Highway Construction Site Erosion and Pollution Control Manual

Implementation Manual

WA-RD 200.2

January 1990

Washington State Department of Transportation
Planning, Research and Public Transportation Division

in cooperation with the
United States Department of Transportation
Federal Highway Administration

WASHINGTON STATE DEPARTMENT OF TRANSPORTATION

TECHNICAL REPORT STANDARD TITLE PAGE

1. REPORT NO. WA-RD 200.2	2. GOVERNMENT ACCESSION NO.	3. RECIPIENT'S CATALOG NO.
4. TITLE AND SUBTITLE HIGHWAY CONSTRUCTION SITE EROSION AND POLLUTION CONTROL MANUAL		5. REPORT DATE January 1990
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Richard R. Horner, Juno Guedry, Michael H. Kortenhof		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS Washington State Transportation Center (TRAC) University of Washington, JE-10 The Corbet Building, Suite 204; 4507 University Way N.E. Seattle, Washington 98105		10. WORK UNIT NO.
		11. CONTRACT OR GRANT NO. GC8286, Task 7
12. SPONSORING AGENCY NAME AND ADDRESS Washington State Department of Transportation Transportation Building, KF-10 Olympia, Washington 98504		13. TYPE OF REPORT AND PERIOD COVERED Implementation Manual
		14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

This study was conducted in cooperation with the U.S. Department of Transportation, Federal Highway Administration.

16. ABSTRACT

The size and length of highway construction projects have always created a relatively large potential to cause soil erosion problems. In recent years, regulations and public interest have stimulated awareness of these problems and efforts to address them. New techniques and products have been developed to reduce erosion at its source or interrupt the transport of eroded soil. However, these developments have not heretofore been systematically and comprehensively tested and compared to one another in effectiveness. The Washington State Department of Transportation (WSDOT) and Federal Highway Administration (FHWA) funded research to perform such tests in order to improve the cost-effectiveness of highway construction site erosion and pollution control. The research involved literature review, experimentation at the laboratory and field scales, and compilation of cost data. This manual was produced to implement the results of this research. The manual presents criteria and guidelines relative to a number of slope covering techniques, silt barriers, sedimentation ponds, and construction management techniques. These criteria and guidelines cover method selection (based on applicability and relative cost-effectiveness), design, installation, and maintenance.

17. KEY WORDS highway construction, erosion control, water pollution, slope stabilization, sedimentation ponds	18. DISTRIBUTION STATEMENT No restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA 22616

19. SECURITY CLASSIF. (of this report)	20. SECURITY CLASSIF. (of this page)	21. NO. OF PAGES	22. PRICE
None	None	60	

DOT FORM 310-022 (11/86) -1216-

Implementation Manual

Research Project GC 8286, Task 7
Construction Erosion Control-II

HIGHWAY CONSTRUCTION SITE EROSION AND POLLUTION CONTROL MANUAL

by

Richard R. Horner
Research Associate Professor

Juno Guedry
Research Assistant

Michael H. Kortenhof
Research Assistant

Department of Civil Engineering
University of Washington, FX-10
Seattle, Washington 98195

Washington State Transportation Center (TRAC)
University of Washington, JE-10
The Corbet Building, Suite 204
4507 University Way N.E.
Seattle, Washington 98105

Washington State Department of Transportation
Technical Monitor
Jack McIntosh
Hydraulic Engineer

Prepared for

Washington State Transportation Commission
Department of Transportation
and in cooperation with
U.S. Department of Transportation
Federal Highway Administration

January 1990

DISCLAIMER

TABLE OF CONTENTS

Cost-Effectiveness Ratings

Techniques discussed in the following sections are rated for relative economy, effectiveness, and cost effectiveness. Relative ratings are expressed in this manual according to the following key:

A — The top 20th percentile on a 0-100 scale (81-100) relative to the indices of all of the techniques tested;

B — Second 20th percentile (61-80);

C — Third 20th percentile (41-60);

D — Fourth 20th percentile (21-40);

E — Last 20th percentile (0-20).

SECTION A

SLOPE COVERING TECHNIQUES

A1. STRAW (APPLIED ALONE)

CHARACTERISTICS

Straw is an excellent mulch material and widely available. Straw fibers effectively absorb raindrop impact, moderate soil temperature, and conserve moisture. Water- and wind-erosion protection is afforded by their tendency to interweave and trap soil. Straw promotes water infiltration, reduces runoff, and enhances vegetation establishment, in addition to reducing erosion. Another advantage is relative ease of application.

PERFORMANCE AND COST

Table A1.1 provides performance and cost data for straw at two application rates. The cost of straw on the basis of six months (one wet season) service life is increased by the expected need to reapply it once or twice in that period. Therefore, straw used alone is best suited where relatively brief protection is needed. Both application densities tested were relatively effective overall, except for elevated organic release from the slope treated with the higher density. However, the relatively high cost for a full season's use reduced the relative cost-effectiveness ratings somewhat for the lighter application and substantially for the heavier.

Table A1.1 Performance and Cost Data for Straw (Applied Alone)

Application Density (tons/acre)	Estimated Cost ($/(acre)(6 months' service life)	Relative Economy Rating	Effectiveness Measure	Relative Effectiveness Rating[a]	Relative Cost-Effectivness Rating[a]
4	3,200	C	Reducing erosion	A	C
			Reducing phosphorus yield	A	C
			Reducing metals yield	A	C
			Reducing organics yield	C	D
			Overall	A	C
1.25	2,500	C	Reducing erosion	A	C
			Reducing phosphorus yield	A	B
			Reducing metals yield	A	B
			Reducing organics yield	A	A
			Overall	A	B

[a] Refer to the key on page 5 of the Introduction for numerical values associated with the ratings.

APPLICATIONS

Application of straw alone is recommended where:

1. immediate protection is required, and ease of application is helpful; and
2. the need for protection is < 3 months.

Careful consideration should be given before a decision is made to use straw if:

1. weed growth would impede future landscaping;
2. there is a fire hazard;
3. the site is relatively windy; and
4. the site is more than 50 feet from the nearest vehicular access point.

SELECTION CRITERIA

Regular agricultural straw is suitable for straw mulch. It should be free from undesirable seeds and coarse material, and it should be air-dried.

DESIGN

Before mulching, install surface runoff control measures such as terraces, interceptors, and level spreaders (see Section D).

INSTALLATION

Straw can be applied by blower or by hand. Most straw blowers have a maximum range of 50 feet. Avoid applying straw uphill or in windy conditions.

Anchoring is critical to successful use of straw mulch. Common anchoring methods are:

1. crimping, disking, rolling, or punching into the soil;
2. covering with netting;
3. spraying with a chemical or fiber binder (tackifier); and
4. keeping moist.

APPLICATIONS

The general applications and cautions stated for straw alone also apply to straw used in conjunction with vegetation establishment (see Subsection A1). Seeding should be done in addition to straw mulching when an area is without active construction activity during the wet season. The straw application density should be 2 to 3 tons/acre. Manure mulching generally should be avoided, especially when the manure will not largely decompose and be incorporated with the soil before any significant runoff occurs where:

1. runoff will discharge to a surface water sensitive to nutrient additions; and
2. runoff will discharge to a surface water sensitive to oxygen depletion.

Care should be taken to limit fertilizer application to no more than the plants' requirements.

SELECTION CRITERIA

See Subsection A1 for straw selection criteria. Follow WSDOT Standard Specification sections 8-01, 8-02, and 9-14 for seed selection and seeding.

DESIGN

See Subsection A1 for general design considerations. Refer to Applications above for cautions relative to fertilizing and manure mulching.

INSTALLATION

See Subsection A1 for considerations relative to applying and anchoring straw.

MAINTENANCE

Maintenance may consist of renewing straw anchorage, reapplying straw, or reseeding.

A3. JUTE MAT

CHARACTERISTICS

Jute mat decomposes in two years or less. It allows light to pass through and grass to grow. The fibers can absorb water, release it slowly later, and thereby reduce surface runoff.

PERFORMANCE AND COST

Table A3.1 provides performance and cost data for the jute mat tested in the research. It was intermediate in effectiveness overall among the measures investigated, but its relatively high cost resulted in low cost-effectiveness ratings.

APPLICATIONS

The relatively high cost of jute mat makes it most applicable to small sites. It is not well suited for rocky soils. Jute can be applied over straw to increase its effectiveness. It is best used in conjunction with seeding.

SELECTION CRITERIA

The material should be undyed, unbleached, and contain no contaminants that could be released to runoff.

Table A3.1. Performance and Cost Data for Jute Mat

Estimated Cost ($/(acre)(6 months' service life)	Relative Economy Rating	Effectiveness Measure	Relative Effectiveness Rating[a]	Relative Cost-Effectivness Rating[a]
3,700	D	Reducing erosion	B	D
		Reducing phosphorus yield	D	E
		Reducing metals yield	B	D
		Reducing organics yield	C	D
		Overall	C	D

[a] Refer to the key on page 5 of the Introduction for numerical values associated with the ratings.

DESIGN

Before placing the mat, install surface runoff control measures such as terraces, interceptors, and level spreaders (see Section D). Staple as specified by the manufacturer.

INSTALLATION

Lay the mat in the direction of water flow, in complete contact with the soil but not stretched. Staple it in place as directed by the manufacturer. Manufacturers state that seed can be broadcast either before or after mat placement.

MAINTENANCE

If the slope is unvegetated and the need for erosion control exceeds three months, inspect the blanket to be sure that it is intact. If it is vegetated, no maintenance should be needed.

A4. SHAVED WOOD (EXCELSIOR) BLANKET

CHARACTERISTICS

The excelsior blanket tested in the experiments consists of a machine-produced mat of dried, shredded, curled wood of 80 percent six-inch or longer fibers. The top side is covered with a photodegradable extruded plastic mesh. The mat is held in place by steel pins or staples.

A high velocity blanket with heavier netting on both sides is also available. This material is suitable for velocities up to approximately 9 to 11 feet/second, compared to 4 to 5 feet/second for the regular blanket.

Excelsior blankets are primarily intended to assist turf development. The test evaluated using excelsior without seeding.

PERFORMANCE AND COST

Table A4.1 presents performance and cost data for the excelsior blanket tested in the research. Excelsior was one of the most expensive options tested and exhibited performance among the poorest in every category. The "springy" excelsior shavings did not adhere closely to the soil contours and allowed water to run relatively unimpeded beneath the mat.

APPLICATIONS

Excelsior blankets should be employed on slopes or in ditches only in conjunction with seeding.

Table A4.1. Performance and Cost Data for the Excelsior Blanket

Estimated Cost ($/(acre)(6 months' service life)	Relative Economy Rating	Effectiveness Measure	Relative Effectiveness Rating[a]	Relative Cost-Effectivness Rating[a]
3,600	D	Reducing erosion	D	E
		Reducing phosphorus yield	D	E
		Reducing metals yield	D	E
		Reducing organics yield	E	E
		Overall	D	E

[a] Refer to the key on page 5 of the Introduction for numerical values associated with the ratings.

SELECTION CRITERIA

Select the regular excelsior blanket for velocities up to 4.8 feet/second with U.S. Soil Conservation Service Type A (clay, clay loam, silty clay) and Type B (loam, silty clay loam, sandy clay loam) soils and for velocities up to 3.9 feet/second with Type C soils (very fine sandy loam, fine sandy loam, and silty loam). For higher velocities, select a high-velocity blanket up to 11.0 feet/second with Type A, up to 9.8 feet/second with Type B, and up to 8.6 feet/second with Type C soils.

DESIGN

Before placing the mat, install surface runoff control measures such as terraces, interceptors, and level spreaders (see Section D). Staple as specified by the manufacturer.

INSTALLATION

On slopes, start laying the mat 3 feet over the crest of the slope or dig anchor ditches. The roll may be placed horizontally or vertically. In ditches, unroll in the direction of water flow. If using two rolls in a ditch, do not put the seam in the center, but offset it by at least 6 inches. Staple as directed by the manufacturer.

MAINTENANCE

When used in conjunction with vegetation, excelsior mat should require no maintenance.

A.5 WOVEN STRAW BLANKET

CHARACTERISTICS

The woven straw blanket tested in the experiments is made of 100 percent wheat straw (0.5 lb./square yard) with photodegradable netting on one side. This particular material is intended for slopes of 4 horizontal:1 vertical or flatter and moderate runoff conditions. The blanket should be stapled in place; a special staple gun is available for this purpose. This blanket assists vegetation establishment. Woven straw blankets are available with netting on both sides, nondegradable netting, in different natural and synthetic fibers, and with preseeding.

PERFORMANCE AND COST

Table A5.1 presents performance and cost data for the woven straw blanket tested. This product was highly effective in all respects except in reducing organics yield, for which it was intermediate among the materials tested. It was the most expensive slope covering tested, which reduced its relative cost-effectiveness.

APPLICATIONS

The woven straw blanket is suitable for use on slopes with or without seeding. Other grades are intended for ditch lining or shoreline stabilization.

The relatively high effectiveness but high cost of this material make it best suited for applications where immediate erosion protection is needed, especially where site runoff will

Table A5.1. Performance and Cost Data for the Woven Straw Blanket

Estimated Cost ($/(acre)(6 months' service life)	Relative Economy Rating	Effectiveness Measure	Relative Effectiveness Rating[a]	Relative Cost-Effectivness Rating[a]
4,100	D	Reducing erosion	A	D
		Reducing phosphorus yield	A	C
		Reducing metals yield	A	D
		Reducing organics yield	B	D
		Overall	A	D

[a] Refer to the key on page 5 of the Introduction for numerical values associated with the ratings.

enter sensitive surface waters. Specific examples include fish spawning and rearing streams sensitive to sediment deposition and lakes and streams sensitive to nutrients.

SELECTION CRITERIA

Select among the various woven straw blanket alternatives on the market according to the slope, quantity of runoff expected, vegetation needs and manufacturers' criteria.

DESIGN

Before placing the blanket, install surface runoff control measures such as terraces, interceptors, and level spreaders (see Section D). Staple as specified by the manufacturer.

INSTALLATION

If vegetation establishment will accompany blanket application, prepare seedbeds and seed before installation. Roll out the blanket in the direction of water flow and allow it to lie loosely on the soil. Staple as directed by the manufacturer.

MAINTENANCE

If the slope is unvegetated and the need for erosion control exceeds three months, inspect the blanket to determine if reinstallation is necessary. If vegetated, no maintenance should be needed.

A6. SYNTHETIC FIBER BLANKET

CHARACTERISTICS

The synthetic fiber blanket tested in the experiments is made of very fine, nonwoven polypropylene fibers reinforced with a polypropylene net (0.5 inch mesh) on one side. The product is light weight, allowing easy application, and nonflammable. It has been reported to degrade in time, but the rate was not stated.

PERFORMANCE AND COST

Table A6.1 presents performance and cost data for the synthetic fiber blanket. It exhibited quite uniform moderate levels of effectiveness for all performance criteria. Relatively high cost reduced its relative cost-effectiveness ratings, however.

APPLICATIONS

The synthetic fiber blanket is suitable for use with or without seeding. It should not be used where rapid degradation and incorporation into the soil are necessary.

DESIGN

Before placing the blanket, install surface runoff control measures such as terraces, interceptors, and level spreaders (see Section D).

Table A6.1. Performance and Cost Data for the Synthetic Fiber Blanket

Estimated Cost ($/(acre)(6 months' service life)	Relative Economy Rating	Effectiveness Measure	Relative Effectiveness Rating[a]	Relative Cost-Effectivness Rating[a]
3,300	D	Reducing erosion	B	D
		Reducing phosphorus yield	B	D
		Reducing metals yield	B	D
		Reducing organics yield	B	C
		Overall	B	D

[a] Refer to the key on page 5 of the Introduction for numerical values associated with the ratings.

INSTALLATION

If vegetation establishment will accompany blanket application, prepare seedbeds and seed before installation. Roll out the blanket in the direction of water flow with the fine fibers against the soil. Pin it as directed by the manufacturer.

MAINTENANCE

If the slope is unvegetated and the need for erosion control exceeds three months, inspect the blanket to determine if reinstallation is necessary. If vegetated, no maintenance should be needed.

A7. WOOD FIBER MULCH

CHARACTERISTICS

The wood fiber mulch tested is produced from 100 percent whole wood chips. It contains a specified range of fiber lengths, with a minimum of 30 percent of the fibers averaging 0.15 inch or longer. The fibers are green to assist uniform application and give a grass-like appearance. The product has no grass growth-inhibiting agents. In three of the four tests of this product a tackifier was also applied.

Wood fiber mulch does not provide much erosion protection by itself, because of the relative small size and weight of the fibers. It does not have sufficient mass per unit volume to absorb the energy of falling raindrops and flowing water. It assists plant establishment, by holding seeds on the slope.

Obtaining a mulching effect (moisture retention and soil temperature moderation) requires an application rate of at least 1 ton/acre, although as little as 0.5 ton/acre can hold seed until germination. A 1.5 ton/acre rate will increase the mulching and erosion control effectiveness. Wood fiber is generally sprayed in a water slurry with grass seed and, often, fertilizer and a tackifier.

PERFORMANCE AND COST

Table A7.1 presents performance and cost data for wood fiber mulch. The applications with the two higher tackifier quantities were the most effective overall among the options tested. Wood fiber mulch without tackifier was the most economical product, and the most cost effective overall.

APPLICATIONS

Wood fiber mulch is preferable to straw mulch where:

1. slopes are 2 horizontal:1 vertical or steeper;
2. vehicular access is not possible within 50 feet;

3. weed growth or fire hazard is a problem; and

4. the mulch must be applied on a windy day.

Lower phosphorus yield also dictates use of wood fiber in preference to straw mulch when runoff will drain to a lake or stream that is sensitive to nutrients. Wood fiber mulch should be applied only in conjunction with seeding.

SELECTION CRITERIA

Use of a tackifier with wood fiber mulch aids in keeping mulch in place until grass is established, and thus yields better initial performance. Increasing the tackifier quantity increases effectiveness but at a cost. The quantity should be selected according to the application (slope, soil, and receiver runoff) and in consultation with an application contractor.

Table A7.1. Performance and Cost Data for Wood Fiber Mulch

Application Rate (tons/acre) (tackifier/ gallons/acre)	Estimated Cost ($/(acre) (6 months' service life))	Relative Economy Rating	Effectiveness Measure	Relative Effectiveness Rating[a]	Relative Cost-Effectivness Rating[a]
1.25/None	1,300	A	Reducing erosion	A	A
			Reducing phosphorus yield	B	A
			Reducing metals yield	B	A
			Reducing organics yield	C	A
			Overall	B	A
1.25/50	1,900	B	Reducing erosion	A	B
			Reducing phosphorus yield	B	B
			Reducing metals yield	B	C
			Reducing organics yield	D	D
			Overall	B	B
1.25/90	2,100	B	Reducing erosion	A	B
			Reducing phosphorus yield	A	D
			Reducing metals yield	A	A
			Reducing organics yield	A	A
			Overall	A	B
1.25/120	2,300	C	Reducing erosion	A	B
			Reducing phosphorus yield	A	C
			Reducing metals yield	A	B
			Reducing organics yield	A	A
			Overall	A	B

[a] Refer to the key on page 5 of the Introduction for numerical values associated with the ratings.

DESIGN

Before applying wood fiber mulch, install surface runoff control measures such as terraces, interceptors, and level spreaders (see Section D).

INSTALLATION

Apply wood fiber at a minimum rate of 0.6 ton/acre on slopes 4:1 or flatter and at 0.75 to 1.5 ton/acre on steeper slopes. Mix wood fiber with water fertilizer, seed, and tackifier as directed by an application contractor.

MAINTENANCE

Grass should be inspected after the usual germination period and reseeded and remulched if poor establishment has occurred. Otherwise, no maintenance should be needed.

A8. CHEMICAL AGENT

CHARACTERISTICS

The chemical agent tested was a polymer supplied as a liquid concentrate. It dries in 1 to 6 hours after application to form a transparent, three-dimensional, film-like crust. It has been reported to be physiologically harmless. It is marketed as an erosion control agent, soil stabilizer during seed germination, tackifier, and dust suppressant.

PERFORMANCE AND COST

Table A8.1 presents performance and cost data for the chemical agent. This treatment exhibited the worst performance in all respects among all options tested. It is not suitable for erosion and pollution control without accompanying seeding. Tests were not performed with seeding.

APPLICATIONS

Chemical agents are recommended only as tackifiers for use with mulches such as straw and wood fiber.

INSTALLATION

Apply a tackifier in a volume recommended by the manufacturer, either by spraying with the mulch or after the mulch has been applied. In the latter case add a small amount of pigmented fiber mulch as a visual aid to ensure complete coverage.

Table 8.1. Performance and Cost Data for Chemical Agent

Estimated Cost ($/(acre)(6 months' service life)	Relative Economy Rating	Effectiveness Measure	Relative Effectiveness Rating[a]	Relative Cost-Effectivness Rating[a]
2,100	D	Reducing erosion	E	E
		Reducing phosphorus yield	E	E
		Reducing metals yield	E	E
		Reducing organics yield	E	E
		Overall	E	E

[a] Refer to the key on page 5 of the Introduction for numerical values associated with the ratings.

MAINTENANCE

Maintain it according to the instructions given for the mulch for which the chemical is serving as a tackifier.

SECTION B

SILT BARRIERS

B1. FILTER FABRIC FENCE

CHARACTERISTICS

A filter fabric fence is a geotextile intended to filter particles from flow and reduce its velocity to promote solids settlement. Three types of filter fabric are used in erosion control applications: woven slit-film, woven monofilament, and non-woven. The non-woven types generally exhibit the best combination of properties. Woven mono-filament types give better sustained performance than the woven slit-film fabrics. The slit-film types are cheaper and are more widely used, but the frequent need for wire mesh support with these lighter fabrics partially or totally offsets the cost savings.

Material strength is fairly uniformly defined by standard strength tests. However, permeability is inconsistently defined. The Effective Opening Size (EOS) is the most common way of representing relative permeability. EOS is the same as the U.S. Standard Sieve size.

PERFORMANCE AND COST

Filter fabric fences do not control erosion, unlike slope coverings. Therefore, no direct cost comparison can be made. In effectiveness, it would receive an "A" rating for reducing solids, phosphorus, and organics yields; a "B" rating for reducing metals yield; and an overall "A" rating. However, its performance was among the poorest in reducing turbidity.

APPLICATIONS

The principal uses for filter fabric fences are at the toe of slopes, as a final barrier at property lines, at sedimentation pond outlets, and around drain inlets. They are also sometimes extended across sedimentation ponds to filter flow passing between the inlet and outlet.

Limitations on filter fabric fence application are:

Maximum slope steepness perpendicular to fence line of 1:1;

Maximum flow path length to the fence of 100 ft.

SELECTION CRITERIA

Choose a filter fabric material that will provide an optimal balance between retention of the soil and unimpeded drainage. Generally, select the lowest EOS (which provides the largest openings) allowable under the following rules:

1. If 50 percent or less (by weight) of the soil particles pass U.S. Standard Sieve No. 200, then select an EOS value to retain 85 percent of the particles but not finer than 100.
2. If more than 50 percent but less than 85 percent (by weight) of the soil particles pass U.S. Standard Sieve No. 200, then select an EOS value of 70 or coarser.
3. If 85 percent (by weight) or more of the soil particles pass U.S. Standard Sieve No. 200, then do not use a filter fabric fence.

The selection of a material also depends on tensile strength (in relation to the use of reinforcing wire and post spacing; see Design), burst strength, and ultraviolet stability. Reinforced fabric is recommended as the standard, but non-reinforced material with wire mesh support can be selected at the contractor's option.

DESIGN

Filter fabric fence design questions include post selection and placement, whether reinforcing wire will be used, and, if so, in what configuration. Figure B1.1 illustrates a typical design.

Use 4-inch diameter wood or 1.33 lb/ft steel posts, or equivalent. With non-reinforced fabrics, use minimum 14 gauge reinforcing wire with mesh openings no larger than 6 inches. Table B1.1 gives additional design guidelines.

TABLE B.1.1. RECOMMENDED FILTER FABRIC FENCE DESIGN COMBINATIONS

Fence Height (ft)	Fabric	Post Spacing (ft)	Fabric Tensile Strength (lb)
3	Non-reinforced, wire mesh support	10	120
3	Reinforced	6	200
1.5	Reinforced	10	100
1.5	Reinforced	3	30

INSTALLATION

Installation steps are as follows. Refer to Figure B.1.1.

1. Align the filter fabric fence along the slope contours to the extent possible.
2. To prevent underflow, install an extra 6-inch flap of fabric in a trench or lay flat on the ground and cover with native material, depending on the manufacturer's recommendations..
3. Set posts at least 1.5 ft deep.
4. If required, fasten wire mesh support to the posts on the upslope side.
5. Attach the fabric on the upslope side. If it is necessary to splice, do so only at a post and overlap at least 6 inches.
6. Backfill the trench with gravel or native material, cover with soil, and compact the fill (alternatively, toe-in 6" flap with native material).

MAINTENANCE

Inspect filter fabric fences after each runoff event and daily during prolonged rain. Repair them as necessary. When sediment buildup becomes excessive, remove the sediments or build a new fence parallel to the old one.

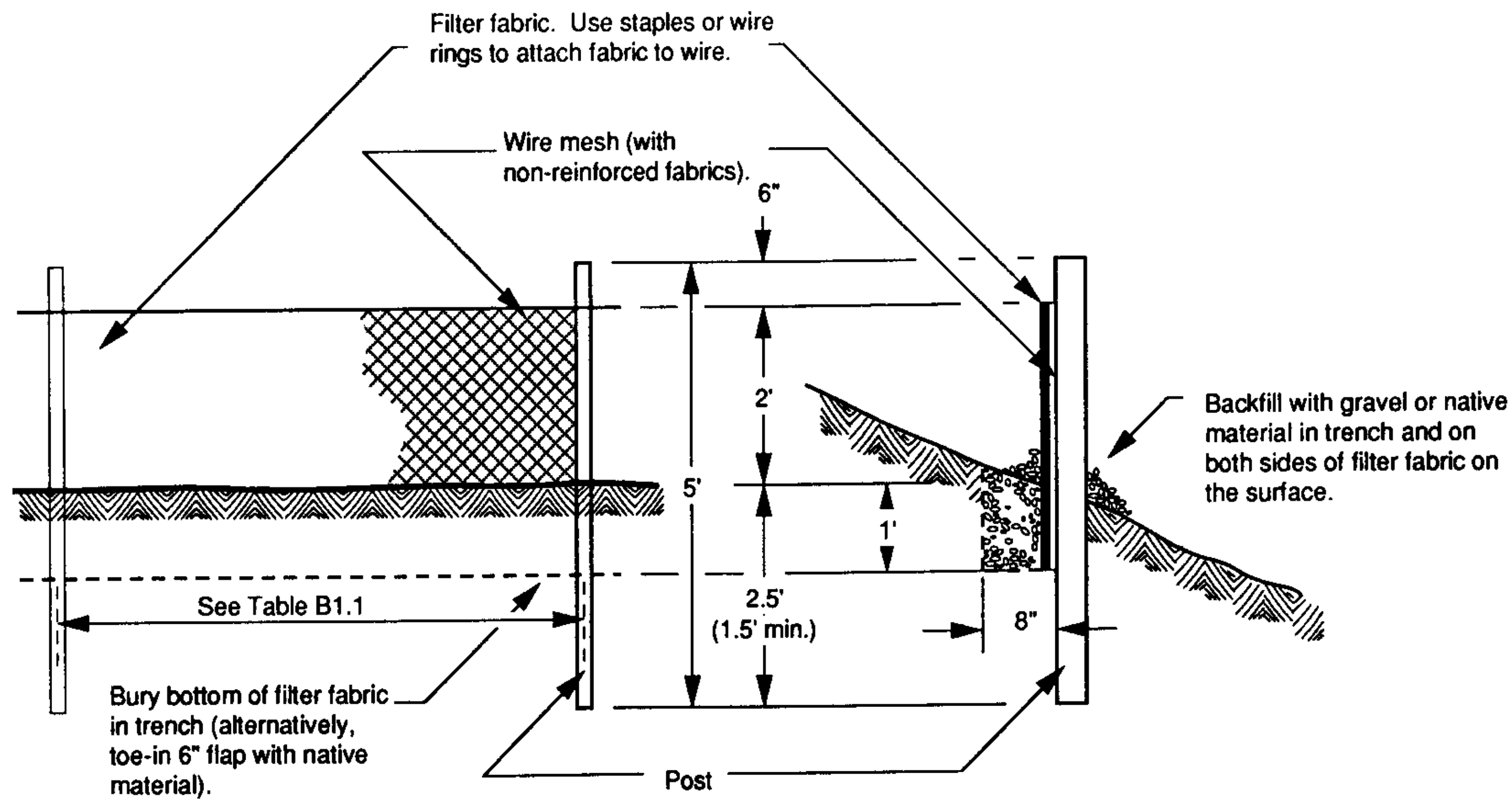


Figure B1.1. Typical Filter Fabric Fence Detail

SECTION C

SEDIMENTATION PONDS

C1. SEDIMENTATION PONDS

CHARACTERISTICS

Sedimentation ponds collect and store eroded particles before they can reach a water body or adjacent property. Preferably, erosion should be prevented at the source, but ponds can supplement erosion control. Construction sedimentation ponds can be adapted to permanent retention/detention pond service for the operating highway, although they should be designed initially or redesigned according to accepted procedures for permanent facilities in this case.

A sedimentation pond can be formed by excavation, construction of an embankment, or a combination. It should not intercept clean water, unless designed for the extra flow.

Common features include

- baffles to check inlet velocity and spread flow throughout the basin;
- discharge;
- emergency overflow;
- means of dewatering; and
- protection from erosion at the inlet and outlet.

Almost all pollutant removal in a sedimentation pond occurs as a result of gravity settling of particles. When residence time is adequate, a number of mechanisms function to reduce nutrients, metals, and organic pollutants.

PERFORMANCE AND COST

Table C1.1 presents performance and cost data for a sedimentation pond designed according to the research results. The pond had high relative effectiveness ratings in every category but was relatively expensive for a single wet season of service. This high cost caused its relative cost-effectiveness ratings to be lower. However, if used for two wet seasons, the cost per season would fall near the level of the lowest cost slope covering options.

Table C1.1 Performance and Cost for a Sedimentation Pond Designed According to Research Findings

Estimated Cost[a] ($/(acre)(6 months' service life)	Relative Economy Rating[a]	Effectiveness Measure	Relative Effectiveness Rating[b]	Relative Cost-Effectivness Rating[b]
< 4,200	≥ D	Reducing solids transport	A	D
		Reducing phosphorus transport	A	C
		Reducing metals transport	B	D
		Reducing organics transport	A	C
		Overall	A	D

[a] Service life exceeds six months; therefore, cost on this basis is less than the number given if the pond is used more than one wet season, and the relative cost-effectiveness ranking could be higher than given.
[b]Refer to the key on page 5 of the Introduction for numerical values associated with the ratings.

APPLICATIONS AND SELECTION CRITERIA

Refer to the introductory section of this guide for guidelines on applications and selection of sedimentation ponds.

DESIGN

The following sedimentation pond design procedure is adapted from the research project. Pond volume is sediment storage plus settling zone volume.

Compute Sediment Storage Volume

The sediment storage volume is the volume required to contain the sediment loading to the pond between cleaning occasions. Estimate the annual loading by using the Universal Soil Loss Equation:

$$Y = A \times R \times K \times LS \times C \times P$$

where: Y = annual sediment yield (tons/year);

A = drainage area (acres);

R = rainfall erosion index;

K = soil erodibility factor;

LS = length-slope factor;

C = cover factor; and

P = erosion control practice factor.

1. Calculate R as follows:

   Western Washington — $R = 10.2\rho^{2.2}$

   Eastern Washington — $R = 27\rho^{2.2}$

   where: ρ = 2-year, 6-hour rainfall (inches)

   (Refer to Section 2-3.4-B, Rainfall Intensity Equation, in WSDOT Highway Hydraulics Manual.)

2. Find K in the U.S. Soil Conservation Service soil survey for the county in which the project is located. If the survey does not list K, determine it from the nomograph in Figure C1.1, corrected according to Table C1.2.

3. Determine LS for the site slope gradient and length from Table C1.3.

4. Calculate a composite C if the site has different types of cover according to

$$C = \frac{\Sigma c_i a_i}{\Sigma a_i}$$

where: Σ indicates summation over areas i = 1,2,3, . . . n with different cover types;

c_i = C for area i; and

a_i = surface area of area i.

For c_i, use the following values:

Bare area — 1.0

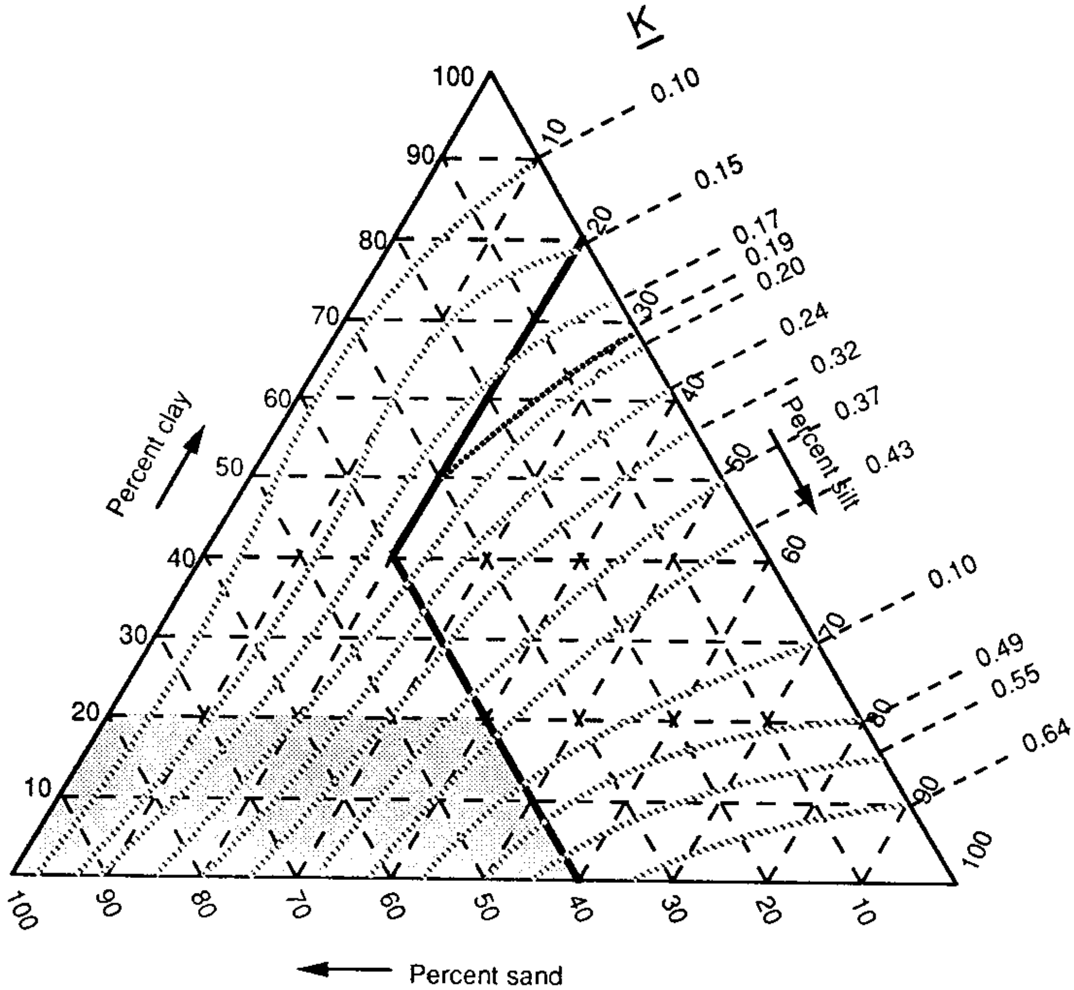
Temporarily seeded — 0.1

Undisturbed native vegetation — 0.01

Where slope covering is used — $c_i = 1 - \frac{E}{100}$

where: E = effectiveness in preventing erosion (%)

(Refer to the appropriate table for the slope covering in Section A of this guide.)



Example: Given: 30% sand, 10% very fine sand, 20% silt, 40% clay

Enter nomograph with 40% total sand and 20% silt. From intersection, trace parallel to K=0.20 line to read K=0.19.

Figure C1.1. Triangular Nomograph for Estimating K Value (See Table C1.2 for adjustments to K value under certain conditions)

Table C1.2. Adjustments to *K* Value

1. For soils with greater than 15% *very fine sand* (vfs) make the following adjustment:

   a. If texture is *coarser than loam*: Subtract 5% from the % vfs and add the difference to the silt content. Consider the remaining 5% vfs to be part of the % total sand.

   b. If texture is *loam and finer*, subtract 10% from the % vfs and add the difference to the silt content. Consider the remaining 10% vfs to be part of the % total sand.

   c. Find the *K* value by using the adjust sand and silt contents.

2. The nomograph assumes 2% organic matter, structure other than grandular, and 0-15% rock content. The correction factors are as follows.

   a. Organic matter. Add or subtract correction factor to *K* value as indicated in the following table.

K value	Correction factor when percent organic matter is 0	1	2	3	4
Greater than 0.040	+0.14	+0.07	0	-0.07	-0.14
0.20-0.40	+0.10	+0.05	0	-0.05	-0.10
Less than 0.20	+0.06	+0.03	0	-0.03	-0.06

   b. Rock content: Rock content is defined as the percent (by volume) of soil particles greater than 2 mm.

Unadjusted *K* value	*K* values adjusted for rock content as follows: 15-35%	35-60%	60-75%
0.10	0.05	0.05	0.02
0.15	0.10	0.05	0.02
0.17	0.10	0.05	0.02
0.20	0.10	0.05	0.02
0.24	0.15	0.10	0.05
0.28	0.15	0.10	0.05
0.32	0.17	0.10	0.05
0.37	0.20	0.10	0.05
0.43	0.24	0.15	0.10
0.49	0.28	0.15	0.10
0.55	0.32	0.17	0.10
0.64	0.37	0.20	0.15

Add or subtract the correction factors at the right to the *K* value to correct for the following structures and permeabilities.

   c. Structure:

Very fine granular	-0.09
Fine granular	-0.06
Moderate or coarse granular	-0.03

   d. Permeability:

Compact soil or pH greater than 9.0	+0.03
Many medium or coarse pores	-0.03

Table C1.3. LS Values

Slope ratio	Slope gradient s, %	10 (3.0)	20 (6.1)	30 (9.1)	40 (12.2)	50 (15.2)	60 (18.3)	70 (21.3)	80 (24.4)	90 (27.4)	100 (30.5)	150 (46)	200 (61)	250 (76)	300 (91)	350 (107)	400 (122)	450 (137)	500 (152)	600 (183)	700 (213)	800 (244)	900 (274)	1000 (305)
		LS values for following slope lengths l, ft (m)																						
	0.5	0.06	0.07	0.07	0.08	0.08	0.09	0.09	0.09	0.09	0.10	0.10	0.11	0.11	0.12	0.12	0.13	0.13	0.13	0.14	0.14	0.14	0.15	0.15
100:1	1	0.08	0.09	0.10	0.10	0.11	0.11	0.12	0.12	0.12	0.12	0.14	0.14	0.15	0.16	0.16	0.16	0.17	0.17	0.18	0.18	0.19	0.19	0.20
	2	0.10	0.12	0.14	0.15	0.16	0.17	0.18	0.19	0.19	0.20	0.23	0.25	0.26	0.28	0.29	0.30	0.32	0.33	0.34	0.36	0.37	0.39	0.40
	3	0.14	0.18	0.20	0.22	0.23	0.25	0.26	0.27	0.28	0.29	0.32	0.35	0.38	0.40	0.42	0.43	0.45	0.46	0.49	0.51	0.54	0.55	0.57
	4	0.16	0.21	0.25	0.28	0.30	0.33	0.35	0.37	0.38	0.40	0.47	0.53	0.58	0.62	0.66	0.70	0.73	0.76	0.82	0.87	0.92	0.96	1.00
20:1	5	0.17	0.24	0.29	0.34	0.38	0.41	0.45	0.48	0.51	0.53	0.66	0.76	0.85	0.93	1.00	1.07	1.13	1.20	1.31	1.42	1.51	1.60	1.69
	6	0.21	0.30	0.37	0.43	0.48	0.52	0.56	0.60	0.64	0.67	0.82	0.95	1.06	1.16	1.26	1.34	1.43	1.50	1.65	1.78	1.90	2.02	2.13
	7	0.26	0.37	0.45	0.52	0.58	0.64	0.69	0.74	0.78	0.82	1.01	1.17	1.30	1.43	1.54	1.65	1.75	1.84	2.02	2.18	2.33	2.47	2.61
12-1/2:1	8	0.31	0.44	0.54	0.63	0.70	0.77	0.83	0.89	0.94	0.99	1.21	1.40	1.57	1.72	1.85	1.98	2.10	2.22	2.43	2.62	2.80	2.97	3.13
	9	0.37	0.52	0.64	0.74	0.83	0.91	0.98	1.05	1.11	1.17	1.44	1.66	1.85	2.03	2.19	2.35	2.49	2.62	2.87	3.10	3.32	3.52	3.71
10:1	10	0.43	0.61	0.75	0.87	0.97	1.06	1.15	1.22	1.30	1.37	1.68	1.94	2.16	2.37	2.56	2.74	2.90	3.06	3.35	3.62	3.87	4.11	4.33
	11	0.50	0.71	0.86	1.00	1.12	1.22	1.32	1.41	1.50	1.58	1.93	2.23	2.50	2.74	2.95	3.16	3.35	3.53	3.87	4.18	4.47	4.74	4.99
8:1	12.5	0.61	0.86	1.05	1.22	1.36	1.49	1.61	1.72	1.82	1.92	2.35	2.72	3.04	3.33	3.59	3.84	4.08	4.30	4.71	5.08	5.43	5.76	6.08
	15	0.81	1.14	1.40	1.62	1.81	1.98	2.14	2.29	2.43	2.56	3.13	3.62	4.05	4.43	4.79	5.12	5.43	5.72	6.27	6.77	7.24	7.68	8.09
6:1	16.7	0.96	1.36	1.67	1.92	2.15	2.36	2.54	2.72	2.88	3.04	3.72	4.30	4.81	5.27	5.69	6.08	6.45	6.80	7.45	8.04	8.60	9.12	9.62
5:1	20	1.29	1.82	2.23	2.58	2.88	3.16	3.41	3.65	3.87	4.08	5.00	5.77	6.45	7.06	7.63	8.16	8.65	9.12	9.99	10.79	11.54	12.24	12.90
4-1/2:1	22	1.51	2.13	2.61	3.02	3.37	3.69	3.99	4.27	4.53	4.77	5.84	6.75	7.54	8.26	8.92	9.54	10.12	10.67	11.68	12.62	13.49	14.31	15.08
4:1	25	1.86	2.63	3.23	3.73	4.16	4.56	4.93	5.27	5.59	5.89	7.21	8.33	9.31	10.20	11.02	11.78	12.49	13.17	14.43	15.58	16.66	17.67	18.63
	30	2.51	3.56	4.36	5.03	5.62	6.16	6.65	7.11	7.54	7.95	9.74	11.25	12.57	13.77	14.88	15.91	16.87	17.78	19.48	21.04	22.49	23.86	25.15
3:1	33.3	2.98	4.22	5.17	5.96	6.67	7.30	7.89	8.43	8.95	9.43	11.55	13.34	14.91	16.33	17.64	18.86	20.00	21.09	23.10	24.95	26.67	28.29	29.82
	35	3.23	4.57	5.60	6.46	7.23	7.92	8.55	9.14	9.70	10.22	12.52	14.46	16.16	17.70	19.12	20.44	21.68	22.86	25.04	27.04	28.91	30.67	32.32
2-1/2:1	40	4.00	5.66	6.93	8.00	8.95	9.80	10.59	11.32	12.00	12.65	15.50	17.89	20.01	21.91	23.67	25.30	26.84	28.29	30.99	33.48	35.79	37.96	40.01
	45	4.81	6.80	8.33	9.61	10.75	11.77	12.72	13.60	14.42	15.20	18.62	21.50	24.03	26.33	28.44	30.40	32.24	33.99	37.23	40.22	42.99	45.60	48.07
2:1	50	5.64	7.97	9.76	11.27	12.60	13.81	14.91	15.94	16.91	17.82	21.83	25.21	28.18	30.87	33.34	35.65	37.81	39.85	43.66	47.16	50.41	53.47	56.36
	55	6.48	9.16	11.22	12.96	14.48	15.87	17.14	18.32	19.43	20.48	25.09	28.97	32.39	35.48	38.32	40.97	43.45	45.80	50.18	54.20	57.94	61.45	64.78
1-3/4:1	57	6.82	9.64	11.80	13.63	15.24	16.69	18.03	19.28	20.45	21.55	26.40	30.48	34.08	37.33	40.32	43.10	45.72	48.19	52.79	57.02	60.96	64.66	68.15
	60	7.32	10.35	12.68	14.64	16.37	17.93	19.37	20.71	21.96	23.15	28.35	32.74	36.60	40.10	43.31	46.30	49.11	51.77	56.71	61.25	65.48	69.45	73.21
1-1/2:1	66.7	8.44	11.93	14.61	16.88	18.87	20.67	22.32	23.87	25.31	26.68	32.68	37.74	42.19	46.22	49.92	53.37	56.60	59.66	65.36	70.60	75.47	80.05	84.38
	70	8.98	12.70	15.55	17.96	20.08	21.99	23.75	25.39	26.93	28.39	34.77	40.15	44.89	49.17	53.11	56.78	60.23	63.48	69.54	75.12	80.30	85.17	89.78
	75	9.78	13.83	16.94	19.56	21.87	23.95	25.87	27.66	29.34	30.92	37.87	43.73	48.89	53.56	57.85	61.85	65.60	69.15	75.75	81.82	87.46	92.77	97.79
1-1/4:1	80	10.55	14.93	18.28	21.11	23.60	25.85	27.93	29.85	31.66	33.38	40.88	47.20	52.77	57.81	62.44	66.75	70.80	74.63	81.76	88.31	94.41	100.13	105.55
	85	11.30	15.98	19.58	22.61	25.27	27.69	29.90	31.97	33.91	35.74	43.78	50.55	56.51	61.91	66.87	71.48	75.82	79.92	87.55	94.57	101.09	107.23	113.03
	90	12.02	17.00	20.82	24.04	26.88	29.44	31.80	34.00	36.06	38.01	46.55	53.76	60.10	65.84	71.11	76.02	80.63	84.99	93.11	100.57	107.51	114.03	120.20
	95	12.71	17.97	22.01	25.41	28.41	31.12	33.62	35.94	38.12	40.18	49.21	56.82	63.53	69.59	75.17	80.36	85.23	89.84	98.42	106.30	113.64	120.54	127.06
1:1	100	13.36	18.89	23.14	26.72	29.87	32.72	35.34	37.78	40.08	42.24	51.74	59.74	66.79	73.17	79.03	84.49	89.61	94.46	103.48	111.77	119.48	126.73	133.59

Table C1.4. *P* Factors for Construction Sites

Surface condition	*P* value
Compacted and smooth	1.3
Trackwalked along contour[a]	1.2
Trackwalked up and down slope[b]	0.9
Punched straw	0.9
Rough, irregular cut	0.9
Loose to 12-inch depth	0.8

[a]Tread marks oriented up and down slope.
[b]Tread marks oriented parallel to contours.

5. Determine P from Table C1.4.

6. Calculate Y:

$$Y = A \times R \times K \times LS \times C \times P$$

If the pond will be used for one wet season or if it will be cleaned once a year, use the calculated Y in the following steps. If it will be used for a different period or cleaned according to a different schedule, adjust Y accordingly.

7. Calculate the sediment storage volume:

$$V_{st} = \frac{Y}{d}$$

where: V_{st} = sediment storage volume (cubic feet)

d = average density of sediment/particles stored (ton/cubic foot)
(Use 0.05 ton/cubic foot to represent trapping particles larger than 0.02 mm in diameter, the medium silt range. Then, $V_{st} = 20\ Y$.)

Compute Particle Settling Zone Volume

1. Find the minimum required water surface area according to

$$A_m = \frac{1.2Q}{v_s}$$

where: A_m = minimum surface area (square feet);

Q = design inflow rate based on the average discharge of a 2-year, 24-hour storm (cubic feet/second); and

v_s = settling velocity of smallest particle to be trapped (feet/second).

(Use $v_s = 0.00096$ feet/second for the 0.02 mm diameter particle as a design basis. Then, $A_m = 1250\,Q$.)

2. Approximate settling zone volume:

$$V_{se} = A_m \times Y_{se}$$

where: V_{se} = settling zone volume (cubic feet); and

Y_{se} = settling zone depth.

(Use a practical minimum of 2 feet for Y_{se}.)

Note: This approximation is based on the simplifying assumption of vertical side walls. Because it is recommended that sedimentation ponds have sloped side walls (see Step 2 under Complete Pond Design) there will actually be more settling zone volume available than approximated by this calculation.

Complete Pond Design (see Figure C1.2)

1. Find the total pond volume by adding the sediment storage and settling zone volumes:

$$V_t = V_{st} + V_{se}$$

where: V_t = total volume (cubic feet)

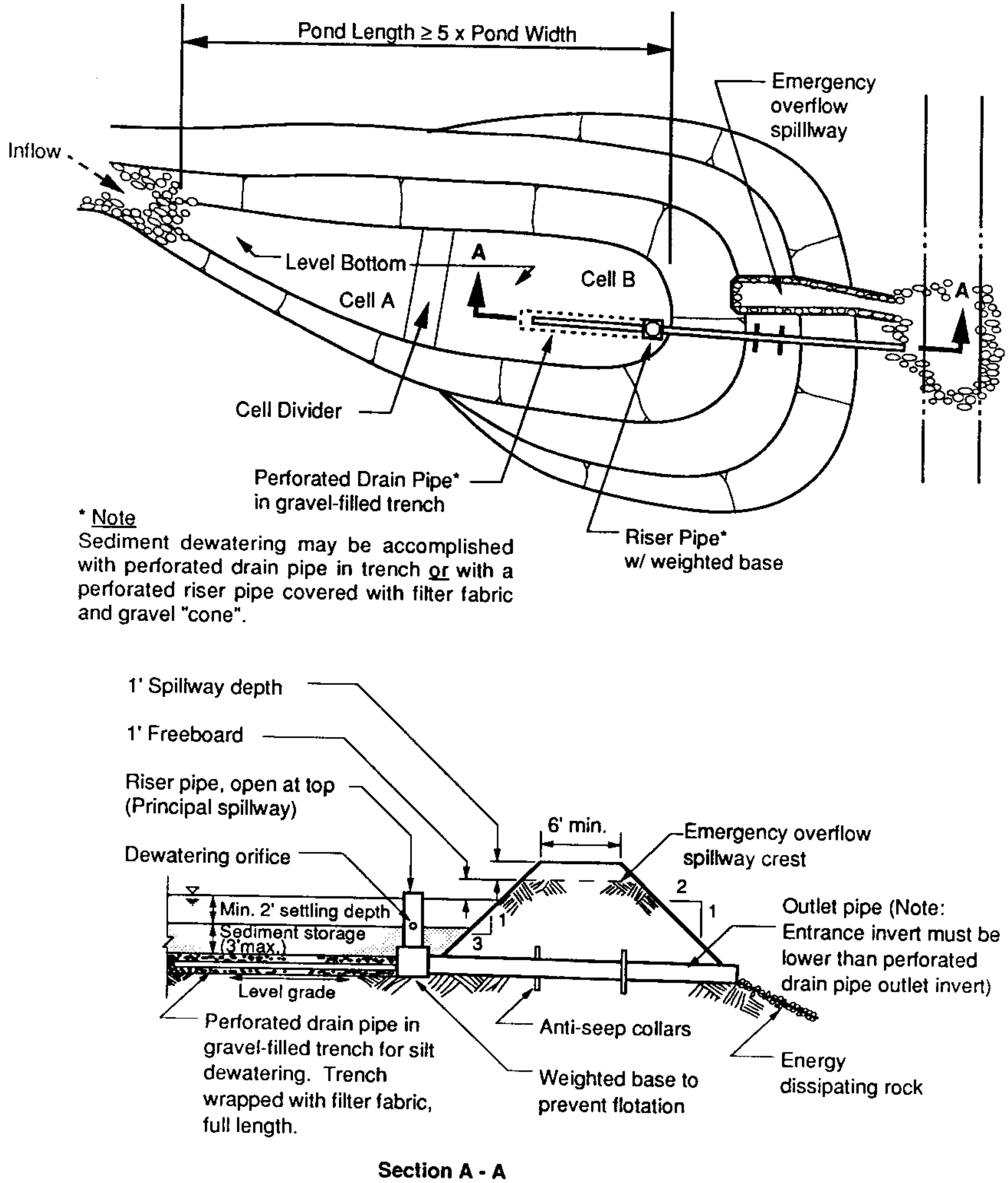


Figure C1.2. Sedimentation Pond

2. Determine pond geometry for the required total volume according to the following guidelines:

- use a 5:1 length:width ratio if possible;
- side slopes of 3 horizontal:1 vertical or flatter are generally recommended for sedimentation ponds;
- limit total depth to 5 feet to avoid anaerobic conditions when flushing is relatively slow.

Use Figure C1.3 to assist in selecting geometry.

3. Divide the basin into two cells with a solid divider, if possible. Sandbags or a compacted embankment (with 3:1 side slopes) can be used. Preferably, the drainage from the first to the second cell should be restricted to a single point (e.g., a riser pipe as described in step 4). An alternative is to use a rock wall through which drainage percolates. If space does not permit two cells, divide the pond with a silt fence.

4. The preferred dewatering method is a perforated riser installed as shown in Figure C1.2. (Other dispersed outlet designs that do not draw flow from near the bed of the pond or the water surface could also be used). Select the riser pipe diameter from the following table:

Maximum Drainage Area (acres)	Minimum Riser Pipe Diameter (inches)
1	12
2	18
3	21
4	24
5	30

5. Size the riser orifice as follows:

$$A_0 = \frac{A_s\,(2h)^{0.5}}{3600\,T\,C_d g^{0.5}}$$

where: A_0 = orifice area (square feet);

A_s = pond surface area (square feet);

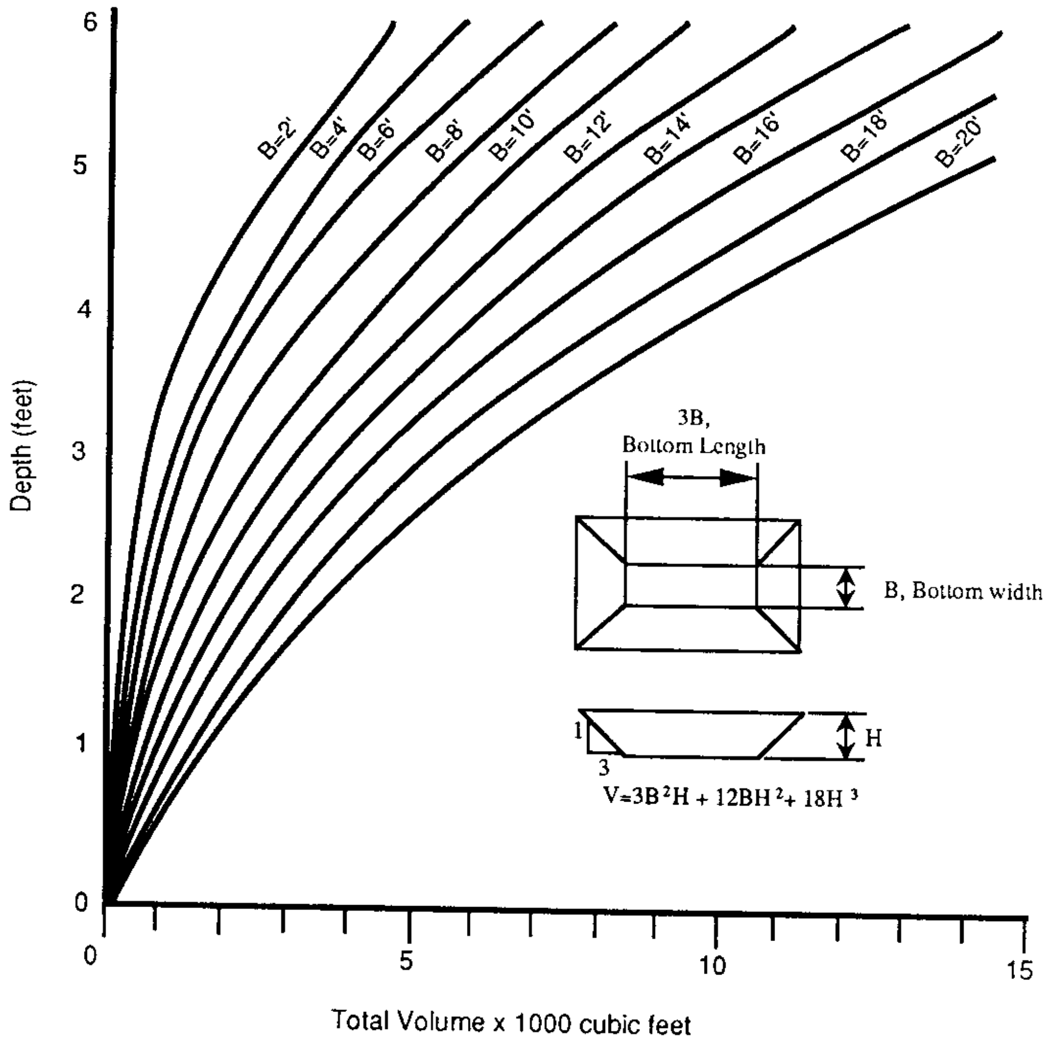


Figure C1.3 Relationships Among Sedimentation Pond Depth, Bottom Width and Volume

h = head of water above orifice (feet);

T = dewatering time (hours);

C_d = coefficient of contraction (10.6 for a sharp-edged orifice); and

g = acceleration of gravity (32.2 feet/second^2).

It is recommended that the dewatering time be as long as possible (e.g., 24 to 72 hours).

The orifice diameter is

$$D = 24\left(\frac{A0}{\pi}\right)^{0.5}$$

where: D = orifice diameter (inches).

If the pond has two chambers, use a riser of the same design to drain from the first to the second.

6. Provide an emergency spillway with a width, in feet, roughly two to three times the number of acres draining to the pond. Reinforce the spillway with 2- to 4-inch rocks.
7. Protect the inlet and outlet areas with rip-rap.
8. Install baffling if situations like those in Figure C1.4 exist. Also install baffles if it is necessary to dissipate especially high entrance velocities.

MAINTENANCE

Following are common sedimentation pond problems and recommended remedies:

1. Sediment storage volume is reduced.	Remove sediment when storage volume is filled. In no case should sediment accumulate closer than 2 feet to the top of the riser.
2. Basin not dewatering between storms.	Clean the riser orifice. Clean or replace the gravel surrounding a subsurface drain.
3. Damaged embankment.	Rebuild and compact damaged areas.

. . . Continued

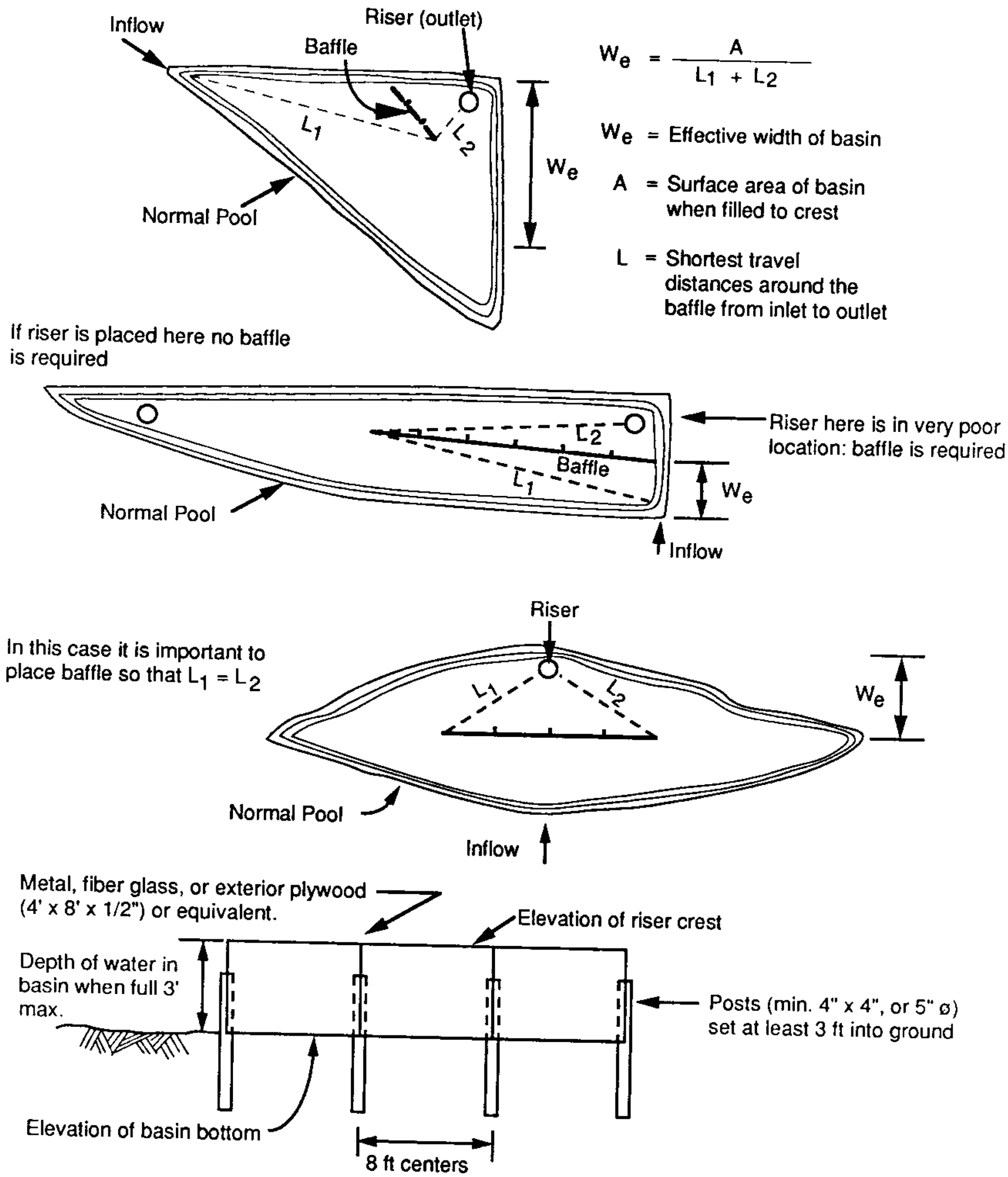


Figure C1.4. Sedimentation Pond Baffles

4. Spillway erosion.	Line the spillway with rock, filter fabric, or pavement.
5. Outlet erosion.	Make sure the outlet is flush with the ground and on a level grade. Install, extend, or repair the rip-rap apron.
6. Riser flotation	Anchor the riser in a concrete footing.
7. Excessive discharge to the pond.	Reroute drainage to another pond, or enlarge the pond.
8. Sediment storage zone fills too quickly.	Increase the depth or stabilize the drainage area by installing erosion prevention measures.

SECTION D

ADDITIONAL TECHNIQUES

D1. ADDITIONAL TECHNIQUES

Table D1.1 lists additional construction site erosion control techniques and summarizes their applications and purposes. Each should be considered for its appropriateness in an overall erosion control plan.

TABLE D1.1 ADDITIONAL TECHNIQUES FOR CONSTRUCTION SITE EROSION CONTROL

Technique	Application and Purpose
Gabions	Wire-mesh baskets containing rocks and tied together. Used as energy dissipaters, channel liners, slope protectors, and retaining walls. Provide backwater to reduce velocity and increase settling and some filtering of large particles as water passes through the rocks. Most useful where large rocks not available.
Grassed channels	Situated to receive drainage and divert it to where sediment removal can occur.
Clearing limits	Marking of the boundary of an approved clearing. Filter fabric fences or grassed channels may be used as boundary markers.
Stabilized construction entrance	Rock pad at the site access to limit the sediment transported from the site by construction equipment.
Construction road stabilization	Application of a base course to the road to reduce erosion caused by traffic and stormwater runoff.
Slope protection measures	Include the following measures to prevent the focusing of runoff on a slope: Pipe slope drains — pipes to carry concentrated runoff down a slope; Subsurface drains — to dewater wet, sloping soils; Level spreaders — shallow channels that convert concentrated runoff to sheet flow and divert it onto areas stabilized by existing vegetation; Interceptor berms and swales — dikes and channels to intercept runoff from drainage areas above unprotected slopes and direct it to a stabilized area.
Check dams	Rock or log dams to reduce velocity in channels.
Inlet protection	Filter fabric fence, block and gravel filter (concrete blocks surrounding inlet, packed with gravel), or gravel and wire mesh filter to prevent sediment from entering a storm drainage system.
Outlet protection	Rock to prevent scour at conveyance outlets.
Rip-rap	Rock to slow the velocity or stabilize slopes with seepage problems and/or noncohesive soils.

TABLE D1.1 ADDITIONAL TECHNIQUES FOR CONSTRUCTION SITE EROSION CONTROL (Continued)

Technique	Application and Purpose
Timing	Scheduling construction to avoid wet season
Selective clearing	Avoid clearing erosion-prone areas
Fit to terrain	A design to avoid the need to clear erosion-prone areas
Terracing	Shaping with alternating sloped and flat zones to avoid extensive runoff concentration
Minimize slope length and steepness	A design to avoid high velocities and extensive runoff concentration
Buffer zones	Letting existing vegetation remain between the construction area and adjacent sensitive areas (lakes, streams, wetlands, homes, etc.)
Stockpiling removed topsoil	Provides a source to aid revegetation and could save costs
Inspection and maintenance	Ensures that control measures are functioning
Seeding	Reestablishes vegetation temporarily or permanently
Sodding	Reestablishes vegetation quickly and permanently
Brush barriers	Filter fences made of materials removed during clearing and grubbing of the site.
Straw bales	Temporary silt barriers that have been found to be relatively ineffective in stopping sediment transport
Plastic sheeting	A slope covering having a relatively short service life and high cost.