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United States
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Federal Highway
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2300–Recreation
April 2008
0823–2813–MTDC

Geosynthetics for Trails in Wet Areas: *2008 Edition*

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USDA Forest Service • Missoula Technology and Development Center
5785 Hwy. 10 West • Missoula, MT 59808-9361
Phone: 406–329–3978 • Fax: 406–329–3719
E-mail: *wo_mtdc_pubs@fs.fed.us*

This document was produced in cooperation with the Recreational Trails Program of the Federal Highway Administration, U.S. Department of Transportation.

Geosynthetics for Trails in Wet Areas:
2008 Edition

James "Scott" Groenier
Project Leader

Steve Monlux
Geotechnical Engineer, Northern Region (retired)

Brian Vachowski
Project Leader, MTDC (retired)

USDA Forest Service
Technology and Development Program
Missoula, MT

7E72A67 FHWA Trail Geosynthetics

April 2008

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Acknowledgments

This report updates "Geosynthetics for Trails in Wet Areas: 2000 Edition," by Steve Monlux and Brian Vachowski. Scott Groenier and Heather Matusiak updated the 2008 edition, and Brian Vachowski helped coordinate the report's review and prepare it for publication. Others throughout the Forest Service assisted by reviewing the drafts. This document was produced with cooperative funding from the Recreational Trails Program of the Federal Highway Administration, U.S. Department of Transportation.

Introduction

Trails in soft, saturated soils present special challenges for trail managers. Muddy trails cause problems for livestock and hikers, both of whom tend to skirt the edges of mud holes. The use along the edge of the trail increases the area being damaged. Improperly constructed trails in wet areas lead to erosion, soil compaction, sedimentation, multiple trails where only one is needed, and unhappy trail users. Traditional trail construction methods for wet areas include turnpike or puncheon. These methods have worked well where rock or wood materials are readily available. However, geosynthetics can increase the effectiveness of construction methods and offer additional alternatives.

Geosynthetics are synthetic materials (usually made from synthetic polymers) used with soil or rock in many types of construction. Their use has grown significantly in road construction for the past 40 years, and in trail construction for the past 15 years.

Guidelines on the use of geosynthetics in trail construction have not been readily available to trail managers. The information presented here applies some roads technology to trail design and construction in six categories:

- General information on geosynthetic products
- Basic geosynthetic design concepts
- Specific design diagrams for trail construction over wet, saturated soils
- A list of product manufacturers and recommended physical properties
- Identification of unsuitable tread fill materials
- Case studies

Highlights...

- Geosynthetic materials can help prevent trails from failing in wet areas.
- The many types of geosynthetic materials perform three major functions: separation, reinforcement, and drainage.
- This report provides information on the different types of geosynthetic materials, explains basic geosynthetic design concepts, and provides detailed product specifications and procurement sources.

Geosynthetics—General Information

Geosynthetics have numerous uses in civil engineering. The basic functions of geosynthetics include:

- **Reinforcement**—The geosynthetic acts as a reinforcing element in a soil mass or in combination with the soil to produce a composite that has improved strength and deformation properties. For example, geotextiles and geogrids are used to add tensile strength to a soil mass when these are vertical or near-vertical changes in grade (reinforced soil walls).
- **Separation**—The geosynthetic acts to separate two layers of soil that have different particle size distributions. For example, geotextiles are used to prevent road base materials from penetrating into soft underlying subgrade soils, maintaining design thickness and roadway integrity. Separators also help to prevent fine-grained subgrade soils from being pumped into permeable granular road bases.
- **Drainage—**The geosynthetic acts as a drain to carry fluid flows through less permeable soils. For example, geotextiles are used to dissipate pore water pressure at the base of roadway embankments.
- **Filtration—**The geosynthetic acts like a sand filter by allowing water to move through the soil while retaining the soil particles. For example, geotextiles are used to prevent soils from migrating into drainage aggregate or pipes while maintaining flow through the system. Geotextiles are also used below riprap and other armor materials in coastal and riverbank protection systems to prevent soil erosion.
- **Containment**—The geosynthetic acts as a relatively impermeable barrier to fluids or gases. For example, geomembranes, thin film geotextile composites, geosynthetic clay liners (GCLs) and field-coated geotextiles are used as fluid barriers to impede the flow of liquids or gases.
- **Erosion Control**—The geosynthetic acts to reduce soil erosion caused by rainfall impact and surface water runoff. For example, temporary geosynthetic blankets and permanent lightweight geosynthetic mats are placed over the otherwise exposed soil surface on slopes. Geotextile silt fences are used to remove suspended particles from sediment-laden runoff. Some erosion control mats are manufactured using biodegradable wood fibers.

Geosynthetic materials (figures 1 and 2) include geotextiles (construction fabrics), geonets, geogrids, and geocomposites, such as sheet drains and geocells. All these materials become a permanent part of the trail, but must be covered with soil or rock to prevent damage by ultraviolet light. Geosynthetic erosion control material also has important uses for slope and bank protection, but this report does not discuss those uses.

Manufacturers of erosion control geosynthetics are listed in the “Geosynthetic Product Information” section. Please contact the manufacturers for additional information. Geoblock, Lockgrid, EcoGrid and Grasspave2 are used for turf reinforcement and will be discussed. Because all these products are synthetic, their use in wilderness should be reviewed and approved before they are used.

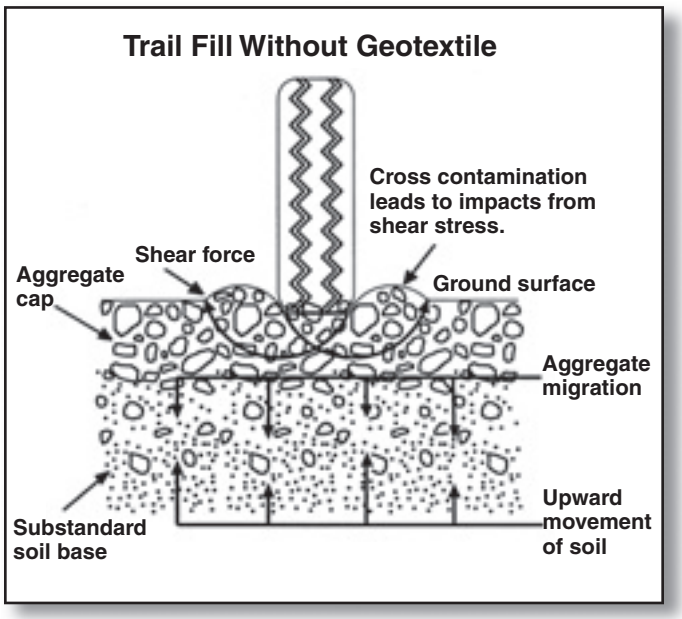

Figure 1—Trail fill material without geotextile. The aggregate will lose strength as the fill material mixes with the subbase.

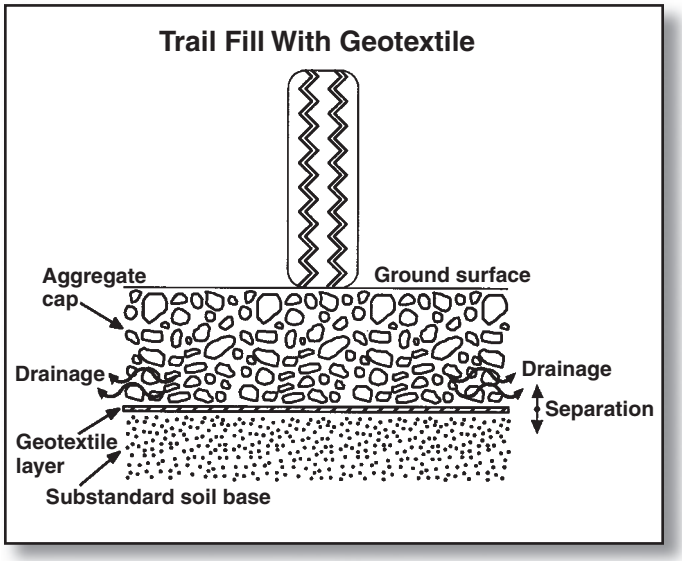

Figure 2—Trail fill material with geotextile. The geotextile layer enhances the trail performance by providing separation, reinforcement, and drainage.

Geotextiles

Geotextiles (figure 3) are the most widely used geosynthetic. Geotextiles are often called construction fabrics. They are constructed from long-lasting synthetic fibers that form a fabric held together by weaving, heat bonding, or other means. Geotextiles are primarily used for separation and reinforcement over wet, unstable soils. They have the ability to support loads through tensile strength and can allow water, but not soil, to seep through. They can also be used in drainage applications where water flow is much greater than normal for wet areas. The physical requirements listed for all geotextiles in the "Geosynthetic Product Information" section are stringent enough that the products will work for properly designed high-flow drainage applications.

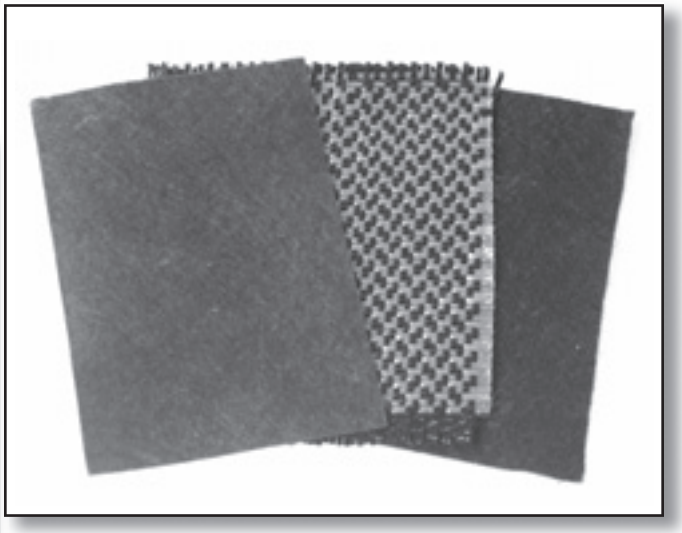

Figure 3—Geotextiles are made from woven and nonwoven fabrics. Felt-like products are easier to work with than slick products that are heat bonded, woven, or made from slit film. Felt-like products are easier to cut and their flexibility makes them easier to place on curved trail sections.

Geonets

Geonets or geonet composites (figure 4) have a thin polyethylene drainage core that is covered on both sides by geotextile. Geonets are primarily used for drainage, but also may function as separation and reinforcement. Because geonets have a core plus two layers of geotextile, they provide more reinforcement than a single layer of geotextile.

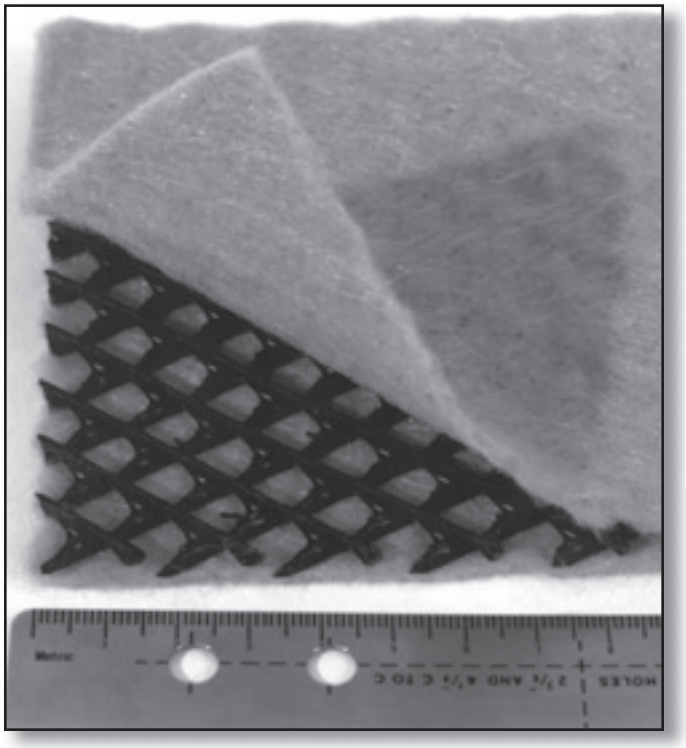

Figure 4—Geonets with the two layers of geotextile shown are considered a geocomposite—the core of geonet allows drainage to the sides that is normally adequate for the seepage found under trails in wet areas. The geotextile provides reinforcement and separation.

Geogrids

Geogrids (figure 5) are made from polyethylene sheeting that is formed into very open gridlike configurations. Geogrids are good for reinforcement because they have high tensile strengths and because coarse aggregate can interlock into the grid structure.

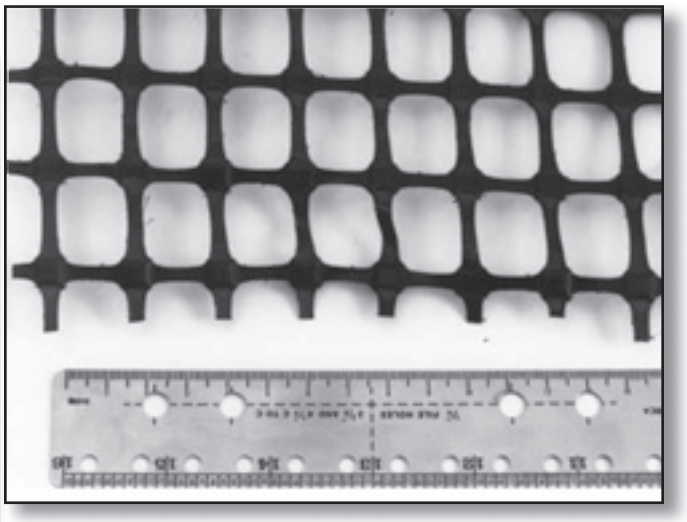

Figure 5—Geogrids are normally placed on top of a layer of geotextile for separation from saturated soils in wet areas.

Geocells

Geocells (figure 6) are usually made from polyethylene strips 50 to 200 millimeters (2 to 8 inches) high that have been bonded to form a honeycomb. The product is shipped collapsed so it is more compact. During installation, the material is pulled open and the honeycomb structure is staked to the ground surface. Each of the cells is filled and compacted. Compacting trail tread material within the cell increases the strength of the layer and reduces settlement into soft, saturated soils. Geocells are good for reinforcement and reduce the amount of fill material required.

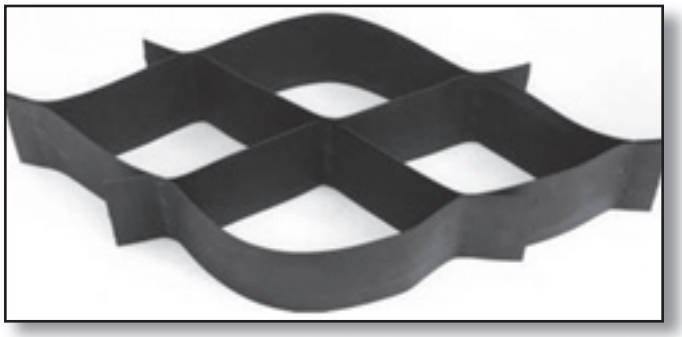

Figure 6—Geocell usually has geotextile under it for separation from wet, saturated soil. Normally, the cells are filled with a soil that drains well.

Geocomposites—Sheet Drains

Sheet drains (figure 7) are a form of geocomposite material made with a drainage core and one or two layers of geotextile. The core of a sheet drain usually is made of a polyethylene sheet formed into the shape of an egg crate. The core provides an impermeable barrier unless it has been perforated by the manufacturer. Perforated cores are always covered with geotextile on both sides to prevent soil from clogging the drainage passages. Geotextile is bonded to one or both sides of the core to provide filtration and separation. When sheet drains are used under trail tread material, they provide separation, reinforcement, and drainage. Because sheet drains have greater bending strength than geotextiles or geonets, less tread fill may be needed above them. Sheet drains also can be installed vertically in covered trenches beside the trail to drain off subsurface water.

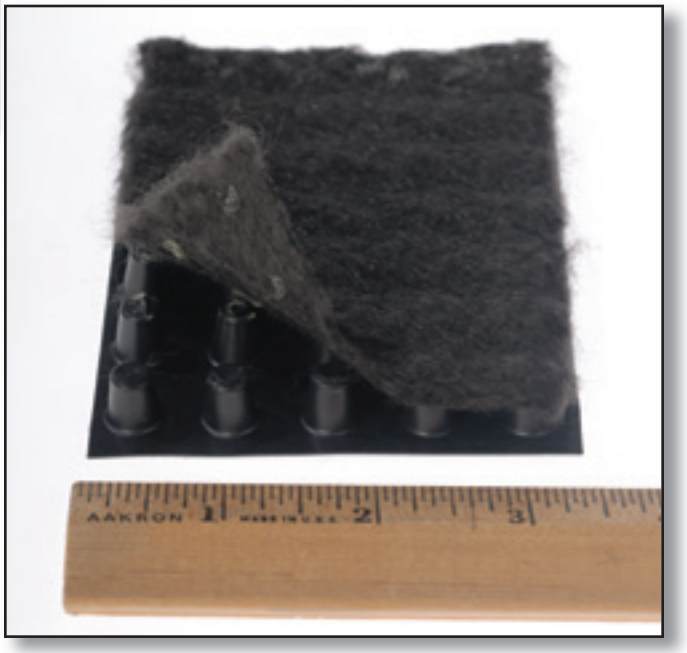

Figure 7—Geocomposites such as sheet drains have a large cross section that allows drainage. If geotextiles are placed under the trail tread, the sheet drain should be oriented with the geotextile on the bottom and the plastic core on top. This orientation reduces the amount of fill needed.

Geo-Others—Turf Reinforcement

Other proprietary products used for reinforcement are considered geo-others. Typically, they are manufactured from recycled plastics to protect turf from rutting, erosion, and soil compaction. Geo-other products include Geoblock (figure 8), Lockgrid, EcoGrid, and Grasspave2 (figure 9). The MTDC report "Managing Degraded Off-Highway Vehicle Trails in Wet, Unstable, and Sensitive Areas" (Meyer 2002) has information on turf reinforcement materials and their installation.

Figure 9—Grasspave2 is another product for turf reinforcement.

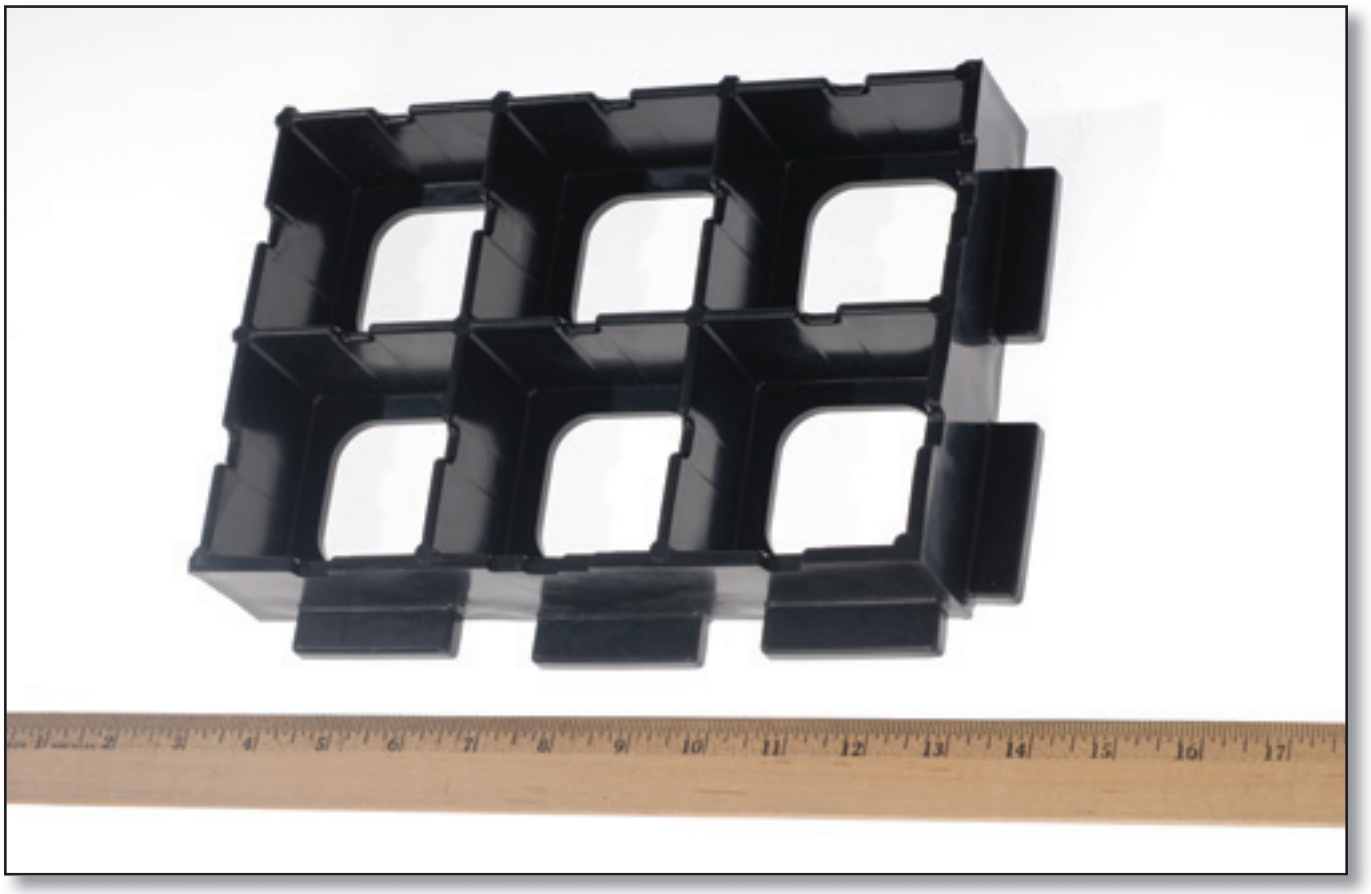

Figure 8—Geoblock, a very stiff material, is one of the many products for turf reinforcement.

Basic Geosynthetic Design Concepts for Trail Construction in Wet Areas

Trails in wet areas often are unstable because they are saturated by subsurface moisture and precipitation. Geosynthetics help create stable trail surfaces by providing:

- **Separation**—Geotextiles, geonets, and geocomposites (sheet drains) keep saturated, weak native soils from contaminating stronger, load-bearing trail surface materials. These materials allow water, but not soil, to pass through them.
- **Drainage**—Geotextiles, geonets, and geocomposites (sheet drains) improve subsurface drainage to avoid saturation and weakening of the trail tread.
- **Reinforcement and Load Distribution**—All geosynthetics provide some degree of tread reinforcement and load distribution. This may decrease the amount of imported fill material needed for trail surfacing.

Geosynthetics are relatively simple to use. Products that meet the physical requirements discussed in the "Geosynthetic Product Information" section are tough enough to be placed over small stumps that stick up from the ground surface after brush has been cleared for trail construction. Cutting stumps and brush to within a few inches of the ground usually is all that is necessary. Normally, joints in geotextiles, geonets, or geogrids should overlap at least 300 millimeters (12 inches). Sometimes sections of material are joined with pins or clips rather than being overlapped. All geosynthetics must be stored in their shipping wrappers until installation because they will deteriorate gradually when exposed to ultraviolet light.

Selecting good material for tread fill is very important. Organic, silt, or clay soils should not be used as tread fill because they become muddy when wet. Use firm mineral soil, coarse-grained soils, granular material, or small well-graded angular rock instead. Soil from wet areas is normally not suitable for use as tread fill. Unsuitable organic soils are easily identified by a dark color and musty odor when damp. Many soils containing clays and silts are just as unstable, but such soils are more difficult to identify. The "Identification of Unsuitable Tread Fill Material" section discusses several methods for identifying unsuitable soils.

The amount of acceptable tread fill material you need over the geosynthetic depends on several site-specific factors (table 1).

In addition to the applications illustrated in the "Specific Design Applications" section, other combinations of geosynthetic materials are possible and perhaps preferable, depending on conditions at the site and the native building materials available there. Once you understand the function of the different types of geosynthetics and product capabilities, you may be able to identify many other applications.

Table 1—Factors affecting the recommended thickness of tread fill material over the geosynthetic material.

Factors Affecting Recommended Tread Thickness	Maximum Thickness Needed	Minimum Thickness Needed
Trail fill quality	Mineral soil with little rock, less than 20% silt or clay	Granular, free-draining materials
Trail tread surface	Horse or motorcycle	Foot traffic
Tread surface moisture content during traffic	Moisture content predominantly high	Moisture content predominantly low
Amount of foundation settlement	Continuously wet areas more than 2 feet deep	Intermittent soft, wet areas less than 2 feet deep
Geosynthetic alternative selected	Single layer of geotextile	Geotextile with other geosynthetics such as geocells
Trail surface crown maintenance	Less than annual	Annual

Specific Design Applications

Most of the applications shown can be integrated into standard trail turnpike construction specifications. To simplify the illustrations, not all the components of a complete turnpike (ditches, curb rocks, or logs, etc.) are shown. Curb logs or rocks may be needed to confine tread fill unless the fill materials are quite granular. Shoulders must be maintained to keep geosynthetics covered to protect them from ultraviolet light and traffic abrasion. The figures are simplified cutaway cross-sectional views of the trail. They normally look much better on paper than they do during construction.

Geosynthetics usually are placed directly on the ground without excavation. Many of the illustrations show the various applications with a sag in the native soil surface along the center of the trail alignment. This sag is caused by adding the weight of the tread fill. The actual amount of settlement is very site specific and depends on soil type, level of saturation, and weight of tread fill used. Less tread fill can be used over geosynthetic products that are rigid or have high bending strengths because the weight of fill is distributed over a larger area. Settlement decreases when less fill is needed to obtain a stable tread surface. For example, much more tread fill is required for a single layer of geotextile (figure 10), than for geocell with geotextile (figure 11). In this example, the cost of importing tread fill must be compared to the increased cost of the geocell.

All alternatives that use tread fill should have a crowned or outsloped surface to help shed water quickly, improve stability, and control erosion and sediment production. Additional tread fill may be needed to rebuild the crown after the trail settles initially. More imported fill will be needed to maintain the crown if tread wear is high. Alternatives are compared in table 2.

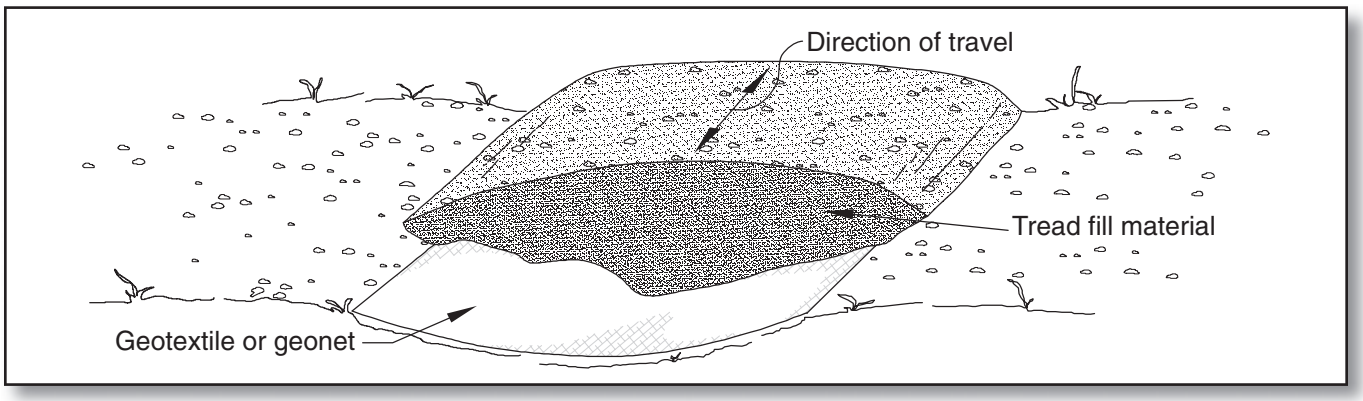

Figure 10—Typical placement of geotextile or geonet through flat, boggy areas.

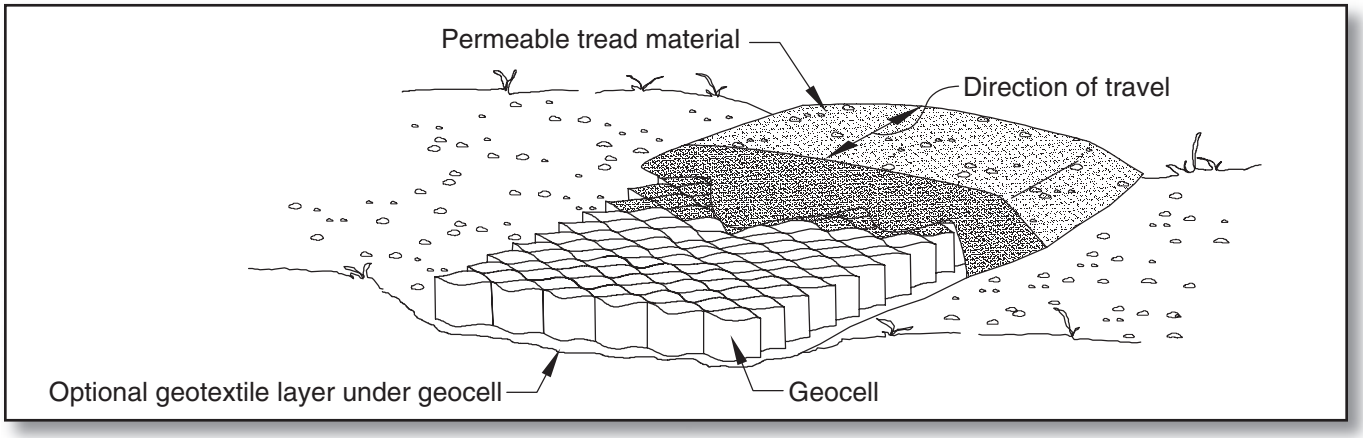

Figure 11—Geocell with geotextile and permeable tread material.

Table 2—Comparisons of alternative geosynthetic applications.

Construction Objectives	Geosynthetic Applications							
	Geotextile only[1]	Geonet only[2]	Geotextile sausage[3]	Geogrid with geotextile	Geogrid with geonet	Sheet drain with geotextile[4]	Sheet drain with geotextile[5]	Geocell with geotextile[6]
Separation (keep tread fill separate from poor soils)	B	B	A	B	B	B	NA.	A
Reinforcement (turnpike over deep layer of very weak soil)	D	D	A	B	A	B	NA.	A
Reduce quantity of imported fill material	D	D	B	B	A	B	C	B
Eliminate trail side ditching	D	C	A	C	C	B	D	B
Ease of product placement	A	B	C	C	C	B	D	C
Cost for geosynthetics	$	$$	$	$$	$$$	$$$	$$$	$$$$
Weight of geosynthetics: kilograms per square meter pounds per square yard	 0.14 0.25	 0.89 1.64	 0.28 0.50	 0.32 0.60	 1.07 1.98	 2.3 4.25	 2.3 4.25	 1.9 3.45

Alternative Rating Code: A=Best alternative; **B**=Better than most; **C**=Not as good as most; **D**=Least effective; **NA**=Not applicable;
$ Least expensive => $$$$ Most expensive

[1]Single layer of geotextile.

[2]Single layer of geonet.

[3]Geotextile with encapsulated free-draining rock. Rock can be large, single-size cobbles, down to relatively clean sands.

[4]Sheet drains under tread fill.

[5]Sheet drains or geonets for drainage cutoff wall. Extensive ditching required.

[6]Geocell with geotextile and permeable tread. Granular fill material required; weights are based on 100-mm-deep cells.

Geotextile or Geonet

Single-layer geotextile or geonet (see figure 10) separates fill material from saturated soils and distributes fill weight so less settling takes place. Because geonets cost more, use them only where drainage and subsurface moisture conditions are worst. Avoid using organic, silt, or clay soils for trail tread material because little subsurface drainage will occur and the trail tread will become muddy in wet weather. Rocky soils or crushed aggregate should be used as a tread material if possible. These materials retain much of their strength when saturated. Excess surface moisture can drain off through these permeable materials if the trail is located on a grade or side slope.

Geotextile With Encapsulated Free–Draining Rock

In the sausage technique (figure 12), the geotextile provides separation from the saturated soil, and the rock provides drainage for excess water. Twenty-five-millimeter (1-inch) flexible plastic pipe outlets for subsurface water may be desirable where trails are constructed on very flat terrain to avoid the "bath tub" effect. If the trail has grade or is built on a sideslope, other drainage options exist. The rock may be single-size material from pea gravel size to cobbles (75 to 300 millimeters or 3 to 12 inches), or it may be a mixture of rock materials that does not contain silt or clay. The rock can be just one layer thick if drainage is all that is needed. For reinforcement, at least 75 millimeters (3 inches) of rock would be recommended. The geotextile is wrapped over the rock layer with a 300-millimeter (12-inch) overlap to ensure encapsulation, because settlement of saturated soil can pull the overlap apart.

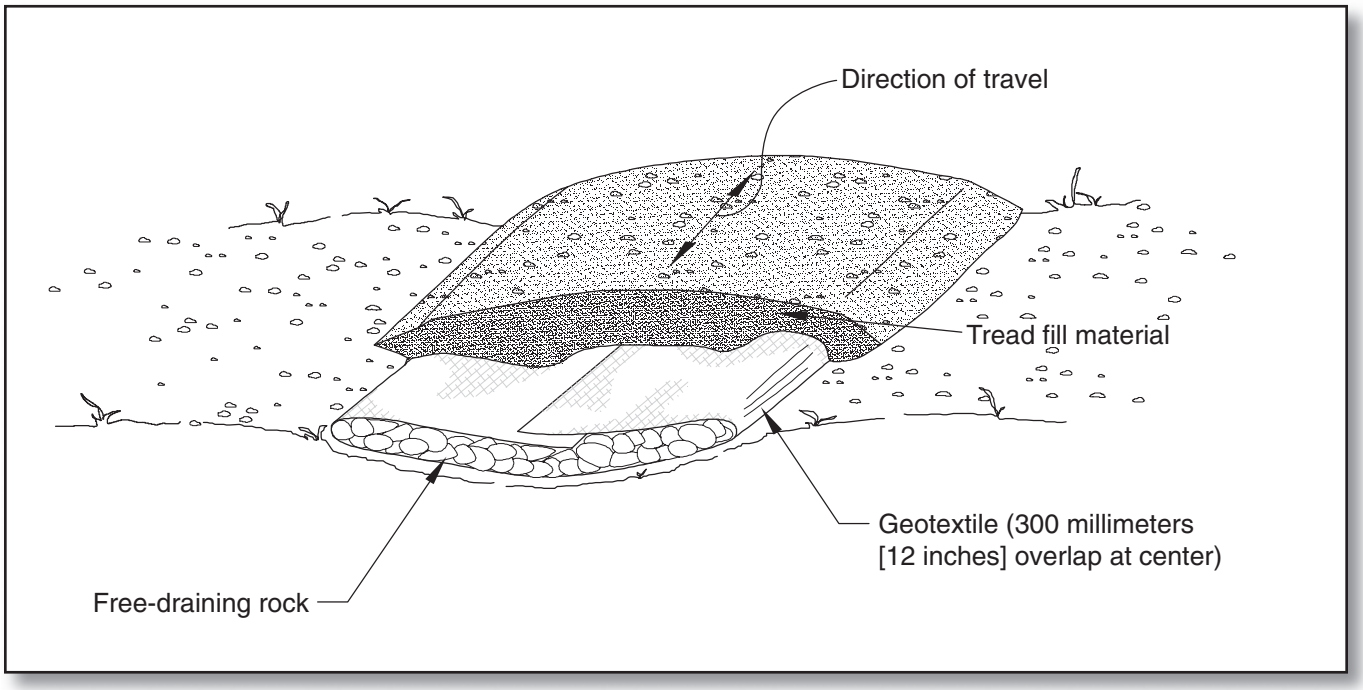

Figure 12—The encapsulation or "sausage" technique, with native rock used for drainage.

Geogrid With Geotextile or Geonet

Figure 13 shows geogrid placed on top of the geotextile or geonet to add bending strength to the system, decrease settling, and reduce the amount of fill material required. Very little drainage is required with this design, unless geonets are used or the tread material is permeable (rocky soils or crushed aggregate). The geogrid should be pulled taut to remove wrinkles before staking. The stakes and poles provide some pretension of the geogrid, better using its strength. The geotextile or geonet provides separation from the saturated soil and keeps the drainage paths along the bottom of the fill material from clogging. See Section 964 of the "Standard Specifications for Construction and Maintenance of Trails" (1996) for additional information.

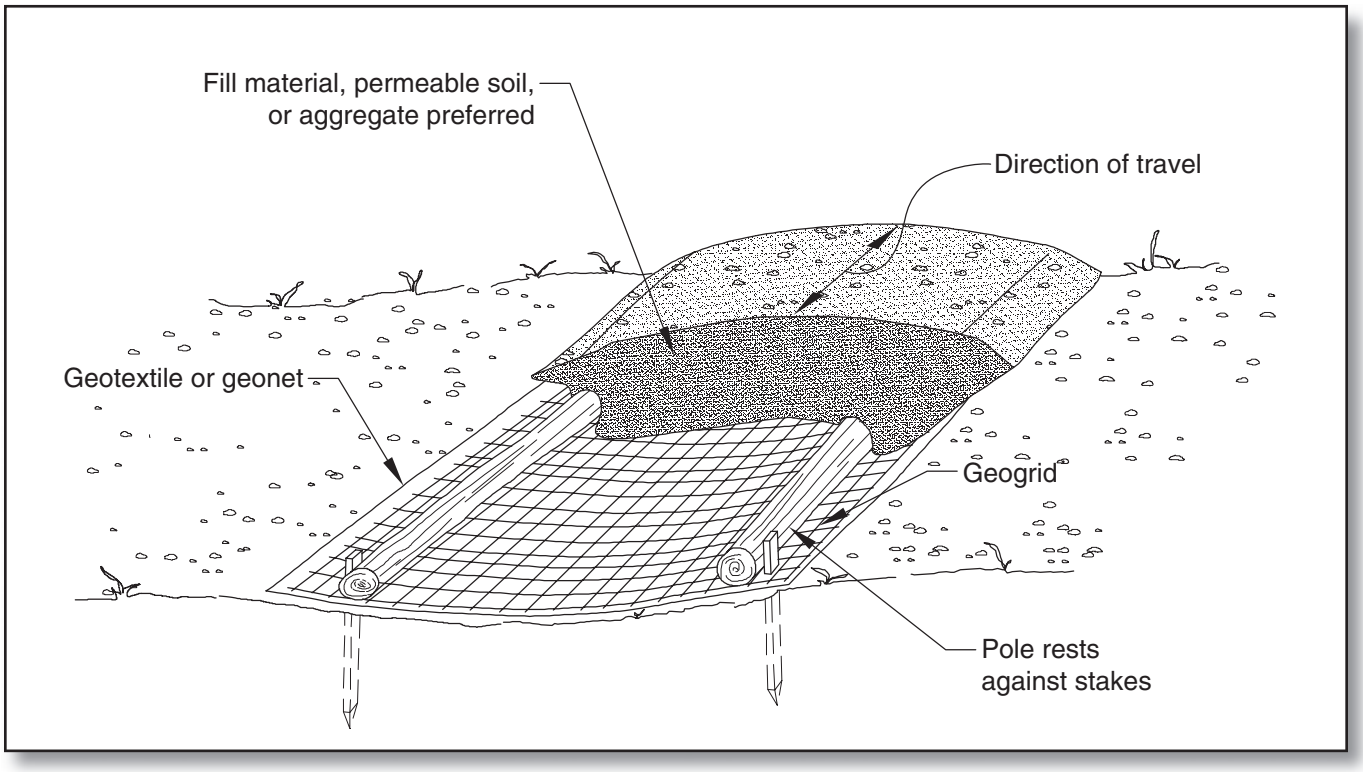

Figure 13—Geogrid with geotextile or geonet.

Sheet Drains Under Tread Fill

Sheet drains under tread fill (figure 14) provide separation from saturated soils and distribute the weight of the trail tread to limit settling. Install the product with the plastic core side facing up and the fabric side facing down. This orientation takes advantage of the plastic core's compressive strength and the fabric's tensile strength, reducing the amount of settling and the amount of tread fill required. Twenty-five-millimeter- (1-inch-) diameter flexible plastic pipe can be used as a drainage outlet to take full advantage of the sheet drain's capabilities. If the trail is on a grade or side slope, an outlet pipe or daylight section could provide drainage.

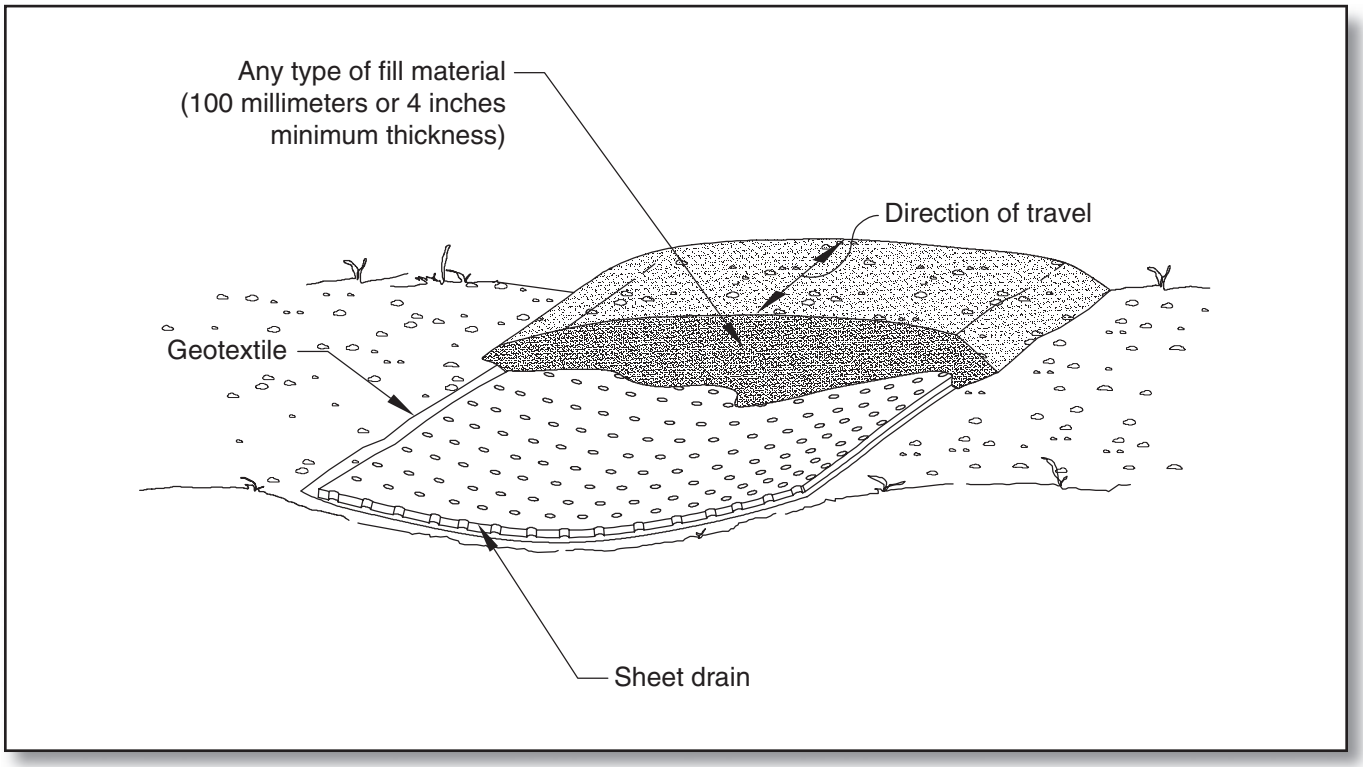

Figure 14—A sheet drain under fill material.

Sheet Drains or Geonets Used as Drainage Cutoff Walls

If a section of trail is on a side slope where subsurface water saturates the uphill side, a cutoff wall can be constructed to intercept surface and subsurface moisture (figure 15), helping drain and stabilize the trail section. This application is especially beneficial where the cut slope sloughs continually, filling ditches. The sheet drain or geonet should be installed within 1 meter (3 feet) of the trail's edge. The proper depth of the collection pipe and location of the sheet drain can be determined by probing the saturated soil with a short length of Number 4 reinforcing steel (rebar). Collector and outlet pipes can be made from flexible plastic pipe. Keep the top edge of the drain above the ground to capture surface runoff moving down the slope. Cover the exposed material with large rocks to protect the material from ultraviolet light. The collector pipe can be drained into an outlet pipe or with a sheet drain or geonet panel installed under the trail. This application requires ditching to intercept and drain water. Ditching is normally more extensive on flatter terrain.

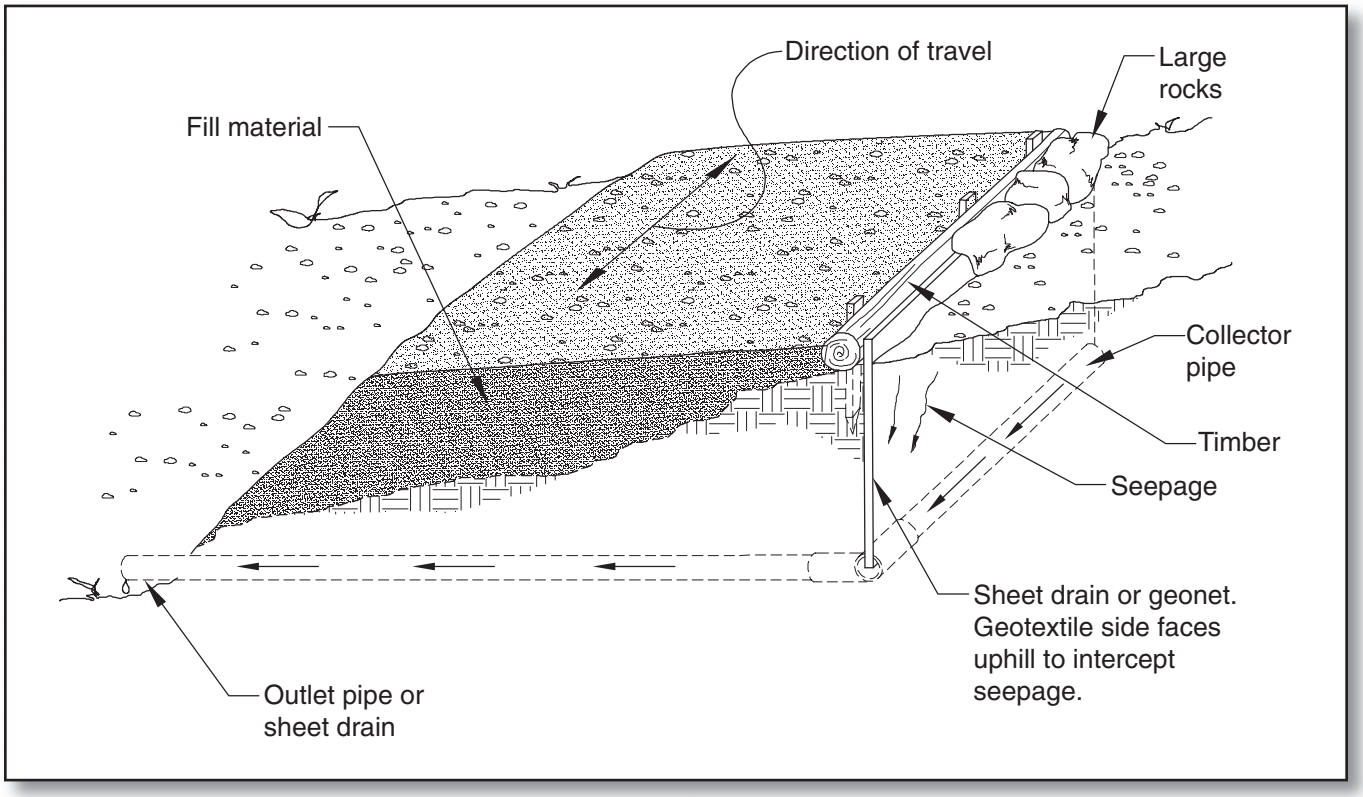

Figure 15—A sheet drain or geonet used to intercept seepage.

Geocell With Geotextile and Permeable Tread Material

Geocell provides confinement chambers that distribute the trail tread loads over a wider area and reduce settling (see figure 11). Geocell works best in sandy soils, rocky soils, crushed aggregate, or free-draining rock, where it increases the tread's load-bearing capacity and prevents feet and hooves from punching holes into the trail. The geotextile provides separation between saturated soil and the tread fill material. Less tread fill will be needed with geotextile because settling is reduced. There is no subsurface drainage if the trail is on flat ground. If the trail has a grade or is built on a side slope, moisture will drain through the permeable tread fill. Organic, silt, and clay soils are not desirable as fill for geocells because these soils will probably remain saturated and unstable, meaning they will not be strong enough to carry the loads on the trail. Geocell does not increase the load-bearing strength of clay or silt.

Geosynthetic Product Information

The following manufacturers and products were included in the "Specifier's Guide for Geosynthetic Materials" published by Geosynthetics Magazine, available from the Industrial Fabric Association International Resource Center, 1801 County Road B.W., Roseville, MN 55133–4061 (800–225–4324). The recommended minimum physical properties listed are from the Forest Service's "Standard Specifications for Construction and Maintenance of Trails" (1996). The recommended physical properties are typically on the low end of those available because trails applications are much less demanding than geosynthetic applications in road construction where heavy machinery and large, angular boulders require stronger products.

This edition of "Geosynthetics for Trails in Wet Areas" does not recommend specific products. Hundreds of suitable products are available from manufacturers and even home improvement centers. Most manufacturers and geotechnical or materials engineers can help you select products if you provide details on soil and moisture conditions and expected loads (trails generally have light loads).

No prices are listed. Prices may change quickly because of changes in the price of the petroleum (the raw material). Call the listed phone numbers for current prices delivered to your area or to contact the local sales representative. Manufacturers may provide prices by the square meter, square yard, square foot, or for full rolls. Unit costs decrease as the amount ordered increases. All geosynthetic products can be cut in the field or cut by the manufacturer to meet your requirements.

Geotextiles

Manufacturer or Company	Phone Number	Web Site
Belton Industries Inc.	800–845–8753	www.beltonindustries.com
Carthage Mills	800–543–4430	www.carthagemills.com
Contech Earth Stabilization Solutions Inc.	866–551–8325	www.contechess.com
Dalco Nonwovens	828–459–2577	www.dalcononwovens.com
Fiberweb PLC	800–321–6271	www.fiberweb.com
GSE Lining Technology Inc.	800–435–2008	www.gseworld.com
Huesker Inc.	800–942–9418	www.huesker.com
LINQ Industrial Fabrics Inc.	800–445–4675	www.linq.com
Maccaferri Inc.	800–638–7744	www.maccaferri-usa.com
Mirafi (TenCate Geosynthetics)	800–685–9990	www.mirafi.com
Propex Inc.	800–621–1273	www.geotextile.com
SKAPS Industries	706–693–3440	www.skaps.com
TNS Advanced Technologies by Maple Textile	800–867–5181	www.mapletextile.com
Vantage Partners LLC	704–871–8700	—
WEBTEC Inc. LLC	800–438–0027	www.webtecgeos.com

Typical Product Unit Weight: 0.13 kilogram per square meter (0.25 pound per square yard)

Critical physical properties for geotextiles used in trail construction:

- Material structure: Nonwoven
- Polymer composition: Polypropylene
- Apparent opening by ASTM D 4751–87: Less than 0.297 millimeter (mesh larger than No. 50)
- Permittivity by ASTM D4491–92: More than 4,060 liters per minute per square meter (more than 100 gallons per minute per square foot)
- Puncture strength by ASTM D4833–88: More than 0.110 kilonewton (more than 25 pounds)
- Mullen burst by ASTM D 3786–87: More than 900 kilopascals (more than 130 pounds per square inch)
- Trapezoid tear strength by ASTM D4533–91: More than 0.110 kilonewton (more than 25 pounds)
- Grab tensile at 50 percent elongation by ASTM D4632–91: More than 0.355 kilonewton (more than 80 pounds)
- Ultraviolet degradation: More than 70 percent retained strength at 150 hours

Notes: The products that work best for trail applications typically are the nonwoven, felt-like materials that are easier to work with rather than heat-bonded or slit-film products that have a slick surface. Physical property requirements are minimum average roll values where applicable. Compare your desired widths with standard roll widths and consult with manufacturers when deciding whether it's best to cut the fabric in the field or have the manufacturer cut it.

Geonets

Manufacturer or Company	Phone Number	Web Site
Agru America Inc.	800–373–2478	www.agruamerica.com
CETCO Lining Technologies	800–527–9948	www.cetco.com
Fiberweb PLC	800–321–6271	www.fiberweb.com
GSE Lining Technology Inc.	800–435–2008	www.gseworld.com
Poly-Flex Inc.	888–765–9359	www.poly-flex.com
Rainy Day Water Inc.	801–975–8915	www.rainydaywater.com
SKAPS Industries	706–693–3440	www.skaps.com
Tenax Corp.	800–356–8495	www.tenaxus.com

Typical product unit weight: 0.89 kilogram per square meter (1.64 pounds per square yard)

Critical physical properties of geonets used in trail construction:

- Polymer composition of core (net or mesh): Medium- or high-density polyethylene.
- Geotextile: Must be attached to both sides of the core and meet or exceed the requirements of AASHTO M 288 Subsurface Drainage Class B with permeability greater than 0.0001 centimeter per second, and an apparent opening size less than 0.297 millimeter (larger than the No. 50 U.S. Standard Sieve).
- Core thickness: Thicker than 5 millimeters by ASTM D5199.
- Compressive strength of core: Stronger than 500 kilopascals by ASTM D1621.
- Transmissivity with gradient of 0.1 and pressure of 10 kilopascals: More than 0.0009 square meter per second (more than 4 gallons per minute per foot).

Notes: Discuss the roll width and length requirements for your project with manufacturers.

Geogrids

Manufacturer or Company	Phone Number	Web Site
Carthage Mills	800–543–4430	www.carthagemills.com
Colbond Inc.	800–365–7391	www.enkamat.com
Contech Earth Stabilization Solutions Inc.	866–551–8325	www.contechess.com
Huesker Inc.	800–942–9418	www.huesker.com
Linear Composites Limited	423–987–6781	www.linearcomposites.com
Maccaferri Inc.	800–638–7744	www.maccaferri-usa.com
Mirafi (TenCate Geosynthetics)	800–685–9990	www.mirafi.com
Strata Systems Inc.	800–680–7750	www.geogrid.com
Synteen Technical Fabrics	800–796–8336	www.synteen.com
Tenax Corp.	800–356–8495	www.tenaxus.com
Tensar International Corp.	888–836–7271	www.tensar-international.com
WEBTEC Inc. LLC	800–438–0027	www.webtecgeos.com

Typical product unit weight: 1.75 kilograms per square meter (0.34 pound per square yard).

Critical physical properties of geogrids used for trail applications:

- Polymer type: High-density polyethylene, polypropylene, or polyester with acrylic or PVC coating
- Mass per unit area by ASTM D5261–92: 175 grams per square meter (more than 5.5 ounces per square yard)
- Maximum aperture size: Machine direction (MD): 100 millimeters (4 inches). Cross direction (XD): 75 millimeters (3 inches)
- Wide-width strip tensile strength at 5-percent strain by ASTM D4595-86: Machine direction (MD): 8 kilonewtons per meter (550 pounds per foot). Cross direction (XD): 6 kilonewtons per meter (410 pounds per foot)

Notes: Specify desired product widths and lengths for the project application.

Geocells

Manufacturer or Company	Phone Number	Web Site
Contech Earth Stabilization Solutions Inc.	866–551–8325	www.contechess.com
Geo Products LLC/Envirogrid	800–434–4743	www.geoproducts.org
Jobsite Products Inc.	800–298–4900	www.jobsiteproducts.com
Layfield Plastics Inc.	800–796–6868	www.layfieldgroup.com
Maccaferri Inc.	800–638–7744	www.maccaferri-usa.com
Presto Products Co.	800–548–3424	www.prestogeo.com
Tenax Corp.	800–356–8495	www.tenaxus.com
WEBTEC Inc. LLC	800–438–0027	www.webtecgeos.com

Typical product unit weight: 1.55 kilograms per square meter (2.9 pounds per square yard)

Critical physical properties of geocells used for trail construction:

- Composition: Polyethylene or high-density polyethylene.
- Geocell weight expanded: Heavier than 1.7 kilograms per square meter (heavier than 50 ounces per square yard).
- Minimum cell seam peel strength by U.S. Army Corps of Engineers Technical Report G:–86–19, Appendix A: 800 newtons (180 pounds).
- Expanded dimensional properties: As specified by the designer—see the manufacturer's dimensions.

Notes: Specify the desired product widths for the project application. The 100-millimeter (4-inch) cell depth should be adequate for trails—depths from 50 to 200 millimeters (2 to 8 inches) are available. Consult manufacturers for the availability of different section widths and alteration of standard section widths to fit your project needs.

Geocomposites—Sheet Drains

Manufacturer or Company	Phone Number	Web Site
American Wick Drain Corp.	800–242–9425	www.americanwick.com
Colbond Inc.	800–365–7391	www.enkamat.com
Contech Earth Stabilization Solutions Inc.	866–551–8325	www.contechess.com
Drainage Products Inc.	860–668–5108	www.drainaway.com
Fiberweb, PLC	800–321–6271	www.fiberweb.com
GSE Lining Technology Inc.	800–435–2008	www.gseworld.com
JDR Enterprises Inc.	800–843–7569	www.j-drain.com
LINQ Industrial Fabrics Inc.	800–445–4675	www.linq.com
Mirafi (TenCate Geosynthetics)	800–685–9990	www.mirafi.com
TNS Advanced Technologies by Maple Textile	800–867–5181	www.mapletextile.com
WEBTEC Inc. LLC	800–438–0027	www.webtecgeos.com

Typical product unit weight: 2.3 kilograms per square meter (4.25 pounds per square yard).

Critical physical properties of sheet drains for trail construction:

- Structure: Single- or double-dimpled core
- Core polymer composition: Polystyrene or polypropylene
- Attached geotextile: Nonwoven on one side if the core is solid, on both sides if the core is perforated. Geotextile must meet or exceed the requirements of AASHTO M 288 Subsurface Drainage Class B with permeability more than 0.0001 centimeter per second and an apparent opening size less than 0.297 millimeter (larger than the No. 50 U.S. Standard Sieve)
- Core thickness by ASTM D5199: Thicker than 10 millimeters (thicker than 0.40 inch)
- Core compressive strength at yield by ASTM D1621: More than 650 kilopascals (more than 95 pounds per square inch)

Notes: Compare desired width with standard sheet width and consult with manufacturers to learn whether the material can be cut easily in the field and how much it would cost to have it cut at the factory. Sheet drains with cores made from thicker materials usually have greater bending strength, limiting the amount of settling in soft soils and reducing the amount of fill material needed. Various core thicknesses are available.

Geo-Others—Turf Reinforcement

Manufacturer or Company	Product	Phone Number	Web Site
Invisible Structures Inc.	Grasspave2	800–233–1510	www.invisiblestructures.com
Norleans Technologies Inc.	Lockgrid	613–834–9313	www.norleanstech.com
Presto Products Co.	Geoblock	800–548–3424	www.prestogeo.com
TerraFirm Enterprises	EcoGrid	866–934–7572	www.terrafirmenterprises.com

Erosion Control

Manufacturer or Company	Phone Number	Web Site
Contech Earth Stabilization Solutions Inc.	866–551–8325	www.contechess.com
Geo Products LLC/Envirogrid	800–434–4743	www.geoproducts.org
American Excelsior Co.	800–777–7645	www.curlex.com
Belton Industries Inc.	800–845–8753	www.beltonindustries.com
Carthage Mills	800–543–4430	www.carthagemills.com
Colbond Inc.	800–365–7391	www.enkamat.com
Contech Earth Stabilization Solutions Inc.	866–551–8325	www.contechess.com
East Coast Erosion Blankets	800–582–4005	www.erosionblankets.com
Fiberweb, PLC	800–321–6271	www.fiberweb.com
Geo Products LLC/Envriogrid	800–434–4743	www.geoproducts.org
Maccaferri Inc.	800–638–7744	www.maccaferri-usa.com
Mirafi (TenCate Geosythetics)	800–685–9990	www.mirafi.com
North American Green	800–772–2040	www.nagreen.com
Presto Products Co.	800–548–3424	www.prestogeo.com
Profile Products LLC	800–508–8681	www.profileproducts.com
Propex Inc.	800–621–1273	www.geotextile.com
SRW Products	800–752–9326	www.srwproducts.com
Tenax Corp.	800–356–8495	www.tenaxus.com
Vantage Partners LLC	704–871–8700	
Watersaver Co. Inc.	800–525–2424	www.watersaver.com
Western Excelsior Corp.	800–833–8573	www.westernexcelsior.com

Identification of Unsuitable Tread Fill Material

Soils from wet areas are normally not suitable for use as tread fill because they are too moisture sensitive and lose strength easily when they become wet. It's important to avoid spending scarce dollars to excavate and haul fill that will fail when wet. Poor materials can be identified by several methods.

Organic Soils: Identified by musty odor when they are damp, and they are dark in color.

Other Unsuitable Tread Fill Materials: The stability of tread fill material is influenced primarily by the amount of silt or clay. If the fill is more than 20 percent silt and clay, the fill will probably become unstable when wet. Rough evaluations for suitability can be done by the following methods.

Method A—Field Comparison

Compare proportions of gravel, sand, and fines in existing trail tread materials with the proportions in borrow sources. Individual "fine-size" material particles are not visible to the naked eye and are classified as silt or clay. If the proportions of gravel, sand, and fines are similar, you can expect the borrow materials to perform as well as the existing trail tread materials. If the borrow source has a lower proportion of fines, you can expect better performance.

Method B—Laboratory Test

Take a 5-kilogram (10-pound) sample of the proposed tread fill material to a materials testing laboratory for a washed sieve analysis to determine the percentage of minus No. 200 material. The minus No. 200 material represents the amount of silt or clay. If the sample has more than 20 percent minus No. 200 material, it is not suitable for fill. A washed sieve analysis typically costs $50 to $100.

Method C—Geotextile Field Test

Build a short section of a small-scale trail over a wet area with a 2-meter (6-foot) square piece of geotextile and the proposed tread fill material. The depth of tread fill should be at least 150 millimeters (6 inches). Saturate the section with as much water as would be expected under the worst conditions. Evaluate the stability of the tread material by stepping onto the tread repeatedly, mimicking traffic.

Case Studies

The following case studies show how geosynthetic materials were used to solve problems on trails. One of the studies points out problems that can arise if geosynthetic materials are installed improperly.

Geoblocks for ATV Trails

The Francis Marion National Forest in South Carolina had serious erosion problems on all-terrain vehicle (ATV) trails. The ATVs were causing ruts. Water collecting in the ruts compounded the problem (figure 16). The forest reinforced the trail with Geoblocks, solving the problem (figure 17). Other national forests and national parks now use turf reinforcement products to reduce erosion and reinforce ATV trails.

Figure 16—An ATV trail in South Carolina before Geoblocks were installed.

Figure 17—The finished trail after Geoblocks were installed in the Francis Marion National Forest.

Geocells for Trail Bridge Approaches

The Tongass National Forest in Alaska is using geocells to build approaches for trail bridges (figure 18). In the past, approaches have sloughed off because of the steep embankments and wet conditions there. The geocells have worked wonders and are highly recommended for trail bridge approaches in the Tongass (figure 19).

Figure 18—Using geocells to construct a trail bridge approach.

Figure 19—A finished trail bridge approach in the Tongass National Forest.

Geotextiles for Underdrains

The Bureau of Land Management in Oregon had trouble with water going over a trail (figure 20). Large rocks were used to create an underdrain (often referred to as a French drain). The large rocks were placed on the ground and a geotextile fabric was laid over the rock (figure 21). The geotextile fabric was used as separation to keep the trail's surface material (crushed rock) from migrating down into the larger rocks. The finished trail (figure 22) allows water to flow through the underdrain.

Figure 20—An ATV Trail on BLM land in Oregon before geosynthetics were used to construct an underdrain.

Figure 21—Constructing an underdrain from large rocks, with geotextile serving as a separator between surface material and large rocks.

Figure 22 —A finished rock and geotextile underdrain.

Geocell Problems

Trail maintainers had the right idea when they decided to install geocells at the approaches to this bridge (figure 23). The geocells would provide a stable approach to the bridge and keep the fill material from soughing. Unfortunately, they did not install the geocells deep enough to allow 2 to 3 inches of gravel cover above them. The geocells were exposed to traffic and gradually unraveled, creating an unsightly and unsafe approach.

Figure 23—Geocells placed too close to the surface may unravel. The top of the geocell should be 2 to 3 inches below the surface of compacted tread fill.

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Geosynthetic Materials Association
http://www.gmanow.com/

Industrial Fabrics Association International
http://www.ifai.com/

International Geosynthetics Society
http://www.geosyntheticssociety.org/guideance.htm

About the Authors

James "Scott" Groenier, professional engineer, began working for MTDC as a project leader in 2003. Scott earned a bachelor's degree in civil and environmental engineering from the University of Wisconsin at Madison and a master's degree in civil engineering from Montana State University. He worked for the Wisconsin and Illinois State Departments of Transportation and with an engineering consulting firm before joining the Forest Service in 1992. He worked as the east zone structural engineer for the Eastern Region and as a civil engineer for the Ashley and Tongass National Forests before coming to MTDC.

Stephen Monlux is an engineering consultant in materials and pavement engineering, contract administration, and technology transfer for several federal agencies, state Local Technical Assistance Program centers, and numerous counties in the Northwest. He was the Northern Region materials engineer for the Forest Service in Missoula, MT, for 26 years.

Brian Vachowski was a project and program leader at the MTDC from 1993 until his retirement in 2008. He received a bachelor's degree in forestry from the University of Massachusetts and a master's degree in outdoor recreation from Utah State University. He has worked for the Nez Perce, Bighorn, Winema, and Routt National Forests.

Library Card

Groenier, James "Scott;" Monlux, Stephen; Vachowski, Brian. Geosynthetics for trails in wet areas: 2008 edition. Tech. Rep. 0823–2813–MTDC. Missoula, MT: U.S. Department of Agriculture Forest Service, Missoula Technology and Development Center. 26 p.

This report updates "Geosynthetics for Trails in Wet Areas: 2000 Edition," by Steve Monlux and Brian Vachowski. Geosynthetics are synthetic materials used with soil or rock in many types of construction. They perform three major functions: separation, reinforcement, and drainage. This report describes several types of geosynthetics; explains basic geosynthetic design concepts for trail construction in wet areas; and provides information about geosynthetic products. Detailed product specifications and procurement sources are listed.

Keywords: Erosion control, FHWA, geocells, geocomposites, geogrids, geonets, geo-others, geosynthetics, geotextiles, sheet drains, trail construction, trail turnpikes

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Produced by:
USDA Forest Service
Missoula Technology and Development Center
5785 Hwy. 10 West
Missoula, MT 59808–9361
Phone: 406–329–3978
Fax: 406–329–3719
E-mail: *wo_mtdc_pubs@fs.fed.us*

For additional information about geosynthetics, contact James "Scott" Groenier at MTDC:
Phone: 406–329–4719
Fax: 406–329–3719
E-mail: *jgroenier@fs.fed.us*

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2000 Edition

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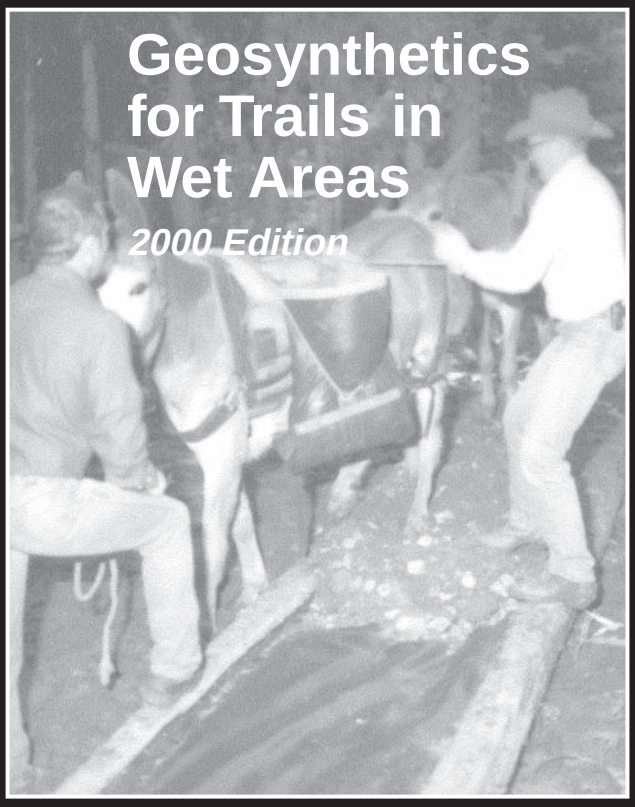


Steve Monlux
Geotechnical Engineer, Northern Region

Brian Vachowski
Project Leader

Technology and Development Program
Missoula, Montana

0E02A40—Geosynthetics for Trails in Wet Areas

August 2000

Contents

Acknowledgments

Steve Monlux is the principal author of this report. Brian Vachowski assisted in review coordination and preparation for publication. Others throughout the Forest Service assisted by reviewing the drafts.

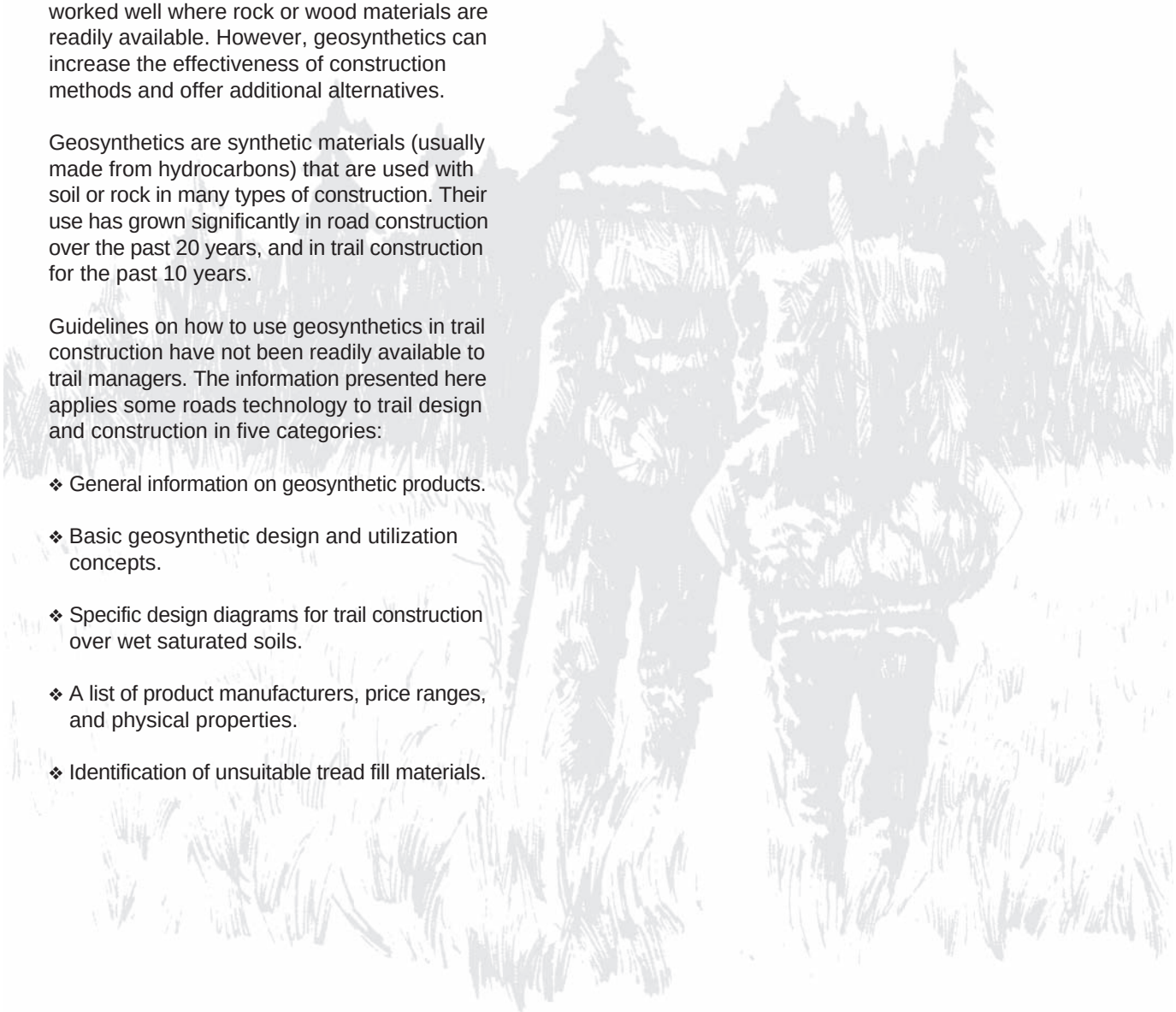
Introduction

Trails in soft, water-saturated soils present special challenges to trail managers. Muddy trails are anathema to livestock and hikers, which tend to skirt the edges of mud holes. This increases the area of damage to sensitive soils. Incorrectly constructed trails in wet areas lead to soil compaction, sedimentation, multiple trails, and unhappy trail users. Traditional trail construction methods for wet areas include turnpike or puncheon. These have worked well where rock or wood materials are readily available. However, geosynthetics can increase the effectiveness of construction methods and offer additional alternatives.

Geosynthetics are synthetic materials (usually made from hydrocarbons) that are used with soil or rock in many types of construction. Their use has grown significantly in road construction over the past 20 years, and in trail construction for the past 10 years.

Guidelines on how to use geosynthetics in trail construction have not been readily available to trail managers. The information presented here applies some roads technology to trail design and construction in five categories:

- General information on geosynthetic products.
- Basic geosynthetic design and utilization concepts.
- Specific design diagrams for trail construction over wet saturated soils.
- A list of product manufacturers, price ranges, and physical properties.
- Identification of unsuitable tread fill materials.



Section 1: Geosynthetics—General Information

Geosynthetics perform three major functions: ***separation***, ***reinforcement***, and ***drainage***. Geosynthetic materials include geotextiles (construction fabrics), geonets, sheet drains, geogrids, and geocells. All these materials become a permanent part of the trail, but must be covered with soil or rock to prevent early deterioration by ultraviolet light. *TrailMaster,* a proprietary product, is also discussed. *TrailMaster* can be used as trail tread, and is placed directly over wet areas. Since all these products are synthetic, their use in wilderness should be reviewed and approved prior to use.

Figure 1—Geotextiles. Felt-like products are easier to work with than heat bonded, slit film, or woven products that have a slick surface texture. They are easier to cut and their flexibility makes them easier to place on curved trail sections.

Geotextiles

Geotextiles (Figure 1) are the most widely used geosynthetic. Geotextiles are often called construction fabrics. They are constructed from long lasting synthetic fibers that are bonded to form a *fabric* held together by weaving, heat bonding, or other means. They are primarily used for ***separation*** and ***reinforcement*** over wet unstable soils. They have the ability to support loads through tensile strength and can allow water, but not soil, to seep through. They can also be used in drainage applications where water flow is much greater than normally exists in wet areas. The physical requirements listed for all geotextiles in Section 4 are stringent enough so the products will also work for properly designed high-flow drainage applications. These representative products are low cost, readily available, and easy to use. There are many other products on the market.

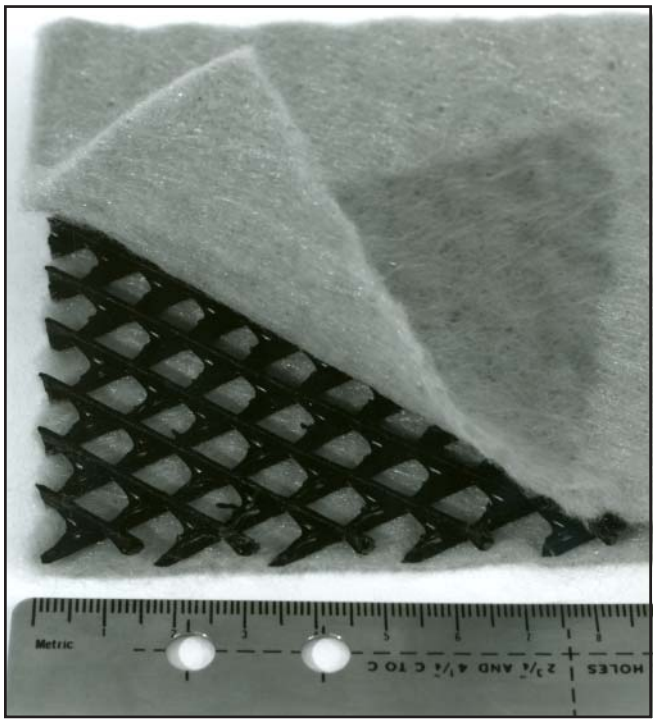


Figure 2—The net-like core of geonet allows sideways drainage that is normally adequate for the amount of seepage found under trails in wet areas.

Geonets

Geonets or geonet composites (Figure 2) have a thin polyethylene drainage core that is covered on both sides with geotextile. They are used for all three functions—***separation***, ***reinforcement***, and ***drainage***. Since geonets have a core plus two layers of geotextile, they provide more reinforcement than a single layer of geotextile.

Sheet Drains

Sheet drains (Figure 3) are another form of composite made with a drainage core and one or two layers of geotextile. The core is usually made of a polyethylene sheet that is formed into an egg-crate shape. The core provides an impermeable barrier unless perforated by the manufacturer. Perforated cores are always covered with geotextile on both sides to prevent soil clogging the drainage passages. Geotextile is bonded to one or both sides of the core to provide filtration and separation. When used under the trail tread material, sheet drains provide ***separation, reinforcement,*** and ***drainage***. Since they have greater bending strength than geotextiles or geonets, less tread fill is often needed. They can also be used vertically in covered trenches beside the trail to drain off subsurface water.

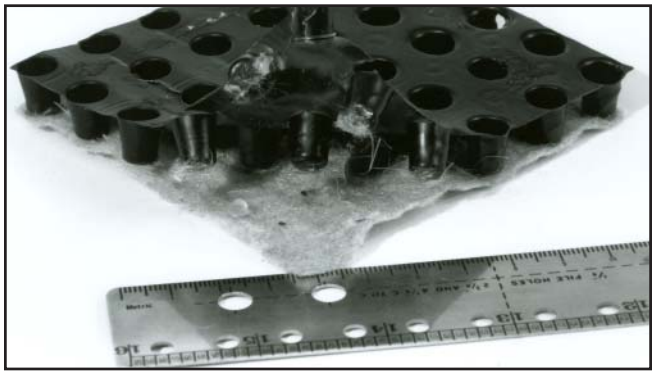


Figure 3—Sheet drains have a large cross-section that provides significant drainage capacity. If placed under the trail tread, orient the sheet drain with the geotextile side on the bottom and the plastic core on top. This orientation reduces the amount of fill needed.

Geogrids

Geogrids (Figure 4) are made from polyethylene sheeting that is formed into very open grid-like configurations. Geogrids are good for ***reinforcement*** because they have high tensile strengths, and coarse aggregate can interlock into the grid structure.

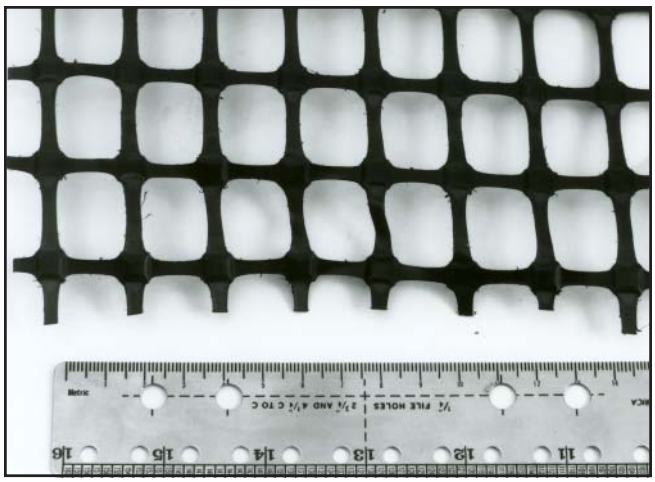


Figure 4—Geogrids are normally placed on top of a layer of geotextile to obtain separation from saturated soils in wet areas.

Geocells

Geocells (Figure 5) are usually made from polyethylene strips from 50 to 200 millimeters (2 to 8 inches) high that are bonded at intermediate points to form a honeycomb structure. The product is shipped in a collapsed and compact form. During installation, the material is pulled open and the honeycomb structure is staked to the ground surface. Each of the cells is filled with select backfill and compacted. Compacting trail tread material within the cell increases the bending strength of the layer, which reduces settlement into soft saturated soils. Geocells are good for ***reinforcement*** and reduce the amount of fill material required.

Figure 5—Geocell usually has geotextile under it to provide separation from wet saturated soils.

Proprietary Products

TrailMaster (Figure 6) is made from 3-millimeter (⅛-inch) thick polypropylene that has 13-millimeter (½-inch) diameter extruded holes about 32 millimeters (1¼ inches) on center. The extrusions extend 16 millimeters (⅛ inch) below the top of the sheet. This product was originally marketed under the *Gripmaster* name and weighs about 2.8 kilograms per square meter (0.57 pounds per square foot). Bending strength is high enough to distribute loads from pack animals over a large enough area so that the material essentially floats on top of saturated soils. *TrailMaster* is excellent for ***reinforcement*** because no fill material is required.

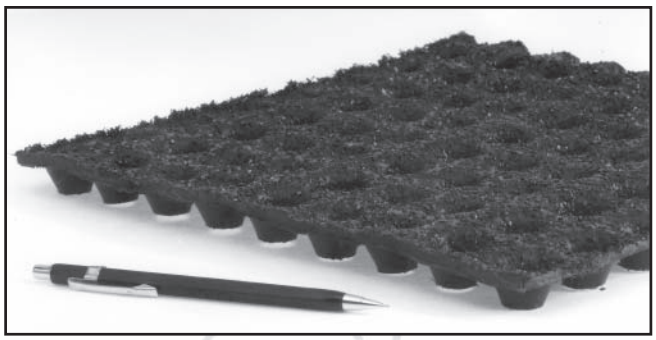


Figure 6—*TrailMaster* is a very stiff material, but it can be rolled up for relatively easy transport.

Section 2: Basic Geosynthetic Design and Utilization Concepts for Trail Construction in Wet Areas

Geosynthetics provide a stable trail surface in wet areas. Unstable trail surfaces are usually caused by saturation from subsurface moisture and precipitation. Geosynthetics assist in obtaining stable surfaces by providing:

❖ **Separation**—Geotextiles, geonets, and sheet drains keep saturated, weak native soils from contaminating stronger, load-bearing trail surface materials. They allow water, but not soil, to pass through.

❖ **Drainage**—Geotextiles, geonets, and sheet drains improve subsurface drainage to avoid saturation and weakening of the trail tread.

❖ **Reinforcement and Load Distribution**—All geosynthetics discussed in this paper provide some degree of tread reinforcement and load distribution. This decreases the amount of imported fill material required. *TrailMaster* provides enough load distribution so it can be placed directly on the saturated soil and also serves as the trail tread with no additional fill needed.

Geosynthetics are relatively simple to use. Products that meet the physical requirements discussed in Section 4 are tough enough to be placed over small stumps that stick up from the ground surface after brushing. Cutting stumps and brush to within a few inches from the ground is usually all that is necessary. Where joints occur in geotextiles, geonets, or geogrids, the overlap should normally be at least 300 millimeters (12 inches). Pins or clips are used at joints for the other products. All geosynthetics must be stored in shipping wrappers until installation since they will gradually deteriorate when exposed to ultraviolet light.

Selecting good tread fill material is very important. Organic, silt, or clay soils should not be used as tread fill since they become muddy during wet weather. Use firm mineral soil, coarse-grained soils, granular material, or small well-graded angular rock instead. Soil from wet areas is normally not suitable for use as tread fill. Unsuitable organic soils are easily identified by a dark color and musty odor when damp. Many soils containing clays and silts are just as unstable, but identification is more difficult. Avoiding unsuitable tread fill is very important because poor materials will fail when wet and costs for excavation and haul are high. Poor materials can be identified in the field by several methods discussed in Section 5.

How much acceptable tread fill material you need over the geosynthetic selected depends on several site-specific factors:

FACTORS AFFECTING TREAD THICKNESS NEEDED	MAXIMUM THICKNESS	MINIMUM THICKNESS
Trail fill quality	Mineral soil with little rock, less than 20-percent silt or clay	Granular, free-draining materials
Trail tread surface	Horse or motorcycle	Foot traffic
Tread surface moisture content during traffic	Predominantly high	Predominantly low
Amount of foundation settlement	Continuously wet areas over 2 feet deep	Intermittent soft, wet areas under 2 feet deep
Geosynthetic alternative selected	Single layer of geotextile (Figure 1)	Geotextile with logs (Figure 9) Geocell, (Figure 13)
Trail surface crown maintenance	Less than annual	Annual

In addition to the nine applications illustrated in Section 3, other combinations are possible and perhaps preferable, depending on mud hole conditions and natural building materials available. Once you understand the design/utilization concepts and product capabilities, try different applications.

Section 3: Specific Design Applications

Most all of the techniques shown can be integrated into standard trail turnpike construction specifications. To simplify the illustrations, not all the components of a complete turnpike (ditches, curb rocks, or logs, etc.) are shown. For many trail locations through flat muddy sites, the traditional trail side ditch and long outlet ditch will not be necessary. Curb logs or rocks are still needed to confine tread fill except where tread fill materials are quite granular. Shoulders must be maintained to keep geosynthetics covered to protect them from ultraviolet light and traffic abrasion. The figures are simplified cutaway cross-sectional views of the trail. They normally look much better on paper than they do during construction.

Geosynthetics are usually placed directly on the natural ground without prior excavation. Many of the illustrations show the various applications with a sag in the native soil surface along the center of the trail alignment. This sag is caused by adding the weight of the tread fill. The actual amount of settlement is very site specific and depends on soil type, level of saturation, and weight of tread fill used. Less tread fill can be used over geosynthetic products that are rigid or have high bending strengths because the weight of fill is distributed over a larger area. Settlements are decreased when less fill is needed to obtain a stable tread surface. For example, much more tread fill is required for a single layer of geotextile (Figure 7), than for geocell with geotextile (Figure 13). In this example, the cost of importing tread fill must be compared to the increased cost of the geocell.

All alternatives that use tread fill should have a crowned or outsloped surface to help shed water quickly and improve stability and control erosion and sediment. Additional tread fill may be necessary to rebuild the crown after initial settlement. More imported fill will be necessary to maintain the crown if tread wear is high. Alternatives are compared in Table 1.

Geotextile or Geonet

Single-layer geotextile or geonet (Figure 7) separates fill material from saturated soils and distributes fill weight so less settling takes place. Since geonets cost more, use them only where drainage and subsurface moisture conditions are worst. Avoid using organic, silt, or clay soils for trail tread material because little subsurface drainage will occur and the trail tread will become muddy in wet weather. Rocky soils or crushed aggregate should be used as a tread material if possible. These materials retain much of their strength

Table 1—Comparisons of geosynthetic alternatives.

Evaluation Criteria of Construction Objectives	Geosynthetic Application									
	Figure 7[1] Geotex	Figure 7[2] Geonet	Figure 8[3]	Figure 9[4]	Figure 10[5] Geotex	Figure 10[6] Geonet	Figure 11[7]	Figure 12[8]	Figure 13[9] Geocell	Figure 14[10]
Separation (keep tread fill separate from poor soils)	B	B	A	A	B	B	B	NA.	A	C
Reinforcement (turnpike over deep layer of very weak soil)	D	D	A	A	B	A	B	NA.	A	B
Reduce quantity of imported fill material	D	D	B	A	B	A	B	C	B	A
Eliminate trail side ditching	D	C	A	B	C	C	B	D	B	A
Ease of product placement	A	B	C	C	C	C	B	D	C	A
Low-cost geosynthetic	A	C	A	B	C	C	C	C	D	D
Cost for geosynthetics per square meter	0.68	4.05	1.36	2.04	4.13	7.50	7.50	7.50	10.08	16.68
per square yard	0.57	3.42	1.14	1.71	3.47	6.32	6.26	6.26	8.45	14.07
Weight of geosynthetics:										
kilogram per square meter	0.14	0.89	0.28	0.42	0.32	1.07	2.3	2.3	1.9	3.0
pound per square yard	0.25	1.64	0.50	0.75	0.60	1.98	4.25	4.25	3.45	5.40

Alternative Rating Code: A = Best alternative; **B** = Better than most; **C** = Not as good as most; **D** = Least effective; **NA.** = Not applicable

[1] Single layer of geotextile.
[2] Single layer of geonet.
[3] Geotextile with encapsulated free-draining rock. Rock can be large, single-size cobbles, down to relatively clean sands.
[4] Geotextile with poles, logs. Must have small trees onsite.
[5] Geogrid with geotextile.
[6] Geogrid with geonet.
[7] Sheet drains under tread fill.
[8] Sheet drains or geonets for drainage cutoff wall. Extensive ditching required.
[9] Geocell with geotextile and permeable tread. Granular fill material required; costs and weights are based on 100-mm-deep cells.
[10] *TrailMaster* with geotextile. Curb logs are required.

when saturated. Excess surface moisture can drain off through these permeable materials if the trail is located on a grade or side slope.

Geotextile With Encapsulated Free-Draining Rock

(Sausage Technique, Figure 8). The geotextile provides separation from the saturated soil, and the rock provides drainage for excess water. Twenty-five-millimeter (1-inch) flexible plastic pipe outlets for subsurface water may be desirable where trails are constructed on very flat terrain to avoid the “bath tub” effect. If the trail has grade or is built on a sideslope, other drainage options exist. The rock may be single-size material from pea gravel size to cobbles (75 to 300 millimeters or 3 to 12 inches), or it may be a mixture of rock materials that does not contain silt or clay. The free-draining rock can be placed to a thickness equal to the maximum size rock if only drainage is desired. If reinforcement is also needed, at least 75 millimeters (3 inches) of rock is recommended. The geotextile is wrapped over the rock layer with a 300-millimeter (12-inch) overlap to ensure encapsulation, since settlement of saturated soil can pull the overlap joint apart.

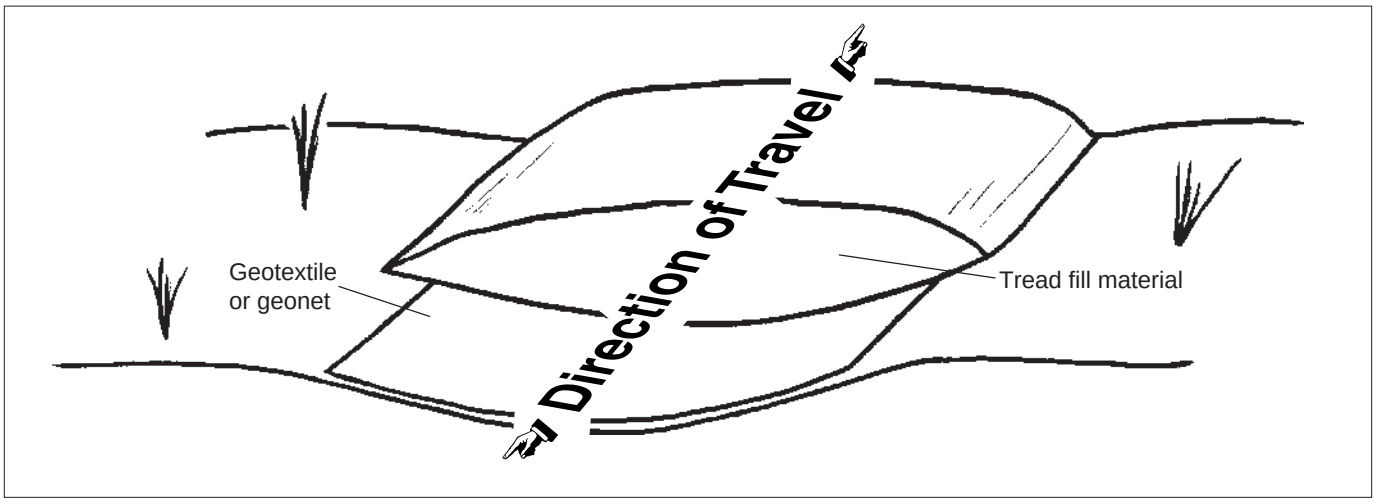


Figure 7—Typical placement of geotextile or geonet through flat, boggy areas. Side or lead-off ditches may not be needed.

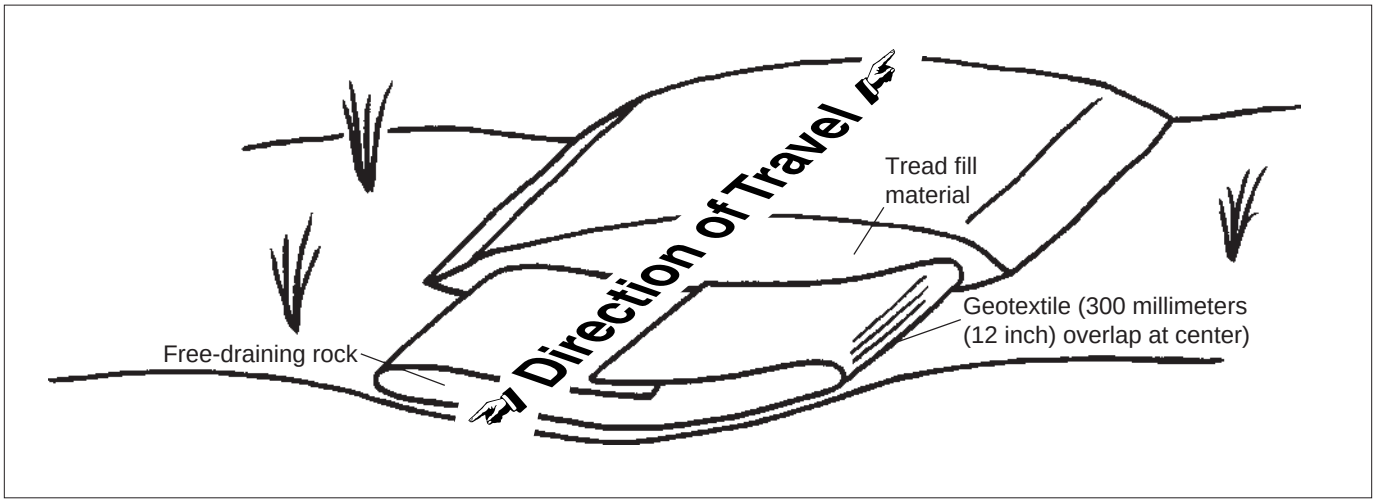


Figure 8—Encapsulation or “sausage” technique where native rock is used for drainage.

Geotextile With Poles or Logs

Figure 9 provides a system that requires less imported fill and resists being pushed down into soft saturated soils. No subsurface drainage is provided with this design, although longitudinal drainage may occur along the poles if the trail is on a grade. Another approach is to place interior logs perpendicular to the trail after cutting them to lengths equal to the trail width. This method does not utilize log bending strengths as effectively and is more labor intensive. An outlet pipe or daylight section would provide drainage where trails are on a grade or side slope.

Settling of saturated soil is minimal; the turnpike structure is light weight since it is primarily wood; the bending strength of wood distributes dead load (tread fill) and live loads (traffic); and wrapping trees together with geotextile distributes concentrated live loads.

This alternative is attractive for areas that have wood and not much rock for obtaining drainage. If the trail alignment is very swampy, this alternative has strong advantages because the flotation and bending strength of wood is utilized. Keeping wood continually wet or dry is necessary to control rotting. Otherwise the life of the structure will be cut to less than half. A layer of geotextile placed down the centerline over the logs will help keep the wood saturated and also keep individual logs from coming up through the trail tread surface.

Geogrid With Geotextile or Geonet

Figure 10 shows geogrid placed on top of the geotextile or geonet adds bending strength to the system and decreases settling. This reduces the amount of fill material required. Very little drainage is required with this design, unless geonets are used or the tread material is permeable (rocky soils or crushed aggregate). The geogrid should be pulled taut to remove wrinkles before staking. The stakes and poles provide some pretension of the grid, to better utilize its strength. The geotextile or geonet provides separation from the saturated soil and keeps the drainage paths along the bottom of the fill material from clogging. See Section 913 of the *Standard Specifications for Construction of Trails* for additional information.

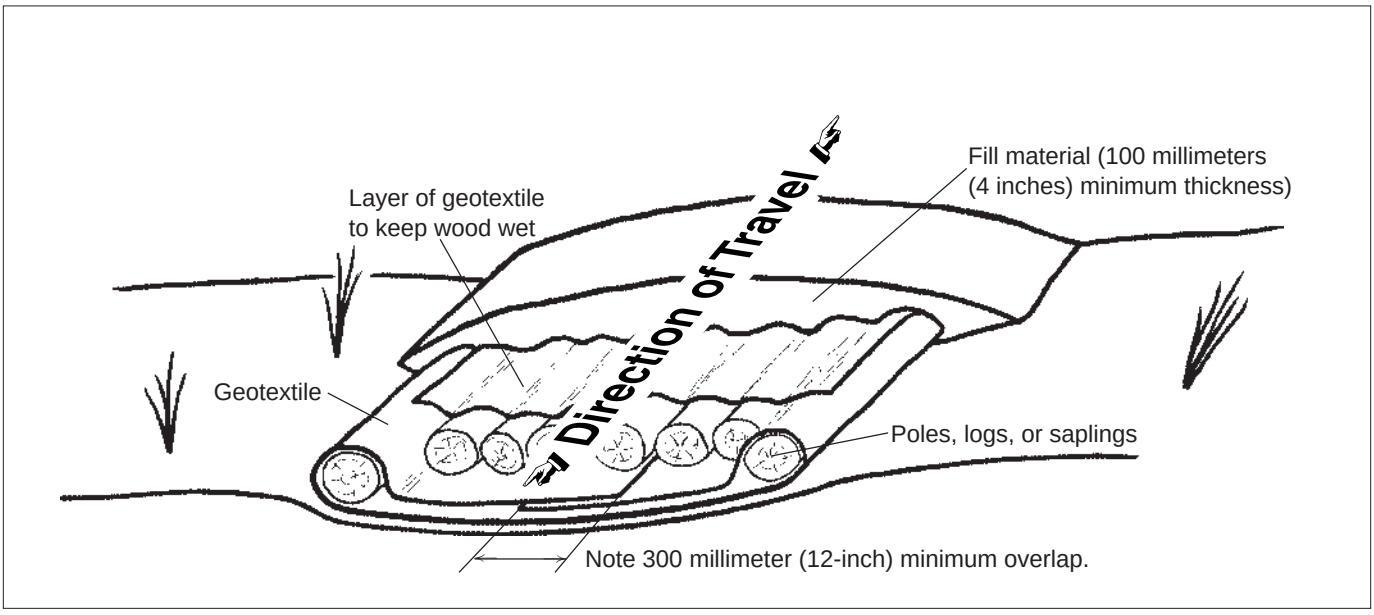


Figure 9—Poles or logs wrapped with geotextile.

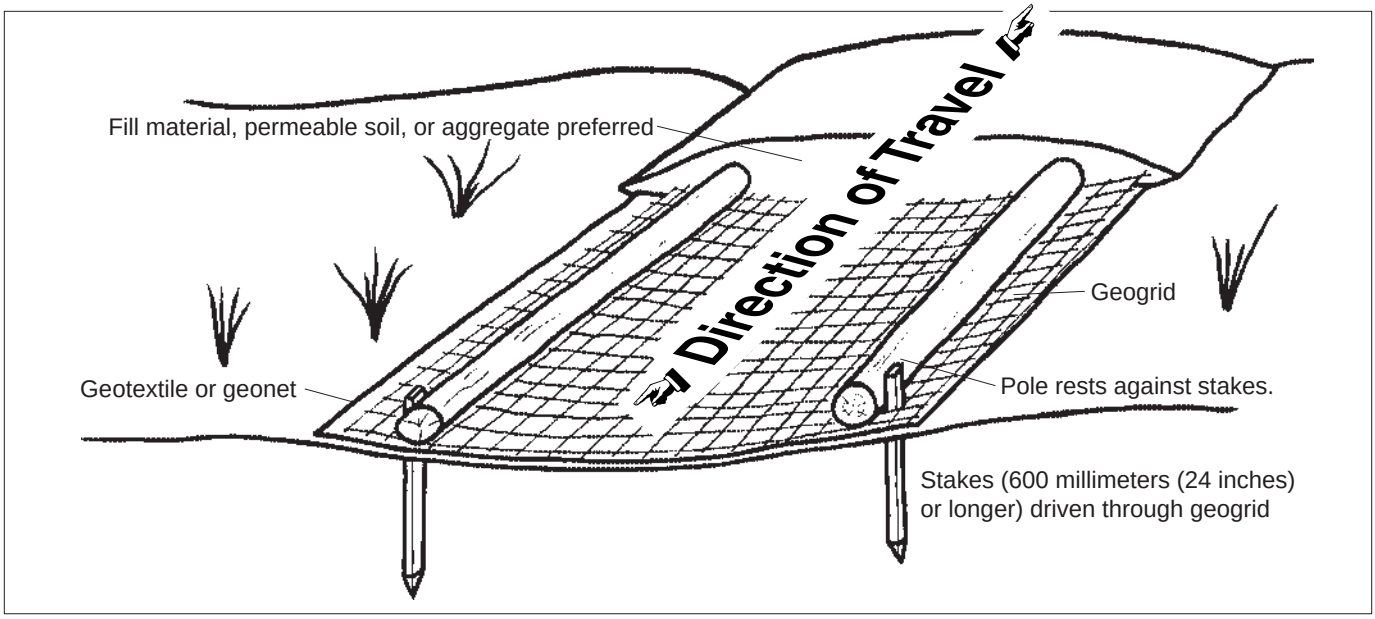


Figure 10—Geogrid with geotextile or geonet.

Sheet Drains Under Tread Fill

Sheet drains under tread fill (Figure 11) provide separation from saturated soils and distribute the trail tread weight to limit settling. Install the product with the plastic core side facing up and the fabric side facing down. This orientation takes advantage of the plastic core compressive strength and the fabric's tensile strength, which will reduce the amount of settling and also the amount of tread fill required. Twenty-five-millimeter (1-inch) diameter flexible plastic pipe can be used as a drainage outlet to take full advantage of the drainage capability of the sheet drain. If the trail is on a grade or side slope, an outlet pipe or daylight section could provide drainage.

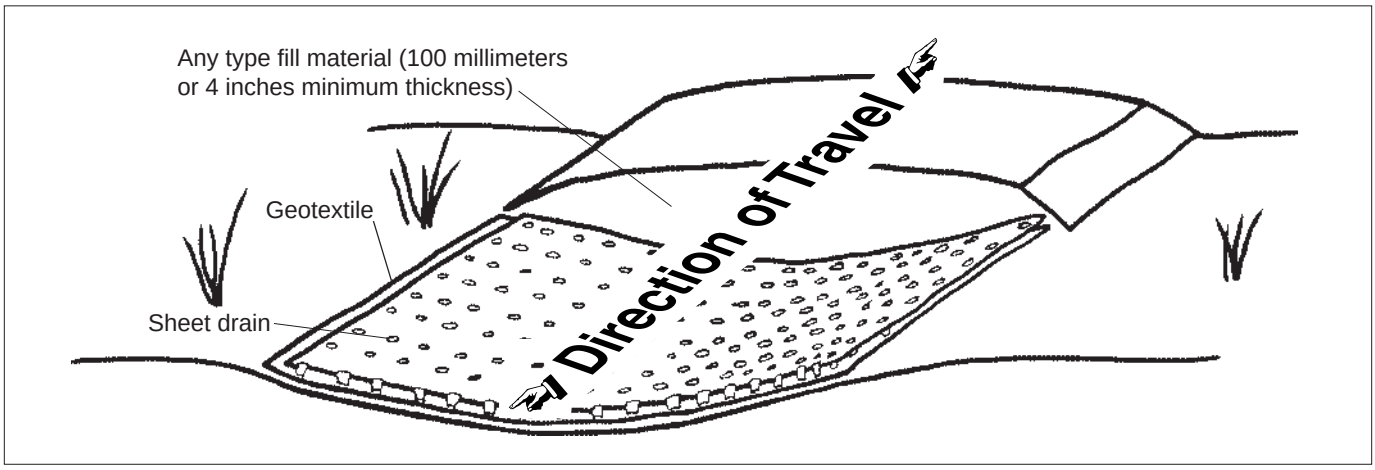


Figure 11—Sheet drain under fill material.

Sheet Drains or Geonets Used as Drainage Cutoff Walls

If the trail section is on a sideslope where subsurface water saturates the uphill side of the trail, a cutoff wall can be constructed to intercept surface and subsurface moisture (Figure 12) and help drain and stabilize the trail section. This application is especially beneficial where cutslope sloughing continually closes ditches. The sheet drain or geonet should be installed within 1 meter (3 feet) of the trail's edge. The proper depth of the collection pipe and location of the sheet drain can be determined by probing the saturated soil with a short length of Number 4 reinforcing steel. Collector and outlet pipes can be made from flexible plastic pipe. Keeping the top edge of the drain above the ground will capture surface runoff moving downslope. Cover the exposed material with large rocks to protect it from deterioration from ultraviolet light. The collector pipe can be drained into an outlet pipe or with a sheet drain or geonet panel under the trail section. This application requires ditching for proper interception and drainage of water. Ditching is normally more extensive on flatter terrain.

Geocell With Geotextile and Permeable Tread Material

The geocell provides confinement chambers that distribute the trail tread loads over a wider area and reduce settling (Figure 13). This works best in sandy soils, rocky soils, crushed aggregate, or free-draining rock. The net effect is to increase the load-bearing capacity of the tread and prevent feet and hooves from punching down into the trail. The geotextile provides separation between saturated soil and the tread fill. Somewhat less tread fill is required because settling is reduced. There is no subsurface drainage if the trail is on flat ground. If the trail has a grade or is built on a sideslope, drainage will occur through the permeable tread fill. Organic, silt, and clay soils are not desirable fill for geocells because these soils will likely remain saturated and unstable, and thus not strong enough to carry the loads placed on the trail. Geocell itself does not increase the load-bearing strength of clay or silt.

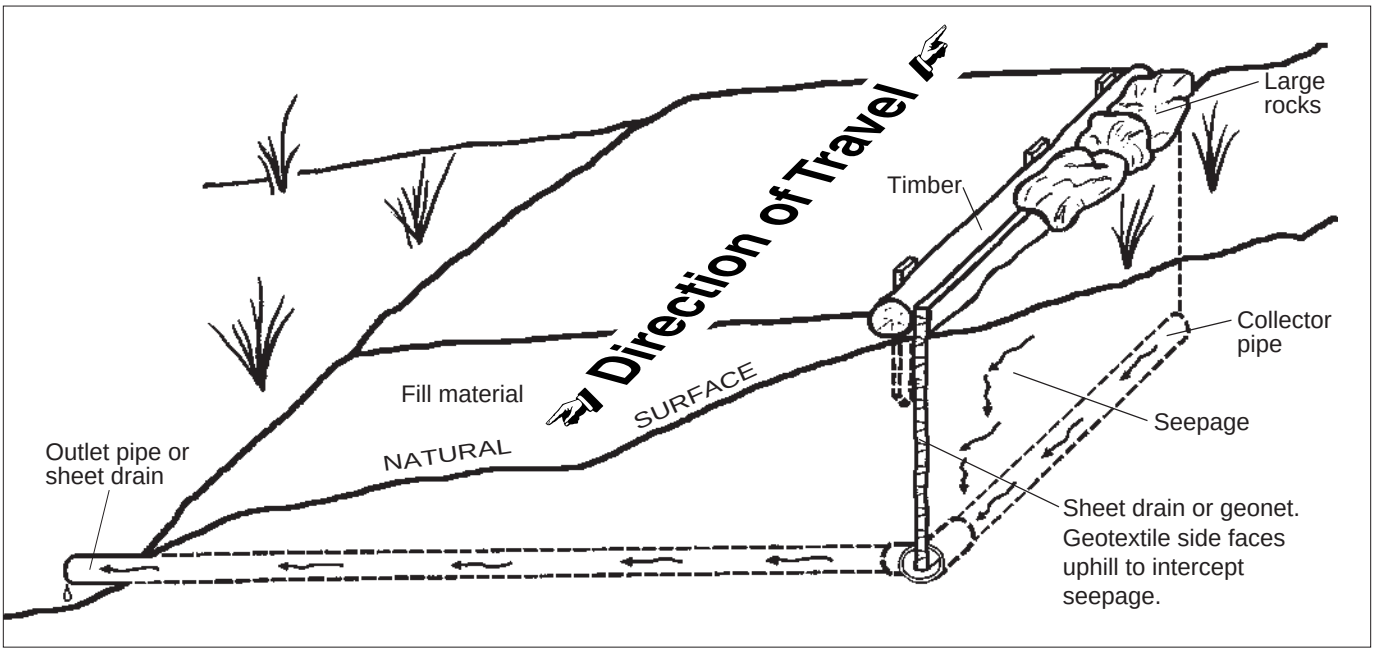


Figure 12—Sheet drain or geonet used to intercept seepage.

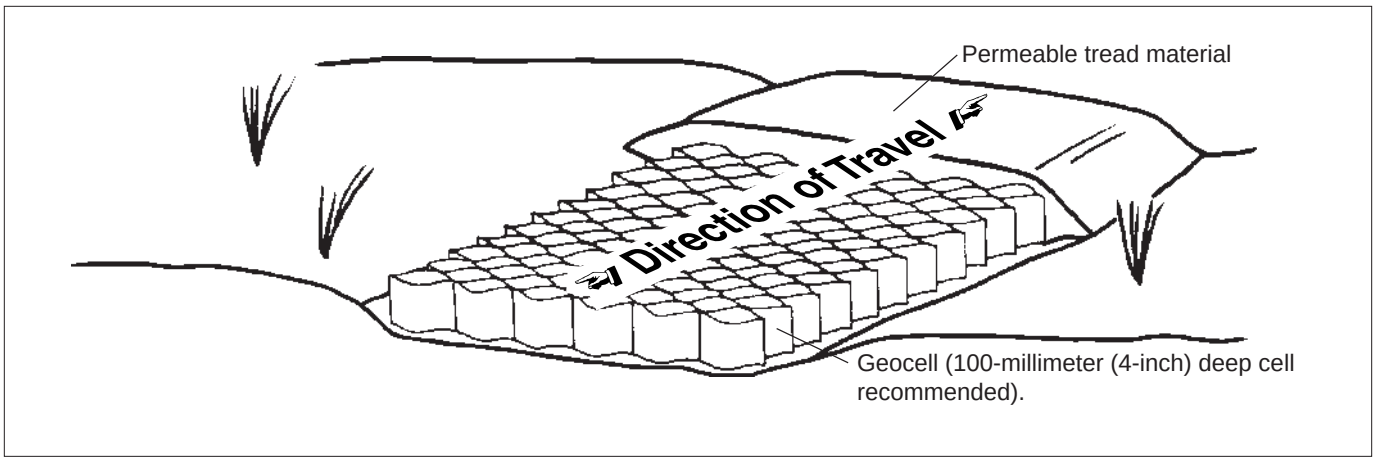


Figure 13—Geocell with geotextile and permeable tread material.

TrailMaster With Geotextile

TrailMaster with geotextile (Figure 14) is made from 3-millimeter (⅛-inch) thick polypropylene with 16-millimeter (⅝-inch) diameter extruded holes about 32 millimeters (1¼ inches) on center. This material is quite rigid, although it can be rolled up for easier transport. It is widely used in horse stalls to keep hooves dry.

It can be used without fill material since it has significant bending and tensile strength and is durable enough to resist abrasion from pack animals and even motorcycles. Since the material is used as the trail surface and grasses can grow through, it also resists erosion better than tread fill materials. The geotextile allows water, but not soil, to be pumped through the *TrailMaster*. The water collected on the surface can be removed by an outlet ditch at the lowest point on flat trail sections, or by using rolling dips or outsloping on other trails. Since the surfacing will deflect under the weight of stock, rebar with hooks on the upper ends must be used to anchor the geotextile and *TrailMaster* to the ground. Rebar staples are normally needed for transverse joints. The poles provide a curb to keep traffic on the surface and also help anchoring. Settling should be minimal since the weight of *TrailMaster* is only 2.8 kilograms per square meter (0.57 pounds per square foot). The high price of this product may be offset by not having to import fill for a turnpike section. It can be cut with a hand saw. Turns in the trail are normally cut on angles, which makes constructing winding trail alignments more difficult.

Before placing a large order, it's a good idea to obtain a sample for examination. This is a manufactured material and does not blend well with natural forest environments. Since installation is relatively quick, it may be especially useful as a temporary surface until a more aesthetically pleasing alternative is constructed.

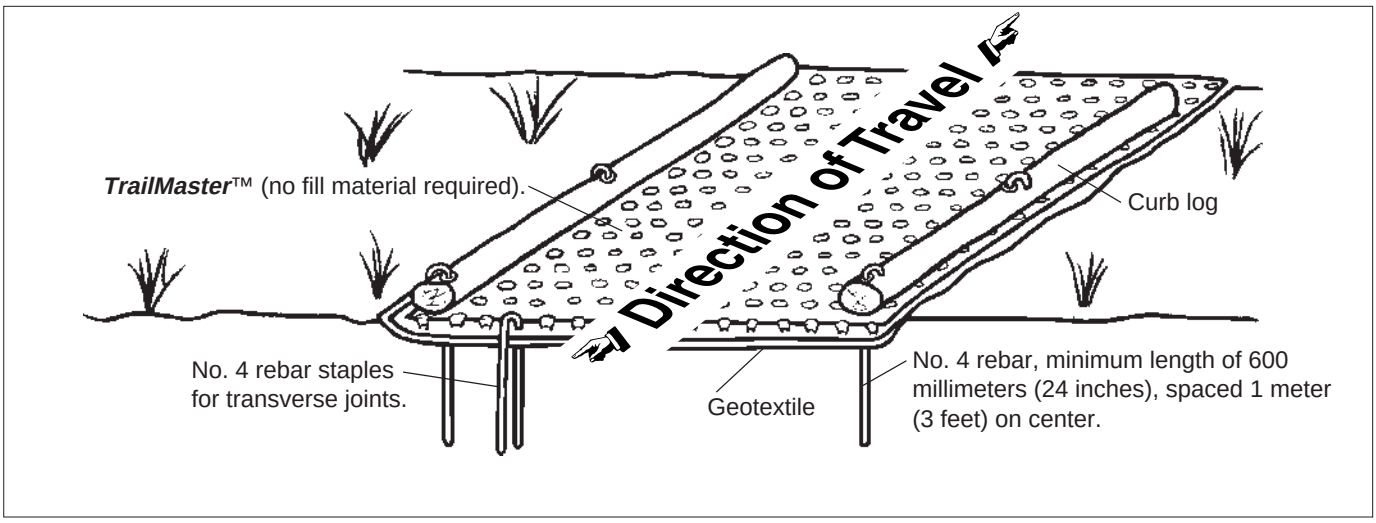


Figure 14—*TrailMaster* with geotextile.

Section 4: Geosynthetic Product Information

General Notes

The listed manufacturers and products were obtained from the *Geotechnical Fabrics Report, 1995 Specifier's Guide*. The products listed meet the physical properties shown for each type of geosynthetic. These physical properties were selected to meet typical muddy trail construction conditions. These properties are on the "low end" of those available since trails applications are much less demanding than geosynthetic applications in road construction where heavy machinery and large angular boulders require heavier products. These products are lighter, easier to work with, and also cost less.

Phone numbers and web sites have been updated using the *Geotechnical Fabrics Report, 2000 Specifier's Guide.* However, we have not updated the product numbers, prices, and specifications. Geosynthetic products that have entered the market since 1995 are not described here. For a copy of the newest *Specifier's Guide,* contact the Industrial Fabric Association International (page 18).

The products listed are ones that are readily available. Many other products from these and other manufacturers may be appropriate. There are literally hundreds of products available from manufacturers and even home improvement centers. Most manufacturers and Geotechnical/Materials Engineers can assist in selecting products if you provide details on soil and moisture conditions and expected loads (light loads for trails).

Price ranges shown are approximate and vary throughout the country due to shipping costs. Call the listed phone numbers for current prices delivered to your area, or for the local sales representative. For comparison, price ranges shown are in dollars per square meter for all products. Price ranges in parenthesis are in dollars per square yard. Manufacturers may provide prices by the square meter, square yard, square foot, or for full roll quantities. Unit costs decrease as the amount ordered increases. Prices shown are based on the minimum one roll quantity, FOB the manufacturing location.

All geosynthetic products can be either field cut or precut by the manufacturer to meet your width requirements and weight handling capability.

Geotextiles

Manufacturers:

COMPANY	PRODUCT
AMOCO Fabrics & Fibers Phone: 800–445–7732	4545
TC Mirafi Phone: 888–795–0808 Web site: http://www.tcmirafi.com	140N
Linq Industries Phone: 800–543–9966 Web site: http://www.linqind.com	1300EX

Price Range: $0.63 to $0.72 per square meter ($0.53 to $0.60 per square yard)

Typical Product Unit Weight: 0.13 kilogram per square meter (0.25 pound per square yard)

Critical Physical Properties for Trail Construction:

- **Material structure:** Nonwoven.
- **Polymer composition:** Polypropylene.
- **Apparent opening by ASTM D 4751-87:** Less than 0.297 millimeters (greater than No. 50 mesh).
- **Permittivity by ASTM D4491-92:** Greater than 4060 liters per minute per square meter (Greater than 100 gallons per minute per square foot).
- **Puncture strength by ASTM D48833-88:** Greater than 0.245 kilonewtons (greater than 55 pounds).
- **Mullen burst by ASTM D 3786-87:** Greater than 1275 kilopascals (more than 185 pounds per square inch).
- **Trapezoid tear strength by ASTM D4533-91:** Greater than 0.18 kilonewtons (more than 40 pounds).
- **Grab tensile at 50 percent elongation by ASTM D4632-91:** Greater than 0.40 kilonewtons (Greater than 90 pounds).
- **Ultraviolet degradation:** Greater than 70 at 150 hours.

Notes: The products listed are nonwoven, felt-like materials that are easier to work with than heat bonded or slit film products that have a slick surface texture. Physical property requirements are minimum average roll values where applicable. Compare desired widths with standard roll widths and consult with manufacturers for field or factory cutting. Costs are based on one roll quantities which normally cover 400 to 500 square meters (475 to 600 square yards).

Geonet (Geonet Composites)

Manufacturers:

COMPANY	PRODUCT
Tenax Phone: 800–356–8495 Web site: http://www.tenax.com	TNT 204042
Tensar Corp. Phone: 800–836–7271 Web site: http://www.tensarcorp.com	DC4205

Price Range: $3.50 to $4.60 per square meter ($2.97 to $3.87 per square yard)

Typical Product Unit Weight: 0.89 kilograms per square meter (1.64 pounds per square yard)

Critical Physical Properties for Trail Construction:

- **Polymer composition of core (net or mesh):** Medium or high-density polyethylene.
- **Geotextile:** Must be attached to both sides of the Core, and meet or exceed the requirements of AASHTO M 288 Subsurface Drainage Class B with permeability greater than 0.0001 centimeters per second, and an apparent opening size less than 0.297 millimeters (greater than the No. 50 U.S. Standard Sieve).
- **Core thickness:** Greater than 5 millimeters by ASTM D5199.
- **Compressive strength of core:** Greater than 500 kilo-pascals by ASTM D1621.
- **Transmissivity with gradient at 0.1, pressure at 10 kilo-pascals:** Greater than 0.0009 meters^2 per second (greater than 4 gallons per minute per foot).

Notes: Discuss the roll width and length requirements for your project with manufacturers.

Sheet Drains

Manufacturers:

COMPANY	PRODUCT
TC Mirafi Phone: 800–445–7732 Web site: http://www.tcmirafi.com	Miradrain 6000
Contech Phone: 800–338–1122 Web site: http://www.contech-cpi.com	C-Drain 15K
Presto Phone: 800–548–3424 Web site: http://www.prestogeo.com	Amerdrain 500

Price Range: $6.50 to $8.50 per square meter ($5.40 to $7.11 per square yard).

Typical Product Unit Weight: 2.3 kilogram per square meter (4.25 pounds per square yard).

Critical Physical Properties for Trail Construction:

- **Structure:** Single- or double-dimpled core.
- **Core polymer composition:** Polystyrene or polypropylene.
- **Attached geotextile:** Nonwoven on one side if core solid, on both sides if core perforated. Geotextile must meet or exceed the requirements of AASHTO M 288 Subsurface Drainage Class B with permeability greater than 0.0001 centimeters per second, and an apparent opening size less than 0.297 millimeters (greater than the No. 50 U.S. Standard Sieve).
- **Core thickness by ASTM D5199:** Greater than 10 millimeters (greater than 0.40 inches).
- **Core compressive strength at yield by ASTM D1621:** Greater than 650 kilopascals (greater than 95 pounds per square inch).

Notes: Compare desired width with standard sheet width and consult with manufacturers for field or factory cutting. Various core thicknesses are available. For example, Presto makes a product called *Akwadrain* that has a 25-millimeter core thickness, with fabric on both sides. It has significantly greater bending strength which helps limit the amount of settling in soft soils, and reduces the amount of fill material required.

Geogrids

Manufacturers:

COMPANY	PRODUCT
Contech Phone: 800–338–1122; Web site: http://www.contech-cpi.com or	BX1100
Tensar Corp. Phone: 800–836–7271 Web site: http://www.tensarcorp.com	BX1100
Carthage Mills Phone: 800–543–4430 Web site: http://www.carthagemills.com	FX-3000
Tenax Phone: 800–356–8495 Web site: http://www.tenax.com	MS300
Huesker Phone: 800–942–9418 Web site: http://www.huesker.com	Fortrac 35/20-20
TC Mirafi Phone: 800–445-7732 Web site: http://www.tcmirafi.com	Miragrid 5T

Price Range: $2.15 to $4.75 per square meter ($1.80 to $4.00 per square yard). Low-cost products are made from polypropylene, higher cost products are made from coated polyester. Both product types are adequate for trails.

Typical Product Unit Weight: 1.75 kilograms per square meter (0.34 pounds per square yard).

Critical Physical Properties for Trail Applications:

- **Polymer type:** Polypropylene or polyester with acrylic or PVC coating.
- **Mass per unit area by ASTM D5261-92:** 175 grams per square meter (greater than 5.5 ounces per square yard).
- **Maximum aperture size:** Machine direction (MD): 25 centimeters (1 inch). Cross direction (XD): 33 centimeters (1.3 inches).
- **Wide-width strip tensile strength at 5-percent strain by ASTM D4595-86:** Machine direction (MD): 8 kilonewtons per meter (550 pounds per foot). Cross direction (XD): 6 kilonewtons per meter (410 pounds per foot).

Notes: Specify desired product widths and lengths for the project application.

Geocells

Manufacturers:

COMPANY	PRODUCT	Expanded Dimensional Properties Individual Cell Depth x Length	 Whole Sheet Length x Width
Presto Phone: 800–548–3424 Web site: http://www.prestogeo.com	Geoweb	100 x 200 mm (4 x 8 in)	6.10 x 2.44 m (20 x 8 ft)
AGH Phone: 800–434–4743 Web site: http://www.aghindustries.com	Envirogrid	Same	Same
WEBTEC Phone: 800–438–0027 Web site: http://www.webtechgeos.com	TerraCell	Same	Same

Price Range: $7.50 to $11.30 per square meter ($6.30 to $9.45 per square yard.

Typical Product Unit Weight: 1.55 kilograms per square meter (2.9 pounds per square yard).

Similar Physical Properties for Listed Products:

- **Composition:** Polyethylene or high-density polyethylene
- **Geocell weight expanded:** Greater than 1.4 kilograms per square meter (greater than 45 ounces per square yard).
- **Minimum cell seam peel strength by U.S. Army Corps of Engineers Technical Report G:-86-19 Appendix A:** 800 newtons (180 pounds).
- **Expanded dimensional properties:** As specified by the designer—see dimensions listed for the products shown above.

Notes: Specify desired product widths for the project application. The 100-millimeter (4-inch) cell depth should be adequate for trails—depths from 50 to 200 millimeters (2 to 8 inches) are available. Consult manufacturers for availability of different section widths and alteration of standard section widths to fit your project needs.

Proprietary Materials

Manufacturers:

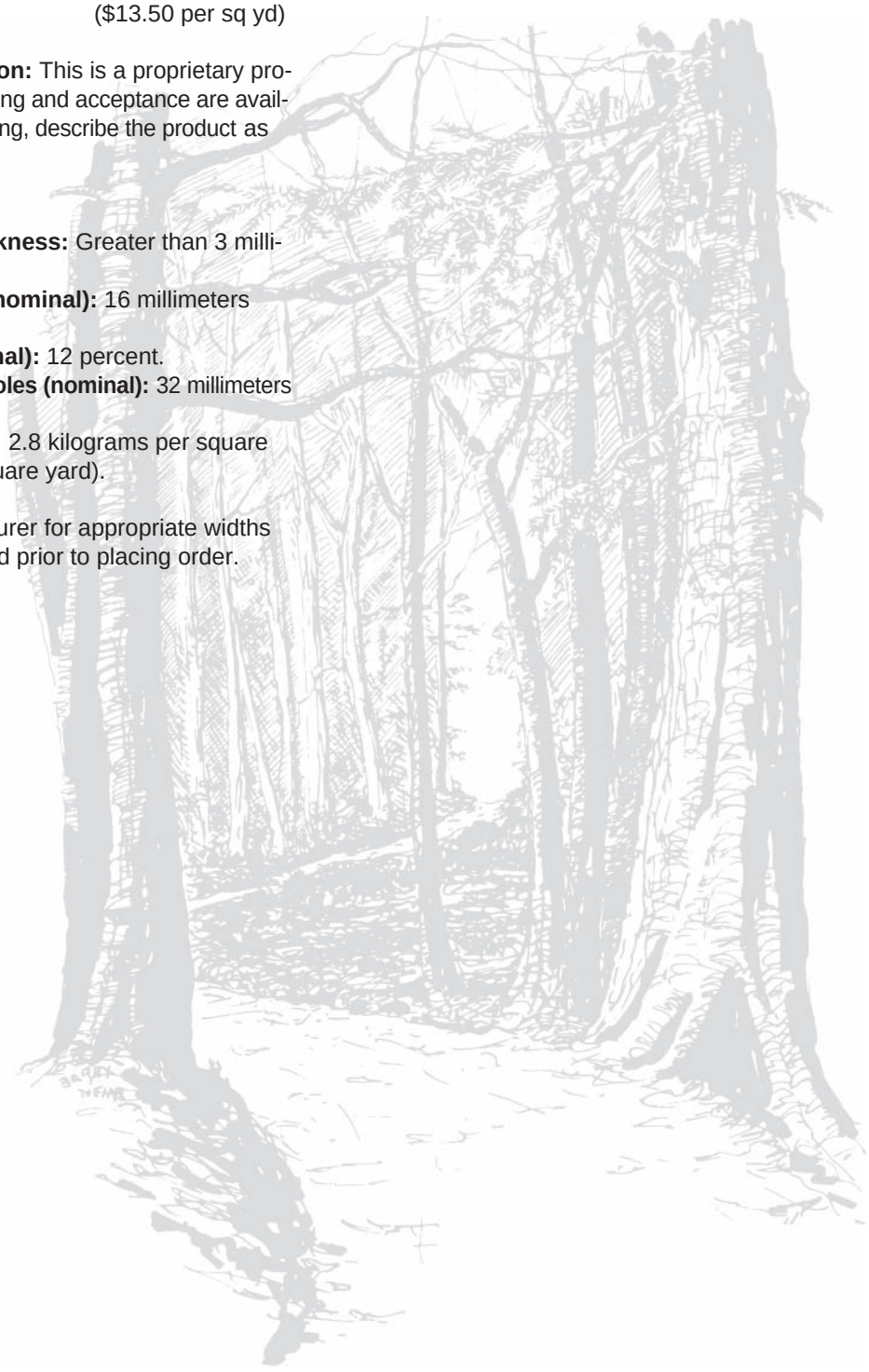
COMPANY	PRODUCT	APPROXIMATE COST
GroundMaster Phone: 800–968–2930	*TrailMaster*	$16 per sq m ($13.50 per sq yd)

Physical Property Description: This is a proprietary product, and no standards for testing and acceptance are available. When specifying or ordering, describe the product as follows:

TrailMaster—

- **Polypropylene sheet thickness:** Greater than 3 millimeters (⅛ inch).
- **Extruded hole diameter (nominal):** 16 millimeters (⅝ inch).
- **Percent open area (nominal):** 12 percent.
- **Space between extruded holes (nominal):** 32 millimeters (1¼ inches).
- **Minimum product weight:** 2.8 kilograms per square meter (5.13 pounds per square yard).

Notes: Consult the manufacturer for appropriate widths and lengths of product desired prior to placing order.



Section 5: Identification of Unsuitable Tread Fill Material

Soils from wet areas are normally not suitable for use as tread fill because they are too moisture sensitive and lose strength easily when they become wet. Avoiding unsuitable tread fill is very important since poor materials will fail when wet, and costs for excavating and hauling are high. Poor materials can be identified by several methods:

Organic Soils: Identified by musty odor when damp, and dark in color.

Other Unsuitable Tread Fill Materials: Stability of tread fill material is primarily influenced by the amount of silt or clay present. If the percentage exceeds 20 percent, the materials will likely become very unstable when wet. Rough evaluations for suitability can be done by the following methods:

Method A—Field Comparison

Make comparisons between existing trail tread materials with borrow sources. Compare the proportions of gravel, sand, and fines. Individual “fine-size” material particles are actually not visible to the naked eye and are classified as silt or clay. If the proportions of gravel, sand, and fines are similar, you can expect the borrow materials to perform as well as the existing trail tread materials. If less fines exist in the borrow source, you can expect better performance.

Method B—Laboratory Test

Take a 5-kilogram (10-pound) sample of the proposed tread fill material to a materials testing laboratory, and have them perform a washed sieve analysis test to determine the percentage of minus No. 200 material. Since the minus No. 200 represents the amount of silt or clay, if the amount exceeds 20 percent, the material is not suitable. Typical cost for this test is between $35 and $50.

Method C—Geotextile Field Test

Build a short section of a small-scale trail over a wet area with a 2-meter (6-foot) square piece of geotextile and the proposed tread fill material. The depth of tread fill should be at least 150 millimeters (6 inches), and should be saturated with water after placement to assimilate moisture contents that one would expect under the worst conditions. Evaluate the stability of the tread material by repeated load testing with your foot.

Additional Information

Industrial Fabric Association International (IFAI)

The *Geotechnical Fabrics Report, Specifier's Guide,* is published annually by IFAI. To purchase a copy of the latest *Specifier's Guide,* to subscribe to *Geotechnical Fabrics Report,* or learn about other publications, check out IFAI's web site at: *http://www.ifai.com*. Here are some other ways to contact IFAI.

IFAI Resource Center
1801 County Road BW
Roseville, MN 55113–4061
Phone: 800–207–0729 or 651–222–2508
Fax: 651–631–9334

Federal Highway Administration

The Federal Highway Administration's Recreational Trails Program provides funds to the States to develop and maintain recreational trails and trail-related facilities for motorized and nonmotorized recreational trail uses. For additional information, see FHWA's Recreational Trails Program web site at: *http://www.fhwa.dot.gov/environment/rectrail.htm.*

Library Card

Monlux, Steve; Vachowski, Brian, 2000. Geosynthetics for trails in wet areas: 2000 edition. Tech. Rep. 0023-2838-MTDC. Missoula, MT: U.S. Department of Agriculture, Forest Service, Missoula Technology and Development Center. 18 p.

Geosynthetics are synthetic materials that are used with soil or rock in many types of construction. They perform three major functions: separation, reinforcement, and drainage.

This report describes several types of geosynthetics; explains basic geosynthetic design and utilizaiton concepts for trail construction in wet areas; and provides geosynthetic product information. Detailed product specifications and procurement sources are listed.

Keywords: geocells, geogrids, geonets, geosynthetics, geotextiles, sheet drains, trail construction, trail turnpikes

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To order a copy of this document, you can use the order form on the FHWA's Recreational Trails Program web site at: *http://www.fhwa.dot.gov/environment/trailpub.htm.* Fill out the order form and fax it to the distributor listed on the order form. If you do not have Internet access, you can send a fax request to 202–366–3409, or request a copy by mail from:

USDOT, Federal Highway Administration
Office of Human Environment, Room 3301
400 7th Street SW
Washington DC 20590

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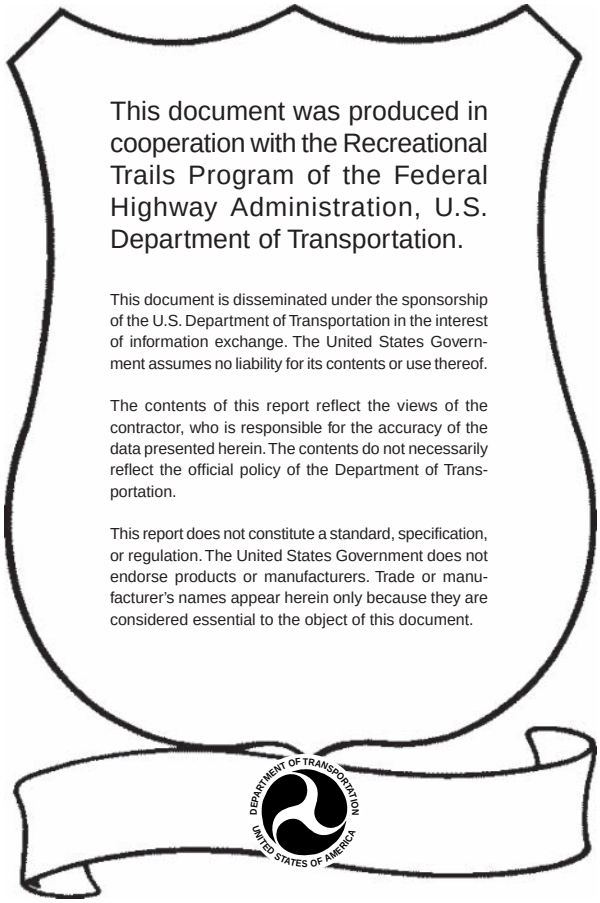
Produced by:

USDA FS, Missoula Technology & Development Center
5785 Hwy. 10 West
Missoula, MT 59808–9361
Phone: 406–329–3978
Fax: 406–329–3719
E-mail: *wo_mtdc_pubs@fs.fed.us*

For further technical information, contact Brian Vachowski at MTDC.

Phone: 406–329–3935
Fax: 406–329–3719
E-mail: *bvachowski@fs.fed.us*



This document was produced in cooperation with the Recreational Trails Program of the Federal Highway Administration, U.S. Department of Transportation.

THE TRAIL FORUM

Conducted by Kim Frederick, Jefferson County Open Space
Lois Bachensky, U.S. Forest Service, Rocky Mountain Region

Geosynthetics for Trails in Wet Areas

By Steve Monlux, USFS R1 Engineering

Trails on soft, water-saturated soils present special challenges. Improper construction of trails in wet areas leads to soil compaction, sedimentation, multiple trails, and unhappy trail users. Turnpike or puncheon has worked well where rock or wood materials are readily available, but the use of geosynthetics can increase the effectiveness of trail construction methods and offers additional alternatives. Geosynthetic materials have been used increasingly in trail construction over the past 10 years. We present here some guidelines and product informationfor trail managers.

Geotextile, *often called* "*construction fabric,*" *is primarily used for* **separation** *and* **reinforcement** *over wet, unstable soils. It can both support loads and allow water but not soil to seep through.*
Geonet *has a thin polypropolene drainage core covered on both sides with geotextile, which provides more* **reinforcement** *in addition to* **separation** *and* **drainage.**
Geogrid *is a more open polyethylene structure with high tensile strength that can interlock coarse aggregate into the grid structure.*

General Guidelines for Geosynthetic Use

Geosynthetics are usually placed directly on the natural ground without prior excavation and covered with trail tread material. Less tread fill can be used over geosynthetic products that are rigid or have high bending strengths because the weight of fill is distributed over a larger area. For example, much more tread fill is required for a single layer of geotextile than for geocell with geotextile. In this example, the cost of importing tread fill must be compared to the increased cost of the geocell.

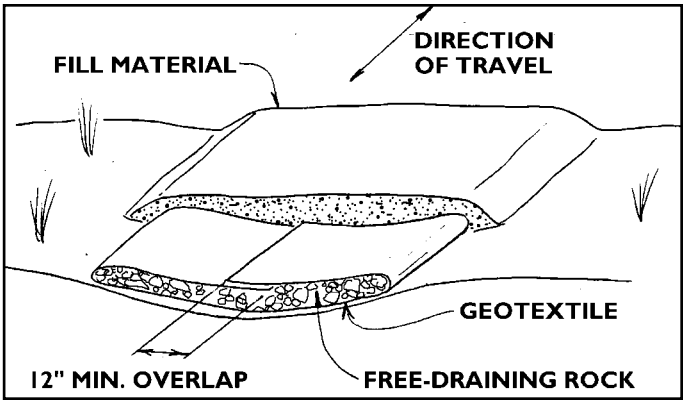
Alternatives that use tread fill should have a crowned surface to shed water quickly, improve stability, and control erosion and sediment. After backfilling, there will be some settlement depending on soil type, level of saturation, and the weight and depth of fill. Additional fill may then be necessary to maintain the crown due to settlement or tread wear. In all cases keep geosynthetics covered to protect them from ultraviolet light and traffic abrasion.

Geotextile or Geonet (single layer)

This basic application places fill on a single layer of geotextile or geonet which (a) separates fill material from saturated soils, and (b) distributes fill weight so less settlement takes place. Since geonets cost more, use them only where drainage and subsurface moisture conditions are worst. Avoid using organic, silty, or clayey soils for trail tread material since little subsurface drainage will occur, and the trail tread will become muddy in wet weather. Rocky soils or crushed aggregate are the best tread materials since they retain much of their strength when saturated. Excess surface moisture can drain off through these permeable materials if the trail is located on a grade or side slope.

Geotextile with Encapsulated Free Draining Rock (Sausage Technique)

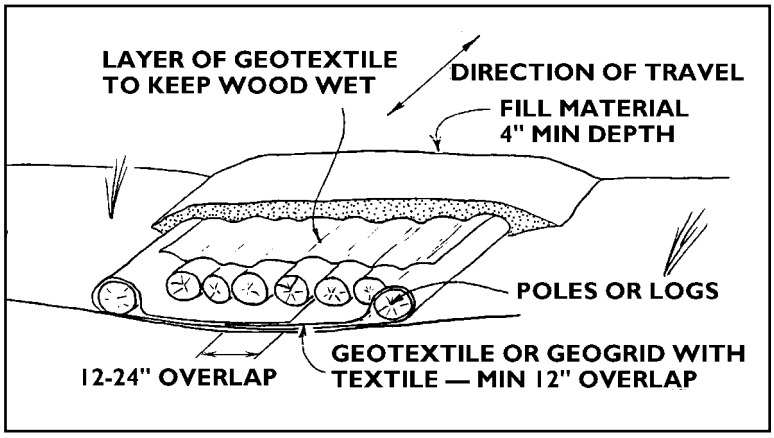
This application involves encapsulating native or free-draining rock in a piece of geotextile and placing fill on top. The geotextile provides separation from the saturated soil, and the rock provides drainage for excess water. One-inch flexible plastic pipe outlets for subsurface water may be desirable where trails are constructed on very flat terrain to avoid the 'bath tub' effect. If the trail has grade, and or if built on a side slope, other drainage options exist.



The rock may be single size material from pea gravel to cobbles (3-12") or a mixture of rock material that does not contain silt or clay. The free-draining rock can be placed to a thickness equal to the largest rock if only drainage is desired. If reinforcement is also needed, at least 3" of rock is recommended. The geotextile is wrapped over the rock layer with a 12" overlap to ensure encapsulation, since settlement of saturated soil can pull the overlap joint apart.

Geotextile with Poles, Logs

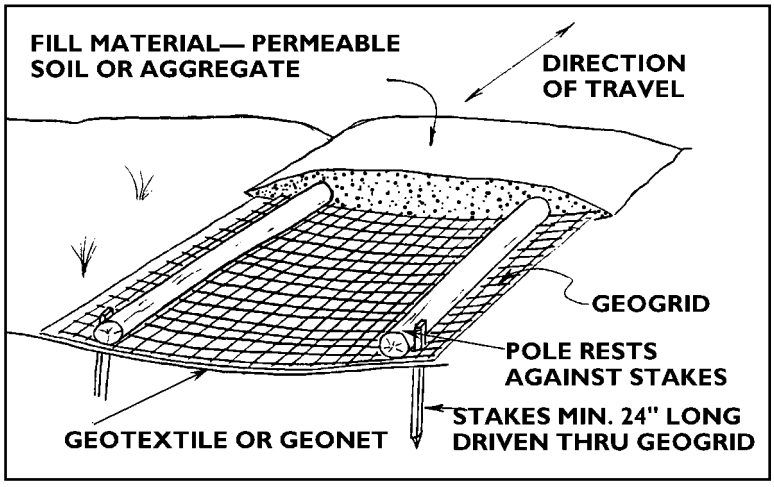
This turnpike application involves wrapping poles, logs, or saplings in geotextile with the poles parallel to the trail. This structure requires less fill and resists being pushed down into soft soils. No subsurface drainage is provided with this design, but longitudinal drainage may occur along the poles if the trail slopes. Another approach is to cut logs to the trail width and place them crosswise, but it does not use log bending strengths as effectively and is more labor intensive. Use an outlet pipe to provide drainage where trails are on a grade or side slope.



Soil settlement is minimal because the wood structure is light weight; the bending strength of wood distributes the weight of fill and traffic; and wrapping trees together with geotextile distributes loads. This method is attractive for areas with wood but not much rock for drainage, and for swampy areas where flotation and bending strength of wood is used. Wood must be kept constantly wet or dry to control rotting. A layer of geotextile down the centerline over the logs will help keep them saturated and securely positioned below the trail tread surface.

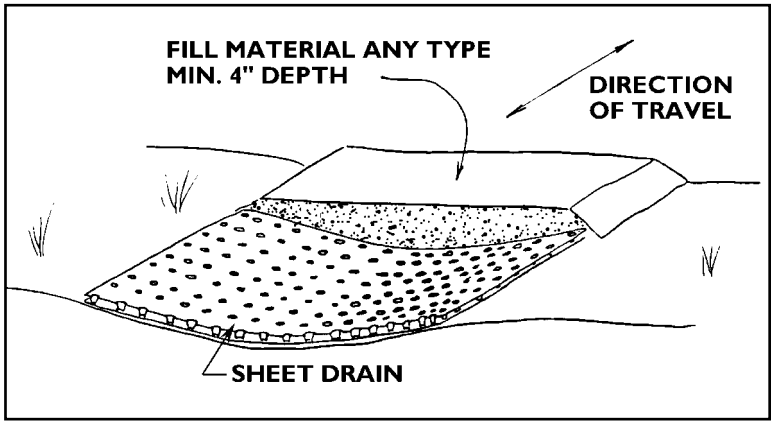
Geogrid with Geotextile or Geonet

Geogrid placed on top of the geotextile or geonet adds bending strength to the system, and decreases settlement and amount of fill material required. Very little drainage is required with this design unless geonets are used, or if the tread material is permeable (rocky soils or crushed aggregate). The geogrid should be pulled taut to remove wrinkles prior to staking. The stakes and poles provide some pre-tension of the grid, to better utilize its strength. The geotextile or geonet provides separation from the saturated soil and keeps the drainage paths along the bottom of the fill material from clogging.

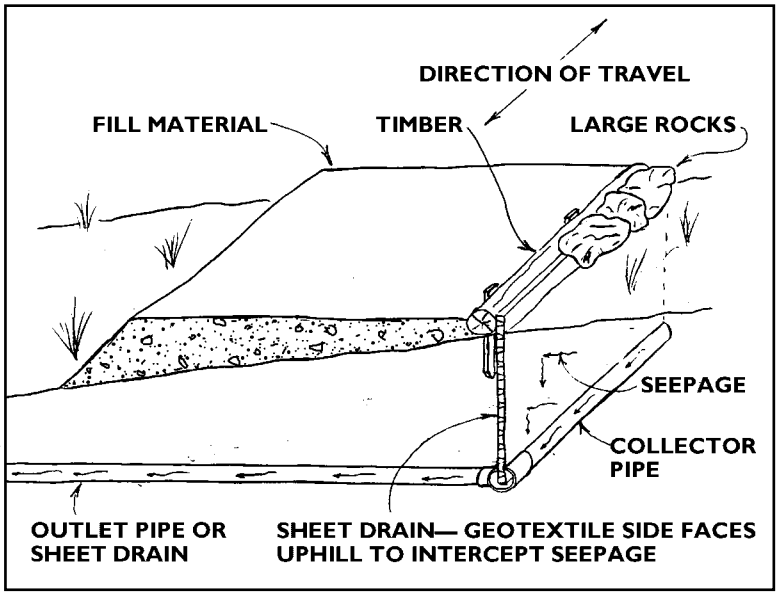


Sheet Drains under Tread Fill

The sheet drain provides separation from saturated soils and distributes the trail tread weight to limit settlement. Install the product with the plastic core side facing up, and the fabric side facing down. This orientation takes advantage of the plastic core compressive strength and the fabric's tensile strength to reduce settlement and fill required. One-inch diameter flexible plastic pipe can be used as a drainage outlet to take full advantage of the drainage capability of the sheet drain.



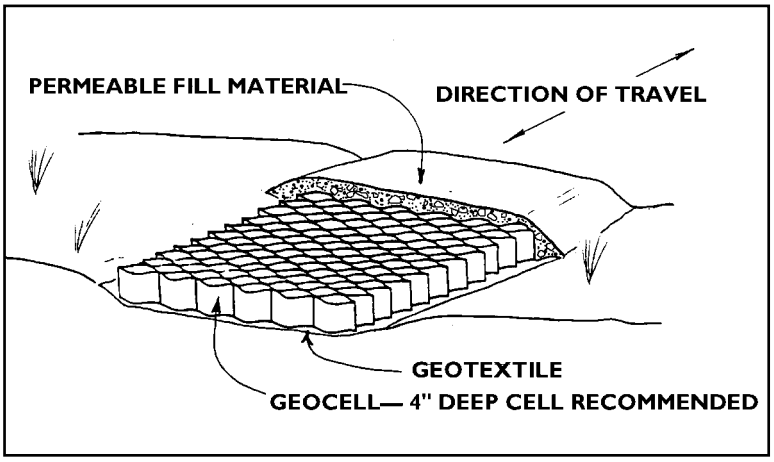
Sheet Drains Used as Drainage Cutoff Walls



If the trail section is on a side slope where subsurface water saturates the uphill side of the trail, a cutoff wall will intercept surface and subsurface moisture and help drain and stabilize the trail section. This application is especially beneficial where cut-slope sloughing fills in ditches. The sheet drain is placed vertically along the uphill side of the trail within 3 feet of the trail's edge.

Probe the saturated soil with a short length of #4 reinforcing steel to determine the proper depth of the collection pipe and location of the sheet. Collector and outlet pipes can be made from flexible plastic pipe. Keep the top edge of the drain above ground to capture surface runoff moving downslope. Cover the exposed sheet drain with large rocks to protect it from deterioration from sunlight. The collector pipe can be drained into an outlet pipe or with a sheet drain panel under the trail section. This application requires ditching for proper interception and drainage of water. More ditching is normally required on flatter terrain.

Geocell Backfilled with Geotextile and Permeable Tread Material



The geocell provides confinement chambers which distribute the trail tread loads over a wider area and reduce settlement. The net effect is it increases the load bearing capacity of the tread and prevents feet and hooves from punching down into the trail. The geotextile provides separation between saturated soil and the tread fill. There is no subsurface drainage if the trail is on flat groundl, but on a side slope, drainage will occur through the permeable tread fill. Sandy or rocky soils, crushed aggregate, or rock are desirable fill for geocells. Geocell itself does not increase the load bearing strength of clay or silt.

GEOSYNTHETIC PRODUCT INFORMATION

The listed manufacturers and products were obtained from the *Geotechnical Fabrics Report, 1995 Specifier's Guide.* The products listed are ones that are readily available. Many other products from these and other manufacturers may be appropriate. Most manufacturers and Geotechnical/Materials Engineers can assist in selecting products if you provide details on soil and moisture conditions, expected loads (light loads for trails), etc.

Prices vary throughout the country due to shipping costs, but for comparison purposes prices are shown in dollars per square yard. Price ranges in parenthesis are in dollars per square yard although manufacturers may use other units or full roll quantities. All geosynthetic products can be either field cut or pre-cut by the manufacturer to meet width requirements and weight handling capability.

GEOTEXTILES Manufacturers

Company Name	Phone Number	Product Name/Number
AMOCO	(800) 445-7732	4545
Nicolon/Mirafi Group	(800) 234-0484	140N
Linq Industries	(803) 873-5800	130 EX

Price range: $.63 to $.72 per square meter ($.53 to $.60 per square yard)
Typical product unit weight: 0.13 Kg/square meter (0.25 lb/square yard)

Notes: These products are non-woven felt-like fabrics that are easier to work with than heat-bonded or slit film products that have a slick surface texture. Compare desired widths with standard roll widths for field or factory cutting. Costs are based on one roll quantities which normally cover 400 to 500 square meters (475 to 600 SY).

GEONET Manufacturers

Company Name	Phone Number	Product Name/Number
Tenax	(800) 874-7437	Tenax TNT 204042
Tensar Corporation	(800) 292-4459	DC 4205

Price range: $3.50 to $4.60 per square meter ($2.97 to $3.87 per square yard)
Typical product unit weight: 0.89 kg/square meter (1.64 lb/square yard)

SHEET DRAINS Manufacturers

Company Name	Phone Number	Product Name/Number
Mirafi	(800) 234-0484	Miradrain 6000
Contech	(513) 425-2165	C-Drain 15K
Presto	(800) 558-3525	Amerdrain 500

Price range: $6.50 to $8.50 per square meter ($5.40 to $7.11 per square yard)
Typical product unit weight: 2.3 Kg/square meter (4.25 lb/square yard)
Notes: Compare desired widths with standard sheet widths and consult with manufacturers for field or factory cutting. Various core thicknesses are available. For example, Presto makes a product called Akwadrain with a 25mm core thickness with fabric on both sides, that has significantly greater bending strength which limits the settlement in soft soils, and reduces the amount of fill material required.

GEOGRID Manufacturers

Company Name	Phone Number	Product Name/Number
Contech	(513) 425-2165	Tensar BX1100
Tensar	(800) 292-4459	Tensar BX1100
Carthage Mills	(513) 761-4141	FX-3000
Tenax	(800) 874-7437	MS 300
Huesker	(800) 942-9418	Fortrac 35/20-20
Mirafi	(800) 234-0484	Miragrid 5T

Price rRange: $2.15 to $4.75 per square meter ($1.80 to $4.00 per square yard). Low-cost products are made from polypropylene, higher-cost products from coated polyester. Both product types are adequate for trails
Typical product unit weight: 1.75 Kg/square meter (0.34 lb/square yard)
Notes: Specify desired product widths and lengths for the project application.

GEOCELL Manufacturers

Company Name	Phone Number	Product Name/Number
Presto	800-558-3525	Geoweb
AGH	713-552-1749	EnviroGrid
WEBTEC	800-438-0027	TerraCell

Price range: $7.50 to $11.30 per square meter ($6.30 to $9.45 per square yard)
Typical product unit weight: 1.55 Kg/square meter (2.9 lb/square yard)
Typical product dimensions: 4" x 8" (Depth x Length) and 20ft x 8ft (Length x Width)
Notes: Specify desired product widths for the project application. The 100 mm (4 inch) cell depth should be adequate for trails - depths from 50 mm to 200 mm (2 to 8 inches) are available. Consult manufacturers for availability of different section widths and alteration of standard section widths to fit your project needs.

This information is taken from a draft report by Steve Monlux of the U. S. Forest Service's Missouula Technology Development Center in Montana. The full report on geosynthetics and their applications for trail construction will be available by October, 1995. For more information on this topic, contact Lois Bachensky, U.S. Forest Service Engineering, Rocky Mountain Region, 740 Simms, Lakewood CO 80225 (303) 275-5199.

The next issue of The Trail Forum will appear in the July issue of Colorado State Trails News. Our planned topic is accessible trails for natural-surface, less-developed areas. Beneficial Designs of Santa Cruz, California, has been doing research on mapping, trail difficulty levels, and improving trail access, and we will report on some of their work and available publications.