Turf Reinforcement Mats

DRAINAGE CONTROL TECHNIQUE

Low Gradient		Velocity Control		Short Term	
Steep Gradient	✓	Channel Lining	✓	Medium-Long Term	
Outlet Control		Soil Treatment		Permanent	✓

Symbol

Photo 1 – Permanent turf reinforcement mat (black) surrounded by temporary erosion control blankets

Photo 2 – Reinforced grass with the grass layer removed as part of a field day demonstration

Key Principles

1. The principal hydraulic design parameter is either the allowable flow velocity or allowable shear stress.
2. The key operational issues include provision of appropriate anchorage (critical if surface flows are possible soon after placement), the provision of good contact with the in-situ soil, and the prompt establishment of grass (if seeding is performed after placement).
3. Synthetic reinforced mats can entrap and/or impact ground-burrowing wildlife.
4. Consideration should be given to the risk and consequences of damage by grass fires.

Design Information

Turf reinforcement mats (TRMs) are a category of *Erosion Control Mats* (ECMs), which fall under the general category of 'Rolled Erosion Control Products' (RECPs).

Not all turf reinforcement mats can provide adequate erosion control in the absence of vegetation (i.e. after grass dieback, fire, or during periods of drought). Some turf reinforcement mats provide only limited defence against the effects of raindrop impact. Such mats have an open structure and usually contain a biodegradable mulch layer.

It is noted that 'hydraulic performance', measured in terms of allowable flow velocity or shear stress, is just one of many issues requiring consideration when selecting the preferred erosion control mat.

With respect to hydraulic performance, selection and design should be based on manufacturer's design specifications in circumstances where reliable data is available (i.e. data confirmed by laboratory testing). Table 1 can be used to identify the appropriate classification (Class) of mat (note; Table 1 does not represent a universally adopted classification system).

Table 1 – Default selection guide for erosion control mats

Class	1						2			3			
Type	**A**	**B**	**C**	**AX**	**BX**	**CX**	**A**	**B**	**C**	**A**	**B**	**C**	**D**
Typical location	Rural			Urban			Embankment, chutes & drainage channels						
Maximum bank slope (X:1)	4.0	2.5	2.0	4.0	2.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.0
Permissible shear stress (Pa)	N/A	50	70	N/A	50	70	N/A	95	95	95	95	170	240
Allowable 'sheet' flow velocity (m/s)	<1	1.1	1.3	<1	1.1	1.3	1.3	1.5	1.5	1.5	N/A		
Allowable 'concentrated' flow velocity (m/s)	<1	2.2	2.6	1.4	2.2	2.6	1.7	3.0	3.0	3.0	3.0	3.7	3.9
Mowing required during plant establishment				✓	✓	✓				✓	✓	✓	✓
Pedestrian traffic likely to occur during plant establishment				✓	✓	✓				✓	✓	✓	✓
Wildlife friendly	✓			✓			✓						
Within 9m of airport runways				✓	✓	✓							

Erosion control blanket/mat classification system

A classification system for erosion control blankets and mats (e.g. Class 1, Type A) is provided in Table 2. In general terms, this classification system is based on the following distinctions.

Class 1 blankets:
Class 1 includes those temporary, light-duty Rolled Erosion Control Products (RECPs) that are primarily used in areas of "sheet" flow, and thus are termed *Erosion Control Blankets*. A further division is made by separating those products best used away from pedestrian areas (Type A, B & C), and those products used in areas where the blankets could be subject to foot traffic or are likely required to experience mowing during the service life of the blanket (Type AX, BX & CX).

Class 2 blankets/mats:
Class 2 includes those temporary, heavy-duty Rolled Erosion Control Products (RECPs) that are primarily used in areas of medium shear stress such as embankment higher than 3m in tropical areas, and drainage channels. These products are termed *Erosion Control Blankets or Mats* depending on their use.

Class 3 mats:
Class 3 comprises permanent, heavy-duty Rolled Erosion Control Products (RECPs) that are primarily used in areas of high shear stress such as drainage channels and spillways/chutes. These products are typically termed *Erosion Control Mats*.

Class 3 - Type B, C and D Turf Reinforcement Mats (TRM) are permanent, 100% synthetic, open-weaved mats that shall be continuously bonded at the filament intersections. TRM mats shall be completely filled with topsoil immediately after installation. Loosely packaged discontinuous filaments are not permitted in this category.

To prevent initial soil loss, Class 3 TRM mats, Type B, Type C, and Type D, must be covered with either an approved soil stabiliser, or approved *Erosion Control Blanket* (Class 1 or 2) immediately following installation. These materials shall be considered incidental to the installation of Class 3 TRM mats.

Table 2 – Classification of erosion control blankets and mats

Class	1						2			3			
Type	A	B	C	AX	BX	CX	A	B	C	A	B	C	D
Typical location [1]	Rural			Urban			Embankment, chutes & drainage channels						
Permissible shear stress (Pa) [2]	N/A	50	70	N/A	50	70	N/A	95	95	95	95	170	240
Maximum slope [3] (X:1)	4.0	2.5	2.0	4.0	2.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.0
RUSLE C-factor (maximum)	0.2			0.2			N/A			N/A			
Used in drainage channels	No	[4]	[4]	No	[4]	[4]	Yes			Yes			
Turf reinforce-ment mat (TRM)	No			No			No			No	Yes		
Minimum service life	3 months [5]			3 months [5]			1 years [6]			Permanent matting			
Thickness (mm)	N/A			N/A	9	9	N/A			N/A			
Able to withstand mowing [7]	N/A			Yes			Yes			Yes			
Able to withstand foot traffic [8]	N/A			Yes			Yes			Yes			
Wildlife friendly [9]	Yes	N/A		Yes	N/A		Yes	N/A		[10]			
Anchor pins	Any			Biodegradable [11]			Any			Any			
Primary blanket or matting component													
Primary material	Organic			Organic			[12]	Organic [13]		Synthetic			
Manufacture	Non-woven			Non-woven			[14]	[15]	[16]	N/A	Woven/welded		
Netting component													
Netting	No	Allowed		No	Allowed		No	[17]	Yes	Yes			
Type	N/A	Any		N/A	Organic		N/A	[18]	[19]	Synthetic			
% of weight (max)	N/A	15%		N/A	15%		N/A	15%		N/A			
Photodegradable	Allowable			Allowable			N/A		Yes	No			
Biodegradable	Allowable			100%			100%		Yes	No			
Stitching properties	N/A	As for netting		N/A	As for netting		N/A	As for netting		As for netting			

Notes:

[1] 'Typical location' is a general classification. The primary objective is to ensure ongoing safety to pedestrian traffic potentially affected by rusty, metallic anchoring pins/staples. Note; galvanised pins/staples are generally not acceptable due to limited anchorage of the blanket/mat.

[2] Failure in shear is defined by either, separation of 10% of the blanket from the soil surface, and/or the equivalent loss of 12mm of soil from the treated area (as per ASTM D6460-99 or equivalent).

[3] Maximum slope applied only when significant rainfall is possible prior to plant establishment.

[4] Blankets/mats can be used within minor (low velocity) drainage channels or on the banks of waterways in locations where revegetation is expected to occur before subject to high flow velocity.

[5] Service life defined by the maintenance of a maximum Cover Factor (C) of 0.20 based on the Revised Universal Soil Loss Equation (RUSLE) prior to establishment of the required vegetation cover. A minimum 6 months service life may be required in locations where vegetation establishment is known to be slow, such as during winter months.

[6] Service life defined by either the maintenance of a maximum Cover Factor (C) of 0.20 based on the Revised Universal Soil Loss Equation (RUSLE) prior to establishment of the required vegetation cover, or separation of 10% of the blanket from the soil surface, and/or the equivalent loss of 12mm of soil from the treated area (as per ASTM D6460-99 or equivalent).

[7] Requirement to allow for mowing of the treated surface without causing damage to the blanket applies to those areas where mowing of the emerging grass will likely be required prior to establishment of the required (e.g 70% cover) vegetation cover.

Table 2 notes (continued):

[8] Requirement to allow for occasional foot traffic without causing damage to the blanket applies to those areas where occasional foot traffic is anticipated prior to establishment of the required (e.g 70% cover) vegetation cover.

[9] Requirement for the blanket to accommodate potential ground-dwelling wildlife is typically required when the blanket is placed adjacent to wildlife areas such as bushland, wildlife corridors, waterways, and land containing grazing animals.

[10] Turf reinforcement mats can potentially affect and/or be damaged by grazing animals.

[11] Anchorage pins/staples may be required to be biodegradable (e.g not metal) in order to minimise the risk of injury to humans, domestic animals, or wildlife following the long-term exposure of rusty or otherwise dangerous obstacles buried in the soil. Biodegradable anchorage pins/staples are also required on all blanket/mat installations within 9m of an airport runway. Note; it is the 'rusting' of metal staples that provides much of their anchorage properties.

[12] Manufactured from 100% jute or coir fibres, or combination there of.

[13] The parent material of Class 2 Type B & C blankets/mats must have a maximum water absorption rate of 300%, by weight (ASTM D1117 or equivalent); and a maximum swell (wet thickness change) of 30% (as per ASTM D1777 or equivalent). The lignin content must be greater than 38% (as per Technical Assoc of the Pulp and Paper Industry test method T222 or equivalent).

[14] Jute and coir products may be either non-woven (thick blankets), or woven (mesh). Warning, jute mesh may not be able to achieve the 1-year service life if located within a moist environment.

[15] Woven mats allowed with a maximum opening of 12mm.

[16] Woven or non-woven material allowed.

[17] Blanket can be reinforced with netting made from organic fibres only (e.g. jute or coir).

[18] Only organic fibres are allowed to avoid wildlife being trapped within the netting.

[19] Non-organic, photodegradable or biodegradable netting allowed.

Table 2presents the flow stability properties of erosion control blankets and mats in terms of permissible shear stress measured in units of Pascals (Pa). Permissible shear stress is considered a more reliable measure of blanket's resistance to damage by water flow and is the measure typically used within Europe and USA; however, allowable flow velocity is more commonly used within Australia.

Table 3 defines the relationship between allowable shear stress (Pa) and allowable flow velocity (m/s) for various values of hydraulic radius (R) and assumed Manning's n roughness presented within the table. The table is appropriate for non-vegetated, three-dimensional turf reinforcement mat (TRM) such as Class 3, Types B, C and D mats.

Table 3 – Equivalent allowable flow velocity (m/s) for a given permissible shear stress (Pa) for non-vegetated turf reinforcement mats

Assumed Manning's roughness	Hydraulic radius (m)	Permissible shear stress (Pa)						
		50	**70**	**95**	**100**	**150**	**170**	**240**
0.06	**0.05**	0.65	0.72	0.79	0.85	0.91	0.97	1.02
0.04	**0.10**	1.09	1.22	1.33	1.44	1.54	1.63	1.72
0.036	**0.15**	1.29	1.45	1.58	1.71	1.83	1.94	2.05
0.033	**0.20**	1.48	1.66	1.81	1.96	2.09	2.22	2.34
0.031	**0.25**	1.64	1.83	2.00	2.16	2.31	2.45	2.59
0.029	**0.30**	1.80	2.02	2.21	2.38	2.55	2.70	2.85
0.026	**0.40**	2.11	2.36	2.58	2.79	2.98	3.16	3.33
0.023	**0.50**	2.47	2.77	3.03	3.27	3.50	3.71	3.91
0.02	**1.0**	3.19	3.57	3.91	4.23	4.52	4.79	5.05
0.02	**1.5**	3.42	3.82	4.19	4.52	4.83	5.13	5.40
0.02	**2.0**	3.59	4.01	4.39	4.74	5.07	5.38	5.67
0.02	**2.5**	3.72	4.16	4.56	4.92	5.26	5.58	5.88
0.02	**3.0**	3.84	4.29	4.70	5.07	5.43	5.75	6.07

For detail design information refer to Hewlett et al. (1987) – CIRIA Report 166, *"Design of Reinforced Grass Waterways".*

Table 4 provides allowable shear stress values recommended in Fifield (2001).

Table 4 – Maximum allowable shear stress and flow velocity [1]

Material	Test Time (hr)	Shear Stress (kg/m^2)
TRM on bare soil	0.5	240
	50	95
TRM on vegetated ground	0.5	380
	50	240
Composite TRM on bare soil	0.5	240
	50	95
Composite TRM on vegetated ground	0.5	380
	50	240

[1] Source: Fifield (2001) *"Designing for Effective Sediment and Erosion Control on Construction Sites".*

Table 5 provides typical Manning's (n) roughness values for non-vegetated turf reinforcement mats (i.e. flow condition during the initial stage of grass establishment).

Table 5 – Manning's roughness for non-vegetated turf reinforcement mats [1]

Material	Flow depth less than 150mm	Flow depth of 150 to 600mm	Flow depth greater than 600mm
Non-vegetated turf reinforcement mats	0.036	0.026	0.020

[1] Source: Fifield (2001) *Designing for Effective Sediment and Erosion Control on Construction Sites*

Table 6 provides typical Manning's (n) roughness values for grassed surfaces with a grass blade length of 50 to 150mm. It should be noted that significant variations can occur in the channel roughness depending on the type, health and density of grass.

Table 6 – Manning's roughness for grassed channels (50–150mm blade length) [1]

Hydraulic Radius (m)	Swale Slope (%)					
	0.1	0.2	0.5	1.0	2.0	5.0
0.1	—	—	—	0.105	0.081	0.046
0.2	—	0.091	0.068	0.057	0.043	0.030
0.3	0.078	0.064	0.053	0.043	0.031	0.030
0.4	0.063	0.054	0.044	0.033	0.030	0.030
0.5	0.056	0.050	0.038	0.030	0.030	0.030
0.6	0.051	0.047	0.034	0.030	0.030	0.030
0.8	0.047	0.044	0.030	0.030	0.030	0.030
1.0	0.044	0.044	0.030	0.030	0.030	0.030
>1.2	0.030	0.030	0.030	0.030	0.030	0.030

[1] Values are presented to three significant figures for convenience, but this should not imply the values are accurate to three significant figures. A Manning's roughness of 0.03 is adopted for hydraulic radius greater than 1.2 metres in accordance with recommendations of original research, however this may not always be appropriate.

Figure 1 presents a diagrammatic representation of a three-dimensional turf reinforcement mat.

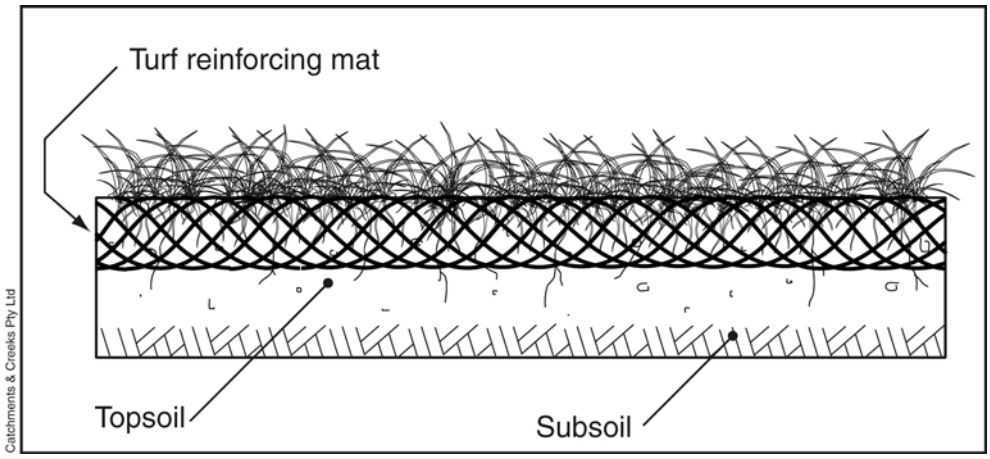

Figure 1 – Diagrammatic representation of a three-dimensional turf reinforcement mat

Figure 2 demonstrates the anchorage (trenching) of the upstream end of each mat.

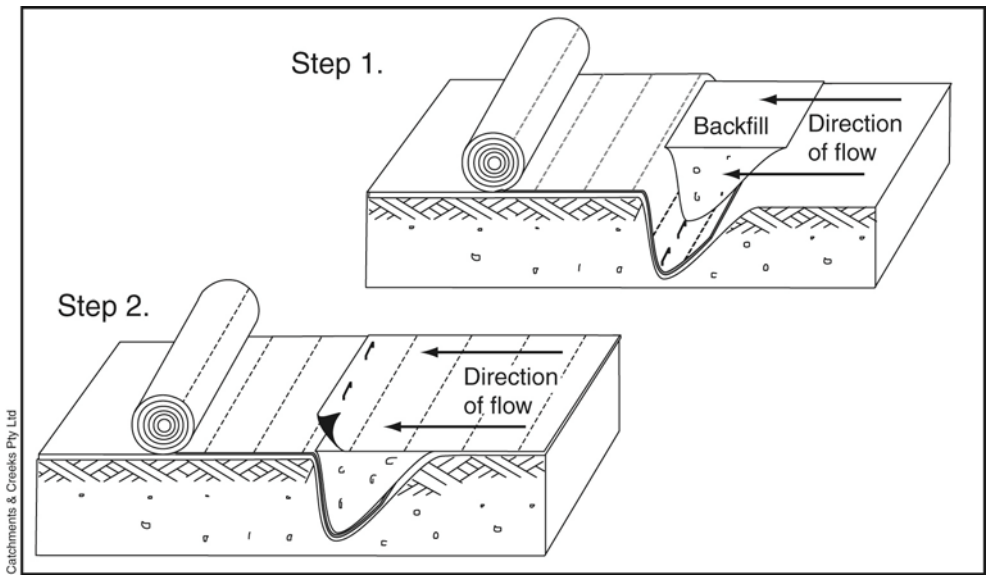

Figure 2 – Anchoring of upstream edge of mat

Figure 3 demonstrates the placement of mats within wide channels that have an effective flow width greater than the width of a single mat.

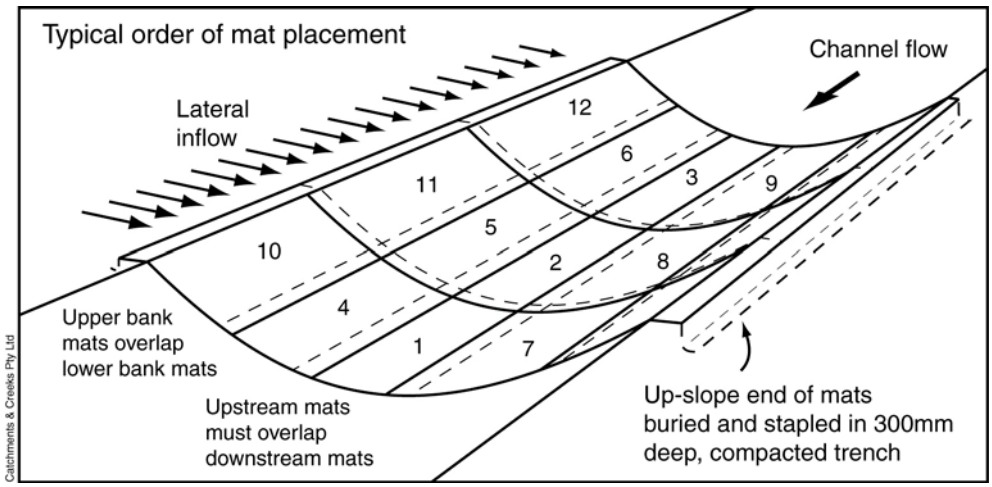

Figure 3 – Placement of mats along channel which received lateral inflow

Photo 6 – TRM prior to placement

Photo 7 – Pre-grown TRM

Photo 8 – Lightly reinforced turf

Photo 9 – Synthetic root reinforcing with organic mulch layer

Photo 10 – TRM containing permanent, synthetic "mulch" layer

Photo 11 – Three-dimensional root reinforcing mat

Photo 12 – TRM showing use of wooden pegs (note emerging grass)

Photo 13 – Use of metal staples is generally discouraged

Description

Turf reinforcement mats (TRMs) are a category of *Erosion Control Mats* (ECMs), which fall under the general category of 'Rolled Erosion Control Products' (RECPs).

Turf Reinforcement Mats (TRMs) usually consist of either a two-dimensional or three-dimensional mesh made from synthetic materials, or a combination of both synthetic and biodegradable materials. They can be either laid on the surface of the channel or buried just below the surface.

Purpose

Typically used to provide permanent protection to high velocity drainage channels and chutes.

Limitations

Synthetic-based products have limited use in fauna inhabited bushland areas where ground-dwelling animals can become entangled in the mesh.

The ability of reinforced grass to withstand grass fires is currently unknown. This issue is particularly important when it is used as a lining in permanent catch drains.

Care must be taken if planting any form of vegetation on these synthetic mats other than grass. The synthetic mesh can choke the root system of larger plants

Advantages

Quick installation.

Able to withstand high flow velocities.

Wide variety of commercially available products exist that are suitable for a variety of uses.

Most products provide instant erosion protection.

Disadvantages

Environmental problems can result from the use of non-biodegradable materials in bushland areas.

Slashing and normal grass cutting can cut or otherwise damage partially buried mats.

Can be difficult to repair if damaged.

Removal of the mat (i.e. during drain widening or relocation) may require removal and disposal of valuable topsoil.

Common Problems

Grass roots can become root bound within the topsoil provided with pre-grown TRM products.

Special Requirements

Four general requirements exist for effective protection against erosion:

- good contact must be achieved;
- seepage flow under the channel liner should be discouraged;
- surface irregularities removed;
- good anchorage must be provided.

Particular attention should be given to the crest, toe and sides to avoid erosion and uplifting.

By definition, turf reinforcement mats are best used in partnership with grass.

Mats should not be placed directly over a dispersive soil. A minimum 100mm (depending on location) layer of non-dispersive soil should placed over the dispersive soil prior to placement of the mat.

Special attention needs to be given to the free movement of lateral inflows towards the invert of the channel. Lateral inflows may be deflected by the upper edge of the mat causing a rill to form that may eventually undermine the mat.

The edge of the mats along the outer edges of the treated area needs to be buried and stapled into a 200mm deep trench. The trench should then be backfilled flush with the surrounding ground to allow the free entry of water into the channel.

Site Inspection

Ensure the lining is adequately anchored to the soil.

Ensure the mats overlap in direction of flow.

Check that lateral inflows can freely enter the channel.

Check for rill erosion along the up-slope edge of the mats.

Installation

The method of installation varies with the type of mat. Installation procedures should be provided by the manufacturer or distributor of the product. A typical installation procedure for non pre-grown TRMs is described below, but should be confirmed with the product manufacturer or distributor.

1. Refer to approved plans for location, extent and construction details. If there are questions or problems with the location, extent, or method of installation contact the engineer or responsible on-site officer for assistance.
2. Turf reinforcement mats shall be stored away from direct sunlight or covered with ultraviolet light protective sheeting until the site is ready for their installation.
3. Remove all trees, brush, stumps, and other objectionable material from the proposed channel area and dispose of properly.
4. Excavate the channel and shape it to neat lines and dimensions as shown on the approved plans. Over-cut the channel 50mm in depth to allow for bulking during seedbed preparations and turf build-up.
5. Ensure any surface irregularities are removed.
6. If the channel is to be grassed, prepare a smooth seed bed of approximately 75mm of topsoil, seed, fertilise, water and rake to remove any remaining surface irregularities.
7. Refer to manufacturer's advice regarding placement of seed before or after placement of the mats.
8. Excavate a 300mm deep by 150mm wide anchor trench along the full width of the upstream end of the area to be treated.
9. At least 300mm of the mat is anchored into the trench with the roll of matting resting on the ground up-slope of the trench.
10. Staple the fabric within the trench at 200 to 250mm spacing using 100mm wide by 150mm penetration length U-shaped, 8 to 11 gauge wire staples. Narrower U-sections may easily tear the matting when placed under stress.
11. In large drainage channel where the width of the channel is more than the width of one mat, install each parallel mat such that mat higher up the channel bank always overlaps the mat lower down the bank by at least 300mm. This usually requires the mats located along the channel bed to be unrolled first, followed by each consecutive parallel mat located higher up the channel bank.
12. When all mats have been anchored within the trench across the full width of the treated area, then the trench is backfilled and compacted. The mats are then unrolled down the slope such that each mat covers and protects the backfilled trench.
13. When spreading the mats, avoid stretching the fabric. The mats should remain in good contact with the soil.
14. If the channel curves, then suitably fold (in a downstream direction) and staple the fabric to maintain the fabric parallel to the direction of channel flow.
15. Staple the surface of the matting at 1m centres. On irregular ground, additional staples will be required wherever the mat does not initially contact the ground surface.
16. At the end of each length of mat, a new trench is formed at least 300mm up-slope of the end of the mat such that the end of the mat will be able to fully cover the trench. A new roll of matting is then anchored within this trench as per the first mat. After this new mat has been unrolled down the slope, the up-slope mat can be pinned in place fully covering the new trench and at least 300mm of the down-slope mat. The process is continued down the slope until the desired area is fully covered.
17. In high-velocity channels, intermediate anchor slots are usually required at 10m intervals down the channel.
18. Anchor the outer most edges (top and upper most sides) of the treated area in a 300mm deep trench and staple at 200 to 250mm centres.
19. Ensure the turf extends up the sides of the channel at least 100mm above the elevation of the channel bed, or at least to a sufficient elevation to fully contain expected any channel flow that is considered likely to occur within the first month after placement.

20. On slopes of 3:1(H:V) or greater, or wherever erosion may be a problem, or in situations where high flow velocities are likely within 2-weeks of placement, secure the individual strips with wooden pegs.
21. If seeding is required post placement of the mats, then apply seed as per supplier's instructions.
22. If pre-grown turf is used, then ensure that intimate contact is achieved and maintained between the turf reinforcement and the soil such that seepage flow beneath the turf is avoided. Once fixed in place, the mats should be rolled with a roller weighing 60 to 90kg/m width, then watered after grass seeding has occurred.
23. Ensure that water entering the channel will flow freely over the finished grass surface.
24. Ensure surface water flowing laterally into the channel will not be deflected along the up-slope edge of the turf causing soil erosion.
25. Damaged matting shall be repaired or replaced.

Additional requirements associated with use near airport pavements

1. Only erosion mats that are double netted shall be allowed within 3.0m of any airport pavement used by aircraft with the exception of airports classified as air carrier or corporate/transport. If the airport is classified as an air carrier or corporate/transport, there will be no erosion mats allowed within 9.0m of pavement used by aircraft.
2. Only biodegradable anchoring devices shall be allowed in the installation of any erosion mat for airport applications. No metal staples will be allowed.

Maintenance

1. During the initial root establishment period, check the treated channel after every runoff-producing rainfall event.
2. If damage has occurred, immediately initiate repairs with turf or by seeding as appropriate.
3. Remove all significant sediment or debris deposition to maintain the required hydraulic capacity of the channel.
4. Maintain a healthy and vigorous grass condition whenever and wherever possible, including watering and fertilising as needed.
5. Maintain a minimum grass blade length of 50mm.
6. Mowing should not be attempted until the turf is firmly rooted, usually 2 to 3 weeks after laying.
7. All reasonable measures shall be taken to collect grass clippings immediately after mowing if their removal by subsequent channel flows would contaminate sensitive downstream waterways or otherwise cause undesirable environmental harm.