



United States
Department of
Agriculture

Forest Service

Technology &
Development
Program

In cooperation with
United States
Department of
Transportation

Federal Highway
Administration

2300–Recreation
April 2008
0823–2813–MTDC



Geosynthetics for Trails in Wet Areas: *2008 Edition*



**You can order a copy of this document using the order form on the FHWA's
Recreational Trails Program Web site at:**

<http://www.fhwa.dot.gov/environment/rectrails/trailpub.htm>

**Fill out the order form and either submit it electronically,
fax it to: 301-577-1421, or mail it to:**

FHWA R&T Report Center
9701 Philadelphia, Ct, Unit Q
Lanham, MD 20706

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



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

This document is disseminated under the sponsorship of the U.S. Department of Transportation in the interest of information exchange. The United States Government assumes no liability for its contents or use thereof.

The contents of this report reflect the views of the contractor, who is responsible for the accuracy of the data presented herein. The contents do not necessarily reflect the official policy of the U.S. Department of Transportation.

This report does not constitute a standard, specification, or regulation. The United States Government does not endorse products or manufacturers. Trade or manufacturer's names appear herein only because they are considered essential to the object of this document.

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

The Forest Service, United States Department of Agriculture (USDA), has developed this information for the guidance of its employees, its contractors, and its cooperating Federal and State agencies, and is not responsible for the interpretation or use of this information by anyone except its own employees. The use of trade, firm, or corporation names in this document is for the information and convenience of the reader, and does not constitute an endorsement by the Department of any product or service to the exclusion of others that may be suitable.

The U.S. Department of Agriculture (USDA) prohibits discrimination in all its programs and activities on the basis of race, color, national origin, age, disability, and where applicable, sex, marital status, familial status, parental status, religion, sexual orientation, genetic information, political beliefs, reprisal, or because all or part of an individual's income is derived from any public assistance program. (Not all prohibited bases apply to all programs.) Persons with disabilities who require alternative means for communication of program information (Braille, large print, audiotape, etc.) should contact USDA's TARGET Center at (202) 720-2600 (voice and TDD). To file a complaint of discrimination, write to USDA, Director, Office of Civil Rights, 1400 Independence Avenue, S.W., Washington, D.C. 20250-9410, or call (800) 795-3272 (voice) or (202) 720-6382 (TDD). USDA is an equal opportunity provider and employer.

Contents

Acknowledgments	ii
Introduction	1
Geosynthetics—General Information	2
Geotextiles	3
Geonets	4
Geogrids	4
Geocells	5
Geocomposites—Sheet Drains	5
Geo-Others—Turf Reinforcement	6
Basic Geosynthetic Design Concepts for Trail Construction in Wet Areas	7
Specific Design Applications	8
Geotextile or Geonet	9
Geotextile With Encapsulated Free-Draining Rock	10
Geogrid With Geotextile or Geonet	11
Sheet Drains Under Tread Fill	12
Sheet Drains or Geonets Used as Drainage Cutoff Walls	13
Geocell With Geotextile and Permeable Tread Material	14
Geosynthetic Product Information	15
Geotextiles	16
Geonets	17
Geogrids	18
Geocells	20
Geocomposites—Sheet Drains	19
Geo-Others—Turf Reinforcement	21
Erosion Control	21
Identification of Unsuitable Tread Fill Material	22
Method A—Field Comparison	22
Method B—Laboratory Test	22
Method C—Geotextile Field Test	22
Case Studies	23
Geoblocks for ATV Trails	23
Geocell for Trail Bridge Approaches	23
Geotextile for Underdrains	24
Geocell Problems	25
References	26
Web Sites	26

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.

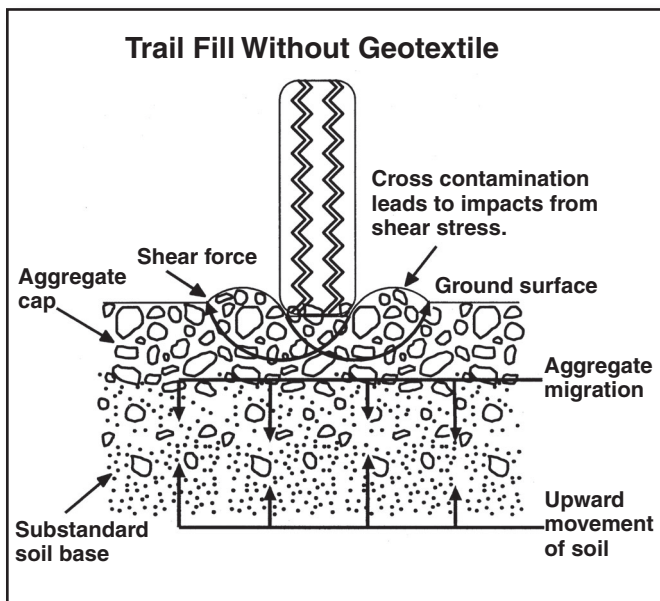


Figure 1—Trail fill material without geotextile. The aggregate will lose strength as the fill material mixes with the subbase.

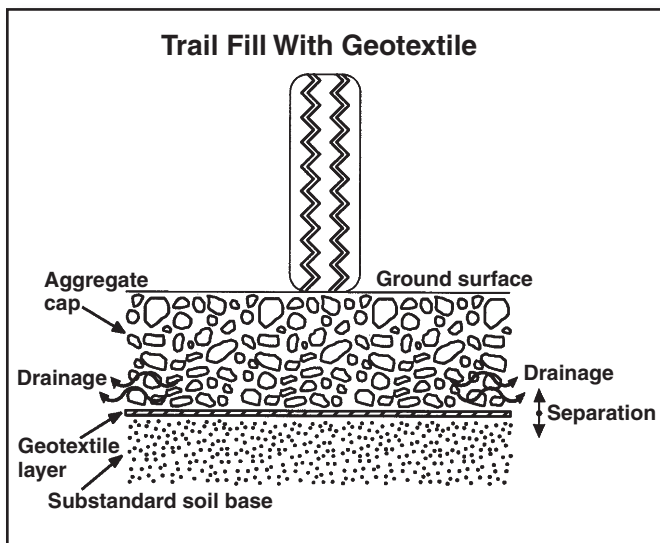


Figure 2—Trail fill material with geotextile. The geotextile layer enhances the trail performance by providing separation, reinforcement, and drainage.

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.

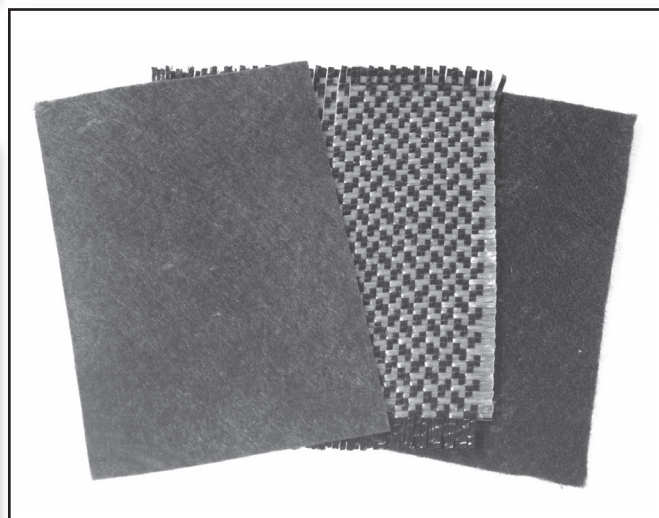


Figure 3—Geotextiles are made from woven and nonwoven fabrics. Felt-like products are easier to work with than slick products that are heat bonded, woven, or made from slit film. Felt-like products are easier to cut and their flexibility makes them easier to place on curved trail sections.

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.

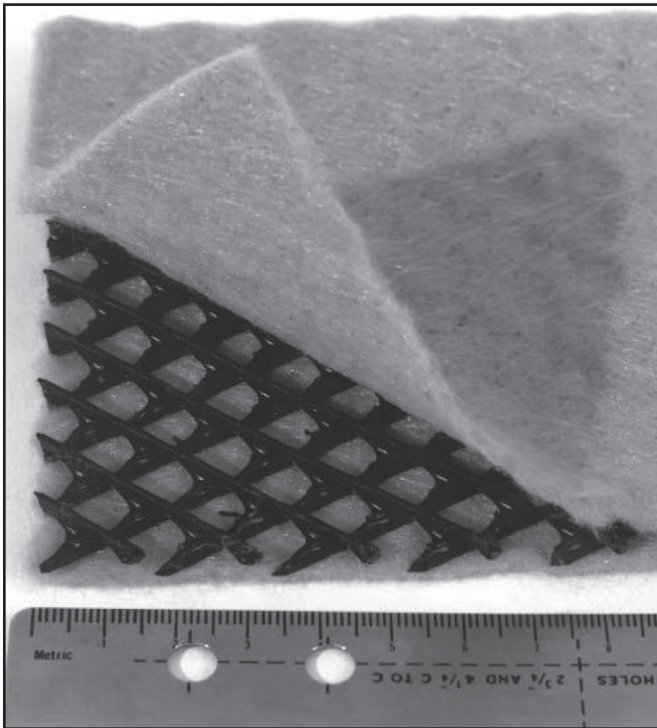


Figure 4—Geonets with the two layers of geotextile shown are considered a geocomposite—the core of geonet allows drainage to the sides that is normally adequate for the seepage found under trails in wet areas. The geotextile provides reinforcement and separation.

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.

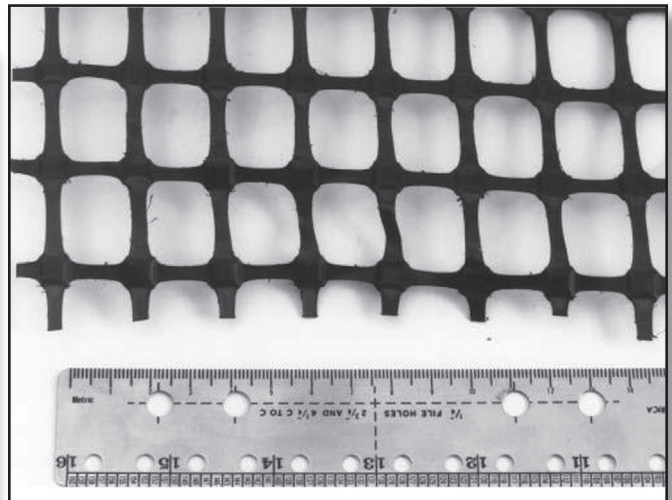


Figure 5—Geogrids are normally placed on top of a layer of geotextile for separation from saturated soils in wet areas.

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.

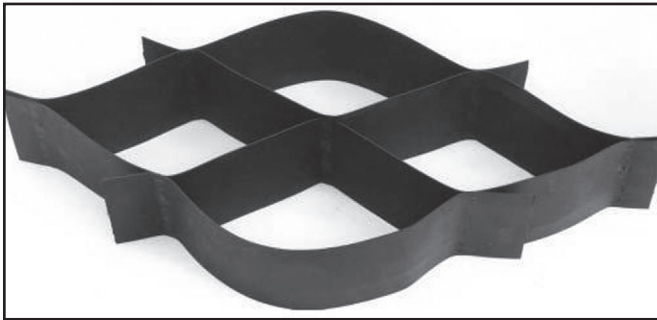


Figure 6—Geocell usually has geotextile under it for separation from wet, saturated soil. Normally, the cells are filled with a soil that drains well.

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.

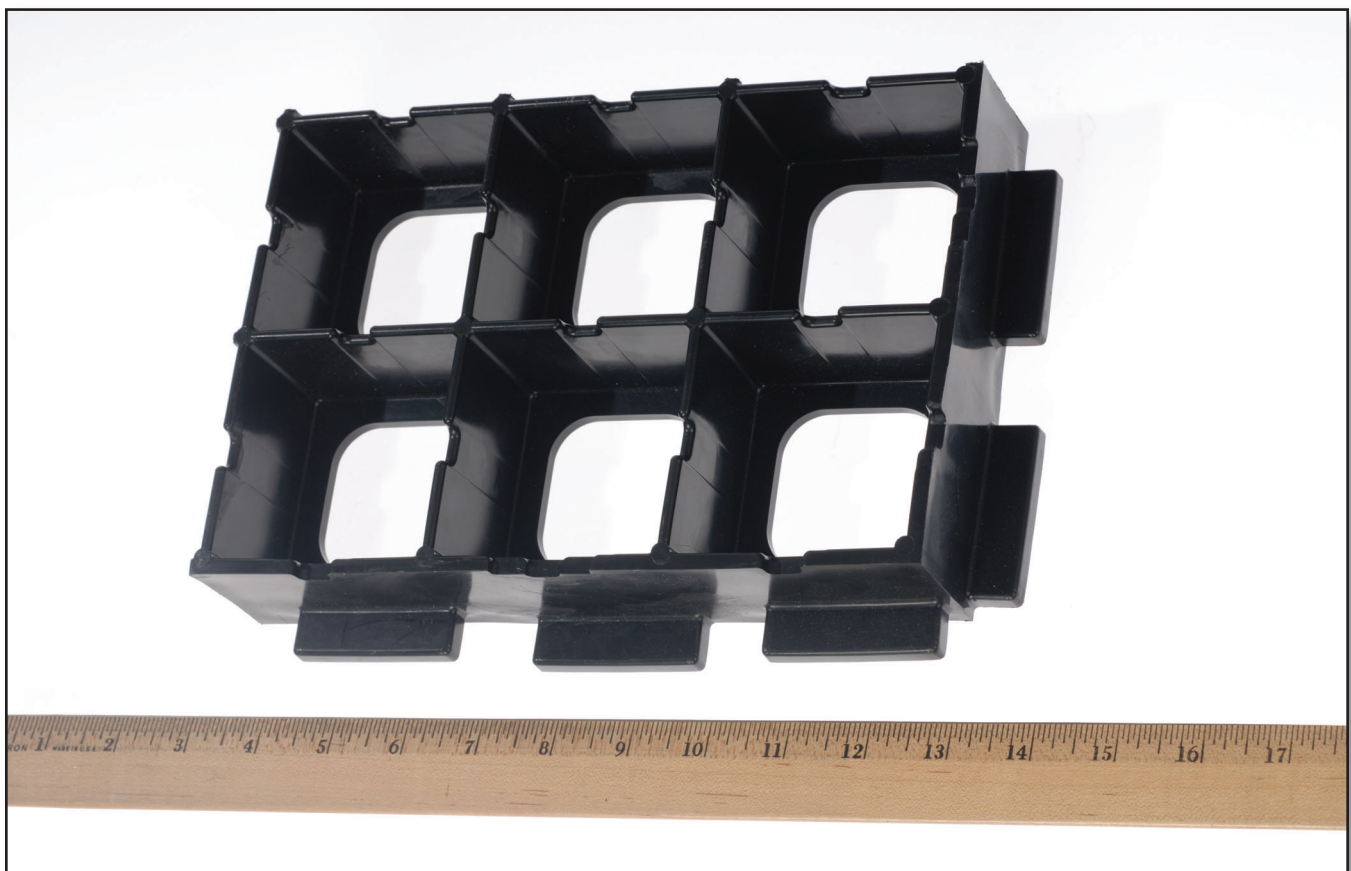


Figure 8—Geoblock, a very stiff material, is one of the many products for turf reinforcement.

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.

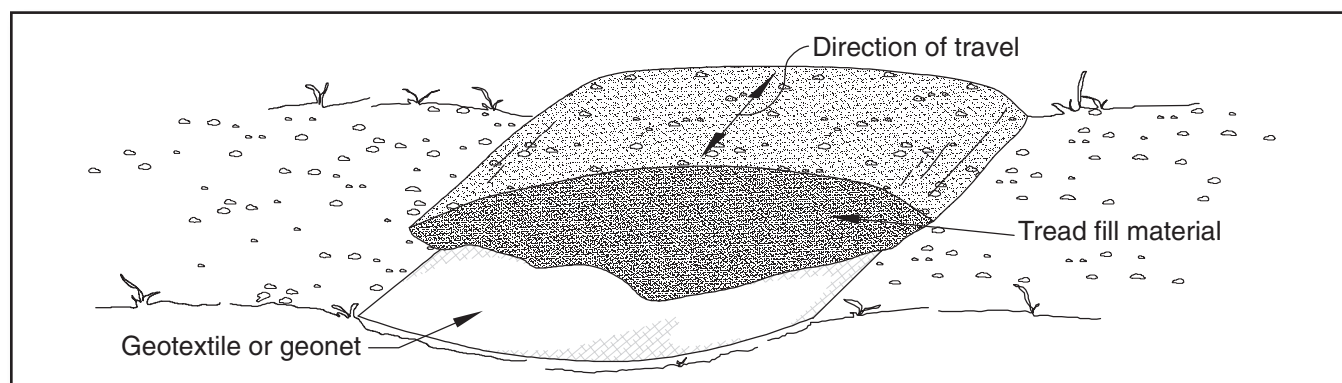


Figure 10—Typical placement of geotextile or geonet through flat, boggy areas.

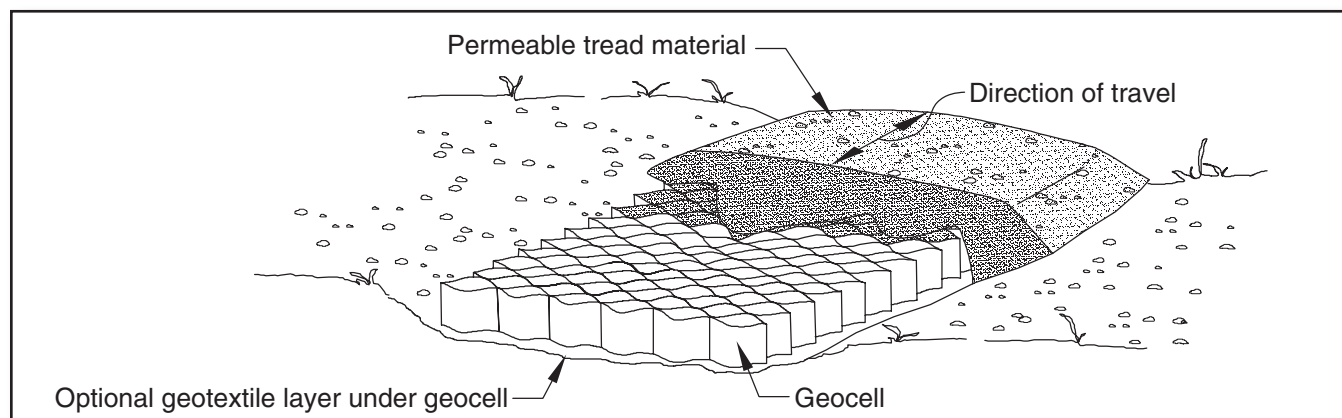


Figure 11—Geocell with geotextile and permeable tread material.

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

¹Single layer of geotextile.

²Single layer of geonet.

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

⁴Sheet drains under tread fill.

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

⁶Geocell 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.

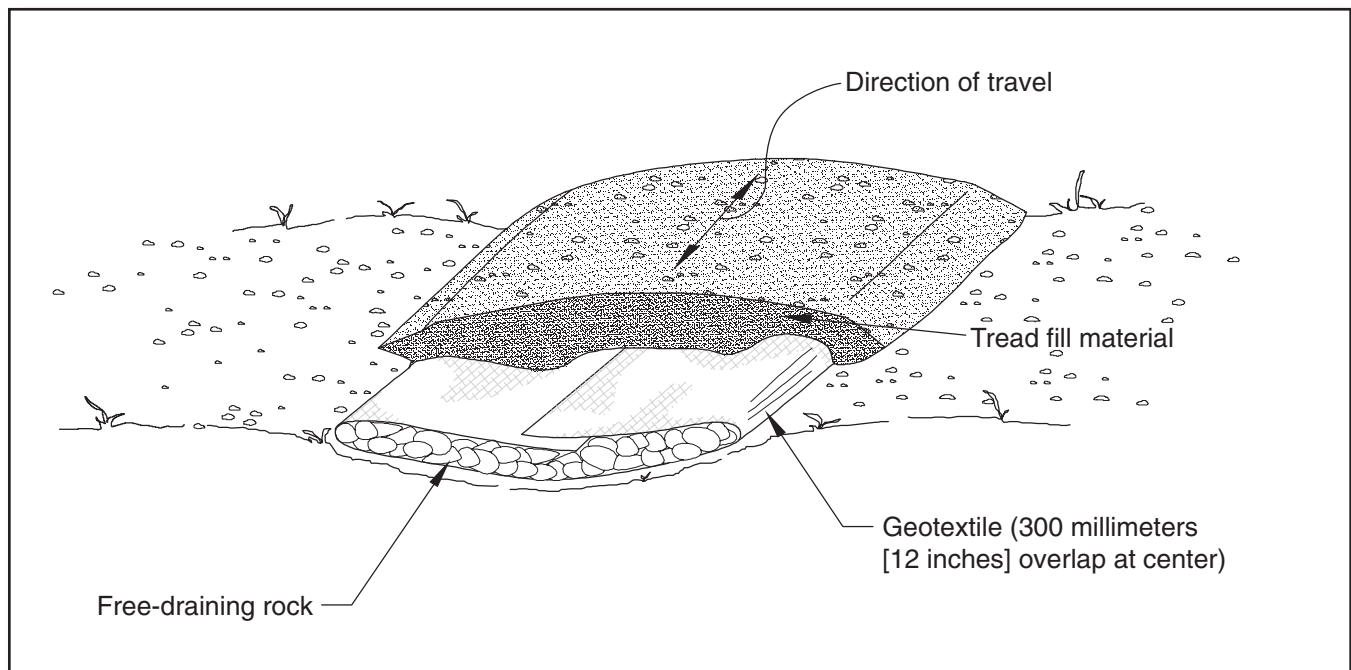


Figure 12—The encapsulation or “sausage” technique, with native rock used for drainage.

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.

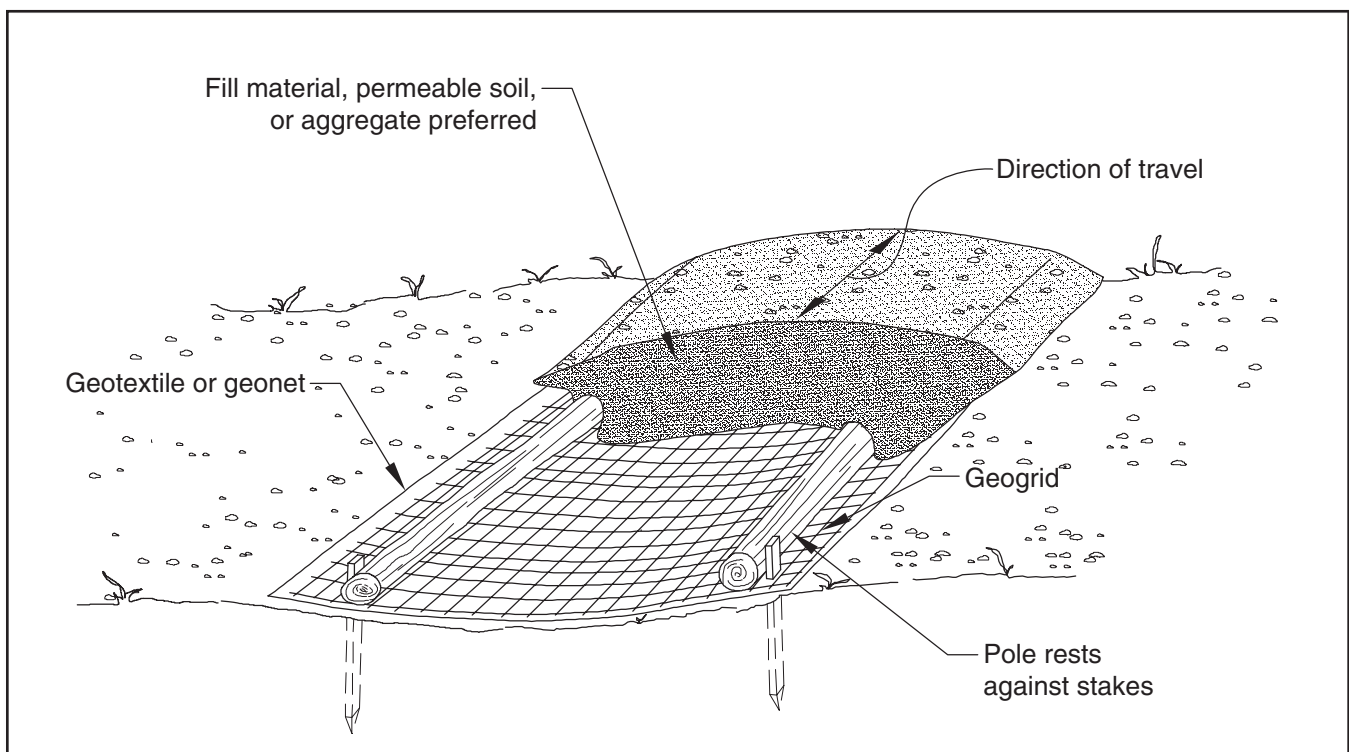


Figure 13—Geogrid with geotextile or geonet.

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.

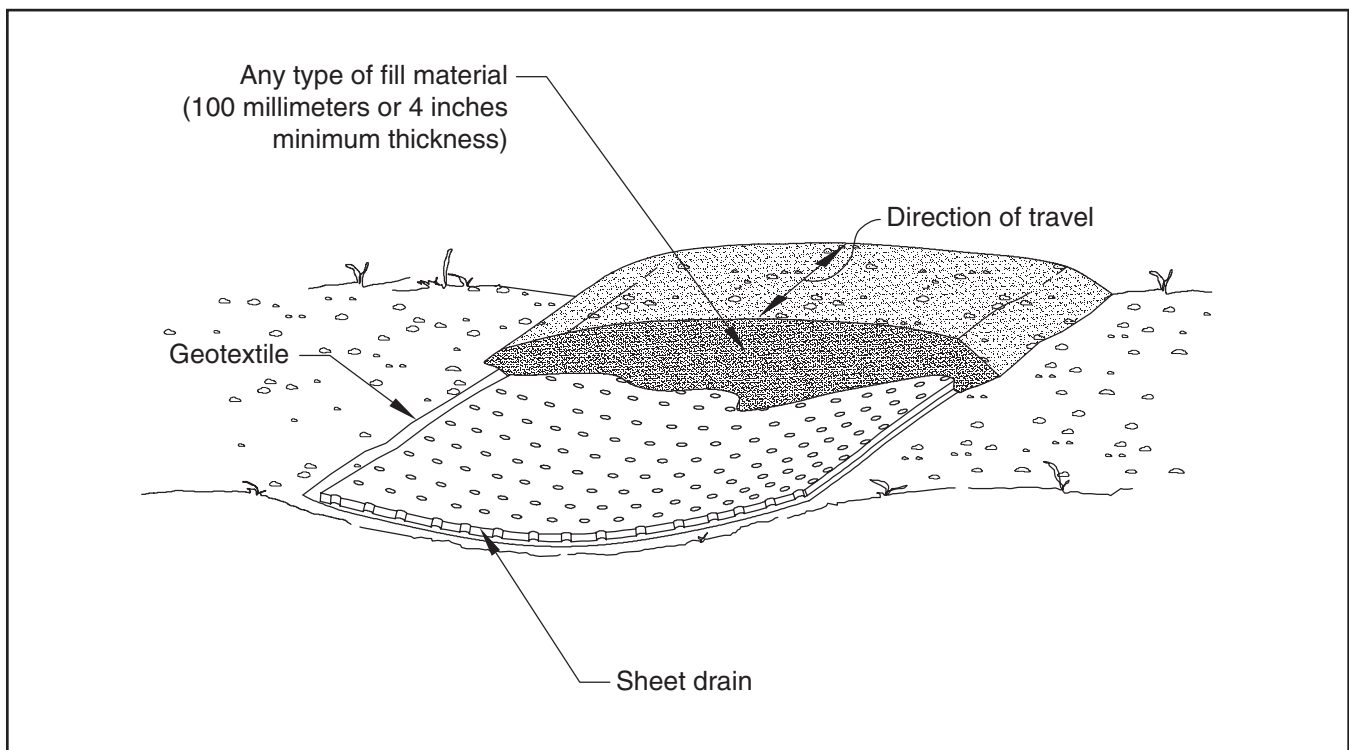


Figure 14—A sheet drain under fill material.

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.

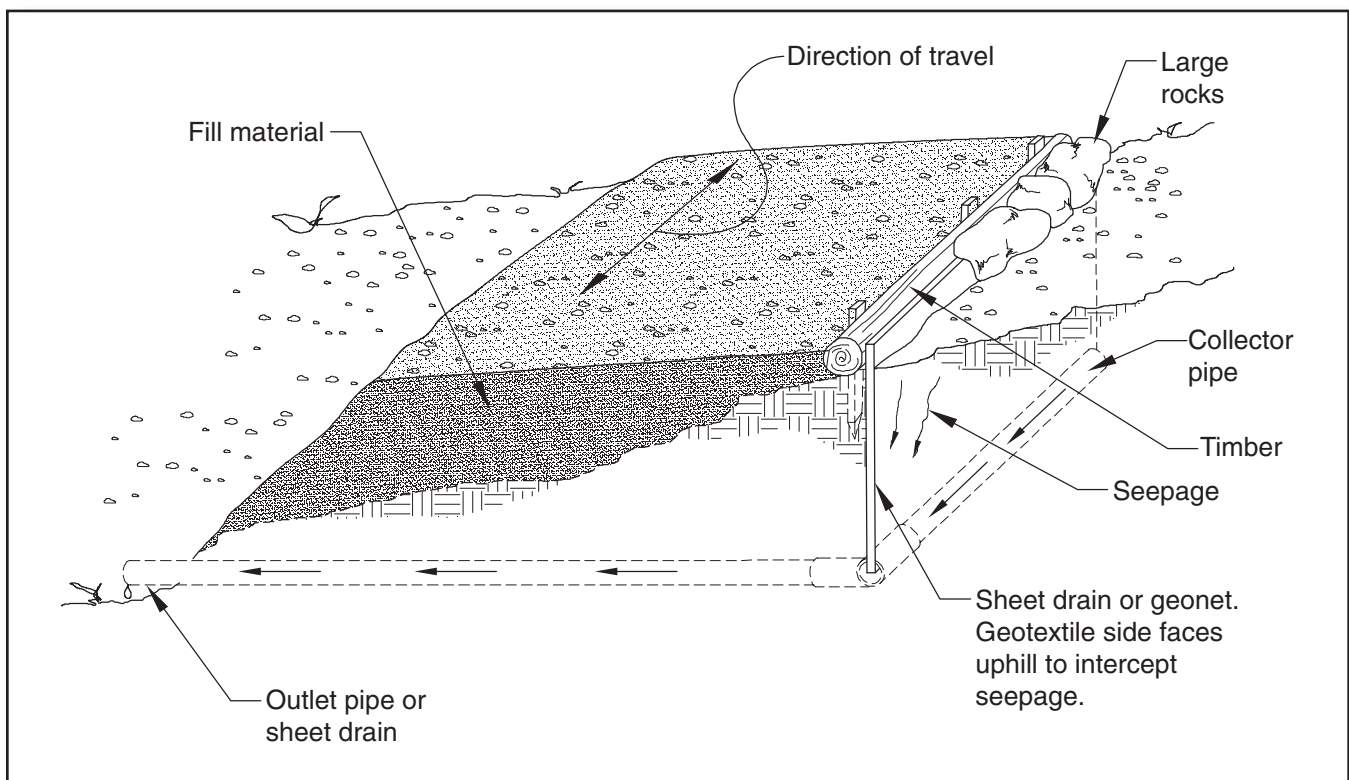


Figure 15—A sheet drain or geonet used to intercept seepage.

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 Geosynthetics)	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.

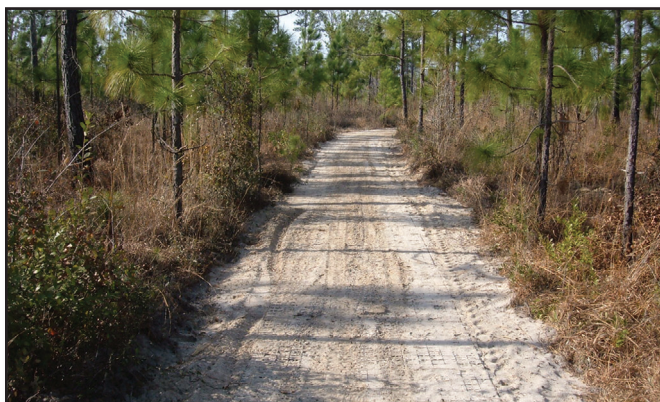


Figure 17—The finished trail after Geoblocks were installed in the Francis Marion National Forest.

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.

References

- Bathurst, R.J. [no date]. Geosynthetics classification. International Geosynthetics Society. Available electronically at: http://geosyntheticssociety.org/source_documents/Classification.pdf.
- Bathurst, R.J. [no date]. Geosynthetics functions. International Geosynthetics Society. Available electronically at: http://geosyntheticssociety.org/source_documents/Functions.pdf.
- Geosynthetic Materials Association (GMA). 2002. Handbook of geosynthetic materials. Roseville, MN: Geosynthetic Materials Association. Available electronically at: http://www.gmanow.com/pdf/GMAHandbook_v002.pdf
- Industrial Fabrics Association International. 2008. Geosynthetics specifier's guide: 2008. Roseville, MN: Industrial Fabrics Association International.
- Koerner, Robert M. 2005. Designing with geosynthetics, 5th ed. Upper Saddle River, NJ: Pearson/Prentice Hall.
- McKean, J.; Inouye, K. 2000. Field evaluation of the long-term performance of geocomposite sheet drains. Tech. Rep. 0077-1804-SDTDC. San Dimas, CA: U.S. Department of Agriculture Forest Service, San Dimas Technology and Development Center. 22 p.
- Meyer, Kevin G. 2002. Managing degraded off-highway vehicle trails in wet, unstable, and sensitive environments. Tech. Rep. 0223-2821-MTDC. Missoula, MT: U.S. Department of Agriculture Forest Service, Missoula Technology and Development Center. 48 p.
- 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.
- Shukla, Sanjay K.; Yin Jian-Hua. 2006. Fundamentals of geosynthetic engineering. London, UK: Taylor & Francis Group. 410 p.
- U.S. Army Corps of Engineers. Engineering use of geosynthetics. 1995. Available electronically at: http://www.army.mil/usapa/eng/DR_pubs/dr_a/pdf/tm5_818_8.pdf
- U.S. Department of Agriculture Forest Service. 1996. Standard specifications for construction and maintenance of trails. Eng. Man. EM-7720-103. Washington, DC: U.S. Department of Agriculture Forest Service.

Web Sites

Geosynthetic Institute
<http://www.geosynthetic-institute.org/>

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

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

**Electronic copies of MTDC’s documents are available
on the Internet at:**

<http://www.fs.fed.us/eng/t-d.php>

**Forest Service and Bureau of Land Management
employees can search a more complete collection of
MTDC’s documents, CDs, DVDs, and videos on their
internal computer networks at:**

<http://fsweb.mtdc.wo.fs.fed.us/search/>

**You can order a copy of this document using the
order form on the FHWA’s Recreational Trails Program
Web site at:**

[http://www.fhwa.dot.gov/environment/rectrails/
trailpub.htm](http://www.fhwa.dot.gov/environment/rectrails/trailpub.htm)

Fill out the order form and either submit it electronically,
fax it to 301–577–1421, or mail it to:

FHWA R&T Report Center
9701 Philadelphia, Ct, Unit Q
Lanham, MD 20706