URBAN BMP COST AND EFFECTIVENESS

SUMMARY DATA

FOR 6217(g) GUIDANCE

EROSION AND SEDIMENT CONTROL DURING CONSTRUCTION

January 29, 1993

WOODWARD-CLYDE

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LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

In November 1990, the U.S Congress passed the Coastal Zone Act Reauthorization and Amendments (CZARA). As part of this reauthorization, Congress created a new, distinct program to address nonpoint source (NPS) pollution of coastal waters (Section 6217). The U.S. Environmental Protection Agency (EPA) and the National Oceanic and Atmospheric Administration (NOAA) jointly drafted Proposed Program Guidance for Section 6217 of CZARA. EPA was given the lead responsibility for developing the Management Measures Guidance required under Section 6217(g).

EPA established five Federal/State Work Groups to assist in preparation of the 6217(g) Guidance. Woodward-Clyde has supported the Urban Work Group through the collection and analysis of information on Best Management Practices (BMPs) used to control urban NPS pollution. The results of these efforts include four books that present cost and effectiveness information on BMPs for:

- Erosion and Sediment Control;
- Post Construction Runoff;
- Onsite Sewage Disposal Systems; and
- Roads, Highways and Bridges.

This report is a summary of the cost and pollutant removal effectiveness information that was gleaned from published literature regarding erosion and sediment controls during construction. The report also contains recommended management practices and systems of management practices for the control of NPS pollution from construction activities.

This document contains information collected from 30 documents. The documents were obtained through literature sources, and telephone contacts with all states and territories with approved Coastal Zone Management Plans. Cost and effectiveness data from the various management practices presented in the documents were reviewed and analyzed to develop summary information for the various BMPs. Data were omitted from consideration where substandard field technique was used in the collection of the data or if results were influenced by atypical climatological or site characteristics (e.g. unusually heavy rainfall or prolonged drought). Also, this analysis only considered BMPs that have been implemented in the field. Experimental practices only applied in a research setting were not considered.

This report contains descriptions of the management practices considered, summary cost and effectiveness information, and recommended practices for use in erosion and sediment control. The Appendix contains the data that were analyzed to develop the summary cost and effectiveness information.

INDEX

MANAGEMENT PRACTICE	PRACTICE DESCRIPTION	PRACTICE EFFECTIVENESS	PRACTICE COST
SEDIMENT CONTROL PRACTICES			
• Construction Entrances	Page 2-8	Page 2-15	Page 2-20
• Filter Fabric Fence	Page 2-7	Page 2-14	Page 2-19
• Inlet Protection	Page 2-8	Page 2-14	Page 2-20
• Sediment Basins	Page 2-6	Page 2-13	Page 2-19
• Sediment Traps	Page 2-7	Page 2-14	Page 2-19
• Straw Bale Barrier	Page 2-7	Page 2-14	Page 2-20
• Vegetative Filter Strips	Page 2-8	Page 2-15	Page 2-20

2.0
EFFECTIVENESS AND COST SUMMARY

This section presents descriptions of the types of Erosion and Sediment Control management practices considered, where and when the application of these practices are appropriate, and the cost and effectiveness of these systems. Although CZARA only regulates construction sites less than 5 acres (NPDES permits apply to sites greater than 5 acres), this document addresses erosion and sediment controls during construction that could be implemented for any size construction site.

Over 30 documents were reviewed to develop summary effectiveness and cost data for erosion and sediment controls. It should be noted that the documents obtained and reviewed do not include all of the published literature regarding erosion and sediment control management practices. However, many of the documents obtained were summaries of many other investigations and the most widely used erosion and sediment control documents were reviewed. The influence of soil type, drainage area, slope and many other site specific factors on effectiveness of erosion and sediment controls are discussed. The effectiveness does not vary greatly regionally and therefore few conclusions can be drawn regarding regional influence on performance.

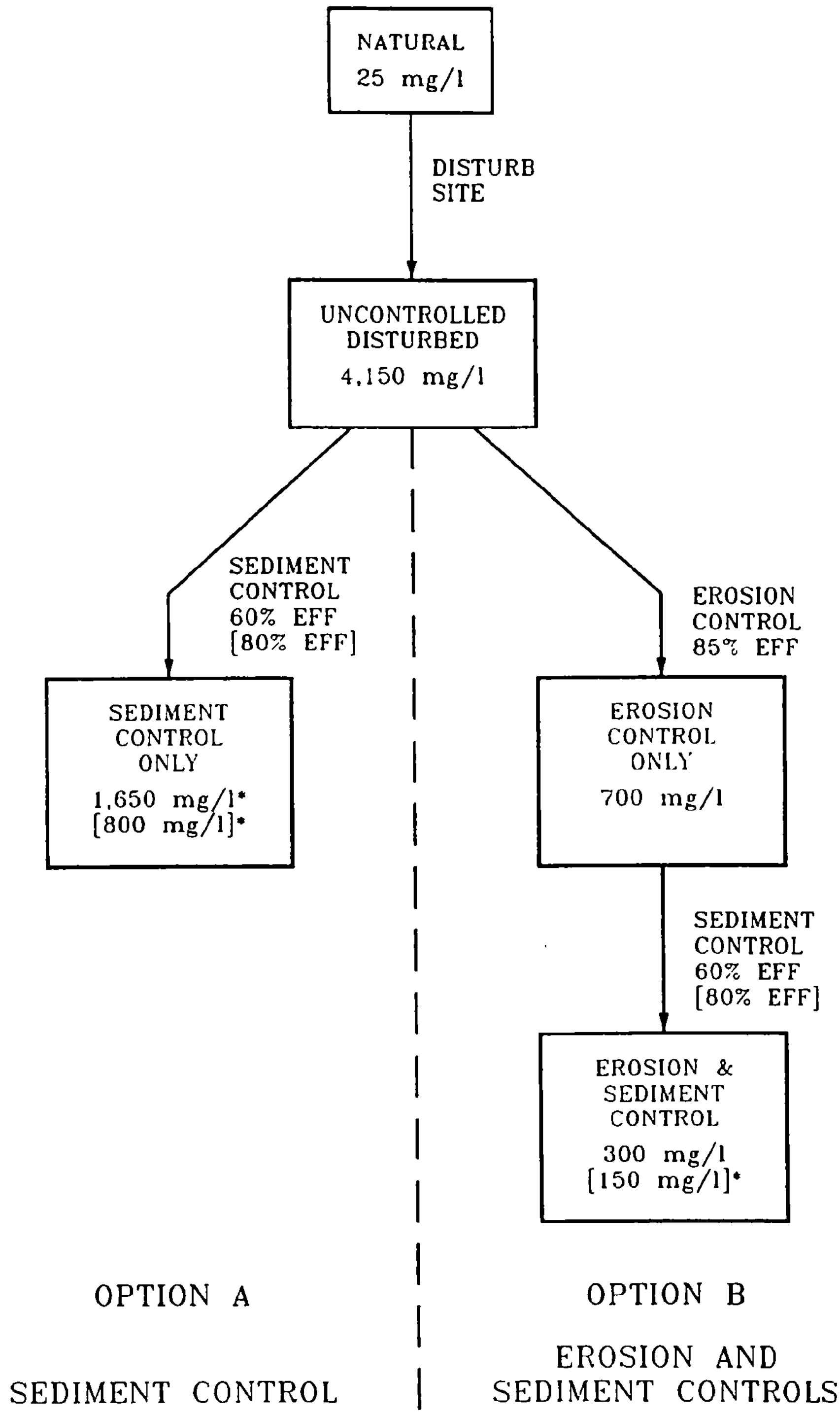
2.1 DESCRIPTION OF EROSION AND SEDIMENT CONTROL MANAGEMENT PRACTICES

The main concern at construction sites is reducing the amount of sediment that leaves the site. Erosion controls are used to reduce the amount of sediment that is detached from the soil and enters the runoff. Sediment controls are used to remove sediment that is in the runoff. As Figure 2-1 illustrates, to effectively reduce the amount of sediment leaving a construction site, erosion controls must be used to prevent the sediment from entering the runoff and sediment controls must be used to remove the sediment which does enter the runoff.

The following is a description of structural and nonstructural erosion and sediment control management practices.

FIGURE 2-1. TSS CONCENTRATIONS FROM MARYLAND CONSTRUCTION SITES

(Schueler et al, 1990)



* Estimated

2.1.1 Erosion Control Practices

Schedule Projects Such that Clearing and Grading Are Done During Time of Minimum Erosion Potential - Often a project can be scheduled during the time of year that the erosion potential of the site is relatively low. In many parts of the country there is a certain period of the year when erosion potential is relatively low and construction scheduling could be very effective, for example in the Pacific region if construction can be completed during the 6 month dry season (May 1 - Oct 31), temporary erosion and sediment controls (ESC) may not be needed. Additionally, some parts of the country have a time of year where erosion potential is very high such as during the spring thaw in northern areas. During this time of year, snowfall generates a constant runoff flow that can carry sediment from bare soil. The soft wet ground is easily turned into mud by construction vehicles that is more easily washed off site. Therefore, in the north, grading should be avoided during the spring thaw. (Goldman et al, 1986)

Stage Construction - Instead of massive clearing of a construction site, clearing should be carefully planned and staged so that only the area being worked on is exposed at any time. As soon as the grading and construction in an area are complete, the area should be stabilized.

Only Clear Areas Essential For Construction - Areas of a construction site are often unnecessarily cleared. Only those areas essential for completing construction activities should be cleared and other areas should remain undisturbed. Additionally, the proposed limits of land disturbance should be physically marked off to ensure they clear only the required land area.

Avoid Disturbing Vegetation On Steep Slopes, Highly Erodible Soils, Or Other Critical Areas - Material stockpiles, borrow areas, access roads and other land disturbing activities can often be located away from critical areas such as steep slopes, highly erodible soils, and areas that drain directly into sensitive water bodies.

Route Construction Traffic To Avoid Existing Or Newly Planted Vegetation - Where possible, construction traffic should travel over areas that must be disturbed for other construction activity. This will reduce the area that is cleared and susceptible to erosion.

Protect Natural Vegetation With Fencing, Tree Armoring, Retaining Walls, Or Tree Wells- Tree armoring protects tree trunks from being damaged by construction equipment. Fencing can also protect tree trunks. The fencing should be placed at the tree's drip line so that construction equipment is kept out of the tree's drip line. The tree drip line is the minimum area around a tree where the tree's root system should not be disturbed by cut, fill, or soil compaction as the result of heavy equipment. When fill or cut must be done near a tree, a retaining wall or tree well should be used to minimize the cutting of the tree's roots or the quantity of fill placed over the tree's roots.

Where Practical Stockpile Topsoil And Reapply To Revegetate Site - Due to the high organic content of topsoil it cannot be used as fill material or under pavement, and therefore after a site is cleared the topsoil is typically removed. Topsoil is essential to establish new vegetation. Consequently, it should be stockpiled and then reapplied to the site for revegetation. Although topsoil salvaged from the existing site can often be used, it must meet certain standards and sometimes topsoil may need to be brought onto the site if the existing topsoil is not adequate for establishing new vegetation.

Cover Or Stabilize Topsoil Stockpiles - Unprotected stockpiles are very prone to erosion and therefore must be protected. Small stockpiles can be covered with a tarp to prevent erosion. Large stockpiles should be stabilized by seeding and/or mulching.

Provide Wind Erosion Controls - These practices control the movement of dust from disturbed soil surfaces and include many different practices. Wind barriers block the air currents and are effective in controlling soil blowing. Many different materials can be used as wind barriers including solid board fence, snow fences and bales of hay. Tillage is also useful in that it scars the soil surface to temporarily prevent or reduce the amount of blowing dust. Sprinkling moistens the soil surface with water and must be repeated as needed to be effective. (Delaware DNR, 1989)

Intercept Runoff Above Disturbed Slopes And Convey It To A Permanent Channel Or Storm Drain - Either earth dikes, perimeter dike/swale or diversions can be used to intercept and convey the runoff. An earth dike is a temporary berm or ridge of compacted soil that channels water to a desired location. A perimeter dike/swale or diversion is a swale with a supporting ridge on the lower side that is constructed from the soil excavated from the adjoining swale (Delaware DNR, 1989). These practices should be used to intercept flow uphill of denuded areas or newly seeded areas to keep the disturbed areas from being eroded from the uphill runoff. The structures should be stabilized within 14 days of installation. A pipe slope drain, also known as a pipe drop structure, is a temporary pipe placed from the top of a slope to the bottom of the slope to convey concentrated surface stormwater down the slope without causing erosion (Delaware DNR, 1989). Pipe slope drains should only be used for small runoff volumes of concentrated flow.

On Long Or Steep Disturbed Or Man-Made Slopes, Construct Benches, Terraces, Or Ditches At Regular Intervals To Intercept Runoff - Benches, terraces, or ditches break up a slope by providing areas of low slope in the reverse direction. This keeps water from proceeding down the slope at increasing volume and velocity. Instead the flow is directed to a suitable outlet (e.g. sediment basin or trap). The frequency of benches, terraces, or ditches will depend on the runoff volume, erodibility of the soils, steepness and length of the slope and rock outcrops. This practice should be used if there is a potential for erosion along the slope.

Retaining Walls - Retaining walls can often be used to decrease the steepness of a slope. By reducing the steepness of a slope, the runoff velocity is decreased and, therefore, the erosion potential is decreased.

Provide Linings For Channels - Construction activities usually increase the velocity and volume of runoff that causes erosion in newly constructed or existing channels. If the runoff during or after construction will cause erosion in a channel, it should be lined. The first choice of lining should be grass or sod since this reduces runoff velocities and provides water quality benefits through filtration and infiltration. If the velocity of the channel would erode the grass or sod then rip-rap, concrete, gabions, or jute netting can be used.

Check Dams - These are small temporary gravel dams constructed across a swale or channel. They are used to reduce the velocity of concentrated flow and, therefore, reduce the erosion in a swale or channel. Check dams should be used when a swale or channel will be used for a short time and therefore it is not feasible or practical to provide a lining to the channel (Delaware DNR, 1989).

Seed - Seeding establishes a vegetative cover on disturbed areas. Seeding is very effective in controlling soil erosion once a thick vegetative cover is established. However, seeding does not always produce as thick and therefore erosion resistant vegetation as seed and mulch or netting. In certain areas, the erosion resistant capacity of seeding can be enhanced by adding fertilizer or by using a drought-resistant seed like wildflower. Since seeding does not provide any protection during the time of vegetative establishment, it should be used only on favorable soils, and very flat areas. Seeding should not be used in sensitive areas. Newly established vegetation does not have as extensive a root system as existing vegetation and therefore is more prone to erosion, especially on steep slopes.

Seed and Mulch - Seeding establishes a vegetative cover on disturbed areas. Seeding is very effective in controlling soil erosion once the vegetative cover is established. The mulching protects the disturbed area prior to the vegetation being established.

Mulching - Mulching involves applying plant fiber residues or other suitable materials on the disturbed soil surfaces. Blankets or nettings are often used. Mulching includes tacked straw, wood chips, jute netting, Excelsior blanket, as well as many other types. Mulching alone should only be used for temporary protection of the soil surface, or when permanent seeding is not feasible. The useful life of mulch varies with the material used and the amount of precipitation. The useful life is approximately 2 to 6 months.

Sodding - Sodding permanently stabilizes an area. Sodding provides immediate stabilization of an area and should be used in critical areas, or where establishment of permanent vegetation by seeding and mulching would be difficult. Sodding is also a preferred option when there is a high erosion potential during the period of vegetative establishment from seeding. However, because of the high cost of sodding, it is typically only used in critical areas where establishment of permanent vegetation by seeding and mulching would be difficult, or where there is a high erosion potential during the period of vegetative establishment from seeding.

2.1.2 Sediment Control Practices

Sediment Basins - Sediment basins, also known as silt basins, are engineered impoundment structures that allow sediment to settle out of the stormwater runoff. Sediment basins are installed prior to full scale grading and remain in place until the drainage area is fully stabilized. They are generally located at the low point of sites, away from construction traffic, where they will be able to trap sediment ladened runoff.

Sediment basins are typically used for drainage areas between 5 and 100 acres. They can be classified as either temporary or permanent structures depending on the length of service of the structure. If they are designed to function less than 36 months they are classified as "temporary," otherwise they are considered as permanent structures. Temporary sediment basins can also be converted into permanent stormwater management ponds. When sediment basins are designed as permanent structures, they must meet all standards for ponds, such as SCS Standards and Specifications No. 378.

Sediment Traps - Sediment traps are small impoundments that allow sediment to settle out of the runoff water. Sediment traps are typically 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. Sediment traps should not be used for drainage areas greater than 5 acres and they have a useful life of approximately 18 to 24 months.

Filter Fabric Fence - Filter fabric fence is available from many manufacturers and in several mesh sizes. Filter fabric fence traps sediment particles and decreases velocities on denuded slopes as stormwater runoff flows through the fabric.

Filter fabric fences should only be used where there is sheet flow (i.e. no concentrated flow), and the maximum drainage area to the fence should be 0.5 acre or less per 100 feet of fence. Filter fabric fences have a useful life of approximately 6 to 12 months.

Straw Bale Barrier - A straw bale barrier is a row of anchored straw bales that detain and filter stormwater runoff. Straw bales are less effective than filter fabric, which can usually be used in place of straw bales.

As with filter fabric fences, straw bale barriers should only be used where there is sheet flow. The maximum drainage area to the barrier should be 0.25 acre or less per 100 feet of barrier. The useful life of straw bales is approximately 3 months.

Inlet Protection - Inlet protection consists of a barrier placed around a storm drain drop inlet. It traps sediment before it enters the storm sewer system. Filter fabric, straw bales, gravel, or sand bags are often used for inlet protection.

Construction Entrances - Construction entrances are pads of gravel over filter cloth or steel bar grates. These are located where traffic leaves a construction site. As the vehicles drive over the gravel or steel bars, mud and sediment are collected from the vehicle's wheels.

Vegetative Filter Strips (VFS) - VFS are low-gradient vegetated areas that convey overland sheet flow. Runoff must be evenly distributed across the filter strip. If the water concentrates and forms a channel, the filter strip will not perform properly. Level spreading devices are often used to distribute the runoff evenly across the strip.

Vegetative filter strips should have relatively low slopes, adequate length, and be planted with erosion resistant plant species. The main factors that influence the removal efficiency are the vegetation type, soil infiltration rate, and flow depth and travel time. These factors are dependent on the contributing drainage area, slope of strip, and strip length. Maintenance requirements for VFS include sediment removal and inspections to ensure that dense, vigorous, vegetation is established and the flow does not concentrate.

2.2 EFFECTIVENESS

The main pollutant leaving construction sites is sediment. Therefore, the effectiveness of siltation and erosion control devices has been measured by the reduction of total suspended solids (TSS) over an uncontrolled construction site. It should be noted that these practices are ineffective at controlling soluble pollutants. All of the reported effectiveness data assumes that the controls are properly designed, constructed and maintained. Where sufficient data were available, quantitative assessment of the effectiveness of a practice was included. Table 3-1 (see Section 3) contains quantitative effectiveness information for these practices. The data that were analyzed to draw the effectiveness conclusions are presented in Appendix B. See Section 3 for a discussion regarding the variability of the effectiveness data.

2.2.1 Erosion Control Practices

Erosion control practices are those practices designed to prevent erosion from occurring and minimizing the amount of sediment that is introduced into runoff. These practices include minimizing disturbed areas, diverting offsite surface runoff from disturbed areas, scheduling of construction activities, and stabilization of areas when construction is completed or suspended for a period of time. These types of practices have been found to be more effective at reducing offsite TSS loads than sediment controls alone. Schueler (1990) reported that erosion control can be 85% effective at reducing TSS loads from construction sites where sediment controls are only 60-80% effective.

The effectiveness of erosion control practices can vary based on land slope, area rainfall frequency and intensity, and soil texture. In general, a system of erosion control practices (e.g. scheduling construction for low rainfall seasons, minimizing disturbed area during construction, and stabilization as soon as construction is completed) leads to the most effective control of TSS.

<u>Schedule Project So Clearing and Grading are Done During Time of Minimum Erosion Potential</u> - Erosion rates depend on rainfall intensity (the R factor in the Universal Soil Loss Equation) (Beasley, 1972), therefore reducing the time that soil is exposed to intense rainfall will reduce the erosion rate. In many parts of the country, there is a certain period of the year when erosion potential is relatively low and construction scheduling could be very effective for example: in the Pacific region, if construction can be completed during the 6 month dry season (May 1 - Oct 31), temporary ESC may not be needed; in the Central, Atlantic, and Gulf Coast areas, significant rainfall occurs in very month and scheduling may not be as effective; and in the northern areas of the country, construction should be avoided during the spring thaw period.

<u>Stage Construction</u> - This practice reduces the time that an area is left unstabilized. Reducing the time that an area is disturbed, and subjected to erosion, reduces the amount of erosion from the site.

<u>Only Clear Areas Essential for Construction</u> - Very little erosion occurs on soil with undisturbed natural vegetation and therefore keeping existing natural vegetation is the most

effective form of erosion control. Additionally, the percent reduction in the total land area disturbed will be directly proportional to the reduction in erosion that can be expected from this practice.

Avoid Disturbing Vegetation on Steep Slopes, Highly Erodible Soils, or Other Critical Areas - Erosion rates on steep slopes are high and steep slopes are difficult to stabilize, therefore it is particularly important to keep from disturbing these areas whenever possible. In addition, retention of existing natural vegetation is the most effective form of erosion control and should be used in critical areas.

Route Construction Traffic to Avoid Existing or Newly Planted Vegetation - Avoiding existing vegetation minimizes the area disturbed and avoiding newly planted vegetation assists in the stabilization of a disturbed area.

Protect Natural Vegetation - Fencing and other items can be used to protect existing vegetation. Tree protections are useful erosion and sediment controls because trees shield soil from the impact of falling rain and the root systems hold soil particles in place.

Stockpile Topsoil and Reapply to Revegetate the Site - Topsoil provides a suitable material and therefore assists in vegetation establishment.

Cover or Stabilize Topsoil Stockpiles - If tarps are used to completely cover stockpiles, then erosion and sediment losses are reduced by 100%. However, tarps are only practical for small stockpiles. For large piles, vegetative or other stabilization practices should be employed. The effectiveness for these types of practices was previously presented in this section.

Provide Wind Erosion Controls - The amount of wind erosion that occurs from a site is a function of the soil erodibility related to cloddiness, soil roughness, wind velocity, soil moisture, length in prevailing wind direction, and equivalent quantity of vegetative cover (Beasley, 1972). Wind barriers reduce the length in the prevailing wind direction, tillage scars increase soil roughness, wetting increases soil moisture, and mulching and other surface covers increase equivalent quantity of vegetative cover, all of which reduce the amount of wind erosion from the site.

Intercept Runoff Above Disturbed Slopes and Convey It To A Permanent Channel or Storm Drain - Soil without established vegetation is very susceptible to erosion; and clean water from uphill disturbed areas can cause erosion on denuded areas or newly seeded slopes. Therefore, diverting runoff by using swales, dikes or pipe slope drains will reduce erosion and sediment transport.

On Long or Steep Disturbed or Man-Made Slopes, Construct Benches, Terraces, or Ditches at Regular Intervals to Intercept Runoff - If slope steepness is doubled, while other factors are held constant, the soil loss potential increased 2-1/2 times. If both slope and length are doubled, the soil loss potential increased 4 times. (Goldman, 1986) Therefore, to prevent erosive velocities, the slope should be broken-up into small reaches. Additionally, the use of terraces (either graded or tile outlet) can also lead to the following reductions in erosion losses (from Beasley, 1972):

Land Slope	Reduction in Erosion
1-12%	70%
12-18%	60%
18-24%	55%

Install Check Dams or Provide Linings for Channels Subjected to Erosive Velocities - Construction often increases the volume and velocity of runoff, which causes erosion in newly constructed or existing channels. Therefore, if the channel has an erosive velocity, it can be lined to reduce channel erosion. Another option is to install check dams to reduce the channel velocity. Schwab et al., 1966 presented the following limiting velocity (the channel velocity above which significant erosion occurs) for natural channels:

Channel Bed Material	For Clear Water	Water Transporting Collodial Silts
	Limiting Velocity, feet/sec	Limiting Velocity, feet/sec
Fine sand colloidal	1.50	2.50
Sandy loam noncolloidal	1.75	2.50
Silt loam noncolloidal	2.00	3.00
Alluvial silts noncolloidal	2.00	3.50
Ordinary firm loam	2.50	3.50
Volcanic ash	2.50	3.50
Stiff clay very colloidal	3.75	5.00
Alluvial silts colloidal	3.75	5.00
Shales and hardpans	6.00	6.00
Fine gravel	2.50	5.00
Graded loam to cobbles when noncolloidal	3.75	5.00
Graded silts to cobbles when colloidal	4.00	5.50
Coarse gravel noncolloidal	4.00	6.00
Cobbles and shingles	5.00	5.50

Seed - Seeding is very effective in reducing erosion once the vegetation has been established. However, newly established vegetation does not have as extensive a root system as existing vegetation and therefore is more prone to erosion, especially on steep slopes.

Seed and Mulch - Seeding and mulching is very effective in reducing erosion once the vegetation has been established. The mulch also provides some protection from erosion prior to plant emergence.

Mulching - The effectiveness of mulching is dependant on the type of mulching material, percent slope, and maintenance effort. Mulching is only effective as a temporary control measure.

Sodding - Sodding is very effective for siltation and erosion control. However, because of the high cost of sodding it is typically only used in critical areas, where establishment of permanent vegetation by seeding and mulching would be difficult, or where there is a high erosion potential during the period of vegetative establishment from seeding.

2.2.2 Sediment Control Practices

Sediment control practices by themselves are generally less effective than erosion controls. However, when used in conjunction with erosion control measures, the effectiveness of the entire system can be as high as 95% effective with offsite TSS loads nearing natural erosion levels (Schueler, 1990). The effectiveness of various sediment control devices is influenced the most by the grain size of the eroded material. The practices are much more effective for sand size particles than for fine silt or clay. The continued effectiveness of these structural controls also relies on adequate maintenance (e.g. cleaning out sediment on a routine basis from a sediment trap). It should be noted that when used in conjunction with erosion controls, the size of some sediment control structures (e.g. sediment basin) can be reduced and the structures often need less maintenance.

Sediment Basins - The effectiveness of sediment basins is dependent but not limited to the following factors: (i) geometry of the basins; such as the length to width ratio (the recommended length to width ratio is often 2-1); (ii) volume of the basins (basins are designed to have either a combined settling/storage volume or specific separated settling and storage zones, basins with 2-zone volume are recommended); and, (iii) amount of time the runoff is detained. The effectiveness of sediment basins for the removal of different size particles depends on the particles settling velocity and basins length and depth.

The effectiveness of a sediment basin decreases over time as the storage area fills with sediments. At the minimum, sediment should be removed from the basin when 60% of the volume for ponds with combined settling/storage zone or when 100% of the storage volume for ponds with separated settling and storage zones are filled with sediment.

Sediment Traps - The effectiveness of sediment traps is proportional to the storage volume and the amount of time the runoff is detained. Silt traps are usually designed for a minimum storage volume of 1800 cubic feet per drainage acre (Minnesota PCA, 1989; Firehock, 1991;

City of Austin, 1988; New York SWCS, 1988; Maryland DE, 1983). The effectiveness of a sediment trap decreases over time as the storage area fills with sediment. Therefore, sediment should be removed when it fills half of the capacity of the trap. Also, if the outlet becomes clogged, it should be cleaned and restored to its original flow capacity.

Filter Fabric Fence - The ability of filter fabric fence to filter suspended solids has been shown to vary based on the size (e.g. sand, clay, silt) of the eroded sediment and the apparent opening size of the fabric. Additionally, filter fabric is only effective for treating unconcentrated or sheet flow.

Straw Bale Barrier - Straw bale barriers are considered less effective than filter fabric fence and are often recommended for use only when no other practice is feasible. Silt fences are usually preferable to straw bales because they have a lower failure rate, are more effective, and have a longer useful life (Baumann, 1990 and Tahoe RPA, 1988).

Inlet Protection - No data were found regarding the effectiveness of inlet protection at controlling erosion and sediment pollution from construction sites. However, inlet protection devices often use filter fabric or straw bales; sand bags; or gravel placed around the inlet, which is similar to silt traps. Therefore, the effectiveness of inlet protection was estimated as somewhat less effective than sediment traps, filter fabric fences and straw bale barriers.

Construction Entrance - Construction entrances reduce the amount of mud and sediment leaving the site on the construction vehicle's wheels.

Vegetative Filter Strips (VFS) - Properly designed and functioning VFS effectively remove sediments by the filtering action of the grass and deposition. Forested filter strips appear to be more effective than grassed strips, but a longer length is required for optional removal rates (Schueler, 1987).

2.3 COST

The cost of erosion and sediment controls varies greatly and is dependent upon many factors such as availability and proximity of materials, time of year and labor rates. The summary costs presented in this document were developed from a review of relevant literature. These costs are presented to give planners an idea of the relative cost of one practice to another and are not recommended for use in estimating or bidding construction contracts. Local suppliers and contractors should be contacted for this purpose. Cost data were generally influenced more by proximity to major urban centers than by region. Consequently, regional variation of cost could not be supported by the data obtained. It may be more effective to consider the cost ranges presented as "national" averages and to adjust the cost on a regional basis using published regional cost variation indexes (e.g., the regional cost index published by the Engineering News Record).

Quantitative cost data are presented in Tables 3-1 and 3-2 in Section 3 of this report. Table 3-1 summarizes the capital and annual maintenance cost of the practices. Table 3-2 summarizes the total annual cost, including annualization of the capital cost. The annualized cost was developed using an interest rate of 5% and a maximum construction time of 2 years. The cost data used to develop these summary costs are presented in the Appendix.

The following is a description (both quantitative and qualitative) of the costs that can be expected in implementing various erosion and sediment control management practices.

2.3.1 Erosion Control Practices

Erosion control practices are generally more effective than sediment control practices and they also tend to be less costly. In fact, the cost of some of the practices such as the avoidance of disturbing vegetation on steep slopes or staging construction are minimal. The cost of erosion controls after construction can vary based on the availability of materials and the time of year when construction is completed.

Schedule Projects So Clearing and Grading are Done During Time of Minimum Erosion Potential - There are no construction costs associated with this practice, however, time delay may result in cost to developer due to development loans, bonds, and market requirements. Additionally, fewer structural controls and decreased maintenance may be needed if construction is completed during drier times of year.

Stage Construction - The cost of implementing this practice should be minimal. Possible costs include having to mobilize certain crews more than once. Additionally, less structural controls and maintenance may be required if this practice is implemented.

Only Clear Areas Essential for Construction - The cost for implementing this practice should be minimal to none. Also, less structural controls and maintenance will be required if less area is disturbed, and final site seeding and stabilization costs will be reduced.

Avoid Disturbing Vegetation on Steep Slopes or Other Critical Areas - The cost of this practice should be minimal. The only cost that should be incurred would be additional travel time and length for construction vehicles.

Route Construction Traffic to Avoid Existing or Newly Planted Vegetation - The cost of implementing this practice could include costs for additional access road construction and travel time. Construction road stabilization ranges in cost from $7-$20 per foot with an average cost of $13/foot (see Appendix C for cost data). It should be noted that implementing this practice should reduce final seeding and site stabilization costs.

Protect Natural Vegetation - The cost of this practice is low and it preserves site aesthetics that may boost or enhance sales for newly constructed developments.

Stockpile Topsoil and Reapply to Revegetate the Site - The cost should be minimal if stockpile area is available and final site seeding costs may be reduced.

Cover or Stabilize Topsoil Stockpiles - Tarp costs vary with size and material. Local vendors should be contacted to obtain actual costs. The cost of using tarps becomes prohibitive when the size of the stockpile increases. For larger stockpiles, the most economic approach is to stabilize the pile with vegetation or mulch.

Provide Wind Erosion Controls - Depending on the amount of control necessary, the cost of wind erosion control practices can vary greatly. The most inexpensive control would be to scar the soil surface to increase roughness. Costs of various mulching materials (e.g, straw) are presented in Tables 3-1 and 3-2 in Section 3. The cost of windbreaks would include the costs of the plants, etc. and the labor for installation.

Intercept Runoff from Disturbed Slopes and Convey It to a Permanent Channel or Storm Drain - The costs for this practice would include construction costs for the intercepting structure (e.g., diversion, dike, swale, or pipe slope drain). The following are estimated costs/linear foot for various runoff intercepting devices (see Appendix C for detailed cost data):

Device	Avg. Cost/Linear Foot	Cost Range Per Linear Foot
Dike	$4	$3 - $5
Diversion	$6	$2 - $12
Swale	$5	$1 - $10
Pipe Slope Drain	$11	$7 - $15

On Long or Steep Disturbed or Man-Made Slopes, Construct Benches, Terraces, or Ditches at Regular Intervals to Intercept Runoff - Terraces and ditches can usually be constructed for about $5/linear foot. This varies based on the amount of earthwork required to complete the device. Bench construction costs include the cost of earthwork and steep slope stabilization.

Install Check Dams or Provide Linings for Channels Subjected to Erosive Velocities - A check dam can usually be constructed for about $500 with the cost ranging from $400 to $600 each (see Appendix C for detailed cost information). The costs for lining channels varies with the type of lining selected. The following are costs for various types of lining:

grass swale: $3-$7/yd^2
sod swale: $8-$12/yd^2
non-grouted rip rap: $35-$50/yd^2
grouted rip rap: $45-$60 yd^2
concrete: $25-$30/yd^2

Seed And Mulch - The cost of seeding alone is approximately one-fourth of the cost of seeding and mulching. However, mulching should typically be done with seeding to protect the area during the period of vegetation establishment.

Mulching - The cost of mulching is comparable to the cost of seeding and mulching. Mulching alone should only be used for temporary protection of the soil surface, or when permanent seeding is not feasible.

Sodding - The cost of sodding is six-times greater than the cost of seeding and mulching. However, sodding is typically done on smaller areas where establishment of permanent vegetation would be difficult or where there is a high erosion potential during the period of vegetative establishment from seeding.

2.3.2 Sediment Control Practices

Sediment control practices tend to cost more than erosion control practices. However, the size of the sediment control structure and maintenance cost can be reduced if it is used in conjunction with erosion control practices. Factors that have the greatest influence on the size and consequently the cost of a structure are drainage area, local rainfall and soil type. These factors influence the amount of runoff and eroded material that must be detained in the structure.

Sediment Basins - The cost of sediment basins is directly related to the volume of the basin. Due to economy of scale, the cost per unit storage decreases as the size of the pond increases. The annual maintenance cost of sediment basins is higher than sediment traps due to maintenance required for the outlet structure.

Sediment Traps - The cost per cubic foot of storage of a sediment trap will vary depending upon how much excavation is needed to obtain the required volume. To report the cost of sediment traps per drainage acre, the trap volume was assumed to be 1800 cubic foot of storage per acre, which is equivalent to 0.5 inches of runoff per acre.

Filter Fabric Fence - In order to report the cost of filter fabric fence per drainage acre, it was assumed that the fence served the maximum allowable area (0.5 acre per 100 feet of fence).

The annual maintenance cost of the filter fabric fence is based on removing accumulated sediment plus replacing the silt fence every 6 months.

Straw Bale Barriers - The cost of straw bale barriers per drainage acre was developed by assuming that the straw bale barrier served the maximum allowable area (0.25 acre per 100 feet of fence). Note, while the cost per linear foot of straw bale barrier is comparable to filter fabric fence, the cost per drainage acre is more than twice that of filter fabric fence.

The annual maintenance cost of straw bale barriers is based on the removal of accumulated sediment and the replacement of the straw bales every 3 months.

Inlet Protection - Many different materials can be used for inlet protection, such as gravel, sand bags and silt fence. The cost per inlet protection is generally in the range of $50-$150 for construction depending on the material used.

Construction Entrance - The costs of constructing construction entrances can vary from $400 to $4,000 with an average cost of about $1,300 (see Appendix C for detailed cost data). A wash rack can also be constructed at the entrance for about $500-$1,000.

Vegetative Filter Strip - The cost of VFS is dependent on the type of vegetation. If the natural vegetation is maintained, the cost is minimal.

Generally, an area that will serve as a VFS should not be cleared and graded, since it is more effective if the natural vegetation is maintained. A VFS should only be seeded or sodded if the area is disturbed for the associated development, otherwise it should remain undisturbed. Therefore, the cost of VFS is assumed only to include the cost for sod or seed and any cost for clearing and grading is a cost associated with site development and not installation of the practice.

3.0
EFFECTIVENESS AND COST SUMMARY TABLES

This section presents quantitative effectiveness and cost summary tables (Tables 3-1 and 3-2) for various erosion and sediment control management practices. These summary tables are based on the detailed effectiveness and cost data presented in the Appendix B and C, respectively. It should be noted that only practices that had enough quantitative data on which to base conclusions are presented in the tables.

Table 3-1 presents both cost and effectiveness information. The effectiveness information includes the average, the range observed in the reviewed literature, the probable range expected from a properly designed and maintained practice, and the references considered in developing the data.

During the literature search for this project, it was apparent that there have been a limited number of monitoring studies completed regarding the effectiveness of these management practices. The results of the studies that were available are summarized in Table 3-1. However, performance monitoring studies are difficult to compare due to the differences in the studies. The following variables are involved in BMP performance monitoring (Schueler, 1992):

- Number of storms monitored
- Type and size of storm monitored
- BMP design variations
- Monitoring technique used
- Pollutant removal calculation technique used
- Seasons monitored
- Characteristics of contributing watershed

It is also difficult to quantify the pollutant removal capabilities of a BMP because the performance varies from storm to storm. The pollutant removal capabilities of a BMP will also vary during the BMP's lifetime (Schueler, 1992).

The cost information is presented in Table 3-1 in terms of capital (including construction) cost and annual maintenance cost. Table 3-2 presents annualized cost information so that comparisons can be made from one practice to another. These costs are presented to give planners an idea of the relative cost of one practice to another and are not recommended for use in estimating or bidding construction contracts.

TABLE 3-1. ESC QUANTITATIVE EFFECTIVENESS AND COST SUMMARY

PRACTICE	DESIGN CONSTRAINTS OR PURPOSE	PERCENT REMOVAL OF TSS	USEFUL LIFE (years)	CONSTRUCTION COST	ANNUAL MAINTENANCE COST (as % construction cost)	TOTAL ANNUAL COST
EROSION CONTROL PRACTICES:						
Seed	Establish vegetation on disturbed area.	After vegetation established- Ave: 90% Observed Range: 50% - 100% References: SCS, 1985 cited in EPA, 1991; Minnesota Pollution Control Agency, 1989; Oberts, 1984 cited in City of Austin, 1988; Delaware Department of Natural Resources, 1989	2*	Ave: $400 per acre Range: $200 - $1000 per acre References: Wisconsin DOT cited in SWRPC, 1991; SWRPC, 1991; Goldman, 1986; Virginia, 1980	Ave: 20% Range: 15% - 25% References: Wisconsin DOT cited in SWRPC, 1991; SWRPC, 1991	$300 per acre
Seed & Mulch	Establish vegetation on disturbed area.	After vegetation established- Ave: 90% Observed Range: 50% - 100% References: SCS, 1985 cited in EPA, 1991; Minnesota Pollution Control Agency, 1989; Oberts, 1984 cited in City of Austin, 1988; Delaware Department of Natural Resources, 1989	2*	Ave: $1,500 per acre Range: $800 - $3,500 per acre References: Goldman, 1986; Washington DOT, 1990; NC State, 1990; Schueler, 1987; Virginia, 1980; SWRPC, 1991	Ave: na (1) Range: na References: None	$1,100 per acre

TABLE 3-1. ESC QUANTITATIVE EFFECTIVENESS AND COST SUMMARY (cont'd)

PRACTICE	DESIGN CONSTRAINTS OR PURPOSE	PERCENT REMOVAL OF TSS	USEFUL LIFE (years)	CONSTRUCTION COST	ANNUAL MAINTENANCE COST (as % construction cost)	TOTAL ANNUAL COST
Mulch	Temporary stabilization of disturbed area.	Observed Range: sand: 20% slope / 50% slope woodfiber @ 1500 lb/ac: 50-60% / 0-20% woodfiber @ 3000 lb/ac: 50-85% / 50-70% straw @ 3000 lb/ac: 90-100% / 95% Silt-loam: 20% slope / 50% slope woodfiber @ 1500 lb/ac: 20-60% / 40-60% woodfiber @ 3000 lb/ac: 60-90% / 60-70% straw @ 3000 lb/ac: 80-95% / 70-90% Silt-clay-loam: 10-30% slope / 30-50% slope woodfiber @ 1500 lb/ac: 5% / – woodfiber @ 3000 lb/ac: 40% / – jute netting: 30-60% / 30% straw @ 3000 lb/ac: 40-70% / 20-40% woodchips @ 10,000 lb/ac: 60-80% / 50-60% mulch blanket: 60-80% / 50-60% Excelsior blanket: 60-80% / 50-60% Multiple treatment (straw & jute): 90% / 90% References: Minnesota Pollution Control Agency, 1989; Kay, 1983 cited in Goldman, 1986	Straw Mulch: 0.25 Woodfiber Mulch: 0.33 Jute Netting: 0.33 Straw and Jute: 0.33	Straw Mulch: Ave: $1,700 per acre Range: $500 - $5,000 per acre References: Wisconsin DOT cited in SWRPC, 1991; Washington DOT, 1990; Virginia, 1980 Woodfiber Mulch: Ave: $1,000 per acre Range: $100 - $2,300 per acre References: Washington DOT, 1990; Virginia, 1980 Jute Netting: Ave: $3,700 per acre Range: $3,500-$4,100 per acre References: Washington DOT, 1990; Virginia, 1980 Straw & Jute: Ave: $5,400 per acre Range: $4,000-$9,100 per acre References: Washington DOT, 1990; Virginia, 1980	Ave: na (1) Range: na References: None	Straw Mulch: $7,500 per acre Woodfiber Mulch: $3,500 per acre Jute Netting: $12,500 per acre Straw and Jute: $18,000 per acre

TABLE 3-1. ESC QUANTITATIVE EFFECTIVENESS AND COST SUMMARY (cont'd)

PRACTICE	DESIGN CONSTRAINTS OR PURPOSE	PERCENT REMOVAL OF TSS	USEFUL LIFE (years)	CONSTRUCTION COST	ANNUAL MAINTENANCE COST (as % construction cost)	TOTAL ANNUAL COST
Sod	Immediate erosion protection where there is high erosion potential during vegetative establishment.	Ave: 99% Observed Range: 98% - 99% References: Minnesota Pollution Control Agency, 1989; Pennsylvania, 1983 cited in EPA, 1991	2*	Ave: $0.2 per sq. ft. [$11,300 per acre] Range: $0.1 - $1.1 References: SWRPC, 1991; Schueler, 1987; Virginia, 1980	Ave: 5% Range: 5% References: SWRPC, 1991	$0.2 per sq. ft. $7,500 per acre
Terraces	Breaks up long or steep slopes	Observed Range: Land Slope — Reduction in Erosion 1-12% — 70% 12-18% — 60% 18-24% — 55% Additionally, if the slope steepness is halved, while other factors are held constant, the soil loss potential decreases 2-1/2 times. If both the slope and length or halved, the soil loss potential is decreased 4 times. References: Goldman, 1986; Beasley, 1972	2*	Ave: $5 per lin. ft. Range: $1 - $12 References: SWRPC, 1991; Goldman, 1986; Virginia, 1991	Ave: 20% Range: 20% References: SWRPC, 1991	$4 per lin. ft.
All Erosion Controls	Reduce amount of sediment entering runoff	Ave: 85% Observed Range: 85% References: Schueler, 1990	—	Varies but typically low	Varies but typically low	Varies but typically low

TABLE 3-1. ESC QUANTITATIVE EFFECTIVENESS AND COST SUMMARY (cont'd)

PRACTICE	DESIGN CONSTRAINTS OR PURPOSE	PERCENT REMOVAL OF TSS	USEFUL LIFE (years)	CONSTRUCTION COST	ANNUAL MAINTENANCE COST (as % construction cost)	TOTAL ANNUAL COST
SEDIMENT CONTROL PRACTICES:						
Sediment Basin	Minimum drainage area = 5 acres, maximum drainage area = 100 acres	Ave: 70% Observed Range: 55% - 100% References: Schueler, 1990; Engle, BW and Jarrett, AR, 1990; Baumann, 1990	2*	Less than 50,000 cu. ft. storage Ave: $0.6 per cu. ft. storage [$1,100 per drainage acre (2)] Range: $0.2 - $1.3 per cu. ft. Greater than 50,000 cu. ft. storage Ave: $0.3 per cu. ft. storage [$550 per drainage acre (2)] Range: $0.1 - $0.4 per cu. ft. References: SWRPC, 1991	Ave: 25% Range: 25% References: Denver COG cited in SWRPC, 1991; SWRPC, 1991	Less than 50,000 cu. ft storage $0.4 per cu. ft. storage $700 per drainage acre (2) Greater than 50,000 cu. ft. storage $0.2 per cu. ft. storage $900 per drainage acre (2)
Sediment Trap	Maximum drainage area = 5 acre	Ave: 60% Observed Range: (-7%) - 100% References: Schueler, et al., 1990; Tahoe Regional Planning Agency, 1989; Baumann, 1990	1.5	Ave: $0.6 per cu. ft storage [$1,100 per drainage acre (2)] Range: $0.2 - $2.0 per cu. ft. References: Denver COG cited in SWRPC, 1991; SWRPC, 1991; Goldman, 1986	Ave: 20% Range: 20% References: Denver COG cited in SWRPC, 1991; SWRPC, 1991	$0.7 per cu. ft. storage $1,300 per drainage acre (2)
Filter Fabric Fence	Maximum drainage area = 0.5 acres per 100 feet of fence. Not to be used in concentrated flow areas.	Ave: 70% Observed Range: 0% - 100% sand: 80% - 99% silt-loam: 50% - 80% silt-clay-loam: 0% - 20% References: Munson, 1991; Fisher, et al., 1984; Minnesota Pollution Control Agency, 1989	0.5	Ave: $3 per lin. ft. [$700 per drainage acre (3)] Range: $1 - $8 per lin. ft. References: Wisconsin DOT cited in SWRPC, 1991; SWRPC, 1991; Goldman, 1986; Virginia, 1991; NC State, 1990	Ave: 100% Range: 100% References: SWRPC, 1991	$7 per lin. ft. $850 per drainage acre (3)

TABLE 3-1. ESC QUANTITATIVE EFFECTIVENESS AND COST SUMMARY (cont'd)

PRACTICE	DESIGN CONSTRAINTS OR PURPOSE	PERCENT REMOVAL OF TSS	USEFUL LIFE (years)	CONSTRUCTION COST	ANNUAL MAINTENANCE COST (as % construction cost)	TOTAL ANNUAL COST
Straw Bale Barrier	Maximum drainage area = 0.25 acres per 100 feet of barrier. Not to be used in concentrated flow areas.	Ave: 70% Observed Range: 70% References: Virginia, 1980 cited in EPA, 1991	0.25	Ave: $4 per lin. ft. [$1,600 per drainage acre (4)] Range: $2 - $6 per lin. ft. References: Goldman, 1986; Virginia, 1991	Ave: 100% Range: 100% References: SWRPC, 1991	$17 per lin. ft. $6,800 per drainage acre (4)
Inlet Protection	Protect storm drain inlet.	Ave: na Observed Range: na References: None	1	Ave: $100 per inlet Range: $50 - $150 References: SWRPC, 1991; Denver COG cited in SWRPC, 1991; Virginia, 1991; EPA cited in SWRPC, 1991	Ave: 60% Range: 20% - 100% References: SWRPC, 1991; Denver COG cited in SWRPC, 1991	$150 per inlet
Construction Entrance	Removes sediment from vehicles wheels.	Ave: na Observed Range: na References: None	2*	Ave: $2,000 each Range: $1,000 - $4,000 References: Goldman, 1986; NC State, 1990 With washrack: Ave: $3,000 each Range: $1,000 - $5,000 References: Virginia, 1991	Ave: na (1) Range: na References: None	$1,500 each $2,200 each

TABLE 3-1. ESC QUANTITATIVE EFFECTIVENESS AND COST SUMMARY (cont'd)

PRACTICE	DESIGN CONSTRAINTS OR PURPOSE	PERCENT REMOVAL OF TSS	USEFUL LIFE (years)	CONSTRUCTION COST	ANNUAL MAINTENANCE COST (as % construction cost)	TOTAL ANNUAL COST
Vegetative Filter Strip	Must have sheet flow.	Ave: 70% Observed Range: 20% - 80% References: Hayes and Hairston, 1983 cited in Casman, 1990; Dillaha, et al., 1989, cited in Glick, et al., 1991; Virginia Department of Conservation, 1987; Nonpoint Source Control Task Force, 1983 cited in Minnesota PCA, 1989; Schueler, 1987	2*	Established from existing vegetation- Ave: $0 Range: $0 References: Schueler, 1987 Established from sod- Ave: $11,300 per acre Range: $4,500 - $48,000 per acre References: Schueler, 1987; SWRPC, 1991	Ave: na Range: na References: None	na

*Useful life estimated as length of construction project (assumed to be 2 years)

na: not available
(1) For Total Annual Cost, assume Annual Maintenance Cost = 20% of construction cost.
(2) Assumes trap volume = 1800 cf/as (=0.5 inches runoff per acre).
(3) Assumes drainage area of 0.5 acre per 100 feet of fence (maximum allowed).
(4) Assumes drainage area of 0.25 acre per 100 feet of barrier (maximum allowed).

TABLE 3-2. ESC ANNUAL COST ESTIMATE

Practice	Capital Cost ($)	Useful Life (Years)	Annual Capital Cost ($)	Annual O&M (% Capital)	Annual O&M ($)	TOTAL ANNUAL COST
Sediment Basin - 12,500 cf storage 40,750 cf storage 196,000 cf storage	 0.80 0.40 0.30	 2* 2* 2*	 0.43 0.22 0.16	 25% 25% 25%	 0.20 0.10 0.08	 $0.6 per cf storage $0.3 per cf storage $0.2 per cf storage
Sediment Trap	0.6 1,100	1.5 1.5	0.6 1,100	20% 20%	0.12 220	$0.7 per cf storage $1,300 per drainage acre (1)
Filter Fabric Fence	3 700	0.5 0.5	6.2 1449	20% 20%	0.6 140	$7 per cf storage $850 per drainage acre (2)
Straw Bale Barrier	4 1,600	0.25 0.25	16.48 6,592	10% 10%	0.4 160	$17 per lin. ft. $6,800 per drainage acre (3)
Seed	400	2*	215	20%	80	$300 per acre
Seed & Mulch	1,500	2*	807	20%	300	$1,100 per acre
Mulch - Straw	1,700	0.25	7,004	25%	425	$7,500 per acre
Mulch - Woodfiber	1,000	0.33	3,130	25%	250	$3,500 per acre
Jute Netting	3,700	0.33	11,581	20%	740	$12,500 per acre
Jute Netting & Straw	5,400	0.33	16,902	20%	1,080	$18,000 per acre
Sod	0.23	2*	0.12	15%	0.03	$0.2 per sq. ft. $7,500 per acre
Inlet Protection	100	1	105	20%	20	$150 per inlet
Terraces	5	2*	2.6	20%	1	$4 per lin. ft.

*Useful life estimated as length of construction project (assumed to be 2 years).
(1) Assumes trap volume = 1800 cf/ac
(2) Assumes drainage area of 0.5 acre per feet of fence (maxiumum allowed)
(3) Assumes drainage area of 0.25 acre per 100 feet of barrier (maximum allowed)

4.0
PREFERRED MANAGEMENT PRACTICES OPTIONS

The primary tool for effectively controlling erosion and sediment from construction activities is a carefully developed comprehensive erosion and sediment control (ESC) plan. This plan should be developed prior to initiating construction activities and should include both erosion controls to prevent the sediment from entering the runoff and sediment controls to remove the sediment that does enter the runoff. The items that should be considered in the development of an erosion and sediment control plan are summarized in Table 4-1.

Erosion controls are source reduction and have the advantage of typically being more effective and less costly than sediment controls. In addition, the use of erosion controls reduces the size and cost of sediment controls required. However, erosion control practices alone cannot usually provide adequate protection for a construction site and therefore, sediment controls are also required. Based on the review and analysis of published ESC effectiveness and cost data, the following management practices should be considered as part of an ESC plan.

a. Time Grading and Construction to Minimize Soil Exposure

1. Schedule projects such that clearing and grading are done during the dry season, or the time of minimum erosion potential. As stated previously, many parts of the country have a time of year when erosion potential is relatively low and construction scheduling could be very effective for example:

   Pacific - if construction can be completed during the 6 month dry season (May 1 - Oct 31), temporary ESC may not be needed.

   Central, Atlantic, Gulf Coast - significant rainfall occurs in every month and this practice may not be effective in these regions.

TABLE 4-1. ITEMS TO CONSIDER IN DEVELOPING AN EROSION AND SEDIMENT CONTROL PLAN

ITEM	DESCRIPTION
Time Grading and Construction to Minimize Soil Exposure	• Schedule projects so clearing and grading are done during the dry season, or the time of minimum erosion potential. Many parts of the country have a time of year when erosion potential is relatively low and construction scheduling could be very effective. • Stage construction so that one area can be stabilized before another is disturbed. This practice reduces the time that an area is left unstabilized.
Retain Existing Vegetation Wherever Feasible	• Clear only those areas that are essential for completing site construction. • Avoid disturbing vegetation on steep slopes or other critical areas and locate material stockpiles, borrow areas, access roads away from critical areas. • Route construction traffic to avoid existing or newly planted vegetation. • Physically mark off limits of land disturbance with tape, signs or barriers. This ensures bulldozer operator knows proposed limits of clearing. • Protect natural vegetation with fencing, tree armoring, retaining walls or tree wells.
Stabilize All Denuded Areas Within 15 Calendar Days After Final Grading. Disturbed Areas That Are Inactive and Will Be Exposed to Rain for 30 Days or More, Should also be Temporarily Stabilized	• During favorable seeding dates and in areas where vegetation can be established, the following should be implemented: - In very flat, non-sensitive area with favorable soils, seeding and fertilizing. - For less erosive soil, on moderately steep slopes with moderately erosive soils in relatively sensitive areas, use seeding and mulching. - For highly erosive soil, very steep slopes, or sensitive areas with highly erosive soils, use seeding with multiple mulching treatments or sodding. • If stabilization is required during time of year that vegetation cannot be established, the following practices shall be implemented: - On moderate slopes or not highly erodible soil mulching should be employed. - On steep slopes or highly erodible soils, multiple mulching treatments should be used. • If in high elevation or desert site where grasses can't survive due to harsh environment at a minimum plant native shrubs. • Before stabilizing an area, make sure necessary controls (e.g., diversion of runoff) are in place. • Where practical stockpile topsoil and reapply to revegetate site. • Cover or stabilize topsoil stockpiles. • For high potential for wind blown sediment transport, prior to stabilization protect with dust controls such as: wind barriers, mulching, tillage, or sprinkling.
Divert Runoff Away from Denuded Areas or Newly Seeded Slopes.	• Above disturbed areas, construct dike or swale or install pipe slope drain to intercept runoff and convey it to a permanent channel or storm drain.
Minimize Length and Steepness of Slopes.	• On long or steep disturbed or man-made slopes, construct benches, terraces, or ditches at regular intervals to intercept runoff.
Prepare Drainageways and Outlets to Handle Concentrated or Increased Runoff.	• Provide lining for any existing or newly constructed channel onsite or offsite so the 2-year storm channel velocity does not cause erosion. • On temporary swales that have erosive velocity but due to their short service life a vegetative lining cannot be established; or if the swale needs protection during establishment of a grass lining, check dams should be installed.
Trap Sediment Onsite (Sediment Controls)	• In areas where greater than 5 acres drain to a point, sediment basins should be installed. • In areas where less than 5 acres of concentrated flow leaves the site, silt traps should be installed. • In areas where sheet flow leaves the site and the drainage area is less than 0.5 ac/100 ft. of flow, filter fabric fence should be installed. • In areas where sheet flow leaves the site and the drainage area is greater than 0.5 ac/100 ft. of flow, perimeter dikes should be installed and flow should be diverted to a sediment trap or sediment basin. • Install inlet protection around all storm drain inlets. • Install construction entrance (gravel pad to collect mud and sediment from wheels) and route all traffic leaving the site to the construction entrance. • Install all sediment controls prior to grading.
Inspect and Maintain Control Measures.	• Remove sediment from sediment traps and filter fence when silted to half capacity. • Inspect and repair, as needed, all controls after each storm event.

Note: These are recommendations only and are not intended to be all inclusive.
Note: Above Table is adapted from Goldman, 1986.

North - avoid construction during the spring thaw period.

2. Stage construction so that one area can be stabilized before another is disturbed. This practice reduces the time that an area is left unstabilized.

b. Retain Existing Vegetation Wherever Feasible

1. Clear only those areas that are essential for completing site construction.

2. Avoid disturbing vegetation on steep slopes or other critical areas. Additionally, material stockpiles, borrow areas, access roads should be located away from critical areas.

3. Route construction traffic to avoid existing or newly planted vegetation.

4. Physically mark off limits of land disturbance with tape, signs or barriers. This ensures bulldozer operator knows proposed limits of clearing.

5. Protect natural vegetation with fencing, tree armoring, retaining walls or tree wells.

c. Stabilize All Denuded Areas Within 15 Calendar Days After Final Grading. Disturbed Areas That Are Inactive and Will Be Exposed to Rain for 30 Days or More, Should also be Temporarily Stabilized.

1. During favorable seeding dates and in areas where vegetation can be established, the following should be implemented:

   a) In very flat, non-sensitive area with favorable soils, seeding and fertilizing can be employed.

   b) If not highly erosive soil, on moderately steep slopes with moderately erosive soils in relatively sensitive areas, seeding and mulching can be employed.

c) If highly erosive soil, on very steep slopes, areas slow to establish vegetation, or sensitive areas with highly erosive soils, seeding with multiple mulching treatments or sodding should be employed.

2. If stabilization is required during time of year that vegetation cannot be established, the following practices should be implemented:

   a) On moderate slopes or not highly erodible soil mulching should be employed.

   b) On steep slopes or highly erodible soils, multiple mulching treatments should be used.

3. If in high elevation or desert site where grasses can't survive due to harsh environment at a minimum plant native shrubs.

4. Before stabilizing an area, make sure necessary controls (e.g., diversion of runoff) are in place.

5. Where practical stockpile topsoil and reapply to revegetate site.

6. Cover or stabilize topsoil stockpiles.

7. Where there is a potential for wind blown sediment transport, prior to stabilization protect with dust controls such as: wind barriers, mulching, tillage, or sprinkling.

d. Divert Runoff Away from Denuded Areas or Newly Seeded Slopes.

1. Above disturbed areas, construct dike or swale or install pipe slope drain to intercept runoff and convey it to a permanent channel or storm drain.

e. **Minimize Length and Steepness of Slopes.**

1. On long or steep disturbed or man-made slopes, construct benches, terraces, or ditches at regular intervals to intercept runoff. Route intercepted runoff to a protected outlet.

f. **Prepare Drainageways and Outlets to Handle Concentrated or Increased Runoff.**

1. Provide lining for any existing or newly constructed channel onsite or offsite so the 2-year storm channel velocity does not cause erosion. If the velocity allows, use a vegetative lining. Otherwise use rock, asphalt, plastic lining or gabions.

2. On temporary swales that have erosive velocity but due to their short service life a vegetative lining cannot be established; or if the swale needs protection during establishment of a grass lining, check dams should be installed.

g. **Trap Sediment Onsite**

1. In areas where greater than 5 acres drain to a point, sediment basins should be installed.

2. In areas where less than 5 acres of concentrated flow leaves the site, silt traps should be installed.

3. In areas where sheet flow leaves the site and the drainage area is less than 0.5 ac/100 ft. of flow, filter fabric fence should be installed.

4. In areas where sheet flow leaves the site and the drainage area is greater than 0.5 ac/100 ft. of flow, perimeter dikes should be installed and flow should be diverted to a sediment trap or sediment basin.

5. Install inlet protection around all storm drain inlets.

6. Install construction entrance (gravel pad to collect mud and sediment from wheels) and route all traffic leaving the site to the construction entrance.

7. Install all sediment controls prior to grading.

h. <u>Inspect and Maintain Control Measures.</u>

1. Remove sediment from sediment traps and filter fence when silted to half capacity.

2. Inspect and repair, as needed, all controls after each storm event.

NOTE: Above Management Practices adapted from Goldman, 1986.

5.0
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APPENDICES

APPENDIX A

STATE REGULATIONS

STATE EROSION AND SILTATION CONTROL (ESC) REGULATIONS[1]

State/Region	Regulation/Guideline*	ESC Plan Requirements	Minimum Site Area	ESC Objective	Days to Revegetate/ Stabilize
Alabama	No state law	—	—	—	—
Alaska	No state law	—	—	—	—
American Samoa	No state law	—	—	—	—
California	No state law	—	—	—	—
Connecticut	No state law	—	—	—	—
Delaware	Sediment and Stormwater Regulations	Plans required statewide	0.11 acre (5,000 sf)	Controls to be installed to comply with ESC Handbook	Perm or temp stabilization shall be completed within 14 calendar days after disturbance.
Florida	Stormwater Discharge Regulations of 1982	Plans required statewide	Any area where permits are required	ESC shall be used as necessary to retain sediment on-site	
Guam	No state law	---	—	—	—
Hawaii	Soil Erosion and Sediment Control, 1976	Plans not required by state law	---		—
Louisiana	No state law	—	—	—	—
Maine - adjacent water body	Natural Resources Protection Act revised 1991	Plans required adjacent to wetland or water body		Ensure soil is stabilized to prevent erosion of shoreline and siltation of water. The ESC must prevent wash of materials into the water.	○ Immediate temp stabilize at completion or if not worked for more than 7 calendar days. ○ Permanent revegetation immediately upon completion, or if temp stabilization was used, within 30 days from time area last worked.
Maryland	Sediment Control Act, 1978	Plans required statewide	0.11 acres (5,000 sf)		○ Seed if activity ceases for more than 14 calendar days. ○ Permanently stabilize within 7 calendar days after completion.

1This information is based on telephone contacts completed in 1991. The State regulations should be consulted for current requirements.

State/Region	Regulation/Guideline	ESC Plan Requirement	Minimum Site Area	ESC Objective	Days to Revegetate/ Stabilize
Massachusetts	No state law	—	—	—	—
Michigan	Soil Erosion & Sedimentation Control Act of 1972	Plans required statewide	1 acre or disturb within 500 ft of water body		o Perm. stabilize within 15 calendar days after final grading. o Temp. stabilize within 30 calendar days if activity ceases.
Minnesota**	Soil and Water Conservation	Plans not required by state law	—		—
Mississippi	No state law	—	—	—	—
New Hampshire	Dredging law				
New Jersey	Soil Erosion and Sediment Control Act	Plans required	o.11 acres (5,000 sf)		
New York	Soil & Water Conservation Law	Plans not required by state law	—		—
North Carolina	Sedimentation Pollution Control Act of 1973	Plans required statewide	1 acre	Shall install ESC sufficient to retain the sediment generated by the land-disturbing.	Stabilize within 30 working days of completion of any phase of grading.
Northern Mariana Island	No state law	—	—	—	—
Ohio**	Non-point Source Regulations of 1989	Plans required statewide	5 acres		Perm or temp stabilize within 7 days after final grade or if will remain dormant for greater than 45 days.

1This information is based on telephone contacts completed in 1991. The State regulations should be consulted for current requirements.

State/Region	Regulation/Guideline	ESC Plan Requirement	Minimum Site Area	ESC Objective	Days to Revegetate/ Stabilize
Oregon	No state law	—	—	—	—
Pennsylvania	Erosion Control, Title 25, Chapter 102	Plans required statewide	All disturbances require plans, state only reviews plans for develop. greater than 25 acre	Control accelerated erosion and resulting sedimentation of waters thereby preventing the pollution of waters from sediment.	o Stabilization as soon as possible after final grade (no specific time limit given). o Temp stabilize when activity ceases for more than 20 days.
Puerto Rico	No state law	—	—	—	—
Rhode Island	Soil Erosion & Sediment Control Act of 1990				
South Carolina - Coastal Zone	South Carolina Coastal Council Stormwater Management Guidelines	Plans required in low and medium density residential areas within 1/2 mile of water body, and all high density residential and commercial			Reseed if construction stops for more than 60 days, prior to completion.
Virgin Islands	Environmental Protection, Shore and Erosion Control	Plans required			
Virginia - Chesapeake Bay	Chesapeake Bay Act of 1988	Plans required in Chesapeake Bay Preservation Areas	0.06 acres (2,500 sf)		o Perm or temp stabilize within 7 days after final grade. o Temp stabilize within 7 days if not at final grade but will remain dormant for longer than 30 days. o Perm stabilize if dormant more than 1 year.
Washington	No state law	—	—	—	—
Wisconsin					

* Includes only Erosion and Sedimentation Control Laws, does not include water quality laws.
** Awaiting Coastal Zone Approval.

1 This information is based on telephone contacts completed in 1991. The State regulations should be consulted for current requirements.

APPENDIX B

EFFICIENCY DATA

Drainage Area	Comments on Use/Applicability/Design	TSS Removal Effectiveness	Useful Life	Study Type	Location	Reference
SEDIMENT TRAP						
NA	NA	(-21) to 99% removal efficiency for storms large enough to produce outflow from structure, overall (-7) to 100% removal efficiency. Difference in removal efficiency is highly dependent on inflow conditions.		Field monitoring results from 2 traps designed based on Maryland's criteria-monitored 6 months, 9 storms	Maryland	0Schueler, et al, 1990
NA	NA	For 2/3 storms in Northeast, less than 50% effective.		NA	Northeast	Sattherwaithe cited in EPA, 1991
Max 5 ac	Required volume = 1800 cf/ac	• Good effectiveness for course sediment, • Moderately effective for medium-sized sediment, • Low effectiveness for fine silt and clay particles. • Higher volume and detention time-higher efficiency.	2 years	NA	Minnesota	Minnesota Pollution Control Agency, 1989
Max 5 ac	Required surface area = 263 sf/ac, minimum depth = 2 ft (1 ac = 526 cf)	Because of cost and space limitations on construction sites, it is usually not feasible to construct a structure with 100% trapping efficiency. Thus, sediment retention structures are typically designed with a removal efficiency of 50 to 75%.	NA	NA	Lake Tahoe	Tahoe Regional Planning Agency, 1988
Max 5 ac	Required surface area = 625 sf/ac, minimum depth = 2 ft (1 ac = 1250 cf)	70-80% effective	18 months or less	NA	Wisconsin	Baumann, 1990

SILTATION AND EROSION CONTROL DATA (Page 2)

Drainage Area	Comments on Use/Applicability/Design	TSS Removal Effectiveness	Useful Life	Study Type	Location	Reference
SEDIMENT TRAP (continued)						
Max 5 ac	Required volume = 2000 cf/ac	NA	NA	NA	Pennsylvania	Pennsylvania DER, 1990
Max 3 ac	Required volume = 1800 cf/ac	NA	18 months	NA	Virginia	Firehock, 1991
Max 5 ac	• Locate at point of discharge • Required volume = 3600 cf/ac	NA	NA	NA	Delaware	Delaware Dept. of Natural Resources, 1989
Max 5 ac	• Locate at point of discharge • Required volume = 1800 cf/ac	NA	NA	NA	Austin, Texas	City of Austin, 1988
Max 5 ac	• Locate at point of discharge • Required volume = 1800 cf/ac	NA	NA	NA	New York	New York Soil and Water Conservation Society, 1988
Max 15 ac	Required volume = 1800 cf/ac	NA	NA	NA	Maryland	Maryland Dept. of the Environment, 1983
SILT FENCE						
NA	NA	80-95% filtering efficiency	NA	In-situ study of 3 different fabrics on 2 mine sites with different soil types.	Utah	Munson, 1991

SILTATION AND EROSION CONTROL DATA (Page 3)

Drainage Area	Comments on Use/Applicability/Design	TSS Removal Effectiveness	Useful Life	Study Type	Location	Reference
SILT FENCE (continued)						
NA	NA	• Sand: 80-99% removal • Coarse silt: 50-80% removal • Silt-clay: 0-20% removal	NA	Lab setting. Suspended solids having 3 distinct soil gradations were tested with 6 synthetic filter fences	Pennsylvania	Fisher, et al., 1984
Max 2 ac	• Water reaching silt fence must be sheet flow. • Maximum uncontrolled slope length above silt fence 150 feet.	For most soils, fence with Apparent Opening Size of 70 will trap more than 90% of sediment.	6 months	NA	Minnesota	Minnesota Pollution Control Agency, 1989
Max 1-2 ac	• Not to be used where there is concentrated flow. • Maximum slope length behind fence 100 ft. • Maximum slope 50%.	More effective than straw bale.	6-12 months	NA	Lake Tahoe	Tahoe Regional Planning Agency, 1988
Max 1/4 acre per 100 ft of fence	• Sheet flow • Maximum slope 50% • Maximum slope length behind fence 100 ft	NA	NA	NA	Wisconsin	Baumann, 1990
Max 1/4 acre per 100 ft of fence	Use only with overland or sheet flow.	NA	NA	NA	Virginia	Firehock, 1991
Max 0.5 ac per 100 ft of fence	Only sheet flow, no concentrated flow.	NA	NA	NA	New York	New York Soil and Water Conservation Society, 1988
Max 0.5 ac per 100 ft of fence	Only sheet flow, no concentrated flow.	NA	NA	NA	Maryland	Maryland Dept. of the Environment, 1983
Max 2 ac	No concentrated flow	NA	NA	NA	Austin, Texas	City of Austin, 1988

SILTATION AND EROSION CONTROL DATA (Page 4)

Drainage Area	Comments on Use/Applicability/Design	TSS Removal Effectiveness	Useful Life	Study Type	Location	Reference
STRAW BALE SEDIMENT BARRIER						
NA	NA	When installed properly and rotten or broken bales are replaced, 67% removal.	NA	NA	Virginia	VA, 1980 cited in EPA, 1991
Max 2 ac	• Not recommended where concentrated flow exists. • Generally used in locations where silt fence can also be used.	• Moderately effective for medium and coarse grained sediment particles. • Not effective for fine silt or clay particles. • Silt fence usually preferable since it has a lower failure rate, is more effective and has a longer life.	NA	NA	Minnesota	Minnesota Pollution Control Agency, 1989
Max 1/2-1 ac	• Should not be used where concentrated flow exists. • Length of slope above barrier should be less than 200 ft.	• Sandbags more effective on paved surfaces. • Filter fences more effective on soil surfaces.	3-6 months	NA	Lake Tahoe	Tahoe Regional Planning Agency, 1988
Max 1/4 ac per 100 ft	Max slope 50%	NA	3 months	NA	New York	New York Soil and Water Conservation Society, 1988
NA	Use only when no other practice feasible.	NA	3 months	NA	Maryland	Maryland Dept. of the Environment, 1983
Max 1/4 ac per 100 ft	• sheet flow • maximum slope 50% • maximum slope length 100 ft	Less effective than filter fabric. May be the most practical BMP where removal of a filter fence is not possible.	3 months	NA	Wisconsin	Baumann, 1990

SILTATION AND EROSION CONTROL DATA (Page 5)

Drainage Area	Comments on Use/Applicability/Design	TSS Removal Effectiveness	Useful Life	Study Type	Location	Reference
STRAW BALE SEDIMENT BARRIER (continued)						
NA	Use only when no other practice feasible.	NA	3 months	NA	Delaware	Delaware Dept. of Natural Resources, 1989
Max 2 ac, max 1/4 ac per 100 ft	Max slope 50%	NA	3 months	NA	Virginia	Firehock, 1991
NA	No concentrated flow	NA	3 months	NA	Pennsylvania	Pennsylvania DER, 1990
Max 0.5 ac	Use only when no other practice feasible.	NA	2 months	NA	Austin, Texas	City of Austin, 1988
SEEDING						
No maximum or minimum area	NA	Temporary seeding may be the single most important factor in reducing construction related erosion.	NA	NA	NA	New York, 1988 cited in EPA, 1991
No maximum or minimum area	NA	Temporary seeding up to 95% effective.	NA	NA	California	SCS, 1985 cited in EPA, 1991
No maximum or minimum area	NA	Only effective once established. After established, can reduce erosion by 99%.	NA	Calculated from SCS Technical Release #55	Minnesota	Minnesota Pollution Control Agency, 1989
No maximum or minimum area	NA	90-95% reduction in erosion once full vegetative cover established.	NA	NA	NA	Oberts, 1984 cited in City of Austin, 1988
No maximum or minimum area	NA	50-100% effective, depending on soil type.	NA	Calculated from SCS Technical Release #55	Delaware	Delaware Dept. of Natural Resources, 1989

SILTATION AND EROSION CONTROL DATA (Page 6)

Drainage Area	Comments on Use/Applicability/Design	TSS Removal Effectiveness	Useful Life	Study Type	Location	Reference
SODDING						
No maximum or minimum area	Good means of establishing vegetation instantly in erosion-prone areas such as swales, steep slopes and areas adjacent to paved surfaces.	Can reduce erosion rates by 99%.	NA	Calculated from SCS Technical Release #55	Minnesota	Minnesota Pollution Control Agency, 1989
No maximum or minimum area	NA	Up to 98% effective.	NA	NA	Pennsylvania	PA, 1983 cited in EPA, 1991
MULCHING						
No maximum or minimum area	Normally used for temporary erosion protection for newly seeded areas and to provide favorable growth conditions around trees and shrubs.	Proper application of mulch can reduce sheet erosion by 94%.	NA	Calculated from SCS Technical Release #55	Minnesota	Minnesota Pollution Control Agency, 1989
No maximum or minimum area	The following shows the loadings from bare soil and the percent reduction of sediment due to the treatments with simulated rain at 6 in/hr.		NA	Test boxes with simulated rainfall at 6 in/hr	NA	Kay, 1983 cited in Goldman, 1986

Soil: uncemented fine sand (after 4 hours)

	20% slope	50% slope
bare soil	100 ton/ac	---
F1500	50%	---
F3000	85%	---
straw	98%	---

Soil: very gravelly coarse sand (after 6 hours)

	20% slope	50% slope
bare soil	10 ton/ac	30 ton/ac
F1500	50%	0%
F3000	50%	50%
straw	100%	95%

SILTATION AND EROSION CONTROL DATA (Page 7)

Drainage Area	Comments on Use/Applicability/Design	TSS Removal Effectiveness	Useful Life	Study Type	Location	Reference
MULCHING (continued)						
	Soil: gravelly sandy loam (after 2 hours) | | 20% slope | 50% slope | bare soil | 5 ton/ac | 30 ton/ac F1500 | 60% | 20% F3000 | 60% | 70% straw | 90% | 95%	Soil: loam (after 2 hours) | | 20% slope | 50% slope | bare soil | 25-60 ton/ac | 40-100 ton/ac F1500 | 20-60% | 40-60% F3000 | 60-90% | 60-70% straw | 80-95% | 70-90%				
	Soil: clay loam (after 6 hours) | | 20% slope | 50% slope | bare soil | 120 ton/ac | --- F1500 | 5% | --- F3000 | 40% | --- straw | 70% | ---	Soil: sandy clay loam (after 6 hours) Effectiveness | 20% slope | 50% slope less effective | excelsior | jute | straw | straw @ 3,000 lb/ac | jute | straw @ 8,000 lb/ac best | | straw @ 3,000 lb/ac and jute				
	F1500: woodfiber applied hydraulically @ 1,500 lb/ac F3000: woodfiber applied hydraulically @ 3,000 lb/ac straw: barley straw @ 3,000 lb/ac tacked with asphalt emulsion @ 200 gal/ac					

Drainage Area	Comments on Use/Applicability/Design	TSS Removal Effectiveness	Useful Life	Study Type	Location	Reference
SEEDING AND MULCHING						
No maximum or minimum area	NA	70-90% effective for suspended solids	NA	NA	NA	Oberts, 1984 cited in British Columbia Research Corp., 1991
No maximum or minimum area	See Attachment A		NA	North Carolina experimental plots of red clay soils - a soil predisposed to erosion, making stabilization and seeding subsequent to disturbance very difficult. April - June, 1981 14 storms (1 - 10yr, 1 - 5 yr, 2 - 2 yr, 4 - 1 yr, 6 - <1 yr)	North Carolina	Lemly, 1982
No maximum or minimum area	See Attachment B		NA	NA	California	Goldman, 1986
STORM DRAIN INLET PROTECTION						
Max 1 ac	NA	• Good removal of coarse and medium sized sediment. • Not effective for fine silt and clay particles.	NA	NA	Minnesota	Minnesota Pollution Control Agency, 1989
TEMPORARY & PERMANENT DIVERSION						
NA	NA	Among the most effective and least costly practice for controlling erosion and sediment.	NA	NA	North Carolina	North Carolina cited in EPA, 1991

SILTATION AND EROSION CONTROL DATA (Page 9)

Drainage Area	Comments on Use/Applicability/Design	TSS Removal Effectiveness	Useful Life	Study Type	Location	Reference
SEDIMENT BASINS						
Max 100 ac	- Combined storage/settling volume = 1800 cf/ac of drainage area - Storage area should be cleaned out when it is 60% full - Length to width ratio 2-1	NA	- Temporary sediment basins must be removed within 36 months after construction of basins - Basins that function beyond 36 months or basins that exceed the requirements for temp. basins shall conform to SCS standards and specs. No. 378 for ponds	NA		New York, 1988
Max 100 ac	- Combined storage/settling volume = 1800-- cf/ac of disturbed area	NA	- Design life = 3 yr.	NA		North Carolina, 1991

Drainage Area	Comments on Use/Applicability/Design	TSS Removal Effectiveness	Useful Life	Study Type	Location	Reference
SEDIMENT BASINS (continued)						
Max 100 ac	Required volume = 1800 cf/ac of drainage area	Removal efficiencies of the basins vary from 33% to 80% for storm large enough to produce outflow and 55% to 100% for all storms within study period. The difference in removal efficiencies is highly dependent on the soil types and size of disturbed areas.	NA	- Field monitoring results from 4 basins during a period of 6 months and total of 9 storms. - 4 sediment basins for drainage area = 20 to 35 ac with disturbed areas = 8 to 35 ac. - Design for these basins are based on Maryland's criteria.		Schueler, 1990
NA	NA	- The removal efficiencies are dependent on the configurations of principal spillway riser. - The range of removal efficiencies is betwen 57 to 87%	NA	- Lab setting - 4 principal spillway riser configurations used in controlling dewatering of sediment basins	NA	Engle, BW and Jarrett, AR, 1990
Max 150 ac	- Surface area of basin is sized to handle 0.015 mm particles - Sediment shall be cleaned out when the sediment storage volume is full.	70 to 80%	Temp. basins = max. 18 months Permanent basins require additional features	NA	Wisconsin	Baumann, 1990

Drainage Area	Comments on Use/Applicability/Design	TSS Removal Effectiveness	Useful Life	Study Type	Location	Reference
SEDIMENT BASINS (continued)						
Max 100 ac	- Combined storage/settling volume = 1800 cf/ac of total drainage area. - Clean out sediments when volume is 60% filled.	NA	Temporary basins = max. 36 months. Permanent basins that function beyond 36 months or basins that exceed the requirements for temp. basins shall conform to SCS standards and specs. No. 378 for ponds.	NA		Maryland DE, 1983
For Area > 5 ac	- Required settling volume = 5000 cf/ac of drainage area - Required storage volume = 2000 cf/ac of disturbed area - Clean out sediments when storage area is full	NA	NA	NA		Pennsylvania DER, 1990
For Area > 5 ac	- Surface area of basins is sized to handle 0.02 mm particles - Storage volume is sized to handle/retain settlements expected to be captured between maintenance clean outs - Storage volume shall be cleaned when it's filled w/sediments	Due to cost and space limitation, basins are designed with removal capacity of 50 to 75%	NA	NA		Tahoe RPA, 1988
SEDIMENT BASINS (continued)						

SILTATION AND EROSION CONTROL DATA (Page 12)

Drainage Area	Comments on Use/Applicability/Design	TSS Removal Effectiveness	Useful Life	Study Type	Location	Reference
Max = 100 ac	- Combine storage/settling volume = 3600 cf/ac of drainage area - Sediments shall be removed when volume is 50% filled.	NA	Temporary basins = 36 months Permanent basins that function beyond 36 months or basins that exceed the requirements of temp. basins shall conform to SCS standards and specs. No. 378 for ponds.	NA	Delaware	Delaware DNR, 1989

NA = Not Available

ATTACHMENT A

EFFECT OF STABILIZATION TREATMENTS ON QUANTITY AND COMPOSITION OF SEDIMENT[A]					
Treatment and Sediment Component	Percent Slope				
	10	20	30	40	50
Asphalt - Tacked straw (approx. 3,000 lb/ac)					
Total	42	39	36	29	23
<0.04 mm	98.5	91	90	89	82
>0.04 mm	1.5	9	10	11	18
Jute netting					
Total	55	43	32	31	30
<0.04 mm	98	90	90	87	81
>0.04 mm	2	10	10	13	19
Mulch blanket					
Total	76	70	61	55	52
<0.04 mm	96.2	89	87	84	76
>0.04 mm	3.8	11	13	16	24
Wood chips (approx. 10,000 lb/ac)					
Total	78	74	63	58	51
<0.04 mm	98	90	89	86	77
>0.04 mm	2	10	11	14	23

ATTACHMENT A

EFFECT OF STABILIZATION TREATMENTS ON QUANTITY AND COMPOSITION OF SEDIMENT[A]					
Treatment and Sediment Component	Percent Slope				
	10	20	30	40	50
Excelsior blanket					
Total	78	73	62	58	52
<0.04 mm	98	89	86	81	76
>0.04 mm	2	11	14	19	25
Chemical binder and asphalt - tacked straw overlain with staple - tacked jute netting					
Total	88	89	89	90	89
<0.04 mm	96.7	87.9	85.3	80	70
>0.04 mm	3.3	12.1	14.7	20	30

[A]Values for total represent the percent reduction, dry weight, of mean total sediment concentration (mg/l) during peak discharge as compared to the untreated plots. Values for other components represent the percent decrease of the proportion of total sediments in these size fractions.

ATTACHMENT B

SUMMARY OF EROSION CONTROL PRACTICES AND EFFECTIVENESS			
Treatment	Comments	Effectiveness Before Plant Establishment[A]	Effectiveness After Plant Establishment[A]
1. Seed and fertilizer broadcast on the surface; seed not covered with soil; no mulch	Inexpensive and fast. Effective only on rough seedbeds with minimal slope and erodibility where seed will be covered naturally with soil.	0	1-4
2. Seed and fertilizer drilled	Lowest-seed-mortality method, but limited to friable areas no steeper than 3:1.	0	6-8
3. Seed, fertilizer, and 1500/lb acre wood fiber applied hydraulically	Advantages include holding seed and fertilizer in place on steep and smooth slopes where there may not be an alternative method.	2	3-5
4. Seed, fertilizer, and 3000/lb acre wood fiber applied hydraulically	More effective than treatment 3 in some cases. Provides more of a true mulch effect than treatment 3 provides.	4	4-6

ATTACHMENT B

SUMMARY OF EROSION CONTROL PRACTICES AND EFFECTIVENESS			
Treatment	Comments	Effectiveness Before Plant Establishment[A]	Effectiveness After Plant Establishment[A]
5. Seed and fertilizer broadcast with hydroseeder. Straw applied with blower at 3000 lb/acre and anchored with 300 lb/acre wood fiber and 60 lb/acre organic binder	Very effective as energy absorber and in encouraging plant establishment. Straw forms small dams to hold some soil. Not for cut slopes steeper than 2:1 or longer than 50 ft (15 m). Cost increases significantly when slopes are over 50 ft (15 m) from access or application is uphill.	5-7	7-9
6. Seed and fertilizer broadcast with hydroseeder. Straw broadcast at 4000 lb/acre, rolled to incorporate and then broadcast again at 4000 lb/acre and rolled again	Very effective. Not possible on most cut slopes. Top-of-slope access is required for rolling equipment.	6-8	8-10
7. Jute or excelsior mats held in place with wire staples. Seed and fertilizer as in treatment 1	Good on small sites and critical slopes. Very expensive. Not recommended on rocky soils. Loses effectiveness if not entirely in contact with soil. More effective if applied over straw.	7-9	8-10
[A]1 = minimal, 10 = excellent. Ratings assume treatments are properly applied.			

APPENDIX C

COST DATA

Erosion and Sedimentation Control Cost Estimates

Measure	unit	Reported Unit Costs Low	High	Ave.	Ave. Cost**	Annual Maint. Cost (% capital cost)	Reference	Notes
Sediment Basin	cu ft	0.1	0.3	0.2 *	0.2	25%	Denver COG cited in SWRPC, 1991	1
Sediment Basin– 12,500 cf	cu ft	0.4	1.3	0.8	0.8	25%	SWRPC, 1991	2
Sediment Basin– 40,750 cf	cu ft	0.2	0.6	0.4	0.4		SWRPC, 1991	2
Sediment Basin– 196,000 cf	cu ft	0.1	0.4	0.3	0.3		SWRPC, 1991	2
				ave=	**0.4**			
Sediment Trap	cu ft	0.4	0.7	0.5 *	0.5	20%	Denver COG cited in SWRPC, 1991	1
Sediment Trap	cu ft	0.2	0.3	0.2	0.2	20%	SWRPC, 1991	2
Sediment Trap– 1 ac drainage	cu ft	0.4	1.9	1.1 *	1.2		Goldman, 1986	1
Sediment Trap– 5 ac drainage	cu ft	0.3	0.7	0.5 *	0.5		Goldman, 1986	1
				ave=	**0.6**			
Filter Fabric Fence	100 lin ft	60	800	340	340		Wisc. DOT cited in SWRPC, 1991	
Filter Fabric Fence	100 lin ft	230	450	340	340	100%	SWRPC, 1991	2
Filter Fabric Fence	100 lin ft	200	600	350	366		Goldman, 1986	
Filter Fabric Fence	100 lin ft	200	500	350 *	350		Virginia, 1991	
Filter Fabric Fence	100 lin ft			300	300		NC State, 1990	
				ave=	**339**			
Straw Bale Dike	lin. ft.	2	5	3	3		Goldman, 1986	
Straw Bale Barrier	lin. ft.	3	6	5 *	5		Virginia, 1991	
Straw Bale Barrier					--	100%	SWRPC, 1991	
				ave=	**4**			
Temporary Seeding	ac	387	581	484	472	15%	Wisc. DOT cited in SWRPC, 1991	
Temporary Seeding	ac	242	968	484	484	25%	SWRPC, 1991	2
Seeding	ac			330	345		Goldman, 1986	
Temporary Seeding– seed, lime, fertilizer	ac	146	292	219 *	269		Virginia, 1980	
Permanent Seeding– seed, lime, fertilizer	ac	232	382	307 *	377		Virginia, 1980	
				ave=	**389**			
Mulching with straw	ac	484	4,840	1,452	1,452		Wisc. DOT cited in SWRPC, 1991	
Straw Mulching	ac	2,500	3,200	2,850 *	2,850		Wash. DOT, 1990	
Straw Mulch– 2 ton/ac w/ asphalt tack	ac			660	810		Virginia, 1980	
				ave=	**1,704**			
Wood Fiber Mulching	ac	1,300	2,300	1,800 *	1,800		Wash. DOT, 1990	
Wood Fiber Mulching	ac			115	141		Virginia, 1980	
				ave=	**971**			
Seeding and Mulching	ac	1,000	1,350	1175 *	1,230		Goldman, 1986	

Erosion and Sedimentation Control Cost Estimates

Measure	unit	Reported Unit Costs Low	High	Ave.		Ave. Cost**	Annual Maint. Cost (% capital cost)	Reference	Notes
Seeding and Mulching	ac	2,400	2,600	2500	*	2,500		Wash. DOT, 1990	
Seeding (and mulching?)	ac			1742		1,742		NC State, 1990	
Hydroseeding with mulch & fertilizer	ac			1750		1,793		Schueler, 1987	
Conventional seeding with mulch & fertilizer	ac			1650		1,691		Schueler, 1987	
Temporary Seeding & Mulching	ac	613	760	687	*	843		Virginia, 1980	
Permanent Seeding & Mulching	ac	700	850	775	*	951		Virginia, 1980	
Seed, Mulch, Fertilizer	ac	968	3388	1452		1452		SWRPC, 1991	3
					ave=	**1,525**			
Netting	ac	3,600	4,100	3900	*	3,900		Wash. DOT, 1990	
Jute Net	ac			2807		3,444		Virginia, 1980	
					ave=	**3,672**			
Matting	ac	3,872	29,040	5,808		**5,808**		SWRPC, 1991	4
Excelsior Blanket	ac			1,500		**1,840**		Virginia, 1980	
Straw Blanket	ac	3,388	40,172	14,036		*******		SWRPC, 1991	5
Seeding, Mulching, Netting	ac	6,050	13,310	9,680	*	10,130		Goldman, 1986	
Seeding with Blanket or Net	ac			8475		8,686		Schueler, 1987	
					ave=	**9,408**			
Sodding	sf	0.16	1.12	0.26		0.26	5%	SWRPC, 1991	6
Sodding	sf	0.13	0.40	0.26		0.26	5%	SWRPC, 1991	2
Sodding	sf			0.25		0.26		Schueler, 1987	
Sodding	sf	0.10	0.14	0.12	*	0.15		Virginia, 1980	
					ave=	**0.23**			
Inlet Protection Device	ea	106	154	130		130	100%	SWRPC, 1991	2
Inlet Protection Device	ea			108		108	20%	Denver COG cited in SWRPC, 1991	
Inlet Protection– Straw Bale	ea	25	100	63	*	63		Virginia, 1991	
Inlet Protection – Straw Bale	ea			129		129		EPA cited in SWRPC, 1991	
Inlet Protection– Filter Fabric & Mesh Wire	ea	35	50	43	*	43		Virginia, 1991	
Inlet Protection– Gravel & Filter Fabric	ea	35	50	43	*	43		Virginia, 1991	
Inlet Protection– Block & Gravel	ea	35	50	43	*	43		Virginia, 1991	
Inlet Protection– Gravel Curb Inlet	ea	35	50	43	*	43		Virginia, 1991	
Inlet Protection– Block & Gravel Curb Inlet	ea	35	50	43	*	43		Virginia, 1991	
Inlet Protection– Stone Rap (Reusable)	ea	35	50	43	*	43		Virginia, 1991	
					ave=	**69**			
Construction Entrance	ea	1,000	4,000	2,000		2,093		Goldman, 1986	
Construction Entrance	ea			1,333		1,333		NC State, 1990	7

Erosion and Sedimentation Control Cost Estimates

Measure	unit	Reported Unit Costs Low	High	Ave.	Ave. Cost**	Annual Maint. Cost (% capital cost)	Reference	Notes
Construction Entrance– without filter cloth	ea	350	700	500 *	500		Virginia, 1991	7
				ave=	1,309			
Construct. Entrance Wash Rack	rack	500	1,000	750 *	750		Virginia, 1991	
Const. Road Stabiliz. – stone only	lin ft	7	13	10 *	10		Virginia, 1991	8
Constr Road Stab– stone & filt fabric	lin ft	13	20	17 *	17		Virginia, 1991	8
				ave=	13			
Diversion Swale	100 lin ft	202	1,198	600	600	20%	SWRPC, 1991	2
Swale	100 lin ft			470	492		Goldman, 1986	
Temp Diversion Dike	100 lin ft	300	500	400 *	400		Virginia, 1991	
Earth Dike	100 lin ft			400	419		Goldman, 1986	
Temp Fill Diversion	100 lin ft	50	100	75 *	75		Virginia, 1991	
Temp Right–of–Way Diversion– Stone	100 lin ft	200	250	225 *	225		Virginia, 1991	
Temp Right–of–Way Diversion– Earth	100 lin ft	150	250	200 *	200		Virginia, 1991	
Diversion	100 lin ft	650	1200	925 *	925		Virginia, 1991	
				ave=	417			
Pipe Slope Drain	lin. ft.	7	15	11	11		Goldman, 1986	
Temp Slope Drain	lin ft	10	20	15 *	15		Virginia, 1991	
Slope Drain	lin ft			15	15		NC State, 1990	
				ave=	14			
SW Conveyance Channel– Grass Lined (Seeded)	cu. yd.	3	7	5 *	5		Virginia, 1991	
SW Conveyance Channel– Grass Lined (Sodded)	cu. yd.	8	12	10 *	10		Virginia, 1991	
SW Conveyance Channel– Non Grouted Riprap	cu. yd.	35	50	43 *	43		Virginia, 1991	
SW Conveyance Channel– Grouted Riprap	cu. yd.	45	60	53 *	53		Virginia, 1991	
SW Conveyance Channel– Concrete	cu. yd.	25	30	27 *	27		Virginia, 1991	
					28			
Brush Barrier	lin ft	2	5	4	4		Virginia, 1991	
Brush Barrier	lin ft			0	0		NC State, 1990	
				ave=	2			
Outlet Protection – nongrouted riprap	ea	194	278	234 *	234		Virginia, 1991	9
Outlet Protection– grouted riprap	ea	250	330	292 *	292		Virginia, 1991	9
Outlet Protection– concrete	ea	138	165	154 *	154		Virginia, 1991	9
Riprap and gravel outlet	ea			500	500		NC State, 1990	
				ave=	295			
Check Dam– log	ea	400	600	500 *	500		Virginia, 1991	
Check Dam– riprap	ea			480	480		NC State, 1990	

Erosion and Sedimentation Control Cost Estimates

Measure	unit	Reported Unit Costs Low	High	Ave.	Ave. Cost**	Annual Maint. Cost (% capital cost)	Reference	Notes
				ave=	490			
Level Spreader	lin ft	3	15	9 *	9		Virginia, 1991	

* determined by averaging high and low values
** costs in 1988 dollars

Notes:
1– assumes 1800 cf/ac of storage
2– calculated from unit costs
3– high & low from 12 reported costs, ave from Means, 1989
4– high & low from 159 reported costs, ave from Means, 1989
5– high & low from 6 reported costs, ave from Means, 1989
6– high & low from 117 reported costs, ave from Means, 1989
7– assumes 50' x 20' pad
8– assume 20' wide
9– assume 5' x 10'