problems.

Pretreatment

1. Evaluate pretreatment needs. Typically, roadways, single-family dwellings, and developments with steep slopes and erodible soils need pretreatment for TSS. Developments producing sustained oil and grease loads should be evaluated for oil and grease pretreatment.
2. Use source control where feasible, including gross pollutant removal, sweeping, and spill containment. Maintain catch basins as needed to minimize inlet debris that could impair the operation of the filter media.
3. Use sedimentation vaults/ponds/tanks, innovative and more efficient catch basins, oil and water separators for runoff with higher oil concentrations where a visible sheen is present (e.g., parking lots and high traffic roadways), or other appropriate pretreatment systems to improve and maintain the operational efficiency of the filter media.
4. Recommend providing at least 25% of the water quality volume in a dry or wet sedimentation chamber as pretreatment to the filter system. Include energy dissipation in the inlet design to reduce resuspension of accumulated sediment.
5. Exit velocities from pretreatment should be nonerosive for the minor design storm.
6. The area of the sedimentation chamber may be determined based on the Camp-Hazen equation (Washington State Department of Ecology 2012). The Center for Watershed Protection (1996) used a settling of 0.0004 feet per second for drainage areas greater than 75% impervious and 0.0033 feet per second for drainage areas less than or equal to 75% impervious to account for the finer particles that erode from pervious surfaces (Equation 17):

$$A_s = -\left(\frac{Q_o}{w}\right)(Ln(1 - E)$$

Equation 17. Area of sedimentation chamber.

Where

A_s = sedimentation basin surface area (square feet)

E = trap efficiency; which is the target removal efficiency of suspended solids (set equal to 90%)

w = particle-settling velocity; for target particle size (silt) use settling velocity = 0.0004 feet per second (ft/s) (0.0033 ft/s for I > 75%, where I is percentage impervious area)

Q_o = rate of outflow from the basin, which is equal to the water quality volume (WQv) divided by the detention time (td); use 24 hours.

TSS Removal

1. Select media based on pollutants of concern, which are typically based on land use and local agency guidelines.
2. Determine TSS loading and peak design flow.
3. For proprietary media filter design, determine TSS loading capacity per cartridge based on manufacturer's loading and flow design criteria to determine number and size of cartridges.
4. Provide at least 75% of the water quality volume in the filter chamber and the sediment chamber.
5. For other media filters that are not in cartridges, size the filter bed using Darcy's law, which relates the velocity of fluids to the hydraulic head and the coefficient of permeability of a medium.

Overflow

1. Bypassing flow above water quality design flow should be included. Overflows operate when the inflow rate is greater than the filtration capacity. The flow capacity of the filter is exceeded when the flow into the filter exceeds the design level or sediment accumulation has reduced the filter's infiltration capacity (Figure 39).

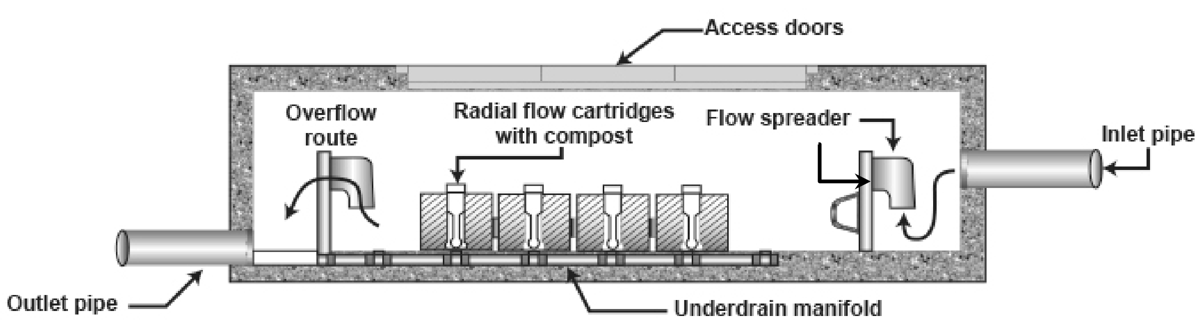


Figure 39. Storm filter schematic (King County 2009).

Construction Guidelines

The tributary drainage area to the media filter should be completely stabilized before media is installed to prevent premature clogging due to upstream erosion and solids loading. Typically the precast or cast-in-place vault is installed over an underdrain manifold pipe system and followed by the media installation. Other arrangements exist, depending on the product.

Maintenance

Media filters require annual maintenance at a minimum and may require inspections and maintenance after large storm events. For proprietary units, follow the manufacturer's maintenance guidelines. Inspection and maintenance activities typically include the following:

1. Inspect for standing water, sediment, trash, and debris and identify potential problems.
2. Ensure the sediment chamber is no more than half full of sediment; remove sediment if necessary.
3. Ensure the filter media is clean of sediments; remove sediments or replace the filter media if necessary.
4. Ensure there is no evidence of deterioration, scaling, or cracking of the concrete vault.
5. Inspect grates (if used).
6. Inspect inlet, outlet, and overflow spillway to ensure good condition and no evidence of erosion.
7. Repair or replace any damaged structural parts.
8. Stabilize any eroded areas around the facility.
9. Ensure storm water flows are not bypassing the facility by testing outflow for filtered nonvisible constituents.

Additional Resources

CASQA (California Stormwater Quality Association). 2004. "Media Filter, TC-40." *Stormwater Best Management Practice Handbook: New Development and Redevelopment*. Menlo Park, CA. *https://www.casqa.org*

EPA (US Environmental Protection Agency. 2014. *Sand and Organic Filters*. Water: Best Management Practices. *https://www.epa.gov/npdes/national-menu-best-management-practices-bmps-stormwater#edu*

King County (King County, Washington). 2009. *King County, Washington Surface Water Design Manual.* Seattle, WA: King County, Department of Natural Resources.

BMP 15: Oil and Water Separators

Description

Hydrocarbons, oils/fats and grease, and other light nonaqueous phase liquids are common contaminants in storm water that have negative impacts to receiving waters and should be removed. Oil and water separators are designed to remove hydrocarbons from storm water runoff. Baffle and coalescing plate separators are two multichambered design configurations for these separators. Oil and water separators may include hydrocarbon filters inserted into a secondary chamber before outflow to adsorb dissolved and fine/unsettleable constituents (Figure 40).

Figure 40. Oil and water separator with coalescing plat separators to remove hydrocarbons (*Mohr Separations Research, Inc.*).

Baffle oil and water separators, also known as American Petroleum Institute (API) separators, are long multichambered vaults separated with baffles designed to remove gross amounts of sediment and hydrocarbon loadings from urban runoff. Large API separators may include sophisticated mechanical equipment for removing oil from the surface and settled solids from the bottom.

Coalescing plate (CP) separators include a series of parallel inclined plates that encourage separation of materials of different densities by attenuating inflow velocity and enabling agglomeration of dispersed nonaqueous particles. The plates are typically made of fiberglass or polypropylene and are closely spaced to improve the hydraulic conditions in the separator and promote oil removal. Another coalescing method uses a filter made of oleophillic (oil-loving) fibers in lieu of plates.

Primary BMP Functions and Controls

☐ Construction	☒ Permanent
☐ Erosion Control	☒ Sediment Control
☒ Source Control	☐ Flood Control
☒ Filtration	☐ Infiltration

Typical Effectiveness for Targeted Pollutants

○	Sediment
○	Nitrogen
○	Phosphorus
◖	Metals
○	Bacteria
●	Hydrocarbons
◖	Litter

Other BMP Considerations

Relative Cost	$$
Maintenance Requirements	High
Ease of Installation	Medium
Freeze/Thaw Resistance	Fair
Max. Tributary Drainage Area	12 acres
Max. Upstream Slope	15%
NRCS Soil Group	ABC
Min. Ground Water Separation	8 feet
Min. Bedrock Separation	8 feet

Applicability

Oil and water separators can be used where potential hydrocarbon contamination is a concern, such as in industrial sites, construction sites, fuel depots, or high traffic areas like multifamily dwellings, apartment complexes, gas stations, or

parking lots. These separators are often used in urban areas where land requirements and cost prohibit the use of larger BMPs or where tank farms are located to treat outflow from secondary containment structures.

Depending on loading conditions, oil and water separators can be located off-line from the primary conveyance/detention system and can be used for pretreatment of runoff before discharge to other BMPs.

Limitations

Relatively short retention times, as compared to other storm water BMPs, may limit pollutant removal capabilities. A sediment basin is recommended upstream of the oil and water separator to prevent sediment from entering the separator and the resuspension of sediment within the separator during periods of high flow.

Oil and water separators should not discharge directly into receiving water bodies, such as streams, if oils have become dissolved or emulsified or if there is the possibility of a petroleum hydrocarbon spill. Dissolved or emulsified substances may include coolants, soluble lubricants, glycols, and alcohols. Further treatment using BMPs, such as grass swales, is recommended downstream of oil and water separators.

Design Basis

The following design parameters apply to all three separator types:

- Appropriate removal covers should be provided to allow access for observation and maintenance.
- Storm water from building rooftops and impervious surfaces are not likely to be contaminated by oil and should not be discharged to the separator.
- Any pump mechanism should be installed downstream of the separator to prevent oil emulsification.
- Sediment loading to the oil and water separators should be minimized to reduce maintenance needs and improve system performance. Practice nonstructural BMPs, such as dry cleanup, to minimize solids flow to separators.

Additional requirements for API and CP separators:

- Separators should be sized for the water quality design storm specified by the local jurisdiction or one-third of a 2-year event if water quality design storm is not specified. Design storm information is presented in section 3.6.3.
- Separators should have a forebay to collect floatables and large settleable solids. Its surface area should be at least 20 square feet per 10,000 square feet of area draining to the separator.

The following are additional requirements for CP separators:

- Coalescing plates should not be spaced less than 3/4 inch apart.
- The angle of the plates should be from 45 to 60 degrees from horizontal.
- Absorbent pillows may be used in separators. Place API and CP-type separators in an afterbay. With the CP separator, absorbent materials should be placed in the manhole/vault.

Used absorbent pillows must to be properly disposed of, and hazardous components must be considered before disposal (e.g., metal concentrations exceeding toxicity characteristic leaching procedure limits).

- Add pretreatment for sediment that could clog CP separators or otherwise impair the long-term effectiveness of the separator.

Sizing Procedure

Oil droplets exist in water in a wide distribution of sizes. Separators are designed to remove a range of all droplet sizes and greater to ensure that the device will achieve design removal efficiency and meet effluent standards (e.g., no visible oil sheen; fat, oil, and grease limits).

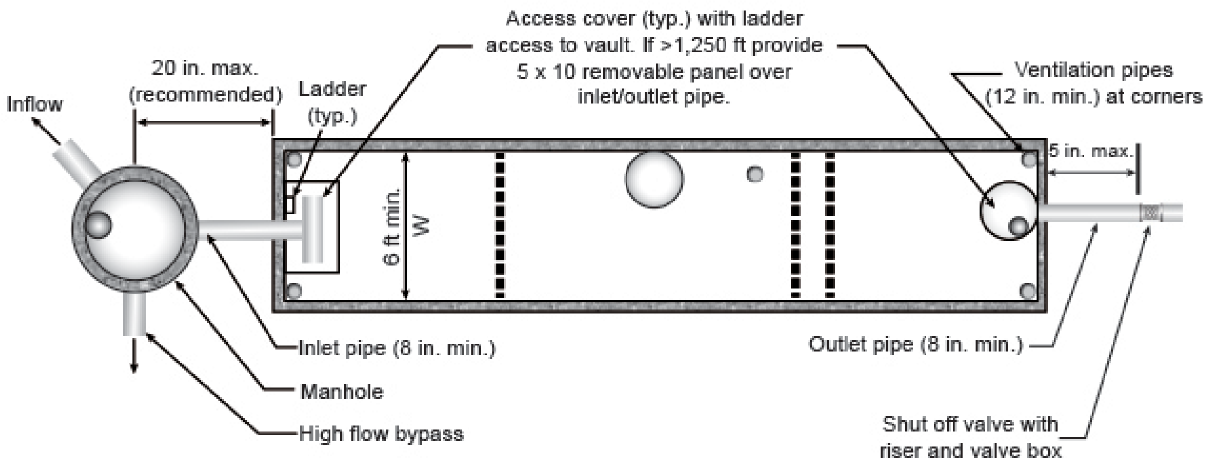
API separators (Figure 41) are usually sized to remove oil droplets 150 microns in size and larger. Smaller droplets rise so slowly that they would require a relatively large vault if removed using an API separator. CP separators (Figure 42) are more appropriate for smaller droplets and are commonly designed to remove 60 to 90-micron sizes and can be designed to remove oil droplets as small as 20 microns. Hydrocarbon filters can also be used for fine droplet impingement and dissolved fraction filtration.

Data are not available on the size distribution of dispersed oil in storm water from commercial or industrial land uses except for petroleum storage terminals. The data indicate that, by volume, about 80% of the droplets are greater than 90 microns in size. Less than 30% are greater than 150 microns. For these guidelines, both the API and CP separators are sized to remove 60 microns and larger droplets at a temperature of 10 ^{o}C giving a rise rate of 0.033 feet per minute (10 millimeters per minute). The large size requirement for treatment of 60-micron and smaller-sized droplets may preclude the use of API separators.

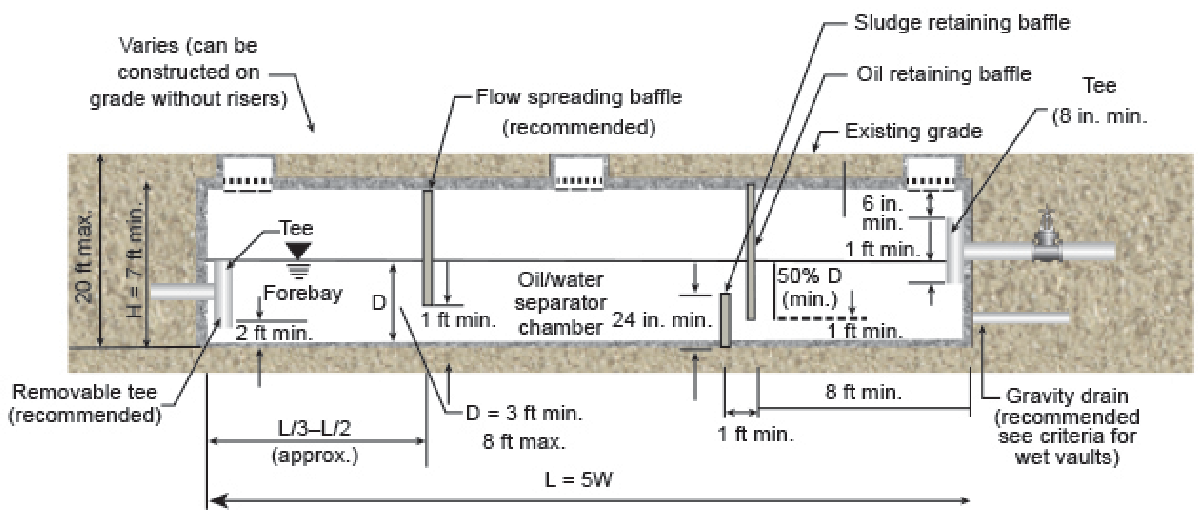
API Separator Sizing

For oil droplets that average 60 microns in size, API separators can be sized using these general guidelines:

- Horizontal velocity, V_h: 3 feet per minute or 15 times the rise rate, V_t (API criteria), whichever is smaller (rise rate of 0.033 feet per minute for average 60-micron size V_t, oil droplets). V_t can also be determined on a site-specific basis using Stoke’s law or determined from empirical equations. For drainage areas less than 2 acres, the design hydraulic velocity, V_h, can be used for the ratio V_h/V_t rather than the API minimum of $V_h/V_t = 15$. However, performance verification of this design basis should be obtained during at least one wet season (Washington State Department of Ecology 2012).
- Depth of 3 to 8 feet
- Depth-to-width ratio of 0.3 to 0.5
- Width of 6 to 20 feet
- Baffle height-to-depth ratios of 0.85 for top baffles and 0.15 for bottom baffles (Figure 41).

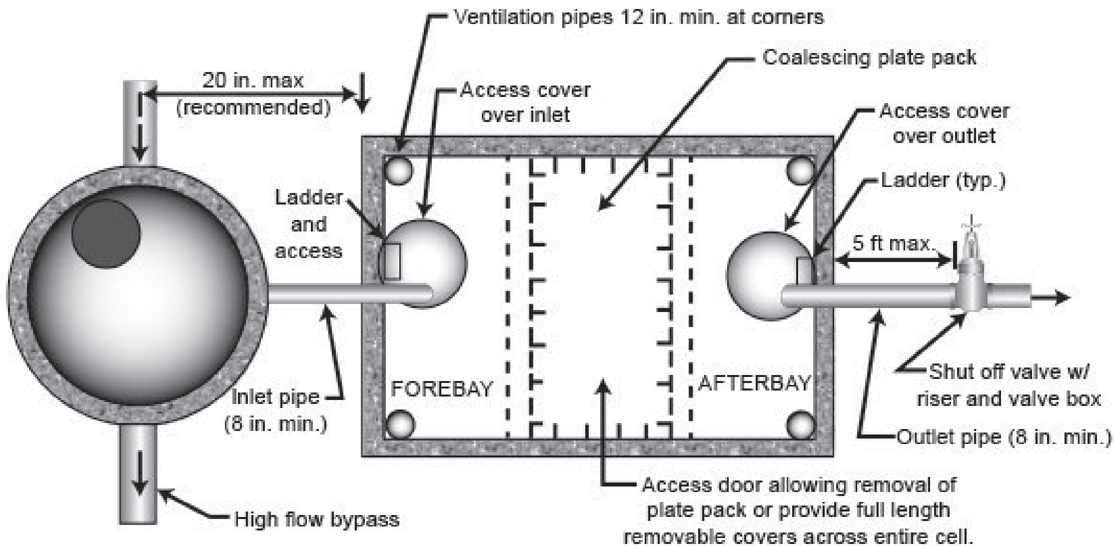


Plan View
NTS

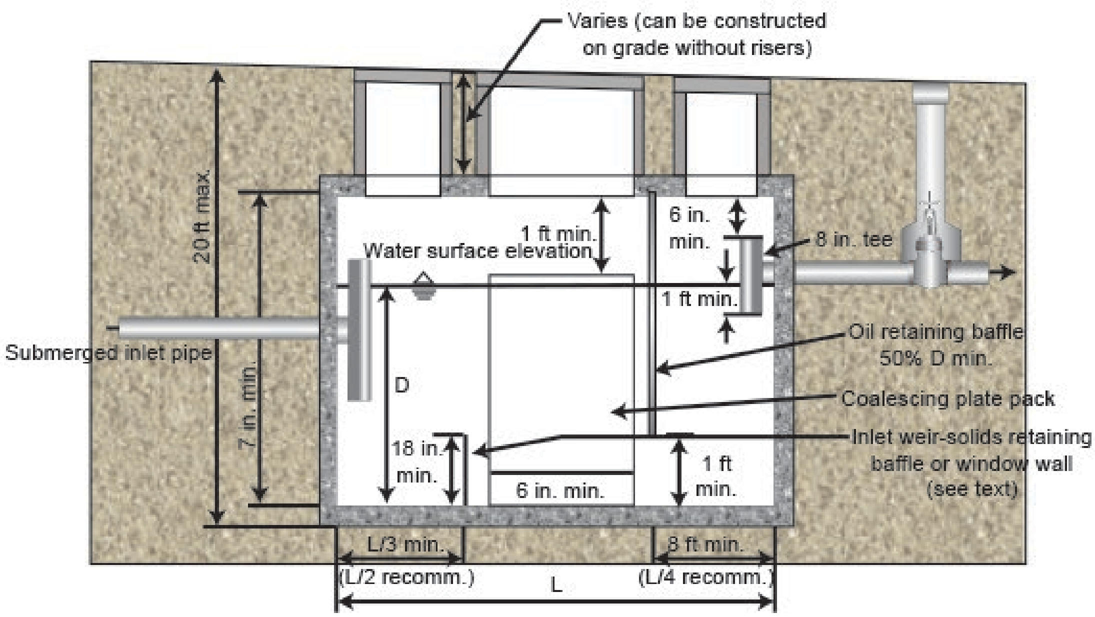


Section View
NTS

Figure 41. API separator.



PLAN VIEW
NTS



SECTION VIEW
NTS

Figure 42. CP separator (King Country 2009).

The separator can be first sized for depth using Equation 18:

$$d = \left(\frac{Q}{2V_h}\right)^{1/2}$$

Equation 18. Depth sizing.

Where

Q = design flow

V_h = design horizontal velocity = 15 V_t

V_t = rise rate = 0.033 feet per minute for 60-micron oil or determined

Calculate the width using the ratios above (i.e., 0.3 to 0.5 depth-to-width ratio). Then calculate length of the separator section using Equation 19:

$$\boldsymbol{L_s = d\frac{V_h}{V_t}F}$$

$$\boldsymbol{L = L_s + L_f + L_a}$$

Equation 19. Separator length.

Where

L_s = length of the separator section

L_f = length of the forebay = L/2 to L/3

L_a = length of the afterbay = L/4, 8-foot minute

L = total length = $L_s + L_f + L_a$

F = turbulence and short-circuiting factor (Figure 43)

CP Separator Sizing

Calculate the projected (horizontal) surface area of plates required using Equation 20:

$$A_h = \frac{Q}{V_t}$$

Equation 20. Coalescing plate area.

Where

A_h = horizontal surface area of the plates (square feet)

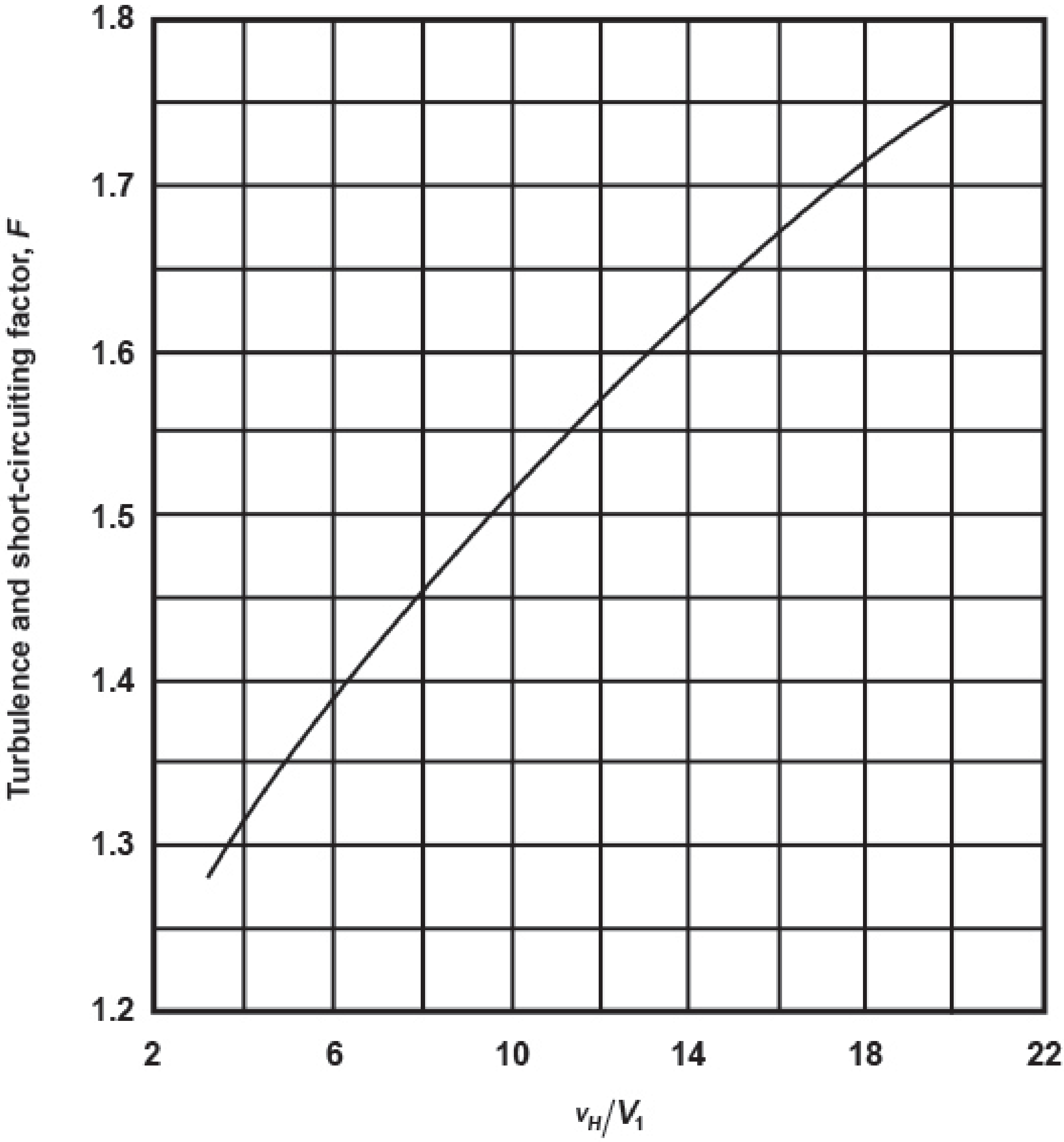
Q = design flow rate (cubic feet per minute)

V_t = rise rate of the oil droplet (feet per minute [ft/min]) = 0.033 ft/min for 60-micron oil droplets

Refer to the manufacturer's recommendations for oil and water separator sizing. Manufacturers of plate packs provide standard size packages that are rated at a particular flow (usually gallons per minute). However, if the manufacturer's flow rating is for conditions different than used above, the engineer should compare the plate surface area with the above calculation. Do not confuse projected plate area with actual plate area.

The width, depth, and length of the plate pack and the chamber in which the plate pack is placed is completely flexible and is a function of the plate sizes provided by the particular pack manufacturer and standard size vaults that are available for small sites.

Additional design and sizing details for both baffle and CP separators are provided in the *King County, Washington, Surface Water Design Manual* (King County 2009)



v_H/V_1	Turbulence Factor (F_1)	$F = 1.2(F_1)$
20	1.45	1.74
15	1.37	1.64
10	1.27	1.52
6	1.14	1.37
3	1.07	1.28

Figure 43. Turbulence and short-circuiting factor (API 1990).

Construction Guidelines

- The installation of proprietary systems such as the API or CP separator systems discussed above must follow manufacturer's construction standards and procedures.
- When installing CP packs in CP separator units, take care to avoid deforming the plates.
- Oil and water separators should be cleaned and flushed before operation.
- Underground tanks should be analyzed for buoyancy, especially if local hydrology increases the risk of floating the vault during periods of high ground water and/or storm events. The system may need to be anchored or ballasted in place according to the manufacturer's standards and recommendations.

Maintenance

- Oil and water separators should be inspected frequently and cleaned as necessary to keep accumulated oil from escaping during storms. As a rule of thumb, they should always be cleaned in the fall to remove material that has accumulated during the dry season, after leaf drop, and again after a significant storm.
- During the first few years of operation, oil and water separators should be inspected according to manufacturer's guidelines, after each storm event, or more frequently depending on site-specific conditions to ensure oil and sediment buildup have not exceeded design depths, the unit is free of litter and other obstructions, and to confirm proper function according to the manufacturer's specifications.
- Oil absorbent pads are to be replaced as needed but should always be replaced in the fall before the wet season and in the spring.
- Construction period inspections should be conducted as required by both the NPDES permit and manufacturer's specifications.
- The effluent shutoff valve is to be closed during cleaning operations.
- Waste oil and residuals should be disposed of according to current DEQ, local government, and health district requirements.
- Any standing water removed during the maintenance operation should be disposed of to a municipal or industrial sewer system at a discharge location approved by the local government.
- Any standing water removed should be replaced with clean water to prevent oil carry-over through the outlet weir or orifice.

Additional Resources

API (American Petroleum Institute). 1990. *Monographs on Refinery Environmental Control - Management of Water Discharges (Design and Operation of Oil-Water Separators)*. 1st ed. Publication 421. Washington, DC: API.

EPA (US Environmental Protection Agency). 1999. *Stormwater Technology Fact Sheet: Water Quality Inlets.* Washington, DC: Office of Water. EPA 832-F-99-029.

ITD (Idaho Transportation Department). 2014. *Best Management Practices.* Boise, ID: ITD.

King County (King County, Washington). 2009. *King County, Washington Surface Water Design Manual.* Seattle, WA: King County, Department of Natural Resources. *http://your.kingcounty.gov/dnrp/library/water-and-land/stormwater/surface-water-design-manual/SWDM-2009.pdf*

Washington State Department of Ecology. 2009. *Stormwater Management Manual for Western Washington*. Lacey, WA. Publ. 12-10-030. *http://www.ecy.wa.gov/programs/wq/stormwater/manual.html*

BMP 16: Centrifugal or Vortex-Separation Structures

Description

Centrifugal separation structures, also known as hydrodynamic or vortex separators, are underground structures that use tangential forces created by the incoming flow of storm water to separate trash, debris, oil, and other pollutants from storm water runoff. These separators are designed with internal components that impart a swirling motion to water entering the device. Separation is accomplished by water entering a cylindrical chamber on a tangential plane that creates a vortex. The flow at the outer edge of the tank moves at a slightly higher velocity than the flow at the center, and, as a result, denser, heavier material moves downward to the center and lighter, floatable materials rise to the surface on the outside (Figure 44).

Figure 44. Inside view of Kristar 48-inch dual vortex separator (*City of Watsonville, CA*).

Additional compartments or chambers trap oil and other floatables. These systems may include a wall to separate TSS from oil and a bypass weir to allow excess flows to bypass the system and prevent the unit from flooding or losing its captured material. Vortex separators do not have any moving parts.

Primary BMP Functions and Controls

☐ Construction	☒ Permanent
☐ Erosion Control	☒ Sediment Control
☒ Source Control	☐ Flood Control
☒ Filtration	☐ Infiltration

Typical Effectiveness for Targeted Pollutants

●	Sediment
○	Phosphorus
◖	Metals
○	Bacteria
●	Hydrocarbons
●	Litter

Other BMP Considerations

Relative Cost	$$$
Maintenance Requirements	Medium
Ease of Installation	Med-Hard
Freeze/Thaw Resistance	Fair
Max. Tributary Drainage Area	Varies
Max. Upstream Slope	N/A
NRCS Soil Group	ABCD
Min. Ground Water Separation	N/A
Min. Bedrock Separation	N/A

Applicability

These systems are ideal in highly urbanized areas because they are space efficient and can be placed under parking lots or installed as a manhole junction box or inlet structure. The systems are most effective when the runoff materials to be removed are heavy particulates, which can be settled, or floatables, which can be skimmed or screened out. These structures are recommended for the following applications:

- Pretreatment for other BMPs
- Retrofit of existing development or redevelopment
- Dense urban development areas
- Storm water hotspot

Limitations

Vortex separators are not effective at removing dissolved pollutants or pollutants that adhere to fine particles, such as nutrients. Performance can be compromised during low flows as a swirl action is most effective when the inlet pipe is carrying full pipe flow. Site constraints, including the availability of suitable land, appropriate soil depth, and stable soil to support the unit structurally, may also limit the applicability of hydrodynamic separators. The slope of the site or collection system may necessitate using an underground unit, which can result in an extensive excavation.

Design Basis

Criteria should be obtained from the manufacturer to ensure that the correct design and sizing criteria are used in selecting the appropriate system for a particular site. In general, the flow-through configuration and treatment limitations will force drainage areas to remain relatively small. Currently, units are available from a number of manufacturers in sizes ranging from 3 to 40 feet in diameter with processing capacity from 1.6 to 300 cubic feet per second. Some units are small enough to fit into conventional manholes.

The system should be sized for the water quality design storm. If the system is too large, it will not have the volume/velocity relationship to achieve the swirl action. For storms greater than the water quality design storm, an overflow, or bypass, should be used to divert storm water to an appropriately sized storage facility with a sedimentation basin or other BMP for treatment.

Construction Guidelines

Vortex separators should be installed according to manufacturer's instructions and specifications.

Maintenance

This system requires regular inspection and maintenance to maximize effectiveness. The specific maintenance requirements and schedule should be prepared by the manufacturer and signed by the owner/operator. The frequency of maintenance not only depends on the type of manufactured system chosen but also the pollutant load from the contributing drainage area.

In general, frequent inspections after every storm or every 30 days are recommended during the first year after installation and whenever heaving contaminant load occurs, such as after winter sanding or soil disturbances. Deposition can be measured with a calibrated dip stick, and sediment should be removed by vacuum pumping when the unit is filled to within 1 foot of capacity. Remove floatables and clean screens when needed. The frequency of inspections can be adjusted after the first year based on observed sediment accumulation rates.

Additional Resources

EPA (US Environmental Protection Agency). 1999. *Storm Water Technology Fact Sheet: Hydrodynamic Separators*. Washington, DC: Office of Water. EPA 832-F-99-017. *http://water.epa.gov/scitech/wastetech/upload/2002_06_28_mtb_hydro.pdf*.

BMP 17: Infiltration Trench

Description

Infiltration trenches are shallow (3 to 12 feet deep), placed in relatively permeable soils and backfilled with a sand filter, coarse stone, and lined with filter fabric. The trench surface can be covered with grating and/or consist of stone, gabion, sand, or a grassed covered area with a surface inlet. Depending on the design, the trenches allow for the partial or total infiltration of storm water runoff into the underlying soil. The trenches also provide storage within the voids of the coarse stone and may include a perforated pipe or a prefabricated bottomless chamber at the bottom of the trench to increase its temporary storage capacity. The trenches may have underdrains to convey water away from the trench in case of storm water overflow (Figure 45).

Figure 45. Infiltration trench (PennDOT 2015).

Primary BMP Functions and Controls

☐ Construction	☒ Permanent
☐ Erosion Control	☒ Sediment Control
☐ Source Control	☐ Flood Control
☐ Filtration	☒ Infiltration

Typical Effectiveness for Targeted Pollutants

●	Sediment
◖	Phosphorus
●	Metals
●	Bacteria
○	Hydrocarbons
○	Litter

Other BMP Considerations

Relative Cost	$$
Maintenance Requirements	Medium
Ease of Installation	Medium
Freeze/Thaw Resistance	Fair
Max. Tributary Drainage Area	5 acre
Max. Upstream Slope	20%
NRCS Soil Group	AB
Min. Ground Water Separation	3 feet
Min. Bedrock Separation	4 feet

Applicability

Infiltration trenches capture and treat small amounts of runoff and are used in relatively small drainage areas. Trenches are one of the few BMPs that are easy to fit into the margin, perimeter, and other less-used areas of developed sites, making them particularly suitable for retrofitting. Unlike infiltration basins installed at the surface, the land above a subsurface trench system can be used for landscaping or parking with the correct design. A trench may also be installed under a drainage swale to provide storage capacity and increase the infiltrative capacity of the swale if allowed by municipalities or other approval jurisdictions. This BMP should typically be located *off-line* from the primary conveyance/detention system to effectively treat pollutants and protect the infiltration soils from clogging. Infiltration trenches are recommended to precede a pretreatment BMP to remove sediments and/or oil and grease that could clog the infiltration soils.

Conservatively, the longevity of trenches is expected to be about 2 to 5 years before partial or full clogging/sealing of the floor. The life span can be significantly increased given good permeable soils

and pretreatment to prevent clogging. The relatively short life span of infiltration facilities can be significantly increased through proper design and maintenance.

Limitations

Appropriate soil conditions and protecting ground water are the most important considerations limiting the use of this BMP. Infiltration rates should be 0.5 inches per hour or greater. Generally, Group A and B soils will convey water at this rate, but site-specific testing should be completed to confirm the infiltration rate. Other soil conditions that will not support using infiltration trenches include the following:

- Soils with more than 40% clay content (subject to frost heave)
- Fill soils, unless the fill material is specially designed to accommodate the facility
- Steep site slopes (greater than 20%) can contribute to slope failures
- Karst topography
- Storm water hotspots

Infiltration trenches are not suitable for sites with exposed chemical or toxic materials or soils contaminated by toxic materials. If the potential for a toxic spill exists, a spill prevention and control plan should be in place.

Infiltration facilities are not suitable in many areas of Idaho where the ground water table is very shallow. Conditions should be observed at the site during the winter and early spring when the water table is at its highest. If the minimum depth to ground water at these times is 3 feet from the proposed bottom of the infiltration trench bed and the other noted soil conditions are right, infiltration can be used. If depth to the water table is less than 3 feet, an increased risk exists for ground water contamination.

Design Basis

The procedure for sizing infiltration trenches should follow a Darcy’s law approach (BMP 12: Sand Filter). Typical dimensions are 3 feet wide and 3 to 12 feet deep with a maximum surface slope of 5% and maximum slope of 1% on the trench bottom. Any length is acceptable although cleanouts or inlet access to the underdrain should be provided every 100 feet. Additional design parameters specific to infiltration trenches are given below.

Soil Investigation

A soil investigation is recommended to determine design parameters for infiltration trenches. At least one test location for every 50 linear feet of trench should be investigated and minimum of two tests for each trench. Soil investigations should describe the NRCS series of the soil, the textural class of the soil horizons, and note any evidence of seasonal high ground water levels, such as mottling. In addition, the location of impermeable soil layers or dissimilar soil layers should be determined. The design infiltration rate (fd) should be equal to one-half the infiltration rate found from the soil textural and structural analysis or from an in-situ infiltration test conducted at the elevation of the bottom of the proposed facility. The measured infiltration rate of the underlying soil can be determined using either the EPA falling head percolation test procedure (EPA 1980), the double-ring infiltrometer test (ASTM 2009), a single-ring infiltrometer test using a ring at least

3 feet in diameter, or alternative infiltration tests (Oregon ASCE 2009). A minimum of three small-scale tests for each proposed infiltration facility is recommended.

Pretreatment

All infiltration trenches are recommended to preceded a pretreatment BMP, such as a presettling basin, vegetated swale, simple sump, or vegetated filter strip at least 20-feet wide. A level spreader (BMP 30) may be used to spread out concentrated flows. Regular maintenance of the pretreatment device is critical to prevent clogging the infiltration trench.

Drawdown Time

In general, infiltration trenches should be designed to completely drain stored runoff within 24 hours. The draining will ensure that the necessary aerobic conditions exist to provide effective treatment of pollutants. If a presettling basin precedes the infiltration trench, the combined drawdown time for both BMPs should be 24 hours.

If trout or salmon streams are in the area, surface holding time should not exceed 12 hours to avoid warming the water and negatively affecting the water for fish habitat. This is not an issue when infiltration is functioning as designed but can be devastating in the event of a failure.

Storage

Storage is provided within the void spaces of the aggregate. Material for the infiltration trench should consist of a clean aggregate with a maximum diameter of 3 inches and a minimum diameter of 1.5 inches. Grade the aggregate so that a few aggregates are smaller than the selected size. Void space for these aggregates is assumed to be 30% to 40%.

Additional storage can be provided using a perforated pipe or a prefabricated bottomless chamber near the bottom of the trench. Sizes for the pipe or chamber depend on the required storage capacity and space available. If chambers are used under a paved surface, consult the manufacturer's recommendation for minimum clearances between the surface and top of the chamber to provide sufficient load capacity.

Geotextile Fabric

The aggregate fill material should be completely surrounded with a geotextile fabric that is defined as nonwoven, spunbonded, and needle punched. In the case of an aggregate surface, the fabric should surround all of the aggregate fill material except for the top 1 foot.

Overflow

An overflow route for surface runoff exceeding the infiltrative capacity of the trench should be identified and evaluated to preclude the development of uncontrolled, erosive, concentrated flow. A nonerosive overflow channel leading to a stabilized watercourse should be provided.

Seepage Analysis and Control

An analysis should be made to determine any possible adverse effects of seepage zones when there are nearby building foundations, basements, roads, parking lots, or sloping sites. Developments on sloping sites often require using extensive cut and fill operations. Using infiltration trenches on fill sites is not recommended unless soils are specifically engineered to accept infiltrative flows. Trenches should be a minimum of 100-feet upslope and 20-feet downslope from any building foundation or water supply well.

Observation Well

An observation well should be installed for every 50 feet of infiltration trench length. The observation well serves two primary functions: indicates how quickly the trench dewaters following a storm and provides a method of observing how quickly the trench fills up with sediment. The observation well should consist of perforated PVC pipe, 2 to 4 inches in diameter. The pipe should be located in the center of the structure and constructed flush with the ground elevation of the trench. Cap the top of the well to discourage vandalism and tampering. More specific construction information can be obtained by contacting IDWR or DEQ (Figure 46).

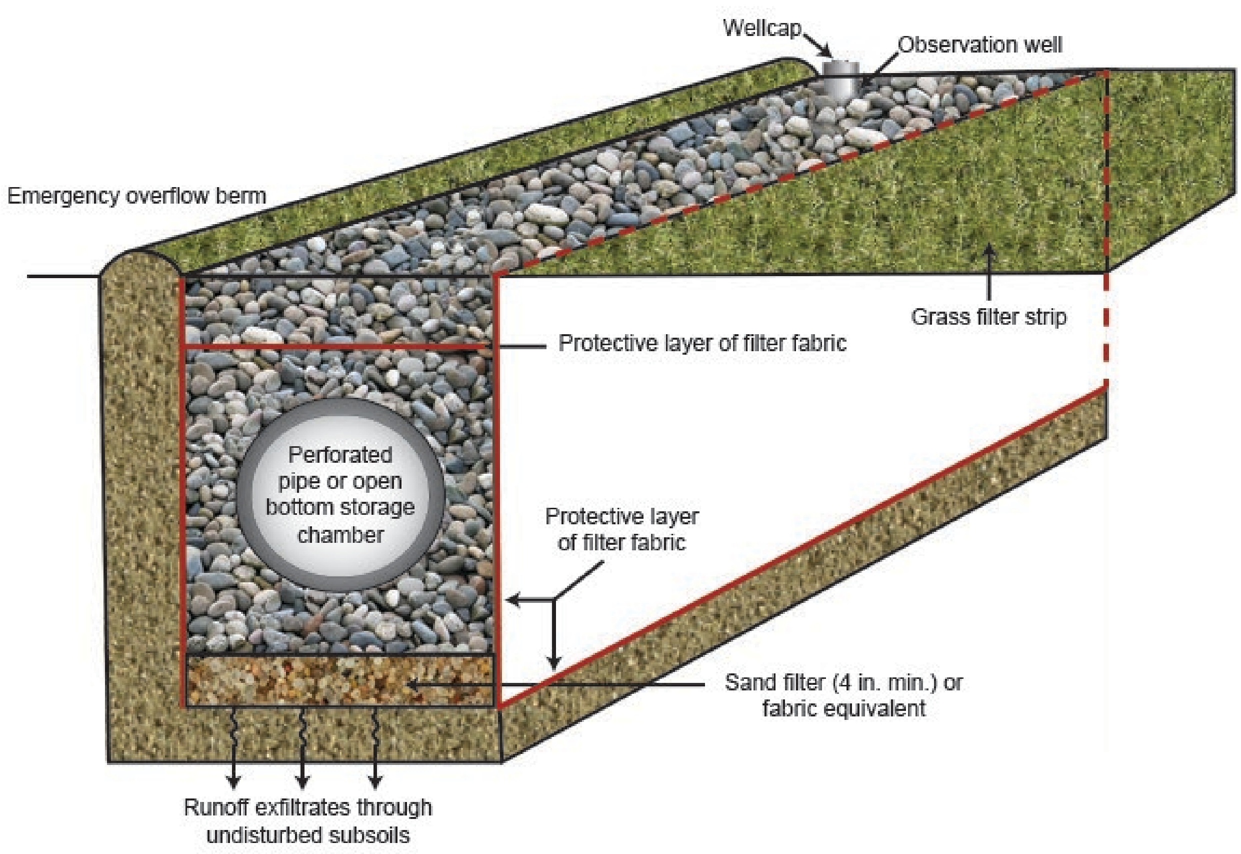


Figure 46. Typical infiltration trench (NCDENR Stormwater BMP Manual, adapted from Schueler et al. 1992).

Construction Guidelines

Construction Timing

An infiltration trench should not be constructed or placed into service until all of the contributing drainage area has been stabilized and approved by the appropriate agency.

Trench Preparation

Excavate the trench to the design dimensions. Excavated materials should be placed away from the trench sides to enhance wall stability. Care should also be taken to keep this material away from slopes, neighboring property, sidewalks, and streets. Cover this material with plastic if it will be left in place for more than 30 days.

Fabric Laydown

Cut the geotextile fabric to the proper width before installation. The cut width should include sufficient material to conform to the trench perimeter irregularities and a 12-inch minimum top overlap.

Place the geotextile over the trench and unroll a sufficient length to place the fabric down into the trench. Stones or other anchoring objects should be placed on the geotextile at the edge of the trench to keep the lined trench open during windy periods. When overlaps are required between rolls, the upstream roll should overlap a minimum of 2 feet over the downstream roll to provide a shingled effect. The overlap ensures geotextile continuity and allows the geotextile to conform to the excavated surface during aggregate placement and compaction.

Stone Aggregate and Pipe Placement

The stone aggregate should be placed in lifts and compacted using plate compactors. A maximum loose lift thickness of 12 inches is recommended. The compaction process ensures geotextile conformity to the excavation sides, reducing potential soil piping, geotextile clogging, and settlement problems.

If a perforated pipe or bottomless chamber is included in the design, place the pipe or chamber 6 inches above the bottom of the trench or according to the manufacturer's recommendations. Do not wrap the pipe with geotextile filter fabric as it tends to clog.

Overlapping and Covering

Following the stone aggregate placement, fold the geotextile fabric over the stone aggregate to form a 12-inch minimum longitudinal overlap. Place the desired fill soil or stone aggregate over the lap at sufficient intervals to maintain the lap during subsequent backfilling.

Exercise care to prevent natural or fill soils from intermixing with the stone aggregate. Remove all contaminated stone aggregate and replace with uncontaminated stone aggregate.

Voids Behind Geotextile

Voids that may be created between the geotextile and excavation sides should be avoided. Native soils should be placed in these voids at the most convenient time during construction to ensure fabric conformity to the excavation sides. Using this remedial process will minimize soil piping, fabric clogging, and possible surface subsidence.

Unstable Excavation Sites

Vertically excavated walls may be difficult to maintain in areas where the soil moisture is high or where soft or cohesionless soils predominate. These conditions require laying back the side slopes to maintain stability; a trapezoidal rather than rectangular cross sections may result. This is acceptable, but any change in the shape of the stone reservoir must be taken into consideration in size calculations.

Traffic Control

Restrict heavy equipment and traffic from traveling over the infiltration areas to minimize compaction of the soil. The trench should be flagged or marked to keep equipment away from the area.

Maintenance

The observation well should be monitored periodically for water level. For the first year after completing construction, the well should be monitored after every large storm (greater than 1 inch in 24 hours), and during the period from October 15 to April 15, inspections should be conducted monthly. From April 16 through October 14, the facility should be monitored on a quarterly basis. Once the performance characteristics of the structure have been verified, the monitoring schedule can be reduced to an annual basis unless the performance data indicate that a more frequent schedule is required.

Sediment buildup in the top foot of stone aggregate or the surface inlet should be monitored on the same schedule as the observation well. A monitoring well in the top foot of the stone aggregate should be required when the trench has a stone surface. Sediment deposits should not be allowed to buildup to the point where it will reduce the rate of infiltration into the trench.

BMPs used for pretreatment should be inspected regularly. Sediment deposits should be removed, and grassy swales or filter strips should be mowed. Repair any erosion (e.g., rills) in pretreatment swales or filter strips that might concentrate runoff flow and cause erosion before the infiltration trench.

Additional Resources

ASTM (American Society for Testing and Materials). 2009. *Standard Test Method for Infiltration Rate of Soils in Field Using Double-Ring Infiltrometer.* West Conshohocken, PA: ASTM International. ASTM D3385–09.

EPA (US Environmental Protection Agency). 1980. *Design Manual: Onsite Wastewater Treatment and Disposal Systems.* Washington, DC: Office of Water Program Operations. EPA 625/1-80-012.

Low Impact Development Center. 2008. *Green Street Practice Examples*. Beltsville, MD.

Oregon ASCE (Infiltration Standards Review Committee, Southwest Washington Branch, Oregon Section of American Society of Civil Engineers). 2009. *A Review of Infiltration Standards and Practices for Clark County.* *http://columbiawestengineering.com/wp-content/uploads/2016/08/Infiltration-Paper-July-2009.pdf*

BMP 18: Bioretention Basin

Description

A bioretention basin is a storm water management landscaping feature designed to mimic natural hydrologic processes that occur in vegetated areas through infiltration and evapotranspiration. A bioretention basin, or *rain garden,* consists of a shallow depression of porous soil covered with a thin layer of mulch planted with grasses, shrubs, and small trees that promote evapotranspiration, maintain soil porosity, encourage biological activity, and promote uptake of some pollutants (Figure 47).

Figure 47. Bioretention basin (Virginia DCR 2011).

The system can include a pretreatment filter strip of grass channel inlet area, a shallow surface water ponding area, a bioretention planting area, a soil zone, an underdrain system, and an overflow outlet structure, depending on the site conditions and land use. Bioretention basins are designed so that water infiltrates and does not pond for long periods of time.

Primary BMP Functions and Controls

☐ Construction	☒ Permanent
☐ Erosion Control	☒ Sediment Control
☐ Source Control	☒ Flood Control
☐ Filtration	☒ Infiltration

Typical Effectiveness for Targeted Pollutants

●	Sediment
●	Phosphorus
◖	Metals
◖	Bacteria
◖	Hydrocarbons
○	Litter

Other BMP Considerations

Overall Cost	$$
Maintenance Requirements	Medium
Ease of Installation	Medium
Freeze/Thaw Resistance	Fair
Max. Tributary Drainage Area	5 acre
Max. Upstream Slope	25%
NRCS Soil Group	ABCD
Min. Ground Water Separation	3 feet
Min. Bedrock Separation	6 feet

Applicability

Bioretention basins typically serve a tributary area of one impervious acre or less and can be used in small landscaped areas such as parking lot islands, street medians, landscape areas between the road and a detached walk, and depressed landscaping beds in lawns. Bioretention basins can be used in highly urbanized landscapes such as commercial or office developments and in residential developments within open space areas or on individual lots.

For larger project sites, bioretention practices can be integrated throughout the project and strategically placed to intercept runoff near the source, preferably lot by lot. Originally designed to provide an element of water quality control, studies have shown that quantity control can be achieved as well. Bioretention systems function similar to infiltration/filtration practices with the added advantage of providing aesthetically pleasing landscaping.

Limitations

The surface of the bioretention basin should be flat, so the basin's use may be limited on steep slopes unless there is room for terracing multiple basins. Bioretention basins should not be located within 10 feet of a building or other structure that may be impacted by oversaturated subgrade soil, especially in areas of expansive soils unless protective measures are taken with consultation of a geotechnical engineer.

Bioretention facilities should not be used in areas with shallow aquifers unless they include an underdrain designed to divert water to an appropriate discharge location and are lined with a geomembrane liner to restrict seepage. An underdrain may also be needed where the native subgrade soils do not allow sufficient infiltration.

In many areas, large bioretention basins that treat more than 1 acre have lower pollutant removal rates than smaller ones. This lower rate is due to higher velocities and often failure of the infiltration system to keep the basin from performing optimally.

Design Basis

Most bioretention devices are off-line basins designed to infiltrate all flow up to the water quality design storm. General design parameters for bioretention facilities include the following:

Pretreatment

If the bioretention basin is located in a watershed with high expected sediment loads, pretreatment will help reduce the likelihood that the planting soil will clog over time. Pretreatment of a basin within a vegetated area could be accomplished by placing a minimum 5-foot wide grassed buffer strip around the facility. The grass buffer strip reduces the velocity of the incoming runoff and filters some of the coarser particulates.

For bioretention basins located adjacent to parking areas, the inflow gutter can be designed at a minimal slope of 0.5% to facilitate sediment and debris deposition before entering the BMP. This design will reduce maintenance of the basin but may increase the amount of sweeping and cleaning required of the gutter.

If the inlet to the basin is through a curb cut with concentrated flow, include energy dissipation at the inlet such as small rock riprap or a level spreader.

Basin Geometry

The facility should be sized to hold the volume of runoff from the water quality design storm. The Low Impact Development Center (2007) offers excel spreadsheets to assist with *bioretention basin design*. Generally, the area of the basin will be equal to 5% to 7% of the tributary drainage area depending on the amount of impervious surface in the watershed.

Ensure a minimum depth of 3 feet from the bottom of the facility to the ground water table. If this is not possible, see design guidelines for underdrains.

The recommended ponding depth is 6 to 9 inches with a maximum of 12 inches. This depth provides some temporary storage while preventing water from standing for long periods of time. If the bioretention basin is located adjacent to a parking lot or other impervious surface, provide a 2 to 3-inch drop from the edge of the pavement to the surface of the basin. This drop will prevent accumulation of debris and plant growth at the entrance to the basin and can prevent water from entering the basin (Figure 48).

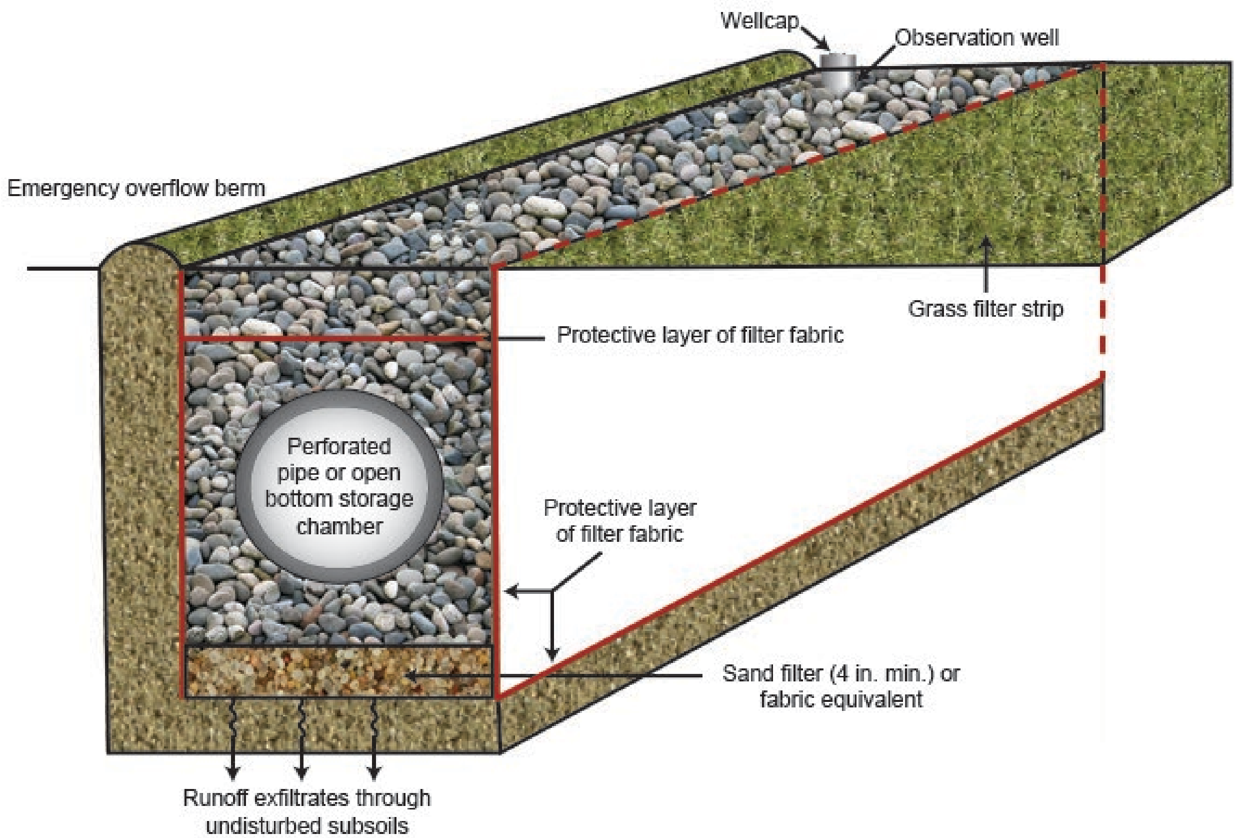


Figure 48. Bioretention detail (Virginia DCR 2011).

Mulch

If ground cover or grass is not immediately established after trees and shrubs are planted, place 2 to 3 inches of aged, fine shredded hardwood over the basin to filter pollutants and protect the planting soil from drying out and eroding. A mulch layer deeper than 3 inches interferes with the cycling of oxygen and carbon dioxide in the soil. Other types of mulch, such as Beauty Bark, tend to float and may clog overflow outlets.

Planting Soil

Planting soil filters pollutants and provides temporary storage for runoff. Planting soil should be a sand/soil mixture at a minimum depth of 4 inches deeper than the bottom of the largest plant root ball. While adequate nutrient removal requires a minimum depth of 2 feet, a depth of 4 feet is desirable.

Depending on its infiltrative capacity, the natural soil can be amended to create the planting soil (BMP 7: Soil Restoration and Enhancement). Soil infiltration capacity should be a minimum of 0.5 inches per hour for the life of the facility. The maximum desirable infiltration rate is 3 inches per hour. A higher maximum infiltration rate may be acceptable if an adequate vegetative cover can be maintained without excessive irrigation. The design infiltration rate should be considered equal to one-half the infiltration rate found from the soil textural analysis or in-situ infiltration tests due to decreases in infiltration rate as the planting mix ages. Thus, the measured infiltration rate should be 1 to 6 inches per hour.

If the natural soil does not meet the minimum measured infiltration rate of 1 inch per hour, the planting soil can be entirely imported and an underdrain may be required to avoid water ponding.

Sand Bed

If an underdrain surrounded by gravel is not used, a sand bed underlying the planting soil provides aeration and ensures infiltration across the entire bottom of the facility. A depth of 1.5 feet of sand is recommended. If the sand bed is extended to the sides of the planting soil, it acts as a sand filter and filters particulates.

Underdrain System

An underdrain system may be needed if the underlying soil does not provide adequate infiltrative capacity, infiltrated water must be diverted from a structure, or if sensitive high ground water is present. The underdrain should be located within a minimum 6-inch deep washed gravel layer under the planting soil. Perforated PVC pipe, commonly 4, 6, or 8 inches in diameter, can be used as an underdrain; select the pipe size based on the capacity needed to remove water substantially faster (10 times) than water enters from the planting soil above. Cleanouts should be provided to facilitate inspection and maintenance of the underdrain (Figure 49).

Overflow System

Overflow of the bioretention basin during large storms should be evaluated. Overflow could be provided via a spillway to another drainage basin that has capacity to handle larger flows. For urban settings, a grated inlet and outlet pipe can be installed in the bioretention basin with the top of the inlet set to the desired maximum water depth in the basin. The outlet pipe can convey larger storm events to another storm drainage facility.

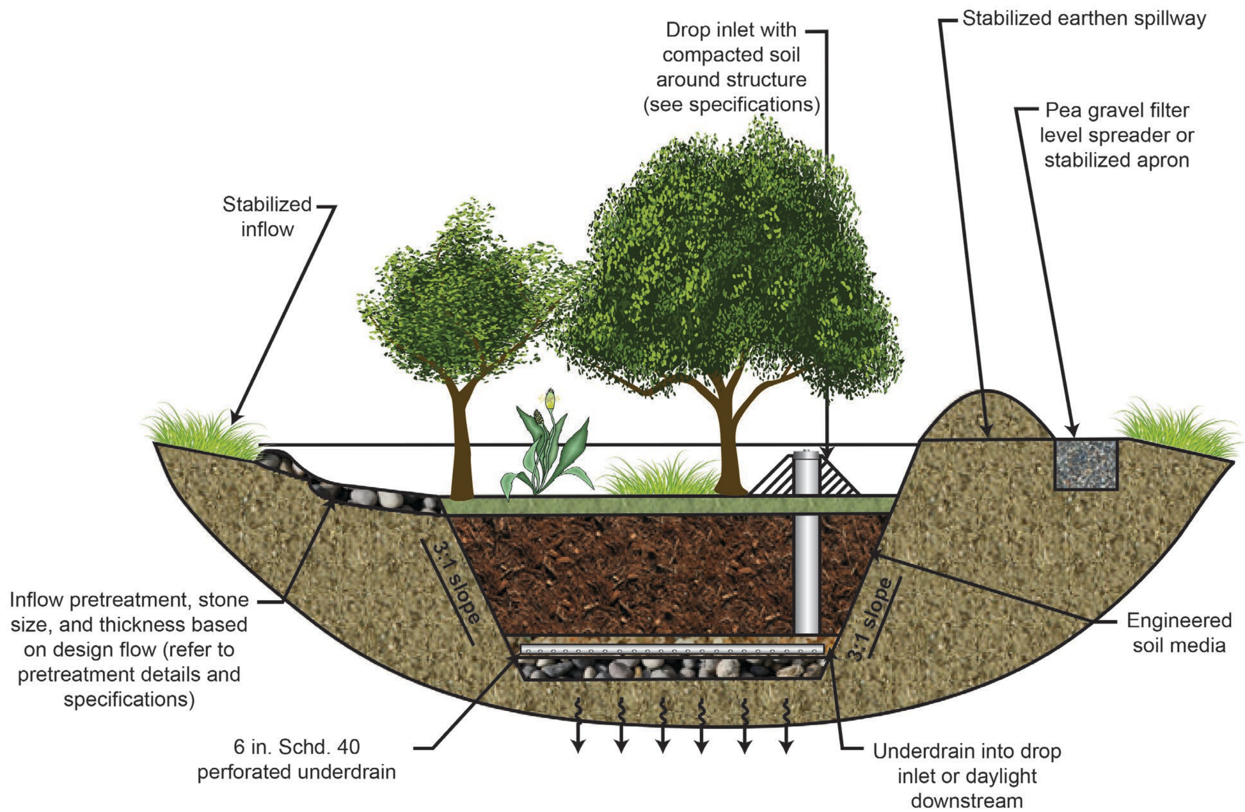


Figure 49. Bioretention inflow and outflow section (Virginia DCR 2011).

Vegetation

Vegetation reduces the potential for erosion and provides evapotranspiration. Select native plant species that are tolerant to pollutant loads and varying soil moisture (referred to as facultative). A mixture of small trees, shrubs, flowers, and grasses should be used. A variety of trees and shrubs should be selected to enhance the aesthetic appeal of the facility. If an underdrain is used, select trees and shrubs that do not have overly aggressive roots that search out water and clog the underdrain pipe.

Plant placement is important to the success of the bioretention basin and should resemble a natural, random pattern. To avoid damage to the plant and possible channelization of flow, woody plants should not be placed where flows enter the bioretention facility. The microclimate of the facility should be considered in vegetation placement. For example, evergreen trees or other wind-tolerant species may be placed on the northern end of the area to block cold winter winds. Plants that tolerate dryer conditions could be placed at the edges and plants that tolerate both wet and dry conditions could be placed in the bottom.

If sod is chosen to vegetate the basin, select sod that has been grown in permeable soils. Sod grown in clay soils will not be effective because the clay soil can restrict water infiltration reducing the expected infiltration rate of the system. If sod grown in clay soils is the only sod available, ask the grower to wash off the soil from the sod to remove all clay material.

Avoid sprinkler irrigation of bioretention areas, although temporary irrigation may be needed for plant establishment.

Construction Guidelines

Schedule

The sequence of various phases of basin construction should be coordinated with the overall project construction schedule. The project should schedule rough excavation of the basin with the rough grading phase to permit use of the material as fill in earthwork areas. The partially excavated basin may serve as a temporary sediment trap or pond to assist in erosion and sediment control during construction. However, basins near the final stages of excavation should never be used prematurely for runoff disposal. Drainage from untreated, freshly constructed slopes within the watershed area would load the newly formed basin with a heavy concentration of fine sediment. This sediment could seriously impair the natural infiltration characteristics of the basin floor. Final grade of an infiltration basin should not be attained until after its use as a sediment control basin is completed.

Specifications for basin construction should state the earliest point in construction progress when storm drainage may be directed to the basins, and the means by which this delay in use should be accomplished. Due to the wide variety of conditions encountered among projects, each project should be separately evaluated to postpone use as long as is reasonably possible. Drainage areas should be stabilized before beginning to use the facility to minimize sediment load to the treatment area.

Excavation

Initial excavation should be carried to within 1 foot of the final elevation of the basin's floor. Final excavation to the finished grade should be deferred until all disturbed areas on the site have been stabilized or protected. The final phase of excavation should remove all accumulated sediment. Relatively light-tracked equipment is recommended for this operation to avoid compacting the basin floor. After the final grading is completed, the basin floor should be deeply tilled with rotary tillers or disk harrows to provide a well-aerated, highly porous surface texture. Fill the bioretention area with planting soil, sand, gravel, and underdrains per the basin design. Placement of the planting soil should be in lifts of 1.5 feet or less and lightly compacted. Expect the soil to settle by up to 20% during the first storm event.

Infiltration Test

An in-situ infiltration test should be conducted after final grading and may be required by the local jurisdiction. Infiltration rates used to design the facility should be verified during construction and if the rates vary, the design should be modified.

Maintenance

Bioretention basins require seasonal landscaping maintenance. In many cases, bioretention areas require intense maintenance initially to establish the plants, but less maintenance is required in the long term. When bioretention basins are first placed into use, they should be inspected on a

monthly basis, and after large storms to ensure adequate drainage is being provided. Water standing longer than 4 days will severely limit the growth of most plants, and mosquitoes and other insects may start to breed. Additionally, the microbial processes of the planting soil that remove nutrients will not work as well if the facility becomes waterlogged and anaerobic.

Once it is determined that the basin is functioning in a satisfactory manner and no potential sediment problems exist, inspection can be reduced to a semiannual basis with additional inspections following the occurrence of a large storm. Litter and debris should be removed as needed.

Trees and shrubs should be inspected twice per year. Any dead or severely diseased vegetation should be removed. Prune and weed to maintain the bioretention area's appearance. Spot mulch when bare spots appear. Every 2 to 3 years, the entire area should be remulched.

Soil should be tested annually to detect toxic concentrations of pollutants. As toxins accumulate, they may impair plant growth and bioretention effectiveness, and soil replacement may be required.

Additional Resources

Bitter S. and J.K. Bowers. 1994. "Bioretention as a Water Quality Best Management Practice." *Watershed Protection Techniques*. 1(3).

EPA (US Environmental Protection Agency). 1999. *Storm Water Technology Fact Sheet*: *Bioretention*. Washington, DC: EPA Office of Water. EPA-832-F-99-012.

ETA (Engineering Technologies Associates, Inc.). 1993. *Design Manual for Use of Bioretention in Stormwater Management*. Prepared for Prince George's County, Maryland, Department of Environmental Resources. Troy, MI.

Hunt, W.F. and N. White. 2001. *Designing Rain Gardens (Bio-Retention Areas).* North Carolina State University Cooperative Extension.

Low Impact Design Center. 2008. *Rain Garden Design Templates*. Beltsville, MD.

Virginia DCR (Virginia Department of Conservation and Recreation). 2011. *Bioretention*. Best Management Practice Fact Sheet 9.

BMP 19: Porous Pavement

Description

Porous pavement refers to permeable hardscape surfaces that have an underlying stone reservoir that temporarily stores and filters surface runoff before it infiltrates into the underlying soil or to a storm drain network. By replacing traditional pavements with porous surfaces, infiltration increases and the volume of storm water that runs off the surface can be reduced. Porous pavements provide both flood control and water quality benefits (Figure 50).

Figure 50. Porous pavement in the Whole Foods parking lot, Boise, Idaho.

Porous pavement options, include porous asphalt, pervious concrete, permeable interlocking pavers, gravel pavers, and grass pavers. Porous asphalt and pervious concrete have surfaces similar to traditional pavement but are manufactured without fine aggregates, which provide void spaces to allow water to pass through the material. Interlocking pavers are blocks, usually made of concrete, with a permeable aggregate joint material. Gravel pavers and grass pavers have a concrete or synthetic fibrous open grid system to provide structural support and reduce soil compaction. The open grid system is filled with gravel or soil and seed.

Primary BMP Functions and Controls

☐ Construction	☒ Permanent
☐ Erosion Control	☐ Sediment Control
☒ Source Control	☒ Flood Control
☒ Filtration	☒ Infiltration

Typical Effectiveness for Targeted Pollutants

●	Sediment
○	Nitrogen
●	Phosphorus
●	Metals
Unknown	Bacteria
●	Hydrocarbons
○	Litter

Other BMP Considerations

Relative Cost	$$
Maintenance Requirements	Low
Ease of Installation	Fair
Freeze/Thaw Resistance	Fair
Max. Tributary Drainage Area	Unlimited
Max. Upstream Slope	10%
NRCS Soil Group	ABCD
Min. Ground Water Separation	2 feet
Min. Bedrock Separation	NA

Applicability

Porous pavement can replace traditional impervious pavement for most pedestrian and vehicular applications. Porous pavement is a good option for urban areas where space is limited, and it is recommended in low traffic volume and low speed applications such as parking areas, low volume roadways, pedestrian walkways, and sidewalks. Porous pavements can be incorporated into municipal green infrastructure and LID programs.

Although not a true porous pavement, open-graded asphalt has been used for decades as a friction course over impervious asphalt on highways to reduce noise, spray, hydroplaning, and skidding.

In cold weather climates, a benefit of porous pavement is that it reduces the risk of ponding and associated black ice conditions in winter. The pavement has a slightly rougher surface texture that provides more traction to vehicles and pedestrians.

Limitations

Using porous pavement in areas that have a high risk of clogging the pavement with fines will require more maintenance and may limit the use of the practice in the following:

- Locations where sand or salts are applied to the pavement surface. Chlorides from road salt also have the potential to contaminate ground water through the porous pavement system.
- Locations where large areas of nonpermeable surfaces contribute storm water to porous pavement. Increased fines from nonpermeable surfaces tend to clog the portions of porous pavement at the interface between permeable and nonpermeable locations.
- High traffic areas or areas with heavy commercial/industrial use. These locations have a higher risk of unraveling and clogging.

Porous pavement is an infiltration practice and should not be applied in high pollutant potential areas due to the risk of ground water contamination. It is also not recommended for any area that could be destabilized due to surface water infiltration, such as near basement foundations, steep slopes, within 100 feet of a drinking water well, within 10 feet of a septic system drainfield, or underground storage tank. Porous pavement should not be used where a geotechnical investigation recommends limiting infiltration practices due to concerns with erosion, slope failure, or downgradient flooding.

Porous pavement can be applied in most regions of the country, but the practice has special design guidelines in cold climates, such as ensuring the stone reservoir extends below the frost line to prevent heaving.

Design Basis

Siting Considerations

Porous pavement has site constraints similar to other infiltration practices, and a potential site should meet the following criteria:

- Underlying soils should have permeability between 0.5 and 3.0 inches per hour.
- Underdrains should be used where native soils do not meet permeability requirements and where frost damage may be an issue.
- To promote infiltration, the bottom of the stone reservoir should be completely flat so that runoff will infiltrate evenly across the entire surface.
- Porous pavement should be located at least 2 to 5 feet above the seasonal high ground water table and at least 100 feet away from drinking water wells.
- Porous pavement should be located in low traffic areas, which do not need to be sanded during the winter.

Design Considerations

Five basic features should be incorporated into all porous pavement practices. Typical cross sections of porous pavement systems are provided in Figure 51 and Figure 52.

1. Pretreatment—In most porous pavement designs, the pavement itself acts as pretreatment to the stone reservoir below. Because the surface serves this purpose, frequent maintenance of the pavement surface is critical to prevent clogging. A fine gravel layer above the coarse gravel treatment reservoir also provides pretreatment. The effectiveness of both pretreatment measures is marginal, which is one reason frequent maintenance is needed to keep the surface clean.
2. Backup option—The *overflow edge* design option is a trench surrounding the edge of the pavement. The trench is connected to the stone reservoir below the surface of the pavement. Although this feature does not in itself reduce maintenance requirements, it acts as a backup in case the surface clogs. If the surface clogs, storm water will flow over the surface and into the trench, where some infiltration and treatment will occur.
3. Treatment—The stone reservoir below the pavement surface should be composed of series of stone layers. These layers are referred to as the choker course, filter course, filter blanket, and reservoir course. The stone reservoir should be sized to attenuate storm flows for the design storm event to be treated. Typically, porous pavement is sized to treat a small event, such as the water quality storm (i.e., the storm that will be treated for pollutant removal), which can range from 0.5 to 1.5 inches. The stone reservoir should be designed to drain within 24 to 48 hours.
4. Conveyance—Water is conveyed to the stone reservoir through the pavement's surface and infiltrates into the ground through the bottom of this stone reservoir. A geosynthetic liner and sand layer should be placed below the stone reservoir to prevent preferential flow paths and to maintain a flat bottom. Porous pavements should be designed to convey larger storms to the storm drain system. To accomplish this, design the storm drain inlet elevations slightly above the surface elevation of the pavement, which allows temporary ponding above the surface, and if the surface clogs, a means exists for large flows to bypass the system.
5. Landscaping—The most important landscaping objective for porous pavements is to ensure that its drainage area is fully stabilized to prevent sediment from landscape areas from clogging the pavement.

Cold Climate Adaptations

In cold climates, the base of the stone reservoir should extend below the frost line to reduce the risk of frost heaving.

For detailed design and construction specifications developed for cold climates, refer to the *UNHSC Design Specifications for Porous Asphalt Pavement and Infiltration Beds* (UNHSC 2009).

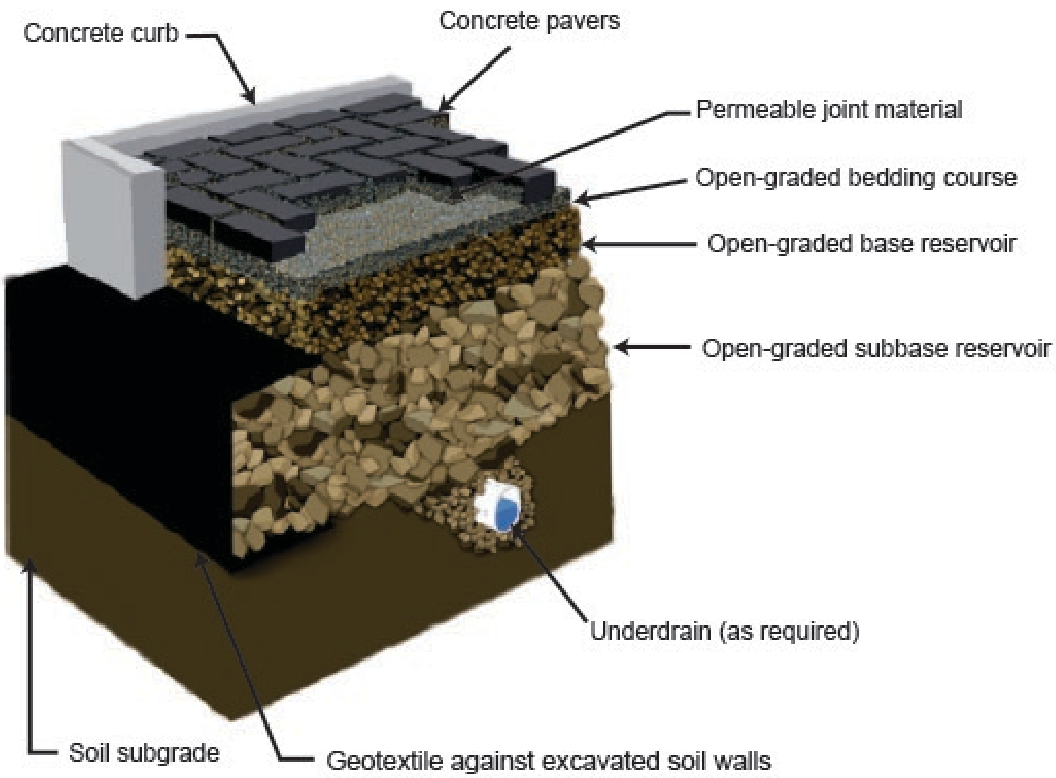


Figure 51. Typical cross section of an interlocking paver system (UNHSC 2009).

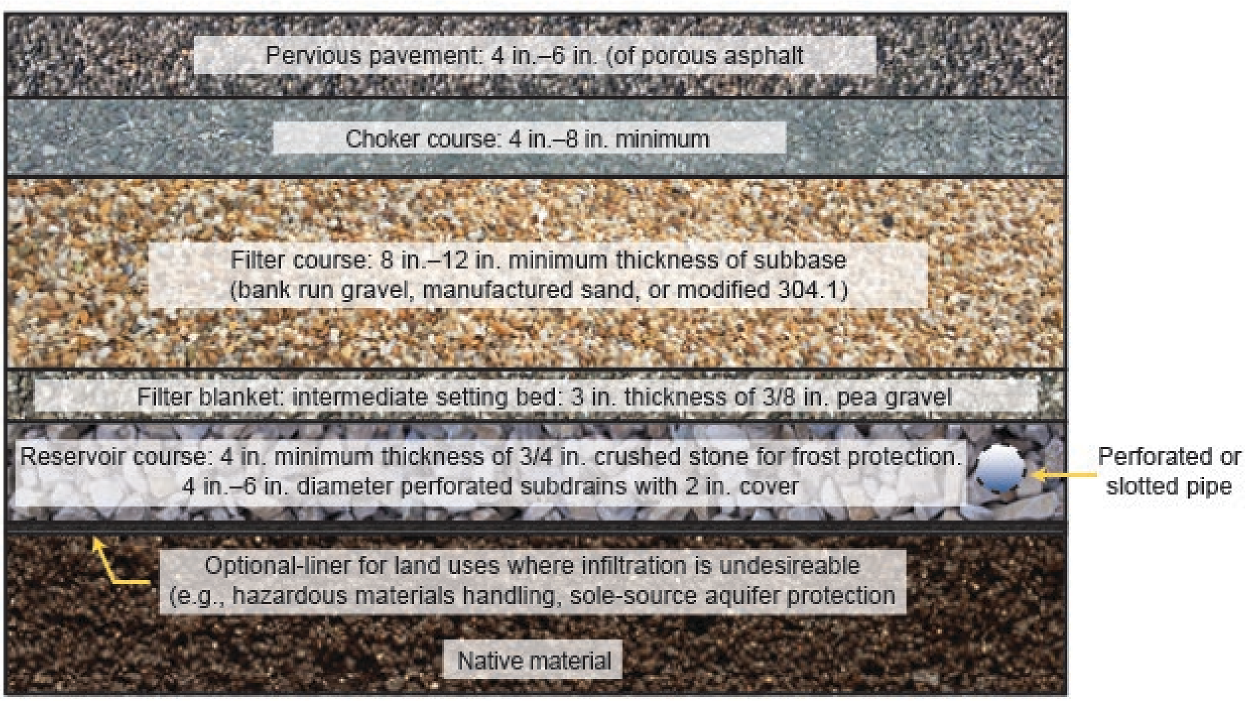


Figure 52. Typical cross section of a porous asphalt system (UNHSC 2009).

Construction Guidelines

In locations where pervious pavement will be installed, the soil subgrade should be protected from excessive compaction during construction (BMP 45).

Maintenance

Porous pavement requires additional maintenance when compared with traditional pavement. Lack of proper maintenance activities result in the failure of pervious pavements, and often owners are not aware of that porous pavement is present on a site. To ensure proper maintenance of porous pavement, a carefully worded maintenance agreement that provides specific guidance on how to conduct routine maintenance and how to repave the surface should be developed. Additionally, signs should be posted on the site identifying porous pavement areas. Typical requirements are as follows:

As Needed

- Mow upland and adjacent areas, and seed bare areas.
- Vacuum sweep frequently to keep the surface free of sediment (typically three to four times per year) especially after fall and winter when the accumulation of debris is greatest.
- Ensure that the pavement surface dewaters between storms.

Monthly—Ensure that the pavement surface is clean of debris and sediments.

Annually—Inspect the surface for deterioration or unraveling.

Cold Weather Periods

- Avoid plowing pavement surface until 2 or more inches of snow accumulation.
- Plow after every storm. If possible, plow with a raised blade to minimize pavement scarring.
- Salt reduction for porous asphalt is recommended on a site-specific basis. Incorporating salt reduction into the cold weather maintenance activities is encouraged.
- Apply deicing treatments during and after storms, as necessary, to control compact snow and ice not removed by plowing.

Additional Resources

Colorado UDFCD (Colorado Urban Drainage and Flood Control District). 2010. *Urban Storm Drainage Criteria Manual, Volume 3 Best Management Practices*. Denver, CO. *http://udfcd.org/wp-content/uploads/2014/07/Title-Page.pdf*

ITD (Idaho Transportation Department). 2014. *Best Management Practices.* Boise, ID: ITD.

UNHSC (University of New Hampshire Stormwater Center). 2009. *UNHSC Design Specifications for Porous Asphalt Pavement and Infiltration Beds.* Durham NH. *http://www.unh.edu/unhsc/sites/unh.edu.unhsc/files/pubs_specs_info/unhsc_pa_spec_10_09.pdf*

Washington State Department of Ecology. 2012. *Stormwater Management Manual for Western Washington*. Lacey, WA. Publ. 12-10-030. *http://www.ecy.wa.gov/programs/wq/stormwater/manual.html*

BMP 20: Vegetated Roofs

Description

A vegetated roof, or *green* roof, is a layer of living vegetation and soil installed on top of a building roof. Vegetated roofs help manage storm water by mimicking a variety of hydrologic processes normally associated with undeveloped areas. Vegetated roofs capture and store storm water while the plants uptake and absorb it in their root zone, encouraging evapotranspiration and preventing storm water from entering the existing drainage network (Figure 53).

Figure 53. Vegetated roof at the University of Idaho.

Applicability

Vegetated roofs can be installed on a wide range of buildings, from large industrial facilities to small accessory structures. Vegetated roofs are in a unique position to reduce storm water loads within highly urbanized areas as they are able to reinhabit previously unused rooftop space. Experimental results in a cold weather climate show an overall average storm water runoff volume reduction of one-third with an average storm event volume reduction of just over one-half. These reductions are achieved through peak flow attenuation, water capture and storage in the soil medium, and root protection fabric and evapotranspiration.

In addition to reduced runoff rates and volumes, vegetated roofs provide a number of ancillary benefits:

- Reduced heat island effect in urban areas.
- May qualify for multiple Leadership in Energy & Environmental Design (LEED) credits for certified buildings.
- May extend roof life span by reducing daily temperature fluctuations and providing shading from ultraviolet light.
- May provide energy savings from additional insulation and evaporative cooling.

Primary BMP Functions and Controls

☐ Construction	☒ Permanent
☐ Erosion Control	☐ Sediment Control
☒ Source Control	☐ Flood Control
☒ Filtration	☐ Infiltration

Typical Effectiveness for Targeted Pollutants

○	Sediment
○	Nitrogen
○	Phosphorus
○	Metals
○	Bacteria
○	Hydrocarbons
○	Litter

Other BMP Considerations

Relative Cost	$$$
Maintenance Requirements	Low
Ease of Installation	Medium
Freeze/Thaw Resistance	Good
Max. Tributary Drainage Area	NA
Max. Upstream Slope	25%
NRCS Soil Group	NA
Min. Ground Water Separation	NA
Min. Bedrock Separation	NA

- May decrease risk of fire during the growing season depending on availability of supplemental irrigation.
- Provides aesthetically pleasing open space in urbanized areas.
- Restoration of ecological value and open space.

Limitations

If a vegetated roof is added to an existing building, the additional load from the vegetated roof must be considered and may prohibit use altogether. Weight depends on substrate depth and vegetation. Buildings need to be examined individually to determine if additional structural support is needed.

Vegetated roofs are a unique storm water BMP in that they intercept storm water precipitation before it becomes runoff. Before *running off*, rainwater is largely free of contaminants and poses little threat to water quality. Effluent from vegetated roofs often contains small amounts of nutrients and sediment not present in the precipitation influent. These concentrations are usually nominal and do not offset the benefit gained from flow reduction resulting in the control of sediment transport and soil erosion at ground level. However, vegetated roofs are primarily a volume and peak flow control technique and are not best suited for water quality treatment.

Additional limitations to vegetated roofs include the following:

- Initial installation costs are greater than conventional roofs (although life cycle costs may be less).
- Supplemental irrigation is required during establishment and periods of prolonged drought.

Design Basis

Vegetated roofs in their most basic form consist of a root-resistant membrane placed between the soil medium and roofing material. Traditionally, the two types of vegetated roofs are intensive and extensive. Intensive roofs, reflecting the intensive amount of effort required to maintain them, have deep substrate depths and tend to be used for agriculture or aesthetic reasons. Extensive roofs with a much shallower soil medium require less maintenance and have lower costs than an intensive roof. Soil depths of intensive roofs are at least 15 to 20 centimeters thick (Getter and Rowe 2006; Oberndorfer et al. 2007). Maximum thickness is limited only by the structural integrity of the building and of the occupant's ability to maintain such a roof. Generally, extensive roofs will increase the load on a roof from 14 to 35 pounds per square feet (lb/ft^2), while intensive roofs increase the weight from 59 to 199 lb/ft^2 or greater (Dunnett and Kingsbury 2004). Extensive vegetated roofs typically are either modular or plant-in-place systems.

Vegetated roofs are engineered systems that address all the critical aspects of design, including the saturated weight of the system and load-bearing capacity of the underlying roof deck; moisture and root penetration resistance of the waterproofing membrane; resistance to wind shear; management of drainage; and the suitability of the proposed plant material. All vegetated rooftops include the following basic component layers, listed from the bottom up and shown in Figure 54:

- Structural support
- Roofing membrane
- Membrane protection and root barrier

- Insulation (optional)
- Filter membrane and drainage layer
- Growing medium
- Vegetation

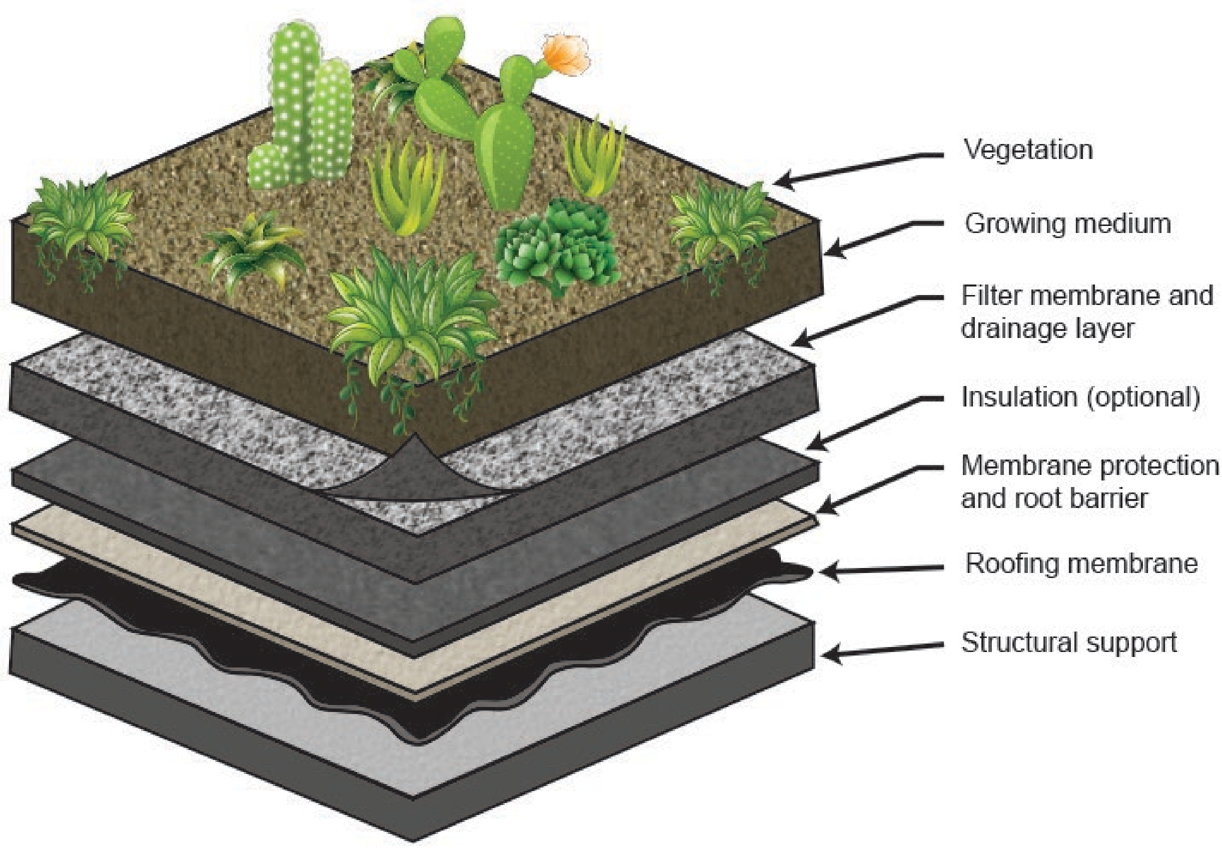


Figure 54. Typical green roof cross section (Colorado UDFCD 2010).

Vegetated rooftops can be built in a variety of ways, but the simplest methods include modular systems that are self-contained containers and can be moved as individual units and plant-in-place systems that are homogeneous across the roof with no vertical dividers. Modular systems traditionally arrive on site preplanted while plant-in-place vegetation is planted when the soil medium is in place and may take a number of weeks to fully establish.

Vegetation is typically comprised of native xeric succulents, grasses, herbs, and/or wildflowers adapted to harsh conditions (minimal soils, seasonal drought, high winds, and strong sun exposure (i.e., alpine conditions) prevalent on rooftops. Native succulents and hardy varieties exist in each state so consult with the local cooperative extension to ensure local vegetation is properly used. Some examples of species include sempervivum, sedum, creeping thyme, allium, phloxes, and anntenaria. Most plants naturally occurring along county roads, expressways, and abandoned sites that do not receive irrigation adapt well to the vegetated roof environment.

In areas where precipitation exceeds the water needs of the plants, a good drainage overflow system should be in place. In drier climates, supplemental irrigation may be needed to help establish the plants and as an additional water source during periods of prolonged drought.

Construction Guidelines

Applicable rules and regulations for rooftop construction should be followed when installing any vegetated roof structure. Check with the local building authority to ensure compliance with relevant building and safety procedures.

Maintenance

Replanting may be required during the first 2 years for certain species that receive more or less shading and/or sun than originally expected. Periodic watering may be advisable during periods of prolonged drought.

Inspect vegetated roofs annually for plant condition, and inspect outlets quarterly and clear of any debris. Weeding should be done on a regular basis as well.

Additional Resources

Building Green. 2003. "A Garden Overhead: The Benefits and Challenges of Vegetated Roofs." *Environmental Building News* 10(11). Special Reprint.

Colorado UDFCD (Colorado Urban Drainage and Flood Control District). 2010. *Urban Storm Drainage Criteria Manual, Volume 3 Best Management Practices*. Denver, CO. *http://udfcd.org/wp-content/uploads/2014/07/Title-Page.pdf*

Dunnett, N. and N. Kingsbury. 2004. *Planting Green Roofs and Living Walls*. Portland OR: Timber Press, Inc.

EPA (US Environmental Protection Agency). 2015. Reducing Urban Heat Islands: Compendium of Strategies—*Green Roofs*. *https://www.epa.gov/sites/production/files/2014-08/documents/greenroofscompendium_ch3.pdf*

EPA (US Environmental Protection Agency). 2015. *Heat Island Cooling Strategies*. *http://www2.epa.gov/heat-islands/heat-island-cooling-strategies*

Getter, K.L. and D.B. Rowe. 2006. "The Role of Extensive Green Roofs in Sustainable Development." *Hortscience* 41(5): 1276–1285.

Johnston, J. and J. Newton. 2004. *Building Green: A Guide to Using Plants on Roofs, Walls, and Pavements*. London: Greater London Authority.

Oberndorfer, E., J. Lundholm, et al. 2007. "Green Roofs as Urban Ecosystems: Ecological Structures, Functions, and Services." *Bioscience* 57(10): 823–833.

Sherrard, Jr .J.A. and J.M. Jacobs. 2012. "Vegetated Roof Water-Balance Model: Experimental and Model Results." *Journal of Hydrologic Engineering* 17(8): 858–868.

BMP 21: Storm Water Planters

Description

Storm water planters are small, landscaped treatment systems placed at or above ground level designed to detain and convey water from roof downspouts or small drainage areas. Storm water planters include an engineered plant soil mix and a variety of plants including grasses, shrubs, and trees (planters containing trees are commonly referred to as tree box filters) within a vertical walled container. As storm water passes down through the soil matrix, pollutants are filtered, adsorbed, and biodegraded by the soil and plants (Figure 55).

Figure 55. Storm water planter at Epler Hall (City of Portland 2014).

Depending on site conditions, planters can be designed to completely or partially infiltrate storm water into the subgrade. The planters can also be designed as lined, flow-through facilities with an impervious bottom and underdrain system connected to a pipe network or a subsequent storm water BMP.

Applicability

Planters are most appropriate for small drainage areas or adjacent to hardscape near the source of storm water runoff.

These systems are best used in series or scattered around a development. The greatest strength of storm water planters are their scalability.

Using planters that capture the first 0.5 inch of rainfall may reduce the size of downstream treatment facilities.

Typical installation locations for storm water planters include the following:

- Next to buildings (if lined with an impervious liner)
- Center of cul-de-sacs
- Landscaped parking islands

Primary BMP Functions and Controls

☐ Construction	☒ Permanent
☐ Erosion Control	☒ Sediment Control
☒ Source Control	☒ Flood Control
☒ Filtration	☒ Infiltration

Typical Effectiveness for Targeted Pollutants

●	Sediment
○	Nitrogen
○	Phosphorus
◖	Metals
◖	Bacteria
●	Hydrocarbons
○	Litter

Other BMP Considerations

Relative Cost	$
Maintenance Requirements	Low
Ease of Installation	Easy
Freeze/Thaw Resistance	Fair
Max. Tributary Drainage Area	<1 acre
Max. Slope	8%
NRCS Soil Group	ABCD
Min. Ground Water Separation	5 feet
Min. Bedrock Separation	5 feet

- As part of streetscapes along sidewalks, at intersections, and within repurposed parking spaces
- Placed on top of existing impervious areas such as rooftops, patios, or courtyards

Limitations

- Planters should be constructed flat with a maximum slope of 0.5% in any direction. Slopes greater than 8% may require terracing to maintain flat slopes within the planters.
- Installing infiltrating planters on or near existing utilities should be avoided due to potential instabilities caused by high moisture content in the soil and/or seepage into the utility.
- Infiltration planters should not be used where a professional geotechnical evaluation determines that there are site concerns about slope failure or where ground water drains to an erosion hazard or landslide hazard area.

Design Basis

While these systems are highly variable in size and appearance, the following criteria can be used when designing storm water planters. Criteria for planting soil, gravel drainrock, piping, and outflow outlet from BMP 18: Bioretention Basin also apply to storm water planters.

Soil Suitability

A geotechnical analysis is an important first step for determining the site soil characteristics and infiltrative capacity. When existing soils are sufficiently permeable (greater than 2 inches per hour [in./hr]) infiltrating, or partially infiltrating, planters may be used. If the permeability is less than 2 in./hr, the planter should be lined and designed as a flow-through, noninfiltrating facility that discharges to an approved discharge point.

Sizing

When sizing storm water planters, consider the drainage area contributing to the planter, expected storm water runoff rates and volumes, and infiltration capacity of the native and engineered soils.

Infiltration planters should be designed to drain within 24 to 36 hours and should only bypass during larger events. Proper drain down times prevent mosquito-breeding habitat and ensure adequate storage volume for the next storm event. In situations where the contributing drainage area contains a high amount of impervious surfaces (e.g., rooftops, driveways, sidewalks, and compacted gravel or soil areas), the footprint of the planters typically ranges from 4% to 15% of the impervious surfaces draining to the system. This footprint should be increased beyond 15% if soils are poorly draining.

Noninfiltrating planters may be smaller than infiltration planters to improve water quality from small, frequent storms as opposed to handling large quantities of runoff. The suggested minimum width for both types of planters is 18 inches, measured within the walls (City of Portland 2014).

Setbacks

Infiltrating storm water planters should be placed a minimum of 10 feet from building foundations. Noninfiltrating systems may be placed closer with an adequately designed overflow.

Dimensions and Slopes

The dimensions required for planter construction is a minimum width of 30 inches for infiltrating systems and 18 inches for flow-through systems with 18 to 30 inches of planting soil mix on top of 6 to 12 inches of drainrock. Ponding depth should be 6 to 12 inches between the soil surface and outflow with 2 inches of freeboard between the outflow and overflow spill elevation. Planter bottoms are intended to be flat and should not be constructed with slopes greater than 0.5% in any direction (Figure 56 and Figure 57).

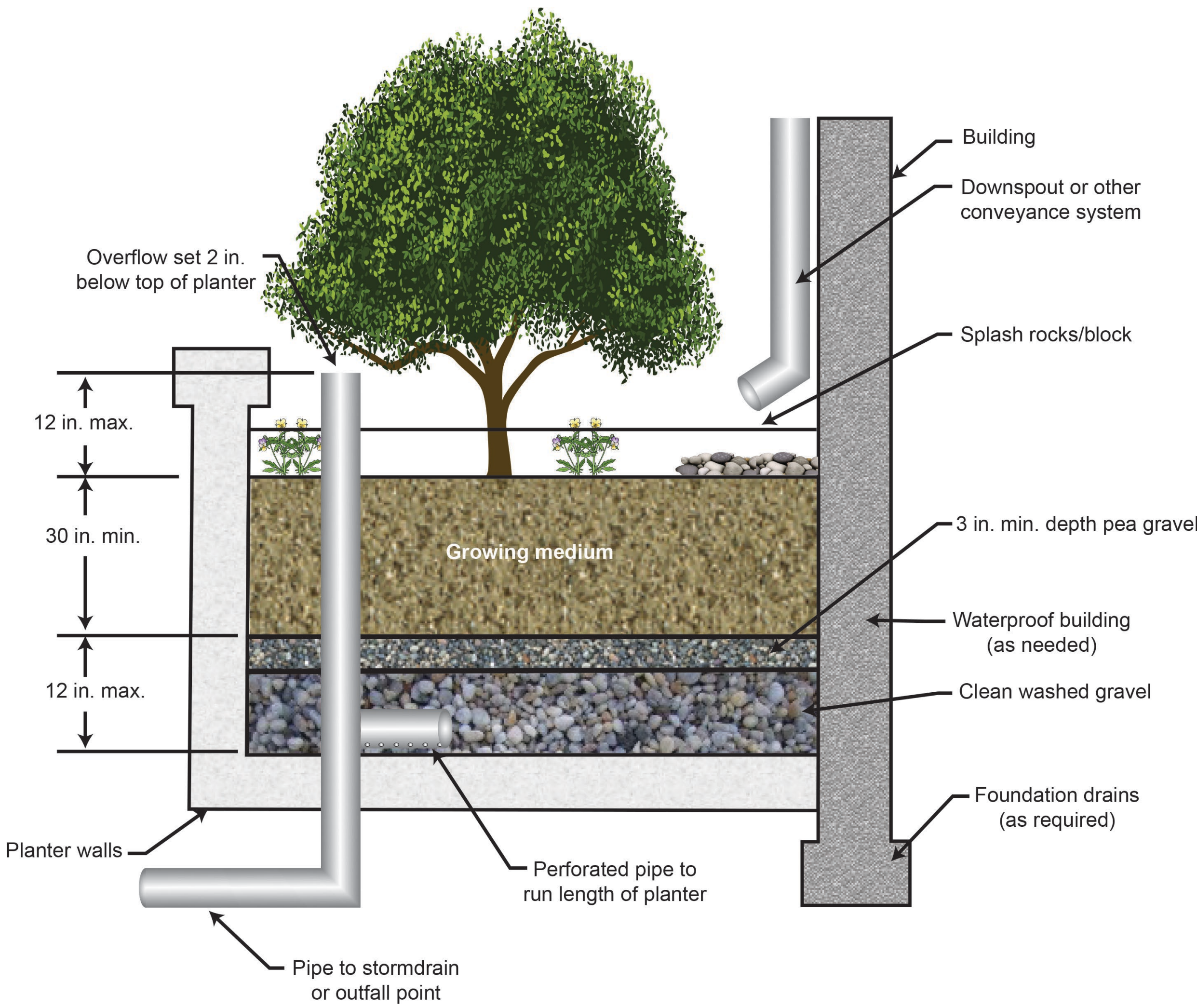


Figure 56. Cross section of an impervious, noninfiltrating, flow-through storm water planter.

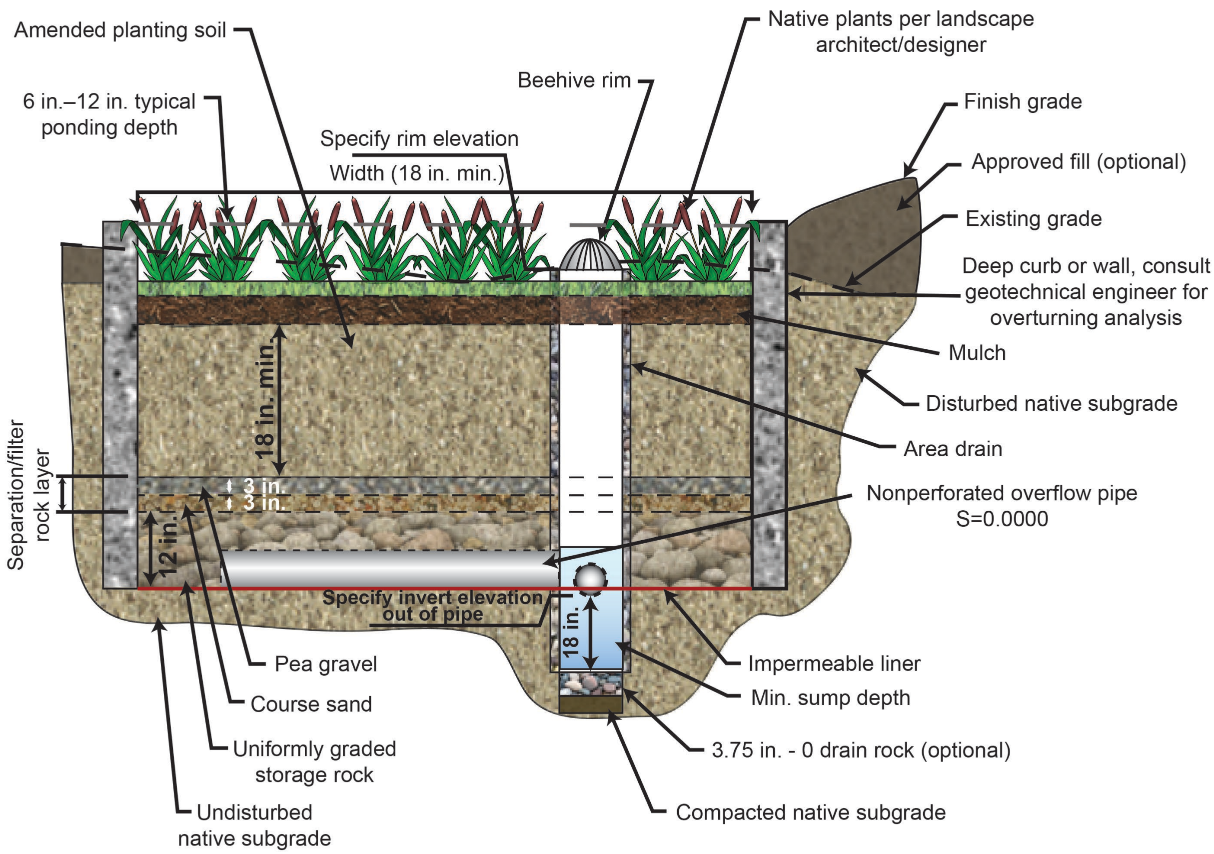


Figure 57. Flow-through filtration planter.

Construction Guidelines

Guidelines in BMP 17: Infiltration Trench and BMP 18: Bioretention Basin should be applied to construction of storm water planters. In addition, consider the following factors:

- Avoid overcompaction of existing soil during construction within 10 feet of where the infiltration planters will be installed (BMP 45: Minimize Soil Compaction).
- Pay special attention to building waterproofing for planters located immediately adjacent to buildings.

Maintenance

For storm water planters, proper maintenance includes structural, soil, and vegetation upkeep. Structural components include clogged or broken inlets/outlets, damaged walls and/or waterproofing liners, and damaged drainpipes. Soil maintenance may include inspection for erosion near the inlets or outlets and poor soil drainage. Planter vegetation may require replanting dead vegetation and pruning or landscaping overgrown vegetation.

Inspections should be performed after large storm events, leaf drop-off, and snowmelt. The suggested seasonal maintenance schedule is provided below.

- Year round—Perform general landscaping needs, weeding, and litter removal.
- Spring—Remove plant die-off debris and any accumulation of fine sediments.

- Summer—Perform structural repairs, such as clearing drains, repairing waterproof membrane, improving filter medium, and irrigating during periods of prolonged drought.
- Fall—Replant vegetation and remove litter after leaf drop-off if needed.
- Winter—Continue to monitor inflow and outflow flow rates. Clean inlets and outlets as needed.

Additional Resources

Cahill, M., D.C. Goodwin, and M. Sowles. 2011. *Stormwater Planters*. Corvallis, OR: Oregon State University Extension Service. *http://extension.oregonstate.edu/stormwater/sites/default/files/Planters_0.pdf*

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Washington State Department of Ecology. 2012. *Stormwater Management Manual for Western Washington*. Lacey, WA. Publ. 12-10-030. *http://www.ecy.wa.gov/programs/wq/stormwater/manual.html*

BMP 22: Wet Pond

Description

A wet pond, or *retention pond*, is a constructed storm water pond with a permanent pool of water that removes pollutants such as suspended solids, organic matter, and metals through settling. The permanent pool of water is partially replaced by storm water runoff during a storm event. In an arid environment, the pool of water may evaporate in between storms. A shallow marsh area located around the perimeter of the pond within the permanent pool volume provides additional pollutant treatment, especially of nutrients and dissolved metals through biological processes (Figure 58).

Figure 58. Wet pond, Edenton, North Carolina (North Carolina State University 2013).

Wet ponds can provide water quality treatment only or they can be designed with additional detention volume above the permanent pool to provide flood control (BMP 23).

Primary BMP Functions and Controls

☐ Construction	☒ Permanent
☐ Erosion Control	☒ Sediment Control
☐ Source Control	☐ Flood Control
☐ Filtration	☐ Infiltration

Typical Effectiveness for Targeted Pollutants

●	Sediment
◖	Phosphorus
◖	Metals
◖	Bacteria
◖	Hydrocarbons
○	Litter

Other BMP Considerations

Relative Cost	$$$
Maintenance Requirements	Medium
Ease of Installation	Hard
Freeze/Thaw Resistance	Fair
Max. Tributary Drainage Area	400 acres
Max. Upstream Slope	15%
NRCS Soil Group	CD
Min. Ground Water Separation	3 feet
Min. Bedrock Separation	3 feet

Applicability

Wet ponds can be used in any location that has adequate space for the pond and a source of water to maintain the permanent pool at least throughout the wet season. The ponds are often used for regional and/or follow-up water quality treatment but are also effective as an on-site BMP.

If well planned, wet ponds can meet a variety of objectives, such as improving water quality, enhancing wildlife habitats, and providing attractive water features. If the facility is planned as an aesthetic feature (e.g., to enhance property values), pretreatment before entering the wet pond is recommended. To optimize pollutant removal, these ponds should not be used for water supply and may have limited recreational benefits.

Limitations

The use of wet ponds is not recommended for arid climates where it may be difficult to maintain a permanent pool of water or establish a shallow marsh

area. Pond use may also be limited in ultraurban settings where land area is inadequate to accommodate the size requirements of a wet pond. Wet ponds are not recommended in areas of karst topography unless the pond is lined to prevent infiltrative flows from undermining the area.

Because wet ponds have a high potential to increase the water temperature when stored in the permanent pool, they are not recommended in areas that drain to cold water (trout) streams or any other system that would be negatively affected by changes in water temperature.

If a wet pond is accepting runoff from a storm water *hotspot*, it should have significant separation between the bottom of the pond and ground water, or it should be lined to prevent ground water contamination. It may be fenced to limit access by people and wildlife as they can pose high safety risks.

In cold climates, freezing of the permanent pool can reduce the effectiveness of the system; it may be more appropriate to use a dry extended detention basin (BMP 23).

Design Basis

Site Selection

The site selection for wet ponds should consider the natural topography of the area, property boundaries, and location of sewer and water utilities. Facilities should be a minimum of 20 feet from any structure, property line, and any vegetative buffer required by the local or state government; 100 feet from any septic tank/drainfield; and 100 feet from any wells or water supplies. Facilities should be a minimum of 50 feet from any steep (greater than 15%) slope. A geotechnical report should address the potential impact of a wet pond on a steep slope.

Aesthetic considerations may also dictate locations. The facility can become an integral part of the environment if designed and placed as an amenity. The amount of land required for a wet pond is approximately 0.5% to 2.0% of the tributary development area (ITD 2014).

For facilities with a shallow marsh area, a relatively constant supply of water throughout the year is necessary to maintain the wetland plants. If the wet pond is designed as permanent pool all year, adequate base flow from the tributary watershed or ground water is needed. The base flow will need to exceed losses from evaporation, evapotranspiration, and seepage (unless the pond is lined) and should be physically and legally available. If there is any doubt that sufficient flow exists, a water balance analysis should be conducted. A tributary drainage area of 25 acres is considered the minimum needed to maintain the permanent pool in humid regions as required by EPA, although some wetlands can be sustained with as little as 5 acres, provided the plants are facultative.

Pretreatment

Pretreatment in the form of landscape retention areas (BMP 18), vegetated swales (BMP 9), or sedimentation forebays (BMP 25) can help settle coarse sediment and reduce the maintenance burden of the pond. Pretreatment prolongs the utility of the wet pond and improves its appearance by reducing nutrient load, which prevents the wet pond from becoming eutrophic with excessive algal blooms, low oxygen levels, and odor.

Permanent Pool Volume

The permanent pool provides storm water quality enhancement between storm runoff events through biochemical processes and sedimentation. When the wet pool volume is large, the greater the potential exists for pollutant removal. If local regulations do not specify a design volume for a wet pond, the permanent pool volume should be equal to or greater than the total volume of runoff from the water quality design storm or the 6-month, 24-hour storm event. Alternatively, an approved continuous runoff model can be used to determine the water quality design storm volume that is equal to the simulated daily volume, representing the upper limit of the range of daily volumes, which accounts for the 91% of the entire runoff volume over a multidecade period of record. Section 3.6 provides additional information on calculating the runoff volume of the design storm.

Pond Geometry

Wet ponds may be single- or multicelled. If the permanent pool volume is less than 4,000 cubic feet, a single-cell design may be sufficient. For larger facilities, a multicelled version is recommended as studies have shown it to be more effective at pollutant removal. The two cells should be separated by a full-length baffle or berm where the first cell contains 25% to 35% of the total permanent pool volume.

The volume provided by each wet pond cell, assuming that the side slopes are consistent between the top and bottom of the cell, can be calculated using Equation 21:

$$V_b = \frac{h(A_1 + A_2)}{2}$$

Equation 21. Volume of a wet pond.

Where

V_b = wetpool volume (cubic feet)

h = wetpool depth (feet)

A_1 = top surface area of wetpool (square feet)

A_2 = bottom surface area of wetpool (square feet)

A minimum 1-foot deep sediment storage space should be provided in the first cell. The minimum depth of the first cell should be 4 feet, not including sediment storage, and the minimum depth of the second cell should be 2.5 feet. The maximum depth of each cell should not exceed 12 feet to avoid anoxic conditions.

Two depth zones are recommended, especially for ponds that are deeper than 3 feet: a safety marsh and wetland bench zone and an open water zone. The safety marsh and wetland bench zone should be located along the perimeter of the pond, 6 to 12 inches deep and a minimum of 4 feet wide. The safety marsh and wetland bench zone helps strain surface flow into the pond, protects the banks by stabilizing the soil at the edge of the pond, and provides biological uptake of nutrients. It also provides a safe, shallow area for people or animals that inadvertently enter the pond to get out before entering the deeper part of the pond.

Long, narrow ponds are preferred, as these are less prone to short-circuiting and tend to maximize available treatment area. The ratio of flow path length to pond width should be at least 3:1 and

preferably 5:1. For ponds with a ratio of 4:1 or greater, a single-cell pond is acceptable. The pond bottom should have a minimal slope (1% to 2%) to provide positive drainage to the outlet while also facilitating sedimentation.

Slightly irregular ponds will have a more natural appearance. Methods for creating a more natural looking pond include using undulating lines for the edges, using varied and gentle slopes on at least three sides of the pond above the permanent pool, adjusting vegetation and ground cover to reflect the surrounding environment, and blending energy dissipating rock at the inlet into the surrounding landscape. Teardrop-shaped ponds with the inlet located at the narrow end can minimize dead zones caused by corners.

Inlet and Outlet

The inlet and outlet should be at opposite ends of the pond where feasible to maximize the flow path length through the facility. If this is not possible, install berms or baffles to increase the flow path and water residence time.

The inlet should enter the first cell in a multicell pond and be submerged 1 foot from the top of the permanent pool water surface elevation. The inlet should also be designed to minimize resuspension of settled sediments by either locating its invert a minimum of 2 feet from the bottom of the pond or providing other means for energy dissipation.

The outlet structure controls the water surface elevation in the pond and prevents floatables from discharging downstream. Either a manhole or catch basin meeting local jurisdiction standards can be used. The outlet pipe that extends from the pond to the outlet structure should be backsloped or have a turned-down elbow and extend 1 foot below the design water quality water surface elevation to prevent floatables and oils from entering the outlet structure. Size the pipe to pass the water quality design flow and have a minimum diameter of 12 inches. The highest elevation of the outlet pipe controls the elevation of the permanent pool and should be set at or above the treatment storage volume elevation. Seepage collars are recommended for any penetrations within the wetted perimeter of the pond.

In cold climates, inlet and outlet structures that are resistant to frost such as weirs and larger diameter pipes may be used. Designing the pond with a continuous flow of water through the pond will help prevent freezing of the inlet and outlet structures.

Berm Embankment and Slope Stabilization

Interior side slopes up to the maximum water surface should be no steeper than 3H:1V and side slopes of 4H:1V are preferred, especially above the safety marsh and wetland bench. Exterior side slopes should be no steeper than 2H:1V. Interior berm embankments should be no steeper than 3H:1V or 2H:1V if the berm is fully submerged below the permanent pool depth. Fencing is recommended when the exterior side slope is steeper than 3H:1V.

Failure of large impoundment structures can cause significant property damage and even loss of life. Pond embankments higher than 6 feet should be designed by a qualified geotechnical-civil engineer licensed in Idaho. For berm embankments of 6 feet or less (including 1 foot of freeboard), the minimum top width should be 6 feet or as recommended by the geotechnical-civil engineer.

Pond berm embankments should be constructed on native consolidated soil (or adequately compacted and stable fill soils analyzed by a geotechnical engineer) free of loose surface soil materials, roots, and other organic debris.

Where they exist, follow local safety standards for impoundment design. Dams greater than or equal to 10 feet high, or reservoirs greater than or equal to 50-acre-feet storage capacity are regulated by IDWR's Dam Safety Program unless specifically exempted per Idaho Code §42-1711.

Exposed earth on the side slopes should be sodded or seeded with the appropriate seed mixture as soon as is practicable. If necessary, geotextile or matting may be used to stabilize slopes while seeding and sodding become established.

Liner

For wet ponds located in highly permeable soils, karst topography, or storm water hotspots, an impermeable liner may be needed to retain the permanent pool and prevent ground water contamination. Storm water hotspots include areas that receive runoff from highways, streets, parking lots, gas stations, or industrial sites that can carry significant heavy metal concentrations. The liner will also minimize fluctuations of the water table and establish marsh vegetation. Either clay or synthetic liners can be used. In such cases, the multiple use functions of the pond should be limited and accessibility should be restricted.

Vegetation

Vegetation provides erosion control and enhances the aesthetics of the wet pond. Planting and preserving water-tolerant trees and other vegetation should be an integral part of the design of the wet pond.

Pool depths less than 3 feet should be planted with emergent wetland plantings where wetland-associated plants will establish themselves naturally. It may be beneficial, however, to accelerate marsh establishment by planting appropriate native vegetation in shallow areas. Certain wetland plant species have a greater capacity for pollutant assimilation and are less maintenance intensive than others. The shallow marsh areas should be planted according to the advice of a wetlands specialist. Nursery sources are recommended wherever possible. Small (2- to 4-inch) planting containers are encouraged to avoid transporting large amounts of potting soil to the pond. White roots and active basal budding indicate a healthy stock.

Most wetlands specialists prefer to have staff on site during the construction phase to ensure that the littoral shelf where the marsh plants will be located is positioned and graded properly. Knowing the exact elevation of the normal water level of the facility after construction is essential to the success of the marsh element of the system.

Wet ponds should be designed with the need for periodic sediment removal in mind. To continue functioning, marshes also require periodic sediment removal. Sediment should be removed from the deepest parts of the basin where vegetation is sparse. Heavily vegetated areas should be disturbed as little as possible. Overhead scooping equipment works well for dredging selected portions of marsh areas.

Overflows

Wet pond retention facility design should include provisions for passing overflows safely through the facility. The outlet structure should have a grate-type opening to provide overflow for larger storm events and an emergency outlet should the outlet pipe become clogged. The bottom of the grate should be set at or above the height needed to pass the water quality design flow through the pond outlet pipe.

An emergency overflow spillway should be provided and designed similar to those for detention facilities (BMP 23). The most common overflow event is snowmelt, but overflows may also result from higher intensity or longer duration storms than the design storm or result from plugged orifices or inadequate storage due to sediment buildup in the facility. Overflow spillways are often designed to safely pass peak runoff from the 100-year storm event.

Gravity Drain

A gravity drain to facilitate maintenance should be provided at an outlet invert of 18 inches above the bottom of the facility. It should be sized to drain the facility in 4 hours or less. If a gravity drain is not feasible due to flat grades and lack of an outlet, a small pump pit could be provided to drain the facility if acceptable to the approving jurisdiction.

Safety, Signage, and Fencing

Ponds that are readily accessible to populated areas should incorporate safety precautions. Steep side slopes (steeper than 3H:1V) at the perimeter should be avoided and dangerous outlet facilities should be protected by enclosure. Warning signs for deep water and potential health risks should be used where appropriate. Signs should be placed so that they are clearly visible and legible from all adjacent streets, sidewalks, or paths. A notice should be posted warning residents of potential waterborne disease that may be associated with swimming or fishing in these facilities (Figure 59).

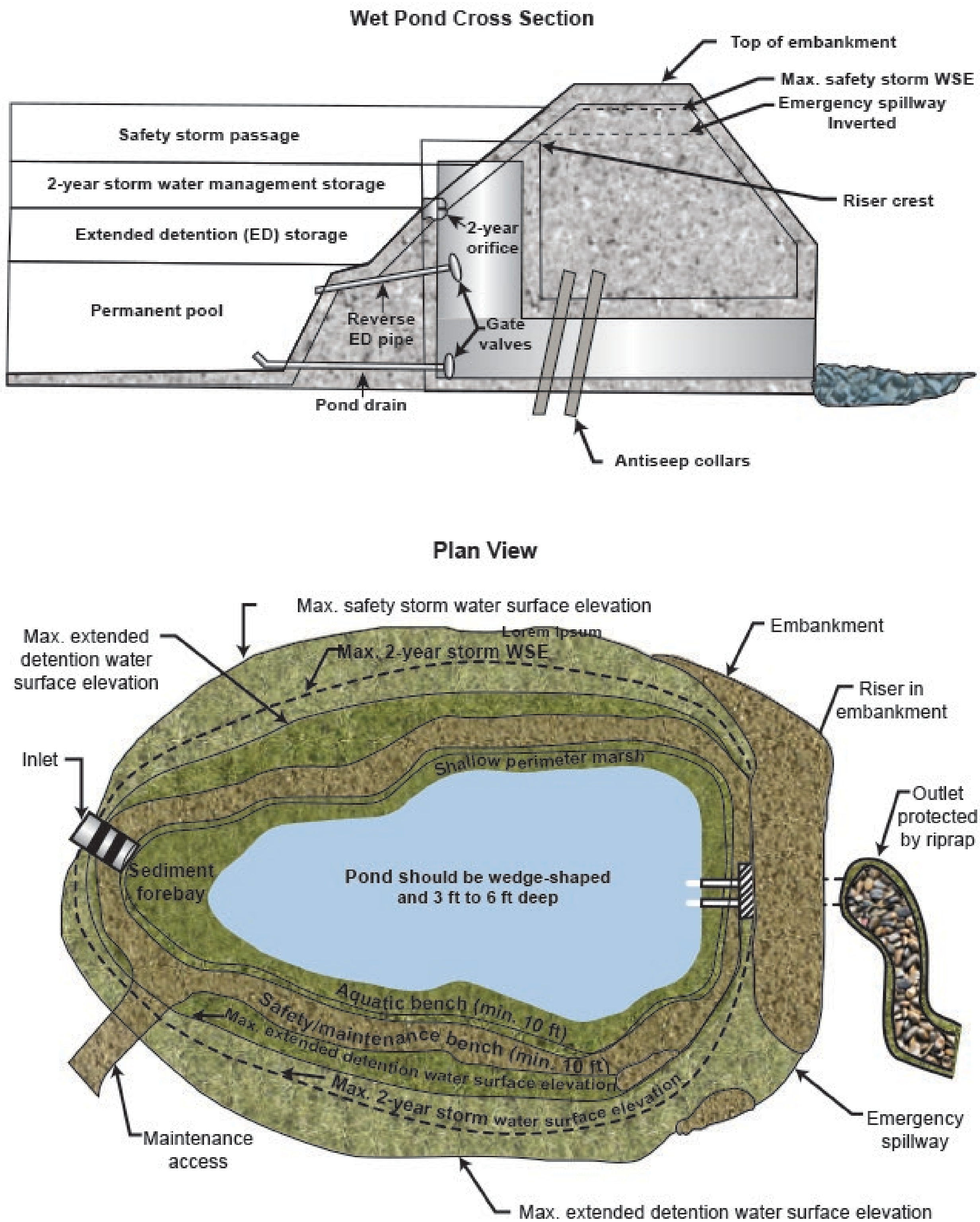


Figure 59. Wet pond plan view and cross section.

Construction Guidelines

Widely acceptable construction standards and specifications, such as those developed by the NRCS or US Army Corp of Engineers, for embankment ponds and reservoirs may aid in building the wet pond.

If the pond area is used as a temporary sediment trap during construction, set the temporary bottom elevation higher than the final pond bottom elevation so accumulated sediment can be removed before final grading. If the sediment meets criteria for a low permeability liner, the pond could be excavated to just below final grade and the sediment left in the bottom of the pond after construction and used as a liner. Sediment used for a soil liner should be graded to provide uniform coverage and thickness.

As with all construction, appropriate erosion control techniques should be used during construction of a wet pond.

Maintenance

Inspections and maintenance should be performed regularly and within 24 hours after large storm events. Trash and debris removal should also be done regularly to prevent the facility from becoming a dumping ground for trash, construction debris, and yard waste.

Sediment forebays or the first cell of a multicell pond should be cleaned of sediment every 2 to 5 years or as needed for proper pond function. Embankments should be inspected for erosion and if erosion is a problem, erosion control devices such as reinforced turf matting or riprap should be installed.

Impoundment structures should be regularly inspected for signs of failure, such as seepage or cracks in the berm. Inspect the structures for animal burrows, erosion, and/or loss of material. Repairs and maintenance should be made immediately to preserve the integrity of the berm including stabilizing the slope, filling any burrow holes, repairing cracks, and stopping seepage.

Weed, mow, and trim vegetation on and around the pond to maintain its health and aesthetic value. The inlet and outlet should be inspected for erosion or undercutting, and clogged or damaged pipes. Erosion control, energy dissipation devices, and pipes should be replaced, cleaned, or repaired as necessary.

Additional Resources

EPA (US Environmental Protection Agency). 2014. "Wet Pond." Water: Best Management Practices. *www.epa.gov/npdes/national-menu-best-management-practices-bmps-stormwater#edu*

ITD (Idaho Transportation Department). 2014. *Best Management Practices.* Boise, ID: ITD. *https://itd.idaho.gov/env/*

King County (King County, Washington). 2009. *King County, Washington Surface Water Design Manual*. Seattle, WA: King County, Department of Natural Resources.

North Carolina State University. 2013. "Stormwater Engineering Group." College of Agriculture and Life Sciences/College of Engineering. *https://stormwater.bae.ncsu.edu/resources/*

BMP 23: Extended Detention Basin

Description

Extended detention basins, or extended detention ponds, are depressed areas designed to detain storm water runoff and release it over an extended time period. The pond outlet is designed to detain the volume of the water quality design storm runoff for a minimum time (usually 48 hours), allowing the particles and associated pollutants to settle. Extended detention basins provide flood control by including additional temporary storage volume for one or more design flood events and staged outlets that control the release rate from the pond (Figure 60).

Figure 60. Dry extended detention basin (ITD 2014).

Extended detention basins can be either wet or dry. Wet extended detention ponds contain a permanent pool of water or wet pond (BMP 22) below the detention volume. Dry extended detention ponds do not maintain a permanent pool of water between storm events, although they may include a micropool or small wetland marsh at the outlet to enhance phosphorous removal.

Primary BMP Functions and Controls

☐ Construction	☒ Permanent
☐ Erosion Control	☒ Sediment Control
☐ Source Control	☒ Flood Control
☐ Filtration	☐ Infiltration

Typical Effectiveness for Targeted Pollutants

●	Sediment
○	Phosphorus
◖	Metals
○	Bacteria
◖	Hydrocarbons
○	Litter

Other BMP Considerations

Relative Cost	$$
Maintenance Requirements	Medium
Ease of Installation	Medium
Freeze/Thaw Resistance	Good
Max. Tributary Drainage Area	400 acres
Max. Upstream Slope	15%
NRCS Soil Group	ABCD
Min. Ground Water Separation	3 feet
Min. Bedrock Separation	3 feet

Applicability

Extended detention basins can be used in any location that has adequate space for the facility. They are well suited for watersheds at least 10 acres in size and where peak flow reduction is desired.

In addition to flood control and water quality benefits, dry ponds may also be used for recreation, such as a playgrounds, ball fields, or picnic areas, which are most appropriately located above the water quality volume elevation. The basins are often used within open space or recreation areas around large residential developments.

Limitations

Use of extended detention ponds may be limited in ultraurban settings where land area is inadequate to accommodate the size requirements of the basin.

These ponds are not recommended for watersheds smaller than 10 acres, which require very small release rates and use small orifice outlets prone to clogging. Smaller BMP facilities that also provide infiltration, such as bioinfiltration swales (BMP 10), bioretention basins (BMP 18), or infiltration trenches (BMP 17), are more applicable for smaller watersheds. Although extended detention basins can reduce peak flows, they do not provide significant volume reduction, which could result in adverse downstream impacts.

Due to the extended time that water is released, warming of the water is possible and extended detention basins are not recommended in areas that drain to cold water (trout) streams or any other system that would be negatively affected by changes in water temperature.

Extended detention basins can accept runoff from a storm water *hotspot*, but they should have significant separation between the bottom of the pond and the ground water, or they should be lined to prevent ground water contamination. Their use is also limited in areas of karst topography unless an impermeable liner is used.

Design Basis

The design and placement of detention facilities should be coordinated with an overall watershed plan for managing storm water runoff. On an individual site level, property owners can effectively attenuate peak storm water flows and provide flood control benefits to downstream properties. However, detention facilities alter the timing and duration of natural storm water runoff and can cause compounded flow peaks or increased flow durations that can contribute to downstream degradation if their impact within the overall watershed is not taken into account. In addition, future land uses should be considered when designing detention facilities; land use planning and regulations may be necessary to preserve the intended function of the facility.

Site Selection

Site selection for extended detention basins should consider the natural topography of the area and property boundaries. Locate the pond in an area with relatively flat or gentle slope and preferably on the downhill or lower elevations of the site. Facilities should be a minimum of 20 feet from any structure, property line, and any vegetative buffer required by the local or state government and a minimum of 50 feet from any steep (greater than 15%) slope. If the basin includes a wet pond, a geotechnical report should address the potential impact of the wet pond on a steep slope.

Consider the availability of maintenance access to the sediment forebay and outlet structure when siting the basin.

Pretreatment

Pretreatment in the form of a sedimentation forebay (BMP 25) can settle coarse sediment in a location that is easily maintained and reduce the maintenance requirements of the pond. The sediment forebay typically accounts for about 3% to 10% of the volume of the water quality design storm runoff and is 12 to 30 inches deep.

Basin Storage Volume

Detention basin design is based on the total contributing drainage area. The water quality capture volume should be equal to the runoff volume of one-third of the 2-year, 24-hour design storm, unless local regulations specify otherwise. Detention volume for larger storm events can be provided above the water quality volume. Section 3.6 provides additional information on calculating the runoff volume of the design storm.

Pond Geometry

Dry ponds are normally single-celled. Long, narrow ponds are preferred, as these are less prone to short-circuiting and tend to maximize available treatment area. The length-to-width ratio should be at least 3:1 and preferably 5:1. The pond bottom should have positive slope from the inlet to the outlet to allow complete drainage. Slopes of at least 3% towards the trickle channel or outlet will keep the bottom dry.

The volume provided within the pond can be calculated using Equation 22:

$$V_b = \frac{h(A_1 + A_2)}{2}$$

Equation 22. Volume of a dry pond.

Where

V_b = basin volume (cubic feet)

h = basin depth (feet)

A_1 = top surface area of basin (square feet)

A_2 = bottom surface area of basin (square feet)

Trickle Channel

Trickle channels should be installed in the upper stage of the basin to ensure that the basin dries out completely. A low-flow trickle channel conveys flow from the inlet to the outlet without eroding the bottom surface or causing stagnant pools of water to form that can retard vegetative growth or provide mosquito-breeding grounds. A soft-bottom, natural channel with a minimum depth of 1.5 feet and slope of 2% is recommended. Concrete trickle channels can be used but they tend to increase the velocity of low flows through the facility and cause increased damage to downstream outfalls.

Micropool

If a permanent wet pool is not included at the outlet (BMP 22: Wet Pond), include a micropool or a small wetland marsh area at the outlet to improve the removal of dissolved pollutants, minimize resuspension of sediment, and reduce outlet clogging. The micropool should be at least 2.5 feet deep with a minimum surface area of 10 square feet. The bottom of the micropool can be concrete or riprap as long at the riprap is not removed during maintenance cleanings. Section 3.5.6 provides more information on BMP design to prevent mosquito breeding.

Inlet and Outlet

The inlet and outlet should be at opposite ends of the pond where it is feasible to maximize the flow path length through the facility. If this is not possible, install berms to increase the flow path and water residence time.

The inlet invert should be located at least 6 inches above the bottom of the sedimentation forebay to allow for sediment storage. At concentrated inlets, energy dissipation should be used to limit erosion and promote particle settling.

The outlet should be designed to release the water quality volume over a 48-hour period. This release can be accomplished using an orifice at the outlet pipe. Locate the outlet orifice at least 6 inches above the bottom of the pond or the top of the micropool. If a single orifice is used, the top portion of the water quality volume will drain more quickly than the lower portion, providing increased treatment for smaller storms. Alternatively, a plate with rows of orifices or a perforated riser pipe can also be used as the water quality outlet. A single orifice can be sized using Equation 23 and Equation 24.

Maximum flow rate based on a drain time of 48 hours:

$$Q = \frac{V}{48\,hrs * 3600\,sec/hr}$$

Equation 23. Outflow rate with 48 hour drain time.

Where

V = water quality design volume (cubic feet)

Q = maximum allowable water quality outflow rate (cubic feet per second)

Water flowing through a plate orifice (orifice coefficient = 0.62):

$$d = \sqrt{\frac{36.88\,Q}{h^{0.5}}}$$

Equation 24. Orifice diameters.

Where

d = orifice diameter (inches)

Q = water quality outflow rate (cubic feet per second)

h = hydraulic head at the orifice (feet)

The outlet should have a trash rack or screen to prevent clogging the outlet pipe. The openings should be small enough to limit clogging the orifice and should not interfere with the hydraulic capacity of the outlet.

A multistage outlet can be designed for detention facilities that attenuate flood flows above the water quality volume. Common designs include multiple outlets that restrict outflow for 2-year, 10-year, and/or 100-year events (Figure 61). An example diagram is shown in Figure 62, and the *Urban Storm Drainage Criteria Manual* (Colorado UDFCD 2010) includes detailed design guidance for detention outlets.

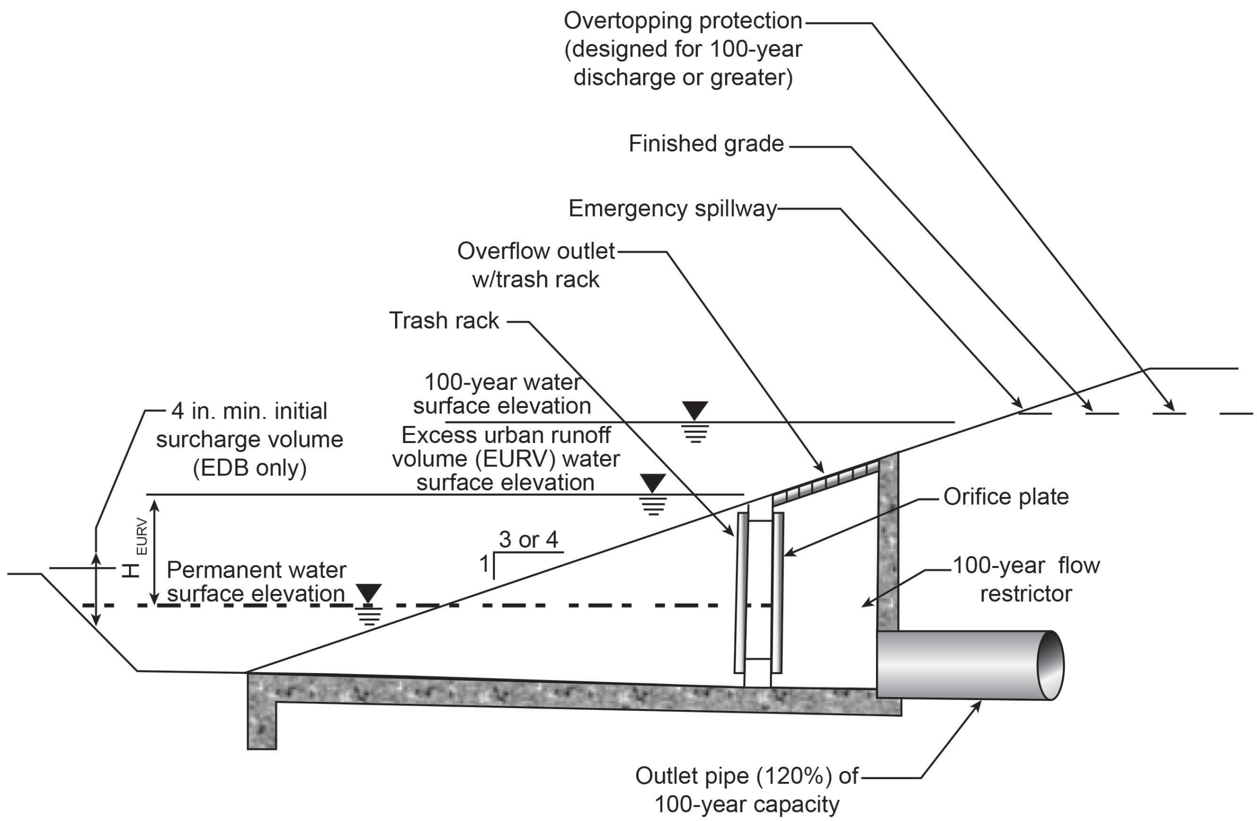


Figure 61. Typical outlet structure for full spectrum detention (Colorado UDFCD 2010).

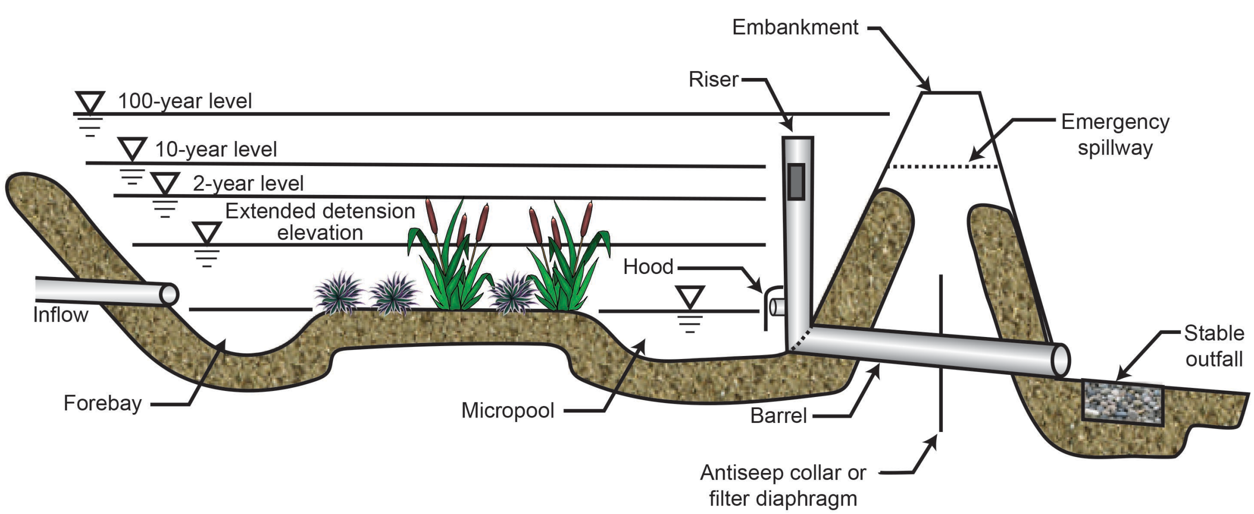


Figure 62. Extended detention outlet structure cross section.

Berm Embankment and Slope Stabilization

Interior and exterior side slopes should be no steeper than 3H:1V for safety and to facilitate mowing and maintenance of the vegetation.

Pond embankments higher than 6 feet should be designed by a qualified geotechnical-civil engineer licensed in Idaho. For berm embankments of 6 feet or less (including a 1-foot freeboard), the minimum top width should be 6 feet or as recommended by the geotechnical-civil engineer. Construct pond berm embankments on native consolidated soil (or adequately compacted and stable fill soils analyzed by a geotechnical report) that is free of loose surface soil materials, roots, and other organic debris.

For wet extended detention ponds that include a permanent pool, use guidance included in BMP 22: Wet Pond for berm embankment and slopes.

Overflows

Detention facility design should include provisions for passing overflows safely through the basin to a downstream conveyance that can handle the flows. Additionally, the discharge velocity of the spillway and all outlets should be less than the erosive velocity of the downstream conveyance. The most common overflow event is during snowmelt, but overflows may also result from higher intensity or longer duration storms than the design storm or result from plugged orifices or inadequate storage due to sediment buildup in the facility.

An emergency overflow spillway on the pond embankment is recommended to safely pass the 100-year storm event. It can be designed as a broad crested weir using the example section shown in Figure 63.

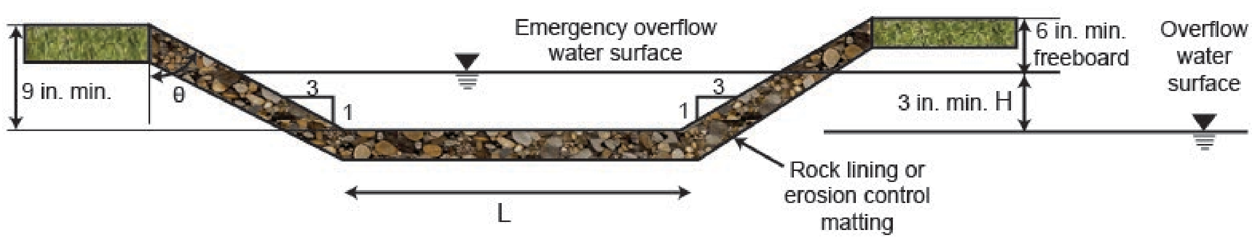


Figure 63. Weir section for emergency overflow spillway (adapted from King County 2009).

The recommended minimum length for a spillway is 6 feet, the minimum flow depth of water over the weir is 3 inches, and the minimum freeboard is 6 inches. Erosion protection should be provided on and downstream of the spillway using riprap, geotextiles, or other appropriate material. For a spillway with the geometry shown above and using a weir coefficient of 0.6, the length of the weir needed to pass the 100-year peak flows can be calculated using Equation 25. An iterative process using a variety of depths to determine an appropriate length may be needed.

$$L = \frac{Q_{100}}{3.21\, H^{\frac{3}{2}}} - 2.4\, H$$

Equation 25. Length of overflow weir spillway (King County 2009).

Where

L = length of weir (feet)

Q_{100} = peak flow from the 100-year runoff event (cubic feet per second)

H = depth of water over weir (feet)

Vegetation

Planting and preservation of desirable native trees and other vegetation should be an integral part of the extended detention facility design (Figure 64). For ponds with a micropool or permanent pool, use the vegetation guidelines for marsh wetland areas in BMP 22: Wet Pond.

Grasses are recommended for berms taller than 4 feet; trees and shrubs are not recommended because they can obstruct the visibility of the slopes and impede the detection of potential structural problems such as animal burrows, slumping, or fractures. For berms less than 4 feet high, small trees with a fibrous root system are recommended. Trees and shrubs that have tap roots or are hydrophilic are not recommended on or near embankments as they can send deep roots into the embankment and cause seepage problems. Trees and shrubs are not recommended within 10 feet of the inlet or outlet structures. Vegetation below the water quality capture volume elevation should be able to withstand both wet and dry periods. If the pond accepts runoff from roads that are treated with salts in the winter, use salt tolerate species in the landscaping.

Exposed earth on the side slopes and pond bottom should be seeded with the appropriate seed mixture as soon as practicable. If necessary, geotextile or matting may be used to stabilize slopes while seeding and sodding become established. Native vegetation is preferred so that irrigation is not required. If irrigation is necessary, place sprinkler heads outside of the basin bottom to avoid sediment clogging.

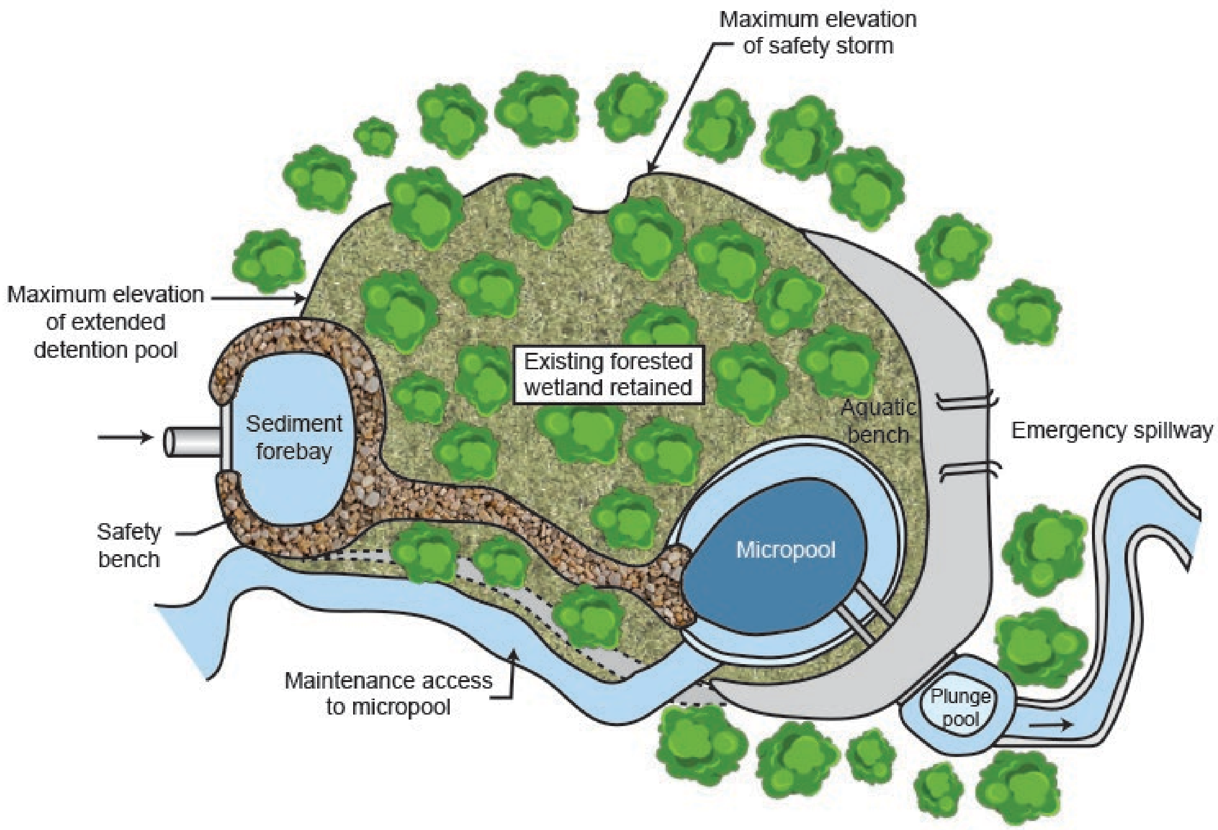


Figure 64. Extended detention basin sample plan view.

Safety, Signage, and Fencing

Basins that are readily accessible to populated areas should incorporate safety precautions. Steep side slopes (steeper than 3H:1V) at the perimeter should be avoided and dangerous outlet facilities should be protected by enclosure. For wet extended detention basins, a safety bench or marsh area around the perimeter of the permanent pool will provide a recovery area for people or animals that accidently enter the pond.

Place signs so that they are clearly visible and legible from all adjacent streets, sidewalks, or paths. For wet extended detention basins with a permanent pool, use warning signs for deep water and potential health risks where appropriate, and post a notice warning residents of potential waterborne disease that may be associated with swimming or fishing in these facilities. In the case of dry ponds, posted signs may prevent calls about flooded playgrounds or ball fields.

Construction Guidelines

Widely acceptable construction standards and specifications such as those developed by the NRCS or US Army Corps of Engineers for embankment ponds and reservoirs may aid in building the impoundment.

Appropriate erosion control techniques should be used during construction of an extended detention basin. During construction, a temporary sediment trap (BMP 66) can be placed where the permanent extended detention basin will be located. If the basin area is used as a temporary sediment trap during construction, set the temporary bottom elevation higher than the final basin bottom elevation so that accumulated sediment can be removed before final grading. However, if the sediment meets criteria for a low permeability liner, the pond could be excavated to just below final grade and the sediment left in the bottom of the pond after construction and used as a liner. Sediment used for a soil liner should be graded to provide uniform coverage and thickness.

Maintenance

Inspections and maintenance should be performed regularly and within 24 hours after large storm events. Trash and debris removal should also be done regularly to prevent the facility from becoming a dumping ground for trash, construction debris, and yard waste.

Clean the sediment forebay and basin bottom of sediment as needed. Embankments should be inspected for signs of failure, such as seepage or cracks in the berm, as well as for animal burrows, erosion, and/or loss of material. Make repairs and complete maintenance immediately to preserve the integrity of the berm including stabilizing the slope, filling any burrow holes, repairing cracks, and stopping seepage.

Weed, mow, and trim vegetation in and around the pond to maintain its health and aesthetic value. Intense recreational uses that could cause grasses to wear and expose bare soil should be discouraged within the detention basin. If soil does become exposed, promptly revegetate the area with sod or seed.

Inspect the inlet and outlet for erosion or undercutting and clogged or damaged pipes. Erosion control, energy dissipation devices, and pipes should be replaced, cleaned, or repaired as necessary.

Additional Resources

Colorado UDFCD (Colorado Urban Drainage and Flood Control District). 2010. *Urban Storm Drainage Criteria Manual, Volume 3 Best Management Practices*. Denver, CO. *http://udfcd.org/wp-content/uploads/2014/07/Title-Page.pdf*

EPA (US Environmental Protection Agency). 2014. "Dry Detention Ponds." Water: Best Management Practices. *www.epa.gov/npdes/national-menu-best-management-practices-bmps-stormwater#edu*

ITD (Idaho Transportation Department). 2014. *Best Management Practices.* Boise, ID: ITD. *http://itd.idaho.gov/env/*

King County (King County, Washington). 2009. *King County, Washington Surface Water Design Manual.* Seattle, WA: King County, Department of Natural Resources.

BMP 24: Constructed Wetlands

Description

Constructed storm water wetlands are shallow man-made ponds or conveyance channels specifically designed to treat storm water runoff. Wetlands treat storm water by slowing runoff and allowing time for sedimentation, filtering, and biological uptake associated with emergent aquatic plants (Figure 65).

Figure 65. Storm water wetland at the Hyatt Hidden Lakes Reserve (City of Boise 2018).

Constructed wetlands differ from natural wetlands or wetlands created as mitigation for the loss of natural wetlands. Constructed storm water wetlands are used to capture pollutants in a managed environment, typically have less biodiversity, and are not intended to replicate the complete array of ecological functions of a wetland. Their value may be limited for providing wildlife habitat, but with proper design, they can still be an aesthetic amenity similar to natural wetlands.

Natural wetlands should not be used to treat storm water runoff. Storm water runoff should be treated before entering natural or existing wetlands or other environmentally sensitive areas.

Primary BMP Functions and Controls

☐ Construction	☒ Permanent
☐ Erosion Control	☒ Sediment Control
☐ Source Control	☒ Flood Control
☐ Filtration	☐ Infiltration

Typical Effectiveness for Targeted Pollutants

●	Sediment
◖	Phosphorus
◖	Metals
○	Bacteria
◖	Hydrocarbons
○	Litter

Other BMP Considerations

Overall Cost	$
Maintenance Requirements	Low
Ease of Installation	Medium
Freeze/Thaw Resistance	Fair
Max. Tributary Drainage Area	50 acres
Max. Upstream Slope	15%
NRCS Soil Group	CD
Min. Ground Water Separation	3 feet
Min. Bedrock Separation	3 feet

Applicability

Use constructed wetlands in any location with adequate space and a source of water to maintain a permanent pool of water and support wetland vegetation. Water depths are relatively shallow, so water loss through evaporation can be significant, especially in arid climates, and should be accounted for when determining the amount of source water needed to maintain the facility. A careful hydrologic analysis of flow should be conducted to determine depth-area relationships, and excessive fluctuations in water level should be avoided. Constructed wetlands are a good choice in areas with high winter ground water levels.

A well-planned constructed wetland can meet a variety of objectives: protecting infrastructure and property, improving water quality, and providing

recreational opportunities. With the emphasis on vegetation, constructed wetlands provide greater habitat enhancement than wet ponds. If the facility is planned as an aesthetic feature (e.g., to enhance property values), pretreatment with BMPs effective in removing nutrients is recommended to reduce algae blooms.

Constructed wetlands can be designed for flood control if additional detention volume is provided above the permanent pool (BMP 23: Extended Detention Basin). As with all detention facilities, a watershed approach to storm water management should be considered.

Limitations

Constructed wetlands are not recommended for use in arid climates where it may be difficult to maintain a permanent pool of water, constant flow, or establish a shallow marsh wetland area. With the shallow depth and potentially large land area needed for constructed wetlands, their use may be limited in ultraurban areas with limited space available. These wetlands are also not recommended in areas of karst topography unless the facility is lined to prevent infiltrative flows from undermining the area.

Because constructed wetlands have the potential to increase the water temperature when it is stored in the permanent pool, they are not recommended in areas that drain to cold water (trout) streams or any other system that would be negatively affected by changes in water temperature.

If a constructed wetland is accepting runoff from a storm water *hotspot*, it should have significant separation between the bottom of the pond and ground water, or it should be lined to prevent ground water contamination. The facility may also need to be lined if soils in the area are very permeable. Fence off the area to limit access by people and wildlife.

Use caution for all constructed wetlands near natural wildlife habitat to ensure that pollutants collected in the wetland do not work their way through the food chain of organisms living in or near the wetland. Other considerations are water fowl attracted to the facility can add nutrients to the water leaving the pond. Improperly designed wetlands can become mosquito-breeding areas.

In cold climates, freezing of the permanent pool can reduce the effectiveness of the system; it may be more appropriate to use a dry extended detention basin (BMP 23).

Design Basis

Site Selection

The site selection for constructed wetlands should consider the natural topography of the area, property boundaries, and location of sewer and water utilities. Facilities should be a minimum of 20 feet from any structure, property line, and any vegetative buffer required by the local or state government; 100 feet from any septic tank/drainfield; and 100 feet from any wells or water supplies. Facilities should be a minimum of 50 feet from any steep (greater than 15%) slope. A geotechnical report should address the potential impact of a constructed wetland on a steep slope.

Base Flow

Unless the permanent pool is established by ground water, a perennial baseflow that exceeds losses must be physically and legally available. Areas of perennial baseflow are also less subject to algae blooms and freezing, enhancing the effectiveness in many areas. The base flow will need to exceed losses from evaporation, evapotranspiration, and seepage (unless the pond is lined). Conduct a water balance analysis to properly design the facility. A tributary drainage area of 25 acres is considered the minimum needed to maintain the permanent pool in humid regions (EPA 2014c), although some wetlands can be sustained with as little as 5 acres, provided the plants are facultative.

Pretreatment

Pretreatment in the form of landscape retention areas (BMP 18), vegetated swales (BMP 9), or sedimentation forebays (BMP 25) can settle coarse sediment, reduce the maintenance burden of the wetland, and protect the wetland vegetation. Pretreatment prolongs the utility of the wetland and improves its appearance by reducing the nutrient load and preventing the wetland and its permanent pool from becoming eutrophic with excessive algal blooms, low oxygen levels, and odor.

A sedimentation forebay, a deeper area where sediments can settle out, should be established along the wetland inflow points to capture sediment. The forebay should have a water depth of 3 to 6 feet and may occupy up to 25% of the normal pool area.

Configuration and Geometry

Storm water wetlands use some of the same design features as wet ponds (BMP 22) although their dominate pollutant removal mechanism is mediated by aquatic vegetation and the microbiological community associated with that vegetation instead of gravity settling. Constructed wetland design is focused on factors that affect plant vigor and biomass instead of water volume. Constructing low-flow channels through emergent vegetation is not recommended as it can cause storm water to short circuit through the channels rather than through the wetland vegetation.

Effective wetland design has complex microtopography where various zones of different depths exist, such as very shallow (less than 6 inches) and moderately shallow (less than 18 inches) areas created by underwater berms in the facility. These areas provide a longer flow path through the wetland to encourage sediment settling and plant diversity. A length-to-width ratio of at least 1.5:1 is recommended to prevent short circuiting.

The simplest form of a constructed wetland includes two cells—sedimentation forebay and wetland vegetation area. If local regulations do not specify a design water quality volume, the volume can be set equal to the runoff volume of one-third of the 2-year, 24-hour design storm. The surface area for the wetland can then be calculated by dividing this volume by 3-feet average water depth. Check that the surface area of the wetland is at least equal to 1% of the drainage area to the facility.

The sedimentation forebay should have a volume approximately equal to 33% of the total volume. Determine the volume of the forebay and surface area of the forebay using its actual depth

(between 3 and 6 feet). Base the water depth distribution for the wetland cell and micropool on the guidelines in Table 14 (Figure 66).

Table 14. Wetland surface area-pool relationships.

Pond Component	Approximate Wetland Pond Surface Area (%)	Design Depth (feet)
Wetland zone with emergent vegetation	5	0.5
Wetland zone with emergent vegetation	15	0.5–1
Micropool and outlet	15	2–3
Forebay	20	3–6

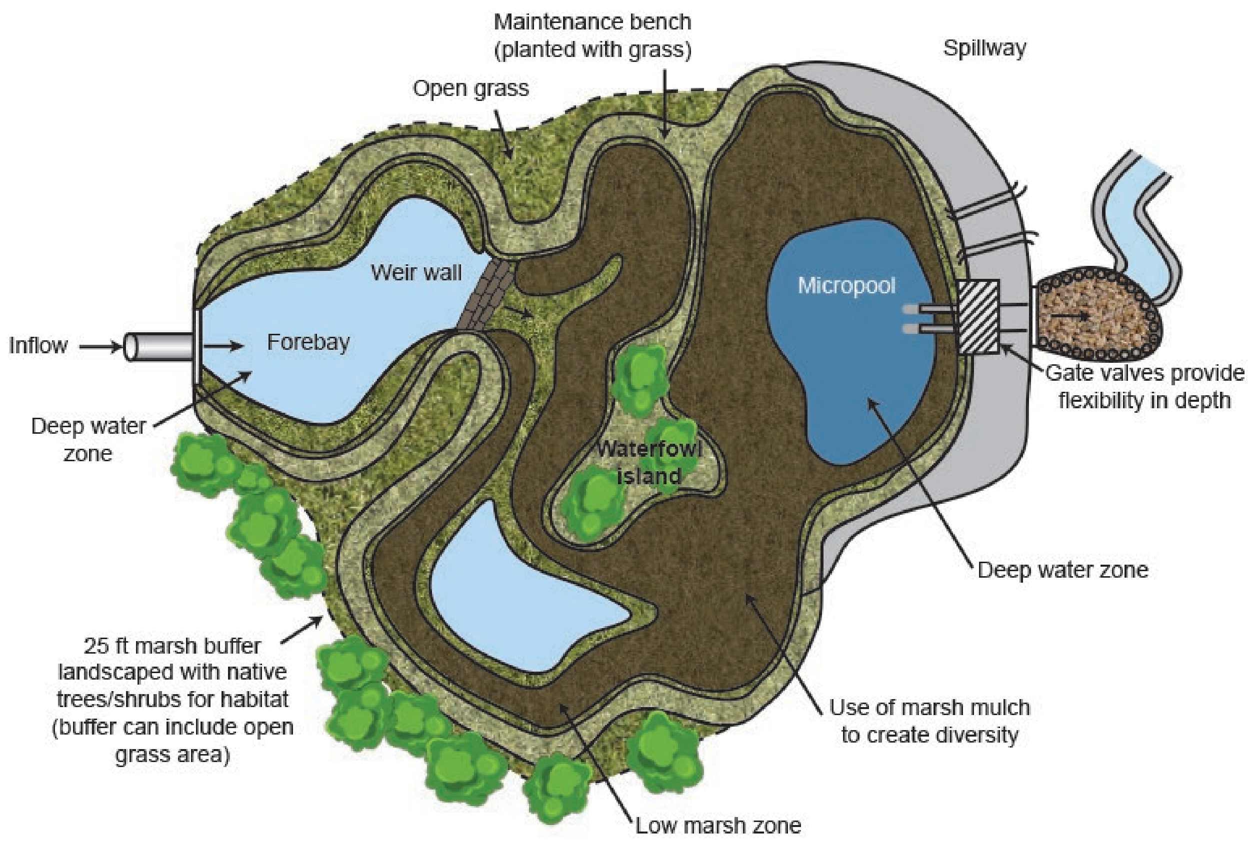


Figure 66. Constructed wetland sample plan view.

Inlet and Outlet

The recommended inlet and outlet design for constructed wetlands is identical to the recommended design for wet ponds (BMP 22).

Berm Embankment and Slope Stabilization

Design of berm embankments and slope stabilization recommendations are the same as for wet ponds (BMP 22).

Soil and Liners

The soil in which the vegetation is planted should be appropriate for the plants selected. Either soil tests indicating the adequacy of the soil or a soil enhancement plan should be considered during design. The soil substrate should be soft enough to permit easy insertion of the plants. If the soil is compacted or vegetation has formed a dense root mat, the upper 6 inches of soil should be disked before planting. If soil is imported, spread it at least 4 inches deep to provide sufficient depth for plant rooting. Enriching nonwetland soils with organic matter can increase vegetative yields.

If the infiltration rate of the natural soil is high and a permanent pool cannot be maintained, a clay liner (or equivalent) may be necessary. Additionally, wetlands in areas of karst topography or storm water hotspots, may also require an impermeable liner to prevent ground water contamination or ground instabilities. If a low permeability liner is used, a minimum of 18 inches of native soil amended with good topsoil or compost (one part compost mixed with three parts native soil) should be placed over the liner. For geomembrane liners, a soil depth of 3 feet is recommended to prevent damage to the liner during planting. Hydric soils are not required.

Vegetation

In a constructed wetland, the vegetation is an integral part of the design. Although wetland-associated plants will establish themselves naturally in shallow marsh areas, it may be beneficial to accelerate wetland establishment by planting appropriate native vegetation and selecting wetland plant species that have greater capacity for pollutant assimilation and are less maintenance intensive than others.

Selection of vegetation should be done by a wetlands specialist. The selection should be based on climate, hydroperiod of the constructed wetland, sensitivity to pollution, and aesthetic appeal. Take the detrimental effects of wind, waves, and water currents into account. A well-planned constructed wetland needs a diverse mixture of floating, emergent, and submergent plants. The plants must withstand the pollutant concentration of the incoming storm water and tolerate some fluctuation in the water level of the wetland.

If a wetland specialist is not available, the following guidelines can aid in wetland plant selection and establishment:

- Determine which wetland species will be most successful within a specific wetland location; use a regional wetland seed mix with a minimum of 2–12 species.
- After the first growing season, inspect the facility and augment the 3 or 4 most successful species with additional plants.

The species of vegetation chosen should maximize heterogeneity and value to all types of wildlife. Although not required, measures to further enhance habitat for wildlife are encouraged. Maximizing vegetation density around the created wetland will discourage the entry of domestic

animals that would prey on wildlife. In larger created wetlands, providing an island for nesting birds is encouraged.

Overflows

Refer to BMP 22: Wet Pond and BMP 23: Extended Detention Basin for overflow guidance.

Gravity Drain

If vegetation will be harvested, provide a gravity drain (BMP 22: Wet Pond).

Safety, Signage, and Fencing

Using thorny vegetation as a barrier instead of fencing enhances the habitat aspect of a constructed wetland. Other signage and safety recommendations that apply to wet ponds (BMP 22) also apply to constructed wetlands.

Studies have shown high accumulation rates of lead, zinc, and copper on and near heavily traveled highways and streets. Runoff from highways and streets can be expected to carry significant concentrations of these heavy metals. If a significant portion of the drainage area into the constructed wetland consists of highways, streets, or parking areas or other known sources of heavy metal contamination, an environmental health hazard potentially exists, and the facility must have adequate signage and be protected with fencing. This situation is of more concern with a constructed wetland rather than the conventional wet pond because wildlife is attracted to marsh areas.

Construction Guidelines

Widely acceptable construction standards and specifications such as those developed by the NRCS or US Army Corps of Engineers for embankment ponds and reservoirs may aid in building impoundments to create the wetland.

If the wetland area is used as a temporary sediment trap during construction, set the temporary bottom elevation higher than the final pond bottom elevation so that accumulated sediment is removed before final grading. However, if the sediment meets criteria for a low permeability liner, excavate the pond to just below final grade and leave the sediment in the bottom of the pond after construction and use as a liner. Sediment used for a soil liner should be graded to provide uniform coverage and thickness. Marsh establishment in facilities that also serve as temporary sediment basins may be difficult during construction due to the need for frequent clean out of accumulated sediment.

As with all construction, appropriate erosion control techniques should be used during wetland construction.

Maintenance

Wetlands should be inspected at least twice per year during the first 3 years for both growing and nongrowing seasons to observe plant species' presence, abundance, and conditions; bottom contours and water depths relative to plans; and sediment, outlet, and buffer conditions.

Maintenance should be scheduled around sensitive vegetation and wildlife seasons. Constructed wetlands will need periodic sediment removal to continue functioning. Remove sediment from the deepest parts of the pond where vegetation is sparse. Heavily vegetated areas should be disturbed as little as possible. Overhead scooping equipment works well for dredging selected portions of wetland areas.

Plants may require watering, physical support, mulching, weed removal, or replanting during the first 3 years. Remove nuisance plant species and replant desirable species.

The effectiveness of harvesting for nutrient control is not well documented (Washington Department of Ecology 2012). Some drawbacks to harvesting include possible damage to the wetlands and the inability to remove nutrients in the belowground biomass.

The presence of wetlands in established urban areas is perceived by many people to be undesirable, and local government and homeowner associations may wish to drain the ponds during late spring and summer if concern is sufficient. However, it is imperative the vegetation in shallow marsh areas not die off during draindown periods; otherwise, the pollutant removal effectiveness of the constructed wetland is severely impacted. In addition, the decaying vegetation can create nuisance conditions.

Perform trash and debris removal regularly so the facility will not become a dumping ground for trash, construction debris, and yard waste. Ensure the access can withstand the weight of heavy equipment.

Embankments should be inspected for erosion and if it is a problem, erosion control devices such as reinforced turf matting or riprap should be installed. Impoundment structures should be regularly inspected for signs of failure, such as seepage or cracks in the berm. Inspect the structures for animal burrows, erosion, and/or loss of material. Repairs and maintenance should be made immediately to preserve the integrity of the berm including stabilizing the slope, filling any burrow holes, repairing cracks, and stopping seepage.

Inspect the inlet and outlet for erosion, undercutting, and clogged or damaged pipes. Erosion control, energy dissipation devices, and pipes should be replaced, cleaned, or repaired as necessary.

Additional Resources

City of Boise. 2015. *Hyatt Hidden Lakes Reserve*. *http://parks.cityofboise.org/parks-locations/parks/hyatt-hidden-lakes-reserve/*

EPA (US Environmental Protection Agency). 2014. *National Menu of Best Management Practices (BMPs) for Stormwater.* National Pollutant Discharge Elimination System. *http://www.epa.gov/npdes/national-menu-best-management-practices-bmps-stormwater#edu*

King County (King County, Washington). 2009. *King County, Washington Surface Water Design Manual.* Seattle, WA: King County, Department of Natural Resources.

Washington State Department of Ecology. 2012. *Stormwater Management Manual for Western Washington*. Lacey, WA. Publ. 12-10-030. *http://www.ecy.wa.gov/programs/wq/stormwater/manual.html*

BMP 25: Presettling/Sedimentation Basin

Description

A presettling basin, or sediment forebay, is a basin or other storage structure designed to dissipate the energy of incoming runoff and detain the runoff to settle out coarse particulates before discharging into downstream primary treatment BMPs (Figure 67).

Presettling basins should have good access and can be constructed of concrete to facilitate sediment removal by heavy equipment. Presettling basins remove little or no pollutants besides those directly associated with sediments and litter.

Figure 67. Sediment forebay (VA DEQ 2011).

Applicability

Presettling basins fill one purpose—to protect more sensitive downstream facilities from excessive sediment loads. These basins are often integrated into the design of larger storm water management structures such as extended detention basins (BMP 23), wet ponds (BMP 22), or constructed wetlands (BMP 24). A presettling basin should be located at each inflow point to the primary BMP.

Primary BMP Functions and Controls

☐ Construction	☒ Permanent
☐ Erosion Control	☒ Sediment Control
☐ Source Control	☐ Flood Control
☐ Filtration	☐ Infiltration

Typical Effectiveness for Targeted Pollutants

◖	Sediment
○	Phosphorus
◖	Metals
○	Bacteria
○	Hydrocarbons
◖	Litter

Other BMP Considerations

Relative Cost	$
Maintenance	Medium
Ease of Installation	Easy
Freeze/Thaw Resistance	Good
Max. Tributary Drainage Area	10 acres
Max. Upstream Slope	15%
NRCS Soil Group	ABCD
Min. Ground Water Separation	3 feet
Min. Bedrock Separation	3 feet

Limitations

Locate presettling basins where easy access is available for maintenance equipment and where the access road can handle heavy equipment. For other limitations, refer to BMP 22: Wet Pond.

Design Basis

Site Constraints

Constraints are similar to wet ponds; however, presettling basins tend to be smaller in size and are easier to fit into small spaces. Locate the ponds a minimum of 20 feet from any structure, property line, and any vegetative buffer required by local government. If the basin allows for infiltration, ensure it is located 100 feet from any septic tank/drainfield.

The basin should be a minimum of 50 feet from any steep slope (greater than 15%). A geotechnical report should address the potential impact of a presettling basin that has a permanent pool of water on a steep slope.

Volume

If the local jurisdiction does not specify standards for sizing a presettling basin, the basin volume should be equal to the runoff volume of one-third of the 2-year, 24-hour design storm or 10% of the total required volume of the primary BMP (EPA 2014c). Section 3.6 provides additional information on storm water runoff volume calculations.

Configuration and Geometry

Presettling basins can be designed to empty completely between storm events or to maintain a permanent pool of water. A dry presettling basin should be carefully designed with riprap or a plunge pool at the inlet to avoid the resuspension of previously deposited sediments. The floor of the basin can be constructed of concrete or lined with grouted boulders to define sediment removal limits.

Presettling basins are normally single-celled. Long, narrow basins are preferred to minimize short-circuiting and maximize available treatment area. The length-to-width ratio should be at least 3:1 and preferably 5:1.

Interior side slopes may be vertical, if concrete; otherwise, they should be no steeper than 3H:1V. Exterior embankment slopes should be 2H:1V or less. The minimum depth should be 3 feet and the maximum depth should be 6 feet.

The bottom of the basin should have a 2% slope to the outlet to allow complete drainage to facilitate maintenance (Figure 68 and Figure 69).

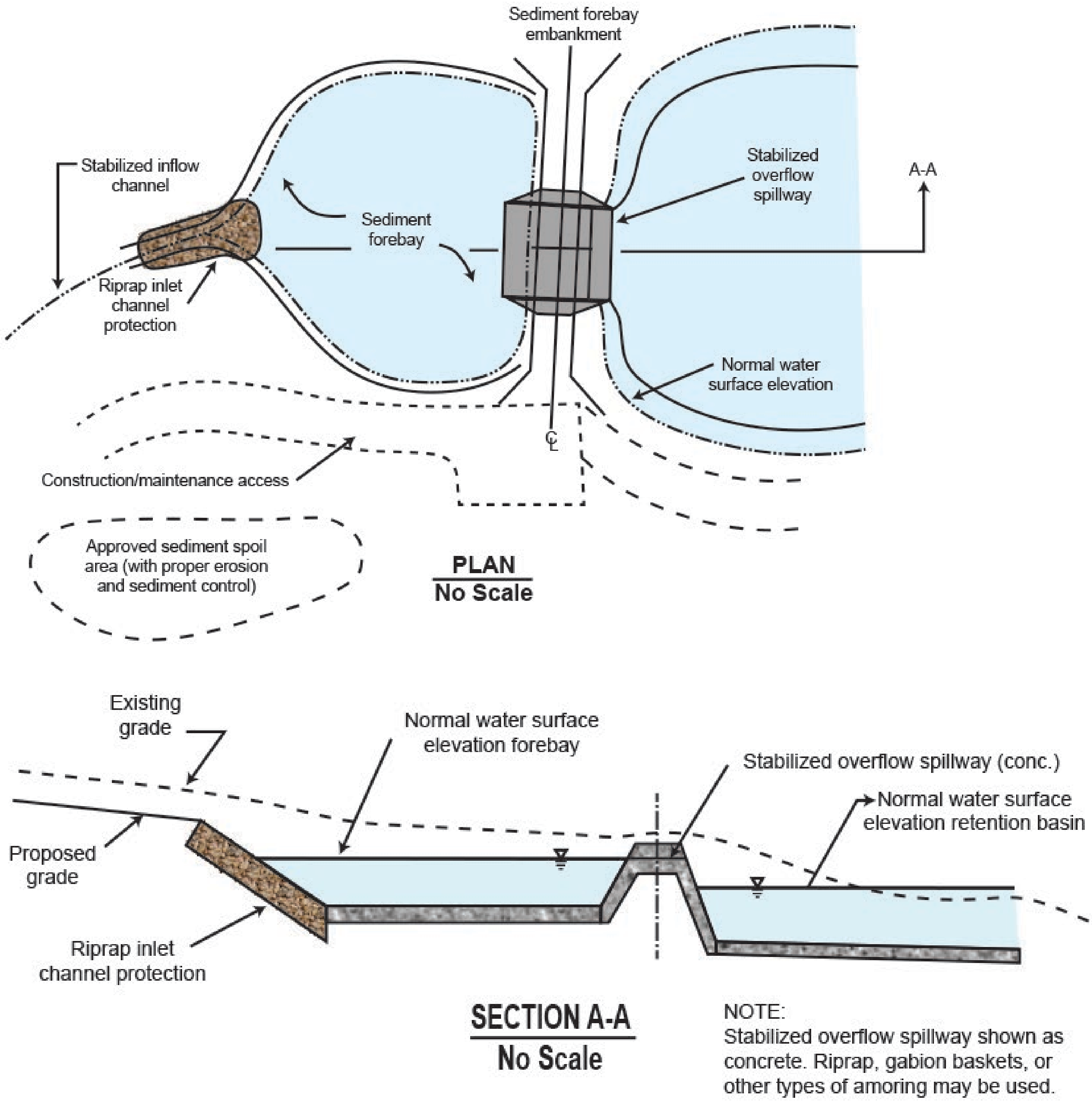


Figure 68. Sedimentation forebay plan and section (VA DEQ 2011).

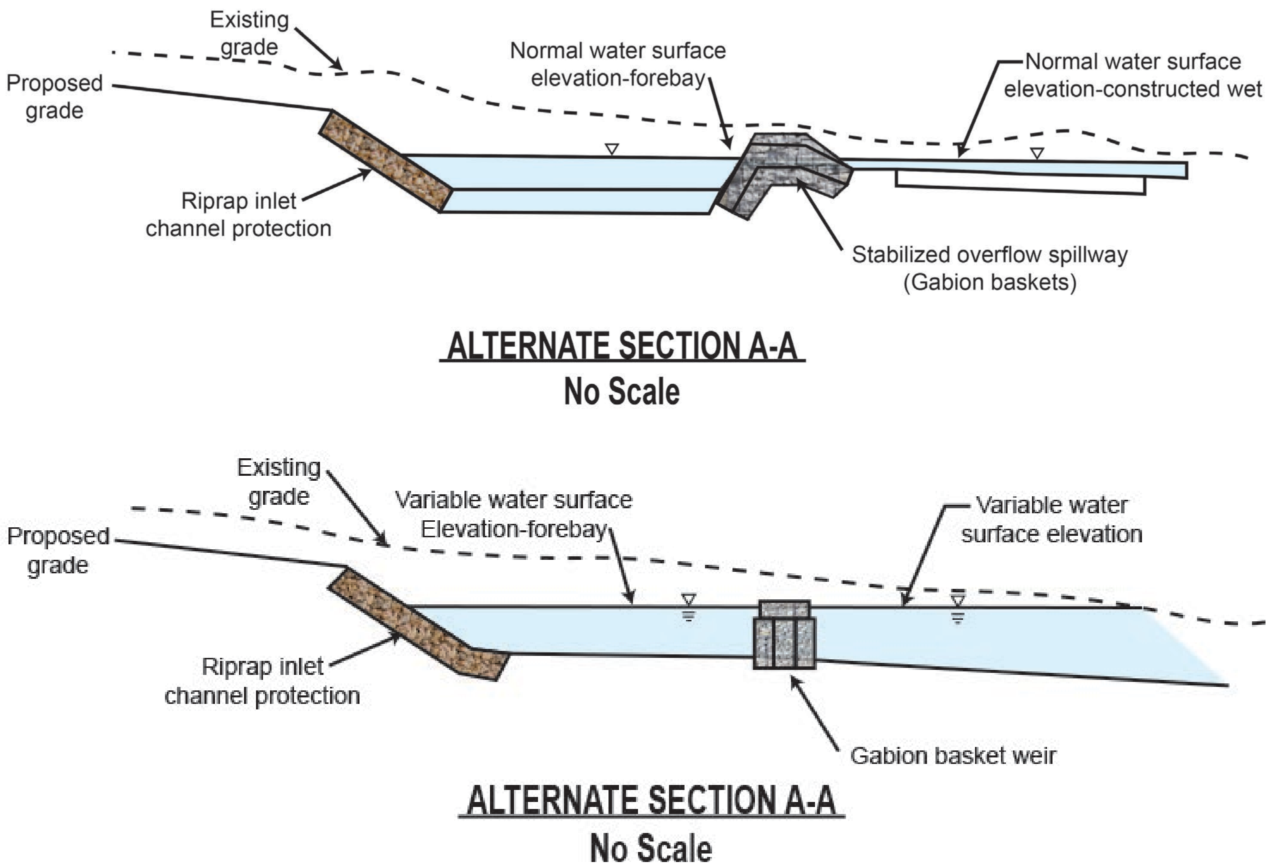


Figure 69. Sedimentation forebay alternate sections (VA DEQ 2011).

Berm Embankment and Slope Stabilization

Berms and embankments constructed to form a presettling basin should follow the same guidelines as wet ponds (BMP 22).

Inlet and outlet Structures

The inlet and outlet should be at opposite ends of the forebay where feasible. If this is not possible, install baffles to increase the flow path and water residence time. Inlets and outlets should also be designed to minimize velocity of the runoff and reduce turbulence.

The inlet should be designed to minimize resuspension of settled sediments by either locating its invert a minimum of 2 feet from the bottom of the pond or providing other means for energy dissipation. The inlet should also discharge runoff uniformly and at low velocity into the presettling basin to maintain near quiescent conditions necessary for sedimentation. It is desirable for the heavier suspended material to drop out near the front of the basin; a drop inlet structure is recommended to facilitate sediment removal and maintenance. Energy dissipation measures may be necessary to reduce inlet velocities that exceed 3 feet per second.

The outlet structure conveys the water quality volume from the presettling basin to the primary treatment BMP (e.g., wetland and sand filtration basin). The outlet structure should be a weir or some other control structure.

Overflows

Presettling basin design should consider the possibility of overflows. Install an overflow spillway in all facilities to bypass flows over or around the restrictor system.

Safety, Signage, and Fencing

Basins that are readily accessible to populated areas should incorporate all possible safety precautions. Protect dangerous outlet facilities with an enclosure, and use warning signs wherever appropriate. Signs should be placed so that at least one is clearly visible and legible from all adjacent streets, sidewalks, or paths.

Construction Guidelines

Widely acceptable construction standards and specifications such as those developed by the NRCS or US Army Corps of Engineers for embankment ponds and reservoirs may aid in building the impoundment. Guidelines for wet ponds (BMP 22) are also applicable, and forebays that are part of a wet pond, extended detention basin, or constructed wetland should be designed together with the primary facility.

Maintenance

Presettling basins should be inspected annually at a minimum. The frequency of cleaning will depend on the condition of the upstream watershed. Debris, sediment, and litter should be removed and properly disposed of as necessary. Due to their function in reducing sediment load to downstream BMPs, presettling basins will need more frequent cleaning than those BMPs. Install a staff gage or other measurement device to indicate the depth of sediment accumulation and level at which cleanout is required.

Trash and debris removal should be performed regularly so the facility does not become a dumping ground for trash, construction debris, and yard waste. Ensure the access can withstand the weight of heavy equipment.

Embankments should be inspected for erosion, and if it is a problem, install erosion control devices such as reinforced turf matting or riprap. Impoundment structures should be regularly inspected for signs of failure, such as seepage or cracks in the berm. The structures should also be inspected for animal burrows, erosion, and/or loss of material. Repairs and maintenance should be made immediately to preserve the integrity of the berm including stabilizing the slope, filling any burrow holes, repairing cracks, and stopping seepage.

The inlet and outlet should be inspected for erosion, undercutting, and clogged or damaged pipes. Erosion control, energy dissipation devices, and pipes should be replaced, cleaned, or repaired as necessary.

Additional Resources

EPA (US Environmental Protection Agency). 2014. *Wet Pond.* Water: Best Management Practices. *https://www.epa.gov/npdes/national-menu-best-management-practices-bmps-stormwater#edu*.

Massachusetts DEP and MassHighway (Massachusetts Department of Environmental Protection and Massachusetts Department of Transportation). 2004. *The MassHighway Storm Water Handbook for Highways and Bridges*. *http://prj.geosyntec.com/npsmanual/source/MassHighways%20Storm%20Water%20Handbook%20for%20Highways%20and%20Bridges.pdf*

VA DEQ (Virginia Department of Environmental Quality). 2011. "Appendix D Sediment Forebay." Ver. 1.0. *Virginia Stormwater Design Specification*. *http://vwrrc.vt.edu/swc/documents/2013/DEQ%20Introduction_App%20D_Sediment%20Forebays_SCraftonRev_03012011.pdf*

Washington State Department of Ecology. 2012. *Stormwater Management Manual for Western Washington*. Lacey, WA. Publ. 12-10-030. *http://www.ecy.wa.gov/programs/wq/stormwater/manual.html*

BMP 26: Underground Detention Facilities

Description

Underground detention facilities retain and/or detain surface storm water runoff below ground. These facilities attenuate peak flows and enhance water quality through sedimentation within a permanent pool of water or a specially designed chamber. Types of underground storage facilities include vaults, wet vaults, tanks, chambers, and premanufactured structures. These facilities are constructed from reinforced concrete (vaults), large diameter corrugated metal pipe (tanks), or high-density polypropylene or polyethylene (chambers) (Figure 70).

Figure 70. Underground retention chambers installed at the Teton County Justice Center in Driggs, Idaho.

Water captured in underground retention facilities with a permanent pool of water may be used for irrigating parking strips, common areas, and general landscaping activities. Underground detention facilities designed to completely drain between storms provide temporary storm water storage and release at a controlled rate through an engineered outlet to surface water or storm drain system or via infiltration into the subsurface.

If the facility is designed to infiltrate into the subsurface, an underground injection permit or shallow injection well inventory form may be required by IDWR. An Idaho Lake Encroachment permit and/or a US Army Corps of Engineers §404 permit may be required to place the outfall. Notify the local DEQ office of any new outfalls.

Primary BMP Functions and Controls

☐ Construction	☒ Permanent
☐ Erosion Control	☒ Sediment Control
☐ Source Control	☒ Flood Control
☐ Filtration	☐ Infiltration

Typical Effectiveness for Targeted Pollutants

●	Sediment
◖	Phosphorus
◖	Metals
○	Bacteria
○	Hydrocarbons
○	Litter

Other BMP Considerations

Relative Cost	$$$
Maintenance Requirements	High
Ease of Installation	Medium
Freeze/Thaw Resistance	Fair
Max. Tributary Drainage Area	5 acres
Max. Upstream Slope	15%
NRCS Soil Group	ABC
Min. Ground Water Separation	2 feet
Min. Bedrock Separation	2 feet

Applicability

Underground storm water storage facilities are most appropriate for commercial, industrial, or roadway projects where surface-based BMPs are infeasible. They are often installed under parking lots or other paved surfaces. This practice is applicable in both new and redevelopment projects in highly urbanized settings. The storage facilities are most effective if used as part of a treatment train along with BMPs, such as porous pavement

(BMP 19), bioretention basins (BMP 18), vegetated roofs (BMP 20), storm water planters (BMP 21), sand filters (BMP 12), or catch basins (BMP 13).

Due to the limitations discussed below, underground detention facilities should only be used after surface-based BMPs, such as wet ponds (BMP 22), extended detention basins (BMP 23), or constructed wetlands (BMP 24), have been thoroughly evaluated and demonstrated to the satisfaction of the local government that they are infeasible.

Limitations

Underground storage facilities cannot provide the equivalent level of treatment accomplished by wet ponds, constructed wetlands, and bioinfiltration swales because neither biological uptake nor vegetative filtration are available as pollutant removal mechanisms. For this reason, storage facilities that discharge to surface waters are discouraged; however, in systems that reuse storm water runoff for landscaping purposes, there is some beneficial nutrient treatment mechanism. Gravity settling of suspended solids within an underground structure is not as effective as open ponds in removing particulates because little or no soil layer exists to permanently stabilize trapped sediments. Sediment can also be remobilized by wash-out or scour during large storm events.

Underground storage facilities are more difficult to inspect and maintain than aboveground systems due to less visibility and restrictive access. Underground systems that release storm water into the subsoil are recommended only for areas with well-drained soils and with adequate separation from ground water to prevent potential contamination.

Underground storage facilities that provide infiltration should be a minimum of 20 feet from any structure, property line, and from any septic tank. Wet vaults and tanks should be a minimum of 100 feet from any domestic well or natural spring. All facilities should be a minimum of 50 feet from any slope steeper than 3H:1V.

The hydrogeological characteristics of the area should be considered before selecting an underground facility with infiltration. The facility's use may be limited in earthquake prone areas due to the potential for liquefaction and in areas of high ground water due to the inability to maintain the minimum vertical separation distance from the water table.

Design Basis

When designing and selecting an underground storage system, take into account the size, shape, and physical characteristics of the site and application-specific conditions. System designs can range from a simple, single storage tank or vault to complex systems consisting of multiple pipes or chambers with accompanying joints, crossovers, inlets, and access points. Table 15 compares design and site considerations for various types of underground systems.

Table 15. Comparison of design considerations for construction materials for underground storm water retention and detention systems (adapted from Parsons Engineering Science, Inc. 2000).

	Concrete Vault	Corrugated Metal Pipe Tank	Plastic Chamber	Other Plastic Systems
Shapes	Rectangular or circular	Circular pipes, or semicircular pipe arches	Semicircular pipe arches	Interconnected cylindrical columns
Spatial Requirements	Primarily continuous space with no angles	Can be fitted into irregular and angled spaces	Can be fitted into irregular and angled spaces	Primarily continuous space with some irregularity
Rigidity/Flexibility	Very rigid, does not require fill to maintain rigidity, not flexible	Rigid, requires fill for stability; can withstand some shifting without breaking or buckling	Rigid, requires fill for stability; not flexible	Rigid, requires fill for stability; not flexible
Fill Requirements	Requires minimum fill above structure	Requires minimum fill between and above pipes	Requires minimum fill between and above pipes	Requires minimum fill above structure; May require geogrid below cells and above existing subsoil
Other Requirements	None	Requires minimum spacing between pipes	Requires minimum spacing between pipes. Water table must be below level of pipe.	Water table must be below level of cells.
Available Sizes	Multiple sizes that can be precast or cast-in-place	12 to 144 inch diameters and pipe arches are available preassembled. Larger diameter pipe and pipe arches are available for assembly on site.	Multiple pipe arch sizes are available; generally 16 to 60 inches high; all are premanufactured.	Multiple cell sizes are available; generally 40 inches long x 40 inches wide x 4 inches high; all are premanufactured
Handling	Requires moving equipment	Requires moving equipment	Can be moved by hand	Can be moved by hand

Volume

Once the type of storage system is selected, the amount of required storage volume should be determined. In general, the design volumes for an underground detention or retention facility should be the same as for aboveground facilities and are based on the runoff from the total tributary drainage area and allowable release rates from the site. Section 3.5.3 provides additional information on calculating the runoff volume of the design storm.

Proprietary systems should be designed according to the manufacturer’s recommendations. Sizing methodologies for proprietary devices vary and can be flow or volume based, or can consider surface and filter hydraulic load.

Water Quality

Water quality enhancement can be provided via particle settling within vault forebays, sump catch basin inlets, or chamber interceptor rows sized to accommodate the water quality capture volume; one-third of the 2-year, 24-hour design storm unless local regulations specify otherwise.

Geometry

Vaults

Typical design details and concepts for wet vaults are shown in Figure 71.

Wet vaults should be divided into two cells using a wall or removable baffle, with the first cell, the forebay, occupying about 25% of the area with a volume equal to the water quality capture volume. If a wall is used, a 5- x 10-foot removable maintenance access must be provided for both cells. If the vault is less than 2,000 ft^3, or if the length-to-width ratio of the vault pool is 5:1 or greater, the baffle or wall may be omitted. If a removable baffle is used, the following criteria apply:

1. The baffle shall extend from a minimum of 1 foot above the design water surface to a minimum of 1 foot below the invert elevation of the inlet pipe.
2. The lowest point of the baffle shall be a minimum of 2 feet from the bottom of the vault, and greater if feasible.

The bottom of the first cell should be sloped toward the access opening. Slope should be between 0.5% and 2%. The second cell may be level (longitudinally) sloped toward the outlet, with a high point between the first and second cells. The vault bottom should slope laterally a minimum of 5% from each side towards the center, forming a broad “v” to facilitate sediment removal.

The highest point of the vault bottom must be at least 6 inches below the outlet elevation to provide for sediment storage over the entire bottom. Sediment storage depth in the first cell should be an average of 1 foot measured from the bottom of the “v.” The second cell should be a minimum of 3 feet deep.

Tanks

Typical design details and concepts for underground detention tanks are shown in Figure 72 and Figure 73.

Generally 36-inch minimum pipe diameter is used for detention tanks. Tanks larger than 36 inches may be connected to each adjoining structure with a short section (2-foot maximum length) of 36-inch minimum diameter pipe. The detention tank bottom should be located 0.5 feet below the inlet and outlet to provide dead storage for sediment.

Chambers and Proprietary Systems

Follow the manufacturer’s recommendations for the geometric layout of the plastic chamber or other proprietary plastic systems.

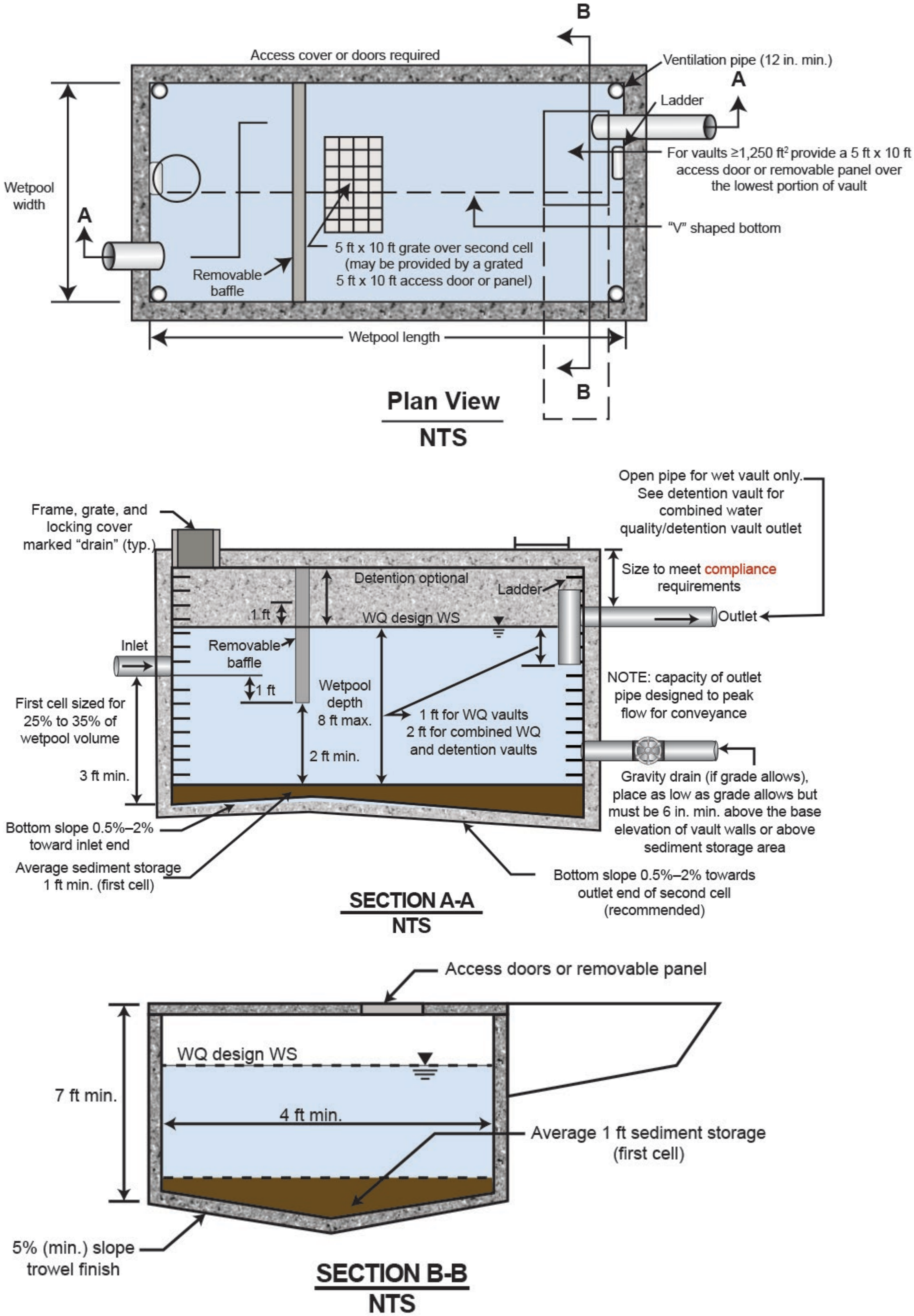


Figure 71. Wet vault (Washington State Department of Ecology 2012).

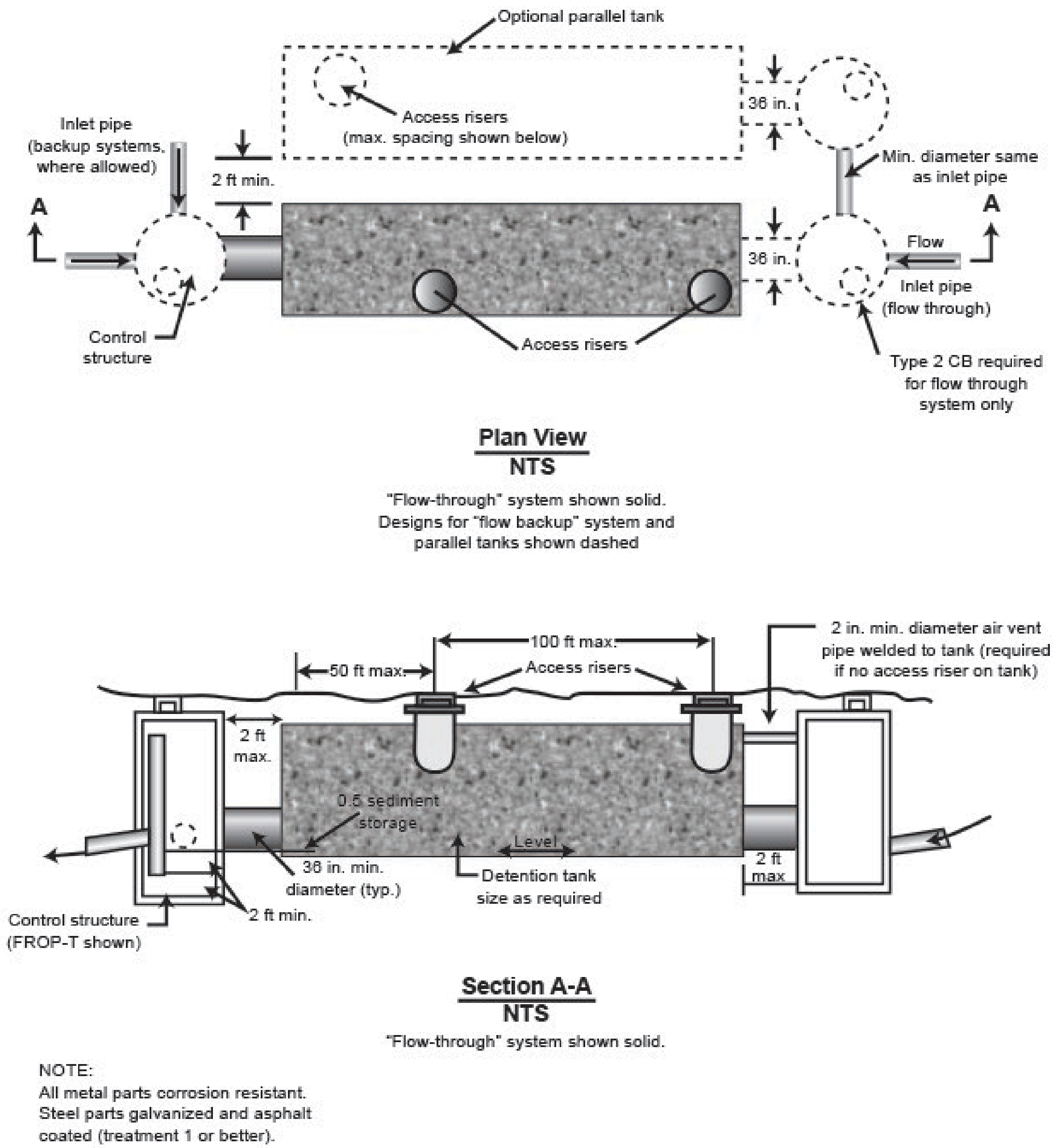


Figure 72. Detention tank (Washington State Department of Ecology 2012).

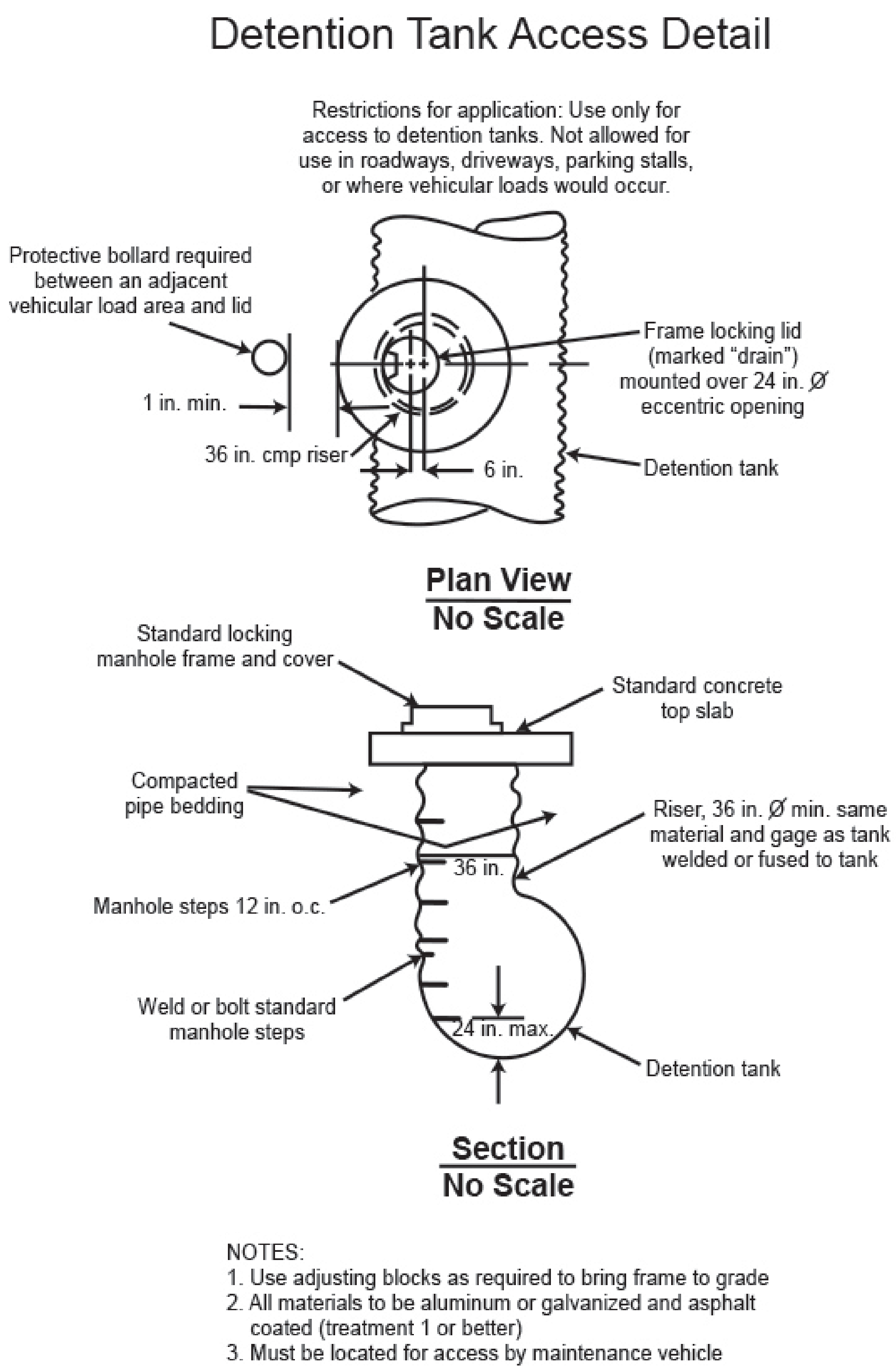


Figure 73. Detention tank access detail.

Materials

Concrete

A minimum of 3,000 pounds per square inch of structural reinforced concrete is required. All construction joints should be provided with water stops. A structural engineer should design precast vaults.

Corrugated Metal Pipe

Pipe material, joints, and protective treatment for tanks should be according to ITD standards and specifications and American Association of State Highway and Transportation Officials (AASHTO) designations. Galvanized metals are discouraged due to potential zinc leaching, which can be toxic to aquatic life, into the environment in standing water situations.

Plastic

Chambers and other proprietary systems should be manufactured from virgin polypropylene or polyethylene resins using ASTM F2787, “Standard Practice for Structural Design of Thermoplastic Corrugated Wall Stormwater Collection Chambers.”

Structural Stability

All vaults, tanks, chambers, and other underground storage facilities should meet structural requirements for overburden support and the AASHTO code HS-20 for traffic load, if appropriate.

Cast-in-place wall sections for vaults should be designed as retaining walls. A structural engineer licensed in Idaho should stamp all structural vault designs. Structural designs for cast-in-place vaults may require a separate commercial building permit from the local government.

Metal tank end plates should be designed for structural stability at maximum hydrostatic load conditions. Flat end plates generally require thicker gauge material than the pipe and/or require reinforcing ribs.

Place vaults and tanks on native material with suitable bedding. Vaults and tanks should not be allowed in fill slopes unless analyzed in a geotechnical report for stability and construction practices. Install proprietary systems according to the manufacturer’s recommendations.

Buoyancy

In moderately pervious soils where seasonal ground water may induce flotation, buoyancy tendencies should be balanced by ballasting with either backfill or concrete backfill, providing concrete anchors, increasing the total weight, or by providing subsurface drains to permanently lower the ground water table. Submit calculations that demonstrate stability.

Minimum Access Requirements

To facilitate inspection and maintenance, all underground storm water facilities should have adequate access openings that are readily accessible by maintenance vehicles. Access roads are

required to at least one access cover for each cell. The access roads should meet the requirements for access roads described in the maintenance details for wet ponds (BMP 22).

Chambers and other proprietary systems should have access according to the manufacturer's recommendations. All underground facility accesses should comply with OSHA confined space requirements, which includes clearly marking entrances to confined space areas.

Vaults

Provide one access cover per 50 feet of length or width and at least one access cover per cell with a ladder to the bottom of the vault. The minimum internal height should be 7 feet, and the minimum width should be 4 feet. The maximum depth to the vault invert should be 20 feet. (Note: concrete vaults may be a minimum of 3 feet in height and width if used as tanks with access manholes at each end.) All vault access openings should have round, solid, locking lids using 1/2- to 5/8-inch diameter allen head screw locks.

Tanks

The maximum depth from finished grade to the bottom of the tank should be 20 feet. Spacing between access openings for tanks should not exceed 100 feet.

Construction Guidelines

Proper installation is important and may require assembly of special baffling or patented inserts that may not be familiar to contractors. Construction observation by the design engineer and a manufacturer's representative for proprietary systems is recommended to ensure proper installation.

Maintenance

Regular inspections and maintenance are important for proper operation of underground detention and retention facilities. Initially, inspections should occur on a quarterly basis with maintenance performed as needed. Inspection frequency may be reduced if, after 2 or more years, the quarterly regimen demonstrates that this will provide adequate maintenance. Table 16 provides guidelines for maintenance.

Table 16. Specific maintenance requirements for detention vaults and tanks (Washington State Department of Ecology 2012).

Defect	Maintenance Component	Conditions When Maintenance is Needed	Results Expected When Maintenance is Performed
I. Storage area—plugged air vents	Debris and sediment	One-half of the end area of a vent is blocked at any point with debris and sediment. Accumulated sediment depth is 10% of the diameter of the storage area for one-half the length of the storage vault or any point exceeds 15% of the diameter. Any crack allowing material to be transported into the facility.	All sediment and debris removed from storage area. Vents free of debris and sediment. All joints between tank and pipe sections are sealed.
II. Manhole cover not in place	Locking mechanism not working	Cover difficult to remove. Ladder rungs unsafe. Cover is missing or only partially in place. Any open manhole requires maintenance. Mechanism cannot be opened by one maintenance person with proper tools. Bolts into frame have <1/2 inch of thread (may not apply to self-locking lids). One maintenance person cannot remove lid after applying 800 pounds of lift. Intent is to keep cover from sealing off access to maintenance. Local government safety officer and/or maintenance person judge that ladder is unsafe due to missing rungs, misalignment, rust, or cracks.	Manhole is closed. Mechanism opens with proper tools. Cover can be removed and reinstalled by one maintenance person. Ladder meets design standards and allows maintenance persons safe access.

Additional Resources

EPA (US Environmental Protection Agency). 2001. *Storm Water Technology Fact Sheet*, *On-Site Underground Retention/Detention*. Washington, DC: Office of Water. EPA 832-F-01-005. *http://water.epa.gov/scitech/wastetech/upload/2002_06_28_mtb_runoff.pdf*.

Washington State Department of Ecology. 2012. *Stormwater Management Manual for Western Washington*. Lacey, WA. Publ. 12-10-030. *http://www.ecy.wa.gov/programs/wq/stormwater/manual.html*

BMP 27: Rainwater Harvesting and Reuse

Description

Rainwater harvesting collects and stores storm water runoff from impervious surfaces for future reuse. Rainwater harvesting and reuse reduce the volume of runoff water that leaves a site and attenuates peak discharges, which reduces the potential for flooding and erosion runoff.

Rainwater is most often captured from rooftops, although runoff from paved surfaces can also be reused if adequate pretreatment occurs to capture oil, grease, and sediment. Storage containers include rain barrels, cisterns, tanks, or premanufactured containment systems. Rain and snow can be reused for irrigation and other nonpotable uses (Figure 74).

Figure 74. Underground rainwater cistern installed at the Banner Bank building, Boise, Idaho.

Primary BMP Functions and Controls

☐ Construction ☒ Permanent
☐ Erosion Control ☐ Sediment Control
☐ Source Control ☒ Flood Control
☐ Filtration ☐ Infiltration

Typical Effectiveness for Targeted Pollutants

◖ Sediment
◖ Phosphorus
◖ Metals
◖ Bacteria
◖ Hydrocarbons
○ Litter

Other BMP Considerations

Relative Cost	$
Maintenance Requirements	Medium
Ease of Installation	Medium
Freeze/Thaw Resistance	Fair
Max. Tributary Drainage Area	N/A
Max. Upstream Slope	N/A
NRCS Soil Group	N/A
Min. Ground Water Separation	N/A
Min. Bedrock Separation	N/A

Applicability

Rainwater harvesting and reuse are applicable on any site and are especially valuable in regions with rainy spring weather and dry summers where supplemental irrigation is often necessary. It can be used on small, residential lots and large, commercial sites. Under Idaho law, diffused surface waters including rainwater, melting snow, and flood waters that are not in a watercourse can be captured and used by a landowner if it does not cause injury to the existing water rights of others.

Limitations

For the practice to be effective, the rainwater collected must be used. On residential lots, landscape areas must be available for rainwater use, and the homeowner must be willing to maintain and operate the system.

Harvesting and reuse systems capture a relatively small storm event so an overflow system is needed. Freezing conditions should also be addressed.

Design Basis

A rainwater harvesting system consists of four basic elements: collection area, conveyance system, storage facilities, and distribution system. In most cases, the collection area is the roof of a house or building. The effective roof area and material used in constructing the roof influence collection efficiency and water quality (OAS 1995). A conveyance system usually consists of gutters or pipes that deliver rainwater falling on the rooftop to a storage unit. Storage facility options include rain barrels, storage tanks, cisterns, or premanufactured systems. The distribution system consists of pipes and pumps that deliver the stored water to the point of reuse.

Figure 75. Rain barrel (CT DEEP 2009).

Storage Systems

Drainpipes, roof surfaces, and storage containers should be constructed of chemically inert materials such as wood, plastic, aluminum, or fiberglass, to avoid adverse effects on water quality (OAS 1995). A variety of storage systems are available in a range of sizes to fit many different applications.

Rain barrels are used at individual homes or commercial or institutional developments where the volume of water to be captured is small (Figure 75). Captured water is most often reused for garden and landscape irrigation, and many rain barrels are equipped with a drain spigot with garden hose threading that can be connected directly to an irrigation system. Rain barrels can be incorporated into the site’s landscape, and premanufactured residential use cisterns come in sizes ranging from 100 to 1,400 gallons.

Cisterns are containers or tanks with greater storage capacity than rain barrels. Cisterns may be comprised of fiberglass, concrete, plastic, brick, or other materials and can be located either above or below ground. The storage capacity of cisterns can range from 200 to 10,000 gallons.

Figure 76. Wood-wrapped cistern (EPA 2016).

Vertical storage containers are stand-alone towers or fat downspouts that usually rest against a building and are designed to hold large volumes of storm water (Figure 76). As the largest of the capture reuse containers, they are best used for intensive irrigation needs or fire suppression requirements for larger commercial buildings. They should be designed by a licensed professional.

Storage beneath structures store storm water runoff below ground, under pavement, and under landscaped surfaces using premanufactured structural plastic storage units. These structures provide large storage volumes without additional structural support for the pavement or landscape

surface, although they will require pumps to convey the water for aboveground uses. These systems should be designed according to the manufacturer's guidelines by a licensed professional.

Sizing Considerations

Several factors must be considered when sizing the rainwater reuse storage container—the collection area, annual rainfall, intended use of rainwater, and cost. Proper sizing requires completing a water budget analysis that considers the balance between the volume of rainwater that can be captured and reuse needs and timing.

Rainwater harvesting systems are generally designed to capture small, frequent storm events. The amount of rainwater that can be captured is a function of the collection area and the average annual precipitation, and can be calculated using Equation 26:

$$V = 0.62 \text{ x } C \text{ x } P \text{ x } A$$

Equation 26. Volume for rainwater capture.

Where

V = available rainwater volume for capture (gallons)

0.62 = unit conversion (gallons per inch per square foot)

C = volumetric runoff coefficient (unitless), typically 0.9 to 0.95 for impervious areas

P = precipitation amount (inches)

A = drainage area to cistern (square feet)

The timing and volume of rainwater that is expected to be captured should be balanced with the volume and timing of reuse water needed. Ideally, use and release of stored water would occur between storm events so storm water storage volume is available for the next storm event, which minimizes tank size and reduces storage costs. In cases where the water reuse need exceeds the available runoff volume, the storage volume can be assumed equal to the available rainwater volume for capture.

Pretreatment

The need for additional treatment to remove oil, grease, or sediment depends on the type of surface within the drainage collection area. Generally, runoff from rooftops contains minimal sediment and low concentrations of pollutants. Paved nonvehicular surfaces or those with light traffic are suitable for water harvesting and may require screening to filter debris from storage units. Screens should be made of a durable, noncorrodible material and be easily maintainable. Installing the outflow pipe on a float with the outlet located below the water surface is a simple way to prevent floatables from entering the reuse system. Storage units that accept runoff from high traffic paved surfaces may need oil and water separators (BMP 15), hydrodynamic separators (BMP 16), or mechanical filters (BMPs 12 and 14).

Overflow

An overflow outlet should be provided so that large storm events can pass through the system. The outlet is often provided a few inches from the top of the cistern and sized to safely discharge the

appropriate design storm when the system is full. The overflow should pass through to a downstream storm water conveyance system designed to handle the major storm event.

The proximity to building foundations should be considered for systems that overflow into an infiltration system. The minimum recommended setback distance for capture and reuse systems is 10 feet.

Siting and Other Considerations

Consider site topography during design; storage containers placed upgradient from the point of reuse can reduce or eliminate pumping needs. Most reuse systems require pressurization to function properly. For example, irrigation systems require at least 15 pounds per square inch (psi) of pressure. Water stored has a pressure of 0.43 psi per foot of water elevation. Thus, a 10-foot tall tank would have a pressure of 0.43 x 10 = 4.3 psi at the bottom of the tank. To add pressure, a pump, pressure tank, and fine mesh filter can be used, which adds to the cost of the system.

Storage containers should be protected from direct sunlight by positioning and landscaping to limit algae growth. Containers should be watertight (joints sealed with nontoxic waterproof material) with a smooth interior surface, and lids should have a tight fit to keep out surface water, animals, dust, and light. Clearly mark storage containers with “Caution: Reclaimed Water, Do Not Drink.” Buried cisterns should have observation risers that extend at least 6 inches above grade.

If the stored water is used to supplement gray water needs, a parallel conveyance system must be installed to separate gray water from other potable water piping systems. Harvested rainwater may be connected to an irrigation system that also receives potable water if it has an approved backflow assembly and meets local plumbing code.

Cold Weather

Climate is an important consideration, and capture/reuse systems should be designed to account for the potential of freezing. Systems should be emptied during the winter months to prevent ice damage. Capturing meltwater from a building will reduce volume, but ice buildup could be a problem unless collection occurs below the frost line.

Construction Guidelines

Premanufactured systems should be installed according to the manufacturer’s instructions.

Maintenance

Rainwater harvesting and reuse systems should be properly maintained. Storage containers should be inspected regularly and after major storm events. Debris should be removed or the system flushed to remove sediment. The inside surfaces of the storage system should be cleaned, and screens, spigots, downspouts, and leaders should be replaced as needed. Check seals periodically to prevent mosquito breeding. Draining the system before winter is also recommended to prevent damage from freezing.

Additional Resources

BASMAA (Bay Area Stormwater Management Agencies Association). 1999. *Start at the Source: Design Guidance Manual for Stormwater Quality Protection*. San Francisco, CA: BASMAA.

Coffman, L. 2000. *Low-Impact Development Design Strategies, an Integrated Design Approach*. Prince George's County, MD: Department of Environmental Resources, Programs and Planning Division. EPA 841-B-00-003.

EPA (US Environmental Protection Agency). 2014. *On-Lot Treatment*. Water: Best Management Practices. *https://www.epa.gov/npdes/national-menu-best-management-practices-bmps-stormwater#edu*

OAS (Organization of American States). 1995. "Rainwater Harvesting from Rooftop Catchments." Section 1.1. *Source Book of Alternative Technologies for Freshwater Augmentation in Latin America and the Caribbean*. *http://www.oas.org/dsd/publications/Unit/oea59e/ch10.htm#1.1 rainwater harvesting from rooftop catchments*

Pima County Flood Control District. 2018. *Water Harvesting.* *http://webcms.pima.gov/cms/one.aspx?portalId=169&pageId=66016*

Texas Water Development Board. 1997. *Texas Guide to Rainwater Harvesting*. Austin, TX. *http://lubbock.tamu.edu/files/2011/10/RainHarv.pdf*.

BMP 28: Conveyance Furrows for Roof Runoff

Description

Conveyance furrows are a series of parallel linear or gradually meandering depressions that slow and convey storm water runoff by being oriented perpendicular to the fall line of a slope. Conveyance furrows can be either vegetated or lined with drainrock. Vegetated furrows can also enhance storm water infiltration and filtering depending on the soil quality, shape, and length of the conveyance furrow (Figure 77).

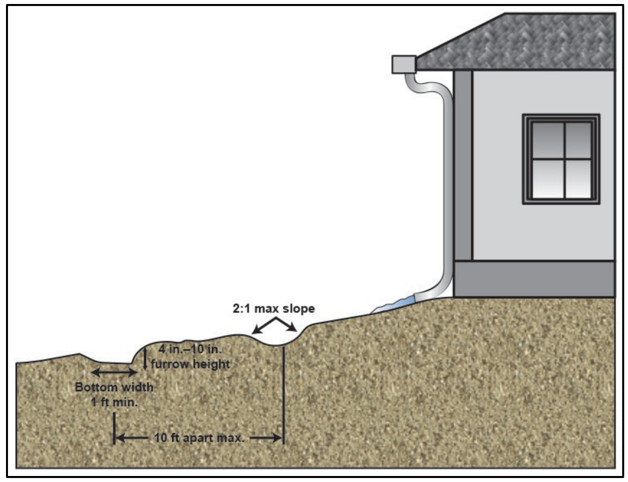


Figure 77. Conveyance furrows (City of Normandy Park 2015).

Unlike terracing (BMP 59), which may be a permanent or temporary measure, furrows are a permanent solution for erosion prevention. Gradient terracing may be used to control runoff from drainage areas up to 10 acres, but furrows are used for smaller contributing drainage areas such as rooftop runoff.

Applicability

Conveyance furrows are most appropriate for steeper slopes (15% or more) within the area between a roof downspout and the roadway.

Limitations

It can be difficult to grade the bottom of the furrow perfectly level and prevent concentration of flows.

Volume and velocity can also be a limiting factor in that too much of either can cause eroded cuts to develop on the downslope edge of the furrows.

The drainage area for conveyance furrows is typically that of a single-family residence but may be used in areas where less than 10,000 ft^2 of impervious surface will result from the proposed project.

Additionally, on smaller lots (less than 2 acres), if the amount of impervious surfaces exceeds either 10% of the total lot area or 5,000 ft^2, whichever is greater, engineered drainage plans may be required.

Primary BMP Functions and Controls

☐ Construction	☒ Permanent
☒ Erosion Control	☒ Sediment Control
☐ Source Control	☐ Flood Control
☒ Filtration	☒ Infiltration

Typical Effectiveness for Targeted Pollutants

●	Sediment
◖	Phosphorus
◖	Metals
○	Bacteria
○	Hydrocarbons
○	Litter

Other BMP Considerations

Relative Cost	$
Maintenance Requirements	Medium
Ease of Installation	Easy
Freeze/Thaw Resistance	Good
Max. Tributary Drainage Area	Less than 10,000 ft^2
Max. Upstream Slope	25%
NRCS Soil Group	ABCD
Min. Ground Water Separation	3 feet
Min. Bedrock Separation	6 feet

Design Basis

The following guidelines apply to conveyance furrows:

- At a minimum, construct one furrow for each foot of vertical drop, with a maximum spacing of 10 feet between furrows along the flow path.
- Construct furrow depressions bottoms in a variety of ways including concave, insloped, or flat.
- To prevent concentration of flows, ensure the downslope edge of the furrows are level and run along the contour of the land. Take care when constructing the level downslope edge as inconsistencies may lead to a concentrated overflow in a single area as opposed to the uniform overflow desired.
- Use uncompacted and amended soil to facilitate vegetative growth and promote infiltration.
- Use vegetated conveyance furrows, although drainrock conveyance furrows are acceptable.
- Line vegetated furrows with an erosion control mat to minimize erosion until plants are established.
- Plant vegetated conveyance furrows with a variety of grasses, annuals, perennials, or woody herbaceous plants that are appropriate for moist and seasonally dry conditions.
- Slope sides no more than 2H:1V.
- Ensure the bottom is a minimum of 1 foot wide.
- Ensure conveyance furrow depth is sized as shown in Table 17.

Table 17. Conveyance furrow depth for roof runoff (SvR Design Company 2006).

Roof or Tributary Drainage Area	Less Than 1% Positive Slope	1%–8% Positive Slope	8%–25% Positive Slope	25%+ Positive Slope
Under 500 ft^2	Not needed	Not needed	Not needed	Not needed
500–1,000 ft^2	Piped flow necessary	3 inches	3 inches	3 inches with velocity reduction
1,000–1,750 ft^2	Piped flow necessary	4 inches	4 inches	4 inches with velocity reduction
Over 1,750 ft^2	Piped flow necessary	Engineer calculations required	Engineer calculations required	Engineer calculations required

Construction Guidelines

Take care during construction to not over compact the area where conveyance furrows will be installed (BMP 45: Minimize Soil Compaction). Vegetated furrows should be stabilized temporarily until permanent vegetation can be established (BMP 54: Matting or BMP 52: Mulching).

Maintenance

After major storm events, check conveyance furrows to ensure the flow path has not been clogged with debris. The furrows should also be inspected annually for rutting, bare spots, or other erosion, and the appropriate repairs should be made.

For furrows that are vegetated, supplemental irrigation may be needed for 1 to 2 years until the vegetation is fully established.

Additional Resources

City of Normandy Park (City of Normandy Park, Washington). 2015. *Normandy Park Municipal Code.* "Drainage and Water Quality." Chapter 13.08. *https://www.codepublishing.com/WA/NormandyPark/html/NormandyPark13/NormandyPark1308.html*

SvR Design Company. 2006. *High Point Community Site Drainage Technical Standards*. Prepared for High Point Community, Seattle WA.

BMP 29: Dispersal Trench for Roof Runoff

Description

By managing roof runoff separately through dispersal trenches, the impact from development on storm water discharge volumes and flow rates can be mitigated, and the size of flow and treatment control systems can be reduced. Downspout dispersal trenches are gravel-filled trenches that spread roof runoff over vegetated, pervious areas. Dispersion attenuates peak flows by slowing entry of runoff into the conveyance system, allowing some infiltration and providing some water quality benefits such as filtration and vegetative uptake (Figure 78).

Figure 78. Dispersal trench (Northern Virginia SWCD 2017).

Dispersal trenches are one of many options to treat roof runoff separately from surface runoff and may either receive runoff directly from a roof downspout or via surface flow.

Primary BMP Functions and Controls

☐ Construction	☒ Permanent
☒ Erosion Control	☐ Sediment Control
☒ Source Control	☒ Flood Control
☐ Filtration	☒ Infiltration

Typical Effectiveness for Targeted Pollutants

○	Sediment
○	Nitrogen
○	Phosphorus
○	Metals
○	Bacteria
○	Hydrocarbons
○	Litter

Other BMP Considerations

Relative Cost	$
Maintenance Requirements	Low
Ease of Installation	Easy
Freeze/Thaw Resistance	Fair
Max. Tributary Drainage Area	7,500 ft^2
Max. Upstream Slope	20%
NRCS Soil Group	ABC
Min. Ground Water Separation	3 feet
Min. Bedrock Separation	3 feet

Applicability

Dispersal trenches are applicable in any situation where site soil conditions have suitable infiltration rates and local regulations allow roof runoff to be directly infiltrated to ground water without treatment. Depending on their design and configuration, dispersal trenches may require filing an underground injection inventory form with IDWR. Check with IDWR for *underground injection well* requirements.

Limitations

Limit use of dispersion to cases where no risk of flooding or erosion to downstream properties may result.

Some sites may be limited by soil groups or steep slopes. The discharge point of dispersion systems shall be setback at least 50 feet from the top of a slope of 15% or greater with a height of 10 feet. A geotechnical analysis and report must be prepared addressing the potential impact of the facility on the slope.

Sites with soils in NRCS soil group D with low hydraulic conductivity may not be suitable for installing dispersal trenches.

Design Basis

The following generalized design process is suggested for downspout dispersion systems (adapted from Thurston County 2016):

- If contributing roof area is less than 700 ft^2, a standard dispersion trench design is recommended. If greater than 700 ft^2, only a dispersion trench with a grade board should be used as shown in Figure 79.
- The trench shall provide at least 10 feet of trench length per 700 ft^2 of roof area. Calculate the trench length required by dividing the roof area in square feet by 700 and then multiplying by 10 to determine the required dispersion trench length in feet (i.e., if roof area is 3,200 ft^2, then the required trench length is 3,200/700 x 10 = 45.7 feet).
- Maximum trench length is 50 feet. If multiple trenches are required, ensure that trench separation of 50 feet is met between trench dispersion systems.
- The trench should be a minimum 10 feet long x 2 feet wide x 2 feet deep.
- A vegetated flow path of at least 25 feet long should be maintained between the outlet of the trench and any property line, structure, critical area, or impervious surface. The width of the dispersion area shall be at least the width of the dispersion trench.
- A 4-inch perforated pipe with a crown elevation 6 inches below the surface of the trench should be installed.
- A small catch basin or yard drain with a 12-inch minimum catch depth and outlet with screen should be provided upstream from the dispersion trench.

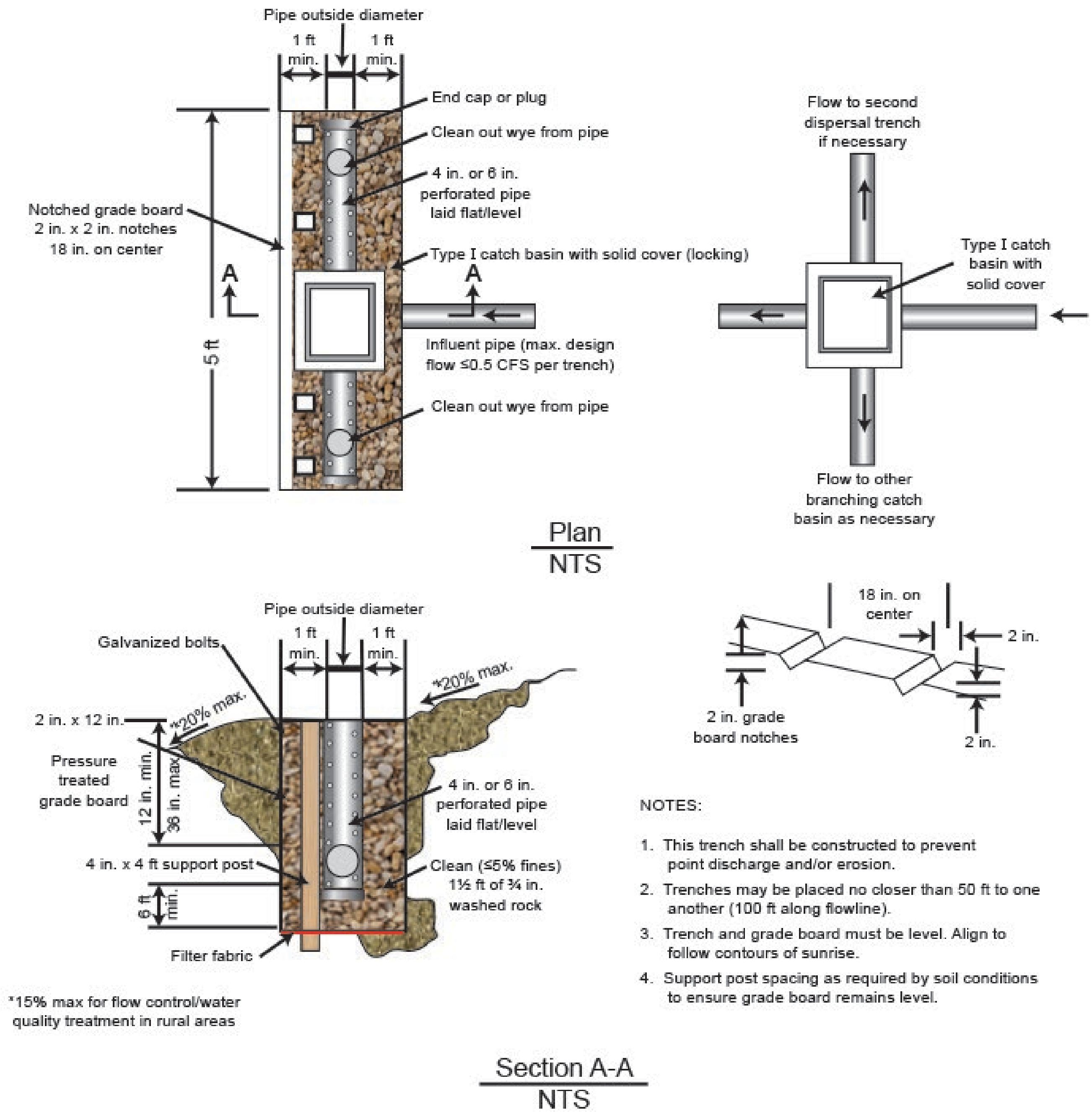


Figure 79. Dispersal trench with grade board (Thurston County 2016; King County 2009).

Construction Guidelines

During construction, cover trenches on the same day they are opened.

Maintenance

Dispersal trenches should be inspected after large storm events and annually after leaf drop-off. Debris from landscaping and leaf drop-off should be frequently removed from the surface of the dispersal trench and the upstream catch basin.

Additional Resources

CASQA (California Stormwater Quality Association). 2004. *California Stormwater Best Management Practices Handbook: New Development and Redevelopment*. Menlo Park, CA. *https://www.casqa.org*

King County (King County Department of Natural Resources and Parks). 2009. *King County Surface Water Design Manual.* Seattle WA.

SvR Design Company. 2006. *High Point Community Site Drainage Technical Standards.* Prepared for High Point Community, Seattle WA.

Thurston County, Washington. 2016. *Thurston County Drainage Design and Erosion Control Manual*. Olympia, WA: Water Resources Division, Department of Resource Stewardship.

BMP 30: Level Spreader

Description

A level spreader dissipates energy and reduces the erosive potential of concentrated flow from channels, pipes, or other conveyance structures by converting the runoff to sheet flow and uniformly distributing the flow over a large stabilized area. Although a level spreader by itself is not considered a pollutant reduction device, it improves the efficiency of other facilities, such as natural buffers (BMP 2), vegetated swales (BMP 9), vegetated filter strips (BMP 11), or infiltration devices that depend on sheet flow to operate properly (Figure 80).

Figure 80. Level spreader (on left) takes concentrated flow from a pipe and distributes it as sheet flow.

Primary BMP Functions and Controls

☐ Construction	☒ Permanent
☒ Erosion Control	☐ Sediment Control
☐ Source Control	☐ Flood Control
☐ Filtration	☐ Infiltration

Typical Effectiveness for Targeted Pollutants

○	Sediment
○	Nitrogen
○	Phosphorus
○	Metals
○	Bacteria
○	Hydrocarbons
○	Litter

Other BMP Considerations

Relative Cost	$
Maintenance Requirements	Low
Ease of Installation	Easy
Freeze/Thaw Resistance	Fair
Max. Tributary Drainage Area	5 acres
Max. Upstream Slope	1%
NRCS Soil Group	BCD
Min. Ground Water Separation	NA
Min. Bedrock Separation	NA

Applicability

Level spreaders are most applicable to discharge where the slopes are gentle, runoff volume is relatively low, and soil will absorb most of the low flow events. The downstream area receiving flow from a level spreader should be fully stabilized and not susceptible to erosion if flow leaves the site or enters surface water.

Limitations

Level spreaders are not recommended in areas with easily erodible soils and/or little vegetation as they do not remove sediment and can quickly lose effectiveness if they are overwhelmed with sediment. Upstream sediment removal BMPs may be needed in addition to the level spreader in certain areas. Level spreaders require large, relatively flat areas to be effective, and they must remain level, which can be difficult to achieve. If the spreader is not absolutely level, flows will concentrate at the low point and create erosive channels. For these reasons, using level spreaders on construction sites may be limited.

Design Basis

Different types of level spreaders are shown in Figure 81, but they all have following in common.

- Concentrated flow enters the spreader through a pipe, ditch, or swale.

- The flow velocity is reduced, and energy is dissipated.
- The flow is distributed throughout a long linear shallow trench or behind a low berm.
- Water then flows over the berm or ditch, and theoretically, flows uniformly along the entire length.

Erosion control matting or a geotextile is recommended immediately downhill and along the entire length of the level spreader, particularly in unstable areas or in areas recently disturbed by construction activity.

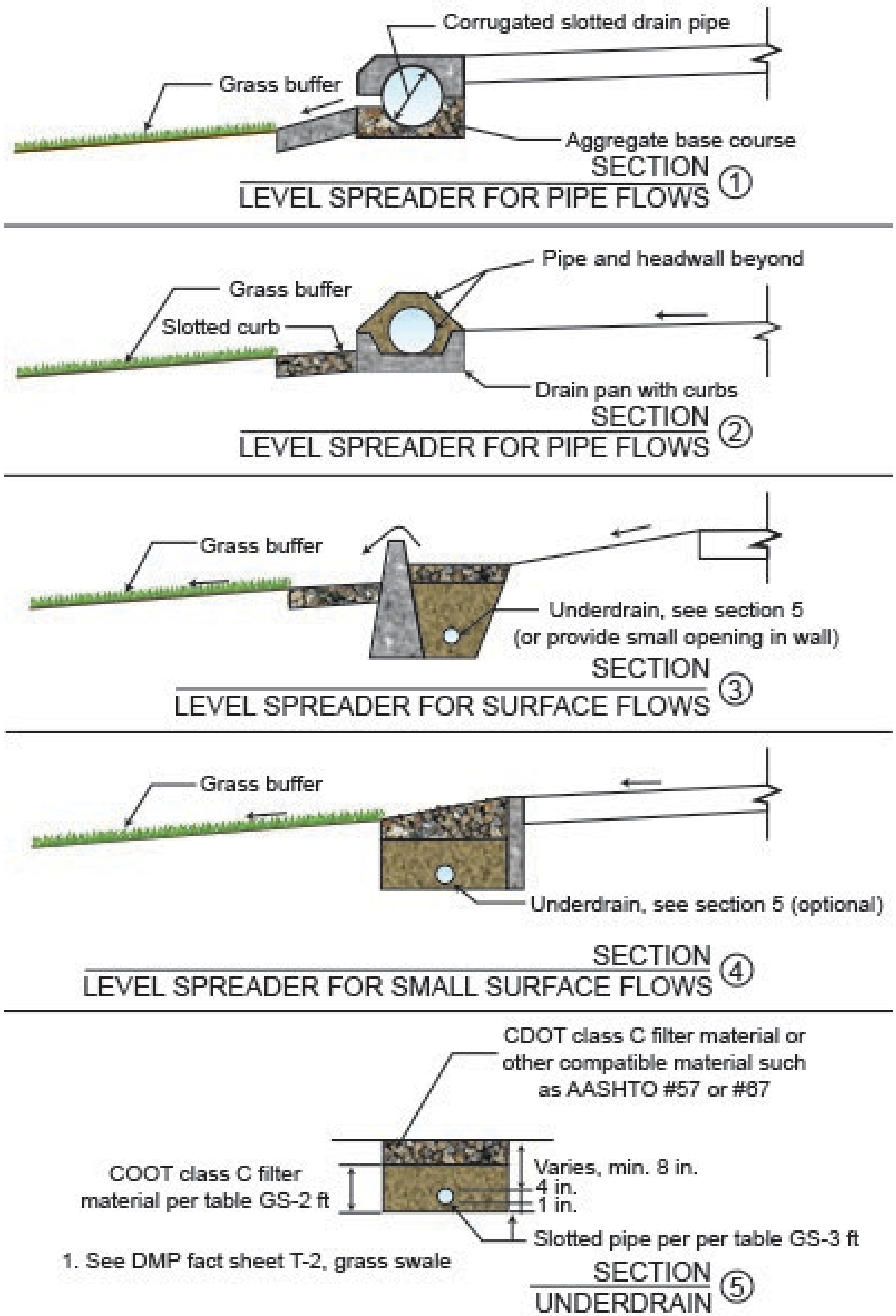


Figure 81. Typical details for level spreaders (Colorado UDFCD 2010).

Level Spreader Slope

The slope leading to the level spreader should be less than 1% for at least 20 feet immediately upstream to keep velocities low. The slope downgradient from the spreader should be 6% or less.

Level Spreader Length

The length of the level spreader should be determined based on peak flow rates and the maximum allowable downstream velocity. Flow over a level spreader is characterized by weir flow conditions, and the required length can be determined given the downstream design velocity and peak flow rate to the spreader. In general, the spreader length should be a minimum of 10 feet and maximum of 130 feet, ensuring a depth of flow over the spreader limited to 6 inches during the design storm event. Assuming that the approach velocity to the level spreader is insignificant, the level spreader length can be determined using Equation 27 for a broad crested weir and Equation 28 for the continuity equation.

$$Q = Cw \cdot L \cdot H^{3/2}$$

Equation 27. Broad crested weir.

Where
- Q = flow
- L = length of level spreader
- Cw = weir coefficient (2.6 to 3.3)
- H = driving head (Figure 82)

$$Q = V \cdot A$$

Equation 28. Continuity.

Where
- Q = flow
- V = velocity (see Level Spreader Design Velocities)
- A = cross-sectional area of flow = (L 2/3 H)

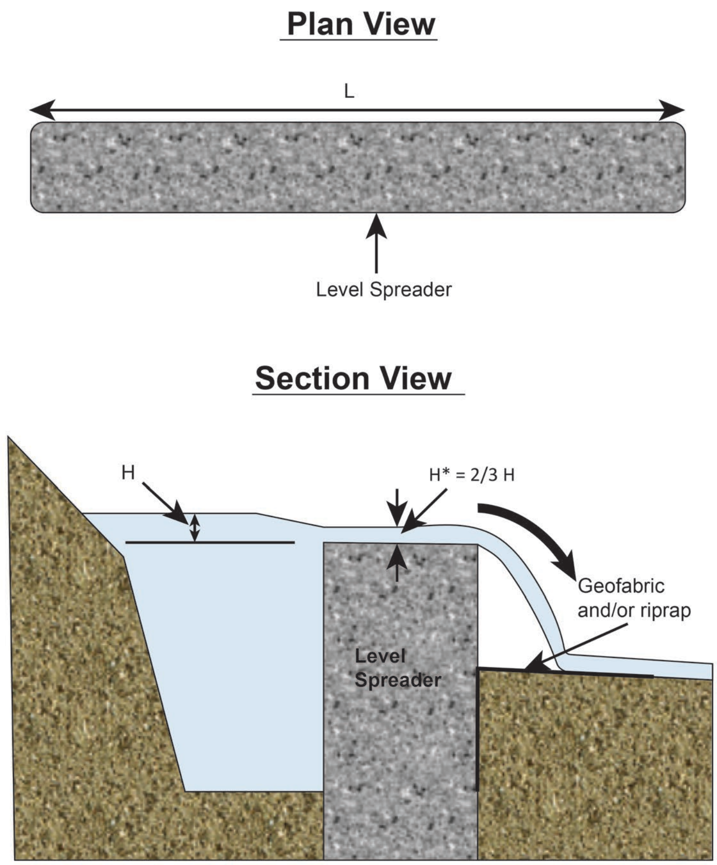


Figure 82. Level spreader as a broad crested weir (Hunt 2001).

Level Spreader Design Velocities

Generally, a design velocity of less than 2 feet per second is desired at the lip of the spreader during the 10-year, 24-hour storm event. If velocities exceed 4 feet per second, install a riprap apron upstream of the level spreader. However, different ground coverings have different allowable velocities (the maximum velocity of water before it causes erosion). A design velocity equal to one-third of the erosive velocity is recommended to account for recollecting flows downstream of the level spreader (Hunt 2001) (Table 18).

Table 18. Allowable and design velocity based on ground cover (adapted from Hunt 2001).

Ground Cover	Allowable Velocity (feet per second)	Design Velocity (feet per second)	Maximum Flow Depth Over Level Spreader, H (feet)
Grass	4	1.33	0.09
Gravel	5	1.5	0.11
Thicket (shrubs, grass)	4	1.33	0.09
Mulch	2	0.67	0.02

Construction Guidelines

The spreader must be constructed absolutely level. Permanent vegetative stabilization should be in place before the level spreader becomes operational.

Avoid constructing level spreaders upstream of disturbed area. If a level spreader is installed above a disturbed area without a good vegetative stand, such as grass or trees, or other ground cover such as mulch or construction matting, erosion rills will quickly form. Even sheet flow can initially cause significant downstream erosion on disturbed areas.

Do not construct level spreaders in newly deposited fill dirt. Virgin earth is much more resistant to erosion than fill. Even with what appears to be a good young stand of grass over fill dirt, erosion is likely to occur. Place level spreaders away from newly deposited earth.

The contractor should avoid placing any material on the structure and should prevent construction traffic from crossing over the structure. If the spreader is damaged by construction traffic, it shall be immediately repaired.

Maintenance

Regularly inspect the level spreader, especially after a large rainfall event. Inspections should note and repair any erosion downgradient of the spreader. Maintenance includes fixing any low spots contributing to the erosion and removing sediment from both in front of and behind the spreader.

Additional Resources

CALTRANS (California Department of Transportation). 2002. *Level Spreader Effectiveness Evaluation Final Report*. Sacramento, CA: Office of Environmental Engineering. CTSW-RT-02-020. *http://www.dot.ca.gov/hq/env/stormwater/pdf/CTSW-RT-02-020.pdf*

Colorado UDFCD (Colorado Urban Drainage and Flood Control District). 2010. *Urban Storm Drainage Criteria Manual, Volume 3 Best Management Practices*. Denver, CO. *http://udfcd.org/wp-content/uploads/2014/07/Title-Page.pdf*

Hunt, W.F. et al. 2001. *Designing Level Spreaders to Treat Stormwater Runoff*. Raleigh, NC: North Carolina State University.

King County (King County, Washington). 2009. *King County, Washington Surface Water Design Manual.* Seattle, WA: King County, Department of Natural Resources.

NC State University Cooperative Extension. 2010. "Level Spreader Update: Design, Construction, and Maintenance." *Urban Waterways*. *http://chesapeakestormwater.net/wp-content/uploads/dlm_uploads/2014/06/LevelSpreaderDesign.Update2010.pdf*

Pennsylvania DEP (Pennsylvania Department of Environmental Protection). 2006. *Pennsylvania Stormwater Best Management Practices Manual*. Harrisburg, PA: Pennsylvania DEP. Document number 363-0300-002.

Washington State Department of Ecology. 2012. *Stormwater Management Manual for Western Washington*. Lacey, WA. Publ. 12-10-030. *http://www.ecy.wa.gov/programs/wq/stormwater/manual.html*

BMP 31: Topsoiling

Description

Topsoiling places material suitable for vegetative growth over disturbed lands. Often topsoiling includes native seeds and propagules in the plant growth mix. Topsoiling may involve transporting soils from off site or reusing the existing topsoil that has been stripped and stockpiled during earlier site development activities (Figure 83).

Sites improved with topsoiling are benefitted by additional biofiltration capacity, increased storm water retention and, through a more established root zone, less watering, fertilizing, and pesticide application requirements.

Figure 83. Placing new topsoil on Pioneer Mountain scenic byway, Orofino, Idaho (*Debco Construction*).

Applicability

Topsoiling is recommended on slopes no greater than 2:1 where native soils are unsuitable for vegetative growth. Topsoiling is an effective way to improve plant establishment on sites where moisture, nutrients, or pH levels are low, or where the existing soil is incapable of supporting root systems. This BMP should be used with BMP 32: Landscaping.

Limitations

Topsoil should not be applied over a subsoil of contrasting permeability. Placing clay-like topsoil over a sandy soil may cause the topsoil to separate from the existing subsoil as water flows between the two soil layers of different permeability. Topsoil should not be applied when the subsoil is frozen or extremely wet.

Stockpiling topsoil for an extended period of time disrupts soil health, resulting in the partial or total loss of microorganisms. Mixing the top foot of stockpiled topsoil with the remainder of the stockpiled topsoil before final placement ensures a uniform distribution of living organisms (BMP 44: Stockpile Management).

Primary BMP Functions and Controls

☐ Construction	☒ Permanent
☒ Erosion Control	☐ Sediment Control
☐ Source Control	☐ Flood Control
☐ Filtration	☐ Infiltration

Typical Effectiveness for Targeted Pollutants

◖	Sediment
○	Nitrogen
○	Phosphorus
○	Metals
○	Bacteria
○	Hydrocarbons
○	Litter

Other BMP Considerations

Relative Cost	$
Maintenance Requirements	Low
Ease of Installation	Easy
Freeze/Thaw Resistance	Fair
Max. Tributary Drainage Area	Unlimited
Max. Site Slope	50%
NRCS Soil Group	ABCD
Min. Ground Water Separation	3 feet
Min. Bedrock Separation	2 feet

Design Basis

To the maximum extent practicable, the moisture-holding capacity of the soil should be maintained or increased by reusing native topsoil or adding soil amendments. The topsoil should be uniformly distributed at a minimum compacted depth of 4 inches on slopes 3:1 or steeper, and 8 inches deep or greater on flatter slopes. The soil should be approved by an agronomist and may consist of loam, sandy loam, clay loam, silt loam, sandy clay loam, or other mixtures. It should be free of subsoil debris such as sticks, invasive species, stones larger than 1.5 inch diameter, and other extraneous materials.

Topsoil can be obtained commercially or stripped, stockpiled, and replaced following construction. Stockpiled topsoil should undergo a laboratory analysis to determine organic content, pH, and soluble salts. A pH of 6.0 to 7.5 and organic content of not less than 1.5% by weight is recommended. Where soil pH is less than 6.0, lime may be applied to adjust pH to 6.5 or higher. Any soils having soluble salt content greater than 500 parts per million should not be reused.

The topsoil should be tailored to the type of permanent native vegetation desired on site. Traditional topsoil will favor grasses, while the addition of acidic high-carbon amendments may encourage more woody species.

Construction Guidelines

The following guidelines apply to the placement of topsoil:

- The existing or established grade of subsoil should be maintained.
- Lime may be uniformly applied over designated areas where the subsoil is highly acidic or high in clay content.
- Before spreading topsoil, scarify the subgrade to 4 inches deep to permit bonding of subsoil to topsoil. Ripping or restructuring (BMP 45: Minimize Soil Compaction) the subgrade may be necessary in areas that have been overly compacted to restore the infiltrative capacity of the subgrade. Tracking a bulldozer vertically over the slope will pack the soil and create horizontal erosion check slots to prevent topsoil from sliding down the slope.
- Where quantities of stockpiled topsoil on site are limited, it is more desirable to cover all areas of exposed subsoil to a lesser depth than to cover partial areas to the suggested minimum depth.
- Topsoil should not be placed when the subgrade is frozen, excessively wet, or in a condition that may otherwise be detrimental to proper grading or proposed sodding or vegetation establishment.
- Immediately after topsoil placement, stabilize the soil using landscaping (BMP 32), mulching (BMP 52), matting (BMP 54), or soil binders (BMP 55) before proceeding to the next construction phase.
- Stockpiled topsoil should be protected from erosion (BMP 44: Stockpile Management).

Maintenance

Before a site is fully established, inspect topsoil periodically and after major storm events for signs of erosion such as rills and gullies. Damaged areas should be repaired with additional topsoil and reseeded as necessary to minimize erosion and loss of topsoil.

Additional Resources

ITD (Idaho Transportation Department). 2014. *Best Management Practices.* Boise, ID: ITD.

Washington State Department of Ecology. 2012. *Stormwater Management Manual for Western Washington*. Lacey, WA. Publ. 12-10-030. *http://www.ecy.wa.gov/programs/wq/stormwater/manual.html*

BMP 32: Landscaping

Description

Landscaping on new or redeveloped sites establishes vegetated cover that stabilizes the soil, reduces storm water runoff through infiltration, minimizes invasive species, acts as a long-term biofiltering system, and improves aesthetics. Landscaping methods include seeding, sodding, and planting perennial grasses, legumes, native shrubs or wild flowers, bushes, and trees (Figure 84).

Figure 84. Native and drought tolerant plants (Driggs, Idaho).

Seeding is the practice of planting seeds on a prepared soil surface. Sodding refers to placing rolls or strips of grass-covered mats held together by dense root systems on the soil surface. Planting establishes vegetation using living plants grown to a specified size or age.

Using native and/or drought-resistant vegetation is strongly encouraged for all landscaping efforts. *Stormwater Plant Materials: A Resource Guide* (City of Boise 2000) or the *North Idaho Native and Beneficial Plant List* (Sterling Codifiers 2014) offers additional design guidance about plant selection and landscaping techniques to maximize water quality benefits.

Primary BMP Functions and Controls

☒ Construction	☒ Permanent
☒ Erosion Control	☒ Sediment Control
☐ Source Control	☐ Flood Control
☒ Filtration	☐ Infiltration

Typical Effectiveness for Targeted Pollutants

◖	Sediment
○	Nitrogen
◖	Phosphorus
◖	Metals
○	Bacteria
○	Hydrocarbons
○	Litter

Other BMP Considerations

Relative Cost	$
Maintenance Requirements	Low
Ease of Installation	Easy
Freeze/Thaw Resistance	Good
Max. Tributary Drainage Area	Unlimited
Max. Site Slope	Varies
NRCS Soil Group	ABCD
Min. Ground Water Separation	3 feet
Min. Bedrock Separation	3 feet

Applicability

Landscaping can be applied and is encouraged on all sites, even those in urban environments. Seeding and sodding can be used for permanent erosion control. Sodding and planting is most appropriate in locations where vegetation establishment is needed quickly, such as immediate erosion control. Possible uses for sod include buffer zones, dikes, swales, slopes, outlets, level spreaders, and filter strips.

Planting is most appropriate for permanent vegetation establishment where seeding and other slope treatments are either not effective or not appropriate. Such areas may include the following:

- Extremely rocky slopes or areas with generally poor soils.
- Areas or sites with established natural vegetation in significant amounts, which are difficult to seed and mulch effectively.
- Areas where special attention to landscape aesthetics or biological diversity is needed.
- Wetlands and wildlife habitat areas where it may be critical to plant the desired species initially so that the site is not overrun by weeds or undesirable plant species that detract from the intended use of the site.
- Where specific types of trees and shrubs are necessary to remove excess moisture from the soil.
- In areas that require soil stabilization and erosion control sooner than can be provided by seeding, such as along streams, rivers, and lakes (the riparian edge).

Limitations

All landscaping should take place at the proper time of year for both the method of application (seeding, sodding, and planting) and the specific species involved. Generally, it is not recommended to landscape during very hot and dry weather. Depending on site conditions and vegetation species used, irrigation may be required either temporarily or permanently to ensure vegetation establishment and prevent die off.

Sodding and planting is more costly than seeding. However, establishing grasses and plants from seed will take longer than sodding or planting. Landscape establishment will occur more quickly in high precipitation areas, usually over 20 inches of rain annually during the growing season, as opposed to arid or semiarid regions. Sodding usually provides less vegetation diversity than either seeding or planting.

Design Basis

Using native drought-resistant vegetation is strongly encouraged for all landscaping efforts. Native species require little or no maintenance (i.e., watering or fertilizing), mimic natural conditions, and may help limit the introduction of invasive species.

All revegetation efforts should be performed according to local requirements, and lists of acceptable landscape plant species should be obtained from an agronomist or the local cooperative extension. Successful landscaping projects depend on selecting suitable species for the site location considering climate and elevation, surrounding species, using healthy vegetation, and revegetating when the season and weather conditions are favorable. The site should be properly prepared and be adequately maintained to ensure long-term survival of the vegetation.

Seeding

Effective seeding requires proper seedbed preparation and should be conducted with various forms of mulching, matting, and annual grass (cereal grain) as a nurse crop to help protect the seed and retain soil moisture.

Before seeding, ensure that site conditions are capable of supporting seeding efforts. If site conditions lack proper nutrient values, organic content, microorganisms, or root restrictions, a

seedbed should be established. Seedbeds may consist of topsoil (BMP 31), compost, or soil enhancements (BMP 7).

Sodding

As long as moisture conditions are adequate, sod may be placed at any time of year. Turf, or sod, consists of matted earth formed by grass and soil bound together by a root layer. Rethinking turf as the primary ground cover does not imply that all grassy areas should be replaced. Turf should be planted only where it is desirable and will be used to support designated land uses (e.g., athletic fields or recreation areas) and in an appropriate amount. Turf grass does not always provide the needed erosion control, so interim use of a cover crop to improve soil fertility and stability between construction completion and final planting may be beneficial. Consult a local agronomist, a soil scientist, or an extension office for the proper selection and application of cover crops.

Follow these guidelines for establishing turf in residential areas:

- Place turf in rear yards close to the residence where the bulk of recreational activity is likely to occur.
- Use drought-tolerant and native species of grass.
- To avoid a monoculture, use various species of turf grass in your landscaped areas.

The soil surface should be at final grade and roughened before laying down sod. Topsoil (BMP 31) may be needed in areas where soil textures or conditions are inadequate (such as dense or impermeable soils). Sod may be placed directly on the ground without topsoil only if it has been specifically grown for sites with no topsoil. Add lime and fertilizers as needed to promote good plant growth conditions. Sodding should take place immediately after the soil bed is established, and it should be rolled or compacted immediately after installation to ensure firm contact with the underlying soil.

Sod is commercially available in rolled strips that can be applied in staggered rows or other patterns. Areas not covered by the specified pattern may be seeded to reduce expense. When placed on steep slopes, lay the sod parallel to flow with staggered joints or peg down (or both) and place chicken wire, jute, or other netting over the sod for extra protection against lifting. If slopes will be mowed, do not place sod on grades greater than 3:1 (Figure 85 and Figure 86**).**

Figure 85. Sod laying pattern.

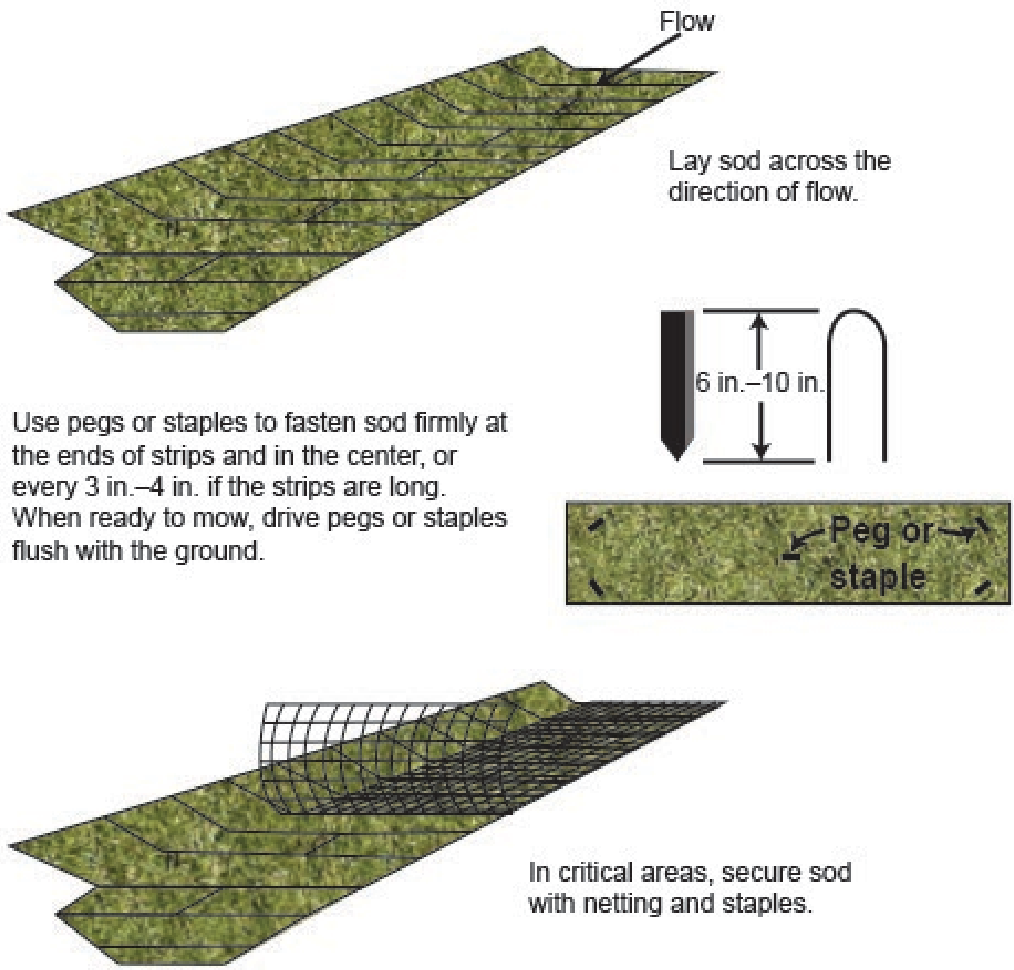


Figure 86. Steep slope details.

Planting

Planted material may be grown from either cuttings or seed. At delivery to a job site, the plants may be potted (in containers), root wrapped, or bare rootstock. Some species are successfully planted as sprigs or tubelings. Vegetative planting may be combined with seeded grasses and legumes that provide immediate surface coverage. Planting methods are shown in Figure 87, Figure 88, and Figure 89.

Examine plant materials before use to ensure that species, container sizes, and root and soil conditions are acceptable. If possible, the growth medium for containerized plants should be similar to the soil type on the revegetation site. Container size guidelines are as follows:

- Tree species may be bare rootstock or potted stock. Pots and containers should be adequate size for the tree, shrub, or plant that it contains.
- Shrub species may be bare rootstock or potted stock.
- Peat pots are not recommended as research shows greater plant mortality from drying. If peat pots are used, remove any exposed peat pot material showing after planting.

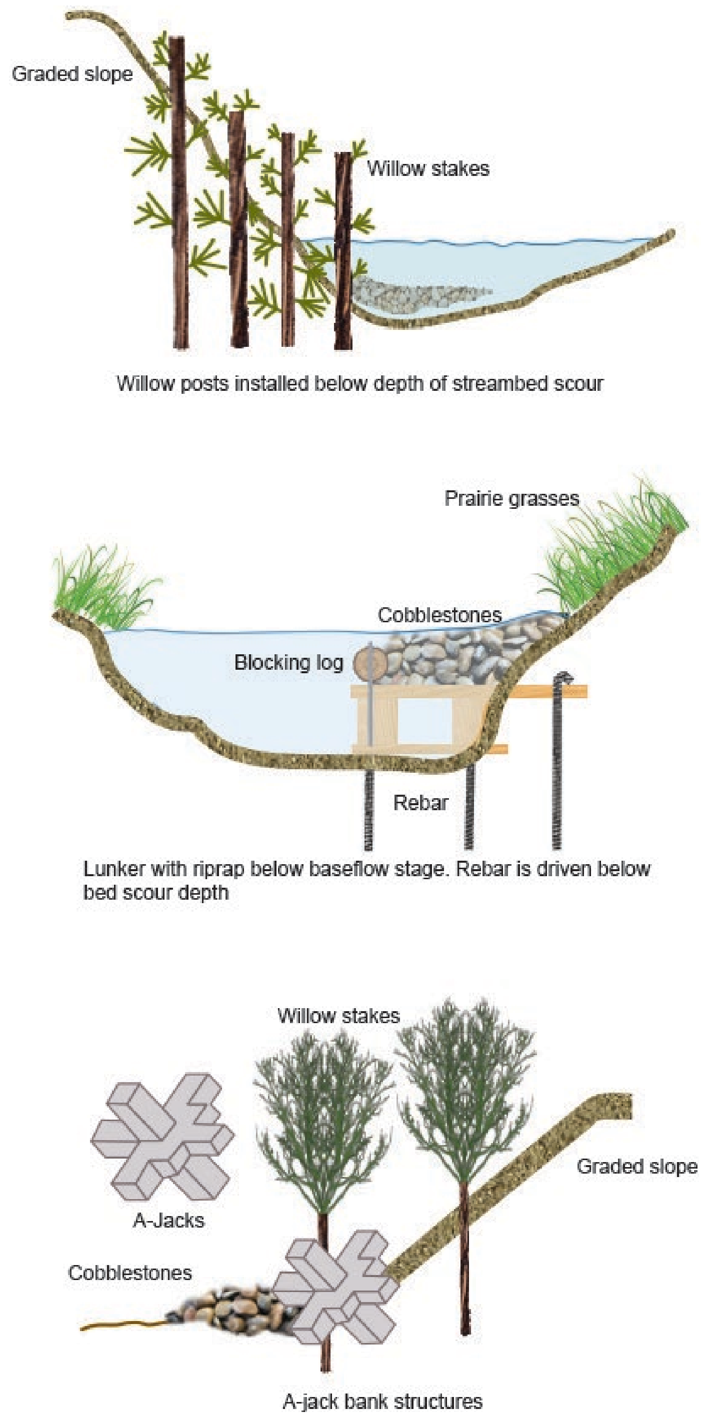


Figure 87. Planting methods on graded slopes.

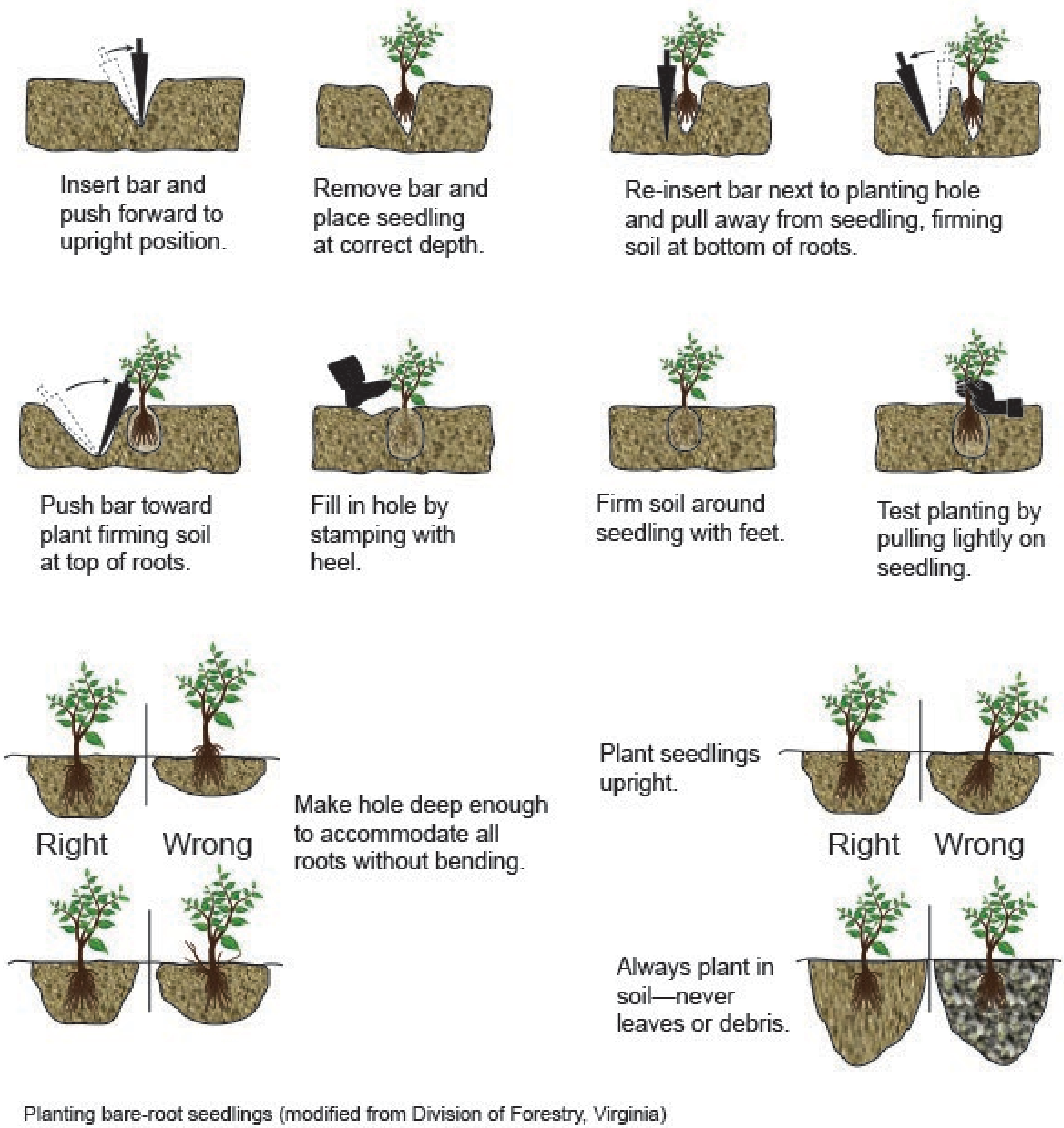


Figure 88. Planting methods for seedlings.

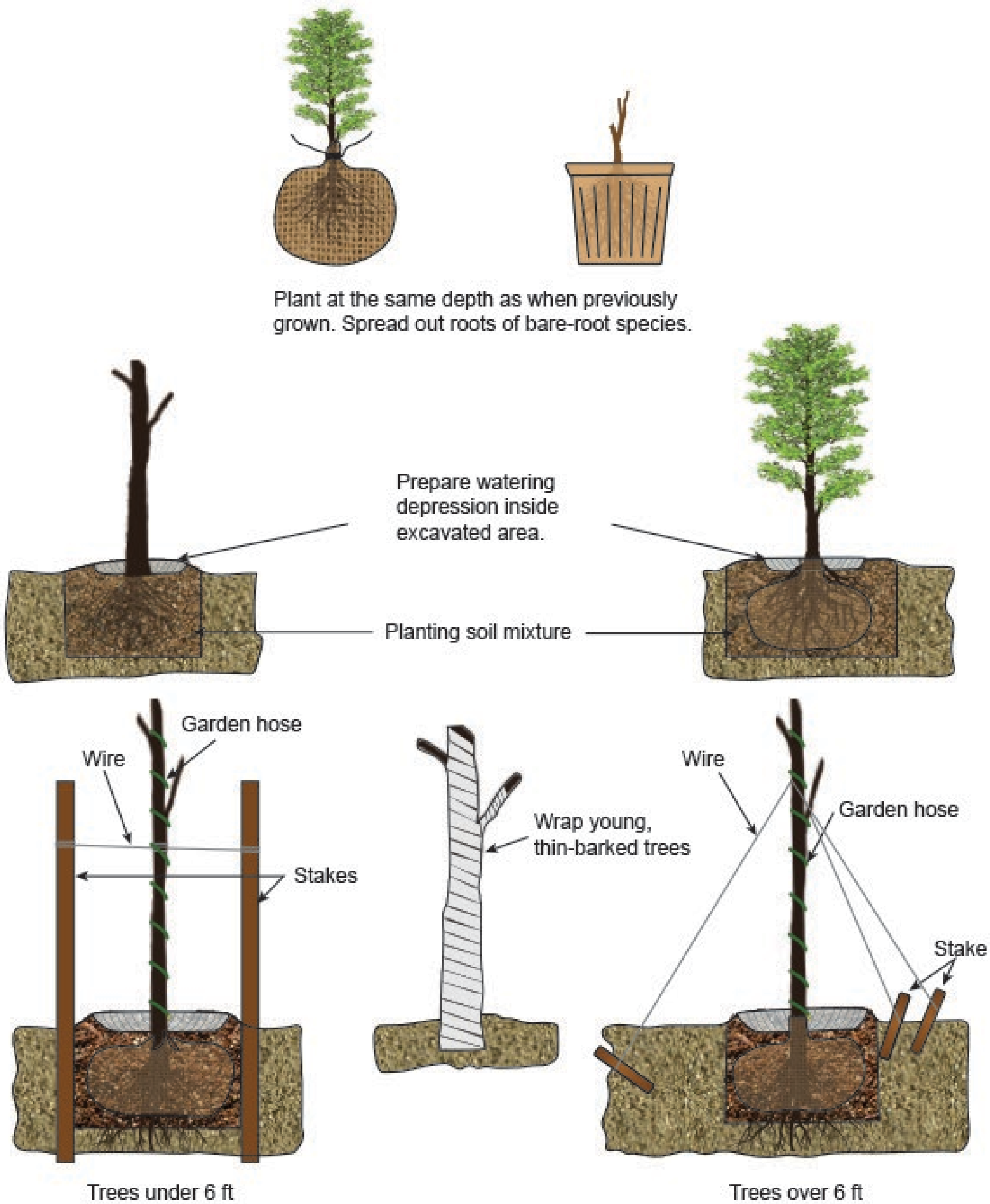


Figure 89. Planting methods for trees.

Construction Guidelines

Before temporary seeding, all runoff control measures should be in place to prevent seed loss during a storm event.

As permanent landscaping is the last phase of reclaiming disturbed soils, all other construction activities should be completed before the final placement of landscaping materials. During construction, avoid compacting areas to be landscaped (BMP 45: Minimize Soil Compaction) as overly compacted planting beds will not vegetation as quickly or thoroughly.

Before planting, the locations of the trees, shrubs, ground covers, and other vegetation should be marked and approved.

Store bundled bare root planting stock, whether tree or shrub species, in a cool, moist place from time of receipt until time of planting. This time should not exceed 10 days. Store potted plant stock in the shade and out-of-doors and maintain a moist soil from the time of receipt to the time of planting. This time should not exceed 30 days.

Maintenance

- Inspect all landscaped areas on a regular basis and after each major storm event to check for areas where corrective measures may have to be made.
- Indicate which areas need to be reseeded, resodded, replanted or where other remedial actions are necessary to ensure the vegetation is permanently established.
- Proper irrigation of landscaped areas during the first 2 years following construction is suggested to increase the survival of the vegetation.
- Any seeded area that has failed to establish at least an 80% ground cover within 1 month should be reseeded. If reseeding is ineffective, an alternative method, such as sodding, should replace seeding efforts.

Additional Resources

City of Boise. 2000. *Stormwater Plant Materials: A Resource Guide*. Boise, ID: Boise Public Works.

Colorado UDFCD (Colorado Urban Drainage and Flood Control District). 2010. *Urban Storm Drainage Criteria Manual, Volume 3 Best Management Practices*. Denver, CO. *http://udfcd.org/wp-content/uploads/2014/07/Title-Page.pdf*

King County (King County, Washington). 2009. *King County, Washington Surface Water Design Manual.* Seattle, WA: King County, Department of Natural Resources.

NRCS (US Department of Agriculture Natural Resources Conservation Service). 2004. *Plant Guide: Kentucky Bluegrass*. Baton Rouge, LA: National Plants Data Center. *http://plants.usda.gov/plantguide/pdf/pg_popr.pdf*

Sterling Codifiers, Inc. 2014. "Appendix B—North Idaho Native and Beneficial Plant List." *Bonner County, Idaho County Code*. Bonner County, ID. *https://evogov.s3.amazonaws.com/media/136/media/61416.pdf*

Washington State Department of Ecology. 2012. *Stormwater Management Manual for Western Washington*. Lacey, WA. Publ. 12-10-030. *http://www.ecy.wa.gov/programs/wq/stormwater/manual.html*

BMP 33: Gabions

Description

Gabions are rectangular wire-mesh cages filled with rock and wired together to form a protective but permeable structure for slope stabilization and erosion control (Figure 90).

Figure 90. Sloped gabion on Salmon River road connection/extension, Orofino, Idaho (*Debco Construction*).

Applicability

Gabions can be used as structural support to mechanically stabilize steep slopes or for bank protection of revetments, weirs, channel linings, culvert headwalls, and culvert outlet aprons. These supports are particularly useful where seepage is anticipated. For related information, refer to BMP 34: Retaining Walls.

Limitations

When used in channels with high sediment loads, the galvanizing wire on the gabion cages quickly wears off, causing rusting and the premature failure of the cages. The presence of gabions prevents establishing native vegetation, increases stream energy, and increases streambed erosion. For these reasons, they tend to alter stream dynamics and adversely affect wildlife habitat. Gabions are not recommended along streams, or they may need to be placed above a specified elevation. Additionally, material costs and professional design requirements may make the use of gabions impractical.

Design Basis

If gabions are placed along streams, they must be designed and installed according to the "Stream Channel Alteration Rules" (*IDAPA 37.03.07*) and CWA §404 permit requirements. Construction plans and specifications for gabions should be completed by a registered professional engineer. The following guidelines are recommended for designing gabions (Figure 91):

Primary BMP Functions and Controls

☐ Construction	☒ Permanent
☒ Erosion Control	☐ Sediment Control
☐ Source Control	☐ Flood Control
☐ Filtration	☐ Infiltration

Typical Effectiveness for Targeted Pollutants

◖	Sediment
○	Nitrogen
○	Phosphorus
○	Metals
○	Bacteria
○	Hydrocarbons
○	Litter

Other BMP Considerations

Relative Cost	$$
Maintenance Requirements	Medium
Ease of Installation	Medium
Freeze/Thaw Resistance	Good
Max. Tributary Drainage Area	Unlimited
Max. Upstream Slope	40%
NRCS Soil Group	ABCD
Min. Ground Water Separation	2 feet
Min. Bedrock Separation	NA

- The structure should be able to handle expected storm and flood conditions.
- On streambank applications, the foundation is an important design feature of the structure. Consider the potential for the stream to erode the sides and bottom of the channel and ensure the gabions will be supported properly.
- The gabion structure should be securely *keyed* into the foundation and abutment surfaces. The rock filling holds the gabions in place by gravity, but tiebacks may be used if conditions warrant additional structural strength.
- Depending on the underlying soil conditions, gabions may need to be placed on a filter blanket, gravel layer, or both.
- Gabions should be fabricated so that the sides, ends, lids, and diaphragms can be assembled at the construction site into a rectangular basket of required sizes.
- Gabions should be of a single-unit construction. The base, ends, and sides should be woven into a single unit or one edge of these members connected to the base section of the gabion so that strength and flexibility at the point of connection are at least equal to that of the mesh.
- Where the gabion's length exceeds its horizontal width, the gabion should be equally divided by diaphragms, of the same mesh and gage as the gabion's body, into cells with length does not exceed the horizontal width. Furnish the gabion with the necessary diaphragms secured in proper position on the base section so that no additional tying at this juncture will be necessary.
- All perimeter edges should be securely selvedged or bound so that the joints formed by tying the selvedges have the same strength as the body of the mesh.
- The fill material for the wire gabions should be rock ranging in size from a minimum of 4 inches to a maximum of 8 inches, both measured in the greatest dimension. Rock should be sound, durable, well graded, and obtained from a source approved by the project engineer.
- To ensure the maximum gabion lifetime, fully understand the chemical and physical environment that the structure will be placed, and select an appropriate level of protection.
- Gabion corrosion resistance can be provided by galvanization (zinc plating), GALFAN coating (zinc/aluminum alloy), PVC coating, simple paint coating, or a combination of methods (such as PVC-coated galvanized steel). Life expectancy is directly related to the environment where the structure is placed. Although galvanization and coatings can protect the underlying steel mesh, these coating will degrade with time, exposing the steel to oxidation and eventual degradation.

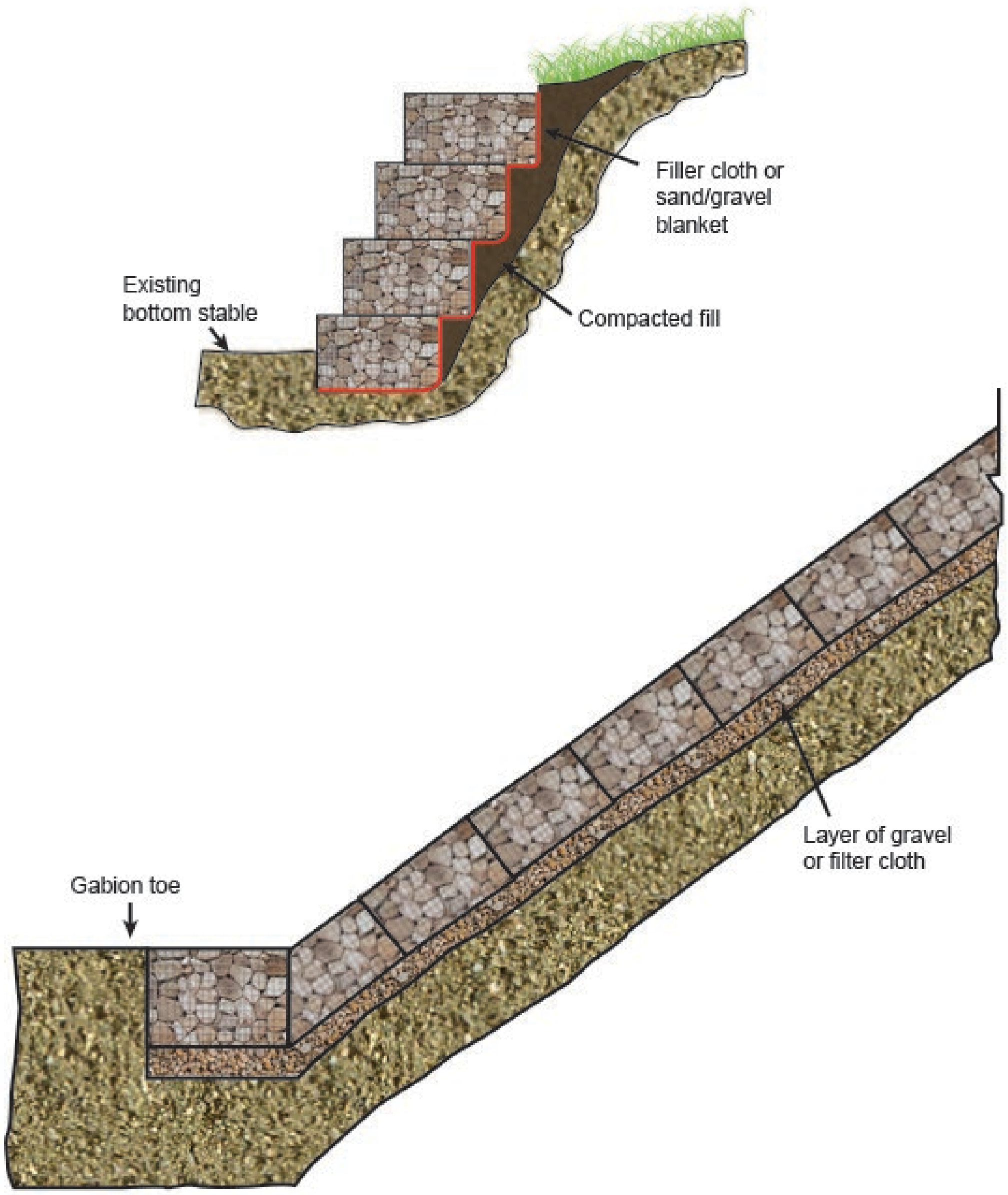


Figure 91. Gabion details.

Construction Guidelines

- Place the empty gabion baskets on a smooth, firm foundation excavated as directed in the plans. Each row, tier, or layer of baskets should be reasonably straight and conform to the line and grade shown on the plans.
- Fasten the empty gabion baskets to the adjacent baskets along the top and vertical edges. Each layer should be fastened to the underlying layer along the front, back, and ends. Perform fastening in the same manner as when assembling the gabion units.
- Unless otherwise indicated on the plans, stagger the vertical joints between basket units of adjacent tiers or layers, along the length of the structure, by at least one cell.

- Before filling each gabion with rock, remove all kinks and folds in the wire mesh and properly align all baskets. A standard fence stretcher, chain fall or steel rod, may be used to stretch the wire baskets and hold alignment.
- Carefully fill the gabion cells with rock placed by hand or machine so that the alignment of the structure will be maintained, bulges will be avoided, and void space minimized.
- Ensure all exposed rock surfaces are reasonably smooth and have neat appearance. No sharp rock edges should project through the wire mesh.
- Fill the gabion cells in any row or layer in stages so that local deformations may be avoided. At no time should any cell be filled to a depth exceeding 12 inches more than any adjacent cell.
- Ensure the layer of rock completely fills the gabion basket so that the lid will bear on the rock when it is secured. The lid should be joined to the sides, ends, and diaphragms in the same manner as specified for joining the vertical edges. The gabion basket lid should be secured so that no more than 1-inch gap remains at any connection.
- Ensure gabion rows or layers not completed at the end of each shift have the last gabion filled with rock tied internally as an end gabion.
- Backfill the area behind the gabion structure with granular material. If required, spread geotextile uniformly over the back of the gabion structure as shown on the plans. Overlap joining edges of the geotextile a minimum of 12 inches and anchor it in position with approved anchoring devices. The contractor should place the backfill material in a manner that will not tear, puncture, or shift the geotextile.

Maintenance

- Inspect regularly and after each major storm. Check for signs of undercutting or other instability.
- Repair damaged areas immediately to restore designed effectiveness and to prevent damage or erosion of the slope or streambank.
- Check wire of cages for rusting and wear. If gabion wire mesh shows wear through more than 25% of its gauge thickness, repair or replace immediately.
- Check gabions for missing rock and replace as needed to prevent loss of structural integrity.

Additional Resources

King County (King County, Washington). 2009. *King County, Washington Surface Water Design Manual.* Seattle, WA: King County, Department of Natural Resources.

BMP 34: Retaining Walls

Description

Retaining walls are constructed against a slope to prevent slope erosion or slope failure (Figure 92). Examples of retaining wall materials include concrete, concrete masonry, rock, wood planking, railroad ties, and mechanically stabilized earth. Retaining walls can also be constructed with rock-filled gabion baskets (BMP 33: Gabions).

Figure 92. Retaining wall along a drive with a steep slope.

Applicability

Retaining walls can be used for permanent slope protection and stabilization on sites with large grade changes where other stabilization measures would be ineffective or aesthetically unacceptable.

Limitations

Retaining walls are often a costly option as they require significant materials and a site-specific design by a registered professional engineer.

Retaining walls made with wood treated with chemicals to retard decay may leach out and cause toxic effects. Treated wood and railroad ties should not be used adjacent to environmentally sensitive areas.

Design Basis

Retaining walls require a site-specific design and wall heights. Requirements for drainage and suitable materials should be determined through on-site inspections. Retaining walls are suggested for erosion control and steep slope mitigation. All types of retaining walls should conform to local building codes and ordinances. Plans and specifications should be prepared by a professional engineer for all installations over 3 feet and those that pose safety risks in the event of a structural failure.

Primary BMP Functions and Controls

☐ Construction	☒ Permanent
☒ Erosion Control	☐ Sediment Control
☐ Source Control	☐ Flood Control
☐ Filtration	☐ Infiltration

Typical Effectiveness for Targeted Pollutants

◖	Sediment
○	Nitrogen
○	Phosphorus
○	Metals
○	Bacteria
○	Hydrocarbons
○	Litter

Other BMP Considerations

Relative Cost	$$$
Maintenance Requirements	Medium
Ease of Installation	Hard
Freeze/Thaw Resistance	Fair
Max. Tributary Drainage Area	Unlimited
Max. Upstream Slope	67%
NRCS Soil Group	ABCD
Min. Ground Water Separation	3 feet
Min. Bedrock Separation	NA

The materials best suited for retaining wall construction vary on a site-by-site basis:

- **Concrete retaining wall**—An engineered concrete wall comprised of poured in place concrete, precast concrete, or interlocking concrete blocks.
- **Masonry retaining wall**—An engineered structure, similar to a concrete retaining wall, constructed with masonry blocks, usually of specific design for aesthetic appeal.
- **Native rock retaining wall**—A low-gravity, or low center of mass, wall constructed of rock materials native to the construction site. It provides an aesthetically attractive method of stabilizing a slope. Native rock is suitable for walls up to about 6.5 feet in vertical height where the slope is steeper than 2:1 behind the wall. They can be higher on slopes of 2:1 (or flatter) gradient with proper engineering design.
- **Wood planking retaining wall**—A retaining wall constructed of wood planking and posts. Wood retaining walls are useful for relatively small slopes of loose material that are underlain by a rigid rock base material or firm, nonplastic subsoil with high shear strength. The firm foundation is necessary to securely anchor the wall. Wood planking retaining walls can be constructed in poorer foundation soils by using longer posts and spacing no greater than 3 feet. Redwood, cedar, or pressure-treated lumber should be used, which will generally last longer than other woods.
- **Railroad tie retaining wall—**A retaining wall constructed of railroad ties, which are useful for relatively small slopes of loose material that are underlain by a rigid base of rock or firm, nonplastic subsoil. The wall should be securely anchored to the rock base or firm subsoil, and the ties should be pinned together with joints staggered.
- **Mechanically stabilized earth (MSE) retaining walls—**MSE retaining walls use some type of anchored structure to retain earthen materials behind a wall. Proprietary options for MSE walls are Hilfiker, Genesis (Keystone/Tensar), and T-wall.

Construction Guidelines

Retaining walls designed by a professional engineer should be constructed according to the plans and specifications for the wall. The following are construction guidelines for walls less than 3 feet.

Native Rock Retaining Walls

- Remove all large rocks from the eroding slope face and stockpile on site.
- Excavate a footing trench along the toe of the slope.
- Place the largest rocks in the footing trench with their longitudinal axis normal to the embankment face. Arrange subsequent rock layers so that each rock above the foundation course has a three-point bearing on the underlying rocks.
- The slope of the wall should be between 0.5:1 and vertical, depending upon the height of the wall, the height of the slope, the width of the right-of-way, or other limitations on space.
- Obtain fill material from the slope and place it behind the rock wall. Slope above the wall should be maintained at 2:1 or less with a slope bench at the toe. Backfill the footing trench with excavated material.
- If a roadway is located at the toe of the wall, pave the roadway up to the base of the rock wall and provide roadway curb for water transport. If a roadway is not located at the toe of the retaining wall, slope the backfilled material away from the wall at 2% and stabilize it.

- Revegetate (BMPs 8 and 32) the stabilized slope immediately with a method applicable to the particular site.

Wood Plank Retaining Wall

- Prepare the site by rough grading the slope surface, then work from the bottom of the slope towards the top.
- Set the bottom course of wood posts into rigid base foundation material and secure with a metal anchor embedded in a concrete foundation.
- Install planking on the upslope side of the posts. Provide sufficient vertical spacing to allow drainage at the base of the wall and between planks.
- Backfill behind the wall with material from the slope above. Slope the backfill material between wood walls at 2% toward the top of the lower wall.
- Proceed in a similar fashion up the slope to the desired height.
- Revegetate the backfilled benches behind the walls according to procedures applicable to the specific site.

Railroad Tie Retaining Wall

- Prepare the site by rough grading the slope surface, then work from the bottom of the slope toward the top.
- Set the bottom course of railroad ties onto a rigid base foundation material and secure with pinning or metal collars.
- Backfill behind the wall with material from the slope above. Slope the backfill material between the tiers of railroad ties at 2% toward the top of the lower wall. If the engineered wall requires a tie-back anchor or *deadman,* install according to the design drawing.
- Proceed in a similar fashion up the slope to the desired height. If the total height exceeds 3 feet, the wall should be designed and approved by a registered engineer.
- Revegetate the backfilled benches behind the walls according to procedures applicable to the specific site.

Maintenance

Retaining walls should be inspected regularly to detect signs of structural failure and to check for damage caused by subsurface drainage or material sloughing. In streambank installations, inspect after extreme events (such as the 50-year design storm and greater) and at the end of the peak runoff period in the spring and look for signs of undercutting and other instability. Make all repairs immediately.

Additional Resources

ITD (Idaho Transportation Department). 2014. *Best Management Practices.* Boise, ID: ITD.

BMP 35: Energy Dissipation Devices

Description

Energy or velocity dissipation devices are located immediately downstream of a pipe, culvert, slope drain, rundown, or other conveyance to reduce the velocity of concentrated storm water flows and prevent scour at the outlet and erosion downstream (Figure 93).

Figure 93. Riprap located below a pipe.

Typical energy dissipation is provided by rock riprap although other devices such as mats, plates, internal dissipators, stilling basins, armored scour holes, or drop structures can also be used. Riprap outlet protection is created by an arranged layer or pile of rock placed over the soil surface below storm drain conveyance outlets.

Primary BMP Functions and Controls

☒ Construction	☒ Permanent
☒ Erosion Control	☐ Sediment Control
☐ Source Control	☐ Flood Control
☐ Filtration	☐ Infiltration

Typical Effectiveness for Targeted Pollutants

◖	Sediment
○	Phosphorus
○	Metals
○	Bacteria
○	Hydrocarbons
○	Litter

Other BMP Considerations

Relative Cost	$
Maintenance Requirements	Medium
Ease of Installation	Easy
Freeze/Thaw Resistance	Good
Max. Tributary Drainage Area	5 acres
Max. Slope	10%
NRCS Soil Group	ABCD
Min. Ground Water Separation	N/A
Min. Bedrock Separation	N/A

Applicability

Install energy dissipation devices at the outlets of pipes, culverts, catch basins, sediment basins, ponds, interceptor dikes, and swales or channel sections where the velocity of flow may cause erosion in the receiving channel. Energy dissipation devices are not typically stand-alone BMPs; they are placed upstream of a BMP to facilitate pollutant removal by the downstream practice. Outlet protection should also be used at outlets where the design flow velocity may result in plunge pools (small, permanent pools located at an inlet or outfall).

Energy dissipation outlet protection should be installed early during construction activities and if necessary left as a permanent BMP after construction is completed.

Limitations

Many types of energy dissipators are available, but many have limitations—such as the type of debris that can be handled, Froude number at the outlet, and tailwater requirements (Table 19). Some limitations to consider with rock riprap include difficulty removing sediment unless the rock is also removed and potential

negative impacts to fish habitat within natural channels. Conveyance outlets on steep slopes (greater than 10%) should have an engineered energy dissipator such as those listed in Table 19 applicable for higher Froude numbers.

Table 19. Energy dissipators and limitations (FHWA 2006).

Dissipator Type	Froude Number[7] (Fr)	Allowable Debris [1]			Tailwater (TW)
		Silt/ Sand	Boulders	Floating	
Flow transitions	na	H	H	H	Desirable
Scour hole	na	H	H	H	Desirable
Hydraulic jump	> 1	H	H	H	Required
Tumbling flow[2]	> 1	M	L	L	Not needed
Increased resistance[3]	na	M	L	L	Not needed
USBR Type IX baffled apron	< 1	M	L	L	Not needed
Broken-back culvert	> 1	M	L	L	Desirable
Outlet weir	2 to 7	M	L	M	Not needed
Outlet drop/weir	3.5 to 6	M	L	M	Not needed
USBR Type III stilling basin	4.5 to 17	M	L	M	Required
USBR Type IV stilling basin	2.5 to 4.5	M	L	M	Required
SAF stilling basin	1.7 to 17	M	L	M	Required
CSU rigid boundary basin	< 3	M	L	M	Not needed
Contra Costa basin	< 3	H	M	M	< 0.5D
Hook basin	1.8 to 3	H	M	M	Not needed
USBR Type VI impact basin[4]	na	M	L	L	Desirable
Riprap basin	< 3	H	H	H	Not needed
Riprap apron[8]	na	H	H	H	Not needed
Straight drop structure[5]	< 1	H	L	M	Required
Box inlet drop structure[6]	< 1	H	L	M	Required
USACE stilling well	na	M	L	N	Desirable

Design Basis

Detailed information on the design of the energy dissipators included in Table 19 is available in the *Hydraulic Design of Energy Dissipators for Culverts and Channels* (FHWA 2006). Gabions, which can be used as energy dissipators, are described in BMP 33. General design information for rock riprap dissipators is provided here because they are commonly used.

Riprap Apron

Riprap aprons are commonly used for temporary protection at the outlet of culverts that are 60 inches in diameter or smaller. Aprons should be constructed at a zero grade with the elevation of the downstream end of the apron equal to the elevation of the receiving channel or adjacent ground. Riprap aprons should be located so that there are no bends in the horizontal alignment.

The width of the apron should extend across the downstream channel bottom and up to the elevation of the normal channel depth or the height of the culvert, whichever is less. The width of the apron adjacent to the pipe should have a width two times the diameter of the outlet pipe, or conform to the pipe end section if used. For stability, key the rock 6 inches deep around the perimeter of the apron.

Determine the length of the apron and size of the riprap using the pipe diameter and design discharge shown in Table 20. The riprap apron should be designed to handle runoff from the largest drainage area and/or design flow to the storm water conveyance. The minimum thickness of the riprap layer should be equal to twice D_{50}. Figure 94 includes a typical plan and cross section for a riprap apron.

Table 20. Riprap apron sizing table (Colorado UDFCD 2010).

PIPE DIAMETER, Do (INCHES)	DISCHARGE, Q (CFS)	APRON LENGTH, La (FT)	RIPRAP D50 DIAMETER MIN (INCHES)
8	2.5 5	5 10	4 6
12	5 10	10 13	4 6
18	10 20 30 40	10 16 23 26	6 9 12 16
24	30 40 50 60	16 26 26 30	9 9 12 16

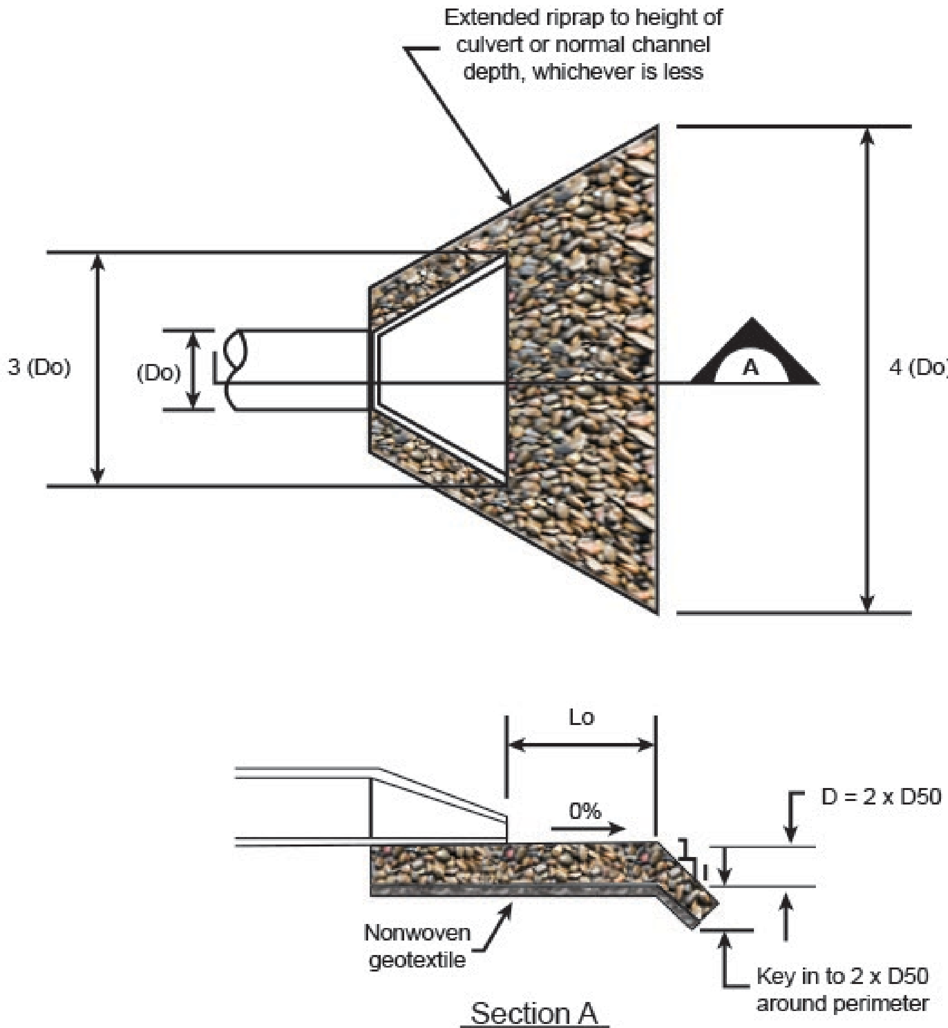


Figure 94. Riprap apron plan (Colorado UDFCD 2010).

Riprap material should be composed of a well-graded mixture of stone size so that 50% of the pieces, by weight, are larger than the D_{50} size. A well-graded mixture is composed primarily of larger stone sizes but with a sufficient mixture of other sizes to fill the smaller voids between the stones. The diameter of the largest stone size should be 1.5 times the D_{50} size.

Stone for riprap should consist of field stone or rough unhewn quarry stone. The stone should be hard and angular and of a quality that will not disintegrate on exposure to water or weathering. The specific gravity of the individual stones should be at least 2.5. Recycled concrete equivalent may be used if it has a density of at least 150 pounds per cubic feet and does not have any exposed steel or reinforcing bars.

A nonwoven geotextile filter is recommended between the riprap and the natural soil to prevent soil movement into and through the riprap. The geotextile filter should meet these base requirements: thickness 10–60 mils, grab strength 90–20 pounds, and conform to the “Standard Test Method for Thickness of Textile Materials” (ASTM D1777) and “Standard Test Method for Breaking Strength and “Elongation of Textile Fabrics” (ASTM D5034 and D5035). Alternatively,

a layer of granular filter material can be used in place of the geotextile. Design granular filter material by comparing particle sizes of the riprap material and the base material using the following relationship (Equation 29):

$$\frac{D_{15}(coarser\ layer)}{D_{85}(finer\ layer)} < 5 < \frac{D_{15}(coarser\ layer)}{D_{15}(finer\ layer} < 40$$

Equation 29. Granular filter size requirements (FHWA 1989).

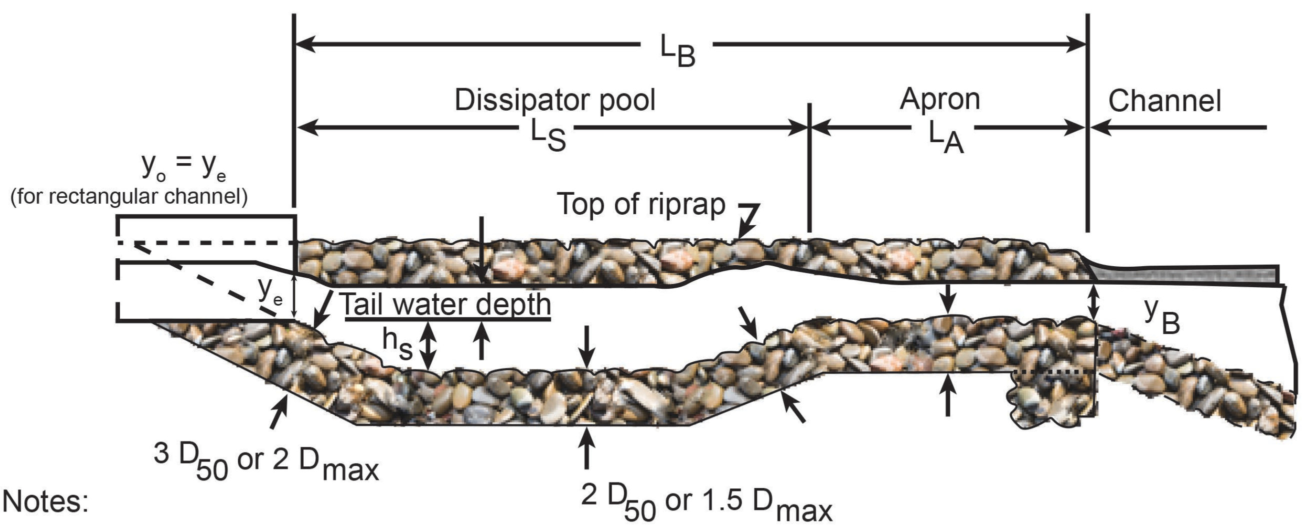
Where

D_{15} = particle diameter at which 15% of the sediment sample is finer

D_{85} = particle diameter at which 85% of the sediment sample is finer

Riprap Basins

A riprap basin can be used as a permanent energy dissipation device at a conveyance outlet. The basin design is based on armoring a preformed scour hole to allow energy to dissipate at the outlet. The recommended geometry is shown in Figure 95 and Figure 96. The quality of the riprap and characteristics of the filter are the same as those outlined above in “Riprap Aprons.”



Notes:

L_A = Apron length
L_B = Basin length
L_S = Energy length
h_s = Scour depth
y_B = Basin depth
y_e = Equivalent depth
y_o = Outlet depth

Figure 95. Profile of riprap basin (FHWA 2006).

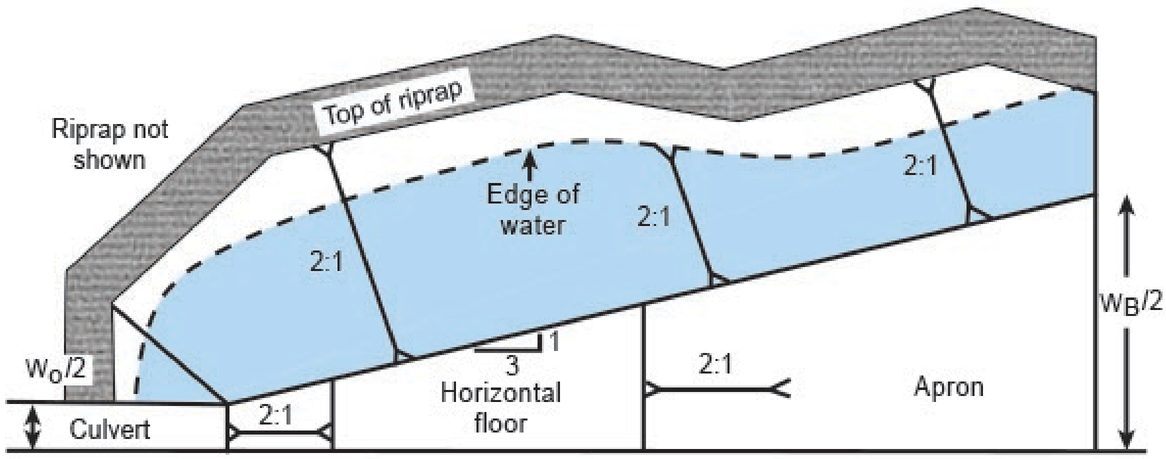


Figure 96. Half plan of riprap basin (FHWA 2006).

Riprap basins have the following features:

- Basin is preshaped and lined with riprap at least $2D_{50}$ thick.
- Riprap floor is constructed at the approximate depth of scour, h_s, that would occur in a thick pad of riprap. The h_s/D_{50} of the material should be greater than 2.
- Length of the energy dissipating pool, L_s, is $10h_s$ but no less than $3W_o$; the length of the apron, L_a, is $5h_s$ but no less than W_o. The overall length of the basin (pool plus apron), L_B, is $15h_s$ but no less than W_o.
- Riprap cutoff wall or sloping apron can be constructed if downstream channel degradation is anticipated.

Fish Passage

In sensitive fish habitat, culverts and their outlets should be designed to avoid impedances to fish and other aquatic fauna. Riprap basins could provide a resting pool, but they should not create a vertical barrier for fish passage. Flows within the culvert and at its inlet and outlet should have velocities and depths comparable to that present in the stream channel.

Construction Guidelines

Complete construction of the outlet protection before allowing erosive flows to pass through the outlet. The subgrade for the filter, riprap, or gabion should be prepared to the required lines and grades. Compact any fill required in the subgrade to a density of approximately that of the surrounding undisturbed material.

Geotextile fabric should be protected from punching, cutting, or tearing; riprap should be placed carefully to avoid damaging the fabric. Stone 4 to 6 inches in diameter may be carefully dumped onto filter fabric from a height not to exceed 12 inches. Stone 8 to 12 inches should be hand placed or the filter fabric covered with 4 inches of gravel and the 8- to 12-inch stone dumped from a height not to exceed 16 inches. Stone greater than 12 inches should only be dumped onto filter fabric protected with a layer of gravel with a thickness equal to one-half the D_{50} rock size with the dump height limited to twice the depth of the gravel protection layer (CASQA 2015).

Any damage to the geotextile filter fabric other than an occasional small hole should be repaired by placing another piece of cloth over the damaged part or by completely replacing the fabric. All overlaps whether for repairs or for joining two pieces of fabric should be a minimum of 1 foot.

The stone for riprap or gabion outlets should be delivered and placed so it is reasonably homogenous with the smaller stones and spalls filling the voids between the larger stones.

Maintenance

Energy dissipation devices should be inspected annually and after heavy storms and high flows. Inspect for scouring under the outlet and dislodged stones, and repair damage promptly. Inspect riprap aprons for displacement of the riprap and damage to the underlying fabric. Repair fabric and replace riprap as necessary. Clean out energy dissipation devices as necessary when approximately half of the void space is filled with sediment and debris. Loose riprap may need to completely removed and replaced to remove sediment.

Additional Resources

CASQA (California Stormwater Quality Association). 2015 *California Stormwater Best Management Practices Handbook: Construction.* Menlo Park, CA. *https://www.casqa.org*

Colorado UDFCD (Colorado Urban Drainage and Flood Control District). 2010. *Urban Storm Drainage Criteria Manual, Volume 3 Best Management Practices*. Denver, CO. *http://udfcd.org/wp-content/uploads/2014/07/Title-Page.pdf*

EPA (US Environmental Protection Agency). 2014. *Riprap.* Water: Best Management Practices. *https://www.epa.gov/npdes/national-menu-best-management-practices-bmps-stormwater#edu*

FHWA (US Department of Transportation Federal Highway Administration). 1989. *Design of Riprap Revetment.* Hydraulic Engineering Circular No. 11. Publication No. FHWA-IP-89-016. *https://www.fs.fed.us/biology/nsaec/fishxing/fplibrary/FHWA_1989_Design_of_Riprap_revetment.pdf*

FHWA (US Department of Transportation Federal Highway Administration). 2006. *Hydraulic Design of Energy Dissipators for Culverts and Channels.* Hydraulic Engineering Circular No. 14, 3rd ed. Publication No. FHWA-NHI-06-06. *http://www.fhwa.dot.gov/engineering/hydraulics/pubs/06086/hec14.pdf*

BMP 36: Construction Timing

Description

Proper timing and sequencing of construction activities minimizes erosion and sediment transport by coordinating land-disturbing activities and erosion and sediment control measures installation and by completing construction during periods of low erosion potential (Figure 97). In construction phasing, only a portion of a site is disturbed at one time, and final stabilization is completed before moving on to another part of the site, which limits potential erosion (BMP 1: Minimize Land Disturbance, BMP 39: Clearing Limits, BMP 38: Preserve Topsoil and Vegetation, and BMP 45: Minimize Soil Compaction).

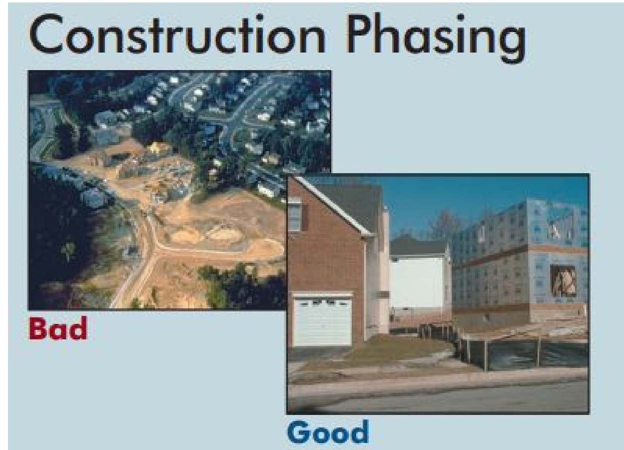


Figure 97. Construction phasing reduces the amount of time soil is exposed (EPA 2003).

Applicability

All construction projects can benefit from upfront planning to phase and sequence construction activities to minimize the extent and duration of disturbance.

Large construction projects and areas where work activities can be timed to coincide with periods of low erosion potential, such as during dry weather, especially benefit from good construction timing. Small projects that are less than 5 acres in size and occur during a short time period during the dry season may qualify for waived NPDES permitting requirements. See EPA's *rainfall erosivity waivers*.

Limitations

Timing construction based on seasonal limitations may not always be possible due to bidding, letting, timing, and contract administration. Additional restrictions may exist on scheduling or sequencing of certain work activities and the maximum allowable exposure of surface area based on environmental permits and requirements.

Primary BMP Functions and Controls

☒ Construction	☐ Permanent
☒ Erosion Control	☒ Sediment Control
☐ Source Control	☐ Flood Control
☐ Filtration	☐ Infiltration

Typical Effectiveness for Targeted Pollutants

●	Sediment
●	Phosphorus
◖	Metals
○	Bacteria
○	Hydrocarbons
○	Litter

Other BMP Considerations

Relative Cost	$
Maintenance Requirements	Low
Ease of Installation	Easy
Freeze/Thaw Resistance	N/A
Max. Tributary Drainage Area	N/A
Max. Upstream Slope	N/A
NRCS Soil Group	ABCD
Min. Ground Water Separation	N/A
Min. Bedrock Separation	N/A

Design Basis

The locations and dimensions of BMPs appropriate to the major phases of development should be clearly identified on the SWPPP map and included in the construction drawings (Table 21). In some cases, several drawings may be needed to show construction-phase BMPs placed according to phases of construction (e.g., clearing and grading, utility installation, active construction, and final stabilization) as erosion and sediment controls needed at a site will change as construction progresses.

Consider site characteristics and permit conditions when deciding what kind of erosion control devices to incorporate into a construction project. Select measures that can be installed without disrupting critical timing or sequencing of other construction or erosion control activities.

Construction Guidelines

Phasing

Typical phasing best practices include the following:

- Conduct work in phases so that some portions of the project site are final-graded and stabilized before the next phase of the project is started.
- Limit the amount of disturbed area at any given time on a site to the extent practical. For example, a 100-acre subdivision might be constructed in five phases of 20 acres each.
- If stockpiled material is carried over from one phase to the next, position carryover material in a location easily accessible for the pending phase so the stabilized area is not disturbed.

Timing and Sequencing

Typical timing and construction sequencing best practices include the following:

- Schedule construction during seasonal low-runoff periods under favorable soil moisture conditions, whenever possible.
- Allow time to install sediment collection systems, drainage systems, and runoff diversion devices before beginning ground-disturbing work in an area.
- Install and maintain effective soil stabilization measures as work progresses, not just when construction is completed.
- Initiate slope stabilization measures within 14 calendar days after construction activities in the portion of the site where earthmoving activities have temporarily or permanently ceased.
- Develop a scheduling/sequencing plan addressing the construction sequencing to reduce erosion potential. If using a Critical Path Method (CPM) for scheduling, incorporate the erosion control and storm water management practices into the method.

Table 21. Recommended BMPs for construction phases (Colorado UDFCD 2010).

Project Phase	Best Management Practice
Predisturbance site access	• Install sediment controls downgradient of access point (on paved streets this may consist of inlet protection) (BMP 66, BMP 74). • Establish vehicle tracking control at entrances to paved street. Fence as needed (BMP 40, BMP 65). • Use construction fencing to define the project's boundaries and limit access to areas of the site not to be disturbed (BMP 41). **Note**: it may be necessary to protect inlets in the general vicinity of the site, even if not downgradient, if there is a possibility that sediment tracked from the site could contribute to the inlets.
Site clearing and grubbing	• Install perimeter controls (e.g., silt fence and wattles) as needed on downgradient perimeter of site (BMP 64, BMP 65). • Limit disturbance to areas planned for disturbance and protect undisturbed areas within the site (e.g., construction fence and flagging) (BMP 1, BMP 2, BMP 3, BMP 39). • Preserve vegetative buffer at site perimeter (BMP 2, BMP 38). • Create stabilized staging area (BMP 37). • Locate portable toilets on flat surface away from drainage paths. Stake in areas susceptible to high winds (BMP 50). • Construct concrete washout area and provide signage (BMP 47). • Establish waste disposal areas (BMP 51). • Install sediment basins (BMP 66). • Create dirt perimeter berms and or brush barriers during grubbing and clearing (BMP 70). • Separate and stockpile topsoil; leave roughened and/or cover (BMP 31). • Protect stockpiles with perimeter control BMPs. Locate stockpiles away from drainage paths and access from the upgradient side so perimeter controls can remain in place on the downgradient side. Use erosion control blankets, temporary seeding, and/or mulch for stockpiles that will be inactive for an extended period (BMP 44). • Leave disturbed area of site in a roughened condition to limit erosion. Consider temporary revegetation for areas of the site that have been disturbed but will be inactive for an extended period (BMP 8, BMP 32, BMP 58). • Water to minimize dust but not to the point that watering creates runoff (BMP 43).
Utility and infrastructure installation	**In addition to the BMPs above**: • Close trench as soon as possible (generally at the end of the day). • Use rough-cut street control or apply road base for streets that will not be promptly paved (BMP 40, BMP 41). • Provide inlet protection as streets are paved and inlets are constructed (BMP 74). • Protect and repair BMPs as necessary. • Perform street sweeping as needed (BMP 75).
Building construction	**In addition to the BMPs above**: • Implement materials management and good housekeeping practices for home building activities (BMP 80, BMP 90). • Use perimeter controls for temporary stockpiles from foundation excavations (BMP 44). • For lots adjacent to streets, lot-line perimeter controls may be needed at the back of curb (BMP 41).
Final grading	**In addition to the BMPs above**: • Remove excess or waste materials (BMP 48, BMP 49, BMP 50, BMP 51). • Remove stored materials (BMP 32).

Project Phase	Best Management Practice
Final stabilization	**In addition to the BMPs above**: • Seed and mulch/ tackify (BMP 32, BMP 52). • Seed and install blankets on steep slopes (BMP 32, BMP 53, BMP 54) • Remove all temporary BMPs when site reaches final stabilization (BMP 62, BMP 68, BMP 70).

Maintenance

Continually monitor site conditions and work progress. Update the project work schedule to maintain appropriate timing and sequencing of construction and control applications. When the construction schedule is altered, erosion and sediment control measures in the SWPPP and construction drawings should be adjusted to reflect exiting conditions. Maintain appropriate erosion and sediment control measures that align with construction phasing and sequencing.

Additional Resources

Colorado UDFCD (Colorado Urban Drainage and Flood Control District). 2010. *Urban Storm Drainage Criteria Manual, Volume 3 Best Management Practices*. Denver, CO. *http://udfcd.org/wp-content/uploads/2014/07/Title-Page.pdf*

ITD (Idaho Transportation Department). 2014. *Best Management Practices.* Boise, ID: ITD.

Washington State Department of Ecology. 2012. *Stormwater Management Manual for Western Washington*. Lacey, WA. Publ. 12-10-030. *http://www.ecy.wa.gov/programs/wq/stormwater/manual.html*

BMP 37: Staging Areas

Description

Staging areas are clearly designated locations where construction equipment, vehicles, stockpiles, waste bins, office trailers, and other construction-related materials may be stored on site. Staging areas should be located, constructed, and maintained to prevent the discharge of sediment, solid waste, dust, trash, debris, or other pollutants from the site (Figure 98).

Figure 98. Construction staging area (Colorado UDFCD 2010).

Applicability

Most construction sites require a staging area. The size of the staging area depends on the size and type of the project and duration of construction.

Primary BMP Functions and Controls

☒ Construction ☐ Permanent
☐ Erosion Control ☒ Sediment Control
☒ Source Control ☐ Flood Control
☐ Filtration ☐ Infiltration

Typical Effectiveness for Targeted Pollutants

● Sediment
◖ Phosphorus
◖ Metals
◖ Bacteria
◖ Hydrocarbons
◖ Litter

Other BMP Considerations

Relative Cost	$
Maintenance Requirements	Medium
Ease of Installation	Medium
Freeze/Thaw Resistance	Good
Max. Tributary Drainage Area	N/A
Max. Upstream Slope	N/A
NRCS Soil Group	ABCD
Min. Ground Water Separation	N/A
Min. Bedrock Separation	N/A

Limitations

Some sites have limited space available, and it may be desirable to place the staging area off site or within an adjacent roadway. Staging areas in roadways require special measures to prevent materials from washing into existing storm inlets.

Measures to prevent storm water from entering the staging area tend to concentrate flow and can result in excessive erosion downstream if additional BMPs are not installed.

Design Basis

Size and Location

Size the staging area so that it provides appropriate space to accommodate storage and parking needs, as well as loading and unloading operations. When designing the stabilized staging area, minimize the area of disturbance to the maximum extent practical as oversizing the staging area may disturb existing vegetation in excess of the project requirements (BMP 1: Minimize Land Disturbance and BMP 39: Clearing Limits). Oversizing increases costs and requires long-term stabilization after the

construction period. Consider using off-site parking areas and restrict vehicle access to the site if possible to minimize the size needed for staging.

Place staging areas where site impacts will be minimized and at least 50 feet away from streams, surface waters, or wetlands. If possible, locate the staging area in a place that will be disturbed, such as the planned location for a road or parking area, and move it as construction progresses to limit the amount of unnecessary site disturbance.

Features

The staging area should have a stabilized surface, either paved or covered with 2- to 4-inch diameter aggregate at 3 to 6 inches deep, and accessed by a stabilized construction entrance. If the staging area is located in an area that would not be otherwise disturbed, consider using construction mats in lieu of rock to minimize long-term stabilization needs. BMP 41: Stabilized Construction Roads and Staging Areas provides more information on surface treatment requirements.

The grading in and around the staging area should control uncontaminated flow by diverting it around areas that may have pollutants and also contain potentially contaminated flows or divert them to treatment facilities.

Surround the staging area by construction fencing to prevent unauthorized access to construction materials. Perimeter sediment controls such as silt fence (BMP 65), sediment fiber rolls (BMP 64), or other measures should also be installed around the area as appropriate.

Materials storage should follow guidelines from BMP 77: Outdoor Storage, BMP 46: Spill Prevention and Control, and BMP 87: Outdoor Loading and Unloading of Materials. To comply with the Construction General Permit (EPA 2012b), storage areas for building products must provide either cover (e.g., plastic sheeting or temporary roofs) to prevent these products from coming into contact with rainwater, or a similarly effective means designed to prevent the discharge of pollutants from these areas.

Materials should be stored separately as appropriate using guidelines from BMP 48: Hazardous Materials Management. Hazardous or toxic wastes should be stored separate from construction and domestic waste. Flammable and combustible material should be segregated and stored in appropriately sized secondary containment.

Flow Diversion

Limiting the flow across staging areas reduces the volume of storm water that may carry pollutants from the area and require treatment. If the staging area cannot be located away from areas expected to receive significant volumes of storm water runoff, flow diversion BMPs, such as storm water conveyances, dikes, or berms, are needed.

Storm Water Conveyances

Storm water conveyances include either temporary or permanent channels, gutters, drains, or sewers. The conveyances are constructed or lined with many different materials, including concrete, clay tiles, asphalt, plastics, metals, riprap, compacted soils, and vegetation. By their

nature, storm water conveyances concentrate flow, and storm water should be routed through stabilized structures to discharge to a receiving water or other storm water BMP.

In planning for storm water conveyances, consider the amount and speed of typical storm water runoff. Also, consider the storm water drainage patterns, so that channels may be located to collect the most flow and built to handle the appropriate runoff volume. When deciding on the type of material for the conveyance, consider the material's resistance, durability, and compatibility with any pollutants it may carry.

Conveyance systems are most easily installed when a facility is initially constructed. Where possible, use existing grades to decrease costs. Grades should be positive to allow for the continued movement of the runoff through the conveyance system; however, grades should not increase velocity, causing excess erosion. When assessing erosion potential, consider the materials used for lining the conveyance and types of outlet controls provided. Reference the following BMPs for additional design parameters.

- BMP 28: Conveyance Furrows for Roof Runoff
- BMP 56: Riprap Slope Protection
- BMP 57: Pipe Slope Drain
- BMP 68: Temporary Swale

Dikes and Berms

Diversion dikes or berms are ridges built to block runoff from passing beyond a certain point. In planning for dike installation, consider the slope of the drainage area, height of the dike, amount of runoff it will need to divert, and type of conveyance that will be used with the dike. Steeper slopes result in higher volumes of runoff and higher velocities, which the dike should be capable of handling. Dikes are limited in their ability to manage large volumes of runoff. Temporary dikes (usually made of dirt) generally only last for 18 months or less but can become permanent structures by stabilizing them with vegetation. Slope protection such as vegetation is crucial for preventing the erosion of the dike. For additional design parameters, see BMP 69: Diversion Dike and BMP 70: Temporary Berms.

Construction Guidelines

Staging areas should be planned and designed before starting construction; however, certain BMPs, such as dikes and berms, may be constructed at any time. Implementing staging areas and associated drainage needs should also be incorporated into BMP 36: Construction Timing.

Specific construction methods apply to the type of conveyance, dikes, berms, graded areas, and pavements being used. Refer to applicable BMPs for construction guidelines.

Maintenance

Maintenance of staging areas includes inspecting and repairing the stabilized surface, repairing perimeter controls, and following good housekeeping practices.

Storm water diversions, such as conveyances and dikes, should be inspected regularly and within 24 hours of a storm event. Daily inspections may be required during periods of prolonged rainfall

as heavy storms may clog or damage the conveyances or wash away parts of temporary dikes. Any necessary repairs should be made immediately to ensure the structure continues to function effectively.

Inspect unpaved, graded areas to check for gullies and other signs of erosion. Inspect paving regularly for cracks that may allow contaminants to seep into the ground. Ensure drains receiving the discharge from the paved area remain free of clogged sediment or other debris so that the water does not back up into areas where pollutants may be.

When construction is complete, debris, unused stockpiles, and materials should be recycled or disposed of properly (Section 3.10.7, "Construction Disposal Alternatives"). Permanently stabilize staging areas with vegetation or other surface cover planned for the development.

Additional Resources

Colorado UDFCD (Colorado Urban Drainage and Flood Control District). 2010. *Urban Storm Drainage Criteria Manual, Volume 3 Best Management Practices*. Denver, CO. *http://udfcd.org/wp-content/uploads/2014/07/Title-Page.pdf*

ITD (Idaho Transportation Department). 2014. *Best Management Practices.* Boise, ID: ITD.

BMP 38: Preserve Topsoil and Vegetation

Description

Protect topsoil and vegetation (e.g., trees, grasses, and other plants) by preventing disturbance or damage to specified areas of the construction site. Preserving natural vegetation and native topsoil prevents soil erosion by minimizing the amount of bare soil exposed to erosive forces (Figure 99). Vegetation also provides storm water detention, biofiltration, and aesthetic value.

Even if existing vegetation will not remain permanently after construction is completed, existing vegetation and topsoil can still be preserved with proper phasing during construction to provide a stable surface cover.

Figure 99. Preserve vegetation (Elkhart County SWCD 2007).

Applicability

This BMP applies to all construction sites with existing vegetation. Areas where preserving vegetation and topsoil can be particularly beneficial are floodplains, wetlands, streambanks, steep slopes, and other areas where structural erosion controls would be difficult to establish, install, or maintain.

Compared to newly planted or seeded areas, preserving natural vegetation has many advantages:

- Handles higher quantities of storm water runoff than newly seeded areas.
- Does not require time to establish.
- Greater filtering capacity because the vegetation and root structure are denser in preserved natural vegetation than in newly seeded areas.
- Requires less maintenance, watering, and chemical application (e.g., fertilizer and pesticides) than new vegetation.
- Enhances aesthetics.
- Provides areas for infiltration, reducing the quantity and velocity of storm water runoff.
- Allows areas where wildlife can remain undisturbed.
- Provides noise buffers and visual screens for construction operations.

Primary BMP Functions and Controls

☒ Construction	☐ Permanent
☒ Erosion Control	☐ Sediment Control
☐ Source Control	☐ Flood Control
☐ Filtration	☐ Infiltration

Typical Effectiveness for Targeted Pollutants

●	Sediment
○	Phosphorus
○	Metals
○	Bacteria
○	Hydrocarbons
○	Litter

Other BMP Considerations

Relative Cost	$
Maintenance Requirements	Low
Ease of Installation	Easy
Freeze/Thaw Resistance	Good
Max. Tributary Drainage Area	N/A
Max. Upstream Slope	N/A
NRCS Soil Group	ABCD
Min. Ground Water Separation	N/A
Min. Bedrock Separation	N/A

Limitations

Preserving natural vegetation may be impractical in some situations because it may constrict the area available for construction activities, or it may not be cost-effective in areas with high land values. In areas with high land values, projects may need to be designed with little or no vegetation intended to remain to maximize development density. For sites with diverse topography, it may be difficult and expensive to save existing vegetation while grading the site for the development.

Design Basis

Successfully preserving vegetation requires good planning and site management. Preserving natural vegetation may affect some aspects of staging, work sequencing, and construction cost. Erosion control measures may be needed around the perimeter of the preserved area to maintain adequate water flow and drainage and prevent damage from excessive erosion or sedimentation.

Identify areas to be protected on the construction plans. Preserve individual natural vegetation, such as trees, shrubs, or vines, although preserving vegetation in clumps may be more practical. Protection areas should extend to the dripline of any trees to be preserved. The dripline marks the edge of the tree’s foliage where drips from rainfall would drop. When selecting trees to be preserved, consider the location, vigor, age, species, and wildlife benefits of the tree. Healthy, older trees that are well-suited to the site conditions and are beneficial to wildlife are most important to preserve.

Vegetation protection areas should be marked in the field before any site disturbance begins. Clearly mark the areas to be preserved with construction fencing and/or a perimeter control, such as silt fencing (BMP 65) or fiber rolls (BMP 64) if the protected area is located downgradient of areas to be disturbed. Use appropriate fence posts and adequate post spacing and depth to completely support the fence in an upright position. No construction activity, including stockpiling, materials storage, or equipment parking, should be allowed within the protected area.

Plants must be protected from three types of injuries possible during construction: impacts, grade changes, and excavations. By instructing employees and subcontractors to honor the limits of protection areas, the vegetation should be protected from these injuries.

Construction Guidelines

Check the project plans for areas designated for preserving natural vegetation. Keep all construction equipment, materials, and waste out of the designated areas. Root pruning and fertilizing before construction is recommended where trees are near the edge of protected areas. These practices should be supervised by a licensed arborist for the maximum survival rate.

Do not modify existing drainage patterns through or into any preservation area unless specifically directed by the plans or approved by the local permitting authority.

Retain protective fencing until all construction activity is complete to avoid damage during site cleanup and final stabilization.

Maintenance

Inspect fencing at regular intervals to ensure it is in place, and the preserved vegetated areas remain undisturbed and are not overwhelmed by sediment. Implement maintenance or restorative actions as needed. Proper maintenance is important to ensure healthy vegetation that can control erosion.

Different species, soil groups, and climatic conditions will require different maintenance activities such as mowing. Perform maintenance regularly, especially during construction.

If damage occurs to a tree, consult an arborist for guidance on how to care for the tree. If a tree in a designated preservation area is damaged beyond repair, remove and replace with a 2-inch diameter tree of the same or similar species. If damage occurs to vegetation, reseed the area with the same or similar species.

Additional Resources

CASQA (California Stormwater Quality Association). 2015. *California Stormwater Best Management Practices Handbook: Construction.* Menlo Park, CA. *https://www.casqa.org*

Colorado UDFCD (Colorado Urban Drainage and Flood Control District). 2010. *Urban Storm Drainage Criteria Manual, Volume 3 Best Management Practices*. Denver, CO. *http://udfcd.org/wp-content/uploads/2014/07/Title-Page.pdf*

Elkhart County SWCD (Elkhart County Soil and Water Conservation District). 2007. *BMP Hall of Fame*. Goshen, IN.

EPA (US Environmental Protection Agency). 2014. *Preserving Natural Vegetation*. Water: Best Management Practices. *https://www.epa.gov/npdes/national-menu-best-management-practices-bmps-stormwater#edu*

King County (King County, Washington). 2009. *King County, Washington Surface Water Design Manual.* Seattle, WA: King County, Department of Natural Resources.

BMP 39: Clearing Limits

Description

Establishing well-defined clearing limits on a construction site reduces the amount of bare soil exposed to erosive forces and prevents erosion and storm water sedimentation. Limits are accomplished by controlling the amount of ground cleared and grubbed at any one time and minimizing the amount of time bare ground is exposed before slope protection or stabilization measures are put into place (Figure 100).

This measure, with appropriate timing (BMP 36: Construction Timing), can reduce unneeded erosion and sedimentation (BMP 1: Minimize Land Disturbance and BMP 38: Preserve Topsoil and Vegetation).

Figure 100. Construction fencing used to define clearing limits on a construction site.

Applicability

This BMP is suitable for all construction sites where areas of undisturbed vegetation will be retained while other vegetation areas must be removed to facilitate construction. Careful coordination of land clearing, grading, and erosion control measures (BMP 36: Construction Timing) should be a design consideration for all projects.

Primary BMP Functions and Controls

☒ Construction ☐ Permanent
☒ Erosion Control ☐ Sediment Control
☐ Source Control ☐ Flood Control
☐ Filtration ☐ Infiltration

Typical Effectiveness for Targeted Pollutants

● Sediment
◖ Phosphorus
◖ Metals
○ Bacteria
○ Hydrocarbons
◖ Litter

Other BMP Considerations

Relative Cost	$
Maintenance Requirements	Low
Ease of Installation	Easy
Freeze/Thaw Resistance	Good
Max. Tributary Drainage Area	N/A
Max. Upstream Slope	N/A
NRCS Soil Group	ABCD
Min. Ground Water Separation	N/A
Min. Bedrock Separation	N/A

Limitations

Establishing clearing limits may not apply on sites where existing vegetation cannot be preserved.

Design Basis

Minimizing land disturbance should occur during the site design phase (BMP 1: Minimize Land Disturbance), and clearing limits should be identified on the SWPPP.

- Before site design begins, delineate all sensitive areas and any vegetation (such as desirable trees) to be preserved within the project site.
- Evaluate the erosion potential of the project site (based on slope, soil group intended season of

work, and use of heavy equipment). Avoid clearing steep slopes whenever possible. Retain the native topsoil and vegetation to the maximum extent possible.

Based on the erosion evaluation, prepare a site plan that minimizes disturbance to sensitive areas, desirable vegetation, steep slopes, and erosive soils. In the project site plan, clearly specify the maximum allowable exposure area (Figure 101).

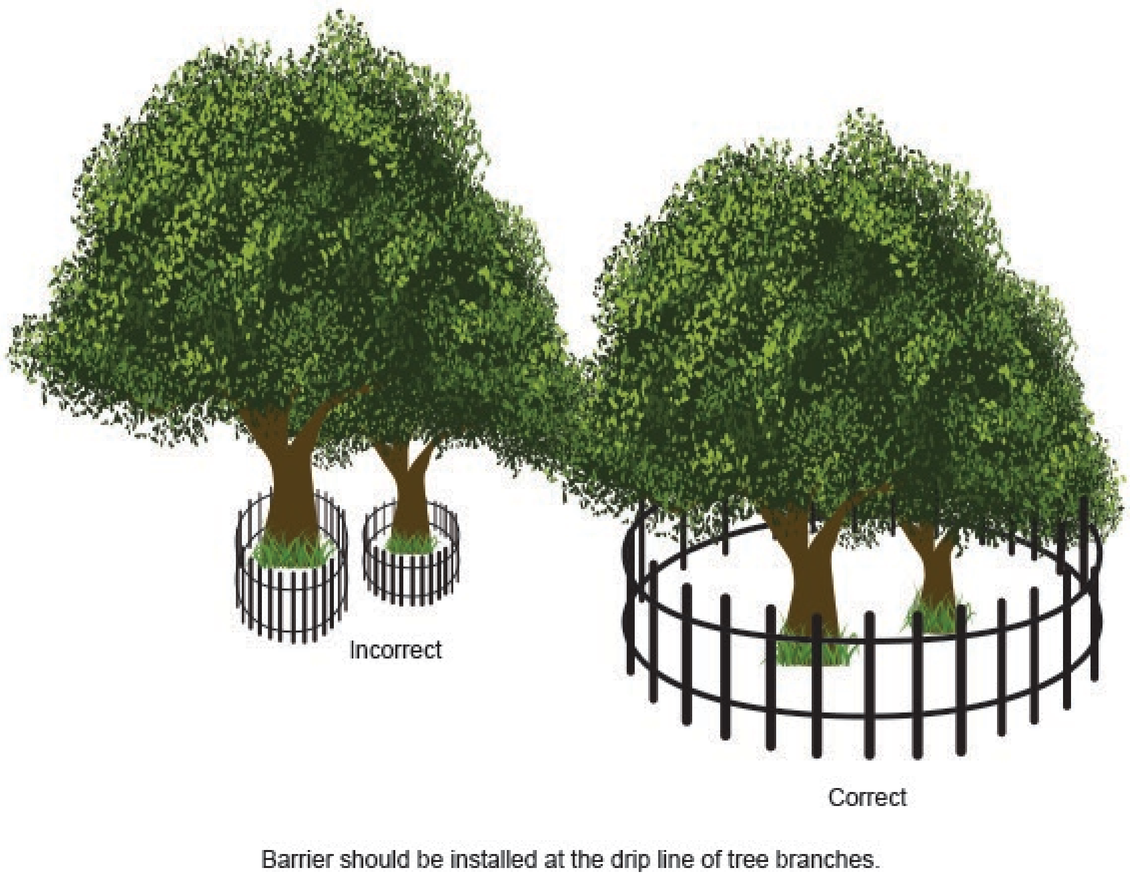


Figure 101. Vegetation barrier installation.

Construction Guidelines

During construction, the clearing limits should be clearly marked with brightly colored tape or plastic or metal safety fencing before beginning any land-disturbing activities, including clearing and grubbing. If tape is used, ensure it is 3 to 6 feet high, supported with sturdy vegetation or stakes, and highly visible.

Inform equipment operators of vegetation areas that should be left undisturbed and those not needed for the specified construction or related staging activities (BMP 38: Preserve Topsoil and Vegetation). Retain the duff layer, native top soil, and natural vegetation in an undisturbed state to the maximum degree practicable. Where clearing is required, follow these practices:

- Minimize compacted native soil by using plywood sheets, mulch, or wood chips.
- Do not place fill or deep cuts within dripline of trees to be preserved.

- Stabilize and reclaim the slope as work progresses to minimize the amount of disturbed soil. At a minimum, stabilization measures should be initiated within 14 days after ceasing work in a given area or as soon as practicable during seasonally arid periods.
- Conduct work in units or stages so that construction and stabilization takes place promptly after clearing and grubbing activities are completed.
- Schedule construction phasing to ensure cleared and graded areas are ready for seeding during the specified seeding season for the site location (BMP 32: Landscaping).
- Implement soil stabilization measures concurrently with the clearing and grading progress work to minimize the length of time that bare ground lies exposed to erosion.

Maintenance

Inspect fencing regularly and repair or replace as needed. Conduct periodic inspections to check for unnecessary ground disturbance. Check for clearing and grubbing beyond the contractor's capability to keep grading and pollution control measures current (according to accepted work schedule). Maintain clearing and grubbing limit markings until work is completed in that area. Remove and properly dispose of the material used in implementing this BMP.

Additional Resources

CASQA (California Stormwater Quality Association). 2004. *California Stormwater Best Management Practices Handbook: New Development and Redevelopment*. Menlo Park, CA. *https://www.casqa.org*

Central Oregon Intergovernmental Council. 2010. *Central Oregon Stormwater Manual.* 2010. Bend, OR.

King County (King County, Washington). 2009. *King County, Washington Surface Water Design Manual.* Seattle, WA: King County, Department of Natural Resources.

Washington State Department of Ecology. 2012. *Stormwater Management Manual for Western Washington*. Lacey, WA. Publ. 12-10-030. *http://www.ecy.wa.gov/programs/wq/stormwater/manual.html*

BMP 40: Vehicle Sediment Control

Description

This BMP describes measures to minimize track out of sediment from construction vehicles exiting the construction site onto off-site streets, other paved areas, and sidewalks. Sediment transported off site onto paved streets is a significant problem because it is difficult to effectively remove, and any sediment not removed ends up in the drainage system.

Figure 102. Stabilized gravel construction entrance examples (EPA 2003).

Temporary devices, such as a pad of coarse aggregate or a construction mat, should be installed at all exits from the construction site to a public roadway to stabilize the road and remove sediment (Figure 102). Additional controls to remove sediment from tires, such as wheel washing, rumble strips, and rattle plates, can also be used where necessary.

Primary BMP Functions and Controls

☒ Construction	☐ Permanent
☐ Erosion Control	☒ Sediment Control
☐ Source Control	☐ Flood Control
☐ Filtration	☐ Infiltration

Typical Effectiveness for Targeted Pollutants

- ● Sediment
- ○ Phosphorus
- ○ Metals
- ○ Bacteria
- ○ Hydrocarbons
- ○ Litter

Other BMP Considerations

Relative Cost	$
Maintenance Requirements	Medium
Ease of Installation	Medium
Freeze/Thaw Resistance	Good
Max. Tributary Drainage Area	N/A
Max. Slope	15%
NRCS Soil Group	ABCD
Min. Ground Water Separation	N/A
Min. Bedrock Separation	N/A

Applicability

Vehicle sediment control is appropriate for all construction sites in the following locations:

- Wherever vehicles are entering or leaving a construction site to or from a public right-of-way, street, alley, sidewalk or parking area.
- At any unpaved entrance/exit location where risk exists of transporting mud or sediment onto paved roads.

Vehicle sediment control is particularly important during wet weather periods when mud is easily tracked off site, during dry weather where dust is a concern, and when poorly drained, clayey soils are present on site.

Limitations

Vehicle sediment control using stabilized construction entrances are most effective when installed on level ground. If wheel washing is needed due to high sediment loads, washwater will need to be available and an additional sediment trap (BMP 66) may need to be installed.

Design Basis

Vehicle sediment controls include aggregate pad construction entrances and turf mat construction entrances. Additional controls may be needed if the stabilized construction entrance does not remove sufficient amounts of sediment from vehicle and equipment tires. The following sections provide design information for these practices.

Access and exits should be limited to one route if possible or two for linear projects such as roadways where more than one access/exit is necessary. Construction entrances should avoid crossing existing sidewalks if possible. If they must cross a sidewalk, the full length of the sidewalk should be covered and protected from sediment leaving the site.

Construct entrances on a level surface, and if feasible, grade to drain towards the construction site to reduce off-site runoff. Runoff from a stabilized construction entrance should drain to a sediment trap or a sediment basin, and a culvert should be installed under the entrance to convey water along the ditch of the public road if necessary.

Aggregate Pad Construction Entrance

A coarse aggregate pad underlain with a geotextile fabric is a common technique for stabilizing construction entrances (Figure 103). The width should be at least 15 feet but not less than the full width of points where ingress or egress occurs. At sites where traffic volume is high, the entrance should be wide enough for two vehicles to pass safely. Flare the entrance where it meets the existing road to provide a sufficient turning radius.

The recommended minimum length should be 50 feet, although 100 feet is preferred. The aggregate should include 3- to 6-inch diameter rock. The placement depth should be 9 inches minimum or as recommended by a soils engineer based on the maximum expected vehicle loads. For entrances that will become permanent or for long-term installations during construction, two layers may be needed with a base layer of 2- to 8-inch diameter crushed stone and a top layer of 2 inch diameter or smaller stone.

Place geotextile filter fabric under the aggregate to prevent fine sediment from pumping up into the rock pad and to reduce maintenance and loss of aggregate. The geotextile should be a nonwoven fabric consisting only of continuous chain polymeric filaments or yarns of polyester. The geotextile should be inert to commonly encountered chemicals, hydrocarbons, and mildew and rot resistant.

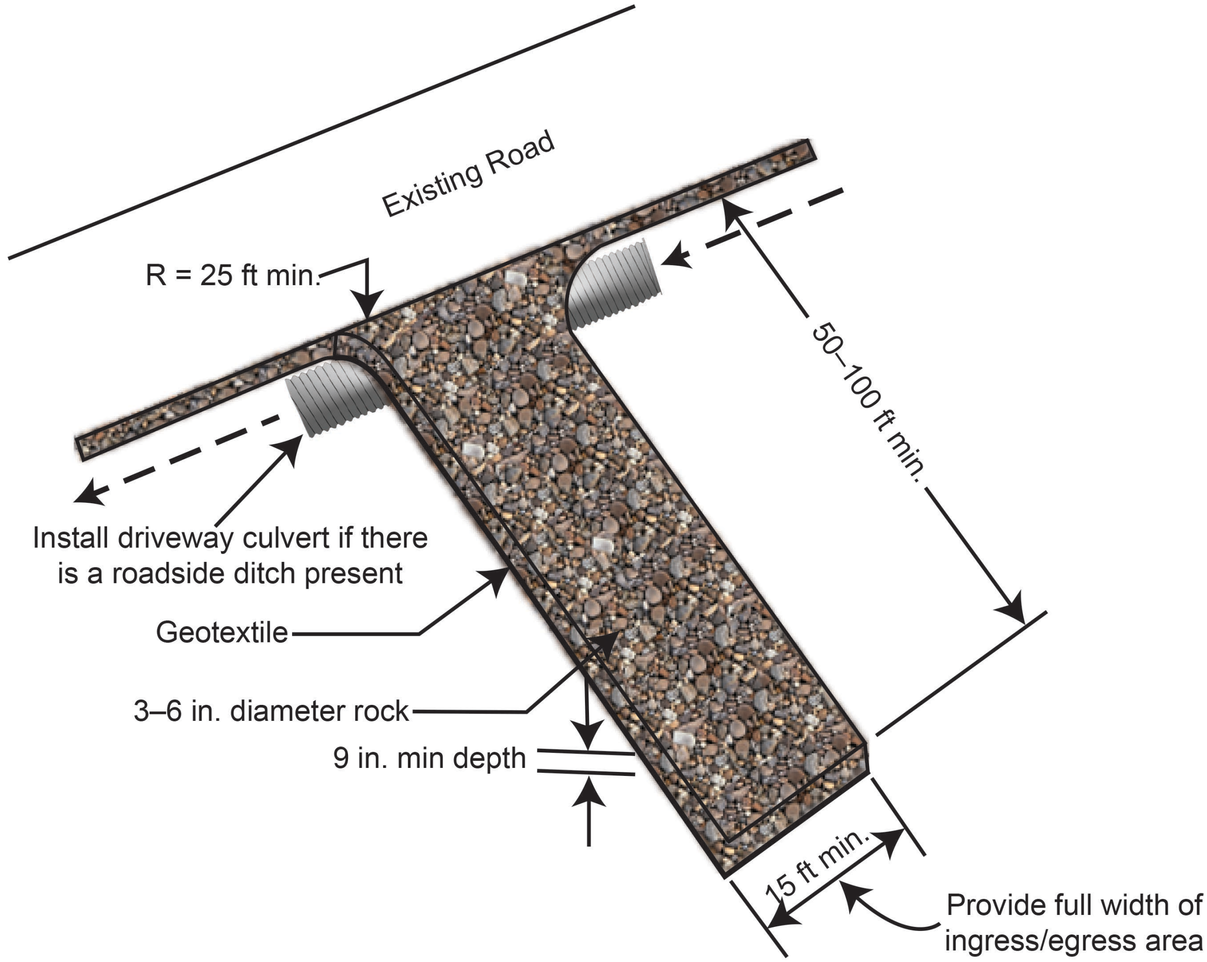


Figure 103. Aggregate pad construction entrance (adapted from King County 2009).

Construction Mat or Turf Reinforcement Mat

For small construction sites with low traffic volume, use a construction mat or turf reinforcement mat to stabilize the entrance (Figure 104 and Figure 105). The mats are made of steel, high-density polyethylene, timber, or a woven geotextile. Turf mats do not remove a significant amount of sediment from vehicles but do stabilize the entrance and prevent vehicles from causing rutting. These mats are especially suited for sites containing saturated soils, wetlands, or soft/poor subgrade as they provide immediate stabilization and some protection to existing vegetation. Some mats can be removed and reused on multiple sites.

Figure 104. Construction mat (*Matrax*).

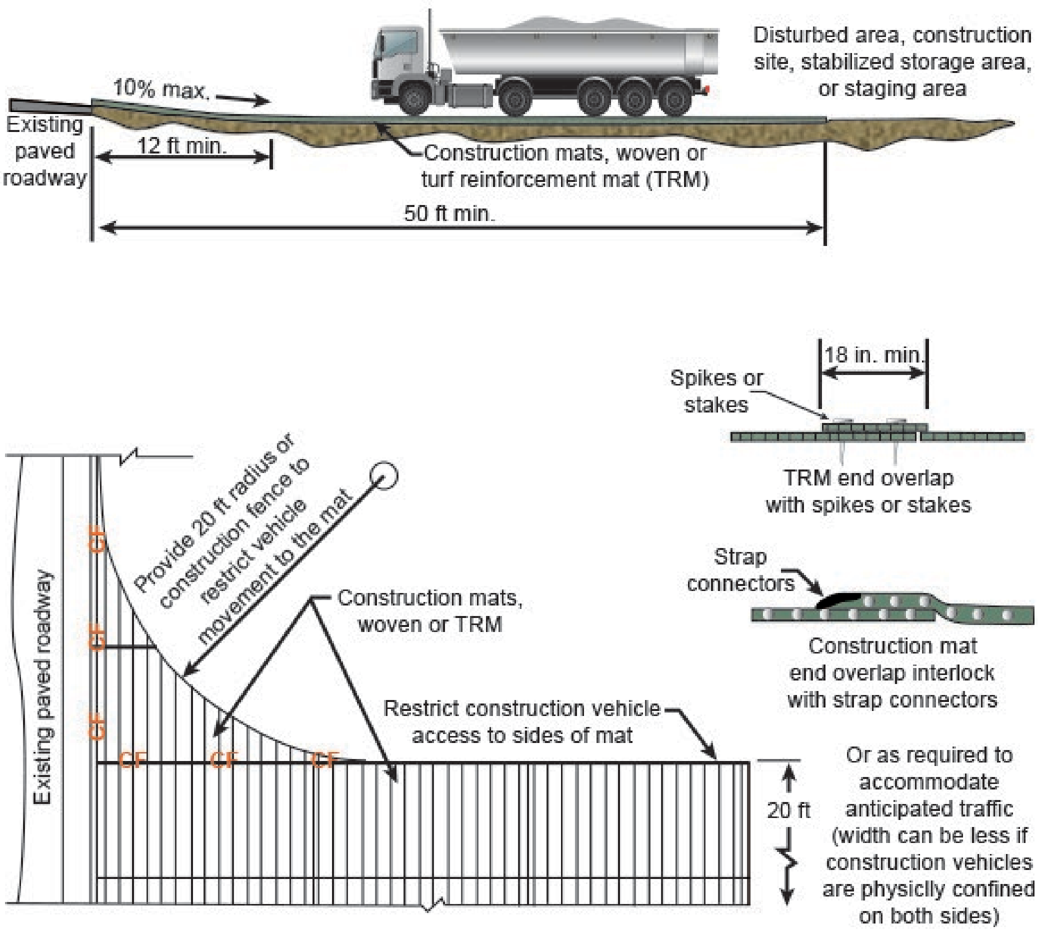


Figure 105. Vehicle-tracking control with construction mat or turf reinforcement mat (Colorado UDFCD 2010).

Additional Controls

If the stabilized construction entrance does not remove sufficient amounts of sediment from vehicle and equipment tires due to site conditions, additional controls may be required. Examples of additional controls include, but are not limited to, wheel washing, mountable berms, rumble strips, and rattle plates.

Wheel-washing facilities can be included within the stabilized construction entrance (Figure 106). It can be as simple as handheld power washing equipment to more advance systems. When washing is required, perform on an area stabilized with aggregate that drains into an approved sediment trap.

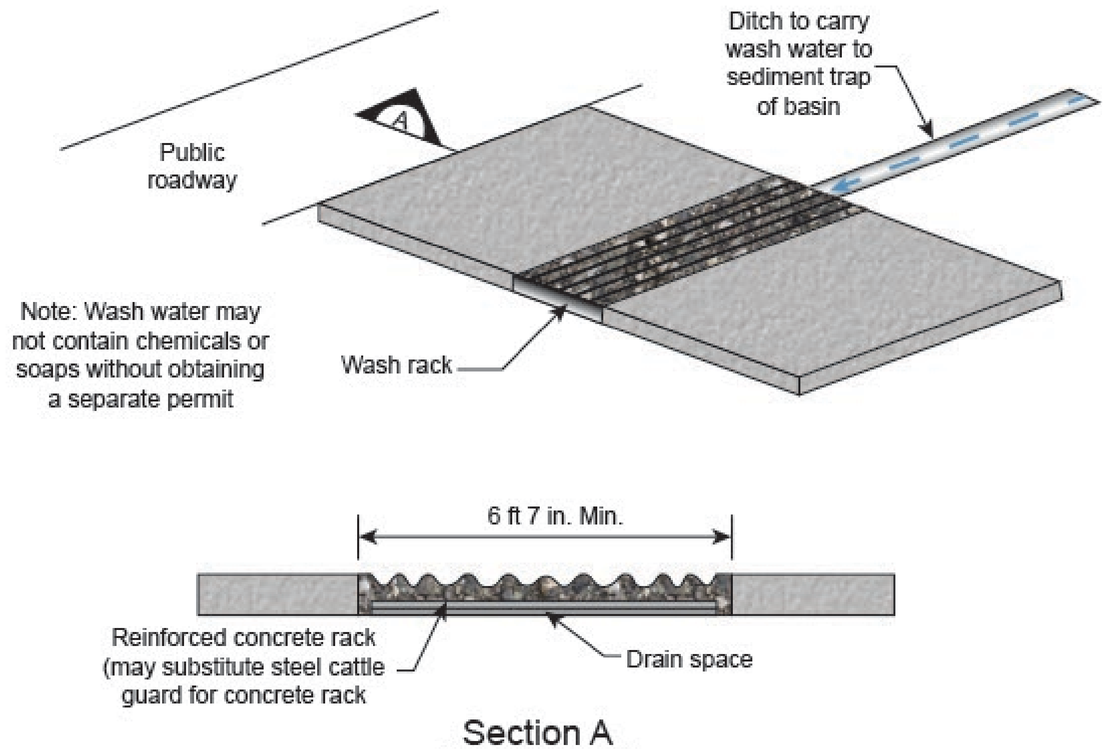


Figure 106. Aggregate vehicle-tracking control with wash rack (Colorado UDFCD 2010).

Mountable berms can be used in construction entrances to *bump* soil off of tires. These berms should be used when the entrance cannot be graded to flow away from the road. A mountable berm traps the pad water and keeps it from entering the adjacent road.

Rumble strips and rattle plates are constructed of steel panels with ridges or corrugations or pipes welded to a steel frame and can be installed within the construction entrance to remove additional sediment from vehicles. Rumble strips loosen and remove dirt and mud from vehicle tires as they pass over the construction entrance. Construct barriers around the sides of the rumble strips to ensure all construction vehicle and equipment tires travel over the rumble strips.

Rumble strip dimensions vary but typically are 8 feet long x 10 feet wide. Place rumble strip panels on a stable base and in the center of an aggregate entrance (Figure 107).

Figure 107. Rattle plates in construction entrance (*The Bag Lady*).

If sediment is tracked out of the construction site and onto off-site streets, sidewalks, or other paved areas, remove the sediment by sweeping, shoveling, or vacuuming. Complete cleanup by the end of the same work day when the track out occurs or by the end of the next work day if track out occurs on a nonwork day. Sediment should not be hosed or swept into an off-site storm water conveyance, storm drain inlet, or surface water.

Construction Guidelines

Stabilized construction entrances and any additional vehicle sediment controls should be installed as the first step in clearing and grading. Clear all vegetation, roots, and all other obstructions to prepare for grading, and ensure the entrance is properly graded and compacted before placing the geotextile fabric in the aggregate construction entrances.

All employees, subcontractors, and suppliers should be required to use the stabilized construction entrance. Place signage to direct construction traffic to the designated stabilized entrance, and use fencing where practical to restrict traffic to the stabilized construction entrance. Vehicle speeds should be limited to control dust (BMP 43: Dust Control). The stabilized construction entrance may be removed after final site stabilization is achieved or after the temporary BMPs are no longer needed. If stabilized entrances are located in a permanent site entrance, a geotechnical engineer should approve the subgrade after removal and before building the permanent entrance.

Maintenance

Inspect construction entrances and additional controls regularly and after storm events. Inspect local roads, sidewalks, and other paved surfaces adjacent to the site daily and sweep or vacuum accumulated sediment. Keep all temporary roadway ditches clear.

Construction entrances should be maintained in a condition that will prevent tracking or flow of mud onto public rights-of-way. Aggregate entrances may require periodic top dressing with additional 2 inches of stone (as conditions demand). If the aggregate pad is clogged with sediment, remove the aggregate and separate and dispose of the sediment. Rumble strips and rattle plates

must be kept clean to function properly. Sweep or scrape panels, and if water is used, discharge the washwater into a sediment trap adjacent to the rumble strips.

Additional Resources

Colorado UDFCD (Colorado Urban Drainage and Flood Control District). 2010. *Urban Storm Drainage Criteria Manual, Volume 3 Best Management Practices*. Denver, CO. *http://udfcd.org/wp-content/uploads/2014/07/Title-Page.pdf*

EPA (US Environmental Protection Agency). 2014. *Construction Entrances*. Water: Best Management Practices. *https://www.epa.gov/npdes/national-menu-best-management-practices-bmps-stormwater#constr*

King County (King County, Washington). 2009. *King County, Washington Surface Water Design Manual.* Seattle, WA: King County, Department of Natural Resources.

BMP 41: Stabilized Construction Roads and Staging Areas

Description

Stabilized construction roads and staging areas are clearly designated areas where construction equipment and vehicles travel and stockpiles, waste bins, material storage, and other construction-related equipment are stored. Stabilizing these areas immediately after grading reduces erosion caused by construction traffic and construction activities (Figure 108).

Methods for reducing erosion on stabilized construction roads are included in BMP 42.

Figure 108. Temporary construction access road (ITD 2014).

Applicability

Stabilize roads and staging areas whenever they are used by construction traffic or where concentrated traffic occurs, such as around materials storage areas. Stabilization is especially important for construction during wet weather, where dust can be a problem, on slopes greater than 5%, and/or adjacent to water bodies. This practice is also important on large sites where heavy equipment traverses the site for large grading operations.

Primary BMP Functions and Controls

☒ Construction	☐ Permanent
☒ Erosion Control	☒ Sediment Control
☐ Source Control	☐ Flood Control
☐ Filtration	☐ Infiltration

Typical Effectiveness for Targeted Pollutants

●	Sediment
○	Phosphorus
○	Metals
○	Bacteria
○	Hydrocarbons
○	Litter

Other BMP Considerations

Relative Cost	$
Maintenance Requirements	Medium
Ease of Installation	Medium
Freeze/Thaw Resistance	Good
Max. Tributary Drainage Area	N/A
Max. Slope	15%
NRCS Soil Group	ABCD
Min. Ground Water Separation	N/A
Min. Bedrock Separation	3 feet

Limitations

During design and planning, minimize the disturbance area to the maximum extent practical. Oversizing the stabilized staging area may result disturbing existing vegetation more than required for the project. Excess disruption increases costs and requirements for long-term stabilization after construction.

Temporary roads that encroach on jurisdictional wetlands require appropriate permits.

Design Basis

Location

Place construction roads and staging areas where site impacts will be minimized and as far away as possible

from streams, surface waters, or wetlands. Sites that include permanent roads or parking areas are recommended for construction roads and staging areas.

Temporary roads should mimic the natural slope, not disrupt natural drainage pathways, and have a maximum longitudinal slope of 15%. Grade the roads to prevent runoff from leaving the site. Roadways should be graded to drain transversely into stabilized drainage swales or gravel berms next to the road. Direct intercepted runoff from the road to a sediment trap (BMP 66) or other sediment control measure.

Surface

Roads and staging areas should be constructed to handle the maximum expected loads during construction, and whenever possible, placed on a firm, compacted subgrade. If design recommendations are not available from a geotechnical or civil engineer, stabilize the surface by either paving or placing 2- to 4-inch diameter aggregate 3 to 6 inches deep.

The aggregate can be crushed rock, gravel base, recycled concrete, or crushed surfacing base course. Early application of road base is generally suitable where a layer of coarse aggregate is specified for final road construction.

Geotextile Fabric

Most installations will include geotextile fabric placed over the entire area to be covered with aggregate. Work on single residential lots will generally not need geotextile fabric unless there is potential for excessive erosion, a high water table, or other risk factors. The geotextile should be a woven or nonwoven fabric consisting only of continuous chain polymeric filaments or polyester yarns. The geotextile should be rot resistant and inert to commonly encountered chemicals, hydrocarbons, and mildew. ITD's *Standard Specifications for Highway Construction*, Section 718 provides guidance on geotextile properties for a variety of applications (ITD 2017).

Fencing

Construction fencing may be needed to limit access of vehicles to roads and staging areas that are stabilized and to prevent unauthorized access to construction materials.

Sediment Control

Perimeter sediment controls such as silt fence (BMP 65), sediment fiber rolls (BMP 64), or other measures may be needed around construction staging areas. Erosion control methods for temporary roads include road sloping, rolling dips, waterbars, open-top box culverts, or level spreaders. BMP 42: Erosion Prevention on Construction Roads provides more information.

Construction Guidelines

Construction roads and staging areas should be stabilized immediately after grading. If construction roads do not adequately reduce track out to adjacent property or roadways, a wheel wash system may be required as described in BMP 40: Vehicle Sediment Control.

Maintenance

Inspect all devices regularly, especially after large storm events. Make repairs promptly to avoid progressive damage. Aggregate should be added as required to maintain a stable driving surface and to stabilize areas that have eroded. Remove accumulated sediments as necessary from roadside swales to ensure proper functioning.

After construction is complete, temporary construction roads and staging areas should be removed and the area, regraded, and restored to preconstruction condition or better using permanent erosion and sediment control BMPs. Remove or stabilized trapped sediment and permanently stabilize disturbed areas. When a temporary construction road or staging area is used for a permanent road or parking surface, the subgrade is subject to inspection before final paving.

Additional Resources

ITD (Idaho Transportation Department). 2017. "Geotextiles." Section 718. *Standard Specifications for Highway Construction*. Boise, ID.

ITD (Idaho Transportation Department). 2014. "Sediment Control Best Management Practices." SC-12 Temporary Roads and Standard Drawing P-1-F. *Best Management Practices*. *http://apps.itd.idaho.gov/apps/env/BMP/PDF%20Files%20for%20BMP/Chapter%201/Chapter%201%20Erosion%20Control%20Best%20Management%20Practices.pdf*

BMP 42: Erosion Prevention on Construction Roads

Description

Haul roads, detours, access roads, and other unpaved or temporary roadbeds associated with a construction project should include erosion prevention measures (Figure 109). BMP 41 provides recommendations for temporary construction roads. Erosion prevention measures for temporary construction roads include the following:

- **Waterbar (or cross ditch)**—A cut and berm built at a downward angle across the roadway, extending from the cut bank to the opposite fill shoulder. Waterbars reduce erosion by diverting storm water runoff from the road surface and directing it to a safe discharge area.
- **Road sloping**—A method of constructing the road with an inward slope of 1% to 2% from the fill slope to the cut slope. Sloped roads are designed to divert surface water off the entire road surface and concentrate flows to discharge into a sediment basin (BMP 66) or another sediment control device.
- **Rolling dip**—A method of constructing the road with shallow, outward-sloping dips or undulations to collect surface runoff and convey it away from the road surface.

Figure 109. Sloped area on side of road directs storm water.

Primary BMP Functions and Controls

☒ Construction	☐ Permanent
☒ Erosion Control	☒ Sediment Control
☐ Source Control	☐ Flood Control
☐ Filtration	☐ Infiltration

Typical Effectiveness for Targeted Pollutants

●	Sediment
○	Phosphorus
○	Metals
○	Bacteria
○	Hydrocarbons
○	Litter

Other BMP Considerations

Relative Cost	$
Maintenance Requirements	Medium
Ease of Installation	Medium
Freeze/Thaw Resistance	Good
Max. Tributary Drainage Area	5 acres
Max. Slope	15%
NRCS Soil Group	ABCD
Min. Ground Water Separation	N/A
Min. Bedrock Separation	3 feet

Applicability

A waterbar is a temporary or permanent drainage facility on light-use, low-maintenance, unpaved roads. Waterbars should be placed above grade changes to prevent water from flowing down steeper portions of roads or skid trails. Bars may also be placed above intersections of roads, skid trails, or landings to protect these disturbed areas.

Road sloping is used as a drainage measure on temporary or low-traffic haul roads where erosion of the roadbed and fill slope is unlikely due to low runoff volume or intensity.

A rolling dip is used as a runoff diversion measure to prevent erosion of the road surface. Rolling dips are effective on long inclines to keep storm water from flowing directly down the road, where it may cause gullying and other damage to the road surface and grade.

Limitations

A waterbar is suitable only for light-use, low-maintenance, unpaved roads. Road sloping is suitable only for low-traffic haul roads where runoff volume and intensity are low. A rolling dip is not suitable on road grades steeper than 5%.

Design Basis

Waterbars are generally constructed using a blade-equipped tractor or by hand. The size of the waterbar depends on the amount of precipitation in the area, soil erodibility, and anticipated traffic (Figure 110).

- The waterbar should extend from the cut-bank side of the road completely across to the fill-slope side.
- Cut dimensions: Up to 18 inches deep across road, 8 to 18 inches deep at outlet, 3 to 4 feet wide.
- Berm dimensions and orientation: 12 to 18 inches high with 5-inches minimum height, skewed at angle of 30° to 40° across road.
- Discharge: Runoff should not be directed onto fill material without proper energy dissipation and drainage away from the fill.

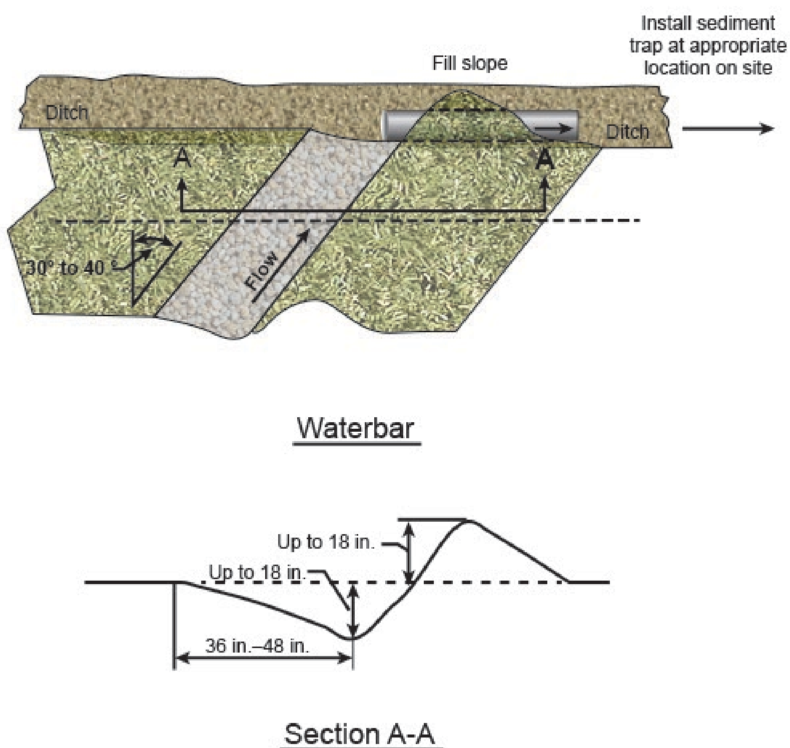


Figure 110. Waterbar (ITD 2014).

Road slope should be approximately 1% to 2% from the fill slope inward to the cut slope. Berms on the outside of the road should be limited or removed to allow water to flow off the road surface. Provide sediment collection or erosion-control measures at the toe of the cut slope to prevent excessive erosion and sediment transport (Figure 111).

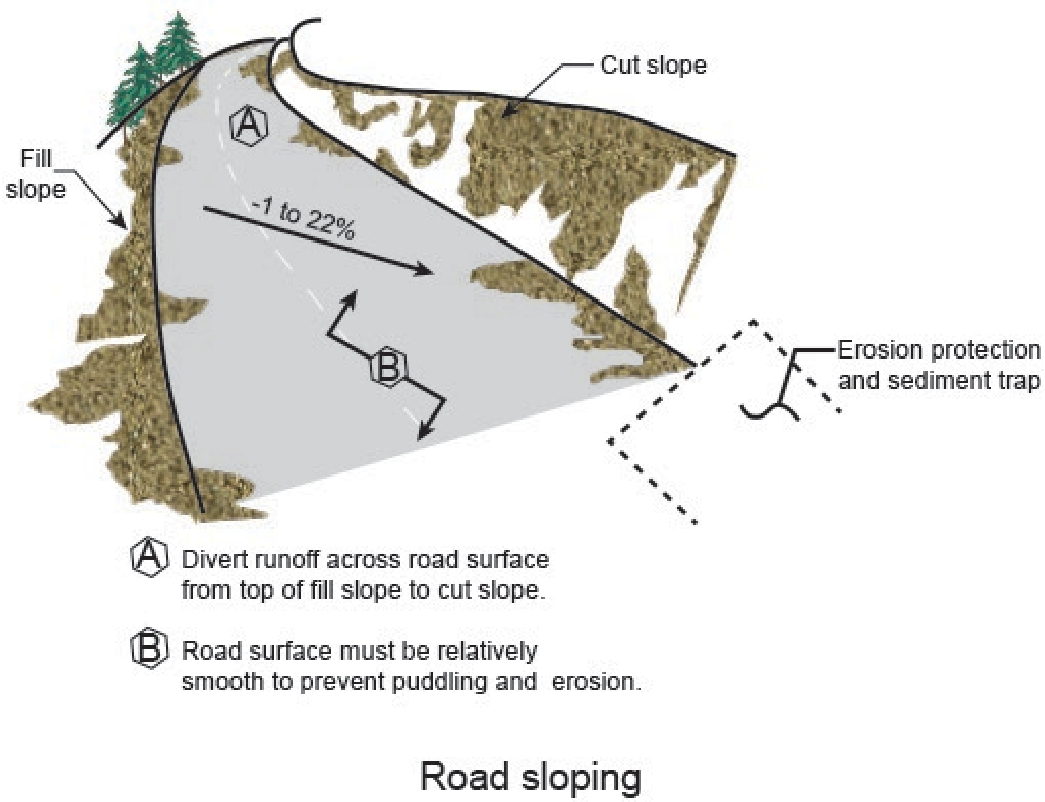
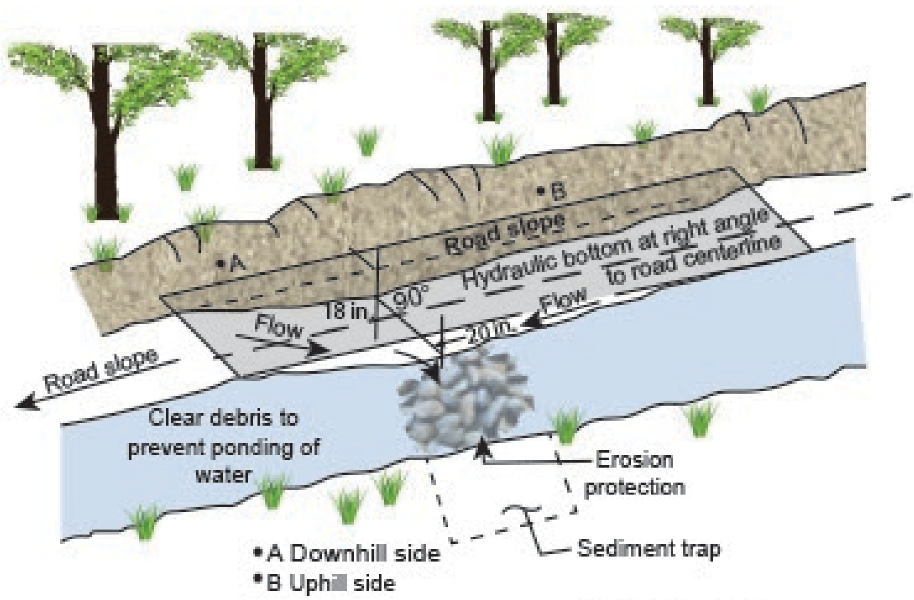


Figure 111. Road sloping (ITD 2014).

A rolling dip applies to roads greater than 150 feet long. When designing rolling dips, consider the unique topography of the site. In general, the dip should be approximately 1 foot below the surface plane of the road. The upgrade approach to the bottom of the dip should be 65 to 75 feet long, and the downgrade approach to the bottom of the dip should be 25 to 35 feet long depending on the longitudinal slope of the road. Align the dip across the road at nearly a 90^o angle, and slope it outward approximately 5% (Figure 112).



Rolling Dip Dimension Table		
% Road Slope	A (Downhill)	B (Downhill)
0%—4%	35 ft	65 ft
4%—6%	25 ft	75 ft

Figure 112. Rolling dip (ITD 2014).

As shown in Figure 110 to Figure 112, concentrated discharge from construction roads should be handled appropriately by routing through sediment control BMPs such as a sediment trap (BMP 66) or portable sediment tank (BMP 67).

Construction Guidelines

Waterbar—Cut each waterbar into solid soil to a minimum depth of 6 inches next to the cut bank and 8 inches at the road shoulder, with an adverse grade on the downroad or downgrade side of the waterbar. Build a continuous, firm berm of soil, at least 6-inches above normal grade, parallel to the waterbar cut on its downhill side. Include a bank tie-in point, cut 6 to 12 inches into the roadbed. For added stability, the bar may be compacted with a nonerosive fill material. The completed waterbar should extend across the full roadway width, aligned at an angle of 30^{o} to 40^{o} relative to the roadway. A dissipation or filter device (such as riprap or silt fence) may be needed below the waterbar to control erosion and trap sediment.

Road Sloping—Build into the road during construction. Install erosion- and sediment-control measures downslope before completing the finish grade of the sloped road. Then construct the outward slope of 1% to 2%, as specified in the contract plans.

Rolling Dip—Build into the road, during construction and follow the natural contours of the land. Install erosion and sediment measures at the low point of the dip (drainage outfall to fill slope) before final grading to direct storm water discharge from the dip. Construct the dip according to

the specifications shown in the contract plans. If not specified, make the dip 1 foot deep, with a 23-foot long approach on the downgrade side and a 66-foot long approach on the upgrade side.

Maintenance

Inspect all devices regularly according to provisions of the contract or project site plan. Make repairs promptly to avoid progressive damage. Remove accumulated sediments as necessary to ensure proper functioning.

Properly constructed waterbars should require little or no maintenance. However, all waterbars need to be open at the lower end so water can easily flow away from the roadway. Hand shovel work may be necessary following high runoff periods or severe storms to ensure unrestricted flow.

For road sloping, minor regrading may be required to maintain slope angle.

For a rolling dip, outflows should be kept free of debris to prevent ponding.

Additional Resources

ITD (Idaho Transportation Department). 2014. “Sediment Control Best Management Practices.” Standard Drawing Erosion and Sediment Control Drawing P-1-F. *Best Management Practices*. *https://apps.itd.idaho.gov/apps/StandardDrawings/All_Standards_2016-06.pdf*

BMP 43: Dust Control

Description

Dust control and wind erosion prevention BMPs keep soil particles from entering the air as a result of land-disturbing construction activities by protecting the soil surface, roughening the surface, and/or reducing the surface wind velocity (Figure 113).

Figure 113. Sprinkling water for dust control on a pathway construction project, Driggs, Idaho.

Dust control practices apply to either disturbed graded areas or construction roadways. For disturbed graded areas, practices such as seeding or sodding (BMP 32), mulching (BMP 52), using soil binders (BMP 55), sprinkling, surface roughing (BMP 58) or practices that provide prompt surface cover can be used. For construction roadways, practices such as using a stabilized surface (BMP 41), sprinkling, or using chemical dust tackifiers are options. Wind barriers can control wind currents and minimize the amount of dust transported into air and water.

Applicability

Use control measures on any construction site where the potential exists for air or water pollution from dust, especially when open, dry areas of soil are anticipated on site and where heavy construction activity such as clearing, grading, excavation, demolition, or excessive vehicle traffic takes place. Dust control is especially important in regions experiencing long periods without rain and during the summer when soil can become dry and vulnerable to transport by wind. In many cases, water erosion control measures incorporated into the project will indirectly prevent wind erosion.

Limitations

Vegetative dust control measures may not be practical during dry periods without a reliable supply of establishment water. Other methods should be stipulated in the project contract to ensure that dust control is not overlooked.

Primary BMP Functions and Controls

☒ Construction	☐ Permanent
☒ Erosion Control	☐ Sediment Control
☐ Source Control	☐ Flood Control
☐ Filtration	☐ Infiltration

Typical Effectiveness for Targeted Pollutants

●	Sediment
○	Phosphorus
◖	Metals
○	Bacteria
◖	Hydrocarbons
○	Litter

Other BMP Considerations

Relative Cost	$
Maintenance Requirements	Medium
Ease of Installation	Easy
Freeze/Thaw Resistance	Good
Max. Tributary Drainage Area	N/A
Max. Upstream Slope	N/A
NRCS Soil Group	ABCD
Min. Ground Water Separation	N/A
Min. Bedrock Separation	N/A

Wind barriers (such as walls or fences) can be part of the long-term dust control strategy in arid and semiarid areas, but they are not a substitute for permanent stabilization.

Chemically treated subgrades may make the soil water repellent, interfering with long-term infiltration and vegetation/revegetation of the site. Some chemical dust suppressants may be subject to freezing and may contain solvents that must be handled properly.

Overwatering may cause erosion and wash sediment or other constituents into the drainage system.

Design Basis

Develop a dust control plan before construction. The plan should evaluate the site with potential dust emission sources identified, provide a selection of dust control methods for each area of the site, determine the maintenance needed, and monitor the effectiveness of the selected dust control measures. The site evaluation should consider the soil type, prevailing wind direction, and effects of other prescribed erosion control measures.

Dust Prevention

The best method of controlling dust is to prevent dust production:

- **Minimize the surface area disturbed—**By limiting the amount of bare soil exposed at one time, less ground is disturbed, less dust is raised while working, and less cleanup is required when work is done. During project design, identify areas where ground disturbance will not be allowed and fence or provide signage during construction. Design and locate haul roads, detours, and staging areas to avoid unnecessary exposure of bare ground.
- **Limit dusty work on windy days—**Minimize amount of ground disturbance occurring when potential for wind erosion is highest. Apply dust suppression measures when needed. Monitor dust suppression efforts to ensure dust emissions are adequately controlled. Depending on weather conditions, adjust to fewer or more frequent application intervals.
- **Clean up dusty spills immediately—**Do not wait for the next scheduled housekeeping; the mess will just get bigger and cleanup will take longer.
- **Plan ahead to limit dust—**Avoid using areas most susceptible to wind erosion. In the storm water site plan, specify staging or work-sequencing techniques that minimize the risk of wind erosion from bare soil. In most cases, a change will be required from traditional construction techniques that allow large areas to be disturbed at the outset of construction and remain exposed for long periods of time.

Graded Areas

Clearing and grading activities create the opportunity for large amounts of dust to become airborne. Stabilize graded areas as soon as practicable after disturbance and do not leave open areas uncovered. The following practices can help with dust control in graded areas:

- **Grow vegetative ground cover—**Exposed areas that are not being paved should be stabilized using vegetation and landscaping (BMP 32) to prevent wind and water erosion. When rainfall is insufficient to establish vegetative cover, mulching (BMP 52) conserves

moisture, prevents surface crusting, reduces run-off erosion, and helps to establish vegetation. It is a critical treatment on sites with erosive slopes.

- **Use wind barriers**—Barriers prevent erosion by obstructing the wind near the ground and preventing the soil from blowing off site. Wind, snow, or silt fences or similar barriers are temporary measures that can reduce wind velocity. Perennial grass, bushes, stands of trees, rock walls, wooden board fences, or earthen banks are more permanent measures that can serve as wind barriers. A wind barrier generally protects soil downwind for a distance of 10 times the height of the barrier. If additional protection is needed, use other methods with the barrier.
- **Surface roughening**—Deep tillage in large open areas brings soil clods to the surface where they rest on top of dust, preventing it from becoming airborne. Tilling or disking should leave 6-inch (minimum) furrows, preferably perpendicular to the prevailing wind direction, to gain the greatest reduction in wind erosion. If the surface cannot be furrowed perpendicular to the prevailing wind direction, roughening the surface by using a ripper/scarifier (grader) or a ripper (cat) will produce the desired result of a 6-inch irregular surface. BMP 58: Slope Roughening provides more information.

Construction Roadways and Storage Areas

Temporary construction roads and storage areas should be stabilized using recommendations in BMP 42: Erosion Prevention on Construction Roads to minimize the amount of dust generated by construction vehicles. Other recommendations for dust control on construction roadways and storage areas include the following:

- **Water and/or sweep often**—Sprinkle the site with water until the surface is wet. Apply at a rate of 3 gallons per acre so that the soil is wet but not saturated or muddy and so that no dust is being generated. To ensure vehicle traffic is not picking up dust from wind action and carryout, water and sweep roadways often. Fewer treatments are necessary in cool, wet weather.
- **Spray-on chemical soil treatments (palliatives)**—Spray-on soil binders form a bond between soil particles keeping them grounded. Chemicals include mineral salts, petroleum resins, asphalt emulsion, acrylics, and adhesives. These treatments must be reapplied periodically to ensure continued effectiveness. Chemical tackifiers should only be used on mineral soils, and the chemicals should not create any adverse effects on storm water, plant life, surface water, or ground water. Check with DEQ to ensure the material to be applied is not harmful and may be used for this purpose.
- **Reduce speed limits**—Reduce speed limits on unpaved surfaces to 10 to 15 miles per hour for well-traveled areas and heavy vehicles. Never exceed 25 miles per hour for any vehicle on any unpaved surface.
- **Prevent transport of dusty material off site**—Minimize transport of dusty material off site by rinsing vehicles before they leave the property, tightly cover loaded trucks, and provide stabilized construction roads and staging areas (BMP 41).
- **Enclose storage and handling areas**—If dusty materials are frequently loaded and unloaded in storage and handling areas, enclose the areas to reduce dust production. Use storage silos, three-sided bunkers, or open-ended buildings. If handling is less frequent, try wind fencing. Conveyor loading may require enclosure or the use of water or foam spray bars both above and below the belt surface to reduce emissions.

- **Keep storage piles covered**—When storage piles are not in use, apply a physical cover or a dust suppressant spray to reduce dust emissions. Limit the working face of the pile to the downwind side. Most emissions come from loading the pile, loadout from the pile, and truck and loader traffic in the immediate area if the pile is batch loaded. Keep the drop height low to reduce dust and the ground at the base of the pile clear of spills.

Construction Guidelines

Dust control measures should be considered and selected before clearing and grading activities. During construction, monitor dust control activities on a regular basis to ensure the measures taken are adequately preventing airborne dust from leaving the site.

Maintenance

Dust control requires constant attention: it is not a one-time or once-in-awhile activity. Dust control sprinkling may have to be done several times a day during hot, dry weather.

Areas protected by mulch, adhesive emulsions, or barriers need to be checked at regular intervals according to the inspection schedule in the storm water plan.

Apply spray-on chemical treatments using the manufacturer's specified rates and according to all federal, state, and local regulations. Chemical products should be stored, handled, and disposed of according to all applicable local and state regulations and policies.

Additional Resources

DEQ (Idaho Department of Environmental Quality). 2013. *Controlling Fugitive Dust at Construction Sites.* Boise, ID: DEQ.

EPA (US Environmental Protection Agency). 2014. *Dust Control*. Water: Best Management Practices. *https://www.epa.gov/npdes/national-menu-best-management-practices-bmps-stormwater#constr*

BMP 44: Stockpile Management

Description

Stockpile management procedures and practices reduce or eliminate air and storm water pollution from stockpiled erodible materials, such as soil, sawdust, landscaping bark, compost, sand, fly ash, stucco, hydrated lime, Portland cement concrete rubble, asphalt concrete, asphalt concrete rubble, aggregate base, aggregate subbase, premixed aggregate, asphalt minder (or *cold mix* asphalt), and pressure-treated wood. Raw material stockpiles can easily erode during storm events and contribute suspended solids, nutrients, metals, and pH changes to storm water runoff (Figure 114).

Figure 114. Covered stockpile (ITD 2014).

Primary BMP Functions and Controls

☒ Construction	☐ Permanent
☒ Erosion Control	☐ Sediment Control
☒ Source Control	☐ Flood Control
☐ Filtration	☐ Infiltration

Typical Effectiveness for Targeted Pollutants

●	Sediment
◖	Phosphorus
◖	Metals
○	Bacteria
○	Hydrocarbons
◖	Litter

Other BMP Considerations

Relative Cost	$
Maintenance Requirements	Low
Ease of Installation	Easy
Freeze/Thaw Resistance	Good
Max. Tributary Drainage Area	N/A
Max. Upstream Slope	N/A
NRCS Soil Group	ABCD
Min. Ground Water Separation	N/A
Min. Bedrock Separation	N/A

Applicability

Implement stockpile management on all construction sites that stockpile and store erodible materials or have land-clearing debris composed, in whole or in part, of sediment or soil.

Limitations

Covering alone may not protect exposed materials from contact with storm water runoff and run-on. Using plastic sheeting to cover stockpiles can increase runoff volume and rates and potentially cause failure of sediment controls placed around the stockpile's perimeter. In extremely windy areas, tarpaulins and sheeting may require additional weights or securing.

Design Basis

Location

Locate stockpiles a minimum of 50 feet away from concentrated storm water flows, drainage courses, and inlets and outside of any natural buffers (BMP 2) and in areas that will remain undisturbed for the longest period of time as construction progresses.

Do not place stockpiles in streets or paved areas unless no other practical alternative exists.

Covering

Covering prevents storm water from coming into contact with potential pollutants, minimizes sediment discharge, and reduces material loss from blowing wind. Covering is a simple, effective, and inexpensive way to reduce or prevent pollution from stockpiles. Materials used as stockpile covers include tarpaulins, plastic sheeting, and pervious fabrics; mulches (BMP 52), vegetation (BMP 32), or soil binders (BMP 55) can be used for soil stockpiles that will be in place for longer periods of time.

Plastic sheeting with nylon reinforcement can be more durable than standard sheeting; avoid sheeting made of photodegradable plastics. Due to the relatively rapid breakdown of most polyethylene sheeting, it is unsuitable for applications over 6 months.

Sediment Control

Place a temporary sediment control barrier around the stockpile's perimeter to protect it from storm water run-on from the site and the site from runoff from the stockpile. Perimeter control barriers such as berms (BMP 70), dikes (BMP 69), fiber rolls (BMP 64), silt fences (BMP 65), or biofilter bags (BMP 63) can be used. For stockpiles located on paved areas, rock socks are recommended for perimeter control, and all inlets with the potential to receive sediment from the stockpile should be protected (BMP 74: Inlet Protection).

Implement dust and wind erosion control practices as appropriate on all stockpiled material. Place bagged materials on pallets and under cover.

Accumulated sediment on pavement or other impervious surfaces should not be hosed down or swept into any storm water conveyance (unless connected to a sediment basin, sediment trap, or similarly effective control), storm drain inlet, or surface water.

Nonactive Stockpile Protection

Nonactive stockpiles of the following materials should be protected as follows:

Soil stockpiles—Cover soil stockpiles or protect with soil stabilization measures and a temporary perimeter sediment barrier at all times. Unless permit requirements or other local regulations specify otherwise, soil stockpiles should be covered or stabilized within 14 days after the stockpile is placed or sooner if site conditions, such as highly erodible soils or expected rainfall, warrant. For site discharges to impaired waters, complete stabilization activities within 7 calendar days.

Stockpiles of Portland cement concrete rubble, asphalt concrete, asphalt concrete rubble, aggregate base, or aggregate subbase—Cover and protect stockpiles with a temporary perimeter sediment barrier at all times.

Stockpiles of *cold mix*—Place cold mix stockpiles on and cover with plastic sheeting, or a comparable material, at all times and surround covered stockpile with a berm.

Stockpiles/storage of pressure-treated wood—Cover pressure-treated wood with plastic sheeting or comparable material at all times and surround with a berm.

Stockpiles of fly ash, stucco, and hydrated lime (basic materials)—At all times, cover stockpiles of materials that may raise the pH of runoff with plastic sheeting and surround with a berm.

Active Stockpile Protection

For actively used stockpiles, the perimeter sediment control barrier should have a stabilized designated access point on the upgradient side of the stockpile. Divert runoff around or away from the stockpile on the upstream side of the stockpile.

Cover all actively used stockpiles before the onset of precipitation. Stockpiles of *cold mix*, treated wood, and basic materials should be placed on and covered with plastic sheeting or a comparable material and surrounded by a berm before the onset of precipitation.

Construction Guidelines

Stockpiles should be protected immediately if they are not scheduled to be used within 14 days of placement.

To cover stockpiles with tarpaulins or plastic sheeting, obtain enough fabric or sheeting to cover the indicated volume or area. Anchor the edges of the covering with stakes, tie-down ropes, large rocks, tires, or other readily available, heavy objects. Maintain an overlap of 3 feet along the borders and securely anchor the overlap area so that it does not separate (by wind or other causes).

Maintenance

During the rainy season, inspect the stockpile BMPs weekly before forecasted rain events, daily during extended rain or high wind events, and after the rain or high wind events end. During the nonrainy season, inspect BMPs every 2 weeks. Make any necessary repairs after inspection.

Repair and/or replace perimeter controls and covers as needed to keep them functioning properly. Sediment should be removed when it reaches one-third of the barrier height.

Frequently inspect coverings for damage and general wear. Repair or replace coverings immediately, or as needed. Inspect plastic sheeting more frequently during periods of high winds or extreme heat.

Additional Resources

CASQA (California Stormwater Quality Association). 2015. "Stockpile Management." *California Stormwater Best Management Practices Handbook: Construction.* Menlo Park, CA. *https://www.casqa.org/resources*

ITD (Idaho Department of Transportation). 2014. "Stockpile Management." *Best Management Practices.* Boise, ID: ITD. *https://apps.itd.idaho.gov/apps/env/BMP/PDF%20Files%20for%20BMP/Chapter%204/WM-4%20Stockpile%20Management.pdf*

BMP 45: Minimize Soil Compaction

Description

Minimizing soil compaction protects and minimizes damage to existing soil quality, structure, and permeability. When soils are overly compacted, their runoff response is similar to an impervious area, especially during large storm events (Schueler 2000). It is important to maintain healthy, noncompacted soils because they minimize storm water runoff by providing infiltration and perform valuable storm water functions such as absorbing and filtering excess nutrients, sediments, and pollutants; maximize water-holding capacity; and provide a healthy root environment for plants (Figure 115).

Figure 115. Soil compaction.

If it is not possible to avoid soil compaction, use soil enhancement techniques (BMP 7) before seeding or planting to support vegetative growth.

Primary BMP Functions and Controls

☒ Construction	☐ Permanent
☐ Erosion Control	☐ Sediment Control
☐ Source Control	☐ Flood Control
☐ Filtration	☒ Infiltration

Typical Effectiveness for Targeted Pollutants

○	Sediment
○	Phosphorus
○	Metals
○	Bacteria
○	Hydrocarbons
○	Litter

Other BMP Considerations

Relative Cost	$
Maintenance Requirements	Low
Ease of Installation	Easy
Freeze/Thaw Resistance	Good
Max. Tributary Drainage Area	N/A
Max. Upstream Slope	N/A
NRCS Soil Group	ABCD
Min. Ground Water Separation	N/A
Min. Bedrock Separation	N/A

Applicability

Soil compaction should be minimized in areas of proposed landscaping or existing vegetation on project sites with relatively healthy soils. It is especially important to minimize soil compaction in areas of proposed permanent infiltration BMPs.

Limitations

Minimizing soil compaction may be difficult to implement on very small development sites.

Design Basis

Minimize soil compaction by designating areas on the project site where construction disturbance is allowed and protect the remaining portion of the site from construction activity. This BMP is closely related to BMP 1: Minimize Land Disturbance, which includes site design techniques to minimize land development impacts and BMP 38: Preserve Topsoil and Vegetation.

The project design should consider soil types and preserve good soils whenever possible. Information on existing soil is found through NRCS and other sources

listed in section 3.1.2. In general, good soil with some organic content and good permeability is desired. Conduct soil tests to determine if the existing soils meet minimum parameters (Hanks and Lewandowski 2003):

- Adequate depth—4 inches for turf vegetation, more for other vegetation
- Organic content of 5% minimum
- Reduce compaction to 1,400 kPa (200 psi), or less, to 10 inches deep. Measure soil compaction with on-site penetrability test using the American Society of Agricultural Engineers soil testing specification of a 20-mm (13/16-inch) insertion rate per second and soil moisture at field capacity.

The storm water management plan should clearly show areas that are designated for no disturbance, minimal disturbance, construction traffic, stockpiling, and storage. To minimize soil compaction, make the no-disturbance area as large as possible.

In no-disturbance areas, construction traffic is excluded by construction fencing or other barriers and clearly marked signage. Protecting healthy, natural soil is the best way to preserve soil functions and allow soil organisms in the existing soil to colonize neighboring disturbed areas after construction.

Minimal disturbance areas may have limited construction activity taking place, and soil restoration and conditioning may be needed to return these areas to a pervious state after construction. Some clearing may take place but no grading, cutting, filling, or construction traffic should occur in areas designated for minimal disturbance. Stabilize these areas, and revegetate as soon as possible after disturbance.

Disturbed areas include stabilized construction roads and storage and stockpiling areas. Locate these activities on portions of the site that will ultimately be developed with impervious surfaces such as roadways or parking lots. If disturbed areas must be placed in a location that will be landscaped or needs to be pervious as part of an infiltration BMP, restore the soil with tilling and soil enhancements (BMP 7).

Soil Conditioning

If soil compaction occurs in areas that will be vegetated, soil enhancements (BMP 7) can improve the soil to support vegetation. Techniques include adding soil amendments, ripping, tilling, and scarification.

Construction Guidelines

When starting construction, no-disturbance and minimal disturbance areas should be clearly delineated with construction fencing, flagging, and/or signage. Ensure all construction personnel are aware of the limits of allowed disturbance. No-disturbance areas should also be protected from excessive sediment and storm water loads. Avoid working on wet soils with heavy equipment.

Extensive and unnecessary topsoil stockpiling should be avoided. When stockpiling is necessary, properly manage the stockpiles (BMP 44: Stockpile Management) at all times. When topsoil is reapplied to disturbed areas, it should be *bonded* with the subsoil by spreading a thin, 2- to 3-inch

layer of topsoil and tilling it into the subsoil before applying the remaining topsoil. Topsoil should meet local specifications suitable to the climate and native landscape.

Maintenance

Construction fencing and signage delineating the disturbance limits should be inspected and repaired or replaced as needed during construction.

After construction, sites with properly minimized soil compaction should require less maintenance than sites that have not. Landscape vegetation will likely be healthier, have higher survival rates, require less irrigation and fertilizer, and have better aesthetics. Infiltration BMPs should function properly and are less likely to require maintenance due to clogging or lack of infiltrative capacity.

Additional Resources

Hanks, D. and A. Lewandowski. 2003. *Protecting Urban Soil Quality: Examples for Landscape Codes and Specifications*. US Department of Agriculture, Natural Resources Conservation Service.

PA DEP (Pennsylvania Department of Environmental Protection). 2006. *Pennsylvania Stormwater Best Management Practices Manual*. *http://www.depgreenport.state.pa.us/elibrary/GetFolder?FolderID=4673.*

Schueler, T. 2000. "The Compaction of Urban Soils." Technical Note #107. *Watershed Protection Techniques* 3(2): 661-665.

SEMCOG (Southeast Michigan Council of Governments). 2008. *Low Impact Development Manual for Michigan.* Detroit, MI. *http://semcog.org/.*

BMP 46: Spill Prevention and Control

Description

A spill prevention and control plan includes procedures for preventing spills of hazardous waste and methods for handling and cleaning up spills (Figure 116). Numerous spill containment methods range from large structural barriers to simple, small drip pans. The benefits vary based on cost, maintenance requirements, and the size of spill control.

Figure 116. Collapsible wall containment berm (*The Spill Source*).

Applicability

Develop a spill prevention and control plan for any construction site where hazardous wastes are stored or used. Hazardous wastes include pesticides, paints, cleaners, petroleum products, fertilizers, deicing materials, and solvents.

Limitations

Some sites may also be subject to the oil pollution regulations specified in 40 CFR 112 and CWA §331, and required to develop a Spill Prevention Control and Countermeasure (SPCC) plan. Check with federal, state, and local agencies that may also have applicable regulations that must be adhered to.

Design Basis

Address the following elements in a spill control and response plan.

Spill Prevention

Prevention is the first line of defense in protecting storm water runoff from contamination due to spills and leaks:

- Use recycled, reclaimed, or reused materials where possible to reduce the amount of new material needed. Substitute less or nontoxic materials for toxic materials.

Primary BMP Functions and Controls

☒ Construction	☐ Permanent
☐ Erosion Control	☐ Sediment Control
☒ Source Control	☐ Flood Control
☐ Filtration	☐ Infiltration

Typical Effectiveness for Targeted Pollutants

○	Sediment
○	Phosphorus
●	Metals
○	Bacteria
●	Hydrocarbons
○	Litter

Other BMP Considerations

Relative Cost	$
Maintenance Requirements	Medium
Ease of Installation	Easy
Freeze/Thaw Resistance	Good
Max. Tributary Drainage Area	N/A
Max. Upstream Slope	N/A
NRCS Soil Group	N/A
Min. Ground Water Separation	N/A
Min. Bedrock Separation	N/A

- Routinely maintain and check the condition of containers holding hazardous waste, and replace containers that are leaky, corroded, or otherwise deteriorating.
- Label all containers according to their contents. Educate all employees on how to prevent spills and how to clean up if a spill occurs. All employees should be able to recognize and report illegal dumping incidents.

Spill Control and Containment

Identify potential spill source locations such as loading and unloading areas, materials storage areas, processing areas, and waste disposal areas. Containment methods include diking, curbing, and drip pans. If a spill occurs, adequately control and contain the spill to prevent contaminating surface water or ground water.

Containment diking consists of temporary or permanent berms or retaining walls designed to hold spills. Diking is one of the best protective measures against storm water pollution because it surrounds the area of concern and keeps spill materials separated from the storm water outside of the diked area (BMP 69: Diversion Dike and BMP 70: Temporary Berms).

Diking is commonly used for controlling large spills or releases from liquid storage and transfer areas because it is an effective containment method around tank truck loading and unloading areas. The size of a containment dike system for tank truck loading and unloading operations should be capable of holding a volume equal to any single tank truck compartment plus some amount of freeboard to ensure that discharge from the secondary containment area will not occur.

Materials used to construct the dike should be strong enough to safely hold spilled materials. The materials used usually depend on what is available on site and the substance to be contained. Dikes may be made of earth (i.e., soil or clay), concrete, synthetic materials (liners), metal, or other impervious materials. Containment dikes may need to be designed with impervious materials to prevent leaking or pollution of storm water, surface water, and ground water supplies.

In general, strong acids and bases may react with metal containers, concrete, and some plastics. Where spills may consist of these substances, consider other alternatives. More reactive organic chemicals may also need to be contained with special liners. If uncertain about the suitability of certain dike construction materials, refer to the Material Safety Data Sheet (MSDS) for the chemical being contained.

Curbing, like containment diking, is a barrier that surrounds an area of concern and prevents spills or leaks from being released to the environment by routing runoff to treatment or control areas. The terms *curbing* and *diking* are sometimes used interchangeably, but curbing is usually small scale and cannot contain large spills like diking. Common materials used for curbing include earth, concrete, synthetic materials, metal, or other impenetrable materials. Asphalt is also a common material used in curbing. Curbing is inexpensive, easy to install, and provides excellent control of run-on. As with diking, materials spilled within a curbed area can be collected for proper disposal and/or recycling.

When using curbing for runoff control, protect the curb by limiting traffic and installing reinforced curbs in areas of concern. Materials spilled within a curbed area can be tracked outside of that area when personnel and equipment leave the area. This tracking can be minimized by grading within

the curbing to direct the spilled materials to a downslope side of the curbed area, keeping the materials away from personnel and equipment that pass through the area. It will also allow the materials to accumulate in one area and make cleanup much easier. Manual or mechanical methods, such as those provided by sump systems, can be used to remove accumulated material from a curbed area.

Drip pans are used to contain very small volumes of leaks, drips, and spills. Drip pans can be depressions in concrete, asphalt, or other impenetrable materials or they can be made of metals, plastic, or any material that does not react with the dripped chemicals. Empty or discarded containers may be used as drip pans. Drip pans catch material or chemical drips that can be cleaned up easily or recycled before contacting storm water. Drip pans can be a temporary or permanent measure.

Use drip pans at any site where valves and piping are present and the potential exists for small-volume leakage and dripping. Although leaks and drips should be repaired and eliminated as part of preventive maintenance programs, drip pans provide a temporary solution where repair or replacement is delayed. In addition, drip pans provide a safeguard when positioned beneath areas where leaks and drips may occur. Drip pans are inexpensive, easy to install, and simple to operate. They allow for reuse or recycling of the collected material.

When using drip pans, consider local weather conditions, the location of the drip pans, materials used for the drip pans, and how the pans will be cleaned. Drip pans should be inspected and cleaned frequently, so place them in areas that are easy to reach. Avoid placing drip pans in precarious positions such as next to walkways or on uneven surfaces. Drip pans in these locations are easily overturned and may present a safety or environmental hazard.

Weather is also an important factor. Heavy winds and rainfall can move or damage drip pans because the pans are small and lightweight. Secure the pans by installing or anchoring them to platforms, place behind wind blocks, or tie the pans down.

Cleanup and Disposal

Clean up spills or contaminated surfaces immediately using dry cleanup measures where possible and eliminating the source of the spill to prevent discharge or further discharge. Adequate supplies should be available at all times to handle spills, leaks, and disposal of used liquids from fueling and maintenance of equipment or vehicles. When cleaning up spills, follow MSDS guidelines to prevent unintentional chemical reactions.

If spilled materials are hazardous, the cleanup materials are also hazardous and must be disposed of properly. If the spill is large, a Hazmat team or private spill cleanup company may be necessary depending on permit requirements.

Reporting

Keep a record of any spills, including the date and time of the incident, causes, duration, response procedures, and persons notified. If a spill occurs, and it is not contained by the on-site containment methods, report it to the proper authorities. Federal regulations require that oil spills

into a navigable water or adjoining shoreline above a certain threshold must be reported to the National Response Center at (800) 424-8802. Oil spills must be reported in the following cases:

- Violate applicable water quality standards.
- Cause a film or *sheen* upon, or discolor, the surface of the water or adjoining shorelines.
- Cause a sludge or emulsion to be deposited beneath the surface of the water or upon adjoining shorelines.

Spills should also be reported to local agencies, such as the fire department, if necessary to assist with cleanup.

Construction Guidelines

Spill prevention and containment measures should be employed as long as hazardous materials are stored on site. Key spill response personnel should be identified before the project starts, and all employees and subcontractors should be trained on spill prevention, response, and cleanup procedures.

Maintenance

Update the spill prevention and control plan when changes occur in staffing, to the site, or where the materials are stored. Regular inspections should be conducted to ensure proper procedures are posted and cleanup equipment is available. Guidelines for maintaining spill containment measures are provided below:

Containment dikes should be inspected during or after significant storms or spills to check for washouts or overflows. Regular testing is recommended to ensure that the dikes can hold spills. Soil dikes may need to be inspected on a more frequent basis.

Changes in vegetation, inability of the structure to retain storm water, dike erosion, or soggy areas indicate problems with the dike’s structure. Damaged areas should be patched and stabilized immediately, where necessary. Earthen dikes may require special maintenance of vegetation, such as mowing and irrigation.

When evaluating the performance of the containment system, pay attention to the overflow system because it is often the source of uncontrolled leaks. If overflow systems do not exist, accumulated storm water should be released periodically. Polluted storm water should be treated before release. Mechanical parts (e.g., pumps) or manual systems (e.g., slide gates and stopcock valves) may require regular cleaning and maintenance.

Curbing is sized to contain small spill volumes, and frequent maintenance is needed to prevent overflow of any spilled materials. Inspect all curbed areas regularly and clean clogging debris. Repair the curb by patching or replacing it as needed to ensure effective functioning. Conduct inspections before forecasted rainfall events and immediately after storm events. If spilled or leaked materials are observed, start cleanup immediately to allow space for future spills. Prompt cleanup of spilled materials will prevent dilution by rainwater, which can adversely affect recycling opportunities.

Drip pan effectiveness depends on site operators paying attention and emptying the pans when they are nearly full. Because of their small holding capacities, drip pans easily overflow if not emptied. Recycling efforts can be affected if storm water accumulates in drip pans and dilutes the spilled material. Ensure clearly specified and easy to follow practices for reuse, recycle, and/or disposal of pans, especially the disposal of hazardous materials. Consider dumping the drip pan contents into a nearby larger-volume storage container and periodically recycling the contents of the storage container.

Frequent inspection of the drip pans is necessary due to the possibility of leaks in the pan itself. Check for random leaking of piping or valves and for irregular, slow drips that may increase in volume. Conduct inspections before forecasted rainfall events to remove accumulated materials. Empty accumulations immediately after each storm event.

Additional Resources

CASQA (California Stormwater Quality Association). 2004. *California Stormwater Best Management Practices Handbook: New Development and Redevelopment*. Menlo Park, CA. *https://www.casqa.org.*

EPA (US Environmental Protection Agency). 2014. *Spill Prevention and Control Plan*. Water: Best Management Practices. *https://www.epa.gov/npdes/national-menu-best-management-practices-bmps-stormwater#edu*.

BMP 47: Construction Equipment Washing and Maintenance

Description

A good construction vehicle and equipment washing and maintenance facility prevents the discharge of pollutants from these operations to surface water or ground water. A typical vehicle/equipment washing and maintenance system is a lined or paved, depressed area that collects the water used in washing trucks, cars, or other construction vehicles/equipment and drains the wastewater into a collection or treatment system (Figure 117).

Ideally, vehicle maintenance should not occur on active construction sites. However, if it must occur, the following practices should be used to minimize or eliminate pollutant discharge.

Figure 117. Vehicle and equipment wash area (CALTRANS 2003).

Primary BMP Functions and Controls

☒ Construction ☐ Permanent
☐ Erosion Control ☒ Sediment Control
☐ Source Control ☐ Flood Control
☐ Filtration ☐ Infiltration

Typical Effectiveness for Targeted Pollutants

● Sediment
● Phosphorus
◖ Metals
○ Bacteria
◖ Hydrocarbons
○ Litter

Other BMP Considerations

Relative Cost	$$
Maintenance Requirements	Low
Ease of Installation	Easy
Freeze/Thaw Resistance	Good
Max. Tributary Drainage Area	N/A
Max. Slope	5%
NRCS Soil Group	ABCD
Min. Ground Water Separation	N/A
Min. Bedrock Separation	N/A

Applicability

Use vehicle washing and maintenance BMPs on all sites where vehicle and equipment cleaning and maintenance are performed. BMPs are particularly important on projects where the soil is silty or a heavy clay, and it is likely that dirt and mud will be transported off site. It is also important for projects taking place during the rainy season and in areas where water is expected to be encountered (high ground water table) during project construction.

Limitations

Limitations depend on the method chosen for disposing of vehicle washwater. If washwater is discharged to a sediment pond on site, sufficient acreage is required. If washwater is discharged to off-site sanitary sewer systems or hazardous waste disposal facilities, the cost of connection or disposal could be a limitation. Discharge of treated washwater to waters of the state (including canals, rivers, ponds, streams, lakes, and ground water) may require pretreatment to remove turbidity or separate oils, as well as federal, state, or local permits.

Design Basis

Washing vehicles generates liquid, semisolid, and solid wastes. These wastes should be contained on site and treated before discharged off site. A stabilized construction entrance (BMP 41) should be installed at the vehicle wash/maintenance area to reduce off-site tracking of mud, dirt, and rocks.

Wash Location and Design

Vehicle washing on site should be located within a structure or building equipped with appropriate disposal facilities. If this is not available, locate outside vehicle wash stations away from storm drain inlets, drainage facilities, and watercourses, and divert site drainage away from the wash area. Vehicle washing and maintenance should be conducted in disturbed areas (staging areas) but should not be conducted in a cut or fill area until grading has been performed or where a high volume of construction traffic exists. Avoid highly erodible soils or frequently wet areas.

Outdoor vehicle wash areas should be lined or paved with concrete or asphalt and have a berm to contain runoff and prevent run-on. It should also be equipped with a sump for collecting and disposing of washwater.

Clearly mark the wash areas with signage and educate employees and subcontractors on proper washing procedures. Include the location of the washing facilities in the SWPPP.

Wash Practices

Use the smallest amount of water and no, or a minimal amount of, detergents if possible. Use a positive shut-off valve and a high-pressure spray to conserve water. Water alone can remove most dirt adequately, but if detergents must be used, they should not contain phosphates. Use biodegradable products that are free of halogenated solvents.

Washwater Discharge

On-site washwater can be contained for evaporative drying with any residual waste disposed of properly. Washwater can also be discharged to surface water if it is permitted and pretreated. Treatment is required for all discharges to waters of the state because they can be contaminated with degreasers, hydrofluoric acid, hydrochloric acid, nitric acid, phosphoric acid, oil, hydraulic fluids, lubrication, and engine cleaning solvents. Contact the local permitting authority to determine proper treatment and disposal methods.

Other discharge options for vehicle washwater include the following:

- Lagoon—A pond-like structure that uses physical, chemical, and biological processes to treat wastewater. They are easy to install and require low maintenance. Safety is a concern, so the area must be fenced from the public.
- Land application system—A method of reusing wastewater by applying it to land for irrigation and to assimilate it into the soil structure. Land application systems require large land area and may need to be permitted.
- Filtering and recycling washwater—A good conservation measure that includes using a sediment basin with a turbidity curtain. Monitoring of the operation could be intensive.

- Municipal wastewater treatment plant—Available only in areas where a municipal wastewater treatment plant exists and the operation is capable of handling the load. This is the best option for limiting liability on larger construction projects. Vehicle and equipment washing activities should be reviewed to determine if oil and sediment controls are needed to comply with any applicable sanitary sewer discharge limits.

Vehicle Maintenance

Vehicle maintenance or repairs should not be conducted in the wash area. Designate a special paved area for vehicle repair.

Properly maintaining and inspecting vehicles and equipment can prevent hazardous chemical leaks. A spill prevention and cleanup plan (BMP 46) should be in place if a hazardous spill or leak occurs.

Properly dispose of any hazardous waste from vehicle maintenance activities, including used oil, antifreeze, solvents, and other automotive-related chemicals (BMP 48).

Construction Guidelines

Vehicle sediment controls including vehicle and equipment washing areas should be installed as the first step in clearing and grading. The location and design should follow the design guidelines listed above.

Maintenance

Ensure the system controls are working as designed and make any repairs as necessary (e.g., repairs to berms or conveyance to any off-site disposal facility). Inspect local roads, sidewalks, and other paved surfaces adjacent to the site daily and sweep up or vacuum accumulated sediment.

Additional Resources

CALTRANS (California Department of Transportation, Division of Construction). 2003. *Construction Site Best Management Practice Manual*. Sacramento, CA.

EPA (US Environmental Protection Agency). 2014. *Vehicle Maintenance and Washing Areas at Construction Sites*. WaterSense at Work: Best Management Practices for Commercial and Institutional Facilities. *https://www.epa.gov/sites/production/files/2017-02/documents/watersense-at-work_final_508c3.pdf*.

BMP 48: Hazardous Materials Management

Description

Good hazardous materials management prevents or reduces pollutant discharge to storm water from hazardous materials by reducing waste generation, properly using materials and disposing of waste, and training employees, contractors, subcontractors, and owners (Figure 118).

Figure 118. Inspector checking hazardous material containers (WV DEP 2015).

In a typical construction activity, hazardous materials and wastes can be discovered during construction (e.g., grading or digging), removed during demolition, or produced by construction activities (e.g., spent materials such as paints and degreasers). Hazardous materials on construction, industrial, commercial, or residential sites can include the following:

- Petroleum products
- Asphalt products
- Concrete curing compounds
- Roofing tar
- Acids
- Palliatives
- Septic waste
- Asbestos
- Stains
- Wood preservatives
- Pesticides
- Paints
- Solvents
- Gasoline
- Cleaners
- Waxes
- Any material listed in 40 CFR 110, 117, 261, or 203.

Primary BMP Functions and Controls

☒ Construction ☒ Permanent
☐ Erosion Control ☐ Sediment Control
☒ Source Control ☐ Flood Control
☐ Filtration ☐ Infiltration

Typical Effectiveness for Targeted Pollutants

○ Sediment
◖ Phosphorus
◖ Metals
◖ Bacteria
● Hydrocarbons
◖ Litter

Other BMP Considerations

Relative Cost	$$
Maintenance Requirements	Medium
Ease of Implementation	Medium
Freeze/Thaw Resistance	N/A
Max. Tributary Drainage Area	N/A
Max. Upstream Slope	N/A
NRCS Soil Group	ABCD
Min. Ground Water Separation	N/A
Min. Bedrock Separation	N/A

Applicability

Proper hazardous materials management should be used on all sites and properties with hazardous materials present.

Meeting the recommendations provided in this BMP is not a substitute for complying with local, state, and

federal regulations for storing, handling, transporting, and disposing of hazardous materials and wastes. Complying with applicable regulations protects human health and the environment from hazardous waste, reduces liability, and prevents unnecessary schedule interruptions (i.e., project or facility shut down due to environmental investigations/enforcement actions).

Applicable and related BMPs include BMP 15: Oil and Water Separators, BMP 46: Spill Prevention and Control, BMP 47: Construction Equipment Washing and Maintenance, BMP 49: Concrete Waste Management, BMP 50: Sanitary and Septic Waste Management, BMP 77: Outdoor Storage, BMP 83: Vehicle and Equipment Refueling, and BMP 84: Vehicle and Equipment Cleaning, Maintenance, and Repair.

Limitations

Hazardous waste that cannot be reused or recycled must be disposed of according to local, state, or federal regulation and by a licensed hazardous waste hauler. Depending on the type and quantity of waste, this requirement may be costly.

Design Basis

Hazardous materials management includes a wide variety of activities, such as reducing waste generation, properly using materials and disposing of waste, and training.

Reduce Hazardous Materials

The best method to prevent contamination from hazardous materials is to reduce the amount of hazardous materials present on a site. These BMPs can be applied to all sites to use less or eliminate hazardous materials when possible and to substitute materials with less toxic substances.

Industrial Sites

Starting a waste reduction program for industrial sites can be economically beneficial because it reduces raw material purchases and lowers waste disposal fees. Reducing the amount of industrial waste generated on site can be accomplished with the following source controls:

- Plan and sequence production.
- Assess process activities by collecting process-specific information, setting pollution prevention targets, and developing, screening, and selecting waste reduction options for further study.
- Modify processes or equipment to generate less waste.
- Implement a material tracking system and usage inventory to increase awareness about material use and reduce waste generation.
- Implement closed loop recycling.

Material Use

Use hazardous materials properly to prevent accidental spills and contamination of storm water runoff. The following guidelines apply to all sites:

- Follow manufacturers' directions in the use of all materials, including application rate and amounts.

- Maintain a clean and orderly work environment.
- Do not mix products together unless specifically recommended.
- Use the entire product before disposing of the container.
- Do not remove original product label from its container.
- Use ground cloths and drip pans under any work outdoors that involves hazardous materials such as oil-based paints, stains, rust removers, masonry cleaners, and others with warning labels. BMP 46: Spill Prevention and Control provides more information.
- If possible, move activities using hazardous materials indoors if adequate ventilation can be provided.
- Never apply pesticides when rain is expected.
- When using hazardous materials, place the container inside a tub or bucket to minimize spills.

Material Storage

Hazardous materials should always be properly stored and labeled. BMP 46: Spill Prevention and Control and BMP 77: Outdoor Storage provide additional information.

- Identify all chemical substances present.
- Label all containers with substance name, hazards, handling, first-aid information, and special instructions.
- Ensure an adequate number of containers with lids or covers is available.
- Protect hazardous waste storage areas:
  - Store the material indoors.
  - Cover outdoor storage areas with a roof.
  - Protect the material with a covering.
  - Keep containers off the ground.

Construction and Industrial Sites

- Identify, control, and enforce well-sited hazardous waste storage areas and disposal/stockpile areas. Locate hazardous waste storage areas away from storm drains and conveyances.
- Locate storage areas away from direct traffic routes.
- Store waste in sealed containers, constructed of suitable materials to prevent leakage and corrosion, and labeled according to applicable Resource Conservation and Recovery Act requirements and all other applicable federal, state, tribal, or local requirements.
- Store all outdoor containers in appropriately sized secondary containment (e.g., spill berms, decks, and spill containment pallets) to prevent spill discharge, or provide a similar, effective means to prevent pollutant discharge from these areas (e.g., storing chemicals in covered area or providing an on-site spill kit).
- Provide labels and signs for the storage area to educate contractors about proper storage and handling and to comply with regulatory requirements. Stack containers according to directions to avoid damage from improper weight distribution.
- Separate hazardous or toxic waste from construction and domestic waste.
- Provide the following engineer safeguards:
  - Overflow protection devices

- Secondary containment in case of leaks or spills.
- Protective guards around tanks and storage areas.
- An impervious barrier such as a liner, concrete pad, or berm.

Households

- Store hazardous materials out of the reach of children. Never transfer or store hazardous materials in food or beverage containers that could be misinterpreted by a child as food or a drink.
- Put *Mr. Yuck* stickers on hazardous household products and teach children to leave them alone. The stickers are available at Idaho CareLine 211 or (800) 926-2588.

Waste Disposal

Hazardous waste and their containers should be disposed of properly according to local, state, and federal regulations. Never dump products labeled as poisonous, corrosive, caustic, flammable, inflammable, volatile, explosive, or dangerous, or with warnings or cautions outdoors, in a storm drain, or down sinks, toilets, or drains. Section 3.10.7 “Construction Disposal Alternatives” provides a quick reference on disposal alternatives for specific construction wastes.

- Arrange for waste collection before containers overflow (additional containers and more frequent pickups will be needed during the demolition phase of a construction project).
- Ensure waste is disposed of by a licensed hazardous waste transporter at an authorized and licensed disposal facility or recycling facility.
- Properly dispose of rainwater in secondary containment areas that may have mixed with hazardous waste.
- Recycle material such as used oil- or water-based paint when practical.
- Latex paints are not hazardous wastes but are not accepted in liquid form at the landfill. Leave latex paint uncovered in a protected place until it is dry and dispose of it with solid waste. Use kitty litter to quickly absorb the liquid, which allows the dry paint to be disposed of with solid waste.

Education and Training

Carelessness and poor judgment often result in problems associated with using and disposing of hazardous materials. Be fully aware of all the hazards at the site to decrease the potential for mishandling wastes that can contaminate storm water. Incorporating employee training (BMP 91) into waste management activities is strongly recommended. Best practices for construction and industrial sites include the following:

- Assign hazardous material inventory to a limited number of trained personnel. Have dedicated personnel keep an up-to-date inventory of all hazardous materials and wastes.
- Provide initial and annual training for employees on the hazards of and proper-handling procedures for hazardous wastes.
- Properly educate employees and subcontract personnel on the following:
  - Hazardous waste storage and disposal procedures.
  - Potential dangers to human health and the environment.
  - On-site safety procedures for hazardous materials.

- Ensure a dedicated construction supervisor oversees all handling of hazardous materials on site.

Maintenance

Regular maintenance of hazardous materials systems is important:

- Check containers with hazardous materials frequently for signs of leakage or damage.
- Replace leaking and/or deteriorating containers. Signs include the following:
  - External corrosion and structural failure
  - Installation problems
  - Evidence of spills or overfills
- Immediately clean up any liquid or dry material spills. Report spills to the proper authorities as required.
- Regularly collect and properly remove hazardous waste and materials from the site.

Additional Resources

CASQA (California Stormwater Quality Association). 2004. *California Stormwater Best Management Practices Handbook, New Development and Redevelopment*. Menlo Park, CA. *https://www.casqa.org.*

Idaho Careline (State of Idaho, Department of Health and Welfare Careline). 2018. *2-1-1 CareLine: Poison Prevention*. *http://healthandwelfare.idaho.gov/Health/InjuryPrevention/Poison/tabid/1389/Default.aspx*

ITD (Idaho Transportation Department). 2014. *Best Management Practices.* Boise, ID: ITD.

BMP 49: Concrete Waste Management

Description

Concrete waste management prevents pollutant discharge to storm water from concrete waste by conducting off-site washout, performing on-site washout in a designated area, and training employees and subcontractors on proper management techniques (Figure 119).

Concrete washwater typically contains toxic metals and is caustic and corrosive with a high pH around 12 (EPA 2012a).

Figure 119. Hay bale temporary washout pit (*On Site Washout*).

Applicability

This BMP applies to all project sites that will generate concrete washwater or liquid concrete waste from on-site concrete mixing or concrete delivery. This includes sites with concrete pours for features such as foundations, footings, curbs, sidewalks, floors, piles, and for projects that generate cementitious (i.e., properties of cement) washwater and solids from materials such as mortar, plaster, stucco, and grout.

Check local permitting requirements and regulations for concrete waste management to ensure compliance.

Primary BMP Functions and Controls

☒ Construction	☐ Permanent
☐ Erosion Control	☐ Sediment Control
☒ Source Control	☐ Flood Control
☐ Filtration	☐ Infiltration

Typical Effectiveness for Targeted Pollutants

○	Sediment
○	Phosphorus
●	Metals
○	Bacteria
○	Hydrocarbons
○	Litter

Other BMP Considerations

Relative Cost	$$
Maintenance Requirements	Medium
Ease of Installation	Easy
Freeze/Thaw Resistance	Good
Max. Tributary Drainage Area	N/A
Max. Upstream Slope	N/A
NRCS Soil Group	ABCD
Min. Ground Water Separation	3 feet
Min. Bedrock Separation	N/A

Limitations

Off-site washout of concrete wastes may not always be possible. On-site washout facilities should be lined or a waterproof containment system should be used if shallow ground water is present to prevent ground water contamination.

Washout areas that are lined with plastic can make it difficult to recycle or reuse hardened concrete because the lining becomes bound up with the concrete.

Using aboveground hay bale washout pits may not be feasible for concrete pumping trucks with low hanging hoppers.

Design Basis

Washing out concrete trucks should be completed at an approved off-site location if possible or in designated on-site areas only. Do not wash out concrete trucks into storm drains, open ditches, streets, or streams. Several types of washout containment systems can be used, and all concrete washout water and solids should be recycled or reused. The approach to the concrete washout areas should be stabilized with gravel (BMP 41) or a paved construction road.

Site Selection

Locate concrete washout areas at least 50 feet from storm drains, open ditches, or water bodies. The washout site should not be located in an area where shallow ground water may be present, such as near natural drainages, springs, or wetlands. Washouts should be located at least 400 feet away from any natural drainage pathway or water body and at least 1,000 feet from wells or drinking water sources.

Place washouts in a location accessible to concrete trucks and where the majority of the concrete will be poured. On large sites with extensive concrete work, use multiple locations to make it more convenient and increase compliance with the BMP guidelines. Provide clear signage at the concrete washout area.

Washout Containers

A washout pit can be constructed either above or below grade. Above grade pits can be constructed with hay bales lined with a polyethylene liner. Below grade pits can be constructed by excavating an area, berming around three sides of the pit, and lining the pit with plastic. A minimum length and width of 10 feet is recommended, although a larger size may be needed to contain the anticipated waste based on the estimated concrete volume to be used. The polyethylene lining should be impermeable with a 16-mil minimum thickness.

Prefabricated concrete washout containers made of vinyl or metal are available from several different vendors. The containers are usually portable, reusable, and easier to install than hay bale washout pits or excavated pits.

Washout boxes or buckets with pumps can be mounted on the back of ready mix concrete trucks. The boxes or buckets are used to capture water from washing the chute after a pour is completed, and the washwater and solids can be returned to the ready mix plant for recycling.

Construction Guidelines

The following practices will reduce storm water pollution from concrete wastes:

- Avoid mixing excess amounts of fresh concrete or cement on site.
- Avoid dumping excess concrete in nondesignated dumping areas.
- Wash out wastes into the temporary pit where the concrete can set, broken up, and disposed of properly.
- When washing concrete to remove fine particles and expose the aggregate, drain the water to a bermed or level area.

- Avoid washing sweepings from exposed aggregate concrete into the street or storm drain. Instead, collect and return sweepings to an aggregate base stockpile or dispose of in the trash.
- Train employees and subcontractors in proper concrete waste management.

After construction is completed, remove concrete waste from the washout pit, and restore and reclaim the area.

Maintenance

Inspect concrete washout facilities daily and after heavy rains to check for leaks and damage to the facility.

If using a temporary pit, dispose of the hardened concrete on a regular basis. Washout pits should be cleaned or additional facilities should be constructed when the washout is 75% full, or there is less than 4 inches of freeboard for an aboveground facility or 1 foot of freeboard for a belowgrade facility.

Inspect the plastic lining of temporary pits to ensure it has not been damaged. Reline as necessary.

Before heavy rains, lower the liquid level in the washout container or cover the container to avoid overflow during the storm.

Additional Resources

EPA (US Environmental Protection Agency. 2012. *Concrete Washout*. Stormwater Best Management Practice. *http://www.epa.gov/npdes/pubs/concretewashout.pdf*

BMP 50: Sanitary and Septic Waste Management

Description

Proper sanitary and septic waste management prevents the pollutant discharge to storm water from sanitary and septic waste by providing convenient, well-maintained septic waste facilities, and arranging for regular service and disposal (Figure 120). Portable sanitary facilities are self-contained units consisting of gravity fed holding tanks that temporarily store human waste.

This BMP does not cover permanent developments that will have permanent sanitary sewer facilities with proper on-site or off-site disposal according to local regulations.

Figure 120. Portable sanitary facility (ITD 2014).

Primary BMP Functions and Controls

☒ Construction	☐ Permanent
☐ Erosion Control	☐ Sediment Control
☒ Source Control	☐ Flood Control
☐ Filtration	☐ Infiltration

Typical Effectiveness for Targeted Pollutants

○	Sediment
○	Phosphorus
○	Metals
●	Bacteria
○	Hydrocarbons
●	Litter

Other BMP Considerations

Relative Cost	$
Maintenance Requirements	Easy
Ease of Installation	Easy
Freeze/Thaw Resistance	N/A
Max. Tributary Drainage Area	N/A
Max. Upstream Slope	N/A
NRCS Soil Group	N/A
Min. Ground Water Separation	N/A
Min. Bedrock Separation	N/A

Applicability

Portable sanitary facilities are often needed to supplement permanent facilities at special events or on construction sites. Per OSHA requirements, construction sites that do not have sanitary sewer service available shall be provided with a toilet facility, unless the crew is mobile and has transportation readily available to a nearby toilet facility.

Limitations

Access to the septic waste facility must be provided so that they can be regularly serviced. A sufficient number of units should be provided to accommodate all personnel on site.

Design Basis

Sanitary and septic wastes for portable and permanent facilities should be disposed of according to state and local requirements. The following guidance applies to placing, operating, and disposing of portable and temporary sanitary systems.

Portable Sanitary Facilities

- Locate portable sanitary facilities in a convenient location but away from high traffic areas. If site conditions allow, place facilities at least 50 feet from a drainage facility or watercourse.
- Ensure that a licensed sanitary and septic waste hauler maintains sanitary and septic facilities and keeps them in good working order. A list of permitted septic tank pumpers is available at: *https://www.deq.idaho.gov/water-quality/wastewater/septic-and-septage/*.
- Avoid using biocides, such as formaldehyde, to prevent odor. Use nonformaldehyde, biological treatments to breakdown wastes and minimize odor.
- Stake or secure portable units to a fixed object to prevent overturning, especially in high wind areas.
- Under section 4.1.2(6) of the Americans with Disabilities Act Accessibility Guidelines, at least 5% of single-user portable toilets clustered at a single location must be accessible.
- Always treat and dispose of portable toilet waste according to state and local requirements. Municipal sewage treatment plants are an acceptable disposal option for untreated portable toilet wastes.
- Do not discharge or bury untreated wastewater.
- Dispose of sewage from recreational vehicles (RVs) at approved facilities, which include wastewater treatment plants, RV parks, dealers or storage facilities, or recreational sites. A list of RV dump stations in Idaho is provided at *http://www.rvdumps.com/idaho/*.

Temporary Septic Systems

- If using an on-site disposal system such as a temporary septic system, comply with local health agency requirements.
- On-site disposal systems must be designed per DEQ's *Technical Guidance Manual for Individual and Subsurface Sewage Disposal Systemshttps://www.deq.idaho.gov/water-quality/wastewater/septic-and-septage/.* If discharging to a centralized sanitary sewer system, contact the local wastewater treatment plant for permitting and other requirements. Ensure that temporary septic systems treat wastes to required levels before discharging.
- Ensure that temporary sanitary facilities discharging to a sanitary sewer system are properly connected to help eliminate illicit discharges.

Maintenance

- Inspect facilities weekly before forecasted rain events and daily during periods of extended rain.
- Contact service contractors immediately if leaks are detected.
- Arrange for regular waste collection for portable facilities.

Additional Resources

CASQA (California Stormwater Quality Association). 2004. *California Stormwater Best Management Practices Handbook: New Development and Redevelopment*. Menlo Park, CA. *https://www.casqa.org*

DEQ (Idaho Department of Environmental Quality). 2018. *Technical Guidance Manual for Individual and Subsurface Sewage Disposal Systems*. Boise, ID: DEQ. *https://www.deq.idaho.gov/water-quality/wastewater/septic-and-septage/*

ITD (Idaho Transportation Department). 2014. *Best Management Practices.* Boise, ID: ITD.

BMP 51: Solid Waste Storage and Disposal

Description

Solid waste, more commonly known as garbage or trash, is any discarded material that is abandoned or recycled. Items that are commonly considered solid waste include product packaging, landscape clippings, paper, bottles, food scraps, construction wastes, paint, and batteries. Solid waste management procedures and practices are designed to prevent or reduce the discharge of litter and other pollutants to storm water (Figure 121). Practices include tracking and reducing waste generation, using proper storage and disposal methods, reusing and recycling when possible, and preventing run-on and runoff from waste management areas.

Figure 121. Pet waste container.

More information on proper handling, storing, and disposing hazardous waste is provided in BMP 48: Hazardous Materials Management. Storing and handling pesticides and other landscaping chemicals is provided in BMP 78: Fertilizer Management and BMP 79: Pesticide Management. BMP 46: Spill Prevention and Control provides information on properly storing and handling liquid waste.

Primary BMP Functions and Controls

☒ Construction	☒ Permanent
☐ Erosion Control	☐ Sediment Control
☒ Source Control	☐ Flood Control
☐ Filtration	☐ Infiltration

Typical Effectiveness for Targeted Pollutants

○	Sediment
○	Phosphorus
○	Metals
●	Bacteria
○	Hydrocarbons
●	Litter

Other BMP Considerations

Relative Cost	$
Maintenance Requirements	Easy
Ease of Installation	Easy
Freeze/Thaw Resistance	N/A
Max. Tributary Drainage Area	N/A
Max. Upstream Slope	N/A
NRCS Soil Group	ABCD
Min. Ground Water Separation	N/A
Min. Bedrock Separation	N/A

Applicability

This BMP applies to industrial operations, construction sites, businesses, residences, public parks, recreation areas, and large outdoor events where solid waste is generated and temporarily stored.

Limitations

For commercial and municipal operations, an effective waste management system requires training employees (BMP 91) and signage. Extra management time may be required to ensure that all personnel follow proper procedures for storing, disposing, and handling solid waste.

Limitations are related to disposing of residential solid waste *(https://www.deq.idaho.gov/waste-management-and-remediation/solid-waste/residential-household-wastes/)* and restrictions on burning household residential waste in burn barrels

or other types of incinerators (*https://www.deq.idaho.gov/air-quality/smoke-and-burning/can-i-burn/*).

Design Basis

The best way to reduce the impact of waste on storm water runoff is to reduce the amount of waste generated. Practices that reduce the amount of solid waste disposed of in a landfill are encouraged, including waste tracking, waste reduction, recycling, and composting. Properly storing and disposing of solid waste that is generated is required to protect environmental and aquatic resources.

Waste Tracking

Tracking the amount of waste materials used on site or in the home increases awareness of the amount of materials used and provides a baseline for waste reduction. Consider the following when tracking waste:

- Prioritize waste streams using manifests, biennial reports, permits, environmental audits, Superfund Amendments and Reauthorization Act Title III reports, emission reports, and NPDES monitoring reports.
- Prepare inventory reports.
- Maintain data on chemical spills.
- Track emissions.
- Review raw material and production data—composition sheets, material safety data sheets, batch sheets, product or raw material inventory records, production schedules, and operator data logs.
- Review economic data:
  - Waste treatment and disposal costs
  - Product utility and economic costs
  - Operation and maintenance labor costs.

Waste Reduction

Waste reduction can be accomplished by selecting products with the least amount of packaging or materials that can be returned and reused, purchasing durable goods rather than disposable ones, and buying in bulk. For industrial or commercial operations, assess process activities where wastes are generated to determine where waste can be eliminated or reduced. This involves collecting process-specific information, setting pollution prevention targets, and developing, screening, and selecting waste reduction options for further study. Modify processes or equipment to generate less waste.

Recycling

Recycling recovers materials from the solid waste stream to make new products, which reduces the amount of virgin raw materials needed to make products and the amount of material going into landfills. Regions vary on the items collected for recycling. Common items that may be recycled include glass, cardboard, some types of plastics, aluminum cans, steel cans, scrap metal, wire,

paper, and gray board. Other nontraditional recyclables include used motor oil, batteries, printer cartridges, and electronics (E-waste).

Some jurisdictions offer curbside recycling to residential and commercial customers. Recycling or material separation may also be required for construction sites.

Composting

Approximately 38% of municipal solid waste consists of organic materials, such as food waste, yard wastes, wood waste, and manure. Composting is the process of creating the optimal conditions for biological decomposition of organic material to produce a stable, nutrient-rich material that can be used as a soil amendment or fertilizer for plants.

Composting can be accomplished on a small scale, such in a residential back yard, or large scale, such as a municipal operation. For either operation, controlled decomposition requires a proper balance of *green* organic materials (e.g., grass clippings, food scraps, manure), which contain large amounts of nitrogen, and *brown* organic materials (e.g., dry leaves, wood chips, branches), which contain large amounts of carbon but little nitrogen.

Storage

For both construction and domestic waste, provide waste containers (e.g., dumpster or trash receptacle) of sufficient size and number to contain all waste expected to be generated. On construction sites, clean up and dispose of waste in designated waste containers on each work day. Waste containers must be cleaned up immediately if they overflow. The following practices are recommended:

- All waste containers kept outside should have lids.
- Storage areas for building products should provide either cover (e.g., plastic sheeting or temporary roofs) to prevent these products from coming into contact with rainwater or use a similarly effective means designed to prevent pollutant discharge from the storage areas.
- Replace leaking waste containers.
- Inspect the storage area regularly to pick up loose scraps of material and dispose of them properly.
- Ensure that toxic liquid wastes (used oils, solvents, and paints) and chemicals (acids, pesticides, additives, and curing compounds) are not disposed of in dumpsters designated for construction debris.
- In areas close to bear habitat, ensure storage containers have bear-proof locks and lids.
- Collect and properly dispose of pet waste at private residences and in public areas.

Run-on and Runoff Prevention

Preventing storm water from entering or running off the waste storage area reduces or eliminates the potential for contaminants from entering the runoff and polluting downstream water bodies. The following best practices prevent run-on and runoff:

- Protect waste materials from direct contact with rain by covering the area with a permanent roof or covering waste piles with temporary covering material, such as reinforced tarpaulin, polyethylene, polyurethane, polypropylene, or hypalon.

- If possible, place waste storage areas indoors after ensuring that all safety concerns such as fire hazards and ventilation are addressed.
- Store waste materials on a paved surface that is bermed or drains to a dead-end holding tank.
- To avoid tracking materials off site, keep the waste management area clean by sweeping and cleaning up spills immediately. Never drive vehicles through spills. If necessary, wash vehicles in designated areas before the vehicles leave the site (BMP 84). Collect and properly dispose of the washwater.
- Cover, enclose, or berm industrial wastewater management areas whenever possible to prevent contact with run-on or runoff.

Disposal

Municipal solid waste should be collected and properly disposed of in a solid waste disposal facility. Hazardous waste must be disposed of in an appropriate disposal and/or recycling facility.

Education

Educate employees, subcontractors, and suppliers on solid and sanitary waste disposal procedures and potential dangers to the environment and human health.

Instruct employees, subcontractors, and suppliers in identifying solid and sanitary wastes, hold regular meetings to update staff on the current standing of wastes on site, and implement a solid waste disposal plan.

Maintenance

Inspect solid waste collection containers regularly and arrange for regular waste collection.

Additional Resources

CASQA (California Stormwater Quality Association). 2004. *California Stormwater Best Management Practices Handbook: New Development and Redevelopment*. Menlo Park, CA. *https://www.casqa.org*

EPA (US Environmental Protection Agency). 2014. *General Construction Site Waste Management*. Water: Best Management Practices.

ITD (Idaho Transportation Department). 2014. *Best Management Practices.* Boise, ID: ITD.

BMP 52: Mulching

Description

Mulching is a temporary soil stabilization or erosion control practice where materials such as straw, grass, grass hay, compost, or wood chips or fibers are placed on or incorporated into the soil surface. Hydraulic mulching, or hydromulching, is a process that combines mulching materials with a tacking agent and is applied in slurry with water to temporarily stabilize bare slopes or other bare areas. Hydromulching is an economical way to protect slopes from erosion (Figure 122).

Figure 122. Wood chips dispensed on the side of a road to help slow runoff.

In addition to stabilizing soils, mulching can reduce the velocity of storm water runoff over an area. When used together with seeding or planting, mulching aids in plant growth by holding the seed, fertilizers, and topsoil in place, helping to retain moisture, and insulating against extreme temperatures.

Primary BMP Functions and Controls

☒Construction ☐Permanent
☒Erosion Control ☒Sediment Control
☐Source Control ☐Flood Control
☐Filtration ☐Infiltration

Typical Effectiveness for Targeted Pollutants

◖	Sediment
◖	Phosphorus
○	Metals
○	Bacteria
○	Hydrocarbons
○	Litter

Other BMP Considerations

Relative Cost	$
Maintenance Requirements	Easy
Ease of Installation	Easy
Freeze/Thaw Resistance	Good
Max. Tributary Drainage Area	2 acres
Max. Upstream Slope (conventional)	50%
Max. Upstream Slope (hydromulch)	15%
NRCS Soil Group	ABCD
Min. Ground Water Separation	N/A
Min. Bedrock Separation	N/A

Applications

Mulching protects the soil surface from splash erosion. It retards runoff, traps sediment, and creates more favorable conditions to assist germination and early plant development. The following mulches are suitable for use at construction sites:

- Vegetative materials—wheat straw, rye straw, barley straw, and grass hay
- Wood products—wood cellulose fibers, wood chips, bark, and sawdust
- Other organic materials—leaves, peat, manure, and compost
- Rock products—gravel and crushed stone
- Fabricated mulch—jute, burlap, coconut (coir), excelsior, and Kraft paper string

Mulch is an immediate, effective, and inexpensive means of controlling dust and erosion and aids revegetation of construction sites. It protects exposed soils subject to heavy erosion, retains moisture (minimizing watering needs), and requires no removal as most of mulching materials deteriorate naturally.

Mulch is often used alone in areas where temporary seeding cannot be used because of the season or climate. It may be used with other treatments for increased effectiveness. Use of mulch may or may not require a binder, netting, or tacking agent to hold the mulch in place. On steep slopes and critical areas, such as waterways, mulch matting is used with netting or can be anchored to hold it in place.

To aid in establishing vegetation, mulch seeded and planted areas where slopes are steeper than 2:1, where runoff is flowing across the area, or when seedlings need protection from bad weather. If the mulching effect is to be maintained longer than 3 months, the preferred mulch is vegetative material. Wheat straw is the most preferred vegetative material, followed by rye straw, barley straw, or grass hay.

Wood chips are suitable for areas that will not be closely mowed and around ornamental plantings. Chips decompose slowly and do not require tacking. Wood chips can be very inexpensive if they are obtained from trees cleared on the site. Chips should not be used on slopes greater than 6% because they tend to wash down slopes.

Bark mulch is suitable for areas planted with grasses that will not be closely mowed. The bark may be applied mechanically or by hand.

Crushed stone and gravel mulches are appropriate for dust control and soil protection on low-use dirt roads, driveways, and other areas of light vehicular activity within the construction site.

Hydromulching is an effective way to increase water retention (reducing erosion) from 6 months up to 1 year. Beyond 1 year, the effectiveness drops off. Hydraulic mulching can be applied to areas that are within about 200 feet of a road or that can otherwise be reached by truck. Small roadside slopes and large, relatively flat areas are well adapted to this method. When adequate moisture exists, the slurry can be combined with seed and fertilizer to initiate stabilization and revegetation in a single application. Mulch usually lasts about 1 year. The growing vegetation is needed to provide continued stabilization.

Limitations

Disadvantages of mulch include the following:

- It may delay germination of some seeds because cover reduces the soil surface temperature.
- Mulch can be easily blown or washed away by runoff if not secured or incorporated. Lightweight mulch, such as straw, requires matting, crimping, or other methods to hold it in place.
- Some mulch materials, such as wood chips, may absorb nutrients necessary for plant growth.
- Straw mulch provides organic matter as it breaks down and is incorporated into the soil. If applications are too heavy, however, soil nutrient levels (especially nitrogen) may decline during decomposition. Prescribed application rates of the straw mulch and specified fertilizer should be strictly followed. Using a fertilizer low in phosphorus is recommended.
- Synthetic spray-on materials are not recommended except for temporary dust/erosion control or for steep, rocky slopes where other mulches and mechanical methods cannot be effectively applied. The synthetic mulches may create impervious surfaces and can have adverse effects on water quality.

- Avoid applying mulch as the only control on long slopes. Break up concentrated flows on these slopes using methods recommended in other BMPs.
- Hydromulching loses effectiveness after 1 year.
- Hydromulching is only suited for physically stable slopes (at natural angle of repose, or less).
- Avoid hydromulching on long uninterrupted slopes. Break up concentrated flows with other BMPs, such as BMP 59: Gradient Terracing or BMP 60: Check Dams.

Design Basis

Stone and Gravel

- After the gravel or stone is applied, construction traffic may move over it. Areas that become compacted or depressed should be remulched to the same level as the remaining area to prevent flows from the site from becoming channelized into these depressions.
- After activities are completed on site, the gravel or stone mulch may be left in place during revegetation operations.
- When used for driveways or dirt roads, a filter blanket should be placed under the gravel.

Straw

- Straw mulch forms a loose layer when applied over a loose soil surface. To protect the mulch from wind drifting and water damage, stabilize it by covering with netting, such as jute, or by spraying it with a tacking agent. Straw mulch should cover the entire seeded area or exposed slope. The mulch should extend into existing vegetation or stabilized areas on all sides to prevent wind or water damage, which may start at the edges of the mulched area
- Apply straw fibers to form a uniform cover of loose straw through which 20% or less of the original ground surface can be seen. No large clumps of unscattered straw should exist after application.
- On small slopes, straw mulch should be applied by hand broadcasting to a uniform depth of 2 to 3 inches. On larger slopes, straw can be blown onto the slope to achieve a uniform cover of 2 to 3 inches.

Wood Chips

- Due to bacterial action during decomposition, nutrient concentrations in the soil may be depressed under a layer of wood chips. Applications should not exceed the specified thickness that would cause a marked decline in some soil nutrients for longer periods.
- When using wood chips to mulch revegetation projects, the specified application of fertilizer should be increased approximately 25% to replenish soil nutrients lost due to breakdown of wood chips.

Mulch Effectiveness

- Crushed stone and gravel mulches retain their effectiveness indefinitely if properly applied and protected from compacting traffic. Sediment generation is reduced 70% to 90%, and nutrient generation is reduced 50% to 70%.

- Straw mulches and hydromulches initially have a high sediment and nutrient reduction, but breakdown of the organic fibers decreases their effectiveness with time. Sediment and nutrient reduction estimates are shown in Table 22.
- Wood chips deteriorate more slowly than wood fiber and, therefore, retain their effectiveness longer. Sediment and nutrient reduction estimates for wood chips is shown in Table 22.

Table 22. Estimated removal efficiencies of mulches.

Age of Mulch	Wood Chips		Hydromulch		Straw (without vegetation)	
	Sediment Reduction (%)	Nutrient Reduction (%)	Sediment Reduction (%)	Nutrient Reduction (%)	Sediment Reduction (%)	Nutrient Reduction (%)
0–2 months	90–95	60–80	70–80	50–70	90–95	60–80
2 months–1 year	90–95	60–80	70–80	50–70	70–90	50–70
1–2 years	80–90	50–70	40–60	20–50	40–60	20–50
More than 2 years	50–60	30–50	10–30	0–10	10–30	0–10

Construction Guidelines

Seeding (temporary or permanent) can take place before or concurrently with mulching. Other surface runoff control measures should be installed before seeding and mulching. If seed is applied before mulch, mulch should be applied to seeded areas immediately after seeding.

Mulches should not be applied when free surface water is present but may be applied to damp ground.

The choice of materials for mulching will be based on the type of soil to be protected, site conditions, season, and economics.

Straw Mulch

The straw should be stabilized to prevent it from being damaged by water or wind (blown away). Use one of the following methods to apply straw mulch:

- Hand punching can be used on small sites, sites with rock and stone on the surface, sites with slopes that are steeper than 3:1, or sites that have been wattled. Take care not to damage wattling or planted vegetation. Use a spade or shovel to punch the straw into the slope until all areas have straw standing perpendicularly to the slope and embedded at least 4 inches into the slope. The straw bunches should resemble the tufts of a toothbrush.
- Roller punching can be used on large, gently sloping sites without significant outcroppings of rock and stone. Do not use roller punching on sites that have been wattled (unless adequate space exists between lines of wattling) or on planted sites. A roller equipped with straight studs not less than 6 inches, from 4 to 6 inches wide, and approximately 3/4-inch thick will best accomplish the desired effect. Studs should stand approximately 8 inches apart and should be staggered. All corners should be rounded to prevent withdrawing the straw from the soil. Vegetative planting may be conducted following roller punching.
- Crimper punching involves specially designed straw-crimping rollers, which are suitable for use wherever roller punching can be used. The crimpers consist of serrated disk blades,

set 4 to 8 inches apart, which force straw mulch into the soil. Crimping should be done in two directions with the final pass conducted across the slope rather than up and down it.

- Tacking agents may be used on any type of site but are best used only on very stony or rocky soils or small, steep slopes. Apply 28.5 cubic feet per acre (ft^3/ac) of the tacking agent or its equivalent over the straw mulch. Agents that are neutral or nearly neutral in color and have demonstrated effectiveness for the soils and climate of the application area are acceptable.
- Matting may be used on large, steep areas that cannot be punched with a roller. Jute or wood excelsior on plastic netting should be applied over unpunched straw (BMP 54: Matting).

Hydromulching

- Wood fiber may be dyed to aid in uniform placement. Dyes should not stain concrete or painted surfaces nor injure plant or animal life when applied at the manufacturer's recommended rate.
- Application of the slurry should proceed until a uniform cover is achieved. The applicator should not be directed at one location for too long or the applied water will cause erosion.
- The hydraulic mulching machine should be equipped with a gear-driven pump and a paddle agitator. Agitation by recirculation from the pump is not acceptable. Agitation should be sufficient to produce homogeneous slurry of tacking agent and mulch (and seed fertilizer, if used).
- Application rates according to the manufacturer's recommendation for each site situation should be used.

Maintenance

Inspect all mulched areas periodically according to the inspection interval prescribed in the project site storm water plan and after runoff-producing storm events. Inspect for damage due to wind, water, or human disturbance. Repair damaged areas of the mulch immediately. If hydromulching, repair damaged areas at the original specifications. Reseed or replant such areas, if necessary, before replacing the mulch cover. Straw mulch and other organic products do not have to be removed when the vegetation becomes established.

Additional Resources

EPA (US Environmental Protection Agency). 2014. "Mulching." *Stormwater Best Management Practices: Compost Blankets*. https://www3.epa.gov/npdes/pubs/compostblankets.pdf

BMP 53: Geotextile

Description

Geotextiles are porous fabrics made by weaving or bonding fibers from synthetic materials such as polypropylene, polyester, polyethylene, nylon, PVC, glass, or mixtures of these materials.

Geotextiles stabilize disturbed soil areas and protect soils from wind or water erosion by providing a continuous sheet over the exposed surface and reducing raindrop impact (Figure 123). The fabrics protect new vegetation and aid in vegetation growth and establishment by preventing topsoil loss and retarding evaporation of soil moisture. Geotextiles can also provide material separation for riprap (BMP 56) or subgrade reinforcement.

Matting (BMP 54) or netting made of biodegradable materials (e.g., jute, wood fiber, straw, coconut, paper, or cotton) used for these purposes is less durable.

Figure 123. Geotextile channel lining (ITD 2014).

Primary BMP Functions and Controls

☒ Construction ☒ Permanent
☒ Erosion Control ☐ Sediment Control
☐ Source Control ☐ Flood Control
☐ Filtration ☐ Infiltration

Typical Effectiveness for Targeted Pollutants

● Sediment
○ Nitrogen
○ Phosphorus
◖ Metals
○ Bacteria
○ Hydrocarbons
○ Litter

Other BMP Considerations

Relative Cost	$$
Maintenance Requirements	Low
Ease of Installation	Easy
Freeze/Thaw Resistance	Good
Max. Tributary Drainage Area	100 acres
Max. Slope	50%
NRCS Soil Group	ABCD
Min. Ground Water Separation	NA
Min. Bedrock Separation	NA

Applicability

Geotextiles can be used on disturbed slopes and within channels, ditches, and swales. They are especially applicable for steep slopes, high flows, off-season planting, or if other factors prevent the use of organic matting. Use geotextiles along streambanks to establish bioengineered revetments where rock or riprap revetments are not appropriate. Geotextile advantages include the following:

- Ease and convenience.
- Quick and effective protection against erosion problems.
- A wide variety of geotextile products are available to match specific needs.
- Synthetic geotextiles may be removed and reused if economically feasible.
- Better resistance to high-flow situations than organic matting.

Limitations

- Effectiveness may be reduced drastically if the fabric is not properly selected, designed, or installed.
- Many synthetic geotextiles are sensitive to light and should be protected from direct sunlight before installation.
- Geotextiles that are not biodegradable should not be used where their presence or appearance is aesthetically unacceptable.
- Geotextiles should not be placed on 50% slopes if they are to be covered with overlying material.
- While geotextiles are affordable, their costs are usually higher than other erosion control techniques. Focus using geotextiles in areas where other erosion control techniques are ineffective (e.g., steep slopes, channels, periods where planting and seeding cannot take place).
- Geotextiles are not well suited in excessively rocky sites where a vegetated cover is unlikely or areas where the final vegetation will be mowed (staples and netting catch in mowers).

Design Basis

Geotextile fabrics are typically either woven or nonwoven polypropylene material. Nonwoven fabrics resemble felt whereas woven fabrics consist of two or more strands of material interlaced at right angles. The fabrics are available in various thicknesses, tensile strengths, permittivity, and ultraviolet stability; the proper material selection depends on the application. Products are available for up to 50% slopes. Typically, woven fabrics are preferred where high strength properties are needed; nonwoven fabrics are preferred where water transmission is needed. Use woven monofilament geotextiles where both strength and filtration are important. For erosion control applications, geotextiles should have the characteristics shown in Table 23.

Table 23. Recommended geotextile properties (CASQA 2004a).

Property	Minimum Value	Testing Method
Thickness	0.06 inches	—
Tensile strength	150 pounds (warp) 80 pounds (fill)	ASTM D 4632
Permittivity	0.07 sec-1	ASTM D 4491
Ultraviolet stability	70%	ASTM D 4355

Some synthetic geotextiles persist a very long time and should be considered a permanent measure. Others remain intact for less than 1 year. Those types designed to help establish vegetation will eventually photo-degrade or decompose. If a short-term degradable product is needed, see BMP 54: Matting.

Anchorage requirements depend on slope, soils, and expected runoff flow rates. General recommendations for anchorage are as follows:

- Anchor the fabric with U-shaped wire staples (minimum 8 gauge), metal geotextile stake pins (0.20 inch diameter with 1.5-inch steel washer), or triangular wooded stakes driven

perpendicularly into the slope face. All anchors should be a minimum of 6 inches long (up to 18 inches recommended in loose soils) and have sufficient penetration to resist pullout.
- Anchor spacing should be denser for steeper slopes. Steep slopes (1:1 to 2:1 H:V) should have a minimum of 2 anchors per square yard. Moderate slopes (2:1 to 3:1 H:V) should have a minimum of 1.5 staples per square yard. Check manufacturer's recommendations for staple patterns and density.

Anchorage can be selected using static analysis for a horizontal anchoring system as provided in Equation 30, Equation 31, and Equation 32. Figure 124 provides a cross-sectional diagram of a horizontally anchored geotextile system.

$$T_{GMallow} = \sigma_{allow} * t$$

Equation 30. Allowable geomembrane tension.

$$\sigma_{allow} = \frac{\sigma_{ult}}{FS}$$

Equation 31. Allowable geomembrane stress used to determine factor of safety.

$$T_{ATallow} = \frac{\gamma * d * L * (\tan \delta_U + \tan \delta_L)}{\cos \beta - \sin \beta * \tan \delta_L}$$

Equation 32. Allowable anchor trench tension.

Where

σ_{allow} = allowable geomembrane stress

t = geomembrane thickness

σ_{ult} = ultimate geomembrane stress (e.g., yield or break)

$T_{ATallow}$ = allowable anchor trench tension

d = thickness of the cover soil

L = embedment length

δ_L = (flexible membrane liners)/soil friction angle (below geomembrane)

δ_U = cover soil and geomembrane friction angle (above geomembrane)

β = side slope angle

FS = factor of safety

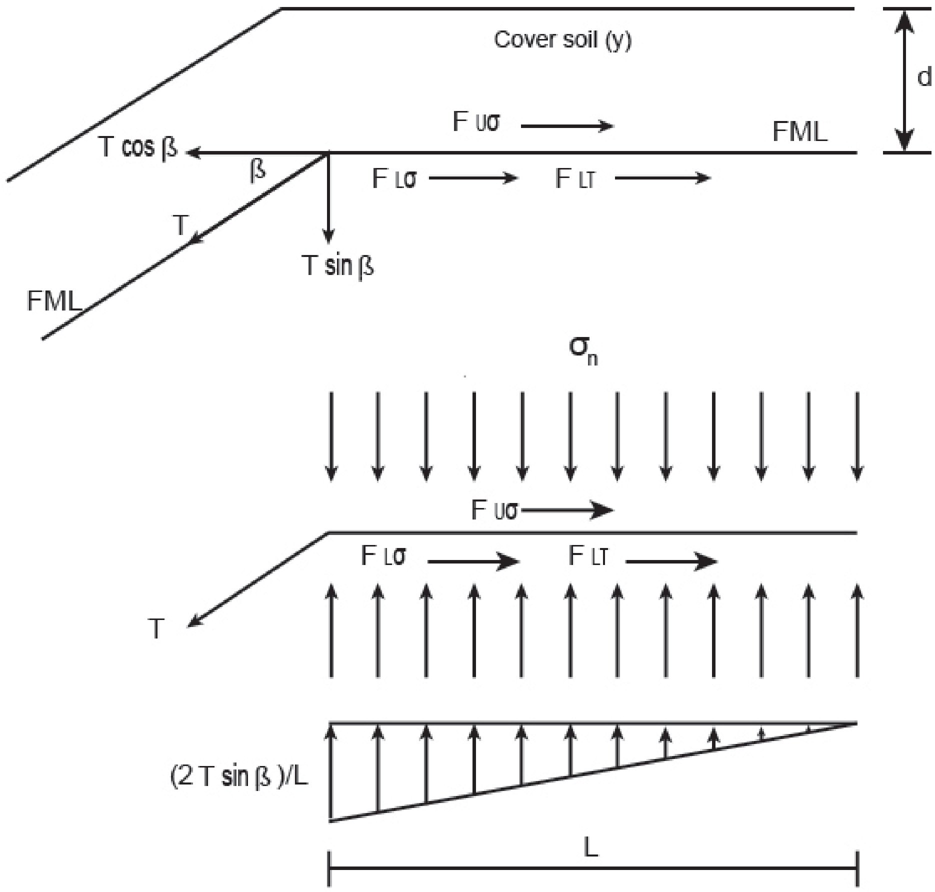


Figure 124. Cross-sectional diagram of a horizontally anchored geotextile system.

Construction Guidelines

When applying a geotextile to an exposed surface, anchor it into place to provide a continuous cover. Follow the manufacturer's recommendations for installation on slopes and within channels (Figure 125). After the fabric is placed, avoid driving equipment over the fabric, especially if wet soil conditions exist. Use the following guidelines for installation:

- The soil should be reasonably smooth. Fill and compact any rills and gullies. Remove protruding rocks and other obstructions.
- Apply the individual rolls up and down the slope, from the top to the bottom—never along the contour.
- Overlap the sides of the rolls at least 4 inches and ensure at least a 3-foot overlap when an uphill roll joins a downhill roll. The uphill roll should overlie the downhill roll.
- Extend the fabric beyond the edge of the mulched or seeded area at least 1 foot at the sides and 3 feet at the top and bottom of the area. If existing vegetation or structures mark the boundaries of the area, the fabric should continue into the stable vegetated area or to the edge of the structure.
- At the top of the area, bury the end of each roll in a trench at least 8 inches deep. Backfill and tamp the trench.

- Ensure the fabric makes uniform contact with the slope face underneath. No *bridging* of rills or gullies should be allowed.
- When using fabric designed for seeding or revegetation, follow the manufacturer's guidelines for proper seedbed preparation, seed application, and/or planting.

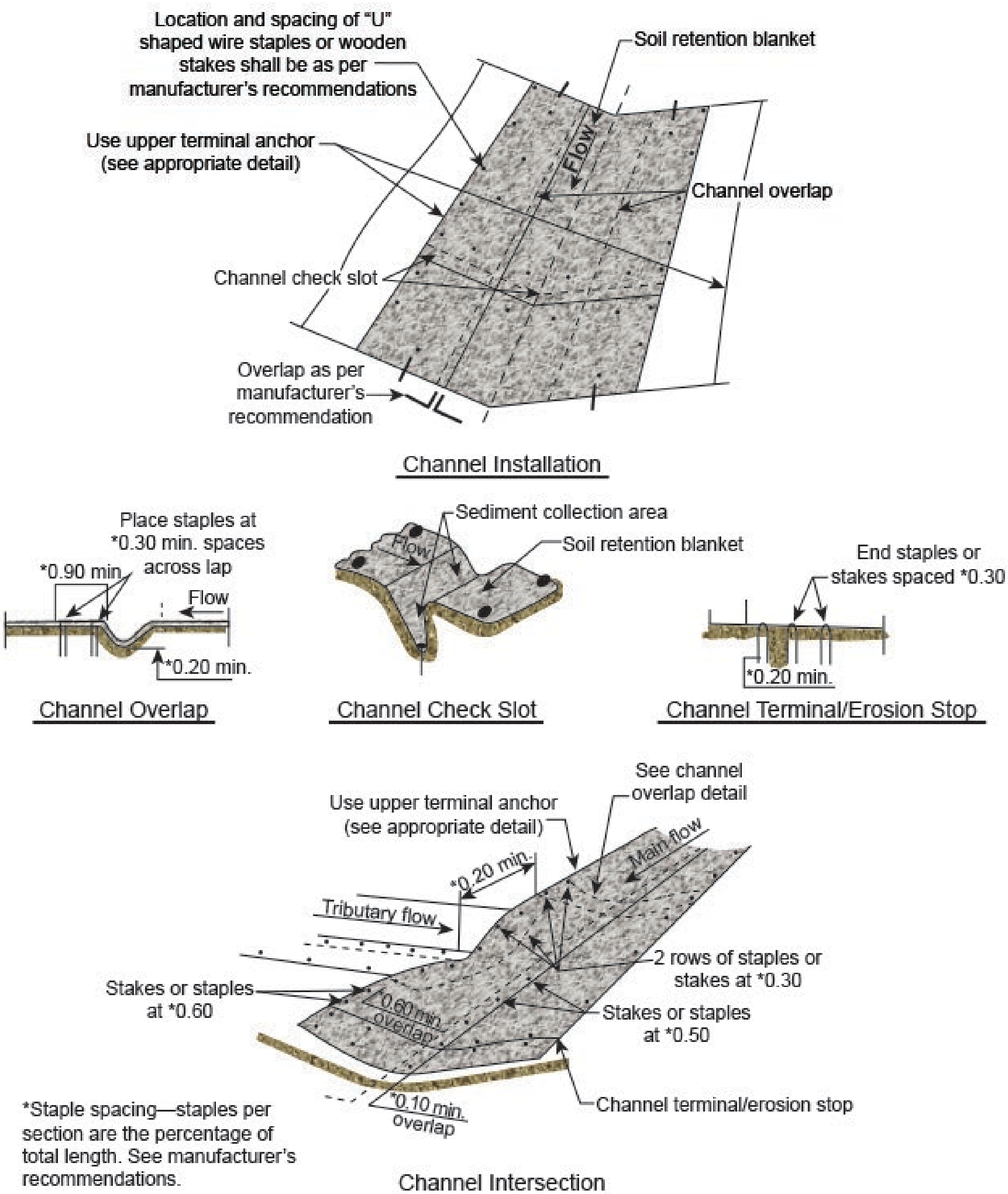


Figure 125. Channel installation.

Maintenance

Inspect weekly or monthly during drier periods and within 24 hours after each runoff-producing storm. To ensure proper functioning, complete one inspection during the first runoff-producing event after installation. Check that the fabric is uniformly in contact with the soil, the lap joints are secure, and staples are flush with the ground. If fabric sheeting is damaged or missing, replace it immediately to restore full protection. Inspect sheeting to ensure that channelization and erosion are not occurring underneath fabric (sediment outwash is the most visible sign).

Products used for temporary control may be removed and reused if it is done without leaving the area susceptible to erosion and the fabric is suitable for reuse.

Additional Resources

CASQA (California Stormwater Quality Association). 2004. *California Stormwater Best Management Practices Handbook: New Development and Redevelopment*. Menlo Park, CA. *https://www.casqa.org*

ITD (Idaho Transportation Department). 2014. *Best Management Practices.* Boise, ID: ITD.

BMP 54: Matting

Description

Matting is a porous net or fibrous sheet laid over the ground surface for slope stabilization and erosion control or used to hold mulch in place and protect it against wind or water damage. Matting may be used to stabilize channels and swales until vegetative cover becomes established. Matting and netting are sometimes classified as geotextiles (BMP 53); in this catalog, matting is considered to be biodegradable materials made from straw, coconut (coir), jute, wood fiber (excelsior), paper, and/or cotton (Figure 126). Some of these organic materials may be held in place by plastic netting.

Figure 126. Jute matting applied over a steep slope in Jackson Hole, Wyoming.

Applicability

While a variety of biodegradable matting materials may be used for erosion control, the main types include woven (jute), wood fibers, and plastic-bonded. Applications for these matting types are listed below.

Jute matting is a heavy fiber net that is generally purchased in rolls and is stapled/anchored to slopes to provide a uniform covering. This covering protects mulches, provides additional water-holding capacity, and aids in moderating environmental fluctuations near the ground surface (as does mulch).

Jute matting can be applied over straw, grass hay, wood fiber, or manure mulches when wind or water damage would occur without a protective net. Matting is the best single method for protecting the integrity of a mulched area. It may be applied alone as an alternative to straw or wood fiber mulches on flat sites for dust control and seed germination enhancement but should not be applied alone where runoff quantities are significant.

Wood fiber (excelsior) matting is made by bonding wood excelsior fibers to a paper or plastic reinforcing net. The matting is purchased in rolls and stapled to slopes to provide a uniform covering

Primary BMP Functions and Controls

☒ Construction	☐ Permanent
☒ Erosion Control	☐ Sediment Control
☐ Source Control	☐ Flood Control
☐ Filtration	☐ Infiltration

Typical Effectiveness for Targeted Pollutants

●	Sediment
○	Phosphorus
◖	Metals
○	Bacteria
◖	Hydrocarbons
○	Litter

Other BMP Considerations

Relative Cost	$
Maintenance Requirements	Medium
Ease of Installation	Easy
Freeze/Thaw Resistance	Good
Max. Tributary Drainage Area	100 acres
Max. Upstream Slope	100%
NRCS Soil Group	ABCD
Min. Ground Water Separation	N/A
Min. Bedrock Separation	2 feet

to protect mulches, provide enhanced water-holding capacity, and aid in moderating environmental fluctuations near the ground surface.

Plastic netting (photo/biodegradable) is a monolithic plastic cloth-like material used primarily to hold straw and other materials in place. Plastic netting is more durable than jute or wood fiber matting. While it is easier to handle and requires less labor, it has no mulch capabilities. Plastic netting alone provides no soil stabilization or erosion control and is best used to hold down mulches until vegetation becomes established.

Matting can be useful in the following circumstances:

- Construction sites becoming temporarily inactive (inactive period greater than 2 weeks and less than 1 year).
- Graded areas receiving permanent revegetation treatment by seeding.
- Bare areas receiving permanent revegetation treatment by seeding.

Limitations

Matting should not be used where overland water flow will exceed 6.5 ft/s. Because of the following characteristics of plastic netting and wood fiber matting, jute matting, straw, or straw-coconut matting are preferred.

Plastic netting does not function as mulch (as does jute matting) because it does not absorb water. When plastic netting is used to anchor straw mulch, it increases the effectiveness of the mulch, but it does not provide direct control of erosion and sedimentation or nutrient generation. Straw mulch rates should be increased 25% when plastic netting is used instead of jute or straw. Plastic netting will degrade over time when exposed to sunlight.

Wood fiber matting is more difficult to put in place than jute and is less predictable in controlling erosion. When properly applied, wood fiber matting can be as effective as jute matting at sediment and nutrient reduction, but it can 10% to 20% less effective when not properly installed.

Biodegradable matting should be chosen to match the expected length of service.

Design Basis

Jute matting should be fiber cloth of a uniform plain weave, undyed and unbleached single jute yarn, 3 to 4 feet wide and weighing an average 0.4 pounds per linear foot of cloth with a tolerance of plus or minus 5%. The matting should have approximately 78 warp ends per width of cloth and 45 weft ends per linear meter of cloth. The yarn should be of a loosely twisted construction having an average twist of not less than 6.3 turns per 4 inches and should not vary in thickness by more than half of its normal diameter.

Wood fiber matting should consist of machine-produced mats of curled wood excelsior, of which 80% have an 8 inches or longer fiber length. The matting should be of consistent thickness with the fiber evenly distributed over the entire area of the blanket (backing). The topside of each blanket should be covered with a 1- x 3-inch weave of twisted Kraft paper or biodegradable plastic mesh that has a high wet strength. Blankets should be fire and smolder resistant and contain no chemical additives. Blankets should be in rolls 3 to 4 feet wide and 130 to 200 feet long.

Plastic netting with mesh opening from 1/10 x 1/10 inches to 1/5 x 1/5 inches should be applied over straw mulch, similar to the method specified below for jute matting.

Effectiveness—Jute matting acts like straw mulch or hydromulch. Sediment reduction is typically 70% to 90% for up to 6 months, 40% to 60% for up to 2 years, and 10% to 30% beyond 2 years. Nutrient reduction is estimated at 50% to 70% for 6 months, 20% to 50% for up to 2 years, and 0% to 10% beyond 2 years.

Due to the difficulty of proper application, wood excelsior matting has a more variable effectiveness than straw, jute, or hydromulch, but when properly applied, it can be as effective. Sediment reduction should range from 50% to 90%, 20% to 60%, and 0% to 30% in 6 months, 2 years, and beyond 2 years, respectively. Nutrient reductions for the same time periods are estimated to be 30% to 70%, 10% to 50%, and 0% to 10%.

Construction Guidelines

The following guidelines apply to all matting and netting installations (Figure 127):

- The soil should be reasonably smooth. Fill and compact any gullies and rills. Rocks, vegetation, or other obstructions that rise above the level of the soil should be removed.
- After site preparation and seeding (if any), roll the netting or matting onto the surface from the top of the slope to the bottom of the slope. Do not install the rolls in a horizontal direction across the slope face; the rolls should follow water flow direction.
- At the top of the area, bury the end of each roll in a trench at least 8 inches deep. Backfill and tamp the trench.
- Overlap the sides of the rolls at least 4 inches and ensure there is at least a 3-foot overlap when an uphill roll joins a downhill roll. The uphill roll should overlie the downhill roll.
- Extend the matting beyond the edge of the mulched or seeded area at least 1 foot at the sides and 3 feet at the top and bottom of the area. If existing vegetation or structures mark the boundaries of the area, the matting should continue into the stable vegetated area or to the edge of the structure.
- Staples should be driven perpendicularly into the slope face. Place them approximately 3 feet apart down the sides and center of the roll and not more than 1 foot apart at the upper end of a roll or at the end overlap of two rolls.
- Staples should be of heavy gauge wire (7/100 inch diameter or greater), bent into a U-shape, with legs at least 6 inches long, and a 1-inch crown. Use longer staples and greater frequency in loose or sandy soil.
- Ensure the matting makes uniform contact with the slope face underneath. No *bridging* of rills or gullies should be allowed.
- If wood fiber matting is to be applied without other mulches, the minimum thickness of mat should be 1.5 inches. If the mat is to be applied over other mulches, the minimum mat thickness should be 0.5 inches.

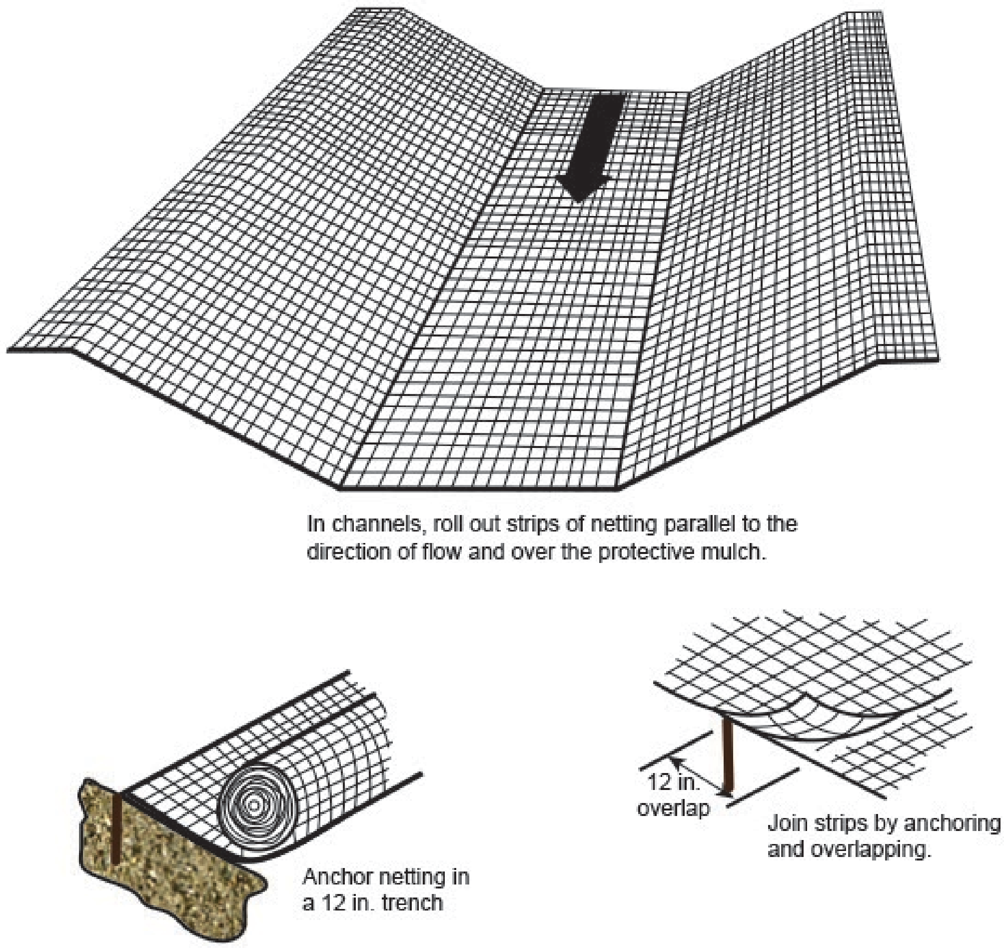


Figure 127. Matting.

Maintenance

Inspect the matting at regular intervals and after each runoff-producing storm event. Repair the matting or netting as necessary to restore complete coverage and full effectiveness. The matting must maintain contact with the group at all times.

Additional Resources

EPA (US Environmental Protection Agency). 2014. *Geotextiles.* Water: Best Management Practices. *https://www.epa.gov/watersense/best-management-practices*

BMP 55: Soil Binders

Description

Disturbed soil is easily eroded by wind or storm water runoff. Soil binders include soil stabilizers applied to disturbed soil to reduce wind and water erosion when construction activities temporarily cease and dust palliatives are used to reduce dust emissions from mechanical and wind forces. Typically dust palliatives do not have the longevity of soil stabilizers (Figure 128).

Figure 128. Soil stabilizer application in Douglas County, Colorado (Colorado UDFCD 2010).

The use of treatment chemicals must comply with federal, state, and local regulations. The type of chemicals used must be approved and documented in the storm water management plan.

Applicability

Soil binders are suitable for use on disturbed soil areas requiring temporary erosion protection on both mild and steep slopes. Binders are often used in areas where work has temporarily stopped but is expected to resume before vegetation can become established. Soil binders are typically used with other BMPs to increase performance, and the treated area should discharge to a sediment basin or other BMP. Apply soil binders to the following:

- Rough-graded soils that will be inactive for a period of time
- Final-graded soils before applying final stabilization (e.g., paving, planting, and mulching)
- Temporary haul roads before placing crushed rock surfacing
- Compacted soil road base
- Construction staging, materials storage, and layout areas
- Soil stockpiles
- Areas that will be mulched

Primary BMP Functions and Controls

☒ Construction	☐ Permanent
☒ Erosion Control	☐ Sediment Control
☐ Source Control	☐ Flood Control
☐ Filtration	☐ Infiltration

Typical Effectiveness for Targeted Pollutants

◖	Sediment
○	Nitrogen
○	Phosphorus
○	Metals
○	Bacteria
○	Hydrocarbons
○	Litter

Other BMP Considerations

Relative Cost	$
Maintenance Requirements	Low
Ease of Installation	Easy
Freeze/Thaw Resistance	Fair
Max. Tributary Drainage Area	Unlimited
Max. Upstream Slope	NA
NRCS Soil Group	ABCD
Min. Ground Water Separation	NA
Min. Bedrock Separation	NA

Limitations

- Soil binders should not be directly applied to water or allowed to enter a water body.
- Do not use soil binders on a slope that flows into a water body if it will result in a discharge of the soil binder, unless it passes through a sediment trap or sediment basin.
- Always use soil binders with other BMPs, but not in place of other BMPs, including erosion and sediment controls.
- Site soil type dictates appropriate the soil binder to be used. Be aware that soil binders may not function effectively on silt or clay soils or in highly compacted areas. Follow the manufacturer's recommendations for use with certain soil conditions.
- Some soil binders may not perform well in low relative humidity.
- Certain soil binders may not cure adequately if exposed to low temperatures within 24 hours of application.
- Avoid using soil binders in high vehicle and pedestrian traffic areas because effectiveness is minimized under these conditions.
- Soil binders are temporary and may need reapplication.

Design Basis

General Considerations

- Soil binders should be nontoxic to plant and animal life. Obtain an MSDS from the manufacturer to ensure site runoff is not exposed to pollutants contained within the soil binder.
- Soil binders designated for erosion and sediment control should be *water soluble*, *linear,* or *noncross linked*.
- All areas not being actively worked on should be covered and protected from rainfall. Soil binders should not be the only cover BMP used.
- Performance of soil binders depends on temperature, humidity, and traffic across treated areas.
- Storm water runoff from soils treated with a soil binder should pass through a sediment control BMP before discharging to surface waters. The type of control BMP suggested varies by the size of the contributing drainage area.
    - When the total drainage area is greater than or equal to 5 acres, soil binder-treated areas should drain to a sediment basin.
    - Areas less than 5 acres should drain to sediment control BMPs, such as a sediment trap, or a minimum of three check dams per acre. Maximize the total number of check dams used to achieve the greatest amount of settling before discharging from the site. Space each check dam evenly in the drainage channel.
- On the sites treated with a soil binder, use silt fencing and fiber rolls to limit sediment discharge to sediment traps and sediment basins.

Selecting a Soil Binder

Soil binder selection depends on site conditions (i.e., environmental factors, soil moisture content, and soil texture). Consult the manufacturer for proper soil binder selection. Products should have a manufacturer's certification that it is nontoxic to plant or animal life and nonstaining to concrete or painted surfaces.

Factors to consider when selecting a soil stabilizer or dust palliative product include its suitability to the situation, soil types and surface materials, and frequency of application.

Suitability to situation—Consider where the product will be applied, if it needs a high resistance to leaching or abrasion, and whether it needs to be compatible with any existing vegetation. Determine the length of time stabilization will be needed and if the product will be placed in an area where it will degrade rapidly.

Soil types and surface materials—Fines and moisture content are key properties of surface materials. Consider a soil stabilizer or dust palliative's ability to penetrate, likelihood of leaching, and ability to form a surface crust on the surface materials. Soil information can be obtained from the project's geotechnical report or from the NRCS website.

Application Frequency—Application frequency can be affected by subgrade conditions, surface type, climate, and maintenance schedule. Frequent applications could lead to high costs. Application frequency may be minimized if the dust palliative has good penetration, low evaporation, and good longevity. Consider that frequent application will also require frequent equipment cleanup.

Several types of soil binders are available: plant-material based (short-lived), plant-material based (long-lived), polymeric emulsion blends, cementitious based, and petroleum based. Plant-material based (short-lived) soil binders should only be used as dust palliatives due to their short-lived nature. Plant materials include guar, psyllium, and starch. Plant-material based (long-lived) includes tall oil pitch/pitch and rosin emulsion, and lignin sulfonate.

Polymeric emulsion blends include acrylic copolymers and polymers; liquid polymers of methacrylates and acrylates; copolymers of sodium acrylates and acrylamides; polyacrylamide and copolymer of acrylamide (PAM); and hyrocolloid polymers. Gypsum is a cementious-based soil binder, and petroleum resin emulsion is a petroleum-based soil binder.

Table 24 and Table 25 provide a summary of the properties of the soil binder types.

Table 24. Soil stabilizer properties for erosion control in nontraffic areas (ITD 2014).

Chemicals	Plant-Material Based (Short-Lived)	Plant-Material Based (Long-Lived)	Polymeric Emulsion Blends	Cementitious-Based Stabilizers
Relative cost	Low	Low	Low	Low
Resistance to leaching	High	High	Low to moderate	Moderate
Resistance to abrasion	Moderate	Low	Moderate to high	Moderate to high
Longevity	Short to medium	Medium	Medium to long	Medium
Minimum curing time before rain	9 to 18 hours	19 to 24 hours	0 to 24 hours	4 to 8 hours
Compatibility with existing vegetation	Good	Poor	Poor	Poor
Mode of degradation	Biodegradable	Biodegradable	Photodegradable/ chemically degradable	Photodegradable/ chemically degradable
Labor intensive	No	No	No	No
Specialized application equipment	Water truck or hydraulic mulcher	Water truck or hydraulic mulcher	Water truck or hydraulic mulcher	Water truck or hydraulic mulcher
Liquid/powder	Powder	Liquid	Liquid/powder	Powder
Surface crusting	Yes, but dissolves on rewetting	Yes	Yes, but dissolves on rewetting	Yes
Cleanup	Water	Water	Water	Water
Erosion control application rate	Varies	Varies	Varies	4,500 to 13,500 L/ha

Note: liter per hectare (L/ha)

Table 25. Soil stabilizer properties for erosion control in traffic areas (ITD 2014).

Chemicals	Ligninosulfonate	Tall Oil Pitch Emulsion	Petroleum Resin Emulsion
Relative cost	Moderate	Moderate	Moderate
Resistance to leaching	Low	High	High
Longevity	Medium	Medium to long	Medium
Minimum curing time before rain	24 hours +	30–60 minute (prime coat) 8–24 hours (mixed Into base)	0–4 hours
Mode of degradation	Biodegradable	Biodegradable	Photo/chemically degradable
Labor intensive	No	No	No
Specialized application equipment	Water truck or hydraulic mulcher	Water truck or hydraulic mulcher	Water truck or hydraulic mulcher
Surface crusting	Yes, but dissolves on rewetting	Yes	Yes
Cleanup	Water	Water, before it dries	Water, before it cures

Construction Guidelines

After selecting an appropriate product, prepare the untreated soil surface before applying the soil binder. Proper application ensures the soil binder's total effectiveness. Follow these guidelines when applying soil binders during construction:

- Soil binder application should adhere to all state and local regulations.
- Follow manufacturer's recommendation for application rates and prewetting of the application area.
- The untreated soil surface should contain sufficient moisture to assist the agent in achieving uniform distribution.
- Before application, roughen embankment and fill areas.
- Consider the drying time for the selected product and apply with sufficient time before anticipated rainfall. Generally, soil stabilizers and dust palliatives require a minimum curing time of 24 hours before they are fully effective. Refer to manufacturer's instructions for specific cure times. Soil stabilizers and dust palliatives shall not be applied during or immediately before rainfall.
- Soil stabilizers and dust palliatives shall not be applied to frozen soil, areas with standing water, under freezing or rainy conditions, or when the air temperature is below 4°C (40°F) during the curing period.
- Some soil binders, when combined with water, are slippery and can be a safety hazard. Take care to prevent spills of soil binder powder onto paved or impervious surfaces. During any application of soil binders, prevent overspray from reaching pavement and creating a safety hazard.
- Avoid overspray onto travel ways, sidewalks, drainage channels, and existing vegetation.
- Do not add soil binders to water discharging from the site.
- Refer to MSDS for worker protection requirements.

Maintenance

Regular inspection and maintenance is important for ensuring the effectiveness of the soil binder. Follow manufacturer's recommendations for reapplication and for maintaining and cleaning equipment after use. The following are additional maintenance guidelines:

- Inspect BMPs before rain events: daily during extended rain events, after rain events, weekly during the rainy season, and at 2-week intervals during the nonrainy season.
- Reapply soil binders according to manufacturer's recommendations or as specified by the supervising erosion control professional.
- Areas where erosion is evident should be repaired and soil binders reapplied as soon as possible.
- While making repairs, exercise care to minimize the damage to protected areas, as any area damaged will require reapplying the soil binders.
- More soil binder applications may be required for steep slopes, silty and clayey soil (NRCS Classification Type "C" and "D" soils), long grades, and high precipitation areas.
- Inspections and maintenance should be recorded in the SWPPP and according to the prescribed schedule.

Additional Resources

EPA (US Environmental Protection Agency). 2014. *Chemical Stabilization*. Water: Best Management Practices *https://www.epa.gov/sites/production/files/2015-11/documents/idde_manualwithappendices_0.pdf*

CASQA (California Stormwater Quality Association). 2004. *California Stormwater Best Management Practices Handbook: New Development and Redevelopment*. Menlo Park, CA. *https://www.casqa.org*

Colorado UDFCD (Colorado Urban Drainage and Flood Control District). 2010. *Urban Storm Drainage Criteria Manual, Volume 3 Best Management Practices*. Denver, CO. *http://udfcd.org/wp-content/uploads/2014/07/Title-Page.pdf*

ITD (Idaho Transportation Department). 2014. *Best Management Practices.* Boise, ID: ITD.

King County (King County, Washington). 2009. *King County, Washington Surface Water Design Manual.* Seattle, WA: King County, Department of Natural Resources.

Washington State Department of Ecology. 2012. *Stormwater Management Manual for Western Washington*. Lacey, WA. Publ. 12-10-030. *http://www.ecy.wa.gov/programs/wq/stormwater/manual.html*

BMP 56: Riprap Slope Protection

Description

Slopes that experience high runoff velocities from concentrated flows can be unstable and cause excessive erosion and sedimentation. Riprap slope protection is created by layers or piles of rock placed over the soil surface. Riprap, when used as slope protection, protects against erosion, stabilizes the slope, and dissipates the energy of surface water flow (Figure 129).

Figure 129. Riprap stabilization of the Salmon River Road, Riggins, Idaho.

If used along a surface water body such as a river, lake, or stream, permits may be required from Idaho Department of Lands, IDWR, and US Army Corps of Engineers (each agency has local offices throughout the state). These agencies may have specifications for placing riprap so inquire early in the design to facilitate obtaining the permits.

Primary BMP Functions and Controls

☐ Construction	☒ Permanent
☒ Erosion Control	☐ Sediment Control
☐ Source Control	☐ Flood Control
☐ Filtration	☐ Infiltration

Typical Effectiveness for Targeted Pollutants

◖	Sediment
○	Nitrogen
○	Phosphorus
○	Metals
○	Bacteria
○	Hydrocarbons
◖	Litter

Other BMP Considerations

Relative Cost	$$
Maintenance Requirements	Low
Ease of Installation	Easy
Freeze/Thaw Resistance	Good
Max. Tributary Drainage Area	5 acre
Max. Upstream Slope	40%
NRCS Soil Group	ABCD
Min. Ground Water Separation	NA
Min. Bedrock Separation	NA

Applicability

Riprap slope protection can be used on channel side slopes or bottoms, cut and fill slopes, streambanks, bridge embankments, below dikes or detention pond spillways, or any area where the velocity of flow may cause erosion.

Limitations

The steepness of the slope limits the applicability of riprap since slopes steeper than 1V:2H can cause riprap loss due to erosion and sliding. It may be difficult to remove sediment from riprap without completely removing and replacing the riprap. If used improperly, riprap can increase erosion. In addition, riprap can be more expensive than other stabilization options.

Design Basis

The design of riprap slope protection depends on the soil conditions, site characteristics, and expected flows. When designing riprap slope protection, apply the following guidelines.

Gradation

Rock riprap material should be composed of a well-graded mixture of angular stone size so that 50% of the pieces, by weight, are larger than the D_{50} size as determined using standard testing methods. A well-graded mixture is defined as a mixture that includes a variety of stone sizes so that the voids between the stones are filled. Riprap gradations that fall within the range of D_{100}/D_{50} and D_{50}/D_{20} from 3.0 to 1.5 are acceptable.

Size

Size the riprap so the permissible shear stress of the riprap material is greater than the hydrodynamic force of water flowing in the channel or over the slope. The permissible shear stress (Table 26) indicates the force required to initiate movement of the stone particles (Equation 33–Equation 35).

Table 26. Typical permissible shear stresses for bare soil and stone linings (FHWA 2005).

Lining Category	Lining Type	Permissible Shear Stress (pounds per square foot)
Bare soil[a] Cohesive (PI = 10)	Clayey sands	0.037–0.095
	Inorganic silts	0.027–0.11
	Silty sands	0.024–0.072
Bare soil[a] Cohesive (PI $\geq$ 20)	Clayey sands	0.094
	Inorganic silts	0.083
	Silty sands	0.072
	Inorganic clays	0.14
Bare soil[b] Cohesive (PI $\leq$ 10)	Finer than coarse sand D_{75} < 0.05 inches	0.02
	Fine gravel D_{75} = 0.3 inches	0.12
	Gravel D_{75} = 0.6 inches	0.24
Gravel mulch[c]	Coarse gravel D_{50} = 1 inch	0.4
	Very coarse gravel D_{50} = 2 inches	0.8
Rock riprap[c]	D_{50} = 0.5 feet	2.4
	D_{50} = 1 foot	4.8

a. Based on Equation 33 assuming a soil void ratio of 0.5 (USDA 1987).
b. Based on Equation 34 derived from USDA (1987).
c. Based on Equation 35 Shield's parameter equal to 0.047

$$\tau_{p,soil} = (c_1 PI^2 + c_2 PI + c_3)(c_4 + c_5 e)^2 c_6$$

Equation 33. Permissible soil shear stress for cohesive soils.

Where:

$\boldsymbol{\tau_{p,soil}}$ = soil permissible shear stress (lb/ft^2)

PI = plasticity index

e = void ratio

$c_1, c_2, c_3, c_4, c_5, c_6$ = coefficients (Table 27)

Table 27. Coefficients for permissible soil shear stress (USDA 1987).

ASTM Soil Classification	Applicable Range	C_1	C_2	C_3	C_4	C_5	C_6 (SI)	C_6 (CU)
GM	$10 \leq PI \leq 20$ $20 \leq PI$	1.07	14.3	47.7 0.076	1.42 1.42	-0.61 -0.61	$4.8x10^{-3}$ 48.	10^{-4} 1.0
GC	$10 \leq PI \leq 20$ $20 \leq PI$	0.0477	2.86	42.9 0.119	1.42 1.42	-0.61 -0.61	$4.8x10^{-2}$ 48.	10^{-3} 1.0
SM	$10 \leq PI \leq 20$ $20 \leq PI$	1.07	7.15	11.9 0.058	1.42 1.42	-0.61 -0.61	$4.8x10^{-3}$ 48.	10^{-4} 1.0
SC	$10 \leq PI \leq 20$ $20 \leq PI$	1.07	14.3	47.7 0.076	1.42 1.42	-0.61 -0.61	$4.8x10^{-3}$ 48.	10^{-4} 1.0
ML	$10 \leq PI \leq 20$ $20 \leq PI$	1.07	7.15	11.9 0.058	1.48 1.48	-0.57 -0.57	$4.8x10^{-3}$ 48.	10^{-4} 1.0
CL	$10 \leq PI \leq 20$ $20 < PI$	1.07	14.3	47.7 0.076	1.48 1.48	-0.57 -0.57	$4.8x10^{-3}$ 48.	10^{-4} 1.0
MH	$10 \leq PI \leq 20$ $20 \leq PI$	0.0477	1.43	10.7 0.058	1.38 1.38	-0.373 -0.373	$4.8x10^{-2}$ 48.	10^{-3} 1.0
CH	$20 \leq PI$	—	—	0.097	1.38	-0.373	48.	1.0

Notes: GM—silty gravels, gravel-sand silt mixtures; GC—clayey gravels, gravel-sand-clay mixtures; SM—silty sands, sand-silt mixtures; SC—clayey sands, sand-clay mixtures; ML—inorganic silts, very fine sands, rock flour, silty or clayey fine sands; CL—inorganic clays of low-to-medium plasticity, gravelly clays, sandy clays, silty clays, lean clays; MH—inorganic silts, micaceous or diatomaceous fine sands or silts, elastic silts; CH—inorganic clays of high plasticity, fat clays

$$\tau_{p,soil} = \alpha D_{75}$$

Equation 34. Permissible soil shear stress for course-grained noncohesive soils.

Where:

$\boldsymbol{\tau_{p,soil}}$ = soil permissible shear stress (lb/ft^2)

D_{75} = soil size where 75% of the material is finer (in.)

α = unit conversion constant, 0.75 (SI), 0.4 (CU)

$$\boldsymbol{\tau_p = F_*(\gamma_s - \gamma)D_{50}}$$

Equation 35. Permissible shear stress for riprap and gravel linings.

Where:

τ_p = permissible shear stress (lb/ft^2)

F_* = Shield's parameter, dimensionless

γ_s = specific weight of the stone (lb/ft^2)

γ = specific weight of the water (62.4 lb/ft^2)

D_{50}= mean riprap size (ft)

The maximum shear stress on a channel bottom can be calculated using Equation 36.

$$\tau = \gamma d s$$

Equation 36. Shear stress at the bottom of a channel.

Where

τ = maximum shear stress at channel bottom (lb/ft^2)

γ= unit weight of water, 62.4 lb/ft^3

d = maximum flow depth (ft)

s = channel gradient (ft/ft)

The maximum shear on the side of a channel is generally less than that on the channel bottom and is given by Equation 37:

$$\tau_s = K_1 \tau$$

Equation 37. Shear stress at the side of a channel.

Where

τ_s = side shear stress (lb/ft^2)

τ = maximum shear stress at channel bottom (lb/ft^2)

K_1= ratio of channel side shear to bottom shear stress

For trapezoidal and triangular channels, where Z is the horizontal dimension (1:Z, V:H) Equation 38 may be applied for K_1:

K_1 = 0.77 for $Z \leq 1.5$

K_1 = 0.066Z 0.67 for $1.5 < Z < 5$

K_1 = 1.0 for $5 \leq Z$

Equation 38. Ratio values for side shear to bottom shear stress.

Thickness

The thickness of the riprap layer varies depending on the application but in no case should it be less than 6 inches. For smaller rock sizes where D_{50} is 15 inches or less, a thickness of 1.5 to 2 times D_{100} is recommended. For D_{50} greater than 15 inches, a thickness of 1.2 to 1 times D_{100} can be used. Table 28 lists some examples of riprap sizes and thicknesses for various unit shear stresses.

Table 28. Example rock riprap sizes and thickness.

Unit Shear Stress (pounds per square foot)	D_{50} (inches)	D_{100} (inches)	Minimum Blanket Thickness (inches)
0.67	2	4	6
2.00	6	9	14
3.00	9	14	20
4.00	12	18	27
5.00	15	22	32
6.00	18	27	32
7.80	21	32	38
8.00	24	36	43

Stone Quality

Riprap should consist of field stone or rough unhewn quarry stone. The stone must be hard and *angular* (to create an interlocking stone blanket) and of a quality that will not disintegrate with exposure to water, weathering, or freeze/thaw cycles. The specific gravity of the individual stones should be at least 2.5 to prevent scour and mobilization of the material. Table 29 lists common rock types and their specific gravities. Note that although talc and sandstone meet the specific gravity requirement, these materials should not be used in riprap construction because of water solubility and scouring concerns. Use best judgment when selecting riprap material.

Table 29. Common rock types and associated specific gravity and density (EDUMine 2018).

Rock Type	Specific Gravity	Ton/yd^3
Basalt	2.8–3.0	2.11–2.36
Granite	2.6–2.7	2.19–2.28
Quartzite	2.6–2.8	2.19–2.36
Gneiss	2.6–2.9	2.19–2.44
Dolomite	2.50–2.60	2.36–2.44
Talc	2.6–2.8	2.19–2.36
Sandstone	2.2–2.8	1.85–2.36

Filter

A filter is a layer of material placed between the riprap and the underlying soil to prevent soil movement into and through the riprap. The need for a filter depends on the characteristics of the native material underlying the riprap, but it is needed in most cases.

Filters can be either gravel or a geosynthetic fabric. Geosynthetic fabrics can be woven or nonwoven monofilament yarns and should have adequate permeability to prevent uplift pressures from forming (Table 30). Other basic requirements include a thickness of 10–60 mils, grab strength of 90–120 pounds, and conform to ASTM D-1777 and ASTM D5034 and D5035.

Table 30. Maximum apparent opening size for geotextile filters (FHWA 1998).

Soil Type	Maximum Apparent Opening Size for Geotextile Filters (millimeters)
Noncohesive, less than 15% passing the 0.075 mm (US #200) sieve	0.43
Noncohesive, 15% to 50% passing the 0.075 mm (US #200) sieve	0.25
Noncohesive, more that 50% passing the 0.075 mm (US #200) sieve	0.22
Cohesive, plasticity index greater than 7	0.30

Gravel filter blankets should be designed by comparing particle sizes of the riprap material and the underlying base material using Equation 39, Equation 40, and Equation 41 (FHWA 2005). The recommended minimum filter thickness is 6 inches.

$$\frac{D_{15\ UPPER}}{D_{85\ LOWER}} < 5$$

Equation 39. Lower particle size ratio.

$$5 < \frac{D_{15\ UPPER}}{D_{15\ LOWER}} < 40$$

Equation 40. Medium particle size ratio.

$$\frac{D_{50\ UPPER}}{D_{50\ LOWER}} < 40$$

Equation 41. Upper particle size ratio.

In the equations above, *upper* refers to the overlying material, and *lower* refers to the underlying material. These relationships must hold between the filter blanket and base material and between the riprap and filter blanket.

Placement

Riprap placement shall follow immediately after filter placement. Place riprap so it forms a dense, well-graded mass of stone with minimum voids. Riprap shall be placed at its full thickness in one lift.

In a channel, place riprap so it extends to the maximum flow depth, or to a point where vegetation will satisfactorily control erosion. Ensure riprap extends to five times the bottom width upstream and downstream at the beginning and ending of the curve and the entire curved section.

On slopes, key the toe of the riprap in at the base. The toe should be excavated to 2 feet deep. The design thickness of the riprap shall be extended to a minimum of 3 feet horizontally from the slope. The finished grade of the riprap should blend with the surrounding area. Figure 130 and Figure 131 show cross sections of riprap placed in channels and on channel side slopes.

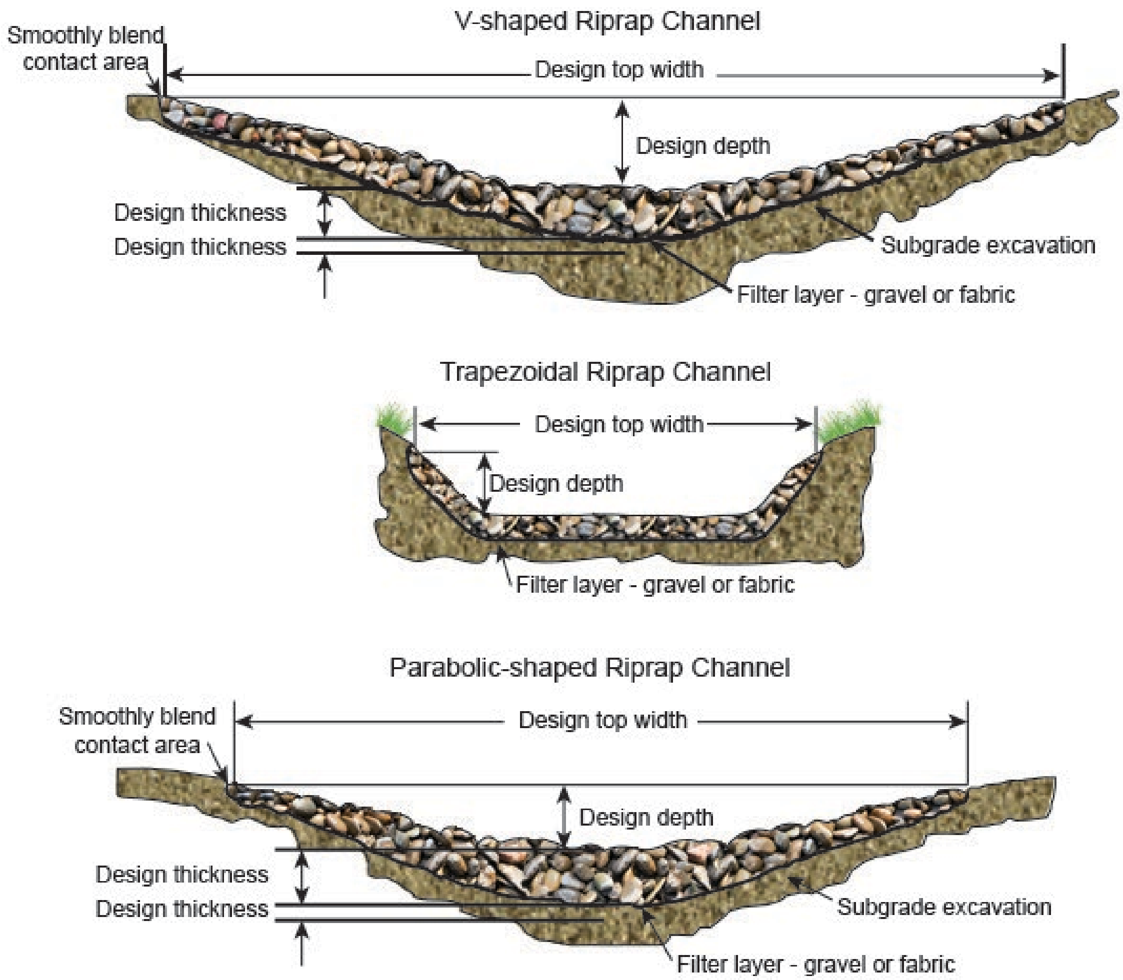


Figure 130. Riprap channel cross sections.

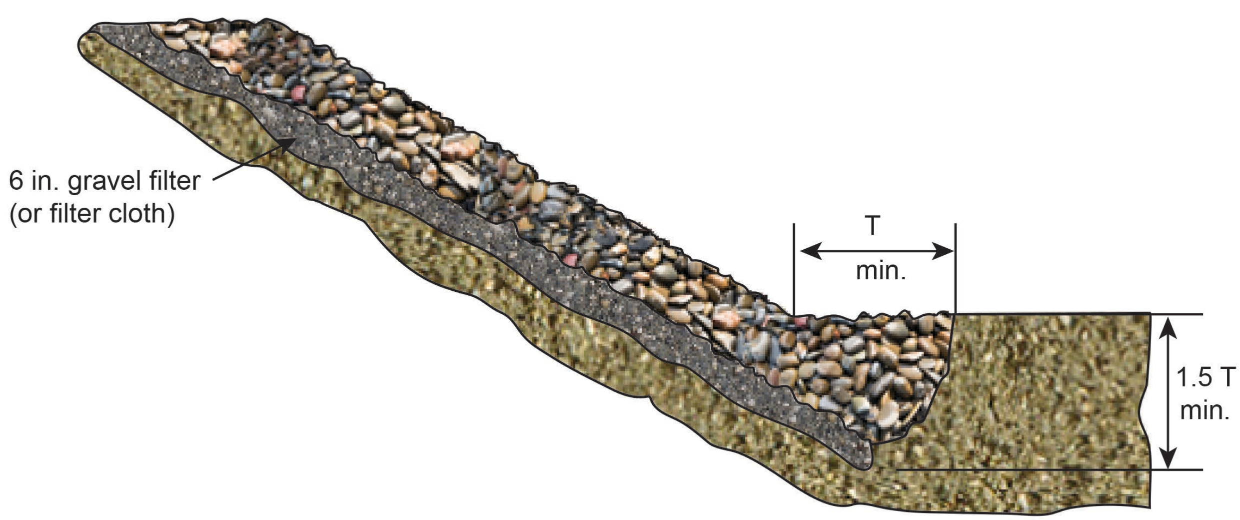


Figure 131. Riprap on channel side slope.

Grouted Riprap

Grouted riprap consists of a stone bed with voids filled with grout or concrete to form a veneer of cementitious-bonded aggregate armor. Grouting riprap is an option if the required stone sizes are not available for a conventional riprap installation or in areas of high shear stress or nonuniform flow conditions, such as at transitions in channel shape or at energy dissipation structures.

Grouted riprap should consist of stone with less than 5% passing a 2-inch sieve and have qualities similar to nongrouted riprap. The median rock size should not exceed 0.67 times the blanket thickness. Figure 132 illustrates the relationship between design velocity and recommended riprap blanket thickness for grouted installations.

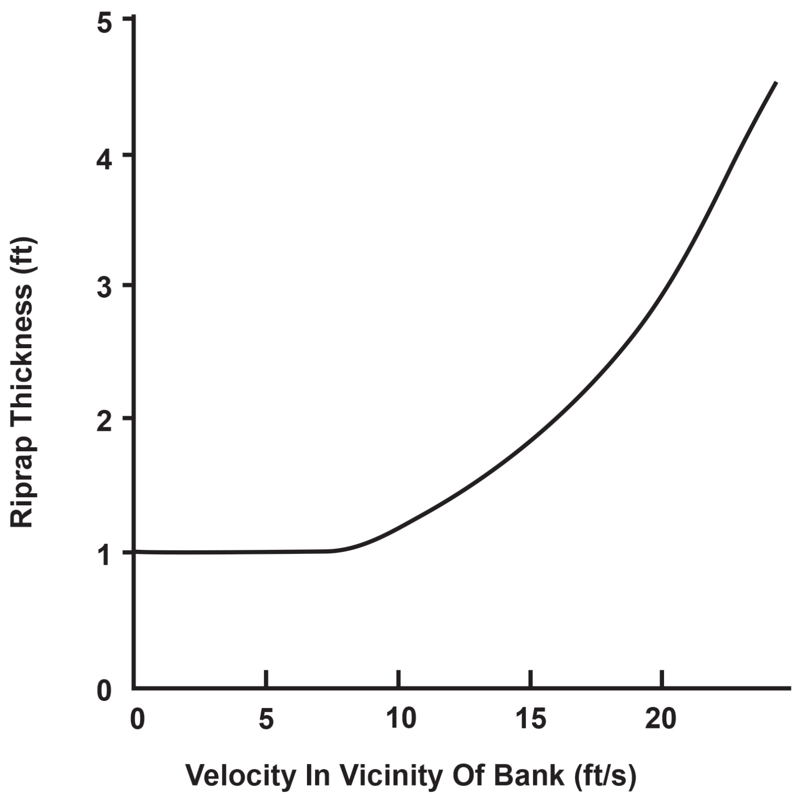


Figure 132. Grouted riprap thickness as a function of flow velocity (UDOT 2004).

Grouted riprap is a rigid revetment and will not conform to changes in the bank geometry due to settlement. Special attention should be placed on edge treatment, foundation design, and mechanisms for hydrostatic pressure relief to avoid failure from undermining or lining breakup. To form a firm foundation, the bank should be free of all trees and debris and tamped or lightly compacted to provide sufficient bearing capacity to support the dry weight of the revetment alone or the submerged weight of the revetment plus the weight of the water in the wedge above the revetment for design conditions, whichever is greater. Pressure relief should be provided using weep holes that extend through the grout surface to the interface with the gravel underdrain layer. Recommended edge treatments and weep holes are illustrated in Figure 133.

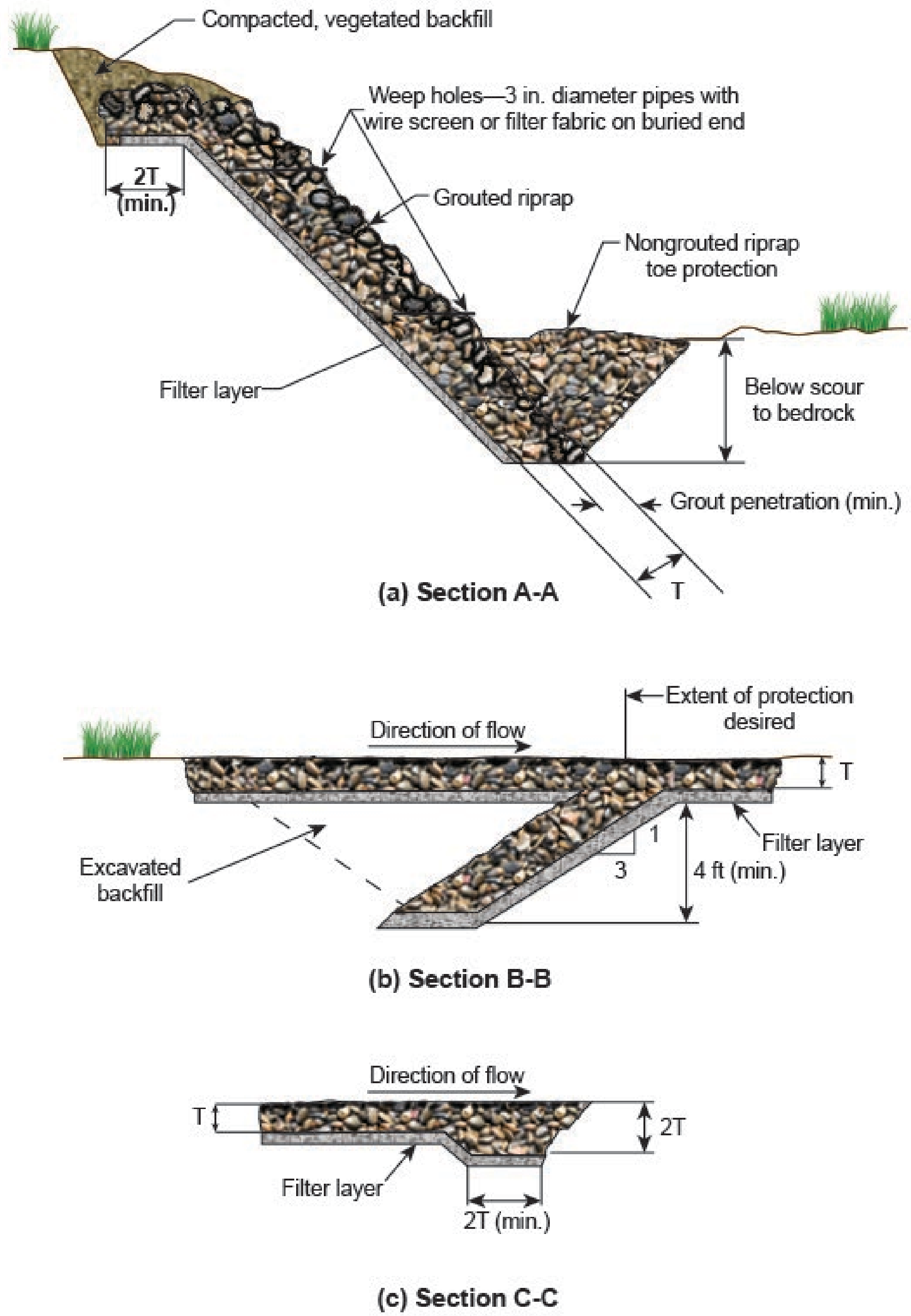


Figure 133. Grouted riprap cross section (top), upstream end treatment (middle), and downstream end treatment (bottom).

Construction Guidelines

- The subgrade for the filter and riprap should be prepared to the final grades. Any fill required in the subgrade should be compacted to a density approximately equal to that of the surrounding undisturbed material.
- Geosynthetic fabric should be protected from punching, cutting, or tearing. Any damage other than an occasional small hole should be repaired by placing another piece of cloth over the damaged part or by completely replacing the cloth. All overlaps whether for repairs or for joining two pieces of cloth should be a minimum of 1 foot.
- Riprap stone should be placed by equipment and constructed to the full course thickness in one operation to avoid displacement of underlying materials.
- The stone for riprap should be delivered and placed in a manner that ensures it is reasonably homogenous with the smaller stones and spalls filling the voids between the larger stones.
- Take care when placing riprap to prevent damage to the filter fabric. A combination of hand or equipment placement may be necessary depending on size and location of the riprap.
- Grout strength of 2,000 to 2,500 psi is recommended for grouted riprap installations.
- Underwater placement of grouted riprap should be avoided.
- Rock should be wet immediately before commencing grouting operations for grouted riprap installation.
- Complete construction of the riprap protection before allowing erosive flows to pass over the protected surface.

Maintenance

Once riprap has been installed, the maintenance needs are relatively low. Inspect after heavy storms and high flows for scouring and any dislodged stones. Repair all damage promptly.

Additional Resources

CASQA (California Stormwater Quality Association). 2004. *California Stormwater Best Management Practices Handbook: New Development and Redevelopment*. Menlo Park, CA. *https://www.casqa.org*

FHWA (US Department of Transportation Federal Highway Administration). 2005. *Design of Roadside Channels with Flexible Linings*. Hydraulic Engineering Circular-15 (HEC-15). Publication No. FHWA-NHI-05-114. *http://www.fhwa.dot.gov/engineering/hydraulics/library_arc.cfm?pub_number=15&id=32*

Hazra and ODOT (Hazra Engineering Company and Oregon Department of Transportation, Geo/Environmental Section). 2005. *ODOT Erosion Control Manual: Guidelines for Developing and Implementing Erosion and Sediment Controls.*

ITD (Idaho Transportation Department). 2014. *Best Management Practices.* Boise, ID: ITD.

UDOT (Utah Department of Transportation). 2004. *UDOT Manual of Instruction—Roadway Drainage, Bank Protection.* *http://www.udot.utah.gov/main/uconowner.gf?n=200403161050503*

BMP 57: Pipe Slope Drain

Description

Steep slopes are more susceptible to erosion, which contributes sediment to storm water runoff. A pipe slope drain carries concentrated runoff down a steep slope that is at high risk for erosion or has already been damaged by erosion. The drain may be used to both convey off-site runoff around a disturbed portion of the site or to drain saturated slopes with the potential for soil slides. Pipe slope drains can be temporary or permanent depending on need, method of installation, and material used (Figure 134).

Figure 134. Pipe slope drain (Colorado UDFCD 2010).

Pipe slope drains are commonly made of flexible tubing or rigid pipe. Temporary slope drains may be composed of plastic sheeting, stone gutters, fiber mats, riprap, concrete ditches, asphalt ditches, or half-round pipe. Outlet protection (BMP 35) should be provided to dissipate energy and reduce erosion potential at the drain outlet.

Primary BMP Functions and Controls

☒ Construction	☒ Permanent
☒ Erosion Control	☐ Sediment Control
☐ Source Control	☐ Flood Control
☐ Filtration	☐ Infiltration

Typical Effectiveness for Targeted Pollutants

◐	Sediment
○	Nitrogen
○	Phosphorus
○	Metals
○	Bacteria
○	Hydrocarbons
○	Litter

Other BMP Considerations

Relative Cost	$
Maintenance Requirements	Low
Ease of Installation	Easy
Freeze/Thaw Resistance	Good
Max. Tributary Drainage Area	10 acres
Max. Upstream Slope	5%
NRCS Soil Group	ABCD
Min. Ground Water Separation	2 feet
Min. Bedrock Separation	5 feet

Applicability

Pipe slope drains are used whenever it is necessary to convey concentrated water down a slope without causing erosion. They are especially effective before a slope has been stabilized or before permanent drainage structures have been established. Pipe slope drains should be used with other BMPs, such as sediment traps (BMP 66) or vegetative buffer strips (BMP 11). Temporary pipe slope drains made of flexible tubing or conduit may be installed before construction of permanent drainage structures.

Pipe slope drains are appropriate in the following general locations:

- From the top of cut or fill slopes where water can accumulate.
- Where earth dikes or other diversion measures have been used to concentrate flows.

- On any slope where concentrated runoff may cause gullies, channel erosion, or saturation of slide-prone soils.
- To drain water collected from aquifers exposed on cut slopes and convey it to the base of the slope.
- On slopes with a gradient of 2H:1V or greater and with at least 10 feet of vertical relief.
- As an emergency spillway for a sediment basin.
- For drainage of new catch basins before installing permanent pipes.
- Diverting roof runoff and small streams from the construction site.
- Large pipe drains may be used to divert stream crossings for culvert replacement projects.

Limitations

- Pipe slope drains are generally not suitable for drainage areas greater than 10 acres; design should be based on engineering hydrologic and hydraulic analysis.
- Severe erosion may result when slope drains fail by overtopping, piping, or pipe separation.
- During large storms, pipe slope drains may become clogged causing slope drain failure and significantly increasing erosion potential.

Design Basis

The following are general guidelines for design and selection of pipe slope drains:

- At a minimum, pipe slope drains should be designed to convey a 2-year, 24-hour storm event, or as required by the local jurisdictions.
- Slope drains should be placed perpendicular to slope contours.
- When possible, drain slope should be a minimum of 3%.
- Outlet protection should be provided to prevent erosion downstream (BMP 35: Energy Dissipation Devices).
- Soil around and under the pipe entrance should be compacted using appropriate methods in 4- to 8-inch lifts to the top of the slope drain to channel runoff to the pipe and prevent piping failure around the inlet.
- Place filter cloth under the inlet and extend it 3 to 5 feet in front of the inlet.
- Securely stake the pipe slope drain to the ground at intervals of 10 feet or less, using grommets provided for this purpose.

Pipe Sizing

As a guide, temporary pipe slope drains should not be sized smaller than shown in Table 31. Drainage areas exceeding 10 acres should be designed by a licensed engineer.

Table 31. Maximum drainage area versus minimum pipe diameter (CASQA 2015).

Maximum Drainage Area (acres)	Minimum Pipe Diameter (inches)
1	12
3	18
5	21
7	24
10	30

Spacing

Space temporary slope drains at a longitudinal interval of 500 feet on a 2% grade, 200 feet on a 4% grade, and as dictated by field conditions on a grade of 5% or greater.

Materials

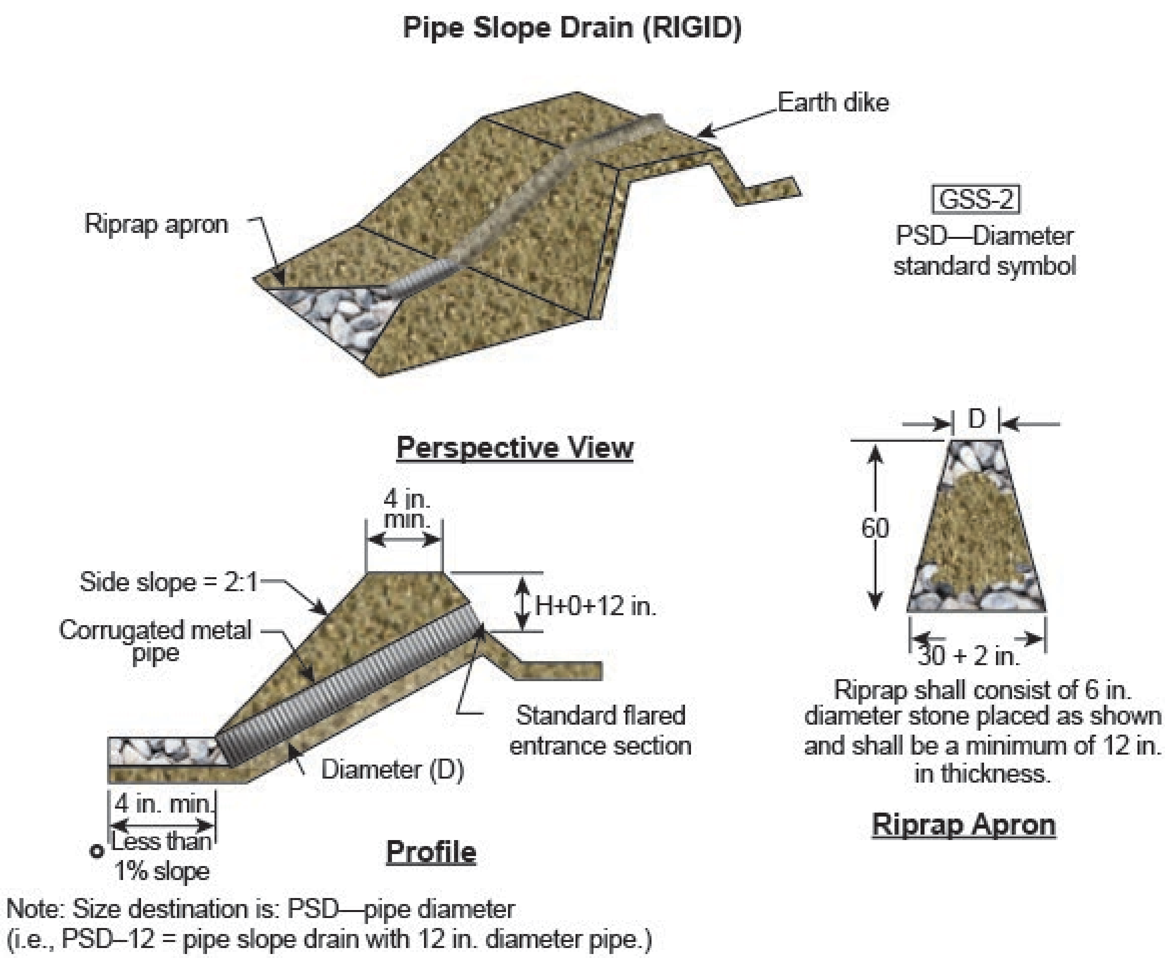
Pipe may be any heavy-duty, flexible tubing corrugated plastic pipe, corrugated metal pipe, bituminous fiber pipe, or specially designed flexible tubing. Perforated pipe shall not be used.

A standard flared end section secured with a watertight fitting should be used for the inlet. Extension collars should be 1-foot long segments of corrugated pipe. All fittings should be watertight.

Construction Guidelines

- Properly install the inlet section of the drain to collect the flow into the drain. It might be necessary to construct cross berms to direct flow into the inlet.
- Place the pipe slope drain on undisturbed or well-compacted soil.
- Ensure all slope drain sections are securely fastened together and have watertight fittings.
- Extend the pipe beyond the toe of the slope and discharge at a nonerosive velocity into a stabilized area, sedimentation trap, or pond. Use rock outlet protection or other energy dissipation devices if necessary.
- Immediately stabilize all areas disturbed by installation or removal of the pipe slope drain.

Figure 135 and Figure 136 provide the construction specifications for pipe slope drains.

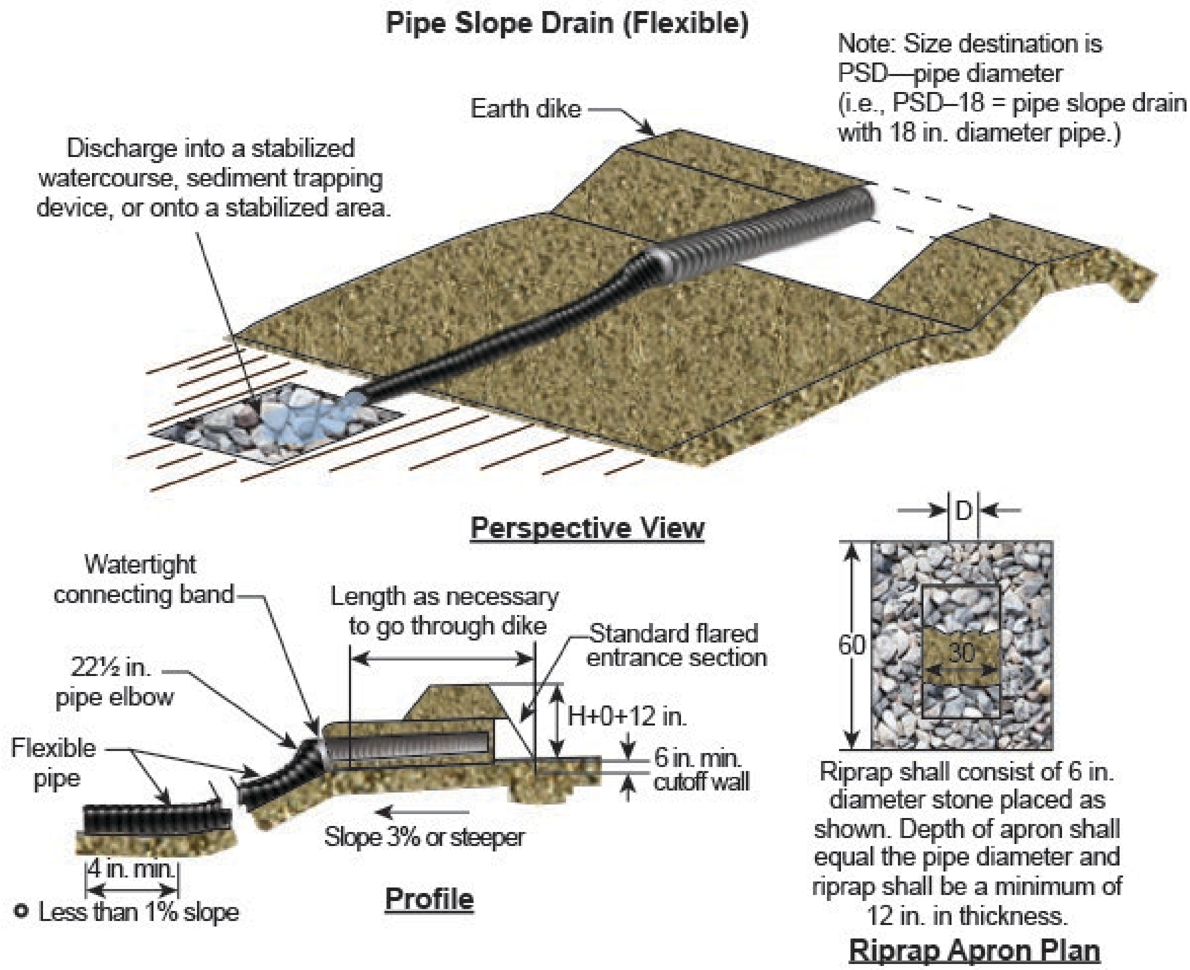


Construction Specifications

1. The pipe slope drain shall have a slope of 3% or steeper.
2. Top of the earth dike over the inlet pipe and all dikes carrying water to the pipe shall be at least 1 ft higher than the top of the pipe.
3. Add 0.3 ft to dike height for settlement.
4. Soil around and under the slope pipe shall be hand tamped in 4 in. lifts.
5. The pipe shall be corrugated metal pipe with watertight 12 in. connecting bands or flange connections.
6. Riprap to be 4–8 in. in a layer at least 8 in. in thickness and pressed into the soil.
7. Periodic inspection and required maintenance must be provided after each rain event.

Maximum drainage area 5 acres

Figure 135. Stabilization structure on graded profile of pipe slope drainage.



- Drainage area must not exceed 5 acres.

Construction Specifications

1. The inlet pipe shall have a slope of 3% or steeper.
2. The top of the earth dike over the inlet pipe and those dikes carrying water to the pipe shall be at least 1 in. higher at all points than the top of the inlet pipe.
3. The inlet pipe shall be corrugated metal pipe with watertight connecting bands.
4. The flexable tubing shall be the same diameter as the inlet pipe and shall be constructed of a durable material with hold-down grommets spaced 10 ft on centers.
5. The flexible tubing shall be securely fastened to the corrugated metal pipe with metal strapping or watertight connecting collars.
6. The flexable tubing shall be securely anchored to the slope by staking at the grommets provided.
7. A riprap apron shall be provided at the outlet. This shall consist of 6 in. diameter stone placed as shown on the above drawing.
8. The soil around and under the inlet pipe and entrance section shall be hand tamped in 4 in. lifts to the top of the earth dike.
9. Follow-up inspection and any needed maintenance shall be performed after each rain event.

Figure 136. Graded stabilization structure for flexible pipe slope drain.

Maintenance

- Inspect temporary slope drain regularly during large storm events and after every storm. Perform necessary repairs immediately. Inspect permanent slope drains periodically and make repairs as needed.
- Ensure water is not bypassing the inlet or undercutting the inlet or pipe. If necessary, install headwalls or sandbags to prevent bypass flow.
- If water is ponding in inappropriate areas, such as staging areas or vehicle traffic lanes, relocate pipe slope drains or divert flow.
- Check for erosion at the outlet point and check the pipe for breaks or clogs. Install additional outlet protection if needed, and immediately repair the breaks and clean any clogs.
- Do not allow construction traffic to cross the pipe slope drain and do not place any material on top of the drain.
- Ensure pipe anchors are firmly in place. Install additional anchors if pipe movement is detected.
- Ensure a temporary slope drain remains in place until the slope is completely stabilized.

Additional Resources

CASQA California Stormwater Quality Association. 2004. *California Stormwater Best Management Practices Handbook: New Development and Redevelopment*. Menlo Park, CA. *https://www.casqa.org*

Colorado UDFCD (Colorado Urban Drainage and Flood Control District). 2010. *Urban Storm Drainage Criteria Manual, Volume 3 Best Management Practices*. Denver, CO. *http://udfcd.org/wp-content/uploads/2014/07/Title-Page.pdf*

Washington State Department of Ecology. 2012. *Stormwater Management Manual for Western Washington*. Lacey, WA. Publ. 12-10-030. *http://www.ecy.wa.gov/programs/wq/stormwater/manual.html*

BMP 58: Slope Roughening

Description

Exposed disturbed soil is highly susceptible to wind and water erosion. Slope roughening by tracking, scarifying, imprinting, or tilling a disturbed area roughens the soil surface to create horizontal grooves, furrows, depressions, crimped mulch, or small steps running parallel to the contour (Figure 137).

Figure 137. Exposed soil temporarily stabilized by roughening the surface (*North Idaho Hydroseeding*).

Slope roughening reduces the speed of runoff, increases infiltration rates, and traps sediment, as well as establishes vegetative cover by providing stable and level areas where seedlings can take hold and grow. Leaving the slope in a roughened condition controls erosion and provides suitable rooting areas for plant seedlings better than a finely graded slope.

Primary BMP Functions and Controls

☒ Construction	☐ Permanent
☒ Erosion Control	☐ Sediment Control
☐ Source Control	☐ Flood Control
☐ Filtration	☐ Infiltration

Typical Effectiveness for Targeted Pollutants

◖	Sediment
○	Nitrogen
○	Phosphorus
○	Metals
○	Bacteria
○	Hydrocarbons
○	Litter

Other BMP Considerations

Relative Cost	$
Maintenance Requirements	Low
Ease of Installation	Easy
Freeze/Thaw Resistance	Good
Max. Tributary Drainage Area	1 acre
Max. Upstream Slope	20%
NRCS Soil Group	BCD
Min. Ground Water Separation	5 feet
Min. Bedrock Separation	3 feet

Applicability

Slope roughening is simple, inexpensive, and immediate short-term erosion control for bare soil where vegetative cover is not planned or not yet established. The practice is appropriate for all slopes including altered slopes, temporary stockpiles, sediment basins, berms, and swales.

Applied with appropriate machinery, this measure is used before permanent seeding/planting (BMP 32: Landscaping). All slopes steeper than 3:1 and greater than 5 feet in vertical height require roughening and may require terracing, grooving, or furrowing before seeding (BMP 59: Gradient Terracing).

Limitations

Site and soil conditions may limit the use of slope roughening. This BMP is limited to slopes in medium to highly cohesive soils or in soft rock that can be excavated without ripping. The method is not applicable in NRCS Type A soils such as sands, moraines, and other depositional soils. Slope angle on the site should be gentle enough to permit access to heavy equipment.

This BMP is not a stand-alone measure and should be implemented with other BMPs, such as mulching (BMP 52), perimeter controls (BMP 64 or BMP 65), or sediment basins (BMP 66). Consider the type of BMP that follows soil roughening as some BMPs are not designed for installation over roughened surfaces. For example, do not use erosion control matting (BMP 54) with soil roughening because the *bridging* effect suspends the blanket above the seed bed.

Slope roughening is a temporary measure because the serrations have limited effectiveness in more than a gentle rain. If the roughening is washed away in a heavy storm, the surface must be reroughened and reseeded.

Tracking with heavy equipment will compact soils, which is not desirable in areas that will be revegetated. Scarifying, tilling, or ripping (BMP 46: Minimize Soil Compaction) are better surface roughening techniques in locations where revegetation is planned.

Design Basis

Different methods can be used to roughen the slope surface, including stair-step grading, grooving (using disks, spring harrows, or teeth on a front-end loader), contour furrowing, and tracking (driving a crawler tractor up and down a slope, leaving the cleat imprints perpendicular to the slope). Figure 138 shows tracking and contour furrows. Selecting an appropriate method depends on the slope's grade, mowing requirements after vegetative cover is established, whether the slope was formed by cutting or filling, and type of equipment available.

Slopes Steeper than 2:1

Any slope steeper than 2:1 should be terraced or stair-step graded, with benches wide enough to retain sediment eroded from the slope above (BMP 59: Gradient Terracing).

Slopes between 3:1 and 2:1

Cut slopes with a gradient steeper than 3:1 but flatter than 2:1 should be stair-step graded or groove cut (Figure 139). Stair-step grading works well with soils containing large amounts of small rock. Each step catches material discarded from above and provides a level site where vegetation can grow. Stairs should be wide enough to work with standard earth-moving equipment. Any equipment that can be safely operated on the slope, including those described above, can perform grooving. Grooves should not be less than 3 inches deep or more than 16 inches apart.

Fill slopes with a gradient steeper than 3:1 but flatter than 2:1 should consist of properly compacted lifts no greater than 8 inches deep. The slope face should consist of loose, uncompacted fill 4 to 6 inches deep that can be left rough or can be grooved as described above, if necessary.

Avoid excessive compacting of the soil surface, especially when tracking, as soil compaction inhibits vegetation growth and causes higher runoff speed. Limit roughening with tracked machinery on soils that do not compact easily, and avoid tracking on clay soils.

Slopes Flatter than 3:1

Any cut or filled slope that will be mowed should have a gradient flatter than 3:1. Such a slope can be roughened with shallow grooves parallel to the slope contour by using normal tilling. Grooves should be close together (less than 10 inches and not less than 1 inch deep).

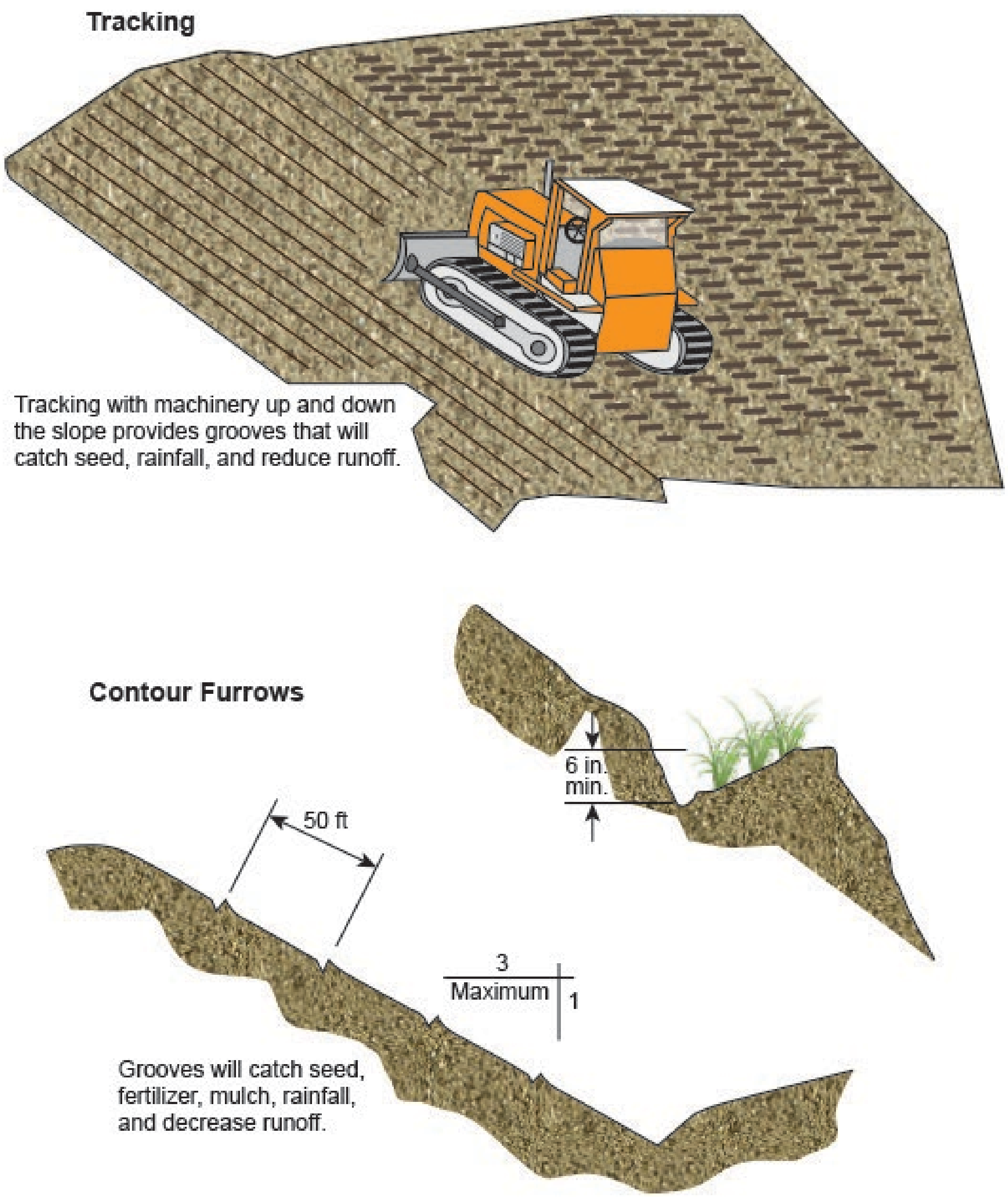


Figure 138. Contour furrow diagram (King County 2009).

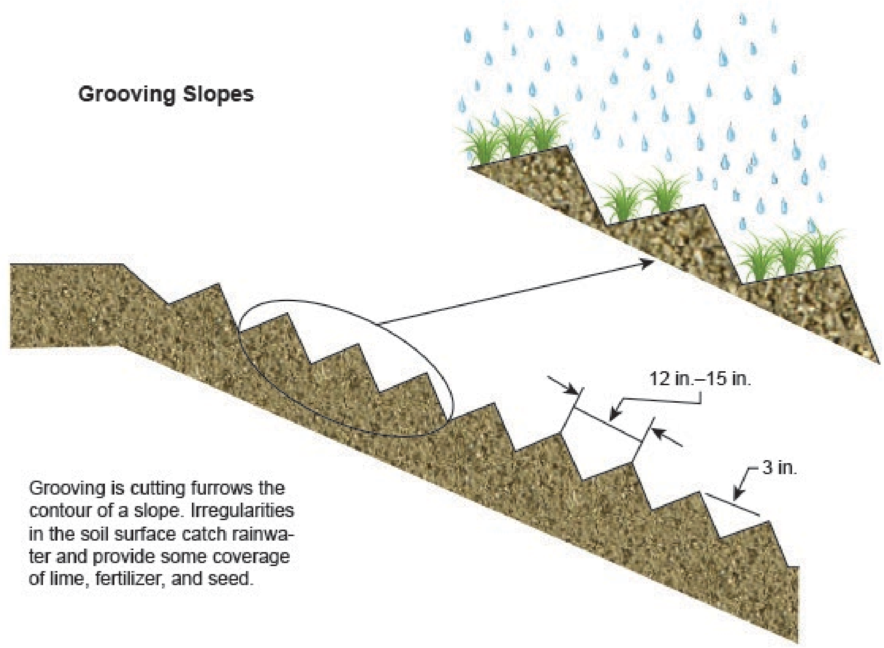


Figure 139. Grooving slope diagram.

Construction Guidelines

While fill slopes can be constructed with a roughened surface, cut slopes that have been smooth graded must be roughened as a subsequent operation. Before slope roughening, BMPs such as seeding, sodding, planting (BMP 32: Landscaping), and temporary mulching (BMP 52: Mulching) may be used to stabilize an area. For steeper slopes and slopes that will be left roughened for longer periods of time, a combination of surface roughening and vegetative stabilization (BMP 8: Vegetation Restoration) can be used.

Timing of Work

Surface roughening should be applied immediately after grading activities have ceased (temporarily or permanently) in an area. To slow erosion, complete slope or surface roughening as soon as possible after the vegetation has been removed from the slope. The roughened areas should be seeded quickly, preferably within 7 days after serration/roughening if weather conditions or water availability permits. For material that ravels or sloughs readily, delay the revegetation effort until at least 30 days after slope serration (BMP 36: Construction Timing).

Equipment

Various types of heavy equipment may be successfully used for slope roughening:

- A front-end loader equipped with disks, harrows, or teeth can make grooves across the slope.
- Driving a crawler tractor up and down the slope will make cleat imprints perpendicular to the slope.
- A dozer, equipped with a special blade containing a series of square grooves and positioned at the same angle as the cut, can serrate the slope along the contours.

Methods

- Minimally compact fill slopes constructed with highly erodible soils or soils containing high clay content before establishing a roughened surface. Avoid excessive compaction, which causes reduced infiltration rates and suppresses vegetation rooting.
- Roughen soils with sand textural components with tracked machinery as these soils are less likely to become unduly compacted.
- Make the grooves or depressions approximately horizontal (or parallel the slope toe if its profile grade is less than 2%).
- Excavate each series of grooves in the opposite direction from the preceding series to minimize buildup of loose material at the ends of the steps or cuts.
- Remove loose material collected at the ends of steps and blend the ends into the natural ground surface.
- If rocks are encountered that are too hard to rip, blend the grooves into the rock.
- For soil roughening adjacent to roadways, remove materials that fall into the ditch line or roadway along with rock fragments larger than one-third the shelf width.
- Construct a slope bench at the bottom of the slope face.

Maintenance

- Inspect the slopes periodically for damage from surface runoff and seepage, and inspect after each runoff-producing storm.
- Prohibit vehicles and equipment from driving over roughened slopes. Tire tracks may smooth out the roughening and increase soil compaction.
- Repair damage caused by construction-related activities as soon as possible.
- If rills appear (small watercourses with steep sides and usually less than 4 inches deep), fill immediately and promptly regrade the slope so it is adequately protected.

Additional Resources

CASQA California Stormwater Quality Association. 2004. *California Stormwater Best Management Practices Handbook: New Development and Redevelopment*. Menlo Park, CA. *https://www.casqa.org*

Colorado UDFCD (Colorado Urban Drainage and Flood Control District). 2010. *Urban Storm Drainage Criteria Manual, Volume 3 Best Management Practices*. Denver, CO. *http://udfcd.org/wp-content/uploads/2014/07/Title-Page.pdf*

EPA (US Environmental Protection Agency). 2014. *Soil Roughening.* Water: Best Management Practices. *http://water.epa.gov/polwaste/npdes/swbmp/Soil-Roughening.cfm*

ITD (Idaho Transportation Department). 2014. *Best Management Practices.* Boise, ID: ITD.

King County Department of Natural Resources and Parks. (2009). *King County Washington Surface Water Design Manual*, King County, WA.

Washington State Department of Ecology. 2012. *Stormwater Management Manual for Western Washington*. Lacey, WA. Publ. 12-10-030. *http://www.ecy.wa.gov/programs/wq/stormwater/manual.html*

BMP 59: Gradient Terracing

Description

Steep slopes have higher potential for eroding and contributing sediment to storm water runoff. Gradient terracing is the practice of grading a steep slope into a series of relatively large, flat sections separated by terraces placed at regular intervals (Figure 140). The terraces shorten the flow lengths of storm water runoff, reduce its velocity, and prevent the formation of rills and gullies. Gradient terraces further reduce erosion damage by capturing surface runoff and directing it to a stable outlet at a nonerosive velocity.

Figure 140. Terraces incorporated into the grading plan (ITD 2014).

Gradient terracing practices involve displacing larger amounts of soil than slope roughening (BMP 58) and features larger interval placement between steps (up to 20 feet wide for terracing versus +/- 1 foot for soil roughening).

Primary BMP Functions and Controls

☐ Construction ☒ Permanent
☒ Erosion Control ☒ Sediment Control
☐ Source Control ☒ Flood Control
☐ Filtration ☐ Infiltration

Typical Effectiveness for Targeted Pollutants

◖ Sediment
○ Nitrogen
○ Phosphorus
○ Metals
○ Bacteria
○ Hydrocarbons
○ Litter

Other BMP Considerations

Relative Cost	$$
Maintenance Requirements	Medium
Ease of Installation	Medium
Freeze/Thaw Resistance	Good
Max. Tributary Drainage Area	10 acres
Max. Upstream Slope	5%
NRCS Soil Group	BCD
Min. Ground Water Separation	8 feet
Min. Bedrock Separation	6 feet

Applicability

Gradient terraces are generally used as a permanent control and are suitable for use on long, steep (4V:1H or steeper) slopes with an existing erosion problem or where water erosion may become an issue.

Limitations

Gradient terraces should not be constructed in areas with sandy or rocky soils, noncohesive or highly erodible soils, or decomposing rock including moraines and other depositional materials. Do not use terraces where a rockfall potential exists or where soft-rock laminations in thin layers are oriented so that the strike is approximately parallel to the slope face and the dip approximates the staked slope line.

Terraces and benches may cause sloughing if too much water infiltrates the soil; these are effective only where suitable runoff outlets will be available.

Gradient terraces may significantly increase cut and fill costs.

Design Basis

Terrace type, number, and spacing depend on the slope, slope length, and other factors. Gradient terraces should be designed and installed according to a professionally prepared grading plan based on a site-specific topographic survey. In general, the following guidelines should be addressed when laying out gradient terraces (Figure 141 and Figure 142):

- Begin the upper most terrace immediately below the top of the cut or fill slope with terraces continuing to the toe of the slope.
- Slopes of 2:1 or steeper may require a stair-step approach with terraces, or benches, at sufficient width to retain sediment from the slope above.
- Outlets should direct the runoff from the terrace system to a point where the outflow will not cause erosion or other damage. Acceptable outlets include grassed waterways, vegetated areas, or tile outlets.
- The design elevation of the water surface of the terrace should not be lower than the junction of the outlet area when both are operating at design flow.
- The terrace should have enough capacity to handle the peak runoff expected from a 2-year, 24-hour design storm without overtopping.
- The maximum vertical spacing of gradient terraces can be determined by the following method (Washington State Department of Ecology 2012) (Equation 42):

$$VI = 0.8s + y$$

Equation 42. Maximum vertical spacing.

Where

VI = vertical interval in feet

s = land rise per 100 feet, expressed in feet

y = soil and cover variable

Values of *y* range from 1.0–4.0 and are influenced by soil erodibility and cover practices. The lower values are applicable to erosive soils where little to no residue is left on the surface. The higher values apply only to erosion-resistant soils where a large amount of residue (1.5 tons of straw/acre equivalent) is on the surface.

- Vertical spacing may be increased by as much as 0.5 feet or 10%, whichever is greater, to provide better alignment or location, avoid obstacles, adjust for equipment size, or reach a satisfactory outlet. The drainage area above the terrace should not exceed the area that would be drained by a terrace with normal spacing.
- Terraces can be constructed with linings to carry water to the outlet and can be used with a dike or similar measure above the terrace to divert run-on from reaching the terraced slope.
- If permanent, establish vegetation on the terraces as soon as practicable (BMP 31: Topsoiling and BMP 32: Landscaping).
- If the terraces are a temporary measure, properly vegetate the slope when it is constructed to final grade.
- Wide terraces with large runoff area can be used with pipe slope drains (BMP 57) to control runoff.

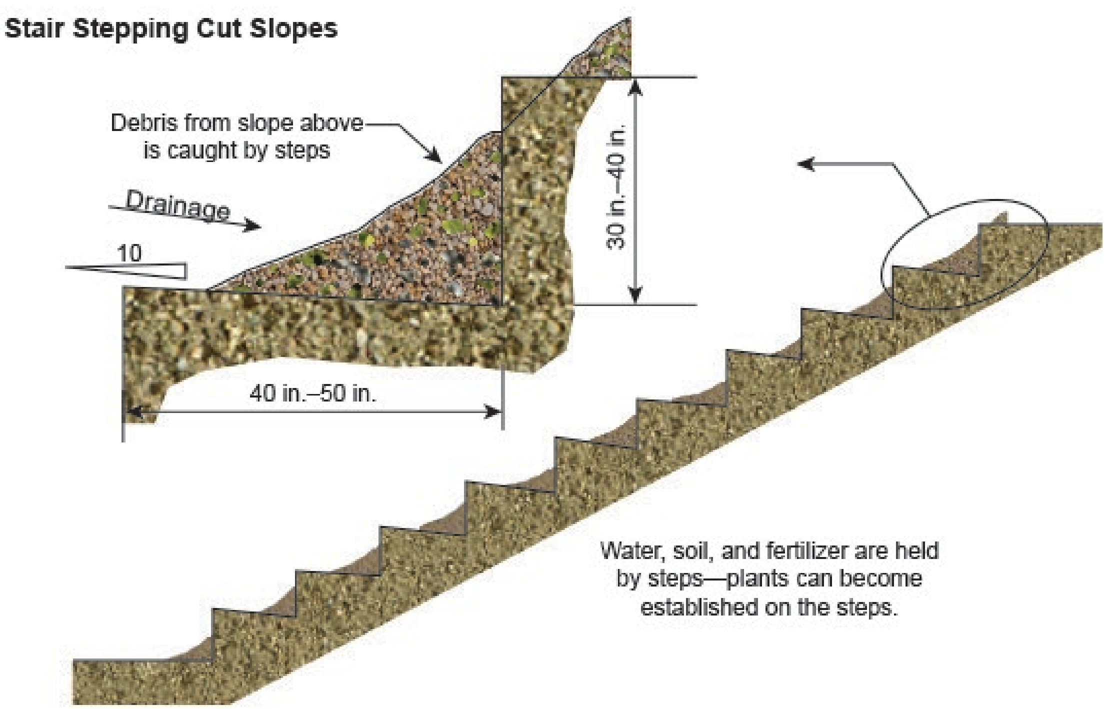


Figure 141. Stair-stepping slopes diagram.

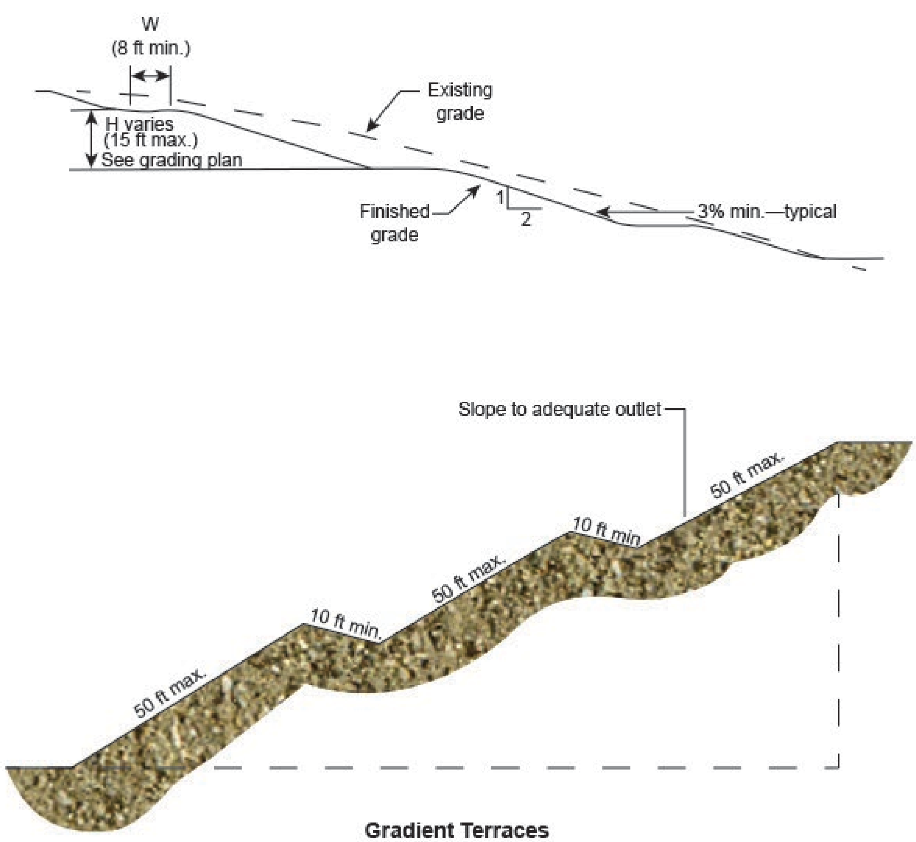


Figure 142. Graded terracing.

Construction Guidelines

When constructing gradient terraces, follow the criteria below:

- Complete construction of gradient terraces using equipment that is capable of meeting the specification established in the construction plans.
- Drain gradient terraces to a stabilized area or appropriate BMP.
- Remove loose material collecting at terrace outlets and blend terrace ends back into the natural surface.

Maintenance

- Inspect the gradient terraces regularly during project construction and inspect them after any major storm.
- If used as a permanent BMP, inspect at least once a year after project completion and major storms.
- Evaluate whether the terrace is functioning effectively as a runoff collection and diversion device, and note whether other stabilization measures (including vegetation) are performing effectively.
- Take prompt action as needed to ensure proper drainage and slope stability.

Additional Resources

Colorado UDFCD (Colorado Urban Drainage and Flood Control District). 2010. *Urban Storm Drainage Criteria Manual, Volume 3 Best Management Practices*. Denver, CO. *http://udfcd.org/wp-content/uploads/2014/07/Title-Page.pdf*

EPA (US Environmental Protection Agency). 2016. *Gradient Terraces*. Water: Best Management Practices. *http://water.epa.gov/polwaste/npdes/swbmp/Gradient-Terraces.cfm*

ITD (Idaho Transportation Department). 2014. *Best Management Practices.* Boise, ID: ITD.

Washington State Department of Ecology. 2012. *Stormwater Management Manual for Western Washington*. Lacey, WA. Publ. 12-10-030. *http://www.ecy.wa.gov/programs/wq/stormwater/manual.html*

BMP 60: Check Dams

Description

Check dams are used to capture sediment, reduce or prevent excessive bank and bottom erosion, and reduce runoff velocity. These small dams are constructed across open channels, swales, or drainageways. Typically constructed out of rock and gravel, logs, treated lumber, sandbags, or manufactured barriers, check dams may be temporary or permanent (Figure 143).

Figure 143. A rock check dam reduces runoff velocity.

Applicability

Check dams are often used in natural or constructed channels or swales where adequate vegetation cannot be quickly established. Temporary check dams are used during construction to slow runoff velocities, capture sediment, and prevent erosion. Permanent check dams can reduce runoff velocities and reduce or prevent erosion in open channels, swales, and drainage ways. Permanent check dams can be used with biofiltration swales (BMP 9) to reduce velocities and enhance filtration.

Limitations

Never place check dams in live flowing streams unless approved by appropriate local, state, and/or federal authorities. Check dams should not be used as stand-alone trapping devices.

Design Basis

- Drainage area to the check dam should be between 1 and 4 acres.
- Check dams should be spaced so that the toe of each upstream dam is never higher than the top of the next downstream check dam. Excavating a sump immediately upstream from the check dam may improve its effectiveness.

Primary BMP Functions and Controls

☒ Construction	☒ Permanent
☐ Erosion Control	☒ Sediment Control
☐ Source Control	☒ Flood Control
☐ Filtration	☐ Infiltration

Typical Effectiveness for Targeted Pollutants

●	Sediment
○	Phosphorus
◖	Metals
○	Bacteria
◖	Hydrocarbons
○	Litter

Other BMP Considerations

Relative Cost	$$
Maintenance Requirements	Medium
Ease of Installation	Medium
Freeze/Thaw Resistance	Good
Max. Tributary Drainage Area	4 acres
Max. Slope	50%
NRCS Soil Group	ABCD
Min. Ground Water Separation	N/A
Min. Bedrock Separation	2 feet

- Maximum toe to crest height should be 2 feet. The center of the dam should be at least 6 inches lower than either edge to form a weir for the outfall.
- The check dam should be as much as 20 inches wider than the banks of the channel to prevent undercutting as overflow water reenters the channel.
- When installing a series of check dams in a channel, provide outlet stabilization below the lowest check dam (where the risk of erosion is greatest) and consider the use of channel linings or protection such as matting or riprap where significant erosion or prolonged submergence may occur.
- Materials (Figure 144 and Figure 145):
  - Stone—2 to 16 inches in diameter
  - Logs—6 to 8 inches in diameter
  - Sandbags filled with pea gravel
  - Filter fabric meeting the standard specifications (BMP 65: Silt Fence)
- Logs should be driven into the ground a minimum of 28 inches.

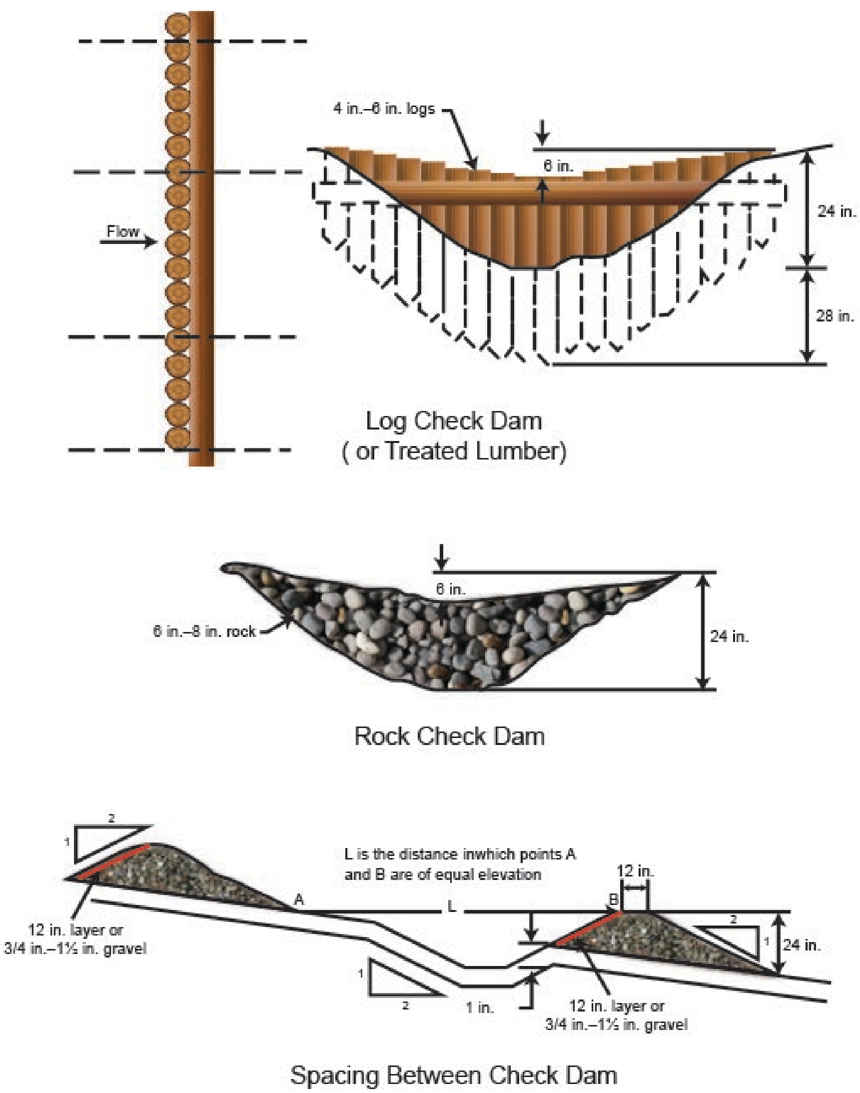


Figure 144. Log and rock check dams.

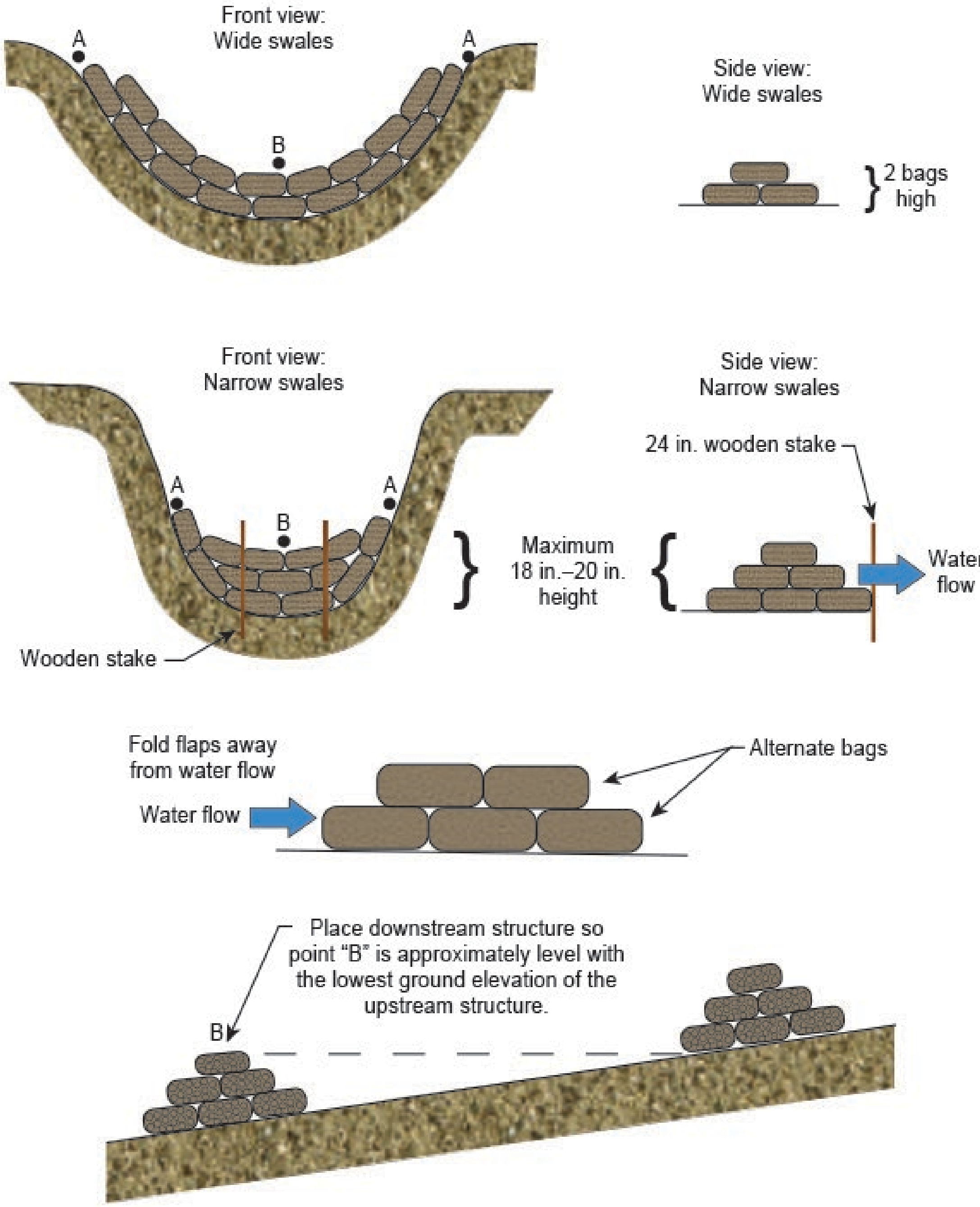


Figure 145. Bag check dam.

Construction Guidelines

Rock check dams—Place the stones on filter fabric either by hand or by using appropriate machinery; do not dump stones in place. Keep the side slopes 2:1 or flatter. Line the upstream side of the dam with a layer of 3/4 to 1-1/2-inch gravel; 12 inches deep is an option for additional channel protection.

Log check dams—Firmly embedded the logs in the ground. Filter cloth may be attached to the upstream side of the dam to retard flow and trap additional sediment. If a filter cloth is used, securely staple it to the top of the dam and adequately anchor in the streambed.

Bag check dams—Ensure all bags are securely sealed. Place the bags by hand or use appropriate machinery to place them in an interlocking pattern.

Manufactured barriers—An array of three-dimensional manufactured barriers is also available: triangular and burrito-shaped, prefilled and fillable on site, reusable and disposable, and temporary and permanent. Triangular silt dikes are temporary, reusable barriers consisting of a triangular urethane foam core covered by permeable, woven geotextile fabric. Usually from 16 to 20 inches wide at the base and 8 to 10 inches high, a silt dike is used at the toe of a slope to contain sediment from runoff or perpendicular to the flow of water in a drainage ditch.

The flexibility of the materials in manufactured barriers allows conformity to many channel configurations:

- Fasten to soil with staples or to rock and pavement with adhesives.
- Build temporary sediment ponds, diversion ditches, concrete wash-out facilities, curbing, water bars, level spreaders, and berms.

Riprap may be necessary on the downstream side of the dam to protect the channel from scour.

Maintenance

- Inspect the check dams regularly and after every runoff-producing storm to ensure structural integrity. Repair as needed to ensure the BMP is in good working order.
- Remove accumulated debris, trash, and leaves. Remove sediment from behind the dam when the depth reaches of one-half the original height of the dam (measure at this center).
- Dispose of all materials properly so pollution problems are not increased at the disposal site.
- Restore stone as necessary so the dams maintain the correct height.
- On bag dams, inspect the sandbag fabric for signs of deterioration.
- Ensure that contributing drainage area has been completely stabilized before removing a temporary check dam.

Additional Resources

EPA (US Environmental Protection Agency). 2014. *Check Dams*. Water: Best Management Practices. *http://water.epa.gov/polwaste/npdes/swbmp/Check-Dams.cfm*

BMP 61: Channel Liners

Description

Channel liners are flexible materials used to line the bottom and/or banks of ditches or channels to prevent and/or reduce erosion, and, to some degree, to capture sediment. Materials include biodegradable matting, geocells, geotextile turf reinforcement mats, riprap, or gabion revet mattresses (Figure 146).

Figure 146. Geocells can be filled with soil and vegetation, rock, or concrete.

Applicability

Channel liners can be used where natural soils or vegetated stabilized soils are not adequate to prevent channel erosion. Channel liners are often used as a temporary stabilization measure until a permanent BMP is installed or established. Geotextiles and matting are especially suited for areas where it may be difficult or expensive to haul riprap.

Limitations

Never use channel liners within waters of the United States unless permits have been obtained from the appropriate state and federal authorities. Any stream alteration should follow the "Stream Channel Alteration Rules" (IDAPA 37.03.07) *https://adminrules.idaho.gov/rules/current/37/370307.pdf*.

Matting may not be suitable for use in ditches or channels with steep side slopes or where the soils are not conducive to proper placement of the matting or lining, depending on manufacturer's specifications. Some geotextile netting may snag fish gills and are not appropriate in streams with important fish habitat.

Riprap and revet mattresses may not be as aesthetically pleasing as more natural channel stabilization methods. These liners can also negatively affect aquatic habitat.

Primary BMP Functions and Controls

☒ Construction	☒ Permanent
☒ Erosion Control	☐ Sediment Control
☐ Source Control	☐ Flood Control
☐ Filtration	☐ Infiltration

Typical Effectiveness for Targeted Pollutants

●	Sediment
○	Phosphorus
○	Metals
○	Bacteria
○	Hydrocarbons
○	Litter

Other BMP Considerations

Relative Cost	$
Maintenance Requirements	Medium
Ease of Installation	Medium
Freeze/Thaw Resistance	Good
Max. Tributary Drainage Area	Varies
Max. Upstream Slope	Varies
NRCS Soil Group	N/A
Min. Ground Water Separation	N/A
Min. Bedrock Separation	N/A

Design Basis

Stable inlets and outlets should be designed and constructed before construction of channel liners. In general, channel liners should be installed on side slopes of 3:1 or flatter and in channels with a low-flow velocity. Riprap can be used on steeper slopes, up to 1:1, and revet mattress and geocells can be used on slopes up to 1.5:1 (Figure 147). The selection of channel-lining material depends on the velocity and shear stress in the channel. Table 32 includes guidance on material selection based on channel velocity.

Table 32. Channel lining and allowable velocity (adapted from ITD 2014).

Channel Type	Velocity (feet per second)	
	Low	Maximum
Unlined earthen ditch	1.0	2.0
Riprap lining	3.2	9.8
Vegetation	2.0	3.9
Revet mattress lining	2.0	14.8
Jute or turf reinforcement mat[a]	1.0	3.3
Geocells[a]	1.0	19.7

a. For more information, refer to the design characteristics of individual products being considered. If individual products are identified in the specification, three products or approved equals should be specified.

The boundary shear stress for a shallow channel where the hydraulic radius is approximated by the flow depth can be calculated using Equation 43:

$$\tau = \gamma \, d \, s$$

Equation 43. Boundary shear stress for shallow channel.

Where
- τ = shear stress (lb/ft^2)
- γ = unit weight of water, 62.4 lb/ft^3
- d = flow depth (ft)
- s = channel gradient (ft/ft)

Table 33 provides guidance on selecting riprap size (d_{50} and d_{max}) and thickness based on channel shear stress. Refer to manufacturer's information for selecting erosion control matting or geocells based on shear stress.

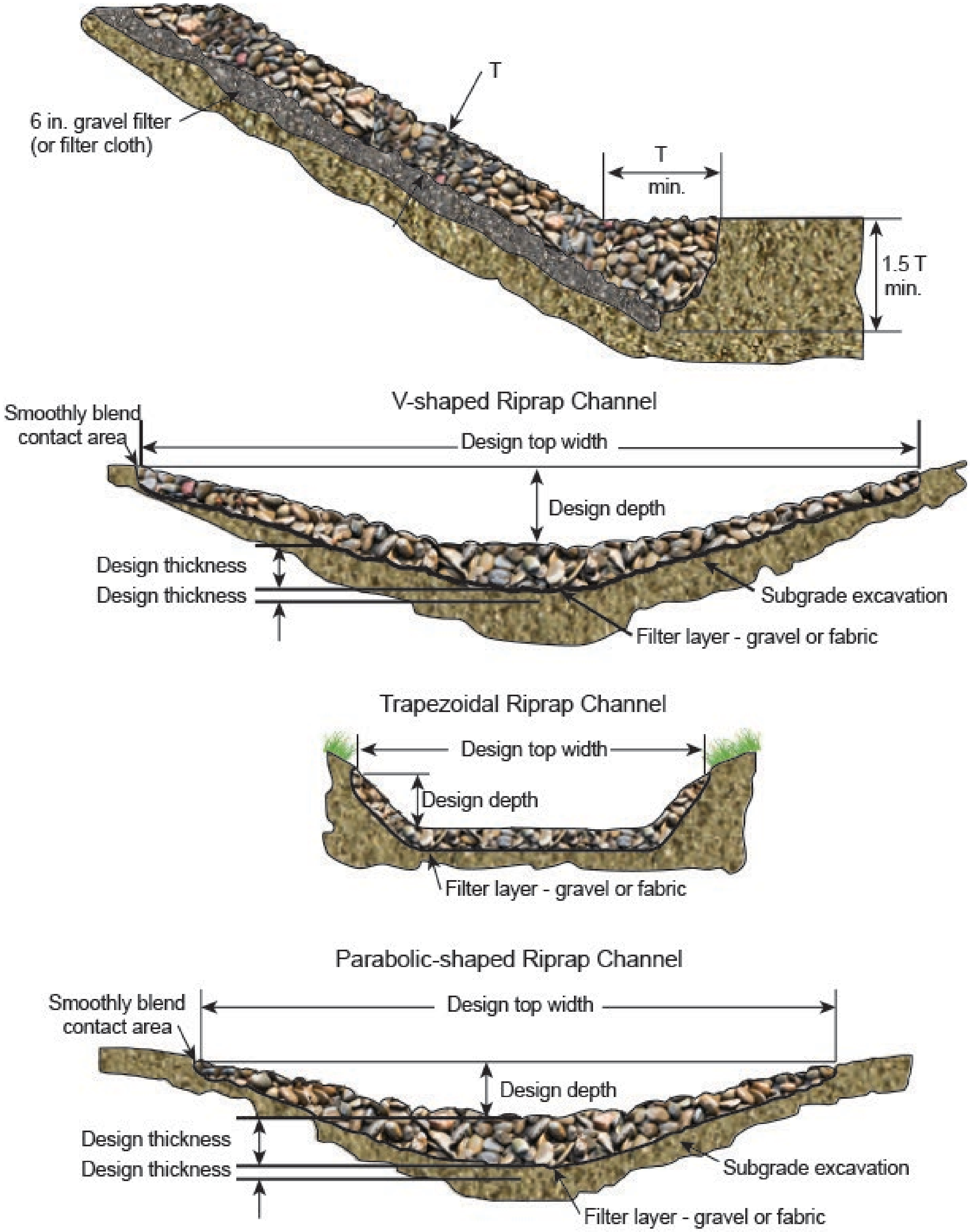


Figure 147. Riprap channel lining.

Table 33. Rock riprap sizes and thickness.

Unit shear stress (pounds per square feet)	d_{50} (inches)	d_{max} (inches)	Minimum blanket thickness (inches)
0.67	2	4	6
2.00	6	9	14
3.00	9	14	20
4.00	12	18	27
5.00	15	22	32
6.00	18	27	32
7.80	21	32	38
8.00	24	36	43

Place riprap and gabion revetments on top of either a stone filter or a geotextile filter fabric to prevent soil movement into or through the riprap. The stone should be keyed in at the bottom of the slope and the filter should be keyed at the top of the bank. Gabion baskets should be constructed of noncorrosive material with a high tensile strength, especially when installed in waters with high corrosivity potential (Figure 148).

In channels with sensitive habitat, the channel design should maintain low flows within the channel, and the riprap size and placement thickness should not cause the stream to go effectively dry. Consult a design professional to determine the channel’s proper width-to-depth ratio.

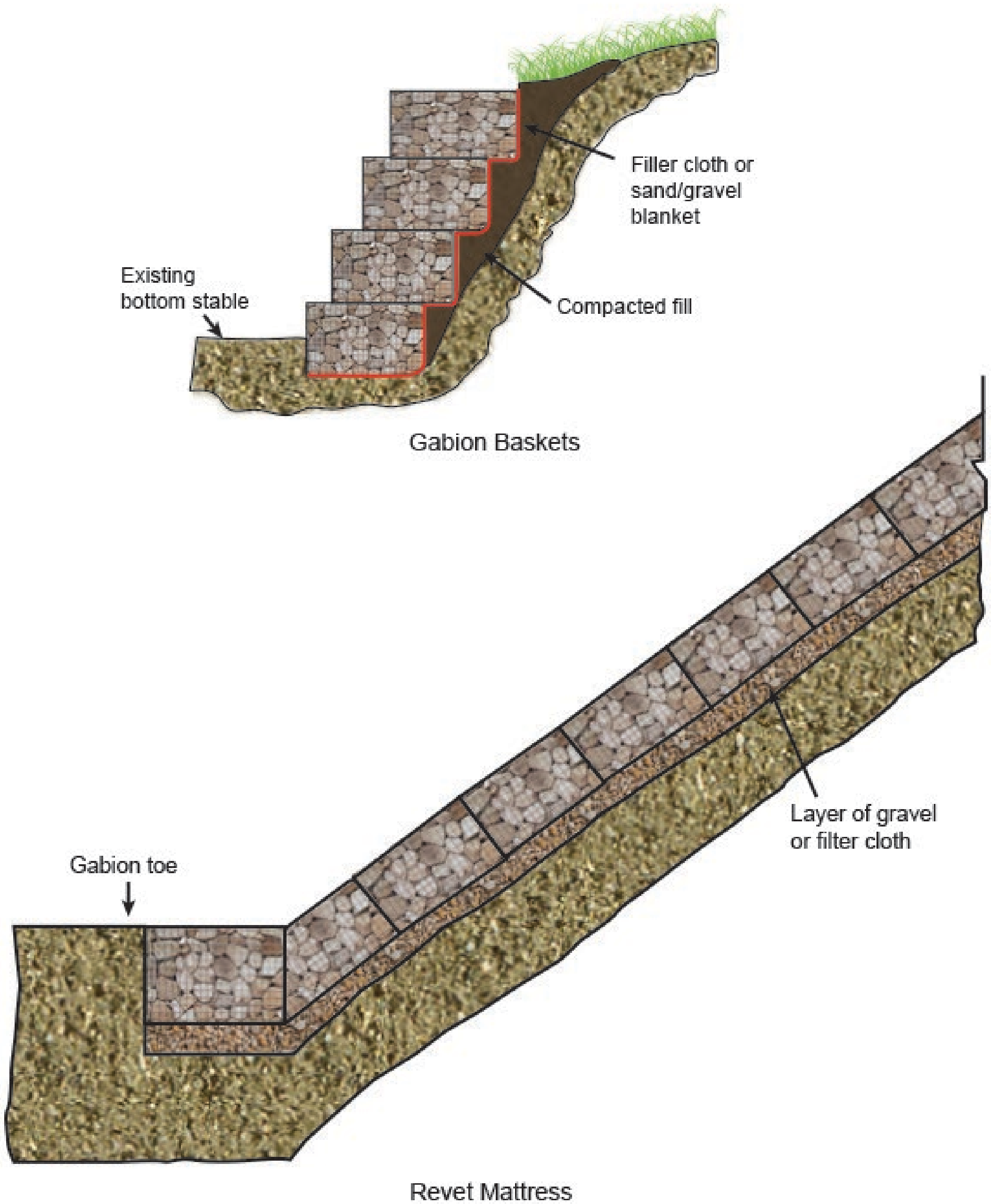


Figure 148. Gabion basket and revet mattress.

Construction Guidelines

For turf reinforcement mats, biodegradable mats, and geocells, follow manufacturer's installation recommendations and the following general guidelines:

- Site preparation—Shape, grade, and compact the bottom and banks as required for a smooth fit. Remove rocks, clods, sticks, and other materials that prevent positive contact with the soil surface. Complete contact of channel liner with the soil surface is critical to keeping water flowing over, not under, the liner.
- Side ditches or channels—Treat in the same manner as the main ditch or channel.
- Channel liner applications—Start at the upstream end of the channel and continue down grade.
- Channel liner overlap—Overlap at least 3 feet of the end of the upstream liner with the top of the next lower liner. Bury the top end of the lower liner at least 6 inches deep. Securely anchor both the top and bottom liner in the area of the overlap. Bury the outer edges of the channel liner in a trench at least 1 foot and properly anchor.
- Make field adjustments as necessary to ensure proper performance.

Install riprap and revet mattress immediately after the area is disturbed and prepare for stone placement. For riprap, the field or quarry stone used should be hard, angular, and resistant to water and weathering.

Maintenance

Make corrections based on weekly erosion control inspections.

After channel lining is installed, ensure all of the liner is in contact with the soil in all places, and critical areas are securely anchored. Inspect channel liners periodically and following each storm event or snowmelt. Repair as necessary. If vegetation is not growing through a mat as designed, reseed as necessary.

Additional Resources

ITD (Idaho Transportation Department). 2014. *Best Management Practices.* Boise, ID: ITD.

BMP 62: Temporary Stream Crossing

Description

A temporary stream crossing provides a safe and stable means for construction vehicles to cross streams or watercourses without moving sediment into streams, damaging the streambed or channel, or causing flooding. A bridge or culvert allows construction vehicles temporary access across a stream or watercourse (Figure 149).

Figure 149. Temporary stream crossing using culverts (Ohio EPA 2014).

Primary BMP Functions and Controls

☒ Construction	☐ Permanent
☐ Erosion Control	☒ Sediment Control
☐ Source Control	☒ Flood Control
☐ Filtration	☐ Infiltration

Typical Effectiveness for Targeted Pollutants

●	Sediment
○	Phosphorus
◖	Metals
○	Bacteria
◖	Hydrocarbons
○	Litter

Other BMP Considerations

Relative Cost	$$
Maintenance Requirements	Easy
Ease of Installation	Hard
Freeze/Thaw Resistance	Good
Max. Tributary Drainage Area	5 acres
Max. Upstream Slope	25%
NRCS Soil Group	ABCD
Min. Ground Water Separation	N/A
Min. Bedrock Separation	6 feet

Applicability

A temporary stream crossing is used when heavy equipment must be moved from one side of a stream channel to another, or where light-duty construction vehicles have to cross the stream channel frequently for a short time period. Temporary stream crossings should be installed only when it is necessary to cross a stream and alternative routes to access the site are not feasible or a permanent crossing is not feasible or not yet constructed.

The specific vehicle loads and conditions of the stream will dictate the type of stream crossing that is appropriate.

Bridges are the preferred method to cross a stream as they provide the least obstruction to flows and fish migration.

Culverts are relatively easy to construct; a pipe (or pipes) can be placed in the channel and covered with aggregate. Temporary culverts can result in disturbance to the channel during construction and removal.

Limitations

- Temporary bridges may be expensive to install.
- Culverts cause greater disturbance during installation and removal. In sensitive stream systems, these impacts may not be justifiable.

- Always attempt to minimize or eliminate the need to cross streams. Temporary stream crossings are a direct source of pollution so make every effort to use an alternate method such as a longer detour. When it is necessary to cross a stream, a well-planned approach minimizes damage to the streambank and reduces erosion.

Using stream crossing measures below the high-water mark of a stream or other water body considered a water of the United States should be carefully evaluated for local, state, and federal permit requirements. All necessary permits must be obtained before commencing work within the water body.

Design Basis

In-stream excavation should be limited to what is necessary to install the temporary bridge or culvert as described below:

General

- Locate the temporary crossing where the least soil disturbance will occur in the existing waterway banks. When possible, locate the crossing at the point receiving minimal surface runoff.
- Locate culverts and bridges so a direct line of approach exists at both the entrance and exit. Do not allow abrupt bends at the entrance or exit unless suitable erosion protection is provided.
- Align the centerline of both roadway approaches with the crossing alignment centerline at a minimum distance of 50 feet from each bank of the waterway being crossed. If physical or right-of-way restraints preclude the 50 feet minimum, provide a shorter distance. All fill materials associated with the roadway approach should be clean rock (nonerodible) and limited to a maximum height of 2 feet above the existing floodplain elevation.
- Construct a water diverting structure such as a swale (across the roadway on both roadway approaches) 50 feet (maximum) on either side of the waterway crossing. This structure will prevent roadway surface runoff from directly entering the waterway. Measure the 50 feet from the top of the waterway bank. Design the diverting structure according to the BMP fact sheet in this catalog for the individual design standard chosen. If the roadway approach is constructed with a reverse grade away from the waterway, a diverting structure is not required.
- Ensure all crossings are as narrow as practical to provide safe passage of equipment and minimize the impact to the streambank and riparian vegetation.
- Remove all temporary crossings within 14 calendar days after the structure is no longer needed.

Materials

- Use only clean rock (3/4 inch to 4 inches). Do not use erodible fill, such as earth or soil materials, for construction within the waterway channel.
- Use filter cloth, consisting of either woven or nonwoven plastic, polypropylene, or nylon, to distribute the load, retain fines, increase drainage of the aggregate, and reduce mixing of the aggregate with the subgrade soil. Filter cloths should be used as required by the specific method.

Considerations for Choosing a Specific Type of Crossing

- Select a design that least disrupts the existing terrain of the stream reach. Consider the effort required to restore the area after the temporary crossing is removed.
- Locate the temporary crossing where the least soil disturbance will occur in the existing waterway banks. When possible locate the crossing at the point receiving minimal surface runoff.
- Consider that the physical constraints of a site may prevent selecting one or more of the standard stream crossings.
- Consider that the time of year may prevent selecting one or more of the standard stream crossings due to fish spawning or migration restrictions.
- Consider vehicular loads, traffic patterns, and crossing frequency when choosing a specific type of stream crossing.
- Keep in mind that crossings require various amounts of maintenance and bridges require the least maintenance.
- Consider that ease of removal and subsequent damage to the waterway are factors in the stream crossings chosen.

Temporary Bridge

- As the preferred method for waterway crossings, temporary bridge construction causes the least disturbance to the waterway bed and banks when compared to culverts or fords (Figure 150).
- Temporary bridges pose the least potential for creating barriers to aquatic migration. The construction of a temporary bridge or culvert should not cause a significant water level difference between the upstream and downstream water surface elevations.
- Most bridges can be quickly removed and reused.

Temporary Culvert

- A temporary access culvert is consists of a section of circular pipe, pipe arches, or oval pipes of reinforced concrete, corrugated metal, or structural plate used to convey flowing water through the crossing (Figure 151).
- Select culvert material and depth of cover based on the expected construction load.
- Temporary culverts are used when the channel is too wide for normal bridge construction, or the anticipated load may prove unsafe for single-span bridges.
- The length of the temporary culvert should extend a minimum of 1 foot beyond a stable side slope from the road crossing.
- Temporary culverts can be salvaged and reused.

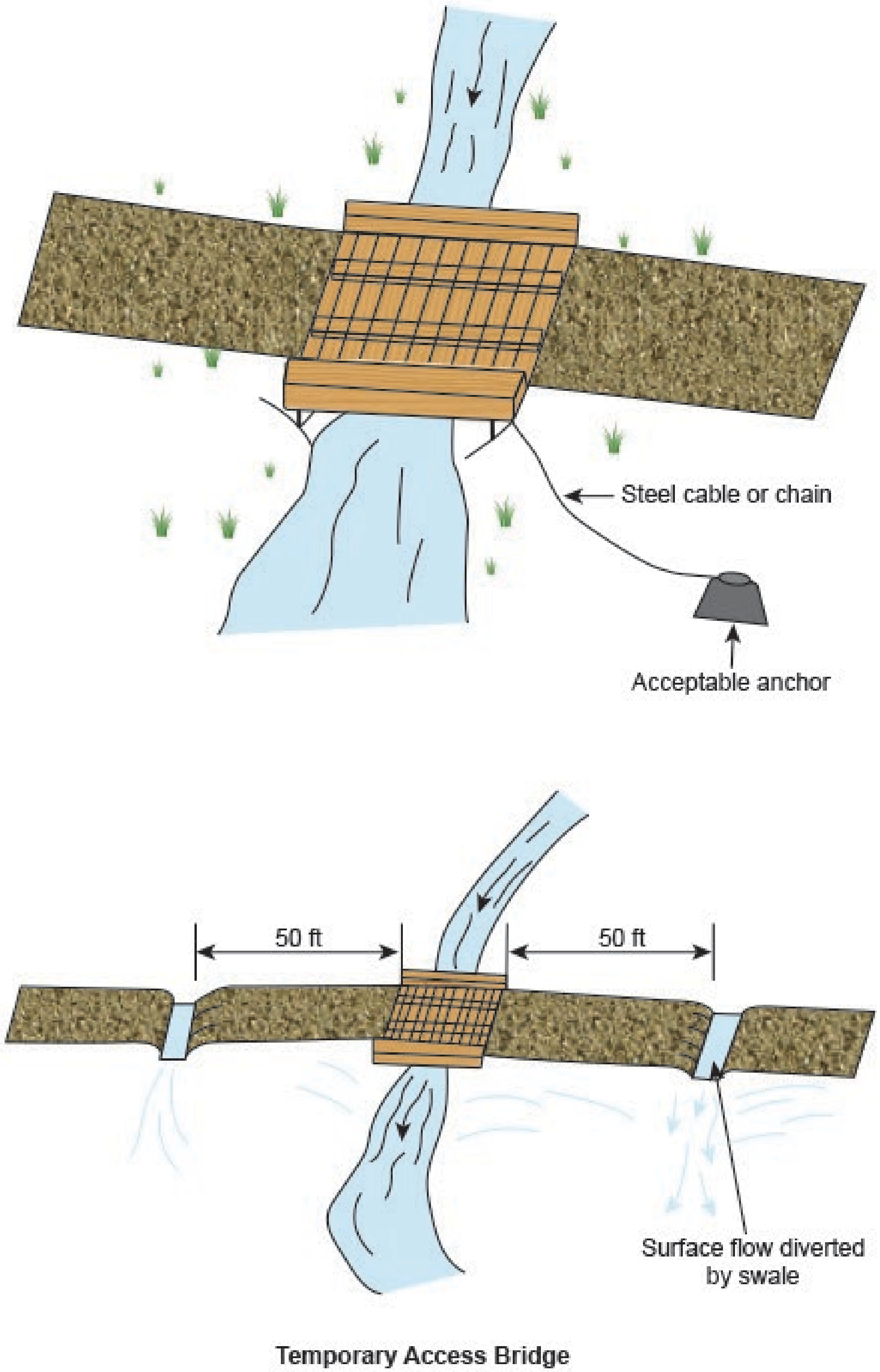


Figure 150. Temporary access bridge.

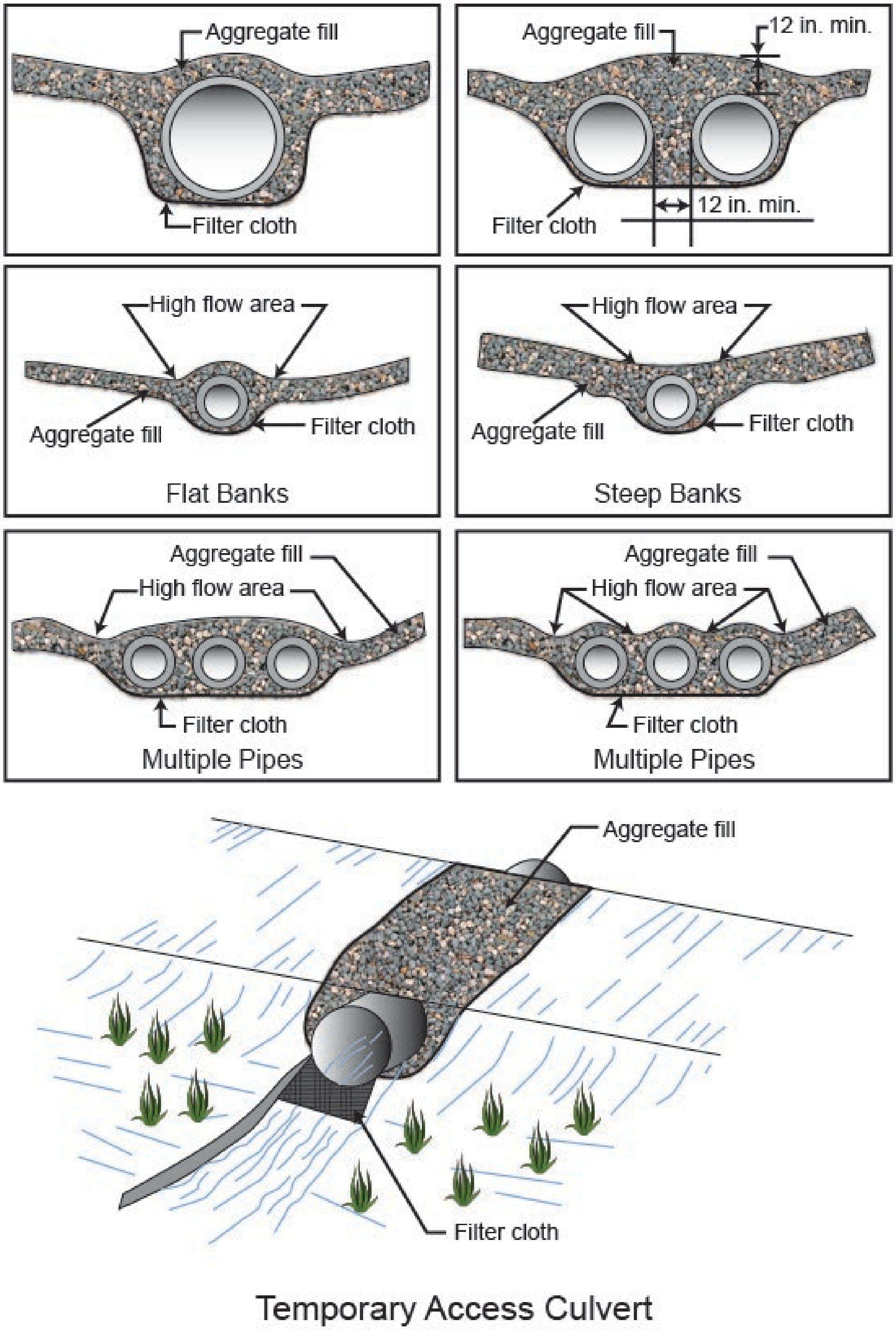


Figure 151. Temporary access culvert.

Construction Guidelines

Temporary Bridge

- Construction, use, or removal of a temporary access bridge will not normally have any time-of-year restrictions since construction, use, or removal should not affect the stream or its banks.
- Construct a temporary bridge structure at or above bank elevation to prevent entrapping floating materials and debris.
- Place abutments parallel to and on stable banks.
- Construct bridges to span the entire channel. If the channel width exceeds 8 feet (as measured from top-of-bank to top-of-bank), a temporary footing, pier, or bridge support may be constructed within the waterway. One additional footing, pier, or bridge support will be permitted for each additional 8-foot width of the channel. No footing, pier, or bridge support will be permitted within the channel for waterways less than 8-feet wide.
- Stringers should either be logs, sawn timber, prestressed concrete beams, metal beams, or other approved materials.
- Decking materials should be of sufficient strength to support the anticipated load. All decking members should be placed perpendicular to the stringers, butted tightly, and securely fastened to the stringers. Butt decking materials tightly to prevent any soil material tracked onto the bridge from falling into the waterway below.
- Run planking (optional) should be securely fastened to the length of the span. Provided one run plank for each track of the equipment wheels. Although run planks are optional, they may be necessary to properly distribute loads.
- Install curbs or fenders along the outer sides of the deck. Curbs or fenders are an option to provide additional safety.
- Securely anchor bridges at only one end using steel cable or chain. Anchoring at only one end prevents channel obstruction if floodwaters float the bridge. Acceptable anchors are large trees, large boulders, or driven steel anchors. Anchoring should be sufficient to prevent the bridge from floating downstream and possibly causing an obstruction to the flow.
- Stabilize all areas disturbed during installation within 14 calendar days of the disturbance.

Temporary Culvert

- All culverts must be strong enough to support the maximum expected loads.
- The size of the culvert pipe should be the largest pipe diameter that will fit into the existing channel without major excavation of the waterway channel or without major approach fills. If a channel width exceeds 3 feet, additional pipes may be used until the cross-sectional area of the pipes is greater than 60% of the cross-sectional area of the existing channel. The minimum culvert size used is a 12-inch diameter pipe.
- The culvert should extend a minimum of 1 foot beyond the upstream and downstream toe of the aggregate placed around the culvert. The culvert should never exceed 40 feet in length.
- Place filter cloth the streambed and streambanks before placing the pipe culvert and aggregate. The filter cloth should cover the streambed and extend a minimum 6 inches and

a maximum of 1 foot beyond the end of the culvert and bedding material. Filter cloth reduces settlement and improves crossing stability.
- Install the invert elevation of the culvert on the natural streambed grade to minimize interference with fish migration (free passage of fish).
- Cover the culvert with a minimum of 1 foot of aggregate. If multiple culverts are used, separate them by at least 12 inches of compacted aggregate fill.
- Stabilize all areas disturbed during culvert installation within 14 calendar days of the disturbance.

Maintenance

- Inspections should be performed periodically and after runoff events to ensure that the bridge, culvert, streambed, and the streambanks are in good condition and that sediment is not entering the stream or blocking fish passage or migration.
- Maintenance should be performed, as needed, to ensure that the structure complies with the standards and specifications, including removing and disposing of any trapped sediment or debris. The decking and curbs of bridges should be kept free of sediment. Sediment should be disposed of outside of the floodplain and stabilized. Areas adjacent to the crossing shall maintain vegetative stabilization.
- When the temporary crossing is no longer needed, all structures, including abutments and other bridging materials, should be removed within 14 calendar days. In all cases, the crossing materials should be removed within 1 year of installation or according to permit requirements.
- Final cleanup should consist of removing the temporary crossing from the waterway, removing all construction materials, restoring the original stream channel cross section, and protecting the streambanks from erosion. All removed materials should be stored outside the waterway floodplain.
- Removing the bridge or culvert and cleaning up of the area should be accomplished without construction equipment working in the waterway channel if possible. Otherwise, turbidity curtains (BMP 71) can be used to minimize downstream turbidity caused by bridge or culvert removal.
- All areas disturbed during removal should be stabilized within 14 calendar days of the disturbance.

Additional Resources

EPA (US Environmental Protection Agency). 2014. *Temporary Stream Crossings*. Water: Best Management Practices. *http://water.epa.gov/polwaste/npdes/swbmp/Temporary-Stream-Crossings.cfm*

BMP 63: Biofilter Bags

Description

Biofilter bags are plastic mesh bags filled with wood chips, compost, or similar biological material used as temporary sediment barriers. Biofilter bags detain storm water runoff and allow a slow rate of discharge to pass through the biological material, which allows sediment to settle and filters runoff. The bags may also be used to divert small amounts of runoff around active work areas or direct runoff to a slope drain, sediment trap, or other filtration/sedimentation BMP (Figure 152).

Figure 152. Compost filter socks used to slow and filter runoff.

Applicability

Biofilter bag barriers are an effective temporary measure that can be rapidly deployed at storm drain inlets, across minor swales and ditches, as diversion dikes and berms, along property lines, to reduce energy from concentrated flow, and for other applications where a temporary barrier is needed and structural strength is not required. These barriers are versatile and can be constructed in many combinations to achieve the required structure.

These are common locations to place biofilter bag barriers:

- At the toe of embankment slopes
- As filter cores for log check dams
- In front of silt fences
- As check dams in unlined ditches
- Surrounding inlets along paved streets (BMP 74: Inlet Protection)
- Around temporary stockpile areas
- Parallel and upgradient of roadways to keep sediment from paved areas

Primary BMP Functions and Controls

☒ Construction	☐ Permanent
☒ Erosion Control	☒ Sediment Control
☐ Source Control	☐ Flood Control
☒ Filtration	☐ Infiltration

Typical Effectiveness for Targeted Pollutants

◖	Sediment
○	Nitrogen
○	Phosphorus
○	Metals
○	Bacteria
○	Hydrocarbons
◖	Litter

Other BMP Considerations

Relative Cost	$
Maintenance Requirements	Low
Ease of Installation	Easy
Freeze/Thaw Resistance	Fair
Max. Tributary Drainage Area	NA
Max. Upstream Slope	10%
NRCS Soil Group	ABCD
Min. Ground Water Separation	NA
Min. Bedrock Separation	NA

Limitations

- Biofilter bags are barriers suitable only where flow rates are low (1 cfs or less).
- The bags have a limited life span and require regular inspections and repair and periodic replacement (approximately every 2–3 months).

- Biofilter bags are easily damaged by construction equipment.
- Without proper staking, biofilter bags will easily fail on slopes.
- Biofilter bags and their accumulated sediment are often not cleaned up properly, which leaves the sediment to wash away with the next rain event.
- If not properly installed, biofilter bags can become buoyant and easily displaced. Like all BMPs, biofilter bags must be properly installed and maintained to be effective.

Design Basis

Biofilter bags come in a variety of sizes, (e.g., 30 x 18 inches and 30 x 9 inches) and may contain between 1 and 2 cubic yards of material each. Design guidelines are as follows (Figure 153):

- A minimum undisturbed buffer zone of 3 feet is needed between the barriers and surface waters to safely remove the barrier and accumulated sediments.
- Embed the biofilter bag barriers to a minimum depth of 6 inches and backfill the entire length of the barrier. Securely anchor each bag with two stakes (2 x 2 inches x 3 feet) or drive in steel drift pins at least 20 inches into the ground.
- Overlap biofilter bags a minimum of 6 inches.
- Place biofilter bags along level contours.
- Place the first barrier row of biofilter bags near the toe of the slope with subsequent spacing continuing upgradient from that point.
- Where multiple slope gradients contribute to the same drainage area, steepness refers to the steepest section contributing to the biofilter bag barrier.
- Space biofilter bag barriers closer on steeper slopes (CASQA 2004a):
  - Slopes between 20:1 and 4:1—Maximum spacing of 20 feet
  - Slopes between 4:1 and 2:1—Maximum spacing of 15 feet
  - Slopes between 2:1 or steeper—Maximum spacing of 10 feet

Construction Guidelines

- Barriers used for sediment control at the toe of slopes should be in place before disturbing the slope. Install these barriers a short distance away from the toe of the slope to increase the effective area but outside of any ditch channel.
- When flows are expected to be high enough to surpass the infiltration capacity of the devices, the center (low point) bags should be wrapped in filter fabric with a 3-foot tail stapled securely and extending from the downgradient side of the barrier to prevent scouring. The ends of the adjacent barriers should tightly overlap one another.
- Any gaps between barriers should be filled with tightly wedged straw.
- For concentrated flow applications, extend the end of the barrier so that the bottoms of the end units are at a higher elevation than the top of the lowest middle unit to ensure that sediment-laden water flows through or over the barrier instead of around the ends.

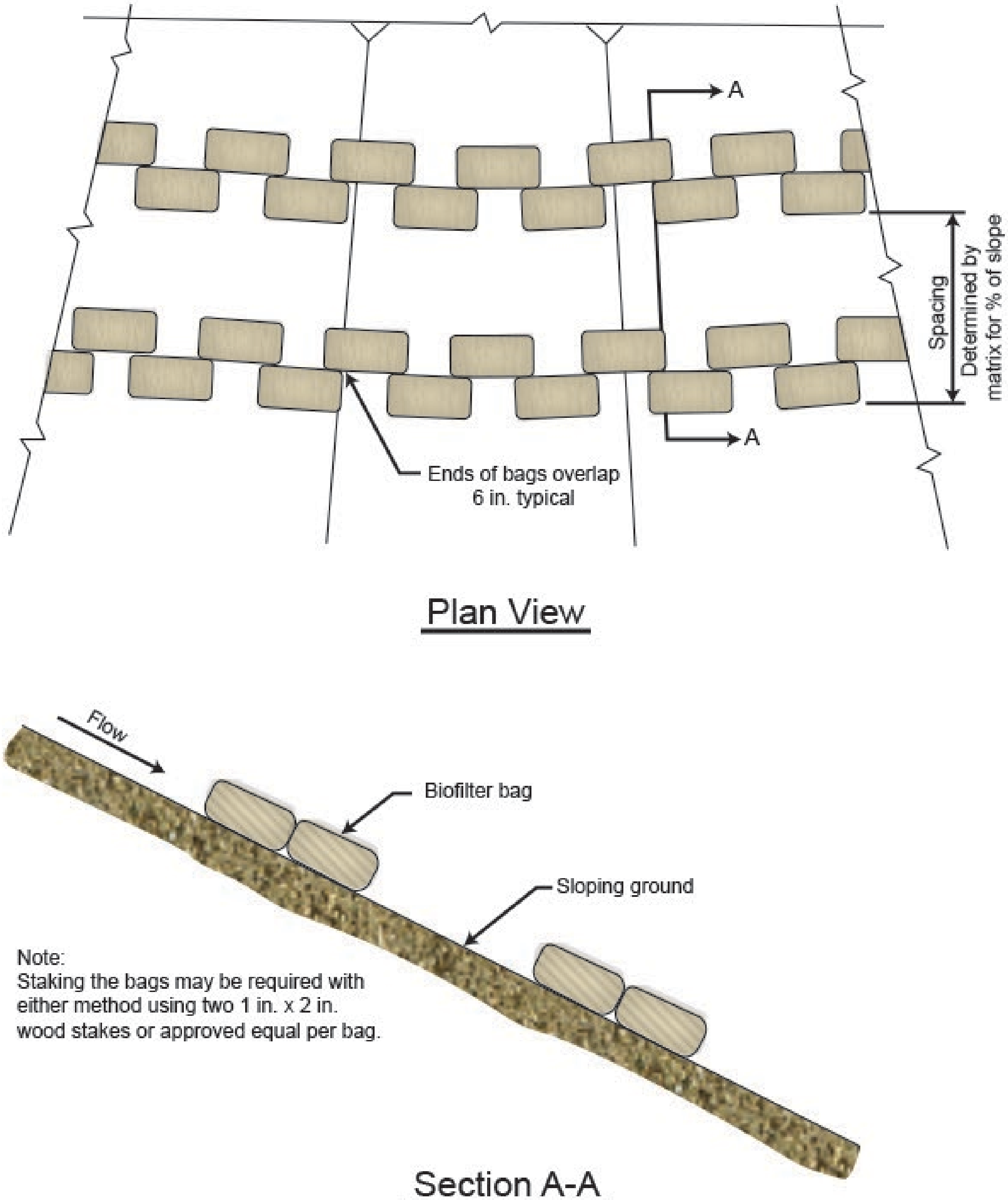


Figure 153. Biofilter bag spacing.

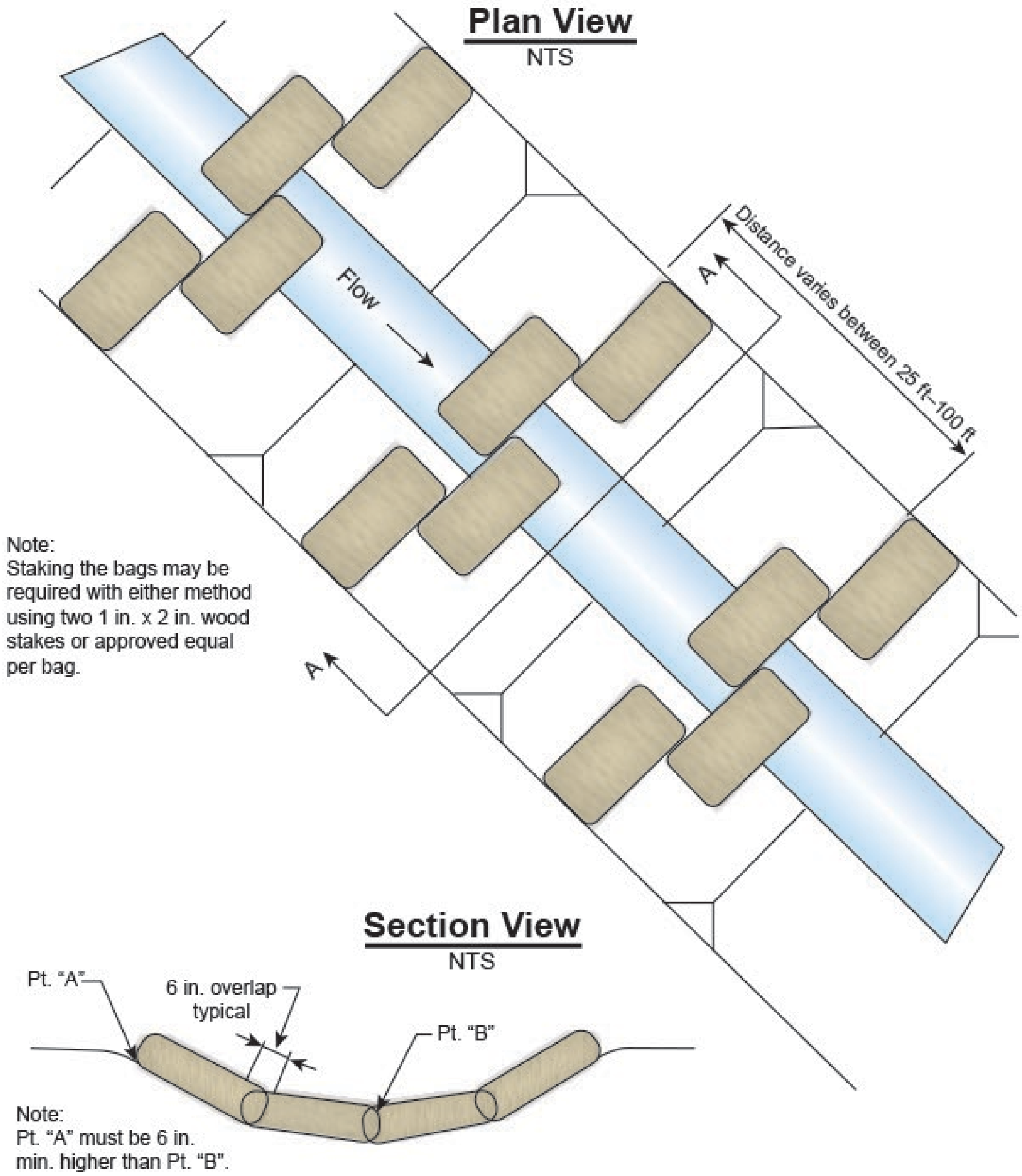


Figure 153. continued. Biofilter bag spacing.

Maintenance

- Perform one inspection during the first runoff-producing event after installation to ensure proper functioning.
- Remove sediment when it reaches one-third of the barrier height.
- Biofilter bags exposed to sunlight must be replaced every 2 to 3 months. Inspect periodically to determine if replacements are needed.
- Immediately repair damaged barriers, undercutting, or end runs.
- If approved, use biofilter bags as landscaping mulch after construction is complete.

- Within 30 days of final site stabilization, remove temporary sediment barriers and any stakes, pins, or rebar used.

Additional Resources

CASQA California Stormwater Quality Association. 2004. *California Stormwater Best Management Practices Handbook: New Development and Redevelopment*. Menlo Park, CA. *https://www.casqa.org*

ODEQ (Oregon Department of Environmental Quality). 2013. *Construction Stormwater Best Management Practices Manual: 1200-C NPDES General Permit.* Portland, OR.

BMP 64: Fiber Rolls

Description

A fiber roll (or wattle or sediment control log) consists of straw, flax, rice, coconut, or other biodegradable material wrapped in ultraviolet degradable polypropylene netting or a biodegradable material such as burlap, jute, or coir. Fiber rolls placed at the toe and on the face of slopes intercept runoff and reduce flow velocity, release the runoff as sheet flow, and provide sediment removal from the runoff. By interrupting the slope length, fiber rolls reduce erosion (Figure 154).

Figure 154. Fiber rolls placed along the top of slope in Sandpoint, Idaho.

Applicability

Fiber rolls can be used in small drainage areas and flatter grades due to their low profile. Applications include the following:

- Along the toe, top, face, and at grade breaks of exposed and erodible slopes to shorten slope length and spread runoff as sheet flow
- At the end of a downward slope where it transitions to a steeper slope
- Along the perimeter of a project
- As check dams in unlined ditches with minimal grades and low velocity flows
- Downslope of exposed soil areas
- Around temporary stockpiles
- As a temporary curb for conveying water to catch basins and pipe slope drains
- For catch-basin inlet protection when they are properly anchored or weighted
- As part of a multilayered perimeter control along a receiving water

Primary BMP Functions and Controls

☒ Construction	☐ Permanent
☒ Erosion Control	☒ Sediment Control
☐ Source Control	☐ Flood Control
☐ Filtration	☐ Infiltration

Typical Effectiveness for Targeted Pollutants

●	Sediment
○	Phosphorus
○	Metals
○	Bacteria
○	Hydrocarbons
○	Litter

Other BMP Considerations

Relative Cost	$
Maintenance Requirements	Medium
Ease of Installation	Easy
Freeze/Thaw Resistance	Good
Max. Tributary Drainage Area	N/A
Max. Upstream Slope	Varies
NRCS Soil Group	ABCD
Min. Ground Water Separation	N/A
Min. Bedrock Separation	N/A

Limitations

Fiber roll limitations include the following:

- Not effective unless trenched and staked.

- Do not use on slopes subject to creep, slumping, or landslides.
- At the toe of slopes greater than 5:1, install rolls a minimum of 20 inches in diameter or install to achieve the same protection (i.e., stacked smaller diameter fiber rolls).
- Difficult to move once saturated.
- Do not use in traffic crossing areas.
- Limited sediment capture zone and should only be used for small drainage areas.

Design Basis

Fiber rolls should be placed along the contour (perpendicular to the slope or fall line) to avoid concentrating flows. The maximum recommended tributary drainage area per 100 lineal feet of roll is approximately 0.25 acres with a disturbed slope length of up to 150 feet and a tributary slope gradient no steeper than 3:1 (Colorado UDFCD 2010). Longer and steeper slopes require additional measures. Table 34 provides a general guideline for spacing the rolls.

Table 34. Fiber roll installation spacing (EPA 2014b).

Slope (H:V)	Spacing measured along face of slope (feet)
1:1	10
2:1	20
3:1	30
4:1	40

In soft, loamy soils, place the rows closer together and trench into the ground 3 to 5 inches. In hard, rocky soils, place the rows farther apart and trench into the ground 2 to 3 inches. The minimum trench depth should be one-quarter to one-third of the thickness of the fiber roll, and the trench width should be equal to the roll diameter.

Fiber rolls should be securely staked through the center of the roll into the ground with wood stakes (nominal classification of 0.75 x 0.75 inches and minimum length of 24 inches) or with willow cuttings. Place stakes 3 to 4 feet apart and at each end of the roll. Extend the stakes 3 to 5 inches above the top of the roll. Rebar can also be used to stake fiber rolls with the rebar flush with the top of the roll. Rebar is not biodegradable, so remove it after the fiber rolls are no longer needed.

The ends of the fiber roll should be turned up the slope to prevent runoff from going around the roll. If more than one fiber roll is placed in a row, the rolls should be overlapped, not abutted.

Secure fiber rolls used along sidewalks or around catch-basin inlets with trenches and/or staking. Alternatively, a roll with gravel, sand, or other ballast material can be used to provide additional weight when staking the roll is not feasible. Place rolls 1 to 1-1/2 feet away from a storm drain inlet (Figure 155 and Figure 156).

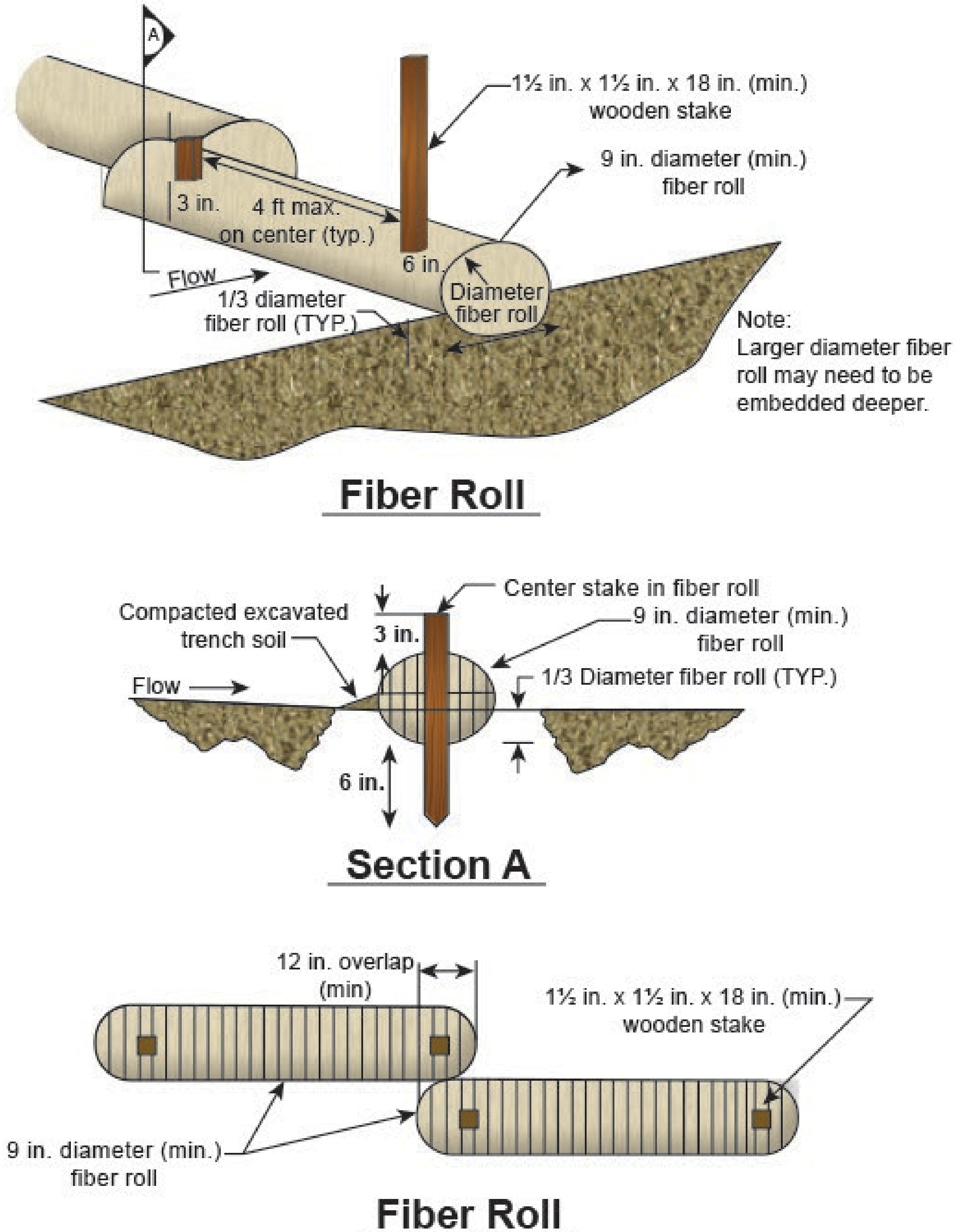
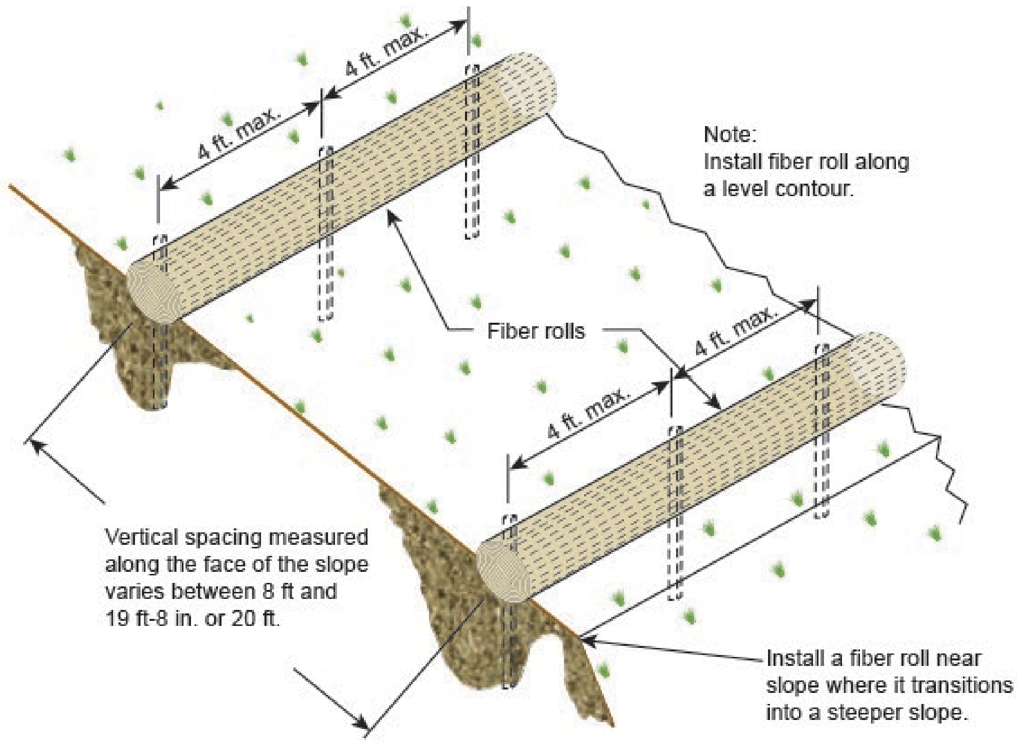
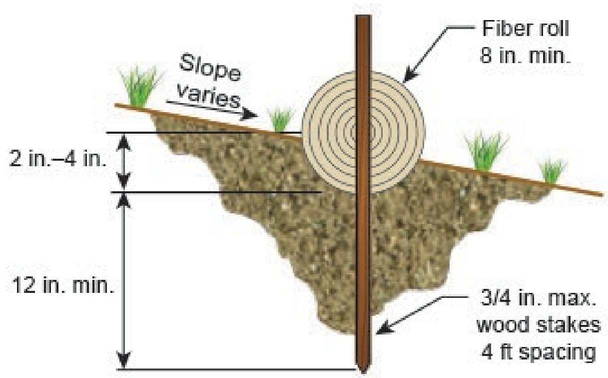


Figure 155. Fiber roll staking, trenching, and joints (Colorado UDFCD 2010).



Typical Fiber Roll Installation

N.T.S.



Entrenchment Detail

N.T.S.

Figure 156. Fiber roll installation.

Construction Guidelines

Use prefabricated fiber rolls 8 to 20 inches in diameter. Install trenches and fiber rolls from the base of the slope and work up. Prepare the slope before installation. Before inserting the wooden stakes, it may be necessary to drive pilot holes using a straight bar through the roll and into the soil.

Maintenance

Fiber rolls should be inspected before forecast rain, daily during extended rain events, after rain events, weekly during the rainy season, and at 2-week intervals during the nonrainy season.

Repair or replace split, torn, unraveling, crushed, or slumping fiber rolls. Secure and reanchor rolls as necessary.

If the fiber roll is used as a sediment capture device or as an erosion control device to maintain sheet flows, periodically remove accumulated sediment to maintain BMP effectiveness. Sediment should be removed before sediment reaches one-half the distance between the top of the fiber roll and the adjacent ground surface. Sediment removed during maintenance may be incorporated into earthwork on the site or disposed of in appropriate location.

When used for slope protection with erosion control blankets, fiber rolls are typically left in place after construction where they will eventually degrade. If they are used as perimeter control or inlet protection, they are typically removed.

Additional Resources

CALTRANS (California Department of Transportation, Division of Construction). 2003. *Construction Site Best Management Practice Manual*. Sacramento, CA.

EPA (US Environmental Protection Agency). 2014. *Fiber Rolls.* Water: Best Management Practices. *http://water.epa.gov/polwaste/npdes/swbmp/Fiber-Rolls.cfm*

BMP 65: Silt Fence

Description

A silt fence is a temporary sediment barrier created with a porous fabric stretched and attached to supporting posts. Woven wire fence backing is necessary with several types of filter fabric commonly used. The silt fence ponds sediment-laden storm water runoff, and the sediment is retained by settling (Figure 157).

Figure 157. Silt fence (York County Conservation District 2009).

Applicability

Silt fences can be used around the perimeter of a disturbed area to intercept sediment while allowing water to percolate through. The fences should remain in place until the disturbed area is permanently stabilized.

Silt fences can also be used along the toe of fills, on the downhill side of large through-cut areas, along streams, at grade breaks on cut/fill slopes, and above interceptor dikes.

Limitations

Silt fence is a popular BMP choice on construction sites, but to work effectively, it must be properly designed, installed, and maintained.

Do not use silt fences where water concentrates in a ditch, channel, or drainageway or where soil conditions prevent the minimum fabric toe-in depth or minimum depth for installation of support posts. If concentrated flow occurs after installation, place rock berms or other corrective measures in the areas of concentrated flow.

Silt fences should not be used in places where vehicle or equipment crossing is expected.

Primary BMP Functions and Controls

☒ Construction	☐ Permanent
☒ Erosion Control	☒ Sediment Control
☐ Source Control	☐ Flood Control
☐ Filtration	☐ Infiltration

Typical Effectiveness for Targeted Pollutants

●	Sediment
○	Phosphorus
◖	Metals
○	Bacteria
○	Hydrocarbons
◖	Litter

Other BMP Considerations

Relative Cost	$
Maintenance Requirements	Medium
Ease of Installation	Easy
Freeze/Thaw Resistance	Good
Max. Tributary Drainage Area	0.25 acres/ 100 lineal feet
Max. Upstream Slope	33%
NRCS Soil Group	ABCD
Min. Ground Water Separation	2 feet
Min. Bedrock Separation	2 feet

Design Basis

Location

Proper placement and design of silt fence is critical to its effectiveness. Silt fence installed along a contour should have a maximum disturbed tributary drainage area of 10,000 ft^2 per 100 feet of fence with a maximum tributary slope length of 150 feet and a tributary slope gradient of 3:1. Longer and steeper slopes require additional measures, such as multiple rows of silt fence or other sediment control. Placement and length should also consider the maximum allowable slope lengths contributing runoff to a silt fence as listed in Table 35.

Table 35. Maximum allowable slope lengths.

Slope Steepness	Maximum Slope Length (feet)
2:1	50
3:1	75
4:1	125
5:1	175
Flatter than 5:1	200

Place the silt fence as close to the contour as possible, with the area below the fence undisturbed or stabilized. Long runs of silt fence should be avoided to limit opportunities for large areas of concentrated water. Extend each end of the silt fence upslope to prevent runoff from going around the end. Multiple J-hooks can be used to break up long runs and provide ministorage areas to pond small amounts of water.

The location and details for silt fence should be shown on the SWPPP map and contain the following minimum requirements:

- Type, size, and spacing of fence posts
- Size of woven wire fences
- Type of filter fabric used
- Method of anchoring the filter fabric
- Method of fastening the filter fabric to the fencing support

Materials

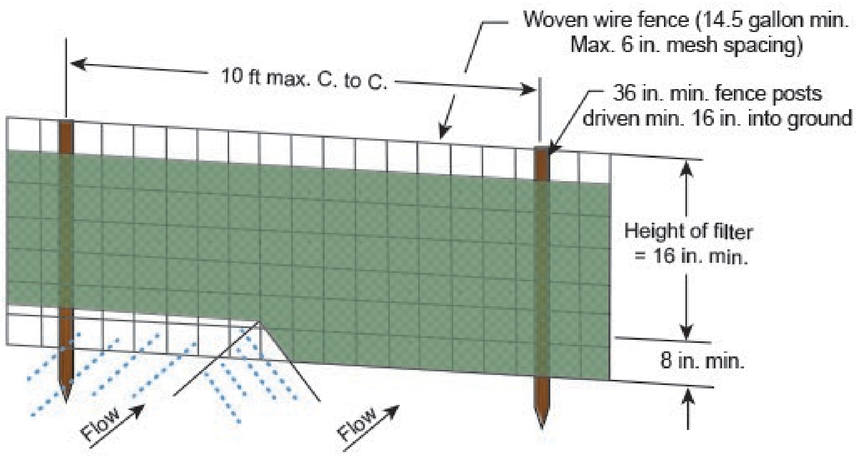
The filter fabric should meet specifications for silt fence materials included in ASTM D6461, unless otherwise approved by the appropriate erosion and sediment control plan approval authority. The fabric can be woven, nonwoven, or monofilament with a minimum width of 36 inches (Figure 158 and Figure 159).

Support posts should be 36 to 48 inches long and can be either wood or steel. Wood posts should be sound quality wood with a minimum cross-sectional area of 3 square inches, typically 2 x 2 inches nominal dimensions. Steel posts can be standard “T” or “U” sections weighing not less than 1 pound per linear foot. Steel posts can be easier to drive into compacted ground to a

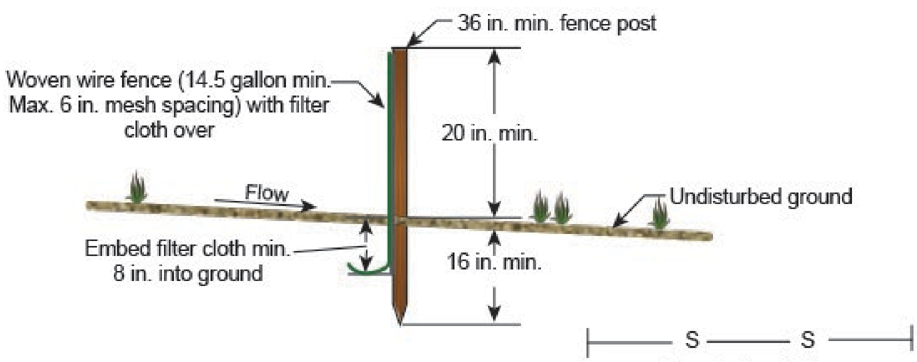
depth sufficient enough to hold the fabric up and support the horizontal load of retained water and sediment.

Woven wire fence can be used to help the silt fence withstand heavy rain or high wind events. Wire fencing should be a minimum 14.5 gage with a maximum 6-inch mesh opening, or as approved.

In lieu of constructing silt fence on site using the above recommended materials, prefabricated units can be used if installed per the manufacturer’s instructions. Prefabricated fences do not allow for variable post spacing or posting after the ground is compacted.



Perspective View



Section

Standard symbol

Construction Notes for Fabricated Silt Fence

1. Woven wire fence to be fastened securely to fence posts with wire ties or staples.
2. Filter cloth to be fastened securely to woven wire fence with ties spaced every 24 in. at top and mid-section.
3. When two sections of filter cloth adjoin each other, they shall be overlapped by 6 in. and folded.
4. Maintenance shall be performed as needed and material removed when bulges develop in the silt fence.

Figure 158. Silt fence diagram.

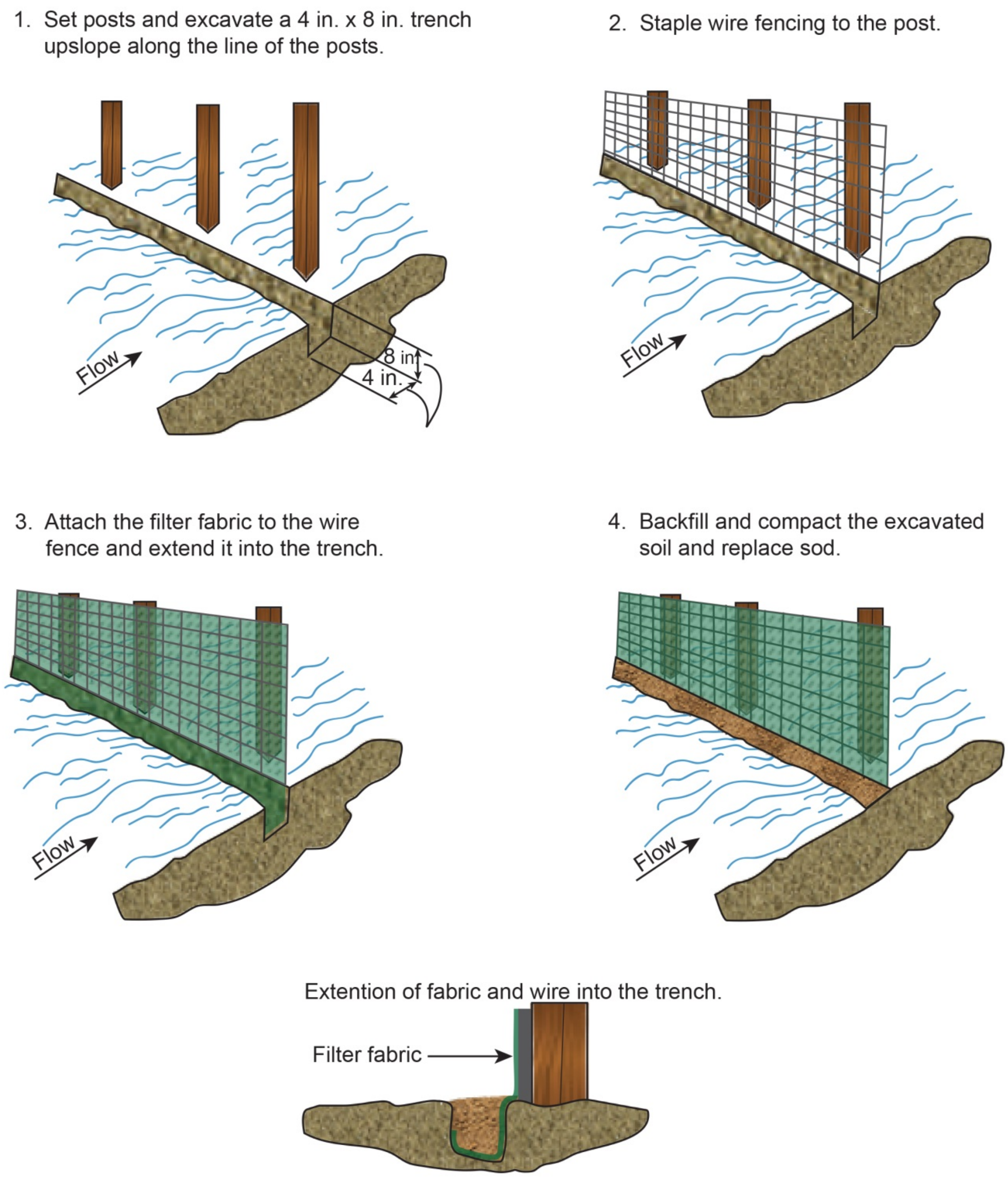


Figure 159. Silt fence construction diagram.

Construction Guidelines

Install the silt fence after cutting and slashing trees and before excavating haul roads, fill benches, or any soil-disturbing construction activity within the contributing drainage areas.

Silt fence can be installed using either the traditional trenching method or the static slicing method. The trenching method places the fence along a 6-inch wide x 8-inch deep trench; the fabric is keyed into the trench; and the trench is backfilled and compacted. To reduce sediment load, replace the vegetation or sod removed to create the trench.

The static slicing method uses a narrow blade pulled behind a tractor to create a 12-inch deep slit where the silt fence fabric is placed. Once the fabric is installed, the soil is compacted on both sides of the slit using tractor tires. The static slicing method achieves better performance with less time and effort than the trenching method (EPA 2012b).

Other guidelines for constructing and installing a silt fence include the following:

- Space posts 10 feet apart when a woven wire fence is used and no more than 6 feet apart when using extra-strength filter fabric (without a wire fence). Extend the posts a minimum of 18 inches into the ground, 24 inches if heavy sediment load is expected, and 30 inches if heavy wire-backed fencing is used. For prefabricated fencing, use the manufacturer's recommendations for post embedment depth.
- If standard strength filter fabric is used, fasten the optional wire mesh support fence to the upslope side of the posts using heavy duty wire staples, tie wires, or hog rings. Extend the wire mesh support to the bottom of the trench. Staple or wire the filter fabric to the fence.
- Extra strength filter fabric does not require a wire mesh support fence. Staple or wire the filter fabric directly to the posts.
- Do not attach filter fabric to trees.
- Where ends of filter fabric come together, overlap, fold, and staple the ends to prevent sediment bypass.
- Where joints in the fabric are required, splice it together only at a support post, with a minimum 6 inch overlap, and securely seal the joint.
- Extend the embedded filter fabric in a flap anchored by backfill to prevent the fabric from pulling out of ground.

Maintenance

Silt fences should be inspected periodically and after runoff events for damage (such as layover or tearing by wind, animals, or equipment) and for the amount of accumulated sediment. Remove the sediment when it reaches one-half the height of the silt fence. Where access is available, machinery can be used; otherwise, the sediment should be removed manually.

- Remove sediment deposits before heavy rain or when high water is anticipated.
- Place sediment deposits in an area protected by sediment and erosion control measures and where little danger of erosion exists.
- The life span of silt fence is generally 5 to 8 months. Remove and replace damaged silt fencing.
- If the silt fence has become clogged and no longer drains, replace it or install a second silt fence either above or below the original fence to collect additional sediment.
- Do not remove the silt fence until land-disturbing activities are completed and contributing drainage areas have been stabilized. Ensure the fabric is cut at ground level; remove the wire and posts and remaining sediment; and rake, seed, and mulch the area immediately.

Additional Resources

EPA (US Environmental Protection Agency). 2012. *Silt Fences*. Stormwater Best Management Practice. *http://www.epa.gov/npdes/pubs/siltfences.pdf*

BMP 66: Sediment Basins and Traps

Description

Sediment basins and traps serve as impoundment areas to detain sediment-laden runoff long enough to allow most of the sediment to settle out. Sediment remains stored in the basin or trap until it can be removed without contaminating additional runoff. Sediment traps are smaller than sediment basins; both can be designed to maintain a permanent pool of water or to drain completely dry (Figure 160).

Sediment basins and traps can be constructed by excavation or by placing an earthen embankment across a low area or drainage swale. Both basins and traps have outlet structures that slowly release runoff and allow time for sedimentation.

Figure 160. Sediment basin designed to remain at a certain depth.

Applicability

While sediment traps and basins are suitable for most construction projects, sediment traps are most appropriate for drainage areas up to 5 acres and are commonly used below construction operations that expose critical areas to soil erosion, including at the outlet of storm water diversion structures, channels, slopes drains, or construction site entrance wash racks.

Sediment basins are appropriate for drainage areas of 5 to 100 acres and are located where a permanent storm water management structure, such as an extended detention basin (BMP 23), wet pond (BMP 22), or constructed wetland (BMP 24), is planned.

Sediment traps and basins function best when used as part of a BMP treatment train system with other erosion and sediment controls (BMP 32: Landscaping and BMP 52: Mulching) located upstream.

Primary BMP Functions and Controls

☒ Construction	☐ Permanent
☐ Erosion Control	☒ Sediment Control
☐ Source Control	☒ Flood Control
☐ Filtration	☐ Infiltration

Typical Effectiveness for Targeted Pollutants

●	Sediment
○	Phosphorus
◖	Metals
○	Bacteria
◖	Hydrocarbons
◖	Litter

Other BMP Considerations

Relative Cost	$
Maintenance Requirements	Medium
Ease of Installation	Easy
Freeze/Thaw Resistance	Fair
Max. Tributary Drainage Area	100 acres
Max. Upstream Slope	25%
NRCS Soil Group	ABCD
Min. Ground Water Separation	3 feet
Min. Bedrock Separation	6 feet

Limitations

Due to their smaller size, sediment traps are more appropriate than sediment basins in linear construction projects where space may be limited.

Sediment traps and basins should not be located within surface waters (including intermittent stream or swales) or natural buffers (BMP 2) and should not collect water from wetlands.

Sediment traps and basins may be impractical for removing very fine sediment (silt and clay) due to the long detention times and large basin size requirements for settling fine sediment. Additional measures such chemical treatment (BMP 72) may be needed for sites with fine silt and clay soils. Soils on the site should be characterized to determine their settleability.

Impounded water can create mosquito breeding habitat. Section 3.5.6 provides more information on mosquito control. Sediment basins and traps may need protective fencing to keep children and wildlife from entering the pond.

Design Basis

Location

Soil testing is the first step in determining if a sediment basin is an appropriate BMP for your site. Test soil that represents the construction site. Imported soils should also be tested. Soil types should be determined down to the deepest excavations on the project.

To capture runoff before discharging off site, locate sediment traps and basins at the downgradient end of the site and the storm water outlet. If sediment traps are formed by constructing a dam embankment, locate the traps to provide the maximum volume capacity behind the structure.

Do not locate the traps where an embankment failure would result in unsafe conditions, property damage, or interrupted use or service of public utilities or roads. Ensure sediment traps are easily accessible for maintenance, sediment removal, and inspections.

Sizing

Sediment traps, which intercept runoff from less than 5 acres, should have a minimum size of 1,800 cubic feet per acre of tributary drainage area (EPA 2014c).

Sediment basins, which generally intercept runoff from more than 5 acres but less than 100 acres, should provide storage for either (1) the calculated volume of runoff from a 2-year, 24-hour storm, (2) 3,600 cubic feet per disturbed acre drained (EPA 2012b), or (3) the volume required to settle the design particle size using the following procedure.

1. Determine the pond surface area required to trap soil particles using Equation 44:

$$A_s = 1.2Q/V_s$$

Equation 44. Pond surface area based on settling velocity.

Where

As = pond surface area (ft^2) for trapping soil particles
Q = design inflow rate (cfs) based on the runoff from the design storm event for the drainage area
Vs = settling velocity for the design soil particle (ft/s)

Unless otherwise specified by the local jurisdiction, a 2-year design storm can be used for most applications. A 10-year design storm should be used if the project size, expected timing and duration of construction, or downstream conditions warrant a higher level of protection. The particle settling velocity can be calculated using a simplified form of Stokes law (Equation 45):

$$V_s = 2.81\ d^2$$

Equation 45. Settling velocity.

Where:

V_s = settling velocity for the design soil particle at 68°F in ft/s
d = diameter of sediment particle in millimeters (mm) (smallest soil grain size determined by wet sieve analysis, or d_{15}, or 0.01 mm for fine silt)

2. Calculate the settling volume required by multiplying the surface area by the settling depth. The settling depth should be a minimum of 3 feet and a maximum of 5 feet.
3. Typically, a sediment storage depth of 3 feet is appropriate unless large volumes of soil are expected from highly erodible site conditions. In this case, use the universal soil loss equation or other applicable estimating methods to design the storage depth on a site-specific basis.
4. Determine the final pond dimensions and volume by adding a sediment storage depth of 3 feet and 3H:1V side slopes from the bottom of the basin. The bottom should have a minimum 2% slope towards the outlet.
5. Adjust the geometry of the basin to effectively combine the settling zone volume and sediment storage volume while preserving the depth and side slope criteria listed above.

As noted, particle sizes of 0.01 mm and smaller have very low V_s so the A_s becomes extremely large, often making the overall basin size requirement too large to be practical. In this case, extra protection measures, such as flocculation (BMP 72), should be taken to capture small silt and clay sediment.

Geometry

The basin or trap should have a minimum length-to-width ratio of 2:1, and ratios between 3:1 and 6:1 are preferred for basins. Runoff should enter the impoundment as far from the outlet as possible to provide maximum retention time. If the minimum length-to-width ratio cannot be achieved, design the basin with earthen baffles or other deflectors to lengthen the flow path within the basin.

For sediment traps, the side slopes should be no steeper than 3:1 and the embankment height no more than 5 feet from the original ground surface. Sediment traps should have a flat bottom.

For sediment basins, sides slopes of 4:1 or flatter is recommended with a maximum side slope of 3:1. The water surface at the crest elevation of the pipe spillway should not exceed 10 feet measured upward from the original ground to the crest elevation of the spillway. Sediment basins should have a bottom that slopes to the outlet structure; avoid using fill to shape the bottom.

Outlet Structures

Sediment traps should have an overflow spillway weir that is at least 4 feet long for a 1-acre drainage area with an additional 2 feet added for each additional drainage acre. Emergency spillways should pass peak flows from the 100-year storm safely with the low-flow sediment outlet clogged.

Sediment basins should also have an overflow spillway and a flow control outlet that ensures adequate residence time to allow particle settling. These controls can be accomplished with a perforated riser pipe or plate, or a floating skimmer. Design the outlet to drain the basin within 24 to 96 hours. The pipe spillway should be armored and discharge at ground elevation below the dam and not more than 12 inches above any streambed.

The outlet structure should withdraw water from the surface to minimize pollutant discharge; however, this situation may not be feasible in areas with extended periods of cold weather.

Erosion controls and velocity dissipation devices should be used at the outlets. Sediment trap cross sections and outlet designs are shown in Figure 161–Figure 164.

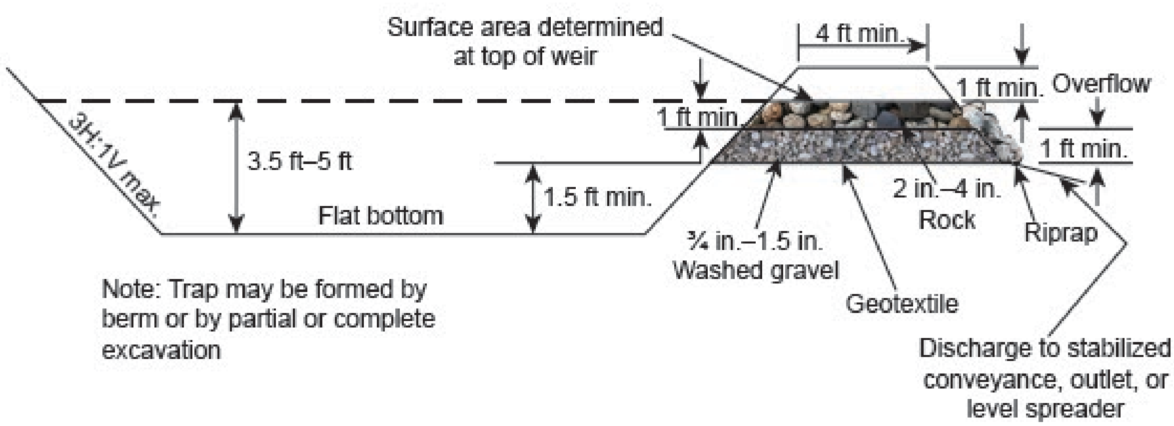


Figure 161. Sediment trap cross section (Washington State Department of Ecology 2012).

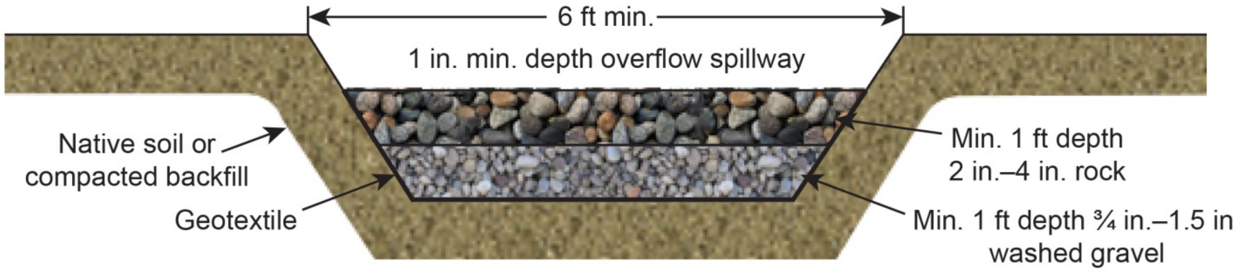


Figure 162. Sediment trap spillway outlet (Washington State Department of Ecology 2012).

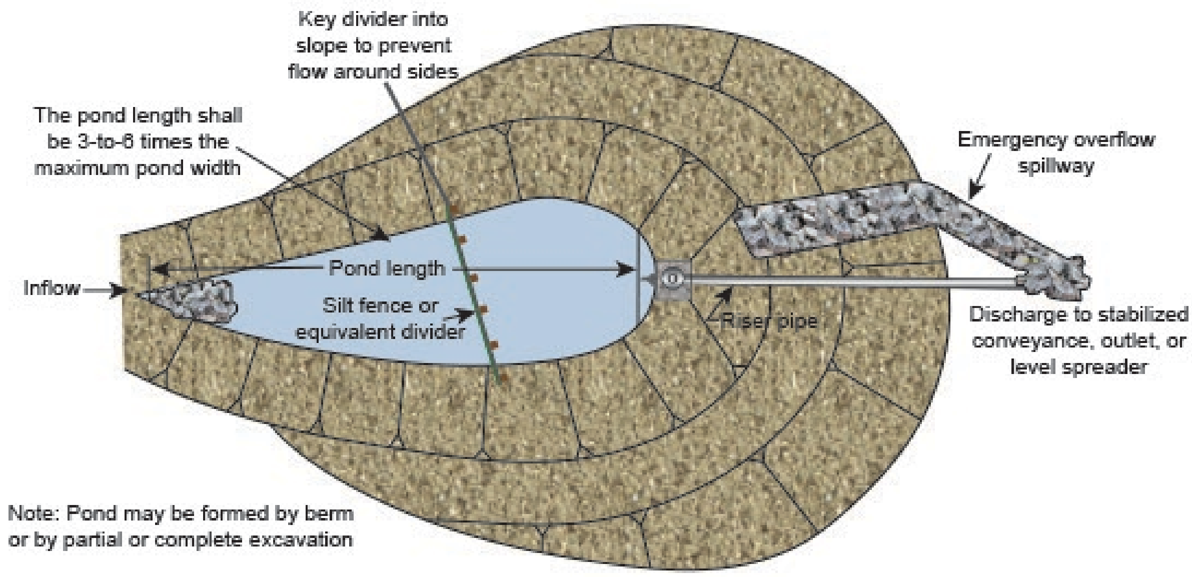


Figure 163. Sediment basin plan view (Washington State Department of Ecology 2012).

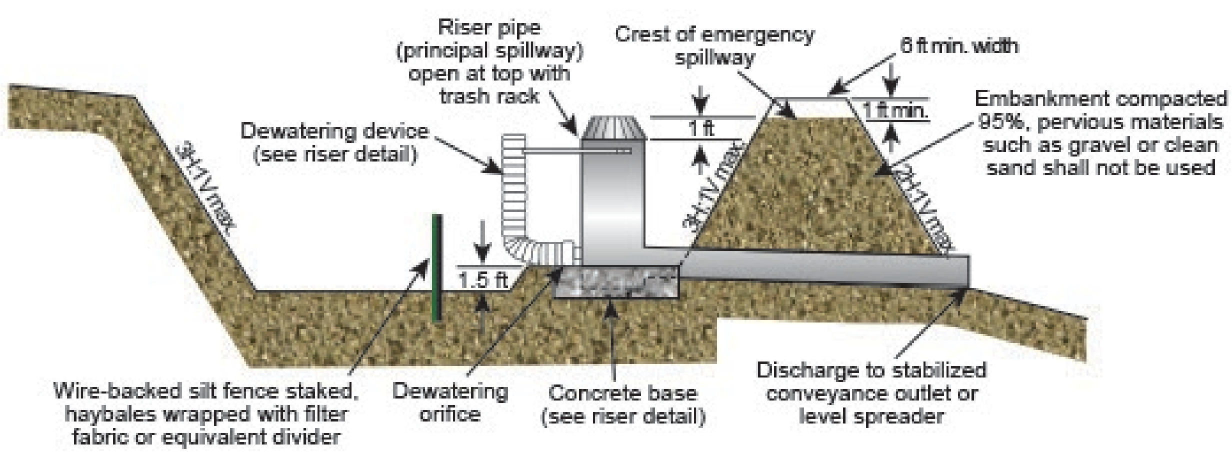


Figure 164. Sediment basin plan cross section (Washington State Department of Ecology 2012).

Construction Guidelines

Before clearing and grading, install sediment basins and traps. Fencing around the basin may be necessary for safety or to discourage vandalism.

Stabilization controls, such as erosion control matting (BMP 54) or vegetation restoration (BMP 8), should be used in the impoundment to prevent erosion, and the emergency spillway should be stabilized with riprap or other erosion control measures.

Dam Embankments

Before dam construction, prepare the dam site by clearing vegetation and removing topsoil. Topsoil should be stored on site for restoration, or if a permanent feature, to aid in revegetation of berm slopes and top. Areas under the embankment and any structural works should be cleared and grubbed, and the topsoil stripped to remove all trees, vegetation, roots, and other material unsuitable for dam construction. To facilitate clean out and restoration, clear the pool area (measured at the top of the pipe spillway) of all brush, trees, or other debris.

Fill material should be of the type and quality suitable for use as a dam embankment. Ensure the material is free of roots, woody vegetation, oversized stones, or rocks exceeding 6 inches in diameter. Do not use frozen material.

Before adding fill, scarify the areas where fill will be placed. Fill materials should be placed in 6-inch maximum lifts and compacted by construction equipment. The embankment should be raised and compacted to an elevation that provides for anticipated settlement to design elevation (allow at least 10% for settlement). Lifts should be continuous over the entire length of the fill and approximately horizontal.

Outlet

Level the bed for the pipe spillway to provide uniform support through its entire length under the dam. All pipe joints should be securely fastened and watertight. The riser should be rigidly and securely fastened to the barrel and the bottom of the riser should be sealed (watertight). The barrel should be placed on a firm foundation according to the lines and grades shown on the plans.

Construct an emergency spillway (as per design) on undisturbed soil—not on fill. The design width and entrance/exit channel slopes are critical to the spillway's ability to successfully protect the dam with a minimum of erosion hazard in the spillway channel. Place at least 1 foot of hand-compacted backfill (maximum 6-inch lifts) over the pipe spillway before allowing construction equipment to cross. Control movement of the hauling and spreading equipment over the fill so the entire surface of each lift will be traversed by not less than one tread tract of the equipment.

Maintenance

Sediment basins and traps should be inspected after each rainfall event and accumulated sediment should be removed to maintain at least one-half of the design capacity at all times. The sediment maintenance volume should be determined and marked before the basin is used.

Regularly inspect embankments for stability and seepage, and clean riser pipes and filter cloth as necessary to deal with clogging and to maintain good drainage from the basin. If gravel is used around the outlet pipe, remove, clean and replace the material as necessary to maintain outlet function.

Removed sediment should be disposed of and stabilized in an approved location so it does not reenter waters of the United States. Sediment may not be dumped into any water of the United States without appropriate permitting.

Sediment basins and traps should remain in operation and be properly maintained until vegetation, or other measures, permanently stabilize the upstream drainage area. Once the area is stabilized, the sediment basin or trap can either be regraded and stabilized with vegetation or, after sediment is removed, converted to a permanent detention basin and reconfigured to meet final design requirements for the permanent facility.

Additional Resources

CASQA (California Stormwater Quality Association). 2015. *California Stormwater Best Management Practices Handbook: Construction.* Menlo Park, CA. *https://www.casqa.org*

Colorado UDFCD (Colorado Urban Drainage and Flood Control District). 2010. *Urban Storm Drainage Criteria Manual, Volume 3 Best Management Practices*. Denver, CO. *http://udfcd.org/wp-content/uploads/2014/07/Title-Page.pdf*

EPA (US Environmental Protection Agency). 2012. *EPA Construction General Permit*. Water: Stormwater. *https://www.epa.gov/npdes/national-menu-best-management-practices-bmps-stormwater#edu*

EPA (US Environmental Protection Agency). 2014. *Sediment Basins and Rock Dams.* Water: Best Management Practices. *https://www.epa.gov/npdes/national-menu-best-management-practices-bmps-stormwater#edu*

EPA (US Environmental Protection Agency). 2014. *Sediment Traps*. Water: Best Management Practices. *http://water.epa.gov/polwaste/npdes/swbmp/Sediment-Traps.cfm*

Fifield, J.S. 2001. *Designing for Effective Sediment and Erosion Control on Construction Sites*. Santa Barbara, CA: Forester Press.

BMP 67: Portable Sediment Tank

Description

Sediment tanks are compartmented containers where sediment-laden water is pumped and held until the sediment settles out by gravity (Figure 165). The treated water can then be discharged to another BMP, storm drainage system, or sanitary sewer system as allowed by state, local, and federal regulations.

Figure 165. Portable sediment tank.

Applicability

Portable sediment tanks can be used on any construction site and are well suited where space is limited, such as in urban settings with inadequate room for a sedimentation basin or trap (BMP 66).

Limitations

Portable sediment tanks are a relatively expensive method to store and treat site runoff due to the materials, equipment, and electricity required. In addition, they require a flat surface for installation.

Design Basis

Design and sizing of sediment tanks should follow the manufacturer's recommendations. Also consider the following guidelines:

- The sediment tank should be located to maximize ease of clean out and disposal of the trapped sediment and to minimize interference with construction activities and pedestrian traffic.
- The required storage volume depends on the expected flows into the tank and capacity of the pump and downstream conveyances.
- A wide variety of container designs may be used if the storage volume is adequate and approval is obtained from the local regulating authorities.
- Depending on the physical characteristics of the soil and sediment, the sediment removal efficiency of the sediment tank can be

Primary BMP Functions and Controls

☒ Construction	☐ Permanent
☐ Erosion Control	☒ Sediment Control
☐ Source Control	☐ Flood Control
☐ Filtration	☐ Infiltration

Typical Effectiveness for Targeted Pollutants

◐	Sediment
○	Nitrogen
○	Phosphorus
◐	Metals
○	Bacteria
○	Hydrocarbons
○	Litter

Other BMP Considerations

Relative Cost	$$$
Maintenance Requirements	Medium
Ease of Installation	Easy
Freeze/Thaw Resistance	Poor
Max. Tributary Drainage Area	Unlimited
Max. Upstream Slope	NA
NRCS Soil Group	NA
Min. Ground Water Separation	NA
Min. Bedrock Separation	NA

increased by using flocculation chemicals, such as aluminum sulfate. A flocculation tank setup accrues additional costs, may require additional permitting, and is considerably more complicated because the rate of flocculent addition must be carefully monitored (BMP 72).

- Discharge from the tank should not cause downstream erosion. Stabilize the outlet pipe as necessary to prevent erosion (BMP 35) and cover it with a filter cloth to prevent sediment from leaving the tank.

Construction Guidelines

The manufacturer's specifications should be followed before, during, and after construction.

Maintenance

Portable sediment tanks should be inspected during and after each storm event. Pay special attention to the outlet structure during inspections. Sediment collected in the tanks should be removed and properly disposed of according to applicable state and federal regulations.

All portable sediment tanks should be inspected and maintained during the life of the project according to the manufacturer's specifications. Continue maintenance and inspection until permanent stabilization measures are in place, then the temporary control measures may be removed.

Additional Resources

NY DOT (New York State Department of Transportation). 2014. *New York State Department of Transportation Stormwater Management Program Plan*. *https://www.dot.ny.gov/divisions/engineering/environmental-analysis/repository/SWMPP_June2014.pdf*

BMP 68: Temporary Swale

Description

To reduce erosion and sedimentation, keep off-site storm water runoff from entering the work area during construction. Runoff generated on site containing sediments should not leave the construction site. A temporary swale is an excavated drainage designed to convey sediment laden-water to a sediment-trapping device or prevent runoff from entering disturbed areas by intercepting and diverting off-site flow to a stabilized outlet (Figure 166).

Figure 166. Roped off swale area.

Temporary swales often have limited applicability unless the excavated channel is sufficiently stabilized so it does not erode under flowing water conditions. An alternative to an excavated swale might be diversions placed on undisturbed ground that direct run-on water to a pipe or other collection device. Clean run-on water is kept clean as it is conveyed through the construction site or diverted so it does not enter the site. Keep run-on water clean to reduce on-site BMP quantity, maintenance, and expense.

Primary BMP Functions and Controls

☒ Construction	☐ Permanent
☒ Erosion Control	☒ Sediment Control
☐ Source Control	☐ Flood Control
☐ Filtration	☐ Infiltration

Typical Effectiveness for Targeted Pollutants

●	Sediment
○	Nitrogen
○	Phosphorus
◖	Metals
○	Bacteria
◖	Hydrocarbons
○	Litter

Other BMP Considerations

Relative Cost	$
Maintenance Requirements	Low
Ease of Installation	Easy
Freeze/Thaw Resistance	Fair
Max. Tributary Drainage Area	10 acres
Max. Upstream Slope	14%
NRCS Soil Group	BCD
Min. Ground Water Separation	3 feet
Min. Bedrock Separation	5 feet

Applicability

Temporary swales can be used on most construction sites in the following situations:

- Installed above a disturbed area to divert flows and reduce runoff.
- Installed below a disturbed area to convey runoff to a sediment trapping device.
- To reduce the amount and velocity of runoff over a large slope face.
- To transport off-site flows across a disturbed area such as a right-of-way.

Limitations

Improper construction of temporary swales may contribute to erosion by concentrating flow and/or adding sediment and turbidity to the storm water. In areas with highly erodible soils, high flows, or steep slopes it may be necessary to use additional soil stabilization or alternative BMPs.

The swale channel should be stabilized with geotextile fabric or other erosion control BMPs to keep run-on water clean.

Design Basis

Unless otherwise stated by local drainage design criteria, temporary swales should conform to predevelopment drainage capacities and should not be overtopped by the peak discharge from a 10-year design storm. Table 36 and Figure 167 provide guidance for designing temporary swales:

Table 36. Temporary swale design guidance.

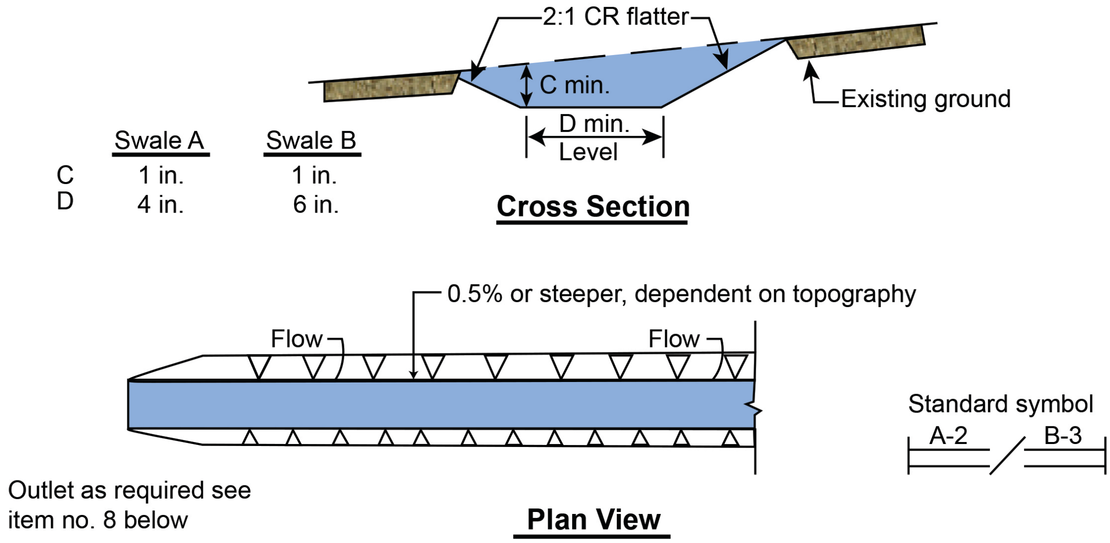
Description	Swale A	Swale B
Drainage area	5 acres or less	5–10 acres
Bottom width of flow channel	4 feet	6 feet
Depth of flow channel	1 foot	1 foot
Side slopes	2:1 or flatter	2:1 or flatter
Minimum grade	0.50%	0.50%
Maximum grade	15%	15%

Temporary swales should not cause additional soil erosion. Temporary swales require additional sedimentation controls such as check dams (BMP 60), velocity dissipation (BMP 35), and temporary channel liners (BMP 61). To account for highly erodible soils, refer to the next higher channel grade stabilization recommendations provided in Table 37.

Table 37. Flow channel stabilization criteria.

Type of Treatment	Channel grade (%)	Flow Channel A (less than 5 acres)	Flow Channel B (5–10 acres)
1	0.5–3.0	Cover with channel liners	Cover with channel liners
2	3.1–5.0	Cover with channel linersor line with 2-inch stone	Cover with channel linersor line with 2-in. stone
3	5.1–8.0	Cover with channel linersor line with 2-inch stone	Line with 4 to 8-inch stone
4	8.1–20	Line with 4 to 8-inch stone	Engineering design

If a temporary swale will be used in the permanent construction plan to convey site runoff, it should be designed and certified by a licensed professional engineer. Swales used to divert flows from a fully stabilized and undisturbed area may not need a downstream sediment-trapping device but should have a stabilized outlet.



Construction Specifications

1. All temporary swales shall have uninterrupted positive grade to an outlet.
2. Diverted runoff from a disturbed area shall be conveyed to a sediment trapping device.
3. Diverted runoff from an undisturbed area shall outlet directly into an undisturbed stabiled area at nonerosive velocity.
4. All trees, brushes, stumps, obstructions, and other objectionable material shall be removed and disposed of so as not to interfere with the proper functioning of the swale.
5. The swale shall be excavated or shaped to line, grade, and cross section as required to meet the criteria specified herein and be free of bank projections or other irregularities that will impede normal flow.
6. Fills shall be compacted by earth-moving equipment.
7. All earth removed and not needed on construction shall be placed so that it will not interfere with the functioning of the swale.
8. Stabilization shall be as per the chart below.

Figure 167. Temporary swale design guidance.

Construction Guidelines

Construct temporary swales before earth-disturbing activities begin. The swale should be stabilized within 10 days of installation with proper seeding (BMP 32) and mulching techniques (BMP 52). Construction traffic over temporary swales should be minimized and eliminated when possible.

Temporary swales should remain in place until after the contributing drainage area is stabilized. If the swale is not part of the permanent construction plan, remove it after construction is completed.

Maintenance

Temporary swales should be inspected before and after rain events, daily during extended events, and weekly during the rainy season. During dry weather periods, inspect swales bimonthly for

signs of erosion and slope instability. Repair damaged areas and remove sediment and debris immediately.

Swales stabilized with vegetation should be mowed regularly to encourage thicker, healthier growth. Minimize fertilizer use because excess nutrients may compound water quality problems.

Additional Resources

CASQA (California Stormwater Quality Association). 2015. *California Stormwater Best Management Practices Handbook: Construction.* Menlo Park, CA. *https://www.casqa.org*

Colorado UDFCD (Colorado Urban Drainage and Flood Control District). 2010. *Urban Storm Drainage Criteria Manual, Volume 3 Best Management Practices*. Denver, CO. *http://udfcd.org/wp-content/uploads/2014/07/Title-Page.pdf*

EPA (US Environmental Protection Agency). 2020. *Temporary Diversion Dikes.* Water: Best Management Practices. *http://water.epa.gov/polwaste/npdes/swbmp/Temporary-Diversion-Dikes.cfm*

Hazra and ODOT (Hazra Engineering Company and Oregon Department of Transportation, Geo/Environmental Section). 2005. *ODOT Erosion Control Manual: Guidelines for Developing and Implementing Erosion and Sediment Controls.*

ITD (Idaho Transportation Department). 2014. *Best Management Practices.* Boise, ID: ITD.

King County (King County, Washington). 2009. *King County, Washington Surface Water Design Manual.* Seattle, WA: King County, Department of Natural Resources.

Washington State Department of Ecology. 2012. *Stormwater Management Manual for Western Washington*. Lacey, WA. Publ. 12-10-030. *http://www.ecy.wa.gov/programs/wq/stormwater/manual.html*

BMP 69: Diversion Dike

Description

Diversion dikes are temporary berms, often excavated from an adjoining temporary swale (BMP 68), used to channel water to a desired location. Diversion dikes protect construction areas from upslope runoff and divert on-site sediment-laden water to sedimentation trapping devices or stable outlets (Figure 168).

A diversion dike located on the perimeter of a site prevents off-site storm water runoff from entering a disturbed area and prevents sediment-laden storm water runoff from leaving the construction site or disturbed area. The outside slope of a perimeter dike that blocks clean off-site water must have a nonerosive surface.

Figure 168. Earth dike diverting flows at a construction site (CALTRANS 2003).

Primary BMP Functions and Controls

☒ Construction ☐ Permanent
☒ Erosion Control ☒ Sediment Control
☐ Source Control ☐ Flood Control
☐ Filtration ☐ Infiltration

Typical Effectiveness for Targeted Pollutants

◖ Sediment
○ Phosphorus
○ Metals
○ Bacteria
○ Hydrocarbons
○ Litter

Other BMP Considerations

Relative Cost	$
Maintenance Requirements	Low
Ease of Installation	Easy
Freeze/Thaw Resistance	Fair
Max. Tributary Drainage Area	10 acres
Max. Upstream Slope	10%
NRCS Soil Group	BCD
Min. Ground Water Separation	5 feet
Min. Bedrock Separation	5 feet

Applicability

Diversion dikes can be used on most construction sites in the following situations:

- Installed above a disturbed area to divert flows and reduce runoff.
- Installed below a disturbed area to convey runoff to a sediment trapping device.
- To reduce amount and velocity of runoff flow over a large slope face.
- At or near the perimeter of a construction area to keep sediment-laden runoff from leaving the site.
- To prevent flooding from adjacent water bodies by installing along roadways and construction site borders.
- For slopes greater than 10% consider using other types of storm drain diversions, such as a pipe slope drain (BMP 57).

Limitations

- Despite the simplicity of an earth-constructed diversion dike, improper design can limit effectiveness and contribute to erosion and flood damage by concentrating flow.

- Earth dikes may create additional disturbed area on site and create barriers to construction equipment.
- Earth dikes should not be constructed on easily eroded soils or on steep slopes unless soil stabilization practices are used.
- When the drainage area above the earth or perimeter dike is greater than 10 acres, consult the NRCS standards and specifications for diversions.

Design Basis

Diversion dikes are often constructed of compacted soil or coarse aggregate. If a swale is used with the dike, it should have a positive grade to a stabilized outlet. To protect against erosion, stabilize the channel with erosion control matting or other stabilization measures as outlined in BMP 68: Temporary Swale. For shallower slopes (less than 5%), stabilization may be achieved with matting (BMP 54) or mulching (BMP 52) techniques. For steeper slopes (greater than 5%) or high flow velocities, additional stabilization and erosion prevention techniques such as check dams (BMP 60), velocity dissipation (BMP 35). and temporary channel liners (BMP 61) should be incorporated into the design.

Dikes with and without swales that will be part of a permanent drainage plan should be designed by a licensed professional engineer. Dikes and swales that are part of the permanent infrastructure for the site can be stabilized long term with landscaping, seeding, and sodding (BMP 32).

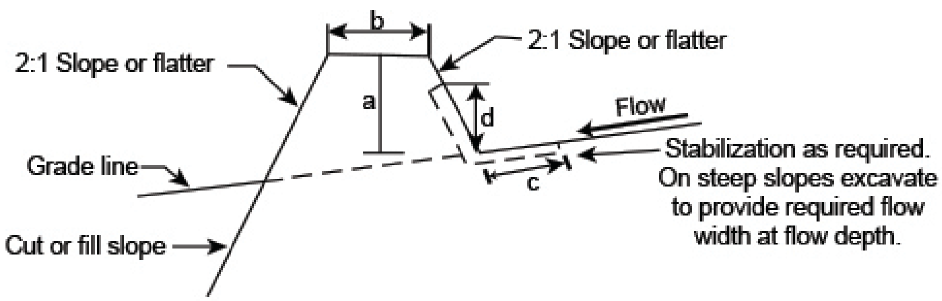
Diversion dikes that convey runoff from disturbed areas should be diverted to a sediment-trapping device. Runoff from undisturbed areas can be channeled to an existing or temporary swale (BMP 68) or to a level spreader (BMP 30).

Table 38 and Figure 169 provide design criteria for earthen diversion dikes, and Figure 170 provides criteria for earth and perimeter dikes. Any perimeter dike/swale should not be constructed outside the property lines without obtaining legal easements from adjacent property owners.

Diversion dikes can also be constructed using other materials, such as jersey barriers with bottom weep holes plugged or piping, which may not have the same erosion potential as earth dikes.

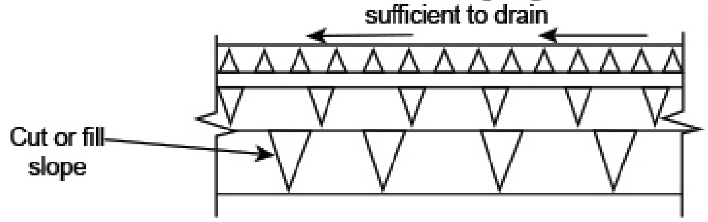
Table 38. Suggested diversion dike design criteria.

Description	Dike A	Dike B
Drainage area	5 acres or less	5–10 acres
Dike height	18 inches	3 feet
Dike width	2 feet	3 feet
Flow width	4 feet	6 feet
Flow depth in channel	8 inches	15 inches
Side slopes	2:1 or flatter	2:1 or flatter

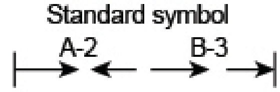


Cross Section

	Dike A (5 ac. or less)	Dike B (5-10 ac.)
a - Dike Height	18 in.	36 in.
b - Dike Width	24 in.	36 in.
c - Flow Width	4 ft	6 ft
d - Flow Dept	8 in.	15 ft



Standard symbol



Construction Specifications

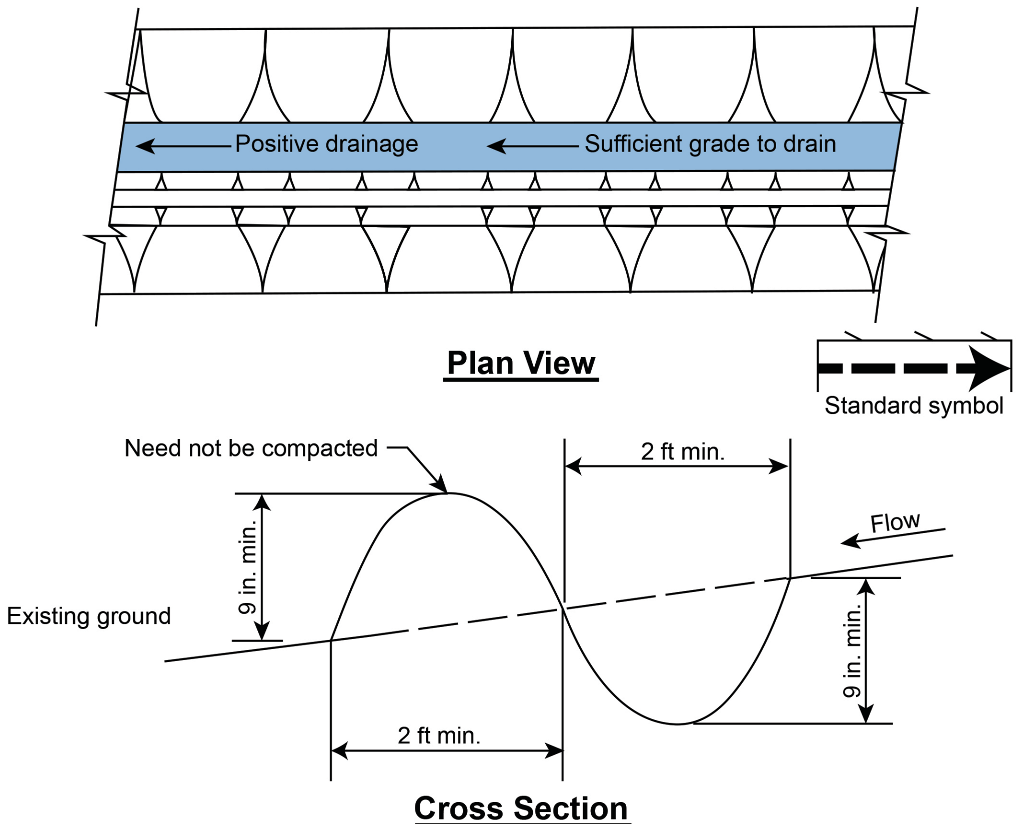
1. All dikes shall be compacted by earth-moving equipment.
2. All dikes shall have positive drainage to an outlet.
3. Top width may be wider and side slopes may be flatter if desired to facilitate crossing by construction traffic.
4. Field location should be adjusted as needed to utilize a stabilized safe outlet.
5. Earth dikes shall have an outlet that functions with a minimum of erosion. Runoff shall be conveyed to a sediment trapping device such as a sediment trap or sediment basin where either the dike channel or the drainage area above the dike are not adequately stabilized.
6. Stabilization shall be: (A) in accordance with standard specifications for seed and straw mulch or straw mulch if not in seeding season. (B) Flow channel as per the chart below.

Flow Chart Stabilization

Type of Treatment	Channel Grade	Dike A	Dike B
1	0.5–3.0%	Seed and straw mulch	Seed and straw mulch
2	3.1–5.0%	Seed and straw mulch	Seed using jute or excelsior; sod; 2 in. stone
3	5.1–8.0%	Seed with jute or sod; 2 in. stone	Lined riprap 4 in.–8 in.
4	8.1–20%	Lined riprap 4 in.–8 in.	Engineering design

7. Periodic inspection and required maintenance must be provided after each rain event.

Figure 169. Earth dike design criteria.



Construction Specifications

1. All perimeter dike/swale shall have uninterrupted positive grade to an outlet.
2. Diverted runoff from a disturbed area shall be conveyed to a sediment trapping.
3. Diverted runoff from an undisturbed area shall outlet into an undisturbed stabilized are at non-erosion velocity.
4. The swale shall be excavated or shaped to line. Grade and cross section as required to meet the criteria specified in the standard.
5. Stabilization of the area disturbed by the dike and swale shall be done in accordance with the standard and specification for seed and straw mulch, and shall be done within 10 days.
6. Periodic inspection and required maintenance must be provided after each rain event.
7. Maximum drainage area limit: 2 acres

Figure 170. Perimeter dike design criteria.

Construction Guidelines

Install the dike before the majority of soil-disturbing construction activity begins. Earth and perimeter dikes should be properly compacted with earth-moving equipment and stabilized at least 10 days after installation. Stabilized outlets should be provided at the terminus of earth and perimeter dikes. Construction traffic over earth and perimeter dikes should be minimized and eliminated when possible.

If not part of the permanent drainage plan, completely remove temporary earth and perimeter dikes after the contributing drainage area is stabilized or when construction is completed.

Maintenance

Inspect dikes before and after rain events, daily during extended events, and weekly during the rainy season. During dry weather periods, inspect dikes bimonthly and look for signs of erosion and slope instability. Check outlets at each inspection and repair as needed to avoid gully formation.

Repair damage to the dike and associated flow channel immediately. Remove sediment and debris regularly. Reseed/stabilize the dike as needed to maintain its stability irrespective of wet or dry weather periods. If material must be added to the dike, ensure it is properly compacted by earth-moving equipment.

Mow vegetation regularly to encourage thicker, healthier growth. Minimize fertilizer use because excess nutrients may compound water quality problems.

Additional Resources

CASQA (California Stormwater Quality Association). 2015. *California Stormwater Best Management Practices Handbook: Construction.* Menlo Park, CA. *http://www.casqa.org.*

Colorado UDFCD (Colorado Urban Drainage and Flood Control District). 2010. *Urban Storm Drainage Criteria Manual, Volume 3 Best Management Practices*. Denver, CO. *http://udfcd.org/wp-content/uploads/2014/07/Title-Page.pdf*

EPA (US Environmental Protection Agency). 2020. *Temporary Diversion Dikes.* Water: Best Management Practices. *http://water.epa.gov/polwaste/npdes/swbmp/Temporary-Diversion-Dikes.cfm*

Washington State Department of Ecology. 2012. *Stormwater Management Manual for Western Washington*. Lacey, WA. Publ. 12-10-030. *http://www.ecy.wa.gov/programs/wq/stormwater/manual.html*

BMP 70: Temporary Berms

Description

A temporary berm is a storm drain diversion with a ridge of compost, gravel bags, or sandbags that redirects runoff contributing to a storm drain line or outfall channel so that it may temporarily discharge into a sediment-trapping device (Figure 171). Temporary berms can also reduce the flow velocity of runoff, partially release the runoff as sheet flow, and provide some sediment removal.

Figure 171. Gravel bag berm (*Natural Building Blog*).

Applicability

Use diversions whenever construction site runoff would otherwise contribute sediment-laden water to a watercourse or to a storm water system that was not originally designed to handle increased pollutant load.

Temporary berms can be used to divert runoff away from newly constructed slopes until vegetation is established or until permanent measures are in place. Temporary berms are most appropriate in areas that have sheet flow drainage characteristics and where perimeter control is needed:

- Along the perimeter of a construction project site
- Downslope of exposed soil areas
- Around temporary stockpiles
- Downslope of paved surfaces

Gravel bag barriers can also be used where flows are moderately concentrated such as in ditches, swales, and around storm drain inlets.

Primary BMP Functions and Controls

☒ Construction	☐ Permanent
☒ Erosion Control	☒ Sediment Control
☐ Source Control	☐ Flood Control
☐ Filtration	☐ Infiltration

Typical Effectiveness for Targeted Pollutants

◖	Sediment
○	Nitrogen
○	Phosphorus
○	Metals
○	Bacteria
○	Hydrocarbons
◖	Litter

Other BMP Considerations

Relative Cost	$
Maintenance Requirements	Low
Ease of Installation	Easy
Freeze/Thaw Resistance	Good
Max. Tributary Drainage Area	5 acres
Max. Upstream Slope	50%
NRCS Soil Group	ABCD
Min. Ground Water Separation	NA
Min. Bedrock Separation	NA

Limitations

Do not use temporary berms for drainage areas greater than 5 acres or for contributing slopes steeper than 5%. For larger areas, a more permanent structure should be used. Temporary berms by themselves do not control erosion or remove significant quantities of sediment from runoff and should be used as part of a treatment train. Additional limitations include the following:

- Diverted flow may increase in volume and velocity causing downstream erosion. Additional BMPs may be needed with temporary berms.
- Installation can be labor intensive and costly, especially for gravel bag berms.
- Compost berms may leach nutrients, such as dissolved phosphorous and nitrogen, and should not be used in areas that drain to phosphorous-sensitive water bodies. When compost berms are no longer needed, immediately use the berms to amend the soil in preparation for landscaping (BMP 32).
- Burlap bags for gravel or sand have limited durability for long-term projects. Degraded bags that rupture when removed can increase pollutant load when the contents spill.
- Diversions will likely require approval from local officials.
- Storm drain diversions should not increase the existing downgradient sediment load.

Design Basis

General Guidelines

When applying a storm drain diversion technique, one of the following approaches may be used;

- **Off-line diversion** of sediment-laden runoff requires constructing a temporary sediment trap (BMP 66) at the outlet location of the diverted flow.
- **In-line diversion** within a storm drain is achieved by temporarily blocking the permanent outfall and installing a temporary outfall ditch or pipe. The temporary outfall conveys storm water flow to a sediment trap or basin. The diversion may be implemented at any point above a permanent outfall or before connecting into an existing storm drain system.
- **Delayed outfall completion** of a permanent storm drain outfall when constructing a new storm water system to temporarily divert storm water flow into a sediment trap (BMP 66), diversion dike (BMP 69), or temporary swale (BMP 68). The chosen BMP should be constructed to one side of the proposed permanent storm drain location whenever possible.

The following sections include general design criteria for compost berms, gravel bag berms, and sandbag berms.

Compost Berm

Compost filter berms perform most effectively when constructed approximately 1–1.5 feet high x 2–3 feet wide with a maximum spacing of 20 feet

Materials used in compost berms can be selected to target site-specific objectives in capturing sediment and other pollutants or supporting vegetation. Ensure the acquired compost is free of weeds and invasive species because compost berms contain constituents that may adversely affect water quality in receiving water bodies. The compost should meet the parameters in Table 39. Determine whether the receiving water bodies are impaired for specific contaminants that may be present in compost (e.g., sediment and nutrients). Table 39 provides recommendations on selecting the best compost for use in filter berms.

Table 39. Compost filter berm material parameters (adapted from Alexander 2003).

Parameters	Filter Berm to be Vegetated	Filter Berm to be Left Unvegetated
pH	5.0–8.5	NA
Soluble salt concentration (electrical conductivity in dS/m)	Maximum 5	NA
Moisture content (%, wet weight basis)	30–60	30–60
Organic matter content (%, dry weight basis)	25–65	25–100
Particle size (% passing a selected mesh size, dry weight basis)	3 inches, 100% passing 1 inch, 90% to 100% passing 3/4 inch, 70% to 100% passing 1/4 inch, 30% to 75% passing Maximum particle size length of 6 inches (no more than 60% passing 1/4 inch in high rainfall/flow rate situations)	3 inches, 100% passing 1 inch, 90% to 100% passing 3/4 inch, 70% to 100% passing 1/4 inch, 30% to 75% passing Maximum particle size length of 6 inches (no more than 50% passing 1/4 inch in high rainfall/flow rate situations)
Stability Carbon dioxide evolution rate	<8	NA
Physical constraints (man-made inerts)	<1	<1

Notes: deciSiemens per meter (dS/m)

Sandbag and Gravel Bag Berms

The following design criteria are suitable for sandbag and gravel bag berms (Figure 172).

Berm dimensions:

- Height—20 inches minimum
- Top width—20 inches minimum
- Bottom width—approximately 4.25 to 5 feet
- Bag size–length 2 to 2.6 feet, width 16 to 20 inches, depth or thickness 6 to 8 inches

Bag material should be woven polypropylene, polyethylene, or polyamide fabric, minimum unit weight 4 ounces per square yard; mullen burst strength exceeding 300 psi (ASTM D3786); and ultraviolet stability exceeding 70% (ASTM D4355).

Fill material for sandbag berms should be clean and free from clay balls, organic matter, and other deleterious materials that could leach from the bag. The filled bags should be between 88 to 132 pounds in mass.

Bag material for gravel bag berms should meet the same design considerations as sandbag berms. Fill material for gravel bag berms should be between 0.4 and 0.8 inch in diameter and clean and free from clay balls, organic matter, and other deleterious materials. The filled bags should be between 28 and 48 pounds in mass.

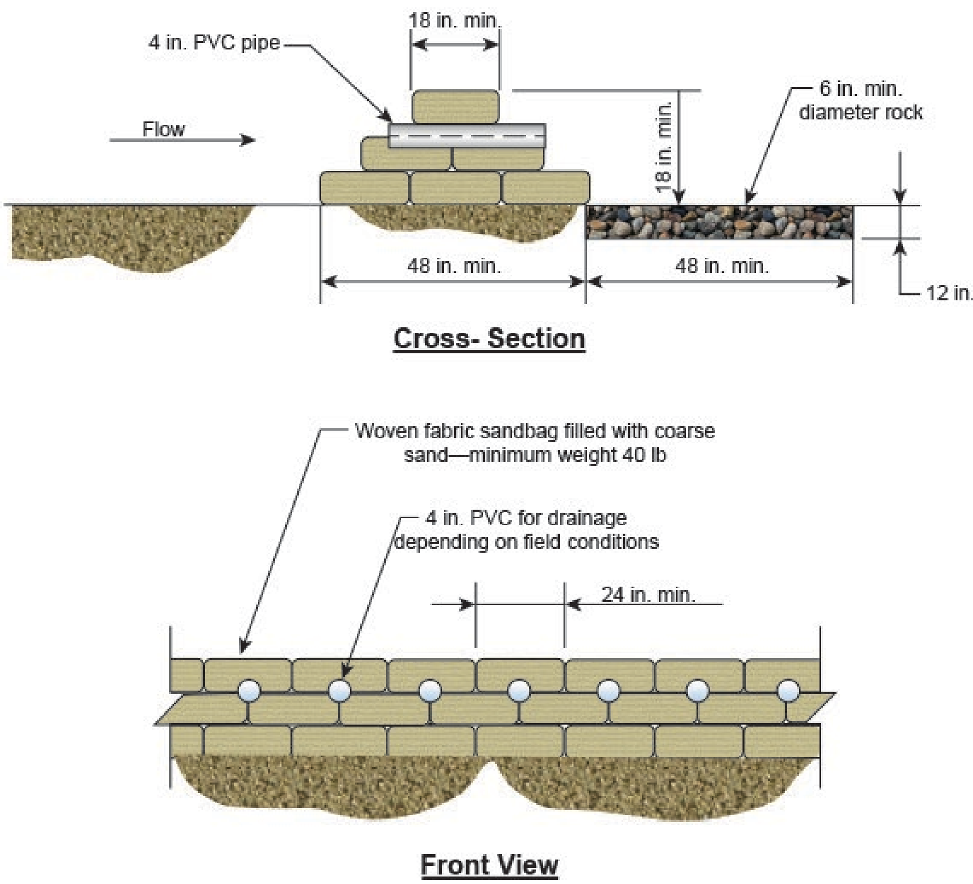


Figure 172. Sandbag berm.

Construction Guidelines

General Guidelines

When the areas contributing sediment to the system have been stabilized, follow the procedures below to restore the system to its planned use.

- Flush the storm drain system to remove any accumulated sediment.
- Remove the sediment control devices, such as traps, basins, dikes, and swales.
- For sites where an inlet was modified, seal the temporary diversion orifice and open the permanent outfall pipe.
- Establish a permanently stabilized outfall channel as noted on the plans.
- Restore the area to grades shown on the plan and stabilize with vegetative measures.
- For basins that will be converted from a temporary to a permanent storm water management measure, remove the accumulated sediment, determine outlets are as designed, and seed all disturbed areas to permanent vegetation.

Temporary berms should be constructed along a level contour when used as a perimeter sediment control device. Turn ends of the berm row upslope in a J-hook fashion to prevent flow around the

ends. At the toe of slopes, place berms 5 to 10 feet away from the toe or as far from the toe as practicable.

Compost Berm

Compost berms may be left in place or spread evenly after construction is completed to revegetate and augment on-site soil. Depending on desired usage, compost can be preseeded before placement as a berm or seeded postconstruction. Allowing compost BMPs to remain in place following construction may be advantageous for sensitive areas and stream buffer zones as they can limit the reentry of heavy construction equipment.

Sandbag and Gravel Bag Berms

Sandbag and gravel bag berms should be installed to prevent flow under or between bags. Stack bags in an interlocking fashion to provide additional strength for resisting the force of the flowing water. Do not stack sandbags more than three high without broadening the foundation using additional sandbags or providing additional stability.

Maintenance

- Establish an ongoing maintenance program to ensure the system functions properly.
- Inspect storm water diversion systems and remove debris within 24 hours after each rainfall event as heavy storms may clog or damage the system.
- Periodically inspect temporary diversion structure outfalls and after each major storm for any visible erosion.
- Periodically inspect and maintain compost berms to ensure unwanted vegetation is eliminated before it is established.
- Reshaped or replace sandbags and gravel bags as needed during inspection. When sediment reaches 6 inches deep, remove and properly dispose of the accumulated sediment.
- Leave temporary berms in place until all protected areas are stabilized, then remove the berms to avoid creating additional sediment loads. Remove sandbags and gravel bags by hand to prevent damage from heavy equipment.

Additional Resources

Alexander, R. *Standard Specifications for Compost for Erosion/Sediment Control (Filter Berms)*. 2003. Specification MP 9-03. American Association of State Highway and Transportation (AASHTO) Provisional Standards Manual. Apex, NC: R. Alexander Associates, Inc. *http://compostingcouncil.org/admin/wp-content/plugins/wp-pdfupload/pdf/32/AASHTO-Specifications.pdf*

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New York State DEC (New York State Department of Environmental Conservation). 2005. *New York State Standards and Specifications for Erosion and Sediment Control*. Albany, NY: Division of Water. *http://www.dec.ny.gov/chemical/29066.html*

ODEQ (Oregon Department of Environmental Quality). 2013. *Construction Stormwater Best Management Practices Manual*. 1200-C NPDES General Permit. Portland, ID: ODEQ.

BMP 71: Turbidity Curtains

Description

With the proper use of erosion and sediment control BMPs, sediment should not enter waters of the United States. However, for construction work that must occur within or immediately adjacent to a water body, the increase in turbidity should be addressed. Turbidity curtains, or silt curtains or particle curtains, contain and settle sediment within lakes, rivers, and other water bodies (Figure 173).

Figure 173. Sediment trapped inside a turbidity curtain.

A turbidity curtain consists of vertically suspended material that hangs from floats along its top and ballast weights at its bottom. The curtains can completely contain sediment and water within a specific area or prevent sediment from moving past the curtain, allowing time for suspended sediment to settle to the bottom of the water body.

Applicable federal, state, and local permits must be obtained before any construction within waters of the United States or use of a silt curtain where pollutants will be added to the water inside the curtain. A silt fence (BMP 65) or silt fence material ***cannot*** be used as a silt curtain; these two BMPs function very differently and are not interchangeable.

Primary BMP Functions and Controls

☒ Construction	☐ Permanent
☐ Erosion Control	☒ Sediment Control
☐ Source Control	☐ Flood Control
☐ Filtration	☐ Infiltration

Typical Effectiveness for Targeted Pollutants

●	Sediment
○	Phosphorus
○	Metals
○	Bacteria
○	Hydrocarbons
◖	Litter

Other BMP Considerations

Relative Cost	$
Maintenance Requirements	Low
Ease of Installation	Medium
Freeze/Thaw Resistance	Fair
Max. Tributary Drainage Area	N/A
Max. Upstream Slope	N/A
NRCS Soil Group	N/A
Min. Ground Water Separation	N/A
Min. Bedrock Separation	N/A

Applicability

Turbidity curtains can be used within rivers, streams, lakes, reservoirs, or other water bodies that are downstream or adjacent to projects that involve ground disturbance, dredging, or filling within or immediately adjacent to a waterway. Project examples include bridge construction, dam removal and restoration, or pipeline crossings.

Limitations

Do not install turbidity curtains within water bodies unless they are specifically engineered to withstand expected water velocity, wind and boat wakes, and

are approved by appropriate local, state, and/or federal authorities. The curtains are not recommended for operations in the open ocean.

Design Basis

Turbidity curtains should be designed and selected for specific site conditions. For sites with flow velocities or currents greater than 5 feet per second, a qualified engineer and product manufacturer should approve of the use (Figure 174).

Many proprietary turbidity curtains are available, and only curtains successfully field tested by the manufacturer should be used. Follow the manufacturer's recommendations for designing and deploying silt curtains. Many manufacturers and state transportation departments classify turbidity curtains into three categories:

- Type I—For small inland lakes, ponds, and canals with calm conditions and no current, sheltered from wind and waves
- Type II—For rivers, lakes, and streams with moving water and moderate current (velocities up to 3.5 feet per second) and/or moderate wind and wave action
- Type III—For nearshore ocean environments and tidal areas and rivers, bays, and lakes with strong currents and high velocities (up to 5 feet per second), and significant wind and wave action (more than 1 foot).

In still, shallow water not subject to wind or currents, the curtain should extend to a depth that allows at least 2 feet of clearance between the bottom of the curtain and the bottom of the water body and be anchored or staked. In moving water or where significant wind or wave action is present, a 10 to 12 foot depth is most practical, even in deep water. Curtains deeper than this can be subject to very large loads with consequent strain on the material and mooring system.

Materials should have ultraviolet light inhibitors and tensile strength sufficient to withstand predicted flows and a slippery surface that causes the sediment particle to slide down the length of the curtain. All material seams and line attachments should be sewn or vulcanized welded into place. Use materials with bright colors, when applicable, to alert boaters or swimmers recreating near the work site.

If hydrocarbons could be present, the turbidity curtain should have a line of oil sorbent boom placed parallel to the curtain for its full length. The floating sorbent boom can be anchored directly to the turbidity curtain to absorb any hydrocarbons before they can contact the curtain.

Flotation devices for turbidity curtains should be flexible, buoyant units contained in an individual flotation sleeve or collar attached to the curtain. If the curtain will be deployed for an extended period of time in an area frequented by waterfowl, floats should be enclosed in a material of sufficient weight to resist the efforts of geese to use the stuffing as nest material. The anchoring systems should be designed based on the anticipated conditions and anchored every 100 feet at a minimum (Figure 175). In areas with high wave action or high flows, anchors may need to be spaced at shorter intervals to prevent tangling. All anchors should have a floating anchor buoy or other identifying mark. A safe means should be available for workers to maintain the silt curtain because resetting the anchors and repairing the curtain are sometimes necessary. Navigation lights should be added if the curtain is to remain deployed all night.

Deployment of the silt curtain is as important as the curtain design. Due to dredging equipment, or currents, obstacles, or other factors, curtains cannot completely circle the project. Manufacturer recommendations on deployment should be followed given these circumstances; it should not be a trial and error process.

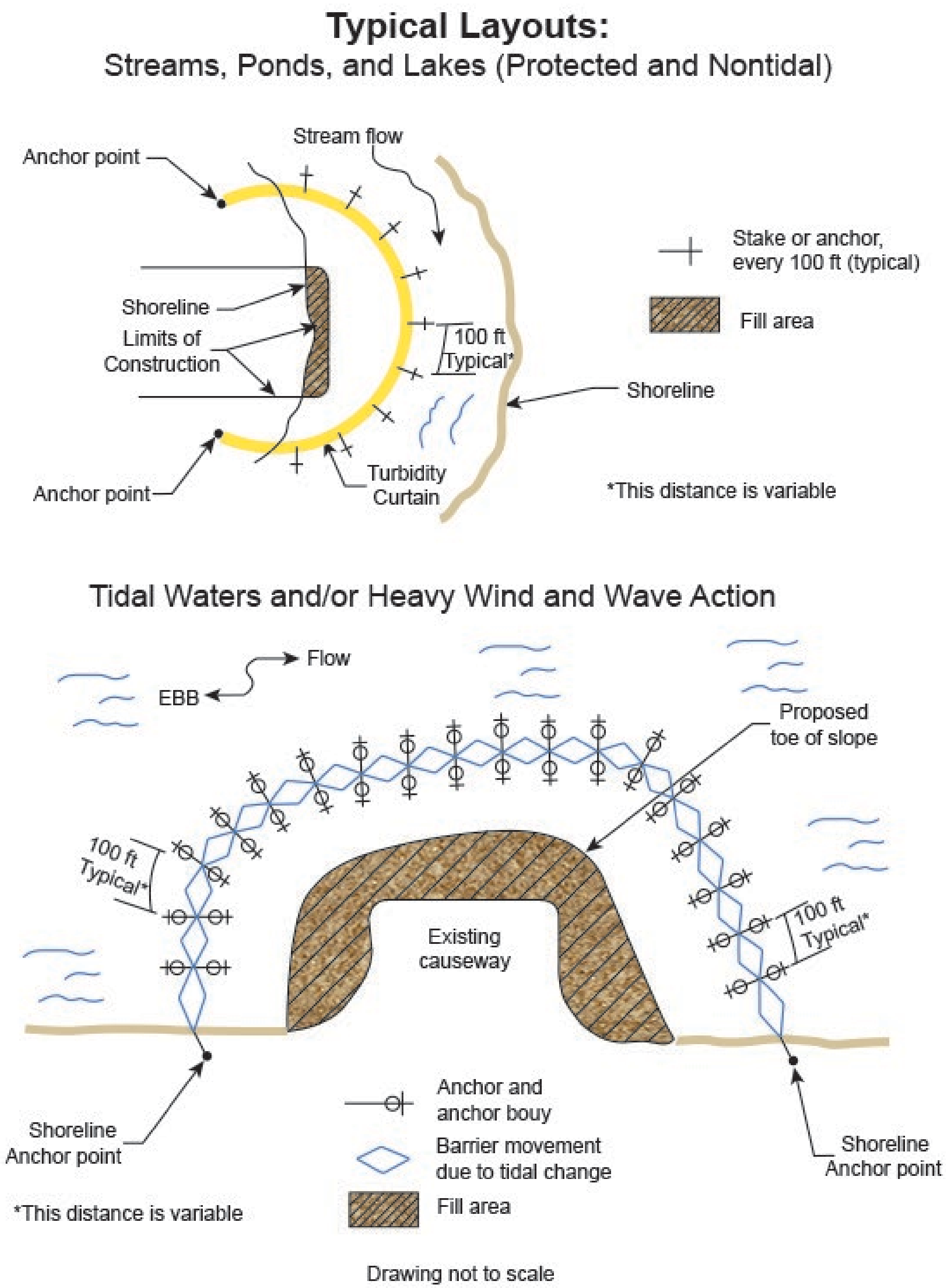


Figure 174. Turbidity curtain typical layouts (City of Portland, Oregon 2008).

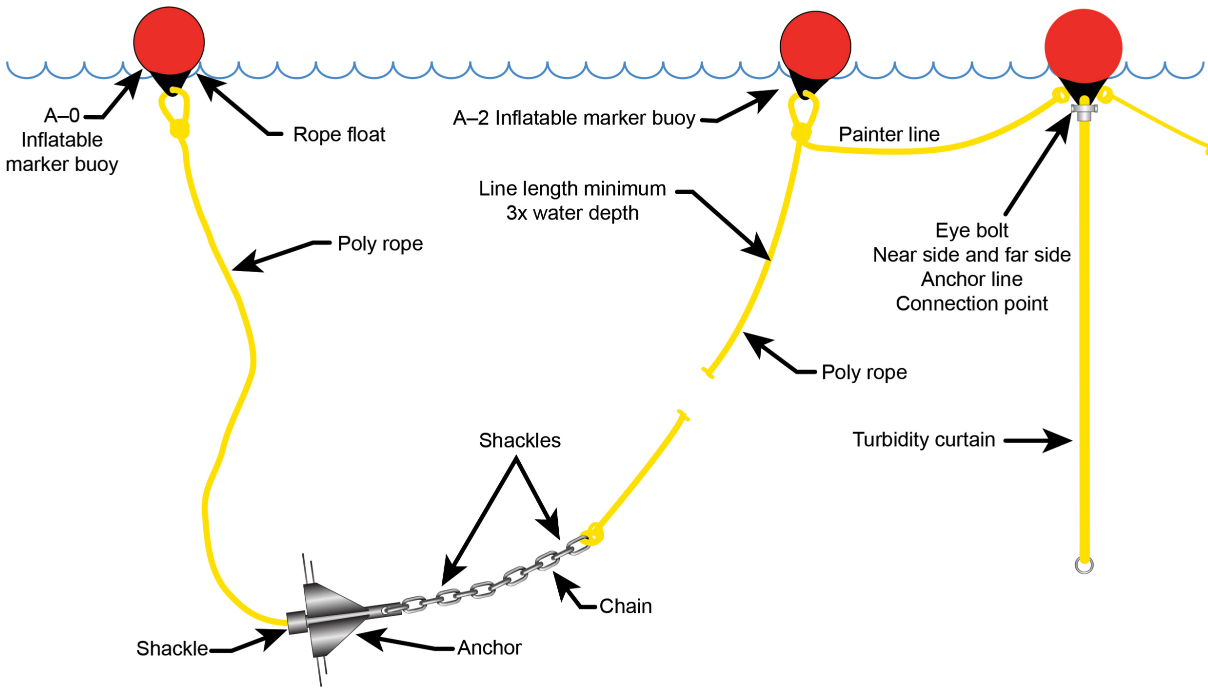


Figure 175. Turbidity curtain anchoring detail (*GEI Works*).

Construction Guidelines

Install turbidity curtains according to applicable permit requirements and follow the manufacturer's recommendations and guidelines for installation and safety measures.

Maintenance

Turbidity curtains should be inspected daily when construction is actively occurring or when it is located in a navigable water body. If turbid water is being released from a curtain, check the bottom anchors, joints, flotation, and material. Ensure the bottom of the curtain is not resting on the bed of the water body because sweeping motion created by wind and boat wakes can create a considerable amount of turbidity. Make repairs as needed, following the manufacturer's instructions for fabric and material repair. If repeated repairs are required for a curtain, the curtain strength relative to the flow velocity may need to be reevaluated or an alternative deployment strategy used.

When the project is finished, wait until the turbidity of the water inside the curtain matches the water outside of the curtain; the curtain can then be removed and cleaned before storage. All cleaning operations should use good sediment control practices to ensure the sediment does not reenter the waterway.

Remove turbidity curtains soon as the water within the curtain clears and matches the clarity of the water outside the curtain. Follow the manufacturer's recommendations for removal, and to prevent sediment resuspension, carefully pull the curtain towards the construction site. The removal area should be clear of any obstructions that could tear the fabric. Properly dispose of trapped sediment.

Additional Resources

City of Portland Oregon. 2008. *Erosion and Sediment Control Manual*. Portland, OR. *https://www.portlandoregon.gov/bds/article/94539*

Elastic/American Marine, Inc. 2015. *Turbidity Curtains*. Carmi, IL. *www.turbiditycurtains.com*

Illinois Urban Manual. 2012. "Silt Curtain-Floating." *Illinois Urban Manual Practice Standard*. *http://www.aiswcd.org/wp-content/uploads/2013/06/urbst9171.pdf*

Abasco. 2017. "Turbidity and Silt Curtain Installation." Sediment Control Products. Humble, TX. *https://www.abasco.com/turbiditycurtaininstallation.html*

BMP 72: Flocculation

Description

High levels of turbidity can significantly degrade the habitat quality of receiving waters for fish and other aquatic life. Flocculation using chemical treatment systems reduces turbidity in storm water by adding a chemical agent, or flocculant, that binds suspended soil particles together to form larger particles that are easier to settle out of the water.

Anionic polymers used with positive calcium ions can effectively flocculants reduce turbidity in storm water without harming aquatic life in the receiving water body. Chitosan is an example of a flocculation polymer; typical additives include DADMAC, gypsum, alum, and aluminum and iron chlorides.

The treatment chemicals used must comply with relevant federal, state, and local requirements. Cationic chemicals require special permitting; contact the appropriate EPA office for authorization. In the storm water management plan, document the chemicals to be used. Use only approved chemicals.

Figure 176. Floc logs located in channel (*Applied Polymer Systems*).

Primary BMP Functions and Controls

☒ Construction	☐ Permanent
☐ Erosion Control	☒ Sediment Control
☐ Source Control	☐ Flood Control
☐ Filtration	☐ Infiltration

Typical Effectiveness for Targeted Pollutants

●	Sediment
◖	Phosphorus
◖	Metals
○	Bacteria
○	Hydrocarbons
○	Litter

Other BMP Considerations

Relative Cost	$$$
Maintenance Requirements	High
Ease of Installation	Medium
Freeze/Thaw Resistance	Good
Max. Tributary Drainage Area	N/A
Max. Upstream Slope	N/A
NRCS Soil Group	ABCD
Min. Ground Water Separation	N/A
Min. Bedrock Separation	N/A

Applicability

Flocculation is used at sites with fine-grained materials (i.e., clays and fine silts), which discharge to sensitive waters with turbidity limits that cannot be achieved using traditional BMPs. It can be used on sites where a sediment retention pond cannot be constructed to the required size due to space limitations or when a pond is not sufficient to control turbidity.

Flocculants are applied to sedimentation ponds or tanks, or applied to water flowing through a channel that empties into a sediment basin using flow-through devices (e.g., floc logs) (Figure 176). Flocculants should only be applied and the flocculated sediments removed from runoff before it enters the water body or used with a turbidity curtain in the receiving water body.

Limitations

Flocculation is not intended to be used as a stand-alone BMP and should be used with other erosion and sediment controls placed before and after the chemical treatment. For example, sediment basins (BMP 66), sand filters (BMP 12), geotextile sediment bags (BMP 53), or other sedimentation controls should be used downstream of a chemical treatment system to settle or filter out flocculated sediment.

Flocculation chemical treatment systems require a higher level of operator expertise and monitoring than other BMPs. Dosages can vary with each storm, treated waters may require pH adjustments, and the potential for aquatic life toxicity due to overdosing are just some complications that require special knowledge. The chemicals require proper storage and handling.

Design Basis

For flocculation to be effective, three fundamental processes must be present: chemical binding, settling, and floc collection. Designing polymer flocculation systems often involves using multiple BMPs that work well together. A specifically trained engineer or chemist should evaluate the chemical treatment system.

Chemical Binding

The key to the chemical binding process is selecting the right chemical flocculant with the proper dose and ensuring it is well mixed. Select chemicals based on the types of soils likely to be exposed during construction and the expected turbidity, pH, and flow rate of storm water flowing into the chemical treatment system or area. Petroleum-based polymers should not be used, and all chemicals must be nontoxic to aquatic organisms.

Hundreds of anionic polymers can be used; site-specific soil sampling and geotechnical analysis by a qualified professional is recommended to determine the most effective polymer or polymer blend and its reaction time. A specific chemical should be matched to specific soil type. Several tests are available to measure the dispersive characteristics of the soil ("Standard Test Method for Particle-Size Analysis of Soil" [ASTM D422], "Dispersive Characteristics of Clay Soil by Double Hydrometer" [ASTM D422-11], and "Standard Test Methods for Identification and Classification of Dispersive Clay Soils by the Pinhole Test" [ASTM D4647]). To be effective, the desired pH of the storm water for polymers is typically 6.5 to 8.5. Because polymers tend to lower the pH, the storm water must have sufficient buffering capacity, which is a function of its alkalinity.

An optimum dosage rate for every combination of sediment and chemical yields the lowest residual turbidity after settling. Increasing the flocculant application rate will not necessarily result in better performance. The chemicals should be used according to good engineering practices with dosing specifications and sediment removal specifications provided by the supplier. Mixing the flocculant into the water with the right amount of energy ensures proper dispersion and chemical binding. Too little energy input into the water during flocculation results in flocs that are too small; too much energy can destroy floc as it is formed. When using passive flocculants, such as floc logs, consult the manufacturer for recommended quantity and location.

Before use in the field, conduct jar tests (ASTM D2035) to demonstrate the turbidity reduction necessary to meet the water quality criteria of the receiving water can be achieved. Test conditions, including but not limited to raw water quality and chemical dosage, should indicate the field conditions. These small scale tests indicate potential treatment capability and the various chemical dose rates required for effective treatment.

Settling and Floc Collection

Downstream of the chemical treatment, a settling or collection system should remove the flocculated sediment; chemically treated storm water should not be directly discharged from the construction site (Figure 177). Before discharge, treated storm water should be sampled and tested for compliance with pH, flocculent chemical concentration, and turbidity limits. The pH should not be below 6.5 to avoid creating a toxic environment for aquatic organisms and should generally be within 0.2 standard units of the receiving water pH. Sampling and testing for other pollutants may also be necessary at some sites.

Because different chemicals require different mixing times and result in various floc sizes, settling rates vary. Settling can be facilitated within a sedimentation pond (BMP 25), a sedimentation tank (BMP 67), mechanical sand filters (BMP 12), or along a constructed channel that widens or becomes shallow to slow velocity. Floc collection can be accomplished using geotextile sediment bags (BMP 53), turbidity curtains (BMP 71), or sediment collection matting.

For batch treatment systems, the combination of the sediment basin or other storm water detention area and treatment capacity should be large enough to treat storm water during multiple day storm events. Bypass should be provided around the chemical treatment system and into a settling pond to accommodate extreme storm events. Primary settling should be encouraged in the sediment basin/storage pond. If the downstream water body does not have flow control requirements, it is recommended, at a minimum, the untreated storm water storage pond is sized to hold 1.5 times the runoff volume of the 10-year, 24-hour storm event. If flow control requirements are present, these will establish sediment basin size, volume, and drawdown design criteria. The simplest approach to sizing the treatment cell is to multiply the allowable discharge flow rate by the desired drawdown time.

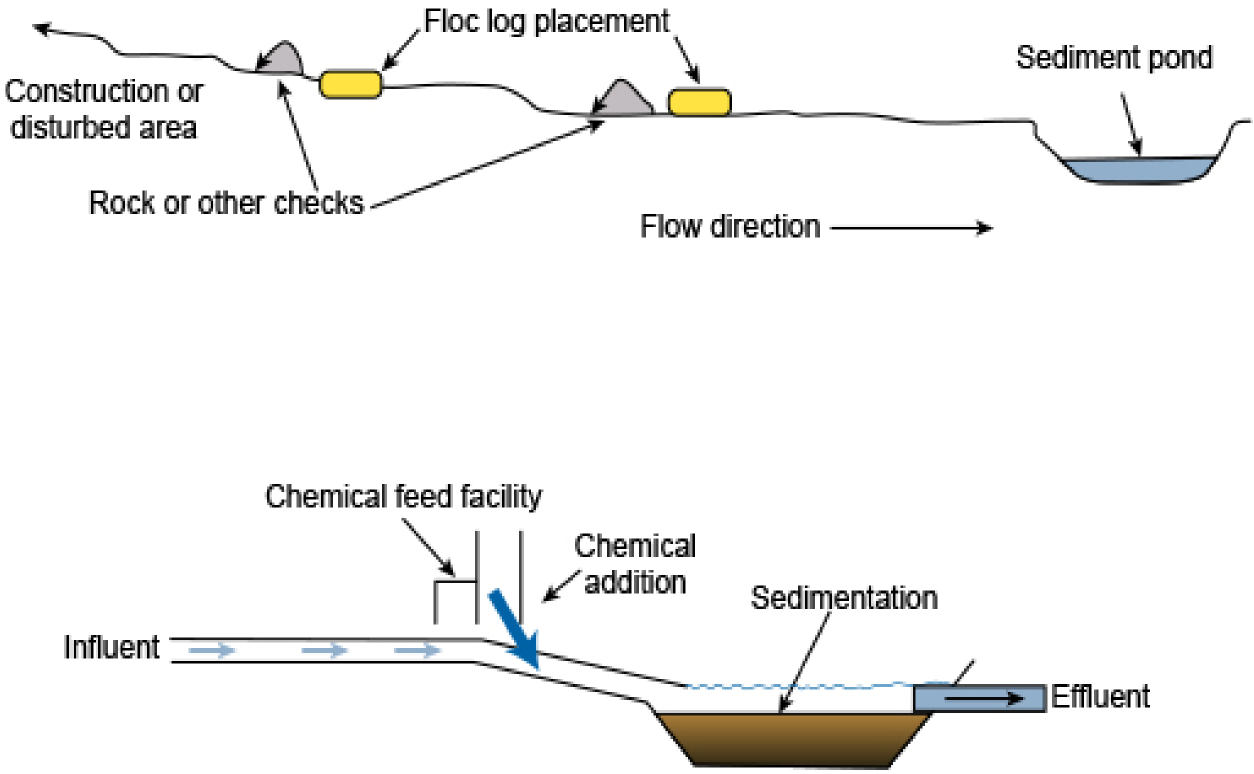


Figure 177. Schematic of chemical treatment along a channel using floc logs (top: *Applied Polymer Systems*) and chemical feed facility (bottom: CALTRANS 2010).

Construction Guidelines

Properly handle chemicals during construction and store in leak-proof containers under storm-resistant cover surrounded by secondary containment structures. Chemical treatment systems must be operated and maintained by properly trained individuals. All persons handling treatment chemicals must be trained in proper use, handling, and dosing. MSDS should be maintained visibly on site.

Maintenance

Chemical storage and dosing equipment must be inspected and maintained and the entire treatment system should be monitored continuously when in use. Monitoring reports and tests records should be kept on site; records include, but are not limited to, logs of pH conductivity, turbidity, temperature, rainfall, total volume treated and discharged, discharge time and flow rate, type and amount of chemicals used, residual chemical in treated water if it is to be discharged into a water body, and settling time.

Sediment sludge should be removed from the floc collection system or pond. Removal is typically required at least once during a wet season, or when the sediment collection area has reached one-third of its capacity. Large amounts of settled sediment in sedimentation basins can be collected and disposed of using excavation equipment. Removed sediment should be stabilized with

vegetation, disposed of at an approved site, or buried. Disposal and final stabilization of the flocculated materials should be planned for in advance and monitored during construction.

Additional Resources

CALTRANS (California Department of Transportation, Division of Construction). 2010. *Treatment BMP Technology Report*. Sacramento, CA. CTSW-RT-09-239.06. *http://www.dot.ca.gov/hq/env/stormwater/pdf/CTSW-RT-09-239-06.pdf*

EPA (US Environmental Protection Agency). 2013. *Polymer Flocculation*. Stormwater Best Management Practice. *http://www.siltstop.com/pictures/US%20EPA%20Polymer%20Flocculant%20Handout,%203-14.pdf*

FHWA (Federal Highway Administration). 2008. *Best Management Practices for Chemical Treatment Systems for Construction Stormwater and Dewatering*. FHWA-WFL/TD-09-001. *https://www.fhwa.dot.gov/innovativeprograms/pdfs/centers/local_aid/BestManagementPracticesforChemicalTreatmentSystems.pdf*

Washington State Department of Ecology. 2012. *Stormwater Management Manual for Western Washington*. Lacey, WA. Publ. 12-10-030. *http://www.ecy.wa.gov/programs/wq/stormwater/manual.html*

BMP 73: Dewatering

Description

Dewatering is used to control and appropriately dispose of ground water or rainwater from excavations or inundated areas. Both storm water and nonstorm water discharges are typically pumped to a dewatering BMP that removes sediment and treats the water as needed and then conveys or pumps it to a receiving water body or well-vegetated area. BMPs used with dewatering are sediment basins (BMP 66), portable sediment tanks (BMP 67), or dewatering filter bags (Figure 178).

Figure 178. Bags used to filter silt and sediment from dewatering operations (*GEI Works*).

Dewatering discharge may require a permit or other authorization from the local drainage authority. Discharges to surface waters and ground waters must comply with IDAPA 58.01.02 and IDAPA 58.01.11. Permits from IDWR may also be needed.

Primary BMP Functions and Controls

☒ Construction	☐ Permanent
☒ Erosion Control	☒ Sediment Control
☐ Source Control	☐ Flood Control
☐ Filtration	☐ Infiltration

Typical Effectiveness for Targeted Pollutants

●	Sediment
○	Phosphorus
○	Metals
○	Bacteria
○	Hydrocarbons
○	Litter

Other BMP Considerations

Relative Cost	$$$
Maintenance Requirements	High
Ease of Installation	Hard
Freeze/Thaw Resistance	N/A
Max. Tributary Drainage Area	N/A
Max. Upstream Slope	N/A
NRCS Soil Group	N/A
Min. Ground Water Separation	N/A
Min. Bedrock Separation	N/A

Applicability

Dewatering BMPs are applicable in the following types of locations:

- Construction sites saturated after a large storm event
- Excavations for building foundations
- Utilities, maintenance, and infrastructure installation and repair project sites:
  - Electrical conduits
  - Vaults/tanks
  - Sewer and storm drain systems
  - Phone and cable lines
  - Gas or other fuel lines
- Excavated sites or graded areas with existing conditions such as ponds and wetlands

Limitations

In Idaho, all dewatering activities regardless of the discharge volume require compliance with the "Water Quality Standards" (IDAPA 58.01.02). Dewatering operations for nonstorm water require and must

comply with applicable permits, local ordinances, and regulations. The presence of contaminated water requires coordinating with the local DEQ office and the local drainage authority to guarantee proper treatment and disposal.

Design Basis

Dewatering BMP selection will vary on site topographic and geological conditions, anticipated discharge quantities, and discharge location. Dewatering discharges should be treated to remove sediment and any contaminants before discharging from the site. Depending on season, flow rate, volume, or residual contamination, the discharge may be allowed to flow to the following:

- The ground and vegetated areas in a manner that ensures no erosion or erosive runoff leaving the site, which may require a permit or other authorization from the local drainage authority.
- The storm drain system, which may require a permit or letter of authorization with discharge restrictions.
- The sanitary sewer, which may require a permit or letter of authorization with discharge restrictions.

Figure 179 illustrates methods for placing a pump to dewater a pond filled with water or using a submersible pump.

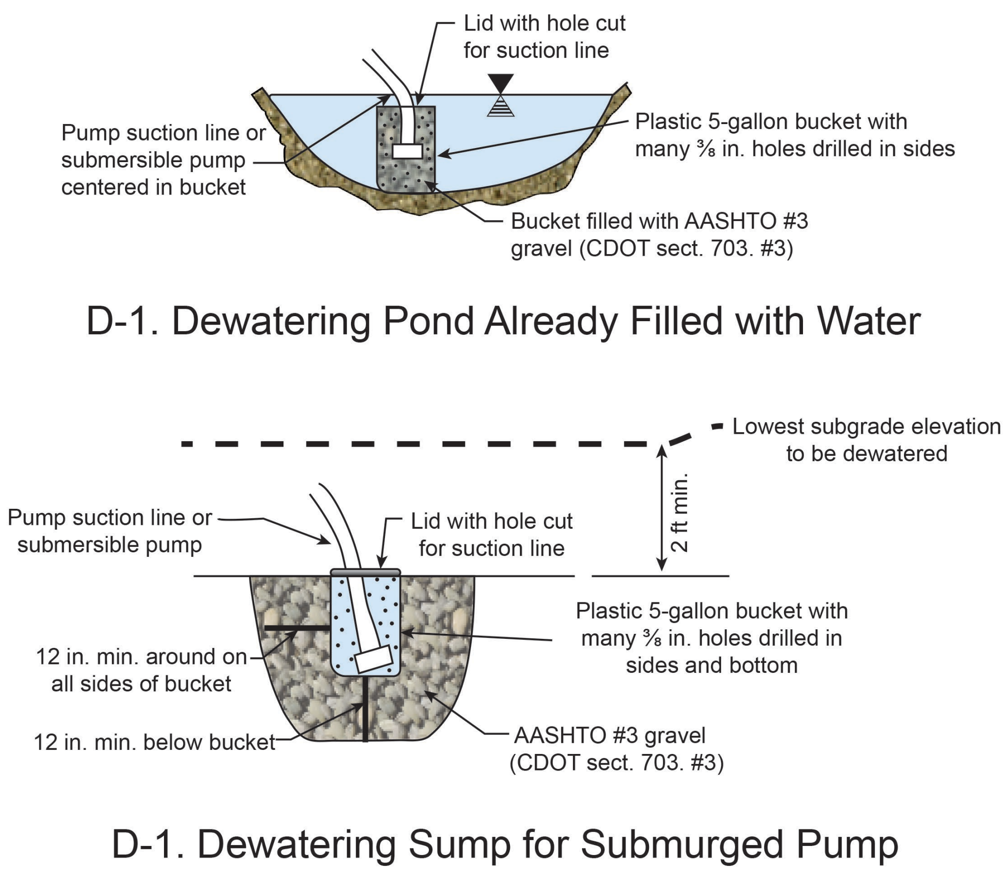


Figure 179. Dewatering for pond already filled with water (top) and dewatering sump for submerged pump (bottom) (Colorado UDFCD 2010).

Treatment

The site should be assessed for the issues listed below to assist the local drainage authority in determining which treatment and discharge option to approve:

- Perform a historical site assessment for soil and ground water records. If contaminants are suspected, the water should be tested by a certified laboratory. Results should be discussed with municipal and DEQ staff before any dewatering activities.
- If the water is cloudy or turbid, the dissolved and/or settleable solids in the water should be filtered or settled out before discharge. Evaluate geotechnical information on soil grain size distribution and hydrometer settling characteristics to select an appropriate filtration and sedimentation BMP.
- In addition to a review of water and/or soil laboratory results, determine if contaminants are present in impounded water by inspecting for odors, discoloration, and/or an oily sheen.
- If contaminants may be, or are present, a certified laboratory should test the proposed discharge waters with results submitted to the local drainage authority. Sampling and testing requirements will be determined on a case-by-case basis depending on site history or suspected pollutants. Contact DEQ or the local authority responsible for receiving water bodies or treatment systems before testing for assistance in identifying the required parameters of concern and any sampling requirements. After review, the local drainage authority will specify if any pretreatment is required before discharge.

To treat water that has been pumped from an inundated area, sedimentation BMPs such as a sediment trap (BMP 66) or a portable sediment tank (BMP 67) can be used. Settling tanks should contain sampling ports for potential contaminant analysis. Effluent should be allowed to settle in a sedimentation BMP for a minimum of 4 hours or until the water is clear (Figure 180).

In some cases, on-site chemical treatments may be required to facilitate removing clays and fine silts. Any use of chemicals to improve effluent water quality should have state and EPA approval before use. BMP 72: Flocculation provides more information on chemical treatment.

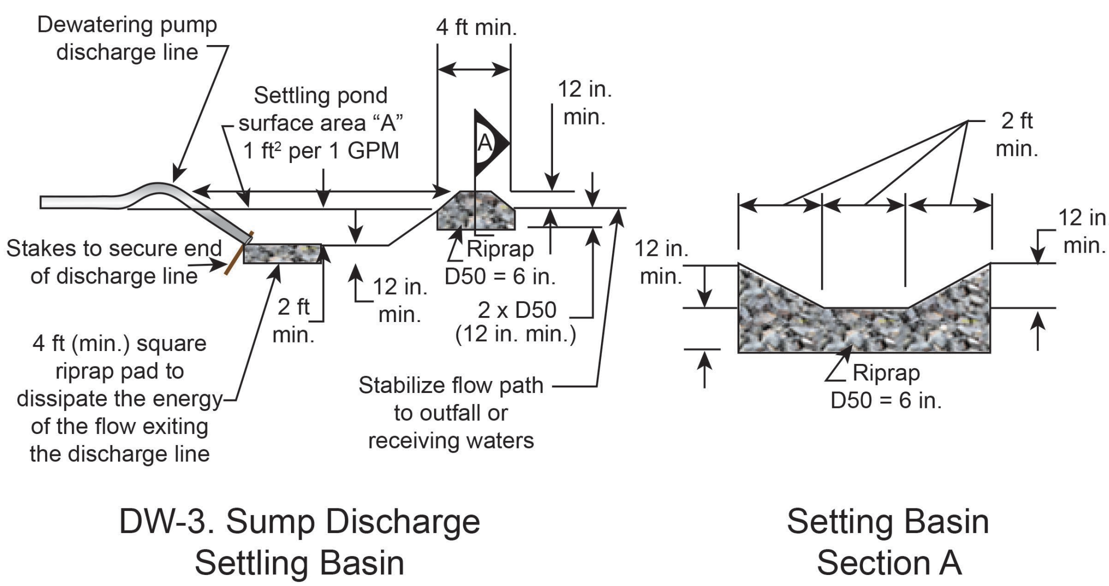


Figure 180. Sump discharge and settling basin (Colorado UDFCD 2010).

Filtering through a sieve or other filter media (swimming pool filter) may be an option for filtering construction dewatering operations. Simple on-site filter systems can be constructed including: wrapping the ends of the suction and discharge pipes with filter fabric; discharging through a series of drums filled with successively finer gravel and sand; and other filtering techniques like those described in BMP 74: Inlet Protection.

Portable tanks can be used to receive pumped water through the top of the tank, which then passes through a filter fabric that retains sediment and the filtered water is discharged through the bottom of the tank. Dewatering tanks can remove settleable solids, some visible oil and grease, some metals, and trash. The tank size depends on flow volume, constituents of concern, and residency period required.

A dewatering filter bag is a square or rectangular bag made of nonwoven geotextile fabric into which water is pumped (Figure 181). The filter bag collects sand, silt, and fines as filtered water seeps out. These systems do not always work on fine clay soils, and they should not be placed within water bodies or wetlands. Depending on site conditions and soil composition, additional downgradient erosion controls such as fiber rolls (BMP 64) or silt fencing (BMP 65) may be needed.

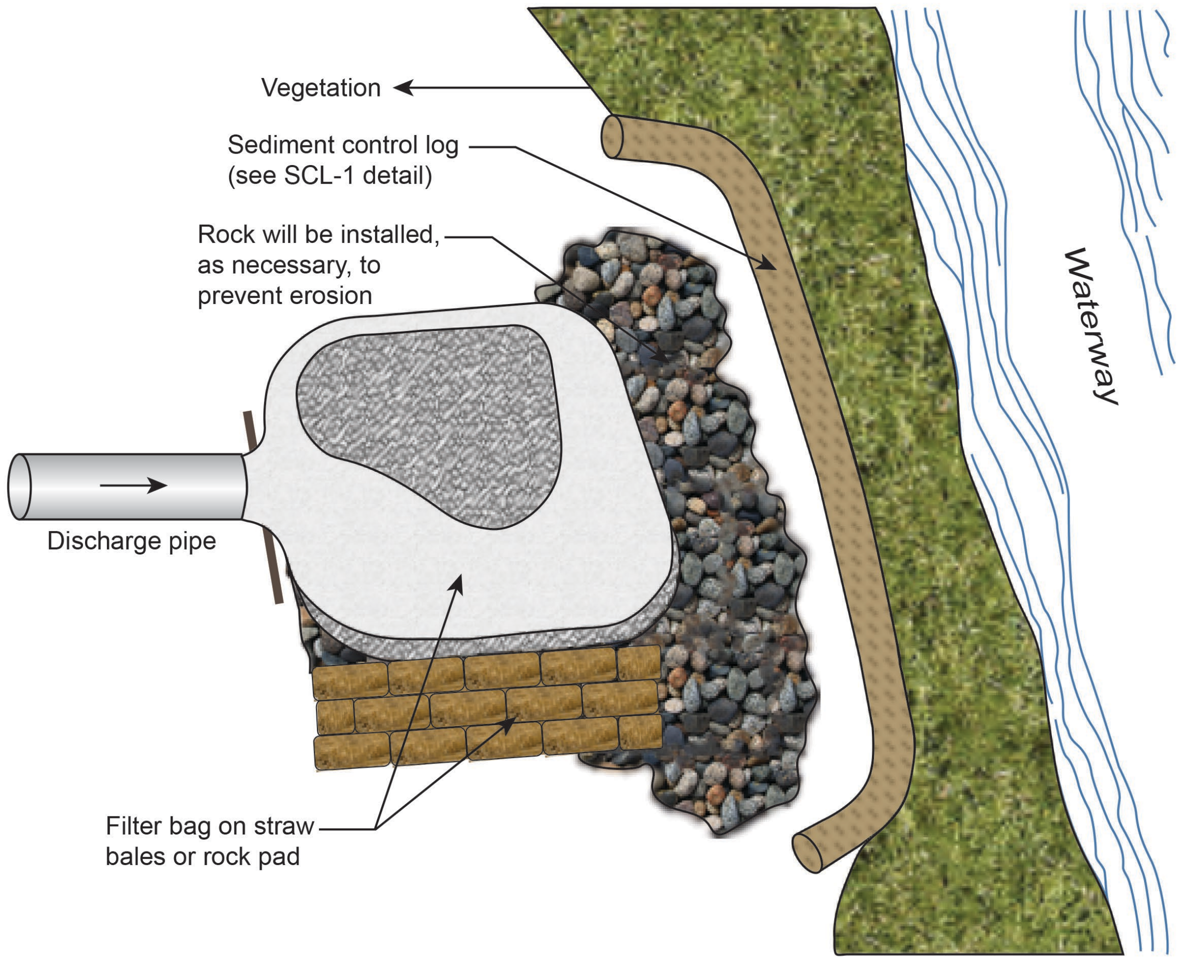
Construction Guidelines

Inspect and verify that dewatering BMPs are in place and functioning before dewatering activities begin. As part of the SWPPP, a dewatering plan should be submitted and reviewed by a certified professional engineer before dewatering-related work. The plan should detail the following:

- Location of dewatering activities and equipment, as well as discharge points
- Expected quantity of water to be discharged
- Pump capacity
- Any additional erosion and sediment control required at the point of discharge
- Water quality sampling locations (if required)

Maintenance

- Check the filtering devices daily to ensure they are unclogged and operating correctly. Maintenance and inspections of dewatering BMPs should be proactive and not reactive. Adjustments may be needed depending on the amount of sediment in the water being pumped.
- Systems should be filled in or otherwise removed when permanent dewatering controls are in place and connected to an approved treatment and receiving system.
- Sediment should be proactively removed from a sediment basin before the basin reaches half full to avoid high flows transporting previously settled material. Filtered sediment material should be dried and reused on site in a mixture with other site soils or should be appropriately disposed of based on composition and levels of contaminants present.



DW-4. Dewatering Filter Bag

Dewatering installation notes:

1. See plan view for:
   - Location of dewatering equipment.
   - Type of dewatering operation (DW-1 to DW-4).
2. The owner of contractor shall obtain a construction discharge (dewatering) permit from the state prior to any dewatering operations discharging from the site. All dewatering shall be in accordance with the requirements of the permit.
3. The owner or operator shall provide, operate, and maintain dewatering systems of sufficient size and capacity to permit excavation and subsequent construction in dry conditions and to lower and maintain the ground water level a minimum of 2–ft below the lowest point of excavation and continuously maintain excavations free of water until backfilled to final grade.

Figure 181. Dewatering filter bag (Colorado UDFCD 2010).

Additional Resources

CASQA (California Stormwater Quality Association). 2015. *California Stormwater Best Management Practices Handbook: Construction.* Menlo Park, CA. *https://www.casqa.org*

Colorado UDFCD (Colorado Urban Drainage and Flood Control District). 2010. *Urban Storm Drainage Criteria Manual, Volume 3 Best Management Practices*. Denver, CO. *http://udfcd.org/wp-content/uploads/2014/07/Title-Page.pdf*

Hazra and ODOT (Hazra Engineering Company and Oregon Department of Transportation, Geo/Environmental Section). 2005. *ODOT Erosion Control Manual: Guidelines for Developing and Implementing Erosion and Sediment Controls.*

ITD (Idaho Transportation Department). 2014. *Best Management Practices.* Boise, ID: ITD.

BMP 74: Inlet Protection

Description

Sediment and debris in storm water runoff from construction sites can clog storm water systems and contaminate downstream receiving water bodies. Inlet protection BMPs temporarily prevent sediment-laden runoff from entering storm drain inlets.

Figure 182. Inlet protection wattle (ITD 2014).

Inlet protection measures include abovegrade barriers (e.g., rock socks, sediment control logs, silt fence, gravel and mesh, or block and gravel), inserts (e.g., bags, racks, baskets, or *witch's hats* described in BMP 13: Catch-Basin Inserts), mats, and over excavations (Figure 182). Take care to not increase flooding with diverted flow from protected inlets.

Applicability

Inlet protection applies when sediment-laden runoff from a construction site threatens to enter an existing inlet or an inlet in place before permanent stabilization. Protection may include inlets in the general proximity of the construction area and is not limited to inlets on the construction site.

Limitations

Inlet protection is not a stand-alone BMP and should be used with other upgradient BMPs, especially in conditions of high flow or heavily laden sediment. Divert drainage areas greater than 1 acre to a sediment trap (BMP 66).

Some inlet protection methods, such as gravel and mesh filters and block and gravel filters, require significant space around the inlet and should not be used unless sufficient space is available to avoid a traffic hazard. Ponding around the inlet structure may also be a problem to traffic on site.

Inlet protection BMPs require a high level of maintenance to function properly. If sediment or other

Primary BMP Functions and Controls

☒ Construction	☐ Permanent
☒ Erosion Control	☒ Sediment Control
☐ Source Control	☐ Flood Control
☒ Filtration	☐ Infiltration

Typical Effectiveness for Targeted Pollutants

●	Sediment
○	Phosphorus
○	Metals
○	Bacteria
○	Hydrocarbons
◖	Litter

Other BMP Considerations

Relative Cost	$
Maintenance Requirements	High
Ease of Installation	Easy
Freeze/Thaw Resistance	Good
Max. Tributary Drainage Area	1 acre
Max. Upstream Slope	5%
NRCS Soil Group	ABCD
Min. Ground Water Separation	2 feet
Min. Bedrock Separation	2 feet

debris clogs the inlet and completely blocks flows, inlet control measures can cause localized flooding and erosion in unprotected areas.

Design Basis

Proper inlet protection design depends on inlet type and site configuration. When selecting the type of inlet protection BMP, consider factors such as type of inlet (e.g., curb or area, sump or on-grade conditions), traffic, anticipated flows, ability to secure the BMP properly, safety, and other site-specific considerations. To function correctly, inlet protection systems must ensure flow does not bypass the inlet and cause downstream erosion or flooding. The BMP should also not block flows from filtering into the inlet or catch basin.

Several types of inlet protection are presented below. Additional inlet protection systems and manufactured devices are available and may be selected for use as appropriate. The following design considerations can be applied to most inlet protection BMPs.

- Slope gradient—The drainage area should be fairly flat, with slopes of 5% or less. With filter fabric designs, the area immediately surrounding the inlet should not exceed a slope of 1%.
- Devices should be installed without inhibiting construction-related traffic or workers, or creating pedestrian hazards.
- Retrieval edges, cords, bars, chains, or other mechanisms should be flagged or marked for retrieval under submerged conditions.
- Ponding—Determine the extent of ponding and associated diverted flow expected at inlet protection locations. Both ponding and diverted runoff should not adversely affect construction-related activities or increase downstream erosion. Diverted flow can be managed through proper inlet protection placement and, where needed, additional erosion and sedimentation controls placed downstream of diverted flow.

Catch-Basin Inserts

Catch-basin insert filters (BMP 13) are available from manufacturers and are placed in the catch basin just below the grating. These inserts are a good choice along active roads with traffic and provide flow bypass without ponding around the inlet or creating a traffic hazard. Use these products according to the manufacturer's recommendations with fabrics and other materials sized to handle projected site runoff and sediment load.

Washed Gravel and Wire Mesh Filter

A washed gravel barrier using wire mesh and filter fabric is placed on top of a grate inlet (Figure 183). This structure does not provide an overflow.

- To achieve maximum trapping efficiency, orient the longest dimension of the basin toward the longest inflow area.
- Remove any obstructions to excavating and grading. Excavate sump area, grade slopes, and properly dispose of soil.
- Secure the inlet grate to prevent seepage of sediment-laden water.

- Place wire mesh over the drop inlet so the wire extends a minimum of 1 foot beyond each side of the inlet structure. Overlap the strips of mesh if more than one is necessary.
- Place filter fabric over the mesh, extending at least 1 foot beyond the inlet opening on all sides.
- Ensure that weep holes in the inlet structure are protected by filter fabric and gravel.
- Place stone or gravel over the fabric/wire mesh to, at least, 20 inches deep.

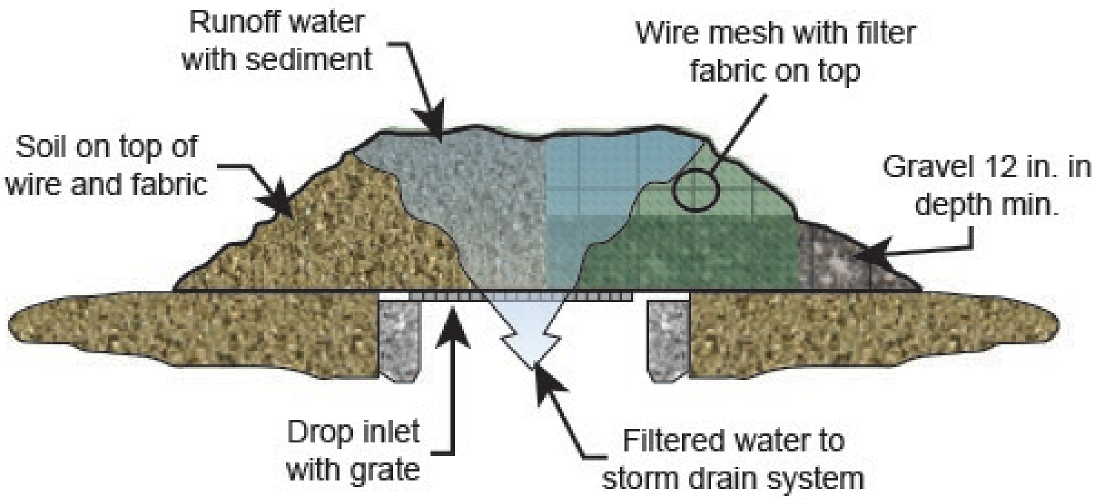


Figure 183. Washed gravel and wire mesh filter.

Block and Gravel Filter

The block and gravel filter is a barrier formed around a curb inlet with concrete blocks and gravel (Figure 184).

- Block and gravel filters can be used in areas of heavy flow, high velocities, and where overflow capability is needed.
- A block-and-gravel inlet protection device can be provided with an overexcavation sediment-trapping sump (Figure 184). The excavation should be 1 to 2 feet deep as measured from the crest or grate of the inlet. Side slopes should be 2:1 maximum. The recommended volume of excavation is 860 ft^3/acre of upgradient ground disturbed.
- To achieve maximum trapping efficiency, the longest dimension of the basin should be oriented toward the longest inflow area.
- Open ends of the block should face outward, not upward, with the ends of adjacent blocks abutting.
- On each side of the structure, lay one block on its side to allow for dewatering (BMP 73) of the pool if needed.
- The block barrier should be 1 to 2 feet high. Depending on block dimensions, the barrier may be placed 4 to 12 inches deep.
- Secure the inlet grate to prevent seepage of sediment-laden water.
- Place wire mesh over the drop inlet so the wire extends a minimum of 12 to 20 inches beyond each side of the inlet structure. Overlap the strips of mesh if more than one is necessary.

- Place filter fabric (optional) over the mesh and extend it at least 20 inches beyond the inlet structure.
- Place concrete blocks over the filter fabric in a single row lengthwise on their sides and flush with the edge of the inlet. Excavate the foundation a minimum of 2 inches below the crest of the inlet. The bottom row of blocks should be against the edge of the structure for lateral support.
- Before backfilling, place wire mesh over the outside vertical end of the blocks so that stone does not wash down the inlet.
- Place gravel against the wire mesh to the top of the blocks.

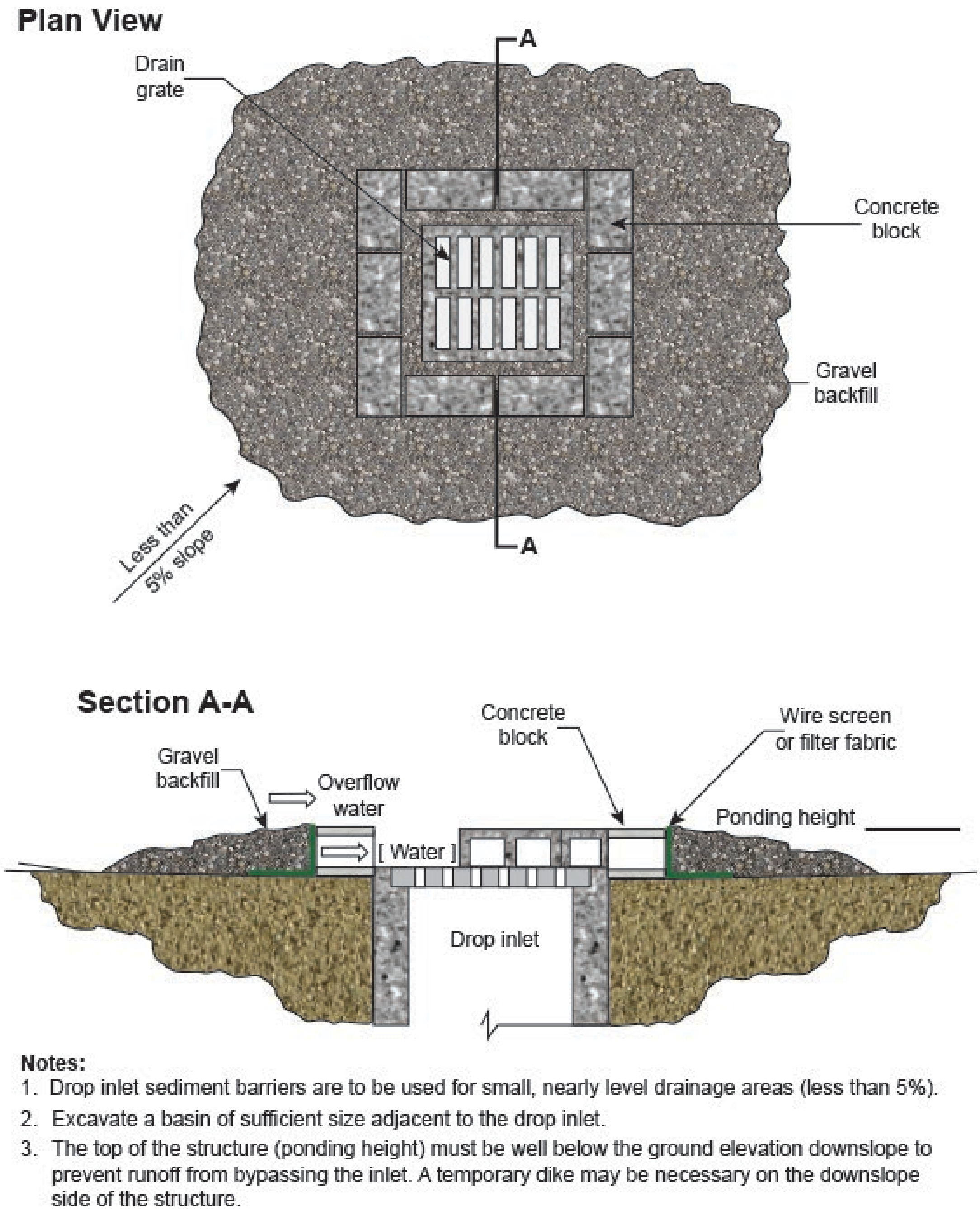


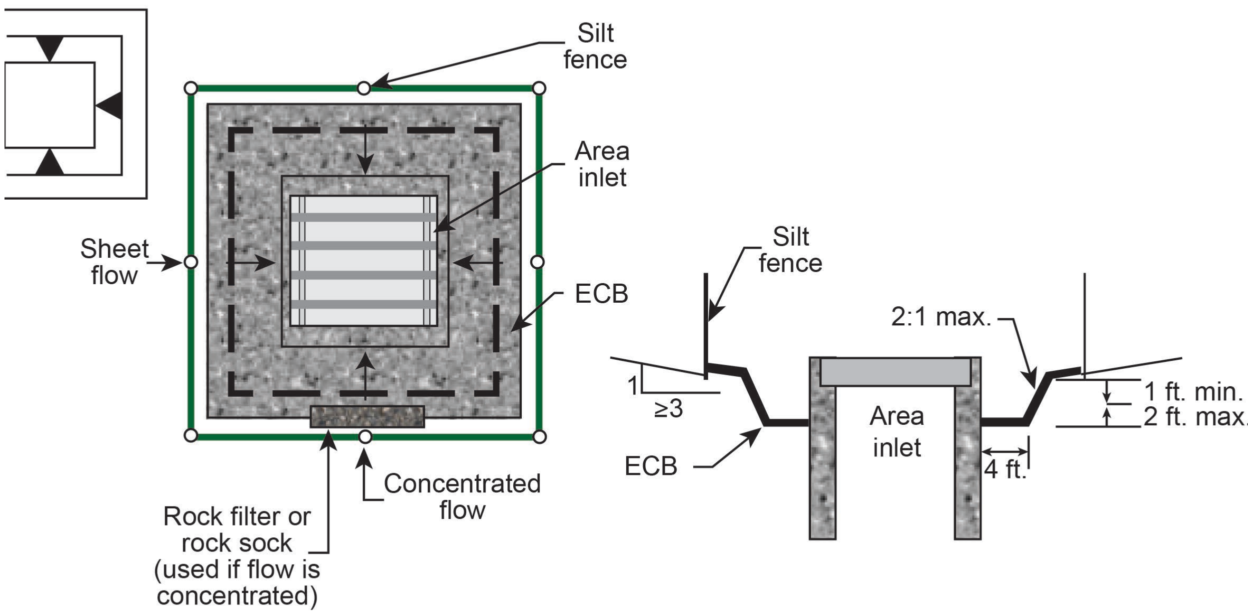
Figure 184. Block and gravel filter (King County 2009).

Swale or Overexcavation Inlet Protection

Swale or overexcavations around an inlet create a sediment-trapping pool that removes sediments by settling and/or flow through a drainage structure protected by filter fabric.

- Excavate completely around inlet to a depth of 1 to 2 feet below notch elevation.
- If the inlet is not in a low point, construct a diversion dike (BMP 69) in the ditch line below it. The top of the dike must be at least 6 inches higher than the top of frame (weir).

- Drive a 2- x 4-inch post 1 foot into the ground at four corners of the inlet. Place nail strips between posts on the ends of the inlet. Assemble the top portion of the 2 x 4 frame using overlap joint shown in Figure 185. The top of frame (weir) should be 6 inches below the edge of the roadway or diversion dike (BMP 69) adjacent to inlet.
- Stretch wire mesh tightly around frame and fasten securely. Ends should meet at the post.
- Stretch the filter cloth tightly over the wire mesh, extending the cloth from top of the frame to 18 inches below the inlet notch elevation. Fasten securely to the frame. Ends should meet at the post, overlapped and folded, and fastened down.
- Backfill around the inlet in compacted 6-inch layers until the layer of earth is even with the notch elevation on the ends and top elevation on the sides.



IP-5. Overexcavation Inlet Protection

Instalation Notes:

1. This form of inlet protection is pimarily applicable for sites that have not yet reached final grade and should be used only for inlets with a relatively small contributing drainage area.
2. When using for concentrated flows, shape basin 2:1 ratio with length oriented towards direction of flow.
3. Sediment must be periodically removed from the overexcavated area.

Figure 185. Overexcavation inlet protection (Colorado UDFCD 2010).

Curb Inlet Protection

- Place a layer of washed stone in front of a curb inlet to filter runoff before entering the inlet.
- Attach a continuous piece of wire mesh to the 2 x 4 weir (measuring throat length plus 2 feet to either side) as shown in (Figure 186).
- Place a piece of approved filter cloth (such as 40–85 sieve) of the same dimensions as the wire mesh over the wire mesh and securely attach to the 2 x 4 weir.

- Securely nail the 2 x 4 weir to 9-inch long vertical spacers located between the weir and inlet face (maximum 6 feet apart).
- Place the assembly against the inlet throat and nail (minimum 2 feet) lengths of 2 x 4 to the top of the weir at the spacer locations. These 2 x 4 anchors should extend across the inlet top and be held in place by gravel-filled bags or alternate weight.
- Place the assembly so the end spacers are a minimum of 1 foot beyond both ends of the throat opening.
- Form the wire mesh and filter cloth to the concrete gutter and against the face of curb on both sides of the inlet. Place clean 2-inch stone over the wire mesh and filter fabric to prevent water from entering the inlet under or around the filter cloth.
- Ensure storm flow does not bypass inlet by installing temporary earth or asphalt dikes directing flow into inlet.

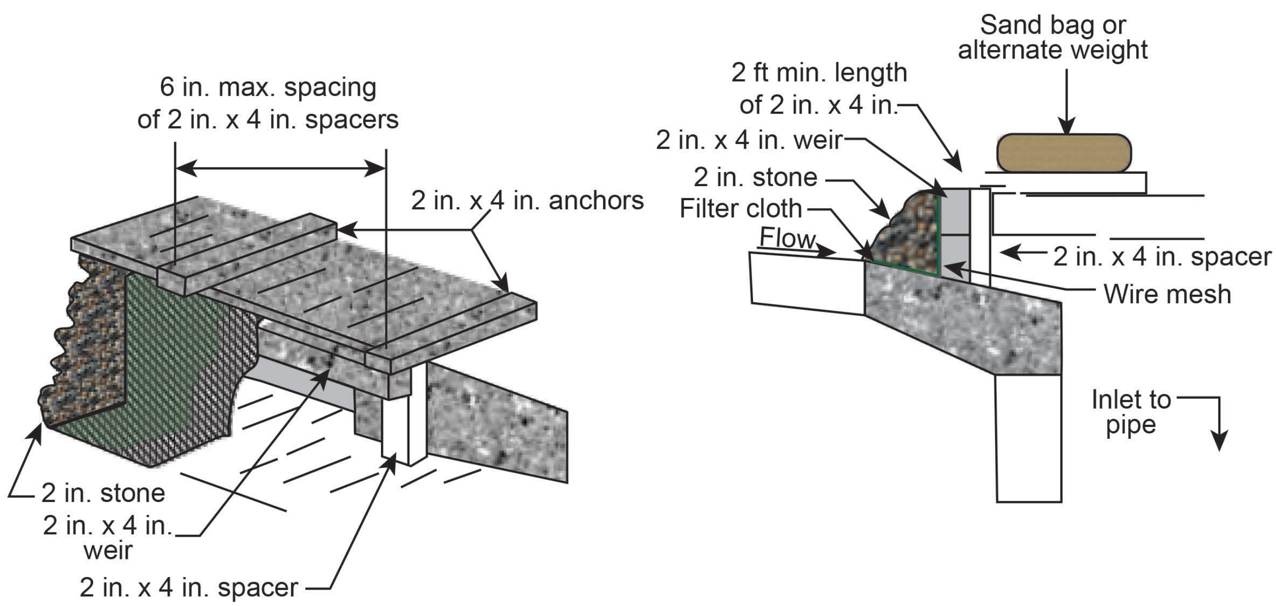


Figure 186. Curb inlet protection detail.

Rock Sock Inlet Protection

Rock socks are bags filled with washed gravel that can be placed around a sump inlet as shown in Figure 187.

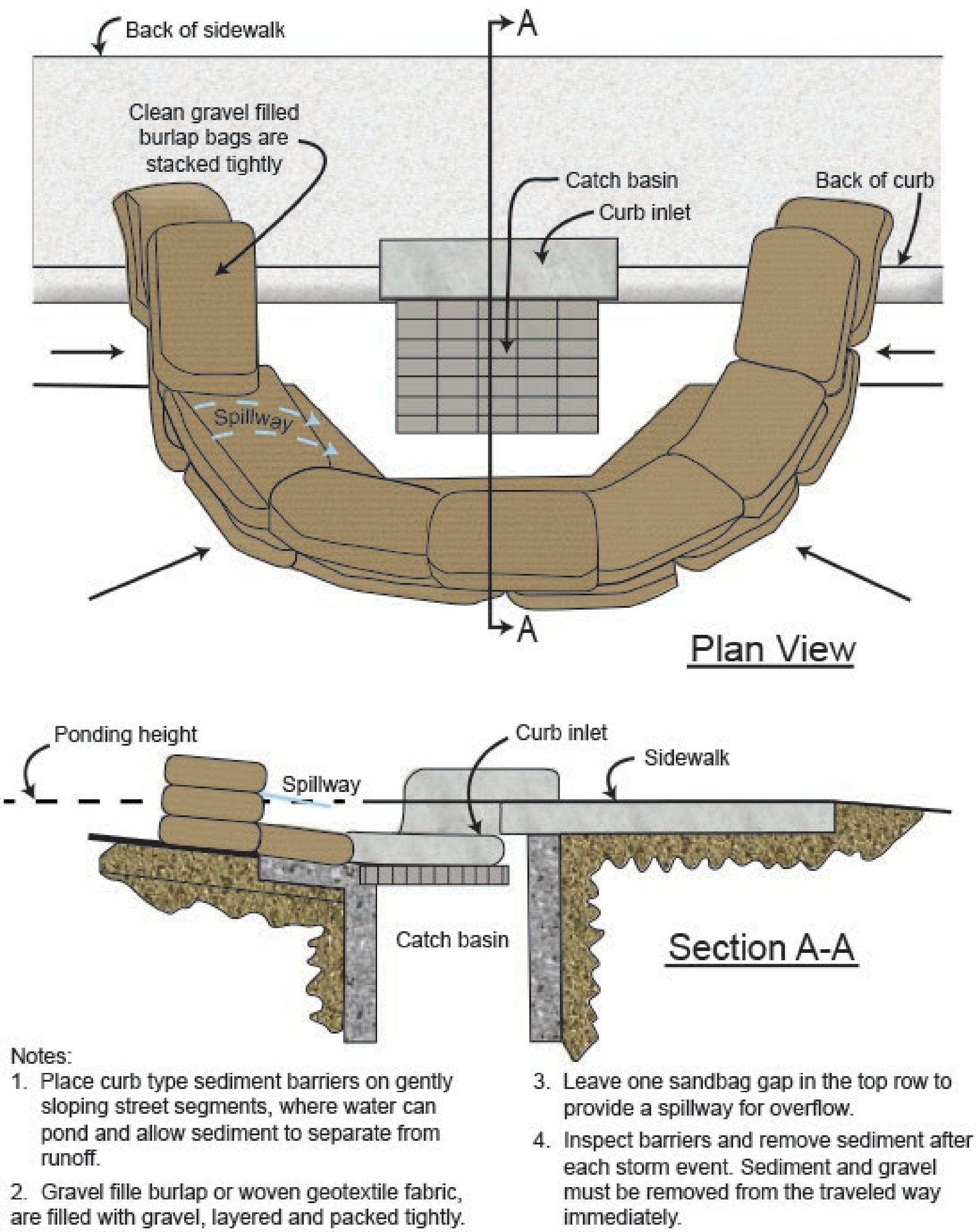


Figure 187. Rock sock inlet protection.

Construction Guidelines

Inlet protection devices should be installed around existing inlets before earth-disturbing activities begin. The type of inlet protection selected should consider if freezing conditions might be experienced during its use. Inspections and field adjustments may be necessary to ensure proper installation and performance.

Inlet protection should remain in place and operational up to 30 days after the drainage area is completely stabilized. Unless cleaned for reuse as a permanent site control or cleaned and left to biodegrade, all inlet inserts should be removed after construction is completed (or after site stabilization is established).

Maintenance

Inspect regularly and after every storm. Make any repairs necessary to ensure inlet protection measures are in good working order. Check for tears in filter fabric that allow untreated sediment-laden runoff to enter into the inlet.

Remove accumulated sediment and restore the trap to its original dimensions when sediment has accumulated to half the design depth of the trap. Remove sediment accumulations located upstream of inlet protection to maintain effectiveness. All sediments removed should be disposed of properly. On gravel-and-mesh devices, clean (or remove and replace) the stone filter if it becomes clogged.

Replace inlet inserts per manufacturer's instructions or when device no longer drains. At no time should devices be punctured or otherwise modified to bypass flows.

Additional Resources

CASQA (California Stormwater Quality Association). 2015. *California Stormwater Best Management Practices Handbook: Construction.* Menlo Park, CA. *http://www.casqa.org/*.

Colorado UDFCD (Colorado Urban Drainage and Flood Control District). 2010. *Urban Storm Drainage Criteria Manual, Volume 3 Best Management Practices*. Denver, CO. *http://udfcd.org/wp-content/uploads/2014/07/Title-Page.pdf*

EPA (US Environmental Protection Agency). 2011. *Storm Drain Inlet Protection*. *https://www.epa.gov/npdes/national-menu-best-management-practices-bmps-stormwater-documents*

Hazra and ODOT (Hazra Engineering Company and Oregon Department of Transportation, Geo/Environmental Section). 2005. *ODOT Erosion Control Manual: Guidelines for Developing and Implementing Erosion and Sediment Controls.*

ITD (Idaho Transportation Department). 2014. *Best Management Practices.* Boise, ID: ITD.

BMP 75: Street Sweeping

Description

Streets, roads, and highways accumulate potential storm water pollutants such as sediment, debris, trash, road salt, and trace metals. Street sweeping, if conducted properly, can reduce the pollutant load to receiving waters, reduce potential clogging of storm sewer systems and downstream BMPs, and control dust (Figure 188).

Figure 188. Regenerative air system sweeper for the City of Hayden, Idaho.

Applicability

Street sweeping can be used in most urban areas where sediment and litter accumulation is a concern. In cold climates, street sweeping used during ice-free periods and after the spring snowmelt removes the salt, sand, and grit applied to the roads throughout the winter. Permeable pavements (BMP 19) should be vacuumed with appropriate equipment as part of basic routine maintenance to ensure the pavement operates effectively.

Streets adjacent to an active construction site should be swept when necessary as part of the construction site storm water management plan. Construction sites should also take measures to control sediment track out (BMP 40: Vehicle Sediment Control) to limit the need for street sweeping.

Limitations

Street sweeping is not effective at removing oil and grease. Older mechanical sweepers are limited in ability to remove fine sediment, and sweepers with newer technology can be costly.

Design Basis

Three types of street-sweeping technologies are available: traditional mechanical sweepers that use a broom and conveyor belt, vacuum-assisted sweepers, and regenerative air sweepers that blast air onto the pavement to loosen sediment particles and vacuum

Primary BMP Functions and Controls

☐ Construction	☒ Permanent
☐ Erosion Control	☒ Sediment Control
☒ Source Control	☐ Flood Control
☐ Filtration	☐ Infiltration

Typical Effectiveness for Targeted Pollutants

●	Sediment
○	Phosphorus
◖	Metals
○	Bacteria
○	Hydrocarbons
●	Litter

Other BMP Considerations

Relative Cost	$$$
Maintenance Requirements	Medium
Ease of Installation	N/A
Freeze/Thaw Resistance	Good
Max. Tributary Drainage Area	N/A
Max. Upstream Slope	N/A
NRCS Soil Group	N/A
Min. Ground Water Separation	N/A
Min. Bedrock Separation	N/A

them into a hopper. For maximum particulate removal, sweepers should be operated at optimum manufacturer-recommended speeds and sweeping patterns, with brushes properly adjusted.

The various sweeping technologies are appropriate in different situations. In general, mechanical broom sweepers remove larger and heavier debris than other technologies and are better for removing construction debris and granular materials such as millings and gravel. Vacuum-assisted sweepers clean rough and potholed roadways and with extended nozzles can efficiently clean street gutters. A benefit of regenerative air sweepers is they do not vent or exhaust back into the atmosphere, but the debris must be small enough to be picked up. Some regenerative air sweepers also use water to control ambient dust and lubricate the impeller.

Schedule

A regular sweeping schedule is recommended with a minimum monthly sweeping of curbed streets during the nonwinter months when the streets are clear of snow. More frequent street sweeping may be needed depending on site conditions and in the vicinity of active construction sites. Complete street sweeping during dry weather. Wet cleaning or flushing of streets should be avoided; use dry methods where possible.

Street-sweeping schedules should be posted with signs along streets and on the municipality's website so that the public knows to not park cars along the street during designated sweeping days.

Consider increasing sweeping frequency based on factors such as traffic volume, land use, field observations of sediment and trash accumulation, and proximity to watercourses:

- Increase sweeping frequency for streets with high pollutant loads, especially in high traffic and industrial areas.
- Conduct street sweepings before the wet season to remove accumulated sediments.
- Increase the sweeping frequency for streets in special problems areas, such as streets around special events, areas of high litter, or high erosion zones.

To evaluate the effectiveness of a street-sweeping program, municipalities should maintain accurate logs of the number of curb-miles swept and the amount of waste collected.

Sweepings Storage and Disposal

Street sweeping material includes sediment, salt, trace metals, leaves, trash, and other debris. The collected sweepings contain pollutants that should be tested before disposal to determine if the material is hazardous. Municipalities must adhere to all federal and state regulations that apply to the sweeping's disposal and reuse.

The debris and dirt from street sweeping activities should be stored and disposed of properly. Swept material should not be stored along the side of the street or near a storm drain inlet. Keep debris storage to a minimum during the wet season or ensure debris piles are contained or covered.

Maintenance

Street-sweeping equipment should be regularly maintained and kept in good working order. Regularly inspect vehicles and equipment for leaks and repair promptly. Keep spare parts in stock to prevent downtime. Maintenance requirements may be greater for certain types of sweepers. Replace old sweepers with new technologically advanced sweepers, such as regenerative air sweepers, that maximize pollutant removal.

Additional Resources

CASQA (California Stormwater Quality Association). 2004. *Stormwater Best Management Practice Handbook: Municipal*. Menlo Park, CA. *http://www.casqa.org/*

EPA (US Environmental Protection Agency). 2017. *Parking Lot and Street Cleaning*.

BMP 76: Storm Water System Cleaning

Description

A storm water system is a network of gutters, catch °basins, inlets, pipes, and detention facilities that collect and convey storm water runoff to a receiving water body. Proper BMP implementation should prevent pollutants from entering the storm water system, but some common pollutants will be found in storm systems including trash and debris, sediments, oil and grease, antifreeze, paints, cleaners and solvents, pesticides, fertilizers, animal waste, and detergents (Figure 189).

Routine cleaning of the storm water system reduces the amount of pollutants that reach receiving waters, prevents clogging of drains and inlets, and ensures the system can function hydraulically to avoid flooding.

Figure 189. Cleaning a sediment trap.

Applicability

Storm water system cleaning should be done periodically on all storm water systems by the municipality or other responsible party, such as homeowner associations, businesses, landowners, or industries for systems located on private land.

Given special attention to portions of the storm water system with relatively flat grades or low flows because they rarely achieve high enough flows to flush out pollutants.

Limitations

The time and cost for storm water system cleaning can be significant. Communities may target recurrent problem areas or prioritize to determine what areas will be maintained and when they will be maintained.

Design Basis

A variety of jet/vacuum vehicles can be used to remove debris from storm water inlets and pipes. This equipment breaks up clogged/accumulated material with high-pressure water jets and vacuums

Primary BMP Functions and Controls

☐ Construction	☒ Permanent
☐ Erosion Control	☒ Sediment Control
☒ Source Control	☐ Flood Control
☐ Filtration	☐ Infiltration

Typical Effectiveness for Targeted Pollutants

●	Sediment
○	Phosphorus
◖	Metals
○	Bacteria
◖	Hydrocarbons
●	Litter

Other BMP Considerations

Relative Cost	$$
Maintenance Requirements	Medium
Ease of Installation	NA
Freeze/Thaw Resistance	Good
Max. Tributary Drainage Area	5 acres
Max. Upstream Slope	25%
NRCS Soil Group	ABCD
Min. Ground Water Separation	3 feet
Min. Bedrock Separation	6 feet

the material from the system. A variety of methods for cleaning inlets are available, including manual cleaning, vacuum cleaning, and vacuum combination jet cleaning.

Schedule

Storm water systems should be regularly inspected, with more frequent inspections during the wet season to check for problem areas where sediment or trash accumulates more often.

Storm water systems should be cleaned so blockage of storm pipe outlets is prevented. The sump in catch basins and inlets should not exceed 40%–50% of its storage capacity. There should never be less than 6 inches of clearance from the debris surface to the invert of the lowest pipe. Catch basins with very little storage volume may need more frequent inspections and cleaning.

Semiannual cleaning of systems in residential streets and monthly cleaning of systems in industrial streets are recommended. Schedule more frequent cleaning in the fall as leaves can contribute 25% of the nutrient load in inlets. Inspection and cleaning before the wet season is recommended.

Staff Training

Operators must be properly trained in inlet maintenance including waste collection and disposal methods. Staff should also be trained to report water quality problems and unauthorized nonstorm water discharges to the proper authorities. Evidence of illegal discharges or illicit connections to the storm water system include paint spills, oil sheen, and discoloring and odors.

Tracking

Accurate records of the number of catch basins cleaned and the amount of waste collected should be kept and may be required by MS4 or other permits held by the municipality. Track the location and maintenance of storm drains using a database and spatial referencing system (e.g., Global Positioning System or geographic information system). Knowing the type and era of the storm drain system can be useful because some inlets/catch basins are self-cleaning while others have some trapping capacity.

Use a recording system for tracking illegal dumping incidents and include the location, quantities, date and time, mode of dumping, and responsible parties (BMP 46: Spill Prevention and Control). Stenciling storm drains with messages such as “Dump No Waste – Drains to Stream” can prevent illegal disposal of pollutants.

Material Disposal

Most waste from storm system cleaning is of acceptable quality for landfills. If it is suspected that waste contains hazardous materials, it should be tested and disposed of accordingly. Water used in storm system cleaning should be collected and properly disposed of at a sanitary wastewater treatment facility.

Additional Resources

CWP (Center for Watershed Protection). 2009. *Urban Stormwater Restoration Manual Series 8: Municipal Practices and Programs.* Ellicott, MD.

EPA (US Environmental Protection Agency). 2017. *Storm Drain System Cleaning*. *https://www.epa.gov/npdes/npdes-stormwater-program*

BMP 77: Outdoor Storage

Description

Storm water can become polluted when contaminants in materials or liquids stored on-site wash off or dissolve into storm water runoff. If raw materials or liquids must be stored outdoors due to indoor space limitations, proper storage techniques can prevent or reduce the discharge of pollutants to storm water.

Contaminant prevention is achieved by reducing contact with storm water, installing safeguards against accidental releases, using secondary containment, conducting regular inspections, and training employees in safe handling and operating procedures and spill cleanup techniques.

Figure 190. Outdoor storage of hazardous materials (*SafeSpace*).

Primary BMP Functions and Controls

☒ Construction	☐ Permanent
☐ Erosion Control	☐ Sediment Control
☒ Source Control	☐ Flood Control
☐ Filtration	☐ Infiltration

Typical Effectiveness for Targeted Pollutants

○	Sediment
○	Phosphorus
◖	Metals
○	Bacteria
◖	Hydrocarbons
○	Litter

Other BMP Considerations

Relative Cost	$$$
Maintenance Requirements	Medium
Ease of Installation	Hard
Freeze/Thaw Resistance	N/A
Max. Tributary Drainage Area	N/A
Max. Upstream Slope	N/A
NRCS Soil Group	N/A
Min. Ground Water Separation	N/A
Min. Bedrock Separation	N/A

Applicability

Proper outdoor storage should be used at all construction sites, industrial sites, commercial facilities, and municipal facilities when storing sensitive materials (Figure 190):

- Soil stabilizers and binders
- Fertilizers, pesticides, and herbicides
- Detergents and other cleaning compounds
- Building material and site waste
- Waste oils and petroleum-based products
- Solvents and liquids
- Construction equipment
- Asphalt and concrete compounds
- Hazardous wastes and materials
- Any substance detrimental to environmental conditions

Limitations

Tarps and temporary protective structures can be susceptible to wind damage. Permanent storage sheds should meet building and fire code requirements and may need a building permit before construction.

Accidental releases of materials from aboveground liquid storage tanks, drums, and dumpsters present

the potential for contaminating storm and ground waters with many pollutants. Properly training employees in spill cleanup procedures prevents contamination. This requires additional time and resources to educate employees.

Design Basis

Depending on location, materials, and storage capacity, some facilities may be covered by the SPCC rule and will be required to prepare and implement a SPCC plan. EPA provides more information at *http://www2.epa.gov/oil-spills-prevention-and-preparedness-regulations/overview-spill-prevention-control-and*. Use the following design approaches to protect materials from rainfall, run-on, runoff, and wind dispersal:

Storage Areas

- All sensitive materials should be covered at all times. Cover the storage area with a roof when possible.
- If material cannot be covered with a roof, protect the material with a temporary covering made of polyethylene, polypropylene, or hypalon, and secure it with weighted tires or sandbags.
- Locate outdoor storage areas on nonpermeable paved surfaces free of cracks and gaps, where possible.
- When sensitive materials cannot be located in a storage container or on a nonpermeable paved surface, line the soil or gravel with an impermeable barrier.
- A minimum slope of 1.5 % is recommended for outdoor storage areas to minimize water pooling on site. Minimizing water pooling is particularly important with materials that may leach pollutants into storm or ground water, such as compost, logs, and wood chips.
- Build a berm around storage areas to minimize storm water run-on and contain unexpected spills.
- Design the storm water system to minimize catch basins in the interior of the area as catch basins in the interior tend to fill rapidly with manufacturing material.
- Always have MSDS available for all materials detrimental to soil and/or water quality. The MSDS should include information on procedures for handling substances in a safe manner and information on physical characteristics, toxicity, reactivity, storage, disposal, and spill-handling procedures.

Container Management

To limit the possibility of storm water pollution, containers used to store dangerous waste or other liquids should be kept inside a building unless this is impractical due to site constraints. If the containers are placed outside, employ the following procedures:

- Place dumpsters used to store items awaiting transfer to a landfill in a lean-to structure or keep otherwise covered. Keep dumpsters in good condition.
- Tell employees to avoid dumping liquids in dumpsters and ensure dumpster lids are always closed.
- Place a fillet (radius) on both sides of the curb to facilitate moving the dumpster.
- Keep waste container drums in an area such as a service bay and ensure the drums have tight-fitting lids affixed at all times. If drums are kept outside, store them in a lean-to type

structure, shed or walled- in container to keep rainfall from reaching the drums. The storage area should have berms and be paved with an appropriate material.

- Label containers or tanks clearly.

Storage of Liquids

With the design approaches listed above, use the following measures to protect liquid in storage containers:

- Store hazardous materials to meet specific federal, state, and local standards. Some sensitive areas, such as source water protection zones, may require special containment.
- Use a *doghouse* shed for storing small liquid containers if the environment is appropriate. A doghouse shed consists of two solid structural walls and two canvas-covered walls. The floor is wire mesh and above secondary containment.
- Place tight-fitting lids on all containers. Secure drums stored in areas where unauthorized persons may gain access to prevent accidental spillage or unauthorized use.
- Liquid storage containers should be resistant to corrosion or damage from the materials stored for the duration of use on site.
- Berm or surround the tank or container with an appropriate secondary containment system with an impervious surface (see below).
- Place drip pans or absorbent materials beneath all mounted taps and at all potential drip and spill locations during filling and unloading.
- Place containers used for removing liquid in a containment area. Use a drip pan at all times.
- Install overflow protection devices to warn the operator or provide automatic shutdown of transfer pumps.
- Install protection guards (bollards) around tanks and piping to prevent construction vehicle damage.
- Label containers or tanks clearly.
- Install an oil and water separator, if necessary, in facilities with *spill ponds.* Facilities using spill ponds designed to intercept, treat, and/or divert spills should contact the appropriate regulatory agency regarding environmental compliance.
- Facilities storing reactive, ignitable, or flammable liquids should comply with fire codes. A SPCC plan may be required when storing contaminated or hazardous liquids on site.

Secondary Containment

Liquid storage tanks should be surrounded by a secondary containment system with an impervious surface. Leaks can be detected more easily and spills can be contained when secondary containment systems, such as berms, dikes, liners, vaults, or double-walled tanks, are installed. In an emergency, dikes can be used for controlling large spills or releases from liquid storage transfer areas.

Containment dikes are berms or retaining walls designed to hold spills. The dike surrounds the area and holds the spill, keeping spill materials separated from storm water. Containment dikes should be large enough to contain 100% of the volume of the largest container plus the amount of rainwater equal to a 25-year storm event. Diked areas used as secondary containment for vehicles containing liquid waste should be capable of holding an amount equal to the volume of the tank

truck compartment. The containment area design must include a means to remove uncontaminated storm water to maintain capacity and effectiveness.

Dike construction material should be impervious and strong enough to safely hold spilled materials. Dike materials consist of earth, concrete, synthetic materials, metal, or other impervious materials. Avoid using metal containers, concrete, and some plastics for dike materials if strong acids or bases will be stored outside. These dike materials could react with strong acids or bases if a spill occurs. More active organic chemicals may require special liners for dikes.

Curbing is common at many facilities in small areas where handling and transfer of liquid materials occur. Curbing is usually small scale and does not contain large spills like diking. Curbing can redirect contaminated storm water away from the storage area and can be used in areas where liquid materials are transferred from one container to another. Asphalt is a common material used for curbing; however, earth, concrete, synthetic materials, metal, or other impenetrable materials may also be used. Curbs should have manually controlled pump systems rather than common drainage systems to collect spilled materials. The curbed area should be inspected regularly to clear clogged debris and maintained frequently to prevent overflow of any spilled materials. Slope the liquid storage area, located inside the curb, to a drain. Install a dead-end holding tank in the drain for used oil or dangerous waste.

Construction Guidelines

All employees should receive training for properly handling outdoor material, liquid storage containers, and spill cleanup procedures. Employees should be familiar with the SPCC plan and have the tools and knowledge to immediately begin cleanup when a spill occurs. When dangerous waste, liquid chemicals, or other wastes are loaded or unloaded at the construction site, ensure properly trained employees are present.

Use engineering safeguards to reduce accidental releases of pollutants and prevent operator errors:

- Overflow protection devices on tank systems warn the operator to shut down transfer pumps when the tank reaches full capacity.
- Protective guards (bollards) around tanks and piping prevent vehicle or forklift damage.
- Clearly tag or label all containers, tanks, and valves.

Maintenance

Good maintenance practices are prevent storm water contamination from materials and liquids stored on site:

- Keep outdoor storage containers in good condition, check regularly for leaks, and ensure storage container lids are on tightly.
- Sweep paved storage areas monthly. Do not hose down areas contributing to storm drains.
- Store and maintain appropriate spill cleanup materials, such as brooms, dustpans, and vacuum sweepers, near the storage area.
- Schedule frequent waste collection to prevent overfilling storage containers.

Conduct the following inspections weekly or before storm events:

- Inspect for damage or cracks and repair or patch curbing as necessary.

- Check for accumulated rainfall in the secondary containment system (remove and discharge properly).
- Check for external corrosion and structural failure.
- Check for spills and overfills due to operator error.
- Check for failure of piping system (pipes, pumps, flanges, coupling, hoses, and valves).
- Check for leaks or spills when pumping liquids or gases from a truck or rail car to a storage facility or vice versa.
- Inspect new tank or container installation for loose fittings, poor welding, and improper or poorly fitted gaskets.
- Inspect tank foundations, connections, coatings, tank walls, and piping system. Look for corrosion, leaks, cracks, scratches, and other physical damage that may weaken the tank or container system. Correct problems or potential problems immediately.
- Inspect tanks, containers, and containment-holding tanks daily for leaks and spills. Replace leaking and/or deteriorating containers and collect all spilled liquids for proper disposal.
- Inspect tank systems and regularly test the tank's integrity to identify problem areas. Registered and specifically trained professional engineers can identify and correct potential problems such as loose fittings, poor welding, and improperly or poorly fitted gaskets on newly installed tank systems.
- During and after significant storms or spills, inspect dikes for washout or overflows.

Additional Resources

CASQA (California Stormwater Quality Association). 2015. *California Stormwater Best Management Practices Handbook: Construction.* Menlo Park, CA. *http://www.casqa.org/*

EPA (US Environmental Protection Agency). 2017. *General Construction Waste Management, Hazardous Waste Storage. https://www.epa.gov/hw/learn-basics-hazardous-waste*

Washington State Department of Ecology. 2012. *Stormwater Management Manual for Western Washington*. Lacey, WA. Publ. 12-10-030. *http://www.ecy.wa.gov/programs/wq/stormwater/manual.html*

BMP 78: Fertilizer Management

Description

Proper fertilizer application, storage, handling, and disposal prevent contamination of surface water and ground water and adverse impacts to aquatic life. Proper management also prevents increased algae growth in water bodies. Nitrogen and phosphorous are the fertilizer components of greatest concern to water quality (Figure 191).

Figure 191. Landscape fertilizing.

Applicability

Good fertilizer management applies to all locations in agricultural production or landscaping, including those maintained by municipalities, individual homeowners, businesses, commercial operations, or homeowner associations.

Limitations

Few limitations are associated with implementing proper fertilizer management practices. Some larger sites in agricultural production or areas with extensive landscaping may require employees trained specifically for managing these facilities. Other options include hiring agricultural or horticultural professionals to manage and maintain these facilities who know the proper use of fertilizers.

Fertilizer applied through an irrigation system (chemigation) has regulatory requirements including equipment inspection before use. For more information, visit the Idaho State Department of Agriculture (ISDA 2006) at *https://agri.idaho.gov/main/chemigation/*. These requirements are designed to protect the source of irrigation water, whether it is ground water, surface water, or a municipal water supply from contamination.

Primary BMP Functions and Controls

☒ Construction	☒ Permanent
☐ Erosion Control	☐ Sediment Control
☒ Source Control	☐ Flood Control
☐ Filtration	☐ Infiltration

Typical Effectiveness for Targeted Pollutants

○	Sediment
●	Nitrogen
●	Phosphorus
○	Metals
○	Bacteria
○	Hydrocarbons
○	Litter

Other BMP Considerations

Relative Cost	$
Maintenance Requirements	Low
Ease of Installation	N/A
Freeze/Thaw Resistance	N/A
Max. Tributary Drainage Area	N/A
Max. Upstream Slope	N/A
NRCS Soil Group	N/A
Min. Ground Water Separation	N/A
Min. Bedrock Separation	N/A

Design Basis

Within landscape areas, one of the best practices to reduce or eliminate the need for fertilizers is to use native and adapted vegetative species. These types of plants do not require additional fertilization because

they grow well in native soil without added fertilizers. Additionally, native and adapted plants require less water and irrigation, which reduces the potential for irrigation runoff water to transport chemicals off site.

For landscaping areas, agricultural fields, or residential gardens that do require replacing soil nutrients through fertilization, select the appropriate fertilizer type and apply it at the appropriate rate and time using the right method. Fertilizers should be selected based on the site's unique soil, plant, and climatic conditions to minimize the amount of nitrogen or phosphorous that is not used by plants and lost either through leaching or runoff.

Fertilizer Selection

Using the appropriate form of nitrogen fertilizer can reduce leaching to ground water sources. For example, nitrate forms of nitrogen fertilizer are readily available to plants but are subject to leaching losses. Nitrate forms should be used when plants are vigorously growing and can use the amount applied. Ammonium nitrogen fertilizers are not mobile because the ammonium form of nitrogen binds to soil particles and the plant roots have to reach the soil particle where the ammonium nitrogen is located. In warm and moist soil conditions, bacteria convert the ammonium nitrogen into the nitrate form, which takes a few days to a few weeks depending on the conditions. In addition, some types of ammonium nitrogen are subject to volatilization and significant losses may occur if not incorporated into the soil after application. Sources of organic nitrogen, such as compost or aged manure, are converted over time by soil microbes into forms available to plants, and are another fertilizer option to use.

Phosphorous fertilizers are less subject to leaching because most forms of phosphorus bind to the soil particles and do not move through the soil column. Surface water runoff that carries soil particles containing phosphorus into rivers or streams are a concern. To minimize phosphorous in surface runoff, use it only when needed as determined through soil testing and at the recommended rates.

Application Rate

Soils should be tested and evaluated for nutrient deficiencies every year to determine the amount of fertilizer needed for a particular location. In addition to soil characteristics, account for other sources that will contribute nitrogen and phosphorous to the soil. Sources of nitrogen include plants in the legume family, irrigation water, and organic matter. A portion of the soil organic matter is converted over time by soil microbes into forms of phosphorous and nitrogen that are available for the plant to use. It may take several years for the phosphorus and nitrogen contained in organic material to become *plant available*. For more information on fertilizer application see the *University of Idaho Extension* (2011).

Application Timing

The timing of fertilizer application is important. Fertilizers should ideally be applied during the time of year that is optimal for maximum vegetation uptake and growth. Generally, in the spring is best with small additional applications in certain areas throughout the growing season. When application practices allow the nitrate form to remain in the soil after the growing season, the nitrate can potentially leach into the ground water. Fertilizers should not be applied during high temperatures, windy conditions, or immediately before or during rainfall events.

Application Techniques

Use application techniques that increase efficiency and allow the lowest effective application rate. Fertilizer placement in the root zone enhances plant nutrient uptake and minimizes losses. Subsurface-applied or incorporated fertilizer should be used instead of surface application of fertilizer. Mechanically incorporate surface-applied fertilizers after application. Never apply fertilizers to frozen ground or near surface waters or storm water conveyance channels and limit use on slopes and areas with high runoff or overland flow.

Fertilizers should be applied according to the label instructions. Overapplying fertilizers can pollute surface water and ground water resources. Mix and load sprayers in an area with spill control in place.

Storage and Handling

Follow label directions for storing and mixing fertilizer and disposing of empty containers. Protect permanent fertilizer storage and mixing sites from spills, leaks, or storm water infiltration and locate them away from wellheads and surface water bodies.

Fertilizers should be stored in enclosed areas, in covered impervious containment (plastic sheeting or temporary roofs), or use a similarly effective means to prevent these chemicals from coming into contact with rainwater (BMP 77: Outdoor Storage and BMP 46: Spill Prevention and Control). MSDS should be readily accessible at all times.

Maintenance

Keep fertilizer application equipment properly calibrated according to the manufacturer's instructions and in good repair. For larger agriculture operations, recalibrate equipment periodically to compensate for wear in pumps, nozzles, and metering systems. Calibrate sprayers when new nozzles are installed.

Keep and review records to evaluate the effectiveness of pesticides used. Comply with all disposal requirements included on the registered fertilizer label.

Additional Resources

Colorado UDFCD (Colorado Urban Drainage and Flood Control District). 2010. *Urban Storm Drainage Criteria Manual, Volume 3 Best Management Practices*. Denver, CO. *http://udfcd.org/wp-content/uploads/2014/07/Title-Page.pdf*

EPA (US Environmental Protection Agency). 2001. *Source Water Protection Practices Bulletin: Managing Agricultural Fertilizer Application to Prevent Contamination of Drinking Water*. *http://nepis.epa.gov/Exe/ZyNET.exe/*

EPA (US Environmental Protection Agency). 2017. *Municipal Landscaping*. *https://archive.epa.gov/greenacres/web/html/index.html*

University of Idaho Extension. 2014. Idaho Master Gardener Program Handbook. 16th ed. Moscow, ID. *http://www.extension.uidaho.edu/mg/resources/handbook/MGHbook.pdf*

BMP 79: Pesticide Management

Description

Pesticides are used to control organisms considered to be pests and include herbicides, insecticides, fungicides, rodenticides, and others. Pesticides must be properly applied, stored, handled, and disposed of to prevent contamination of surface water and ground water (Figure 192).

Figure 192. Pesticide application.

Applicability

Good pesticide and herbicide management applies in all locations with landscaping, including those maintained by municipalities, individual homeowners, businesses, commercial operations, or homeowner associations.

Limitations

Some pesticides are categorized as *restricted use* pesticides because they are excessively hazardous to the environment or the applicator. These pesticides may only be used by a certified applicators licensed by the State of Idaho. EPA (2015) provides a list of restricted pesticides *http://www2.epa.gov/pesticide-worker-safety/restricted-use-products-rup-report*.

All pesticides are regulated by the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) and any use of a pesticide in a "manner inconsistent with label instructions is a violation of this Act."

Design Basis

One of the best practices to reduce or eliminate the need for pesticides and herbicides is to use native and adapted vegetative species within landscape areas. Native and adapted plants require less water and irrigation, which reduces the potential for irrigation runoff water to transport chemicals off site. Many native plants are also naturally resistant to pests.

Primary BMP Functions and Controls

☒ Construction ☒ Permanent
☐ Erosion Control ☐ Sediment Control
☒ Source Control ☐ Flood Control
☐ Filtration ☐ Infiltration

Typical Effectiveness for Targeted Pollutants

○ Sediment
● Nitrogen
● Phosphorus
○ Metals
○ Bacteria
○ Hydrocarbons
○ Litter

Other BMP Considerations

Relative Cost	$
Maintenance Requirements	Low
Ease of Installation	N/A
Freeze/Thaw Resistance	N/A
Max. Tributary Drainage Area	N/A
Max. Upstream Slope	N/A
NRCS Soil Group	N/A
Min. Ground Water Separation	N/A
Min. Bedrock Separation	N/A

Pesticides and herbicides should be selected according to the characteristics of the site and the particular pest or weed. Half-life, solubility, and adsorption should be compared to site characteristics to determine the safest chemical. Pesticides should readily degrade in the environment and/or have properties that strongly bind it to the soil.

Application Guidelines

All pesticides, herbicides, and other chemicals should be applied according to the product label instructions. Avoid overapplying chemicals that can pollute surface water and ground water resources.

Pesticides and herbicides should not be applied during high temperatures, windy conditions, or immediately before or during rainfall events. Freshly treated wet applications should dry thoroughly before human or animal traffic enter the area. Mix and load sprayers in an area where spill control is in place.

Records and signage of pesticide application, emergency information, and pesticide safety may be required by EPA's Pesticide Worker Protection Standard: *https://www.epa.gov/pesticide-worker-safety/pesticide-worker-protection-standard-how-comply-manual*.

Owners of agricultural establishments and members of their immediate families are exempt from many worker protection requirements.

Local regulations may limit the application of pesticides around wells and surface water. Generally, pesticides should not be sprayed in proximity of open waters, including wetlands, ponds, stream, sloughs, or ditches, unless they are approved for use near wetlands and ponds to control aquatic weeds or mosquitos. Section 3.5.6 provides more information on mosquito control for storm water BMPs.

Integrated Pest Management

Integrated pest management (IPM) focuses on long-term prevention of pests or their damage by managing the ecosystem using targeted biological, chemical, cultural, and physical measures that remove pests with minimal or no use of chemical pesticides. IPM programs generally include five major components as follows:

1. Pest identification
2. Monitoring and assessing pest numbers and damage
3. Guidelines for when management action is needed—consider pest occurrence and history when developing pest management strategies
4. Preventing pest problems
5. Using a combination of biological, cultural, physical/mechanical and chemical management tools

IPM Management Tools

Biological control is the use of natural enemies—predators, parasites, pathogens, and competitors—to control pests and their damage. Invertebrates, plant pathogens, nematodes, weeds,

and vertebrates have many natural enemies. For example, introduce natural enemies of pests such as lady beetles (or lady bugs) and green lacewings. Pesticide use may kill these natural enemies.

Cultural controls reduce pest establishment, reproduction, dispersal, and survival. Changing irrigation practices can reduce pest problems—too much water can increase root disease and weeds. Proper plant selection, planting time, and planting method can reduce susceptibility to insects, pests, and diseases.

Mechanical and physical controls kill a pest directly or make the environment unsuitable for it. Traps for rodents are examples of mechanical control. Physical controls include mulches for weed management, solar heating, handpicking, mowing, hoeing, steam sterilization of the soil for disease management, or barriers such as screens to keep birds and insects out or *collars* around seedlings. The use of soil amendments, such as compost, is known to control some common diseases in plants and installing an amended soil and landscape system can preserve both plant and soil systems. Rotate annual garden plants to reduce the buildup of soil-borne pests. Clean up plant litter and remove weeds before they go to seed. Remove infested plant residue from the garden so pests do not overwinter.

Chemical control uses pesticides. In IPM, pesticides are used only when needed and in combination with other approaches for more effective, long-term control. Pesticides are selected and applied to minimizes possible harm to people and the environment. Consider applying environmentally friendly chemical alternatives such as insecticidal soaps, horticultural oils, and other such measures when practical and effective and when mechanical approaches are impractical.

With IPM, use the most selective pesticide to do the job and the safest for other organisms and air, soil, and water quality; use pesticides in bait stations rather than sprays; or spy-spray a few weeds instead of an entire area. Spot treat pests rather treating the entire area, and time pesticide application to minimize host plant damage and maximize pest control.

Storage and Handling

Do not store large quantities of pesticides for long periods of time. Adopt the *first in, first out* principle and use the oldest products first.

Pesticides should be stored in enclosed areas, in covered impervious containment (plastic sheeting or temporary roofs), or in a similar manner to prevent the chemicals from coming into contact with rainwater (BMP 77: Outdoor Storage and BMP 46: Spill Prevention and Control). MSDS should be readily accessible at all times.

Maintenance

Keep pesticide equipment properly calibrated according to manufacturer's instructions and in good repair. Recalibrate equipment periodically to compensate for wear in pumps, nozzles, and metering systems. Calibrate sprayers when new nozzles are installed. Keep and review records to evaluate the effectiveness of pesticides used. Comply with all disposal requirements included on the registered pesticide, herbicide, or insecticide label.

Additional Resources

Colorado UDFCD (Colorado Urban Drainage and Flood Control District). 2010. *Urban Storm Drainage Criteria Manual, Volume 3 Best Management Practices*. Denver, CO. *http://udfcd.org/wp-content/uploads/2014/07/Title-Page.pdf*

EPA (US Environmental Protection Agency). 2016. *Municipal Landscaping*. *https://archive.epa.gov/greenacres/web/html/index.html*

University of Idaho Extension. 2016. *Idaho Master Gardener Program Handbook*. 18th ed. Moscow, ID. *http://www.extension.uidaho.edu/mg/resources/handbook/MGHbook.pdf*

BMP 80: Building and Grounds Maintenance

Description

To prevent or reduce pollutant discharge to storm water from buildings and grounds maintenance, wash and clean up with as little water as possible, prevent and clean up spills immediately, keep debris from entering the storm drains, and maintain the storm water collection system. Overwatering, overfertilizing, improper herbicide or pesticide application, and improper disposal of trimmings and clippings can all contribute to serious water pollution problems (Figure 193).

Figure 193. Leaf clean up in Idaho Falls, Idaho.

General Information

Common maintenance activities generate wastes that must be properly disposed. Buildings and grounds maintenance involves landscaping, general maintenance, pest control, parking area and storm water system maintenance, and waste removal. Painting and other building repairs are covered in BMP 90.

Primary BMP Functions and Controls

☒ Construction	☒ Permanent
☐ Erosion Control	☐ Sediment Control
☒ Source Control	☐ Flood Control
☐ Filtration	☐ Infiltration

Typical Effectiveness for Targeted Pollutants

○	Sediment
●	Nitrogen
●	Phosphorus
○	Metals
○	Bacteria
○	Hydrocarbons
○	Litter

Other BMP Considerations

Relative Cost	$
Maintenance Requirements	Low
Ease of Installation	N/A
Freeze/Thaw Resistance	N/A
Max. Tributary Drainage Area	N/A
Max. Upstream Slope	N/A
NRCS Soil Group	N/A
Min. Ground Water Separation	N/A
Min. Bedrock Separation	N/A

Landscaping

- Leave or plant drought-tolerant vegetation to reduce water, fertilizer, and pesticide needs.
- Save water and prevent pollution by watering lawns sensibly. Lawns and gardens typically need the equivalent of 1 inch of rainfall per week. Overwatering to the point of runoff can carry polluting nutrients to the nearest water body.
- Conserve water by using irrigation practices such as drip irrigation, soaker hoses, or microspray systems.
- Consider planting a vegetated buffer zone adjacent to streams or other water bodies.
- Compost all yard clippings, or use them as mulch to save water and keep down weeds.
- Practice organic gardening and reduce or eliminate the need for pesticides and fertilizers.
- Pull weeds instead of spraying them.

General Maintenance

- Dispose of all waters from cleaning carpets, upholstery, and other surfaces into the sink or toilet and not the street or storm drain.
- Water from pressure washing decks, driveways, roofs, or other hard surfaces may contain suspended solids and other pollutants that should not be directly discharged to drainage systems. Redirect pressure washing wastewater to vegetated areas or areas such as gravel, lawns, landscaping, or bare soil for infiltration. If this cannot be accomplished, filter the washwater through filter fabric or other filtering media to collect the suspended solids before discharging the water to a drainage system. Remove filter fabric upon completion and dispose of it in the trash.
- If chemicals are used during the pressure-washing process, the wastewater should be collected and disposed of in a sanitary sewer system or discharged to a landscaped area where it can infiltrate on site.
- Sweep parking lots, storage areas, driveways, and sidewalks monthly to collect dust, waste, and debris. Avoid hosing down the area to a storm drain.
- Dispose of washwater, sweepings, and sediments properly. Section 3.10.7 provides disposal alternatives.
- Ensure that rooftop drains drain directly to an on-site storm drain system or a grass-covered area.

Safe Substitutes for Pest Control

Pest control should be done in a safe manner to prevent washing pesticides into the storm water system and causing water pollution. Some environmentally safe substitutes for pesticides include the following:

- Garden aphids and mites—Mix 1 tablespoon of liquid soap and 1 cup of vegetable oil. Add 1 teaspoon of this mixture to a cup of water and spray. (Oil may harm vegetable plants in the cabbage family.)
- Caterpillars—When caterpillars are eating, apply products containing Bacillus thuringiensis to leaves.
- Ants—Place boric acid powder or hydramethylnon baits in problem areas, cracks, and insect walkways. It is a mild poison, so ensure it is inaccessible to children and pets.
- Roaches—Apply boric acid powder to cracks and entry points (see ants above). Place bay leaves on pantry shelves.

Parking Area and Storm Sewer Maintenance

Evaluate any parking area that drains to the same storm drain system for suitable BMPs. Sweeping the parking area periodically and cleaning the catch basins (if they are part of the drainage system) are suitable BMPs. A vacuum sweeper is the best method of sweeping, rather than mechanical brush sweeping. Mechanical brush sweeping does not remove fine particulates as effectively as a vacuum sweeper.

Catch basins in parking lots generally need to be cleaned every 6 to 12 months, or whenever the holding tank is one-half full. A holding tank that is more than one-half full is not effective at removing additional particulate pollutants from the storm water. If the storm drain lines have a low

gradient, (less than 0.5 feet in elevation drop per 100 feet of line), material may settle in the lines during small, frequent storms. If the storm drain system has not been cleaned recently, check the lines. If the lines are not cleaned, the catch basins will likely fill up (during the next significant storm) with material washed from the lines. Install *turndown* elbows or similar devices on the outlets of the catch basins to retain floatables or oil and grease.

Sediments from parking areas and storm sewer maintenance are generally low in metals and other pollutants. To ensure that metals or other pollutants are not present, the material should be tested. If contaminant concentrations are high, use other BMPs to eliminate or reduce pollutants.

Using a vacuum truck to clean the storm drain system will generate dirty water, so disposed of the water properly.

Clearly mark the storm drain inlets, either with a color code (to distinguish from process water inlets if present) or with a painted stencil. The stencil should read "DO NOT DUMP WASTE." Ensuring that storm drain inlets are clearly marked reduces inadvertent dumping of liquid wastes.

Waste Removal

For a quick reference on disposal alternatives for specific wastes, see section 3.10.7.

- Compost piles should be located on an unpaved area where runoff can soak into the ground or be filtered by grass and other vegetation. Compost piles should be located in an area of the property not prone to water ponding during storms and kept well away from wetlands, streams, lakes, and other drainage paths.
- Avoid putting hazardous or nondecomposable waste in the pile.
- Cover the compost pile to keep storm water from washing nutrients into waterways and to keep excess water from cooling down the pile, which will slow down the rate of decomposition.
- Build bins of wood, chicken wire or fencing material to contain compost so it cannot be washed away. Building a small earthen dike around a compost pile is an effective means of preventing nutrient-rich compost drainage from reaching storm water paths.
- Do not blow or rake leaves into the street, gutter, or storm drains. Never dispose of grass clippings or other vegetation in or near storm drains, streams, or lakes.
- In communities with curbside yard waste recycling, place clippings and pruning waste in approved containers for pickup, or take clippings to a landfill that composts yard waste.

BMP 81: Loading Dock Design Features

Description

When raw materials are handled in loading dock areas, precipitation or storm water runoff that comes in contact with such materials may become contaminated. Properly designed outdoor loading docks with covers and containment features reduce the chance of pollution entering storm water runoff (Figure 194).

Figure 194. Covered truck loading dock (Colorado UDFCM 2010).

Applicability

This BMP applies to the following material transfer areas:

- Loading/unloading areas
- Bay doors without docks
- Any building access point designed to receive a truck, trailer, or specifically intended to receive or distribute materials to and from trucks or trailers

Primary BMP Functions and Controls

☐ Construction ☒ Permanent
☐ Erosion Control ☐ Sediment Control
☒ Source Control ☐ Flood Control
☐ Filtration ☐ Infiltration

Typical Effectiveness for Targeted Pollutants

○ Sediment
○ Phosphorus
○ Metals
○ Bacteria
◖ Hydrocarbons
◖ Litter

Other BMP Considerations

Relative Cost	$$
Maintenance Requirements	Easy
Ease of Installation	Medium
Freeze/Thaw Resistance	Good
Max. Tributary Drainage Area	N/A
Max. Slope	N/A
NRCS Soil Group	ABCD
Min. Ground Water Separation	N/A
Min. Bedrock Separation	N/A

Limitations

Some features of loading dock facilities may have limitations such as underground holding tanks with shutoff valves that are engineering intensive and an expensive requirement.

Design Basis

Cover

Whenever possible, loading docks should be designed with a permanent covering. The roof cover should be sufficiently sized to prevent any precipitation from reaching the protected contents underneath. Proactively covering loading docks is an effective method of source control.

The first 3 feet of the paved area, measured from the building or dock face, should be covered and hydraulically isolated by grading, berms, or drains to prevent uncontaminated storm water from running onto the area and carrying away pollutants.

Isolation

Bay doors and other indoor material transfer areas should prevent runoff from entering the building. This design may be achieved through grading, berming, or drains transferring runoff to an appropriate collection point.

Holding Tank

Use berms, curbs, dikes, or slopes to prevent run-on to paved loading areas so storm water is not added to waste in a holding tank. Dikes can be made of timbers, concrete curbing, or other similar materials (BMP 69).

Ensure the inlet carries liquid to a holding tank with large enough capacity to contain the entire volume of a potential spill, in addition to runoff from the applicable design event, while the valve is closed. Consult with a professional engineer when sizing the holding tank. The tank should be equipped with an outflow pipe to allow discharge of normal uncontaminated runoff to the storm drain. Keep the holding tank outlet valve closed at all times except when storm water or other acceptable fluids need to be discharged.

The use of an oil and water separator (BMP 15) upgradient and in-line with the holding tank may be effective removing petroleum-based pollutants before discharge to the holding tank. The upper contaminated layer in the oil and water separator can then be removed at less cost than treatment and/or transport of contaminated liquid in the holding tank.

If the inlet connects to a storm drain, test accumulated liquid before discharging to the storm drain. Ensure the liquid does not contain pollutants before you discharge it to the storm drain. This discharge may require an NPDES permit.

If the inlet connects to a sanitary sewer, test accumulated liquid before discharging to the sanitary sewer (BMP 50). Ensure its quality is within the parameters specified in the wastewater discharge permit before opening the valve for discharge.

Paving

Pave and grade the sloped or recessed loading area to direct flow toward either a central collection point or toward a dead-end holding tank. Pave the area with concrete if materials such as gasoline will be handled; gasoline can react with asphalt. If the area is already paved with asphalt, apply a sealant to the surface. Ensure that the paved surface is free of gaps and cracks.

Other

Retain the needed equipment and trained personnel on site (BMP 91) for immediate cleanup of spills (BMP 46).

Maintenance

- Inspect the holding tank regularly to ensure it is not overfilled.
- Test the holding tank contents before discharge or disposal.
- Inspect and maintain berms, curbs, dikes, or slopes regularly.

Additional Resources

Central Oregon Intergovernmental Council. 2010. *Central Oregon Stormwater Manual*. Bend, OR.

Colorado UDFCD (Colorado Urban Drainage and Flood Control District). 2010. *Urban Storm Drainage Criteria Manual, Volume 3 Best Management Practices*. Denver, CO. *http://udfcd.org/wp-content/uploads/2014/07/Title-Page.pdf*

Washington State Department of Ecology. 2012. *Stormwater Management Manual for Western Washington*. Lacey, WA. Publ. 12-10-030. *http://www.ecy.wa.gov/programs/wq/stormwater/manual.html*

BMP 82: Equipment Yard Design Features

Description

Equipment yards storing vehicles and equipment can generate wastes, such as solvents, antifreeze, oils, and greases, from cleaning and maintenance activities or improperly maintained equipment. Properly designed equipment yards control storm water pollution by reducing or eliminating polluted runoff from contaminating storm water and preventing unnecessary run-on of storm water onto the site (Figure 195).

Spill prevention controls (BMP 46) and on-site personnel training (BMP 91) should also be implemented in equipment yards.

Figure 195. Equipment yard during construction of the Salmon River Road, Riggins, Idaho.

Applicability

These design features apply to all equipment yards, both temporary construction and permanent facilities, and wherever vehicles or equipment are stored, cleaned, maintained, or fueled.

Limitations

A large area may be required for structural equipment yard BMPs to accommodate proper grading, berming, or segregated service areas. If the equipment yard cannot be designed properly, consider storing equipment off site in a more suitable location.

Design Basis

Ideally, equipment storage, maintenance, and process areas should be covered and the area around it graded to drain away from the building or covered area.

- The roof cover option used at a given site is subject to the site layout, available space, affordability, and limitations imposed by other regulations. Examples of storage options include, but are not limited to, the following:

Primary BMP Functions and Controls

☒ Construction	☒ Permanent
☐ Erosion Control	☐ Sediment Control
☒ Source Control	☐ Flood Control
☐ Filtration	☐ Infiltration

Typical Effectiveness for Targeted Pollutants

●	Sediment
○	Phosphorus
◖	Metals
○	Bacteria
◖	Hydrocarbons
○	Litter

Other BMP Considerations

Relative Cost	$$
Maintenance Requirements	Medium
Ease of Installation	Medium
Freeze/Thaw Resistance	N/A
Max. Tributary Drainage Area	N/A
Max. Upstream Slope	N/A
NRCS Soil Group	N/A
Min. Ground Water Separation	N/A
Min. Bedrock Separation	N/A

- A prefabricated storage shed to enclose and cover materials (ensure these structures meet applicable building and fire codes).
- A lean-to structure against an existing building to cover materials and prevent contact with rain.
- A stand-alone canopy that provides cover but no walls.

If the equipment yard cannot be covered, the following recommendations minimize storm water run-on and runoff from the area:

- Grade the equipment yard to drain to a longitudinal drain or install curbs or berms to direct all storm water to a central collection point in the yard and then to the sanitary sewer according to applicable industrial pretreatment requirement and approval of the sewer authority.
- Consider paving the surface with concrete in areas where asphalt may react with spilled liquids (BMP 46: Spill Prevention and Control).
- Provide BMPs such as an oil and water separators (BMP 15) if there is the possibility for oil to be released. All sites should implement source controls (BMP 46).
- Segregate the area where vehicles are serviced and install special permanent controls:
  - Drain the area to a single collection point, preferably connected to a holding tank. Consult with a professional engineer for proper sizing of the holding tank for the required design storm. The drain may require an oil and water separators (BMP 15) or sand and grease trap and should be approved by local regulatory authorities.
  - Grade the activity area higher than the parking lot or surround the activity area with a berm, curb, or dike to prevent storm water run-on.
  - Construct a special area that segregates the *dirtiest* equipment (e.g., roof tar and asphalt paving equipment) from other equipment. Use berms, curbs, or dikes to keep discharges, leaks, and runoff separate from other activity areas.

Maintenance

- Regularly maintain oil and water separators and sand and grease traps.
- Periodically inspect equipment yard pavement, berming, and curbing for gaps or cracks, and repair immediately.

Additional Resources

CASQA California Stormwater Quality Association. 2004. *California Stormwater Best Management Practices Handbook: New Development and Redevelopment*. Menlo Park, CA. http://www.casqa.org/

Washington State Department of Ecology. 2012. *Stormwater Management Manual for Western Washington*. Lacey, WA. Publ. 12-10-030. http://www.ecy.wa.gov/programs/wq/stormwater/manual.html

BMP 83: Vehicle and Equipment Refueling

Description

BMPs for transferring fuel to vehicles, equipment, or storage tanks prevent storm water pollution from heavy metals, toxic materials, and oil and grease (Figure 196). Controlling the source of contaminants is particularly important because these contaminants are not easily removed by other storm water treatment controls. Source control can be provided through careful design of the initial fuel storage area, retrofitting existing installations, and using proper spill control and cleanup procedures.

Figure 196. Mobile fueling truck (ITD 2014).

Ideally, vehicles and equipment used on construction sites would use permanent, off-site refueling stations because these stations are usually better equipped to handle fuel spills according to local, state, and federal regulations. If off-site facilities cannot be used, properly designed fleet or equipment fueling areas can control storm water pollution by reducing or eliminating pollutants entering storm water.

Primary BMP Functions and Controls

☒ Construction	☒ Permanent
☐ Erosion Control	☐ Sediment Control
☒ Source Control	☐ Flood Control
☐ Filtration	☐ Infiltration

Typical Effectiveness for Targeted Pollutants

○	Sediment
○	Phosphorus
◖	Metals
○	Bacteria
●	Hydrocarbons
○	Litter

Other BMP Considerations

Relative Cost	$$
Maintenance Requirements	Medium
Ease of Installation	Easy
Freeze/Thaw Resistance	NA
Max. Tributary Drainage Area	NA
Max. Upstream Slope	NA
NRCS Soil Group	NA
Min. Ground Water Separation	NA
Min. Bedrock Separation	NA

Applicability

This BMP applies to both temporary fueling facilities for construction sites and permanent commercial or industrial fueling facilities. Construction sites often use either mobile refuelers or aboveground storage tanks with secondary containment. Mobile fueling, also known as fleet fueling, wet fueling, or wet hosing, is the practice of filling vehicle fuel tanks using tank trucks that are driven to the yards or sites where the vehicles to be fueled are located. BMP 77 provides more information on secondary containment and outdoor storage of liquid materials.

Limitations

Retrofitting existing fueling areas to minimize storm water exposure or spill runoff is more difficult than using good design and initially installing fueling areas that incorporate storm water BMPs.

Maintenance is critical for proper functioning of oil and water separators.

Design Basis

Vehicle and Equipment Fueling Design Features

- Cover the fueling area to prevent rain from falling directly on the activity area. The cover's minimum dimensions should be equal to or greater than the area within the grade break or the fuel dispensing area to ensure adequate coverage.
- Equip the storm drain and sewer inlets that drain the fueling area with a shutoff valve to keep fuel out of the drain in the event of a fuel spill. Keep the valve closed at all times except during rain events where no contamination is present. Curtail fueling activities when the shutoff valve should be open, or use a large drip pan under the vehicle to capture any spilled fuel.
- Separate the fueling area from the rest of the facility, not only to contain any fuel spills, but also to prevent storm water run-on. Select from the following drainage design guidelines:
  - Grade the fueling area so it is either *mounded* or elevated. A mounded grading scheme is recommended.
  - Grade the entire fueling area to drain to a single collection point inlet. Design the grading to prevent run-on.
  - Install high berms around the area to redirect water from a large storm to a single collection point inlet.
  - Install a holding tank where accumulated liquids can be pumped.
  - Pave the fueling area with concrete rather than asphalt; asphalt can react with or absorb gasoline and other materials.
  - Apply a suitable sealant to protect the asphalt from spilled fuels in areas where covering the asphalt is not feasible and the fuel island is surrounded by pavement.
  - Install an oil and water separator (BMP 15) to collect spills if a dead-end holding tank is not used.
  - Install vapor recovery nozzles to control drips as well as air pollution.

Spill Management and Reporting

- Prepare an emergency response plan with designated personal available on site or on call to properly implement and manage spills (BMP 46).
- Keep appropriate absorbents on hand and convenient to fueling areas.
- Report uncontrolled spills to local agencies such as the local police department or fire department.
- Report significant spills into a water body to the National Response Center at (800) 424-8802.

Designated Fueling Area

For facilities with large amounts of mobile equipment that currently use a mobile fuel truck to fuel the equipment, consider establishing a designated fueling area. Except for tracked equipment, such as bulldozers or small forklifts, most vehicles can travel to a designated area with little lost time. Place temporary *caps*, such as a bentonite mat or a spill mat, over nearby catch basins or manhole covers to prevent spilled fluid from entering the storm drain. Upon fueling is completed, remove the mat and dispose as hazardous waste.

The following spill control measures (BMP 46) reduce spilling or reduce the loss of spilled fuels from the site:

- Discourage *topping off* vehicle fuel or underground storage tanks. Topping off tanks increases the risk of spilling fuel onto the ground.
- Use secondary containment when transferring fuel from the tank truck to the fuel tank.
- Store and maintain appropriate spill cleanup materials in a location known to all employees near the fueling operation; ensure that employees are familiar with the site's spill control plan and proper spill cleanup procedures.
- Use absorbent materials on small spills. Remove the absorbent materials promptly and dispose as hazardous waste.
- Obey all federal and state requirements for both underground and aboveground storage tanks.
- Avoid mobile fueling of industrial equipment around the facility; transport the equipment to designated fueling areas.
- Train employees in proper fueling procedures.
- Do not leave fueling operations unattended.

Maintenance

- Using a qualified professional, periodically test aboveground and belowground tanks for integrity.
- Inspect and maintain holding tanks, oil and water separators, and on-site treatment or recycling units regularly.
- Inspect the holding tank regularly to ensure it is not overfilled.
- Test holding tank contents before discharge or disposal.
- Inspect and maintain berms, curbs, dikes, or slopes regularly.
- Regularly clean oil and water separators at the appropriate intervals.
- Keep ample supplies of spill cleanup materials on site.
- Inspect fueling areas and storage tanks regularly.
- Repair and patch berms as needed.

Additional Resources

CASQA (California Stormwater Quality Association). 2015. *California Stormwater Best Management Practices Handbook: Construction.* Menlo Park, CA. http://www.casqa.org/

EPA (US Environmental Protection Agency). 2012. *EPA Construction General Permit*. National Pollutant Discharge Elimination System Stormwater Program. *http://www.epa.gov/npdes/stormwater-discharges-construction-activities#overview*

EPA (US Environmental Protection Agency). 2020. *Municipal Vehicle Fueling*. *https://www.epa.gov/npdes/oil-and-gas-stormwater-permitting#undefined*

ITD (Idaho Transportation Department). 2014. *Best Management Practices.* Boise, ID: ITD.

King County (King County, Washington). 2009. *King County, Washington Surface Water Design Manual.* Seattle, WA: King County, Department of Natural Resources.

BMP 84: Vehicle and Equipment Cleaning, Maintenance, and Repair

Description

Proper vehicle and equipment cleaning, maintenance, and repair procedures prevent pollutants, heavy metals, and toxic materials from entering ground water and surface water supplies and creating public health and environmental risks (Figure 197). Wastes often generated by cleaning, maintenance, and repair activities include, but are not limited to the following:

- Solvents
- Antifreeze
- Brake fluids
- Batteries
- Motor oils
- Fuels
- Lubrication greases

Figure 197. Vehicle maintenance prevents pollution.

Primary BMP Functions and Controls

☒ Construction ☒ Permanent
☐ Erosion Control ☐ Sediment Control
☒ Source Control ☐ Flood Control
☐ Filtration ☐ Infiltration

Typical Effectiveness for Targeted Pollutants

● Sediment
○ Phosphorus
◖ Metals
○ Bacteria
◖ Hydrocarbons
○ Litter

<u>Other BMP Considerations</u>

Relative Cost	$$
Maintenance Requirements	Medium
Ease of Installation	Medium
Freeze/Thaw Resistance	N/A
Max. Tributary Drainage Area	N/A
Max. Upstream Slope	N/A
NRCS Soil Group	N/A
Min. Ground Water Separation	N/A
Min. Bedrock Separation	N/A

Applicability

This BMP applies in all locations where vehicle and equipment cleaning, maintenance, and repair take place with a focus on permanent facilities, such as auto repair shops, industrial facilities, fleet storage facilities, and residential homes. BMP 47: Construction Equipment Washing and Maintenance provides information on temporary facilities located on construction sites.

Limitations

Many common vehicle maintenance and washing routines contribute to environmental pollution. Businesses that are unable to comply with the following guidelines should have their vehicles washed at a commercial establishment or mobile washer that conforms to these specifications.

Vehicle and equipment cleaning, maintenance, and repair can generate significant pollutant concentrations and may require permitting,

monitoring, pretreatment, and inspections. Contact local wastewater treatment plant staff for additional information and the appropriate local authority to guarantee compliance with local standards.

Space and time limitations may preclude all work being conducted indoors.

Training is a key aspect of this BMP—ensure employees are trained to properly to prevent spills and leaks.

Design Basis

Vehicle and Equipment Cleaning

Washing vehicles and equipment outdoors or in areas where washwater flows onto the ground can pollute storm water and ground water due to the presence of diesel, gasoline, hydraulic fluid, or oil residues in the washwater. Facilities that wash or steam clean a large number of vehicles or equipment should consider contracting this work to a commercial business, which is generally better equipped to handle and dispose of washwater properly. Contracting out this work can also be economical because it eliminates the need for a separate washing/cleaning operation.

Steam cleaning and washing should be conducted on site only if the site is equipped to capture all the water and other wastes. If washing/cleaning must occur on site, wash vehicles in a designated area. Direct liquid to designated areas where it can be pretreated to remove pollutants before discharge to the sanitary sewer.

Disposal Site Options

Storm Drain—Discharges from vehicle and equipment cleaning, maintenance and repair activities should never be directed to storm drains. In areas designated for cleaning, maintenance, and repair activities, stencil “DO NOT DUMP WASTE” on the storm drain inlets.

Sanitary Sewer—Pump into sanitary system cleanout/sink or into an on-site private sanitary sewer manhole; verify with the facility manager that it is not a storm drain manhole. Solids separation will be required before disposal to prevent clogging the system.

Landscape or Soil Area—Discharge should be directed to an area sufficient to contain all the water. (Note: Be aware that soapy washwater may degrade habitat and adversely affect landscaping). The area should be used for minimum discharge flows only. Repetitive use of the same area or excessive wash volume to the same area may be illegal. Discuss discharge practices with property owner.

If disposal to the sanitary sewer and/or to a landscaped area is not possible, contract with a company capable of hauling the washwater off site to an authorized disposal site.

Designated Wash Areas

The designated wash areas must provide the following:

- Clearly labeled
- Paved with concrete
- Covered and contained to prevent contact with storm water
- Sloped for washwater collection
- Connected to the sanitary sewer or to a dead-end holding tank
- Equipped with an oil and water separator
- Allowable to rinse down the body of a vehicle with just cold water without implementing any BMPs

Several proprietary products are commercially available that enable runoff collection.

Some unavoidable evaporation may occur from paved surfaces. If a significant amount of washwater runoff evaporates at the site before it can be collected, and the site is routinely used for this purpose, the paved area itself should be cleaned every 6 months, or at the end of the wash service contract, whichever comes first. Any washwater used during this procedure should be collected and discharged to a sanitary sewer.

Cleaning and Degreasing Engines, Equipment, and Auto and Truck Drive Trains

It is likely that pollutants (petroleum products and metals) from engine-cleaning activities are concentrated in these washwaters, so the local wastewater treatment plant will require treatment before discharge into the sanitary sewer. Contact the local wastewater treatment plant for requirements and additional information.

If a sanitary sewer is not available or treatment of the washwater is not feasible, contact a company capable of hauling (i.e., tanker truck) the washwater off site to dispose at an authorized site.

Household Automobile Washing

- Wash your car directly over a vegetated or pervious area or ensure the washwater drains to a vegetated or pervious area, which allows the water and soap to soak into the ground instead of running off into a local water body.
- Ideally, no soap or detergent should be used, but if you do use one, select one without phosphates.
- Sweep driveways and street gutters before washing vehicles to cleanup dirt, leaves, trash, and other materials that may flow to the storm drain along with your washwater. This practice reduces storm drain maintenance costs and protects water quality.
- Use commercially available products that allow you to clean a vehicle without water. Developed for areas where water is scarce, these products save water and reduce pollution.
- Use a nozzle on the hose to save water.
- Do not wash your car if rain is expected.
- Consider not washing your car at home. Use a commercial car wash with a recycle system that discharges wastewater to the sanitary sewer for treatment.

Vehicle and Equipment Maintenance and Repair

Vehicle or equipment maintenance and repair is a potentially significant source of storm water pollution. Activities that can contaminate storm water include engine repair and service (e.g., parts cleaning, spilled fuel, and oil), fluid replacement, and outdoor equipment storage and parking (leaking engines). When performing maintenance and repair, the following practices should be addressed:

- Keep equipment and the equipment yard clean; ensure oil and grease accumulations do not build up excessively.
- Ensure incoming vehicles are checked for oil and fluid leaks.
- Use a properly sized drip pan underneath leaking vehicles and equipment when storing vehicles or performing maintenance. Drain pans (usually 1 x 1 foot) are generally too small to contain certain equipment fluids, such as antifreeze. Drip pans (3x 3 feet) may have to be purchased or fabricated when needed.
- Store idle equipment under cover.
- Inspect equipment for leaks on a regular basis, particularly vehicles parked or stored long term.
- Use an indoor garage or vehicle maintenance area designed to prevent storm water pollution. Avoid changing motor oil or performing equipment maintenance in inappropriate areas.
- Recycle greases, used oil or oil filters, antifreeze, cleaning solutions, automotive batteries, hydraulic fluids, and transmission fluids. Collect and store these recyclable materials separately in secondary containment.
- Ensure oil filters are completely drained for at least 24 hours before recycling or disposing of them.
- Do not pour materials down storm drains or hose down work areas; sweep work areas instead.
- Use rags for small spills, a damp mop for general cleanup, and dry absorbent materials for larger spills. Avoid hosing down areas. Dry floor-cleaning methods may not be sufficient for some spills (BMP 46).
- Clean equipment yard storm drain inlets regularly and especially after large storms.
- Train employees in spill prevention and cleanup procedures.
- Store cracked batteries in a nonleaking secondary container, even if all the acid has drained out. If a battery is dropped, treat it as if it is cracked and store it in a containment area until you are sure it is not leaking.

Waste Reduction

- Parts are often cleaned using solvents such as trichloroethylene, 1,1,1-trichloroethane, or methylene chloride. Dispose of these cleaners as hazardous waste.
- Clean without using liquid cleaning products (e.g., using a wire brush) whenever possible to reduce hazardous waste.
- Use liquid cleaners at a centralized station so the solvents and residues stay in one area.
- Locate properly sized drip pans, drip boards, and drying racks to direct drips back into a solvent tank or fluid-holding tank for reuse.

Safer Alternatives

If possible, eliminate or reduce the amount of hazardous materials and waste by substituting nonhazardous or less hazardous materials:

- Use noncaustic detergents instead of caustic cleaning agents for parts cleaning (ask your supplier about alternative cleaning agents).
- Use phosphorus free cleaners whenever possible.
- Use detergent-based or water-based cleaning systems in place of organic solvent degreasers.
- Replace toxic solvents with nontoxic solvents.
- Choose recyclable cleaning agents.
- Reduce the number of solvents used to make recycling easier and lower hazardous waste management costs. Often, one solvent can perform a job as well as two solvents.

Interior Shop Area Cleaning

When possible, follow these shop area cleaning BMPs:

- Do not hose down the shop floor into streets or parking lots. Dry sweep regularly.
- Use nontoxic cleaning products. Baking soda paste works well on battery heads, cable clamps and chrome; mix the soda with a mild, biodegradable dishwashing soap to clean wheels and tires; for windows, mix white vinegar or lemon juice with water.
- To reduce or eliminate waste, fix sources of drips or leaks where possible. Routinely inspect the engine compartment, and regularly replace worn seals on equipment.
- To avoid or control spills and leaks:
  - Prepare and use easy to find spill containment and cleanup kits. Include safety equipment and cleanup materials appropriate to the type and quantity of materials that could spill.
  - Pour kitty litter, sawdust, or cornmeal on spills.
  - Change fluids carefully. Use a drip pan to avoid spills. Prevent fluid leaks from stored vehicles. Drain fluids such as unused gas, transmission and hydraulic oil, brake and radiator fluid from vehicles or parts kept in storage. Simple work practices reduce the chance of spills.
  - Use a funnel to pour liquids (like lubricants or motor oil) and place a tray underneath to catch spills. Place drip pans under the spouts of liquid storage containers. Clean up spills immediately.
  - See BMP 46: Spill Prevention and Control for more information.

Household Automobile Maintenance

- Recycle all oils, antifreeze, solvents, and batteries. Many local car parts dealers and gas stations accept used oil. A household hazardous waste facility in your area may accept oil, oil filters, antifreeze, and solvents. Some communities and counties hold household hazardous waste turn-in days that will accept car wastes including old batteries. Old batteries can be worth money, so call battery shops find out if they purchase used batteries.

- Never dump new or used automotive fluids or solvents on the ground, in a storm drain or street gutter, or in a water body. Eventually, the waste will make its way to local surface waters or ground water, including the water we drink.
- Do not mix wastes. The chlorinated solvents in some carburetor cleaners can contaminate a huge tank of used oil, rendering it unsuitable for recycling. Keep wastes in separate containers, label properly, and store them out of the weather.
- To dispose of a used oil filter, punch a hole in the top and let it drain for 24 hours. A large funnel in the top of the oil storage container comes in handy for draining. After draining the filter, wrap it in two layers of plastic and dispose of it in your regular garbage or recycle at a local household hazardous waste facility if one is available.
- Use care in draining and collecting antifreeze to prevent accidental spills. Spilled antifreeze can be deadly to cats and dogs that ingest it.
- Perform service activities on concrete or asphalt or over a plastic tarp to make spill cleanup easier. Keep a bag of kitty litter available to absorb spills. If a spill occurs, sprinkle a layer of absorbent on the spill, let it absorb for a while, and then sweep it up. Place the contaminated litter in a plastic bag, tie it up, and dispose in the regular garbage. Do not leave kitty litter in the rain as it is difficult to clean up.
- For outside autobody work, use a tarp to catch material from grinding, sanding, and painting. Double bag the waste in plastic and place it in the garbage.

Reporting

Report uncontrolled spills to the local police or fire departments. A significant spill into a water body should be reported to the National Response Center at (800) 424-8802.

Maintenance

- Inspections shall be conducted as required by the NPDES permit or contract specifications.
- BMPs should be inspected weekly, before rain events, daily during rain events, and after rain events.
- Inspect and maintain berms, curbs, dikes, or slopes regularly.
- Regularly clean oil and water separators at the appropriate intervals.
- Keep ample supplies of spill cleanup materials on-site.
- Inspect and maintain holding tanks, oil and water separators, and on-site treatment or recycling units regularly.

Additional Resources

CASQA (California Stormwater Quality Association). 2015. *California Stormwater Best Management Practices Handbook: Construction.* Menlo Park, CA. *http://www.casqa.org/*

EPA (US Environmental Protection Agency). 2012. *EPA Construction General Permit*. National Pollutant Discharge Elimination System Stormwater Program. *http://www.epa.gov/npdes/stormwater-discharges-construction-activities#overview*

EPA (US Environmental Protection Agency). 2017. *Municipal Vehicle and Equipment Maintenance*. *https://www.epa.gov/npdes/national-menu-best-management-practices-bmps-stormwater-documents*

EPA (US Environmental Protection Agency). 2017. *Menu of BMPs: Municipal Vehicle and Equipment Washing*. *https://www3.epa.gov/npdes/pubs/sector_s_airtransmaint.pdf*

ITD (Idaho Transportation Department). 2014. *Best Management Practices.* Boise, ID: ITD.

BMP 85: Remote Access Roads and Rail Corridors

Description

Remote access roads, such as forest roads, active roads, incidental haul roads, inactive roads, and low-volume logging roads, as well as rail corridors can contribute to storm water pollution and added runoff due to increases in impervious area, contamination from materials used during construction, and more vehicular traffic. Properly designed and maintained storm water controls will minimize adverse effects from roads and rail corridors (Figure 198).

Figure 198. Remote access road with rolling drain dip (University of Idaho 2015).

<u>Primary BMP Functions and Controls</u>

☒ Construction	☒ Permanent
☒ Erosion Control	☐ Sediment Control
☒ Source Control	☐ Flood Control
☐ Filtration	☐ Infiltration

<u>Typical Effectiveness for Targeted Pollutants</u>

●	Sediment
◖	Phosphorus
◖	Metals
◖	Bacteria
●	Hydrocarbons
○	Litter

<u>Other BMP Considerations</u>

Relative Cost	$$
Maintenance Requirements	Medium
Ease of Installation	Medium
Freeze/Thaw Resistance	N/A
Max. Tributary Drainage Area	N/A
Max. Upstream Slope	N/A
NRCS Soil Group	N/A
Min. Ground Water Separation	N/A
Min. Bedrock Separation	N/A

Applicability

All linear projects such as access roads, rail corridors, streets, and utility projects within right of ways pose unique storm water management challenges and should follow the guidelines in this BMP.

Limitations

Certain site layout and use requirements, such as a narrow right of way, may prohibit implementing portions of this BMP.

Design Basis

- Follow design criteria for appropriate transportation corridor BMPs to remove storm water pollutants, control erosion, and promote infiltration.
- Maintain all BMPs used along roads and corridors according to the respective guidelines.

Access and Construction Guidelines

When available, existing roads and disturbed areas should be used before constructing new roads. For new roads, consider the following (Figure 199):

- The *right of way* is generally publicly owned land acquired for and devoted to

transportation purpose, under and adjacent to the highway. The right-of-way line marks the limit between the land secured for public use and adjacent private property.

- *Clearing limits* determine the removal all obstructing vegetation as designated on the ground or on the road construction drawings.
- *Roadway* or *construction limits* define the area of active construction.

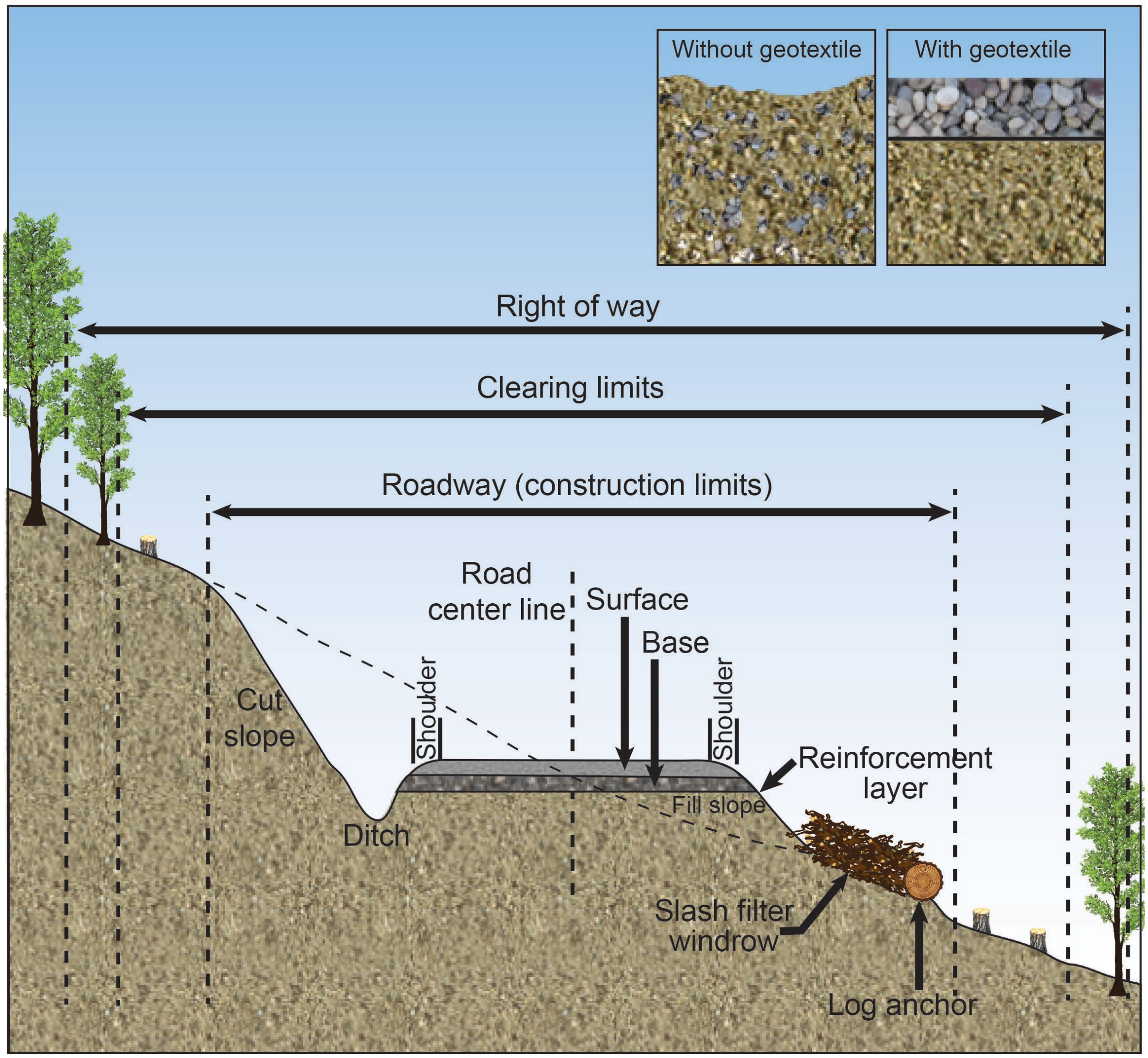


Figure 199. Typical cross section for new road construction (University of Idaho 2015).

General recommendations include the following:

- Grade roads high in the center, or crown, and slope outward to divert water to the sides of the road. Storm water should not be allowed to drain across the width of the road but carried in ditches or roadside culverts. An exception would be locations where the road must be superelevated around sharp turns.
- Some soils may produce road sections with a *soft bottom*, where the road surface does not compact properly. In these situations, rock surfacing may become buried in the subgrade and require reapplication. A variety of synthetic materials, called geotextiles (BMP 53), can be effective for separating rock and soil layers.

- Common forest road drainage techniques include rolling drain dips, cross ditches, relief culverts and roadside ditching. Each of these options is discussed in *Idaho Forestry Best Management Practices Manual* (University of Idaho 2015) at *http://www.uidaho.edu/extension/idahoforestrybmps*.
- Slash filter windrows, structures made out of waste logs and compacted slash, are placed along the roadside to prevent erosion. Combining slash filter windrows with other BMPs such as seeding (BMP 32) and mulching (BMP 52) provides the most effective method of reducing sediment delivery to streams.
- In less stable soils that tend to give way easily, gentle cut and fill slope angles above and below the driving surface will decrease erosion from these slopes.
- On more stable soils or solid rock, less material is likely to tumble down onto the road surface or give way below it, allowing for steeper cut slope angles.

Before road construction begins, determine the appropriate road profiles for each section of the road, as well as cut and fill slope angles.

Full-bench construction excavates the hill slope so that the entire road surface is cut into the hillside and no fill is deposited on the downhill side (Figure 200). Excavated material is hauled to stable disposal locations. The Idaho Forest Practices Act (IDAPA 20.02.01.040) requires "roads constructed on slopes greater than 60% in unstable or erodible soils shall be full benched without fill slope disposal. Fills must be kept to a minimum at stream and draw crossings. A variance is required if a full bench is not used."

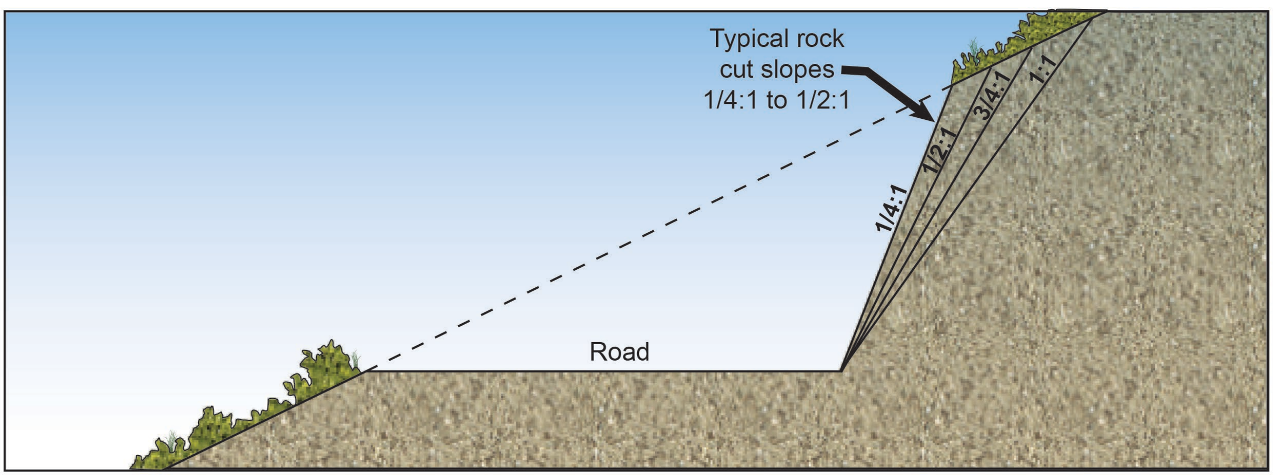


Figure 200. Full-bench construction (University of Idaho 2015).

Balanced cut and fill construction uses materials excavated on the uphill side of a road as compacted fill material on the downslope side (Figure 201). In Idaho, this is the most common road construction method where full-bench methods are not required. The road design should match the soil group, generally with more moderate slope angles for less stable soils.

If small dips or draws must be filled and/or small hills must be removed, balance the cuts and fills and keep material hauling a short a distance if possible. If material must be moved long distances from cut areas to fill locations, costs can increase rapidly.

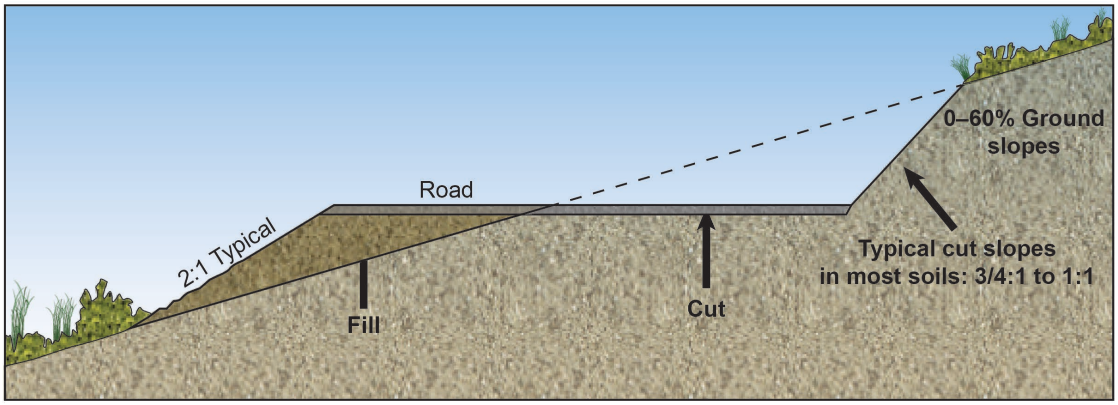


Figure 201. Balanced cut and fill construction (University of Idaho 2015).

Through-cut construction is used where the ground must be cut through to avoid an overly steep road grade, such as on the crest of a steep hill (Figure 202).

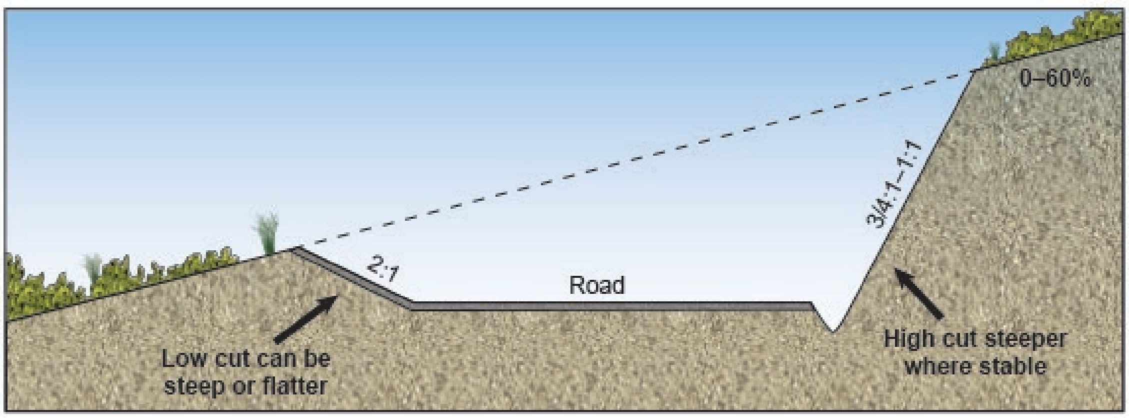


Figure 202. Through-cut construction (University of Idaho 2015).

Through-fill construction is the opposite of a through cut. It is a segment of road that is entirely composed of fill material, with fill slopes on both sides of the road. Through-fill construction is often used on flat terrain where water is likely to pond and to cross draws or wet or swampy ground (Figure 203).

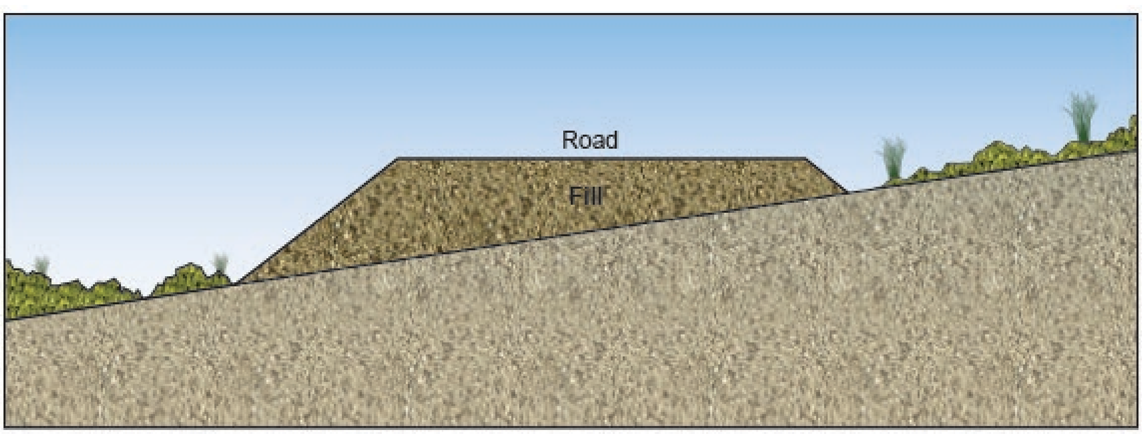


Figure 203. Through-fill construction (University of Idaho 2015).

Rail Corridor Guidelines

- Use less-toxic wood preservatives, such as ammoniacal copper zinc arsenate or copper naphthenate, instead of creosote and pentachlorophenol on railroad ties or use concrete or other nonwooden ties. While these preservatives are approved for railroad ties, they are not generally suggested for general public or residential use.
- Control spills and dust from railroad unloading (BMP 87). If the rail line delivers or picks up liquids in bulk or in containers, add spill-control loading docks with shutoff valves (BMPs 46 and 81). If parked railroad cars drip fluids, install a drip pan between the rails at the loading dock.

Maintenance

Inspect roadside BMPs according to their respective maintenance and inspection requirements.

Additional Resources

EPA (US Environmental Protection Agency). 2014. Chromated Copper Arsenate (CCA): *Consumer Safety Information Sheet: Inorganic Arsenical Pressure-Treated Wood*. *https://www.atsdr.cdc.gov/CCA-Treated_Wood_Factsheet.pdf* *http://www.beyondpesticides.org/assets/media/documents/infoservices/pesticidesandyou/spring%2003/cca%20factsheet.pdf*

Railway Tie Association. 2015. *Information, Education, Research & Development, Stewardship.* *http://www.rta.org/*

University of Idaho. 2015. *Idaho Forestry Best Management Practices*. Moscow, ID: College of Natural Resources. *http://www.uidaho.edu/extension/idahoforestrybmps/*

BMP 86: Nonstorm Water Discharges to Drains

Description

Nonstorm water discharge can occur via an illicit connection, which is any nonapproved physical connection to a publicly maintained storm drain system, or via illegal dumping into a storm drain (Figure 204). Nonstorm water discharges may be composed of solids or liquids that have not been permitted by the public entity responsible for operating and maintaining the storm water system. Facilities subject to EPA storm water permit regulations may be required to certify that the storm water collection system has been tested or evaluated for the presence of nonstorm water discharges.

Figure 204. Messages on storm drain inlets can prevent illicit discharges.

Nonstorm water discharges to the storm water collection system may include any water used directly in the manufacturing process (process wastewater), used motor oil, radiator coolant, antifreeze, outdoor secondary containment water, vehicle and equipment washwater, sink and drinking fountain wastewater, sanitary wastes, or other wastewaters. Section 3.10.7 "Construction Disposal Alternatives" provides more information on properly disposing materials.

Primary BMP Functions and Controls

☒ Construction	☒ Permanent
☐ Erosion Control	☐ Sediment Control
☒ Source Control	☐ Flood Control
☐ Filtration	☐ Infiltration

Typical Effectiveness for Targeted Pollutants

●	Sediment
◖	Phosphorus
◖	Metals
○	Bacteria
◖	Hydrocarbons
◖	Litter

Other BMP Considerations

Relative Cost	$
Maintenance Requirements	Medium
Ease of Installation	Easy
Freeze/Thaw Resistance	N/A
Max. Tributary Drainage Area	N/A
Max. Upstream Slope	N/A
NRCS Soil Group	N/A
Min. Ground Water Separation	N/A
Min. Bedrock Separation	N/A

Applicability

This BMP applies to all storm water management systems. Nonstorm water discharges may happen at any time during the life of a system and reporting such discharges should occur whenever discovered.

While nonstorm water discharge control measures are usually implemented by municipal governments, they may also be relevant to campus-scale developments, private homeowner associations, or industrial operations.

Limitations

- Many facilities do not have accurate, up-to-date schematic drawings of existing drainage networks and associated contributing areas, which makes evaluating the system difficult.
- Video or visual inspections can identify illicit connections to the storm sewer, but further testing is sometimes required (e.g., dye, smoke, and laboratory testing) to identify sources.

Design Basis

Practice guidelines for preventing nonstorm water discharges to drains include three general categories: identification, eliminating illicit connections, and public education. Proper spill prevention, control, and response measures (BMP 46) are important for preventing storm water contamination from accidental spills. Using an integrated municipal storm water and wastewater planning approach can prevent illicit connections and facilitate sustainable and comprehensive solutions that protect human health and improve water quality. See EPA's Integrated Municipal Storm Water and Wastewater Planning at *https://www.epa.gov/npdes/national-menu-best-management-practices-bmps-storm water-documents.*

Identify Nonstorm Water Discharges

The following approaches may identify nonstorm water discharges or illicit connections to a storm water system:

- **On-site inspection**—Inspect each discharge point during dry weather. While on site, review both visual factors (i.e., staining or unusual colors in runoff, traces of oil, excessive sediment, and abnormally high flow) and any unusual odors present at the outfall. Storm water runoff may continue for 3 days or more after an event, and ground water may infiltrate into the underground storm water collection system. Understand these drainage aspects in addition to base flow conditions when visually assessing a system.
- **Field survey**—Inspect the contributing drainage area for structures, buildings, industrial areas, and impervious surfaces located near the nonstorm water discharge location. Note where these contributing areas join the storm drain system in question.
- **Piping schematic review**—Review *as-built* piping schematics for all systems to determine if there are any connections to the storm water collection system. The piping schematic is a map of pipes and drainage systems used to carry wastewater, cooling water, and sanitary wastes. Drawings may need to be obtained from a variety of sources, such as municipalities, state agencies, and city and county building departments.
- **Smoke testing—**Use smoke testing of wastewater and storm water collection systems to detect connections between the two systems. During dry weather, the storm water collection system is filled with smoke and then traced to sources. The appearance of smoke at the base of a toilet indicates a possible connection between the sanitary and the storm water systems.
- **Dye testing**—Perform a dye test by releasing a dye into either the sanitary or process wastewater system and examine the discharge points from the storm water collection system for the dye color.
- **Video inspection**—Use mobile video cameras remotely through storm water system lines to observe possible illicit connections into storm water systems. Public works staff can observe and record the videos and note any visible illegal connections.

- **Laboratory testing**—Sample water quality for high levels of fecal coliform, petroleum hydrocarbons, or other contaminants to determine the source of the nonstorm water discharge. Follow appropriate sampling standards to ensure accurate results.

Eliminate Illicit Connections

- If illicit connections are identified, promptly notify the owner of the illicit connection or discharge incidents at the time of discovery and remove the nonstorm water discharge. Prevent any new illicit connections by identifying where the appropriate connection should be made or what disposal alternative is available.
- Replumb sewer lines and properly connect the lines to the sanitary sewer system if applicable.
- Isolate problem areas from the storm water system.
- Plug illicit discharge points.
- Document that nonstorm water discharges have been eliminated by recording tests performed, methods used, dates of testing, and any on-site drainage points observed.

The following can prevent any new illicit connections:

- Ensure that existing building and plumbing codes prohibit physical connections of nonstorm water discharges to the storm drain system.
- Have a permit program in place to review and approve any proposed connection into a storm sewer.
- Require visual inspection of new developments or redevelopments during the construction phase to ensure that proper plumbing connections are implemented. Train field inspectors and develop field inspection procedures that prevent new illicit connections of sanitary sewer lines to storm sewers.

Public Education

Public education and awareness reduce illegal dumping and some types of illicit discharges. For example, many citizens may not be aware that storm water systems drain to streams rather than wastewater treatment plants or may not be aware of the environmental damage caused by discharging soapy water, pet waste, and other household wastes into the storm system. Developing a public outreach strategy is a key aspect in meeting the minimum measures for public education and public involvement required by MS4 permits. Per the EPA minimum measure, MS4 entities must complete the following:

- Distribute educational materials to the community or
- Conduct equivalent outreach activities about the impacts of storm water discharges on water bodies and the steps that the public can take to reduce pollutants in storm water runoff.

Public outreach strategies must reach the following:

- Public agencies and officials
- Program managers, inspectors, and municipal employees
- Business and industry owners and operators
- Nongovernmental organizations and volunteers
- Students, citizens, and the general public

Outreach is used to increase awareness and education, or inspire action. A good campaign is tailored to a selected audience, addresses current practices, and motivates change. Local governments should choose those public awareness and education approaches most effective for their communities and the intended audiences:

- Enact and publicize information from ordinances that prohibit illegal dumping and illicit connections. Many local governments already have such ordinances; however, citizens are often unaware of them. Publicity, including news articles, door hangers, utility bill inserts, radio or TV advertisements, or website highlights, increase awareness. These efforts are particularly effective when connected to a specific water quality problem such as a nearby stream or lake impairments due to bacteria and/or nutrients.
- Community-based social marketing programs can effectively invoke change through social pressure. Social marketing can be used to understand the audience, develop an effective message, and get the message out.
- Use storm drain stenciling of messages, such as "No Dumping - Drains to Stream/River/Lake," on storm drains to discourage dumping directly into the storm drain.
- Provide citizens with readily available contact information to report illegal dumping. Install a *hotline* telephone number to handle calls from citizens reporting illegal dumping or accidental spills.
- Create brochures and other guidance related to illegal discharges to the storm drain. Educational efforts should alert business owners that nonstorm water discharges are not allowed and provide guidance on BMPs to implement. For example, power washing discharges are process wastewater that may not be discharged to the storm sewer system. When power washing is conducted, storm drain inlet protection, wet vacuuming, collection systems, and/or other appropriate measures to prevent washwater from entering the storm drain system should be implemented.
- Provide well-marked proper disposal or collection sites for wastewater.
- Provide information on proper disposal of hazardous waste and local programs for hazardous waste collection or drop-off.
- Employee training (BMP 91) should especially emphasize proper disposal of nonstorm water discharges.

Maintenance

Periodically inspect and maintain storm drain inlets, especially those with a history of illicit connections. Clean out catch basins so that accumulated pollutants do not wash down the storm drains.

Additional Resources

Cunningham Environmental Consulting, 2011. *Social Marketing Strategies for Stormwater Business Outreach: Summary of Recent Research in the Puget Sound Region: Assistance for Developing and Implementing Local Programs*. Bainbridge Island, WA.

EPA (US Environmental Protection Agency). 2010. *Getting in Step: A Guide for Conducting Watershed Outreach Campaigns* 3rd ed. Washington, DC: Office of Water. EPA 841-B-10-002. *http://cfpub.epa.gov/npstbx/files/getnstepguide.pdf*

EPA (US Environmental Protection Agency). 2011. *Nonpoint Source (NPS) Outreach Toolbox*. *http://cfpub.epa.gov/npstbx/*

Washington State Department of Ecology. 2012. *Stormwater Management Manual for Western Washington*. Lacey, WA. Publ. 12-10-030. *http://www.ecy.wa.gov/programs/wq/stormwater/manual.html*

BMP 87: Outdoor Loading and Unloading of Materials

Description

Often the loading and unloading of materials must take place outside. Material loading or unloading can occur off vehicles, from containers, or by direct liquid transfer. Materials spilled, leaked, or lost during loading and unloading may collect in the soil or on other surfaces and be carried away by storm water runoff. Additionally, rainfall may wash pollutants from machinery used to unload or move materials.

To prevent these pollutants from entering storm water runoff, limit the exposure of material to rainfall, prevent storm water run-on, check equipment regularly for leaks, and contain spills during transfer operations (Figure 205).

Figure 205. Covered loading dock prevents storm water contamination.

Primary BMP Functions and Controls

☒ Construction ☒ Permanent
☐ Erosion Control ☐ Sediment Control
☒ Source Control ☐ Flood Control
☐ Filtration ☐ Infiltration

Typical Effectiveness for Targeted Pollutants

○ Sediment
○ Phosphorus
◖ Metals
○ Bacteria
◖ Hydrocarbons
◖ Litter

Other BMP Considerations

Relative Cost	$
Maintenance Requirements	Medium
Ease of Installation	Easy
Freeze/Thaw Resistance	N/A
Max. Tributary Drainage Area	N/A
Max. Upstream Slope	N/A
NRCS Soil Group	ABCD
Min. Ground Water Separation	N/A
Min. Bedrock Separation	N/A

Applicability

This BMP applies to all construction, industrial, and commercial activities that require outdoor loading and unloading of materials.

Limitations

Space and time limitations may prevent all transfers from being performed indoors or in covered areas, such as a loading dock (BMP 81: Loading Dock Design Features). Dry weather transfers are not always possible.

Design Basis

Loading or unloading of liquids should occur indoors whenever possible to reduce the chance of spills that are not completely contained from entering storm water runoff. Direct discharges from outdoor loading areas to the sanitary sewer or treatment plant, or treat in a manner consistent with local wastewater treatment plant requirements and permit requirements.

Use the following guidelines for outdoor loading and unloading of materials:

- Whenever possible, cover outside loading and unloading docks to reduce exposure of materials to rain.
- Use overhangs or door skirts that enclose the trailer.
- Park tank trucks in designated areas where spills or leaks can be contained if necessary while materials are being delivered.
- Design loading and unloading areas (BMP 81) to prevent storm water run-on. Use design techniques such as grading or berming (BMP 70) and position roof downspouts to direct storm water away from loading and unloading areas.
- Have an emergency spill cleanup plan readily available and train employees (BMP 91) in spill containment and cleanup (BMP 46).
- Establish disposal areas for cleanup materials next to or near each loading and unloading area.
- Use drip pans under hoses and pipe connections during liquid transfer operations.
- Train employees, such as fork lift drivers, to properly transfer materials and contain and clean up spills.

For loading and unloading tank trucks to aboveground and belowground storage tanks, the following procedures should be used:

- Pave and grade the sloped or recessed loading area to direct flow toward either a central collection point, an inlet with a shutoff valve, or toward a dead-end holding tank.
- Design the transfer area to prevent run-on of storm water from adjacent areas. Slope the pad and berm around the uphill side of the transfer area to reduce run-on.
- Design the transfer area to prevent runoff of spilled liquids from the area.
- Replace aged or worn valves and piping. Select a style of valve that can be safely and effectively operated given the constraints of the location and product.
- Post signage at the point of delivery describing the proper procedure for opening and shutting valves and valve safety locks to ensure valves are fully turned off and to prevent opening by accident or vandalism.

For loading and unloading rail cars to outside storage tanks, use the following procedures:

- Place appropriate spill control equipment at locations where spillage may occur, such as hose connections, hose reels, and filler nozzles. Use drip pans when making or breaking connections.
- Install drip pan systems between the rails to collect spillage from tank cars.
- Remove solid debris as soon as operations permit.
- Avoid hosing off paved surfaces. Use a vacuum truck or sweeper for large areas.

Maintenance

The following maintenance activities should be conducted on a regular basis:

- Conduct facility inspections and make repairs as necessary. The frequency of repairs may depend on the age of the facility.
- Check loading and unloading equipment for leaks in valves, pumps, flanges, and connections.

- Inspect access roads and parking lots to identify and clean up spills on an on-going basis.
- Inspect the holding tank to ensure it is not overfilled.
- Test the holding tank contents before discharge or disposal.
- Inspect and maintain berms, curbs, dikes, or slopes.

Additional Resources

Central Oregon Intergovernmental Council. 2010. *Central Oregon Stormwater Manual*. Bend, OR.

Colorado UDFCD (Colorado Urban Drainage and Flood Control District). 2010. *Urban Storm Drainage Criteria Manual, Volume 3 Best Management Practices*. Denver, CO. *http://udfcd.org/wp-content/uploads/2014/07/Title-Page.pdf*

ITD (Idaho Transportation Department). 2014. *Best Management Practices.* Boise, ID: ITD.

Washington State Department of Ecology. 2012. *Stormwater Management Manual for Western Washington*. Lacey, WA. Publ. 12-10-030. *http://www.ecy.wa.gov/programs/wq/stormwater/manual.html*

BMP 88: Outdoor Process Equipment

Description

Industrial and commercial outdoor process activities that may adversely impact storm water runoff include, but are not limited to, compressors, cooling towers, air conditioners, rock grinding or crushing, painting or coating, grinding or sanding, parts degreasing or cleaning, and wastewater and solid waste treatment and disposal. Proper outdoor process equipment operations and maintenance prevents storm water contamination from substances such as toxic compounds, oil and grease, heavy metals, nutrients, suspended solids, and other pollutants (Figure 206).

Figure 206. Cooling tower at the Amalgamated Sugar Company in Nampa, Idaho.

Storm water runoff from certain industrial facilities may require coverage under the Multi-Sector General Permit administered by EPA. Refer to the following EPA website for information (EPA 2015): *https://www.epa.gov/sites/production/files/2015-10/documents/msgp2015_finalpermit.pdf* .

Primary BMP Functions and Controls

☐ Construction	☒ Permanent
☐ Erosion Control	☐ Sediment Control
☒ Source Control	☐ Flood Control
☐ Filtration	☐ Infiltration

Typical Effectiveness for Targeted Pollutants

◖	Sediment
○	Phosphorus
◖	Metals
○	Bacteria
◖	Hydrocarbons
○	Litter

Other BMP Considerations

Relative Cost	$$
Maintenance Requirements	Low
Ease of Installation	Easy
Freeze/Thaw Resistance	N/A
Max. Tributary Drainage Area	N/A
Max. Upstream Slope	N/A
NRCS Soil Group	ABCD
Min. Ground Water Separation	N/A
Min. Bedrock Separation	N/A

Applicability

The guidelines in this BMP apply to all existing and planned industrial and commercial areas.

Limitations

Space and cost limitations may prevent enclosing or covering equipment. All outdoor storage buildings, coverings, and awnings should meet building and fire code requirements.

Design Basis

In outdoor process equipment areas, infiltration may be regulated and should be managed appropriately and in many cases, containment may be required. Discharges from these activities should be prevented, collected, and diverted from the storm water management systems. The following guidelines apply for proper handling of outdoor process equipment wastes:

- Identify all equipment and activities that may impact storm water.
- Whenever possible, move the activity indoors.
- Perform an activity only during dry periods.
- Substitute nontoxic materials for toxic materials; consider implementing a substance substitution program. More information on substance substitution is found at
  - Chemhat: *http://www.chemhat.org/*; Substitution Portal: *http://www.subsport.eu/*
  - State of Washington, Department of Ecology Quick Chemical Assessment Tool: *https://ecology.wa.gov/Regulations-Permits/Guidance-technical-assistance/Preventing-hazardous-waste-pollution/Safer-alternatives/Quick-tool-for-assessing-chemicals*
  - Green Screen: *http://www.greenscreenchemicals.org/*
- Alter the activity to prevent exposure of pollutants to storm water.
- Cover the area with permanent or temporary roofing.
- If an area used by an activity is large enough to make full enclosure prohibitively expensive, provide just a roof and leave the sides open. Providing a roof eliminates the need for ventilation and lighting systems, yet still provides some protection from rain.
- Use ground cloths and/or drip pans where applicable.
- Cover exposed outdoor open process tanks (i.e., dip tanks) when they are not in use.
- Minimize storm water contact with outside manufacturing operations with berming (BMP 70) and drainage routing.
- Connect the process equipment area, through floor drains, to the sanitary sewer or to the facility wastewater treatment system. Contact the wastewater treatment plant staff, and obtain any applicable permits before connecting to a wastewater system.
- Use storm drain inlet protection (BMP 74) to capture particulate pollutants. Do not install storm drains in areas used for equipment repair.
- Store and maintain appropriate spill cleanup materials in a location known to all employees. Ensure employees are trained (BMP 91) in spill control plan and cleanup procedures, as well as storm water discharge prohibitions. Document training using a log or another method. Air compressors and other equipment sometimes produce small quantities of blowdown water that can contain lubricating oil and other pollutants. Blowdown water may not be discharged to the storm drain. Connect the blowdown to the sanitary sewer (with prior approval from the wastewater treatment plant) and place drip pans beneath any leaks.
- Condensate on exterior surfaces or compressors, building cooling equipment, and other machinery may be directed to the storm drain. Route condensate to a storm drain so it does not pick up pollutants as it flows across the site. Contact wastewater treatment plant staff for information on what can be discharged to the sanitary sewer system.
- Recycle wastes whenever possible instead of disposing unwanted materials.
- Separate wastes for easier recycling. Keep hazardous and nonhazardous wastes separate, do not mix used oil and solvents, and keep chlorinated solvents separate from nonchlorinated solvents.

Maintenance

- Perform routine preventive maintenance, including checking process equipment for leaks, malfunctions, staining on and around equipment, and other evidence of leaks.
- Sweep the processing area daily where applicable. Avoid hosing down and focus on dry cleaning techniques in areas where washwater can run into a storm drain.

Additional Resources

CASQA (California Stormwater Quality Association). 2014. *California Stormwater Best Management Practices Handbook: Industrial and Commercial*. Menlo Park, CA. *http://www.casqa.org/*

Lake Forest (City of Lake Forest, CA.) 2015. *Outdoor Process Equipment Operations and Maintenance*. Industrial and Commercial Business Activities.

Weber County (Weber County, Utah). 2009. *Industrial BMPs*. *http://www.webercountyutah.gov/Engineering/swm/*

BMP 89: Contaminated Soil Management

Description

Soil on construction, highly urbanized, or industrial sites can become contaminated with chemicals, hydrocarbons, oils, or other materials from spills, illicit discharges, or leaks from underground storage tanks. Properly managing contaminated soil prevents pollution of storm water runoff (Figure 207).

Figure 207. Soil contamination.

Applicability

Soil at construction, highly urbanized, or industrial sites must be managed if the soil becomes contaminated.

Limitations

Contaminated soil that cannot be managed on site must be disposed off site by a licensed hazardous waste hauler, which can be costly. The presence of contaminated soil can indicate contaminated ground water, requiring costly cleanup by a certified professional.

Design Basis

Storm water pollution from contaminated soil can be prevented or reduced by conducting preconstruction surveys, inspecting excavations regularly, and remediating contaminated soil promptly. Procedures and practices presented in this BMP are general, so the contractor should identify appropriate practices and procedures for the specific contaminates known to exist or discovered on site. Site cleanup may also require involving state and federal agencies. Owners and contractors should ensure their actions are consistent with any cleanup plans and agency directives. For more information, contact the local DEQ office at *https://www.deq.idaho.gov/regional-offices/* and for contaminated site cleanup and other waste management issues, visit: *https://www.deq.idaho.gov/waste-management-and-remediation/sampling-investigation-and-cleanup/*

Primary BMP Functions and Controls

☒ Construction	☐ Permanent
☐ Erosion Control	☒ Sediment Control
☒ Source Control	☐ Flood Control
☐ Filtration	☐ Infiltration

Typical Effectiveness for Targeted Pollutants

●	Sediment
◖	Phosphorus
◖	Metals
○	Bacteria
◖	Hydrocarbons
○	Litter

Other BMP Considerations

Relative Cost	$
Maintenance Requirements	Medium
Ease of Installation	Easy
Freeze/Thaw Resistance	N/A
Max. Tributary Drainage Area	N/A
Max. Upstream Slope	N/A
NRCS Soil Group	ABCD
Min. Ground Water Separation	N/A
Min. Bedrock Separation	N/A

Prevent Contamination

Preventing leaks and spills of hazardous materials (BMP 46) on site can avoid costly cleanup and lost project time. Review measures to prevent spills, such as those described in the project SWPPP, SPCC plan, and permit requirements, and keep appropriate materials on hand to reduce the impact if a spill should occur. Inform personnel of the importance of spill prevention before work begins. Contamination prevention is much less expensive than soil removal and disposal.

Identify Contaminated Soil

Conduct a thorough, preconstruction survey inspection of the site, and review documents related to the site. These documents may include history of land use on the site; records of spills, accidents, or unauthorized dumping; or agency records of past cleanup efforts. Inspect excavations during construction activities regularly, especially on sites more likely to be contaminated based on past site use. Look for signs of contaminated soils or surfaces:

- Noticeable spills
- Leaking containers or equipment
- Discolored soil
- Differences in soil properties
- Unexpected odors
- Underground tanks, pipes, and debris
- Acid or alkaline solutions from exposed soil or rock formations high in acid or alkaline forming elements.

Initial investigation of suspected soils should be sampled using an appropriate protocol (e.g., soil sampling guide: *http://www.epa.gov/OUST/cat/mason.pdf* or DEQ's Brownfields program: *https://www.deq.idaho.gov/waste-management-and-remediation/sampling-investigation-and-cleanup/brownfields-in-idaho/*) and analyzed at a certified laboratory. After this initial effort, more intensive sampling should be guided by a sampling and analysis plan and a quality assurance plan with possible oversight from state or federal agencies.

Handling and Disposing of Contaminated Soil

If contaminated soil is found on site, work with the appropriate regulatory agencies and follow state and federal regulations to develop options for treatment and/or disposal. Agencies include the US Department of Transportation, EPA, OSHA, DEQ, and state or local regulatory authorities. The following are general guidelines for handling contaminated soil:

- Minimize on-site storage of contaminated soil and remove and dispose of the soil properly according to applicable regulations (section 3.10.7).
- Whenever possible, avoid temporarily stockpiling contaminated soil on site. When stockpiling is necessary, use the following precautions:
    - Store the contaminated soil in a covered area or with plastic sheeting or tarps.

- Berm (BMP 70) and trench around the stockpile to prevent storm water run-on and runoff. Place stockpiles as far away from storm drains and waterways as the worksite allows.
- Some contaminants require personal protective equipment (PPE) and other actions to prevent workers from becoming contaminated. Train workers to use these measures before handling contaminated soil and have the necessary PPE readily available.

Construction and Maintenance

The water pollution control manager, foreman, or construction superintendent should monitor contaminated soil storage and disposal. Air quality should also be monitored continuously during excavation operations. Well-educated and trained personnel (BMP 91) are essential for properly managing contaminated soil.

Additional Resources

CASQA California Stormwater Quality Association. 2004. *California Stormwater Best Management Practices Handbook: New Development and Redevelopment*. Menlo Park, CA. http://www.casqa.org/

ITD (Idaho Transportation Department). 2014. *Best Management Practices.* Boise, ID: ITD.

BMP 90: Building Repair, Remodeling, and Construction

Description

Building repair, remodeling, and construction activities are common on any site, including small, single-family home construction projects and large industrial sites. Building activities may vary from minor building repair to major remodeling or construction of new facilities. Many of these activities generate contaminants that may pollute storm water. Solvents, paints, paint and varnish removers, finishing residues, kerosene, adhesive residues, and asbestos materials are examples of contaminants present during repair and remodeling activities (Figure 208).

Figure 208. Lead-based paint removal.

Introducing these pollutants into storm water runoff may be prevented by using soil erosion controls, enclosing or covering building material storage areas, using good housekeeping practices, using safer alternative products, and training employees.

Primary BMP Functions and Controls

☒ Construction	☐ Permanent
☐ Erosion Control	☒ Sediment Control
☒ Source Control	☐ Flood Control
☐ Filtration	☐ Infiltration

Typical Effectiveness for Targeted Pollutants

●	Sediment
○	Phosphorus
◖	Metals
○	Bacteria
◖	Hydrocarbons
◖	Litter

Other BMP Considerations

Relative Cost	$
Maintenance Requirements	Medium
Ease of Installation	Easy
Freeze/Thaw Resistance	N/A
Max. Tributary Drainage Area	N/A
Max. Upstream Slope	N/A
NRCS Soil Group	N/A
Min. Ground Water Separation	N/A
Min. Bedrock Separation	N/A

Applicability

These BMP guidelines apply wherever discharge of pollutants to storm water from building repair, remodeling, and construction is possible.

Limitations

- Hazardous waste that cannot be reused or recycled should be disposed of by a licensed hazardous waste hauler or taken to a hazardous waste disposal facility.
- CESQG should either dispose of the waste in the landfill or at a household hazardous waste collection facility that may take this type of waste for a fee. CESQGs generate 100 kilograms or less per month of hazardous waste or 1 kilogram or less per month of acutely hazardous waste.

For more information on CESQG requirements, see 40 CFR 261.5 at *http://www.ecfr.gov/cgi-bin/text-idx?SID=fd0088f229a2b010b961949aabfbef41&mc=true&node=pt40.26.261&rgn=div5#se40.26.261_15*.
- Safer alternative products may not be available, suitable, or effective in every case.
- Physical site constraints such as site layout, square footage, and terrain may be a limiting factor when attempting to implement BMPs.

Design Basis

The following housekeeping practices reduce the risk of storm water contamination from building repair, remodeling, and construction activities.

Good Housekeeping

- Keep the work site clean and orderly. Straighten up and sweep the area regularly to remove debris. Avoid hosing down the area to a storm drain. Educate employees on proper housekeeping practices (BMP 91: Employee Training).
- Reuse and recycle construction material when possible.
- Inform on-site contractors of company policy and include appropriate provisions in the contract to ensure proper housekeeping and disposal practices are implemented.
- Advise truck drivers to not wash vehicles over the storm drain. Have a designated wash area that does not drain to a storm drain (BMP 84: Vehicle and Equipment Cleaning, Maintenance, and Repair). Put an impermeable tarp over wood, gravel, or other material piles. Sweep up wood chips, paint chips, and other residues daily, and conduct a thorough cleanup at the end of the project (BMP 77: Outdoor Storage).
- Use soil erosion control techniques, such as matting (BMP 54), mulching (BMP 52), or soil binders (BMP 55), if bare ground is temporarily exposed.
- Store and dispose of waste materials properly. Sections 3.10.5–3.10.7 provide disposal alternatives. Many old buildings contain asbestos in wall texture, flooring, paint, caulking, or roofing that must be removed and disposed of properly by qualified personnel. To determine if asbestos is present, qualified personnel should take a sample of the material to a lab for testing.
- Use safer alternative products such as those labeled green, nontoxic, or organic.

Soil and Erosion Control

- If the work involves exposing large areas of soil, employ the appropriate soil erosion and control techniques such as BMP 32: Landscaping.
- If old buildings are being torn down and not replaced in the near future, stabilize the site using measures described in BMP 90: Building, Repair, Remodeling, and Construction.

Painting Operations

- Lead paint, which is a hazard to children, may be present in buildings constructed before 1978. Reduce the risk of lead exposure by hiring a certified lead inspector to check for lead paint in the work area. When cutting into surfaces painted with lead paint, even if the paint is covered by layers of newer paint, creating hazardous lead dust is a risk. Homeowners

conducting building renovations should set up safely, control the dust, and clean up completely. To minimize lead hazards, hire a trained lead-safe certified renovation, repair, and painting contractor. These contractors have been trained in special methods to minimize dust and clean up thoroughly, reducing the chance of lead contamination. To permanently eliminate the lead, hire a trained and certified lead abatement contractor to abate, or remove, the lead from the area before work begins.
- If painting requires scraping or sandblasting the existing surface, use an impermeable ground cloth to collect the chips. Dispose of the residue properly. If the paint contains lead or tributyl tin, it is considered a hazardous waste and should be disposed of properly.
- Spray painting operations should be properly enclosed or covered to avoid drift. Use temporary scaffolding to hang drop cloths or draperies to prevent drift. Use application equipment that minimizes overspray. Avoid spray painting and sandblasting on windy days. Be aware of air quality restrictions on spray paints that contain volatile chemicals. Substitute water-based spray paints for paints that contain volatile chemicals.
- While ensuring proper ventilation, mix paint indoors so that if a spill occurs, the spill will not be exposed to rain and consequently washed into a storm drain. Even during dry weather, a spill cleanup will never be 100% effective. Dried paint will eventually erode from a surface and wash away in storms. Alternatively, mix paint outdoors on a disposable, impermeable mat with an edge to prevent spills.
- If using water-based paints, clean the equipment in a sink connected to the sanitary sewer. Clean up oil-based paint where waste paint and solvents can be collected and handled as small quantity hazardous waste. Do not pour the waste paint down a sink or storm drain. Properly store leftover paints for further use or properly dispose of them. Section 3.10.7, "Construction Disposal Alternatives" provides more information.
- Store paints, solvents, or others similar materials in a covered area if these materials must be left outdoors. If welding occurs in the area, keep paints and solvents in explosion proof cabinets or containers.
- Use ground or drop cloths under painting, scraping, and sandblasting activities. Use either a ground cloth or oversized tub for spill containment when mixing paint and cleaning tools.

Wood Preservatives, Pavement Seal Coating, and Other Outdoor Surface Treatments

- Quickly clean up spills when using sealants on wood, pavement, or roofs. When repairing roofs, line the gutters with rags, or if small particles have accumulated in the gutter, either sweep or wash out the gutter and trap the particles at the outlet of the downspout. A sock or geofabric placed over the outlet may effectively trap the materials. Remove the sock after completing the job and dispose in the trash.
- If the downspout is tight-lined, place a temporary plug at the first convenient point in the storm drain and pump out the water with a vactor truck.

Storm Drainage System

- During modifications or upgrades if it is discovered that floor drains are not connected to a sanitary sewer system and the potential for contaminant discharge exist, permanently cap the drains.

- Evaluate the surrounding storm drainage system—the remodel or addition may necessitate an upgrade.
- Ensure that nearby storm drains are clearly marked to minimize the chance of inadvertent disposal of residual paints and other liquids (BMP 86: Nonstorm water Discharges to Drains).
- After construction is completed, clean the storm drain system.
- Use a storm drain cover, inlet protection (BMP 74) or other runoff control to keep pollutants, dust, sediment, or washwater from entering the storm drain system.

Maintenance

When implementing these BMPs, use the respective maintenance guidelines.

Additional Resources

EPA (US Environmental Protection Agency). 2015. *Categories of Hazardous Waste Generators*. *http://www2.epa.gov/hwgenerators/categories-hazardous-waste-generators#cesqg*

EPA (US Environmental Protection Agency). 2015. *Renovation, Repair, and Painting Program*. Lead. *http://www2.epa.gov/lead/renovation-repair-and-painting-program*

ITD (Idaho Transportation Department). 2014. *Best Management Practices.* Boise, ID: ITD.

BMP 91: Employee Training

Description

Employee training ensures proper installation, maintenance, and subsequent operational success of storm water BMPs. In-house employee training programs are established to teach employees about storm water management, potential contaminant sources, and BMPs (Figure 209).

Programs should provide personnel with an understanding of SWPPP for municipal facilities or construction sites as appropriate. Cover BMP operation and maintenance, safety hazards, practices for preventing discharges, and procedures for responding quickly and properly to toxic and hazardous material incidents.

Figure 209. Employee meeting in Valley County, Idaho (*Midas Gold*).

Applicability

Employees directly involved in storm water activities or potentially polluting activities should receive general storm water and targeted BMP training tailored to their activities. Training should include municipal employees, construction personnel and supervisors, and commercial or industrial operators who oversee storm water BMPs. Education all staff, regardless of field responsibilities, about general storm water awareness and detection of illicit discharges.

Limitations

Common challenges an employee training program may encounter include the following:

- Lack of commitment from senior management
- Poor communication between all parties involved
- Lack of employee motivation
- Lack of incentive to become involved in BMP implementation

Primary BMP Functions and Controls

☒ Construction	☒ Permanent
☐ Erosion Control	☐ Sediment Control
☒ Source Control	☐ Flood Control
☐ Filtration	☐ Infiltration

Typical Effectiveness for Targeted Pollutants

◖	Sediment
◖	Phosphorus
◖	Metals
◖	Bacteria
◖	Hydrocarbons
◖	Litter

Other BMP Considerations

Relative Cost	$
Maintenance Requirements	Easy
Ease of Implementation	Easy
Freeze/Thaw Resistance	N/A
Max. Tributary Drainage Area	N/A
Max. Upstream Slope	N/A
NRCS Soil Group	N/A
Min. Ground Water Separation	N/A
Min. Bedrock Separation	N/A

Approaches and Best Management Practices

The following are specific criteria for implementing an employee training program:

- Ensure strong commitment and periodic input from senior management.
- Communicate frequently to ensure adequate understanding of the storm water management plan goals and objectives.
- Use experience from past spills to prevent future spills.
- Make employees aware of BMP monitoring and spill reporting procedures.
- Develop operating manuals and standard procedures.
- Continue education in an on-going, yearly process.

An employee training program should be an on-going, yearly process. Typically, training combines formal classroom-style programs held on an annual basis with more frequent weekly *tailgate* meetings held on site and covering general project updates and short BMP training sessions. Consider the following training suggestions:

- Integrate storm water training with existing training programs that are required for your business or municipality by other regulations such as the Hazardous Waste Operations and Emergency Response (HAZWOPER) standard (29 CFR 1910.120) and SPCC plan (40 CFR 112). Many commercial and industrial facilities have employee training programs that address health- and safety-related issues. Training on storm water management and BMPs can and should be incorporated into these programs.
- In Section 3.10.7, "Construction Disposal Alternatives," use Table 11 to train employees in proper and consistent methods for disposing of materials.
- Check employees' work practices periodically to ensure BMPs are properly implemented. Post informational and reminder signs in common work areas and stencil "DO NOT DUMP WASTE" messages on storm drains.
- Be aware that site owners are also responsible for customer activities. Ask customers to avoid discarding liquids into trashcans or liquids or solids into storm drains.
- Employ ongoing education through
    - Posters and bulletin boards
    - Employee meetings and training courses
    - Field training programs followed by a discussion of site-specific BMPs by trained personnel

Maintenance

After training, managers should periodically check the employees work to ensure that BMPs are being installed and maintained properly. Ensure facility SWPPP and BMP guidance documents are available to employees after training is completed.

Additional Resources

CASQA California Stormwater Quality Association. 2004. *California Stormwater Best Management Practices Handbook: New Development and Redevelopment*. Menlo Park, CA. http://www.casqa.org/

EPA (US Environmental Protection Agency). 1999. *Employee Training*. Stormwater Management Fact Sheet. *http://www3.epa.gov/npdes/pubs/empltrng.pdf*

EPA (US Environmental Protection Agency). 2015. *Municipal Employee Training and Education*. National Pollutant Discharge Elimination System (NPDES). *https://www.epa.gov/npdes/tmdl-npdes-permits-training-user-guides*

BMP 92: Restaurant Control Practices

Description

Common restaurant pollutants may include high-use parking areas, outdoor storage of solid and liquid waste, oil and grease disposal, restaurant cooking vent filters, and cleaning materials contaminated with food waste on site. Proper restaurant management practices can prevent storm water contamination from restaurant waste (Figure 210).

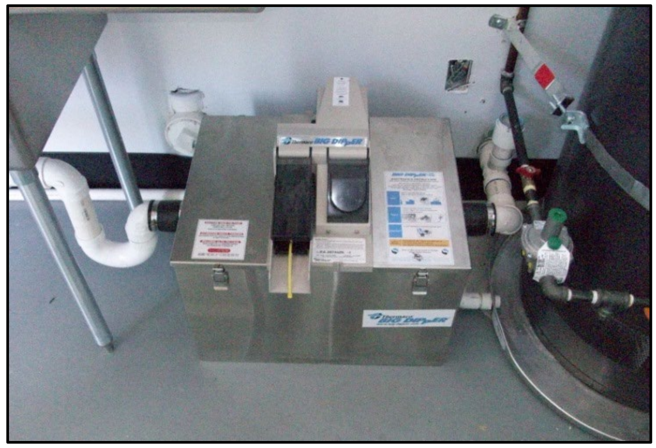


Figure 210. Kitchen grease trap (City of Meridian 2016).

Applicability

Businesses that provide prepared food to the public including drive-through facilities, grocery stores, and food trucks.

Limitations

Common challenges to encourage proper restaurant BMPs include the following:

- Lack of commitment from management
- Poor communication between full-time and part-time, and seasonal staff
- Lack of employee motivation
- No plan for proper disposal of wastes

Primary BMP Functions and Controls

☐ Construction	☒ Permanent
☐ Erosion Control	☐ Sediment Control
☒ Source Control	☐ Flood Control
☐ Filtration	☐ Infiltration

Typical Effectiveness for Targeted Pollutants

○	Sediment
●	Phosphorus
◖	Metals
◖	Bacteria
○	Hydrocarbons
○	Litter

Other BMP Considerations

Relative Cost	$$
Maintenance Requirements	Medium
Ease of Installation	Medium
Freeze/Thaw Resistance	N/A
Max. Tributary Drainage Area	N/A
Max. Upstream Slope	N/A
NRCS Soil Group	N/A
Min. Ground Water Separation	N/A
Min. Bedrock Separation	N/A

Best Practices and Guidelines

Conduct Employee and Client Education

Employees can prevent pollution when they are properly trained (BMP 91) and aware of BMPs. In the employee training program, promote the following BMPs:

- Inspect storage containers regularly and keep in good condition.
- Place materials inside rigid, durable, water-tight, and rodent-proof containers with tight fitting covers.

- Store materials inside a building or build a covered area paved and designed to prevent runoff from entering storm drains (BMP 77: Outdoor Storage).
- Place plastic sheeting over materials or containers and secure the cover with ties and weighted objects. (Not appropriate for storing liquids.)
- Post BMPs where employees and customers can see them. Showing customers you protect the environment is a good form of public outreach and education.
- Explain BMPs to other food businesses through merchant associations or chambers of commerce. Raise employee and customer awareness by stenciling "DO NOT DUMP WASTE" on storm drains near the work place.

Cleaning Restaurant Floor Mats and Exhaust Filters

- Do not wash restaurant equipment outdoors or allow washwater to enter a storm drain. Clean floor mats, grills, and filters inside a mop sink that discharges to an approved grease interception device (BMP 15: Oil and Water Separators). Ensure designated wash areas are properly connected to the sanitary sewer system.
- Never clean greasy equipment in an area where wastewater can flow to the gutter, storm drain, or street.
- Cover, repair, or replace leaky dumpsters and compactors and have dedicated drains beneath the trash receptacles connected to the sanitary sewer.

Kitchen Grease

- Save oil, grease, and meat fat for recycling in tallow bins or other sealed containers. **Never pour these materials into sinks, floor drains, or storm drains**. Do not contaminate recyclable fats with waste grease from an oil and water interceptor or grease trap.
- Place "No Grease" signs above kitchen sinks and in front of dishwashers to minimize the amount of grease discharged to the grease interceptor.
- Collect excess frying grease into a separate container for proper disposal.
- Local recycling/hauling company may pick up and dispose or recycle grease and/or tallow.

Kitchen Waste Disposal

- Ensure that kitchen drains are properly connected to the sanitary sewer system.
- Purchase recycled products where possible, which also ensures a use for recyclable materials. Recycle materials that are readily recycled in your area:
  - Food waste (nongreasy, nonanimal food waste can be composted)
  - Paper and cardboard (many forms of nonchemically treated paper products may also be composted)
  - Glass
  - Plastics
  - Aluminum and tin containers
  - Wood pallets
  - Oil and grease.
- Separate wastes. Keep recyclable wastes and compost in separate containers according to the type of material if required by the local waste hauler.
- Use nondisposable products. Serve food on reusable dishware rather than paper, plastic, or Styrofoam and use cloth napkins rather than paper ones.

- Buy the least toxic products available. Look for *nontoxic*, *nonpetroleum based*, *free of ammonia, phosphates, dye or perfume*, or *readily biodegradable* on the label. Avoid chlorinated compounds, petroleum distillates, phenols, and formaldehyde. Use water-based products whenever possible. Look for and use *recycled* and *recyclable* containers.

Outdoor Areas

- Keep outside areas free of trash and debris. Clean outdoor eating areas frequently using dry cleaning methods such as sweeping or vacuuming.
- Dry sweep pavement areas including *drive-through* areas, parking lots, outdoor eating areas, and dumpster or tallow bin areas frequently. If using water for cleaning, use a mop and bucket and dispose of washwater in a mop sink or floor drain plumbed to the sanitary sewer.
- Major cleaning of exterior surfaces should include capturing all washwater and disposing it to the sanitary sewer to comply with local regulations. Do not allow washwater to enter the street gutter or storm drain.
- Do not use grassy swales for disposing washwater from equipment maintenance or routine cleaning. Grassy swales are used for infiltration of storm water only. Ensure all employees are aware washwater should not be dumped into grassy swales.
- Special events such as those held in parking lots or fields require advanced planning to accommodate wastewater or process water disposal. Remind food vendors and attendees storm water inlets and grassy swales are not available for disposing washwater or any liquid and post visible signage around these facilities.

Maintenance

Maintain (routinely clean or pump out) grease control equipment. Check interceptor regularly to ensure it is less than 25% full of grease and settled solids, contains outlet Ts, and the structure is in good operating condition. Keep records on site of grease control equipment pumping, cleaning, and maintenance.

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BMP 93: Marinas

Description

Marinas may pose a threat to the health of aquatic systems and may create environmental hazards when these facilities are poorly planned or managed. Pollution from storm water runoff from marinas can be greatly reduced by properly siting marinas and using the best available design and construction practices and appropriate operation and maintenance practices (Figure 211).

Figure 211. Boat storage and moorage on Lake Coeur d'Alene, Idaho.

Applicability

This BMP applies to all marinas located adjacent and/or above a water body where materials and equipment are used on boats, docks, or other platforms.

Primary BMP Functions and Controls

☒ Construction	☒ Permanent
☒ Erosion Control	☒ Sediment Control
☒ Source Control	☐ Flood Control
☐ Filtration	☐ Infiltration

Typical Effectiveness for Targeted Pollutants

○	Sediment
◖	Nitrogen
◖	Phosphorus
◖	Metals
◖	Bacteria
●	Hydrocarbons
●	Litter

Other BMP Considerations

Relative Cost	$ to $$$
Maintenance Requirements	Variable
Ease of Installation	Variable
Freeze/Thaw Resistance	NA
Max. Tributary Drainage Area	NA
Max. Upstream Slope	NA
NRCS Soil Group	NA
Min. Ground Water Separation	NA
Min. Bedrock Separation	NA

Limitations

Certain activities commonly performed at a marina site, such as dredge and fill operations may be federally regulated under CWA §404 permit and §401 certification and may require implementing other BMPs such as dewatering (BMP 73) and sediment and erosion control (BMP 42). Other applicable permits include the EPA's Vessel General Permit and MSGP for marinas.

Design Basis

Marina Siting and Design

In selecting a marina site and developing a design, consider the need for efficient flushing of marina waters as a prime factor along with safety and vessel protection. Sites located on open water or at the mouths of streams and tributaries have higher flushing rates. Sites located in coves or toward the heads of creeks and tributaries tend to have lower flushing rates and are less suited for marina site placement.

Shoreline Stabilization

Activities associated with a marina and boating operations may cause shoreline erosion. BMP 38: Preserve Topsoil and Vegetation and BMP 41: Stabilized Construction Roads and Staging Areas will minimize shoreline erosion. These approaches have shown the greatest success in low-wave-energy areas where underlying soil types provide the stability required for plant growth. Under suitable conditions, an important advantage of vegetation is its relatively low initial cost. In areas of heavy erosion, BMP 56: Riprap Slope Protection may be required to stabilize shorelines. Identifying the cause of the erosion problem is essential for selecting the appropriate technique to address the problem.

Offshore marine structures to stabilize shorelines and navigation channels include bulkheads, jetties, and breakwaters. These structures are designed to dissipate incoming wave energy that could otherwise contribute to shoreline erosion. While structures may provide shoreline protection, unintended consequences may arise including accelerated scouring and increased erosion of unprotected downstream shorelines. Gabions (BMP 33) and energy dissipation devices (BMP 35) dissipate incoming wave energy and reduce scouring. Bulkhead retaining walls are appropriate in some circumstances but can have negative impacts on aquatic habitat due to changes they can cause to the beach profile and composition. Riprap and other quarried stone can impact the pH of the receiving waters, causing harm to native fish and wildlife. Practices incorporating more native materials, such as trees used for log-toes and matting with native vegetation, should be considered first.

Storm Water Runoff

Source controls and structural facilities can be used to control storm water runoff from a marina and include storm water filters (BMP 14), wet ponds (BMP 22), wetlands (BMP 24), infiltration basins and trenches (BMPs 17 and 18), dewatering systems (BMP 73), grassed swales and vegetated filter strips (BMPs 9 and 11), porous pavement (BMP 19), oil-grit separators (BMP 15), catch basins, catch-basin inserts (BMP 13), outdoor storage (BMP 77), and hydrodynamic separators (BMP 16).

Source control BMPs apply to activities occurring on site and reduce or control the potential for pollutant discharge. Source controls include, but are not limited to, the following:

- Using drip pans and absorbent materials for equipment and vehicles.
- Ensuring an adequate supply of spill cleanup materials available on site.
- Placing drip pans under all vehicles and equipment on docks, barges, or other structures over water bodies when the vehicle or equipment is expected to be idle for more than 1 hour.
- Providing watertight curbs or toe boards to contain spills and prevent materials, tools, and debris from leaving boats, platforms, and docks.
- Properly storing materials to prevent discharges to receiving waters via wind (BMP 77: Outdoor Storage).
- Identifying types of spill control measures to employ, including material and equipment storage. Ensure staff is trained in using the materials, deployment and access of control measures, and reporting measures.

Waste Management

Solid waste can be controlled at marinas by designating work areas for boat repair and maintenance, regularly maintaining these areas, and providing proper disposal and recycling facilities. Establishing fish cleaning areas, cleaning rules, educating boaters, and implementing fish composting where appropriate may also limit unnecessary fish waste. Offering septic pumping for slip owners manages both solid and liquid waste at marinas.

Fueling Operations

Prevent potential pollution from fueling stations by locating and designing fueling stations so spills can be contained in a limited area that provides spill containment equipment and have a spill contingency plan available. Equipment fueling information is included in BMP 83.

Fuel and oil are commonly released into surface waters during bilge pumping, fueling operations through the fuel tank air vent, and fueling from spills directly into surface waters and into boats. Oil and grease from the operating and maintaining inboard engines are a source of petroleum in bilges. Achieve petroleum control by using automatic shutoff nozzles and fuel and air separators on air vents or tank stems of inboard fuel tanks to reduce the amount of fuel spilled into surface waters during boat fueling. To minimize spills, promote using oil-absorbing materials in the bilge areas of all boats with inboard engines.

Construction Guidelines

When a marina is sited and constructed, current regulations for materials related to bulkheads, piers, and pilings should be reviewed. Guidelines are periodically updated as materials are determined to be hazardous to the environment, particularly marina coatings and treatments.

Maintenance

Boat Operations

Management practices can affect boat operations, such as prohibiting motorized vessels from areas containing important shallow-water habitat and establishing and enforcing no-wake zones to decrease turbidity.

To protect water quality, boat cleaning practices should include hand washing the boat hull on land and using phosphate-free and biodegradable detergents and cleaning compounds. If required to clean the boat hull while on the water, do so by mechanical means only (i.e., scraping, scouring, or rubbing) without using detergents or chemical cleaners.

Purge boat coolant should into a proper receptacle and replace with freshwater before launch or pickup by the owner.

General Operations

- Inspect and verify activity-based BMPs are in place before beginning marina activities. While activities associated with the BMP are under way, inspect BMPs according to general permit requirements for the associated project type and risk level. At a minimum,

inspect BMPs weekly before forecasted rain events, daily during extended rain events, and after rain events.
- Ensure employees and subcontractors implement the appropriate measures for storing and using materials and equipment.
- Inspect and maintain all associated BMPs and perimeter controls to ensure continuous protection of the water courses, including waters of the United States.
- At all times, avoid breaking up fuel spills with a detergent. Use oil absorbent materials to capture fuel spills and petroleum-based products discharged to surface waters.
- In case of spills, contact the appropriate local authority as soon as possible.

General marina operations should follow BMP 46: Spill Prevention and Control, BMP 83: Vehicle and Equipment Refueling, BMP 84: Vehicle and Equipment Cleaning, Maintenance, and Repair, BMP 50: Sanitary and Septic Waste Management, and BMP 51: Solid Waste Storage and Disposal.

Additional Resources

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BMP 94: Swimming Pool and Spa Maintenance

Description

Discharges from public or private swimming pools, spas, hot tubs, and fountains can negatively impact surface water quality if the facility is not operated and maintained properly. Pollutants of concern include chemicals used for disinfectant, such as chlorine, chloramine or bromine, as well as algaecides, diatomaceous earth, phosphorous, and nitrogen.

Water from spas and hot tubs are also at an elevated temperature. This water, if improperly discharged to the storm drain system, can have negative effects on receiving water and be toxic to terrestrial and aquatic ecosystems.

Properly operating and maintaining pools, spas, hot tubs, and fountains used for recreational or decorative purposes will minimize potential environmental impacts (Figure 212).

Figure 212. Check pool chemical levels.

BMP Classification

☐ Structural ☒ Nonstructural
☒ Permanent ☐ Construction
☐ Preconstruction/Site Planning

Primary BMP Functions and Controls

☐ Erosion Control ☐ Sediment Control
☐ Infiltration ☐ Flood Control
☒ Site Management ☒ Source Control

Typical Effectiveness for Targeted Pollutants

○ Sediment
○ Phosphorus
◖ Metals
◖ Bacteria
◖ Hydrocarbons
○ Litter

Other BMP Considerations

Relative Initial Cost	$
Ease of Implementation	Easy
Ongoing Maintenance and Costs	Low

Applicability

These BMPs apply to all public or private pools, spas, hot tubs, and fountains that use chemicals and/or are heated.

Additionally, public swimming pools must comply with the "Rules Governing Construction & Operation of Public Swimming Pools in Idaho" (IDAPA 16.02.14) and obtain permits from the applicable Idaho public health district. Owners and operators must comply with those regulations, policies, and procedures. The following guidelines do not exempt or supersede any requirements of the regulatory agencies.

Best Practices and Guidelines

Minimize Discharges

The best way to limit the impact of discharges from pools, spas, and fountains is to minimize the amount of discharges and avoid fully draining the facility if

possible. To minimize the need to drain these types of facilities, the following periodic maintenance steps should be performed according to manufacturer's specifications:

- Develop and regularly update a facility maintenance plan
- Clean the pool, spa, or hot tub regularly and remove unwanted residue buildup and floating solids.
- Maintain proper levels of chlorine or other disinfecting chemicals.
- Maintain water filtration and circulation requirements and reoxygenate if necessary.
- Manage pH levels and water hardness to reduce copper pipe erosion that can stain the facility and pollute receiving waters.

Discharge to Sanitary Sewer or Storm Drain System

If the facility must be drained, water should be discharged to a sanitary sewer or a storm drain system with approval from the sanitary sewer or storm drain system authority. Do not discharge to a septic tank as it may cause the system to fail. If discharging to a public sanitary sewer or storm drain system is not possible, a suitable disposal method approved by DEQ should be established. Whenever possible, hire a professional pool service company to collect all pool water for proper disposal. Confirm the pool company has the proper permits and where the water is disposed.

Discharges to Ground

If pool and spa water is allowed to be discharged to the ground, a natural pervious or landscaped area, or to a storm drainage system, these practices should be followed before discharge:

- Water quality
  - Dechlorinate and pH-adjust the water. Contact a pool chemical supplier to obtain proper neutralizing chemicals or discharge after the chlorine has reached a nondetect level using a standard testing method.
  - Reoxygenate by turning on the aeration system, if necessary.
  - Ensure the water is free of any coloration, dirt suds, algae, or acid-cleaning wastes.
  - Allow the water to cool to air temperature
- Control the location and rate of flow to minimize soil erosion and local flooding. Water discharged to the ground should not cross property lines and should not produce runoff.

Diatomaceous Earth

Diatomaceous earth used in pool filters is harmful to many aquatic species and cannot be disposed in surface waters, on the ground, into storm drainage systems, or into septic systems. Dry the earth out as much as possible; bag it in plastic, and dispose at the landfill. When cleaning diatomaceous earth filters, backwash onto dirt and ensure only infiltration, and not runoff, occurs.

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Glossary

Adjustable gate valve	A knife gate valve, activated by a handwheel, used to control the internal diameter of reverse-slope pipe, or to allow rapid opening of the pond drain pipe.
Adsorption	Adhesion of the molecules of a gas, liquid, or dissolved substance to a surface. Adsorption differs from absorption in that adsorption is the assimilation or incorporation of a gas, liquid, or dissolved substance into another substance.
Aggregate	Stone or rock gravel used to fill in an infiltration device such as a trench or porous pavement. Clean-washed aggregate has been washed clean so that no sediment is included.
Aquatic bench	A 10- to 15- foot bench around the inside perimeter of a permanent pool that is approximately 1 foot deep. Normally vegetated with emergent plants, the bench augments pollutant removal, provides habitat, conceals trash and water levels, and enhances safety.
Areal	An expanse of land or a region
Artificial marsh creation	Simulation of natural marsh features and functions via topographic and hydraulic modifications on nonmarsh landscapes. Typical objectives for artificial marsh creation include ecosystem replacement or storm water management.
Bacteria	Single-celled microorganisms that lack chlorophyll; some cause disease, and others are necessary to sustain life (see fecal coliform bacteria).
Bacterial decomposition or microbial decomposition	Microorganisms, or bacteria, have the ability to degrade organic compounds as food resources and to absorb nutrients and metals into their tissues to support growth.
Bank run	Gravelly deposits consisting of smooth round stones, generally indicating the existence of a prehistoric sea. Such deposits are usually found in coastal plain regions.
Bank stabilization	Methods of securing the structural integrity of earthen stream channel banks with structural supports to prevent bank slumping and undercutting of riparian trees, and overall erosion prevention. To maintain the ecological integrity of the system, recommended techniques use willow stakes, imbricated riprap, or brush bundles.
Bankfull discharge	A condition where streamflow completely fills the stream channel up to the top of the bank. In undisturbed watersheds, the discharge condition occurs on average every 1-1/2 to 2 years and controls the shape and form of natural channels.

Baseflow	The portion of stream flow that is not from storm runoff and is supported by ground water seepage into a channel.
Best management practice (BMP)	In this catalog, a BMP is a source or treatment control designed to reduce pollution in storm water runoff. Source controls are measures or devices designed to keep pollutants out of runoff. Examples include covers and roofs on outdoor storage processing areas and berms and sumps around outdoor source areas. Treatment controls are typically structural devices designed to temporarily store or treat urban storm water runoff to reduce flooding, remove pollutants, and provide other amenities (e.g., enhance aesthetics and wildlife habitat).
Biochemical oxygen demand (BOD)	The quantity of dissolved oxygen used by microorganisms (e.g., bacteria) during the biochemical oxidation of matter (both organic and oxidizable inorganic matter) over a specified period of time.
Biofiltration	The use of natural materials and vegetation to trap and remove pollutants from storm water. Grass swales and constructed wetlands can be used for biofiltration.
Biological monitoring	Periodic surveys of aquatic biota as an indicator of the general health of a water body. Biological monitoring surveys can span the trophic spectrum, from macroinvertebrates to fish species.
California bearing ratio (CBR)	A penetration test for evaluating the mechanical strength of road subgrades and basecourses.
Catchbasin	A structure at the point where a street gutter empties into a sewer, built to catch debris that would not easily pass through the sewer.
Catchment area	See contributing watershed area. Also known as drainage catchment area.
Cation exchange capacity (CEC)	The total capacity of a soil to hold exchangeable cations. CEC is an inherent soil characteristic and is difficult to alter significantly. It influences the soil's ability to hold onto essential nutrients and provides a buffer against soil acidification.
Channel	A natural or artificial waterway that periodically or continuously contains moving water. It has a definite bed and banks that confine the water.
Channel erosion	The widening, deepening, and headward cutting of small channels and waterways, due to erosion caused by moderate to larger floods.

Check dam	A small dam (a) placed perpendicular to a stream to enhance aquatic habitat, or (b) placed perpendicular in biofiltration swales to reduce water velocities, promote sediment deposition, and enhance infiltration.
Check valve	A device to provide positive closure that effectively prohibits the flow of material in the opposite direction of normal flow when operation of the irrigation system, pumping plant, or injection unit fails or is shut down (ASAE 1989).
Chemical oxygen demand (COD)	The quantity of maximum oxidizable matter in a sample.
Coalescing plate (CP) separator	A device made up of a series of parallel inclined plates that are closely spaced which is used to promote the removal of oil and other nonaqueous particles from storm water.
Compost storm water filter (CSF)	The filter that percolates storm water through compost, trapping particulates and adsorbing dissolved materials such as metals and nutrients.
Contributing watershed area	Portion of the watershed contributing its runoff to the site or BMP in question.
Conveyance system	The drainage facilities, both natural and human-made, which collect, contain, and provide for the flow of surface water and urban runoff from the highest points on the land down to receiving waters. The natural elements of the conveyance system include swales and small drainage courses, streams, rivers, lakes, and wetlands. The human-made elements of the conveyance system include gutters, ditches, pipes, channels, and most retention/detention facilities.
Cross section	A vertical section of a stream channel or structure that provide a side view of the structure; transect taken at right angles to flow direction.
Culvert	A covered channel or a large-diameter pipe that directs flow below the ground level.
Clean Water Act (CWA)	Federal Water Pollution Control Act (33 USC §1251 et seq. 1972), commonly known as the CWA, establishes the structure for regulating discharges into waters of the United States and establishes surface water quality standards.
Debris	Any material, organic or inorganic, floating or submerged, moved by a flowing stream.
Deciduous	Trees that shed leaves in the fall/winter.
Delta-T	Magnitude of change in the temperature of downstream waters.

Design storm	A rainfall event of specified size and return frequency (e.g., a storm that occurs only once every 2 years) used to calculate the runoff volume and peak discharge rate to a BMP.
Detention	The temporary storage of storm water runoff in a structural device (BMP) to reduce the peak discharge rates and to provide settling of pollutants.
Detention pond	A constructed pond or vault that temporarily stores storm water runoff and releases it at controlled rates.
Detention time	Time required for detention of storm water runoff in a storm water quality facility (see Detention).
Dewatering	Refers to a process used in detention/retention facilities, where water is completely discharged or drawn down to a preestablished pool elevation. Dewatering allows the facility to recover its design storage capacity in a relatively short time after a storm event.
Discharge	Outflow—The flow of a stream, canal, or aquifer. Discharge of a canal or stream into a lake, river, or ocean. In hydraulics, flow rate (i.e., fluid flow); a volume of fluid passing a point per unit of time, expressed as cubic feet per second, cubic meters per second, gallons per minute, gallons per day, or millions of gallons per day.
Dissolved oxygen (DO)	Oxygen present (dissolved) in water and available for use by fish and other aquatic animals. If the amount of DO in the water is too low, aquatic animals will suffocate.
Diversion	A channel, embankment, or other man-made structure constructed to divert water from one area to another (Soil Conservation Society of America 1982).
Downstream scour	Downstream channel erosion usually associated with an upstream structure that has altered hydraulic conditions in the channel.
Drainage basin or subbasin	See Watershed.
Drawdown	The gradual reduction in water level in a pond BMP due to the combined effect of infiltration and evaporation.
Dripline	An imaginary line around a tree or shrub at a distance from the trunk equivalent to the canopy spread.
Drop structure	Placement of logs with a weir notch across a stream channel. Water flowing through the weir creates a plunge pool downstream of the structure and creates fish habitat.

Dry pond conversion	Modification made to an existing dry storm water management pond to increase pollutant removal efficiencies. For example, the modification may involve a decrease in orifice size to create extended detention times, or the alteration of the riser to create a permanent pool and/or shallow marsh system.
Dry weather flow	Flow occurring during the dry season (May–September), which may be associated with reservoir releases or releases of water from industrial or residential activities.
Dry well	A well where storm water is disposed for infiltration. These devices are not recommended for areas with high water table conditions.
Earthen berm	An earthen mound used to direct the flow of runoff around or through a BMP.
Embankment	A bank (of earth or riprap) used to keep back water.
Emergent plant	An aquatic plant that is rooted in the sediment but whose leaves are at or above the water surface. Such wetland plants provide habitat for wildlife and waterfowl in addition to removing storm water pollutants.
End-of-pipe control	Water quality control technologies suited for the control of existing urban storm water at the point of storm sewer discharge to a stream. Due to typical space constraints, these technologies are usually designed to provide water quality control rather than quantity control.
Energy dissipation	The loss of kinetic energy of moving water due to internal turbulence, boundary friction, change in flow direction, contraction, or expansion.
Erosion	The wearing away of the land surface by running water, wind, ice, or other geological processes.
Exfiltration	The downward movement of runoff through the bottom of an infiltration BMP into the subsoil.
Extended detention (ED)	A storm water design feature that provides gradual release of a volume of water (0.25–1.0 inches per impervious acre) over a 12- to 48-hour interval time to increase settling of urban pollutants, and protect channel from frequent flooding.
Extended detention (ED) control device	A pipe or series of pipes extending from the riser of a storm water pond and used to gradually release storm water from the pond over a 12- to 48-hour interval.

Extended detention (ED) pond	A conventional ED pond temporarily detains a portion of storm water runoff for up to 24 hours after a storm using a fixed orifice. ED ponds allow urban pollutants to settle out. ED ponds are normally dry between storm events and do not have any permanent standing water. An enhanced ED pond is designed to prevent clogging and resuspension and provides greater flexibility in achieving target detention times. A pond may be equipped with plunge pools near the inlet, a micropool at the outlet, and use an adjustable reverse-sloped pipe at the ED control device.
Extended detention zone	A pondscaping zone extending from the normal pool to the maximum water surface elevation during extended detention events. Plants within this zone must withstand temporary inundation from 5 to 30 times per year.
Filter fabric	See Geotextile fabric.
Floodplain	Any lowland bordering a stream and inundated periodically by its waters.
Flow splitter	An engineered, hydraulic structure designed to divert a portion of stream flow to a BMP located out of the channel, or to direct storm water to a parallel pipe system, or to bypass a portion of baseflow around a pond.
Forebay	An extra storage area provided near an inlet of a BMP to trap incoming sediments before they accumulate in a pond BMP.
Fragipan	A loamy, brittle subsurface horizon low in porosity and content of organic matter and low or moderate in clay but high in silt or very fine sand.
Freeboard	The vertical distance between the design water surface elevation and the elevation of the bank, levee, or revetment that contains the water.
Frequent flooding	A phenomenon in urban streams where the number of bankfull and subbankfull flood events increases sharply after the development. The frequency of these disruptive floods is a direct function of watershed imperviousness.
Fringe marsh creation	Planting emergent aquatic vegetation along the perimeter of open water to enhance pollutant uptake, increase forage and cover for wildlife and aquatic species, and improve the appearance of a pond.
Gabion	A large rectangular box of heavy gauge wire mesh that holds large cobbles or boulders. Used in streams and ponds to change flow patterns, stabilize banks, or prevent erosion.

Geomembrane	Lining of filter fabric on the bottom and sides of porous pavement to prevent lateral or upward movement of soil into the stone reservoir.
Geotextile fabric	Textile of relatively small mesh or pore size used to (a) allow wallow water to pass through while keeping sediment out (permeable), or (b) prevent both runoff and sediment from passing through (impermeable). Also known as filter fabric.
Grading	The cutting and/or filling of the land surface to a desired slope or elevation.
Grassed swale	An earthen conveyance system where the filtering action of grass and soil infiltration are used to remove pollutants from urban storm water. An enhanced grass swale, or biofilter, uses checkdams and wide depressions to increase runoff storage and promote greater settling of pollutants.
Gravel	Sediment particles larger than sand and ranging from 2 to 64 mm (0.25 to 3 inches) in diameter.
Gravitational settling	The tendency of particulate matter to drop out of storm water runoff as it flows downstream when runoff velocities are moderate and/or slopes are not too steep.
Ground water table	The level below which the soil is saturated—the pore spaces between the individual soil particles are filled with water. Above the ground water table and below the ground surface, water in the soil does not fill all pore spaces.
Habitat	A place where a biological organism lives. The organic and nonorganic surroundings that provide life requirements such as food and shelter.
Head	Pressure
Heavy metals	Metals of relatively high atomic weight, including but not limited to chromium, copper, lead, mercury, nickel, and zinc. These metals are generally found in minimal quantities in storm water but can be highly toxic even at trace levels.
Hotspots	Hotspots are commercial, industrial, institutional, municipal, or transportation-related operations that generate or can generate relatively high concentrations of pollutants, such as hydrocarbons, trace metals, or toxicants, and/or present a higher potential risk for spills, leaks, or illicit discharges. Examples are vehicle service, fueling, maintenance and equipment cleaning areas; vehicle fleet storage areas; airports; industrial sites; landfills/solid waste facilities; laundries and dry cleaners; shopping centers; and outdoor storage and loading/unloading areas of hazardous materials.

Impermeable	Properties that prevent the movement of water through the material.
Impervious surface	Material that resists or blocks the passage of water.
Infiltration	The penetration of water through the ground surface into subsurface soil or the penetration of water from the soil into sewer or other pipes through defective joints, connections, or manhole walls. The infiltration rate is expressed in terms of inches/hour. Infiltration rates will be slower when the soil is dense (e.g., clays) and faster when the soil is loosely compacted (e.g., sands). Also refers to seepage of ground water into sewer pipes through cracks and joints.
Inlet	(1) A drainage passway. (2) A short, narrow waterway connecting a bay, lagoon, or similar body of water with a large parent body of water. (3) An arm of the sea (or other body of water) that is long compared to its width and may extend a considerable distance inland.
Level spreader	A device used to spread out storm water runoff uniformly over the ground surface as sheet flow (i.e., not through channels). Level spreaders prevent concentrative, erosive flows from occurring and enhance infiltration.
Lowflow channel	An incised or paved channel from inlet to outlet in a dry basin, designed to carry low runoff flows and/or baseflow directly to the outlet without detention.
Micropool	A smaller permanent pool used in a storm water pond due to extenuating circumstances (i.e., concern over the thermal impacts of larger ponds, impacts on existing marshes, or lack of topographic relief).
Microtopography	Contours along the bottom of a shallow wetland system. A complex microtopography creates a great variety of environmental conditions that favor the unique requirements of many different species of marsh plants.
Multiple pond system	A collective term for a cluster of pond designs that incorporate redundant runoff treatment techniques within a single pond or series of ponds. These pond designs employ a combination of two or more of the following: extended detention, permanent pool, shallow marsh, or infiltration. The wet ED pond is an example of a multiple pond system.

Natural buffer	A low sloping area of maintained grassy or woody vegetation located between a pollutant source and a water body. A natural buffer is formed when a designated portion of a developed piece of land is left unaltered from its natural state during development. A natural vegetative buffer differs from a vegetated filter strip in that it is natural and does not need to be used solely for water quality purposes. To be effective, the areas must be protected against concentrated flow.
National Pollutant Discharge Elimination System (NPDES)	A provision of the Clean Water Act prohibiting discharge of pollutants into waters of the United States unless a special permit is issued by EPA, a state, or a tribal government.
Nutrients	Elements or substances, such as nitrogen or phosphorus, needed for the growth and development of living things (e.g., plants). Large amounts of these substances reaching water bodies can lead to reduced water quality and eutrophication by promoting excessive aquatic algae growth. Some nutrients can be toxic at high concentrations.
Observation well	A test well installed in certain infiltration and filtration BMPs to monitor draining times after installation.
Off-line BMP	A water quality facility designed to treat a portion of storm water that has been diverted from a stream, storm drain, or other conveyance.
Off-line treatment	A BMP system located outside of the stream channel or drainage path. A flow splitter is typically used to divert runoff from the channel and into the BMP for subsequent treatment.
Oil and water (or oil and grit) separator	A BMP consisting of a three-stage underground retention system designed to remove heavy particulates and absorbed hydrocarbons. Also known as a water quality inlet.
Outfall	The point of discharge for a river, drain, pipe, etc.
Parallel pipe system	A technique for protecting sensitive streams. Excess storm water runoff is piped in a parallel direction along the stream buffer instead of discharged directly into the stream.
Passive treatment facility	A facility that uses natural materials and vegetation to cleanse storm water and/or reduce storm water flow. Examples include grass swales, constructed wetlands, etc.
Percolation	The downward movement of water through the soil.
Permanent pool	A 3- to 10-foot deep pool in a storm water pond system that provides removal of urban pollutants through settling and biological uptake. (Also referred to as a wet pond).
Permeability	The quality of a soil horizon that enables water or air to move through it.

Physical infiltration	The separation of particulates from runoff by grass, leaves, and other organic matter on the surface, as the runoff passes across or through the ground.
Pilot channel	A riprap or paved channel that routes runoff through a BMP to prevent erosion of the surface.
Plunge pool	A small permanent pool located at either the inlet to a BMP or at the outfall from a BMP. The primary purpose of the pool is to dissipate the velocity of storm water runoff, but it also can provide some pretreatment, as well.
Pollutant	Generally, any substance introduced into the environment that adversely affects the usefulness of a resource.
Pollution	Impairment of water quality caused by man-made waste discharges or natural processes.
Pondscaping	A method of designing the plant structure of a storm water marsh or pond using inundation zones. The proposed marsh or pond system is divided into zones that differ in the level and frequency of inflow. For each zone, plant species are chosen based on their potential to thrive, given the inflow pattern of the zone.
Porous pavement	An alternative to conventional pavement whereby runoff is diverted through a porous asphalt layer and into an underground tone reservoir. The stored runoff then gradually infiltrates into the subsoil. Porous pavement is not recommended for use in areas with high water table conditions.
Positive drainage	A drainage condition in which water flows away from a structure or site.
Retrofit	The creation/modification of storm water management systems in developed areas by constructing wet ponds, infiltration systems, marsh plantings, streambank stabilization, and other BMP techniques to improve water quality and create aquatic habitat. A retrofit consists of constructing a new BMP in the developed area, enhancing an older storm water management structure, or a combination of improvement and new construction.
Reverse slope pipe	A pipe extending downward from the riser into the permanent pool that sets the water surface elevation of pool. The lower end of the pipe is located up to 1 foot below the water surface. This technique is a useful for regulating ED times in a storm water wetland, and the pip seldom clogs.
Riparian zone	A relatively narrow strip of land that borders a stream or river, often coinciding with the maximum water surface elevation of the 100-year storm.

Riparian reforestation	Replanting the banks and floodplain of a stream with native forest and shrub species to stabilize erodible soils, improve both surface and ground water quality, increase stream shading, and enhance wildlife habitat.
Riprap	A combination of large stone, cobbles, and boulders used to line channels, stabilize banks, reduce runoff velocities, or filter out sediment.
Riser	A vertical pipe extending from the bottom of a pond BMP used to control the discharge rate from a BMP for a specified design storm.
Root zone	The part of the soil that is, or can be, penetrated by plant roots (Soil Conservation Society of America 1982).
Rototilling	Mechanical means of tilling, or rotating, the soil.
Runoff	See storm water runoff.
Runoff conveyance	Methods for safely conveying storm water to a BMP to minimize disruption of the stream network and promote infiltration or filtering the runoff.
Runoff frequency spectrum	The frequency distribution unit are runoff volumes generated by a long-term continuous time-series of rainfall events. Used to develop BMP and storm water sizing rules.
Runoff pretreatment	Techniques to capture or trap coarse sediments before they enter a BMP, preserve storage volumes, or prevent clogging with in the BMP. Examples include forebays and micropools for pond BMPs, and plunge pools, grass filter strips, and filter fabric for infiltration BMPs.
Run-on	Off-site flow onto a site.
Safety bench	A 10- to 15- foot wide bench located just outside the perimeter of a permanent pool. The bench extends around the entire shoreline to provide maintenance access and eliminate hazards.
Sand filter	A technique for treating storm water, where the first flush of runoff is diverted into a self-contained bed of sand. The runoff is then strained through the sand, collected in underground pipes, and returned back to the stream or channel. An enhanced sand filter uses layers of peat, limestone, and/or topsoil and may also have a grass cover crop. The adsorptive media of an enhanced sand filter is expected to improve removal rates.
Scour	Concentrated erosive action of flowing water in streams that removes material from the bed and banks.

Sediment	The product of erosion processes; the solid material, both mineral and organic, that is in suspension, is being transported, or has been moved from its site of origin by air, water, gravity, or ice (USDA-SCS 1991).
Sedimentation	The process of sand and mud settling and building up on the bottom of a creek, river, lake, or wetland.
Sediment forebay	Storm water design feature that uses a small basin to settle out incoming sediments before they are delivered to a storm water BMP. Particularly useful in tandem with infiltration devices, wet ponds, or marshes.
Seedbanks	The large number and diversity of dormant seeds of plant species existing in the soil. The seeds may exist within the soil for years before they germinate under the proper moisture, temperature, or light conditions. Within marsh soils, this seedbank helps to maintain aboveground plant diversity and can also be used to rapidly establish marsh plants within a newly constructed storm water marsh.
Seepage	Water escaping through or emerging from the ground along an extensive line or surface as contrasted with a spring, where the water emerges from a localized spot (Soil Conservation Society of America 1982).
Septic	Produced by anaerobic decomposition of organic matter with accompanying foul odors.
Sheet flow	Water, usually storm runoff, flowing in a thin layer over the ground surface (Soil Conservation Society of America 1982).
Short circuiting	The passage of runoff through a BMP in less than the theoretical or design treatment time.
Slope	The degree of deviation of a surface from horizontal, measured as a percentage, as a numerical ratio, or in degrees (Soil Conservation Society of America 1982).
Sinuosity	A measure of the wiggliness of a watercourse (Gordon, McMahon, and Finlayson 1992). While sinuosity has a number of definitions, the most commonly used is the sinuosity index: $SI = \frac{\text{Channel (Thalweg) Distance}}{\text{Downvalley distance}}$
Source control	A pollution control measure that operates by keeping pollutants from entering storm water
Storm drain (or storm sewer)	Above and belowground structures for transporting storm water to streams or outfalls for flood control purposes.

Storm water runoff	Excess precipitation not retained by vegetation, surface depressions, or infiltration, which collects on the surface and drains into a surface water body.
Storm water site plan	A plan prepared during the project design phase to show the BMPs and techniques that will be used to control storm water pollution during construction and after construction is complete.
Storm water treatment	Detention, retention, filtering, or infiltration of a given volume of storm water to remove urban pollutants and reduce frequent flooding.
Stream buffer	A variable width strip of vegetated land adjacent to a stream that is preserved from development activity to protect water quality and aquatic and terrestrial habitats.
Subsoil	The bed or stratum of earth lying below the surface soil.
Substrate amendments	A technique to improve the texture, and organic content of soils in a newly excavated pond system. The addition of organic rich soils is often required to ensure the survival of aquatic and terrestrial landscaping around ponds.
Suspended sediment	The very fine soil particles that remain in suspension in water for a considerable period of time (Soil Conservation Society of America 1982).
Swale	A natural depression or wide shallow ditch used to temporarily store, route, or filter runoff.
Topography	The relative positions and elevations of the natural or man-made features of an area that describe the configuration of its surface (Soil Conservation Society of America, 1982).
Total maximum daily load (TMDL)	The sum of individual waste load allocations for point sources and load allocations for nonpoint sources and natural background. The Idaho Department of Environmental Quality has the authority to set TMDLs for water quality-limited bodies.
Toxic	Related to or caused by a poison, hazardous waste, or toxin.
Trash and debris removal	Mechanical or manual removal of debris, snags, and trash deposits from the streambanks to improve the appearance of the stream.
Underdrain	Plastic pipes with holes drilled through the top that are installed on the bottom of a sand filter to collect and remove excess runoff.
Urban runoff	Storm water that passes through and out of developed areas to a stream or other body of water (see storm water runoff).

Vacuum sweeping	Method of removing quantities of coarse-grained sediments from porous pavements to prevent clogging. Not effective in removing fine-grained pollutants.
Vegetated filter strip	A vegetated section of land designed to accept runoff as overload sheet flow from upstream development. It may adopt any natural vegetated form, from grass meadow to small forest. The dense vegetative cover facilitates pollutant removal. A filter strip cannot treat high-velocity flows; therefore, they are generally recommended for use in agriculture and low-density development. A vegetated filter strip differs from a natural buffer in that the strip is not natural; rather, it is designed and constructed specifically for pollutant removal. A filter strip can also be an enhanced natural buffer, but the removal capability of the natural buffer is improved through engineering and maintenance activities such as land grading or installing a level spreader. A filter strip also differs from a grassed swale in that a swale is a concave vegetated conveyance system, where a filter strip has a fairly level surface.
Velocity	The distance water travels in a given direction in a stream during an interval of time.
Watershed or drainage basin	A geographic area where all surface water drains into a particular body of water (e.g., a river or stream).
Weephole	A small opening or pipe left in a revetment or bulkhead to allow ground water drainage.
Weir	A structure extending across the width of a channel intended to impound, delay, or in some way alter the flow of water through the channel. A check dam is a type of weir as is any kind of dam.
Wet pond	A conventional wet pond has a permanent pool of water for treating incoming storm water runoff. In enhanced wet pond designs, a forebay is installed to trap incoming sediments where they can be easily removed; a fringe marsh is also established around the perimeter of the pond.
Wet weather flow	Water derived primarily from rain, melting snow, or irrigation during the wet season (i.e., October–April) that flows over the surface of the ground.

Wetland	A conventional wetland for storm water quality control is a shallow pool that creates suitable growing conditions for marsh plants. Designed to maximize pollutant removal through marsh uptake, retention, and settling. A wetland is a constructed system typically not located within a delineated natural wetland. In addition, a storm water wetland differs from an artificial wetland created to comply with mitigation requirements and does not replicate all the ecological functions of natural wetlands. An enhanced storm water wetland is designed for more effective pollutant removal and species diversity. Its design includes a forebay, complex microtopography, and pondscaping with multiple species of marsh trees, shrubs, and plants.
Wetland mitigation	Regulatory requirement to replace wetland areas destroyed or impacted by proposed land disturbances with artificially created wetland areas.
Wetland mulch	A technique for establishing low or high marsh areas where the top 12 inches of marsh soil from a donor marsh are spread thinly over the surface of a created marsh site as a mulch. The seedbank and organic matter of the mulch helps to rapidly establish a diverse marsh system.
Wetland plant uptake	Marsh plant species rely on nutrients (i.e., phosphorous and nitrogen) as a food source; they may intercept and remove nutrients from either surface or subsurface flow.