APPENDIX J

Erosion Control

United States Environmental Protection Agency

Stormwater Best Management Practice

Compost Blankets

Permits for Clean Water NPDES

Minimum Measure

Construction Site Stormwater Runoff Control

Subcategory

Erosion Control

Purpose and Description

A compost blanket is a layer of loosely applied composted material placed on the soil in disturbed areas to reduce stormwater runoff and erosion. This material fills in small rills and voids to limit channelized flow, provides a more permeable surface to facilitate stormwater infiltration, and promotes revegetation. Seeds can be mixed into the compost before it is applied. Composts are made from a variety of feedstocks, including yard trimmings, food residuals, separated municipal solid waste, and municipal sewage sludge (biosolids). Controlling erosion protects water quality in surface waters, such as streams, rivers, ponds, lakes, and estuaries; and increasing stormwater infiltration replenishes groundwater aquifers. Applying a compost blanket also works well as a stormwater best management practice (BMP) because it:

- Retains a large volume of water, which aids in establishing vegetation growth within the blanket,
- Acts as a cushion to absorb the impact energy of rainfall, which reduces erosion,
- Stimulates microbial activity that increases the decomposition of organic matter, which increases nutrient availability and improves the soil structure,
- Provides a suitable microclimate with the available nutrients for seed germination and plant growth, and
- Removes pollutants such as heavy metals, nitrogen, phosphorus, fuels, grease and oil from stormwater runoff, thus improving downstream water quality (USEPA 1998).

Applicability and Limitations

Compost blankets can be placed on any soil surface: flat, steep, rocky, or frozen. The blankets are most effective when applied on slopes between 4:1 and 1:1 (horizontal run:vertical rise); such as construction sites, road embankments, and stream banks; where stormwater runoff can occur as sheet flow. On the steeper slopes (1:1) the compost blanket should be used in conjunction with netting or other confinement systems to further stabilize the compost and slope, or the compost particle size and depth should be specially designed for this application. Compost blankets should not be placed in locations that receive concentrated or channeled flows either as runoff or a point source discharge. If compost blankets are placed adjacent to highways and receive concentrated runoff from the traffic lanes, they should be protected by compost berms, or a similar BMP that diffuses or diverts the concentrated runoff before it reaches the blanket (Glanville, Richard, and Persyn 2003). Because a compost blanket can be applied to the ground surface without having to be incorporated into the soil, it provides excellent erosion and sediment control on difficult terrain, such as steep or rocky slopes (Figures 3, 4). Projects where the cost of transporting and applying composts is most easily justified are situations that demand both immediate erosion control and growth of vegetative cover, such as projects completed too late in the growing season to establish natural vegetation before winter or areas with poor quality soils that don't readily support vegetative growth (Glanville, Richard, and Persyn 2003).

Figure 1. *Applying a compost blanket on a bare and eroding slope*

Figure 2. *Same slope after revegetation*

Figure 3. *Applying a compost blanket on a steep, rocky slope*

Figure 4. Same slope after revegetation

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What Is Compost?

Compost is the product of controlled biological decomposition of organic material that has been sanitized through the generation of heat and stabilized to the point that it is beneficial to plant growth. It is an organic matter resource that has the unique ability to improve the biological, chemical, and physical characteristics of soils or growing media. Compost contains plant nutrients but is typically not characterized as fertilizer (USCC 2008).

This decomposition of organic material is produced by metabolic processes of microorganisms. These microbes require oxygen, moisture, and food in order to grow and multiply. When these three factors are maintained at optimal levels, the natural process of decomposition is greatly accelerated. The microbes generate heat, water vapor, and carbon dioxide as they transform the raw materials into a stable soil conditioner. Compost can be produced from many raw organic materials, such as leaves, food scraps, manure, and biosolids. However, the mature compost product bears little physical resemblance to the raw material from which it originated.

Figure 5. *Mature compost product*

How Is Compost Beneficial?

Biological Benefits

Provides an excellent substrate for soil biota. The activity of soil microorganisms is essential for productive soils and healthy plants. Their activity is largely based on the presence of organic matter. Soil microorganisms include bacteria, protozoa, and fungi. They are not only found within compost, but will also proliferate within the soil under a compost blanket. These microorganisms play an important role in organic matter decomposition, which leads to humus formation and nutrient availability. Some microorganisms also promote root activity; specific fungi work symbiotically with plant roots, assisting them in extracting nutrients from the soils.

Suppresses plant diseases. The incidence of plant diseases may be influenced by the level and type of organic matter and microorganism present in soils. Research has shown that increased populations of certain microorganisms may suppress specific plant diseases, such as pythium blight and fusarium wilt.

Chemical Benefits

Provides nutrients. Compost blankets contain a considerable variety of macro- and micronutrients essential for plant growth. Since compost contains relatively stable sources of organic matter, these nutrients are supplied in a slow-release form.

Modifies and stabilizes pH. The pH of composts differ. When necessary, a compost may be chosen that is most appropriate for revegetating a particular construction site.

Physical Benefits

Improved soil structure and moisture management. In fine-textured soils (i.e., clay or clay loam), the addition of compost will increase permeability, and reduce stormwater runoff and erosion. The soil-binding properties of compost are due to its humus content. Humus is a stable residue resulting from a high degree of organic matter decomposition. The constituents of humus hold soil particles together, making them more resistant to erosion and improving the soil's ability to hold moisture.

Effectiveness of Compost, Topsoil, and Mulch

Because of the biological, chemical, and physical benefits it can provide, compost makes a more effective erosion control blanket than topsoil. An Iowa State University study (Glanville, Richard, and Persyn 2003), sponsored by the Iowa Department of Natural Resources and Iowa Department of Transportation (DOT), compared the quantity of runoff from road embankments treated with topsoil and with compost blankets. The test plots were exposed to simulated, high intensity rainfall (3.7 inches/hour) lasting for 30 minutes. Results showed that the amount of runoff from the embankment treated with a compost blanket was far less than the runoff from the embankment treated with topsoil.

Mulch is a protective covering placed around plants for controlling weeds, reducing evaporation, and preventing roots from freezing. It is made of various substances usually organic, such as hardwood or pine bark. A compost blanket is a much more effective BMP for erosion control and revegetation than mulch. A University of Georgia research study (Faucette and Risse 2002) reported that correctly applied compost blankets provide almost 100 percent soil surface coverage, while other

methods (e.g., straw mats and mulches) provide only 70 to 75 percent coverage. Uniform soil coverage is a key factor in effective erosion and sediment control because it helps maintain sheet flow and prevents stormwater from forming rills under the compost blanket.

Compost Quality

Compost Properties

Maturity. Maturity indicates how well the compost will support plant growth. One maturity test measures the percent of seeds that germinate in the compost compared to the number of seeds that germinate in peat based potting soil. For example, if the same number of seeds was planted in the potting soil (control) and in a marketed compost product, and 100 of them germinate in the potting soil and 90 germinate in the compost, the compost's maturity would be 90 percent. Another maturity test compares the growth and vigor of seedlings after they have been growing in both compost and potting soil.

Stability. Stability determines how "nice" the compost is. While microbial decay is actively transforming the feedstocks into compost, the unstable mixture may have unpleasant characteristics such as odors. However, after the decay process is completed, the stable compost product no longer resembles the feedstock or has offensive characteristics. During the composting process, CO_2 is produced because the microbes are actively respiring. So the microbial respiration (CO_2 evolution) rates can be measured and used to determine when the microbial decay is completed and the compost product has stabilized.

Presence of Pathogens. The pathogen count indicates how sanitary the compost is. EPA has defined processes for composting biosolids that reduce the number of pathogenic organisms to nondetectible levels and ensure the resulting compost will be sufficiently heat treated and sanitary. These processes to further reduce pathogens (PFRP) are defined in 40 CFR, Part 503, Appendix B, Section B. Compost quality specifications often require compost to be treated by a PFRP process, so there are no measurable pathogenic microorganisms present.

Other compost properties that may be found in compost quality specifications are plant nutrients and heavy metal concentrations, pH, moisture content, organic matter content, soluble salts, and particle size.

Compost Quality Testing

A compost testing, labeling, and information disclosure program, the Seal of Testing Assurance Program, has been established by the United States Composting Council (USCC), a private, nonprofit organization. Under this program testing protocols for determining the quality and condition of compost products at the point of sale have been jointly approved and published by the USCC and U.S. Department of Agriculture. These Test Methods for Evaluating Compost and Composting, the TMECC Testing Protocols are conducted by independent laboratories to help compost producers determine if their compost is safe and suitable for its intended uses, and to help users compare various compost products and verify the product safety and market claims. The goal of the program is to certify the compost products have been sampled and tested in accordance with these approved protocols. Compost producers who participate in this program have committed to having their products tested by an approved laboratory according to the prescribed testing frequency and protocols and to providing the test results to anyone upon request. The products of participating compost producers carry the USCC certification logo and product information label.

Compost Quality Specifications

The Federal Highway Administration supported developing specifications for compost used in erosion and sediment control through a cooperative agreement with the Recycled Materials Resource Center at the University of New Hampshire. The original compost blanket specifications (Alexander 2003) were developed under this grant. Working with the USCC and Ron Alexander (Alexander 2003), the American Association of State Highway and Transportation Officials finalized and approved these specifications (AASHTO 2010), which include: narrative criteria (e.g., no objectionable odors or substances toxic to plants), numerical specifications [e.g., pH, soluble salts, moisture content, organic matter content, particle size, stability, and physical contaminants (e.g., metal, glass, plastics)], and pathogen reduction using the EPA processes to further reduce pathogens. These AASHTO specifications also recommend the TMECC testing protocols. A number of states have now developed specifications for the compost they use in erosion and sediment control. Examples are the California DOT specifications and Texas DOT specifications.

Compost Blanket Installation

Once any trash and debris have been removed from a site, a compost blanket can be uniformly applied usually between 1 and 3 inches thick using a bulldozer, skid steer, manure spreader, or hand shovel. Application rates (thickness) are often included in compost blanket specifications. The compost blanket should extend at least 3 feet over the shoulder of the slope to ensure that stormwater runoff does not flow under the blanket (Alexander 2003). On very rocky terrain or if the slope is too steep for heavy equipment, a pneumatic blower truck is needed to apply the compost (Figure 6). If the slope is steep, a compost blanket may work best in conjunction with other BMPs, such as compost socks placed across the slope to reduce the runoff velocity (Figure 7) or compost berms placed at the top of the slope to divert or diffuse concentrated runoff before it reaches the compost blanket (Figure 8).

Figure 6. *Using a pneumatic blower truck to apply a compost blanket on a rocky 1:1 slope*

Figure 7. *Using compost socks to reduce the runoff velocity*

Figure 8. *Using a compost berm to divert or defuse highway runoff before it reaches the compost blanket*

Fabric netting can also be used to hold the compost blanket on steep slopes (Figure 9). The netting is usually stapled to the slope (Figure 10), and then the compost is blown on the slope and into the netting.

Mature compost for erosion control on moderate slopes is shown in Figure 11, with a red pen for size comparison. The compost in Figure 5 is too fine for erosion control. Coarser compost should be avoided on slopes that will be landscaped or seeded, as it will make planting and crop establishment more difficult. But coarse and/or thicker compost is recommended for areas with higher annual precipitation or rainfall intensity, and even coarser compost is recommended for areas subject to wind erosion (Alexander 2003).

Figure 9. *Netting stabilizing a compost blanket*

Figure 10. *Stapling netting to the slope*

Figure 11. *Compost for erosion control on moderate slopes*

Grass, wildflower, or native plant seeds appropriate for the soil and climate can be mixed into the compost. Although seed can be broadcast on the compost blanket after installation, it is typically incorporated into the compost before it is applied, to ensure even distribution of the seed throughout the compost and to reduce the risk of the seed being washed from the surface of the compost blanket by stormwater. Wood chips may also be added to reduce the erosive effect of rainfall's impact energy.

Figure 12. *Impact of rainfall*

Inspection and Maintenance

The compost blanket should be inspected periodically and after each major rainfall. If areas of the compost blanket have washed out, another layer of compost should be applied. In some cases, it may be necessary to add another BMP to control the stormwater, such as a compost filter sock or silt fence. On slopes greater than 2:1, establishing thick, permanent vegetation as soon as possible is the key to successful erosion and sediment control. Restricting or eliminating pedestrian traffic on such areas is essential (Faucette and Ruhlman 2004).

Climate Change Mitigation

In 2005 an estimated 246 million tons of municipal solid wastes were generated in the United States. Organic materials including yard trimmings, food scraps, wood waste, paper and paper products are the largest component of our trash and make up about two-thirds of the solid waste stream. When this organic matter decomposes in landfills, the carbon is converted to methane (CH_4) and other volatile organic compounds, which are released into the atmosphere and contribute to global warming. EPA has identified landfills as the single largest source of methane, a potent greenhouse gas that is 23 times more efficient at trapping heat than carbon dioxide (CO_2). Landfills contribute approximately 34 percent of all man-made methane released into the atmosphere in the United States (USEPA 2007). Two approaches for mitigating climate change are reducing carbon emissions and sequestering carbon in the atmosphere.

Reducing carbon emissions. When organic materials are composted and then recycled, the composting feedstocks are diverted from already burdened municipal landfills, and landfill-generated methane gas emissions are reduced.

Figure 13. *As compost like this is recycled, green house gasses are reduced*

Sequestering Carbon. Carbon sequestration is the act of removing carbon dioxide from the atmosphere and storing it in carbons sinks, such as oceans, plants and other organisms that use photosynthesis to convert carbon from the atmosphere into biomass. Forest ecosystems and permanent grasslands are prime examples of terrestrial carbon sinks that sequester carbon. We no longer have the vast expanses of prairies and eastern forests, but we are using compost blankets to revegetate construction sites, road banks, and green roofs; and this vegetation sequesters carbon.

Figure 14. *Compost blankets will nurture revegetation, which sequesters carbon and prevents erosion*

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Minimum Measure: Construction Site Stormwater Runoff Control

Subcategory: Erosion Control

Dust control measures can be used to prevent dust from being transported by wind (Source: Dust Pro, Inc., no date)

Description

Dust control BMPs reduce surface activities and air movement that causes dust to be generated from disturbed soil surfaces. Construction sites can generate large areas of soil disturbance and open space for wind to pick up dust particles. Limited research at construction sites has established an average dust emission rate of 1.2 tons/acre/month for active construction (WA Dept. of Ecology, 1992). Airborne particles pose a dual threat to the environment and human health. First, dust can be carried offsite, thereby increasing soil loss from the construction area and increasing the likelihood of sedimentation and water pollution. Second, blowing dust particles can contribute to respiratory health problems and create an inhospitable working environment.

Applicability

Dust control measures are applicable to any construction site where there is the potential for air and water pollution from dust traveling across the landscape or through the air. Dust control measures are especially important in arid or semiarid regions, where soil can become extremely dry and vulnerable to transport by high winds. Implement dust control measures on all construction sites where there will be major soil disturbances or heavy equipment construction activity such as clearing, excavation, demolition, or excessive vehicle traffic. Earthmoving activities are the major source of dust from construction sites, but traffic and general disturbances can also be major contributors (WA Dept. of Ecology, 1992). The dust control measures that are implemented at a site will depend on the topography and land cover of the site

and its soil characteristics and expected rainfall.

Siting and Design Considerations

When designing a dust control plan for a site, the amount of soil exposed will dictate the quantity of dust generation and transport. Therefore, construction sequencing and disturbing only small areas at a time can greatly reduce problematic dust from a site. If land must be disturbed, consider using temporary stabilization measures before disturbance. A number of methods can be used to control dust from a site; not all will be applicable to a site. The owner, operator, and contractors responsible for dust control at a site will have to determine which practices accommodate their needs according to specific site and weather conditions. The following is a brief list of some control measures and design criteria.

- *Sprinkling/Irrigation*. Sprinkling the ground surface with water until it is moist is an effective dust control method for haul roads and other traffic routes (Smolen et al., 1988). This practice can be applied to almost any site.
- *Vegetative Cover*. In areas not expected to handle vehicle traffic, vegetative stabilization of disturbed soil is often desirable. Vegetative cover provides coverage to surface soils and slows wind velocity at the ground surface, thus reducing the potential for dust to become airborne.
- *Mulch*. Mulching can be a quick and effective means of dust control for a recently disturbed area (Smolen et al., 1988).
- *Wind Breaks*. Wind breaks are barriers (either natural or constructed) that reduce wind velocity through a site and, therefore, reduce the possibility of suspended particles. Wind breaks can be trees or shrubs left in place during site clearing or constructed barriers such as a wind fence, snow fence, tarp curtain, hay bale, crate wall, or sediment wall (USEPA, 1992).
- *Tillage*. Deep tillage in large open areas brings soil clods to the surface where they rest on top of dust, preventing it from becoming airborne.
- *Stone*. Stone can be an effective dust deterrent for construction roads and entrances or as a mulch in areas where vegetation cannot be established.
- *Spray-on Chemical Soil Treatments (palliatives)*. Examples of chemical adhesives include anionic asphalt emulsion, latex emulsion, resin-water emulsions, and calcium chloride. Chemical palliatives should be used only on mineral soils. When considering chemical application to suppress dust, determine whether the chemical is biodegradable or water-soluble and what effect its application could have on the surrounding environment, including waterbodies and wildlife.

Table 1 shows application rates for some common spray-on adhesives, as recommended by Smolen et al. (1988).

Table 1. Application rates for spray-on adhesives (Source: Smolen et al., 1988)

Spray-on adhesive	Water dilution	Type of nozzle	Application (gal/acre)
Anionic asphalt emulsion	7:1	Coarse spray	1,200
Latex emulsion	12.5:1	Fine spray	235

Resin in water	4:1	Fine spray	300

Limitations

Applying water to exposed soils can be time intensive, and if done to excess, could result in excess runoff from the site or vehicles tracking mud onto public roads. Use chemical applications sparingly and only on mineral soils (not muck soils) because their misuse can create additional surface water pollution from runoff or contaminate ground water. Chemical applications might also present a health risk if excessive amounts are used.

Maintenance Considerations

Because dust controls are dependent on specific site and weather conditions, inspection and maintenance requirements are unique for each site. Generally, however, dust control measures involving application of either water or chemicals require more monitoring than structural or vegetative controls to remain effective. If structural controls are used, inspect them regularly for deterioration to ensure that they are still achieving their intended purpose.

Effectiveness

- *Mulch*. Can reduce wind erosion by up to 80 percent.
- *Wind Breaks/Barriers*. For each foot of vertical height, an 8- to 10-foot deposition zone develops on the leeward side of the barrier. The permeability of the barrier will change its effectiveness at capturing windborne sediment.
- *Tillage*. Roughening the soil can reduce soil losses by approximately 80 percent in some situations.
- *Stone*. The size of the stones can affect the amount of erosion to take place. In areas of high wind, small stones are not as effective as 20 cm stones.
- *Spray-on Chemical Soil Treatments (palliatives)*. Effectiveness of polymer stabilization methods range from 70 percent to 90 percent, according to limited research.

Cost Considerations

Costs for chemical dust control measures can vary widely depending on specific needs of the site and the level of dust control desired.

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Geotextiles **EPA NPDES Fact Sheet**

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Minimum Measure: Construction Site Stormwater Runoff Control

Subcategory: Erosion Control

Geotextile mats not only protect ground surfaces from wind and stormwater erosion but also allow vegetative growth (Source: Rolanka International, 2000)

Description

Geotextiles are porous fabrics also known as filter fabrics, road rugs, synthetic fabrics, construction fabrics, or simply fabrics. Geotextiles are manufactured by weaving or bonding fibers that are often made of synthetic materials such as polypropylene, polyester, polyethylene, nylon, polyvinyl chloride, glass, and various mixtures of these materials. As a synthetic construction material, geotextiles are used for a variety of purposes such as separators, reinforcement, filtration and drainage, and erosion control (USEPA, 1992). Some geotextiles are made of biodegradable materials such as mulch matting and netting. Mulch mattings are jute or other wood fibers that have been formed into sheets and are more stable than normal mulch. Netting is typically made from jute, wood fiber, plastic, paper, or cotton and can be used to hold the mulching and matting to the ground. Netting can also be used alone to stabilize soils while the plants are growing; however, it does not retain moisture or temperature well. Mulch binders (either asphalt or synthetic) are sometimes used instead of netting to hold loose mulches together. Geotextiles can aid in plant growth by holding seeds, fertilizers, and topsoil in place. Fabrics come in a wide variety to match the specific needs of the site and are relatively

inexpensive for certain applications.

Applicability

Geotextiles can be used in various ways for erosion control on construction sites. Use them as matting to stabilize the flow of channels or swales or to protect seedlings on recently planted slopes until they become established. Use matting on tidal or stream banks, where moving water is likely to wash out new plantings. Geotextiles can be used to protect exposed soils immediately and temporarily, such as when active piles of soil are left overnight. They can also be used as a separator between riprap and soil, which prevents the soil from being eroded from beneath the riprap and maintains the riprap's base.

Siting and Design Considerations

There are many types of geotextiles available; therefore, the selected fabric should match its purpose. To ensure the effective use of geotextiles, keep firm, continuous contact between the materials and the soil. If there is no contact, the material will not hold the soil, and erosion will occur underneath the material.

Limitations

Geotextiles (primarily synthetic types) have the potential disadvantage of disintegrating when exposed to light. Consider this before installing them. Some geotextiles might increase runoff or blow away if not firmly anchored. Depending on the type of material used, geotextiles might need to be disposed of in a landfill, making them less desirable than vegetative stabilization. If the geotextile fabric is not properly selected, designed, or installed, its effectiveness may be reduced drastically.

Maintenance Considerations

Inspect geotextiles regularly to determine if cracks, tears, or breaches have formed in the fabric; if so, repair or replace the fabric immediately. It is necessary to maintain contact between the ground and the geotextile at all times. Remove trapped sediment after each storm event.

Effectiveness

Geotextiles' effectiveness depends on the strength of the fabric and proper installation. For example, when protecting a cut slope with a geotextile, it is important to properly anchor the fabric. This will ensure that it will not be undermined by a storm event.

Cost Considerations

Costs for geotextiles range from $0.50 to $10.00 per square yard, depending on the type chosen (SWRCP, 1991).

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Gradient Terraces **EPA NPDES Fact Sheet**

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Minimum Measure: Construction Site Stormwater Runoff Control

Subcategory: Erosion Control

Terraces can be incorporated into the grading plan to shorten the length of the slope and reduce the velocity of stormwater flows (Source: Boaze et. al, 2000)

Description

Gradient terraces are earthen embankments or ridge and channel systems that reduce erosion by slowing, collecting and redistributing surface runoff to stable outlets that increase the distance of overland runoff flow. Terraces hold moisture and help trap sediments, minimizing sediment-laden runoff.

Applicability

Gradient terraces perform most effectively in barren areas with an existing or expected water erosion problem. Gradient terraces are effective only if suitable runoff outlets are available. Do not build terraces on slopes comprised of rocky or sandy soil because these soil types may not adequately redirect flows.

Siting and Design Considerations

Gradient terraces should be properly spaced and constructed with an adequate grade, and they should have adequate and appropriate outlets toward areas not susceptible to erosion or other damage. Acceptable outlets include grassed waterways, vegetated areas, or tile outlets.

General specifications require that:

- Whenever possible, use vegetative cover in the outlet.
- At the junction of the terrace and the outlet, make the terrace's water surface design-elevation no lower than the outlet's water surface design-elevation when both are performing at design flow.
- When constructing the terrace system, follow dust control procedures.
- When constructing the terrace system, follow proper vegetation/stabilization practices.

Limitations

Gradient terraces are inappropriate for use on sandy or shallow soils, or on steep slopes. If too much water permeates a terrace system's soils, sloughing could occur, potentially increasing cut and fill costs.

Maintenance Considerations

Inspect the terraces after major storms and at least once annually to ensure that they are structurally sound and have not eroded.

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Mulching **EPA NPDES Fact Sheet**

http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=41&minmeasure=4
Accessed 10-18-2013

Minimum Measure: Construction Site Stormwater Runoff Control

Subcategory: Erosion Control

Grass mulching is applied to stabilize exposed soils and to reduce stormwater runoff velocity

Description

Mulching is an erosion control practice that uses materials such as grass, hay, wood chips, wood fibers, straw, or gravel to stabilize exposed or recently planted soil surfaces. Mulching is highly recommended and is most effective when used in conjunction with vegetation. In addition to stabilizing soils, mulching can reduce stormwater velocity and improve the infiltration of runoff. Mulching can also aid plant growth by holding seeds, fertilizers, and topsoil in place, preventing birds from eating seeds, retaining moisture, and insulating plant roots against extreme temperatures.

Mulch matting is made from materials such as jute or other wood fibers that are formed into sheets and are more stable than loose mulch. Use jute and other wood fibers, plastic, paper, or cotton individually or combine them into mats to hold mulch to the ground. Use netting to stabilize soils while plants are growing; although, netting does not retain moisture or insulate against extreme temperatures. Mulch tackifiers made of asphalt or synthetic materials are sometimes used instead of netting to bind loose mulches.

Applicability

Mulching is often used in areas where vegetation cannot be established. Mulching can provide immediate and inexpensive erosion control. On steep slopes and critical areas, such as those near

waterways, use mulch matting with netting or anchoring to hold it in place. Use mulches on seeded and planted areas where slopes are steeper than 2:1 or where sensitive seedlings require insulation from extreme temperatures or moisture retention.

Siting and Design Considerations

When possible, natural mulches should be used for erosion control and plant material establishment. Suggested materials include loose straw, netting, wood cellulose, or agricultural silage. All materials should be free of seed. Anchor loose hay or straw by applying tackifier, stapling netting over the top, or crimping with a mulch crimping tool. Materials that are heavy enough to stay in place (for example, gravel or bark or wood chips on flat slopes) do not need anchoring. Other examples of organic mulches include hydraulic mulch products with 100 percent post-consumer paper content, yard trimming composts, and wood mulch from recycled stumps and tree parts. Use inorganic mulches such as pea gravel or crushed granite in unvegetated areas.

Mulches may or may not require a binder, netting, or tacking. To ensure effective use of netting and matting material, keep firm, continuous contact between the materials and the soil. If there is no contact, the material will not hold the soil and erosion will occur underneath the material. Grading is not necessary before mulching. Use biodegradable netting, if possible.

There must be adequate coverage to prevent erosion, washout, and poor plant establishment. If an appropriate tacking agent is not applied, or is applied in insufficient amounts, mulch will be lost to wind and runoff. The channel grade and liner must be appropriate for the amount of runoff, or the channel bottom will erode. Also, apply hydromulch in spring, summer, or fall to prevent deterioration of mulch before plants can become established. Table 1 presents guidelines for installing mulches.

Table 1. Typical mulching materials and application rates

Material	Rate per acre	Requirements	Notes
Organic Mulches			
Straw	1 - 2 tons	Dry, unchopped, unweathered; avoid weeds	Spread by hand or machine; must be tacked or tied down
Wood fiber or wood cellulose	½ - 1 ton		Use with hydroseeder; may be used to tack straw; do not use in hot, dry weather
Wood chips	5 - 6 tons	Air dry; add fertilizer N, 12 lb/ton	Apply with blower, chip handler, or by hand; not for fine turf areas
Bark	35 yd^3	Air dry, shredded, or hammermilled, or chips	Apply with mulch blower, chip handler, or by hand; do not use asphalt

			tack
Nets and mats			
Jute net	Cover area	Heavy, uniform; woven of single jute yarn; use with organic mulch	Withstands water flow
Excelsior (wood fiber) mat	Cover area		
Fiberglass roving	½ - 1 ton	Continuous fibers of drawn glass bound together with a non-toxic agent	Apply with compressed air ejector; tack with emulsified asphalt at a rate of 25 - 35 gal/1000 ft^2

Limitations

Mulching, matting, and netting might delay seed germination because the cover changes soil surface temperatures. The mulches themselves are subject to erosion and may be washed away in a large storm. Maintenance is necessary to ensure that mulches provide effective erosion control.

Maintenance Considerations

Anchor mulches to resist wind displacement. When protection is no longer needed, remove netting and compost it or dispose of it in a landfill. Inspect mulched areas frequently to identify areas where it has loosened or been removed, especially after rainstorms. Reseed these areas, if necessary, and replace the mulch cover immediately. Apply mulch binders at rates recommended by the manufacturer. If washout, breakage, or erosion occurs, repair, reseed and remulch surfaces, and install new netting. Continue inspections until vegetation is firmly established.

Effectiveness

Mulching effectiveness varies according to the type of mulch used. Soil loss reduction for different mulches ranges from 53 to 99.8 percent. Water velocity reductions range from 24 to 78 percent. Table 2 shows soil loss and water velocity reductions for different mulch treatments.

Table 2. Measured reductions in soil loss for different mulch treatments (Source: Harding, 1990, as cited in USEPA, 1993)

Mulch characteristics	Soil loss reduction (%)	Water velocity reduction (% relative to bare soil)
100% wheat straw/top net	97.5	73
100% wheat straw/two nets	98.6	56
70% wheat straw/30% coconut fiber	98.7	71
70% wheat straw/30% coconut fiber	99.5	78
100% coconut fiber	98.4	77

Nylon monofilament/two nets	99.8	74
Nylon monofilament/rigid/bonded	53.0	24
Vinyl monofilament/flexible/bonded	89.6	32
Curled wood fibers/top net	90.4	47
Curled wood fibers/two nets	93.5	59
Antiwash netting(jute)	91.8	59
Interwoven paper and thread	93.0	53
Uncrimped wheat straw, 2,242 kg/ha	84.0	45
Uncrimped wheat straw, 4,484 kg/ha	89.3	59

Cost Considerations

Costs of seed and mulch average $1,500 per acre and range from $800 to $3,500 per acre (USEPA, 1993).

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Riprap **EPA NPDES Fact Sheet**

Date accessed 10-18-2013
http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=39&minmeasure=4

Minimum Measure: Construction Site Stormwater Runoff Control

Subcategory: Erosion Control

Riprap can be used to stabilize drainageways and outlets to prevent erosion

Description

Riprap is a layer of large stones used to protect soil from erosion in areas of concentrated runoff. Riprap can also be used on slopes that are unstable because of seepage problems.

Applicability

Use riprap to stabilize cut-and-fill slopes; channel side slopes and bottoms; inlets and outlets for culverts, bridges, slope drains, grade stabilization structures, and storm drains; and streambanks and grades.

Siting and Design Considerations

Riprap can be unstable on very steep slopes, especially when rounded rock is used. For slopes steeper than 2:1, consider using materials other than riprap for erosion protection.

Consider the following design recommendations for riprap installation (Smolen et al., 1988):

- *Gradation*. Use a well-graded mixture of rock sizes instead of one uniform size.
- *Quality of stone*. Use riprap material that is durable so that freeze and thaw cycles do not decompose it in a short time; most igneous stones, such as granite, have suitable

durability.

- *Riprap depth*. Make the riprap layer at least two times as thick as the maximum stone diameter.
- *Filter material*. Apply a filter material--usually a synthetic cloth or a layer of gravel--before applying the riprap. This prevents the underlying soil from moving through the riprap.
- *Riprap Limits*. Place riprap so it extends to the maximum flow depth, or to a point where vegetation will be satisfactory to control erosion.
- *Curves*. Ensure that riprap extends to five times the bottom width upstream and downstream of the beginning and ending of the curve and the entire curved section.
- *Riprap Size*. The size of the riprap material depends on the shear stress of the flows the riprap will be subject to, but it ranges from an average size of 2 inches to 24 inches in diameter (Idaho Department of Environmental Quality, no date).
- *Wire Riprap Enclosures*. Consider using chain link fencing or wire mesh to secure riprap installations, especially on steep slopes or in high flow areas.

Limitations

The steepness of the slope limits the applicability of riprap, because slopes greater than 2:1 can cause riprap loss due to erosion and sliding. If used improperly, riprap can actually increase erosion. In addition, riprap can be more expensive than other stabilization options.

Maintenance Considerations

Inspect riprap areas annually and after major storms. If riprap has been damaged, repair it promptly to prevent a progressive failure. If repairs are needed repeatedly at a location, evaluate the site to determine if the original design conditions have changed. Also, you might need to control weed and brush growth in some locations.

Effectiveness

When properly designed and installed, riprap can prevent erosion from the protected area.

Cost Considerations

The cost of riprap varies depending on location and the type of material selected. A cost of $35 to $50 per square yard of nongrouted riprap has been reported, while grouted riprap ranges from $45 to $60 per square yard (1993 dollars; Mayo et al., 1993).

References

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Seeding **EPA NPDES Fact Sheet**

Date Accessed 10-24-13
http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=42&minmeasure=4

Minimum Measure: Construction Site Stormwater Runoff Control

Subcategory: Erosion Control

Hydroseeding is a popular technique for applying seeds, fertilizer, and chemical stabilizers in a single application (Source: Terra Firma Industries, 2000)

Description

Seeding is used to control runoff and erosion on disturbed areas by establishing perennial vegetative cover from seed. It reduces erosion and sediment loss and provides permanent stabilization. This practice is economical, adaptable to different site conditions, and allows selection of a variety of plant materials.

Applicability

Seeding is well-suited in areas where permanent, long-lived vegetative cover is the most practical or most effective method of stabilizing the soil. Use seeding on roughly graded areas that will not be regraded for at least a year. Vegetation controls erosion by protecting bare soil surfaces from displacement by raindrop impacts and by reducing the velocity and quantity of overland flow. Seeding's advantages over other means of establishing plants include lower initial costs and labor needs.

Siting and Design Considerations

Seed or plant permanent vegetation in areas 1 to 4 months after the final grade is achieved unless temporary stabilization measures are in place. Maximize successful plant establishment with

planning; considering soil characteristics; selecting plant materials that are suitable for the site; preparing, liming, and fertilizing the seedbed adequately; planting timely; and maintaining regularly. Major factors that dictate the suitability of plants for a site include climate, soils, and topography. Prepare and amend the soil on a disturbed site to provide sufficient nutrients for seed germination and seedling growth. Loosen the soil surface enough for water infiltration and root penetration. If soils are too acidic, increase the pH to between 6.0 and 6.5 with liming or choose plants that are appropriate for the soil characteristics at your site. Protect seeds with mulch to retain moisture, regulate soil temperatures, and prevent erosion during seedling establishment.

Limitations

The effectiveness of seeding can be limited by high erosion during establishment, the need to reseed areas that fail to establish, limited seeding times, or unstable soil temperature and soil moisture content during germination and early growth. Seeding does not immediately stabilize soils; therefore, use temporary erosion and sediment control measures to prevent pollutants from disturbed areas from being transported off the site.

Maintenance Considerations

Maintenance for seeded areas will vary depending on the level of use expected. Use long-lived grass perennials that form a tight sod and are fine-leaved for areas that receive extensive use, such as homes, industrial parks, schools, churches, and recreational areas. Whenever possible, choose native species that are adapted to local weather and soil conditions to reduce water and fertilizer inputs and lower maintenance overall. In arid areas, consider seeding with non-grass species that are adapted to drought conditions, called xeriscaping, to reduce the need for watering.

Low-maintenance areas are mowed infrequently or not at all and do not receive lime or fertilizer regularly. Plants must be able to persist with minimal maintenance over long periods of time. Use grass and legume mixtures for these sites because legumes fix nitrogen from the atmosphere. Sites suitable for low-maintenance vegetation include steep slopes, stream or channel banks, some commercial properties, and "utility" turf areas such as road banks.

Grasses should emerge within 4-28 days and legumes 5-28 days after seeding, with legumes following grasses. A successful stand has the following characteristics:

- Vigorous dark green or bluish green (not yellow) seedlings
- Uniform density, with nurse plants, legumes, and grasses well intermixed
- Green leaves that remain green throughout the summer--at least at the plant bases

Inspect seeded areas for failure and, if needed, reseed and repair them as soon as possible. If a stand has inadequate cover, reevaluate the choice of plant materials and quantities of lime and fertilizer. Depending on the condition of the stand, repair by overseeding or reseeding after complete seedbed preparation. If timing is bad, overseed with rye grain or German millet to thicken the stand until a suitable time for seeding perennials. Consider seeding temporary, annual species if the season is not appropriate for permanent seeding. If vegetation fails to grow, test the

soil to determine if low pH or nutrient imbalances are responsible.

On a typical disturbed site, full plant establishment usually requires refertilization in the second growing season. Use soil tests to determine if more fertilizer needs to be added. Do not fertilize cool season grasses in late May through July. Grass that looks yellow might be nitrogen deficient. Do not use nitrogen fertilizer if the stand contains more than 20 percent legumes.

Effectiveness

Perennial vegetative cover from seeding has been shown to remove between 50 and 100 percent of total suspended solids from stormwater runoff, with an average removal of 90 percent (USEPA, 1993).

Cost Considerations

Seeding costs range from $200 to $1,000 per acre and average $400 per acre. Maintenance costs range from 15 to 25 percent of initial costs and average 20 percent (USEPA, 1993).

References

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Sodding **EPA NPDES Fact Sheet**

Date accessed 10-24-13.
http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=43&minmeasure=4

Minimum Measure: Construction Site Stormwater Runoff Control

Subcategory: Erosion Control

Grass sod is laid on exposed soil to stabilize the soil and to reduce the velocity of stormwater runoff (Source: Landscape USA, no date)

Description

Sodding is a permanent erosion control practice and involves laying a continuous cover of grass sod on exposed soils. Sodding can stabilize disturbed areas and reduce the velocity of stormwater runoff. Sodding can provide immediate vegetative cover for critical areas and stabilize areas that cannot be readily vegetated by seed. It also can stabilize channels or swales that convey concentrated flows and reduce flow velocities.

Applicability

Sodding is appropriate for any graded or cleared area that might erode, requiring immediate vegetative cover. Locations that are well-suited to sod stabilization include:

- Residential or commercial lawns and golf courses where prompt use and aesthetics are important
- Steeply sloped areas
- Waterways and channels carrying intermittent flow
- Areas around drop inlets that require stabilization

Siting and Design Considerations

Sodding eliminates the need for seeding and mulching. Sod can be laid during times of the year when seeded grasses are likely to fail. Water the sod frequently within the first few weeks of

installation. Select a type of sod that is composed of plants adapted to the site conditions. Sod composition should reflect environmental conditions and the function of the area where it will be laid. Know the genetic origin of the sod, and make sure it is free of noxious weeds, diseases, and insects. Ensure that the sod is machine cut at a uniform soil thickness of 15 to 25 mm (not including top growth or thatch) at the time of establishment.

If a soil test determines the need, prepare the soil and add lime and fertilizer. Lay the sod in strips perpendicular to the direction of waterflow and stagger it in a brick-like pattern. Staple the corners and middle of each strip firmly. Peg jute or plastic netting over the sod to protect against washout during establishment. In the area to be sodded, clear all trash, debris, roots, branches, stones and clods larger than 2 inches in diameter. Ensure that sod is harvested, delivered, and installed within a period of 36 hours. If it is not transplanted within this period, inspect and approve the sod before its installation.

Limitations

Compared to seed, sod is more expensive and more difficult to obtain, transport, and store. To ensure successful establishment, prepare the soil and provide adequate moisture before, during, and after installation. If sod is laid on poorly prepared soil or an unsuitable surface, the grass will die quickly because it is unable to root. After installation, inadequate irrigation can cause root dieback or cause the sod to dry out.

Maintenance Considerations

To maintain adequate moisture in the root zone and to prevent dormancy, water the sod, especially within the first few weeks of installation. When mowing, do not remove more than one-third of the shoot. Maintain grass height between 2 and 3 inches. After the first growing season, determine if additional fertilization or liming is needed. Permanent, fine turf areas require yearly maintenance fertilization. Fertilize warm-season grass in late spring to early summer; fertilize cool-season grass in late winter and again in early fall.

Effectiveness

Sod removes up to 99 percent of total suspended solids in runoff, but its sediment trapping efficiency is highly variable depending on hydrologic, hydraulic, vegetation, and sediment characteristics.

Cost Considerations

Average construction costs of sod average $0.20 per square foot and range from $0.10 to $1.10 per square foot; maintenance costs are approximately 5 percent of installation costs (USEPA, 1993).

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Soil Retention **EPA NPDES Fact Sheet**

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http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=47&minmeasure=4

Minimum Measure: Construction Site Stormwater Runoff Control

Subcategory: Erosion Control

A permanent retaining wall prevents slope failure

Description

Soil retention measures are structures or practices that hold soil in place or keep it contained within a site boundary. They include grading or reshaping the ground to lessen steep slopes or shoring excavated areas with wood, concrete, or steel structures. Some soil-retaining measures are used only for erosion control, while others are also used to protect workers during excavation projects.

Applicability

Assess site conditions before breaking ground and, where possible, reduce steep slopes by grading. When sites have very steep slopes or loose, highly erodible soils that cause other methods, such as chemical or vegetative stabilization or regrading, to be ineffective, use reinforced soil-retaining structures. As much as possible, maintain the preconstruction drainage pattern.

Siting and Design Considerations

Examples of reinforced soil retaining structures include:

- *Skeleton sheeting*. An inexpensive soil bracing system that consists of construction grade

lumber used to support the excavated face of a slope. This method requires the soil to be cohesive.

- *Continuous sheeting*. Involves using a material, such as face-steel, concrete, or wood, to cover the entire slope continuously, with struts and boards placed along the slope to support it.
- *Permanent retaining walls*. Walls of concrete masonry or wood that are left in place after construction is complete to provide continued support of the slope.

The proper design of reinforced soil-retaining structures is crucial for erosion control and safety. To ensure safety of the retaining structure, have a qualified engineer design it--one who understands all the design considerations, such as the nature of the soil, location of the ground water table, and the expected loads. Ensure that hydraulic pressure does not build up behind the retaining structure and cause it to fail.

Limitations

To be effective, design soil-retention structures to handle expected loads. Heavy rains can damage or destroy these structures and result in sediment inputs to waterbodies. The structures must be properly installed and maintained to avoid failure.

Maintenance Considerations

Inspect soil-stabilization structures periodically, especially after rainstorms, to check for erosion, damage, or other signs of deterioration. Repair any damage to the actual slope or ditch, such as washouts or breakage, before reinstalling materials for the soil-stabilization structure.

Effectiveness

Soil-retention structures, if properly designed and installed, can effectively prevent erosion in areas with steep slopes and erodible soils. The potential for failure depends on the design, installation, and maintenance of the structures, and the likelihood of catastrophic events such as heavy rains, earthquakes, and landslides.

Cost Considerations

If planned appropriately, slope reduction can be accomplished during site development with minimal additional cost. Soil stabilization structures can be expensive because they require a professional engineer to develop a design (estimated to be 25 to 30 percent of construction costs [Ferguson et al., 1997]). Depending on the size of the proposed structure and the relief of the surrounding area, excavation and installation costs can be high. Capital costs include mobilization, grading, grooving, tracking and compacting fill, and installing the structures. Labor costs for regular inspection and repairs are also a consideration.

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Soil Roughening **EPA NPDES Fact Sheet**

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http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=44&minmeasure=4

Minimum Measure: Construction Site Stormwater Runoff Control

Subcategory: Erosion Control

Exposed soils can be temporarily stabilized by driving a tractor over the surface

Description

Soil roughening is a temporary erosion control practice often used in conjunction with grading. Soil roughening involves increasing the relief of a bare soil surface with horizontal grooves by either stair-stepping (running parallel to the contour of the land) or using construction equipment to track the surface. Slopes that are not fine graded and left in a roughened condition can also reduce erosion. Soil roughening reduces runoff velocity, increases infiltration, reduces erosion, traps sediment, and prepares the soil for seeding and planting by giving seed an opportunity to take hold and grow.

Applicability

Soil roughening is appropriate for all slopes, but works especially well on slopes greater than 3:1, on piles of excavated soil, and in areas with highly erodible soils. This technique is especially appropriate for soils that are frequently disturbed, because roughening is relatively easy. To slow erosion, roughen the soil as soon as possible after the vegetation has been removed from the slope or immediately after grading activities have ceased (temporarily or permanently). Use this practice in conjunction with seeding, planting, and temporary mulching to stabilize an area. A combination of surface roughening and vegetation is

appropriate for steeper slopes and slopes that will be left bare for longer periods of time.

Siting and Design Considerations

Roughened slope surfaces help establish vegetation, improve infiltration, and decrease runoff velocity. A rough soil surface allows surface ponding that protects lime, fertilizer, and seed and decreases erosion potential. Grooves in the soil are cooler and provide more favorable moisture conditions than hard, smooth surfaces. These conditions promote seed germination and vegetative growth.

Avoid excessive soil compacting, because this inhibits vegetation growth and causes higher runoff velocity. Limit roughening with tracked machinery to sandy soils that do not compact easily; also, avoid tracking on heavy clay soils, especially when wet. Seed roughened areas as quickly as possible, and follow proper dust control procedures.

Depending on the type of slope and the available equipment, use different methods for roughening soil on a slope. These include stair-step grading, grooving, and tracking. When choosing a method, consider factors such as slope steepness, mowing requirements, whether the slope is formed by cutting or filling, and available equipment. Choose from the following methods for surface roughening:

- *Cut slope roughening for areas that will not be mowed.* Use stair-step grades or groove-cut slopes for gradients steeper than 3:1. Use stair-step grading on any erodible material that is soft enough to be ripped with a bulldozer. Also, it is well suited for slopes consisting of soft rock with some subsoil. Make the vertical cut distance less than the horizontal distance, and slope the horizontal portion of the step slightly toward the vertical wall. Keep individual vertical cuts less than 2 feet deep in soft materials and less than 3 feet deep in rocky materials.

- *Grooving*. This technique uses machinery to create a series of ridges and depressions that run across the slope along the contour. Make grooves using any appropriate implement that can be safely operated on the slope, such as disks, tillers, spring harrows, or the teeth on a front-end loader bucket. Make the grooves less than 3 inches deep and less than 15 inches apart.

- *Fill slope roughening for areas that will not be mowed.* Fill slopes with a gradient steeper than 3:1 should be placed in lifts less than 9 inches, and properly compact each lift. The face of the slope should consist of loose, uncompacted fill 4 to 6 inches deep. If necessary, roughen the face of the slopes by grooving the surface as described above. Do not blade or scrape the final slope face.

- *Cuts, fills, and graded areas that will be mowed.* Make mowed slopes no steeper than 3:1. Roughen these areas with shallow grooves less than 10 inches apart and deeper

than 1 inch using normal tilling, disking, or harrowing equipment (a cultipacker-seeder can also be used). Excessive roughness is undesirable where mowing is planned.

- *Roughening with tracked machinery*. To avoid undue compaction of the soil surface, limit roughening with tracked machinery only to sandy soils. Operate tracked machinery perpendicularly to the slope to leave horizontal depressions in the soil. Tracking is generally not as effective as other roughening methods.

Limitations

Soil roughening is not appropriate for rocky slopes. Tracked machinery can excessively compact the soil. Typically, soil roughening is effective only for gentle or shallow depth rains. If roughening is washed away in a heavy storm, re-roughen the surface and reseed.

Maintenance Considerations

Inspect roughened areas after storms to see if re-roughening is needed. Regular inspection should indicate where additional erosion and sediment control measures are needed. If rills (small watercourses that have steep sides and are usually only a few inches deep) appear, fill, regrade, and reseed them immediately. Use proper dust control methods.

Effectiveness

Soil roughening provides moderate erosion protection for bare soils while vegetative cover is being established. It is inexpensive and simple for short-term erosion control when used with other erosion and sediment controls.

Cost Considerations

Soil roughening requires minimal materials but requires using heavy equipment.

References

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Temporary Slope Drain **EPA NPDES Fact Sheet**

Data accessed 10-24-13
http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=48&minmeasure=4

Minimum Measure: Construction Site Stormwater Runoff Control

Subcategory: Erosion Control

Description

A temporary slope drain is a flexible conduit for stormwater that extends the length of a disturbed slope to divert the flow and serve as a temporary outlet. Temporary slope drains, also called pipe slope drains, convey runoff without causing erosion on or at the bottom of the slope. This practice is a temporary measure, typically used for less than 2 years. It is used during grading operations until permanent drainage structures are installed and until slopes are permanently stabilized.

Applicability

Temporary slope drains can be used on most disturbed slopes to eliminate gully erosion from concentrated flows.

Siting and Design Considerations

A temporary slope drain used with a diversion conveys stormwater flows and reduces erosion until permanent drainage structures are installed.

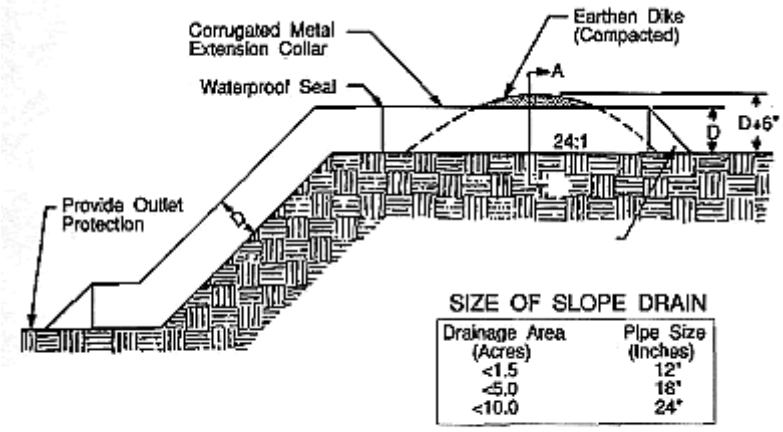
The following are design recommendations for temporary slope drains:

- The drain pipe should consist of heavy-duty material manufactured for the purpose and have grommets for anchoring at a spacing of 10 feet or less.
- Observe the minimum slope drain diameters for varying drainage areas.
- The entrance to the pipe should consist of a standard flared section of corrugated metal. The corrugated metal pipe should have watertight joints at the ends. The rest of the pipe is typically corrugated plastic or flexible tubing. For flatter, shorter slopes, a polyethylene-lined channel is sometimes used.
- Make sure the height of the diversion at the pipe is the diameter of the pipe plus 0.5 foot.
- Place the outlet at a reinforced or erosion-resistant location.

Limitations

The area drained by a temporary slope drain should not exceed 5 acres. Physical obstructions substantially reduce the drain's effectiveness. Other concerns are failures from overtopping

because of inadequate pipe inlet capacity, and reduced diversion channel capacity and ridge height.



Drains can be installed along a steep exposed slope to divert runoff and prevent erosion (Source: Urban Drainage and Flood Control District, 1999)

Maintenance Considerations

Inspect the slope drain after each rainfall to determine whether capacity was exceeded or blockages occurred. Make needed repairs promptly. Reroute construction equipment and vehicular traffic around slope drains to avoid damage.

References

FHWA (Federal Highway Administration). 1995. *Best Management Practices for Erosion and Sediment Control*. FHWA-SLP-94-005. Federal Highway Administration, Sterling, VA.

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Temporary Stream Crossings EPA NPDES Fact Sheet

Data accessed 10-24-13
http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=49&minmeasure=4

Minimum Measure: Construction Site Stormwater Runoff Control

Subcategory: Erosion Control

Description

A temporary steam crossing is used to provide a safe, stable way for construction vehicle traffic to cross a watercourse. Temporary stream crossings provide streambank stabilization, reduce the risk of damage to the streambed or channel, and minimize sediment loading from construction traffic. The crossing might be a bridge, a culvert, or a ford.

Applicability

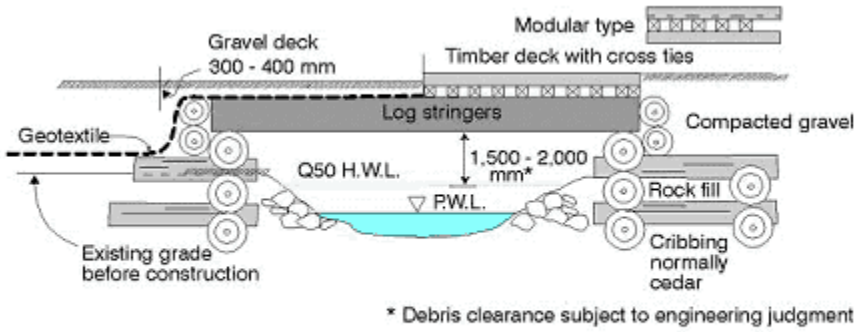
Temporary stream crossings are appropriate where heavy construction equipment must be moved from one side of a stream channel to the other. They can also be used where lighter construction vehicles will cross the stream repeatedly during construction.

A bridge or culvert is the best choice for most temporary stream crossings because each can support heavy loads. The materials used to construct most bridges and culverts can be salvaged after they are removed. A ford is a shallow area in a stream that can be crossed safely. Fords are appropriate in steep areas where flash flooding might occur and where normal flow is shallow or intermittent across a wide channel. Fords should be used only where stream crossings are expected to be infrequent.

Siting and Design Considerations

Because of the potential for stream degradation, flooding, and safety hazards, avoid stream crossings whenever possible. Consider alternative routes to accessing a site before planning to erect a temporary stream crossing. If a stream crossing is necessary, select an area where the potential for erosion is low. If possible, select the stream crossing structure during a dry period to reduce sediment transport into the stream.

If over-stream bridges are needed, construct them only under the supervision and approval of a qualified engineer.



Properly installed stream crossings can prevent destruction of stream habitat (Source: British Columbia Ministry of Forests, no date)

When constructing a culvert, use filter cloth to cover the streambed and streambanks to reduce settlement and make the culvert structure more stable. The filter cloth should extend at least 6 inches and no more than 1 foot beyond the end of the culvert and bedding material. The culvert piping should not exceed 40 feet in length and should be of sufficient diameter to allow flow to pass completely during peak flow periods. Cover the culvert pipes with at least 1 foot of aggregate. If multiple culverts are used, separate the pipes with at least 1 foot of aggregate.

Construct fords of stabilizing material such as large rocks.

Limitations

Bridges can be a safety hazard if not properly designed and constructed. Bridges might also be costly in terms of repairs and lost construction time if they are washed out or collapse (Smolen et al., 1988).

Construction and removing culverts usually disturb the surrounding area, and erosion and downstream soil movement often occur. Culverts can create obstructions to flow in a stream and get in the way of migrating fish. Depending on their size, culverts can be blocked by large debris in a stream and are vulnerable to frequent washout.

The approaches to fords are likely to erode. In addition, excavating the streambed and approach to lay riprap or other stabilization material causes major stream disturbance. Mud and other debris are transported directly into the stream unless the crossing is used only during periods of low flow.

Take care to obtain all necessary permits for work in and around streams. Review local, state, and federal regulations before starting any stream-related work.

Maintenance Considerations

Inspect temporary stream crossings at least once a week and after all significant rainfall events. If any structural damage to a bridge or culvert is reported, stop using the structure until it is repaired. Repair streambank erosion immediately.

Inspect fords closely after major storm events to make sure stabilization materials remain in place. If material has moved downstream during periods of peak flow, replace the lost material immediately.

Effectiveness

The effectiveness of a temporary stream crossing depends on the applicability of the crossing type, proper design and installation, and long-term maintenance needs.

Cost Considerations

Implementation costs for a temporary stream crossing depend on the site needs, crossing type, maintenance needs, and other site-specific factors. Typically, temporary bridges are more expensive to design and construct than culverts. Bridges also have higher maintenance and repair costs if they fail.

References

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Runoff Control

Check Dams **EPA NPDES Fact Sheet**

Date Accessed 10-25-13
http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=36&minmeasure=4

Minimum Measure: Construction Site Stormwater Runoff Control

Subcategory: Runoff Control

Check dams are used to reduce the energy of stormwater to prevent erosion

Description

Check dams are relatively small, temporary structures constructed across a swale or channel. They are used to slow the velocity of concentrated water flows, a practice that helps reduce erosion. As stormwater runoff flows through the structure, the check dam catches sediment from the channel itself or from the contributing drainage area. However, check dams should not be used as a substitute for other sediment-trapping and erosion-control measures. Check dams are typically constructed out of gravel, rock, sandbags, logs or treated lumber, or straw bales. They are most effective when used with other stormwater, erosion, and sediment-control measures.

Applicability

Check dams are temporary measures used in swales or channels where it is impractical to implement other flow-control practices (such as lining the channel) (USEPA, 1993).

Check dams are effective in small channels with a contributing drainage area of two to 10 acres. Multiple check dams, spaced at appropriate intervals, can be effective. Dams used in a series should be spaced so that the base of the upstream dam is at the same elevation as the top of the next downstream dam (VDCR, 1995).

Siting and Design Considerations

Check dams can be made of a variety of materials. They are most commonly made of rock, logs, or sandbags. When using rock, the material diameter should be two to 15-inches. Logs should have a diameter of six to eight-inches. Regardless of the material used, build the check dam carefully to ensure its effectiveness. That is, do not simply dump the material into the channel. That would be inappropriate, and it might actually increase erosion.

A check dam should not be more than three-feet high, and the center of the dam should be at least six-inches lower than its edges. This design creates a weir effect that helps to channel flows away from the banks and prevent further erosion. Dams can be made more stable by implanting the material approximately six-inches into the sides and bottom of the channel (VDCR, 1995). When installing a series of check dams in a channel, install outlet stabilization measures below the final dam in the series. Because this area is likely to be vulnerable to further erosion, the use of other stabilization measures like riprap or geotextile lining is highly recommended.

Limitations

Do not build check dams in live, flowing streams unless approved by an appropriate regulatory agency (USEPA, 1992; VDCR, 1995). The primary function of check dams is to slow runoff in a channel. Do not use them as a standalone substitute for other sediment-trapping devices. Also, fallen leaves can clog check dams, so in the fall it may be necessary to increase inspections and maintenance.

Maintenance Considerations

Inspect check dams after each storm event to ensure their structural integrity. The center of a check dam should always be lower than its edges. Additional stone may have to be added to maintain the correct height. During inspection, remove large debris, trash, and leaves. When the sediment has reached a height of approximately one-half the original height of the dam (measured at the center), remove accumulated sediment from the upstream side of the dam. When check dams are removed, care must be taken to remove all dam materials to ensure proper flow within the channel. If erosion or heavy flows cause the edges of a dam to fall to a height equal to or below the height of the center, repair it immediately. In addition, before removing a check dam, remove all accumulated sediment. Remove a check dam only after the contributing drainage area has been completely stabilized. Use permanent vegetation to stabilize the area from which the dam material is removed.

Effectiveness

Field experience has shown that rock check dams are more effective than silt fences or straw bales to stabilize wet-weather ditches (VDCR, 1995). For long channels, check dams are most effective when used in a series, creating multiple barriers to sediment-laden runoff.

Cost Considerations

The cost of check dams varies according to the material they are made of and the width of the channel to be dammed. EPA (1992) estimated that check dams constructed of rock cost about $100 per dam, although Brown and Schueler (CWP, 1997) estimated that rock check dams cost approximately $62 per installation, including the cost for filter fabric bedding. Logs and sandbags may be less expensive alternatives to install, but their use may result in higher maintenance costs.

References

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Grass-Lined Channels **EPA NPDES Fact Sheet**

Date accessed 10-25-13
http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=38&minmeasure=4

Minimum Measure: Construction Site Stormwater Runoff Control

Subcategory: Runoff Control

A grass-lined channel can be used to filter and convey runoff

Description

A grass-lined channel conveys stormwater runoff through a stable conduit. Vegetation lining the channel slows down concentrated runoff. Because grassed channels are not usually designed to control peak runoff loads by themselves, they are often used with other BMPs, such as subsurface drains and riprap stabilization.

Where moderately steep slopes require drainage, grassed channels can include excavated depressions or check dams to enhance runoff storage, decrease flow rates, and improve pollutant removal. Peak discharges can be reduced by temporarily holding them in the channel. Pollutants can be removed from stormwater by filtration through vegetation, by deposition, or in some cases by infiltration of soluble nutrients into the soil. The degree of pollutant removal in a channel depends on how long the water stays in the channel and the amount of contact with vegetation and the soil surface. Local conditions affect the removal efficiency.

Applicability

The first choice of lining should be grass or sod because this reduces runoff velocity and provides water quality benefits through filtration and infiltration. If the velocity in the channel would erode the grass or sod, riprap, concrete, or gabions can be used (USEPA, 2004). Geotextile materials can be used in conjunction with either grass or riprap linings to provide

additional protection at the soil-lining interface. Use grassed channels in areas where erosion-resistant conveyances are needed, including areas with highly erodible soils and moderately steep slopes (though less than 5 percent). Install them only where space is available for a relatively large cross section. Grassed channels have a limited ability to control runoff from large storms, so do not use them in areas where flow rates exceed 5 feet per second.

Siting and Design Considerations

Site grass-lined channels in accordance with the natural drainage system. They should not cross ridges. The channel design should not have sharp curves or significant changes in slope. The channel should not receive direct sedimentation from disturbed areas and should be sited only on the perimeter of a construction site to convey relatively clean stormwater runoff. To reduce sediment loads, separate channels from disturbed areas by using a vegetated buffer or another BMP.

Basic design recommendations for grassed channels include the following:

- Construct and vegetate the channel before grading and paving activities begin.
- Make sure design velocities are less than 5 feet per second.
- Consider using geotextiles to stabilize vegetation until it is fully established.
- Consider covering the bare soil with sod, mulches with netting, or geotextiles to provide reinforced stormwater conveyance immediately.
- Use triangular channels with low velocities and small quantities of runoff; use parabolic grass channels for larger flows and where space is available; use trapezoidal channels with large, low-velocity flows (low slope).
- Install outlet stabilization structures if the runoff volume or velocity might exceed the capacity of the receiving area.
- Slope the sides of the channel less than 2:1; slope triangular channels along roads 2:1 or less for safety.
- Remove all trees, brushes, stumps, and other debris during construction.

Effectiveness

Grass-lined channels can effectively transport stormwater from construction areas if they are designed for expected flow rates and velocities and if they do not receive sediment directly from disturbed areas.

Limitations

If grassed channels are not properly installed, they can change the natural flow of surface water and adversely affect downstream waters. And if the design capacity is exceeded by a large storm event, the vegetation might not be adequate to prevent erosion and the channel might be destroyed. Clogging with sediment and debris reduces the effectiveness of grass-lined channels for stormwater conveyance.

Maintenance Considerations

The maintenance requirements for grass channels are relatively minimal. While vegetation is being established, inspect the channels after every rainfall. After vegetation is established, mow it, remove litter, and perform spot vegetation repair. The most important objective in grassed channel maintenance is to maintain a dense and vigorous growth of turf. Periodically clean the vegetation and soil buildup in curb cuts so that water flow into the channel is unobstructed. During the growing season, cut the channel grass no shorter than the level of the design flow.

Cost Considerations

Costs of grassed channels range according to depth. The cost of a 1.5-foot-deep grassed channel with 3:1 side slopes and a 2-foot-wide channel bottom is estimated to cost between $202 and $625 per 100 feet of channel length. The cost of a 3-foot-deep grassed channel with 3:1 side slope adn a 2-foot-wide bottom is expected to cost between $397 and $1,198 for 100 feet of channel (SEWRPC, 1991). Grassed channels can be left in place permanently after the construction site is stabilized to contribute to long-term stormwater management. The channels, in combination with other practices that detain, filter, and infiltrate runoff, can substantially reduce the size of permanent detention facilities like stormwater ponds and wetlands, thereby reducing the overall cost of stormwater management.

References

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Permanent Slope Diversions **EPA NPDES Fact Sheet**

Date accessed 10-25-13
http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=33&minmeasure=4

Minimum Measure: Construction Site Stormwater Runoff Control

Subcategory: Runoff Control

Description

Permanent slope diversions are designed to transport runoff down a slope in a manner that minimizes the potential for erosion. Diversions can be constructed by creating channels laterally across slopes to intercept the down-slope flow of runoff. The channels have a supporting earthen ridge on the bottom sides to reduce slope length, collect stormwater runoff, and deflect the runoff to outlets that convey it without causing erosion.

Applicability

Diversions should be considered for use on slopes where uncontrolled runoff might cause property damage due to erosion or resulting sedimentation. They can also be used to promote the growth of vegetation by redirecting flows while the vegetation is becoming established.

Siting and Design Considerations

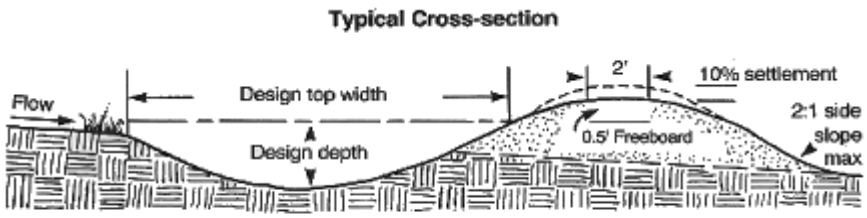
A properly designed earthen ridge typically has side slopes no steeper than 2:1, a width at the design water elevation of at least 4 feet, a minimum freeboard of 0.3 foot, and a 10 percent settlement factor included in the design (reference?).

A stormwater conveyance channel can be vegetated or hardened (e.g., with rock or concrete). Both types should be sufficient in shape and size to carry stormwater runoff away from developing areas without any erosion damage. Paved flumes are not recommended unless very high flows with excessive erosive power are expected because faster runoff might exacerbate erosion at the flume's outfall. Paved flumes also prevent surface runoff from infiltrating, which can cause increased volumes and erosive forces of the runoff that leaves the site. Adequate outfall protection should be provided to prevent damage from the discharge of high-velocity flows. Where possible, vegetated channels should be used to minimize flow velocity and to enhance pollutant removal. Riprap, gabions, or turf reinforcement mats can provide additional channel stabilization.

The following are general specifications required for channel construction:

- Remove all obstructions and unsuitable material, such as trees, roots, brush, and stumps, and any excess soil from the channel area and dispose of them properly.

- Make sure the channel meets grade and cross section specifications, and compact any fill used to ensure equal settlement.
- Parabolic and triangular, grass-lined channels should not have a top width of more than 30 feet.
- Trapezoidal, grass-lined channels may not have a bottom width of more than 15 feet unless there are multiple or divided waterways, they have a riprap center, or other methods of controlling the meandering of low flows are provided.
- If grass-lined channels have a base flow, provide a stone center or subsurface drain or another method for managing the base flow.



Site planners incorporate diversions into the overall grading plan to direct clean runoff away from exposed areas

All channels must have outlets that are protected from erosion. Locate structurally lined aprons or other appropriate energy-dissipating devices at channel outlets to slow stormwater flows and prevent scouring at stormwater outlets, protect the outlet structure, and minimize the erosion potential downstream. Construction specifications for outlet protection practices require the following:

- No bends occur in the horizontal alignment.
- There is no slope along the length of the apron, and the invert elevations are equal at the receiving channel and the apron's downstream end.
- No overfall at the end of the apron is allowed.
- If a pipe discharges into a well-defined channel, the channel's side slopes may not be steeper than 2:1.
- The apron is lined with riprap, grouted riprap, concrete, or gabion baskets; all riprap conforms to standards and specifications; and the median-sized stone for riprap is specified in the plan.
- Filter cloth, conforming to standards and specifications, must be placed between riprap and the underlying soil to prevent any soil movement through the riprap.
- All grout for grouted riprap must be one part Portland cement for every three parts sand, mixed thoroughly with water. Once stones are in place, the spaces between them are to be filled with grout to a minimum depth of 6 inches, with the deeper portions choked with fine material.
- All concrete aprons must be installed as specified in the plan.
- The end of the paved channel in a paved channel outlet must be smoothly joined with the receiving channel section, with no overfall at the end of the paved section.

Limitations

Immediately after constructing a vegetated ridge and channel, seed and mulch them along with any disturbed areas that drain into the diversion. To prevent soil from moving into the diversion, sediment-trapping measures must remain in place in case the upslope area is not stabilized. Remove all obstructions and unsuitable material, such as trees, brush, and stumps, from the channel area and dispose of them so the diversion can function properly. The channel must meet grade and cross section specifications. Make sure any fill used is free from excessive organic debris, rocks, or other unsuitable material. Compact the fill to ensure equal settlement. Permanently stabilize disturbed areas according to applicable local standards and specifications. Stabilize the area around the channel that is disturbed by channel construction so that it is not subject to erosion similar to that of the slope the channel is built to protect.

Maintenance Considerations

Inspect diversions after every rainfall and at least once every 2 weeks before final stabilization. Clear channels of sediment, make repairs when necessary, and reseed seeded areas if a vegetative cover is not established.

Costs

Costs of slope drains vary based on pipe (material) selection, length, and the outlet protection that is used. Supplied and installed costs (not inlcuding trenching) for corregated steel pipe ranges from less than $20 per linear foot for 12" pipe to more than $50 per linaer foot for 3o" pipe and from less than $25 per linear foot to $130 per linear foot (also supplied and installed, exclusing trenching) for PVC pipe (CASQA Handbook)

References

CASQA, 2003.*California Constrcution BMP Handbook*Section 3; EC-11-Slope Drain Fact Sheet. http://www.cabmphandbooks.org/Construction.asp

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Temporary Diversion Dikes **EPA NPDES Fact Sheet**

Date accessed 10-25-13
http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=53&minmeasure=4

Minimum Measure: Construction Site Stormwater Runoff Control

Subcategory: Runoff Control

Diversion dikes can be used to contain stormwater onsite

Description

An earthen perimeter control usually consists of a dike or a combination dike and channel constructed along the perimeter of and within the disturbed part of a site. An earthen perimeter control is a ridge of compacted soil, often accompanied by a ditch or swale with a vegetated lining, at the top or base of a sloping disturbed area. Depending on its location and the topography of the landscape, an earthen perimeter control can achieve one of two goals.

When on the upslope side of a site, earthen perimeter controls help to prevent surface runoff from entering a disturbed construction site. An earthen structure located upslope can improve working conditions on a construction site. It can prevent an increase in the total amount of sheet flow runoff traveling across the disturbed area and thereby lessen erosion on the site.

Earthen perimeter control structures also can be located on the downslope side of a site. They divert sediment-laden runoff created onsite to onsite sediment-trapping devices, preventing soil loss from the disturbed area.

These control practices are called temporary diversion dikes, earth dikes, and interceptor dikes. No matter what they are called,, all earthen perimeter controls are constructed in a similar way with a similar objective--to control the velocity or route (or both) of sediment-laden stormwater

runoff.

Applicability

Temporary diversion dikes apply where it is desirable to divert flows away from disturbed areas such as cut or fill slopes and to divert runoff to a stabilized outlet (USEPA, 1992). The dikes can be erected at the top of a sloping area or in the middle of a slope to divert stormwater runoff around a disturbed construction site. In this way, earth dikes can be used to reduce the length of the slope across which runoff travels, reducing the erosion potential of the flow. If diversion dikes are placed at the bottom of a sloping disturbed area, they can divert flow to a sediment-trapping device. Temporary diversion dikes are usually appropriate for drainage basins smaller than 5 acres. With modifications they can service areas as large as 10 acres. With regular maintenance, earthen diversion dikes have a useful life span of about 18 months.

To prevent stormwater runoff from entering a site, earthen perimeter controls can be used to divert runoff from areas upslope around the disturbed construction site. A continuous, compacted earthen mound is constructed along the upslope perimeter of the site. As an additional control measure, a shallow ditch can accompany the earthen mound.

Siting and Design Considerations

The siting of earthen perimeter controls depends on the topography of the area surrounding the construction site. Another factor is whether the goal is to prevent sediment-laden runoff from entering the site or to keep stormwater runoff from leaving the site. When determining the appropriate size and design of earthen perimeter controls, consider the shape and drainage patterns of the surrounding landscape. Also consider the amount of runoff to be diverted, the velocity of runoff in the diversion, and the erodibility of soils on the slope and in the diversion channel or swales (WA State Dept. of Ecology, 2005).

Construct diversion dikes and fully stabilize them before any major land disturbance begins. This approach makes the diversion measure effective as an erosion and sediment control device.

The top of earthen perimeter controls designed as temporary flow diversion measures should be at least 2 feet wide. The bottom width at ground level is typically 6 feet. The minimum height for earth dikes should be 18 inches, with side slopes no steeper than 2:1. At points where vehicles will cross the dike, make sure the slope is no steeper than 3:1 and make the mound gravel rather than soil. This design makes the dike last longer and strengthens the point of vehicle crossing.

If a channel is excavated along the dike, its shape can be parabolic, trapezoidal, or V-shaped. Before any excavating or mound-building, remove all trees, brush, stumps, and other objects in the path of the diversion structure. Till the base of the dike before laying the fill. The maximum design flow velocity should range from 1.5 to 5.0 feet per second, depending on the vegetative cover and soil texture.

Most earthen perimeter structures are designed for short-term, temporary use. If the expected life span of the structure is more than 15 days, seed the earthen dike and the accompanying ditchwith

vegetation immediately after construction. This increases the stability of the perimeter control and can decrease the need for frequent repairs and maintenance.

Limitations

Earth dikes are an effective means of diverting sediment-laden stormwater runoff around a disturbed area. But the concentrated runoff in the channel or ditch has increased erosion potential. Direct diversion dikes to sediment-trapping devices, where sediment can settle out of the runoff before it is discharged to surface waters. Sediment-trapping devices that work with temporary diversion structures include sediment basins, sediment chambers/filters, and any other structures designed to allow sediment to be collected for proper disposal.

If a diversion dike crosses a vehicle roadway or entrance, its effectiveness can be reduced. When possible, design diversion dikes to avoid crossing vehicle pathways.

Maintenance Considerations

Inspect earthen diversion dikes after each rainfall to ensure continued effectiveness. Maintain dikes at their original height. Repair any decrease in height due to settling or erosion immediately. To remain effective, earth dikes must be compacted at all times. Regardless of rainfall frequency, inspect dikes at least once every 2 weeks for evidence of erosion or deterioration.

Effectiveness

When properly placed and maintained, earth dikes used as temporary diversions can control the velocity and direction of stormwater runoff. Used by themselves, they do not have any pollutant removal capability. They must be used with an appropriate sediment-trapping device at the outfall of the diversion channel.

Cost Considerations

The cost of constructing an earth dike can be broken down into two components: (1) site preparation (including excavation, placement, and compacting of fill) and grading, and (2) site development, including topsoiling and seeding for vegetative cover. The Southeastern Wisconsin Regional Planning Commission (1991) estimated the total cost of site preparation to be $46.33 to $124.81 for a 100-foot dike with 1.5-foot-deep, 3:1 side slopes. The cost of site development was estimated at $115.52 to $375.44. The total cost was between $162 and $500. The cost for constructinig diversion berms range from $15 to $55 per ft for both earthwork and stabilization and depends on the availability of suitable material, site location, and access. Small dikes range from $2.50 to $6.50 per linear ft and large dikes cost about $2.50 per cubic yard of earth (CASQA, 2003).

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Sediment Control

Compost Filter Berms **EPA NPDES Fact Sheet**

Date accessed 10-25-13
http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=119&minmeasure=4

Minimum Measure: Construction Site Stormwater Runoff Control

Subcategory: Sediment Control

Description

Vegetated compost filter berm. Note sediment on upstream side of berm and clear water on downstream side. Source: S. McCoy, Texas Commission on Environmental Quality.

A compost filter berm is a dike of compost or a compost product that is placed perpendicular to sheet flow runoff to control erosion in disturbed areas and retain sediment. It can be used in place of a traditional sediment and erosion control tool such as a silt fence. The compost filter berm, which is trapezoidal in cross section, provides a three-dimensional filter that retains sediment and other pollutants (e.g., suspended solids, metals, oil and grease) while allowing the cleaned water to flow through the berm. Composts used in filter berms are made from a variety of feedstocks, including municipal yard trimmings, food residuals, separated municipal solid waste, biosolids, and manure.

Compost filter berms are generally placed along the perimeter of a site, or at intervals along a slope, to capture and treat stormwater that runs off as sheet flow. A filter berm also can be used as a check dam in small drainage ditches. The berms can be vegetated or unvegetated. Vegetated filter berms are normally left in place and provide long-term filtration of stormwater as a post-construction best management practice (BMP). Unvegetated berms are often broken down once construction is complete and the compost is spread around the site as a soil amendment or mulch.

Filter berms, in general, provide an effective physical barrier in sheet flow conditions; however, the use of compost in the filter berm provides additional benefits. These benefits include the following:

- The compost retains a large volume of water, which helps prevent or reduce rill erosion and aids in establishing vegetation on the berm.
- The mix of particle sizes in the compost filter material retains as much or more sediment than traditional perimeter controls, such as silt fences or hay bale barriers, while allowing a larger volume of clear water to pass through the berm. Silt fences often become clogged with sediment and form a dam that retains stormwater, rather than letting the filtered stormwater pass through.

- In addition to retaining sediment, compost can retain pollutants, such as heavy metals, nitrogen, phosphorus, oil and grease, fuel, herbicides, pesticides, and other potentially hazardous substances, from stormwater.improving water quality downstream of the berm (USEPA, 1998).
- Nutrients and hydrocarbons adsorbed and/or trapped by the compost filter can be naturally cycled and decomposed through bioremediation by microorganisms commonly found in the compost matrix (USEPA, 1998).

Applicability

Compost filter berms are applicable to construction sites with relatively small drainage areas, where stormwater runoff occurs as sheet flow. Common industry practice is to use compost filter berms in drainage areas that do not exceed 0.25 acre per 100 feet of berm length and where flow does not typically exceed 1 cubic foot per second (see Siting and Design Considerations discussion for more detail). Compost filter berms can be used on steeper slopes with faster flows if they are spaced more closely or used in combination with other stormwater BMPs such as compost blankets or silt fences.

Siting and Design Considerations

Compost Quality: Compost quality is an important consideration when designing a compost filter berm. Use of sanitized, mature compost will ensure that the compost filter berm performs as designed and has no identifiable feedstock constituents or offensive odors. The compost used in filter berms should meet all local, state, and Federal quality requirements. Biosolids compost must meet the Standards for Class A biosolids outlined in 40 Code of Federal Regulations (CFR) Part 503. The U.S. Composting Council (USCC) certifies compost products under its Seal of Testing Assurance (STA) Program. Compost producers whose products have been certified through the STA Program provide customers with a standard product label that allows comparison between compost products. The current STA Program requirements and testing methods are posted on the USCC EXIT Disclaimer website.

The nutrient and metal content of some composts are higher than some topsoils. This, however, does not necessarily translate into higher metals and nutrient concentrations or loads in stormwater runoff. A recent study by Glanville, et al. (2003) compared the stormwater runoff water quality from compost- and topsoil-treated plots. They found that although the composts used in the study contained statistically higher metal and nutrient concentrations than the topsoils used, the total masses of nutrients and metals in the runoff from the compost-treated plots were significantly less than plots treated with topsoil. Likewise, Faucette et al. (2005) found that nitrogen and phosphorus loads from hydroseed and silt fence treated plots were significantly greater than plots treated with compost blankets and filter berms. In areas where the receiving waters contain high nutrient levels, the site operator should choose a mature, stable compost that is compatible with the nutrient and pH requirements of the selected vegetation. This will ensure that the nutrients in the composted material are in organic form and are therefore less soluble and less likely to migrate into receiving waters.

The American Association of State Highway Transportation Officials (AASHTO) and many

individual state Departments of Transportation (DOTs) have issued specifications for filter berms (AASHTO, 2003; USCC, 2001). These specifications describe the quality and particle size distribution of compost to be used in filter berms, as well as the size and shape of the berm for different scenarios. The filter berm media parameters developed for AASHTO specification MP 9-03 are shown in Table 1 as an example (Alexander, 2003). Research on these parameters continues to evolve; therefore, the DOT or Department of Environmental Quality (or similar designation) for the state where the filter berm will be installed should be contacted to obtain any applicable specifications or compost testing recommendations.

Design: Filter berms installed to control erosion and sediment on a slope or near the base of a slope are trapezoidal in cross section, with the base generally twice the height of the berm. The height and width of the berm will vary depending upon the precipitation and the rainfall erosivity index (EPA, 2001) of the site. Example compost filter berm dimensions for various rainfall scenarios developed for AASHTO specification MP 9-03 are shown in Table 2 (Alexander, 2003). Example filter berm dimensions based on the site slope and slope length developed by the Oregon Department of Environmental Quality (ODEQ) are shown in Table 3 (ODEQ, 2004).

The compost filter berm dimensions should be modified based on site-specific conditions, such as soil characteristics, existing vegetation, site slope, and climate, as well as project-specific requirements. Coarser compost products are generally used in regions subject to high rainfall or wind erosion.

Table 1. Example Filter Berm Media Parameters

Parameters[1,4]	Units of Measure	Berm to be Vegetated	Berm to be left Unvegetated
pH[2]	pH units	5.0.8.5	Not applicable
Soluble salt concentration[2] (electrical conductivity)	dS/m (mmhos/cm)	Maximum 5	Not applicable
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 in. (75 mm), 100% passing - 1 in. (25 mm), 90 . 100% passing - 0.75 in. (19 mm), 70 . 100% passing	- 3 in. (75 mm), 100% passing - 1 in. (25 mm), 90 . 100% passing - 0.75 in. (19 mm), 70 . 100% passing

		- 0.25 in. (6.4 mm), 30 . 75% passing Maximum particle size length of 6 in (152 mm) Avoid compost with less than 30% fine particle (1mm) to achieve optimum reduction of total suspended solids No more than 60% passing 0.25 in (6.4 mm) in high rainfall/flow rate situations	- 0.25 in. (6.4 mm), 30 . 75% passing Maximum particle size length of 6 in (152 mm) Avoid compost with less than 30% fine particle (1mm) to achieve optimum reduction of total suspended solids No more than 60% passing 0.25 in (6.4 mm) in high rainfall/flow rate situations
Stability[3] Carbon dioxide evolution rate	mg CO_2.C per gram of organic matter per day	<8	Not applicable
Physical contaminants (manmade inerts)	%, dry weight basis	<1	<1

Source: Alexander, 2003

[1] Recommended test methodologies are provided in [Test Methods for the Evaluation of Composting and Compost EXIT Disclaimer].
[2] Each plant species requires a specific pH range and has a salinity tolerance rating.
[3] Stability/maturity rating is an area of compost science that is still evolving, and other test methods should be considered. Compost quality decisions should be based on more than one stability/maturity test.
[4] Landscape architects and project engineers may modify the above compost specification ranges based on specific field conditions and plant requirements.

Table 2. Example Compost Filter Berm Dimensions for Various Rainfall Scenarios

Annual Rainfall/ Flow Rate	Precipitation/year (Rainfall Erosivity Index)	Berm Dimensions (height x width)
Low	1 . 25 in. (20 . 90)	1 ft x 2 ft to 1.5 ft x 3 ft (30 cm x 60 cm to 45 cm x 90 cm)
Average	26 . 50 in. (91 . 200)	1 ft x 2 ft to 1.5 ft x 3 ft (30 cm x 60 cm to 45 cm x 90 cm)

High	e 51 in. (e 201)	1.5 ft x 3 ft to 2 ft x 4 ft (45 cm x 90 cm to 60 cm x 120 cm)

Source: Alexander, 2003

Table 3. Example Compost Filter Berm Dimensions Based on Slope and Slope Length

Slope	Slope Length	Berm Dimensions (height x width)
<50:1	250 ft	1 ft x 2 ft
50:1 . 10:1	125 ft	1 ft x 2 ft
10:1 . 5:1	100 ft	1 ft x 2 ft
3:1 . 2:1	50 ft	1.3 ft x 2.6 ft
>2:1	25 ft	1.5 ft x 3 ft

Source: ODEQ, 2004

Siting: For sites in high rainfall areas or where there are severe grades or long slopes, larger dimension berms should be used. The project engineer may also consider placing berms at the top and base of the slope, constructing a series of berms down the profile of the slope (15 to 25 feet apart), or using filter berms in conjunction with a compost blanket.

Installation: The compost berm can be installed by hand; by using a backhoe, bulldozer, or grading blade; or by using specialized equipment such as a pneumatic blower or side discharge spreader with a berm attachment. The compost should be uniformly applied to the soil surface, compacted, and shaped to into a trapezoid. Compost filter berms can be installed on frozen or rocky ground. The filter berm may be vegetated by hand, by incorporating seed into the compost prior to installation (usually done when the compost is installed using a pneumatic blower or mixing truck with a side discharge), or by hydraulic seeding following berm construction. Proper installation of a compost filter berm is the key to effective sediment control.

Limitations

Compost filter berms can be installed on any type of soil surface; however, heavy vegetation should be cut down or removed to ensure that the compost contacts the ground surface. Filter berms are not suitable for areas where large amounts of concentrated runoff are likely, such as streams, ditches, or waterways, unless the drainage is small and the flow rate is relatively low.

Maintenance Considerations

Compost filter berms should be inspected regularly, as well as after each rainfall event, to ensure that they are intact and the area behind the berm is not filled with silt. Accumulated sediments should be removed from behind the berm when the sediments reach approximately one third the height of the berm. Any areas that have been washed away should be replaced. If the berm has experienced significant washout, a filter berm alone may not be the appropriate BMP for this area. Depending upon the site-specific conditions, the site operator could remedy the problem by increasing the size of the filter berm or adding another BMP in this area, such as an additional compost filter berm or compost filter sock, a compost blanket, or a silt fence.

Effectiveness

Numerous qualitative studies have reported the effectiveness of compost filter berms in removing settleable solids, total suspended solids, and various organic and inorganic contaminants from stormwater. These studies have consistently shown that compost filter berms are at least as effective as other traditional erosion and sediment control BMPs in controlling sediment; however, the results of the studies varied depending upon the site conditions. One quantitative study conducted in Portland, Oregon (W&H Pacific, 1993) compared the effectiveness of a silt fence and a mixed yard debris compost filter berm to a control plot during five storm events. The study found that the filter berm was over 90 percent effective in removing settleable and total suspended solids when compared to the control plot and was approximately 66 percent more effective than the silt fence. Another quantitative study performed by the Snohomish County, Washington, Department of Planning and Development Services (Caine, 2001) showed no decrease in turbidity with a silt fence but a 67 percent reduction in turbidity using a compost filter berm.

Cost Considerations

The TCEQ reports that compost filter berms cost $1.90 to $3.00 per linear foot when used as a perimeter control and $3 to $6 per linear foot when used as a check dam (McCoy, 2005). The ODEQ reports that compost filter berms cost approximately 30 percent less to install than silt fences (Juries, 2004). These costs do not include the cost of removal and disposal of the silt fence or the cost of dispersing the compost berm once construction activities are completed. The cost to install a compost filter berm will vary, depending upon the availability of the required quality of compost in an area.

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Compost Filter Socks **EPA NPDES Fact Sheet**

Date accessed 10-25-13
http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=120&minmeasure=4

Minimum Measure: Construction Site Stormwater Runoff Control

Subcategory: Sediment Control

Description

Installation of filter socks in a road ditch by Earth Corps for Indiana Department of Transportation. The filter socks will be staked through the center. Source: Filtrexx International, LLC.

A compost filter sock is a type of contained compost filter berm. It is a mesh tube filled with composted material that is placed perpendicular to sheet-flow runoff to control erosion and retain sediment in disturbed areas. The compost filter sock, which is oval to round in cross section, provides a three-dimensional filter that retains sediment and other pollutants (e.g., suspended solids, nutrients, and motor oil) while allowing the cleaned water to flow through (Tyler and Faucette, 2005). The filter sock can be used in place of a traditional sediment and erosion control tool such as a silt fence or straw bale barrier. Composts used in filter socks are made from a variety of feedstocks, including municipal yard trimmings, food residuals, separated municipal solid waste, biosolids, and manure.

Compost filter socks are generally placed along the perimeter of a site, or at intervals along a slope, to capture and treat stormwater that runs off as sheet flow. Filter socks are flexible and can be filled in place or filled and moved into position, making them especially useful on steep or rocky slopes where installation of other erosion control tools is not feasible. There is greater surface area contact with soil than typical sediment control devices, thereby reducing the potential for runoff to create rills under the device and/or create channels carrying unfiltered sediment.

Additionally, they can be laid adjacent to each other, perpendicular to stormwater flow, to reduce flow velocity and soil erosion. Filter socks can also be used on pavement as inlet protection for storm drains and to slow water flow in small ditches. Filter socks used for erosion control are usually 12 inches in diameter, although 8 inch, 18 inch, and 24 inch– diameter socks are used in some applications. The smaller, 8 inch–diameter filter socks are commonly used as stormwater inlet protection.

Compost filter socks can be vegetated or unvegetated. Vegetated filter socks can be left in place to provide long-term filtration of stormwater as a post-construction best management practice

(BMP). The vegetation grows into the slope, further anchoring the filter sock. Unvegetated filter socks are often cut open when the project is completed, and the compost is spread around the site as soil amendment or mulch. The mesh sock is then disposed of unless it is biodegradable. Three advantages the filter sock has over traditional sediment control tools, such as a silt fence, are:

- Installation does not require disturbing the soil surface, which reduces erosion
- It is easily removed
- The operator must dispose of only a relatively small volume of material (the mesh)
- These advantages lead to cost savings, either through reduced labor or disposal costs. The use of compost in this BMP provides additional benefits, include the following:
    - The compost retains a large volume of water, which helps prevent or reduce rill erosion and aids in establishing vegetation on the filter sock.
    - The mix of particle sizes in the compost filter material retains as much or more sediment than traditional perimeter controls, such as silt fences or hay bale barriers, while allowing a larger volume of clear water to pass through. Silt fences often become clogged with sediment and form a dam that retains stormwater, rather than letting the filtered stormwater pass through.
    - In addition to retaining sediment, compost can retain pollutants such as heavy metals, nitrogen, phosphorus, oil and grease, fuels, herbicides, pesticides, and other potentially hazardous substances—improving the downstream water quality (USEPA, 1998).
    - Nutrients and hydrocarbons adsorbed and/or trapped by the compost filter can be naturally cycled and decomposed through bioremediation by microorganisms commonly found in the compost matrix (USEPA, 1998).

Applicability

Compost filter socks are applicable to construction sites or other disturbed areas where stormwater runoff occurs as sheet flow. Common industry practice for compost filter devices is that drainage areas do not exceed 0.25 acre per 100 feet of device length and flow does not exceed one cubic foot per second (see Siting and Design Considerations). Compost filter socks can be used on steeper slopes with faster flows if they are spaced more closely, stacked beside and/or on top of each other, made in larger diameters, or used in combination with other stormwater BMPs such as compost blankets.

Siting and Design Considerations

Compost Quality: Compost quality is an important consideration when designing a compost filter sock. Use of sanitized, mature compost will ensure that the compost filter sock performs as designed and has no identifiable feedstock constituents or offensive odors. The compost used in filter socks should meet all local, state, and Federal quality requirements. Biosolids compost must meet the Standards for Class A biosolids outlined in 40 Code of Federal Regulations (CFR) Part 503. The U.S. Composting Council (USCC) certifies compost products under its Seal of Testing Assurance (STA) Program. Compost producers whose products have been certified through the STA Program provide customers with a standard product label that allows

comparison between compost products. The current STA Program requirements and testing methods are posted on the USCC EXIT Disclaimer website.

The nutrient and metal content of some composts are higher than some topsoils. This, however, does not necessarily translate into higher metals and nutrient concentrations or loads in stormwater runoff. A recent study by Glanville, et al. (2003) compared the stormwater runoff water quality from compost- and topsoil-treated plots. They found that although the composts used in the study contained statistically higher metal and nutrient concentrations than the topsoils used, the total masses of nutrients and metals in the runoff from the compost-treated plots were significantly less than plots treated with topsoil. Likewise, Faucette et al. (2005) found that nitrogen and phosphorus loads from hydroseed and silt fence treated plots were significantly greater than plots treated with compost blankets and filter berms. In areas where the receiving waters contain high nutrient levels, the site operator should choose a mature, stable compost that is compatible with the nutrient and pH requirements of the selected vegetation. This will ensure that the nutrients in the composted material are in organic form and are therefore less soluble and less likely to migrate into receiving waters.

The American Association of State Highway Transportation Officers (AASHTO) and many individual State Departments of Transportation (DOTs) have issued quality and particle size specifications for the compost to be used in filter berms (USCC, 2001; AASHTO, 2003). The compost specifications for vegetated filter berms developed for AASHTO Specification MP 9-03 (Alexander, 2003) are also applicable to vegetated compost filter socks (personal communication, B. Faucette, R. Tyler, and N. Goldstein, 2005). These specifications are provided as an example in Table 1. Installations of unvegetated compost filter socks, however, have shown that they require a coarser compost than unvegetated filter berms. The Minnesota DOT erosion control compost specifications for “compost logs” recommend 30 to 40 percent weed-free compost and 60 to 70 percent partially decomposed wood chips. They recommend that 100 percent of the compost passes the 2-inch (51 mm) sieve and 30 percent passes the 3/8-inch (10 mm) sieve. Research on these parameters continues to evolve; therefore, the unvegetated filter sock parameters shown in Table 1 are a compilation of those that are currently in use by industry practitioners (personal communication, B. Faucette, R. Tyler, R. Alexander, and N. Goldstein, 2005). The DOT or Department of Environmental Quality (or similar designation) for the state where the filter sock will be installed should be contacted to obtain any applicable specifications or compost testing recommendations.

Design: Filter socks are round to oval in cross section; they are assembled by tying a knot in one end of the mesh sock, filling the sock with the composted material (usually using a pneumatic blower), then knotting the other end once the desired length is reached. A filter sock the length of the slope is normally used to ensure that stormwater does not break through at the intersection of socks placed end-to-end. In cases where this is not possible, the socks are placed end-to-end along a slope and the ends are interlocked. The diameter of the filter sock used will vary depending upon the steepness and length of the slope; example slopes and slope lengths used with different diameter filter socks are presented in Table 2.

Siting: Although compost filter socks are usually placed along a contour perpendicular to sheet flow, in areas of concentrated flow they are sometimes placed in an inverted V going up the

slope, to reduce the velocity of water running down the slope. The project engineer may also consider placing compost filter socks at the top and base of the slope or placing a series of filter socks every 15 to 25 feet along the vertical profile of the slope. These slope interruption devices slow down sheet flow on a slope or in a watershed. Larger diameter filter socks are recommended for areas prone to high rainfall or sites with severe grades or long slopes. Coarser compost products are generally used in regions subject to high rainfall and runoff conditions.

Table 1. Example Compost Filter Parameters

Parameters [a,1,4]	**Units of Measure**[a]	**Vegetated Filter Berm/Sock**[a]	**Unvegetated Filter Sock**[b]
pH[2]	pH units	5.0 – 8.5	6 – 8
Soluble salt concentration[2] (electrical conductivity)	dS/m (mmhos/cm)	Maximum 5	Not applicable
Moisture content	%, wet weight basis	30 – 60	30 – 60
Organic matter content	%, dry weight basis	25 – 65	25 – 65
Particle size	% passing a selected mesh size, dry weight basis	- 3 in. (75 mm), 100% passing - 1 in. (25 mm), 90 – 100% passing - 0.75 in. (19 mm), 70 – 100% passing - 0.25 in. (6.4 mm), 30 – 75% passing Maximum particle size length of 6 in. (152 mm) Avoid compost with less than 30% fine particle (1 mm) to achieve optimum reduction of total suspended solids No more than 60% passing 0.25 in. (6.4 mm) in high rainfall/flow rate	- 2 in. (51 mm), 100% passing - 0.375 in. (10 mm), 10% – 30% passing

		situations	
Stability[3] Carbon dioxide evolution rate	mg CO_2-C per gram of organic matter per day	<8	(same as vegetated)
Physical contaminants (manmade inerts)	%, dry weight basis	<1	<1

Sources: [a]Alexander, 2003; [b]Personal communication, B. Faucette, R. Tyler, N. Goldstein, R. Alexander, 2005

Notes:

[1] Recommended test methodologies are provided in [Test Methods for the Evaluation of Composting and Compost EXIT Disclaimer].
[2] Each plant species requires a specific pH range and has a salinity tolerance rating.
[3] Stability/maturity rating is an area of compost science that is still evolving, and other test methods should be considered. Compost quality decisions should be based on more than one stability/maturity test.
[4] Landscape architects and project engineers may modify the above compost specification ranges based on specific field conditions and plant requirements.

Table 2. Example Compost Filter Sock Slopes, Slope Lengths, and Sock Diameters

Slope	Slope Length (feet)	Sock Diameter (inches)
<50:1	250	12
50:1–10:1	125	12
10:1–5:1	100	12
3:1–2:1	50	18
>2:1	25	18

Source: Oregon Department of Environmental Quality (ODEQ), 2004

Installation: No trenching is required; therefore, soil is not disturbed upon installation. Once the filter sock is filled and put in place, it should be anchored to the slope. The preferred anchoring method is to drive stakes through the center of the sock at regular intervals; alternatively, stakes can be placed on the downstream side of the sock. The ends of the filter sock should be directed upslope, to prevent stormwater from running around the end of the sock. The filter sock may be vegetated by incorporating seed into the compost prior to placement in the filter sock. Since compost filter socks do not have to be trenched into the ground, they can be installed on frozen ground or even cement.

Limitations

Compost filter socks offer a large degree of flexibility for various applications. To ensure optimum performance, h eavy vegetation should be cut down or removed, and extremely uneven surfaces should be leveled to ensure that the compost filter sock uniformly contacts the ground surface. Filter socks can be installed perpendicular to flow in areas where a large volume of stormwater runoff is likely, but should not be installed perpendicular to flow in perennial waterways and large streams.

Maintenance Considerations

Compost filter socks should be inspected regularly, as well as after each rainfall event, to ensure that they are intact and the area behind the sock is not filled with sediment. If there is excessive ponding behind the filter sock or accumulated sediments reach the top of the sock, an additional sock should be added on top or in front of the existing filter sock in these areas, without disturbing the soil or accumulated sediment. If the filter sock was overtopped during a storm event, the operator should consider installing an additional filter sock on top of the original, placing an additional filter sock further up the slope, or using an additional BMP, such as a compost blanket in conjunction with the sock(s).

Effectiveness

A large number of qualitative studies have reported the effectiveness of compost filter socks in removing settleable solids and total suspended solids from stormwater (McCoy, 2005; Tyler and Faucette, 2005). These studies have consistently shown that compost filter socks are at least as effective as traditional erosion and sediment control BMPs and often are more effective. Compost filter socks are often used in conjunction with compost blankets to form a stormwater management system. Together, these two BMPs retain a very high volume of stormwater, sediment, and other pollutants.

The compost in the filter sock can also improve water quality by absorbing various organic and inorganic contaminants from stormwater, including motor oil. Tyler and Faucette (2005) conducted a laboratory test using 13 types of compost in filter socks. They found that half of the compost filter socks removed 100 percent of the motor oil introduced into the simulated stormwater (at concentrations of 1,000 – 10,000 milligrams per liter [mg/L]) and the remaining compost filter socks removed over 85 percent of the motor oil from the stormwater.

Cost Considerations

The Texas Commission on Environmental Quality reports that the cost of a 12-inch diameter compost filter sock ranges from $1.40 to $1.75 per linear foot when used as a perimeter control (McCoy, 2005). The costs for an 18-inch diameter sock used as a check dam range from $2.75 to $4.75 per linear foot (McCoy, 2005). These costs do not include the cost of removing the compost filter sock and disposing of the mesh once construction activities are completed; however, filter socks are often left on site to provide slope stability and post-construction stormwater control. The cost to install a compost filter sock will vary, depending upon the availability of the required quality and quantity of compost and the availability of an experienced installer.

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Construction Entrances **EPA NPDES Fact Sheet**

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http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=35&minmeasure=4

Minimum Measure: Construction Site Stormwater Runoff Control

Subcategory: Sediment Control

Stabilized construction entrances allow dirt to be removed from tire treads and collected as trucks leave construction sites

Description

The purpose of stabilizing entrances to a construction site is to minimize the amount of sediment leaving the area as mud and sediment attached to vehicles. Installing a pad of gravel over filter cloth where construction traffic leaves a site can help stabilize a construction entrance. As a vehicle drives over the pad, the pad removes mud and sediment from the wheels and reduces soil transport off the site. The filter cloth separates the gravel from the soil below, keeping the gravel from being ground into the soil. The fabric also reduces the amount of rutting caused by vehicle tires. It spreads the vehicle's weight over a soil area larger than the tire width.

In addition to using a gravel pad, a vehicle washing station can be established at the site entrance. Using wash stations routinely can remove a lot of sediment from vehicles before they leave the site. Diverting runoff from vehicle washing stations into a sediment trap helps to make sure the sediment from vehicles stays onsite and is handled properly.

Applicability

Typically, stabilized construction entrances are installed where construction traffic leaves

or enters an existing paved road. But site entrance stabilization should be extended to any roadway or entrance where vehicles enter or leave the site. From a public relations point of view, stabilizing construction site entrances can be worth the effort. If the site entrance is the most noticeable part of a construction site, stabilizing the entrance can improve both the appearance and the public perception of the construction project.

Siting and Design Considerations

Stabilize all entrances to a site before construction and further site disturbance begin. Make sure the stabilized site entrances are long and wide enough to allow the largest construction vehicle that will enter the site to fit through with room to spare. If many vehicles are expected to use an entrance in any one day, make the site entrance wide enough for two vehicles to pass at the same time with room on either side of each vehicle. If a site entrance leads to a paved road, make the end of the entrance flared so that long vehicles do not leave the stabilized area when they turn onto or off the paved roadway. If a construction site entrance crosses a stream, swale, or other depression, provide a bridge or culvert to prevent erosion from unprotected banks. Make sure stone and gravel used to stabilize the construction site entrance are large enough so that they are not carried offsite by vehicles. Avoid sharp-edged stone to reduce the possibility of puncturing tires. Install stone or gravel at a depth of at least 6 inches for the entire length and width of the stabilized construction entrance.

Limitations

Although stabilizing a construction entrance reduces the amount of sediment leaving a site, some soil might still be deposited from vehicle tires onto paved surfaces. To further reduce the chance of these sediments polluting stormwater runoff, sweep the paved area adjacent to the stabilized site entrance. For sites that use wash stations, a reliable water source to wash vehicles before leaving the site might not be initially available. Water might have to be trucked to the site at additional cost.

Maintenance Considerations

Maintain stabilization of the site entrances until the rest of the construction site has been fully stabilized. You might need to add stone and gravel periodically to each stabilized construction site entrance to keep the entrance effective. Sweep up soil tracked offsite immediately for proper disposal. For sites with wash racks at each site entrance, construct sediment traps and maintain them for the life of the project. Periodically remove sediment from the traps to make sure they keep working.

Effectiveness

Stabilizing construction entrances to prevent sediment transport offsite is effective only if

all the entrances to the site are stabilized and maintained. Stabilizing the site entrances might not be very effective unless a wash rack is installed and routinely used (Corish, 1995). This can be problematic for sites with multiple entrances and high vehicle traffic.

Cost Considerations

Without a wash rack, construction site entrance stabilization costs range from $1,000 to $4,000. On average, the initial construction cost is around $2,000 per entrance. Including maintenance costs for a 2-year period, the average total annual cost is approximately $1,500. If a wash rack is included in the construction site entrance stabilization, the initial construction costs range from $1,000 to $5,000, and the average initial cost is $3,000 per entrance. The total cost, including maintenance for an estimated 2-year life span, is approximately $2,200 per year (USEPA, 1993).

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Fiber Rolls **EPA NPDES Fact Sheet**

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Minimum Measure: Construction Site Stormwater Runoff Control

Subcategory: Sediment Control

Description

Photo from Earth Saver Erosion Control Products, 2005.

Fiber rolls (also called fiber logs or straw wattles) are tube-shaped erosion-control devices filled with straw, flax, rice, coconut fiber material, or composted material. Each roll is wrapped with UV-degradable polypropylene netting for longevity or with 100 percent biodegradable materials like burlap, jute, or coir. Fiber rolls complement permanent best management practices used for source control and revegetation. When installed in combination with straw mulch, erosion control blankets, hydraulic mulches, or bounded fiber matrices for slope stabilization, these devices reduce the effects of long or steep slopes (Earth Saver Erosion Control Products, 2005). Fiber rolls also help to slow, filter, and spread overland flows. This helps to prevent erosion and minimizes rill and gully development. Fiber rolls also help reduce sediment loads to receiving waters by filtering runoff and capturing sediments.

Applicability

Fiber rolls can be used in areas of low shear stress. Avoid using them in channels that are actively incising or in reaches with large debris loads or potential for significant ice buildup (Maryland Department of the Environment, 2000). Fiber rolls have been used to control erosion in a variety of areas--along highways and at construction sites, golf courses, ski areas, vineyards, and reclaimed mines. According to the California Stormwater Quality Association (CASQA, 2003), fiber rolls can be suitable in the following settings:

- 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
- Downslope of exposed soil areas
- Around temporary stockpiles

Siting and Design Considerations

Fiber rolls should be prefabricated rolls or rolled tubes of geotextiles fabric. When rolling the tubes, make sure each tube is at least 8 inches in diameter. Bind the rolls at each end and every 4 feet along the length of the roll with jute-type twine (California Stormwater Quality Association, 2003).

Slope ground projects

On slopes, install fiber rolls along the contour with a slight downward angle at the end of each row to prevent ponding at the midsection (California Straw Works, 2005). Turn the ends of each fiber roll upslope to prevent runoff from flowing around the roll. Install fiber rolls in shallow trenches dug 3 to 5 inches deep for soft, loamy soils and 2 to 3 inches deep for hard, rocky soils. Determine the vertical spacing for slope installations on the basis of the slope gradient and soil type. According to California Straw Works (2005), a good rule of thumb is:

1:1 slopes = 10 feet apart

2:1 slopes = 20 feet apart

3:1 slopes = 30 feet apart

4:1 slopes = 40 feet apart

For soft, loamy soils, place the rows closer together. For hard, rocky soils, place the rows farther apart. Stake fiber rolls securely into the ground and orient them perpendicular to the slope. Biodegradable wood stakes or willow cuttings are recommended. Drive the stakes through the middle of the fiber roll and deep enough into the ground to anchor the roll in place. About 3 to 5 inches of the stake should stick out above the roll, and the stakes should be spaced 3 to 4 feet apart. A 24-inch stake is recommended for use on soft, loamy soils. An 18-inch stake is recommended for use on hard, rocky soils.

Projects without slopes

Fiber rolls can also be used at projects with minimal slopes. Typically, the rolls are installed along sidewalks, on the bare lot side, to keep sediment from washing onto sidewalks and streets and into gutters and storm drains. For installations along sidewalks and behind street curbs, it might not be necessary to stake the fiber rolls, but trenches must still be dug. Fiber rolls placed around storm drains and inlets must be staked into the ground. These rolls should direct the flow of runoff toward a designated drainage area. Place them 1 to 1½ feet back from the storm drain or inlet.

Photo from IECA, 2005.

Limitations

The installation and overall performance of fiber rolls have several limitations, including the following (California Stormwater Quality Association, 2003):

- Fiber rolls are not effective unless trenched.
- Fiber rolls can be difficult to move once saturated.
- To be effective, fiber rolls at the toe of slopes greater than 5:1 must be at least 20 inches in diameter. An equivalent installation, such as stacked smaller-diameter fiber rolls, can be used to achieve a similar level of protection.
- If not properly staked and entrenched, fiber rolls can be transported by high flows.
- Fiber rolls have a very limited sediment capture zone.
- Fiber rolls should not be used on slopes subject to creep, slumping, or landslide.

Maintenance Considerations

The maintenance requirements of fiber rolls are minimal, but short-term inspection is recommended to ensure that the rolls remain firmly anchored in place and are not crushed or damaged by equipment traffic (Murphy and Dreher, 1996). Monitor fiber rolls daily during prolonged rain events. Repair or replace split, torn, unraveled, or slumping fiber rolls. Fiber rolls are typically left in place on slopes. If they are removed, collect and dispose of the accumulated sediment. Fill and compact holes, trenches, depressions, or any other ground disturbance to blend with the surrounding landscape.

Effectiveness

Unlike other BMPs that could cause water to back up and flow around the edges, fiber rolls allow water to flow through while capturing runoff sediments. Fiber rolls placed along the shorelines of lakes and ponds provide immediate protection by dissipating the erosive force of small waves. As an alternative to silt fences, fiber rolls have some distinct advantages, including the following (Earth Saver, 2005):

- They install more easily, particularly in shallow soils and rocky material.
- They are more adaptable to slope applications and contour installations than other erosion and sediment control practices.
- They are readily molded to fit the bank line.
- They blend in with the landscape and are less obtrusive than other erosion and sediment controls such as silt fence.
- They do not obstruct hydraulic mulch and seed applications.
- They can be removed or left in place after vegetation is established.

Fiber rolls can provide slope protection for 3 to 5 years (California Straw Works, 2005). They slowly decompose into mulch, and the netting breaks down into small pieces. The San Diego State University Soil Erosion Research Laboratory reported that the use of fiber roll products reduced offsite sediment delivery by 58 percent (International Erosion Control Association, 2005).

The Flint Creek watershed, which covers approximately 28 square miles of Lake and Cook

counties in northeastern Illinois, was listed in the Illinois Water Quality Report (1994-1995) as being impaired due to nonpoint source pollution from land development, channelization, and urban runoff. Along with other bioengineering techniques, fiber rolls were installed along the shorelines of the creek to reduce the effects of wave action. Native plants were installed in the fiber rolls. As a result, the growth of vegetative cover increased and helped to stabilize the slopes along the banks of the creek. Ultimately, the water quality of Flint Creek was improved (USEPA, 2002).

Cost Considerations

Material costs for fiber rolls range from $20 to $30 per 25-foot roll (CASQA, 2003). Labor hours should also be allocated for installation, monitoring, and maintenance. Because fiber rolls are usually left along slopes and are biodegradable, labor costs for removing them are avoided. However, sediment removal and disposal are still necessary in areas where sediment accumulates to at least one-half the distance between the top of the fiber roll and the ground surface.

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Minimum Measure: Construction Site Stormwater Runoff Control

Subcategory: Sediment Control

Description

A gravel or stone filter berm is a temporary ridge made up of loose gravel, stone, or crushed rock. It slows and filters flow and diverts it from an open traffic area. It acts as an efficient form of sediment control. One type of filter berm is the continuous berm, a geosynthetic fabric berm that captures sand, rock, and soil.

Applicability

Gravel or stone filter berms are most suitable in areas where traffic needs to be rerouted because roads are under construction, or in traffic areas within a construction site.

Siting and Design Considerations

Consider the following guidelines when building a berm:

- Use well-graded gravel or crushed rock to build the berm, with rock size ranging from 3/4 inches to 3 inches in diameter containing less than 5 percent fines (Massachusetts DEP, 2003).
- Space berms according to the steepness of the slope. Space them closer together as the slope increases.
- Remove and dispose of sediment that builds up, and replace the filter material. Regular inspection should indicate how often sediment needs to be removed.

Limitations

Berms are intended to be used only in gently sloping areas (less than 10 percent). They do not last very long unless they are maintained regularly because they are prone to clogging with mud and soil from vehicle tires.

Maintenance Considerations

Inspect the berm after every rainfall to make sure sediment has not built up and that vehicles have not damaged it. It is important to make repairs at the first sign of deterioration to keep the

berm functioning properly.

Effectiveness

The effectiveness of a rock filter berm depends on rock size, slope, soil and rainfall amount. The continuous berm is not staked into the ground, and no trenching is required. Effectiveness has been rated at up to 95 percent for sediment removal. Effectiveness depends on local conditions such as hydrologic, hydraulic, topographic, and sediment characteristics.

Cost Considerations

Construction materials for filter berms (mainly gravel) are relatively low in cost. Installing a berm and regularly cleaning and maintaining it can result in substantial labor costs. Costs are lower in areas of less traffic, gentler slopes, and low rainfall.

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Sediment Basins and Rock Dams **EPA NPDES Fact Sheet**

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Minimum Measure: Construction Site Stormwater Runoff Control

Subcategory: Sediment Control

Sediment basins are used to trap sediments and temporarily detain runoff on larger construction sites

Description

Sediment basins and rock dams can be used to capture sediment from stormwater runoff before it leaves a construction site. Both structures allow a pool to form in an excavated or natural depression, where sediment can settle. The pool is dewatered through a single riser and drainage hole leading to a suitable outlet on the downstream side of the embankment or through the gravel of the rock dam. The water is released more slowly than it would be without the control structure.

A sediment basin is constructed by excavation or by erecting an earthen embankment across a low area or drainage swale. The basin can be temporary (up to 3 years) or permanent. Some sediment basins are designed to drain completely during dry periods. Others are constructed so that a shallow pool of water remains between storm events.

Rock dams are similar to sediment basins with earthen embankments. These damming structures are constructed of rock and gravel. They release water from the settling pool gradually through the spaces between the rocks.

Applicability

Sediment basins are usually used for drainage areas of 5 to 100 acres. They can be temporary or permanent. Sediment basins designed to be used for up to 3 years are usually described as temporary. Those designed for longer service are considered permanent. Temporary sediment basins can be converted into permanent stormwater runoff management ponds, but they must meet all regulatory requirements for wet ponds.

For EPA Construction General Permit permittees, a sediment basin or its equivalent should accomplish the following for drainage areas of different sizes:

- *10 or more acres of disturbed area:* For common drainage locations that serve an area with 10 or more acres disturbed at one time, a temporary (or permanent) sediment basin that provides storage for a calculated volume of runoff from the drainage area from a 2-year, 24-hour storm, or equivalent control measures, must be provided where attainable until final stabilization of the site. Where no such calculation has been performed, a temporary (or permanent) sediment basin providing 3,600 cubic feet of storage per acre drained, or equivalent control measures, must be provided where attainable until final stabilization of the site. When computing the number of acres draining into a common location, it is not necessary to include flows from offsite areas and flows from on-site areas that are either undisturbed or have undergone final stabilization where such flows are diverted around both the disturbed area and the sediment basin. In determining whether installing a sediment basin is attainable, the operator may consider factors such as site soils, slope, available area on-site, etc. In any event, the operator must consider public safety, especially as it relates to children, as a design factor for the sediment basin, and alternative sediment controls must be used where site limitations would preclude a safe design.

For drainage locations which serve 10 or more disturbed acres at one time and where a temporary sediment basin or equivalent controls is not attainable, smaller sediment basins and/or sediment traps should be used. At a minimum, silt fences, vegetative buffer strips, or equivalent sediment controls are required for all down slope boundaries (and for those side slope boundaries deemed appropriate as dictated by individual site conditions).

- *Less than 10 acres of disturbed area:* For drainage locations serving less than 10 acres, smaller sediment basins and/or sediment traps should be used. At a minimum, silt fences, vegetative buffer strips, or equivalent sediment controls are required for all down slope boundaries (and for those side slope boundaries deemed appropriate as dictated by individual site conditions) of the construction area unless a sediment basin providing storage for a calculated volume of runoff

from a 2-year, 24-hour storm or 3,600 cubic feet of storage per acre drained is provided.

Sediment basins are applicable in drainage areas where it is expected that other erosion controls, such as sediment traps, will not adequately prevent offsite transport of sediment. Whether to construct a sediment basin or a rock dam depends on the materials available, the location of the basin, and the desired capacity for holding stormwater runoff and settling sediment.

Rock dams are suitable where earthen embankments would be difficult to construct and where rocks for the dams are readily available. They are also desirable where the top of the dam structure is to be used as an overflow outlet. Rock dams are best for drainage areas of less than 50 acres. Earthen damming structures are appropriate where failure of the dam will not result in substantial damage or loss of property or life. If sediment basins with earthen dams are properly constructed, they can handle runoff from drainage basins as large as 100 acres.

Siting and Design Considerations

Investigate potential sites for sediment basins during the initial site evaluation. Construct the basins before any grading takes place in the drainage area. For permanent structures, a qualified professional engineer experienced in designing dams should complete the basin design.

Limit sediment basins with rock dams to a drainage area of 50 acres. Limit the rock dam height to 8 feet with a top width of at least 5 feet. Side slopes for rock dams should be no steeper than 2:1 on the basin side of the structure and 3:1 on the outlet side. Cover the basin side of the rock dam with fine gravel from top to bottom for at least 1 foot. This slows the drainage rate from the pool that forms and gives sediments time to settle. The detention time should be at least 8 hours.

Outfit sediment basins with earthen embankments with a dewatering pipe and riser set just above the sediment removal cutoff level. Place the riser pipe at the deepest point of the basin and make sure it extends no farther than 1 foot below the level of the earthen dam. Place a water-permeable cover over the primary dewatering riser pipe to prevent trash and debris from entering and clogging the spillway. To provide an additional path for water to enter the primary spillway, you can drill secondary dewatering holes near the base of the riser pipe, but make sure you protect the holes with gravel to keep sediment out of the spillway piping.

To ensure adequate drainage, use the following equation to approximate the total area of dewatering holes for a particular basin (Smolen et al., 1988):

$A_o = (A_s \times (2h) / (T \times C_d \times 20{,}428)$

where

A_o = total surface area of dewatering holes, ft^2;

A_s = surface area of the basin, ft^2;

h = head of water above the hole, ft;

C_d = coefficient of contraction for an orifice, approximately 0.6; and

T = detention time or time needed to dewater the basin, hours.

In all cases, an appropriate professional should design such structures. The designer should consider local hydrologic, hydraulic, topographic, and sediment conditions.

Limitations

Do not use a sediment basin with an earthen embankment or a rock dam in an area of continuously running water (live streams). Do not use a sediment basin in an area where failure of the earthen or rock dam will result in loss of life or damage to homes or other buildings. Do not use sediment basins in areas where failure will prevent the use of public roads or utilities.

Maintenance Considerations

Routine inspection and maintenance of sediment basins is essential to their continued effectiveness. Inspect basins after each storm event to ensure proper drainage from the collection pool and determine the need for structural repairs. Replace material eroded from earthen embankments or stones moved from rock dams immediately. Locate sediment basins in an area that is easily accessible to maintenance crews for removal of accumulated sediment. Remove sediment from the basin when the storage capacity has reached approximately 50 percent. Remove trash and debris from around dewatering devices promptly after rainfall events.

Effectiveness

The effectiveness of a sediment basin depends primarily on the sediment particle size and the ratio of basin surface area to inflow rate (Smolen et al., 1988). Basins with a large surface area-to-volume ratio are the most effective. Studies have shown that the following equation relating surface area and peak inflow rate gives a trapping efficiency greater than 75 percent for most sediment in the Coastal Plain and Piedmont regions of the southeastern United States (Barfield and Clar, in Smolen et al., 1988):

$A = 0.01q$

where A is the basin surface area in acres and q is the peak inflow rate in cubic feet per second.

USEPA (1993) estimates an average total suspended solids removal rate for all sediment basins of 55 percent to 100 percent. The average effectiveness is 70 percent.

Cost Considerations

For a sediment basin with less than 50,000 ft^3 of storage space, the cost of installing the basin ranges from $0.20 to $1.30 per cubic foot of storage (about $1,100 per acre of drainage). The average cost for basins with less than 50,000 ft^3 of storage is approximately $0.60 per cubic foot of storage (USEPA, 1993). If constructing a sediment basin with more than 50,000 ft^3 of storage space, the cost of installing the basin ranges from $0.10 to $0.40 per cubic foot of storage (about $550 per acre of drainage). The average cost for basins with greater than 50,000 ft^3 of storage is approximately $0.30 per cubic foot of storage (USEPA, 1993).

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Sediment Filters and Sediment Chambers **EPA NPDES Fact Sheet**

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Minimum Measure: Construction Site Stormwater Runoff Control

Subcategory: Sediment Control

Description

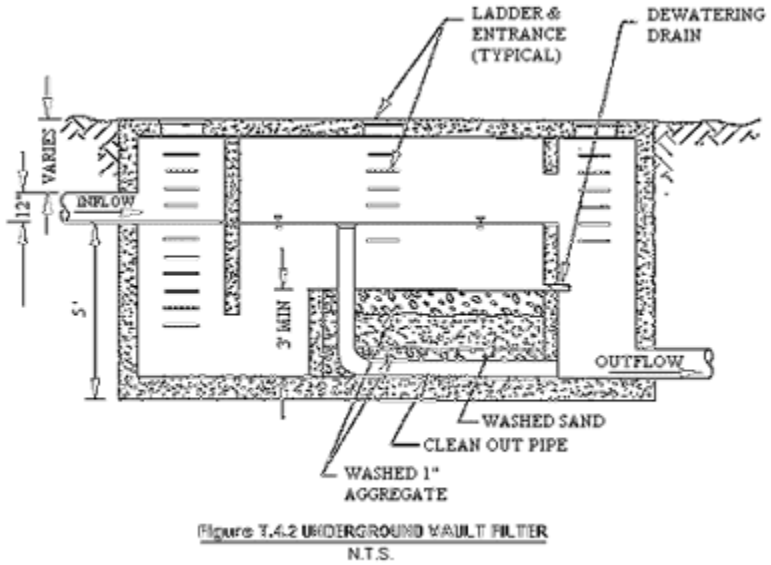
Sediment filters are sediment-trapping devices typically used to remove pollutants (mainly particulates) from stormwater runoff. Sediment filters have four components: (1) inflow regulation, (2) pretreatment, (3) filter bed, and (4) outflow mechanism. Sediment chambers are one component of a sediment filter system.

Inflow regulation is diverting stormwater runoff into the sediment-trapping device. After runoff enters the filter system, it enters a pretreatment sedimentation chamber. This chamber is used as a preliminary settling area for large debris and sediments. It is usually no more than a wet detention basin. As water reaches a predetermined level, it flows over a weir into a bed of some filter medium. The medium is typically sand, but it can consist of sand, soil, gravel, peat, compost, or a combination. The filter bed removes small sediments and other pollutants from the stormwater as it percolates through the filter medium. Finally, treated flow exits the sediment filter system via an outflow mechanism. It returns to the stormwater conveyance system.

Sediment filter systems can be confined or unconfined, on-line or off-line, and aboveground or belowground. Confined sediment filters are constructed with the filter medium contained in a structure, often a concrete vault. Unconfined sediment filters are made without a confining structure. For example, sand might be placed on the banks of a permanent wet pond detention system to create an unconfined filter. On-line systems retain stormwater in its original stream channel or storm drain system. Off-line systems divert stormwater.

Applicability

Sediment filters might be a good alternative for small construction sites where a wet pond is being considered as a sediment-trapping device. They are widely applicable, and they can be used in urban areas with large amounts of highly impervious area. Confined sand filters are man-made systems, so they can be applied to most development sites and have few constraining factors (MWCOG, 1992). However, for all sediment filter systems, the drainage area to be serviced should be no more than 10 acres.



Schematic representation of a sediment filter

The type of filter system chosen depends on the amount of land available and the desired location. The Austin sand filter and the Delaware sand filter are examples of sediment filter systems. The Austin sand filter is a surface filter system that can be used in areas with space restrictions. If space is at a premium, an underground filter might be the best choice. For effective stormwater sediment control at the perimeter of a site, consider the Delaware sand filter. It consists of two parallel, trench-like chambers installed at a site's perimeter. The first trench (sediment chamber) provides pretreatment sediment settling before the runoff spills into the second trench (filter medium).

Siting and Design Considerations

The available space is likely to be the most important siting and design consideration. Another important consideration when deciding to install sediment-filtering systems is the amount of available head. Head is the vertical distance available between the inflow of the system and the outflow point. Because most filtering systems depend on gravity to move water through the system, if enough head is not available, the system will not be effective. It might cause more harm than good. For surface and underground sand filters, a minimum head of 5 feet is suggested (Claytor and Schueler, 1996). Perimeter sand filters like the two-chambered Delaware sand filter should have a minimum available head of 2 to 3 feet (Claytor and Schueler, 1996).

The depth of filter media will vary depending on media type. For sand filters it is recommended that the sand (0.04-inch diameter or smaller) be at least 18 inches deep, with at least 4 to 6 inches of gravel for the bed of the filter. Throughout the life of a sediment filter system, there will be a need for frequent access to assess effectiveness and perform routine maintenance and emergency repairs. Because most maintenance requires manual rather than mechanical removal of sediments and debris, locate filter systems to allow easy access.

Limitations

Sediment filters are usually limited to removing pollutants from stormwater runoff. To provide flood protection, they have to be used with other stormwater management practices. Do not use sediment filters on fill sites or near steep slopes (Livingston, 1997). In addition, sediment filters are likely to lose effectiveness in cold regions because of freezing conditions.

Maintenance Considerations

Maintenance of stormwater sediment filters can be relatively high compared to other sediment-trapping devices. Routine maintenance includes raking the filter medium and removing surface sediment and trash. These chores will likely need to be done by hand rather than by mechanical means. Depending on the medium used in the structure, the filter material might have to be changed or replaced up to several times a year. How often depends on, among other things, rainfall intensity and the expected sediment load.

Inspect sediment filters of all media types monthly and after each significant rainfall event to make sure they are filtering properly. Remove trash and debris during inspections. Remove sediment from the filter inlets and sediment chambers when 75 percent of the storage volume has been filled. Because filter media have the potential for high loadings of metals and petroleum hydrocarbons, have the filter medium analyzed periodically to prevent it from reaching levels that would classify it as a hazardous waste. This is especially true on sites where solvents or other potentially hazardous chemicals are used. Implement spill prevention measures as necessary. Replace the top 3 to 4 inches of the filter medium once a year, or more frequently if the water level does not go down within 36 hours of a storm event.

Effectiveness

Treatment effectiveness depends on factors like treatment volume; whether the filter is on-line or off-line, confined or unconfined; and the type of land use in the contributing drainage area. MWCOG (1992) states that sand filter removal rates are "high" for sediment and trace metals and "moderate" for nutrients, biochemical oxygen demand, and fecal coliform bacteria. Removal rates can be increased slightly by using a peat/sand mixture as the medium because peat has adsorptive properties (pollutants attach to it) (MWCOG, 1992). The estimated pollutant removal capabilities for various filter systems are shown in Table 1.

Table 1. Pollutant removal efficiencies for sand filters

Source	Filter system	TSS[a] (%)	TP[a] (%)	TN[a] (%)	Other pollutants
Claytor and Schueler, 1996	Surface sand filter	85	55	35	Bacteria: 40%-80% Metals: 35%-90%
	Perimeter sand filter	80	65	45	Hydrocarbons: 80%
Livingston, 1997	Sand filter (general)	60-85	30-75	30-60	Metals: 30%-80%

[a]TSS=total suspended solids; TP=total phosphorus; TN=total nitrogen.

Cost Considerations

MWCOG (1992) estimates the cost of construction for sand filters at $3.00 to $10.00 per cubic foot of runoff treated. Annual costs are estimated at about 5 percent of construction costs.

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Sediment Traps **EPA NPDES Fact Sheet**

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Minimum Measure: Construction Site Stormwater Runoff Control

Subcategory: Sediment Control

Sediment traps are used to collect sediment-laden runoff from disturbed areas on construction sites

Description

Sediment traps are small impoundments that allow sediment to settle out of construction runoff. They are usually installed in a drainageway or other point of discharge from a disturbed area. Temporary diversions can be used to direct runoff to the sediment trap (USEPA, 1993). Sediment traps detain sediments in stormwater runoff to protect receiving streams, lakes, drainage systems, and the surrounding area. The traps are formed by excavating an area or by placing an earthen embankment across a low area or drainage swale. An outlet or spillway is often constructed using large stones or aggregate to slow the release of runoff (USEPA, 1992).

Applicability

Sediment traps are commonly used at the outlets of stormwater diversion structures, channels, slope drains, construction site entrance wash racks, or any other runoff conveyance that discharges waters containing sediment and debris.

Siting and Design Considerations

Sediment traps can simplify stormwater management on a construction site by trapping

small amounts of sediment at multiple spots (USEPA, 1992). Note the natural drainage patterns, and place the traps in areas with the highest erosion potential. Design alternative diversion pathways to accommodate potential overflows.

Design a sediment trap to maximize the surface area for infiltration and sediment settling. This increases the effectiveness of the trap and decreases the likelihood of backup during and after periods of high runoff intensity. Site conditions dictate specific design criteria, but the minimum storage capacity should be 1,800 ft^3 per acre of total drainage area (Smolen et al., 1988). The volume of a natural sediment trap can be approximated using the following equation (Smolen et al., 1988):

$$\text{Volume } (ft^3) = 0.4 \times \text{surface area } (ft^2) \times \text{maximum pool depth } (ft)$$

In the siting and design phase, take care to situate sediment traps for easy access by maintenance crews. This allows for periodic inspection and maintenance. When excavating an area for a sediment trap, make sure the side slopes are no steeper than 2:1 and the embankment height no more than 5 feet from the original ground surface. Machine-compact all embankments to ensure stability. To reduce flow rate from the trap, line the outlet with well-graded stone.

The spillway weir for each temporary sediment trap should be at least 4 feet long for a 1-acre drainage area and increase by 2 feet for each additional drainage acre added, up to a maximum drainage area of 5 acres.

Limitations

Do not use sediment traps for drainage areas greater than 5 acres (USEPA, 1993). The effective life span of these structures is usually limited to 24 months (Smolen et al., 1988). Although sediment traps allow eroded soils to settle, their detention periods are too short for removing fine particles like silts and clays.

Maintenance Considerations

The primary maintenance consideration for temporary sediment traps is removing accumulated sediment. Do this periodically to ensure that the trap continues to operate effectively. Remove sediments when the basin reaches about 50 percent sediment capacity. Inspect the sediment trap after each rainfall event to ensure that the trap is draining properly. Also check the structure for damage from erosion. Check the depth of the spillway and maintain it at a minimum of 1.5 feet below the low point of the trap embankment.

Effectiveness

Sediment trapping efficiency is a function of surface area and peak inflow rate (Smolen et al., 1988). Traps that provide pools with large length-to-width ratios have a greater chance of success. Sediment traps have a useful life of about 18 to 24 months (USEPA,

1993), but their effectiveness depends on the amount and intensity of rainfall and erosion, and proper maintenance. USEPA (1993) estimates an average total suspended solids removal rate of 60 percent. An efficiency rate of 75 percent can be obtained for most Coastal Plain and Piedmont soils by using the following equation (Barfield and Clar, in Smolen et al., 1988):

Surface area at design flow (acres) = (0.01) peak inflow rate (cfs)

Cost Considerations

The cost of installing temporary sediment traps ranges from $0.20 to $2.00 per cubic foot of storage (about $1,100 per acre of drainage). The average cost is sbout $0.60 per cubic foot of storage (USEPA, 1993).

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United States Environmental Protection Agency

Stormwater Best Management Practice

Silt Fences

Permits for Clean Water NPDES

Minimum Measure

Construction Site Stormwater Runoff Control

Subcategory

Sediment Control

Purpose and Description

The purpose of a silt fence is to retain the soil on disturbed land (Figure 1), such as a construction site, until the activities disturbing the land are sufficiently completed to allow revegetation and permanent soil stabilization to begin. Keeping the soil on a construction site, rather than letting it be washed off into natural water bodies (e.g., streams, rivers, ponds, lakes, estuaries) prevents the degradation of aquatic habitats and siltation of harbor channels. And not letting soil wash off onto roads, which readily transport it to storm sewers, avoids having sewers clogged with sediment. The cost of installing silt fences on a watershed's construction sites is considerably less than the costs associated with losing aquatic species, dredging navigation channels, and cleaning sediment out of municipal storm sewers.

Figure 1. *Silt fence retaining sediment*

A silt fence is a temporary sediment barrier made of porous fabric. It's held up by wooden or metal posts driven into the ground, so it's inexpensive and relatively easy to remove. The fabric ponds sediment-laden stormwater runoff, causing sediment to be retained by the settling processes. A single 100 foot (ft) run of silt fence may hold 50 tons of sediment in place. Most construction sites today do have silt fences. But many do not work effectively because they are not well designed, installed, or maintained. The focus of this fact sheet is—how to make silt fences work.

Design

The three principal aspects of silt fence design are: proper placement of fencing, adequate amount of fencing, and appropriate materials.

Proper Placement of Fencing

Placement is important because where a fence starts, runs, and ends is critical to its effectiveness. Improper placement can make the fence a complete waste of money. Analyze the construction site's contours to determine the proper placement. Segment the site into manageable sediment storage areas for using multiple silt fence runs. The drainage area above any fence should usually not exceed a quarter of an acre. Water flowing over the top of a fence during a normal rainfall indicates the drainage area is too large. An equation for calculating the maximum drainage area length above a silt fence, measured perpendicular to the fence, is given in Fifield, 2011. Avoid long runs of silt fence because they concentrate the water in a small area where it will easily overflow the fence. The lowest point of the fence in Figure 4 is indicated by a red arrow. Water is directed to this low point by both long runs of fence on either side of the arrow. Most of the water overflows the fence at this low point and little sediment is trapped for such a long fence.

Figure 2. *Create manageable sediment storage areas*

Figure 3. *Water should not flow over the filter fabric during a normal rainfall*

Figure 4. *Avoid long runs of silt fence*

Use J-hooks as shown in Figures 5 and 6, which have ends turning up the slope to break up long fence runs and provide multiple storage areas that work like mini-retention areas. If the fence doesn't create a ponding condition, it will not work well. The silt fence in Figure 7 doesn't pond water or retain sediment. Stormwater will run around the fence carrying sediment to the street, which will transport the water and its sediment load to the storm sewer inlet.

Figure 5. *Use J-hook fences to break up long fence runs*

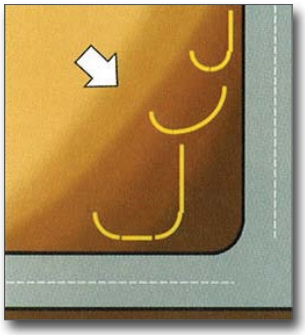

Figure 6. *J-hook silt fences provide multiple storage areas*

Figure 7. *This silt fence doesn't work*

Water flowing around the ends of a silt fence will cause additional erosion and defeat its purpose. The bottom of each end of the fence should be higher than the top of the middle of the fence (Figure 8). This insures that during an unusually heavy rain, water will flow over the top rather than around either end of the fence. Only fine suspended material will spill over the top, which is not as harmful as having erosion at the ends. When there is a long steep slope, install one fence near the head of the slope to reduce the volume and velocity of water flowing down the slope, and another fence 6–10 ft from the toe of the slope to create a sediment storage area near the bottom. A common misconception is that you only have to worry about water running off steep slopes. However, steep slopes may have a relatively small water collection area. The total drainage area of a gentle slope, if large (Figure 10), can be more important than its slope in determining sediment loss. A silt fence should not be placed in a channel with continuous flow (channels in Figures 8 and 9 don't have a continuous flow), nor across a narrow or steep-sided channel. But when necessary a silt fence can be placed parallel to the channel to retain sediment before it enters the watercourse.

Figure 8. *Proper installation, bottom of both ends are above the top of the middle*

Figure 9. *Poor installation, water can flow around the ends causing additional erosion*

Figure 10. *Gentle slopes may require a silt fence*

Paved streets are major conduits of stormwater and silt, and they drain to storm sewer inlets. The best solution is to retain as much sediment as possible before it reaches paved surfaces. Install a silt fence at the inlet side of a storm sewer or culvert, rather than at the discharge where there is greater velocity and less storage area. Streets cut in the grade, but not yet paved, are also prime erosion conduits. If the streets are not going to be paved right away, they need a containment barrier such as a silt fence. Finally as a construction site's dynamics change, the silt fence layout should be adjusted when necessary to maintain its effectiveness.

Designers and contractors should also consider diverting sediment-laden runoff water to a sediment detention pond. If the site can provide a large enough area, this is usually the most effective and economical best management practice for retaining sediments. Silt fences are needed when there is insufficient space for a detention pond or when roads and other structures are in the way.

Adequate Amount of Fencing

The amount of fencing means the total linear length of the silt fencing runs on the construction site. A reasonable rule-of-thumb for the proper amount of silt fence is—100 ft of silt fence per 10,000 square foot (sq ft) of disturbed area. Soil type, slope, slope length, rainfall, and site configuration are all important elements in determining the adequate silt fence protection for a site, and to what extent it fits the 100 ft per 10,000 sq ft rule-of-thumb. If the amount of fencing provides the volume of runoff storage needed, then over-flowing the silt fence runs will be minimized. This is the basic test; if fences are over-flowing after a moderate rainfall event, the amount of fencing probably needs to be increased to avoid undercutting, washouts, and fence failures.

Appropriate Materials

There are different types of porous fabrics available, e.g., woven, non-woven, mono-filament, but all types tend to clog rapidly and don't provide lasting filtration. The support posts and installation method are more important than the fabric type for overall sediment retention. However, a lightweight fabric tends to tear where it is attached to the posts. Posts must hold the fabric up and support the horizontal load of retained water and sediment. Hardwood posts (2″ x 2″) are potentially strong enough to support the loads, but are difficult to drive into the ground more than 6–8″. To hold 2 ft of sediment and water, the posts should be driven 2 ft into the ground. Steel posts are best because they can be driven into compacted soil to a depth of 2 ft. The support posts should be spaced 3–4 ft apart where water may run over the top of the fence, 5 ft in most other areas, and 6–7 ft where there isn't a considerable horizontal load. Improper post depth and spacing is often the cause of sagging fabric and falling posts. Some authorities believe a more robust wire or chain link supported silt fence is needed to withstand heavy rain events. However, this may double the cost of a silt fence installation and entails disposing of more material in a landfill when the fence is removed. Installing silt fencing having five interacting features: (1) proper placement based on the site's contours, (2) adequate amount of fencing without long runs, (3) heavy porous filter fabric, (4) metal posts with proper depth and spacing, and (5) tight soil compaction on both sides of the silt fence will usually obviate the need for wire or chain link reinforced fencing. Prefabricated silt fences, e.g., fabric attached to wooden posts in a 100 ft package, doesn't provide for posting after the ground is compacted or allow variable post spacing.

Figure 11. *Chain link supported silt fence*

Silt Fence Installation

Two commonly used approaches for installing silt fences are the static slicing method and the trenching method.

Static Slicing Method

The static slicing machine pulls a narrow blade through the ground to create a slit 12″ deep, and simultaneously inserts the silt fence fabric into this slit behind the blade. The blade is designed to slightly disrupt soil upward next to the slit and to minimize horizontal compaction, thereby creating an optimum condition for compacting the soil vertically on both sides of the fabric. Compaction is achieved by rolling a tractor wheel along both sides of the slit in the ground 2 to 4 times to achieve nearly the same or greater compaction as the original undisturbed soil. This vertical compaction reduces the air spaces between soil particles, which minimizes infiltration. Without this compaction infiltration can saturate the soil, and water may find a pathway under the fence. When a silt fence is holding back several tons of accumulated water and sediment, it needs to be supported by posts that are driven 2 ft into well-compacted soil. Driving in the posts and attaching the fabric to them completes the installation.

Figure 12. *Static slicing machine*

Figure 13. *Tractor wheel compacting the soil*

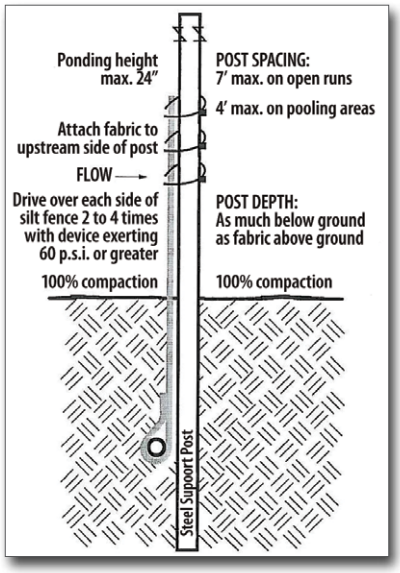

Figure 14. *Silt fence installation using the static slicing method*

Trenching Method

Trenching machines have been used for over twenty-five years to dig a trench for burying part of the filter fabric underground. Usually the trench is about 6″ wide with a 6″ excavation. Its walls are often more curved than vertical, so they don't provide as much support for the posts and fabric. Turning the trencher is necessary to maneuver around obstacles, follow terrain contours or property lines, and install upturns or J-hooks. But trenchers

Figure 15. *Trenchers make a wider excavation at turns*

Figure 16. *Poor compaction has resulted in infiltration and water flowing under this silt fence causing retained sediment washout*

can't turn without making a wider excavation, and this results in poorer soil compaction, which allows infiltration along the underground portion of the fence. This infiltration leads to water seeking pathways under the fence, which causes subsequent soil erosion and retained sediment washout under the fence. The white line on the fence in Figure 16 and red arrow both mark the previous sediment level before the washout. Post setting and fabric installation often precede compaction, which make effective compaction more difficult to achieve. EPA supported an independent technology evaluation (ASCE 2001), which compared three progressively better variations of the trenching method with the static slicing method. The static slicing method performed better than the two lower performance levels of the trenching method, and was as good or better than the trenching method's highest performance level. The best trenching method typically required nearly triple the time and effort to achieve results comparable to the static slicing method.

Proper Attachment

Regardless of the installation method, proper attachment of the fabric to the posts is critical to combining the strength of the fabric and support posts into a unified structure. It must be able to support 24″ of sediment and water. For steel posts use three plastic ties per post (50 lb test strength), located in the top 8″ of the fabric, with each tie hung on a post nipple, placed diagonally to attach as many vertical and horizontal threads as possible. For wooden posts use several staples per post, with a wood lath to overlay the fabric.

Perimeter Silt Fences

When silt fences are placed around the perimeter of a stock pile or a construction site, the conventional silt fence design and materials discussed previously may not be sufficient.

Stock pile example. A stock pile of dirt and large rocks is shown in Figures 17 and 18 with a silt fence protecting a portion of its perimeter. Rocks that roll down the pile would likely damage a conventional silt fence. The bottom of the porous fabric is held firmly against both the ground and base of precast concrete, highway, barriers by light-colored stones. An alternative installation would be having the concrete barriers rest directly on the bottom edge of the filter fabric, which would extend under the barriers about 10″, so the barriers' weight will press the fabric against the ground to prevent washout. Water passing through the silt fence (red arrow in Figure 18) flows to a storm sewer culvert inlet, which is surrounded by a fabric silt fence (yellow arrows in Figures 17 and 18) that reduces the runoff's velocity and allows settling before the water is discharged to a creek.

Figure 17. *Back of silt fence on part of the stock pile's perimeter*

Figure 18. *Front of silt fence on part of stock pile's perimeter*

Bridge abutment example. During the construction of a bridge over a river between two lakes, an excavation on the river bank was needed to pour footings for the bridge abutment. The silt fence along the excavation's perimeter, composed of concrete highway barriers with orange filter fabric, was designed to prevent stormwater from washing excavated spoil into the river and to fend off the river during high flows. A portion of the orange filter fabric that has blown away from the concrete barriers shows the need to overlap and reinforce the joints where two sections of filter fabric are attached.

Figure 19. *Silt fence for bridge abutment excavation*

Highway example. Because of the proximity of a construction site to a highway, a concrete barrier was required by Minnesota's DOT to protect the highway and an underground fiber optic cable next to the highway from construction activities. The concrete barrier was used to support a silt fence along the perimeter of a large amount of dirt that was stock piled before being used for fill at a different location.

Figure 20. *Silt fence protecting a highway and underground fiber optics cable*

Figure 21. *Silt fence protecting a lake shore*

Lake shore example. The lake's shoreline is being restored with plant plugs and seeded with native plant species. A plywood, perimeter, silt fence is used to trap sediment from a construction site on the right-side of the picture, protect the lake shore from boat-wake erosion, and to prevent geese from eating the seeds and young plants. This fencing will be removed when 70% vegetative cover is achieved.

Inspection and Maintenance

Figure 22. *A silt fence full of sediment that needs maintenance*

Silt fences should be inspected routinely and after runoff events to determine whether they need maintenance because they are full (Figure 22) or damaged by construction equipment. The ASTM silt fence specification (ASTM 2003) recommends removing sediment deposits from behind the fence when they reach half the height of the fence or installing a second fence. However, there are several problems associated with cleaning out silt fences. Once the fabric is clogged with sediment, it can no longer drain slowly and function as originally designed. The result is normally a low volume sediment basin because the cleaning process doesn't unclog the fabric. The soil is normally very wet behind a silt fence, inhibiting the use of equipment needed to move it. A back hoe is commonly used, but, if the sediment is removed, what is to be done with it during construction? Another solution is to leave the sediment in place where it is stable and build a new silt fence above or below it to collect additional sediment as shown in Figure 23. The proper maintenance may be site specific, e.g. small construction sites might not have sufficient space for another silt fence. Adequate access to the sediment control devices should be provided so inspections and maintenance can be performed.

Figure 23. *New silt fence below the old fence*

Permanent Soil Stabilization

When the land disturbing activities are sufficiently completed to allow permanent soil stabilization on the site, the silt fences and sediment basins are removed. The fabric and damaged posts go to the landfill. Steel posts and some of the wooden posts can be reused. Then the sediment is spread over the site to provide fertile soil, and the area can be seeded and mulched to support revegetation.

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Figure 11. *Pete Schumann, Fairfax County, Virginia, Department of Public Works and Environmental Services*

Figure 17–21. *Dwayne Stenlund, CPESC, Minnesota Department of Transportation*

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Storm Drain Inlet Protection **EPA NPDES Fact Sheets**

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Minimum Measure: Construction Site Stormwater Runoff Control

Subcategory: Sediment Control

Description

There are many different ways to prevent sediment from entering storm drains.

Storm drain inlet protection measures prevent soil and debris from entering storm drain drop inlets. These measures are usually temporary and are implemented before a site is disturbed.

There are several types of inlet protection:

Excavation around the perimeter of the drop inlet: Excavating a small area around an inlet creates a settling pool that removes sediments as water is released slowly into the inlet through small holes protected by gravel and filter fabric.

Fabric barriers around inlet entrances: Erecting a barrier made of porous fabric around an inlet creates a shield against sediment while allowing water to flow into the drain. This barrier slows runoff while catching soil and other debris at the drain inlet.

Block and gravel protection: Standard concrete blocks and gravel can be used to form a barrier to sediments that permits water runoff to flow through select blocks laid sideways.

Sandbags can also be used to create temporary sediment barriers at inlets. For permanent inlet protection after the surrounding area has been stabilized, sod can be installed. This permanent measure is an aesthetically pleasing way to slow stormwater near drop inlet entrances and to remove sediments and other pollutants from runoff.

Applicability

All temporary inlet protection should have a drainage area no greater than 1 acre per inlet. Temporary controls should be constructed before the surrounding landscape is disturbed. Excavated drop inlet protection and block and gravel inlet protection are applicable to areas of high flow, where drain overflow is expected. Fabric barriers are recommended for smaller, flatter drainage areas (slopes less than 5 percent leading to the drain). Temporary drop inlet control measures are often used in sequence or with other erosion control techniques.

Siting and Design Considerations

With the exception of sod drop inlet protection, install these controls before any soil disturbance in the drainage area. Excavate around drop inlets at least 1 foot deep (2 feet maximum), excavating a volume of at least 35 yd^3 per acre disturbed. Side slopes leading to the inlet should be no steeper than 2:1. Design the shape of the excavated area such that the dimensions fit the area from which stormwater is expected to drain. For example, the longest side of an excavated area should be along the side of the inlet expected to drain the largest area.

Stake fabric inlet protection close to the inlet to prevent overflow onto unprotected soils. Stakes should be at least 3 feet long and spaced no more than 3 feet apart. Construct a frame for fabric support during overflow periods, and bury it at least 1 foot below the soil surface. It should rise to a height no greater than 1.5 feet above the ground. The top of the frame and fabric should be below the downslope ground elevation to keep runoff from bypassing the inlet.

Block and gravel inlet barriers should be at least 1 foot high (2 feet maximum). Do not use mortar. Lay the bottom row of blocks at least 2 inches below the soil surface, flush against the drain for stability. Place one block in the bottom row on each side of the inlet on its side to allow drainage. Place 1/2-inch wire mesh over all block openings to prevent gravel from entering the inlet. Place gravel (3/4 to 1/2 inch in diameter) outside the block structure at a slope no greater than 2:1.

Do not consider sod inlet protection until the entire surrounding drainage area is stabilized. Lay the sod so that it extends at least 4 feet from the inlet in each direction to form a continuous mat around the inlet. Lay the sod strips perpendicular to the direction of flows. Stagger them so that the strip ends are not aligned. The slope of the sodded area should not be steeper than 4:1 approaching the drop inlet.

Limitations

To increase the effectiveness of these practices, use them with other measures, such as small impoundments or sediment traps (USEPA, 1992). In general, stormwater inlet protection measures are practical for areas receiving relatively clean runoff that is not heavily laden with sediment. They are designed to handle drainage from areas less than 1 acre (CASQA, 2003). To prevent clogging, storm drain control structures must be maintained frequently. If sediment and other debris clog the water intake, drop inlet control measures can actually cause erosion in unprotected areas.

Maintenance Considerations

Check all temporary control measures after each storm event. To maintain the capacity of the settling pools, remove accumulated sediment from the area around the drop inlet (excavated area, area around fabric barrier or block structure) when the capacity is reduced by half. Remove additional debris from the shallow pools periodically. The weep holes in excavated areas around inlets can become clogged, preventing water from draining out of the pools. If that happens, it might be difficult and costly to unclog the intake.

Effectiveness

Excavated drop inlet protection can be used to improve the effectiveness and reliability of other sediment traps and barriers, such as fabric or block and gravel inlet protection. The effectiveness of inlet protection alone is low for erosion and sediment control, long-term pollutant removal, and habitat and stream protection.

Cost Considerations

The cost of implementing storm drain inlet protection measures varies depending on the control measure used. Initial installation costs range from $50 to $150 per inlet depending on the materials used, with an average cost of $100 (USEPA, 1993). Maintenance costs can be high (up to 100 percent of the initial construction cost annually) because of the frequent inspection and repair needs. The Southeastern Wisconsin Regional Planning Commission has estimated the cost of installing inlet protection devices at $106 to $154 per inlet (SEWRPC, 1991).

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Vegetated Buffers **EPA NPDES Fact Sheets**

Date accessed 10-25-13
http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=50&minmeasure=4

Minimum Measure: Construction Site Stormwater Runoff Control

Subcategory: Sediment Control

Buffers at the perimeters of construction sites are similar to agricultural buffers in that they trap sediments and remove pollutants in runoff from exposed areas (Source: Nova Scotia Department of Agriculture and Fisheries, 2000)

Description

Vegetated buffers are areas of natural or established vegetation maintained to protect the water quality of neighboring areas. Buffer zones slow stormwater runoff, provide an area where runoff can permeate the soil, contribute to ground water recharge, and filter sediment. Slowing runoff also helps to prevent soil erosion and streambank collapse.

Applicability

Vegetated buffers can be used in any area able to support vegetation. They are most effective and beneficial on floodplains, near wetlands, along streambanks, and on unstable slopes.

Siting and Design Considerations

To establish an effective vegetative buffer, follow these guidelines:

- Make sure soils are not compacted.
- Make sure slopes are less than 5 percent unless temporary erosion control mats are also

used.

- Determine buffer widths after carefully considering slope, vegetation, soils, depth to impermeable layers, runoff sediment characteristics, type and amount of pollutants, and annual rainfall.
- Make sure buffer widths increase as slope increases.
- Intermix zones of vegetation (native vegetation in particular), including grasses, deciduous and evergreen shrubs, and understory and overstory trees.
- In areas where flows are concentrated and fast, combine buffer zones with other practices such as level spreaders, infiltration areas, or diversions to prevent erosion and rilling.

Limitations

Adequate land must be available for a vegetated buffer. If land cost is high, buffer zones might not be cost-effective. In addition, adequate vegetative cover must be maintained in the buffer to keep it effective. Vegetated buffers work well with sheet flows, but they are not appropriate for mitigating concentrated stormwater flows.

Maintenance Considerations

Keeping vegetation healthy in vegetated buffers requires routine maintenance. Depending on species, soil types, and climatic conditions, maintenance can include weed and pest control, mowing, fertilizing, liming, irrigating, and pruning. Inspection and maintenance are most important when buffer areas are first installed. Once established, vegetated buffers do not require maintenance beyond the routine procedures and periodic inspections. Inspect them after heavy rainfall and at least once a year. Focus on encroachment, gully erosion, the density of the vegetation, evidence of concentrated flows through the areas, and any damage from foot or vehicular traffic. If more than 6 inches of sediment has accumulated, remove it.

Effectiveness

Several studies indicate greater than 90 percent reductions in sediment and nitrate concentrations when vegetated buffers are used. Buffer/filter strips do a reasonably good job of removing phosphorus attached to sediment, but they are not so effective at removing dissolved phosphorus (Gilliam, 1994).

References

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Good Housekeeping

United States Environmental Protection Agency

Stormwater Best Management Practice

Concrete Washout

Permits for Clean Water NPDES

Minimum Measure

Construction Site Stormwater Runoff Control

Subcategory

Good Housekeeping/Materials Management

Description of Concrete Washout at Construction Sites

Concrete and its ingredients

Concrete is a mixture of cement, water, and aggregate material. Portland cement is made by heating a mixture of limestone and clay containing oxides of calcium, aluminum, silicon and other metals in a kiln and then pulverizing the resulting clinker. The fine aggregate particles are usually sand. Coarse aggregate is generally gravel or crushed stone. When cement is mixed with water, a chemical reaction called hydration occurs, which produces glue that binds the aggregates together to make concrete.

Concrete washout

After concrete is poured at a construction site, the chutes of ready mixed concrete trucks and hoppers of concrete pump trucks must be washed out to remove the remaining concrete before it hardens. Equipment such as wheelbarrows and hand tools also need to be washed down. At the end of each work day, the drums of concrete trucks must be washed out. This is customarily done at the ready mixed batch plants, which are usually off-site facilities, however large or rural construction projects may have on-site batch plants. Cementitious (having the properties of cement) washwater and solids also come from using such construction materials as mortar, plaster, stucco, and grout.

Environmental and Human Health Impacts

Concrete washout water (or washwater) is a slurry containing toxic metals. It's also caustic and corrosive, having a pH near 12. In comparison, Drano liquid drain cleaner has a pH of 13.5. Caustic washwater can harm fish gills and eyes and interfere with reproduction. The safe pH ranges for aquatic life habitats are 6.5 – 9 for freshwater and 6.5 – 8.5 for saltwater.

Construction workers should handle wet concrete and washout water with care because it may cause skin irritation and eye damage. If the washwater is dumped on the ground (Fig. 1), it can run off the construction site to adjoining roads and enter roadside storm drains, which discharge to surface waters such as rivers, lakes, or estuaries. The red arrow in Figure 2 points to a ready mixed truck chute that's being washed out into a roll-off bin, which isn't watertight. Leaking washwater, shown in the foreground, will likely follow similar

Figure 1. *Chute washwater being dumped on the ground*

Figure 2. *Chute washwater leaking from a roll-off bin being used as a washout container*

paths to nearby surface waters. Rainfall may cause concrete washout containers that are uncovered to overflow and also transport the washwater to surface waters. Rainwater polluted with concrete washwater can percolate down through the soil and alter the soil chemistry, inhibit plant growth, and contaminate the groundwater. Its high pH can increase the toxicity of other substances in the surface waters and soils. Figures 1 and 2 illustrate the need for better washout management practices.

Best Management Practice Objectives

The best management practice objectives for concrete washout are to (a) collect and retain all the concrete washout water and solids in leak proof containers, so that this caustic material does not reach the soil surface and then migrate to surface waters or into the ground water, and (b) recycle 100 percent of the collected concrete washout water and solids. Another

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objective is to support the diversion of recyclable materials from landfills. Table 1 shows how concrete washout materials can be recycled and reused.

Table 1 – Recycling concrete washout materials

Uses of Recycled Materials	Concrete Washout Materials					
	Washwater	Cement fines[a]	Fine aggregate	Coarse aggregate	Hardened concrete	Unused wet concrete
Reused to washout additional mixer truck chutes or drums	x					
Reused as a ready mixed concrete ingredient	x	x[b]	x	x		
Reused as an ingredient of precast concrete products, e.g., highway barriers, retaining wall blocks, riprap	x	x	x	x		x
Reused as crushed concrete products, e.g., road base or fill		x	x	x	x	
Reused to pave the yards of ready mixed concrete plants						x
Returned back to a surface water, e.g., river, lake, or estuary	x[c]					

a. Fine particles of cementitious material (e.g., Portland cement, slag cement, fly ash, silica fume)

b. Recyclable, if allowed by the concrete quality specifications

c. Treated to reduce the pH and remove metals, so it can be delivered to a municipal wastewater treatment plant, where it is treated further and then returned to a natural surface water

Washwater recycling, treatment, disposal

Washwater from concrete truck chutes, hand mixers, or other equipment can be passed through a system of weirs or filters to remove solids and then be reused to wash down more chutes and equipment at the construction site or as an ingredient for making additional concrete. A three chamber washout filter is shown in Figure 3. The first stage collects the coarse aggregate. The middle stage filters out the small grit and sand. The third stage has an array of tablets that filter out fines and reduces the pH. The filtered washwater is then discharged through a filter sock. An alternative is to pump the washout water out of the washout container (Fig 4) and treat the washwater off site to remove metals and reduce its pH, so it can be delivered to a publicly owned treatment works (POTW), also known as a municipal wastewater treatment plant, which provides additional treatment allowing the washwater to be discharged to a surface water. The POTW should be contacted to inquire about any pretreatment requirements, i.e., the National Pretreatment Standards for Prohibited Dischargers (40CFR 403.5) before discharging the washwater to the POTW. The washwater can also be retained in the washout container and allowed to evaporate, leaving only the hardened cementitious solids to be recycled.

Figure 3. *Concrete washout filter*

Figure 4. *Vacuuming washwater out of a washout container for treatment and reuse*

Solids recycling

The course aggregate materials that are washed off concrete truck chutes into a washout container can be either separated by a screen and placed in aggregate bins to be reused at the construction site or returned to the ready mixed plant and washed into a reclaimer (Fig. 5). When washed out into a reclaimer, the fine and course aggregates are separated out and placed in different piles or bins to be reused in making fresh concrete. Reclaimers with settling tanks separate cement fines from the washwater, and these fines can also be used in new concrete unless prohibited by the user's concrete quality specifications.

Figure 5. *Ready mixed truck washing out into a reclaimer*

Hardened concrete recycling

When the washwater in a construction site concrete washout container has been removed or allowed to evaporate, the hardened concrete that remains can be crushed (Fig. 6) and reused as a construction material. It makes an excellent aggregate for road base and can be used as fill at the construction site or delivered to a recycler. Concrete recyclers can be found at municipal solid waste disposal facilities, private recycling plants, or large construction sites.

Figure 6. *Crushed concrete stockpile and crusher*

Wet concrete recycling

Builders often order a little more ready mixed concrete than they actually need, so it is common for concrete trucks to have wet concrete remaining in their drum after a delivery. This unused concrete can be returned to the ready mixed plant and either (1) used to pour precast concrete products (e.g., highway barriers, retaining wall blocks, riprap), (2) used to pave the ready mixed plant's yard, (3) washed into a reclaimer, or (4) dumped on an impervious surface and allowed to harden, so it can be crushed and recycled as aggregate. Unused wet concrete should not be dumped on bare ground to harden at construction sites because this can contribute to ground water and surface water contamination.

Washout Containers

Different types of washout containers are available for collecting, retaining, and recycling the washwater and solids from washing down mixed truck chutes and pump truck hoppers at construction sites.

Chute washout box

A chute washout box is mounted on the back of the ready mixed truck. If the truck has three chutes, the following procedure is used to perform the washout from the top down: (1) after the pour is completed, the driver attaches the extension chute to the washout box, (2) the driver then rotates the main chute over the extension chute (Fig. 7) and washes down the hopper first then the main chute, (3) finally the driver washes down the flop down chute and last the extension chute hanging on the box. All washwater and solids are captured in the box. After the wash down, washwater and solids are returned to the ready mixed plant for recycling. A filter basket near the top of the washout box separates out the coarse aggregates so they can be placed in a bin for reuse either at the construction site or back at the cement plant.

Figure 7. *Chute washout box*

Chute washout bucket and pump

After delivering ready mixed concrete and scraping the last of the customer's concrete down the chute, the driver hangs a washout bucket shown in Figure 8 (see red arrow) on the end of the truck's chute and secures the hose to insure no leaks. The driver then washes down the chute into the bucket to remove any cementitious material before it hardens. After washing out the chute, the driver pumps (yellow arrow points to the pump) the washwater, sand, and other fine solids from the bucket up into the truck's drum to be returned to the ready mixed plant, where it can be washed into a reclaimer. A removable screen at the bottom of the washout bucket prevents course aggregate from entering the pump. This course aggregate can also be returned to the plant and added to the coarse aggregate pile to be reused. All the materials are recycled.

Figure 8. *Chute washout bucket and pump*

Hay bale and plastic washout pit

A washout pit made with hay bales and a plastic lining is shown in Figure 9. Such pits can be dug into the ground or built above grade. The plastic lining should be free of tears or holes that would allow the washwater to escape (Fig. 10). After the pit is used to wash down the chutes of multiple ready mixed trucks and the washwater has evaporated or has been vacuumed off, the remaining hardened solids can be broken up and removed from the pit. This process may damage the hay bales and plastic lining. If damage occurs, the pit will need to be repaired and relined with new plastic. When the hardened solids are removed, they may be bound up with the plastic lining and have to be sent to a landfill, rather than recycled. Recyclers usually accept only unmixed material. If the pit is going to be emptied and repaired more than a few times, the hay bales and plastic will be generating additional solid waste. Ready mixed concrete

Figure 9. *Hay bale and plastic washout pit*

Figure 10. *Leaking washout pit that has not been well maintained*

trucks can use hay bale washout pits, but concrete pump trucks have a low hanging hopper in the back that may prevent their being washed out into bale-lined pits.

Vinyl washout container

Figure 11. *Vinyl washout pit with filter bag*

The vinyl washout container (Fig. 11) is portable, reusable, and easier to install than a hay bale washout pit. The biodegradable filter bag (Fig. 12) assists in extracting the concrete solids and prolongs the life of the vinyl container. When the bag is lifted, the water is filtered out and the remaining concrete solids and the bag can be disposed of together in a landfill, or the hardened concrete can be delivered to a recycler. After the solids have been removed several times and the container is full of washwater, the washwater can be allowed to evaporate, so the container can be reused. The washwater can be removed more quickly by placing another filter bag in the container and spreading water gelling granules evenly across the water. In about five minutes, the water in the filter bag will turn into a gel that can be removed with the bag. Then the gel and filter bag can be disposed to together.

Figure 12. *Extracting the concrete solids or gelled washwater*

Metal washout container

The metal roll-off bin (Fig. 13) is designed to securely contain concrete washwater and solids and is portable and reusable. It also has a ramp that allows concrete pump trucks to wash out their hoppers (Fig. 14). Roll-off providers offer recycling services, such as, picking up the roll-off bins after the washwater has evaporated and the solids have hardened, replacing them with empty washout bins, and delivering the hardened concrete to a recycler (Fig. 15), rather than a landfill. Some providers will vacuum off the washwater, treat it to remove metals and reduce the pH, deliver it to a wastewater treatment plant for additional treatment and subsequent discharge to a surface water. Everything is recycled or treated sufficiently to be returned to a natural surface water.

Figure 13. *Mixer truck being washed out into a roll-off bin*

Figure 14. *Pump truck using the ramp to wash out into a roll-off bin*

Figure 15. *Delivering hardened Concrete to a recycler*

Another metal, portable, washout container, which has a rain cover to prevent overflowing, is shown in Figure 16. It is accompanied by an onsite washwater treatment unit, which reduces the pH and uses a forced weir tank system to remove the coarse aggregate, fine aggregate, and cement fines. The washwater can then be reused at the construction site to wash out other mixer truck chutes and equipment. The solids are allowed to harden together and can be taken to a concrete recycler (Fig. 17) to be crushed and used as road base or aggregate for making precast products, such as retaining wall blocks. All materials are recycled.

Figure 16. *Washout container with a rain cover and onsite washwater treatment*

Figure 17. *Delivering hardened concrete to a recycler*

Siting Washout Facilities

Concrete washout facilities, such as washout pits and vinyl or metal washout containers, should be placed in locations that provide convenient access to concrete trucks, preferably near the area where concrete is being poured. However they

should not be placed within 50 feet of storm drains, open ditches, or waterbodies. Appropriate gravel or rock should cover approaches to concrete washout facilities when they are located on undeveloped property. On large sites with extensive concrete work, washouts should be placed at multiple locations for ease of use by ready mixed truck drivers. If the washout facility is not within view from the pour location, signage will be needed to direct the truck drivers.

Operating and Inspecting Washout Facilities

Concrete washout facilities should be inspected daily and after heavy rains to check for leaks, identify any plastic linings and sidewalls have been damaged by construction activities, and determine whether they have been filled to over 75 percent capacity. When the washout container is filled to over 75 percent of its capacity, the washwater should be vacuumed off or allowed to evaporate to avoid overflows. Then when the remaining cementitious solids have hardened, they should be removed and recycled. Damages to the container should be repaired promptly. Before heavy rains, the washout container's liquid level should be lowered or the container should be covered to avoid an overflow during the rain storm.

Educating Concrete Subcontractors

The construction site superintendent should make ready mixed truck drivers aware of washout facility locations and be watchful for improper dumping of cementitious material. In addition, concrete washout requirements should be included in contracts with concrete delivery companies.

Reference

NRMCA 2009. Environmental Management in the Ready Mixed Concrete Industry, 2PEMRM, 1st edition. By Gary M. Mullins. Silver Springs, MD: National Ready Mixed Concrete Association.

Websites and Videos

Construction Materials Recycling Association
www.concreterecycling.org

National Ready Mixed Concrete Association
www.nrmca.org

National Ready Mixed Concrete Research and Education Foundation
www.rmc-foundation.org

Additional information and videos on concrete washout containers and systems can be found by a web search for "concrete washout."

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Spill Prevention and Control Plan **EPA NPDES Fact Sheets**

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Minimum Measure: Construction Site Stormwater Runoff Control

Subcategory: Good Houskeeping/Materials Management

Absorbent snakes can be used to protect storm drains from spills (Spill911, no date)

Description

Spill Prevention and Control Plans (SPCP) should clearly state measures to stop the source of a spill, contain the spill, clean up the spill, dispose of contaminated materials, and train personnel to prevent and control future spills.

Applicability

SPCPs are applicable to construction sites where hazardous wastes are stored or used. Hazardous wastes include pesticides, paints, cleaners, petroleum products, fertilizers, and solvents.

Siting and Design Considerations

When developing an SPCP, a construction site operator should identify potential spill or source areas, such as loading and unloading, storage, and processing areas; places where dust or particulate matter is generated; and areas designated for waste disposal. Also, evaluate spill potential for stationary facilities, including manufacturing areas, warehouses, service stations, parking lots, and access roads. Conduct this evaluation during the project planning phase, and reevaluate it during each phase of construction.

The SPCP should define material handling procedures and storage requirements and outline

actions necessary to reduce spill potential and impacts on stormwater quality. This can be achieved by:

- Recycling, reclaiming, or reusing process materials, thereby reducing the amount of process materials that are brought into the facility
- Installing leak detection devices, overflow controls, and diversion berms
- Disconnecting any drains from processing areas that lead to the storm sewer
- Performing preventative maintenance on storm tanks, valves, pumps, pipes, and other equipment
- Using material transfer procedures or filling procedures for tanks and other equipment that minimize spills
- Substituting less or non-toxic materials for toxic materials

The SPCP should document the locations of spill response equipment and procedures to be used and ensure that procedures are clear and concise. The plan should include step-by-step instructions for the response to spills at a facility. In addition, the spill response plan should:

- Identify individuals responsible for implementing the plan
- Define safety measures to be taken with each kind of waste
- Specify how to notify appropriate authorities, such as police and fire departments, hospitals, or municipal sewage treatment facilities for assistance
- State procedures for containing, diverting, isolating, and cleaning up the spill
- Describe spill response equipment to be used, including safety and cleanup equipment

The plan can be a procedural handbook or a poster to be placed in several locations at the site.

Limitations

Training is necessary to ensure that all workers are knowledgeable enough to follow procedures outlined in the SPCP. Make equipment and materials for cleanup readily accessible, and mark them clearly so workers can follow procedures quickly and effectively.

Maintenance Considerations

Update the SPCP regularly to accommodate any changes in the site, procedures, or responsible staff. Conduct regular inspections in areas where spills might occur to ensure that procedures are posted and cleanup equipment is readily available.

Effectiveness

An SPCP can be highly effective at reducing the risk of surface and ground water contamination; however, to ensure that procedures are followed, a construction site operator should provide worker training, appropriate materials and equipment for cleanup, and adequate staff time.

Cost Considerations

Spill prevention and control plans can be inexpensive to implement; however, adequate time and resources are needed to properly handle and dispose of spills.

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