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Food, Agricultural and Biological Engineering

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Vegetative Filter Strips: Application, Installation and Maintenance

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The loss of sediment, plant nutrients and crop protection products, such as pesticides, from cropland has been identified as a significant environmental problem. Researchers, and state and federal agencies, have developed best management practices (BMPs) to help control the movement of potential agricultural pollutants into water resources. Vegetative filter strips have been identified as a BMP that has the potential to remove substantial amounts of sediment, and some nutrients and pesticides, from cropland and urban runoff.

Understanding the proper application, installation and maintenance aspects of filter strips is important for the landowner or farmer, especially before investing time and money. This publication summarizes the key aspects of the application, installation and maintenance of filter strips for Ohio conditions. Filter-strip function and some research findings from across the United States are included. This fact sheet is intended for farmers and landowners who have a basic knowledge of best management practices, and for educational, technical and regulatory agency personnel who work with farmers and landowners in Ohio.

Extension Fact Sheet AEX-466 provides a general overview of filter strips, and AEX-468 summarizes the economic benefits of various filter strip options compared to a corn-soybean rotation. In addition, much of the water terminology used in this publication is defined in AEX-460. These and other publications are available through your county office of Ohio State University Extension. For technical assistance with the planning, design and layout of a filter strip, contact your county USDA-Soil Conservation Service (SCS) office.

Filter Strips

Filter strips are land areas of either planted or indigenous vegetation, situated between a potential, pollutant-source area and a surface-water body that receives runoff (Figure 1). The term 'buffer strip' is sometimes used interchangeably with filter strip, but filter strip is the preferred usage. Runoff may carry sediment and organic matter, and plant nutrients and pesticides that are either bound to the sediment or dissolved in the water. A properly designed and operating filter strip provides water-quality protection by reducing the amount of sediment, organic matter, and some nutrients and pesticides, in the runoff at the edge of the field, and before the runoff enters the surface-water body. Filter strips also provide localized erosion protection since the vegetation covers an area of soil that otherwise might have a high erosion potential.

Often constructed along stream, lake, pond or sinkhole boundaries, filter strips installed on cropland not only help remove pollutants from runoff, but also serve as habitat for wildlife, and provide an area for field turn rows and haymaking. In some instances, a filter strip could be used as pasture in a controlled-grazing, livestock management system, if livestock are kept fenced out of the stream or lake. Additionally, filter strips may provide increased safety by moving machinery operations away from steep stream and ditch banks.

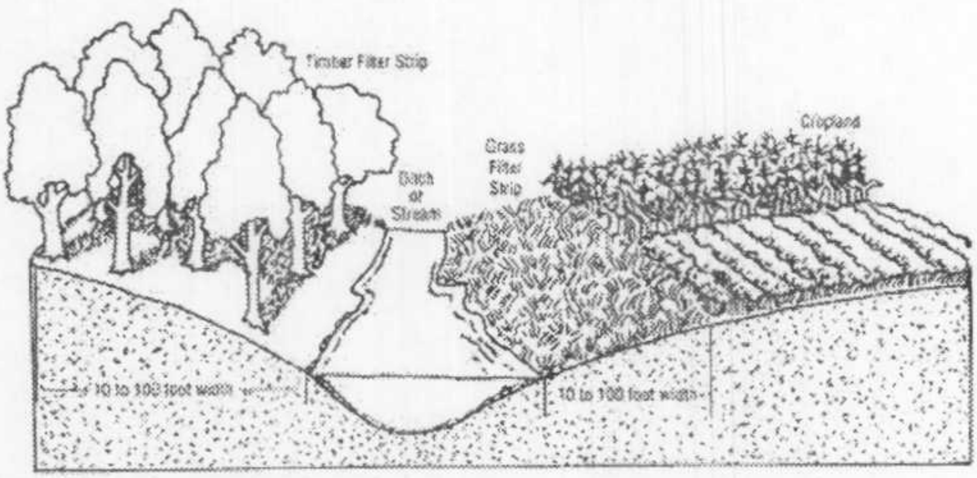

Figure 1. Vegetative filter strip.

Filter strips are an edge-of-the-field best management practice. They often are used in conjunction with other sound agricultural and land management practices, such as contour plowing, pest scouting, conservation tillage, crop rotations, strip cropping, soil testing, and proper nutrient and pest management. Because of their potential environmental benefits, filter strips are recommended by a number of state and federal agencies as an urban and agricultural best management practice. A summary of many Ohio programs that support the installation of filter strips, including grass/legume and forested filters, is provided in AEX-468.

Processes

The purpose of a filter strip is to trap sediment, plant nutrients, organic matter and chemicals as runoff from cropland or urban areas passes through the vegetated area. Filter strips generally are more effective in trapping sediment, and therefore, sediment-bound nutrients and pesticides, than soluble nutrients and pesticides. Nutrients that bind to sediment include phosphorus and ammonium; soluble nutrients include nitrate. In addition, the filter will be much more effective when the runoff passes through the vegetation in the form of shallow, uniform flow compared to conditions where the flow is concentrated in small channels or gullies. Concentrated flow channels may actually allow the runoff to bypass the vegetation in the filter strip. Shallow, uniform flow provides for maximum contact time for the removal of pollutants by several physical processes, including deposition and infiltration. Biological and chemical processes may help break down and utilize nutrients and pesticides that are trapped in the filter.

Deposition

As runoff moves through the filter strip, sediment and other suspended materials may be filtered from the runoff, largely by deposition. Deposition is the dominant process for the trapping of sediment, and most often sediment is deposited within the first few feet of the filter. As runoff enters the filter strip, the velocity of the runoff decreases, and sediment begins to settle out of the runoff. Large, sand- and silt-sized particles, and soil aggregates settle from the runoff within a relatively short distance into the filter. Small, finer particles, such as clay, may take a longer distance to settle out. Depending upon the quantity and velocity of the runoff, there may be little or no deposition of the fine, clay particles before the runoff exits the filter strip. Trapping sediment in the filter also helps to trap nutrients and pesticides that are sediment-bound.

Infiltration

Infiltration is the movement of water into the soil surface. In a filter strip, infiltration occurs as the runoff moves through the filter where it encounters vegetation, which helps decrease the flow velocity. Time is available for part of the runoff to infiltrate into the soil surface, and then percolate through the soil profile. The amount of infiltration and percolation depends upon soil characteristics. In addition, plant residues on the soil surface help increase infiltration, and plant roots in the soil profile may help improve soil structure, and increase soil aggregation and porosity, which help increase percolation. The filter strip actually helps reduce runoff by increasing infiltration, compared to possible conditions in the adjacent cropland. As runoff velocity is decreased, deposition and increased infiltration may occur. Also, some material suspended in the runoff may be filtered out as infiltration occurs.

Water-soluble nutrients and pesticides that move with water also may enter the soil profile in the filter area. Depending on soil characteristics, these chemicals may be used by the crop or broken down by a combination of biological and chemical processes. However, if the soil is highly permeable (sandy, gravelly, etc.), these soluble chemicals may move with percolating water into an aquifer, or move horizontally in the soil profile by interflow to a surface-water body.

Biological and Chemical

Plant nutrients and pesticides that become trapped in a filter strip may be degraded or transformed, by biological and chemical processes, into other compounds that may be used by the vegetation growing in the filter. Also, these processes may degrade or transform the nutrient or pesticide into a compound that may have greater potential to leave the filter strip and enter ground or surface water. Biological and chemical processes, such as the volatilization, degradation, adsorption and absorption of pesticides, and nitrogen and phosphorus transformations, may influence the filter strip's long-term ability to remove and use nutrients and pesticides. The effect of these processes on the filter's ability to trap nutrients and pesticides is much more complicated to define compared to that for sediment trapping alone.

Research Findings

Research indicates that filter strips are effective in the control of many agricultural and urban nonpoint source pollutants, but especially sediment. Field research, using both natural rainfall and artificial rainfall techniques, is usually conducted by collecting runoff samples from test sites where runoff from filter strips can be compared to similar conditions without a filter strip.

Field research on filter-strip width, using grass as the filter material, has been conducted in Indiana, Iowa, Maryland, and Virginia (Table 1). The results indicate that filter strips are very effective in removing sediment from runoff, with the average reduction ranging from 56 to 95 percent, depending on soil characteristics, slope, rainfall and runoff conditions, and filter width. Most of the studies in Table 1 evaluated only 2 filter widths. Filter-strip width is an important factor, but the Indiana study results indicated that a filter width greater than 8' showed very little increase in effectiveness, at least for those study conditions. The results from the Iowa demonstrations indicated no improvement in filter effectiveness beyond a 30-foot filter width.

For those filter-width studies where sediment, phosphorus and nitrogen trapping were evaluated, the results indicate that filter strips were more effective in consistently removing sediment than either phosphorus or nitrogen. The results for nitrogen and phosphorus removal were highly variable; total phosphorus removal ranged from 0 to 83 percent, and total nitrogen removal ranged from 27 to 87 percent.

The results summarized in Table 1 generally are typical of most filter-strip studies, especially for sediment trapping. A limited number of other studies have evaluated filter-strip trapping of nitrogen and phosphorus, suspended organic matter and some pesticides. In general, the range in the results is quite large, and results are highly variable. In a Virginia study that evaluated nitrate and ammonium trapping, nitrate removal ranged from 46 to 75 percent, but ammonium losses from the filter actually increased. Over a range of filter-strip applications, work in Illinois, Georgia (15 years), and elsewhere have documented a 10 to 90 percent reduction in nitrate concentrations for forested and grass filter strips, and a range of -114 to 85 percent reduction in phosphorus concentrations (a negative number indicates an increase). A recent study in Iowa indicated a 28 to 35 percent removal for the pesticide atrazine for a 15-foot long filter, compared to a 51 to 60 percent removal for a 30-foot filter.

The interaction between the form of the compound (i.e., soluble nitrate versus soil-bound ammonium; soluble versus soil-bound phosphorus; and soluble versus soil-bound pesticides), soil characteristics (clay and organic matter content, infiltration rate, permeability, etc.) and the type of vegetation in the filter is a complex problem to evaluate. Research on the use of filter strips for trapping sediment, organic matter, and plant nutrients for both agricultural and urban applications needs to be continued. However, since the research on pesticides is very limited, efforts here should be increased.

Table 1. Average percent removal of pollutants in runoff[1].

Location	Rainfall Source	Soil Texture	Slope (%)	Flow Conditions[2]	Filter Strip Width (feet)	Sediment	Percent Removal Nitrogen[3]	Phosphorus
Indiana (1979)	Rainfall Simulator	Silt loam	OLF	2	56	-[4]	-	-
				4	70	-	-	-
				8	94	-	-	-
				12	95	-	-	-
Virginia (1989)	Rainfall Simulator	Silt loam	11-16	OLF	15	70	54	61
					30	84	73	79
				CF	15	83	83	85
					30	93	82	87
Maryland (1989)	Rainfall Simulator	Sandy loam	3-4	OLF	15	66	0	27
					30	83	48	46
Iowa5 (1991)	Natural Rainfall	Silt loam	7	OLF	10	72	-	-
					20	83	-	-
					30	97	-	-
			12	OLF	10	88	-	-
					20	90	-	-
					30	96	-	-
Virginia (1992)	Natural Rainfall	Silt loam	4-12	OLF	13	65	-	-
					26	65	-	-
Iowa (1993)	Rainfall Simulator	Silt loam	3-6	OLF	15	72	-	-
					30	76	-	-

1 Percent removal compared to similar conditions with no vegetative filter strip.

2 Characteristics of runoff as it entered filter strip; OLF - shallow uniform overland flow; CF - concentrated flow.

3 Values given are for total nitrogen and total phosphorus.

4 Data not collected in this study.

5 Demonstration sites were not replicated; sediment removal for 40- and 60-foot wide filters were generally same as for 30-foot width.

Table 2. Predicted pollutant removal in runoff[1].								
State/Site	Filter Width (feet)	Drainage Area[2] (acre)	Slope (%)	Soil Texture	Vegetation Quality[3]	Percent Removal		
						Sediment	Phosphorus[4]	Nitrogen
Illinois								
1	99	2.5	7.3	Silt Loam	Fair	42	36	36
2	99	28	4	Silt Loam	Good	67	68	68
Iowa								
1	66	39	2.2	Loam	Excellent	75	71	71
2	99	30	3.8	Silt Loam	Fair	61	54	54
Ohio								
1	66	9.9	2.6	Silt Loam	Good	71	72	72
2	99	32	0.6	Silty Clay Loam	Good	71	73	73

1 CREAMS model predictions on CRP sites in Illinois, Iowa, and Ohio; percent removal compared to similar conditions with no filter strip.

2 Land area draining into filter-strip area.

3 Poor, Fair, Good and Excellent relate to uniformity of cover and resistance to flow.

4 Values are total phosphorus and nitrogen.

Application

The proper application of a filter strip should consider the type and quantity of the potential pollutant (sediment, nutrient, pesticide, organic matter, etc.), soil characteristics (clay and organic matter content, infiltration rate, permeability, etc.), slope steepness, shape and area of the field draining into the filter. The type of vegetation applicable to the climatic conditions in your area, and time of year to properly establish that vegetation, also are important considerations. Remember that a filter strip is an edge-of-the-field best management practice, and should be used in conjunction with other best management practices that are designed to reduce erosion and agricultural chemical loss within the field.

Width

The SCS has developed general recommendations, based upon research, on the minimum filter-strip width for particular ranges of slope steepness (Figure 2). However, filter-strip width also is affected by soil characteristics, and the shape and size of the land area draining into the filter. The values in Figure 2 are recommended minimum widths, and could be adjusted upward if the sediment entering the filter has a high percentage of clay-sized particles, which take a longer distance to filter out compared to silt- and sand-sized particles. In addition, for slopes with a steepness of greater than 10 percent, there is increased potential for the runoff to be of sufficient volume and velocity to flow too fast through the filter, possibly laying over the vegetation and dramatically reducing its effectiveness.

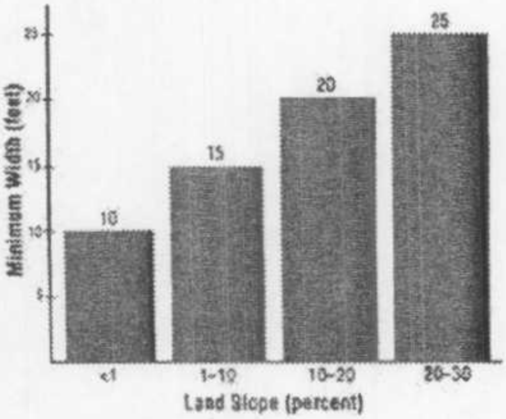

Figure 2. Recommended filter strip minimum width based upon percent slope (Standards and Specifications No. 393, USDA-SCS Field Office Technmical Guide, 1988).

Much field research supports the use of filter widths in the range of 10 to 40 feet. However, ratios of the field drainage area to the filter area should be no greater than 50:1, and preferably in the range of 3:1 to 8:1. Based on a survey of more than 2,700 CRP sites in the United States, the ratio of drainage area to filter area averaged approximately 3:1.

Placement

As mentioned earlier, filter strips are usually installed along stream, lake, pond or sinkhole boundaries. A reason that some filter strips are not very effective is that the runoff entering the filter is in the form of concentrated flow. For maximum trapping efficiency, the runoff must reach the filter in the form of shallow, uniform flow. Therefore, the filter strip must be placed in a position that will intercept the runoff before it becomes concentrated in natural drainage channels within the field. In addition, filters should be constructed on the contour to help provide proper entrance conditions for shallow, uniform flow to enter the filter. Filter strips are not recommended for concentrated flow areas. Installing a terrace or grass waterway may be necessary to carry the concentrated flow through the field (contact SCS for assistance).

Vegetation

Plants selected for filter strips should have dense top-growth to provide good, uniform soil cover, and a fibrous root system for stability. In addition, the type of vegetation selected should be adapted to local soil and climatic conditions, and have good regrowth following dormancy and cutting. If the filter vegetation is to be used for hay or seed, other factors such as crop yield and feed quality need to be considered.

Grasses are more effective than broadleaf plants for erosion control since they form a dense sod, have a fibrous root system and provide a more complete ground cover. For filter-strip applications in Ohio, cool-season grasses are more desirable than warm-season grasses since they grow more vigorously in the spring and fall when little or no crop canopy is present and rainfall can be intense. Sod forming grasses are preferred over bunchgrasses since they provide more uniform ground cover. Bunchgrasses should only be used in combination with other plant species.

Establishment characteristics of various grass and forage species applicable for Ohio filter-strip applications are given in Table 3. Legumes may be seeded along with grasses to improve soil fertility and forage quality, but they are not as effective as grasses in filtering sediment. Legume and grass species with different growth habits should be selected so that competition between species is reduced. In general, legumes require near-neutral soil pH and moderate- to well-drained soil conditions for acceptable growth and persistence. The following section provides additional notes about the grasses and legumes listed in Table 3.

Table 3. Characteristics of perennial cool-season grasses and legumes in Ohio[1].

Species[2]	Seedling Vigor[3]	Tolerance to Soil Limitations			Persistence	Relative Maturity[6]
		Drought	Drainage[4]	Low pH[5]		
Grasses						
Garrison Grass	M	M	VPD	M	H	Med-Late
Kentucky Bluegrass	M	L	SPD	M	H	Early
Orchardgrass	H	M	SPD	M	M	Early-Med
Perennial Ryegrass	H	L	SPD	M	L	Early-Med
Reed Canarygrass	L	H	VPD	H	H	Late
Smooth Bromegrass	H	H	SPD	M	H	Med-Late
Switchgrass	L	H	WD	M	H	Late
Tall Fescue	H	M	SPD	H	M	Med
Timothy	M	L	SPD	M	H	Late
Legumes						
Alfalfa	H	H	WD	L	H	Early-Med
Alsike	M	L	VPD	H	L	Late
Birdsfoot Trefoil	L	M	SPD	H	M	Med-Late
Red Clover	H	L	SPD	M	L	Med-Late
White or Ladino Clover	M	L	PD	M	H	Early

1 Abstracted from Ohio Agronomy Guide and other sources.

2 Notes for all species except Garrison Grass and Switchgrass abstracted from Ohio Agronomy Guide; for Garrison Grass and Switchgrass, contact SCS).

3 L - Low; M - Medium; and 4-H - High.

4 Minimum adequate drainage necessary for acceptable growth; Drainage class: WD - well drained; SPD - somewhat poorly drained; PD - poorly drained; and VPD - very poorly drained.

5 Ability to tolerate pH below 6.0 (acidic soil conditions).

6 Relative time during season (early, middle, late) of flower appearance in spring; depends on species and variety.

Grasses

Garrison Grass: A sod-forming grass that grows well on very poorly drained soils. It has a shorter height, is more palatable as a forage and is more salt resistant compared to Reed Canarygrass. Thus, it may be an alternative to Reed Canarygrass, but experience in Ohio is limited.

Kentucky Bluegrass: A long-lived perennial that produces a dense, shallow root system and moderately short and thick top growth. It is a good choice.

Orchardgrass: A perennial bunchgrass that forms a more open sod. This grass has greater summer growth compared to other cool-season grasses, and should be seeded in a mixture with a legume or other grasses. It is an early maturing forage grass that requires early harvest for optimum feed quality and palatability.

Perennial Ryegrass: A bunch grass with rapid spring growth that adapts to a wide range in soil fertility. It has excellent forage quality, but produces lower yields compared to orchardgrass. Generally, it is used in combination with other forages.

Reed Canarygrass: This sod forming perennial, with high yield potential, has tall, dense growth that makes it ideal for trapping silt. It is sometimes recommended for healing gully erosion, however, in wet soil conditions, vigorous growth can choke waterways. Problems with poor palatability associated with alkaloids can be avoided by planting low-alkaloid variety, such as Palaton or Venture.

Smooth Bromegrass: An upright-growing perennial that spreads by self-seeding and short rhizomes. It produces a dense sod and is a good choice for erosion control.

Switchgrass: This grass is sometimes recommended for filter strips even though it is warm-season variety. It may be difficult to establish - a full stand may take up to 3 years to obtain. Most of its growth occurs in the summer, not in the spring when erosion potential usually is the greatest. Therefore, it is not recommended as a top choice as rapid-growth erosion control vegetation. However, switchgrass provides excellent wildlife habitat because it remains standing through winter, providing good nesting cover. It tolerates droughty soils with low fertility.

Tall Fescue: A deep-rooted bunch-type grass even though it has short rhizomes. A thick stand produces an even sod if kept mowed or grazed. If the filter is used for grazing, livestock managers should be aware of problems with fescue toxicosis, which may result in poor animal performance and livestock health problems. Fescue toxicosis is caused by toxins produced by a fungal endophyte that is seed-borne. This problem can be avoided by planting endophyte-free seed (see Agronomy Facts, AGF-008, Fescue Toxicosis). This grass is not recommended for wildlife habitat development.

Timothy: A perennial bunchgrass that forms more open sod. It should be seeded in a mixture with a legume or other grasses.

Legumes

Alfalfa: This legume is well-suited to a wide range of soil conditions. It has a high nutrient value and is high yielding on well-drained soils. Alfalfa should be used in a mixture with sod grasses for erosion control.

Alsike: A short-lived perennial that is adapted to a cool climate and wet soils; it can even tolerate periodic flooded conditions and acid soils. It should be seeded in a mixture with sod grasses for erosion control.

Birdsfoot Trefoil: This legume has a well-developed root system and generally is adapted to a moderate climate. Because of its nonbloating nature, birdsfoot trefoil can be used without grass in a pasture situation. It has excellent feed quality and should be seeded in a mixture with sod grasses for erosion control.

Red Clover: A relatively short-lived perennial that is best suited to moderate temperatures and adequate moisture. It is good for hay and pasture, and for improving soil tilth. Red clover is easy to establish with no-till methods, and should be seeded in a mixture with sod grasses for erosion control.

White or Ladino Clover: This legume adapts to fertile soils with sufficient soil moisture. High moisture levels make it difficult to harvest as a hay crop. To reduce the possibility of bloat in grazing cattle, this clover should be grown in a mixture with grasses. Its fibrous root system makes it well suited for erosion control.

Table 4 provides recommendations on grasses and legumes, various mixtures and seeding rates for specific filter-strip applications in Ohio. Seeding depends on the type of vegetation selected. For example, legumes and cool-season grasses can be seeded earlier in the spring than warm-season grasses, which should not be seeded in late summer (Table 5). Ohio State University Extension recommends the inoculation, with the appropriate inoculant, of all legumes before seeding.

Although grasses and legumes are the most common types of vegetation planted in filter strips, forested filter strips also have many applications in Ohio. For more information on forested filter-strip applications, contact your county Extension, SCS, and Soil and Water Conservation District (SWCD) offices.

Table 4. Recommended seeding mixtures and rates for specific filter-strip applications in Ohio[1].

Seeding Mixture	Rate[2] (lb/acre)	Suitability[3] CRP Filter	Sediment Filter	Animal Waste Filter[4]
[5]Birdsfoot Trefoil and Timothy or Orchardgrass	6	x	x	
	4	x	x	
	4	x	x	
Orchardgrass and Tall Fescue and Ladino Clover	6-8	x	x	
	20	x	x	
	0.5	x	x	
Tall Fescue	25	x	x	
Reed Canarygrass	25	x	x	
Reed Canarygrass and Tall Fescue	15	x	x	
	15	x	x	
Timothy or Orchardgrass and Ladino Clover	4	x	x	
	6-8	x	x	
	0.5-1	x	x	
Alfalfa and Timothy or Smooth Bromegrass or Orchardgrass	10	x	x	
	2-4	x	x	
	6	x	x	
	4	x	x	
[6]Alfalfa and Red Clover and Timothy or Smooth Bromegrass or Orchardgrass	7	x	x	
	3	x	x	
	2-4	x	x	
	6	x	x	

	4	x	x	
Red Clover and Alsike or Ladino Clover and Timothy or Smooth Bromegrass or Orchardgrass	6	x	x	
	2	x	x	
	0.25	x	x	
	2-4	x	x	
	6	x	x	
	4	x	x	
Switchgrass	6	x	x	
Garrison Grass	12	x	x	x

1 USDA-SCS Ohio Field Office Technical Guide, 1988; abstracted from Ohio Agronomy Guide and other sources; refer to Agronomy Guide for additional information on all species except for Garrison Grass and Switchgrass; for Garrison Grass and Switchgrass, contact SCS).

2 Use this rate if near-100% germination is possible; otherwise, increase rate.

3 Species with "x" are approved in mixtures shown for these USDA filter-strip applications; contact county SCS office for explanation of USDA filter-strip applications and programs.

4 Filter strips are not recommended as sole method for treatment of animal wastes.

5 Explanation: Use combination of Birdsfoot Trefoil and Timothy, or combination of Birdsfoot Trefoil and Orchardgrass.

6 Explanation: Use combination of Alfalfa and Red Clover and Timothy, or combination of Alfalfa and Red Clover and Smooth Bromegrass, or combination of Alfalfa and Red Clover and Orchardgrass.

Table 5. Recommended seeding dates for filter strips in Ohio[1].

Vegetation		Northern Ohio	Southern Ohio
Legumes and Cool-Season Grasses	Frost Seeding	Later Winter to March 15	Late Winter to March 1
	Spring	April 1 to May 10	March 15 to April 30
	Late Summer[2]	August 1 to 30	August 1 to September 15
Warm-Season Grasses	Later Spring	April 15 to June 1	April 1 to June 1
	Dormant	November 15 to Early Spring	November 30 to Early Spring

1 USDA-SCS Ohio Field Office Technical Guide, 1988; abstracted from Ohio Agronomy Guide.

2 When seeding mixture includes a legume, plant by August 20 in northern Ohio, and by August 30 in southern Ohio.

Special Applications

Designing filter strips for treating wastewater or polluted runoff from concentrated livestock areas requires special consideration of soil drainage, discharge frequency, temporary storage, alternative filters, and other factors. Filter strips should be used as a component of an overall waste management system, and not as a sole method of treatment. For criteria to be used in the design of filter strips for animal waste, polluted runoff and wastewater applications, consult the Ohio Livestock Waste Management Guide (Extension Bulletin 604) and Extension Fact Sheet, AEX-706.

Some USDA support programs specify vegetation alternatives that are considered either acceptable or unacceptable for certain applications, including those listed in Table 4. For more information on filter-strip applications, and the various state and federal programs, contact your county Extension, SCS, USDA-Agricultural Stabilization and Conservation Service (ASCS) or SWCD offices.

Installation

In general, the same considerations apply for the installation of a filter strip as for the establishment of a pasture or meadow. The Ohio Agronomy Guide provides information on the establishment of pastures and meadows, much of which applies to filter strips. However, land grading or other soil surface preparations may be necessary to ensure that the filter will function properly, and that runoff will enter the filter in the form of shallow, uniform flow. A filter strip designed by a technical agency (i.e., SCS or SWCD) will show the final filter grade and dimensions on the plan or staked in the field.

Once the type of vegetation is selected, soil fertility should be evaluated, and the seeding method selected. The amount of fertilizer and lime to be applied to the filter should be determined from the soil analysis taken from the cropland. Recent experience in Ohio suggests that only about 50 percent of the time will additional fertilizer need to be applied. For example, of 19 filter strips installed in 1991-92 within the Indian Lake watershed, covering 114 acres, none needed lime, and only about half needed fertilizer. Of the filters that were fertilized, only nitrogen (N), phosphorous (P), and potassium (K) were applied; no micro-nutrients were needed. On average, 27 lb/ac of N, 49 lb/ac of P, and 61 lb/ac K were applied.

Two types of tillage systems generally are used when seeding filter strips: conventional or no-till seeding. The recommended steps for conventional seeding of a filter strip are:

- Broadcast lime and fertilizer according to soil test recommendations.
- Incorporate lime and fertilizer with a disk or field cultivator.
- Prepare a firm seedbed (use of a cultipacker or cultimulcher is a good choice).
- Plant the seed shallow (1/4 inch deep) with a drill, cultipacker seeder or by broadcasting the seed; follow by cultipacking, making sure the seed is on a firm seed bed to obtain good seed-to-soil contact.

To seed and apply fertilizer properly using a conventional tillage method may require three to four tillage passes: fertilizer application, seedbed preparation, and planting. Using a no-till management system requires only a fertilizer spreading application and a no-till drill operation. With either management system, proper seed placement and good seed-to-soil contact are critical to successful forage establishment.

Rapid filter-strip establishment is critical. During periods of dry weather, germination of the seed and early establishment of the vegetation in the filter may require irrigation.

Maintenance

Proper maintenance is required for maximum filter-strip effectiveness, just as for most other structural or non-structural best management practices, and normal crop production practices. Maintenance for grass and legume filters consists of several simple steps:

1. Inspect the filter strip frequently, especially after intense rainfall events and runoff events of long duration. Small breaks in the sod and small erosion channels quickly become large problems.

2. Minimize the development of erosion channels within the filter. Even small channels may allow much of

the runoff from the field to bypass the filter. These areas should be repaired and reseeded immediately to help ensure proper flow of runoff through the filter.

3. Reseed or interseed bare areas of the filter. Since it may be difficult to re-establish vegetation in an established filter strip, the use of mulch or sod can help to reduce some problems.

4. Mow and remove hay as required (or as allowed by certain USDA programs) to maintain moderate vegetation height. Mowing two to three times per year may be necessary. The vegetation should not be mowed closer than 6 inches. If haying is not desirable (or allowed), more frequent mowing may be needed to prevent thatch buildup and smothering of vegetation. To avoid destruction of wildlife nesting areas, delay mowing until after mid-July. Fall mowing of the filter no closer than 6 inches will provide adequate winter habitat for wildlife.

5. Soil test periodically and apply soil amendments according to test results and recommendations.

6. Control trees, brush, noxious weeds, and Canada thistle in the filter using either mechanical means or herbicides. Contact your county Extension office for recommendations on the proper chemicals to control weeds.

Maintenance for forested filters consists of most of these simple steps. In addition, other factors may need to be considered. Contact your county Extension, SCS, or SWCD offices for information on forested filters.

Effectiveness

In addition to field research, computer models can be used to evaluate the potential for runoff, erosion, and nutrient and pesticide movement from field conditions with and without filter strips. The model CREAMS (Chemical, Runoff, Erosion, and Agricultural Management Systems), developed by the USDA-Agricultural Research Service, was used to evaluate the effectiveness of filter strips at 230 sites, from 29 states in the United States, participating in the USDA-Conservation Reserve Program (CRP). Results from computer simulations for CRP sites in Illinois, Iowa and Ohio are presented in Table 2.

CREAMS modeling, over a 30-year period, found that filter strips will reduce the amount of sediment, total phosphorus and total nitrogen in cropland runoff. Overall, the study showed that the quality of vegetation in the filter strip is an important factor in determining filter-strip effectiveness. Filter strips with poor quality vegetation actually may have increased amounts of sediment leaving the filter. In addition to vegetation quality, the slope of the land adjacent to the filter strip is an important factor. Runoff from steeper slopes has greater velocity, and therefore, greater ability to detach and transport soil particles, as well as transport nutrients and pesticides that are either soil-bound or in solution.

Filter-strip effectiveness depends on soil characteristics, slope steepness, landscape shape, the ratio of the filter area to the area generating the runoff, filter width, and the type and quality of the vegetation in the filter. Overall, little information from field research is available about the long-term effectiveness of filter strips. However, computer simulations can provide some insight into how well filters may perform over time.

The effectiveness of filter strips, drawn from studies referenced in this publication and others, have been summarized. In general, vegetative-filter strips are:

- Effective in reducing the amount of sediment and nutrients in runoff from cropland.
- More effective in removing sediment than nutrients (research results on reducing nutrient losses are highly

variable compared to sediment).

- More effective for runoff in the form of shallow, uniform flow compared to concentrated flow conditions.
- More effective when vegetation in the filter is of high quality.
- Most effective in removing sediment in the first 8 to 12 feet of the strip (filter width must be longer to effectively trap fine clay-sized particles compared to silt- and sand-sized particles).
- Most effective when the filter-strip width, location, and vegetation is matched to the soil, slope and drainage conditions at the specific site.
- Less effective as the cropland area drained through the vegetated area is increased.
- Less effective when the depth of flowing water moving through the filter is greater than the height of the vegetation in the filter (vegetation tends to lay over, which may help protect the filter-strip area from erosion, but the filter's trapping efficiency decreases dramatically).
- Less effective as sediment and nutrients build up in the vegetation.
- Less effective in trapping sediment and nutrients if runoff events occur very frequently (little or no rest or growth period between events).
- Less effective in some agricultural areas where flow from surface and subsurface drainage improvements bypasses the filter.
- Less effective when the filter strip is grazed during establishment or during wet soil conditions.
- Less effective when the filter strip is not maintained.

Summary

Filter strips can be a very useful BMP to help reduce the amount of sediment and nutrients leaving the field. Filter-strip effectiveness is dependent on soil characteristics, land size, slope and shape, quality of vegetative cover within the filter, and local land use and climatic factors. In addition, periodic filter-strip maintenance is required to maintain its effectiveness in improving and protecting water quality. Remember, a filter strip is an edge-of-the-field best management practice, and should be used in conjunction with other best management practices that make an impact within the field.

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