
APPENDIX C

EROSION AND SEDIMENTATION CONTROL BEST MANAGEMENT PRACTICES (BMPs)

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INTRODUCTION

A revised List of Tables and List of BMPs have been included in this 2011 edition of the Erosion and Sediment Control Manual. New items have been **bolded** in this list.

Items which have undergone change from the 2003 edition are:

2003 BMP Number	2003 BMP Name	Type of Change
3.	Brush or Rock Filter Berm	Removed
4.	Continuous (earth-filled geotextile) Berm	Revised
5.	Earth Dyke Barrier	Revised
8.	Aggregate Filled Sand Bag Check Dam	Removed
9.	Log Check Dam	Removed
10.	Synthetic Permeability (Ditch) Barrier	Revised
11.	Straw Bale Check Dam	Removed
16.	Gravel Blankets	Removed
24.	Hydroseeding-Hydromulching	Revised
28.	Fibre Rolls and Wattles	Revised
29.	Chemical Stabilization (Tackifiers)	Removed

All BMPs had a general review. However, the major changes to the 2011 edition of the ESC Manual are:

- Adding new Streambank Stabilization Techniques
- Categorizing BMPs into Erosion Control, Sediment Control and Streambank Stabilization Techniques
- Removing, adding, and revising various BMPs

Users of this manual are cautioned that these BMPs are for guidance only and that a specific site design is required by the engineer or designer.

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14	Riprap Armouring
15	Cellular Confinement System
21	Offtake Ditch
22	Seeding
25	Topsoiling
26	Sodding
34	Slope Texturing
36	Polyacrylamide (PAM)
37	Compost Blanket

Sediment Control

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4	Continuous Perimeter Control Structures
5	Berm Interceptor
6	Storm Drain Inlet Sediment Barrier
12	Straw Bale Barrier
17	Energy Dissipators
18	Sediment Traps and Basins
19	Slope Drains
20	Groundwater Control
38	Rolls
38	Wattles (Live Fascine)

Erosion and Sediment Control

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7	Rock Check Dam
10	Synthetic Permeable Barrier
23	Mulching
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30	Riparian Zone Preservation
31	Pumped Silt Control Systems
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Streambank Stabilization Techniques

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7	Rock Check Dam
10	Synthetic Permeable Barriers
12	Straw Bale Barrier

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Table C-1: Erosion Control Measures - Source Control

No.	BMP Name	Applications				Comments	
		Slopes	Ditches and Channels	Large Flat Surface Areas	Borrow and Stockpile Area	Advantages	Limitations
25	Topsoiling	✓	✓	✓	✓	Placing topsoil provides excellent medium for vegetation root structure development, organic content promotes plant growth, reuse organics (topsoil or peat) stripped from the site at start of grading; absorbs raindrop energy to minimize erosion potential	Cannot be effective without seeding and allowing time for plant growth; not appropriate for slopes steeper than 2H:1V (steep slopes will require soil covering over topsoil and specialized design); dry topsoil susceptible to wind erosion, susceptible to erosion prior to establishment of vegetation
22	Seeding	✓	✓	✓	✓	Inexpensive and relatively effective erosion control measure, effectiveness increases with time as vegetation develops, aesthetically pleasing, enhances terrestrial and aquatic habitat	Must be applied over prepared surface (topsoiled), grasses may require periodic maintenance (mowing), uncut dry grass may be a fire hazard, seeding for steep slopes may be difficult, seasonal limitations on seeding effectiveness may not coincide with construction schedule, freshly seeded areas are susceptible to runoff erosion until vegetation is established, reseeding may be required for areas of low growth
23	Mulching	✓	✓	✓	✓	Used alone to protect exposed areas for short periods, protects soil from rainsplash erosion, preserves soil moisture and protects germinating seed from temperature extremes, relatively inexpensive measure of promoting plant growth and slope protection	Application of mulch on steep slopes may be difficult, may require additional specialized equipment May deplete available nitrogen Nitrogen rich fertilizer may need to be added
24a 24b	Hydroseeding / Hydromulching	✓	✓	✓	✓	Economical and effective on large areas, mulch tackifier may be used to provide immediate protection until seed germination and vegetation is established, allows re-vegetation of steep slopes where conventional seeding/mulching techniques are very difficult, relatively efficient operation, also provides wind erosion control	Site must be accessible to hydroseeding / hydromulching equipment (usually mounted on trucks with a maximum hose range of approximately 150 m), may require subsequent application in areas of low growth as part of maintenance program

Table C-1: Erosion Control Measures - Source Control

No.	BMP Name	Applications				Comments	
		Slopes	Ditches and Channels	Large Flat Surface Areas	Borrow and Stockpile Area	Advantages	Limitations
26	Sodding	✓	✓	✓	✓	Provides immediate vegetation and protection, instant buffer strip and/or soft channel lining, can be used on steep slopes, relatively easy to install, may be repaired if damaged, aesthetically pleasing	Expensive, labour intensive to install, sod may not be readily available in all areas of the province, relatively short 'shelf-life' (sod can't be stored on-site for excessive periods of time)
14	Riprap Armouring	✓	✓			Most applicable as channel lining with geotextile underlay, used for soils where vegetation not easily established, effective for high velocities or concentrations, permits infiltration, dissipates energy of flow from culvert inlets/outlets, easy to install and repair, very durable and virtually maintenance free	Expensive, may require heavy equipment to transport and place rock, may not be feasible in areas of the province where rock is not readily available, may be labour intensive to install (hand installation); generally thickness of riprap is higher when compared to gabion mattress
13	Rolled Erosion Control Products (RECP)	✓	✓			Provides a protective covering to bare soil or topsoiled surface where need of erosion protection is high, can be more uniform and longer lasting than mulch, wide range of commercially available products	RECP use is labour intensive to install, temporary blankets may require removal prior to restarting construction activities, RECP not suitable for rocky slopes, proper site preparation is required to seat RECP onto soil correctly; high performance is tied to successful vegetation growth
15	Cellular Confinement System	✓	✓		✓	Lightweight cellular system and easily installed, uses locally available soils or grout for fill to reduce costs	Not commonly used in Alberta highway construction, expensive, installation is labour intensive (hand installation), not suitable for slopes steeper than 1H:1V
27a	Live Staking	✓		✓	✓	Establishes vegetative cover and root mat, reduces flow velocities on vegetative surface, traps sediment laden runoff, aesthetically pleasing once established, grows stronger with time as root structure develops, usually has deeper root structure than grass	Expensive, may be labour intensive to install, not commonly used in Alberta highway construction projects, revegetated areas are subject to erosion until plants are established, plants may be damaged by wildlife, watering is usually required until plants are established

Table C-1: Erosion Control Measures - Source Control

No.	BMP Name	Applications				Comments	
		Slopes	Ditches and Channels	Large Flat Surface Areas	Borrow and Stockpile Area	Advantages	Limitations
30	Riparian Zone Preservation	✓	✓	✓	✓	Preserve a native vegetation buffer to filter and slow runoff before entering sensitive (high risk) areas, most effective natural sediment control measure, slows runoff velocity, filters sediment from runoff, reduces volume of runoff on slopes	Freshly planted vegetation for newly created riparian zones requires substantial periods of time before they are as effective as established vegetation at controlling sediment
32	Scheduling	✓	✓	✓	✓	Identifies protection issues and plans for efficient, orderly construction of BMPs; minimizes bare soil exposure and erosion hazard; allows early installation of perimeter control for sediment entrapment; and early installation of runoff control measures	
34	Slope Texturing	✓			✓	Roughens slope surface to reduce erosion potential and sediment yield; suitable for clayey soils	Additional cost; not suitable for silty and sandy soils; not practical for slope length <8 m for dozer operation up/down slope
36	Polyacrylamide (PAM)	✓	✓		✓	Increase cohesion of soil particles, thus enhancing terrestrial and aquatic habitat and improving water quality	Not for application to surface waters. Not commonly used in highway construction projects and may be expensive. Treatment area must be accessible to spray equipment. Temporary measure only. Performance decreases due to exposure to UV light and time
35	Straw Mulching & Crimping (Straw Anchoring)	✓			✓	Economical method of promoting plant growth and slope protection	Availability of straw. "Punching" of straw does not work on sandy soils. Application of straw by hand is labour intensive. If using straw blowers, treatment area must be accessible to trucks for transport of weeds
37	Compost Blanket	✓		✓	✓	Economical. Appropriate on slopes 2H:1V to level surface.	Application on steep slopes may be difficult. Treatment area should be accessible to blower trucks

Table C-2: Erosion Control Measures - Runoff Control

No.	BMP Name	Applications				Comments	
		Slopes	Ditches and Channels	Large Flat Surface Areas	Borrow and Stockpile Area	Advantages	Limitations
34	Slope Texturing	✓		✓	✓	Contouring and roughening (tracking) of slope face reduces runoff velocity and increases infiltration rates; collects sediment; holds water, seed and mulch better than smooth surfaces; promotes development of vegetation, provides loss of soil reduction in soil erosion compared with untracked slopes	May increase grading costs, may cause sloughing in sensitive (wet) soils, tracking may compact soil, provides limited sediment and erosion control and should not be used as primary control measure
21	Offtake Ditch	✓		✓	✓	Collects and diverts sheet flow or runoff water at the top of a slope to reduce downslope erosion potential, incorporated with permanent project drainage systems	Channel must be sized appropriately to accommodate anticipated flow volumes and velocities, lining may be required, may require design by qualified personnel, must be graded to maintain positive drainage to outlets to minimize ponding
17	Energy Dissipator	✓	✓			Slows runoff velocity and dissipate flow energy to non-erosive level in relatively short distances, permits sediment collection from runoff	Small diameter rocks/stones can be dislodged; grouted riprap armouring may breakup due to hydrostatic pressures, frost heaves, or settlement; may be expensive, may be labour intensive to install; may require design by qualified personnel for extreme flow volumes and velocities
19	Slope Drains	✓				Directs surface water runoff into drain pipe instead of flowing over and eroding exposed soils of slope face	Must be sized appropriately to accommodate anticipated flows, erosion can occur at inlet/outlet if protection is not incorporated into design, slope drain must be anchored to slope

Table C-2: Erosion Control Measures - Runoff Control

No.	BMP Name	Applications				Comments	
		Slopes	Ditches and Channels	Large Flat Surface Areas	Borrow and Stockpile Area	Advantages	Limitations
2	Gabions		✓			Relatively maintenance free, permanent drop structure, long lasting (robust), may be less expensive than riprap, allows smaller diameter rock/stones to be used, relatively flexible, commercially available products, commonly used in Alberta highway construction projects; suitable for resisting high flow velocity	Construction may be labour intensive (hand installation), extra costs associated with gabion basket materials
7	Rock Check Dam		✓		✓	Permanent drop structure with some filtering capability, cheaper than gabion and armouring entire channel, easily constructed, commonly used in Alberta highway construction projects	Can be expensive in areas of limited rock source, not appropriate for channels draining areas larger than 10 ha (4 acres), requires extensive maintenance after high flow storm events, susceptible to failure if water undermines or outflanks structure
10	Synthetic Permeable Barriers		✓			Reusable/moveable, reduces flow velocities and dissipate flow energy; retains some sediments; used as grade breaks in conjunction with sturdy permanent drop structures along steep grades	Not to be used as check structures, must be installed by hand in conjunction with RECP, become brittle in winter and are easily damaged by construction equipment or recreational vehicles, only partially effective in retaining some sediment, primarily used for reducing flow velocities and energy dissipation
20	Groundwater Control (Subsurface Drain)	✓				Relief subsurface groundwater seepage and winter ice build-up; lower groundwater table to minimize piping erosion; enhance slope stability performance	Requires design by a qualified person; can be a slope instability issue

Table C-2: Erosion Control Measures - Runoff Control

No.	BMP Name	Applications				Comments	
		Slopes	Ditches and Channels	Large Flat Surface Areas	Borrow and Stockpile Area	Advantages	Limitations
38 28	Rolls (Fibre) Wattles	✓				Function well in freeze-thaw conditions, low cost solution to sheet flow and rill erosion on slopes, low to medium cost flow retarder and silt trap, can be used on slopes too steep for silt fences or straw bale barriers, biodegradable	Labour intensive to install (hand installation), designed for slope surfaces with low flow velocities, designed for short slope lengths with a maximum slope of 2H:1V, not widely used on Alberta highway construction projects
37	Compost Blanket	✓		✓	✓	Economical. Appropriate on slopes 2H:1V to level surface	Application on steep slopes may be difficult. Treatment area should be accessible to blower trucks

Table C-3: Sediment Control Measures

No.	BMP Name		Applications				Comments	
			Slopes	Ditches and Channels	Large Flat Surface Areas	Borrow and Stockpile Area	Advantages	Limitations
30	Filtering and Entrapment	Riparian Zone Preservation	✓	✓	✓	✓	Preserve a native vegetation buffer to filter and slow runoff before entering sensitive (high risk) areas, most effective natural sediment control measure, slows runoff velocity, filters sediment from runoff	Freshly planted vegetation for newly created riparian zones requires substantial periods of time before they are as effective as established vegetation at controlling sediment
12		Straw Bale Barrier		✓	✓	✓	Relatively inexpensive if bales are locally available, biodegradable, cheaper and easier to install than other barriers	Short service life due to biodegradation, straw bales may not be readily available in all areas of the province, maximum barrier height of one straw bale, require extensive maintenance after high flow storm events, require proper keying and staking
38		Rolls (Fibre)	✓				Function well in freeze-thaw conditions, low cost solution to sheet flow and rill erosion on slopes, low to medium cost flow retarder and silt trap, can be used on slopes too steep for silt fences or straw bale barriers, biodegradable	Labour intensive to install (hand installation), designed for slope surfaces with low flow velocities, designed for short slope lengths with a maximum slope of 2H:1V, not widely used on Alberta highway construction projects
28		Wattles						
31		Pumped Silt Control Systems (Silt Bags)		✓			Filter bag is lightweight and portable, simple set up and disposal, sediment-laden water is pumped into this filter bag, different aperture opening sizes (AOS) available from several manufacturers; normally for emergency use only	May be expensive, requires special design, not usually readily used in Alberta highway construction projects, requires a pump and power source for pump, suitable for only short periods of time and small volumes of sediment laden water, can only remove particles larger than aperture opening size (AOS)
1		Silt Fence	✓		✓	✓	Economical, most commonly used sediment control measure allows water to pond and settle out coarse grained sediment, more effective than straw bale barriers	May fail under high runoff events, applicable for sheet flow erosion only, limited to locations where adequate space is available to pond collected runoff, sediment build up needs to be removed on a regular basis, damage to silt fence may occur during sediment removal, usable life of approximately one year

Table C-3: Sediment Control Measures

No.	BMP Name		Applications				Comments	
			Slopes	Ditches and Channels	Large Flat Surface Areas	Borrow and Stockpile Area	Advantages	Limitations
5	Filtering and Entrapment	Berm Interceptor	✓		✓	✓	Easy to construct, relatively inexpensive as local soil and material is used	Geotechnical design required for fill heights in excess of 3 m, may not be suitable for all soil types or sites; riprap spillway and/or permeable outlet may be required
2		Gabions		✓			Relatively maintenance free, permanent drop structure, long lasting (robust), may be less expensive and thickness than riprap, allows smaller diameter rock/stones to be used, relatively flexible, commercially available products, commonly used in Alberta highway construction projects; suitable for resisting high flow velocity	Construction may be labour intensive (hand installation), extra costs associated with gabion basket materials
7		Rock Check Dam		✓		✓	Permanent drop structure with some filtering capability, cheaper than gabion and armouring entire channel, easily constructed, commonly used in Alberta highway construction projects	Can be expensive in areas of limited rock source, not appropriate for channels draining large areas, requires extensive maintenance after high flow storm events, susceptible to failure if water undermines or outflanks structure
10	Filtering and Entrapment	Synthetic Permeable Barriers		✓			Reusable/moveable, reduces flow velocities and dissipates flow energy; retains some sediments; used as grade breaks in conjunction with sturdy permanent drop structures along steep grades	Partially effective as check dam structure, must be installed by hand in conjunction with RECP, become brittle in winter and are easily damaged by construction equipment or recreational vehicles, only partially effective in retaining some sediment, primarily used for reducing flow velocities and energy dissipation
4		Continuous Perimeter Control Structures	✓		✓	✓	Temporary measure; divert and intercept sheet or overlaid flow to form pond and allow sedimentation; flexibility of shape of construction; no trenching	Require specialized continuous berm machine to manufacture earth-filled geotextile berm on site; sandy/gravel soil is preferable fill material
6		Storm Drain Inlet/Sediment Barrier			✓		Temporary measure; easy to install and remove	Limited sediment entrapment capacity; requires regular clean-out maintenance

Table C-3: Sediment Control Measures

No.	BMP Name		Applications				Comments	
			Slopes	Ditches and Channels	Large Flat Surface Areas	Borrow and Stockpile Area	Advantages	Limitations
37		Compost Blanket	✓		✓	✓	Economical. Appropriate on slopes 2H:1V to level surface	Application on steep slopes may be difficult. Treatment area should be accessible to blower trucks
32	All BMPs	Scheduling	✓	✓	✓	✓	Identifies protection issues and plans for efficient, orderly construction of BMPs; early installation of perimeter control for sediment entrapment; early dimension planning of runoff control measures	
18	Impoundment	Sediment Traps/Basins		✓		✓	May be constructed of a variety of materials, collects sediment laden runoff and reduces velocity of flow and deposition of sediment, can be cleaned and expanded as needed, capable of handling large volumes of sediment laden runoff	"Last resort" measure. Normally requires 250 m ³ /ha storage volume per area of exposed soil, Can require large areas of land, requires periodic maintenance to remove sediment build up, requires design by qualified personnel, usually requires 'back-up' control measures in case pond/basin overflows

Table C-4: Streambank Applications

BMP # and Name	Comments	
	Advantages	Limitations
#27a Live Staking	Establishes vegetative cover and root mat, reduces flow velocities on vegetative surface, traps sediment laden runoff, aesthetically pleasing once established, grows stronger with time as root structure develops, usually has deeper root structure than grass	Expensive, may be labour intensive to install, not commonly used in Alberta highway construction projects, revegetated areas are subject to erosion until plants are established, plants may be damaged by wildlife, watering is usually required until plants are established
#27b Brushlayering	Provide immediate soil stability and habitat Can be used with other toe protection such as, rootwads, coir rolls, and log toes. Combining live brushlayering with rock toes is an effective and relatively low cost technique for revegetating and stabilizing streambanks. Provides a source of shade and nutrients, while slowing velocities along the bank during flooding flows. They provide a flexible strengthening system to fill slopes. Act as horizontal drains and favourably modify the soil water flow regime	Live cuttings are most effective when implemented during the dormancy period of chosen plant species. Brushlayers are vulnerable to failure before rooting occurs, and they are not effective at counteracting failure along very deep-seated failure planes
#39 Brush Mattress	Provides a dense network of branches that quickly stabilize a slope or streambank. Will trap sediments during high water and eventual plant growth will enhance aquatic habitat. Well suited for combined installation with many other streambank or slope stabilization techniques such as Vegetated Riprap, Live Stakes, Live Fascines, Rootwad Revetment, Live Siltation, and Coconut Fibre Rolls. Provides immediate surface protection against floods, greatly reducing water velocity at the soil surface. Cuttings are usually available locally. Relatively economical technique. Captures sediment during floods, assisting in rebuilding of bank. Produces riparian vegetation rapidly and enhances wildlife habitat value	Does not show high success on streams where basal ends cannot be kept wet for the duration of the growing season. They should be installed during the dormant season for woody vegetation and Installation is labour intensive
#40 Live Siltation	A very effective and simple conservation method using local plant materials. Can be constructed in combination with rock toes, Rootwad Revetments, Coconut Fibre Rolls, Live Fascines, and Brush Mattresses. Valuable for providing immediate cover and fish habitat while other revegetation plantings become established. The protruding branches provide roughness, slow velocities, and encourage deposition of sediment. The depositional areas are then available for natural recruitment of native riparian vegetation	If using a living system, cuttings must be taken during the dormancy period
#41 Willow Posts and Poles	Willow posts and poles are inexpensive to acquire, install, and maintain, provide long-term protection. They may be inserted into stone or soil backfill and thus become incorporated with the structure as they root. They can also be incorporated into many techniques during construction (e.g., Vegetated Riprap, Vegetated Gabions), and can be planted in the keyways of many structures. Aquatic and terrestrial habitat is provided and/or improved. Willows act as pioneer species, and allow other plant species to colonize the area after the willows have become established	Willow posts and poles have higher survival rates when planted during their dormant season, so planning should be adjusted accordingly. Optimum stabilization is not achieved until the willows become established, typically at least one season after installation, although they provide some reinforcement immediately following installation

Table C-4: Streambank Applications

BMP # and Name	Comments	
	Advantages	Limitations
#42 Rock Vanes	<p>Rock vanes can successfully reduce near-bank velocities and shear stress, vegetation establishment is greatly improved. Vanes are often combined with other biotechnical soil stabilization measures for bank areas between the vanes. Provide aquatic habitats superior to resistive, continuous structures like Riprap and Longitudinal Stone Toe. Controlled scour at the vane tip, the creation of pool/riffle bed complexity, and increased deposition of the upstream end are the major environmental benefits of vanes. Vanes provide fish rearing and benthic habitat, creates or maintains pool and riffle habitat, provides cover and areas for adult fish, and velocity refugia.</p> <p>The redirection of impinging flows away from the bank and the sedimentation on the upstream side of the vane creates areas where vegetation can effectively re-establish. Areas of active bank erosion become depositional, vegetate, and subsequently, become permanently stable. The technique is appropriate under a range of flow conditions and bed materials and can be used in series to redirect flows around bends. Vane installation does not require extensive bank reshaping, and most heavy equipment work can be done from the top of the bank, further reducing site disturbance. Vanes require less rock and heavy equipment than riprap for a similar length of protected bank.</p>	<p>Unintended impacts can result from improper design and construction. If the vane is not properly keyed into the bank, it is likely to fail, creating new localized erosion problems. Improper vane angle and crest elevation can redirect flow in unintended directions, triggering downstream erosion</p>
#43 Longitudinal Stone Toe	<p>Willow posts and poles may be incorporated into key sections and used to revegetate the middle and upper bank above stone toe. May be combined with a number of other different techniques and the results enhance aquatic habitats. Longitudinal Stone Toe with Spurs is a variation on this technique. Bank grading, reshaping, or sloping is usually not needed (existing bank and overbank vegetation need not be disturbed or cleared), nor is a filter cloth or gravel filter needed. If stone is placed from the water side, existing bank vegetation need not be disturbed. It is very cost-effective and is relatively easy to design, specify and construct. It is easily combined with other bank stability techniques that provide superior habitat compared to pure riprap</p>	<p>Only provides toe protection and does not protect mid- and upper bank areas. Some erosion of these areas should be anticipated during long-duration, high energy flows, or until the areas become otherwise protected. Stone toe is not suitable for reaches where rapid bed degradation (lowering) is likely, or where scour depths adjacent to the toe will be greater than the height of the toe.</p>

Table C-4: Streambank Applications

BMP # and Name	Comments	
	Advantages	Limitations
#44 Vegetated Mechanically Stabilized Earth (VMSE)	The presence of vegetation softens the stark visual appearance of conventional mechanically stabilized earth structures and provides potential habitat for riparian wildlife. Overhanging branches of the live brushlayers provide shade for fish and a substrate for insects and other organisms that the fish feed upon. They permit much steeper slopes to be constructed than would be possible with live brushlayers alone. Brushlayering treatment by itself is normally restricted to slopes no steeper than 1V:2H. VMSE can be constructed with a slope as steep as 1V:0.5H. The vegetation shields the fabric against damaging UV radiation, and provides visual and riparian habitat benefits. The brushlayers act as horizontal drains that favourably modify the groundwater regime in the vicinity of the slope face, thereby improving stability against mass slope failure	A VMSE structure must be constructed during the dormancy period to insure good vegetative propagation and establishment. Alternatively, the live cuttings may be harvested during dormancy, and placed in temporary cold storage until they are ready for use during an out-of-dormancy period, viz., during the summer months (increases the cost). Materials procurement is more demanding, and installation more complex, because of the blending of two distinct methods, viz., conventional MSE and live brushlayering, into a single approach. Costs will also be more than brushlayering used alone, because of the added expense of the geotextile and the additional labour required to handle and construct the wraps. VMSE streambank structures must be constructed during periods of low water because of the need to excavate and backfill a trench with rock in the streambed to provide a stable foundation.
#45 Vegetated Rip-Rap	When graded or "self-launching" stone are used, riprap is self-adjusting to small amounts of substrate consolidation or movement. The revetment can sustain minor damage and still continue to function adequately without further damage. The rough surface of the riprap dissipates local currents and minimizes wave action more than a smooth revetment (like concrete blocks). Stones are readily available in most locations, and materials are less expensive than many other "hard armouring" techniques. The rock provides a large amount of aquatic habitat it's easily repaired. The fibrous roots of the chosen vegetation prevents washout of fines, stabilizes the native soil, anchors armour stone to the bank, and increases the lift-off resistance. The vegetation also improves drainage of the slope by removing soil moisture for its own use. Vegetated riprap has a more natural appearance, and is therefore more aesthetically pleasing, which is frequently a matter of great importance in high-visibility areas. The vegetation also supplies the river with carbon-based debris, which is integral to many aquatic food webs, and birds that catch fish or aquatic insects will be attracted by the increased perching space next to the stream. The brushlayering methods reach out over the water, and provide shade and organic debris to the aquatic system.	Vegetated riprap may be inappropriate if flow capacity is an issue, as bank vegetation can reduce flow capacity, especially when in full leaf along a narrow channel. In remote areas large rocks may be difficult to obtain and transport, which may greatly increase costs. Riprap may present a barrier to animals trying to access the stream.
#38 Rolls (Coir)	Durable with high tensile strength. Rolls and Mats accumulate sediment while plants grow and roots develop. Biodegradable. Can be combined with brushlayering to provide immediate shoreline or streambank protection.	Coir Rolls are relatively expensive. Technique should be implemented during the dormancy period of the cuttings used for brushlayering and staking.

Table C-5: Procedural BMPs (Planning Strategies) for Erosion and Sediment Control

BMP Objective	Applications				Comments	
	Slopes	Ditches and Channels	Large Flat Surface Areas	Borrow and Stockpile Area	Advantages	Limitations
Minimize Exposed Soils	✓	✓	✓	✓	Decrease of disturbed soil area decreases erosion potential and decreases quantity of erosion and sediment control measures required thus decreasing costs	May require topsoiling/seeding completed areas before stripping of new areas
Observe Environmental Timing Restrictions	✓	✓	✓	✓	Minimizes possible negative impacts on fish and wildlife	May affect schedule of adjoining works
Maximize Work During Favourable Weather	✓	✓	✓	✓	Increasing work capacity in favourable conditions minimizes volume of work required in less desirable (wet) conditions, thus decreasing potential for erosion and sediment loss	May require additional resources to increase scale of production/construction
Install BMPs Early	✓	✓	✓	✓	Early installation of erosion and sediment control measures ensures sediment losses are minimized during construction	May cause difficulties with site access or traffic
Avoid Wet Weather Periods	✓	✓	✓	✓	Avoiding construction in wet weather periods minimizes erosion potential	Shutdowns may prolong/delay construction activities
Topsoil and Seed Early	✓	✓	✓		Topsoiling and seeding as early as possible covers exposed soil and reduces erosion potential	
Surface Roughening (Slope Texturing)	✓		✓	✓	Surface roughening reduces erosion: 12% for a dozer ripping on the contour, 52% for track walking up and down the slope, 54% for sheep's foot rolling, and 76% for imprinting	Equipment may need to be retasked at a slight increase in costs
Preserve and Use Existing Drainage Systems	✓	✓	✓	✓	Preserve existing drainage routes and vegetation	May affect scheduling of certain construction activities
Control Construction Traffic				✓	Avoids over-trafficking sensitive areas or areas with increased disturbance	Forcing traffic into localized areas may increase disturbance in high-traffic areas
Signage	✓	✓	✓	✓	Clearly labelling sensitive zones or areas	Increased costs of signs

Table C-5: Procedural BMPs (Planning Strategies) for Erosion and Sediment Control

BMP Objective	Applications				Comments	
	Slopes	Ditches and Channels	Large Flat Surface Areas	Borrow and Stockpile Area	Advantages	Limitations
					not to be disturbed makes workers aware of where work cannot occur	
Scheduling of Work	✓	✓	✓	✓	Placement of topsoil and seeding should be scheduled throughout construction phase. New sections should not be stripped far in advance of construction	May require construction to be completed in one area before starting in another.
Stockpile Control				✓	Stockpiles should be located well away from watercourses and environmentally sensitive areas	May result in longer haul distances.
Direct Surface Water Flow Around Site	✓	✓	✓	✓	Keeps surface water from off-site from increasing erosion	Diversion ditches may require erosion and sediment control measures to be implemented.

Silt Fence	B.M.P. #1
Sediment Control	

Description and Purpose

- Permeable fabric barriers installed vertically on support posts along contours to collect sediment laden sheet flow runoff
- Causes water to pond allowing sediment to settle out as water filters through fabric
- Entraps and minimizes coarse sediment from sheet flow or overland flow from entering waterbodies
- Perimeter control for sediment transport and deposition

Applications

- Temporary measure
- Used at bottom of cut or fill slopes to collect sediment laden runoff
- Used along streams (or channels) banks
- Used around stockpiles
- Midslope grade-break (using "J-hook" or "smile" pattern to effect ponding, filtering and sedimentation)

Advantages

- Low permeability silt fences have high filtering capabilities for fine sand to coarse silt
- Filter fence more effective than straw bales at filtering out sediment

Limitations

- Applicable for sheet flow, cannot handle concentrated channel flow volumes
- May fail under high runoff events
- Limit to locations suitable for temporary ponding of sediment laden runoff
- Low permeability silt fences may not be strong enough to support weight of water retained behind it and may require reinforcement (i.e., wire mesh and stronger support)
- Sediment build up needs to be removed on a regular basis
- Damage to fence may occur during sediment removal
- Useable life of approximately one year dependent on regular maintenance

Silt Fence	B.M.P. #1
Sediment Control	

Construction

- Two methods of installation are commonly used
 - Trench method
 - Mechanical (slicing) installation method (e.g. Tommy Silt Fence Machine or equivalent)
- Trench Method
 - Select location of silt fence (usually along contours)
 - Drive support posts a minimum of 0.3 m into ground, spaced a maximum of 2 m apart
 - Excavate trench approximately 0.15 m deep by 0.15 m wide for entire length of fence along upstream side of posts
 - Attach the wire mesh or snow fencing, if used as reinforcement, to upstream side of posts with staples
 - Extend filter fabric to base of trench and attach over wire mesh or snow fence, if used, on upstream side of posts
 - Backfill and compact soil in trench, being careful not to damage fence
- Mechanical Installation Method
 - Select location of silt fence (usually along contours)
 - Use mechanical installation machine to embed the fabric a minimum of 0.15 m into the ground. One mechanical installation method is by slicing (with special equipment) the geotextile fabric embeds into the ground without excavation and backfill. There is only minor disturbance of the ground. Tamping of ground is required for compaction.
 - Drive support posts a minimum of 0.3 m into ground, spaced a maximum of 2 m apart
 - Attach the wire mesh or snow fencing, if used as reinforcement to silt fence fabric, to upstream side of posts with staples
 - Extend filter fabric to base of trench and attach over wire mesh or snow fence, if used, on upstream side of posts

Construction Considerations

- Site Selection

Silt Fence	B.M.P. #1
Sediment Control	

- Size of drainage area should be no greater than 0.1 ha per 30 m length of silt fence
- Maximum flow path length above silt fence should be no greater than 30 m
- Maximum slope gradient above the silt fence should be no greater than 2H:1V
- Fence should be placed on contour to produce proper ponding
- Fence should be placed far enough away from toe of slope to provide adequate ponding area (minimum of 1.8 m away from toe of slope is recommended)
- Ends of fence should be angled upslope to collect runoff
- Fence should not extend more than 0.6 m above grade
- Posts can be wood or metal material dependent on design and ground conditions
- Posts should be placed on downstream side of fence
- Posts should not be spaced greater than 2 m apart
- Wire mesh or standard snow fencing may be placed between the posts and fabric barrier to provide additional strength and support reinforcement
- Geotextile should be cut from a continuous roll to avoid joints (if joints are necessary, the wrapping of fabric around the fence post and a minimum overlap of 0.2 m with staples should be used to attach the fabric to the post)
- Fence (and wire mesh or snow fence, if used) should be attached to posts with heavy duty staples, tie wires, or hog rings
- Fence (and wire mesh or snow fence, if used) should be dug into a trench at least 0.15 m deep to prevent undercutting of fence by runoff
- Trench backfill should be compacted
- Long runs of silt fence are more prone to failure than short runs
 - Maximum length of each section of silt fence should be 40 m
 - Silt fence should be installed in 'J' hook or 'smile' configuration, with maximum length of 40 m, along contours allowing an escape path for ponded water (minimizes overtopping of silt fence structure)

Inspection and Maintenance

- Inspection frequency should be in accordance with the PESC and TESC Plans
- Repair undercut fences and repair or replace split, torn, slumping or weathered fabric immediately

Silt Fence	B.M.P. #1
Sediment Control	

- Sediment build up should be removed once it accumulates to a depth of 0.2 m
- Remove fence after vegetation is established
- Deactivate fabric by cutting-off top portion of fabric above ground; bottom trenched-in portion of fence fabric can be left in-ground thus minimizing ground disturbance

Similar Measures

- Straw Bales
- Rock Barrier
- Permeable/Synthetic Barriers

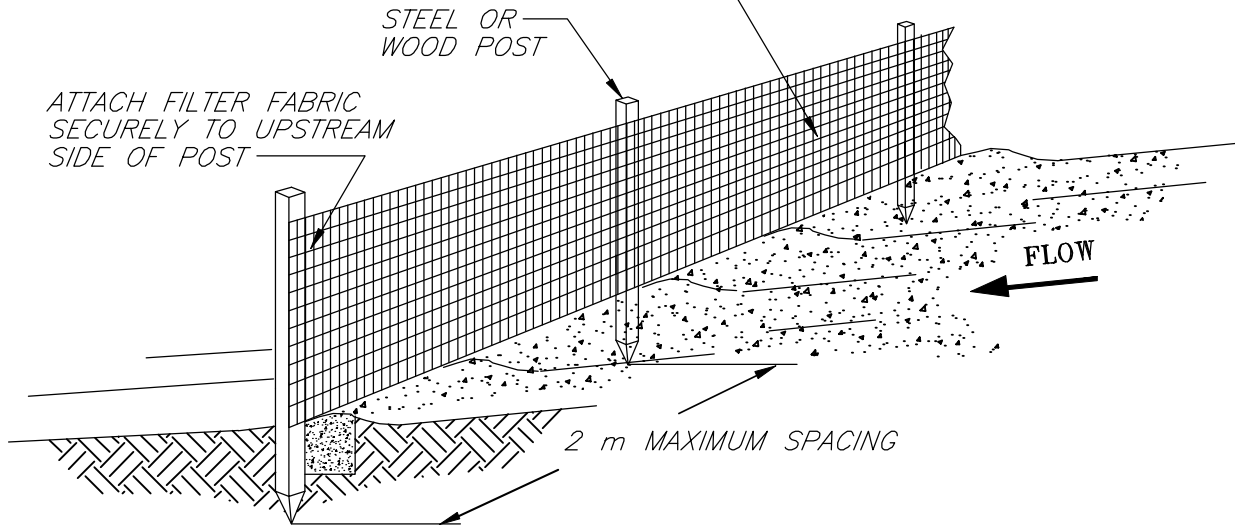
Design Considerations

- For a silt fence system to work as a system, the following factors should be considered:
 - a) quantity – adequate number and frequency of fence for efficient ponding and sedimentation
 - b) installation – workmanship
 - c) compaction – backfill and trenching of fabric
 - d) support – posts adequately embedded, appropriate selection of post material and spacing
 - e) attachment – secure fabric to post
- Install silt fences in a 'J' hook or 'smile' configuration

EXTRA STRENGTH FILTER FABRIC
NEEDED WITHOUT WIRE MESH SUPPORT

STEEL OR
WOOD POST

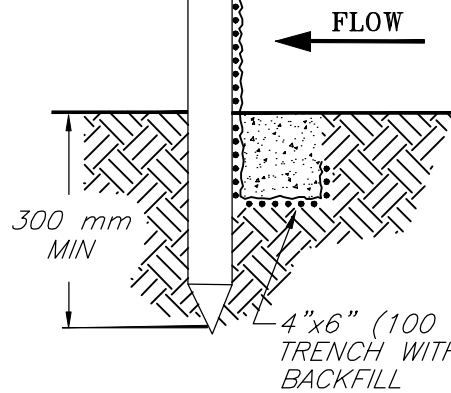
ATTACH FILTER FABRIC
SECURELY TO UPSTREAM
SIDE OF POST



2 m MAXIMUM SPACING

STEEL OR WOOD POST
1 m HIGH MAX.

MAX. PONDING HEIGHT



TRENCH METHOD DETAIL

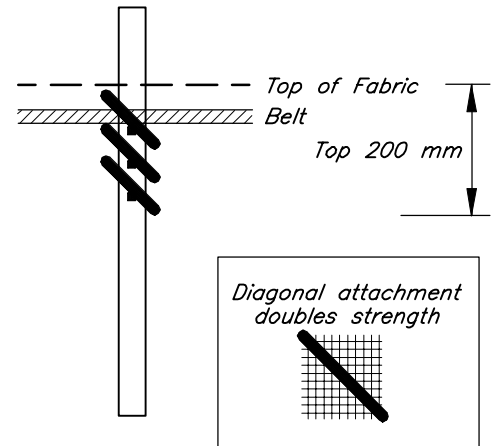
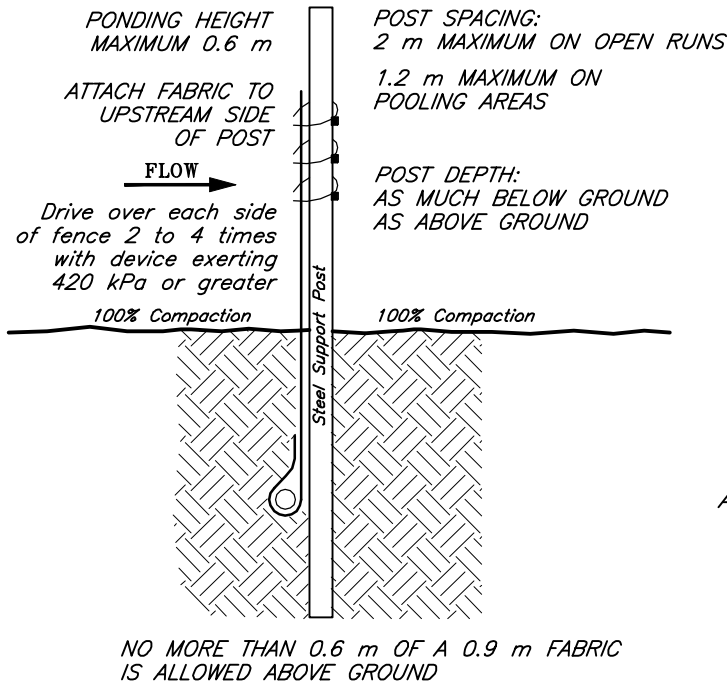
NOTES:

1. SILT FENCE SHALL BE PLACED ON SLOPE CONTOURS TO MAXIMIZE PONDING EFFICIENCY.
2. INSPECT AND REPAIR FENCE DAILY AND AFTER EACH STORM EVENT AND REMOVE SEDIMENT WHEN ACCUMULATED SILT REACHES 200 mm.
3. REMOVED SEDIMENT SHALL BE DEPOSITED TO AN AREA WILL NOT CONTRIBUTE SEDIMENT OFF-SITE.
4. THIS FIGURE IS PROVIDED FOR GUIDANCE ONLY AND DOES NOT CONSTITUTE A DESIGN. A SITE SPECIFIC DESIGN IS REQUIRED FROM DESIGNER/ENGINEER.

NOT TO SCALE

SILT FENCE
(TRENCH METHOD)

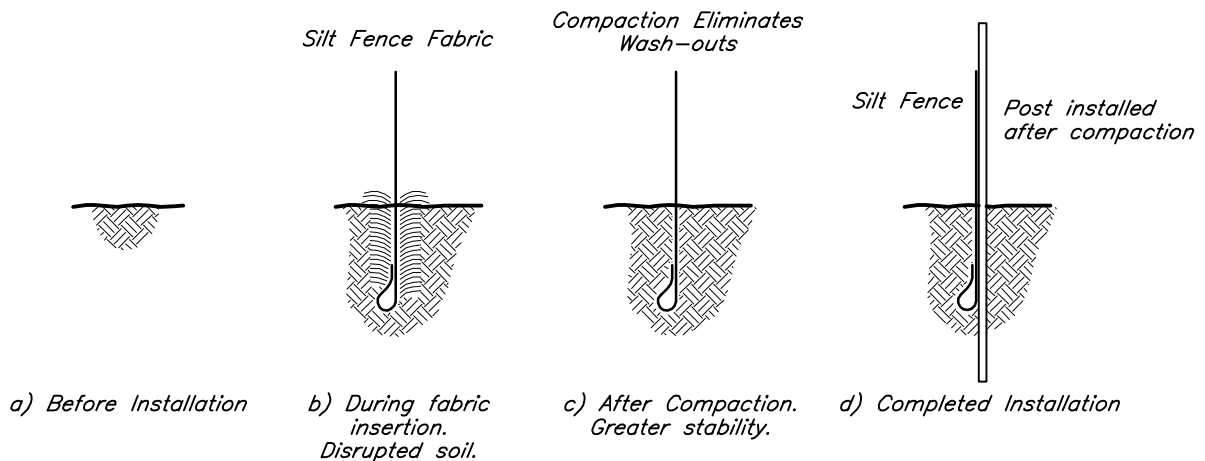
FILE: SILTFENC



ATTACHMENT DETAILS:

- Gather fabric at posts, if needed.
- Utilize three ties per post, all within top 200 mm of fabric.
- Position each tie diagonally, puncturing holes vertically a minimum of 25 mm apart.
- Hang each tie on a post nipple and tighten securely.
- Use cable ties (50 lbs) or soft wire.

MECHANICAL (SLICING) METHOD



MECHANICAL (SLICING) METHOD INSTALLATION SEQUENCE

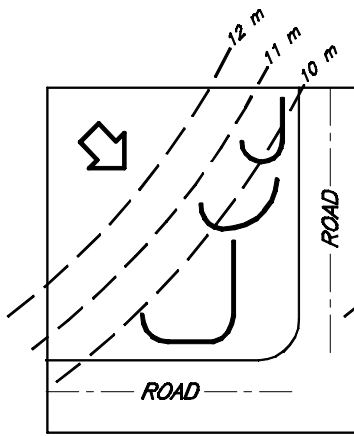
NOTES:

1. INSTALLATION MACHINE MUST ALLOW CONTINUOUS SLICING AND EMBEDMENT OF GEOTEXTILE INTO GROUND WITH MINOR GROUND DISTURBANCE.
2. INSTALLATION MACHINE TYPES WILL VARY WITH MANUFACTURER.
3. THIS FIGURE IS PROVIDED FOR GUIDANCE ONLY AND DOES NOT CONSTITUTE A DESIGN. A SITE SPECIFIC DESIGN IS REQUIRED FROM DESIGNER/ENGINEER.

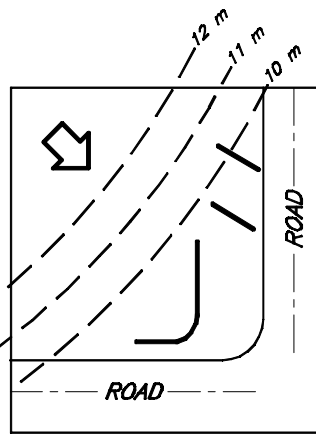
NOT TO SCALE

SILT FENCE (MECHANICAL METHOD)

SOURCE: CARPENTER T. 2000

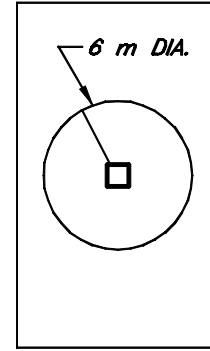
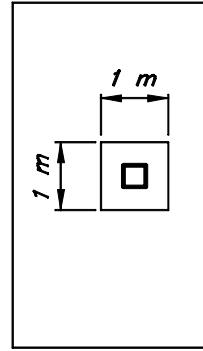


CORRECT

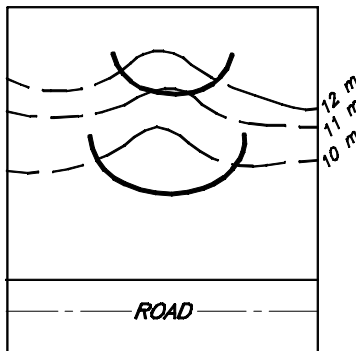


INCORRECT

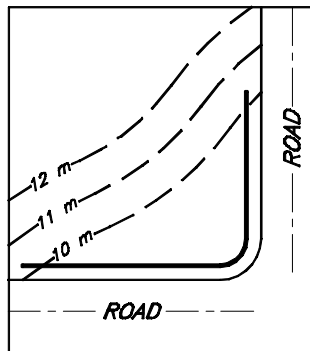
"J" CONFIGURATION



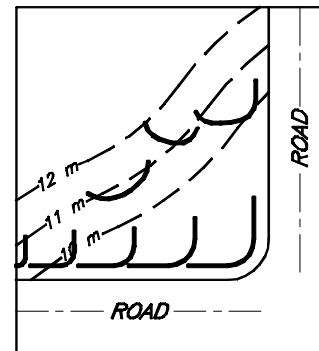
SILT FENCE BARRIER
AT STORM INLET



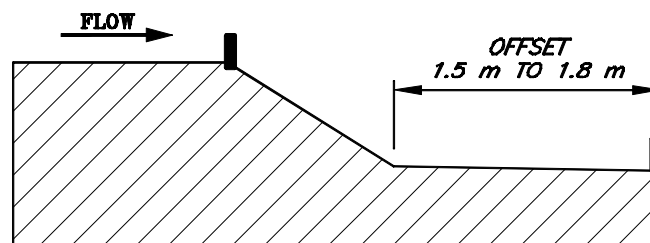
"SMILE"
CONFIGURATION



AVOID LONG
INSTALLATION



COMBINATION OF "SMILE"
AND "J" CONFIGURATIONS



LOCATION AT TOP AND BOTTOM OF SLOPE

NOT TO SCALE

NOTE:

1. THIS FIGURE IS PROVIDED FOR GUIDANCE ONLY AND DOES NOT CONSTITUTE A DESIGN. A SITE SPECIFIC DESIGN IS REQUIRED FROM DESIGNER/ENGINEER.

SOURCE: CARPENTER T. 2000

**SILT FENCE
(CONFIGURATION PLAN)**

Gabions (a - c)	B.M.P. #2
Erosion Control and Sediment Control	(a-c)

Description and Purpose

- Consist of rock placed inside wire baskets to protect steep or erodible slopes from sheet flow erosion
- Protects erodible stream channel banks from potentially high erosive concentrated flow velocities or high tractive forces

a) Slope and Banks

b) Single Gabion Drop Structure for Ditch Channel

c) Double Gabion "Energy Dissipator" Drop Structure for Ditch Channel

Applications

- Permanent measure
- May be used on stream bank aprons and blankets where flow velocities do not exceed 6 m/s
- May be constructed to 0.5H:1V as a low height slope toe protection structure
- May be used on slopes up to 1.5H:1V as slope protection, a grade break and flow check
- Gabion matting is an alternative to riprap armouring of channels
- May be used to construct dikes or weirs
- Used as a drop structure (check structure) to reduce grade between structures and as flow check in channels
- Used as a splash pad to slow down flow velocity and dissipate flow energy

Advantages

- Relatively maintenance free
- Long lasting and sturdy structure
- Lower thickness requirement for gabion (can be 1/2 to 1/3 riprap thickness) compared with riprap thickness for identical severe hydraulic conditions.
- Allows smaller diameter rock material to be used where it would normally be erodible with riprap placement
- Gabions are porous, free-draining and flexible so they are less affected by frost heaving and hydrostatic pressures

Gabions (a - c)	B.M.P. #2
Erosion Control and Sediment Control	(a-c)

- Trap sediment and support plant growth to effect higher channel resistance to flow; however, cumulative build-up of silt may render gabions less effective with diminished height

Limitations

- Construction is labour intensive
- Extra costs associated with wire for mesh cages and rock fill plus geotextile fabric or sand filter layer

Construction

- Prepare subgrade at designated gabion location on mineral soil
- Excavate trench a minimum of 0.15 m deep to 'key-in' gabion structure
- Construct gabion basket as per manufacturer's recommendations
- Line interior of basket with non-woven geotextile OR a gravely sand filter layer (if required by design) along areas where the basket is in contact with soil
 - Geotextile must be non-woven fabric to act as a separator (filter) between rock-infill and subgrade soils to minimize infiltration of fine grained particles into the gabion structure
- Backfill basket with rock with wire bracing at 1/3 points (or 0.3 m spacings)
- Install gabion basket top
- Backfill trench and compact soil around edges of completed basket

Construction Considerations

- Gabions should be placed on a properly graded surface
- Non-woven geotextile should be used to prevent loss of underlying material and infiltration of fine grained particles into the gabion structure
- Rock in the baskets may be placed by hand to enhance dense packing of stones and decrease void spaces
- Construct gabions with internal wire diaphragms to maintain structural stability and shape

Inspection and Maintenance

- Inspection frequency should be in accordance with the PESC and TESC Plans and should be inspected after major storm events, especially where undermining at the toe of the gabion is a concern

Gabions (a - c)	B.M.P. #2
Erosion Control and Sediment Control	(a-c)

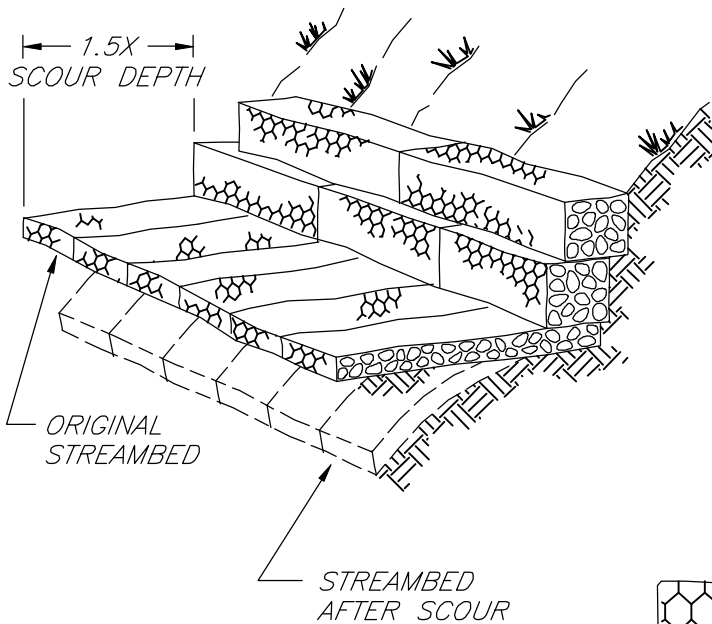
- Repair as necessary; repair may include hand grading and/or infilling undermined area with rocky material
- Removal of silt should be determined based on depth of siltation, channel erosion and establishment of vegetation

Similar Measures

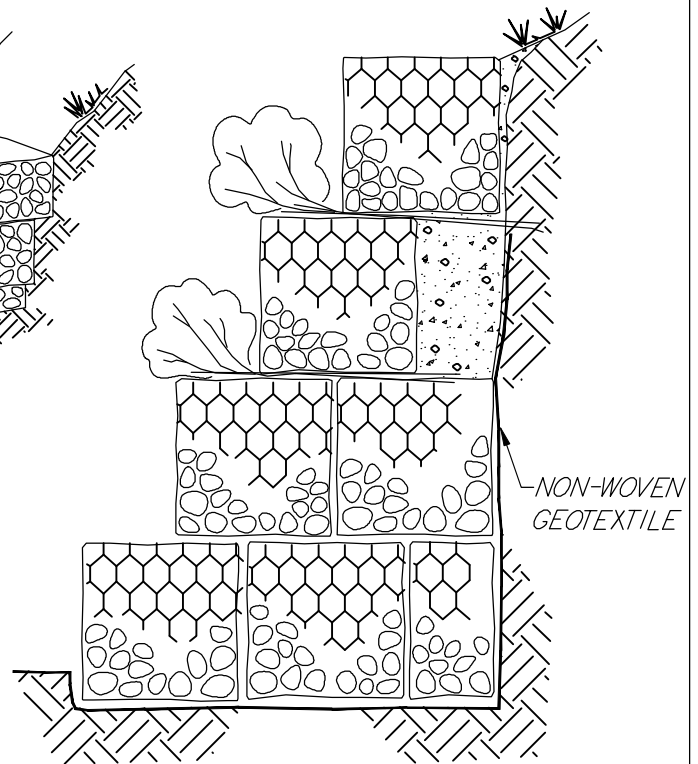
- Berms/Barriers
- Check Dams
- Permeable/Synthetic Barriers
- Rock/Brush barriers
- Sand/Gravel Bag Barriers

Design Considerations

- The design should include an energy dissipator (i.e., a gabion mat as a splash pad) at toe of downstream side of gabion drop structure if overtopping of the gabion is anticipated

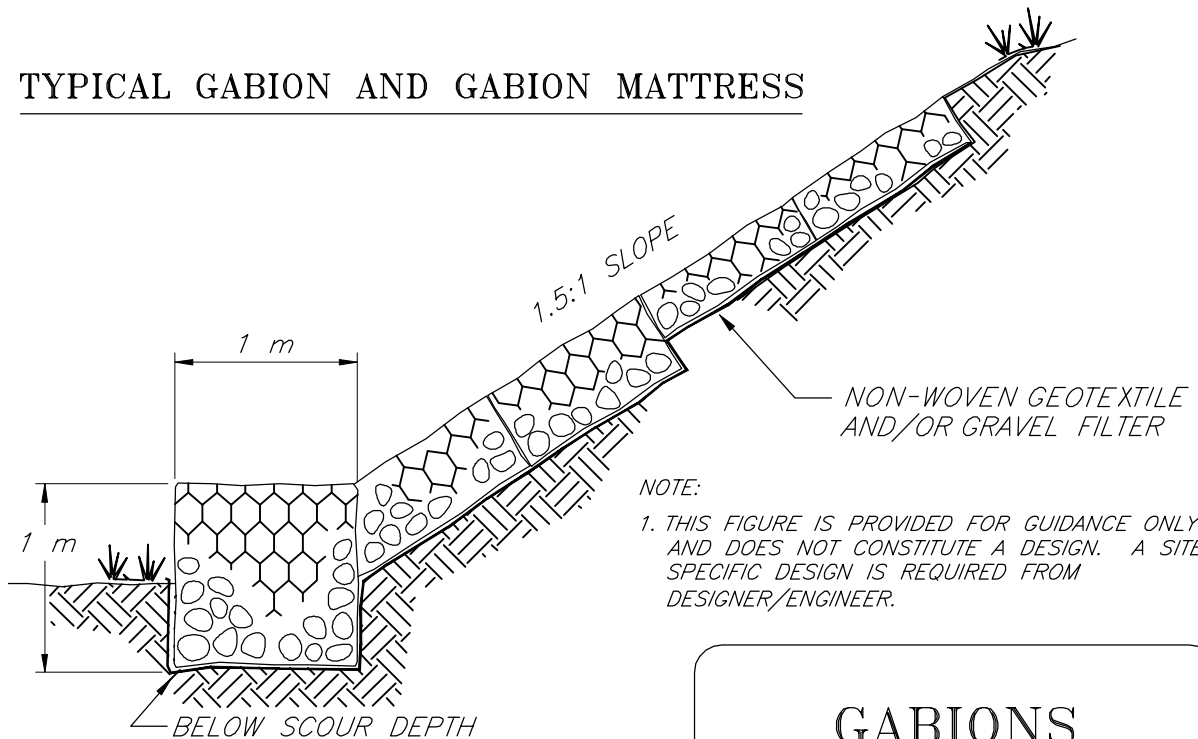


TYPICAL GABION APRON



TYPICAL VEGETATED ROCK GABION

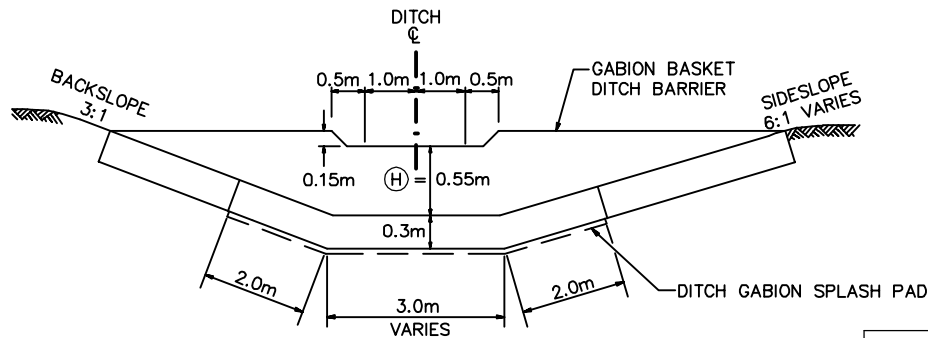
TYPICAL GABION AND GABION MATTRESS



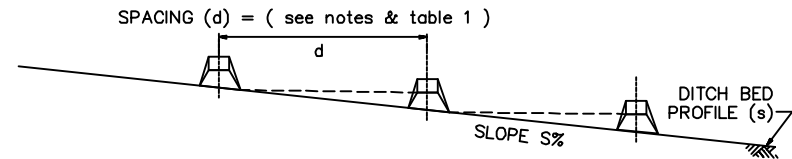
NOTE:

1. THIS FIGURE IS PROVIDED FOR GUIDANCE ONLY AND DOES NOT CONSTITUTE A DESIGN. A SITE SPECIFIC DESIGN IS REQUIRED FROM DESIGNER/ENGINEER.

**GABIONS
(SLOPE AND BANK)**



FRONT VIEW FROM DOWNSTREAM
TYPICAL DITCH CROSS-SECTION
GABION BASKET DITCH BARRIER
N.T.S.



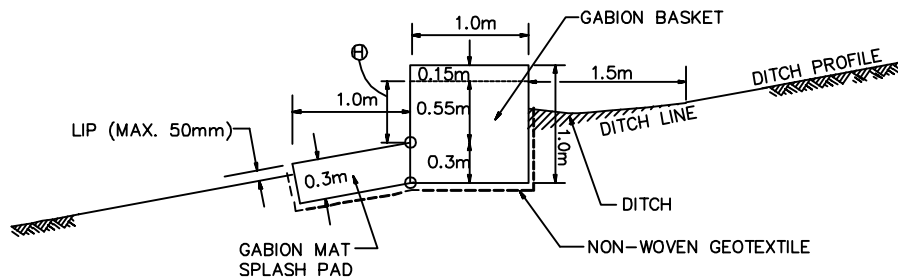
TYPICAL BARRIER SPACING
N.T.S.

SUGGESTED SPACING (d)		REMARKS
S (%)	(m)	
5-7	30	OPTION TO INSTALL A GRADE BREAK (s.a. WEAVE BARRIER) BETWEEN STRUCTURES.
7-8	25	A DOUBLE GABION FOLLOWS EVERY 2 SINGLE GABIONS.
>8%	≤15	DESIGN BY ENGINEER REQUIRED.

TABLE 1

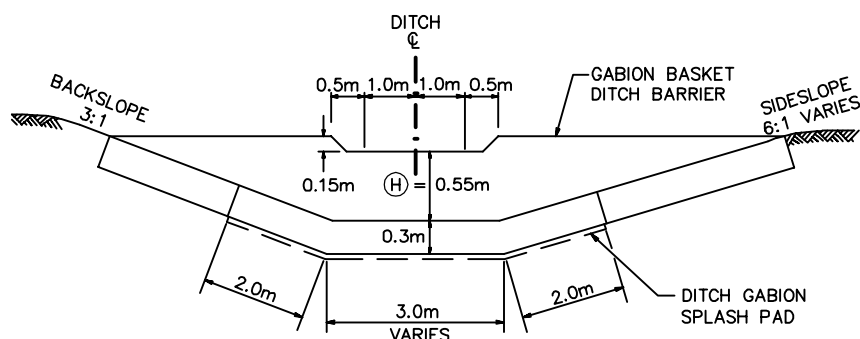
NOTES:

- SUITABLE FOR MEDIUM TO STEEP GRADES AND CHANNELS LEADING TO WATER COURSE $4\% < S < 10\%$.
- i) SPACING TO BE DETERMINED BY ENGINEER BASED ON HYDRAULIC CONDITIONS.
ii) USE IN CONJUNCTION WITH DOUBLE GABIONS OR OTHER BARRIER STRUCTURES.
- SOIL COVERING BETWEEN STRUCTURES SUGGESTED FOR STEEP GRADE SOIL DITCH.
- THIS FIGURE IS PROVIDED FOR GUIDANCE ONLY AND DOES NOT CONSTITUTE A DESIGN. A SITE SPECIFIC DESIGN IS REQUIRED FROM DESIGNER/ENGINEER.

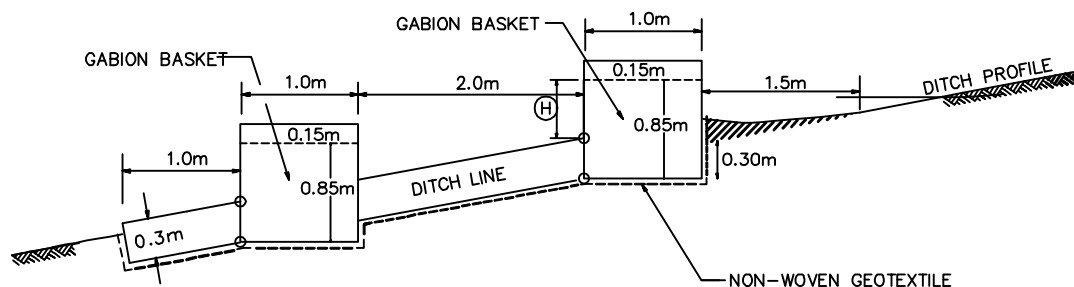


CROSS-SECTION VIEW
"SINGLE GABION" BASKET DITCH BARRIER
& GABION MAT SPLASH PAD
N.T.S.

**GABIONS
SINGLE GABION
DROP STRUCTURE FOR
DITCH CHANNEL**

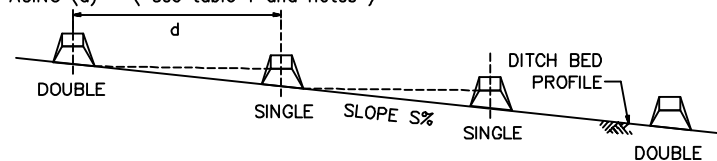


FRONT VIEW FROM DOWNSTREAM
TYPICAL DITCH CROSS-SECTION
GABION BASKET DITCH BARRIER
N.T.S.



CROSS-SECTION VIEW
"DOUBLE GABION" ENERGY DISSIPATION GABION STRUCTURE
(TWO SINGLE GABIONS COMBINED)
N.T.S.

SPACING (d) = (see table 1 and notes)



TYPICAL BARRIER SPACING
N.T.S.

SUGGESTED SPACING (d)		REMARKS
S (%)	(m)	
6-8	25 35*	INTER-SPACED WITH 2 SINGLE GABIONS BETWEEN STRUCTURES *SEE NOTES
>8%	≤15	DESIGN BY ENGINEER REQUIRED

TABLE 1

NOTES:

- SUITABLE FOR STEEP GRADES (6%<S<12%) AND CHANNELS LEADING TO WATER COURSE
- i) SPACING (d) TO BE DETERMINED BY ENGINEER BASED ON HYDRAULIC CONDITIONS.
ii) USE IN CONJUNCTION WITH SINGLE GABION AND/OR OTHER GRADE BREAK STRUCTURES.
- SUGGESTED TWO SINGLE GABIONS AT INTERVAL BETWEEN DOUBLE GABIONS.
- SOIL COVERING BETWEEN STRUCTURES SUGGESTED FOR STEEP GRADE SOIL DITCH.
- IF $d^* = 35$ m at 7 to 8% GRADE
 - GRADE BREAK (s.a. PERMEABLE WEAVE BARRIER) SHOULD BE PLACED BETWEEN STRUCTURES.
 - LONG SPACING ALLOWABLE WHEN HYDRAULIC CONDITIONS NOT SEVERE.
- THIS FIGURE IS PROVIDED FOR GUIDANCE ONLY AND DOES NOT CONSTITUTE A DESIGN. A SITE SPECIFIC DESIGN IS REQUIRED FROM DESIGNER/ENGINEER.

GABIONS
DOUBLE GABION
"ENERGY DISSIPATOR"
DROP STRUCTURE
FOR DITCH CHANNEL

Brush or Rock Filter Berm Removed	B.M.P. #3
--------------------------------------	-----------

Description and Purpose

- Constructed of sand or gravel-filled geotextile, or formed structures comprised of compost, shredded wood mulch, and natural fibres
- Used to divert and intercept sheet or overland flow
- May be used to form ponds and allow sediment to settle out
- Compost should possess no objectionable odours or substances toxic to plants
- Compost contains plant nutrients but is typically not characterized as a fertilizer

Applications

- Temporary measure
- May be used in place of silt fences or straw bale barriers to retain sediment on construction sites
- Compost used on AT projects must meet Canadian Council of Ministers of the Environment (CCME) Guidelines for Compost Quality (trace elements, maturity/stability, pathogens), which are adopted by Alberta Transportation and found on AT Products List (www.transportation.alberta.ca).
- May be used in place of silt fences or straw bale barriers to retain sediment on construction sites

Advantages

- Trenching may not be required as weight and flexibility of structure typically allows continuous contact with ground surface

Limitations

- Sand or gravel filled geotextile requires Continuous Structure Machine (CBM) for construction
- Requires specialized blower truck, hose and attachments for berm installation

Construction

- Install structure a minimum of 2 m away from toe of slope to provide adequate ponding area on upstream side of structure
- Follow operating procedures for CBM
- Use of woven geotextile is preferred due to higher tensile strength and small deformation

Continuous Perimeter Control Structures

Sediment Control

B.M.P. #4

- If required, PVC drainage pipes (e.g., 50 mm) may be inserted in downstream side of structure, spaced 100 to 150 mm apart, to facilitate drainage
- If required and appropriate, slits may be cut in upstream side of structure to facilitate filtering and drainage

Compost filter berm installation:

- Parallel to the base of the slope, or around the perimeter of affected areas, construct a trapezoidal berm at the following dimensions:

Annual Rainfall/Flow Rate	Total Precipitation	Berm Dimensions (height x width)
Low	25 mm – 635 mm	30 cm x 60 cm – 45 cm x 90 cm
Average	635 mm – 1270 mm	30 cm x 60 cm – 45 cm x 90 cm
High	>1270 mm	45 cm x 90 cm – 60 cm x 120 cm

- Base of berm is twice the height
- Compost shall be uniformly applied using an approved spreader unit - including pneumatic blowers, specialized berm machines, etc
- Seeding the berm may be done in conjunction with pneumatic blowing
- Compost can be blown into a netted sock to be used as a berm

Construction Considerations

- Structure constructed of sand, aggregate, or other pervious soil encased in geotextile fabric
- Maximum structure height is approximately 0.4 m
- Higher permeability fill materials should be used in 'drainage chambers' in low areas
- Compost filter berm dimensions and blanket application rates vary with soil characteristics, existing vegetation and climatic conditions
- Use larger berm application rate in high rates of precipitation and rainfall intensity, and snow melt
- Use larger berms in severe grade and long slope lengths
- Berms may be placed at the top and the base of a slope
- A series of berms may be used down a slope (5 to 8 m apart)
- Berms may be used in conjunction with a compost blanket, especially in regions with spring melt, and sites with severe grades and long slopes

Continuous Perimeter Control Structures	B.M.P. #4
Sediment Control	

- Use smaller berm application rate in lower precipitation rates and rainfall intensity regions
- Use larger berms where they are required to be in place or function for more than one year

Inspection and Maintenance

- Inspection frequency should be in accordance with PESC and TESC Plans.
- Inspect for sediment accumulation and remove sediment when depths reach approximately one-third the structure height
- Inspect for toe undermining, weathered/deteriorated geotextile, and end runs and erosion of the filter and repair immediately
 - Damaged sections may be repaired by restapling or placing another section of continuous structure upstream of the damaged section to provide seal
- If the structure is encased in a geotextile fabric, removal of structure is accomplished by splitting the structure, spilling fill material and removing fabric
- Removal of berm is accomplished by splitting the berm and sock, spilling fill material and removing sock

Similar Measures

- Structures/Barriers
- Sand/Gravel Bag Barriers
- Silt Fence
- Compost Berm

Berm Interceptor	B.M.P. #5
Sediment Control	

Description and Purpose

- Earth dyke barrier constructed of compacted soil to intercept and divert flow of runoff water away from erodible slopes, sensitive areas or water bodies
- A spillway outlet of erosion-resistant granular material constructed to allow exit of diverted water to less sensitive areas

Applications

- Temporary or permanent measure
- Used instead of, or in conjunction with, diversion ditches
- Perimeter control
- Placed along contours and/or at toe of slope to divert run-off from sensitive areas
- Used to divert water to sediment control structures

Advantages

- Easy to construct
- Can be converted to sedimentation/impoundment pond with the design of a permeable filter berm at the exit spillway area (see BMP #13)

Limitations

- Generally, earth dyke barriers can be 1 to 2 m in height. Design by a geotechnical engineer is required for barriers greater than 3 m in height in accordance with dam design guidelines and regulatory requirements. The consequences of failure will influence the level of design and construction requirements

Construction

- Construct barrier from bottom up by placing and compacting subsequent lifts of soil
- Degree of compaction of each lift to be specified by the design engineer based on consequences of failure

Berm Interceptor	B.M.P. #5
Sediment Control	

Construction Considerations

- The barrier should be trapezoidal in cross-section
- Low barriers should have the slopes suited to the construction material used
 - 1.5H:1V for granular soils
 - 2H:1V or flatter for compacted mixed or fine grained soils
 - Slope should be flattened to a minimum of 3H:1V for uncompacted fine grained soils

Inspection and Maintenance

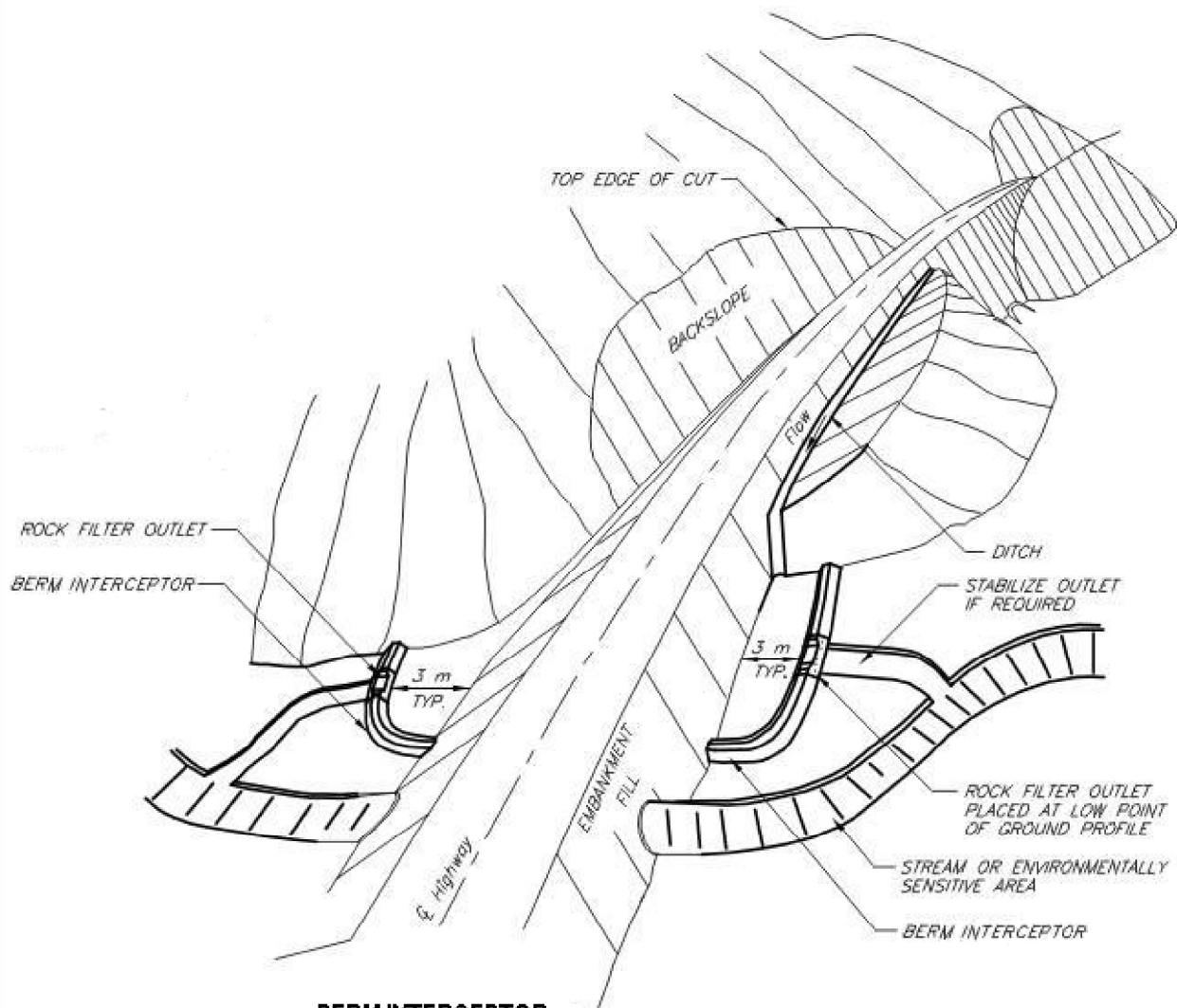
- The degree and extent of inspection and maintenance performed on a earth dyke barrier is directly related to the consequences of failure. An engineer experienced in embankment design and inspection may be required for design, inspection, design of remedial measures, and supervision of their implementation
- Inspection frequency should be in accordance with the PESC and TESC Plans
- Piping failures may be remedied by replacing saturated soils with drier compacted soil and/or by placement of geotextile over the failed area and placing a stabilizing toe berm constructed of granular materials
- Inspect for sediment accumulation and remove sediment when depths reach approximately one-half the barrier height
- Deactivate and remove barrier once slope soils have stabilized and return barrier location to an acceptable condition

Similar Measures

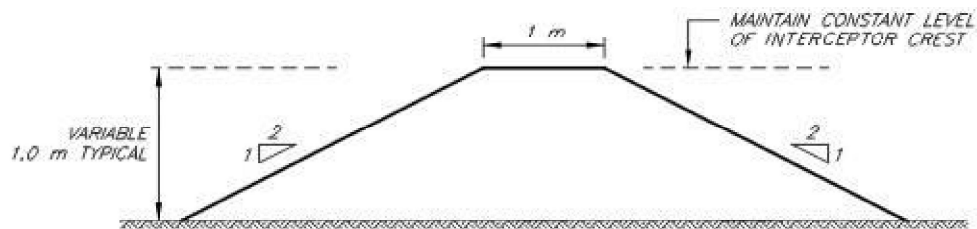
- Berms
- Sand/Gravel Bag Barriers

Design Considerations

- Geotechnical design required for barriers constructed of fine grained soils and greater than 3 m in height



BERM INTERCEPTOR
TYPICAL LOCATION



TYPICAL SECTION
BERM INTERCEPTOR

NOTES:

1. SILT ACCUMULATION TO BE REMOVED WHEN HALF BERM INTERCEPTOR HEIGHT COVERED.
2. THIS FIGURE IS PROVIDED FOR GUIDANCE ONLY AND DOES NOT CONSTITUTE A DESIGN. A SITE SPECIFIC DESIGN IS REQUIRED FROM DESIGNER/ENGINEER.

**BERM
INTERCEPTOR**

Storm Drain Inlet Sediment Barrier (a-f)	B.M.P. #6
Sediment Control	(a-f)

Description and Purpose

- Temporary devices constructed to minimize the amount of sediment entering a storm drain by ponding sediment laden runoff at the inlet
- Storm Drain Inlet protection can consist of the following measures:
 - a) Block and Gravel Sediment Barrier – Option 1
 - b) Block and Gravel Curb Inlet Sediment Barrier – Option 2
 - c) Sand Bag Curb Inlet Sediment Barrier – Option 1
 - d) Sand Bag Curb and Gutter Sediment Barrier – Option 2
 - e) Straw Bale / Gravel Sediment Barrier - Option
 - f) Silt Fence Sediment Barrier - Option

Applications

- Temporary measure
- Used where storm drains are operational prior to establishing vegetation on disturbed drainage areas
- Can be effective where drainage enters municipal sewers or watercourses
- Used for small, nearly level (less than 5% grade) drainage areas
- Used as curb inlet barriers in gently sloping ditches and gutters
- Used where drainage area is 0.4 ha (1 ac) or less
- Used in open areas subjected to sheet flow and concentrated flows less than 0.014 m³/s (0.5 cfs)
- Block and gravel bag barriers are applicable when sheet flows or concentrated flows exceed 0.014 m³/s (0.5 cfs) and is necessary to allow for overtopping to prevent flooding
- Excavated drop inlet sediment traps are appropriate where relatively heavy flows are expected and overflow capacity is required

Advantages

- Easy to install and remove
- Sand bags may be reusable

Limitations

Storm Drain Inlet Sediment Barrier (a-f)	B.M.P. #6
Sediment Control	(a-f)

- Ponding around inlet may result in excessive local flooding
- Use only when ponding will not encroach into vehicular traffic, onto erodible surfaces and slopes or beyond the limits of the construction site
- Frequent removal of sediment required for high flow situations

Construction

- Place inlet sediment barrier around entrance to drain/pipe. The option appropriate for use is dependent on site conditions.
- Silt fence barrier can be used for soil surfaces
- Gravel or aggregate filled sand bags should be used for asphalt or concrete surfaces
- Aggregate filled sand bags
 - Place sand bags stacked one or two bags high around inlet
- Gravel barriers
 - Place concrete blocks stacked one or two blocks high, with cavities of blocks aligned with direction of flow, around inlet
 - Wrap 13 mm (1/2 inch) wire mesh around concrete blocks
 - Place 25 mm to 38 mm diameter rock around block and wire mesh assembly ensuring rock extends down from top of blocks to asphalt or concrete surfacing
- Gravel filter curb inlet
 - Place concrete blocks stacked one or two blocks high around inlet, with cavities of blocks aligned with direction of flow, forming a 'U' shape
 - Wrap 13 mm (1/2 inch) diameter wire mesh around concrete blocks
 - Place 25 mm to 38 mm diameter rock around block and wire mesh assembly ensuring rock extends down from top of blocks to asphalt or concrete surfacing

Construction Considerations

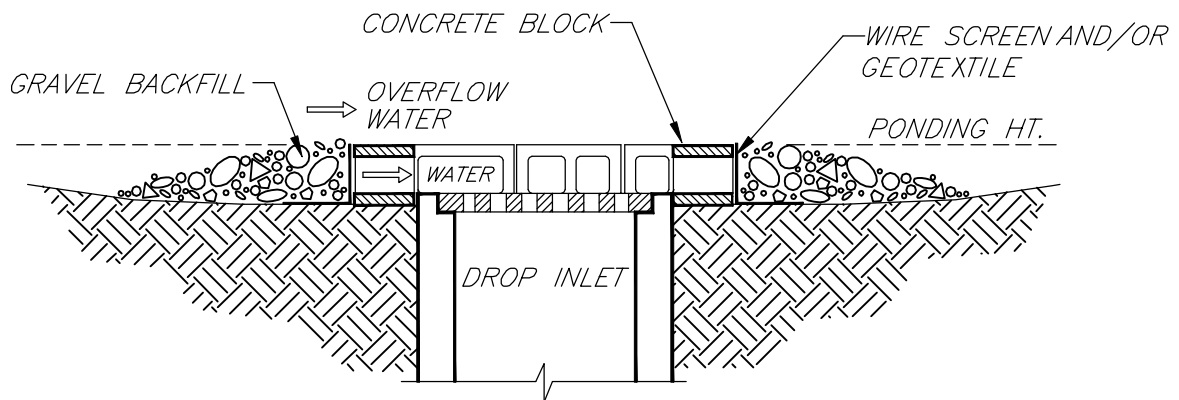
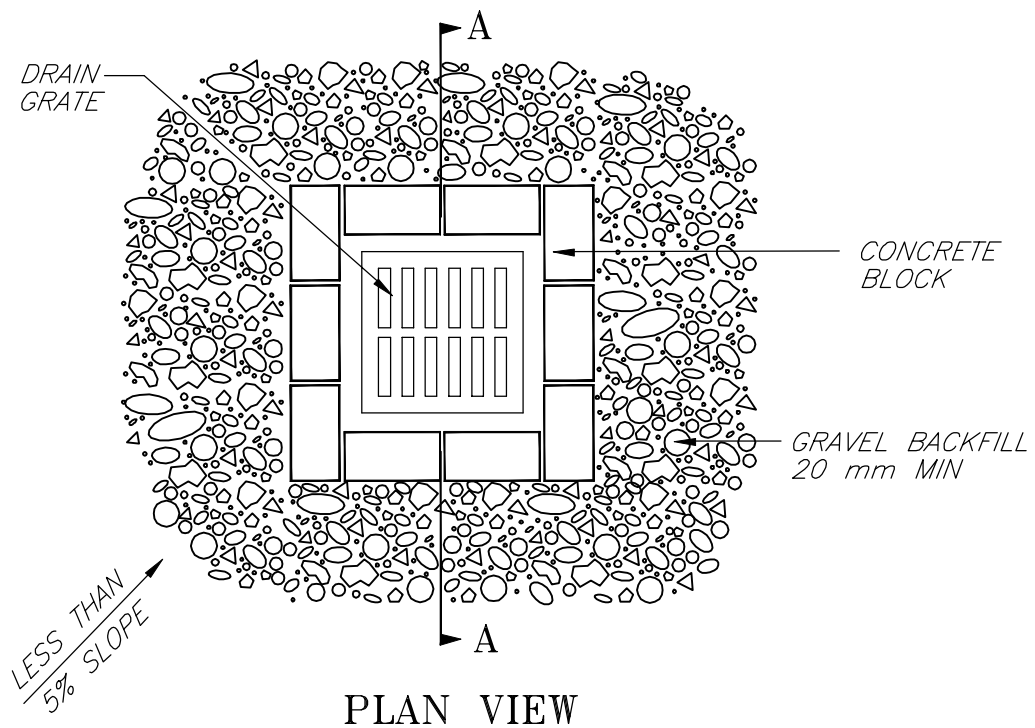
- Gravel or aggregate filled sand bags should be used for asphalt or concrete surfaces
- Aggregate filled sand bags
 - Sand bags should be filled with pea gravel, drain rock, or other free draining material

Storm Drain Inlet Sediment Barrier (a-f)	B.M.P. #6
Sediment Control	(a-f)

- Gravel or aggregate filled sand bags should be filled only $\frac{3}{4}$ full to allow sand bag to be flexible to mould to contours, maintaining continuous contact with surface
- Barrier should be placed at least 0.1 m from inlet to be protected
- Several layers of sand bags should be overlapped and tightly packed against one another
- A one sand bag wide gap should be left in the lowest point of the upper layer to act as an emergency spillway
- Gravel filter inlet berm and gravel filter curb inlet
 - Slope gravel towards inlet at a maximum slope of 2H:1V
 - Maintain at least 0.3 m spacing between toe of gravel and inlet to minimize gravel entering inlet
 - 25 mm wire mesh may be placed over inlet to prevent gravel from entering inlet
- For drainage areas larger than 0.4 ha (1 ac) runoff should be directed towards a sediment retention device designed for larger flows before allowing water to reach inlet protection structure
- Use aggregate sand bags filled with 25 mm diameter rock in place of concrete blocks for gravel filter inlet berm or gravel filter curb inlet

Inspection and Maintenance

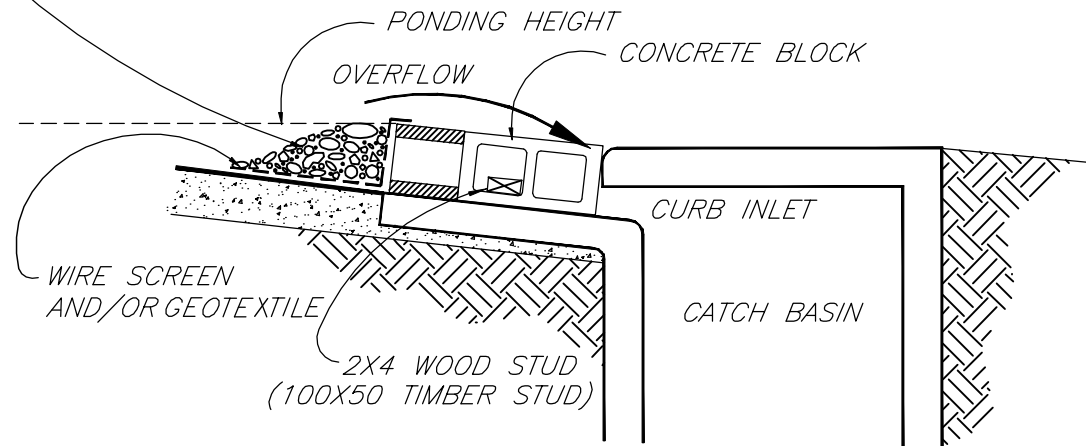
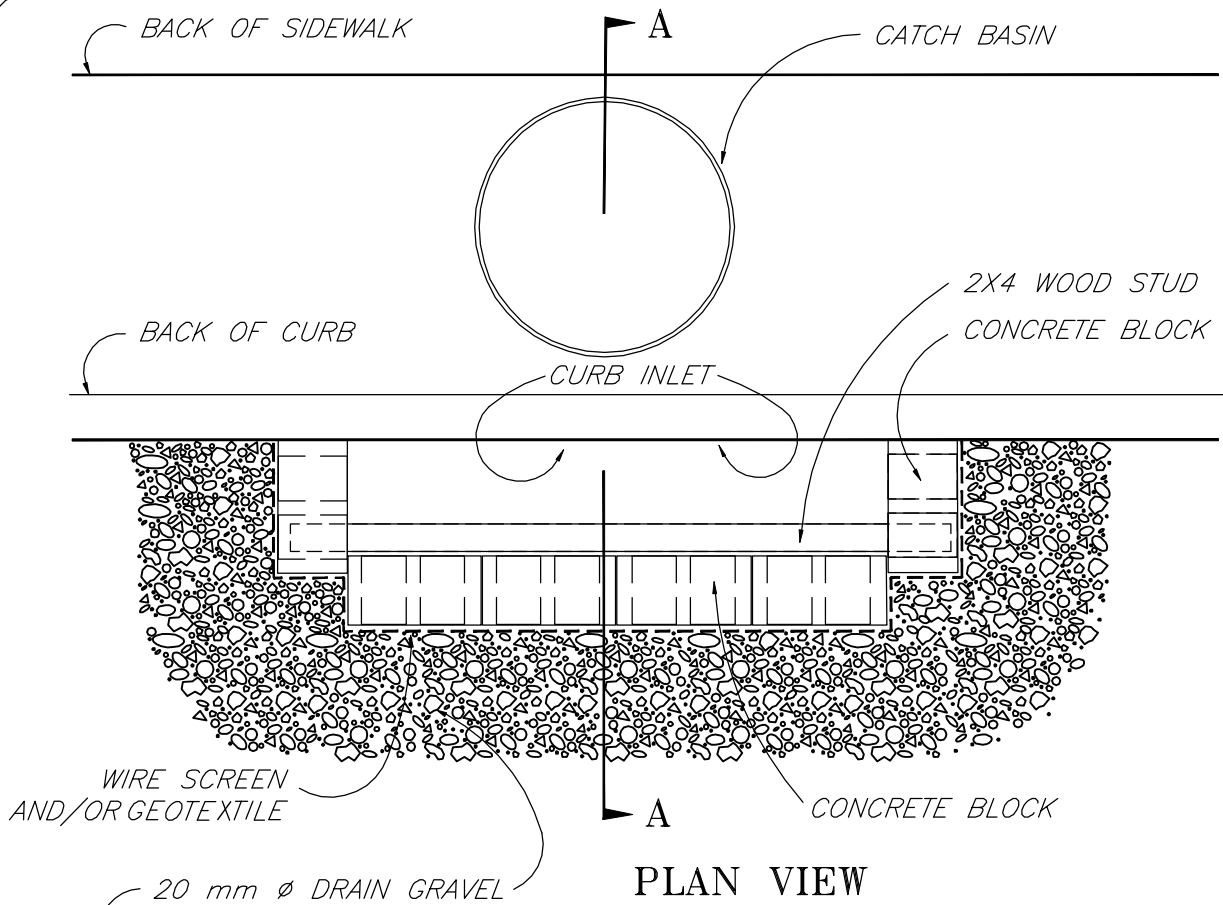
- Inspection frequency should be in accordance with the PESC and TESC Plans
- Remove sediment build up after each storm event
 - Sediment and gravel should not be allowed to accumulate on roads
- Replace gravel if it becomes clogged with sediment
- Remove all inlet protection devices when inlet protection is no longer required



NOTES:

1. STORM DRAIN DROP INLET SEDIMENT BARRIERS ARE TO BE USED FOR SMALL, NEARLY LEVEL DRAINAGE AREAS. (LESS THAN 5%).
2. EXCAVATE A BASIN OF SUFFICIENT SIZE ADJACENT TO THE STORM DRAIN DROP INLET.
3. THE TOP OF THE STRUCTURE (PONDING HEIGHT) MUST BE WELL BELOW THE GROUND ELEVATION DOWNSLOPE TO PREVENT RUNOFF FROM BYPASSING THE INLET. A TEMPORARY DYKE MAY BE NECESSARY ON THE DOWNSLOPE SIDE OF THE STRUCTURE.
4. THIS FIGURE IS PROVIDED FOR GUIDANCE ONLY AND DOES NOT CONSTITUTE A DESIGN. A SITE SPECIFIC DESIGN IS REQUIRED FROM DESIGNER/ENGINEER.

**STORM DRAIN DROP INLET
SEDIMENT BARRIER**
(BLOCK AND GRAVEL - OPTION 1)

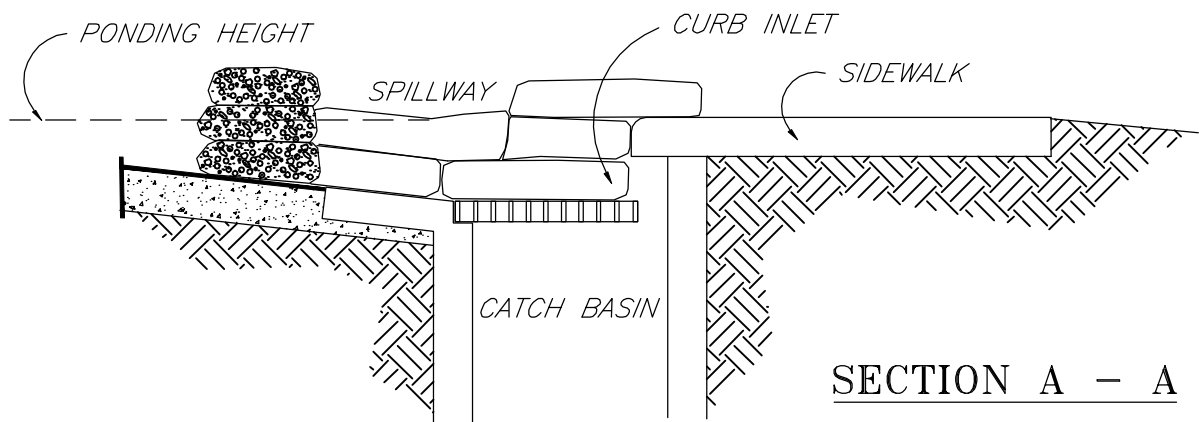
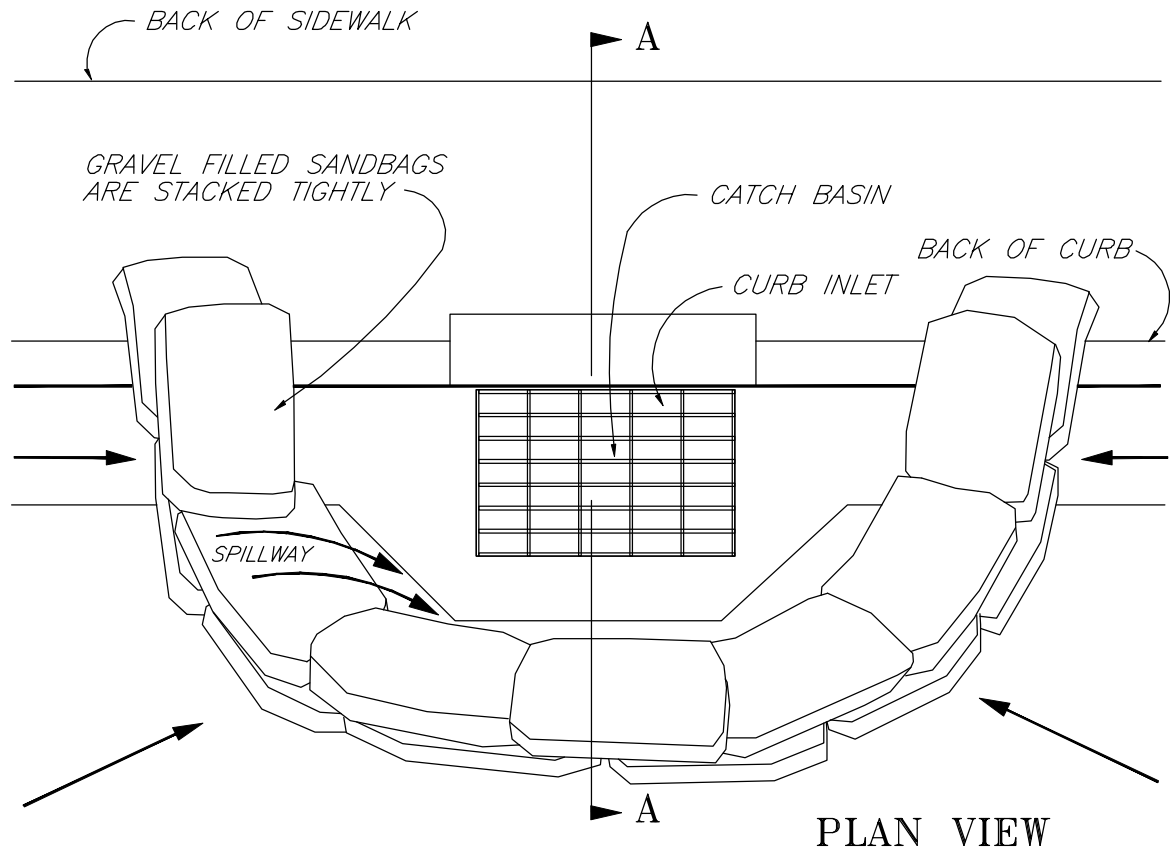


NOTES:

1. USE BLOCK AND GRAVEL TYPE SEDIMENT BARRIER WHEN CURB INLET IS LOCATED IN GENTLY SLOPING STREET SEGMENT, WHERE WATER CAN POND AND ALLOW SEDIMENT TO SEPARATE FROM RUNOFF.
2. BARRIER SHALL ALLOW FOR OVERFLOW FROM SEVERE STORM EVENT.
3. INSPECT BARRIERS AND REMOVE SEDIMENT AFTER EACH STORM EVENT. SEDIMENT AND GRAVEL MUST BE REMOVED FROM THE TRAVELED WAY IMMEDIATELY.
4. THIS FIGURE IS PROVIDED FOR GUIDANCE ONLY AND DOES NOT CONSTITUTE A DESIGN. A SITE SPECIFIC DESIGN IS REQUIRED FROM DESIGNER/ENGINEER.

SECTION A - A

**STORM DRAIN CURB INLET
SEDIMENT BARRIER
(BLOCK AND GRAVEL - OPTION 2)**



NOTES:

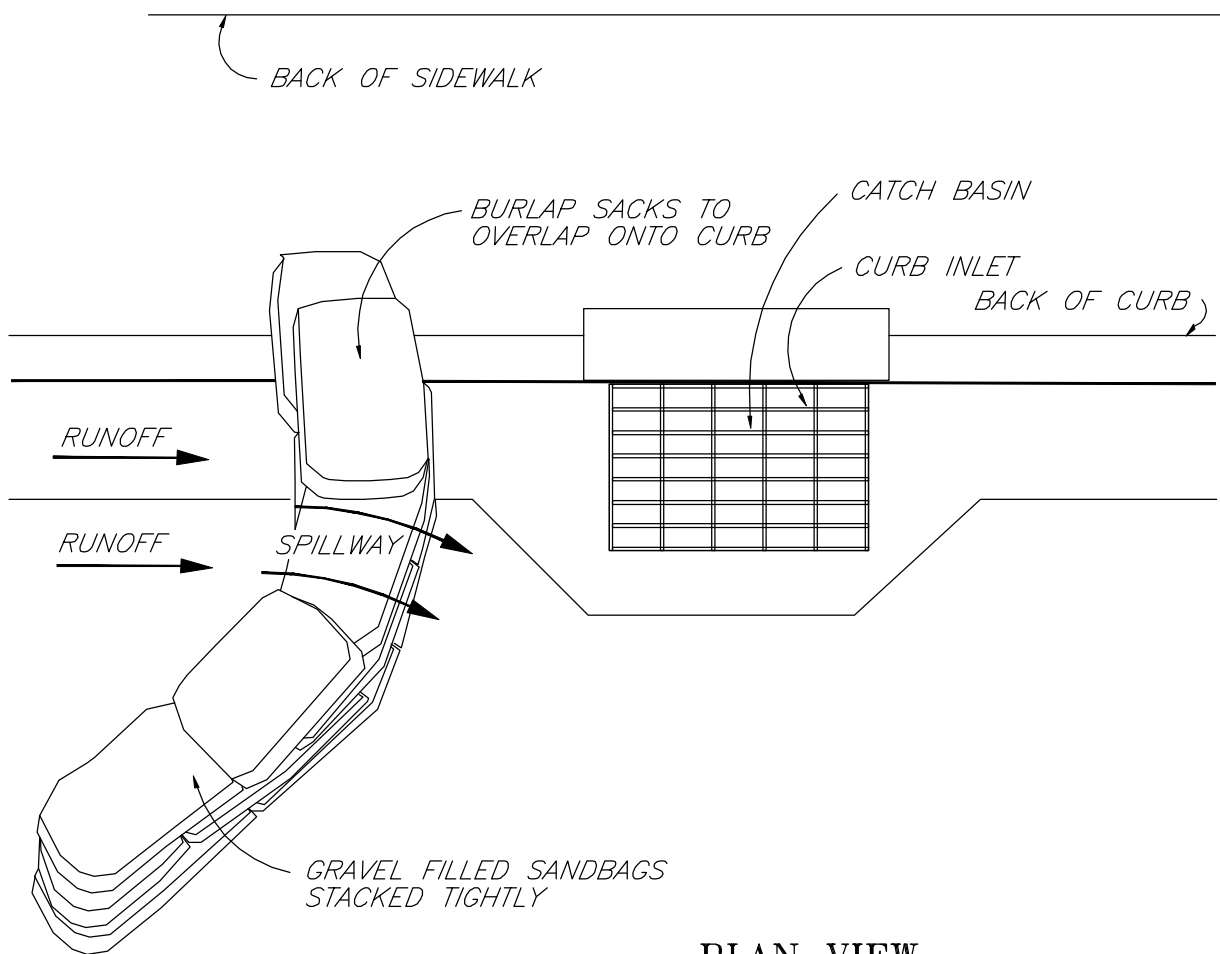
1. PLACE CURB TYPE SEDIMENT BARRIERS ON GENTLY SLOPING STREET SEGMENTS WHERE WATER CAN POND AND ALLOW SEDIMENT TO SETTLE OUT.
2. SANDBAGS, OF EITHER BURLAP OR WOVEN GEOTEXTILE FABRIC, ARE FILLED WITH GRAVEL, LAYERED AND PACKED TIGHTLY.
3. LEAVE ONE SANDBAG GAP IN THE TOP ROW TO PROVIDE A SPILLWAY FOR OVERFLOW.
4. INSPECT BARRIERS AND REMOVE SEDIMENT AFTER EACH STORM EVENT. SEDIMENT AND GRAVEL MUST BE REMOVED FROM THE TRAVELED WAY IMMEDIATELY.
5. THIS FIGURE IS PROVIDED FOR GUIDANCE ONLY AND DOES NOT CONSTITUTE A DESIGN. A SITE SPECIFIC DESIGN IS REQUIRED FROM DESIGNER/ENGINEER.

**STORM DRAIN CURB INLET
SEDIMENT BARRIER
(SANDBAGS - OPTION 1)**

From: Salix-Applied Earthcare - EROSION DRAW 3.0
1994 JOHN McCULLAH



FILE: SANDCURB

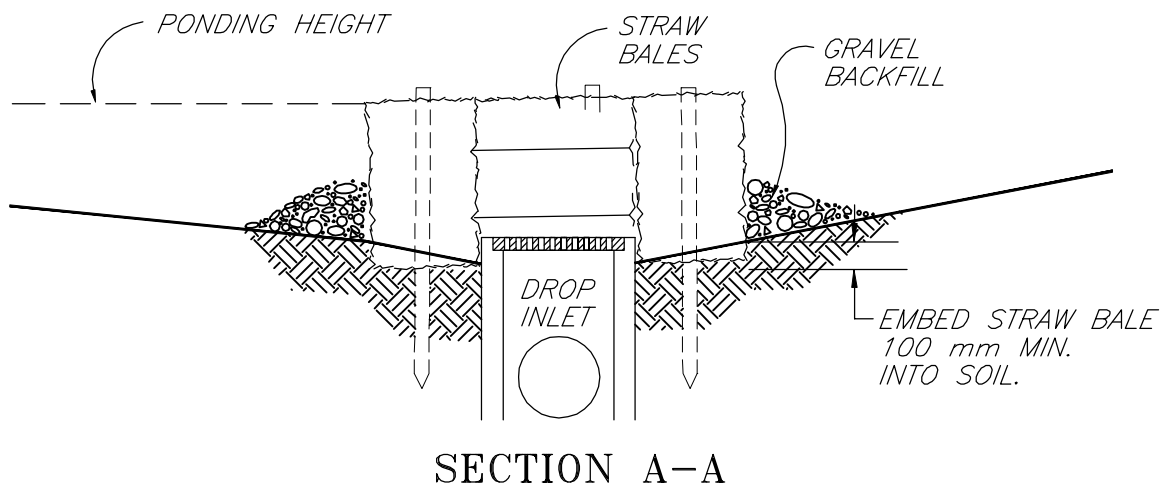
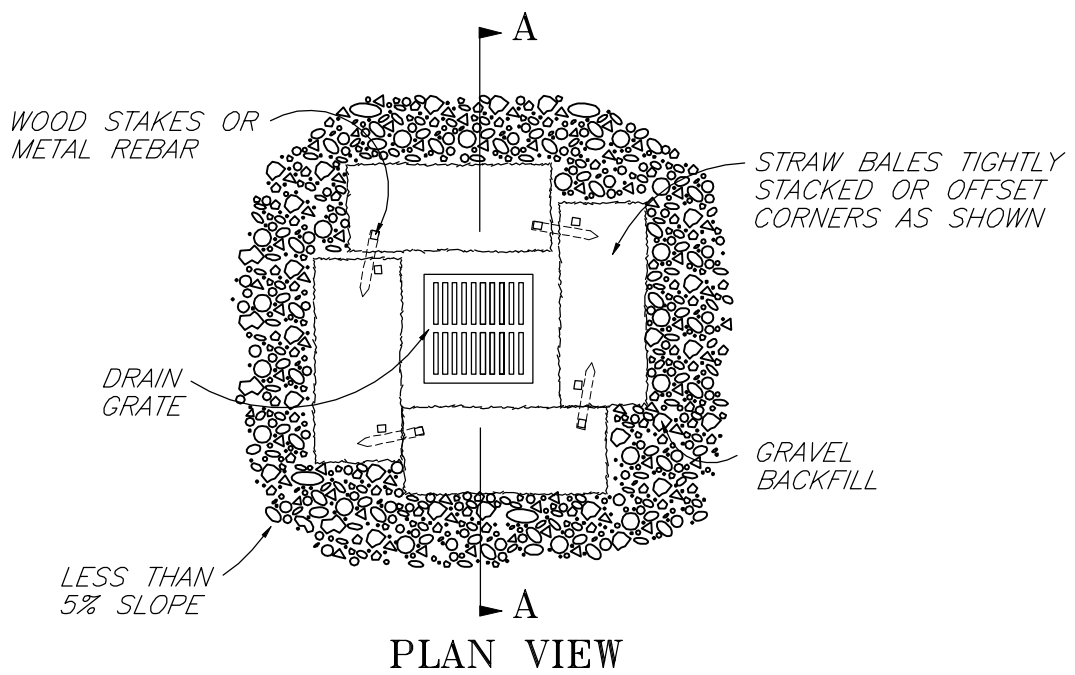


PLAN VIEW

NOTES:

1. PLACE CURB TYPE SEDIMENT BARRIERS ON GENTLY SLOPING STREET SEGMENTS, WHERE WATER CAN POND AND ALLOW SEDIMENT TO SETTLE OUT.
2. SANDBAGS OF EITHER BURLAP OR WOVEN 'GEOTEXTILE' FABRIC, ARE FILLED WITH GRAVEL, LAYERED AND PACKED TIGHTLY.
3. LEAVE A ONE SANDBAG GAP IN THE TOP ROW TO PROVIDE A SPILLWAY FOR OVERFLOW.
4. INSPECT BARRIERS AND REMOVE SEDIMENT AFTER EACH STORM EVENT. SEDIMENT AND GRAVEL MUST BE REMOVED FROM THE TRAVELED WAY IMMEDIATELY.
5. DESIGN CENTRE SPILLWAY LOWER THAN OUTSIDE EDGE TO MINIMIZE FLOW OUTFLANGING.
6. THIS FIGURE IS PROVIDED FOR GUIDANCE ONLY AND DOES NOT CONSTITUTE A DESIGN. A SITE SPECIFIC DESIGN IS REQUIRED FROM DESIGNER/ENGINEER.

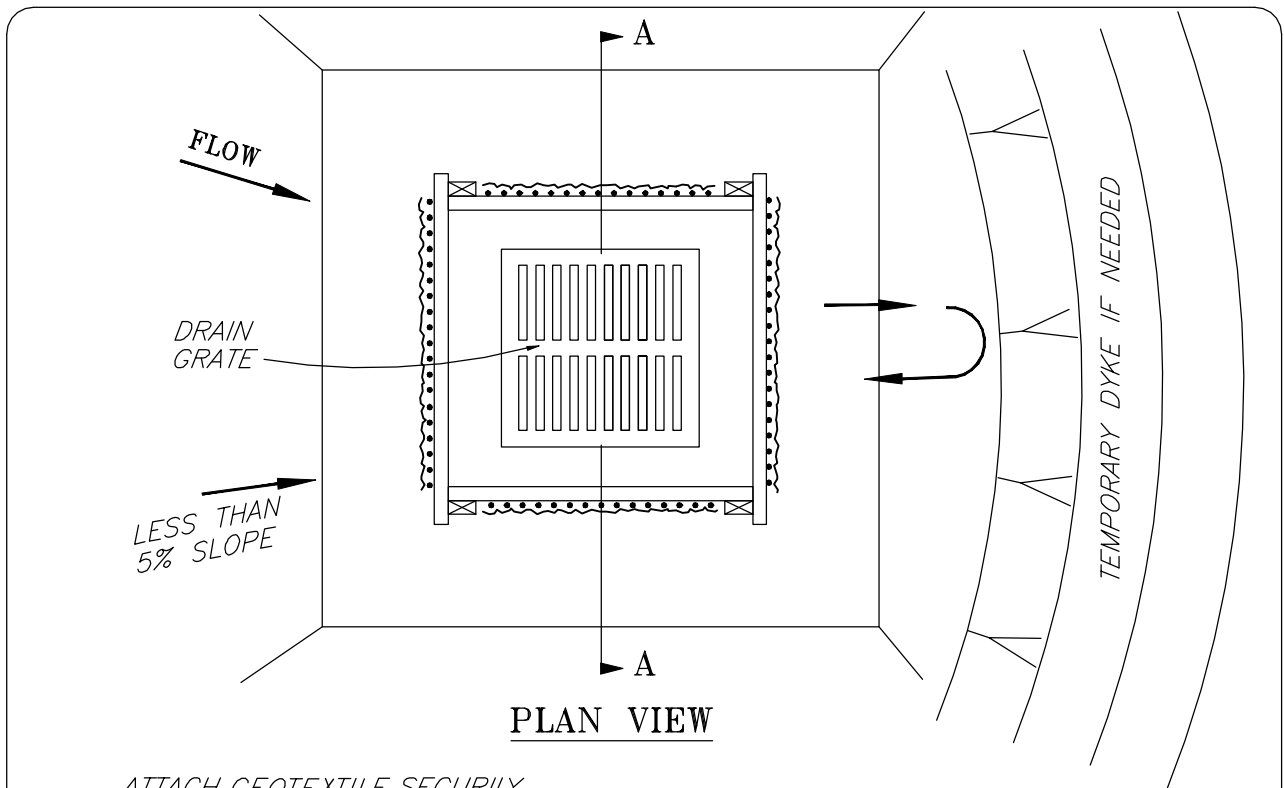
**STORM DRAIN INLET
CURB AND GUTTER
SEDIMENT BARRIER
(SANDBAGS - OPTION 2)**



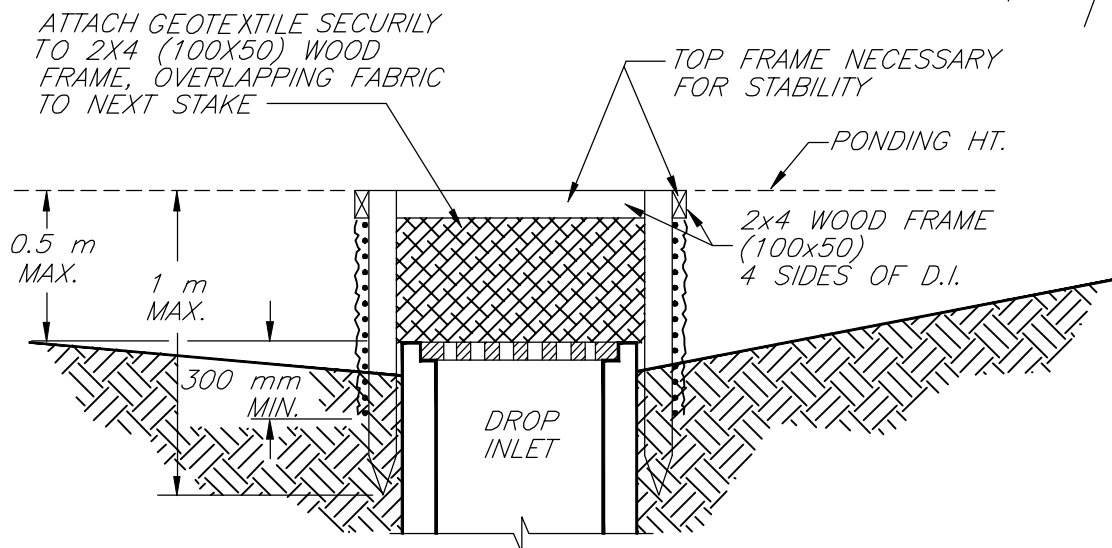
NOTES:

1. DROP INLET SEDIMENT BARRIERS ARE TO BE USED FOR SMALL, NEARLY LEVEL DRAINAGE AREAS. (LESS THAN 5%)
2. EMBED THE BALES 100 mm INTO THE SOIL AND OFFSET CORNERS OR PLACE BALES WITH ENDS TIGHTLY ABUTING. GRAVEL BACKFILL WILL PREVENT EROSION OR FLOW AROUND THE BALES.
3. THE TOP OF THE STRUCTURE (PONDING HEIGHT) MUST BE WELL BELOW THE GROUND ELEVATION DOWNSLOPE TO PREVENT RUNOFF FROM BYPASSING THE INLET. EXCAVATION OF A BASIN ADJACENT TO THE DROP INLET OR A TEMPORARY DIKE ON THE DOWNSLOPE OF THE STRUCTURE MAY BE NECESSARY.
4. THIS FIGURE IS PROVIDED FOR GUIDANCE ONLY AND DOES NOT CONSTITUTE A DESIGN. A SITE SPECIFIC DESIGN IS REQUIRED FROM DESIGNER/ENGINEER.

**STORM DRAIN DROP INLET
SEDIMENT BARRIER
(STRAW BALE / GRAVEL - OPTION)**



PLAN VIEW



SECTION A-A

NOTES:

1. DROP INLET SEDIMENT BARRIERS ARE TO BE USED FOR SMALL, NEARLY LEVEL DRAINAGE AREAS. (LESS THAN 5%)
2. USE 2"x4" (100X50mm) WOOD OR EQUIVALENT METAL STAKES, 1 m MINIMUM LENGTH.
3. INSTALL 2"x4" (100X50mm) WOOD TOP FRAME TO INSURE STABILITY.
4. THE TOP OF THE FRAME (PONDING HEIGHT) MUST BE WELL BELOW THE GROUND ELEVATION DOWNSLOPE TO PREVENT RUNOFF FROM BY-PASSING THE INLET. A TEMPORARY DYKE MAY BE NECESSARY ON THE DOWNSLOPE SIDE OF THE STRUCTURE.
5. THIS FIGURE IS PROVIDED FOR GUIDANCE ONLY AND DOES NOT CONSTITUTE A DESIGN. A SITE SPECIFIC DESIGN IS REQUIRED FROM DESIGNER/ENGINEER.

NOT TO SCALE

**STORM DRAIN DROP INLET
SEDIMENT BARRIER
(SILT FENCE - OPTION)**

Rock Check Dam	B.M.P. #7
Erosion Control and Sediment Control	

Description and Purpose

- Small dam constructed of rock placed across steep channel
- Decrease flow velocities to reduce erosion caused by storm runoff
- Sediment laden runoff is detained allowing sediment to settle out

Applications

- Temporary or permanent measure
- Reduces long steep grade to intervals of gentle grades between successive structures
- Reduces flow velocities and kinetic energy to decrease erosion potential caused by runoff
- Sediment laden runoff is retained behind structure allowing sediment to settle out
- May be used in channels that drain 4 ha (10 ac) or less
- May be used in steep channels where storm water runoff velocity is less than 1.5 m/s (5 fps)

Advantages

- Cheaper than using riprap armouring or gabion structures in a ditch
- Easy to construct

Limitations

- Not appropriate for high flow velocity >1.5 m/sec; (use gabion structures for flow velocity >1.5 m/sec)
- Not appropriate for channels draining areas larger than 4 ha (10 ac)
- Not to be placed in grass lined channels unless erosion is anticipated
- Susceptible to failure if water undermines or outflanks structure

Construction

- Excavate a trench key a minimum of 0.15 m in depth at the rock check structure location
- Place non-woven geotextile fabric over footprint area of rock check
- Construct structure by machine or hand
- Structure should extend from one side of the ditch or channel to the other

Rock Check Dam	B.M.P. #7
Erosion Control and Sediment Control	

- Structure should be constructed so that centre of the crest is depressed to form a centre flow width which is a minimum of 0.30 m lower than the outer edges
- Height of structures should be less than 0.8 m in height to avoid impounding large volumes of runoff
- Downstream slope of the check dam should be 5H:1V (minimum)
- Upstream slope of the check dam should be 4H:1V (minimum)

Construction Considerations

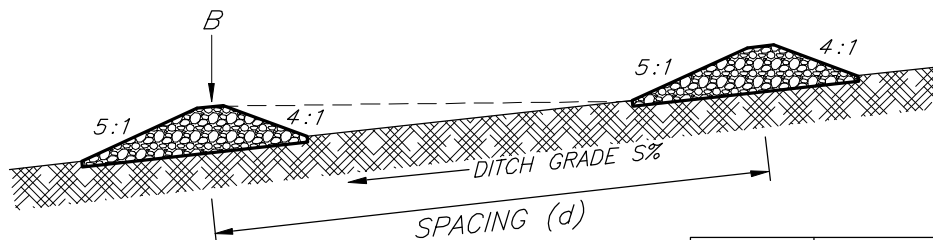
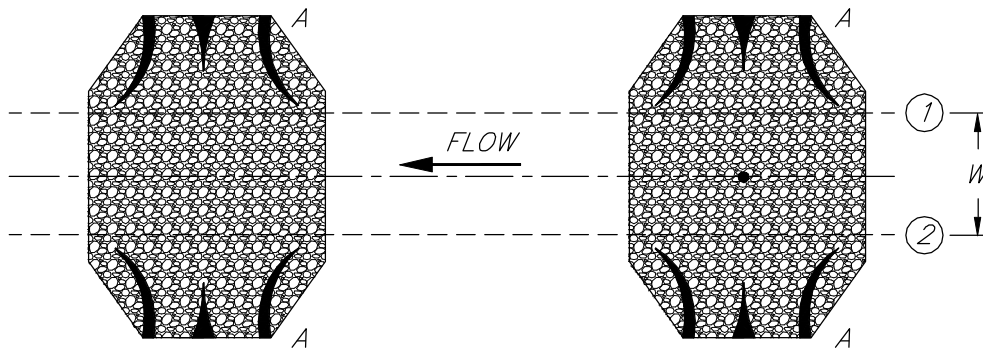
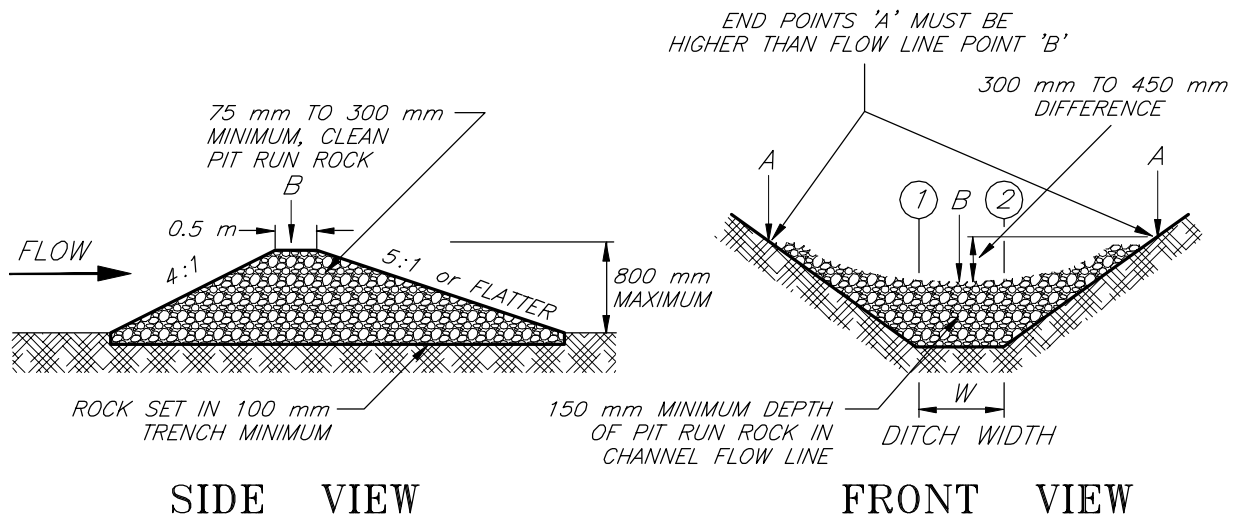
- Should be designed with roadside design clear zone requirements in mind.
- Height and spacing between structures should be designed to reduce steep channel slope to intervals of flatter gradient
- Rock check structures should be constructed of free draining aggregate
- Aggregate used should have a mean diameter (D_{50}) of between 75 mm and 150 mm and must be large enough to remain in place during high velocity flow situations. Maximum rock diameter should not exceed 150 mm if the structure is to be used as a sediment trap.
- If rock check structures are to be placed in channels with significant high flows, they must be properly designed for stone size and structure spacings

Inspection and Maintenance

- Inspection frequency should be in accordance with the PESC and TESC Plans
- Remove sediment build up before it reaches one half the check structure height
- Erosion repairs should be made immediately to prevent failure of the structure
- Replace dislodged aggregate immediately with heavier aggregate or gabion structures

Similar Measures

- Synthetic Permeable (Ditch) Barriers



NOTES:

1. SUITABLE FOR FLOW VELOCITY ≤ 1.5 m/s.
2. SUITABLE FOR DRAINAGE AREA ≤ 4 ha.
3. SUITABLE FOR GRADES FROM 5% TO 8%.
4. SPACING (d) AND ROCK SIZE (D_{50}) TO BE DETERMINED BY ENGINEER BASED ON HYDRAULIC CONDITIONS.
5. THIS FIGURE IS PROVIDED FOR GUIDANCE ONLY AND DOES NOT CONSTITUTE A DESIGN. A SITE SPECIFIC DESIGN IS REQUIRED FROM DESIGNER/ENGINEER.

D_{50} of ROCK (mm)	MAXIMUM FLOW DEPTH OVER ROCK (mm)
75	50
150	100

SUGGESTED ROCK DIAMETER AND OVERFLOW DEPTHS

**ROCK
CHECK DAM**

NOT TO SCALE

Aggregate Filled Sand Bag Check Dam Removed	B.M.P. #8
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Log Check Dam Removed	B.M.P. #9
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Description and Purpose

- Double panel, low profile, uni-body porous synthetic barriers used to dissipate flow energy and reduce velocity
- Barriers of patented design constructed of lightweight and durable synthetic materials
- May be used to create a grade break to reduce flow energy and velocities allowing some sediment to settle out at the upstream barrier panel of the barrier structure
- Can be used to dissipate flow energy and trap sediment during the period of revegetation; should be removed at successful re-establishment of vegetation

Applications

- Temporary structure
- May be placed across trapezoidal ditch to dissipate flow energy and reduce flow velocities
- Can be used to supplement as grade breaks along ditch interval between permanent drop structures along steep ditch grades
- May be used as midslope grade breaks along contours of midslope or at toe of disturbed slopes
- Usually used as grade breaks along ditch (3 to 7% grade) in conjunction with erosion control matting or non-woven geotextile as soil covering mattings; usually used in conjunction with permanent gabion structure (i.e., gabion) at steep grade (+6%) areas
- Designed to be reusable

Advantages

- Prefabricated
- Reusable/moveable
- More appropriate for installing at transition areas of changing grades of channels so that hydraulic jumps (or change of flow regime from supercritical to subcritical) may be simulated to dissipate flow energy, thus minimizing erosion potential
- Provide portable drainage control for construction sites, ditches, channels, roads, slopes
- The double panel porous barrier may allow significant energy loss as the flow of water undergoes from supercritical flow to sub-critical flow from the upstream panel

to the downstream panel with a more laminar flow evolving downstream and roughly parallel to the stream bed. Less turbulence and erosion energy may be created when compared with cascading, over-topping and tumbling flow from drop structures (i.e., gabions, check structures, straw bales)

- Barriers constructed of UV resistant material may be left in place for final channel stabilization as UV degradation is low
- Biodegradable synthetic option available
- Observed to enhance aggregation of silt material and to function as a sediment barrier with the formation of an earth block at behind the upstream barrier panel area; the downstream flow exiting at the downstream barrier panel may be of laminar nature and less erosive

Limitations

- More appropriate for use as a grade break and may be installed between permanent drop structures
- Partially effective in retaining some sediment and reducing flow velocities
- Less sturdy as drop structures in resisting high flow impact
- Not to be designed as drop structures
- Must be hand installed
- Become brittle in winter and may be easily damaged by highway maintenance activities or by public
- At the time of deactivation of the structure after vegetation establishment, metallic anchor pins, if not biodegradable, may require removal at time of completed revegetation
- Stick-up of metallic anchor pin above ground may be a nuisance and may be a human hazard and cause damage to maintenance equipment
- The use of biodegradable anchor pins is advisable

Construction

- Install as per manufacturers recommended installation instructions
- Normally installed in conjunction with erosion control matting in ditches and channels
- Prepare soil surface
- Install basal layer of erosion mat or geotextile fabric; key-in basal mat/fabric at upstream end

<p>Synthetic Permeable Barrier</p> <p>Erosion Control and Sediment Control</p>	<p>B.M.P. #10</p>
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- Place and anchor barrier panels with adequate pin anchors to basal soils

Construction Considerations

- Maintain intimate contact between base of barrier and soil with laying of basal matting/fabric intimate to ground surface
- Ensure side panel of barrier is extended to outer edges of channel to sufficient height to provide freeboard of channel flow

Inspection and Maintenance

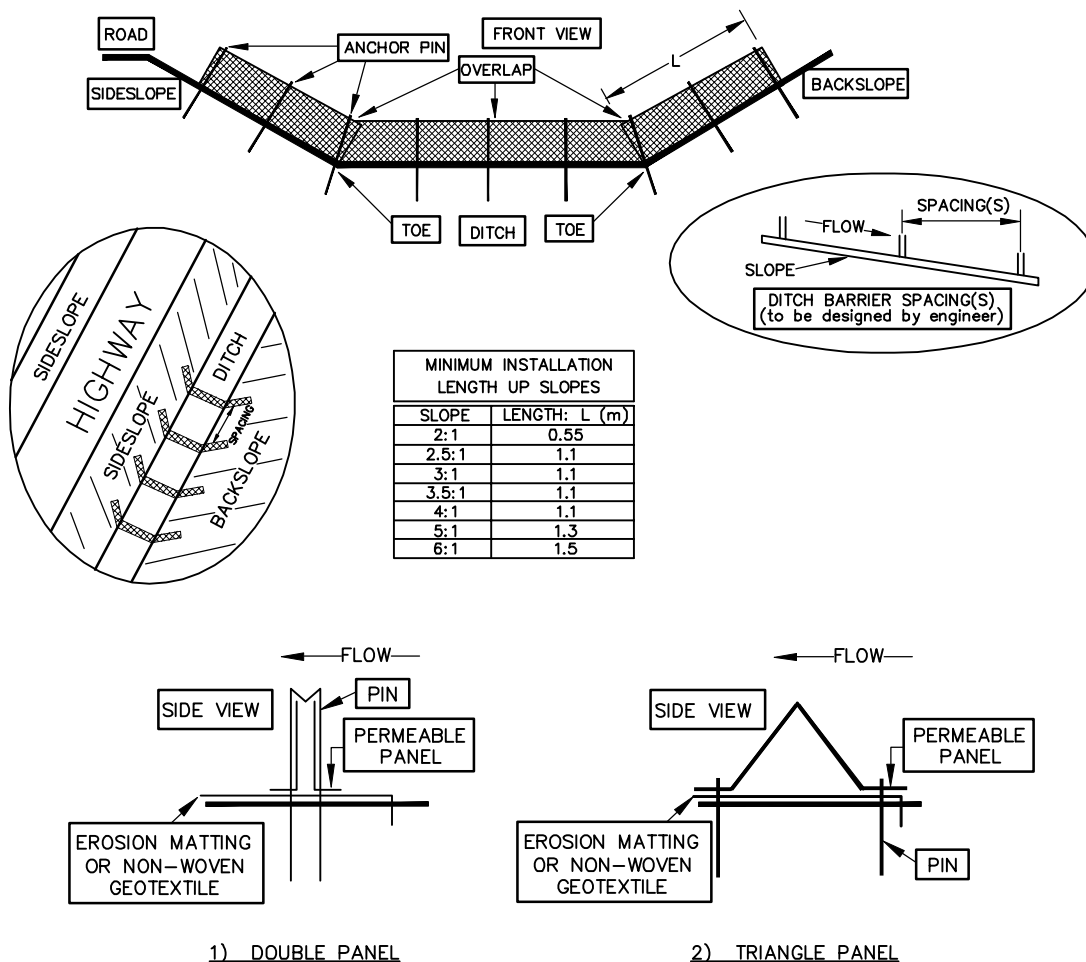
- Inspection frequency should be in accordance with the PESC and TESC Plans
- Remove sediment build-up before it reaches one-half the check structure height
- Do not damage barrier panel during removal of sediment
- Partial or non-removal of sediment build-up will create a non-permeable barrier and low level earth mini-drop structure which will force water flow over-topping the barrier. The option of non-removal of sediments may be open to converting the sediment build-up into a "vegetated earth mini-drop structure" along the ditch with the non-removal of synthetic permeable barrier in-place. This will require topsoil and seeding (or intensive mulch seeding) to promote vegetation growth
- If erosion is noted at the toe or upslope edges of the structure, hand regrading or suitable repairs should be made immediately to prevent failure of the structure
- Remove and deactivate at 1 year after vegetation is established

Similar Measures

- Silt fences or straw bales partially equivalent in retaining sediment

Design Considerations

- Install synthetic permeable barrier along ditch interval between permanent drop structures (i.e., gabion); can be economic alternative and supplemental to (i) total hard armouring of complete channel length, or (ii) high frequency of gabion installation required for high flow applications in steep ditch grade



SYNTHETIC PERMEABLE DITCH BARRIER N.T.S.

NOTES:

1. FOR USE MAINLY AS A GRADE BREAK STRUCTURE FUNCTIONING AS A FLOW ENERGY DISSIPATOR AND VELOCITY RETARDER.
2. FOR SECONDARY USE AS SEDIMENT BARRIER.
3. REQUIRES NON-WOVEN GEOTEXTILE FABRIC OR BIODEGRADABLE (COCONUT FIBRE PREFERABLE) EROSION BLANKET MAT AT BASE AND KEY-IN TO SOIL AT UPSTREAM END.
4. MAY BE INSTALLED AS GRADE BREAK AT GRADE TRANSITION AREAS TO CREATE DISSIPATION OF FLOW ENERGY AND A MORE LAMINAR FLOW REGIME DOWNSTREAM OF STRUCTURE.
5. THIS FIGURE IS PROVIDED FOR GUIDANCE ONLY AND DOES NOT CONSTITUTE A DESIGN. A SITE SPECIFIC DESIGN IS REQUIRED FROM DESIGNER/ENGINEER.

SYNTHETIC
PERMEABLE
BARRIERS

Straw Bale Check Dam Removed	B.M.P. #11
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Straw Bale Barrier	B.M.P. #12
Sediment Control	

Description and Purpose

- A barrier of strawbale primarily used as a perimeter sediment control measure
- May be used to intercept and detain sediment laden runoff allowing a portion of the sediment load to settle out

Applications

- Temporary measure
- Suitable for flow velocities of 0.3 m/s or less
- Usually placed at 1m to 2 m offsets from toe of disturbed slopes
- Size of drainage area should be no greater than 0.1 ha per 30 m length of straw bale sediment barrier
- Maximum flow path length upstream of barrier should be less than 30 m
- Maximum slope gradient above the barrier should be no greater than 2H:1V
- May be used in conjunction with filter fabric as external wrap to encapsulate the bale

Advantages

- Straw bales are biodegradable
- Only requires one row of straw bales
- Easier to install than other barriers and economical if straw bales are readily available

Limitations

- Not appropriate for flow velocities greater than 0.3 m/s
- Require extensive maintenance following high velocity flows associated with storm events
- Not as robust as some continuous perimeter control structures
- Susceptible to undermining and erosion damage if not properly keyed into substrate soil or if joints are not completely infilled with straw
- Short service life
- Must be installed by hand
- Not to be used on asphalt or concrete covered surfaces

Straw Bale Barrier Sediment Control	B.M.P. #12
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- Availability of appropriate bales may be limited in certain areas of the province
- Maximum straw bale barrier height of one straw bale or 0.5 m maximum height

Construction

- Straw bale barrier should be located a minimum distance 1.8 m away from the toe of the slope to provide adequate ponding and sedimentation area
- Excavate a trench approximately 0.10 m deep with a width of one straw bale at the straw bale barrier location
- Place straw bales in excavated trench along contour, perpendicular to flow direction
 - Ensure twine or wire is not in contact with the soil
 - Ensure straw bale is in continuous contact with base of trench
 - Ends of barrier should be angled upslope to form enclosure to contain runoff
- Infill all joints with loose straw
- Drive two 50 mm by 560 mm section wooden stakes 1.2 m long through each straw bale, ensuring each stake is embedded a minimum of 0.15 m into soil
- Backfill and compact the upstream and downstream edges of the check structure to seat the straw bales into the subgrade

Construction Considerations

- Maximum lengths of barriers should be 40 m, including 'J-hook' or 'smile' (similar to silt fence in BMP #1) configuration, to allow escape route for excess runoff
- Barrier should be placed far enough away from toe of slope to provide adequate ponding and sedimentation area (minimum of 1.8 m away from toe of slope is recommended)
- Ends of barriers should be angled upslope (in a 'J-hook' or 'smile' configuration) to form enclosure to collect runoff
- Straw bales should be:
 - Machine-made
 - Weed free cereal crop straw such as wheat, oats, rye, or barley
 - Tightly compacted and bound with two rows of wire or synthetic string and shall show no signs of weathering
 - No more than one year old

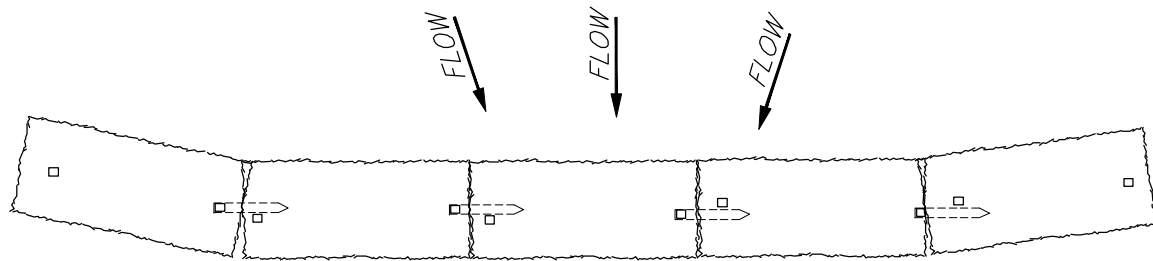
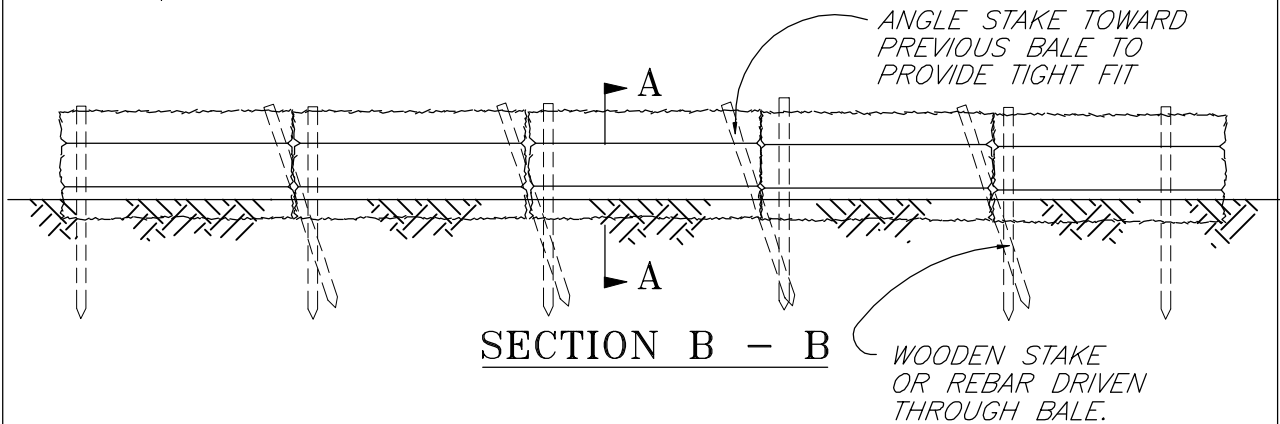
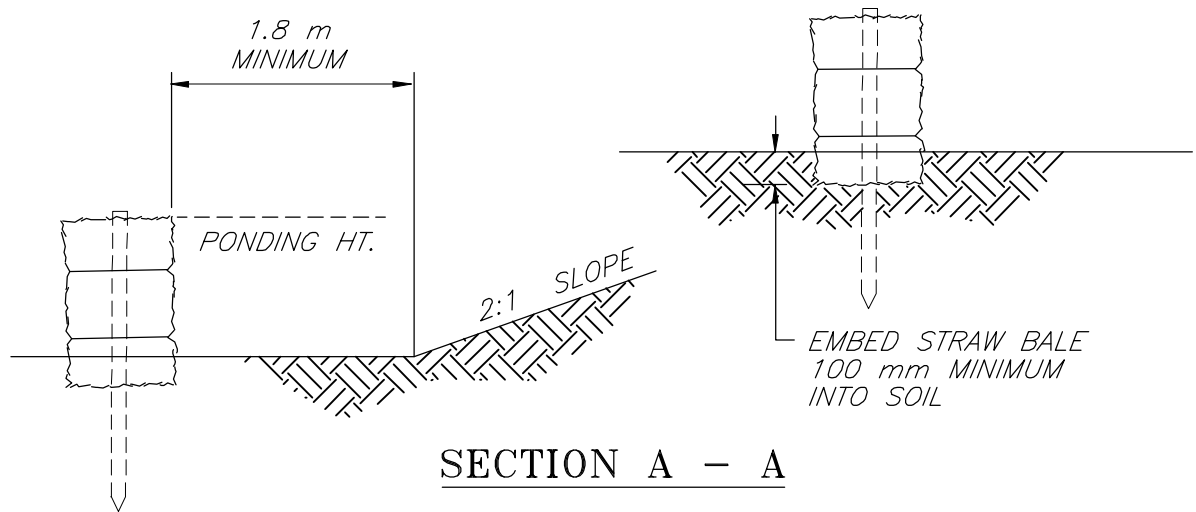
Straw Bale Barrier	B.M.P. #12
Sediment Control	

Inspection and Maintenance

- Inspection frequency should be in accordance with the PESC and TESC Plans
- Remove sediment build up before it reaches one half the check barrier height
- Erosion repairs should be made immediately to prevent failure of the structure
- Replace damaged, decayed or dislodged straw bales immediately

Similar Measures

- Silt fences
- Continuous Perimeter Control Structures
- Berm Interceptors



NOTES:

1. THE STRAW BALES SHALL BE PLACED ON SLOPE CONTOUR.
2. BALES TO BE PLACED IN A ROW WITH THE ENDS TIGHTLY ABUTTING.
3. KEY IN BALES TO PREVENT EROSION OR FLOW UNDER BALES.
4. THIS FIGURE IS PROVIDED FOR GUIDANCE ONLY AND DOES NOT CONSTITUTE A DESIGN. A SITE SPECIFIC DESIGN IS REQUIRED FROM DESIGNER/ENGINEER.

**STRAW BALE
BARRIER**

Rolled Erosion Control Products (RECP)

- a) Channel Installation
- b) Slope Installation
- c) Straw Rolls

Erosion Control

B.M.P. #13

Description and Purpose

- Biodegradable or synthetic soil coverings used for temporary or permanent protection of disturbed soils at slopes and channels
- Categories of Rolled erosion control products (RECP) can be:
 - Erosion control blankets (ECB) (generally biodegradable and temporary)
 - Turf reinforcement mats (TRM)
 - Composite turf reinforcement mats (C-TRM)
- RECP may be manufactured of organic material, synthetic material, or as a composite of organic and synthetic materials
- Protect disturbed soils from raindrop impact and surface runoff erosion, increase water infiltration into soil, retains soil moisture and decreases evaporation loss
- Protect seeds from raindrop impact, runoff, and predators
- Stabilizes soil temperature to promote seed germination and enhance vegetation growth

Applications

- Temporary or permanent measure
- May be used to protect disturbed, exposed soils for cut or fill slopes at gradients of 2.5H:1V or steeper
- May be used on slopes where erosion potential is high
 - Silts and sands have higher erosion potential than high plastic clays
- May be used on slopes where vegetation is likely to be slow to develop
- May be used to protect disturbed exposed soils in ditches and channels (with high flow velocities) by providing additional tractive resistance cover in conjunction with a successful high density vegetative growth established

Advantages

- Degree of erosion protection is higher, more uniform, and longer lasting than for sprayed-on products (e.g., mulches)
- Wide range of commercially available temporary (biodegradable) or permanent products

Rolled Erosion Control Products (RECP)

- a) Channel Installation
- b) Slope Installation
- c) Straw Rolls

Erosion Control

B.M.P. #13

Limitations

- Non-performance of RECP may result from the following:
 - Low density vegetation growth (beneath RECP) due to non-favourable weather and growth conditions (i.e., soil type, moisture, storm events at critical times). It is noted that values of tractive resistance of RECP products for vegetative growth may be generally tested in laboratory after a growth period (e.g., 3 months) under greenhouse growth conditions. The effectiveness of RECP, especially along channels, is very dependent on success of vegetation growth on site. It is important that the designer should assess the effectiveness of RECP in accordance with site, soil, terrain and vegetation growth conditions
 - Hydraulic uplift of RECP and erosion of underlying soils can occur under rapid snow melt conditions when dammed up melt water generates a hydraulic head and high flow velocity generated in constricted snow melt channel. This situation can occur along steep channels interlaced with drop structures and with RECP lining installed in-between the drop structures. Ponding of melt water and non-anchored RECP joint areas allow flow entry beneath the RECP and generate hydraulic heads to uplift the RECP. This can occur along un-anchored edges of RECP at upper edges of ditch when snow melt occurs at tops of ditch and flow beneath the RECP. This is especially critical when underlying soil is easily erodible. (e.g., fine grained non-cohesive silty soils). It is important to trench-in and anchor the edges of the RECP installations and installed anchor pin (staples) at sufficient dense intervals
 - Ice build-up from groundwater seepage source can uplift and dislocate the RECP and causing flow beneath the RECP to erode the substrate soils. Winter ice accumulation may be related to groundwater regime and investigative design on subsurface drainage by a geotechnical engineer is required
- Can be labour intensive to install
- Must be installed on unfrozen ground
- Temporary blankets may require removal before implementation of permanent measures
- Rolled erosion control products (RECP) are not suitable for rocky sites
- Proper surface preparation is required to ensure intimate contact between blanket and soil
- Plastic sheeting can be used at sensitive slopes with precautions:
 - Plastic sheeting RECP product can be easily torn, ripped, non-biodegradable, and should be disposed of in a landfill

Rolled Erosion Control Products (RECP)

- a) Channel Installation
- b) Slope Installation
- c) Straw Rolls

Erosion Control

B.M.P. #13

- Plastic sheeting product, if used, results in 100% runoff, thus increasing erosion potential in downslope areas receiving the increased flow volumes
- Plastic sheeting should be limited to temporary covering of sensitive soil stockpiles or temporary covering of small critical unstable slope areas

Construction (Slopes)

- RECP should be installed in accordance with manufacturer's directions

The following is a general installation method:

- Prepare surface and place topsoil and seed
- Surface should be smooth and free of large rocks, debris, or other deleterious materials
- Blanket should be anchored at top of slope in a minimum 0.15 m by 0.15 m trench for the entire width of the blanket
- The blanket should be rolled out downslope
 - (1) Where the blanket roll is not long enough to cover the entire length of the slope, a minimum 0.15 m by 0.15 m check slot should be excavated at the location of the lap, and the downslope segment of blanket anchored in the check slot, similar to the method used for the top of the slope, or (2) when blankets must be spliced down the slope, place blanket end over end (shingle style with approximately 0.10 m overlap. Staple through overlapped area at 0.3 m intervals.
 - The upslope portion of blanket should overlap the downslope portion of blanket, shingle style, at least 0.15 m with staple anchors placed a maximum 0.3 m apart
 - Adjacent rolls of blanket should overlap a minimum 0.1 m
 - Anchors should be placed along central portion of blanket spaced at 4/m² minimum (0.5 m spacing) for slopes steeper than 2H:1V and 1/m² (1 m spacing) for slopes flatter than 2H:1V
 - Anchors along splices between adjacent rolls should be placed 0.9 m apart

Construction (Channels)

- **A Blanket should be installed in accordance with manufacturers directions**

The following is a general installation method

- Prepare surface and place topsoil and seed

Rolled Erosion Control Products (RECP)

- a) Channel Installation
- b) Slope Installation
- c) Straw Rolls

Erosion Control

B.M.P. #13

- Surface should be smooth and free of large rocks, debris, or other deleterious materials
- Begin by excavating a minimum 0.15 m deep and 0.15 m wide trench at the upstream end of channel and place end of RECP into trench
 - Use a double row of staggered anchors approximately 0.1 m apart (i.e., 0.2 m linear spacing) to secure RECP to soil in base of trench
 - Backfill and compact soil over RECP in trench
- Roll centre RECP in direction of water flow on base of channel
- Place RECP end over end (shingle style) with a minimum 0.15 m overlap downgrade
 - Use a double row of staggered anchors approximately 0.1 m apart to secure RECP to soil
- Full length edge of RECP at top of sideslopes must be anchored in a minimum 0.15 m deep and 0.15 m wide trench
 - Use a double row of staggered staple anchors a maximum of 0.1 m apart (i.e., 0.2 m linear spacing) to secure RECP to soil in base of trench
 - Backfill and compact soil over RECP in trench
- Overlap RECP on sideslopes (shingle style down channel) a minimum of 0.1 m over the centre RECP and secure RECP to soil with anchors spaced a maximum of 0.2 m apart
- In high flow channels, a check slot across the width of the channel is recommended at a maximum spacing of 10 m to anchor the ends of the RECP to the underlying soil
 - Use a double row of staggered staple anchors a maximum of 0.1 m apart (0.2 m linear spacing) to secure RECP to soil in base of check slot
 - Backfill and compact soil over RECP in check slot
- Anchor terminal ends of RECP in a minimum 0.15 m deep and 0.15 m wide trench
 - Use a double row of staggered anchors a maximum of 0.1 m apart (i.e., 0.2 m linear spacing) to secure RECP to soil in base of trench
 - Backfill and compact soil over RECP in trench

Rolled Erosion Control Products (RECP)

- a) Channel Installation
- b) Slope Installation
- c) Straw Rolls

Erosion Control

B.M.P. #13

Construction Considerations

- Slopes should be topsoiled and seeded prior to placing RECP
- Ensure blanket is in intimate contact with the soil by properly grading soil, removing rocks or deleterious materials, prior to placing blanket
- In channels, blankets should extend to above the anticipated flow height, with a minimum 0.5 m of free board
- For turf reinforcement mat (TRM), blanket should be placed immediately after topsoiling
- Blanket should be anchored by using wire staples, metal geotextile stake pins, or triangular wooden stakes
 - All anchors should be a minimum of 0.15 to 0.2 m in length
 - For loose soils, use longer anchors
- Blankets should be placed longitudinal to direction of flow, with fabric not stretched but maintaining contact with underlying soil
- It is essential to understand product specifications and follow manufacturers instructions on installation methods

Product Quality Assurance/Quality Control (QA/QC) Certification

RECPs should be certified by the supplier/manufacturer to ensure product performance and compliance with specified property requirements. A certificate for QA/QC testing of manufactured products is required. The performance and QA/QC testing should be carried out by reputable laboratories (e.g., TxDOT – Hydraulic and Erosion Control Laboratory OR equivalent laboratory) to ensure a commonly acceptable QA/QC standard. Dependent on product type and intended performance, the product information certificate should be provided by the product supplier/manufacturer to include the following:

- Manufacturer's Certificate on
- Performance specification
 - Permissible Tractive Resistance (include testing methods and vegetative growth conditions)
 - Permissible Flow Velocity (if available)
 - Longevity (for biodegradable or non-biodegradable products)

Rolled Erosion Control Products (RECP)

- a) Channel Installation
- b) Slope Installation
- c) Straw Rolls

Erosion Control

B.M.P. #13

- Minimum Average Roll Values (MARVs) along with specified testing methods for
 - Physical properties
 - Mass per unit area
 - Thickness
 - Tensile strength
 - UV Resistance
 - Other physical properties (for non-woven below Erosion Mat (if specified))
 - Grab tensile strength
 - Grab elongation
 - Puncture strength
 - Trapezoidal tear
 - UV Resistance

Inspection and Maintenance

- Areas covered with blankets should be inspected/remediated regularly or in accordance with the PESC and TESC Plans, especially after periods of severe rainfall or storm events, to check for blanket separation or breakage
- Any damaged or poorly performing areas should be repaired/remediated immediately. Regrading of the slope by hand methods may be required in the event of rill or gully erosion.
- Inspection and maintenance should continue until dense vegetation is established
- Areas with low vegetation density should be reseeded
- After approximately one year, a top dressing of fertilizer may be applied to improve vegetation cover and assist degradation of temporary blankets

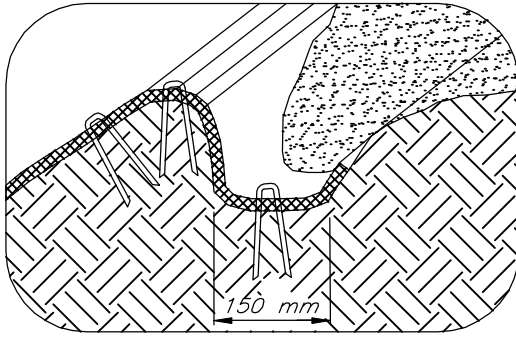
Similar Measures

- Mulching (for slopes only)
- Riprap (primarily in channels)
- Gabion mattresses (primarily in channels)

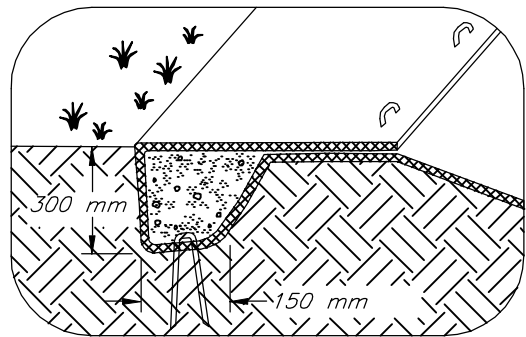
Rolled Erosion Control Products (RECP) a) Channel Installation b) Slope Installation c) Straw Rolls Erosion Control	B.M.P. #13
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Design Considerations

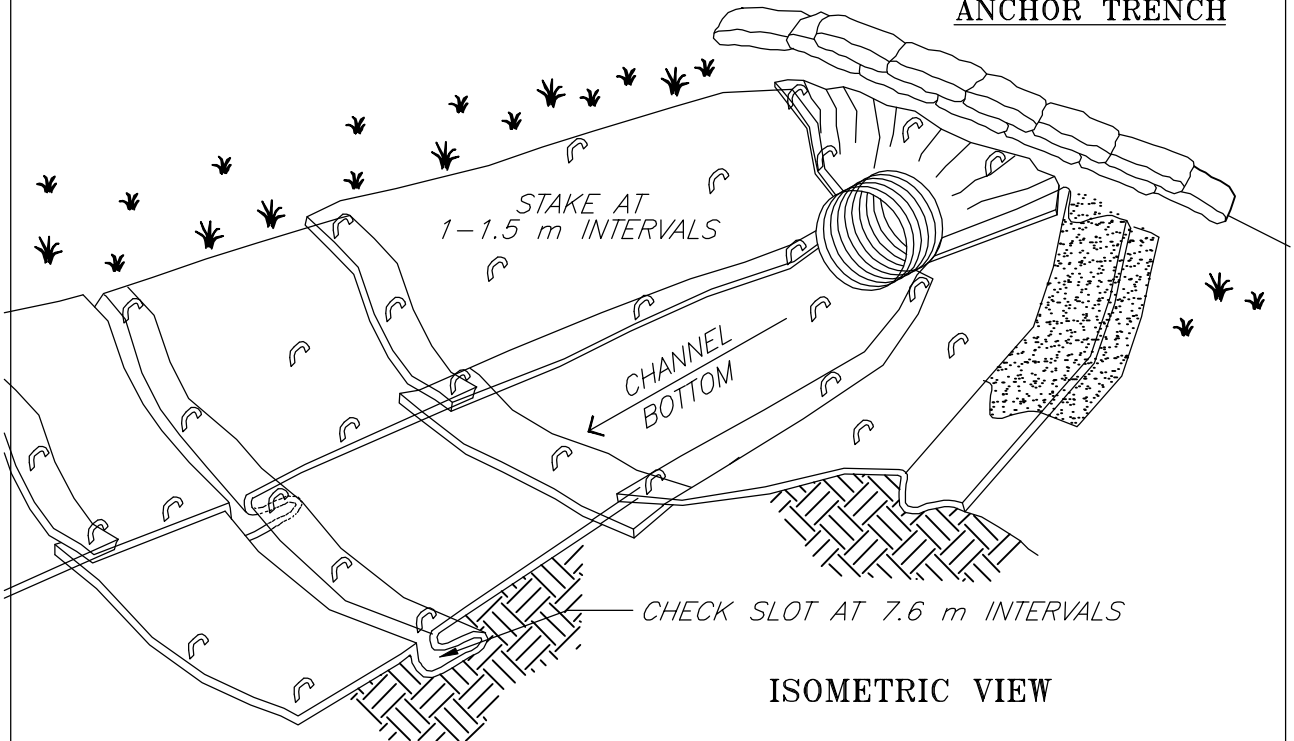
- Assess hydraulic flow conditions and tractive stress on channel
- Assess local soil, weather and growth conditions (favourable/non-favourable) for revegetation (within 3 to 12 months) to allow a determination on use or non-use of RECP as a protective measure. If the revegetation conditions are assessed favourable, the use of RECP can be considered
- Assess suitability of a RECP product using tractive resistance data tested for (i) bare soil, and (ii) vegetated (a specified duration of growth period) condition
- It is noted that tractive resistance data are adopted as selection criteria of RECP and permissible velocity data can be provided for reference.



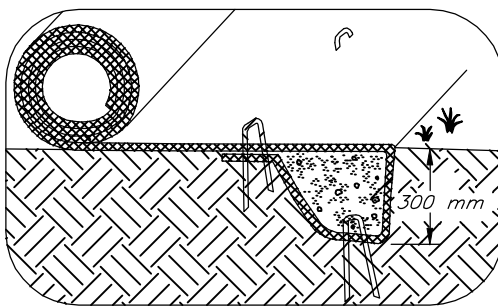
LONGITUDINAL ANCHOR TRENCH



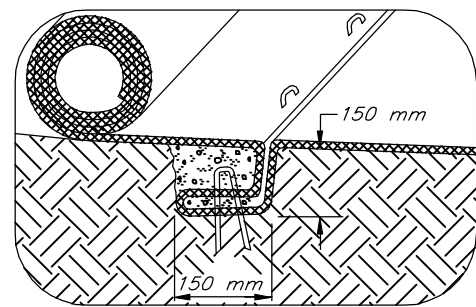
TERMINAL SLOPE AND CHANNEL ANCHOR TRENCH



ISOMETRIC VIEW



INITIAL CHANNEL ANCHOR TRENCH



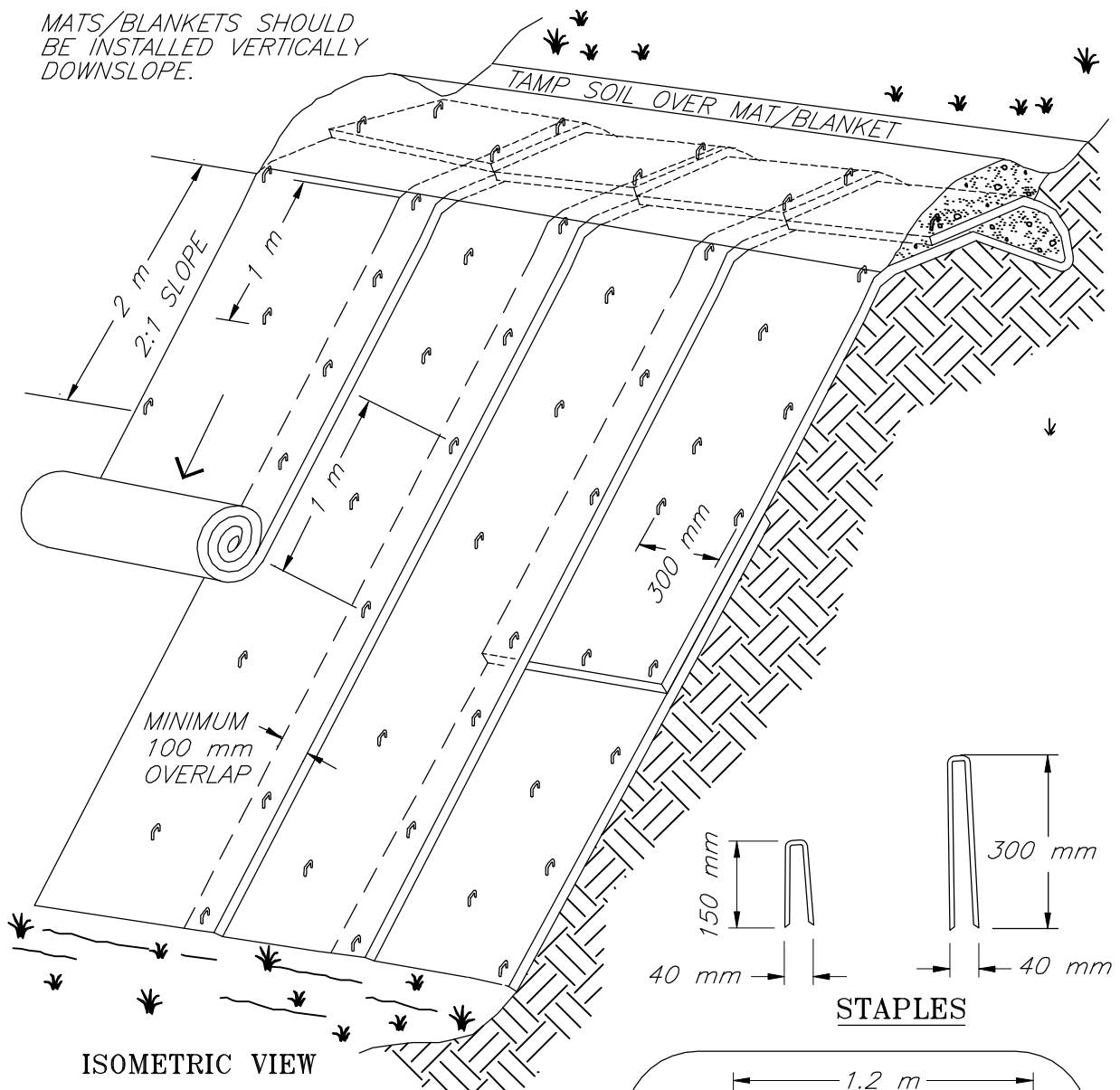
INTERMITTENT CHECK SLOT

NOTES:

1. CHECK SLOTS TO BE CONSTRUCTED PER MANUFACTURERS SPECIFICATIONS.
2. STAKING OR STAPLING LAYOUT PER MANUFACTURERS SPECIFICATIONS.
3. THIS FIGURE IS PROVIDED FOR GUIDANCE ONLY AND DOES NOT CONSTITUTE A DESIGN. A SITE SPECIFIC DESIGN IS REQUIRED FROM DESIGNER/ENGINEER.

**ROLLED EROSION CONTROL PRODUCTS (RECP)
CHANNEL INSTALLATION**

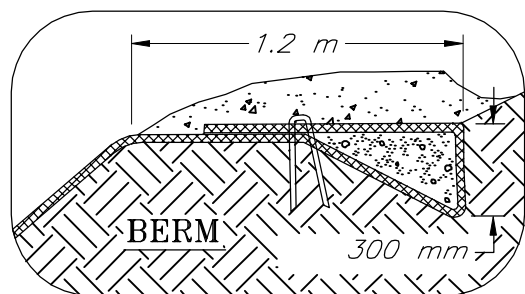
MATS/BLANKETS SHOULD
BE INSTALLED VERTICALLY
DOWNSLOPE.



TYPICAL SLOPE SOIL STABILIZATION

NOTES:

1. SLOPE SURFACE SHALL BE FREE OF ROCKS, CLODS, STICKS AND GRASS. MATS/BLANKETS SHALL HAVE GOOD SOIL CONTACT.
2. APPLY PERMANENT SEEDING BEFORE PLACING BLANKETS.
3. LAY BLANKETS LOOSELY AND STAKE OR STAPLE TO MAINTAIN DIRECT CONTACT WITH THE SOIL. DO NOT STRETCH.
4. CHECK SLOTS, STAKING, STAPLING AND OTHER CONSTRUCTION DETAILS PER MANUFACTURES SPECIFICATIONS.
5. THIS FIGURE IS PROVIDED FOR GUIDANCE ONLY AND DOES NOT CONSTITUTE A DESIGN. A SITE SPECIFIC DESIGN IS REQUIRED FROM DESIGNER/ENGINEER.



ROLLED EROSION CONTROL PRODUCTS (RECP) SLOPE INSTALLATION

Riprap Armouring a) Slope Protection b) Channel Protection Erosion Control	B.M.P. #14 (a & b)
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Description and Purpose

- Large, loosely placed cobbles or boulders placed along channel banks or slopes to protect underlying soil from erosion due to flowing water
- Can protect slopes and channel banks against erosion

Applications

- Permanent measure
- May be used on channel banks and slopes with flow velocities ranging from 2 m/s to 5 m/s (dependent on rock size and thickness); appropriate for slopes that do not exceed 2H:1V
- Riprap only needs to be placed at lower portion of channel section to the anticipated flow height (mean annual peak flow) plus freeboard
 - Other form of soft armouring (RECP blankets, seeding) can be used to promote vegetation to protect soil at upper portion of channel slopes, above riprap
- Must be used in conjunction with a non-woven geotextile underlay acting as a filtration separator with basal soil
- For fluctuating high flow channel, the riprap should be underlain by a layer of granular filter material for cyclic drawdown long-term performance with/without an extra layer of non-woven geotextile as underlay

Advantages

- Easy to install and easy to repair
- Very durable, long lasting, and virtually maintenance free
- Flexible

Limitations

- Expensive form of channel lining and stabilization
- Requires heavy equipment and transport of rock to site
- May not be feasible in areas where suitable rock is not available
- Riprap may have to be placed by hand
- Normally 2 to 3 times riprap thickness is required in comparison with gabion mattress thickness for equivalent protection performance under identical hydraulic conditions

Riprap Armouring

- a) Slope Protection
- b) Channel Protection

Erosion Control

**B.M.P. #14
(a & b)**

- Use of gabion is preferred at flow greater than 3 m/s due to larger nominal size of riprap and thickness required for erosion protection during flow velocities of this magnitude
- Can be classified as uniform or graded. Uniform riprap would contain stones which would contain a mixture of stones ranging from small to large. Graded riprap forms a flexible self healing cover

Construction

- Grade the slope or channel to final design grade
- Place filter (underlay) layer on prepared slope
 - Filter layer can consist of non-woven geotextile underlay and/or well graded granular material dependent on hydraulic conditions
- Place riprap layer
- Riprap should consist of a graded mixture of sound, durable stone with at least 50% of the riprap material being larger than 200 mm in diameter
- Riprap should be sized according to the following gradation and mass:

		Riprap Class			
		1M	1	2	3
Nominal Mass	kg	7	40	200	700
Nominal Diameter	mm	175	300	500	800
None heavier than:	kg	40	130	700	1800
	or mm	300	450	800	1100
No less than 20% or more than 50% heavier than:	kg	10	70	300	1100
	or mm	200	350	600	900
No less than 50% or more than 80% heavier than:	kg	7	40	200	700
	or mm	175	300	500	800
100% heavier than:	kg	3	10	40	200
	or mm	125	200	300	500

Percentage quoted are by mass.

Sizes quoted are equivalent spherical diameters, and are for guidance only.

Source: AT Bridge Spec. 2010

Riprap Armouring a) Slope Protection b) Channel Protection Erosion Control	B.M.P. #14 (a & b)
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- Non-woven geotextile fabric underlay below riprap should meet the following specifications and physical properties:

**Non-Woven Geotextile Filter Fabric
Specifications and Physical Properties**

	Class 1M, 1 and 2	Class 3
Grab Strength	650 N	875 N
Elongation (Failure)	50%	50%
Puncture Strength	275 N	550 N
Burst Strength	2.1 MPa	2.7 MPa
Trapezoidal Tear	250 N	350 N
Minimum Fabric Overlap to be 300 mm		

Source: AT Bridge Spec. 2010

Construction Considerations

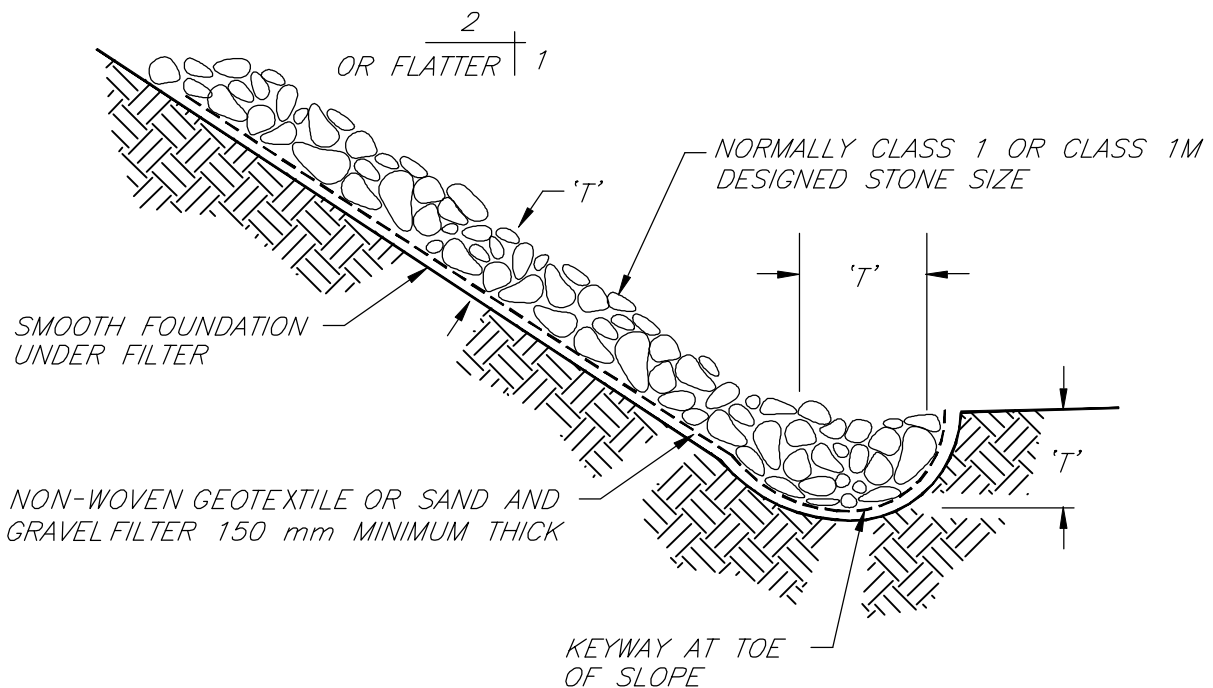
- Riprap should be placed in a uniform thickness across the channel so as not to constrict channel width
- Blasted rock is preferred (if available)
- Riprap layer should be 1.5 to 2 times the thickness of the largest rocks used, 1.5 to 3 times the thickness of the D_{50} material, and not less than 300 mm in thickness

Inspection and Maintenance

- Inspection frequency should be in accordance with the PESC and TESC Plans
- Periodic inspections to check for erosion of protected material or movement of riprap

Similar Measures

- Rolled erosion control products (RECP) well vegetated; not for use at severe flow and high velocity areas
- Gabion mattresses



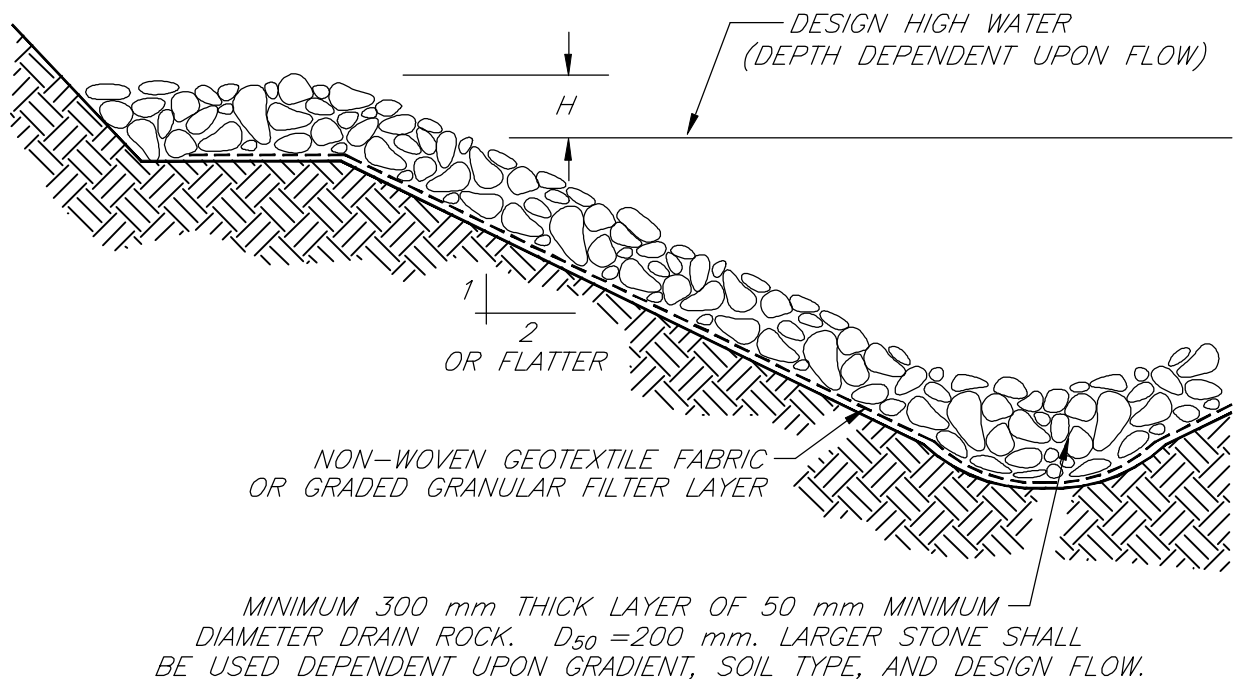
TYPICAL SECTION

NOTE:

1. 'T' = THICKNESS: THICKNESS SHALL BE DETERMINED BY THE ENGINEER.
MINIMUM THICKNESS = 300 mm. (i.e. $1.5 \times D_{50}$) FOR $D_{50} = 200$ mm.
2. THIS FIGURE IS PROVIDED FOR GUIDANCE ONLY AND DOES NOT CONSTITUTE A DESIGN. A SITE SPECIFIC DESIGN IS REQUIRED FROM DESIGNER/ENGINEER.

**RIPRAP
ARMOURING
FOR SLOPE**

DESIGN HEIGHT (H), WIDTH AND STONE SIZE SHALL
BE DETERMINED BY THE ENGINEER



TYPICAL SECTION

NOTES:

1. RIPRAP GRADATION AND THICKNESS SHALL BE DETERMINED BY THE ENGINEER IN ACCORDANCE WITH HYDRAULIC CONDITIONS.
2. THIS FIGURE IS PROVIDED FOR GUIDANCE ONLY AND DOES NOT CONSTITUTE A DESIGN. A SITE SPECIFIC DESIGN IS REQUIRED FROM DESIGNER/ENGINEER.

**RIPRAP
ARMOURING
FOR CHANNEL**

Cellular Confinement System	B.M.P. #15
Erosion Control	

Description and Purpose

- 3-dimensional, plastic matting with open cells filled with topsoil or aggregate
- 3-dimensional structure stabilizes cut or fill slopes
- Cells confine infilled topsoil or aggregate and protect root zone while permitting surface drainage

Applications

- Permanent measures
- May be used with granular infill on cut or fill slopes up to a slope of 1H:1V
- May be used with granular infill on slopes and in ditches where flow velocities are 3 m/s or less
- May be used as a flexible channel lining
- May be used in temporary low-water stream crossing as granular pad for stream fording
- Matting is light, expandable, and easy to transport and place
- Use of native fill materials reduces costs; local granular fill is preferred

Limitations

- Not widely used in Alberta highway construction
 - Availability can be limited, therefore expensive in some areas
- Installation can be labour intensive
- Not to be used on slopes steeper than 1H:1V
- Slopes of 1H:1V can be hazardous to work on

Construction

- Cellular Confinement System should be installed in accordance with manufacturer's directions
- The following is a general installation method
 - Slope should be graded to design elevations and grades
 - Rocks or other deleterious debris should be removed from matting location

Cellular Confinement System

Erosion Control

B.M.P. #15

- Matting should be installed in a trench as deep as the matting is thick, extending 0.6 to 1.2 m beyond crest of slope, and matting should be installed so that the top of the matting is flush with surrounding soil
 - Every other cell along crest of slope should be anchored to soil using 'J' pins or other suitable sturdy anchoring device
- The matting should be rolled out downslope
- Where the blanket roll is not long enough to cover the entire length of the slope, the downslope section of matting should be butt-jointed to the upslope section and secured using staples, hog rings, or other suitable fasteners
- Adjacent rolls of matting should be butt-jointed and secured using staples, hog rings, or other suitable fasteners
- Anchors are placed at 1 m intervals down the slope
 - Additional anchors may be required to ensure matting is in intimate contact with soil
 - Additional anchors may be required along edges of matting
- Backfilling should start at the crest of the slope and proceed downslope
 - For topsoil, overfill cells approximately 25 to 50 mm and lightly compact so that top of topsoil is flush with matting
 - For granular fill, overfill cells approximately 25 mm and tamp compact so that top of fill is flush with matting
- Seeding should be applied after fill placement

Construction Considerations

- Properly grading soil surface, removing rocks or deleterious materials, prior to placing matting to ensure matting is in intimate contact with the soil
- Matting should be placed longitudinal to direction of flow or downslope
- Use only a single layer of matting
- Matting elevation should be subexcavated to thickness of matting so that the top of the matting is flush with the adjacent terrain
- Infill from top of slope ensuring placement height of fill into cellular mat is less than 1 m

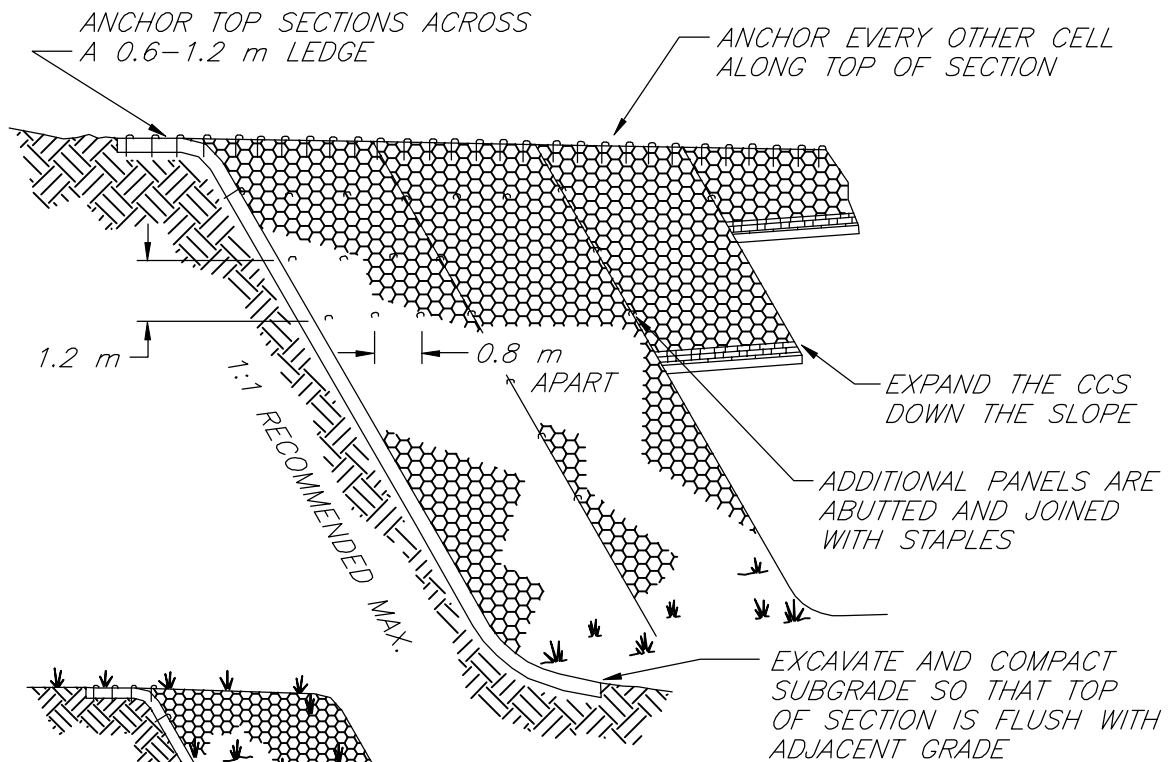
Cellular Confinement System	B.M.P. #15
Erosion Control	

Inspection and Maintenance

- Area covered with matting should be inspected regularly or in accordance with the PESD and TESC Plans, especially after periods of heavy rainfall storms to check for damage or loss of material
 - Any damaged areas should be repaired immediately
- Temporary inspection should continue until vegetation is established
 - Areas where vegetation fails to grow should be reseeded immediately
- If matting is broken or damaged and washout of the underlying soil occurs, the matting should be repaired or replaced after regrading the slope

Similar Measures

- Rolled erosion control products (RECP)
- Riprap armouring



OVERFILL TOPSOIL
25-50 mm AND
LIGHTLY COMPACT

**CCS INFILLED WITH TOPSOIL
AND VEGETATED WITH GRASS**

**CCS INFILLED WITH
AGGREGATE**

OVERFILL WITH LOOSE
GRANULAR MATERIAL
25 mm AND COMPACT

NOTES:

1. SURFACE OF SLOPE SHALL BE
LEVELED WITH GULLIES FILLED
AND WELL COMPACTED.
2. SHAPE AND COMPACT SUBGRADE
SURFACES TO DESIGN ELEVATIONS
AND GRADES.
3. THE CELLS SHALL BE ANCHORED
SECURELY TO PREVENT DISPLACE-
MENT AND DEFORMATION OF
PANELS WHEN BACKFILLING.
4. INFILL FROM CREST OF THE
SLOPE TO TOE TO PREVENT
DISPLACEMENT. LIMIT DROP
HEIGHT TO 1 m.
5. THIS FIGURE IS PROVIDED FOR
GUIDANCE ONLY AND DOES NOT
CONSTITUTE A DESIGN. A SITE
SPECIFIC DESIGN IS REQUIRED FROM
DESIGNER/ENGINEER.

NOT TO SCALE

**CELLULAR CONFINEMENT
SYSTEM FOR SLOPE
STABILIZATION**

Gravel Blankets Removed	B.M.P. #16
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Energy Dissipators

- a) for Culvert Outlet
- b) for Trough at Bridge Headslope

B.M.P. #17

Sediment Control

Description

- a) Hard armour (riprap, gravel, concrete) placed at pipe outlets, in channels, and at downstream side of check structures to reduce velocity and dissipate energy of concentrated flows (BMP 17a)
- b) Standard Drain Trough Terminal Protection Structure generally used at bridge headslope (BMP 17b)
 - Minimizes scour at flow impact location with dissipated flow energy

Applications

- Permanent measure
- May be used at outlets of pipes, drains, culverts, conduits, or channels with substantial flows
- May be used at slope drain outlets located at the bottom of mild to steep slopes
- May be used where lined channels discharge into unlined channels
- May be used as splash pad on downstream side of gabions, check structures, berms, barriers, and silt fences to prevent erosion caused by overtopping of structure

Advantages

- Reduces flow energy in a relatively small area

Limitations

- Small rocks or stones can be dislodged during high flows
- Grouted riprap may breakup due to hydrostatic pressure, frost heave, or settlement
- May be expensive if construction materials (riprap, gravel, or concrete) is not readily available
- May be labour intensive to place and construct
- Extreme flow velocities may require paved outlet structures, stilling basins, plunge pools, drop structures, baffles, or concrete splash pads which will require special design by qualified personnel. Energy dissipators constructed of riprap may not be adequate for extreme flow velocities

Energy Dissipators

- a) for Culvert Outlet
- b) for Trough at Bridge Headslope

B.M.P. #17

Sediment Control

Construction

- Grade the area to final design grades and elevations
- Sub-excavate energy dissipator location to thickness of energy dissipator
- Place filtration bedding material on base of excavation
 - Bedding can be comprised of well graded sand and gravel or non-woven geotextile
 - Acts as separating filter between fine grained subgrade and riprap size energy dissipator material
- Place energy dissipator material (riprap, gravel, concrete) over filtration bedding material
 - Top of energy dissipator should be flush with surrounding grade

Construction Considerations

- Length of energy dissipator (L_a) at outlets shall be of sufficient length to dissipate energy
 - $L_a = 4.5 \times D$ (where D is the diameter of the pipe or channel at the outlet)
 - Energy dissipator should extend upstream of the outlet approximately a minimum distance of $0.5 \times D$
- Width of energy dissipator (W_a) at outlets shall be of sufficient width to dissipate energy
 - $W_a = 4 \times D$
- Thickness of energy dissipator (d_a) at outlets shall be of sufficient thickness to dissipate energy
 - $d_a = 1.5 \times \text{maximum rock diameter}$ (with a minimum thickness of 0.30 m)
- Energy dissipator (splash pad, apron) shall be set at zero grade and aligned straight, with the direction of flow at the outlet
- Bedding (filtration) layer can comprise either non-woven geotextile or a minimum of 0.15 m well graded sand and gravel layer
- Energy dissipator should be constructed of well-graded riprap
 - Minimum $D_{50} = 150$ mm. Preferable $D_{50} = 300$ mm
 - Minimum thickness = a) $1.5 \times D_{50}$ or b) 0.30 m to 0.45 m thickness (a or b whichever is greater)

Energy Dissipators a) for Culvert Outlet b) for Trough at Bridge Headslope Sediment Control	B.M.P. #17
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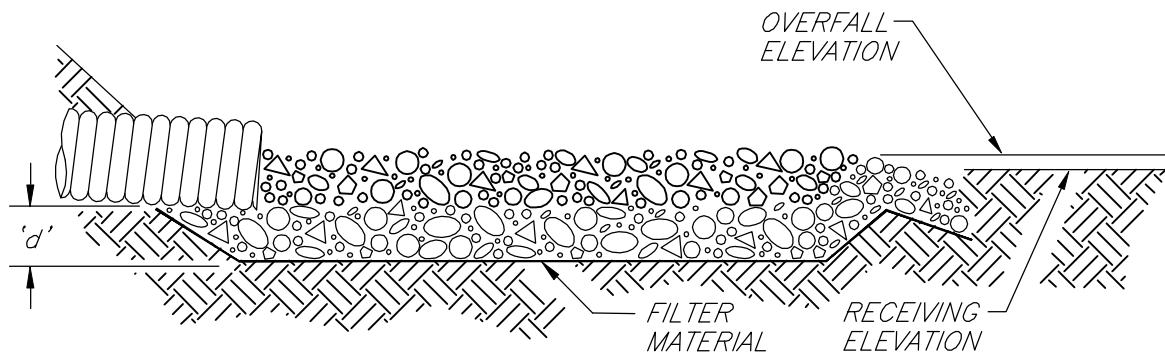
- Energy dissipator shall be designed to accommodate a 10-year peak runoff or the design discharge of the upstream channel, pipe, drain, or culvert, whichever is greater
- The energy dissipator shall be constructed flush with the surrounding grade and shall be directly in line with direction of outlet flow

Inspection and Maintenance

- Inspection frequency should be in accordance with the PESC and TESC Plans
- Any damage should be repaired immediately

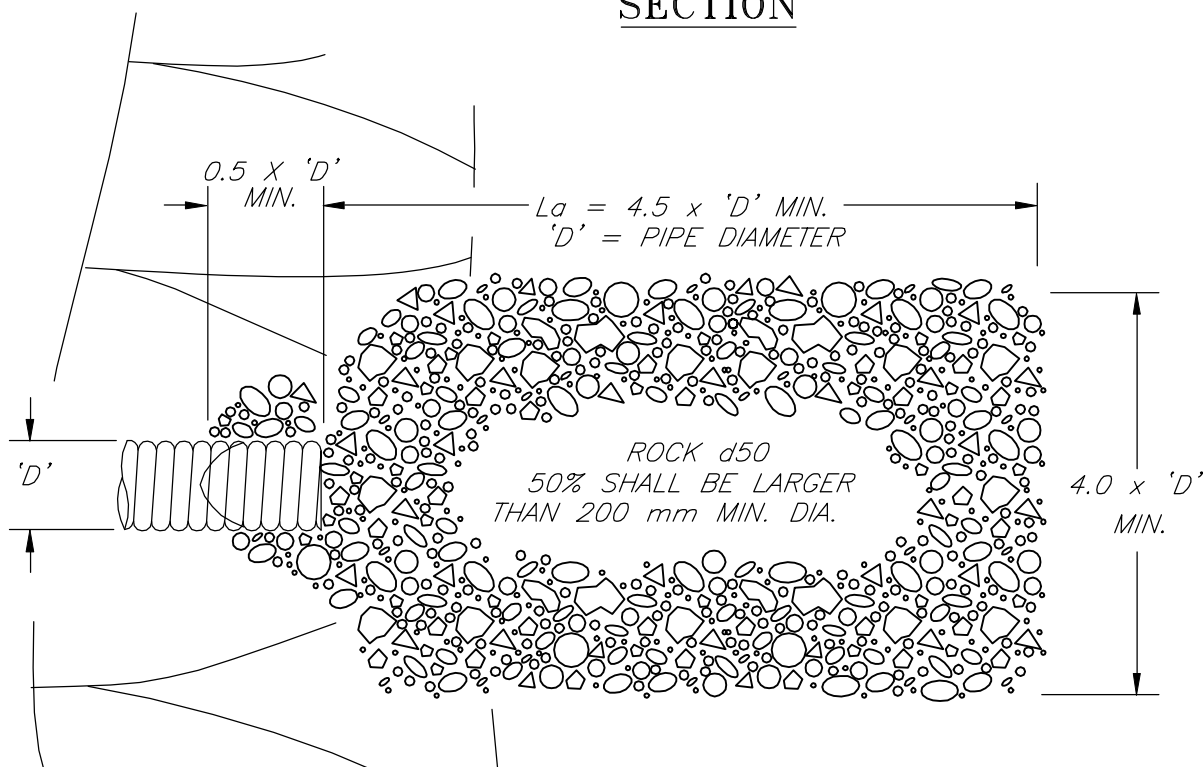
Similar Measures

- Gabion mattresses



B) MINIMUM THICKNESS = 300 mm. (i.e. $1.5 \times D_{50}$) FOR $D_{50} = 200$ mm.

SECTION

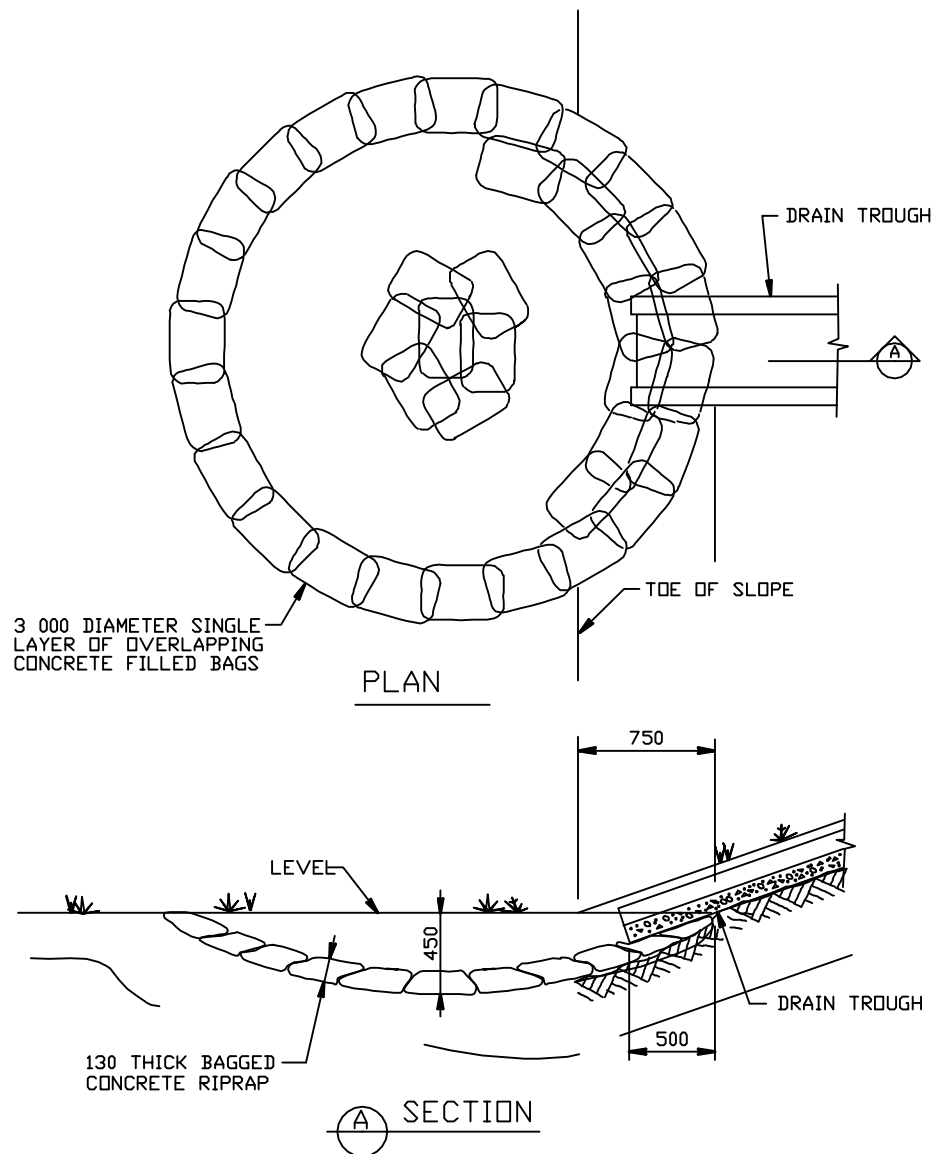


PLAN

NOTES:

1. 'La' = LENGTH OF APRON. DISTANCE 'La' SHALL BE OF SUFFICIENT LENGTH TO DISSIPATE ENERGY.
2. APRON SHALL BE SET AT A ZERO GRADE AND ALIGNED STRAIGHT.
3. FILTER MATERIAL SHALL BE FILTER FABRIC OR 150 mm THICK MINIMUM GRADED GRAVEL LAYER.
4. FOR PIPE DIAMETER > 600 mm, DESIGN BY ENGINEER IS REQUIRED.
5. THIS FIGURE IS PROVIDED FOR GUIDANCE ONLY AND DOES NOT CONSTITUTE A DESIGN. A SITE SPECIFIC DESIGN IS REQUIRED FROM DESIGNER/ENGINEER.

ENERGY DISSIPATOR FOR CULVERT OUTLET



GENERAL NOTES

- DIMENSIONS ARE GIVEN IN mm. DETAILS ARE NOT TO SCALE.
- PLACING OF BAGGED CONCRETE RIPRAP SHALL START AT THE BOTTOM CENTRE OF THE DISHED AREA AND SHALL PROCEED IN A CONTINUOUS SPIRAL FASHION OUTWARD UNTIL THE ENTIRE DISH IS COVERED. EACH CONCRETE FILLED BAG SHALL LAP OVER THE EDGES OF THE PREVIOUSLY PLACED BAGS.

SOURCE: ALBERTA TRANSPORTATION SPECIFICATIONS FOR BRIDGE CONSTRUCTION
DRAWING: S-1410-91

- THIS FIGURE IS PROVIDED FOR GUIDANCE ONLY AND DOES NOT CONSTITUTE A DESIGN. A SITE SPECIFIC DESIGN IS REQUIRED FROM DESIGNER/ENGINEER.

**ENERGY DISSIPATOR
FOR SEMI-CIRCULAR TROUGH
DRAIN TERMINAL PROTECTION
FOR BRIDGE HEADSLOPE**

Sediment Traps and Basins

- a) Riser Outlet Option
- b) Permeable Rock Berm Outlet Option

B.M.P. #18

Sediment Control

Description and Purpose

- Low height dam enclosure for impoundment of sediment laden storm water, sedimentation of silt size particles and release of treated storm water
- Used to trap sediment laden run off and promote settlement of sediment prior releasing to enter downstream or watercourses
- Constructed by excavating a pond or building embankments above the original ground surface
- Sediment traps and basins can be divided on size of pond impoundment enclosure
 - Basin (Type I) for pond area $\geq 500 \text{ m}^2$
 - Trap (Type II) for pond area $\leq 500 \text{ m}^2$

Applications

- Permanent measure
- Used at terminal or selective intermediate points of concentrated runoff for impoundment of runoff and sedimentation of silt prior to release of treated runoff downstream
- Used as sedimentation control measure at perimeter of construction sites where sediment laden run off may enter watercourses, storm drains, or other sensitive areas
- Used where there is a need to impound a significant amount of sediment from significant areas of land disturbance
- Sediment basins (Type I) used for disturbed drainage areas greater than 2.0 ha
- Sediment traps (Type II) used for disturbed drainage areas of 2.0 ha, or less
- Where practical, contributing drainage areas should be subdivided into smaller areas and multiple sedimentation impoundment installed

Advantages

- High capacity of runoff impoundment and more efficient means of sedimentation necessary along perimeters of construction sites with high risk sensitive environmental areas and watercourses
- Sediment can be cleaned out easily
- Robust
- Can be deactivated easily by breaching the enclosure dyke

Sediment Traps and Basins

- a) Riser Outlet Option
- b) Permeable Rock Berm Outlet Option

B.M.P. #18

Sediment Control

Limitations

- Sediment traps and basins do not remove 100% of the sediment; net efficiency for sedimentation of silt may be around 50% dependent on design
- Anticipated service life of 3 years or longer due to possible clogging of outlets in the long-term
- Sedimentation traps and basins with a riser outlet should have an auxiliary spillway with adequate erosion protection to permit overflow in the event that the riser pipe outlet clogs during a storm event
- For drainage areas greater than 40 ha, multiple basins may be required
- Efficiency on sedimentation is very dependent on surface area; sediment basins require large surface areas to permit settling of sediment
- Fences and signage may be required to reduce danger to the public
- May provide breeding habitat for mosquitoes and other pests
- Sediment traps only remove medium and large diameter silt particles and upstream erosion or sediment control measure is required to reduce the amount of sediment laden to the runoff at downstream sensitive areas
- Periodic removal of sediment build up is required

Construction

- The consequences of failure for any water retaining structure will determine the level of effort in the design and construction phases. The construction guidelines presented herein are minimum requirements. A geotechnical engineer should design water retaining structures if the consequences of failure warrant.
- All footprint area for embankment dyke should be stripped of vegetation, topsoil, and roots to expose mineral subgrade soils
- Embankment fill material should be clean mineral soil with sufficient moisture to allow proper compaction
 - Fill should be placed in lifts not exceeding 150 mm in compacted thickness and should be compacted to a minimum of 95% Standard Proctor maximum dry density (SPD)
- The main outlet structure should be installed at farthest possible point from inlet
 - Outlet should be placed on firm, smooth ground and should be backfilled to 95% SPD
 - Proper inlet and outlet protection should be installed to protect from scour

Sediment Traps and Basins

- a) Riser Outlet Option
- b) Permeable Rock Berm Outlet Option

B.M.P. #18

Sediment Control

- Outlet pipe should consist of corrugated steel pipe to protect (against pinching and blockage)
- The embankment should be topsoiled, seeded or protected with gravel or riprap immediately after construction
- Construct an emergency spillway to accommodate flows not carried by the principle outlet
 - Emergency spillway should consist of an open channel (earth or vegetated) over native undisturbed soil (not fill)
 - If spillway is elevated, it should be constructed of riprap
 - Spillway crest should be depressed at least 0.15 m below embankment

Construction Considerations

- Preferable to strip to mineral soil only along the footprint area required for dyke construction; can leave pond floor centre area cleared but unstripped
- Can be constructed by excavating, constructing embankments, or a combination of the two methods
- Baffles should be provided to prevent short-circuiting of flow from inlet to outlet
- Construct sediment ponds and basins at site perimeter and environmentally sensitive areas prior to wet season and construction activities
- Sediment pond/basin bottom should be flat or gently sloping towards outlet
- Dyke slopes should not be steeper than 2H:1V and should be compacted
- Basins should be located where:
 - Low embankment can be constructed across a swale or low natural terrain
 - It is accessible for maintenance work, including sediment removal

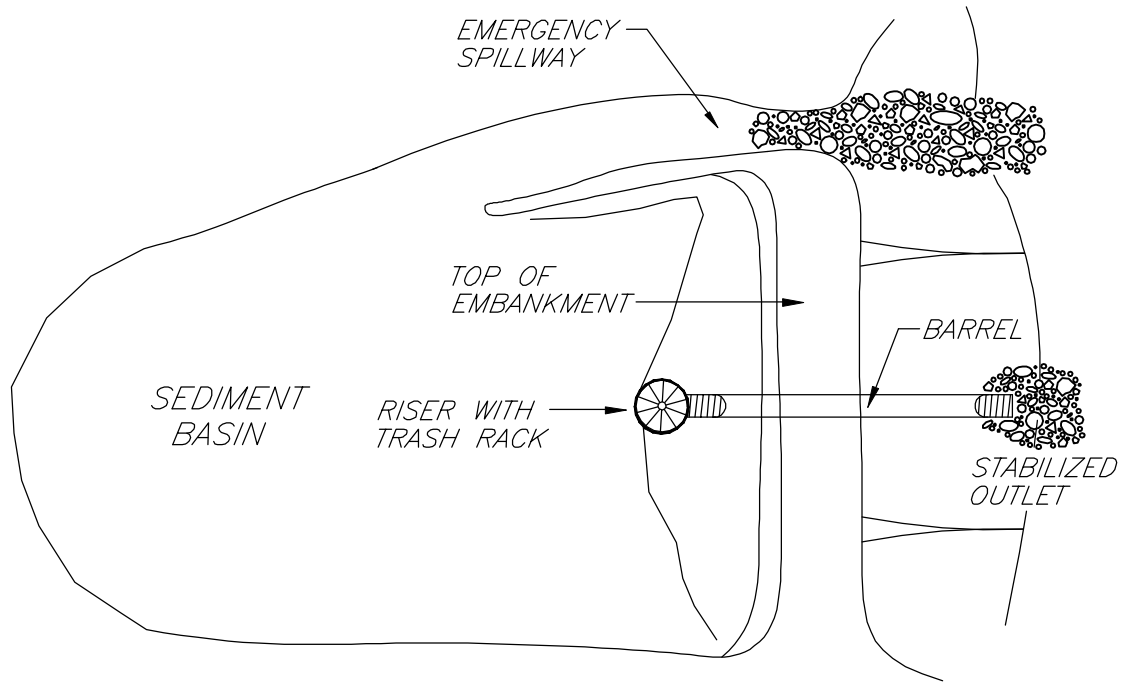
Inspection and Maintenance

- Regular inspection is required to identify seepage, structural soundness, outlet damage or obstruction and amount of sediment accumulation
- Inspection frequency should be in accordance with the PESC and TESC Plans
- Sediment should be removed upon reaching 1/2 height of the containment berm or within 0.4 m of crest of embankment
- Sediment traps may be deactivated or removed after vegetation of previously disturbed upstream areas has been established

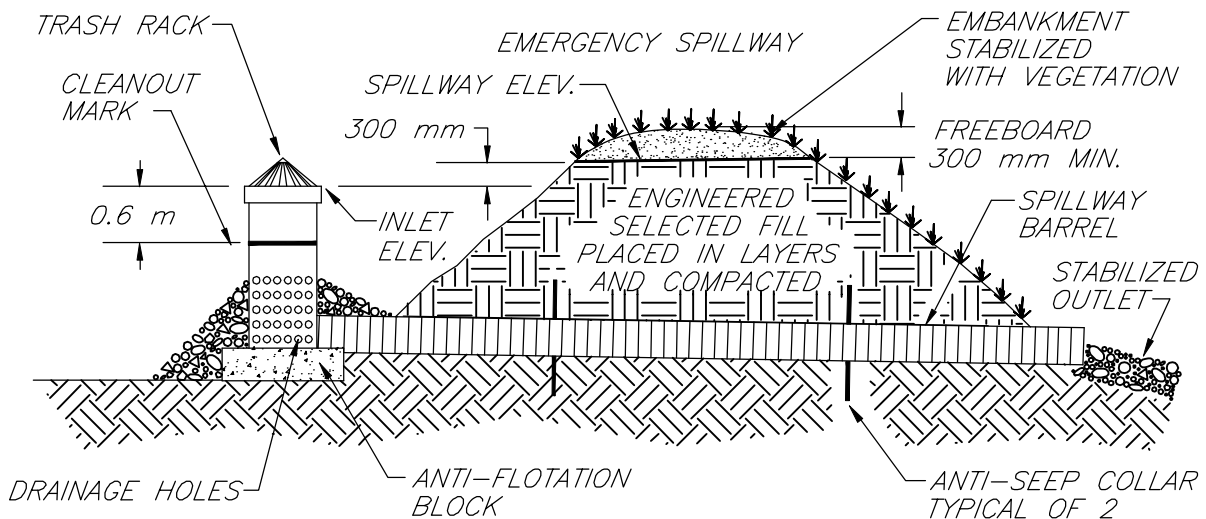
Sediment Traps and Basins a) Riser Outlet Option b) Permeable Rock Berm Outlet Option Sediment Control	B.M.P. #18
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Design Considerations

- The design can consist of (a) a riser outlet option or (b) a permeable rock berm outlet option. (The permeable rock berm outlet option is preferable for Alberta highway construction)
- Minimum particle size for riprap rock shall be 200 mm
- If the design of a riser outlet is utilized
 - Main outlet pipe shall be fabricated from corrugated steel pipe conforming to CSA Standard CAN 5-G401-M81 or the latest revision thereof
 - Outlet pipe shall consist of a horizontal pipe welded to a similar vertical riser at a 45° mitre joint
- Close to the base of the riser pipe, a 100 mm diameter hole shall be fabricated and a mesh with 12 mm square openings tack welded over the hole as a screen
 - A similar hole shall be provided along the riser pipe immediately above the elevation of the maximum sediment build-up (usually 0.4 m below crest of embankment)



PLAN



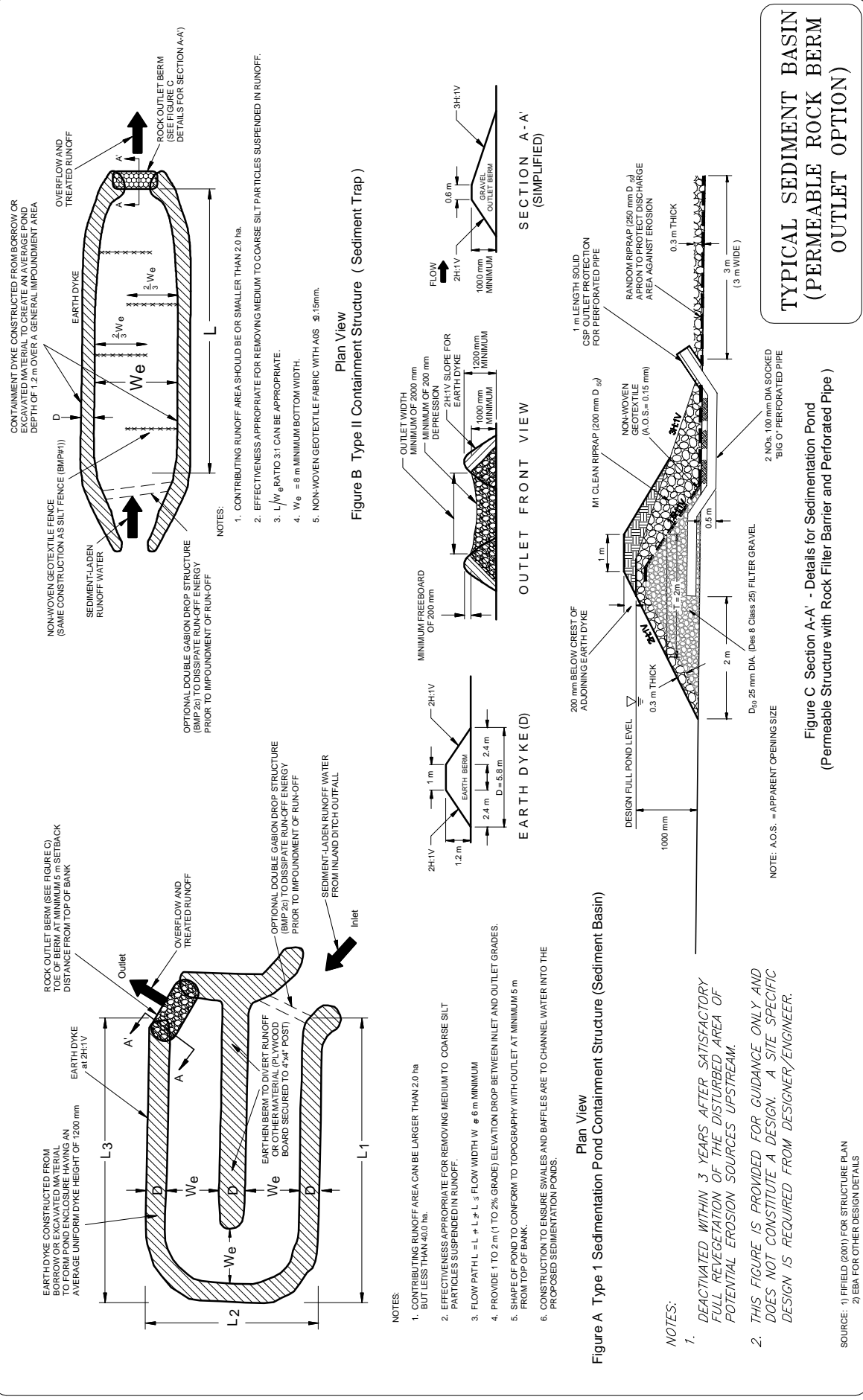
SECTION

NOTES:

1. THE TEMPORARY SEDIMENT BASIN, DESIGNED BY A QUALIFIED PROFESSIONAL, IS REQUIRED FOR DISTURBED AREAS GREATER THAN 2.02 HECTARES (5 ACRES) WITH A DRAINAGE AREA LESS THAN 40.4 HECTARES (100 ACRES).
2. THE SEDIMENT BASIN MAY BE REMOVED WITHIN 3 YEARS.
3. HEIGHT OF ENGINEERED SELECTED FILL EQUAL TO 1 m.
4. FOR CONFIGURATION AND FLOW CHAMBER DESIGN (i.e. LENGTH(L) & WIDTH(W_e) OF BASIN), REFER TO BMP 18b.
5. THIS FIGURE IS PROVIDED FOR GUIDANCE ONLY AND DOES NOT CONSTITUTE A DESIGN. A SITE SPECIFIC DESIGN IS REQUIRED FROM DESIGNER/ENGINEER.

**TYPICAL SEDIMENT
BASIN
(RISER OUTLET
OPTION)**

FILE: SEDBASIN



Slope Drains

- a) Slope Drain
- b) Overside Drain

Sediment Control

B.M.P. #19

Description and Purpose

- Heavy duty, flexible pipe "Big O" that carries water from top to bottom of fill or cut slope to prevent concentrated water flowing downslope and eroding face of slope

Applications

- Temporary or permanent measure
- Used on cut or fill slopes where there is a high potential for upslope runoff waters to flow over the face of the slope causing erosion, especially at areas where runoff converges resulting in concentrated runoff flows (e.g., possible breach of low catchwater ditch at top of a cut slope)
- Used in conjunction with some form of water containment or diversion structures, such as diversion channels, berms, or barriers, to convey upslope runoff water and direct water towards slope drain

Limitations

- Pipes must be sized correctly to accommodate anticipated flow volumes
- Water can erode around inlet if inlet protection is not properly constructed
- Erosion can occur at base if outlet protection or energy dissipator is not constructed
- Slope drain must be anchored securely to face of slope

Construction

- Construct diversion or intercept channel, ditch block, barrier, or other inflow apron structure at crest of slope to channel flow toward the slope drain inlet
- Install slope drain through inlet berm or barrier with a minimum of 0.45 m of soil cover above top of drain pipe to secure the inlet
 - Install scour inlet protection (such as riprap, sand bags)
- Install energy dissipator (such as riprap, gravel, concrete) at downslope outlet end of slope drain
 - Outlet must not discharge directly onto unprotected soil
- Secure the pipe from movement by tying to steel anchor stakes, hold-down grommets, or other approved anchor method
 - Space anchors on each side of drain pipe at maximum 3 m intervals along entire length of drain pipe

Slope Drains

- a) Slope Drain
- b) Overside Drain

Sediment Control

B.M.P. #19

- Anchor stakes should have a minimum 1 m embankment

Construction Considerations (For guidance only)

- Use coiled drain pipe for low flows only
- If constructing inflow apron at crest of slope out of sandbags, only fill each sandbag $\frac{3}{4}$ full, this will allow sandbag to be flexible enough to mould around drain pipe and remain in continuous contact with the ground
- Several slope drains may be required if upslope drainage areas are too large for one drain pipe

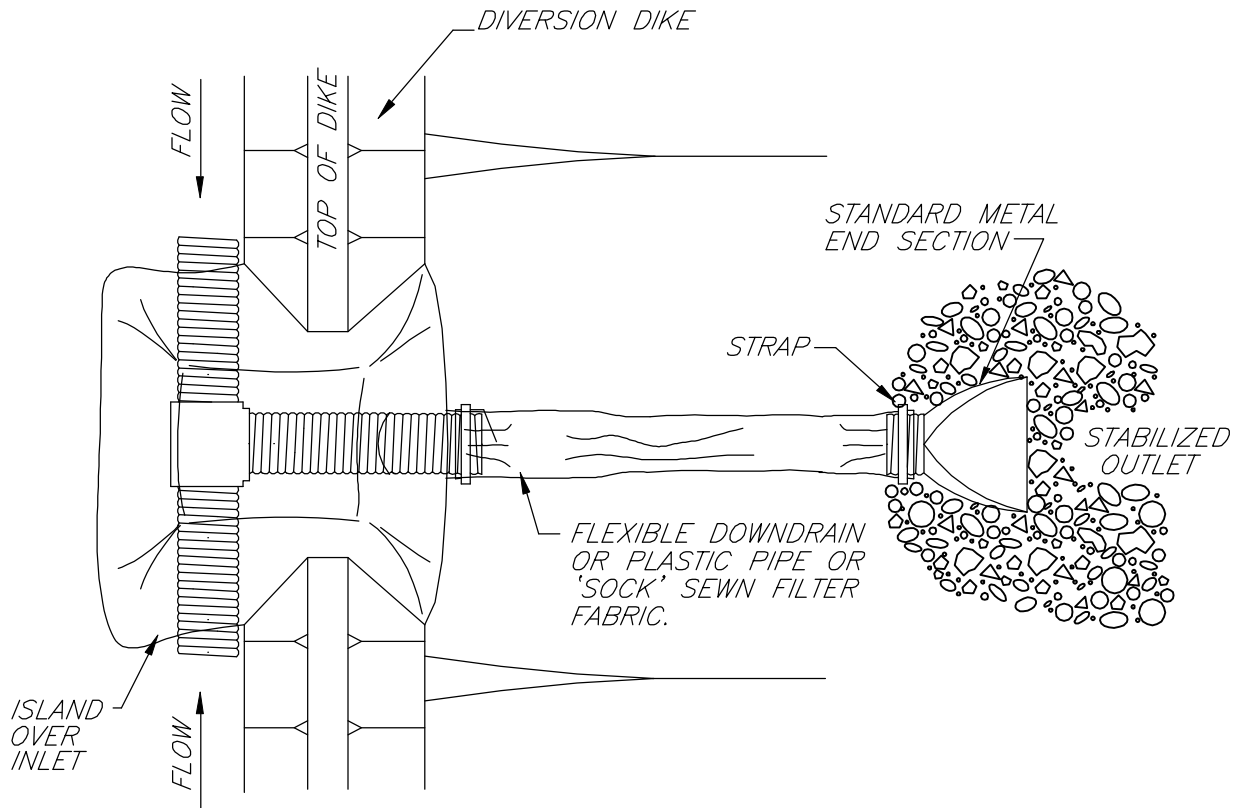
Size of Slope Drain	
Maximum Drainage Area (ha)	Pipe Diameter (mm)
0.2	300
0.6	450
1.0	530
1.4	600
2.0	760

Inspection and Maintenance

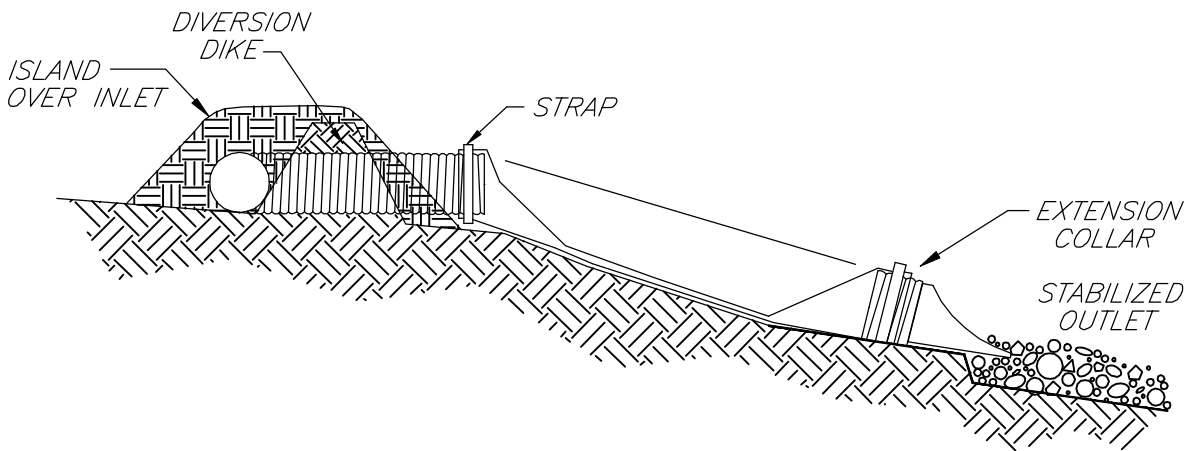
- Inspection frequency should be in accordance with the PESC and TESC Plans
- Repair any damaged section of pipe immediately
- **If evidence exists of pipe movement, install additional anchor stakes to secure and anchor at zones of movement**
- Remove sediment from upslope inflow apron area after each storm event otherwise either downslope sediment transport will occur or cause the drainpipe to be plugged which could result in overtopping of inflow apron structure and sheet flow over slope face

Similar Measures

- Rock lined channel
- Permanent Pipe (slope drains)
 - Corrugated steel pipe (CSP) down drain (AT Drawing No. CB-6 2.4 M17)
 - Half-round corrugated steel (1/2 CSP) downslope drain (AT Drawing No. CB-6 2.4 M4) for low flow areas such as bridge headslopes



PLAN VIEW

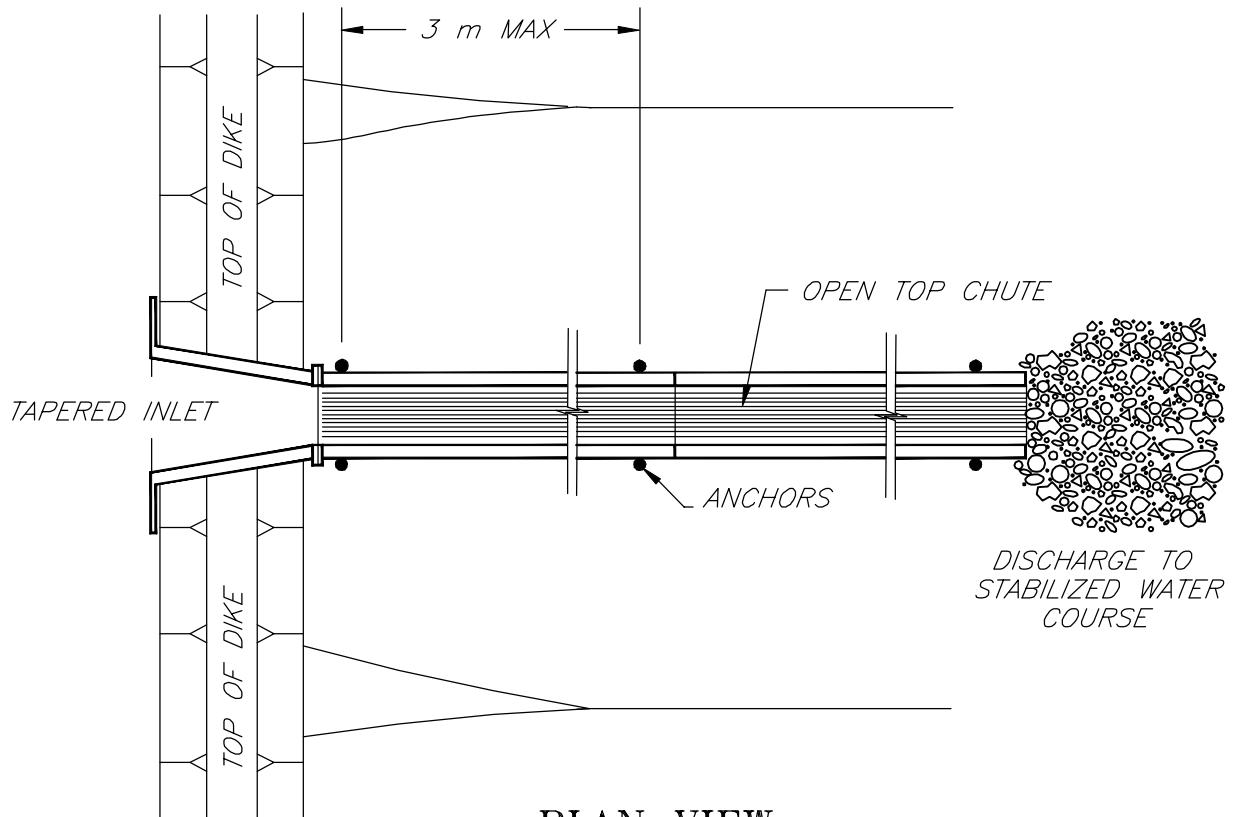


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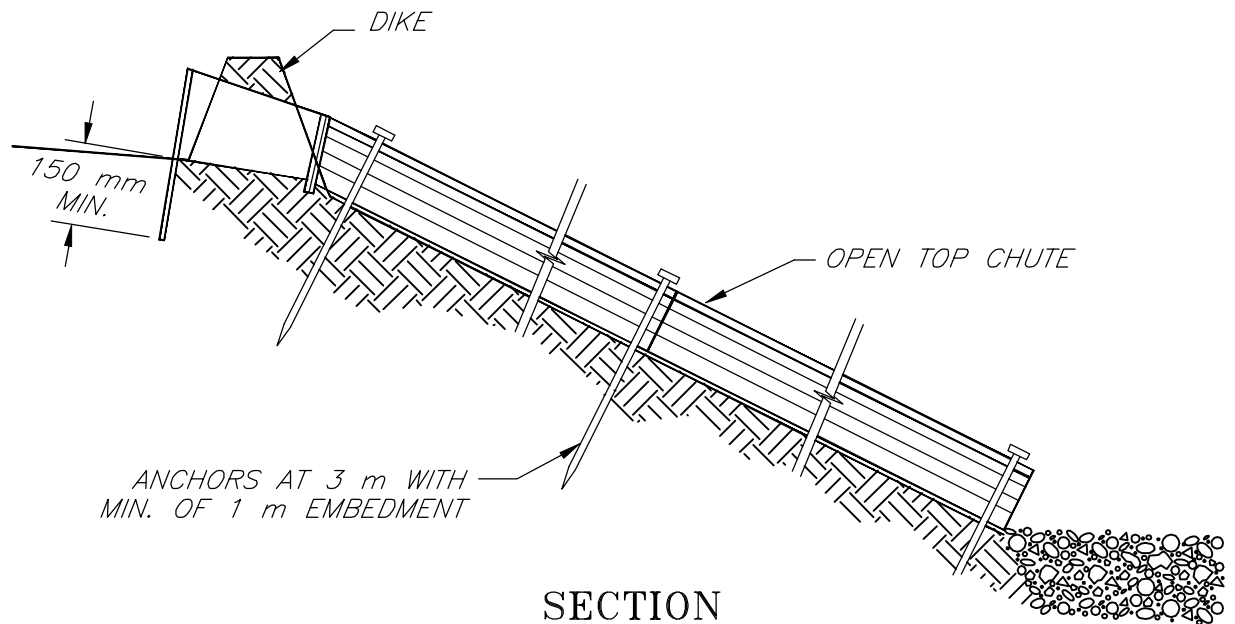
NOTE:

1. THIS FIGURE IS PROVIDED FOR GUIDANCE ONLY AND DOES NOT CONSTITUTE A DESIGN. A SITE SPECIFIC DESIGN IS REQUIRED FROM DESIGNER/ENGINEER.

SLOPE DRAIN



PLAN VIEW



SECTION

NOTE:

1. THIS FIGURE IS PROVIDED FOR GUIDANCE ONLY AND DOES NOT CONSTITUTE A DESIGN. A SITE SPECIFIC DESIGN IS REQUIRED FROM DESIGNER/ENGINEER.

OVERSIDE DRAIN

Groundwater Control (Subsurface Drains or Finger Drains) Sediment Control	B.M.P. #20
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Description and Purpose

- Drains that intercept and collect subsurface groundwater and divert it from slope, thus lowering groundwater table to minimize piping erosion reducing seepage flow on slopes and increase slope stability
- Relief drains (perforated finger-drains or French drains) to mitigate high groundwater table to minimize piping erosion

Applications

- Permanent measure
- Used on cutslopes where groundwater seepage exits on slope face

Limitations

- Must be designed by a geotechnical engineer
- Can be expensive to install
- Plugging of drainage outlet can be detrimental to cause build-up of pore pressure; it is mandatory to protect the outlet area to ensure free draining condition

Construction

- Excavate trench at subsurface drain location
- Install drain pipe
- Backfill with clean, coarse drainage gravel and/or non-woven geotextile fabric to provide filtration separation with adjacent soils

Construction Considerations

- When signs of seepage and unstable excavation slope are encountered at excavations, it is advisable to install trench protection measures for safety (i.e., trench box)
- Carry out work as soon as possible to mitigate seepage damage, soil loss and deterioration of unstable slope
- Excavate and install drains to the grade and spacings according to design and recommendations made by the geotechnical engineer
- Protect outlet of drainage with sturdy pipe to ensure free draining condition
- Drains and pipes should be designed with frost penetration and the freezing of pipes in mind

Groundwater Control (Subsurface Drains or Finger Drains) Sediment Control	B.M.P. #20
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Inspection and Maintenance

- Drains installed below grade will require manhole at frequent intervals (100 m maximum) to facilitate inspection and maintenance
- Flushing and maintenance clean out of drains can be carried out through manhole locations

Offtake Ditch (Intercept Ditch)	B.M.P. #21
Erosion Control	

Description and Purpose

- Channels or swales commonly located along the crest of cuts slopes to intercept and convey runoff away from flowing down a newly excavated bare soil slope and to minimize erosion of slope from overland sheet flow
- Can be tied to outfall to slope drains (or downdrains) which carry water from higher slope elevations to lower elevation of a slope

Applications

- Permanent measure
- Effective method of intercepting runoff to avoid excessive sheet flow over slope and causing erosion, especially on cut slopes in highly erodible soils (sand and silt)
- Can be used in conjunction with slope drains which was installed down a large cut slope
- May be lined with vegetation, rip rap, erosion control blankets, or some other erosion protection measure, but this requirement may be appropriate only at highly sensitive and high risk environmental areas
- Can be used in conjunction with sediment control measures, such as check structures or permeable synthetic barriers as normal channel design, but this requirement may be appropriate only at highly sensitive and high risk environmental areas

Limitations

- Ditch may require lining to minimize soil erosion from concentrated flow
- Ditch may require design by qualified personnel if flow velocities and/or volumes are large
- Channel must be graded to maintain adequate depth, positive drainage to avoid ponding and breaching of channel flow, which may lead to overtopping of the channel to result flow to cause in downslope erosion
- Removal of sediment build up and ditch maintenance may be difficult due to limited access space as offtake ditches are commonly constructed at crest of slopes

Construction

- Use backhoe to form ditch a minimum offset distance of 2 m between crest of highway slope and top of offtake ditch sideslope, thus providing a dyke width of 1 m
 - Place and compact excavated soil to form a dyke between crest of highway slope and offtake ditch channel to provide adequate depth (1 m) of the offtake ditch

Offtake Ditch (Intercept Ditch)	B.M.P. #21
Erosion Control	

- The consequence of failure on this dyke will determine the level of compaction effort required
- Sideslopes of ditch should not be steeper than 2H:1V (depending upon material type)
- Depth of ditch (from base of ditch to top of embankment) should be a minimum of 1 m in depth; width of ditch should be 1 m minimum
- Ditch grade should be graded a minimum of 1% to promote positive drainage and outfall

Construction Considerations

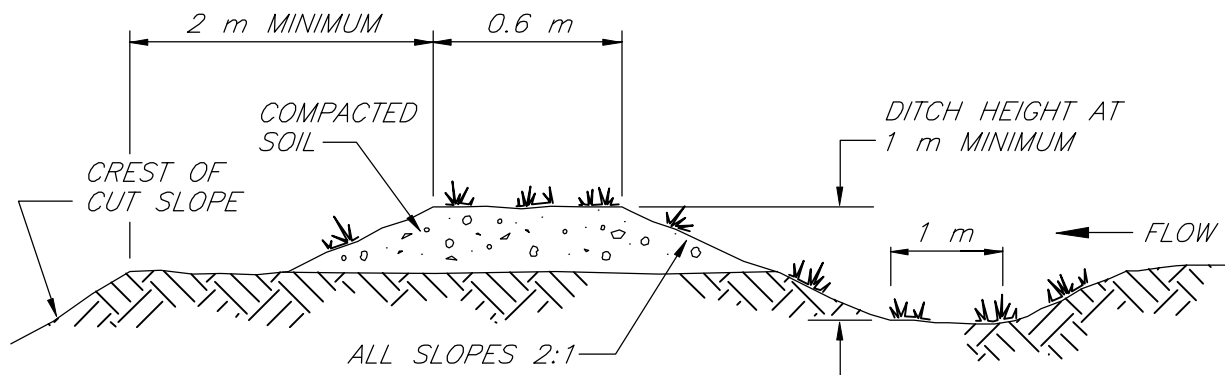
- Channel should be graded towards nearest outfall (draw) or drainage pipe

Inspection and Maintenance

- Inspection frequency should be in accordance with the PESC and TESC Plans
- Repair any damage to channel immediately

Similar Measures

- Berms
- Barriers



TYPICAL OFFTAKE DITCH

NOTES:

1. THE DITCH BEHIND THE DYKE SHALL HAVE POSITIVE GRADE TO A STABILIZED OUTLET.
2. THE DYKE SHALL BE ADEQUATELY COMPACTED TO PREVENT FAILURE.
3. FOR SENSITIVE HIGH RISK AREAS, THE DITCH SHALL BE STABILIZED WITH TEMPORARY OR PERMANENT SEEDING OR RIPRAP.
4. THIS FIGURE IS PROVIDED FOR GUIDANCE ONLY AND DOES NOT CONSTITUTE A DESIGN. A SITE SPECIFIC DESIGN IS REQUIRED FROM DESIGNER/ENGINEER.

**OFFTAKE DITCH
(INTERCEPT DITCH)**

Seeding	B.M.P. #22
Erosion Control	

Description and Purpose

- The planting or placing seed into soils of cut slope or fill embankment slopes after a layer of organic topsoil is spread over the slope
- Provides erosion protection through development of a shallow root structure from seed germination and plant growth

Applications

- Permanent or temporary measure
- Temporary seeding with rapidly growing plants may be applied to interim stockpile/excavation areas which will be exposed for more than 30 days
- Permanent seeding may be applied to exposed bare soil areas which have been graded to final contours
- Permanent seeding may be applied to landscape corridors, slopes and channels by broadcasting, furrowing or spraying on with mulch tackifier
- Provides habitat for wildlife after vegetation establishment
- Can be enhanced with a protective layer of mulches or rolled erosion control products (RECPs) to improve growth environment

Advantages

- Enhances terrestrial and aquatic habitat with vegetation growth re-establishment
- Aesthetically pleasing with vegetation cover
- Grows stronger with time as root structure develops
- Generates vegetation to enhance infiltration of runoff and transpiration of groundwater
- Seeding with a mixture of grasses and herbaceous legumes in disturbed areas is an inexpensive method of stabilizing the soil, particularly if the area is flat to gently sloping
- Cost of seeding disturbed areas is relatively low and its effectiveness on a long-term basis is relatively high

Limitations

- Grasses may require regular maintenance (mowing) along ditches
- Uncut dry grass may present a fire hazard and site distance obstruction adverse to highway safety

Seeding	B.M.P. #22
Erosion Control	

- Seeding of steep slopes may be difficult without using measures such as RECP's or hydroseeding-hydromulching methods
- Seasonal windows on planting (early spring or fall) may not coincide favourably with construction schedule
- Areas that have not been covered with seeded topsoil are susceptible to erosion until vegetation is established if RECPs are not used
- Use of topsoil and mulch can reduce rain drop erosion potential during germination and until vegetation is established
- Additional erosion control measures, such as RECPs, may be required for steep slopes and channels
- Reseeding will be required in areas of limited plant growth
- Time to establish root structure may be unacceptable for some high risk areas; shallow sodding should be considered for these areas

Construction

- The site to be seeded should be prepared prior to seeding
- Surface should be graded to design grades and then topsoiled
- Seedbed should be 75 to 150 mm deep, with the top 75 mm consisting of topsoil free of large clods or stones
- Seed should be applied immediately after seedbed preparation using broadcast seed spreaders, cyclone (broadcast) spreaders, or seed drills to ensure uniformity of application
- Seedbed should be harrowed, raked, or chain-dragged to ensure proper seed-soil contact
- Fertilizer should then be applied after seeding

Construction Considerations

- Seeding rate for all mixes should be 25 kg/ha minimum
- Fall rye may be added to each mix to provide early growth and protection from soil erosion.
- Fall rye seeding rate is 5 kg/ha
- Selection of proper vegetation seed mix depends on soil conditions, climate conditions, topography, land use, and site location

Seeding	B.M.P. #22
Erosion Control	

- Planting of seeds by hydraulic seeding and mulching techniques should be considered for slopes steeper than 3H:1V where seedbed preparation is difficult, or where application of seed, mulch, and fertilizer in one continuous operation is desirable
- Sod may be installed for faster results, however it is very costly but essential for high risk sensitive areas
- If mulch is placed as a germination medium for seeds, the mulch layer may be further protected with a biodegradable matting to prevent mulch from being washed or blown away

Inspection and Maintenance

- Inspection frequency should be in accordance with the PESC and TESC Plans
- Freshly seeded areas should be inspected frequently to ensure growth is progressing
- Additional stormwater control measures should be considered for areas damaged by runoff
- Reseedings may be required within 1 to 5 year intervals after initial seeding
- Small bare spots may need to be reseeded several times at subsequent years after initial application
- Larger areas may need to be completely retreated
- Cutting or mowing grasses will encourage the establishment and spread of the grass

Similar Measures

- Hydraulic seeding and mulching
- Sodding

Design Considerations

- Seed application rate of 25 kg/ha may be used; if fall rye is to be added, it should have an application rate of 5 kg/ha
- When using a seed drill or Brillion seeder, grasses and legumes shall not be planted deeper than 1 cm
- Bacterial inoculants must be used when seeding with legumes
- A specific inoculant shall be used for the legume being seeded in accordance with the supplier's recommendations

Seeding	B.M.P. #22
Erosion Control	

- Fertilizer, in lieu of a soil test, shall be as stated in the design, or follow supplier's recommendations
- Fertilizer shall be applied at a rate of 50 to 75 kg of nitrogen/ha, depending upon site conditions
- Fertilizer use shall be carefully controlled as this may increase nutrient loading to receiving streams if runoff is not controlled properly
- Seeding shall occur during periods when germination can be successful and plants have sufficient time to become established before the end of the growing season (approximately May 15 to June 1 and/or August 15 to September 15)
- Seeding should not occur after the 50% frost probability date for the site
- Mulch is required when broadcast seeding or if seeding is carried out after the date specified in which fall seeding should not be carried out
- For specific needs of local growth environment, specific design and advice from local seed supplier or Professional Agrologist may be required

Alberta Transportation has adopted seed mixes (provided below) depending on site location. The various areas of the province used in selecting the seed mix are presented (Alberta Transportation Seed Mixture Zones Map).

Seeding	B.M.P. #22
Erosion Control	

Alberta Transportation
Grass Seed Mixtures used on Highway and Bridge Projects

This Special Provision (Spc_G039.wpd (2005)) is to be used in conjunction with AT Standard Specification 2.20 "Seeding" and Design Bulletin No. 25. The Consultant must perform the vegetation assessment and the soil testing for fertilizer (if required) as part of his design work.

Zone 1 - Peace River District - north and west of High Level:

Seed Mix Zone	Native Seed Mix - Zone 1		% by Dry Weight
	Common Name	Latin Name	
1 Wetland Mixedwood	Slender Wheat Grass	<i>Agropyron trachycaulum</i>	40%
	Fringed Brome ⁽¹⁾	<i>Bromus ciliatus</i>	15%
	Tufted Hairgrass	<i>Deschampsia cespitosa</i>	15%
	Northern Wheat Grass	<i>Agropyron dasystachyum</i>	10%
	Rocky Mountain Fescue	<i>Festuca saximontana</i>	10%
	Fowl Bluegrass	<i>Poa palustris</i>	10%

Note ⁽¹⁾: Fringed Brome seed shall be coated.

Agronomic Seed Mix - Zone 1		
Common Name	Latin Name	% by Dry Weight
Pubescent Wheat Grass	<i>Agropyron trichophorum</i>	40%
Dahurian Wildrye	<i>Elymus dahuricus</i>	22%
Sheep Fescue	<i>Festuca ovina</i>	30%
Perennial Ryegrass	<i>Lolium perenne</i>	8%

Zone 2 - Athabasca District (south of Athabasca) and Grande Prairie District

Seed Mix Zone	Native Seed Mix - Zone 2		% by Dry Weight
	Common Name	Latin Name	
2 Dry Mixedwood	Slender Wheat Grass	<i>Agropyron trachycaulum</i>	35%
	Fringed Brome ⁽¹⁾	<i>Bromus ciliatus</i>	20%
	Tufted Hairgrass	<i>Deschampsia cespitosa</i>	10%
	Northern Wheat Grass	<i>Agropyron dasystachyum</i>	15%
	Rocky Mountain Fescue	<i>Festuca saximontana</i>	10%
	Fowl Bluegrass	<i>Poa palustris</i>	10%

Note ⁽¹⁾: Fringed Brome seed shall be coated.

Seeding	B.M.P. #22
Erosion Control	

Agronomic Seed Mix - Zone 2		
Common Name	Latin Name	% by Dry Weight
Pubescent Wheat Grass	<i>Agropyron trichophorum</i>	40%
Dahurian Wildrye	<i>Elymus dahuricus</i>	22%
Sheep Fescue	<i>Festuca ovina</i>	30%
Perennial Ryegrass	<i>Lolium perenne</i>	8%

Zone 3 - Athabasca District (north of Athabasca) and Hwy. Nos. 88, 750, 986

Seed Mix Zone	Native Seed Mix - Zone 3		% by Dry Weight
	Common Name	Latin Name	
3 Central Mixedwood	Slender Wheat Grass	<i>Agropyron trachycaulum</i>	35%
	Fringed Brome ⁽¹⁾	<i>Bromus ciliatus</i>	10%
	Tufted Hairgrass	<i>Deschampsia cespitosa</i>	10%
	Canada Wildrye	<i>Elymus canadensis</i>	10%
	Rocky Mountain Fescue	<i>Festuca saximontana</i>	20%
	Tickle Grass	<i>Agrostis scabra</i>	10%
	Fowl Bluegrass	<i>Poa palustris</i>	5%

Note ⁽¹⁾: Fringed Brome seed shall be coated.

Agronomic Seed Mix - Zone 3		
Common Name	Latin Name	% by Dry Weight
Pubescent Wheat Grass	<i>Agropyron trichophorum</i>	40%
Dahurian Wildrye	<i>Elymus dahuricus</i>	22%
Sheep Fescue	<i>Festuca ovina</i>	30%
Perennial Ryegrass	<i>Lolium perenne</i>	8%

Seeding	B.M.P. #22
Erosion Control	

Zone 4 - Lethbridge District (east of Hwy 22), Calgary District (east of Hwy 22), and Hanna District

Seed Mix Zone	Native Seed Mix - Zone 4		% by Dry Weight
	Common Name	Latin Name	
4 Mixedgrass and Dry Mixedgrass	Slender Wheat Grass	<i>Agropyron trachycaulum</i>	30%
	Canada Wildrye	<i>Elymus canadensis</i>	15%
	Mountain Brome	<i>Bromus carinatus</i>	15%
	Northern Wheat Grass	<i>Agropyron dasystachyum</i>	10%
	Western Wheat Grass	<i>Agropyron smithii</i>	5%
	Indian Rice Grass	<i>Orzyopsis hymenoides</i>	5%
	Alkali Grass	<i>Puccinellia distans</i>	10%
	Needle and Thread Grass	<i>Stipa comata</i>	10%

Agronomic Seed Mix - Zone 4		
Common Name	Latin Name	% by Dry Weight
Pubescent Wheat Grass	<i>Agropyron trichophorum</i>	32%
Dahurian Wildrye	<i>Elymus dahuricus</i>	30%
Sheep Fescue	<i>Festuca ovina</i>	30%
Cereal Rye	<i>Secale cereale</i>	8%

Zone 5 - Stony Plain, Vermillion, and Red Deer (east of Hwy 22) Districts:

Seed Mix Zone	Native Seed Mix - Zone 5		% by Dry Weight
	Common Name	Latin Name	
5 Central Parkland	Slender Wheat Grass	<i>Agropyron trachycaulum</i>	25%
	Northern Wheat Grass	<i>Agropyron dasystachyum</i>	10%
	Fringed Brome ⁽¹⁾	<i>Bromus ciliatus</i>	15%
	Green Needle Grass	<i>Stipa viridula</i>	15%
	Canada Wildrye	<i>Elymus canadensis</i>	10%
	Indian Rice Grass	<i>Orzyopsis hymenoides</i>	10%
	Nuttall's Alkali Grass	<i>Puccinellia nuttalliana</i>	10%
	Western Wheat Grass	<i>Agropyron smithii</i>	5%

Note ⁽¹⁾: Fringed Brome seed shall be coated.

Seeding	B.M.P. #22
Erosion Control	

Agronomic Seed Mix - Zone 5		
Common Name	Latin Name	% by Dry Weight
Pubescent Wheat Grass	Agropyron trichophorum	32%
Dahurian Wildrye	Elymus dahuricus	30%
Sheep Fescue	Festuca ovina	30%
Cereal Rye	Secale cereale	8%

Zone 6 -Lethbridge, Calgary, and Red Deer Districts all located west of Hwy 22):

Seed Mix Zone	Native Seed Mix - Zone 6		% by Dry Weight
	Common Name	Latin Name	
6 Lower Foothills	Slender Wheat Grass	Agropyron trachycaulum	30%
	Smooth Wildrye	Elymus glaucus	20%
	Northern Wheat Grass	Agropyron dasystachyum	10%
	Tickle Grass	Agrostis scabra	10%
	Fringed Brome ⁽¹⁾	Bromus ciliatus	10%
	Tufted Hairgrass	Deschampsia cespitosa	10%
	Foothills Rough Fescue	Festuca campestris	10%

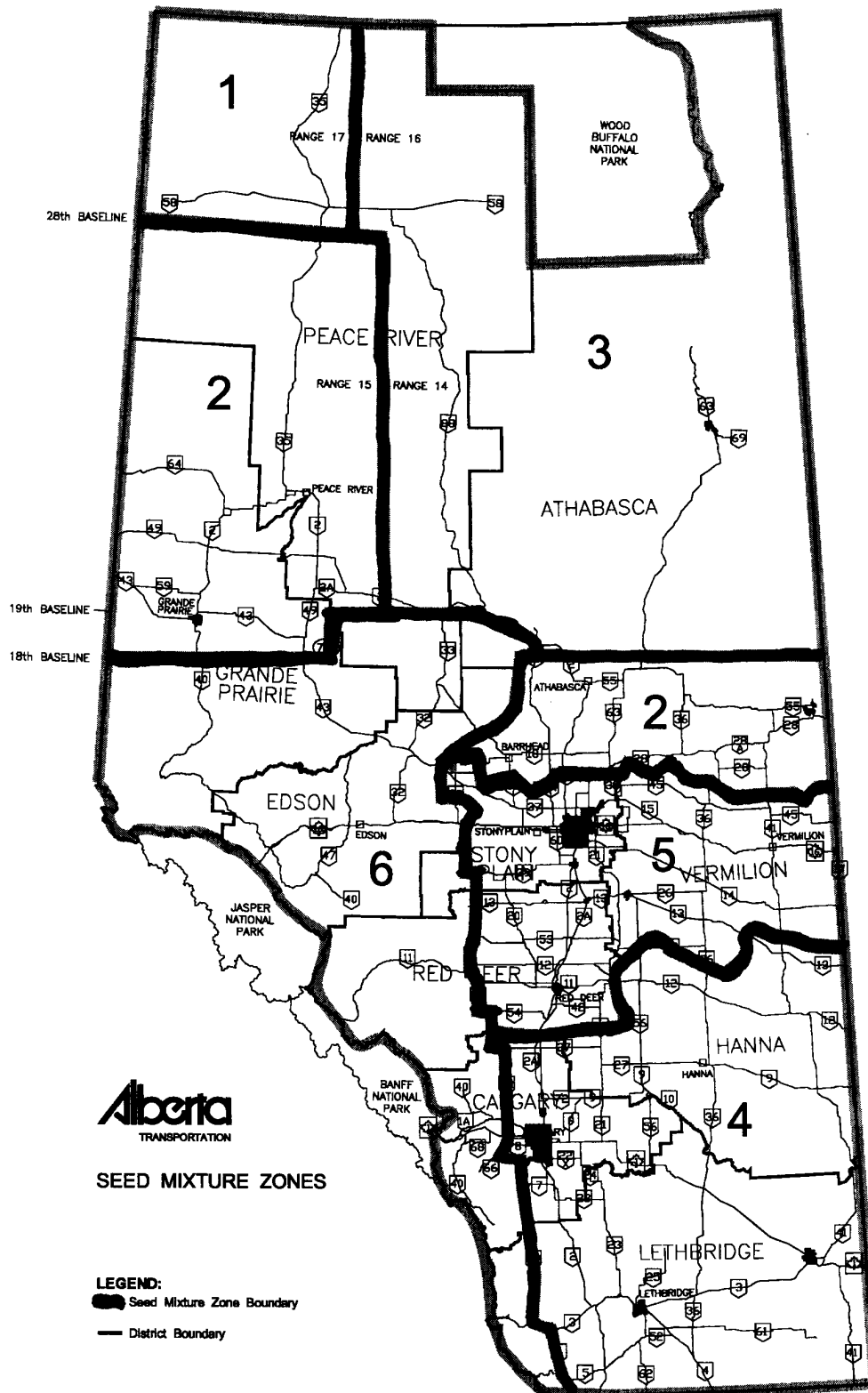
Note ⁽¹⁾: Fringed Brome seed shall be coated.

Agronomic Seed Mix - Zone 6		
Common Name	Latin Name	% by Dry Weight
Pubescent Wheat Grass	Agropyron trichophorum	40%
Dahurian Wildrye	Elymus dahuricus	22%
Sheep Fescue	Festuca ovina	30%
Perennial Ryegrass	Lolium perenne	8%

Seeding

Erosion Control

B.M.P. #22



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SEEDMIXZONE.DWG

JUNE 2011

DIVISION #22 - IX

<p>Mulching</p> <p>Sediment Control and Erosion Control</p>	<p>B.M.P. #23</p>
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Description and Purpose

- Application of organic material or other normally biodegradable substances as a protection layer to the soil surface (i) to minimize raindrop/runoff erosion and conserve a desirable soil moisture property for plant growth, and/or (ii) to promote seed germination and plant growth
- Mulches conserve soil moisture, reduce runoff velocities and surface erosion, control weeds, help establish plant cover, and protect seeds from predators, raindrop impact, and wind/water erosion

Applications

- Temporary measure
- Can be used as an organic cover or growth medium for seeds where topsoil is not readily available
- Can be used to provide temporary and permanent erosion control
- May be used with or without seeding in areas that are rough graded or final graded
- May be applied in conjunction with seeding to promote plant growth
- May comprise organic mulches (such as straw, wood fibres, peat moss, wood chips, pine needles, compost) or chemical mulches (such as vinyl compounds, asphalt, rubber, or other substances mixed with water)
- Chemical mulches may be used to bind other mulches in a hydroseeding-hydromulching application

Advantages

- Relatively cheap method of promoting plant growth and slope protection

Limitations

- Application of mulch may be difficult on steep slopes
- May require spray-on method to apply mulch with tackifier to provide adhesion to steep slopes

Installation

- Prepare soil surface by removing large rocks or other deleterious materials
- Apply topsoil and seed, if required, and if topsoil is readily available
- Apply mulch as per supplier's recommendations

- Certain mulches may require additional anchoring to minimize loss of mulch due to wind or water erosion

Construction Considerations

- Install mulches as per manufacturers' or suppliers' recommendations
- Organic Mulches
 - Straw
 - Refers to stalks or stems of small grain (primarily wheat) after drying and threshing
 - Straw should be free of weeds
 - Loose straw is very susceptible to movement by blowing wind and water runoff and should be anchored either with chemical tackifier or some form of netting
 - When properly secured to surface, straw is highly suitable for promoting good grass cover quickly, however, it may be a fire hazard in dry conditions
 - Raw Wood Fibre
 - Mixture of cellulose fibres; a minimum of 4 mm in length extracted from wood
 - Wood fibres usually require a soil binder and should not be used as erosion control during periods of hot dry weather in the summer or for late fall seeding unless it is used in conjunction with another suitable mulch as it is prone to removal by blowing wind or water runoff
 - Wood fibre is primarily used in hydroseeding-hydromulching operations where it is applied as part of a slurry and when used in conjunction with a tackifier; it is well suited for tacking straw mulch on steep slopes
 - Peat Moss
 - Comprises partly decomposed mosses and organic matter under conditions of excessive moisture
 - Usually available in dried and compressed bundles
 - Should be free of coarse material
 - Useful soil conditioner to improve organic content of soil promoting plant growth
 - Highly susceptible to removal by blowing wind and water runoff if dry and spread on top of soil
 - Wood Chips
 - By-products of timber processing comprised of small, thin pieces of wood

- Decompose slowly
- Suitable for placing around individual plants (shrubs and trees) and for areas that will not be closely mowed
- Highly resistant to removal by blowing wind and water runoff
- Bark Chips (Shredded Bark)
 - By-products of timber processing comprised of small, thin pieces of tree bark
 - Suitable for areas that will not be closely mowed
 - Have good moisture retention properties and are resistant to removal by blowing wind and water runoff
- Pine Needles
 - Comprise needles from coniferous trees (pine, spruce)
 - Needles should be air dried and free of coarse material
 - Decompose slowly
 - Suitable for use with plants that require acidic soils
 - Resistant to removal by blowing wind and water runoff
- Compost (Straw Manure)
 - Comprised of organic residues and straw that have undergone biological decomposition until stable
 - Should be well shredded, free from coarse material, and not wet
 - Has good moisture retention properties and is suitable as a soil conditioner promoting plant growth
 - Relatively resistant to removal by blowing wind and water runoff if not dried out completely
- Chemical Mulches
 - Comprised of acrylic co-polymers, vinyl compounds, asphalt, rubber, or other substances mixed with water
 - Usually used in hydroseeding-hydromulching applications
 - Should be applied in accordance with suppliers' recommendations

<p>Mulching</p> <p>Sediment Control and Erosion Control</p>	<p>B.M.P. #23</p>
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Inspection and Maintenance

- Inspection frequency should be in accordance with the PESC and TESC Plans
- Areas damaged by washout or rilling should be regraded if necessary and recovered with mulch immediately
- Additional stormwater control measures should be considered for areas of severe rilling erosion damaged by runoff
- Small bare spots may need to be reseeding and recovered with mulch

Similar Measures

- Topsoiling
- Hydraulic seeding and mulching (hydroseeding, hydromulching)
- Rolled erosion control products (RECP)

Hydroseeding	B.M.P. #24a
Sediment Control and Erosion Control	

Description and Purpose

- The spraying-on of a slurry to a slope or channel surface to provide a layer of seed and growth bedding medium
- The slurry consists of seed, fertilizer, mulch, tackifiers, and water which are mixed together in a tank
- Enables quick re-vegetation of very steep or rocky/gravelly slopes where re-vegetation by any other method would be very difficult or unsafe; frequent re-seeding and special mix design may be required
- When sprayed on the soil, the slurry forms a continuous blanket with seeds and protects the soil from wind and water erosion and raindrop impact by aggregating (or adhering) them in place
- The slurry conserves moisture, reduces soil moisture evaporation, and decreases soil surface crusting due to evaporation or drying of soil

Applications

- Temporary measure
- Slurry is held in suspension through consistent agitation and is sprayed onto disturbed areas using high pressure pumps
- Can be used for spray-on seeding covering large areas efficiently after placement of topsoil
- Can be used to provide temporary and permanent erosion control prior to establishment of vegetation
- May be used to provide soil stabilization for seeding disturbed soil areas
- Can also be used with higher efficiency and large area coverage with advantages over conventional methods (broadcast seeders, drill seeders)
- Can be used in areas where little topsoil is available

Limitations

- Site must be accessible to hydroseeding equipment
 - Usually mounted on trucks
 - Maximum hose range of approximately 150 m
- May require subsequent spraying to reseed bare spots or areas with low growth

Hydroseeding	B.M.P. #24a
Sediment Control and Erosion Control	

Construction

- Prepare soil surface by removing large rocks or other deleterious materials
- Apply topsoil if available
- Spray on hydroseed-hydromulch as per supplier's recommendations

Construction Considerations

- Seed
 - Seed selection should be made in accordance with Alberta Transportation approved seed mixes
 - Alberta Transportation has adopted seed mixes used on Alberta Highway and Bridge Projects depending on site location (see BMP #22 Seeding)
 - The various areas of the province used in selecting the seed mix are presented in the Seed Mix Zones map (see BMP #22 Seeding)
 - Seed mixes have been developed based on historic performance results throughout Alberta

Inspection and Maintenance

- Inspection frequency should be in accordance with the PESC and TESC Plans
- Areas damaged by runoff may need to be repaired and/or protected from further erosion
- Small bare spots may need to be reseeded

Similar Measures

- Seeding
- Mulching
- Rolled erosion control products (RECP)

Hydromulching	B.M.P. #24b
Sediment Control and Erosion Control	

Description and Purpose

- The spraying-on of a slurry to a slope or channel surface to provide a layer of growth bedding medium
- The slurry consists of seed, fertilizer, mulch, tackifiers, and water which are mixed together in a tank
- The slurry conserves moisture, reduces soil moisture evaporation, and decreases soil surface crusting due to evaporation or drying of soil

Applications

- Temporary measure
- Can be used in areas where little topsoil is available

Advantages

- Relatively cheap and efficient spraying method of promoting plant growth as well as erosion protection
- Allows spray-on re-vegetation of steep slopes where conventional re-vegetation methods are very difficult
- Minimizes effort required to re-vegetate disturbed areas as hydromulching usually only requires one spray-on operation in comparison with planting and farrow method
- Relatively efficient operation with high coverage rates
- Provides dust control and protection from wind erosion

Limitations

- Site must be accessible to hydromulching equipment
 - Usually mounted on trucks
 - Maximum hose range of approximately 150 m

Construction

- Prepare soil surface by removing large rocks or other deleterious materials
- Apply topsoil if available
- Spray on hydromulch as per supplier's recommendations

Construction Considerations

- Hydraulic Mulches
 - Cellulose
 - Comprised of recycled paper from newspapers, magazines, or other paper sources
 - Rapid method for applying seed, fertilizer, mulch, and water in almost any disturbed areas
 - Usually installed without tackifier in slurry
 - Short fibre lengths and lack of tackifier limits erosion control effectiveness and does little to moderate moisture content and temperature within the soil
 - Residual inks within the recycled paper may leach into soil, potential problem on environmentally sensitive areas
 - Longevity significantly shorter than for wood fibre mulches or bonded fibre matrices (BFM)
 - Cheaper than wood fibre mulches and bonded fibre matrices (BFM)
 - Wood Fibre
 - Comprised of whole wood chips
 - Industry standard, provides quick and uniform method and medium for re-vegetating large areas quickly and economically
 - Longer fibre lengths than for cellulose mulches
 - Longer lasting and has better wet-dry characteristics than cellulose mulches
 - Provides limited erosion control even when sprayed on with tackifiers
 - Provides limited moderation of soil moisture content and temperature when applied at higher rates
 - Cheaper than BFM, however, less effective than BFM
 - More expensive than cellulose mulches, however, more effective than cellulose mulches

– Bonded Fibre Matrices (BFM)

- Slurry comprised of either cellulose mulch, wood fibre mulch, or a combination of the two
- Mulches are bound together using chemical bond, mechanical bond, or a combination of the two
- All fibres and binding agents are premixed by manufacturer, ensuring uniformity and consistency throughout the application
- Well suited for sites with existing desirable vegetation and where worker safety and minimal ground disturbance are desired
- Degree of protection similar to that obtained from rolled erosion control products (RECP)
- Quicker installation/application than for RECP
- Chemically bonded BFM may require a 'set-up' or curing/drying period
 - Application must be limited to periods where there is no threat of rain during curing period
 - Mechanically bonded BFM have no curing time and are effective immediately after application
- Application on dry soils is not recommended
- More expensive than cellulose and wood fibre mulches
- More effective than cellulose or wood fibre mulches

▪ Tackifiers

- May include vinyl compounds, asphalt, rubber, or other substances mixed with water

Inspection and Maintenance

- Inspection frequency should be in accordance with the PESC and TESC Plans
- Areas damaged by runoff may need to be repaired and/or protected from further erosion.

Similar Measures

- Seeding
- Mulching
- Rolled erosion control products (RECP)

Topsoiling	B.M.P. #25
Erosion Control	

Description and Purpose

- The covering of exposed mineral soils with soils of high organic content to minimize raindrop erosion potential
- Provides a medium for vegetation to grow

Applications

- Temporary or permanent measure
- May be used to provide a bedding medium for seed germination and a cover to exposed soil that is not suitable to promote vegetation growth
- May be used on slopes with a maximum gradient of 2H:1V
- Normally topsoil is placed prior to seeding, mulching, hydroseeding-hydromulching, seeding and installing rolled erosion control products (RECP), or planting of trees/shrubs

Advantages

- Placing topsoil provides enriched organic medium for vegetation root structure to grow
- Topsoil organic content provides nutrients to promote plant growth
- Absorb raindrop energy to reduce erosion

Limitations

- Not appropriate for slopes steeper than 2H:1V
- Placing and grading topsoil can be time consuming and expensive
- Dry topsoil may be removed by blowing wind
- Topsoil may not be readily available in some areas

Construction

- Prepare ground surface to final grade by removing large rocks or other deleterious materials
- Apply topsoil with dozer or light track equipment to design thickness
- Track walk upslope or downslope (do not overcompact topsoil by heavy equipment; only track walk one pass) to provide a contour of roughness of topsoil to further minimize erosion

Topsoiling	B.M.P. #25
Erosion Control	

Construction Considerations

- Topsoil should be free of weeds which may inhibit re-vegetation of desirable plants (i.e., grass)
- Subgrade should be roughened by track walking up/down the slope prior to topsoiling to promote adhering of topsoil to subgrade (surface roughening of subgrade is especially required if topsoiling is not scheduled immediately after completion of the grade)
- Topsoil should be moistened regularly during periods of hot dry weather to minimize wind erosion
 - Hydroseeding-hydromulching topsoil will minimize wind erosion of topsoil

Design Considerations

- Perform pre and post disturbance survey
- Consider use of a soil mimic in areas with little topsoil or topsoil with poor growth nutrients
- Perform a preconstruction topsoil assessment to determine topsoil thickness hence design thickness

Inspection and Maintenance

- Inspection frequency should be in accordance with the PESC and TESC Plans
- Areas damaged by washout or rilling should be regraded and re-topsoiled immediately

Similar Measures

- Hydroseeding-hydromulching
- Mulching
- Rolled erosion control products (RECP)

Sodding	B.M.P. #26
Erosion Control	

Description and Purpose

- Use of grass sod to cover and stabilize disturbed areas of bare soil
- Rapidly establishes vegetative cover in environmentally sensitive areas where complete cover of the disturbed soil surface is essential and conventional or hydroseeding and mulching may not be effective to erosion protection for high risk areas
- Acts as a vegetative buffer
- Sod may be nursery or field sod composed of one or more species/cultivars of grasses and may contain associated plants such as legumes

Applications

- Temporary or permanent measure
- Irrigation (watering) required after placement
- May be used to protect soil surface from water and wind erosion where adequate topsoil and fertilizer can be provided
- Best used for areas that have steep grades or require immediate protection, or at locations where aesthetic appearance is a priority

Advantages

- Immediate protection for sensitive area from water and wind erosion
- Aesthetically pleasing

Limitations

- Expensive
- Labour intensive to install
- Sod may not be readily available in all areas of the province
- Field sod is not specifically produced for sale as turf and is generally not certified as to its composition or degree of weed infestation
- Sod can't be stored on-site for long periods of time

Construction

- Prepare smooth ground surface by removing large rocks or other deleterious materials
- Apply design thickness of topsoil and fertilizer (if required)

- Lay sod strips on prepared surface with long axis perpendicular to direction of slope (or in channels, perpendicular to anticipated direction of flow)
 - Butt-joint ends of adjacent sod strips tightly together
 - Roll or tamp each sod strip to ensure continuous contact between topsoil and underside of sod strip
 - Secure each strip of sod with an anchor embedded a minimum of 0.15 m into underlying soil
 - Anchors should be spaced a maximum distance of 0.6 m apart
- Adjacent rows of sod strips should have staggered joints

Construction Considerations

- Sod must not be placed on frozen ground
- During hot and dry periods, topsoil should be cool and wetted by irrigation prior to placing sod strips
- Freshly installed sod should be irrigated (watered) to moisten the topsoil to minimum depth of 0.1 m
 - Irrigation aids in the development of root matrix within the topsoil
- Successful installation requires the use of freshly cut, healthy sod
 - Storage time of cut sod on-site prior to installation should be kept to as short a time period as possible

Inspection and Maintenance

- Inspection frequency should be in accordance with the PESC and TESC Plans
 - Areas damaged by washout or rilling should be regraded and resodded immediately
- Additional erosion control measures should be considered for rilled or gullied areas
- Small bare spots may need to be resodded
- Sodded areas should be maintained by periodically fertilizing, irrigating (watering), mowing, and weed control, depending on location and maintenance plan
- Sod that is to be mowed periodically as part of its maintenance plan should not be mowed within one month of installation
- Grass clipping from mowing operations should be left on the sod unless they accumulate to a depth greater than 1 cm

Sodding Erosion Control	B.M.P. #26
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Similar Measures

- Mulching
- Hydroseeding
- Hydromulching
- Rolled erosion control products (RECP)

Live Staking Streambank Stabilization Technique	B.M.P. #27a
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Description and Purpose

- Consists of installing woody plantings (trees and shrubs) to develop a root matrix within the soil, increasing subsurface soil strength and stabilizing slopes with deeper root systems than grasses
- Reduces erosion potential of slopes and channel banks

Applications

- Temporary or permanent measure
- May be used on slopes stable enough to support vegetation; however, there is a low success rate for steep slopes and channel banks with gradients greater than 1H:1V
- May be used on slopes and channel banks with adequate sunlight, moisture, and wind protection to support vegetation
- May be used as bio-engineering stabilization in cases where there have been historical shallow slope instability, soil movements on eroded slopes and gullies
- May be used along channels to provide higher channel roughness to reduce flow velocity and in sedimentation ponds to provide higher sedimentation duration of runoff impoundment

Advantages

- Promotes development of organic mat
- Dense leaves and large diameter plant stalks increases channel roughness and reduces flow velocities in channel thus decreasing erosion potential
- Traps sediment laden runoff and stabilizes soil
- Aesthetically pleasing once developed
- Grows stronger with time as root structure develops
- Usually has deeper root penetration than grass with greater depth of stabilization
- Manual planting may be attempted on steep slopes that are sensitive to machinery disturbance or represent an area of high erosion potential

Limitations

- Can be labour intensive to install
- Some level of uncertainty as success of plant growth is dependent on various unknown site parameters (i.e., moisture, soil, terrain, weather, seeding conditions, etc.)
- Re-vegetated areas are susceptible to erosion until vegetation develops; and should be used in conjunction with hydroseeding and/or mulching
- Plants may be damaged by wildlife
- Potential for low success rate
- Few precedents as this measure is generally not used on AT construction projects

Construction

- Used on cut or fill slopes or in ditches/channels
- Comprised of willow or poplar stakes inserted into the ground; other indigenous plants may be acceptable
- Individual dormant willow or poplar stakes should be cut to a minimum length of 0.5 m using pruning shears
 - Cuts should be made at a 45° angle a minimum of 0.05 m (5 cm) below a leaf bud
 - All side shoots should be trimmed to within 0.05 m of the main stem
- Install live stakes in a 1 m by 1 m grid
- Make a pilot hole a minimum of 0.3 m in depth to insert live stake into
 - Use iron bar, broom handle or other tool to make pilot hole
- Insert live stake into pilot hole and lightly tamp soil around live stake
- A minimum of two leaf buds should remain above grade

Construction Considerations

- Successful installation requires the use of freshly cut branches or stakes
 - Storage time of cut branches/stakes on-site prior to installation should be kept to as short a time period as possible
- Successful growth dependant on soil moisture and rainfall conditions
- Consultation with agrologist, greenhouse growers, local expertise can be beneficial in selecting and procuring appropriate species for planting

Live Staking Streambank Stabilization Technique	B.M.P. #27a
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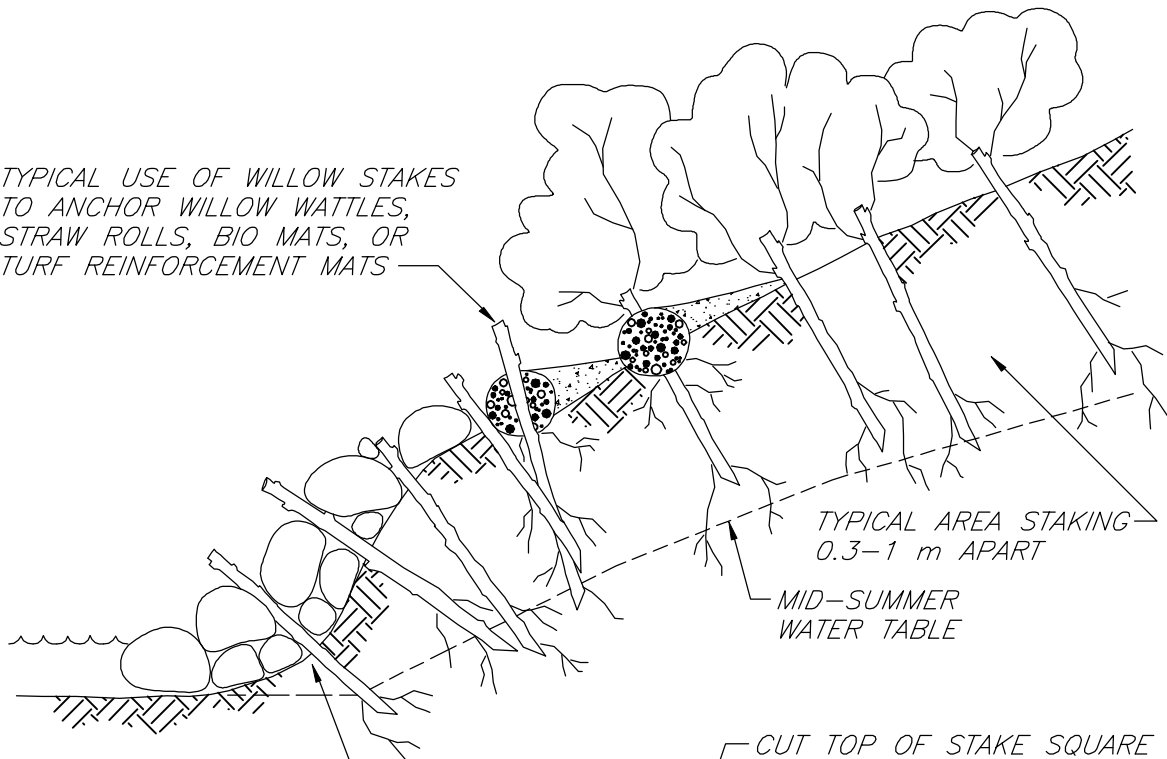
Inspection and Maintenance

- Inspection frequency should be in accordance with the PESC and TESC Plans
 - Areas damaged by washout or erosion rilling should be replanted immediately
- Additional stormwater control measures should be considered for severe rilling areas damaged by runoff
- Watering plants is required for first one to two months after planting

Similar Measures

- Seeding
- Mulching
- Hydroseeding
- Hydromulching
- Rolled erosion control products (RECP)
- Brush layering

TYPICAL USE OF WILLOW STAKES TO ANCHOR WILLOW WATTLES, STRAW ROLLS, BIO MATS, OR TURF REINFORCEMENT MATS



TYPICAL — DRIVE OR PLANT WILLOW STAKES THROUGH OPENINGS IN RIPRAP OR GABIONS

PLANT 80% OF STAKE LENGTH INTO THE GROUND

0.5 m MIN.

CUT TOP OF STAKE SQUARE

2 TO 5 BUDS SCARS SHALL BE ABOVE THE GROUND. ADDITIONAL LENGTH SHOULD BE REMOVED.

TRIM BRANCHES CLOSE

20-75 mm DIAMETER

MAKE ANGLED CUT AT BUTT-END, PLANT BUTT-END DOWN

NOTES:

1. HARVEST AND PLANT STAKES DURING THE DORMANT SEASON.
2. USE HEALTHY, STRAIGHT AND LIVE WOOD AT LEAST 1 YEAR OLD.
3. MAKE CLEAN CUTS AND DO NOT DAMAGE STAKES OR SPLIT ENDS DURING INSTALLATION, USE A PILOT BAR IN FIRM SOILS.
4. SOAK CUTTINGS FOR 24 HOURS (MIN.) PRIOR TO INSTALLATION.
5. TAMP THE SOIL AROUND THE STAKE.
6. THIS FIGURE IS PROVIDED FOR GUIDANCE ONLY AND DOES NOT CONSTITUTE A DESIGN. A SITE SPECIFIC DESIGN IS REQUIRED FROM DESIGNER/ENGINEER.

NOT TO SCALE

LIVE STAKING

Description and Purpose

- Consists of installing woody plantings (trees and shrubs) to develop a root matrix within the soil, increasing subsurface soil strength and stabilizing slopes with deeper root systems than grasses
- Reduces erosion potential of slopes

Applications

- Temporary or permanent measure
- May be used on slopes stable enough to support vegetation; however, there is a low success rate for steep slopes with gradients greater than 1H:2V
- May be used on slopes with adequate sunlight, moisture, and wind protection to support vegetation
- May be used as bio-engineering stabilization in cases of historical shallow slope instability soil movements on eroded slopes and gullies
- May be used to reduce flow velocity and in sedimentation ponds to provide higher sedimentation duration of runoff impoundment
- Particularly appropriate for highway embankments that encroach upon riparian areas or floodways
- Slopes that need additional geotechnical and erosion reinforcement are good candidates for brushlayering
- Steeper slopes require the use of inert reinforcements such as geotextiles (ECBs, TRMs, coir netting), wire (twisted or welded gabion wire) or geogrids
- If either steady, long term seepage or temporary bank return flows after flood events are a problem, the brushlayers act as a horizontal drainage layer or conduits that relieve internal pore water pressure

Advantages

- Promotes development of organic mat
- Dense leaves and large diameter plant stalks increases channel roughness and reduces flow velocities in channel thus decreasing erosion potential
- Traps sediment laden runoff and stabilizes soil
- Aesthetically pleasing once developed
- Grows stronger with time as root structure develops

- Usually has deeper root penetration than grass with greater depth of stabilization
- Manual planting may be attempted on steep slopes that are sensitive to machinery disturbance or represent an area of high erosion potential
- Of all vegetative biotechnical techniques, brushlayering has the greatest capacity for becoming successfully established, even in severe sites
- The use of synthetic geotextiles or geogrids provides long-term durability and greater security, especially if woody and herbaceous vegetation is established
- Can be used with other toe protection such as, rootwads, coir rolls, and log toes. Combining live brushlayering with rock toes is an effective and relatively low cost technique for re-vegetating and stabilizing streambanks
- Provide immediate soil stability and habitat
- Brushlayers and the pioneer vegetation that develops with them allow the establishment of a stable soil-root complex
- Both living and non-living brushlayers along streambanks enhance fish habitat, while slowing velocities along the bank during flooding flows
- They provide a flexible strengthening system to fill slopes. A bank can sag or distort without pulling apart the brushlayers
- Act as horizontal drains and favourably modify the soil water flow regime

Limitations

- Can be labour intensive to install
- Some level of uncertainty as success of plant growth is dependent on various unknown site parameters (i.e., moisture, soil, terrain, weather, seeding conditions, etc.)
- Plants may be damaged by wildlife
- Potential for low success rate
- Few precedents as this measure is generally not used on AT construction projects
- Brushlayers are vulnerable to failure before rooting occurs, and they are not effective at counteracting failure along very deep-seated failure planes

Construction

- First construct any lower bank or in-stream stabilizing measures such as a rock or log toe structure
- Excavate the first horizontal bench, sloping back into the hillslope at about 10%

- Install any drainage required along the back of each bench
- Place branches that are at least 1.8 m long on the bench
- Branches should crisscross at random with regard to size and age
- Place 20 branches per linear m on the bench, with the butts of the branches along the inside edge of the bench
- 20-45 cm of the growing tip should protrude beyond the face of the slope
- Cover and compact (add water if necessary) the brushlayer with 15 cm lifts of soil to reach the designed vertical spacing, typically 0.5 m to 1.2 m apart
- Slope the top of each fill bench back into the hill
- Construct another brushlayer
- When placed, the protruding tips of the cuttings are above the butts due to the back slope of the bench
- Proceed up the bank as desired
- The erosion and failure potential of the slope (i.e., drainage, soil type, rainfall, and length and steepness of the slope) determine spacing between the brushlayers
- On long slopes, brushlayer spacing should be closer at the bottom and spacing may increase near the top of the slope

Construction Considerations

- Successful installation requires the use of freshly cut branches or stakes
 - Storage time of cut branches/stakes on-site prior to installation should be kept to as short a time period as possible
- Successful growth dependant on soil moisture and rainfall conditions
- Consultation with agrologist, greenhouse growers, local expertise can be beneficial in selecting and procuring appropriate species for planting
- Installed during soil fill operations which result in the branches being inserted deeply into the slopes and thereby increasing the likelihood that the branches will encounter optimum soil and moisture conditions
- Live cuttings are most effective when implemented during the dormancy period of chosen plant species
- Live willow branches (or cuttings of other adventitiously-rooting species) at least 1.8 m long, with a minimum diameter of 20 mm
- Heavy equipment is usually employed for the construction of embankments

- A bucket loader and/or backhoe or excavator can facilitate the work
- Water should be available for achieving optimum soil moisture

Inspection and Maintenance

- Inspection frequency should be in accordance with the PESC and TESC Plans
- Inspect planted areas at least twice per year or after significant storm events (1:2 year storm and/or 40 mm rainfall in 24 hours)
 - Areas damaged by washout or erosion rilling should be replanted immediately
- Additional stormwater control measures should be considered for severe rilling areas damaged by runoff
- Watering plants is required for first one to two months after planting
- The live cuttings or branches should establish successfully without irrigation requirements given the proximity to water
- Inspect the cuttings for adequate vegetative establishment (as evidenced by root and shoot production from the imbedded stems) and for signs of localized erosion such as rilling from runoff or sloughing from stream scour
- Brushlayer treated streambanks should also be inspected for localized slope movements or slumps
- These localized slope failures and/or areas of poor vegetative establishment can often be repaired by re-installing the brushlayers in these zones
- The site should be examined for possible signs of flanking erosion, which must be addressed with ancillary protective measures lest the flanking threatens the integrity and effectiveness of the protective brushlayer fill
- As with all resistive streambank structures, flanking is always a potential problem
- If frozen soil is employed in constructing the soil lifts between brushlayers, some settlement may occur when the soil thaws. This settlement may falsely signal a slope failure
- The most likely causes of failure are the following:
 - Inadequate reinforcement from the brushlayer inclusions, i.e., too large a vertical spacing or lift thickness for the given soil and site conditions, slope height, slope angle, and soil shear strength properties
 - Inadequate tensile resistance in the brushlayers as result of too small an average stem diameter and/or too few stems per unit width

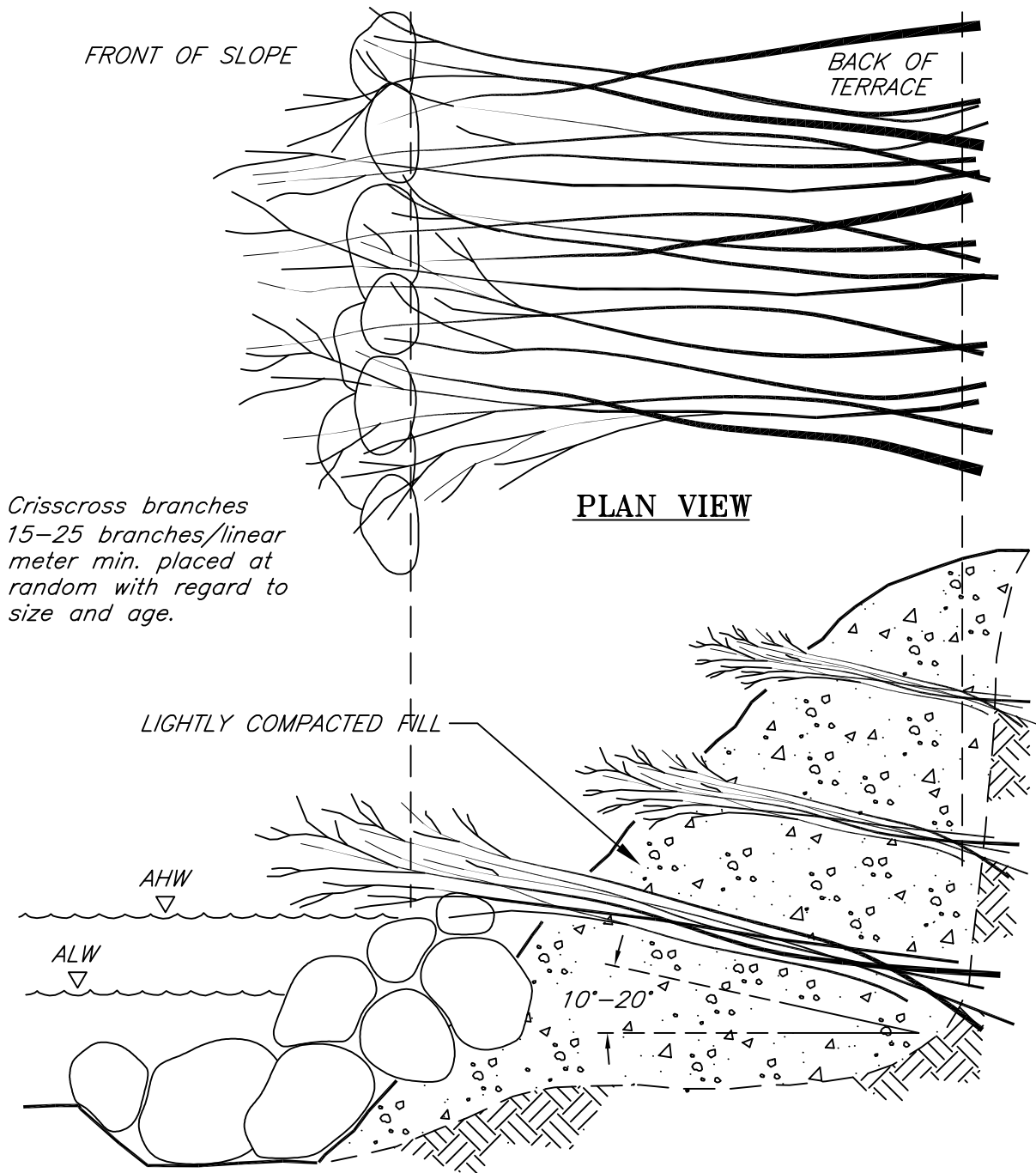
- Failure to properly consider seepage conditions and install adequate drainage measures, e.g., chimney drain, behind brushlayer fill, and conversely inadequate moisture applied during installation, and inadequate attention to construction procedures and details

Design Considerations

- Live branches and brushy cuttings are used to make brushlayers
- Up to 30% of the brush may be non-rooting species that provide immediate strength to the soil mass, but will then rot away
- Plant material harvesting and installation should be performed during its dormant season (late fall to early spring) or in other seasons if soil moisture is available
- The ideal plant materials for brushlayers are those that:
 - root easily
 - are long, straight and flexible
 - are in plentiful supply near the job site
- Willow makes ideal brushlayer material, and some species of *Baccharis*, *Cornus*, and *Populus* also have very good rooting ability
- All cuttings should be soaked for a minimum of 24 hours, whether they are stored or harvested and immediately installed
- Brushlayer reinforced fills must have adequate internal stability
- This means that the tensile inclusions, i.e., the brushlayers, should have a sufficient unit tensile resistance and/or be placed in sufficient numbers to resist breaking in tension
- The inclusions must also be sufficiently long and "frictional" enough to resist failure by pullout
- Allowable velocity for brushlayering is 3.7 m/s and allowable shear stress is 19 to 300 N/m² depending on how long the brushlayers have had to establish
- Schiechl & Stern (1996) suggest an allowable shear stress of 140 N/m²

Similar Measures

- Seeding
- Mulching
- Hydroseeding
- Hydromulching
- Rolled erosion control products (RECP)
- Live Staking



NOTES:

1. Tilt branches down into the slope 10°-20° min.
2. Brushlayering may be constructed with non-compacted or compacted backfill without damage to the brush layer.
3. Branches irrespective of length, should protrude 20-45 cm beyond the face of the slope.

BRUSHLAYERING WITH ROCK TOE PROTECTION

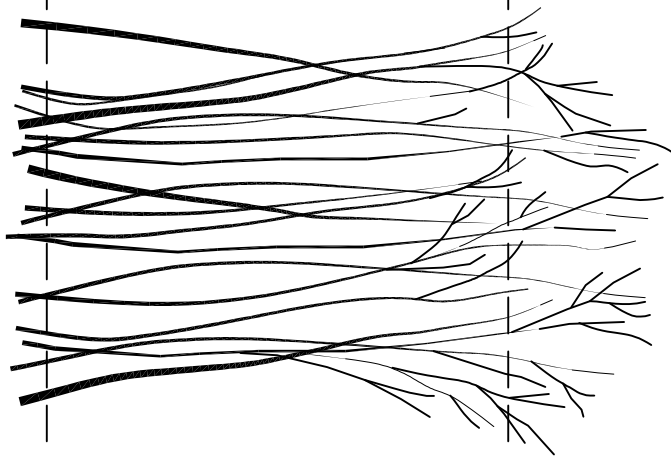
1999 JOHN McCULLAH



FILE: BRLAY-RT

BACK OF
TERRACE

FRONT OF SLOPE

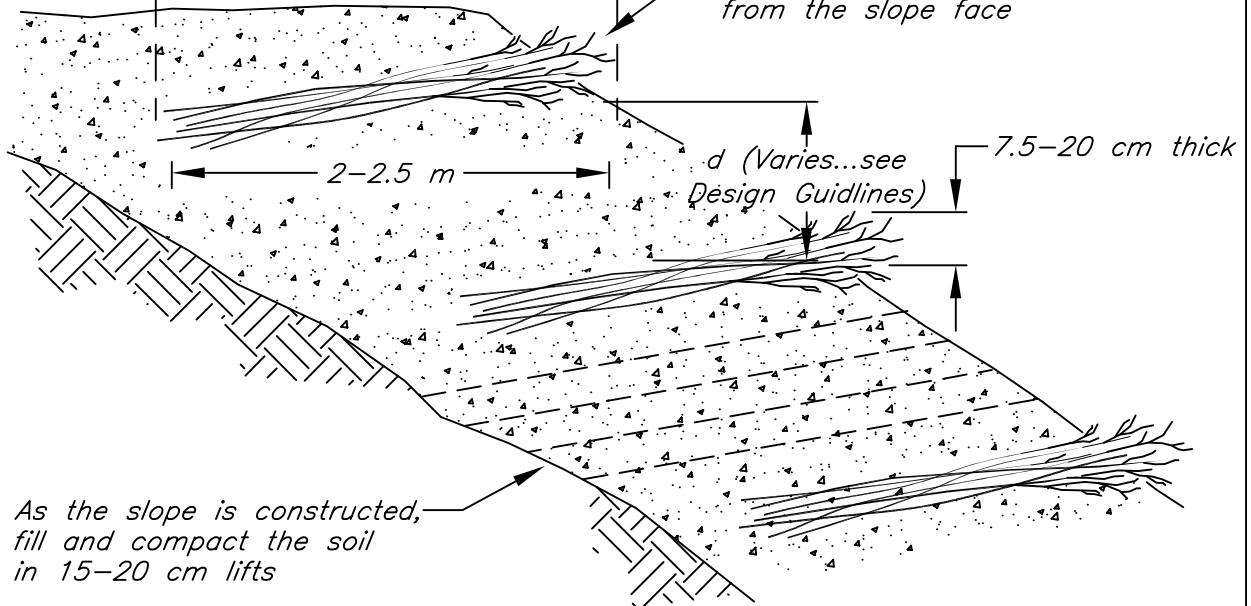


*Crisscross branches
15–25 branches/linear
meter min. placed at
random with regard to
size and age.*

PLAN VIEW

*Cover brushlayer immediately with
15 cm of fill soil, water and
compact according to specifications*

*Growing tips should protrude
from the slope face*



TYPICAL BRUSHLAYERING WITH SLOPE CONSTRUCTION

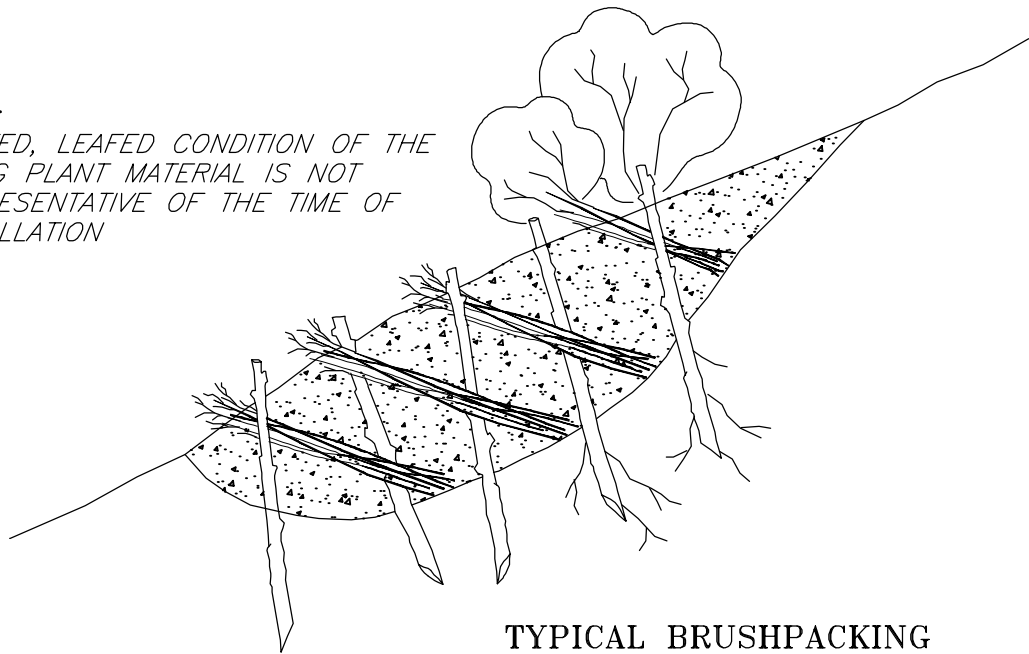
BRUSHLAYERING

1996 JOHN McCULLAH



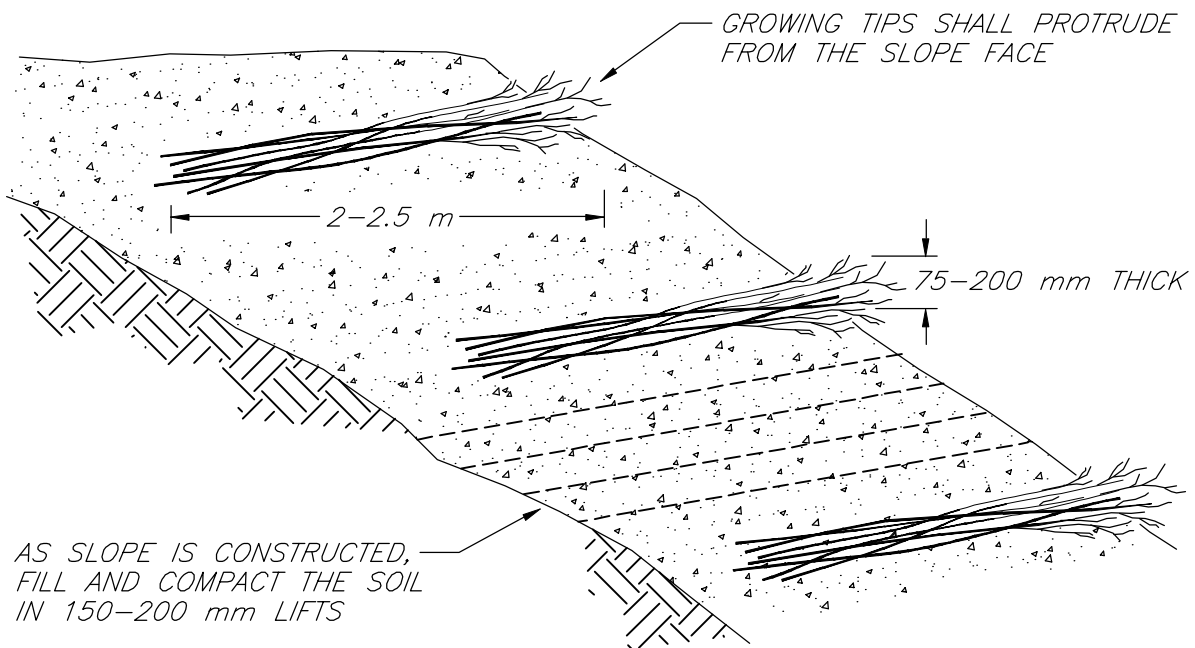
FILE: BRSHLAYR

NOTE:
ROOTED, LEAFED CONDITION OF THE
LIVING PLANT MATERIAL IS NOT
REPRESENTATIVE OF THE TIME OF
INSTALLATION



TYPICAL BRUSHPACKING

COVER BRUSHLAYER IMMEDIATELY WITH
150 mm OF FILL SOIL, WATER AND
COMPACT ACCORDING TO SPECIFICATIONS



TYPICAL BRUSHLAYERING
WITH SLOPE CONSTRUCTION

NOTE:

1. THIS FIGURE IS PROVIDED FOR GUIDANCE ONLY AND
DOES NOT CONSTITUTE A DESIGN. A SITE SPECIFIC
DESIGN IS REQUIRED FROM DESIGNER/ENGINEER.

FILE: BRSHLAYR

BRUSHLAYERING

Wattles (Live Fascine)	B.M.P. #28
Sediment Control	

Description and Purpose

- Wattles consist of bundled live fascine to stake into the soil along slope contours
- Normally live staking can be installed to anchor the wattles to provide deep root vegetation with potential favourable moisture retention provided by wattles
- Wattles also capture sediment, organic matter, and seeds carried by runoff

Applications

- Temporary measure
- May be used on slopes stable enough to support vegetation (steep, confined, slopes and channel banks with gradients greater than 1H:1V may have low success potential)
- May be used on slopes and channel banks with adequate sunlight, moisture, and wind protection to support vegetation
- May be used as grade breaks, where slopes transition from flatter to steep gradients
- May be used on lake shores as wave break to assist in revegetation and stabilization of banks
- Can be used in conjunction with live staking as bioengineering measure

Advantages

- Grade break measure to lower sheet and rill erosion potential
- Can be used on slopes too steep for silt fences or straw bales sediment barriers

Limitations

- Designed for low sheet flow velocities
- Designed for short slopes with a maximum gradient of 1H:1V
- May be labour intensive to install
- Few precedents as this measure is generally not used on AT construction projects
- Susceptible to undermining and failure if not properly keyed into the soil

Construction

- Prepare slope face and remove large rocks or other deleterious materials

Wattles (Live Fascine)	B.M.P. #28
Sediment Control	

- Excavate small trenches a minimum of 0.15 m deep and 0.15 m wide across the width of the slope, perpendicular to slope direction, starting at the toe of the slope and working upwards towards crest of slope
- Space trenches a maximum of 3 to 8 m apart along the slope incline, with steeper slopes having trenches spaced closer together
- Place wattles into trench ensuring continuous contact between wattles and soil surface
- Butt-joint adjacent wattle segments tightly against one another
- Use a metal bar to make pilot hole through middle of the wattle a minimum depth of 0.3 m into underlying soil
- Pilot holes should be spaced a maximum of 1 m apart
- Secure wattle to soil using wooden stake or other appropriate anchor; live stake may be used as alternate anchor
- Place soil excavated from trench on upslope side of wattle and compact to minimize undermining of wattle by runoff
- Seed the soil along the upslope and downslope sides of the wattle to promote vegetation growth

Construction Considerations

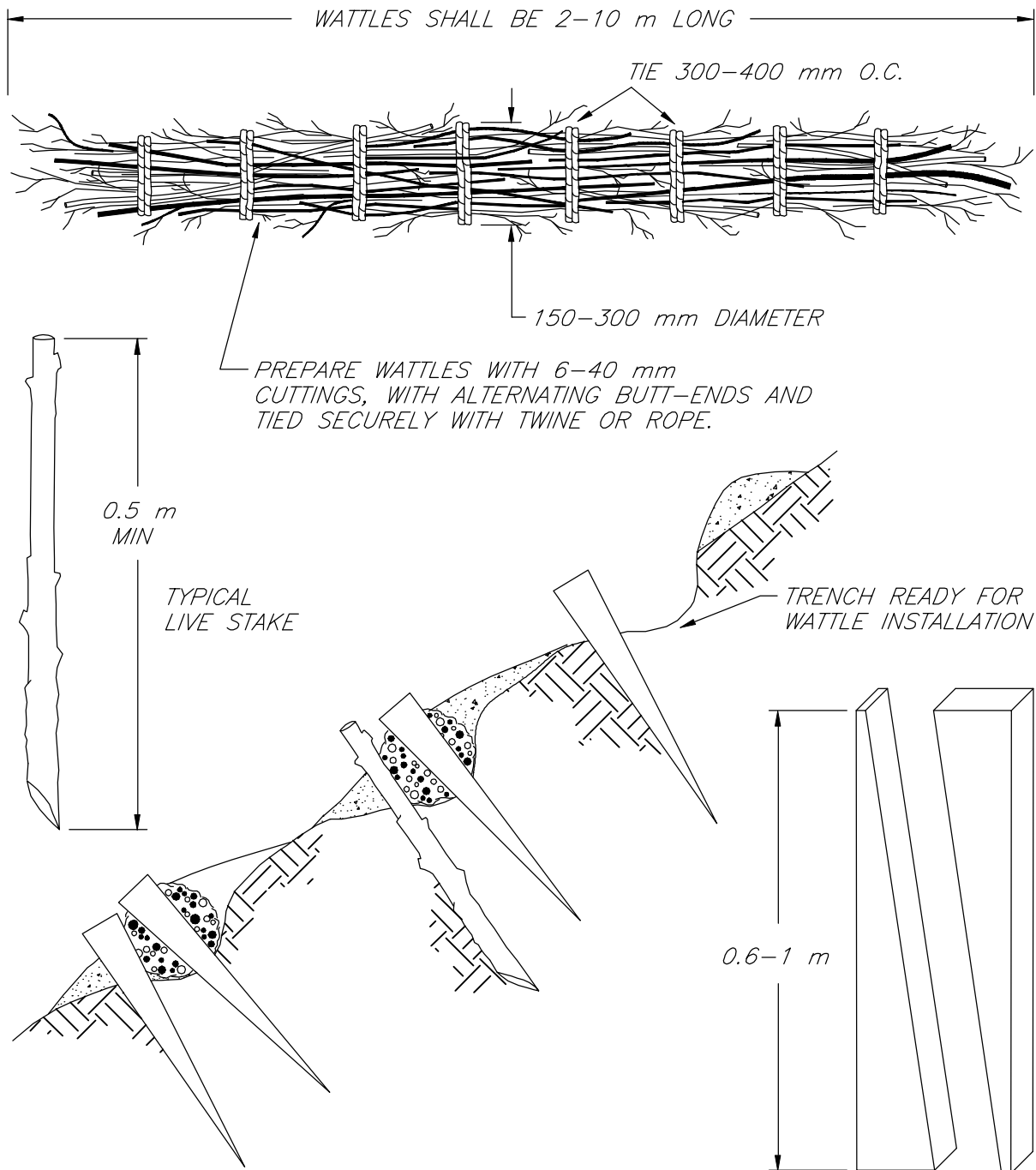
- Use live stakes in place of wooden stakes
- If the slope soil is loose and uncompacted, excavate trench to a minimum depth of 2/3 of the diameter of the wattle
- For steep slopes, additional anchors placed on the downslope side of the wattle may be required

Inspection and Maintenance

- Inspection frequency should be in accordance with the PESC and TESC Plans
- Areas damaged by washout or rutting should be repaired immediately
- Additional stormwater control measures should be considered for rilling areas damaged by runoff

Similar Measures

- Synthetic permeable barriers



NOTES:

1. HARVEST AND INSTALL WATTLES DURING DORMANT SEASON.
2. INSTALL WATTLES ON SLOPE CONTOURS.
3. ALL WORK PROCEEDS FROM THE BOTTOM OF THE SLOPE TO THE TOP.
4. FILL OR PARTIALLY COVER WATTLE WITH SOIL FROM SLOPE OR TRENCH ABOVE.
5. COMPACT AND WORK SOIL INTO COMPLETED WATTLES.
6. THIS FIGURE IS PROVIDED FOR GUIDANCE ONLY AND DOES NOT CONSTITUTE A DESIGN. A SITE SPECIFIC DESIGN IS REQUIRED FROM DESIGNER/ENGINEER.

TYPICAL CONSTRUCTION STAKE
SAW 2X4 (100X50 mm) LUMBER
ON DIAGONAL

NOT TO SCALE

WATTLE (LIVE FASCINE)

Chemical Stabilization (Tackifiers) Removed	B.M.P. #29
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Riparian Zone Preservation	B.M.P. #30
Sediment Control and Erosion Control	

Description and Purpose

- Protection of existing plants and trees adjacent to all natural water bodies (riparian zones) adjacent to construction areas
- Existing vegetation acts as an effective vegetative buffer strip as a form of erosion and sediment control measure

Applications

- Permanent measure
- Existing established vegetation acts as an effective sediment control and erosion control buffer strip barrier to slow down flows and allow sedimentation filtration to occur
- May be used along property boundaries to minimize sediment transport off construction site despite non-presence of watercourse adjacent

Advantages

- Existing dense vegetation is more effective than any man-made structures or devices for sediment or erosion control, however, other forms of sediment and erosion control measures may be required on construction sites in addition to preserved riparian zones
- Any denuding of vegetation along steep valley slope with highly erodible soil will be detrimental and conducive to long-term sedimentation yield; it is important only to strip necessary areas along the footprint of construction. Preservation of riparian zone is mandatory along river valley slopes and along the edge corridor of waterbodies

Limitations

- Preservation of riparian zones may interfere with construction efficiency
- Careful planning is required to work around preserved riparian zones

Construction

- It is highly important to preserve an established vegetative buffer as freshly planted vegetation generally require substantial growth periods before they are as effective as established riparian zones
- Wherever possible, retain as much existing vegetation as possible between construction areas and sensitive zones (wetlands, marshes, streams, floodplains, etc.) to entrap sediment and to minimize sediment transport off of the construction site into the sensitive zones

Riparian Zone Preservation	B.M.P. #30
Sediment Control and Erosion Control	

- Define and delineate riparian zones to be preserved in Environmental Construction Operations Plan (ECO Plan) prior to commencement of construction
- Clearly mark riparian zones to be preserved in the field (with construction fencing, survey flagging, or other highly visible measure) so all personnel involved with construction operations can identify areas to be preserved

Construction Considerations

- Riparian zones must be fenced off immediately to minimize trespassing and to ensure effectiveness of riparian zone is maintained
- Do not allow equipment to enter areas not necessary to construction
- Based on site-specific situations established buffer zones of adequate width

Inspection and Maintenance

- Inspection frequency should be in accordance with the PESC and TESC Plans
- Maintain fences protecting riparian zones from trespassing

Pumped Silt Control Systems (Filter Fabric Bags) Sediment Control and Erosion Control	B.M.P. #31
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Description and Purpose

- The extraction of sediment is effected by pumping sediment laden runoff into a bag manufactured with a permeable geotextile. Water will filter through the filter bag with the sediment being retained within the filter bag

Applications

- Temporary measure
- Can be used in high risk areas to supplement performance of containment pond systems
 - An example area would be where containment pond space is limited on construction site and appropriate sized containment pond cannot be constructed adjacent to high risk areas
- Useful for additional extraction of sediment dewatering sumps, sediment ponds, or other retention facilities with accumulations of sediment laden runoff

Advantages

- Filter bag is lightweight and portable
- Simple cleanup and disposal
- Sediment is captured within filter bag for removal from site

Limitations

- May be expensive
 - Extra costs associated with cost of filter bags and costs of pumping out retention facilities
- Power supply for pumps may be required
- Useful for only short periods of time and small volumes of water
- Can only retain particle sizes larger than the Apparent Opening Size (AOS) of the filter fabric bag
- Refer to manufacturers' product performance information
- Generally for available non-woven filtration geotextile, AOS values of 0.15 mm range or lower can be realistically manufactured. Potentially, only particle size larger than the design AOS value can be removed from the bag types. It is important to require manufacturer to provide performance specification and physical properties of the bags. The designer and supplier of the filter bag should choose

Pumped Silt Control Systems (Filter Fabric Bags) Sediment Control and Erosion Control	B.M.P. #31
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the fabric and AOS based on the anticipated gradation of the sediments to ensure the sediments are retained in the bag.

- Few precedents as this measure is generally not used on AT construction projects, however, it can be resorted as emergency measure for highly sensitive sites

Implementation

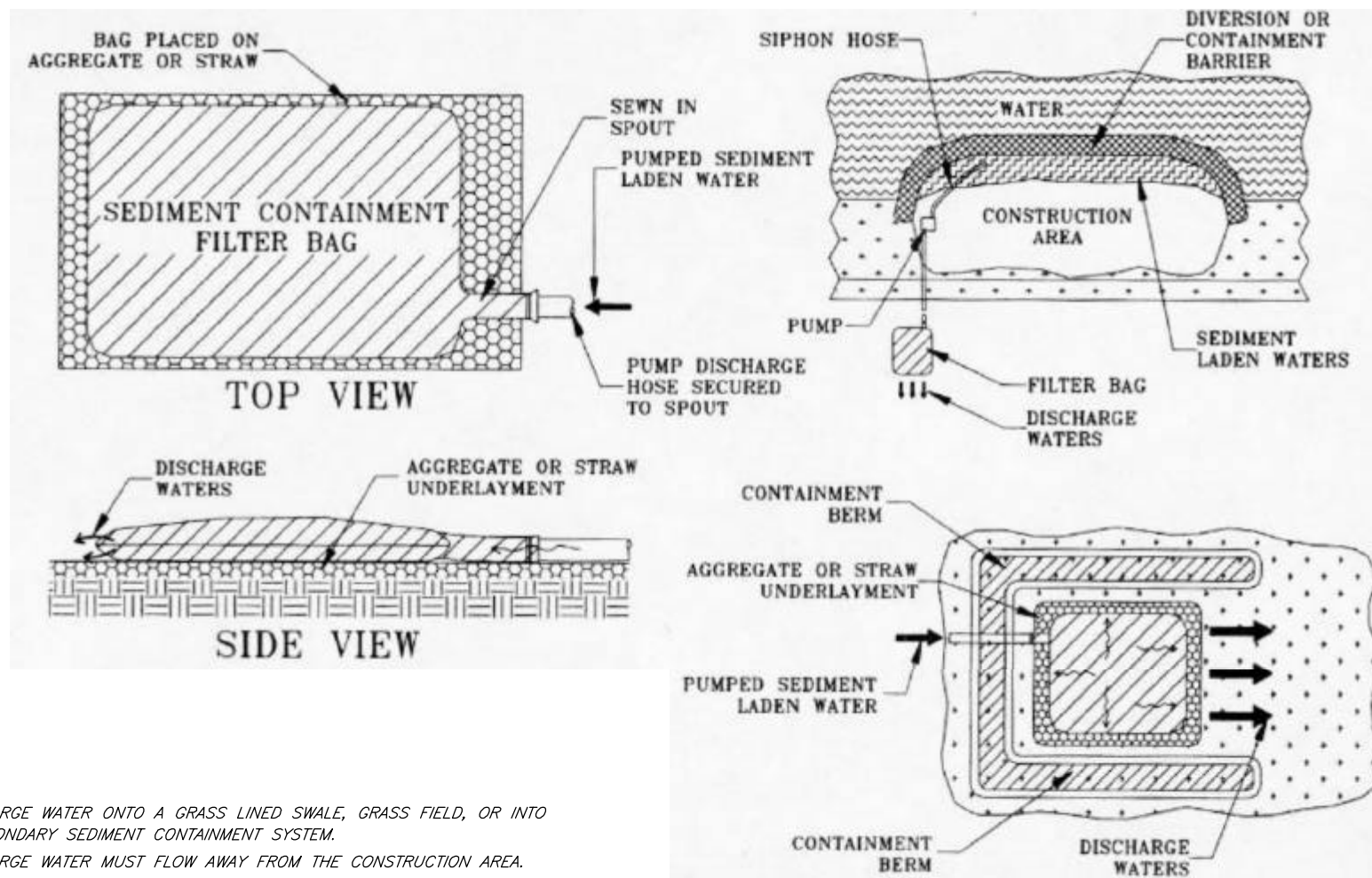
- Place filter bag on free-draining base (such as gravel pad or straw pile) on a slight slope, with opening to silt bag facing upslope
- Attach hose to opening of filter bag
 - Ensure tight seal to prevent discharge of sediment laden runoff outside of bag
- Attach hose to pump and insert extraction hose into retention facility to be dewatered
- Turn on pump and remove sediment laden water until filter bag is full of sediment
- Disengage pump once filter bag is full, tightly close opening to filter bag to prevent spilling of sediment and remove bag
- Repeat process (using new filter bags) until retention facility is dewatered to acceptable levels

Implementation Considerations

- Full filter bags can be removed from site or buried in designated locations on-site
- Care should be taken to ensure filter bag is not overfilled, which may cause filter bag to tear, spilling sediment
- Care should be taken when transporting full filter bags to ensure filter bag is not torn

Inspection and Maintenance

- Inspect all hoses and connections before and during pumping operations to minimize leaks



NOTES:

1. DISCHARGE WATER ONTO A GRASS LINED SWALE, GRASS FIELD, OR INTO A SECONDARY SEDIMENT CONTAINMENT SYSTEM.
2. DISCHARGE WATER MUST FLOW AWAY FROM THE CONSTRUCTION AREA.
3. SEDIMENT CAPTURED BY THE FILTER BAG MUST BE REMOVED AND STABILIZED.
4. THIS FIGURE IS PROVIDED FOR GUIDANCE ONLY AND DOES NOT CONSTITUTE A DESIGN. A SITE SPECIFIC DESIGN IS REQUIRED FROM DESIGNER/ENGINEER.

SOURCE: FIFIELD 2001

PUMPED SILT CONTROL SYSTEM

Description and Purpose

- Scheduling the sequence and timing arrangement of construction activities (1) to efficiently maximize the amount of erosion protection installed (such as topsoiling and seeding) as soon as a portion of grade construction is completed, and (2) to limit the portion of land disturbance (construction) compatible with the efficient rate of construction of erosion control measures achievable
- Incorporating erosion and sedimentation control concerns during the scheduling phase will minimize the amount and duration of bare soil exposure to erosion elements and ensure erosion and sedimentation control measures are implemented at an appropriate time
- Scheduling may be designed during planning stages by the contractor and altered during construction to suit actual conditions encountered

Applications

- Temporary measure

Advantages

- Ensures erosion and sedimentation control issues are identified during the planning stage by the Contractor
- May be used to minimize bare soil exposure and erosion hazard with careful planning and utilization of equipment in construction projects

Limitations

- May be more costly as erosion control measures (such as topsoiling and seeding) have to be implemented immediately after completion of each phase or a short section of construction

Implementation

- Incorporate a schedule with erosion protection perspective to form part of the overall construction plan
- Determine sequencing and timetable for the start and end of each item, such as clearing, grubbing, stripping, etc.
- Incorporate installation of appropriate erosion and/or sediment control measures in construction schedule
- Allow sufficient time before rainfall begins to install erosion and/or sediment control measures

Scheduling	B.M.P. #32
Sediment Control and Erosion Control	

- Whenever possible, schedule work to minimize extent of site disturbance at any one time
- Incorporate staged topsoiling and revegetation of graded slopes as work progresses
 - Don't leave all topsoiling and revegetation until the very end of the project

Inspection and Maintenance

- Routinely verify that construction activities and the installation of erosion and sediment control measures is progressing in accordance with schedule
 - If progress deviates from schedule, take corrective action
- When changes to the project schedule are unavoidable, alter the schedule as soon as practicable to maintain control of erosion

Description and Purpose

- Comprised of a gravel pad located at site access points (entrances) that are used to reduce the amount of sediment carried off construction sites by vehicles
- Collect sediment from vehicle washing and retains sediment on construction site
- Should include water supply to wash off excess soil from vehicles prior to exiting the construction site

Applications

- Temporary measure
- For use anywhere vehicles enter or exit a construction site

Advantages

- Retains sediment on construction site, where it belongs
- Reduces deposition of sediments on public roads which may be carried by runoff into natural watercourses or drains

Limitations

- Sediment control measures should be installed to collect sediment laden runoff from gravel pad
- Installation of gravel pads may be limited by space constraints

Implementation

- Install gravel pad at planned entrances to worksite
 - Gravel pad (minimum of 15 m in length) should be of sufficient length to accommodate longest anticipated vehicle entering or exiting the site
 - Width of pad should be sufficient to accommodate the widest anticipated vehicle entering or exiting the site (minimum of 3.6 m in width)
 - Thickness of gravel pad should be a minimum of 0.30 m thick (0.3 m thickness is preferred for highway projects) and should comprise 50 to 150 mm diameter coarse aggregate placed on top of woven geotextile filter fabric
- Install temporary sediment control measures (such as straw bale barriers or silt fences) to collect washed off sediment from gravel pad

Stabilized Worksite Entrances Sediment Control and Erosion Control	B.M.P. #33
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Construction Considerations

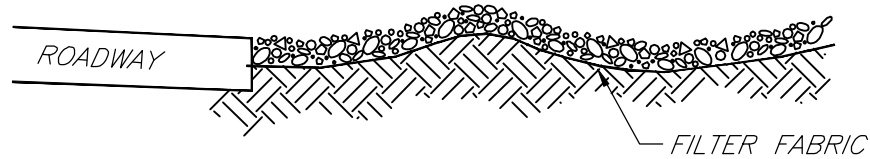
- Should be constructed at all access points to construction sites
 - If impractical to construct at all access points, limit vehicle access traffic to stabilized worksite entrances only
- Entrances located with steep grades or at curves on public roads should be avoided
- Woven geotextile filter fabric should be used as underlay below gravel pad as strength requirement
- Install an elevated ridge adjacent to roadway if gradient of the gravel pad is steeper than 2%, sloped towards the roadway

Inspection and Maintenance

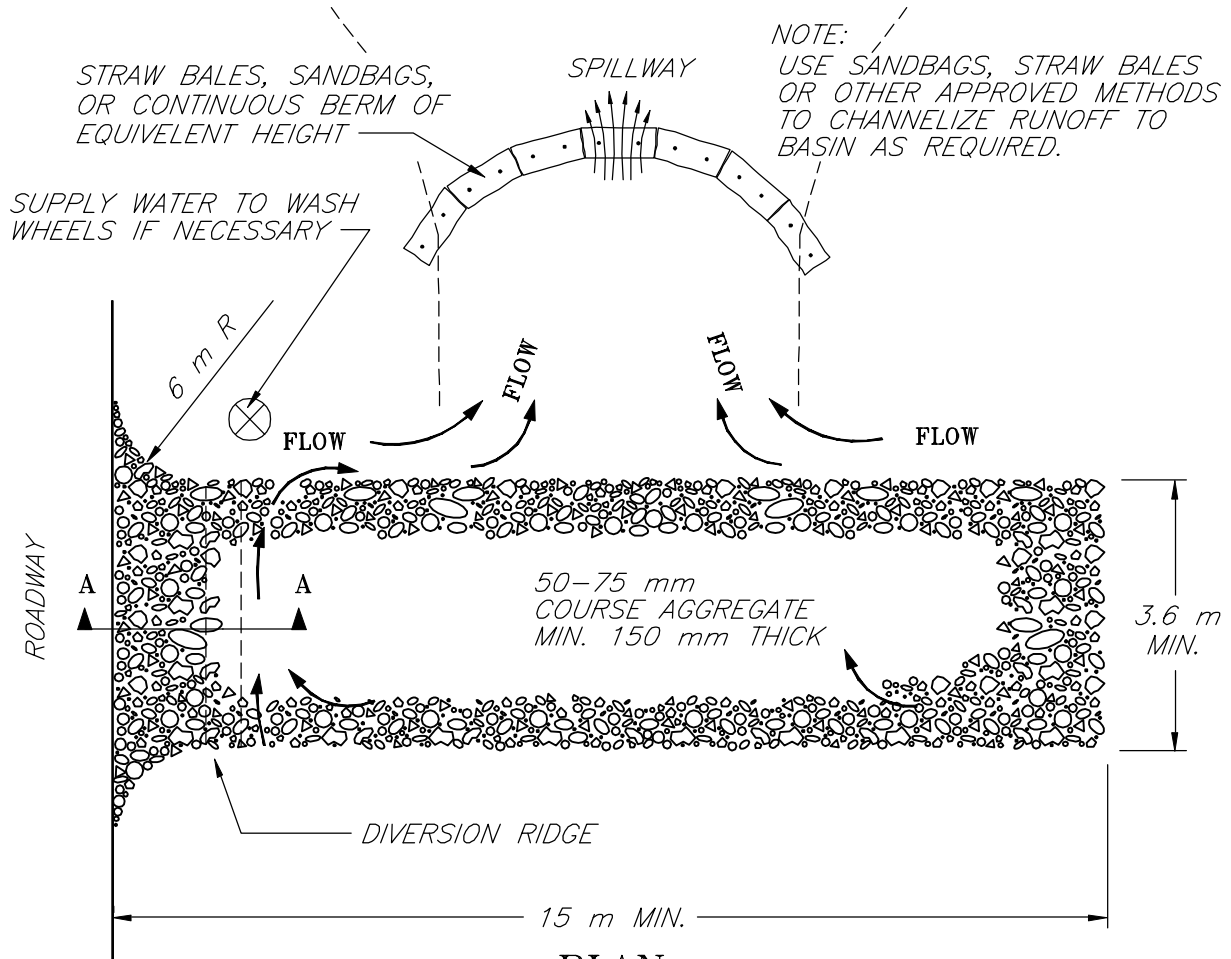
- Inspection frequency should be in accordance with the PESC and TESC Plans
- Granular material should be regraded when required
 - Material may need to be added to fill large voids to maintain a minimum pad thickness of 0.30 m
- Inspect and clean out downstream sediment control measures at least once per week and after periods of significant rainfall
- Material accidentally deposited onto public roads should be cleaned as soon as possible

DIVERSION RIDGE REQUIRED
WHERE GRADE EXCEEDS 2%

2 % OR GREATER



SECTION A - A



PLAN

NOTES:

1. THE ENTRANCE SHALL BE MAINTAINED IN A CONDITION THAT WILL PREVENT TRACKING OR FLOWING OF SEDIMENT ONTO PUBLIC RIGHT-OF-WAYS. THIS MAY REQUIRE TOP DRESSING, REPAIR AND/OR CLEANOUT OF ANY MEASURES USED TO TRAP SEDIMENT.
2. WHEN NECESSARY, WHEELS SHALL BE CLEANED PRIOR TO ENTRANCE ONTO PUBLIC RIGHT-OF-WAY.
3. WHEN WASHING IS REQUIRED, IT SHALL BE DONE ON AN AREA STABILIZED WITH CRUSHED STONE THAT DRAINS INTO AN APPROVED SEDIMENT TRAP OR SEDIMENT BASIN.
4. FOR HIGHWAY CONSTRUCTION, 300mm THICKNESS OF GRAVEL IS PREFERRED.
5. THIS FIGURE IS PROVIDED FOR GUIDANCE ONLY AND DOES NOT CONSTITUTE A DESIGN. A SITE SPECIFIC DESIGN IS REQUIRED FROM DESIGNER/ENGINEER.

TEMPORARY
GRAVEL
CONSTRUCTION
ENTRANCE/EXIT

Slope Texturing (a-c)	B.M.P. #34
Sediment Control	(a - c)

Description and Purpose

- Texturing of slopes, either by roughening the surface, tracking the surface, or installing grooves or benches
 - Texturing reduces the runoff velocity, traps sediment, and increases the infiltration of water into the soil
- a) Surfacing Roughening
 - b) Grooved or Serrated Slope
 - c) Benched Slope

Applications

- Temporary measure
- May be used to roughen the exposed soils on the slope surface in the direction of water flow to minimize erosion and to entrap some sediments
- May be used on fresh cut or fill slopes (8 m length or longer; practical travel reach of a dozer) with gradients of generally 3H:1V or steeper (2H:1V as general steepness limit) constructed in cohesive soils
- May be used on slope subgrade that will not be immediately topsoiled, vegetated or otherwise stabilized
- May be applied to topsoiled slope to provide track serration to further reduce erosion potential
- May be used in graded areas with smooth and hard surfaces
- As part of slope design, benching may be used to effect a reduction of erosion hazard where a long slope length needs to be shortened into smaller sectional lengths with mid-benches; normally a 3 m wide bench can be appropriate
 - Benching is usually a permanent slope design feature and should only be designed by a qualified geotechnical engineer
 - Benching of a long slope section to divide into short sections can reduce erosion hazard in the range of 30 to 50% (e.g., sediment yield for 15 m high 3H:1V slope with mid-bench)

Advantages

- Reduces erosion potential of a slope
- Texturing will create protrusions to increase surface roughness to reduce overland flow velocities and erosion energy
- Texturing will create minor spaces to entrap a portion of the coarse sediment and reduces amount of sediment transported downslope
- Texturing of slopes will benefit development of vegetation
- Texturing of slopes aids in performance of mulches and hydroseeding
- Texturing with track-walking up/downstream may effect a 50% reduction of sediment yield compared with untracked slope

Limitations

- Surface roughening and tracking may increase grading costs
- Surface roughening and tracking may cause sloughing in certain soil types (i.e., sandy silt) and seepage areas; geotechnical advice is recommended
- Texturing provides limited sediment and erosion control and should be used as a temporary measure prior to topsoiling
 - Should be used in conjunction with other erosion and sediment control measures (i.e., offtake ditches) to limit the sheet flow downslope

Construction

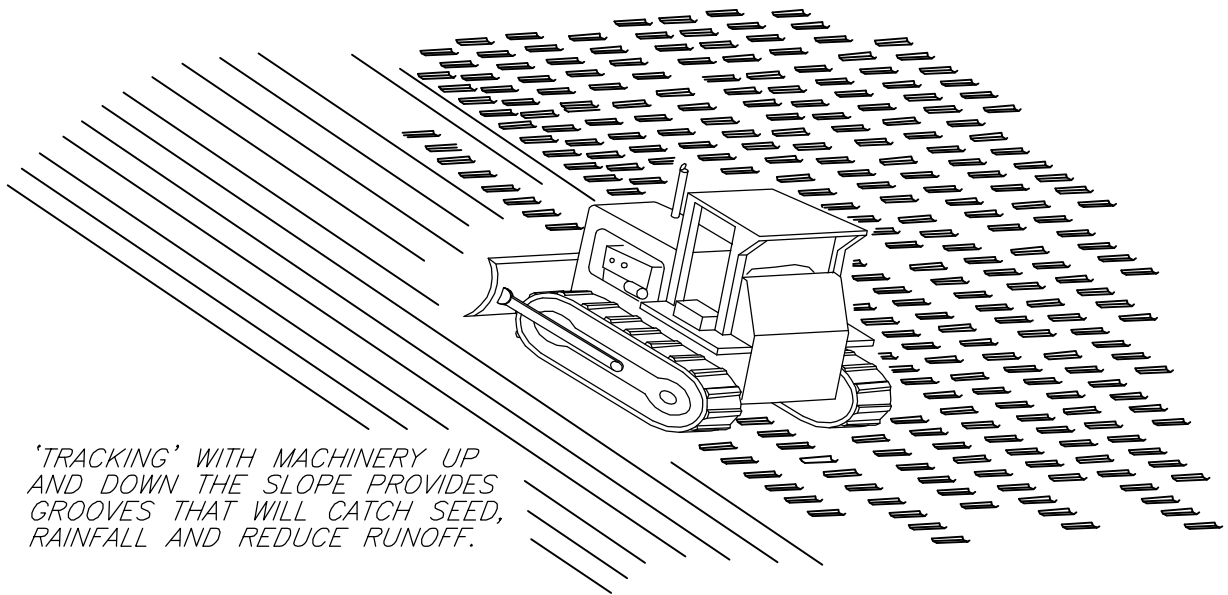
- Surface Roughening
 - Leave soil in rough grade condition, do not smooth grade soil
 - Large lumps of soil will aid in decreasing runoff velocities, trap sediment, and increase infiltration of water
- Surface Tracking
 - Using tracked construction equipment to move up and down the slope, leaving depressions perpendicular to the slope direction; limit passes to prevent overcompaction of the surface
 - Depressions in the soil will aid in decreasing runoff velocities, trap sediment, and increase infiltration of water
- Grooving
 - Excavating shallow furrows across the width of the slope, perpendicular to the direction of the slope

Slope Texturing (a-c)	B.M.P. #34
Sediment Control	(a - c)

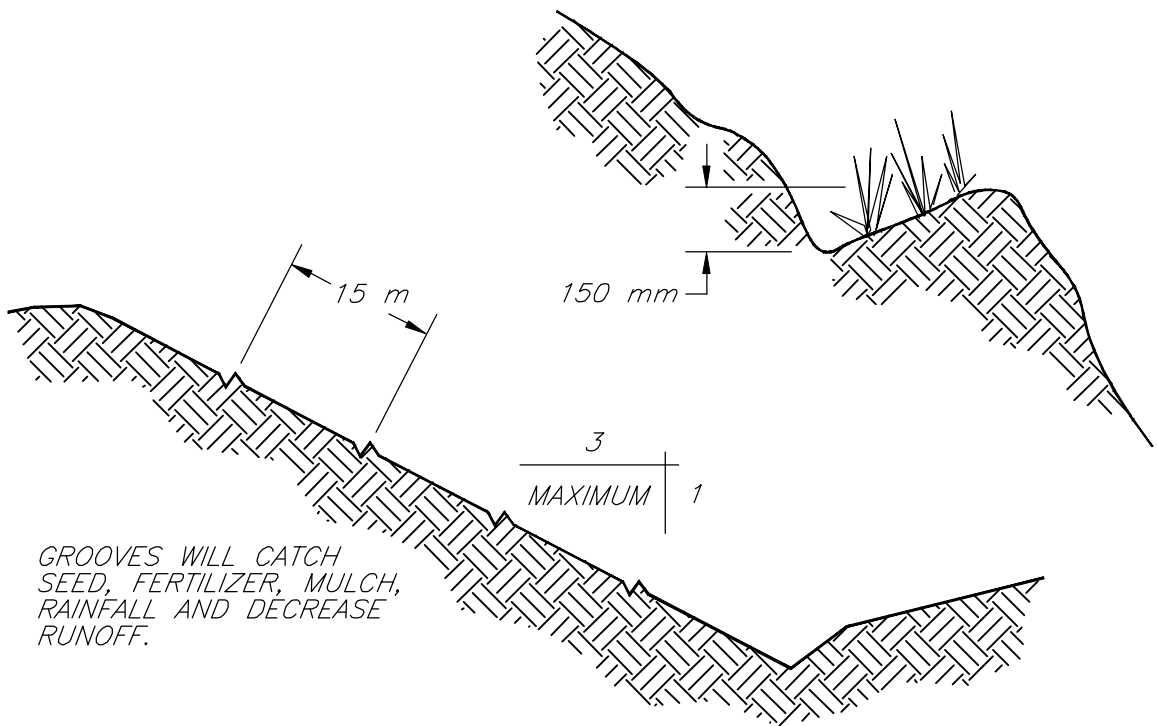
- If used, contour grooves should be approximately 0.1 to 0.2 m in depth
- Grooves can be made by using equipment or hand
- Benching
 - Construction of narrow, flatter sections of soil on the slope, perpendicular to the direction of the slope
 - Benches should be designed by qualified geotechnical engineer

Construction Considerations

- During tracking operations, care must be taken to minimize disturbance to the soil where the equipment turns or changes direction
- Minimize the number of tracking passes to 1 or 2 times to avoid overcompaction, which can negatively impact the vegetation growth
- It is practical to track roughen a slope length of greater than 8 m for practical up/down slope operation of a small bulldozer. It is important to minimize the loosening of soil caused by turning movement of the bulldozer at the end of each pass. As the erosion potential is lower for slope of low vertical height (<3 m height and 3H:1V slope), the tracking of low height slope is not required and not practical for bulldozer tracking operation.



TRACKING



CONTOUR FURROWS

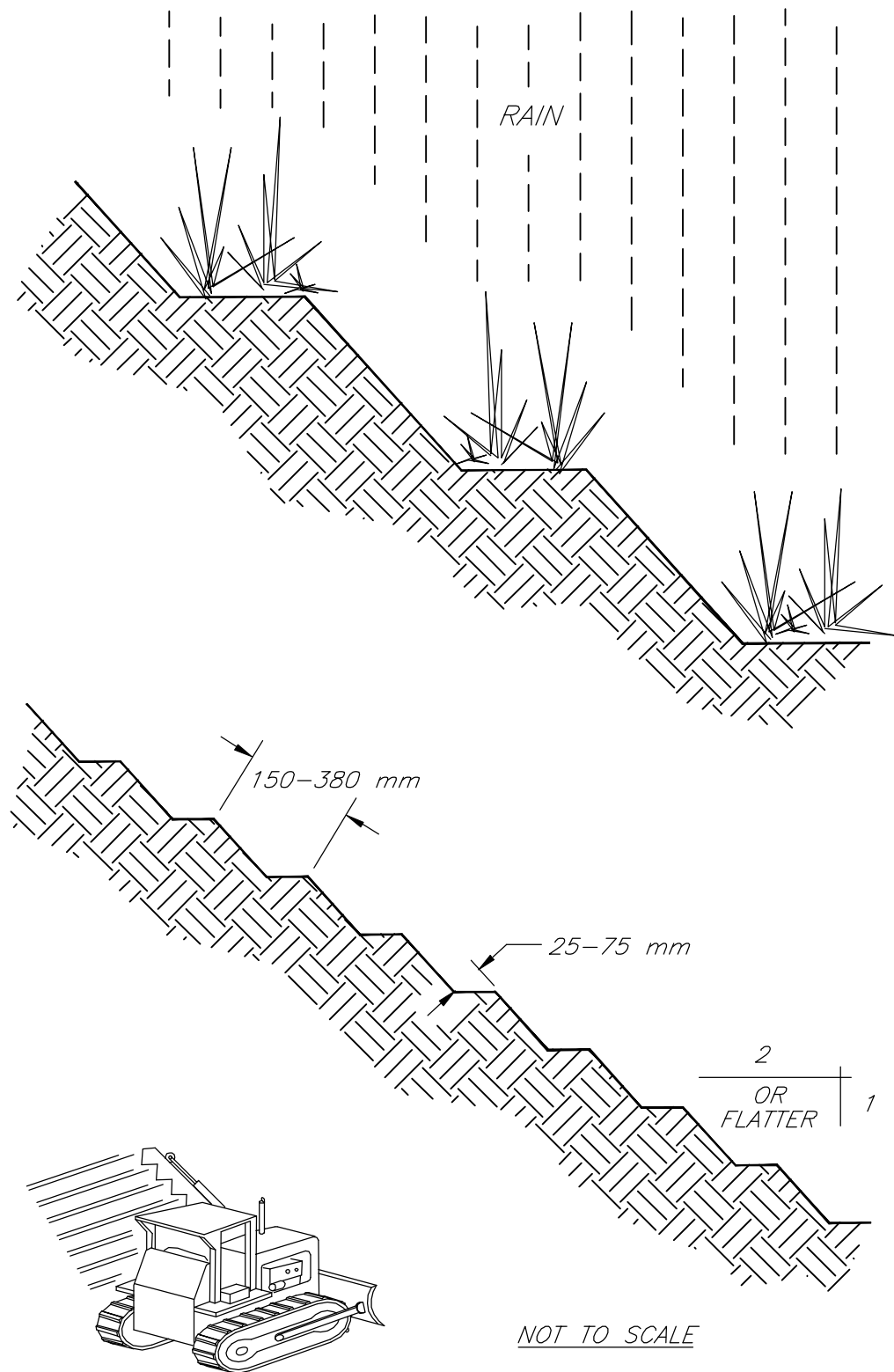
SURFACE ROUGHENING



FILE: SERSLOPE

**Government
of Alberta** ■

Transportation



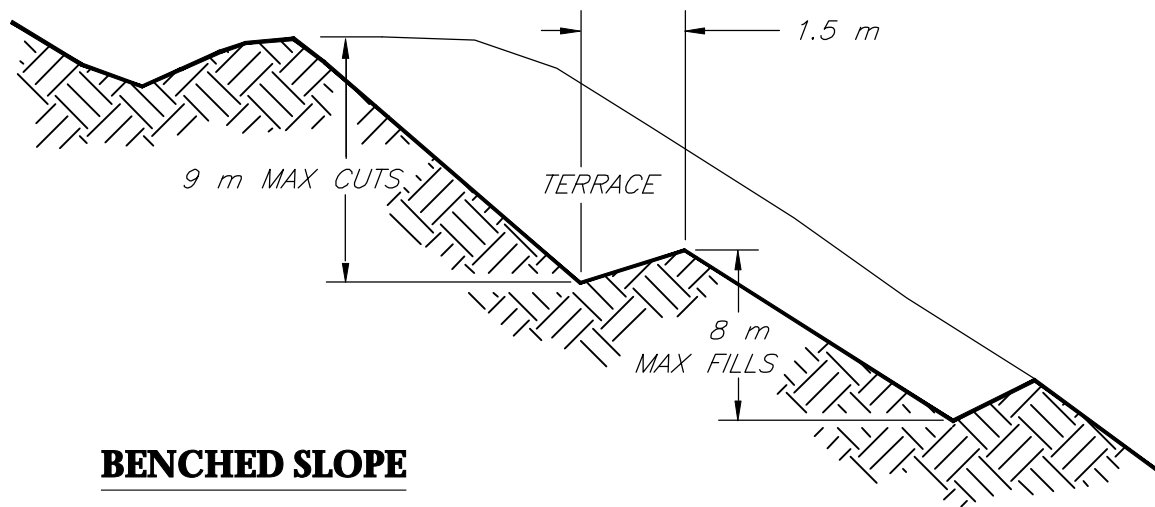
NOTE:

GROOVE BY CUTTING SERRATIONS ALONG THE CONTOUR. IRREGULARITIES IN THE SOIL SURFACE CATCH RAINWATER, SEED, MULCH AND FERTILIZER.

**GROOVED OR
SERRATED SLOPE**



FILE: STPSLOPE



BENCHED SLOPE

NOT TO SCALE

BENCHED SLOPE

Straw Mulching & Crimping

(Straw Anchoring)

Sediment Control and Erosion Control

B.M.P. #35

Description and Purpose

- Straw mulch consists of placing a uniform layer of straw and incorporating it into the soil with a studded roller or anchoring it with stabilizing emulsion
- Protects the soil surface from the impact of rain drops, preventing soil particles from being dislodged

Applications

- Temporary measure
- Used for soil stabilization as a temporary surface cover on disturbed areas until soils can be prepared for revegetation and permanent vegetation is established
- Also used in combination with temporary and/or permanent seeding strategies to enhance plant establishment

Advantages

- Relatively cheap method of promoting plant growth and slope protection

Limitations

- Availability of erosion control contractors and straw may be limited prior to the rainy season due to high demand
- There is a potential for introduction of weed-seed and unwanted plant material
- When straw blowers are used to apply straw mulch, the treatment areas must be within 45 m of a road or surface capable of supporting trucks
- Straw mulch applied by hand is more time intensive and potentially costly
- Wind may limit application of straw and blow straw into undesirable locations
- May have to be removed prior to permanent seeding or soil stabilization
- "Punching" of straw does not work in sandy soils
- Crimping will tend to leave an uneven surface
- Netting can become displaced and entangled in mowing equipment

Straw Mulching & Crimping

(Straw Anchoring)

Sediment Control and Erosion Control

B.M.P. #35

Installation

- Apply loose straw at a minimum rate of 3,570 kg/ha, or as indicated in the projects special provisions, either by machine or by hand distribution
- If stabilization emulsion will be used to anchor the straw mulch in lieu of incorporation, roughen embankment or fill areas by rolling with a crimping or punching-type roller or by track walking before placing the straw mulch
- Track walking should only be used where rolling is impractical
- The straw mulch must be evenly distributed on the soil surface
- Anchor the mulch in place by using a tackifier or by “punching” it into the soil mechanically (incorporating)
- A tackifier acts to glue the straw fibres together and to the soil surface
- The tackifier shall be selected based on longevity and ability to hold the fibres in place
- A tackifier is typically applied at a rate of 140 kg/ha
- In windy conditions, the rates are typically 2000 kg/ha
- Methods for holding the straw mulch in place depend upon the slope steepness, accessibility, soil conditions and longevity
- On small areas, a spade or shovel can be used to incorporate straw mulch
- On slopes with soils, which are stable enough and of sufficient gradient to safely support construction equipment without contributing to compaction and instability problems, straw can be “punched” into the ground using a knife-blade roller or a straight bladed coulter, known commercially as a “crimper”
- The mulch crimping device consists of a series of dull flat discs with notched edges spaced approximately 20 cm apart
- The mulch should be impressed in the soil to a depth of 3 to 8 cm
- Mechanical anchoring, or crimping, is recommended only for slopes flatter than 2:1
- Mulch on slopes steeper than 2:1 should be anchored to the soil with netting
- On small areas and/or steep slopes, straw can also be held in place using a plastic or jute netting
- The netting shall be held in place using wire staples, geotextile pins or wooden stakes

Straw Mulching & Crimping

(Straw Anchoring)

Sediment Control and Erosion Control

B.M.P. #35

Construction Considerations

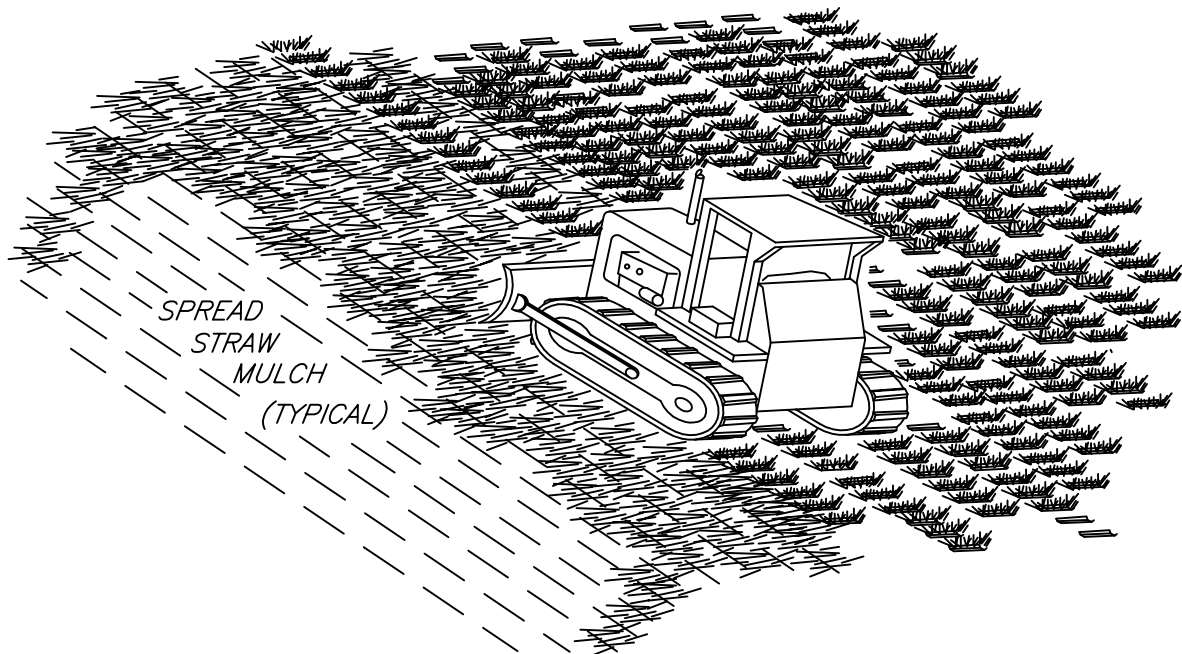
- Straw shall be derived from clean long stemmed grass hay or cereal shaft (e.g., wheat or barley), free from undesirable weed and seed
- A minimum of 65% of the mulch, by weight, should be 25 cm or more in length
- Expected longevity: < 3 months
- A tackifier is the preferred method for anchoring straw mulch to the soil on slopes
- Crimping, punch roller-type rollers, or track-walking may also be used to incorporate straw mulch into the soil on slopes
- Track walking shall only be used where other methods are impractical
- Avoid placing straw onto the traveled way, sidewalks, line drainage channels, sound walls, and existing vegetation
- Straw mulch with tackifier shall not be applied during or immediately before rainfall

Inspection and Maintenance

- Inspection frequency should be in accordance with the PESC and TESC Plans
- The straw needs to last long enough to achieve erosion control objectives
- Areas where erosion is evident should be repaired and BMPs re-applied as soon as possible
- Care should be exercised to minimize damage to protected areas
- Repair any damaged ground cover and re-mulch exposed areas
- Re-application of straw mulch and tackifier may be required to maintain effective soil stabilization over disturbed areas and slopes
- Maintain all slopes to prevent erosion after any rainfall event

Similar Measures

- Mulching



'TRACKING' WITH MACHINERY ON SANDY SOIL PROVIDES ROUGHENING WITHOUT UNDUE COMPACTION.

STRAW MULCHING & CRIMPING

NOTES:

- 1. ROUGHEN SLOPE WITH BULLDOZER*
- 2. BROADCAST SEED AND FERTILIZER.*
- 3. SPREAD STRAW MULCH 76mm THICK. (2 1/2 TONS PER ACRE)*
- 4. PUNCH STRAW MULCH INTO SLOPE BY RUNNING BULLDOZER UP AND DOWN SLOPE.*

STRAW MULCHING & CRIMPING

Polyacrylamide (PAM)	B.M.P. #36
Erosion Control	

Description and Purpose

- The land application of product containing anionic polyacrylamide (PAM) as temporary soil binding agents to reduce soil erosion
- To reduce erosion from wind and water on construction sites and agricultural lands

Applications

- This temporary practice is intended for direct soil surface application to sites where the timely establishment of vegetation may not be feasible or where vegetative cover is absent or inadequate
- Such areas may include construction sites where land-disturbing activities prevent the establishment or maintenance of a vegetative cover

Advantages

- Enhances terrestrial and aquatic habitat with vegetation growth re-establishment
- Aesthetically pleasing with vegetation cover
- Improved water quality, infiltration, soil fertility and visibility

Limitations

- This temporary practice is not intended for application to surface waters
- It is intended for application within construction storm water ditches and storm drainages which feed into pre-constructed sediment ponds or basins

Installation

- **Only the anionic form of PAM shall be used. Cationic PAM is toxic and shall NOT be used**
- PAM and PAM mixtures shall be environmentally benign, harmless to fish, wildlife and plants
- PAM and PAM mixtures shall be non-combustible
- When applying ensure uniform coverage to the target and avoid drift to non-target areas including waters
- Anionic PAM, in pure form, shall have less than or equal to 0.05% acrylamide monomer by weight
- To maintain less than or equal to 0.05% of acrylamide monomer, the maximum application rate of PAM, in pure form, shall not exceed 227kg/ha/year

Polyacrylamide (PAM)	B.M.P. #36
Erosion Control	

- Do not over apply PAM
- Seeding rate for all mixes should be 25 kg/ha minimum

Design Considerations

- Excessive application of PAM can lower infiltration rate or suspend solids in water, rather than promoting settling
- Users of anionic PAM shall obtain and follow all Material Safety Data Sheet requirements and manufacturer's recommendations
- Obtain written application methods and rate for PAM and PAM mixtures
- Additives such as fertilizers, solubility promoters or inhibitors, etc., to PAM shall be non-toxic
- Gel bars and logs of anionic PAM mixtures may be used in ditch systems
- Anionic PAM is available in emulsions, powders and gel bars or logs
- The use of seed and mulch for additional erosion protection beyond the life of the anionic PAM is recommended
- Use setbacks when applying anionic PAM near natural waterbodies
- Consider that decreased performance can occur due to ultra-violet light and time after mixing when applying anionic PAM
- In flow concentration channels, the effectiveness of anionic PAM for stabilization decreases
- Never add water to PAM; add PAM slowly to water. If water is added to PAM, "globs" can form which can clog dispensers, signifying incomplete dissolving of the PAM and therefore increasing the risk of under application
- Not ALL polymers are PAM

Inspection and Maintenance

- Reapplying anionic PAM to disturbed areas including high use traffic areas

Similar Measures

- Hydraulic seeding and mulching
- Compost

Compost Blanket	B.M.P. #37
Erosion Control	

Description and Purpose

- Compost is the product resulting from the controlled biological decomposition of organic material, occurring under aerobic conditions
- Compost has been sanitized through the generation of heat and stabilized to the point that it is appropriate for its particular application
- Active composting is typically characterized by a high temperature phase that sanitizes the product and allows a high rate of decomposition
- It is followed by a lower temperature phase that allows the product to stabilize while still decomposing at a slower rate
- Compost should possess no objectionable odours or substances toxic to plants
- Compost contains plant nutrients but is typically not characterized as a fertilizer
- May derive from agricultural, forestry, food or industrial residues, bio-solids, leaf and yard trimmings, manure, tree wood, or source-separated or mixed solid waste

Applications

- Compost blanket are commonly used for temporary erosion and sediment control
- The technique is appropriate for slopes up to 2H:1V grade and on level surface
- Only used in areas that have sheet flow drainage patterns (not for areas that receive concentrated flows)
- Compost used on AT projects must meet Canadian Council of Ministers of the Environment (CCME) Guidelines for Compost Quality (trace elements, maturity/stability, pathogens), which are adopted by Alberta Transportation and found on AT Products List (www.transportation.alberta.ca)

Advantages

- Relatively cheap method of promoting plant growth and slope protection

Limitations

- Application of compost may be difficult on steep slopes
- May require spray-on method to apply compost to steep slopes
- Requires specialized blower truck, hose and attachments for blanket installation

Installation

Compost Blanket

Erosion Control

B.M.P. #37

- Slightly roughen (scarify) slopes and remove large clods, rocks, stumps, roots larger than 50 mm in diameter and debris on slopes where vegetation is to be established
- Apply compost at the rates as follows:

Annual Rainfall/Flow Rate	Total Precipitation	Application Rate for Vegetated Compost Surface	Application Rate for Unvegetated Compost Surface
Low	25 mm – 635 mm	12.5 mm – 19 mm	25 mm – 37 mm
Medium	635 mm – 1270 mm	19 mm – 25 mm	37 mm – 50 mm
High	>1270 mm	25 mm – 50 mm	50 mm – 100 mm

- Compost shall be uniformly applied using an approved spreader, e.g., bulldozer, site discharge manure spreaders
- A pneumatic blower unit propels the compost directly at the soil surface, thereby preventing water from moving between the soil-compost interface
- Seeding can be incorporated during the compost application

Construction Considerations

- Use higher blanket application rate in high rates of precipitation and rainfall intensity, and snow melt
- Compost may be used in conjunction with a compost blanket, especially in regions with spring melt, and sites with severe grades and long slopes
- In regions subjecting to wind erosion, a coarser compost product or higher blanket application rate is preferred
- Use lower blanket application rate in lower precipitation rates and rainfall intensity regions

Inspection and Maintenance

- Inspection frequency should be in accordance with the PESC and TESC Plans
- Areas damaged by washout or rilling should be regraded if necessary and re-covered with compost immediately

Similar Measures

- Rolled erosion control products (RECP)
- Hydroseeding
- Hydromulching

Rolls

- a) Coir Roll
- b) Fibre Roll

Streambank Stabilization Techniques and Erosion Control

B.M.P. #38

Description and Purpose

- Coir Rolls are long cylindrical tubes that are composed of interwoven coconut fibres which are bound together with durable coir netting. Coir rolls are particularly applicable for wetland, streambank, and shoreline projects. Coir rolls are most commonly available in 300mm diameters and 6m lengths. These rolls can be linked together to form longer tubes, and are often used in combination with other biotechnical techniques, such as brush layering or live siltation. Coir logs encourage siltation and wetland/floodplain creation
- Fibre rolls are installed across slope contours as a grade break to reduce erosion potential by reducing overland flow velocities
- Straw roll consists of bundled straw (or natural fibre) wrapped in photo-degradable open-weave plastic netting staked into the soil along slope contours as a grade break to reduce erosion potential
- Normally live staking can be installed to anchor the Fibre Rolls to provide deep root vegetation with potential favourable moisture retention provided by fibre roll
- Fibre Rolls also capture sediment, organic matter, and seeds carried by runoff

Applications

- The tough, long-lasting coconut fibres make coir rolls appropriate for wetland, streambank, and shoreline applications. Coir rolls work well when immediate erosion control is needed. Brushlayers work well with coir roll applications, adding further stabilization with a live root system, while also providing excellent habitat features. The coir roll provides a base for the brushlayer cuttings to be laid upon at an appropriate angle which benefits the growth of cuttings. The cuttings provide further protection from breaking waves and high flows
- Fibre Rolls may be used on slopes stable enough to support vegetation (steep, confined, slopes and channel banks with gradients greater than 1H:1V may have low success potential)
- Fibre Rolls may be used along long slopes as a grade break to shorten slope length between line of fibre rolls at different contour elevations
- Fibre Rolls may be used as grade breaks, where slopes transition from flatter to steep gradients

Advantages

- The coir material is natural and long lasting (5 to 7 years), and has high tensile strength

Rolls

- a) Coir Roll
- b) Fibre Roll

Streambank Stabilization Techniques and Erosion Control

B.M.P. #38

- The fibre rolls and mats accumulate sediment while the plants grow and the plant roots develop. Eventually the coir material biodegrades and the cohesive strength of the root systems and flexible nature of the plants become the primary stabilizing element
- The coir roll/brushlayering combination provides immediate shoreline and streambank protection, with additional benefits of riparian enhancement when the cuttings become established
- Coir Rolls address ecological concerns by encouraging vegetation and wildlife habitat, and are an alternative to stone revetments or other structural measures
- The high tensile strength coconut fibres, fibre netting and the wooden stakes used to anchor the material make up the initial structural components of the system, while plant root and top growth increase the strength and baffle effects of the structure
- Fibre Rolls can be used on slopes too steep for silt fences or straw bales sediment barriers
- In time, plastic netting will degrade due to the sunlight and straw will degrade and be incorporated into the soil
- Fibre Rolls primary purpose is erosion control, however fibre rolls do provide some sediment control

Limitations

- This technique should be implemented during the dormancy period of the cuttings used for brushlayering and staking
- Coir Rolls are relatively expensive
- Fibre Rolls are designed for low sheet flow velocities
- Fibre Rolls are designed for short slopes with a maximum gradient of 1H:1V
- Fibre Rolls may be labour intensive to install
- Straw rolls have short life span due to natural degradation
 - Usually only functional for two seasons
- Susceptible to undermining and failure if not properly keyed into the soil
- Labour intensive maintenance may be required to ensure rolls are in continuous contact with the soil, especially when used on steep slopes or sandy soils

Rolls

- a) Coir Roll
- b) Fibre Roll

Streambank Stabilization Techniques and Erosion Control

B.M.P. #38

Construction

- Determine annual water elevation
- Mark the annual water level on a stake driven into the substrate, 0.3 or 0.6 m offshore. Installing the materials and plants at the correct elevation is the most important aspect to assure success of the installation. Determine, on site, where the installation will begin and end
- Determine soil level by laying a straight cutting on the coir roll with approximately 20% of the cutting sticking out past the roll, and with the basal ends dipping down into the soil
- Begin installation at the downstream end (if using in a streambank project)
- Prepare the site for installation of coir roll and coir mats by removing any large rocks, obstructions or material that may prevent the coir from making direct and firm contact with the soil. Coir rolls must be level, installed along a horizontal contour. Place coir rolls parallel to the stream bank or shoreline. It is very important to key the ends of the coir rolls firmly into the shoreline or stream bank, so waves and flows will not scour behind the rolls and compromise the integrity of the structure
- Install the coir roll such that 50 mm of the roll extends above the annual water elevation
- Adjacent rolls shall be laced together, end-to-end, tightly and securely
- If using brushlayer cuttings prepare soil bed behind installed coir rolls for laying. It is important that the bud ends of the live cuttings angle up to some degree from the basal ends. Lay cuttings in this fashion, slightly crisscrossed for additional strength
- Next, backfill over cuttings with soil, covering the lower 80% of the branches. At this time, soil can be levelled and prepared for a soil wrap for additional height and soil stability
- If simply covering the cuttings with soil, compact slightly and grade slope to appropriate angle. Use water to wash soil in between branch layers
- If using plant materials, such as container-grown, pre-rooted plant plugs or willow stakes, they should be planted into the coir rolls and through the coir mats and netting
- To install plant plugs and willow stakes into the coir roll, use a planting iron or pilot bar into the roll and wedge it back and forth to create a hole for the plant. It is extremely important that the root system of the plant be placed below the water

Rolls

- a) Coir Roll
- b) Fibre Roll

Streambank Stabilization Techniques and Erosion Control

B.M.P. #38

level for certain species. All plants shall be checked to ensure that they have been firmly installed in the fibre material

- Mulch and seed exposed areas with native species
- Prepare slope face and remove large rocks or other deleterious materials
- Excavate small trenches a minimum of 0.15 m deep and 0.15 m wide across the width of the slope, perpendicular to slope direction, starting at the toe of the slope and working upwards towards crest of slope
- Space trenches a maximum of 3 to 8 m apart along the slope incline, with steeper slopes having trenches spaced closer together
- Place fibre rolls into trench ensuring continuous contact between fibre roll and soil surface
- Butt-joint adjacent fibre roll segments tightly against one another
- Use a metal bar to make pilot hole through middle of the fibre roll a minimum depth of 0.3 m into underlying soil
- Pilot holes should be spaced a maximum of 1 m apart
- Secure fibre roll to soil using wooden stake or other appropriate anchor; live stake may be used as alternate anchor
- Place soil excavated from trench on upslope side of fibre roll and compact to minimize undermining of fibre roll by runoff
- Seed the soil along the upslope and downslope sides of the fibre roll to promote vegetation growth

Construction Considerations

- All work site disturbance should be minimized. Protect any existing plant, when possible, and avoid additional disturbance that can lead to erosion and sedimentation
- Install additional erosion and sediment control measures such as temporary diversion dikes, silt fences and continuous berms, as needed, before beginning work
- Coir rolls can be used in the stream as a sediment barrier, silt curtain, and/or coffer dam to control sediment while work is being done in the water
- Topsoil should be saved, if possible, and replaced once the subsoil has been removed or regraded. Soil shall be stored away from the water's edge and it shall be moved to its final location and stabilized as quickly as possible

Rolls

- a) Coir Roll
- b) Fibre Roll

Streambank Stabilization Techniques and Erosion Control

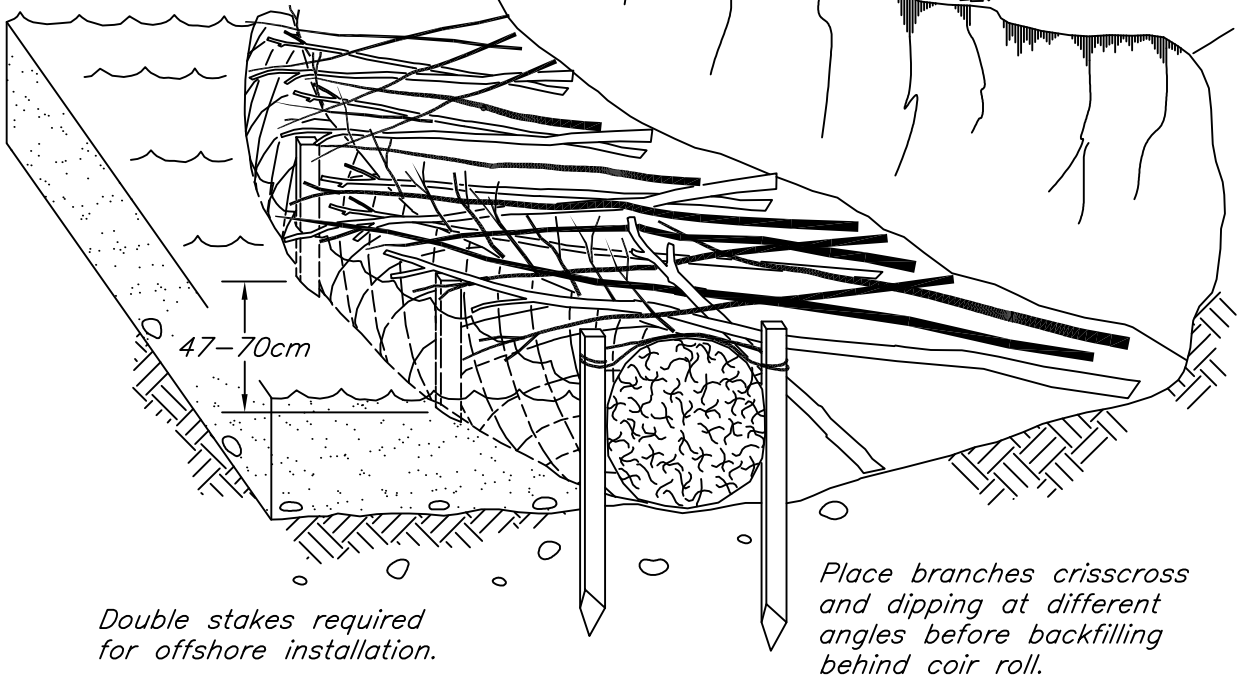
B.M.P. #38

- For typical applications at the water's edge, coir rolls are held in place with a single row of stakes, 300 mm on center. Stakes may be driven through the netting on the outer edge of the roll. It is very difficult to drive stakes through the high-density rolls, however, a stake can be driven with the help of a pilot hole through the low density coir rolls
- Lacing among the stakes is recommended for coir mats exposed to extreme conditions such as ice, waves, or flooding
- Coir rolls shall be placed along streambanks or shorelines at a height sufficient to protect the bank from flows or waves. Additional coir rolls may be placed above the lower rolls, in a tile-like fashion, to protect the upper shore or stream bank
- Use live stakes in place of wooden stakes
- If the slope soil is loose and uncompacted, excavate trench to a minimum depth of 2/3 of the diameter of the fibre roll
- For steep slopes, additional anchors placed on the downslope side of the fibre roll may be required

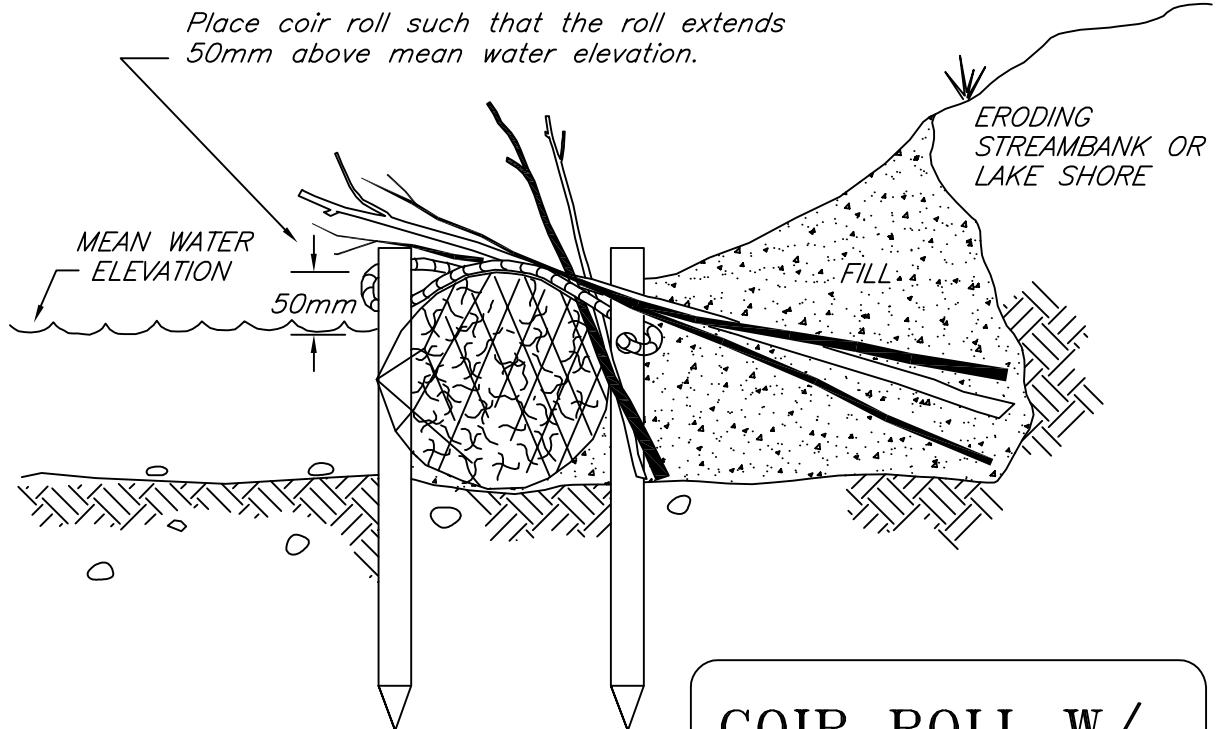
Inspection and Maintenance

- Inspection frequency should be in accordance with the PESC and TESC Plans
- Check plants to ensure that they have been firmly installed in the fibre material
- Water plants, if necessary, during the establishment phase
- Check all materials periodically or after storms to ensure they remain properly secured. Make necessary repairs promptly
- All temporary and permanent erosion control practices shall be maintained and repaired as needed to ensure continued performance of their intended use
- Areas damaged by washout or rutting should be repaired immediately
- Additional stormwater control measures should be considered for rilling areas damaged by runoff

Place coir rolls parallel to the streambank along a horizontal contour.

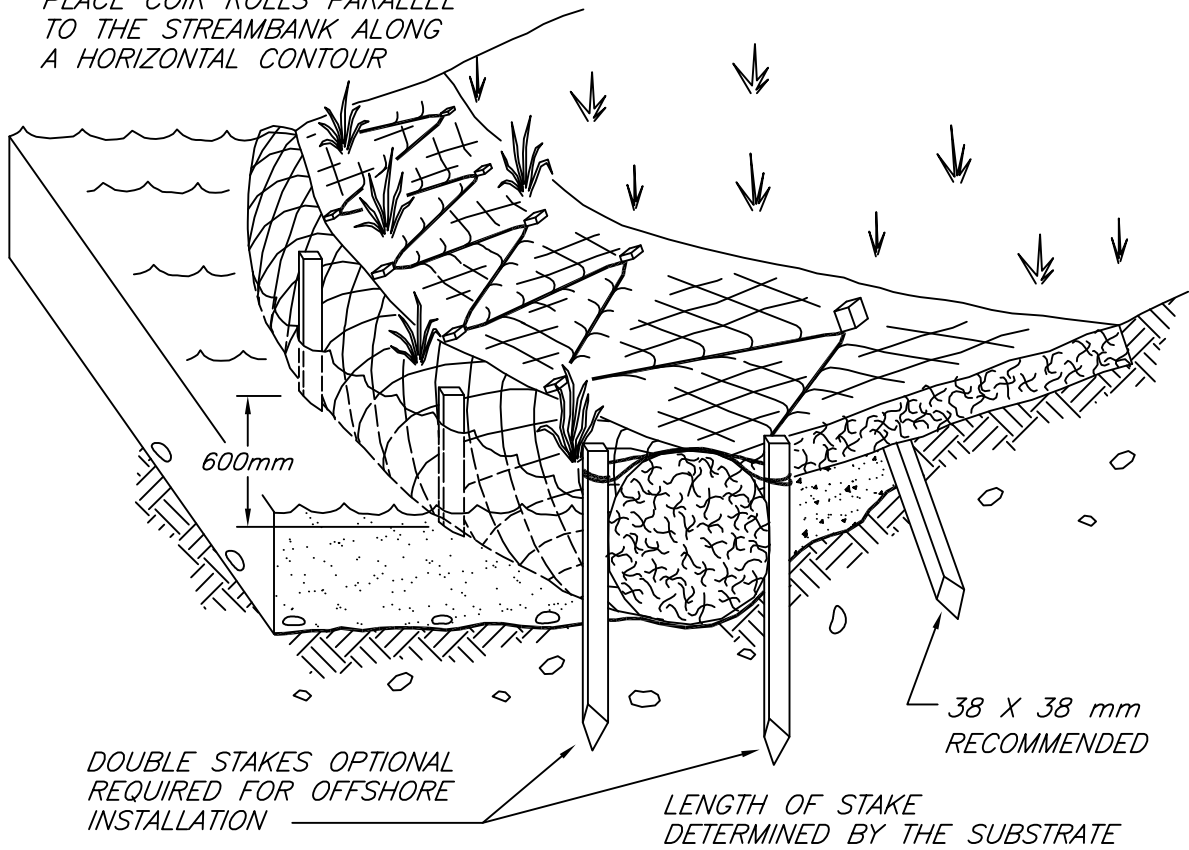


Place coir roll such that the roll extends 50mm above mean water elevation.

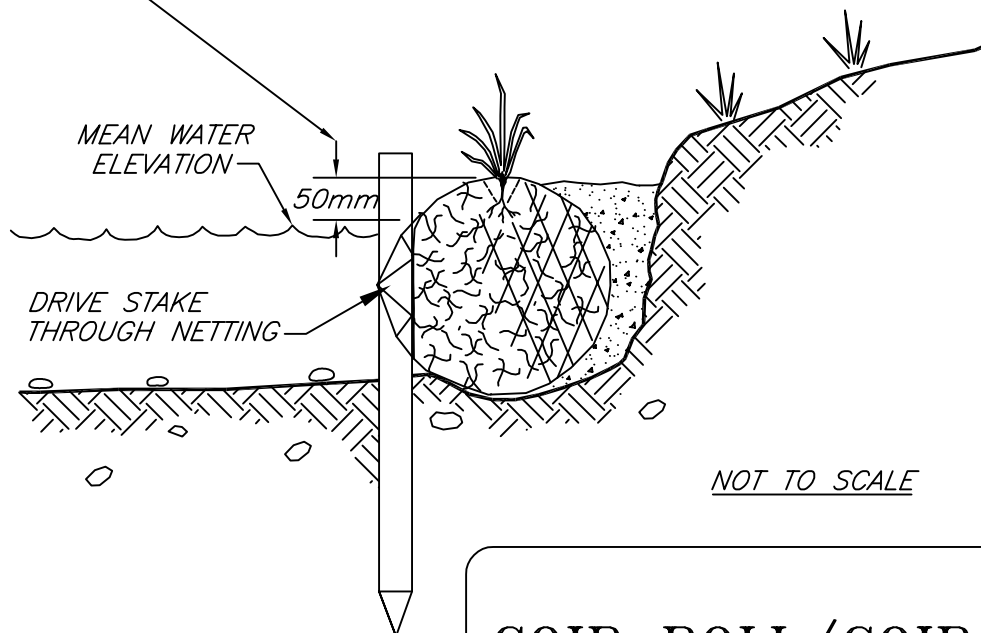


**COIR ROLL W/
BRUSHLAYERING**

PLACE COIR ROLLS PARALLEL
TO THE STREAMBANK ALONG
A HORIZONTAL CONTOUR



PLACE COIR ROLL SUCH THAT THE ROLL EXTENDS
50 mm ABOVE MEAN WATER ELEVATION



COIR ROLL/COIR MATS

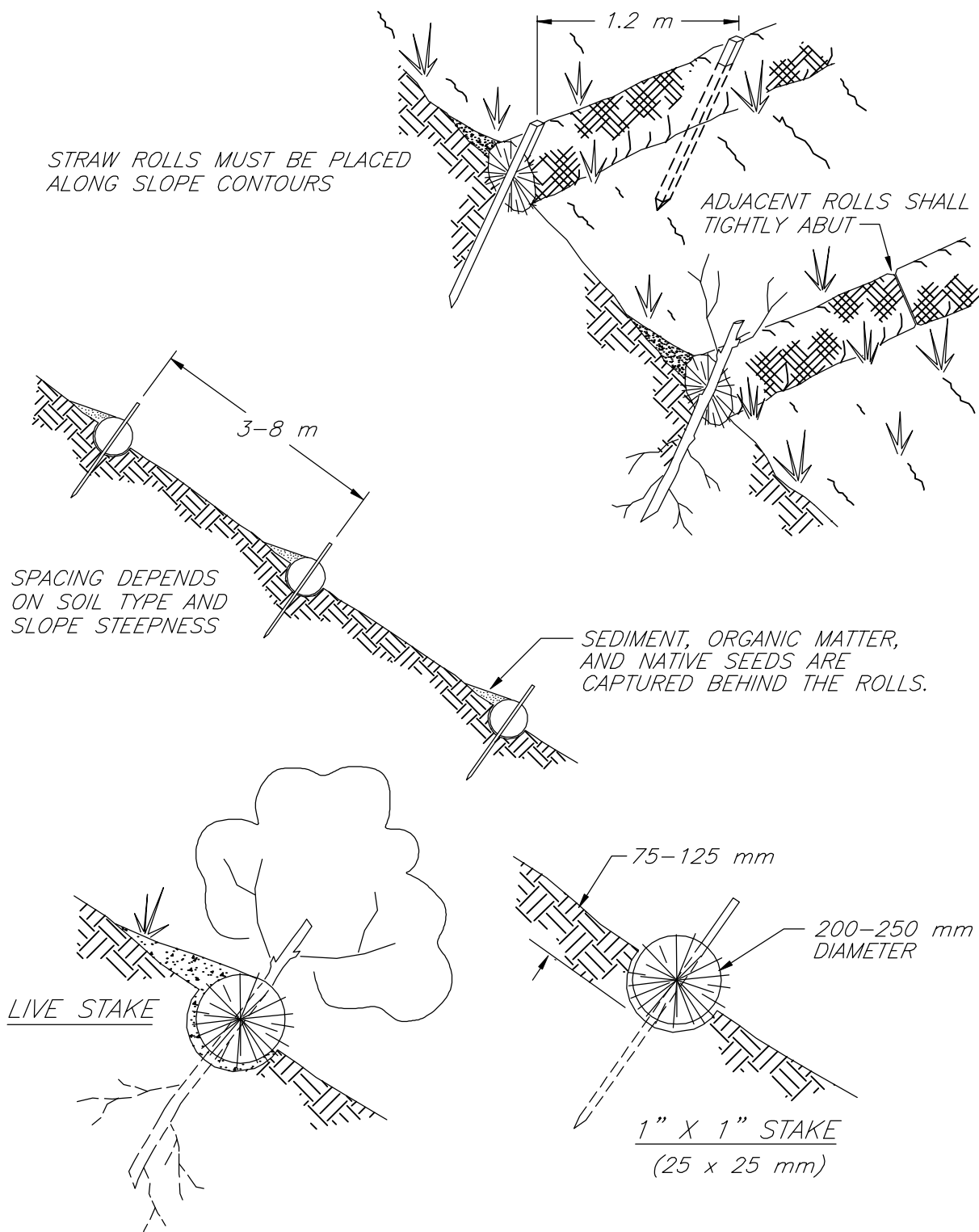
1996 JOHN McCULLAH



FILE: COIRRM



FILE: STRWROLL



NOTE:

1. STRAW ROLL INSTALLATION REQUIRES THE PLACEMENT AND SECURE STAKING OF THE ROLL IN A TRENCH, 75-125 mm DEEP, DUG ON CONTOUR. RUNOFF MUST NOT BE ALLOWED TO RUN UNDER OR AROUND ROLL.
2. THIS FIGURE IS PROVIDED FOR GUIDANCE ONLY AND DOES NOT CONSTITUTE A DESIGN. A SITE SPECIFIC DESIGN IS REQUIRED FROM DESIGNER/ENGINEER.

**STRAW
ROLLS**

Description and Purpose

- Consists of a thick (15 to 30 cm) blanket of living cuttings and soil fill placed on a streambank or lake shore to simultaneously re-vegetate and armour the bank. It provides scour control and re-vegetation and is constructed using live willow branches or other species that root easily from cuttings. The dense layer of brush increases roughness, reduces velocities at the bank face, and protects the bank from scour, while trapping sediment and providing habitat directly along the waters' edge

Applications

- Appropriate for eroding streambanks or slopes where immediate protection is needed from flooding stream flows or wave-induced erosion
- Willow is the most common plant material used because of its rooting ability
- Suitable for streams where willow is naturally occurring and where the soil and moisture conditions are favourable
- Planted relatively shallow, as compared to brushlayering, therefore it is most successful on streams where the basal ends of the cuttings will be kept moist during most of the growing season, but flows do not exceed the tolerance of the structure

Advantages

- Provide a dense network of branches that quickly stabilize a slope or streambank
- As the live branches root and grow, not only do they provide cover, but the soil is reinforced with an underground matrix of spreading roots
- If used on streambanks, a brush mattress will trap sediments during high water and eventual plant growth will enhance aquatic habitat
- If used on slopes, a brush mattress collects soil, providing germination sites for other plants
- Well suited for combined installation with many other streambank or slope stabilization techniques
- Often combined with Vegetated Riprap, Live Stakes, Live Fascines, Rootwad Revetment, Live Siltation, and Coconut Fibre Rolls
- Provides immediate surface protection against floods, greatly reducing water velocity at the soil surface
- Well-anchored mattress provides some resistance to scour
- Cuttings are usually available locally

- Relatively economical technique
- Captures sediment during floods, assisting in rebuilding of bank
- Produces riparian vegetation rapidly
- Enhances wildlife habitat value

Limitations

- Does not show high success on streams where basal ends cannot be kept wet for the duration of the growing season
- They should be installed during the dormant season for woody vegetation
- Installation is labour intensive

Construction

- Prepare the slope or streambank by clearing away large debris and grading the slope so the branches will lay flat on the bank
- If bank is not graded evenly, air pockets will form during backfilling, causing poor stem to soil contact, and ultimately resulting in poor sprouting
- Do not compact the slope over 85%, as it will inhibit rooting
- Excavate a horizontal trench, 20 to 30 cm deep at the toe of the streambank
- Lay the cuttings flat against the graded slope, slightly crisscrossed, with the basal ends placed as deeply into the trench as possible, and just below any toe protection to be installed
- Continue to lay the cuttings along the face of the bank or slope until 80% groundcover is achieved
- The mattress will be about 6-30 cm thick
- It will take 10 to 50 branches per m of mattress
- Pound a grid of stakes, 60 to 90 cm long, into the mattress at 0.9 to 1.2 m centers
- Do not pound the stakes completely in, as this will be done after tying
- Longer stakes can be used in sandy soil and shorter stakes in heavy soils
- Secure the brush mattress by using cord, rope, or 10 to 12 gauge galvanized annealed wire, tied with clove hitches in a diamond pattern between each row of stakes
- After securing the mattress with cord or wire, drive the stakes in further to compress the mattress tightly against the slope

- Secure the toe of the mattress using a suitable technique such as Vegetated Riprap, Live Fascines, Rootwad Revetments or Coconut Fibre Rolls
- Backfill around and in between the branches of the mattress by using material excavated from the trench, and additional soil if needed
- Work the soil in well around the branches
- Tamp soil by walking on it, and lightly water the soil with buckets or a hose to wash it down into the stems, and ensure good stem to soil contact
- It is necessary for the thicker, basal ends of the mattress to get good soil cover for rooting; at least 1/4 of the depth of the mattress is recommended
- Leaving some branches exposed above the soil will facilitate sprouting

Construction Considerations

- Brushy cuttings (stems having leaves and twigs) of tree and shrub species capable of propagating from cuttings, typically willow species
- 10 to 50 branches per m of bank to be protected should be harvested
- The cuttings should be long (1.5 to 3 m), straight, brushy, 2 to 3 year old branches up to 4 cm in diameter
- For optimum success, the fascines should be soaked for 24 hours or installed on the same day they are harvested and prepared
- Wooden construction stakes and/or live stakes will be needed
- The length of stakes will vary based on soil conditions
- Biodegradable natural fibre or polypropylene rope is usually preferable to wire
- A sledgehammer will be needed for driving in wooden stakes, or a dead-blow mallet and pilot bar (rebar) for live stakes

Inspection and Maintenance

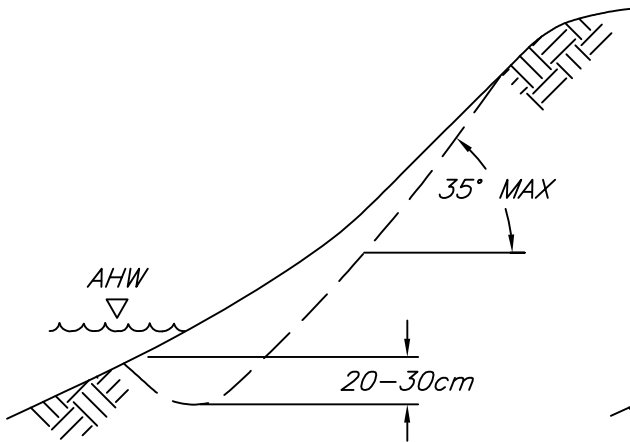
- During the first growing and flood season, periodic maintenance is necessary to make sure the stakes and cord/wire are still securing the mattress to the streambank, and to verify that flows are not getting behind the mattress
- Inspect for flanking or undermining of the revetment

Design Considerations

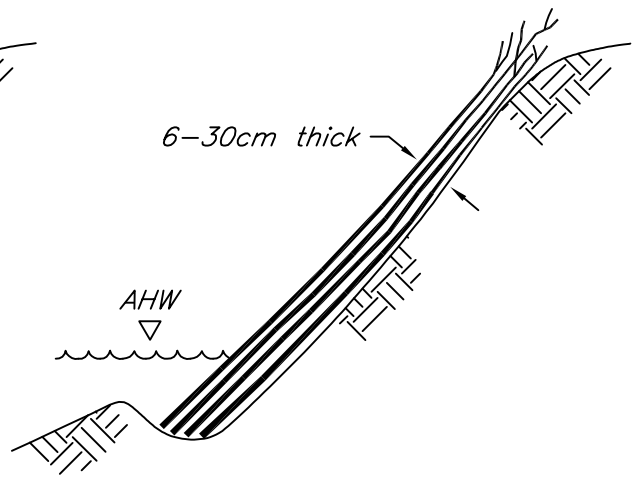
- The optimal bank slope for brush mattresses is 1V:2H, because stem to soil contact can be maximized at that angle; however, mattresses can successfully be installed at angles of 1V:1.25H or steeper, but sprouting will occur mostly at the basal ends

Brush Mattress	B.M.P. #39
Streambank Stabilization Techniques	

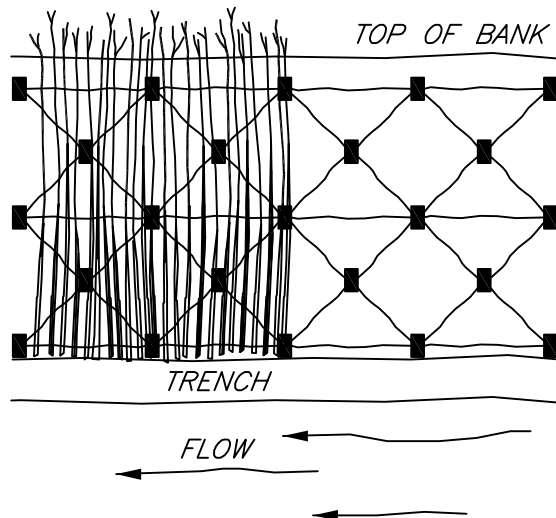
- In some cases, fill will be required to bring the bank to the desired grade
- If rock fill is used, at least 45 cm of soil should be placed over the rock to ensure proper stem to soil contact for the cuttings
- It is important to protect the brush mattress against flanking and undermining
- Some type of toe protection is necessary, and depending upon the erosivity of the bank, keys or refusals may be necessary at upstream and downstream ends
- Rock toe protection is useful with brush mattresses
- If there is any overbank runoff occurring, flows should be diverted around the brush mattress and outleted in a stable area
- If piping is evident, a granular filter should be installed underneath the brush mattress
- The survival of cuttings that do not have their basal ends near the annual low water level is questionable in arid and semi-arid environments
- Studies have shown that brush mattresses have stabilized a bank in a test flume against velocities exceeding 7 m/s



Step 1: Excavate trench and grade bank.

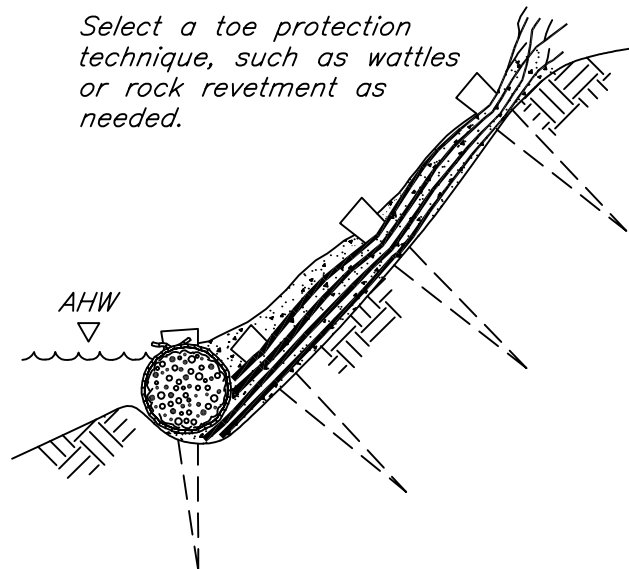


Step 2: Place willow branches making sure that the butt ends reach the bottom of the excavated trench, and are below the mean low water level.



Step 3: Place notched stakes on 1.0m centers, and secure the mattress by lacing twine, rope or wire in a diamond pattern between the stakes.

Select a toe protection technique, such as wattles or rock revetment as needed.



Step 4: Drive the stakes deeply into the bank to tightly compress the branches against the soil. Cover and partially bury the mattress to encourage rooting.

BRUSH MATTRESS

Description and Purpose

- A re-vegetation technique used to secure the toe of a streambank, trap sediments, and create fish rearing habitat. It can be constructed as a living or a non-living brushy system at the water's edge and helps to secure the toe of a streambank

Applications

- An appropriate practice along an outer bend with sufficient scour or toe protection

Advantages

- Can be constructed in combination with rock toes, Rootwad Revetments, Coconut Fibre Rolls, Live Fascines, and Brush Mattresses
- A very effective and simple conservation method using local plant materials
- Valuable for providing immediate cover and fish habitat while other re-vegetation plantings become established
- The protruding branches provide roughness, slow velocities, and encourage deposition of sediment
- The depositional areas are then available for natural recruitment of native riparian vegetation

Limitations

- If using a living system, cuttings must be taken during the dormancy period

Construction

- Construct a V-shaped trench at the annual high water (AHW) level, with hand tools or a backhoe
- Excavate a trench so that it parallels the toe of the streambank and is approximately 0.6 m deep
- Lay a thick layer of willow branches in the trench so that 1/3 of the length of the branches is above the trench and the branches angle out toward the stream
- Place a minimum of 40 willow branches per m in the trench
- Backfill over the branches with a gravel/soil mix and secure the top surface with large washed gravel, bundles/coir logs, or carefully placed rocks
- Both the upstream and downstream ends of the live siltation construction need to transition smoothly into a stable streambank to reduce the potential for the system to wash out

Live Siltation	B.M.P. #40
Streambank Stabilization Techniques	

- More than one row of live siltation can be installed
- A living and growing siltation system typically is installed at AHW
- A non-living system can be constructed below AHW during low water levels
- If it is impossible to dig a trench, the branches can be secured in place with logs, armour rock, bundles made from wattles, or coir logs

Construction Considerations

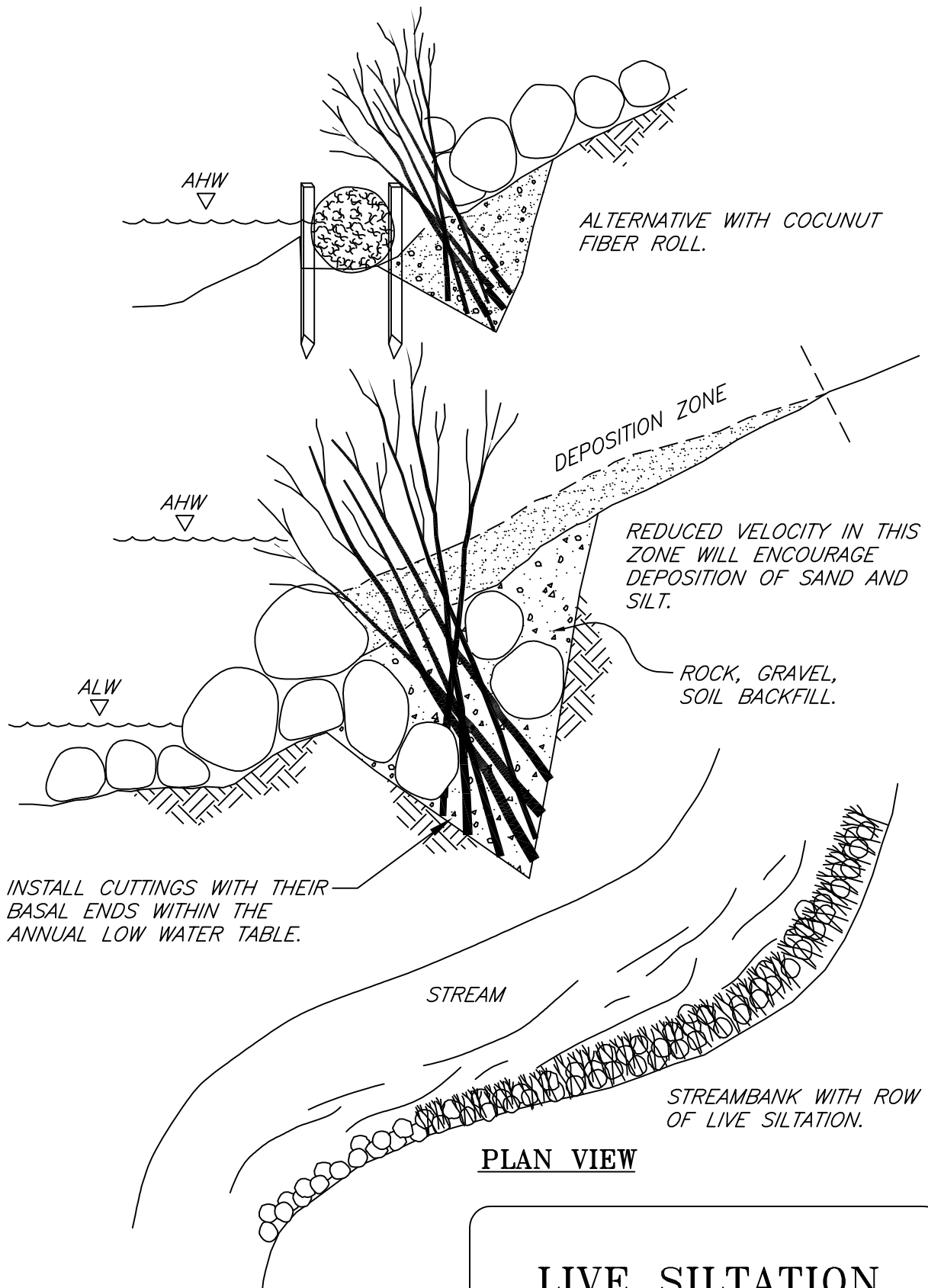
- Natural stone, willow wattles, logs or root wad revetments are needed for toe and scour protection
- The live siltation will require live branches of shrub willows 1 to 1.5 m in length
- Branches should be dormant, and need to have the side branches still attached
- Any woody plant material, such as alder, can be installed for a non-living system

Inspection and Maintenance

- Inspection frequency should be in accordance with the PESC and TESC Plans
- During the first year, the installation should be checked for failures after all 1-year return interval and higher flows, and repaired as necessary
- During summer months of the first year, ensure that cuttings are not becoming dehydrated
- Cuttings will not promote siltation if not located at the water's edge
- If located further up the bank, cuttings may dry out, and will only trap sediments and slow velocities during high flows
- Cuttings may not grow well if not handled properly prior to installation

Design Considerations

- Cuttings should be placed adjacent to the water's edge to ensure effective sediment trapping and velocity reduction at the toe of slope
- At least 40 branches per m should be installed
- This technique may be used for velocities up to 2 m/s, but velocities should be at least 0.25 m/s for the system to function properly



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FILE: LIVESILT

Description and Purpose

- Willow trees and shrubs may be propagated by planting cuttings
- Although smaller (<4 cm) diameter cuttings (stakes) grow more vigorously than older, larger materials (posts and poles), larger materials provide mechanical bank protection during the period of plant establishment
- Dense arrays of posts or poles reduce velocities near the bank or bed surface, and long posts or poles reinforce banks against mass instabilities occurring in shallow failure planes
- Willow posts and poles can be used in most areas in need of re-vegetation
- Those most conducive to this practice are midbank areas on banks with a 1V:2H slope or shallower
- Although posts and poles can be planted in the toe and upper bank areas, vigorous growth is rare, due to drowning and desiccation of the poles, respectively

Applications

- Willow species are lead pioneers in riparian zones throughout much of North America
- Once established, they provide cover and create conditions conducive to colonization by native species that comprise the riparian community
- Functional riparian zones provide habitats for a wide range of aquatic and terrestrial plants and animals, generally improve bank stability, mediate water quality, and improve visual resources

Advantages

- Willow posts and poles are excellent additions to any technique that requires excavation, particularly when the depth and location of the excavation intercepts soils conducive to willow growth
- Willow posts and poles may be inserted into stone or soil backfill and thus become incorporated with the structure as they root
- They can also be incorporated into many techniques during construction (e.g., Vegetated Riprap, Vegetated Gabions), and can be planted in the keyways of many structures
- When placed along a channel with perennial flow, willows generally will not survive when planted at the toe, but may serve as short-term sacrificial protection for plantings at higher elevations

Streambank Stabilization Techniques

- If permanent protection is needed, structural measures like stone toe are recommended
- Willow posts and poles are inexpensive to acquire, install, and maintain
- Willow posts and poles provide long-term protection
- The mature willows provide canopy cover for aquatic and terrestrial fauna, which also lowers stream temperatures
- Aquatic and terrestrial habitat is provided and/or improved
- Willows act as pioneer species, and allow other plant species to colonize the area after the willows have become established

Limitations

- Willows generally do not grow into the stream or above the top of bank
- Willow posts and poles have higher survival rates when planted during their dormant season, so planning should be adjusted accordingly
- Optimum stabilization is not achieved until the willows become established, typically at least one season after installation, although they provide some reinforcement immediately following installation

Construction

- Poles and posts should be deeply (1 to 2 m) planted in holes created using a metal "stinger" mounted on a hydraulic hoe, or an auger

Construction Considerations

- Willow poles, approximately 5 to 15 cm in diameter, and 1.8 to 3 m in length
- Optimum hole digging equipment is a backhoe with "Waterjet Stinger", normal Stinger or auger
- An excavator bucket can also be used

Inspection and Maintenance

- Inspection frequency should be in accordance with the PESC and TESC Plans
- Willow posts should be inspected for vigor, dehydration, and animal browsing problems
- Desiccation and browsing are the two biggest reasons for failure
- Often, willow post installations need to be fenced for a year or so, especially in agricultural areas, to allow the willows to get established

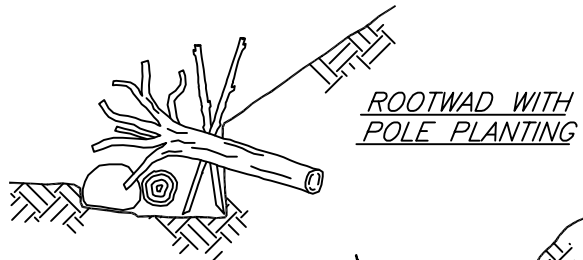
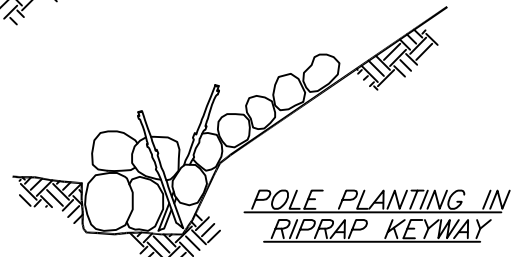
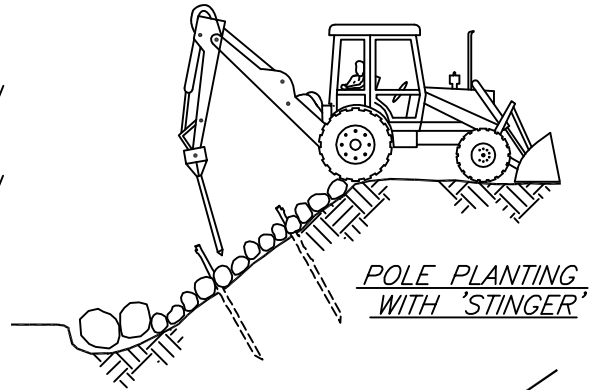
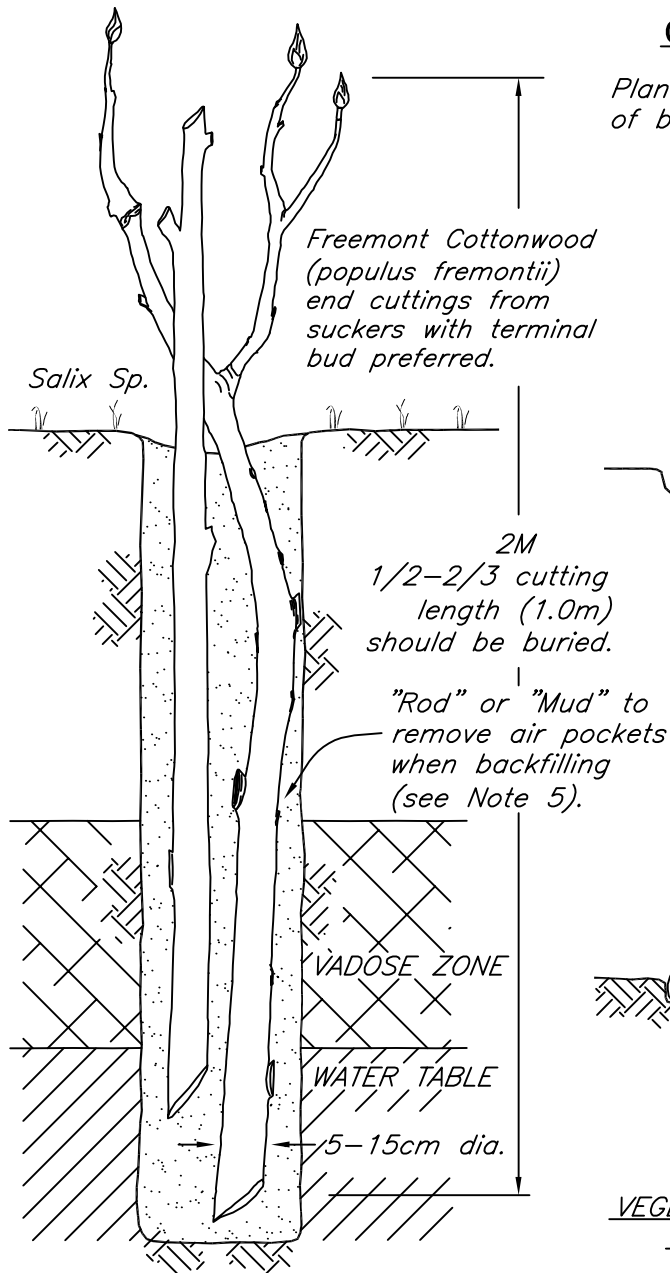
- Willows that are not planted deeply enough, have too much of their stem exposed, or do not have good stem to soil contact can dry out and die before getting established

Design Considerations

- Willow cuttings should be planted while dormant, and care should be taken to prevent desiccation or dormancy break of cuttings between harvest and planting
- Poles and posts should be deeply (1 to 2 m) planted in holes created using an auger or metal "stinger" mounted on a hydraulic hoe, or an excavator bucket
- Poles should be planted to such a depth that desiccation does not occur during summer (for sites with water tables lower than the stream) and poles are not undermined by local scour during high flows
- Augered holes offer the advantage that soils adjacent to the planted stem are not compacted
- Good contact between the plant stem and soils is essential, so holes that do not collapse must be refilled with compacted soil to prevent desiccation of the plants due to air pockets
- High flows that occur shortly after planting can ensure collapse of the holes and filling of air pockets
- Water jetting, in which stems are rapidly inserted into soils that are locally liquefied using a high-pressure stream of water, offers many advantages over other planting techniques when applied to sandy soils
- Only a small portion of the pole should remain above the surface of the ground – about 80% of the cutting should be buried, to prevent desiccation and ensure good stem to soil contact
- Willow success is governed by soil texture and moisture regime
- Workers in drier climates have stressed the importance of planting willow posts deeply enough to maintain contact with groundwater throughout the growing season

CONSTRUCTION TECHNIQUES

Plant poles deeply during construction of biotechnical streambank work.



NOTES:

1. Pole cuttings of willow or cottonwood are longer and have a larger diameter than branch cuttings or live stakes.
2. Larger diameter cuttings have a greater supply of stored energy (stored photosynthesis) than smaller diameter cuttings.
3. Pole cuttings are better suited for highly erodible areas and sites with fluctuating water levels.
4. The pole cuttings should extend through the vadose zone and into the permanent water table. At least 1/2 to 2/3 of the pole should be below the ground, at least 1.0m, and long enough to emerge above adjacent vegetation.
5. "Muddying" – filling the hole with water and then soil to make a mud slurry can remove air pockets.

WILLOW POSTS & POLES

Description and Purpose

- Vanes are redirective, discontinuous, transverse structures angled into the flow in order to reduce local bank erosion by redirecting flow from the near bank to the center of the channel
- The instream tips of the structures are typically low enough to be overtopped by all flows and crests slope upward to reach bankfull stage elevation at the bank
- Structures angled upstream redirect overtopping flows away from the protected bank
- Vanes are installed to provide toe protection and rectify lateral instability by redirecting flow away from eroding banks, while providing greater environmental benefits than stone blanket or revetment
- Vanes can increase scour at the tips, backwater area, edge or shoreline length, and the diversity of depth, velocity and substrate
- When properly positioned, a vane deflects flow away from the bank and induces deposition upstream and downstream of the structure
- This redirection of flow reduces velocity and shear stress along the bank while creating a secondary circulation cell that transfers the energy toward the middle of the channel
- Rock vanes, protruding 1/3 bankfull width into the channel and oriented at an upstream angle between 20° and 30°, move the thalweg an average of 20% bankfull width away from the eroding bank. Therefore, vanes, whether made of rock and/or logs, redirect water away from streambanks into the center of the channel
- This serves to decrease shear stress on banks, as well as creating aquatic habitat in the scour pools formed by the redirected flow
- By increasing shear stress in the center of the channel, the vanes create a stable width/depth ratio, maintain channel capacity and maintain sediment transport capacity and competence
- J-hook vanes can also be paired and positioned in a channel reach to initiate meander development or migration

Applications

- Vanes are installed on the outside of stream bends where high velocity and shear stress is causing accelerated bank erosion
- Can often be used at sites where riprap revetments are traditionally applied but greater environmental benefits are desired
- Vanes and other redirective, discontinuous practices should be applied with caution to project sites where infrastructure is immediately adjacent to the protected bank
- Can be combined with longitudinal stone toe or toe or vegetated riprap if continuous resistive protection is also necessary
- Vanes have been successfully installed in rivers and streams with bankfull widths ranging from 9 m to 150 m, with gradients between 0.05 to 0.0003, and in a variety of bed materials
- The ability of vanes to redirect flows and shift local scour and stream power to the center of the channel makes the technique particularly effective where bridge infrastructure is threatened by scour or flanking
- Vanes can be used where it is necessary to preserve as much of the existing bank vegetation as possible, and where aquatic habitat and substrate complexity is an important consideration
- Unlike riprap revetment, which requires reshaping of the bank for installation, vanes require bank disturbance only where keys are placed. This provides opportunities for using vanes in combination with soil bioengineering techniques

Advantages

- Since rock vanes can successfully reduce near-bank velocities and shear stress, vegetation establishment is greatly improved
- Vanes are often combined with other biotechnical soil stabilization measures for bank areas between the vanes
- Vegetated ground cover techniques such as Turf Reinforcement Mats, Erosion Control Blankets, Live Stakes, Live Brush Mattress, and Vegetation Alone are appropriate candidates for combination
- Rock vanes are sometimes used in conjunction with continuous and resistive armouring measures, such as Cobble or Gravel Armour, Vegetated Riprap or Longitudinal Stone Toe, when additional protection between the vanes is required
- Live Brushlayering, Willow Poles, and Live Siltation are extremely effective when implemented at the bank during excavation of the keyways

- Posts and Poles can be used to create overhanging cover for pools up- or downstream from cross vanes
- Intermittent structures such as vanes provide aquatic habitats superior to resistive, continuous structures like Riprap and Longitudinal Stone Toe
- Controlled scour at the vane tip, the creation of pool/riffle bed complexity, and increased deposition of the upstream end are the major environmental benefits of vanes
- Vanes provide fish rearing and benthic habitat, creates or maintains pool and riffle habitat, provides cover and areas for adult fish, and velocity refugia
- Using a redirective measure instead of a continuous, resistive bank armouring technique has several advantages
- Vane installation can often be accomplished from the top of the bank, and does not require bank regrading, which minimizes the impacts to existing vegetation and reduces the amount of site disturbance needed for installation
- The redirection of impinging flows away from the bank and the sedimentation on the upstream side of the vane creates areas where vegetation can effectively re-establish. Thus, areas of active bank erosion become depositional, vegetate, and subsequently, become permanently stable
- Vanes can be used to reduce streambank erosion, rectify lateral instability, and modify flow direction and local scour, while simultaneously gaining environmental benefits
- The technique is appropriate under a range of flow conditions and bed materials and can be used in series to redirect flows around bends
- Vane installation does not require extensive bank reshaping, and most heavy equipment work can be done from the top of the bank, further reducing site disturbance
- Vanes require less rock and heavy equipment than riprap for a similar length of protected bank
- When used to protect bridge infrastructure, vanes placed upstream of abutments force the thalweg toward the center of the channel

Limitations

- Unintended impacts can result from improper design and construction
- If the vane is not properly keyed into the bank, it is likely to fail, creating new localized erosion problems

- Improper vane angle and crest elevation can redirect flow in unintended directions, triggering downstream erosion

Construction

- Construction will require excavation of a key into the bank at minimum of 3 m to a height of bankfull elevation
- If the bank is higher than bankfull, a bench at bankfull elevation can be built to key in the vane
- The keyways should be constructed by digging a trench, placing rock and installing vegetation, and backfilling
- If vegetative techniques are used, such as Willow Post and Poles or Live Siltation, the chances of successful establishment can be increased by "watering in" the cuttings
- Self launching rock can be placed on the existing substrate, however, if footer rocks are necessary, then excavation of the trench for the footer rocks will be required
- The depth of the trench varies depending on bed material
- For a gravel or cobble bed stream, a depth of twice the diameter of the average vane rock is recommended for the footer trench
- The footer rocks should be placed with a gap between the stones equal to 1/3 their diameter which allows them to interlock as the vane adjusts and equilibrates
- In sandy bed material, or where excessive scour is predicted, the trench depth should be four times the diameter of the average vane rock and the gaps between the rocks should be eliminated
- It may be feasible to place a filter fabric geotextile under the footer stones on sand-bed streams

Construction Considerations

- Vanes are generally constructed with graded rock; however, successful vanes have also been constructed from single logs and log cribs with stone fill
- An excavator or backhoe is usually needed to construct the keyways and place the vane rocks

Inspection and Maintenance

- Inspection frequency should be in accordance with the PESC and TESC Plans
- The vane should be inspected regularly

- Maintenance staff should determine:
 - Is the vane intact?
 - Are flows being redirected where expected?
 - Is there any unintended scour?
 - Is there deposition on the upstream side of the vane?
 - Has the vane (or vane series) created or exacerbated erosion or lateral instability downstream of the structure?
- If the vane is not properly keyed into the bank, it is likely to fail, creating new localized erosion problems
- Improper vane angle and height can redirect flow to unintended places, creating further bank erosion downstream of the structures

Design Considerations

- Regardless of project goals, the key design/construction elements of vanes are length, angle, crest elevation, slope, rock size, the placement of appropriate footer rocks, and vane spacing if using the structures in series
- **Hydraulic Considerations:**
 - The primary hydraulic design consideration for vanes is the water surface elevation of bankfull stage
 - Cross vanes are independent of design high-water and freeboard and vegetation establishment is the most common bank protection from bankfull stage to top of bank.
- **Length:**
 - The vane should extend 1/4 to 1/3 the bankfull width of the channel
 - However, this maximum applies to small streams; the larger the channel, the shorter the vane should be relative to the channel width.
- **Angle:**
 - Optimum results are obtained when the vane is oriented upstream at an angle with the protected bank between 20° and 30°. A 20° angle requires a longer vane, but protects a greater length of bank
 - When orienting vanes for the specific goal of protecting bridge infrastructure, i.e., directing flow through and reducing scour at bridge abutments, a 30° angle is generally more effective at reducing scour at the abutment and moving maximum scour depth toward the center of the channel than the 20° angle

- **Height:**

- The crest elevation of the bank end of the vane should be equal to the bankfull or AHW stage elevation
- The key into the bank is also designed to bankfull elevation
- The vanes must be keyed into the bank at least 3 m
- If the bank is higher than bankfull, build a bench at bankfull elevation to key in the vane

- **Crest Slope:**

- Vanes are designed to be overtopped at the tip by all but the lowest flows and should pitch from the bank to the tip of the vane with a 3 to 7% slope
- Steeper vanes act more like spurs or barbs and have different effects on scour and velocity

- **Rock Gradation and Shape:**

- When possible, vanes should be constructed with graded (self-launching) stone. Self-launching stone will automatically stabilize the toe of the structure in any scour holes that form
- Where additional scour is anticipated, more stone may be added to widen the weir crest
- In this way, stone may be sacrificed without modifying the crest elevation
- Weirs and vanes placed on sand beds devoid of gravel may subside as sand is washed from beneath the stone; this problem may be addressed by placing filter fabric or a filter layer of finer stone underneath the stone spur
- In very sandy-bottomed streams, it is advantageous to build vanes using "shot rock" or well-graded stone that includes fines, as they prevent 'through-flow' of sand, and subsequent scour

- **Rock Size:**

- The size of the rock will depend upon the stream size and shear stress
- See comments below under "Hydraulic Loading" on rock sizing.

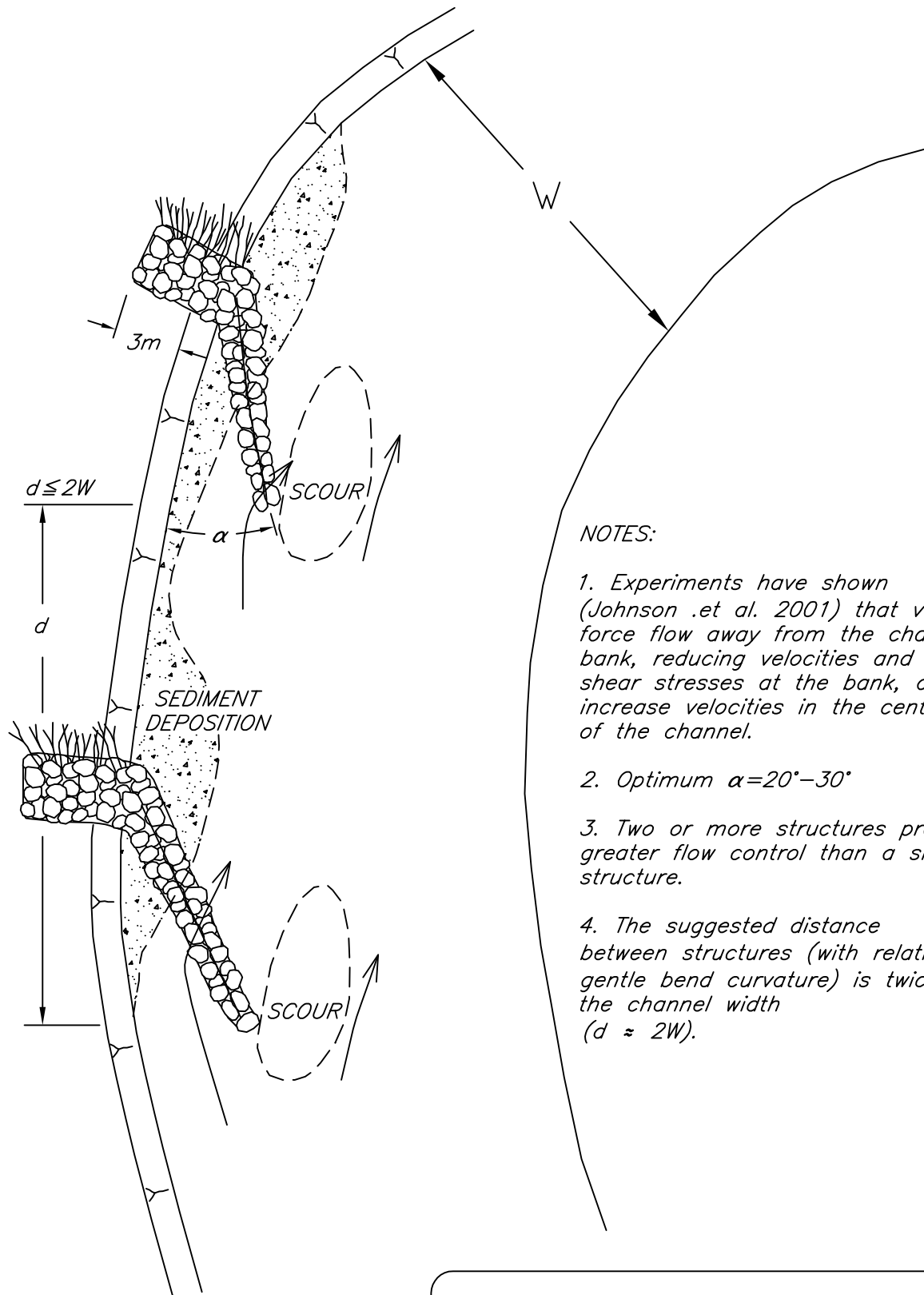
- **When to use footers:**

- The footer rocks should be heavier, longer, and flatter than the average vane rocks

- As a rule of thumb, the weight of the heaviest footer rock is comparable to the heaviest rock used for riprap for the design flow
- In sandy streams an extra layer of footer rocks may be necessary to compensate for the additional scour
- Even in small sand bed streams, 2 m of scour next to a structure like this is not uncommon

- **Spacing:**

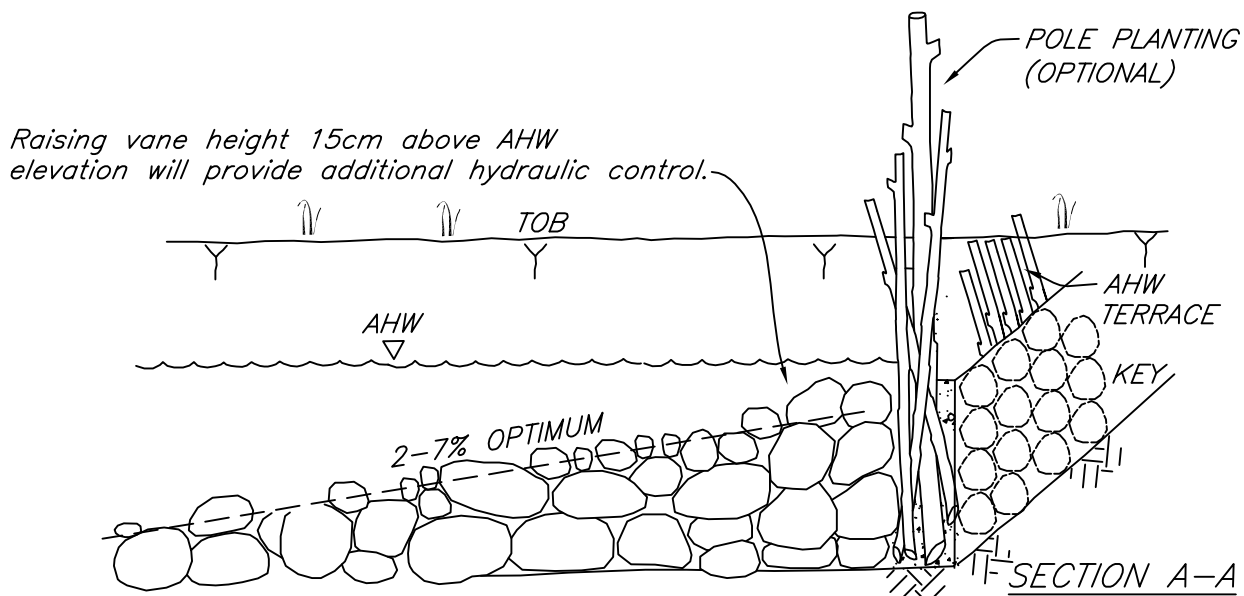
- The distance from the convergence point of impinging flows along the eroding bank (or upstream corner of a bridge abutment) to the upstream tip of the vane should be twice the channel width
- When using vanes in series, the spacing between the upstream tips of the vanes should also be twice the channel width
- When using vanes in a series along an outer bend, the upstream vane should be located at the point where impinging flows are first causing erosion
- The second vane is to be located at the point on the bank that will be impacted by the redirected flows
- This method of spacing requires that the design be based on the flow angles, flow depth and flow direction from the anticipated design storm stage
- As a general rule, small to moderate rivers, less than 20 m wide and where the vane projects approximately 1/3 the width, require spacing that is approximately twice the channel width
- Permissible shear and velocity for rock vanes is related to the size of rock used in construction
- Other factors, such as the angularity of the stone, the thickness of the layers of stone, and the angle at which the faces of the stone structure are constructed also come into play
- The Maynard (1995) equation gives a D_{50} stone size for an angular stone riprap revetment of 0.875 m if the near-bank vertically-averaged velocity is 3.5 m/s, and flow depth = 1 m, and stone is placed on a bank slope of 1V:1.5H
- Use of riprap larger than this is unusual



NOTES:

1. Experiments have shown (Johnson .et al. 2001) that vanes force flow away from the channel bank, reducing velocities and shear stresses at the bank, and increase velocities in the center of the channel.
2. Optimum $\alpha = 20^\circ - 30^\circ$
3. Two or more structures provide greater flow control than a single structure.
4. The suggested distance between structures (with relatively gentle bend curvature) is twice the channel width ($d \approx 2W$).

TYPICAL VANE



TYPICAL VANE BANK
KEY DETAIL
(WITH POLE PLANTING)

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Description and Purpose

- Stone toe is continuous bank protection consisting of a stone dike placed longitudinally at, or slightly streamward of the toe of an eroding bank
- Cross-section of the stone toe is triangular in shape
- Success of this method depends upon the ability of stone to self-adjust or "launch" into any scour holes formed on the stream side of the revetment
- Does not need to follow the bank toe exactly, but should be designed and placed to form an improved or "smoothed" alignment through the stream bend. The "smoothed" longitudinal alignment results in improved flow (less turbulence) near the toe of the eroding bank
- It is especially effective in streams where most erosion is due to relatively small but frequent events
- It protects the toe so that slope failure of a steep bank landward of the stone toe will produce a stable angle
- Such a bank is often rapidly colonized by natural vegetation

Applications

- Longitudinal stone toe can be applied in some situations where the bankline needs to be built back out into the stream, where the existing stream channel needs to be realigned, where the outer bank alignment makes abrupt changes (scallops, coves, or elbows), or where the stream is not otherwise smoothly aligned

Advantages

- A variety of techniques can be used with Longitudinal Stone Toe
- Willow posts and poles may be incorporated into key sections and used to re-vegetate the middle and upper bank above stone toe
- Longitudinal stone toe has proven cost-effective in protecting lower banks and creating conditions leading to stabilization and re-vegetation of steep, caving banks
- Live Siltation, Live Brushlayering, Live Brush Mattresses, Live Staking, Live Fascines, Turf Reinforcement Mats, Erosion Control Blankets, Geocellular Containment Systems, Vegetated Articulated Concrete Blocks, Vegetated Riprap, Soil and Grass Covered Riprap, and Vegetated Gabion Mattress may all be used to provide rapid re-vegetation and additional protection on middle and upper banks
- Cobble or Gravel Armour, Vanes with J Hooks, Cross Vanes, Boulder Clusters, and Newbury Rock Riffles may be used to enhance benthic and water column habitats

- Longitudinal Stone Toe with Spurs is a variation on this technique
- It has documented environmental benefits, especially for aquatic habitat
- Stone interstices provide cover and habitat for smaller fish and other organisms, and rocky surfaces provide stable substrate for benthic invertebrates. However, fish habitat provided by Longitudinal Stone Toe has been found generally inferior to that provided by intermittent, redirective measures like Spur Dikes, Vanes, or Bendway Weirs
- Vegetative cover can become established, even growing through the rock, and can provide canopy and a source of woody debris
- Bank grading, reshaping, or sloping is usually not needed (existing bank and overbank vegetation need not be disturbed or cleared), nor is a filter cloth or gravel filter needed
- If stone is placed from the water side, existing bank vegetation need not be disturbed
- It is very cost-effective and is relatively easy to construct
- It is simple to design and specify
- It is easily combined with other bank stability techniques that provide superior habitat compared to pure riprap

Limitations

- Only provides toe protection and does not protect mid- and upper bank areas
- Some erosion of these areas should be anticipated during long-duration, high energy flows, or until the areas become otherwise protected
- Stone toe is not suitable for reaches where rapid bed degradation (lowering) is likely, or where scour depths adjacent to the toe will be greater than the height of the toe

Construction

- Longitudinal stone toe should be constructed in an upstream to downstream sequence
- Requires heavy equipment for excavation of the keys (tie-backs) and efficient hauling and placement of stone
- Can be constructed from within the stream, from roadways constructed along the lower section of the streambank itself, or from the top

- The preferred method is from the point bar side of the stream (especially possible with ephemeral or intermittent streams), as this causes the least disturbance of existing bank vegetation
- The least preferred is from the top of the bank, as it disturbs or destroys more bank vegetation and the machine operator's vision is limited
- Usually, the keyways are excavated first and rock is dumped into the key
- The rock is then formed into tie-backs (if needed) and finally the stone toe is constructed along a "smoothed" alignment, preferably with a uniform radius of curvature throughout the bend
- In a multi-radius bend, smooth transitions between dissimilar radii are preferred

Construction Considerations

- Stone for the structure should be well graded and properly sized
- The Maynard (1995) equation gives a D_{50} stone size for an angular stone riprap revetment of 0.875 m if the near-bank vertically averaged velocity is 3.5 m/s, and flow depth = 1 m, and stone is placed on a bank slope of 1V:1.5H

Inspection and Maintenance

- Inspection frequency should be in accordance with the PESC and TESC Plans
- Stone toe structures rarely require maintenance
- Maintenance and monitoring requirements should be linked to consequences of failure
- Features that should be monitored are similar to those for all stone structures:
 - Loss of stone due to subsidence, leaching of underlying sediments, ravelling or excessive launching
 - Extreme scour or bed lowering on the stream side of the toe can cause the entire mass of stone to launch, creating an opening or gap in the longitudinal structure
 - If this situation is anticipated or encountered, the problem can be remedied by adding more rock for additional width
 - Longitudinal stone toe may be flanked during extremely high flows if the key trenches are incorrectly built or if the tiebacks are spaced too widely or are constructed with inadequate amounts of stone
 - These terminal key trenches at the upstream and downstream ends should be excavated into the bank at an angle of approximately 30° with the primary flow

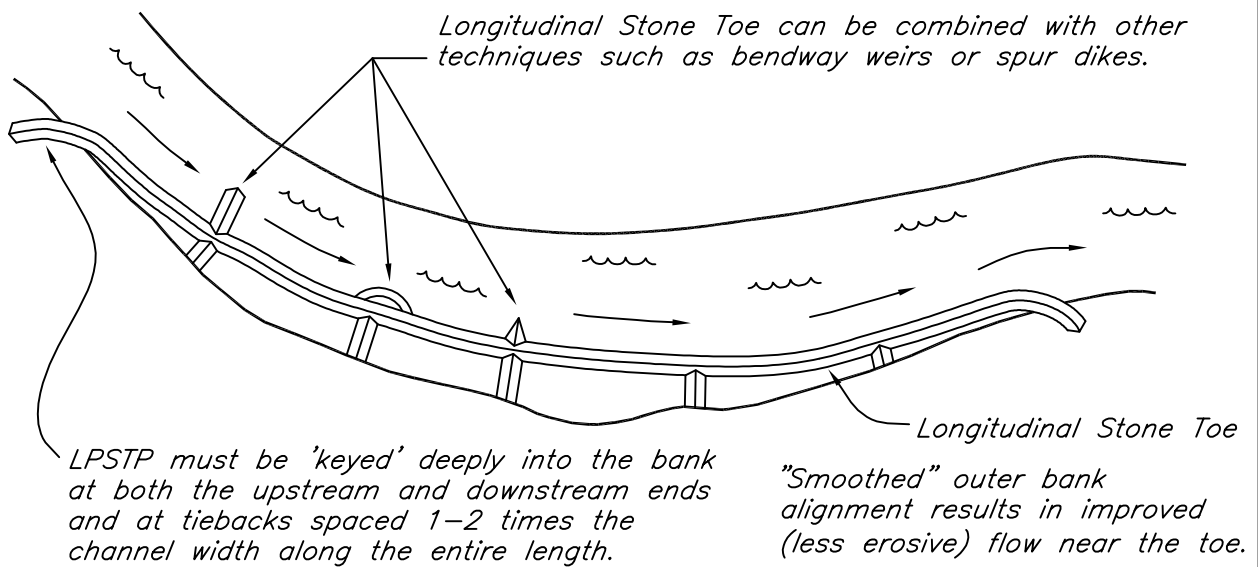
direction and of sufficient length that flows will not be able to get around them during the design storm

Design Considerations

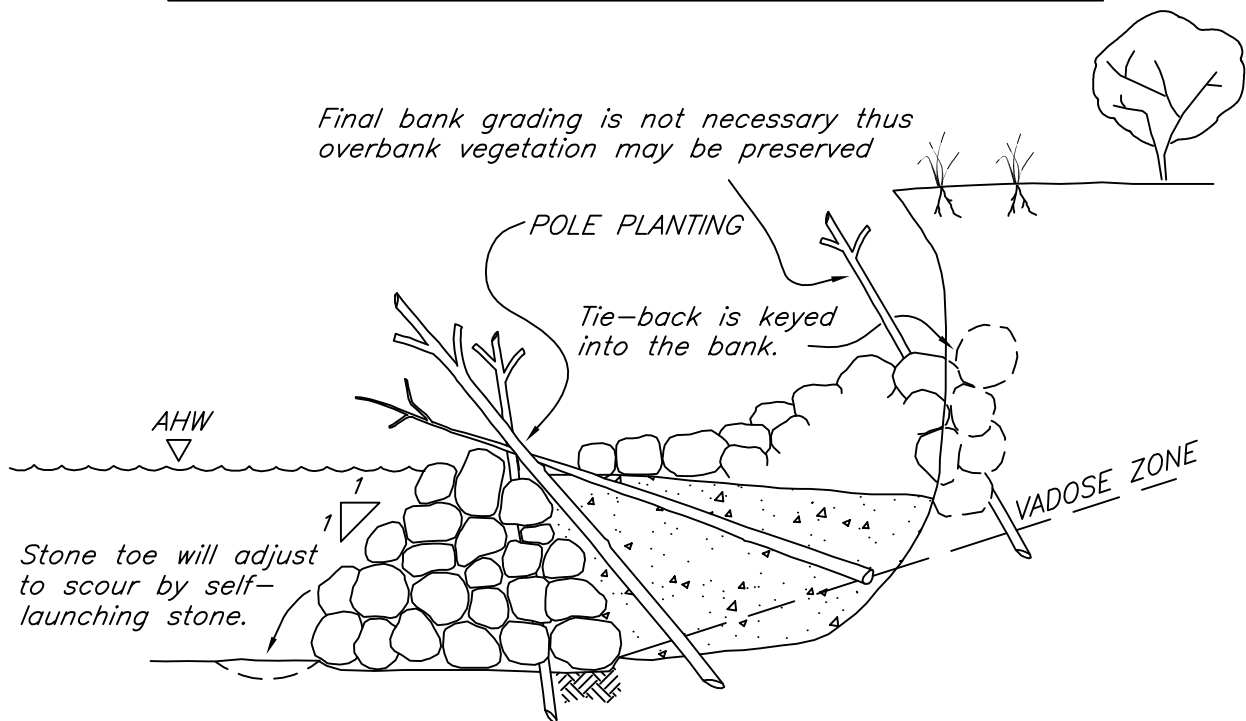
- Longitudinal stone toe can be specified by weight per unit length or to a specific crest elevation
- A specific crest elevation may be specified when the bed of the stream is uneven or deep scour holes are evident
- Longitudinal fill stone toe or weighted riprap toe are similar to stone toe except that the cross-section may be rectangular rather than triangular or peaked
- The dimensions for the weighted riprap toe are based on projected scour depth and a minimum "thickness", which corresponds to stone toe height of 2.5 to 4 times the maximum stone diameter - about 1 to 1.5 m
- Longitudinal stone toe side slopes should be equal to the angle of repose
- Typically stone toe applied at a rate of 3 metric tons of stone per lineal m of protected bank will have a height of approximately 1 m
- Stone toe constructed with 6 metric tons/m stands approximately 1.5 m tall, whereas 1.5 metric tons/m is approximately 0.6 m tall
- Longitudinal stone toe must be keyed deeply into the bank at both the upstream and downstream ends and at regular intervals along its entire length
- On small streams, 25 to 30 m spacing between keys (tie-backs) is typical, while on larger streams and smaller rivers, one or two multiples of the channel width can be used as a spacing guide
- Excavation of trenches for keys provides a good opportunity for deep planting willow posts or poles
- The toe itself does not need to be keyed into the streambed because of its ability to "self-launch"
- However, in areas where the bed of the stream is uneven or deep scour holes are evident, the crest of the structure should be constructed to a specific elevation
- The key trenches at the upstream and downstream ends should be excavated into the bank at an angle of approximately 30°, with the primary flow direction and of sufficient length that flows will not be able to get around them during the design storm
- A gentle angle is important for the end keyways, often referred to as "refusals", because it allows for smooth flow transitions coming into and flowing out of the treated reach

Longitudinal Stone Toe Streambank Stabilization Techniques	B.M.P. #43
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- Tiebacks or "refusals" oriented at 90° to the bank have resulted in many failures at the downstream end of the structure, due to flow expansion at that point
- Permissible shear and velocity for longitudinal stone toe is related to the size of rock used in construction
- Other factors, such as the angularity of the stone, the thickness of the layers of stone, and the angle at which the faces of the stone structure are constructed also come into play



TYPICAL LPSTP CONTINUOUS BANK PROTECTION



NOTES:

1. Longitudinal stone toe is a good choice when continuous bank protection is needed for the toe, but the mid and upper banks are relatively stable and/or biotechnical practices are suitable.
2. The success of Longitudinal Stone Toe depends on the ability of the well-graded stone to self adjust or "launch" into any scour holes formed on the stream side of the stone toe.

LONGITUDINAL STONE TOE

Description and Purpose

- Vegetated Mechanically Stabilized Earth (VMSE) technique consists of live cut branches (brushlayers) interspersed between lifts of soil wrapped in natural fabric, e.g., coir, or synthetic geotextiles or geogrids
- The live brush is placed in a criss-cross or overlapping pattern atop each wrapped soil lift in a manner similar to conventional brushlayering
- The fabric wrapping provides the primary reinforcement in a manner similar to that of conventional mechanically-stabilized earth
- The live, cut branches eventually root and leaf out, providing vegetative cover and secondary reinforcement as well
- In some cases, the vegetative treatment may consist of using a coarse netting for the soil wraps and establishing a herbaceous or grass cover by hydroseeding through the openings in the fabric
- VMSE can be viewed as a union between conventional, mechanically stabilized earth methods that utilize inert, tensile inclusions, and brushlayering, a soil bioengineering technique that utilizes live, cut branches as the tensile soil inclusions
- Fabric wraps provide the primary reinforcement and mechanical stabilization, permitting much steeper slopes to be constructed than would be possible with live brushlayers alone

Applications

- This technique provides an alternative to vertical retaining structures, e.g., timber pile walls, and to techniques that require slope flattening or bank lay back, which results in excessive right-of-way encroachment at the top of bank
- The use of synthetic geotextiles or geogrids provides greater long-term durability and security
- The fabric or geotextile wrap also provides additional protection to upper portions of streambanks that are subject to periodic scour or tractive stresses
- If either steady, long term seepage or temporary bank return flows after flood events are a problem, the brushlayers act as a drainage layer or conduits that relieve internal pore water pressure, and favourably modify the groundwater flow regime within the slope to minimize slope stability problems

Streambank Stabilization Techniques

Advantages

- The presence of vegetation mutes or softens the stark visual appearance of conventional mechanically stabilized earth structures and provides potential habitat for riparian wildlife
- Overhanging branches of the live brushlayers provide shade for fish and a substrate for insects and other organisms that the fish feed upon
- Branches also input leaves and twigs into the stream
- Since the inert fabric wraps or geosynthetic tensile inclusions provide reinforcement and mechanical stabilization, they permit much steeper slopes to be constructed than would be possible with live brushlayers alone
- Brushlayering treatment by itself is normally restricted to slopes no steeper than 1V:2H. VMSE can be constructed with a slope as steep as 1V:0.5H
- The vegetation shields the fabric against damaging UV radiation, and provides visual and riparian habitat benefits
- In addition, when live brushlayers are used, they provide secondary reinforcement, both from the stems themselves, and from rooting along their imbedded lengths
- The brushlayers act as horizontal drains that favourably modify the groundwater regime in the vicinity of the slope face, thereby improving stability against mass slope failure

Limitations

- A VMSE structure must be constructed during the dormancy period to insure good vegetative propagation and establishment
- Alternatively, the live cuttings may be harvested during dormancy, and placed in temporary cold storage until they are ready for use during an out-of-dormancy period, i.e., during the summer months (increases the cost)
- Materials procurement is more demanding, and installation more complex, because of the blending of two distinct methods, i.e., conventional MSE and live brushlayering, into a single approach
- Costs will also be more than brushlayering used alone, because of the added expense of the geotextile and the additional labour required to handle and construct the wraps
- VMSE streambank structures must be constructed during periods of low water because of the need to excavate and backfill a trench with rock in the streambed to provide a stable foundation

Streambank Stabilization Techniques

Construction

- A VMSE installation begins at the base of the slope and proceeds upwards
- The structure should be supported on a rock toe or base and be battered or inclined at an angle of at least 10 to 20° to minimize lateral earth forces
- The following guidelines and procedures apply:
 - Excavate a trench to a competent horizon below the likely depth of scour, and backfill it with rock to provide a base for the VMSE structure
 - The top surface of the rock should be inclined with the horizontal to establish the desired minimum batter angle for the overlying structure
 - Construct an earthen structure reinforced with either polymeric geogrids (or coir fabric) and live brush on top of the rock base
 - Place select fill material on the geogrid (or fabric) and compact it in 7.5 cm lifts to a nominal thickness ranging from 30 to 76 cm
 - Thinner lifts are used at the base of the structure, where shear stresses are higher
 - Temporary batter boards may be required at the front face to confine the select fill during the installation process and to form an even face
 - When geogrids are used, burlap strips at least 1.2 m wide can be inserted between the earthen fill and the geogrids at the front face to contain the fines and prevent initial ravelling of the fill through the apertures in the geogrid
 - The geogrid or fabric sheet should be allowed to drape down or protrude beyond the front edge of each underlying lift of earthen fill to create at least a 0.9 m overlap when it is pulled up and over the next lift
 - The exposed sections of geogrid or fabric layers are pulled up and over the faces of the fill layers and staked in place
 - The geogrids should be pulled as uniformly as possible before staking to develop initial tension in the geogrid or fabric. A tractor or winch pulling on a long bar with hooks or nails along its length works well for this purpose
 - The tensioned geogrid overlap sections should be secured in place using wood construction stakes spaced every 0.9 m
 - Layers of live cut branches are then placed criss-crossed atop the underlying wrapped soil lift
 - 25 to 50 mm of topsoil should be mixed in with the cut branches

Streambank Stabilization Techniques

- The top soil can be placed beforehand or spread over the top of a brushlayer
- Up to three layers of live, cut branches interspersed with 25 to 50 mm of topsoil can be placed in this manner
- The process is repeated with succeeding layers of earth fill, live brush and geogrids (or fabric) until the specified height or elevation is reached
- The recommended earthen lift thickness between geogrid (or fabric) layers depends on various soil and site variables, properties of the reinforcements, and desired safety factor
- The maximum vertical spacing and imbedded length of successive geogrid or reinforcement layers are determined from the specified safety factor, slope angle, soil shear strength, allowable unit tensile strength, and interface friction properties of the reinforcement layer

Construction Considerations (Materials and Equipment)

- The technique can also be used in conjunction with other techniques, particularly resistive techniques, designed primarily to protect the bank toe (Vegetated Riprap and Rootwad Revetments) and redirective techniques (Bendway Weirs, Spur Dikes, and Vanes)
- If excessive seepage daylights from or exits the bank, then a vertical drainage course can be interposed between the bank and the VMSE structure
- Select long branches of native tree species that are capable of vegetative propagation. Willows are the most commonly used plant material, because they generally root well from cuttings.
- Alder, cottonwood (*Populus deltoides*), and dogwood (*Cornus*) can also be used effectively, particularly when mixed in with willow
- The length of the branches will vary depending upon the desired depth of reinforcement, but they should be long enough to reach the back of an earthen buttress placed against a streambank while protruding slightly beyond the face
- The diameter of the live cuttings will also vary depending on their length, but typically should range from 19 to 51 mm at their basal ends.

Inspection and Maintenance

- Inspection frequency should be in accordance with the PESC and TESC Plans
- There are no compelling maintenance requirements in the case of VMSE installed along a streambank
- The vegetation should establish successfully without irrigation requirements given the proximity to water
- Monitoring should consist of inspecting the geogrids (or fabric) for signs of breakage or tearing from scour damage or possibly from excessive tensile stresses due to higher than expected lateral earth pressures
- Signs of uncontrolled seepage, such as weeping or wet spots in the structure, should also be noted
- The site should be examined for possible signs of flanking erosion, which must be addressed with ancillary protective measures lest the flanking threaten the integrity and effectiveness of the VMSE structure itself
- Common modes of failure:
 - Inadequate primary reinforcement from the inert tensile inclusions (fabric or geotextile), i.e., improper vertical spacing or lift thickness, insufficient allowable unit tensile resistance in the selected fabric or geotextile, too short an embedment length, etc., for the given soil and site conditions, i.e., slope height, slope angle, and soil shear strength properties
 - Failure to properly consider seepage conditions and install adequate drainage measures, e.g., chimney drain behind VMSE structure
 - Inadequate attention to construction procedures and details

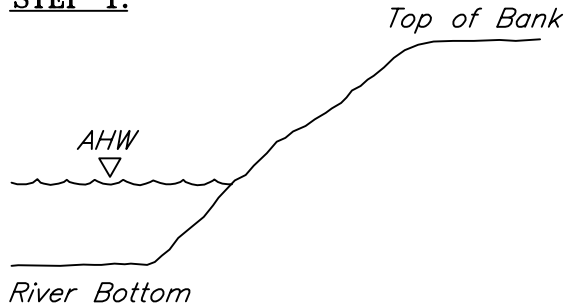
Design Considerations

- It is critical that factors such as scour depth be determined for each particular project and be incorporated into project design
- Many different types of inclusions with various shapes and properties can be used to reinforce and buttress earthen slopes. These inclusions range from imbedded metal strips, geogrids fabricated from polymeric nets, and natural or synthetic geotextiles or fabrics
- Shear stresses that develop in the soil matrix are transferred into tensile resistance in the imbedded inclusions via friction along the soil-inclusion interface

Streambank Stabilization Techniques

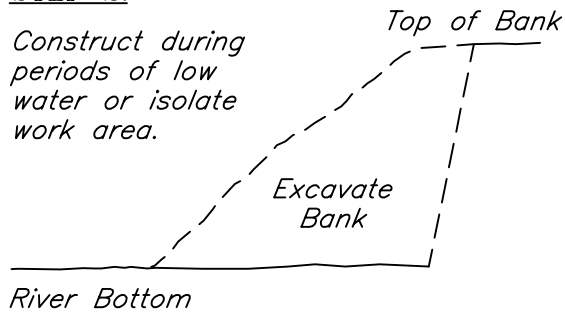
- Mechanically stabilized earth retaining structures must satisfy external stability requirements, i.e., have adequate resistance to sliding, overturning, and bearing capacity failure
- The tensile inclusions or reinforcements in these structures must have a sufficient unit tensile resistance and/or be placed in sufficient numbers to resist breaking in tension
- The inclusions must also be sufficiently long and "frictional" enough to resist failure by pullout
- Synthetic geogrids fabricated from high-tensile strength polymeric materials are widely used in reinforced earth embankments and retaining walls. Geogrids tend to have superior pullout resistance compared to geotextile or fabric sheets. They can be used either in a wrap-around fashion to provide both backfill reinforcement and containment at the front face
- Live cuttings act as tensile inclusions and help to stabilize a slope, embankment, or structural fill
- The main considerations in the design of geogrid or geotextile reinforced earthen slopes and embankment fills is the required vertical spacing (d) and total length (L) of the reinforcing layers
- The total length (L) is comprised of a length or distance required to reach the expected failure surface in the backfill and an additional length, the effective or imbedment length (L_E), extending beyond the failure surface required to prevent pullout
- The reader should consult with a geotechnical engineer

STEP 1.



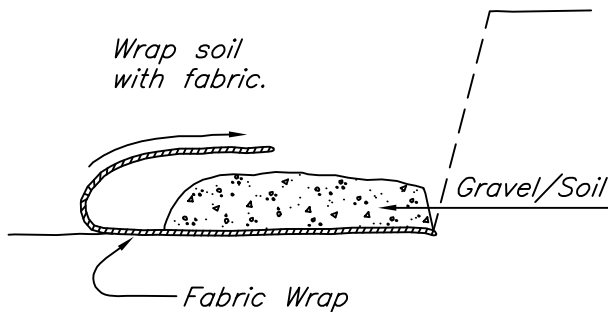
STEP 2.

Construct during periods of low water or isolate work area.



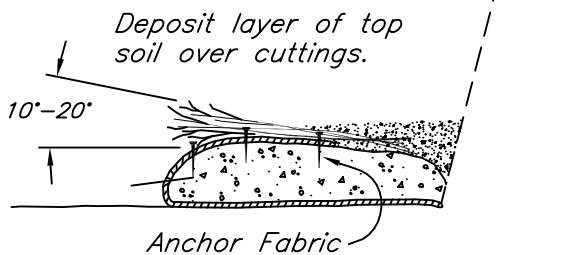
STEP 3.

Wrap soil with fabric.



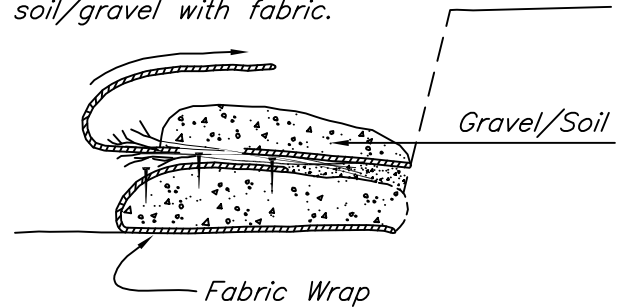
STEP 4.

Crisscross layers of dormant cuttings and/or transplants.



STEP 5.

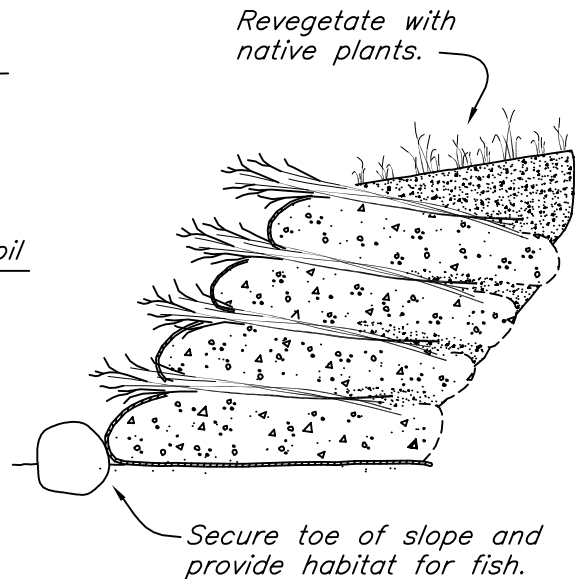
Wrap second layer of soil/gravel with fabric.



STEP 6.

Repeat steps 3, 4, 5 until desired height of bank is reached.

Revegetate with native plants.



**VEGETATED MECHANICALLY
STABILIZED EARTH
STEP BY STEP**

Vegetated Riprap	B.M.P. #45
Streambank Stabilization Techniques	

Description and Purpose

- Vegetative Rip-Rap combines the widely-accepted, resistive, and continuous rock revetment techniques with vegetative techniques. It consists of a layer of stone and/or boulder armouring that is vegetated, optimally during construction, using pole planting, brushlayering and live staking techniques
- Continuous and resistive bank protection measures, such as riprap and longitudinal rock toes are primarily used to armour outer bends or areas with impinging flows
- The stream energy is resisted by the continuous protection, and is subsequently directed downward into the streambed
- The riprap will resist the hydraulic forces, while roots and branches increase geotechnical stability, prevent soil loss (or piping) from behind the structures, and increase pull-out resistance
- The roots, stems, and shoots will help anchor the rocks and resist 'plucking' and gouging by ice and debris

Applications

- Vegetated Rip-Rap is appropriate where infrastructure is at risk, and where redirective and discontinuous bank protection measures have been rejected or deemed inappropriate
- Vegetative Rip-Rap techniques are sometimes considered mitigation for some of the impacts caused by riprap
- Incorporating large and dense trees may be beneficial where thermal pollution is occurring, along north-facing banks (trees will cast shade) and where cover is necessary to protect fish (rearing habitat)

Advantages

- Correctly designed and installed, Vegetated Rip-Rap offers an opportunity for the designer to attain the immediate and long-term protection afforded by riprap with the habitat benefits inherent with the establishment of a healthy riparian buffer
- Above ground components of the plants will create habitat for both aquatic and terrestrial wildlife, provide shade (reducing thermal pollution), and improve aesthetic and recreational opportunities
- When graded or "self-launching" stone is used, riprap is self-adjusting to small amounts of substrate consolidation or movement
- The revetment can sustain minor damage and still continue to function adequately without further damage

- The rough surface of the riprap dissipates local currents and minimizes wave action more than a smooth revetment (like concrete blocks)
- Stones are readily available in most locations, and materials are less expensive than many other "hard armouring" techniques
- The rock provides a large amount of aquatic habitat
- Rip-Rap is easily repaired by placing more rock where needed
- The fibrous roots of the chosen vegetation prevents washout of fines, stabilizes the native soil, anchors armour stone to the bank, and increases the lift-off resistance
- The vegetation also improves drainage of the slope by removing soil moisture for its own use
- Vegetated Rip-Rap has a more natural appearance, and is therefore more aesthetically pleasing, which is frequently a matter of great importance in high-visibility areas
- In addition, environmental clearances are frequently easier to obtain if the project has biotechnical and habitat enhancement benefits incorporated into the design
- There are many environmental benefits offered by Vegetated Rip-Rap, most of which are derived from the planting of willows or other woody species in the installation
- The willow provides canopy cover to the stream, which gives fish and other aquatic fauna cool places to hide
- The vegetation also supplies the river with carbon-based debris, which is integral to many aquatic food webs, and birds that catch fish or aquatic insects will be attracted by the increased perching space next to the stream
- An additional environmental benefit is due to the use of rock, as the surface area of the rocks is substrate that is available for colonization by invertebrates
- The small spaces between the rocks also provide benthic habitat and hiding places for small fish and fry
- The brushlayering methods reach out over the water, and provide shade and organic debris to the aquatic system

Limitations

- Vegetated Rip-Rap may be inappropriate if flow capacity is an issue, as bank vegetation can reduce flow capacity, especially when in full leaf along a narrow channel
- In remote areas large rocks may be difficult to obtain and transport, which may greatly increase costs

- Riprap may present a barrier to animals trying to access the stream

Construction

The vegetation obtained should be poles of adventitiously-rooting native species (such as willow, cottonwood or dogwood), with a minimum diameter of 38 mm, and be sufficiently long to extend into the vadose zone below the riprap.

Vegetated Rip-Rap with Willow Bundles

- Grade the bank to the desired slope where the riprap will be placed, such that there is a smooth base
- Dig a toe trench for the keyway (if required) below where the riprap will be placed
- Place 10 to 15 cm (5 to 8 stem) bundles on the slope, with the butt ends placed at least 30 cm in the low water table
- This will probably involve placing the poles in the toe trench before the rock is placed, if standard riprap rock is being used
- Digging shallow trenches for the willows prior to placing them on the slope will decrease damage to the cuttings from the rocks, and may increase rooting success because more of the cuttings will be in contact with soil
- The bundles should be placed every 1.8 m along the bank, and be pointed straight up the slope
- Once the bundles are in position, place the rock on top of it to the top of the slope
- The bundles should extend 0.3 m above the top of the rock
- If the bundles are not sufficiently long, they will probably show decreased sprouting success, and therefore, a different technique should be chosen

Vegetated Rip-Rap with Bent Poles

- Grade back the slope where the riprap will be placed, such that there is a smooth base
- Dig a toe trench for the keyway (if required) below where the riprap will be placed
- If non-woven geotextile is being used, lay the fabric down on the slope, all the way into the toe trench, and cut holes in the fabric about 0.6 to 0.9 m above the annual low water level
- Slip the butt ends of the willow poles through the fabric and slide them down until the bases are at least 15 cm into the perennial water table, or at the bottom of the toe trench, whichever is deepest

- If using filter gravel, lay it down on the slope, and place a layer of willow poles on top of the gravel, with the bases of the cuttings at least 15 cm into the perennial water table, or at the bottom of the toe trench, whichever is deepest
- Place the largest rocks in the toe trench
- Ensure that they lock together tightly, as they are the foundation for the structure
- Place the next layer of boulders such that it tapers back slightly toward the streambank
- Bend several willow poles up, such that they are perpendicular to the slope, and tight against the first layer of rocks
- Now place the next layer of rocks behind these poles
- Placement will require an excavator with a thumb, as someone will have to hold the poles while the rocks are placed
- As the poles are released, they should be trimmed to 30 cm above the riprap
- This last step should be repeated until all the poles have been pulled up, and the entire slope has been covered

Vegetated Rip-Rap with Brushlayering and Pole Planting

There are two methods of constructing brushlayered riprap; one involves building up a slope, and the other works with a pre-graded slope – neither method can be used with non-woven geotextile

Method 1 (building up a slope):

- Lay the bank slope back to somewhat less than the desired finished slope
- Dig a toe trench, if needed, and lay the key rocks into the trench. Pack soil behind these rocks, with filter gravel in between the soil and rocks
- Continue installing riprap 0.9 to 1.2 m up the bank
- Slope the soil back into the bank at a 45° angle, such that the bottom of the soil slope is in the vadose zone
- Place a layer of willow cuttings on top of the soil, with the butt ends extending into the vadose zone, and the tips of the branches sticking out 30 to 60 cm
- Place the next layer of stones on top of the initial rocks, but graded slightly back, and repeat the soil and brush layering process
- When finished, trim the ends of the willow branches back to 30 cm
- Do not cut shorter than 30 cm, as the plant will have difficulty sprouting

Vegetated Riprap	B.M.P. #45
Streambank Stabilization Techniques	

Method 2 (pre-graded slope):

- Lay the bank slope back to the desired finished grade, and dig a toe trench if self-launching stone is not being used
- Place the largest rocks in the key-way, and fill in behind with filter gravel and soil
- Continue installing riprap 0.9 to 1.2 m up the bank
- Place the bucket of an excavator just above the layer of rocks at a 45° angle
- Pull the bucket down, still at a 45° angle, until the water table is reached, or the stream is dry, to the elevation at the bottom of the key trench
- Pull up and back on the bucket; this will provide a slot in the bank into which willow poles can be placed
- Throw in some willow poles (about 18 poles per linear m), ensuring that the butt ends are at the bottom of the trench
- Release the scoop of earth, and allow it to fall back in place on the slope
- Then place the next layer of rock on top of the branches, flush with the slope
- If self-filtering stone is not being used, filter gravel should be placed behind the rocks
- Repeat the process, beginning again with pulling back a scoop of soil
- Continue this process to the top of the slope, or if preferred, use joint-planted riprap on the upper slope, where it is difficult to reach the perennial water table with the excavator bucket
- When finished, trim the ends of the branches back such that only 30 cm extends beyond the revetment

Construction Considerations

- The technique can also be used in conjunction with other techniques, particularly resistive techniques, designed primarily to protect the bank toe (Vegetated Rip-Rap and Rootwad Revetments) and redirective techniques (Bendway Weirs, Spur Dikes, and Vanes)
- While riprap is very effective at arresting bank erosion and providing relatively permanent bank protection the environmental consequences can be less than desirable and should, therefore always be taken into account when selecting an environmentally-sensitive streambank stabilization treatment
- Scour counter-measures are sometimes required for continuous and resistive rock bank protection
- One alternative is a rock-filled key trench, designed with appropriate scour analysis

Vegetated Riprap	B.M.P. #45
Streambank Stabilization Techniques	

- Another counter-measure that may be employed is the use of graded, self-launching stone

Filter Material:

- Some sort of filter material is typically used to prevent piping of fine soils from below the riprap, if self-launching stone is not used
- There are two choices: non-woven geotextile fabric or graded filter gravel
- Non-woven geotextile fabrics are not recommended for use in Vegetated Rip-Rap, as roots have difficulty penetrating the fabric
- If non-woven geotextile fabric is required, one can cut holes in the fabric where the vegetation is placed
- Small slits in the fabric are especially appropriate with the bent pole method
- Filter gravel is the preferred filter media for Vegetated Rip-Rap

Rock Size:

- There are two options for rocks – self-launching/self-filtering rock or standard riprap
- The advantage of self-launching/self-filtering rock is that the revetment will build its own toe, by self-launching, in any scour hole that forms
- The different sizes of rock act as their own filter medium, so no geotextile fabric or filter gravel is needed
- This decreases cost, and also makes installation less labour-intensive for two of the three methods of installation
- Using self-launching stone is dependent on a source of graded rock, which is not always available

Inspection and Maintenance

- Riprap should be visually inspected as frequently as outlined in the PESC and TESC Plans, with focus on potential weak points, such as transitions between undisturbed and treated areas
- Soil above and behind riprap may show collapse or sinking, or loss of rock may be observed
- Inspect riprap during low flows annually, to ensure continued stability of the toe of the structure
- Treat bank or replace rock as necessary

Vegetated Riprap	B.M.P. #45
Streambank Stabilization Techniques	

Design Considerations

- It often takes many years for riprap to become vegetated if vegetation is not integrated into its design and construction at the outset
- Flanking, overtopping or undermining of the revetment due to improperly installed or insufficient keyways is one of the biggest reasons for failure of riprap
- Improperly designed or installed filter material can also cause undermining and failure of the installation
- Undersized stones can be carried away by strong currents, and sections of the revetment may settle due to poorly consolidated substrate
- Vegetation may require irrigation if planted in a nondormant state, or in extremely droughty soils

Vegetated Rip-Rap with Willow Bundles

Is the simplest to install, but it has a few drawbacks:

- This technique typically requires very long (3 to 7m) poles and branches, as the cuttings should reach from 15 cm below the low water table to 30 cm above the top of the rock
- Only those cuttings that are in contact with the soil will take root, and therefore, the geotechnical benefits of the roots from those cuttings on the top of the bundle may not be realized

Vegetated Rip-Rap with Bent Poles

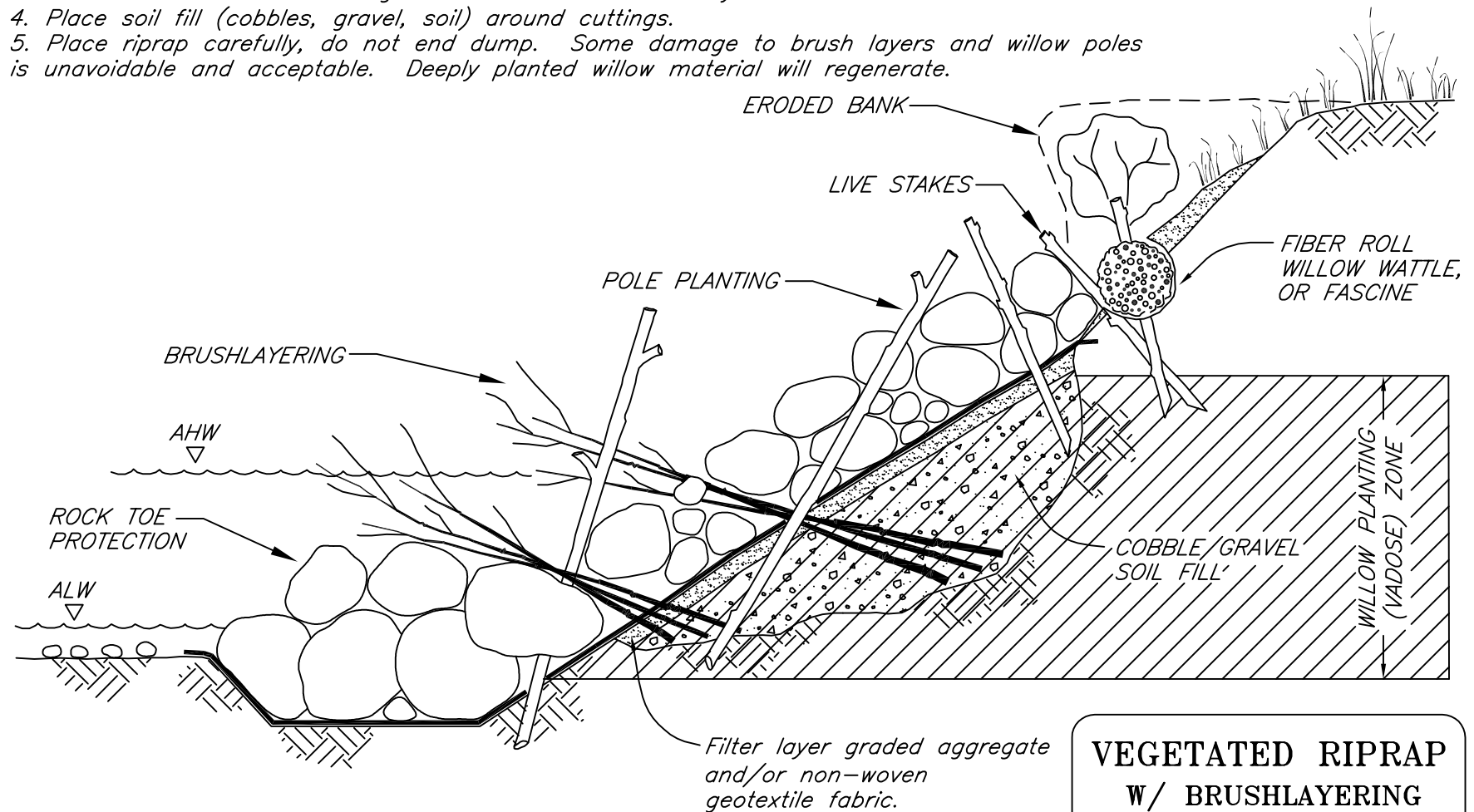
- Is slightly more complex to install
- A variety of different lengths of willow cuttings can be used, because they will protrude from the rock at different elevations
- The angle can be three to one, or forty-five degrees
- A tree and root growth will develop the entire length of each pole planted

Vegetated Rip-Rap with Brushlayering and Pole Planting

- Is the most complex type of riprap to install, but also provides the most immediate habitat benefits
- The installation of this technique is separated into 2 methods; one method describes installation when building a bank back up, while the other is for a well-established bank
- If immediate aquatic habitat benefits are desired, this technique should be used
- May not provide the greatest amount of root reinforcement, as the stem-contact with soil does not extend up the entire slope

NOTES:

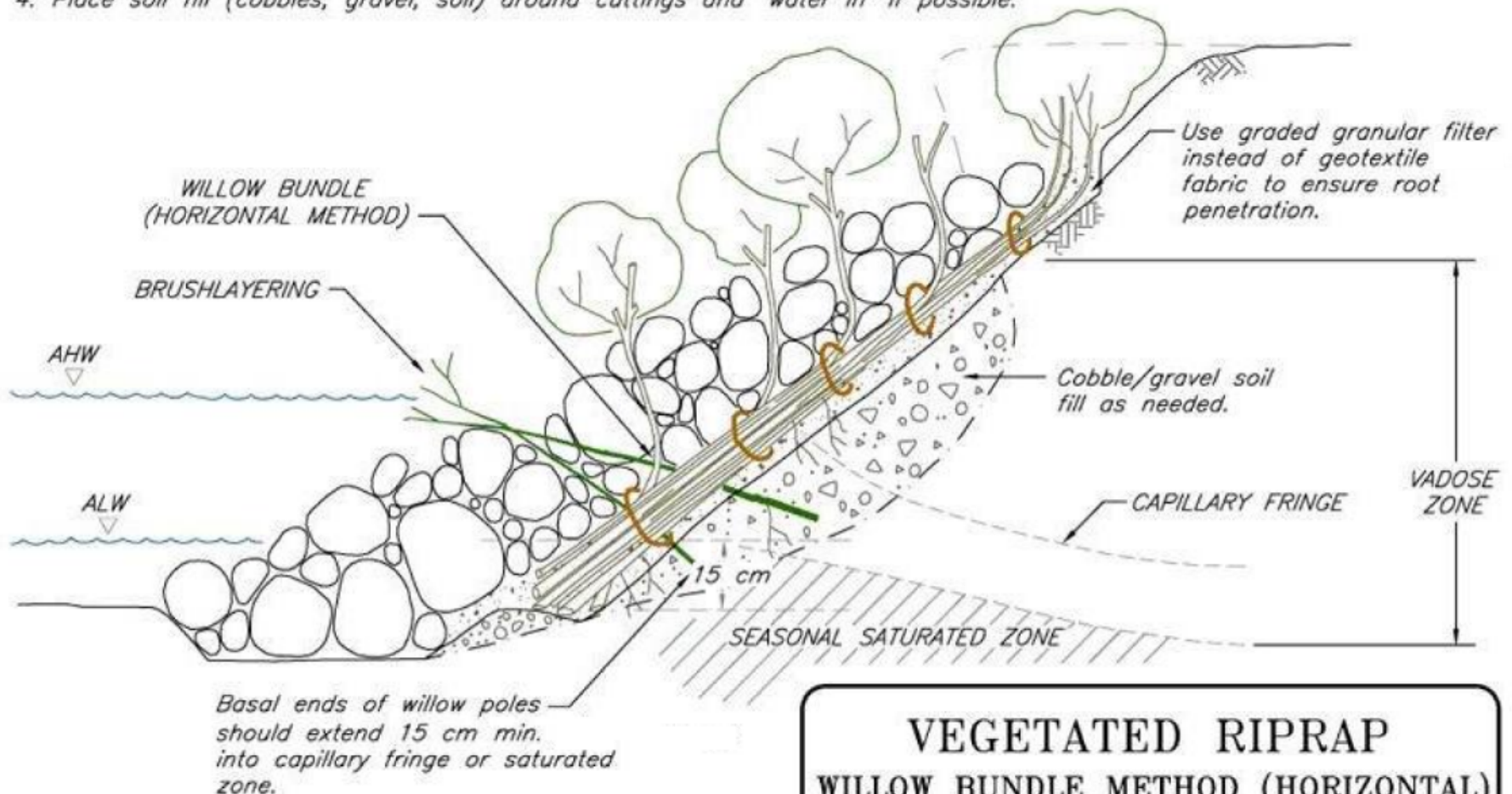
1. Install willow pole planting and brushlayering during bank grading and riprap placement to ensure good contact with 'native ground' and/or soil fill.
2. Willow poles and brush layers shall extend down into expected soil moisture zones (vadose).
3. Cut small holes or slits in geotextile fabric as necessary.
4. Place soil fill (cobbles, gravel, soil) around cuttings.
5. Place riprap carefully, do not end dump. Some damage to brush layers and willow poles is unavoidable and acceptable. Deeply planted willow material will regenerate.



**VEGETATED RIPRAP
W/ BRUSHLAYERING
& POLE PLANTING**

NOTES:

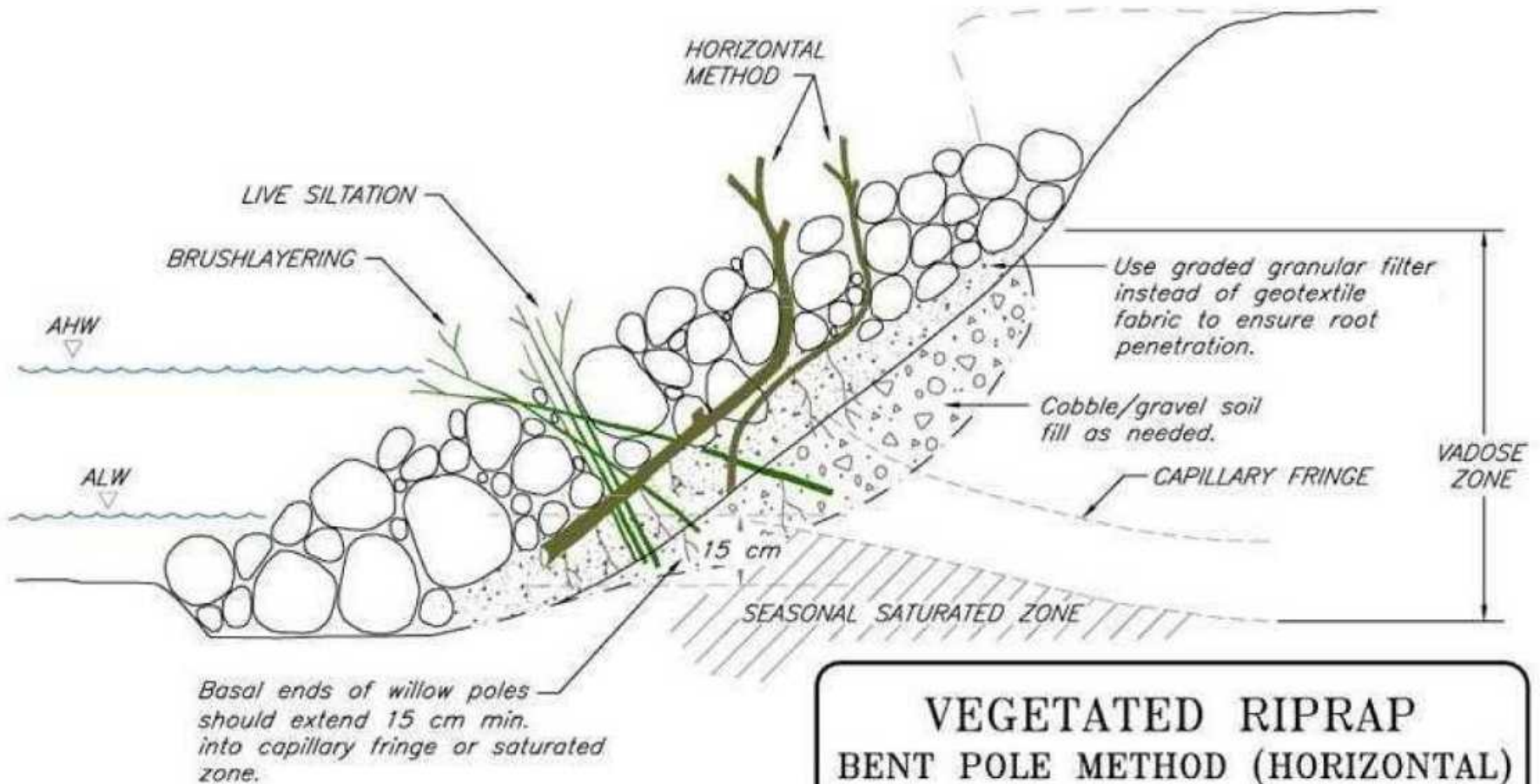
1. As a general rule, place basal ends of the cuttings 15 cm into the capillary fringe or seasonal saturated zone.
2. Bend individual poles up through the riprap during placement while ensuring contact of the stem with native ground. Laying poles 'horizontally' is an efficient and cost-effective way to maximize rooting.
3. Graded, granular filter is preferable to geotextile fabric to improve root penetration or slip poles through slits cut into fabric.
4. Place soil fill (cobbles, gravel, soil) around cuttings and 'water in' if possible.



**VEGETATED RIPRAP
WILLOW BUNDLE METHOD (HORIZONTAL)**

NOTES:

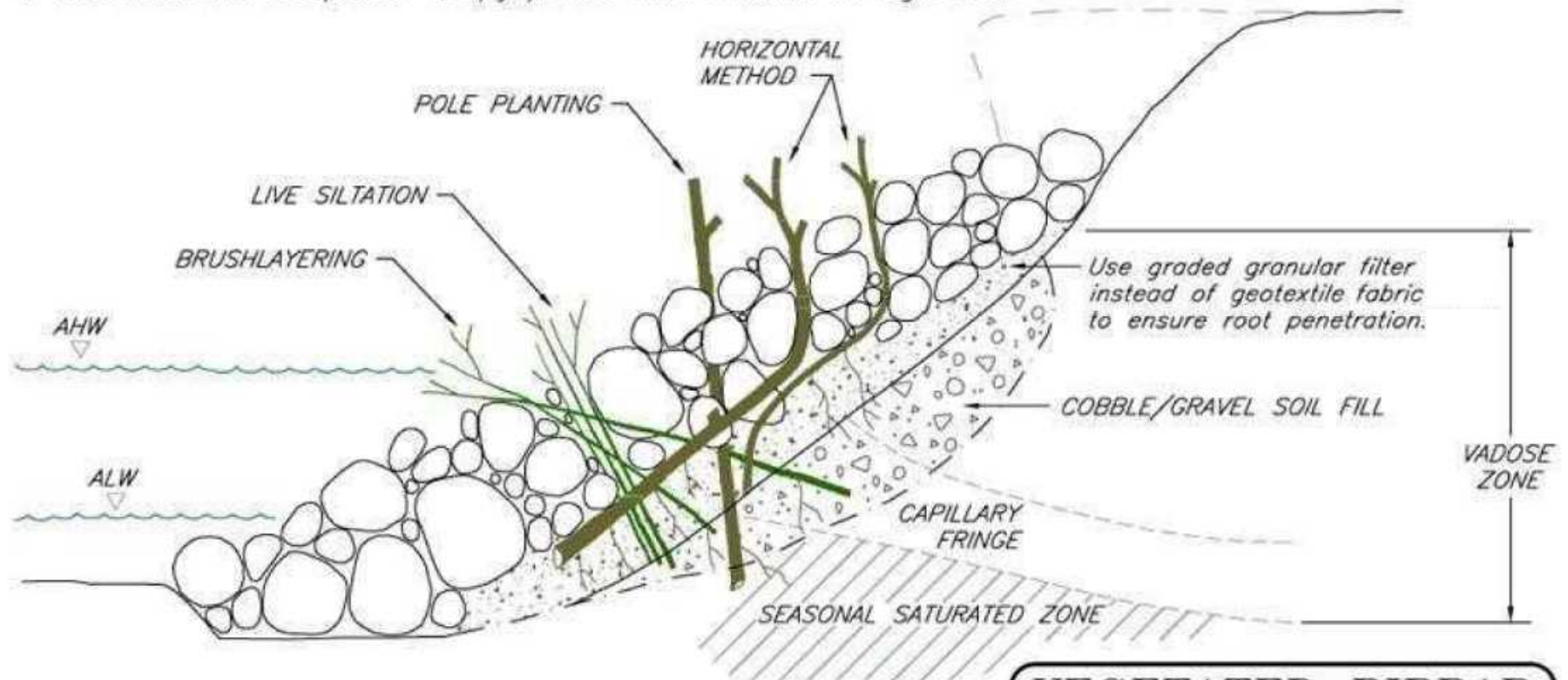
1. Integrate brushlayering, pole planting and live siltation techniques during rock placement to ensure contact with native ground. Laying poles 'horizontally' is an efficient and cost-effective way to maximize rooting.
2. As a general rule, place basal ends of the cuttings 15 cm into the capillary fringe or seasonal saturated zone.
3. Graded, granular filter is preferable to geotextile fabric to improve root penetration or slip poles through slits cut into fabric.
4. Place soil fill (cobbles, gravel, soil) around cuttings and 'water in' if possible.



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NOTES:

1. Integrate brushlayering, pole planting and live siltation techniques during rock placement to ensure contact with native ground.
2. Plant deeply if possible. Place cuttings deeply into vadose zone, into the capillary fringe or 15 cm into the seasonal saturated zone (water table).
3. Graded, granular filter is preferable to geotextile fabric to improve root penetration or slip poles through slits cut into fabric.
4. Place soil fill (cobbles, gravel, soil) around cuttings and 'water in' if possible.
5. Place riprap carefully, do not end dump. Some damage to brush layers and willow poles is unavoidable and acceptable. Deeply planted willow material will regenerate.



**VEGETATED RIPRAP
DURING CONSTRUCTION
SUMMARY OF TECHNIQUES**

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