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Vegetative Filter Strips for Nonpoint Source Pollution Control in Agriculture

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VEGETATIVE FILTER STRIPS: WHAT ARE THEY?

Orchards, vineyards, and row crops have the greatest erosion rates in irrigated agriculture, especially those that are managed with bare soil between tree or vine rows. The vegetative filter strip (VFS) offers one way to control erosion rates and keep soil in the field rather than letting it be carried off site in drainage water. A VFS is an area of vegetation that is planted intentionally to help remove sediment and other pollutants from runoff water (Dillaha et al., 1989).

Vegetative filter strips protect surface water bodies in a number of ways:

- They intercept surface water runoff and trap as much as 75 to 100 percent of the water's sediment.
- They capture nutrients in runoff, both through plant uptake and through adsorption to soil particles.
- They promote degradation and transformation of pollutants into less-toxic forms.
- They remove over 60 percent of certain pathogens from the runoff.

KEY DESIGN ELEMENTS FOR VEGETATIVE FILTER STRIPS

The United States Environmental Protection Agency (EPA) encourages growers to use engineered vegetative treatment systems such as VFSs at sites where these systems are likely to bring about a significant reduction in nonpoint source (NPS) pollution (US EPA, 2002). You can establish VFSs downslope from crop fields or animal production sites to control NPS pollutants that would otherwise escape with runoff. In orchards, you can use multiple VFSs installed perpendicular to the direction of surface water runoff to reduce soil erosion and even avoid expenses associated with herbicide application. The strips also have the potential to reduce the level of some pesticides in runoff by enhancing water infiltration and retention in the field. For example, contaminants such as phosphorus and certain pesticides such as pyrethroids that bind strongly to soil particles get trapped and retained in VFSs.

Key elements to consider when designing VFSs are discussed at the US EPA's Web site (http://www.epa.gov/OWOW/NPS/MMGI/Chapter7/index.html) under section II.C., "Management Measure for Vegetated Treatment Systems." These elements include

- **Slope.** Vegetative filter strips work best on slopes of less than 5 percent and are not recommended for slopes greater than 15 percent. They are ineffective on hilly plots or in terrain that allows concentrated water flow. If you see evidence of concentrated flow in the form of channels or rills you should use other erosion control strategies instead, such as establishing terraces, dykes, berms, or vegetative barriers.

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- **Site preparation.** The land where filter strips are to be planted should be roughened by disking and harrowing or by raking to prepare a good seedbed. After that you can seed the strips with a mixture of grasses and legumes to establish a stand.
- **Soil conditioning.** Before planting, apply any soil amendments that would ordinarily be used for crops grown on your land including fertilizer, lime, compost, or gypsum.
- **Width.** Strip width is an important variable influencing the effectiveness of VFSs because the period of contact between runoff water and vegetation in the filter strip increases as the strip's width increases (Tables 1 and 2). Generally speaking, the wider the filter strip, the better it will perform. One effective approach in sloping terrain is to plant grasses in bands about 6 feet (1.8 m) wide along hillside contours every 10 to 100 feet (3–30 m), depending on slope. The bands run crosswise on the hillside, perpendicular to the line of the slope. A single, dense VFS about 30 feet (9 m) wide is appropriate when you are protecting riparian areas, especially when an in-field system of strips is not possible. On flat terrain, 10- to 15-foot (3–4.5 m) wide filter strips at field boundaries and along irrigation ditches and roads are effective (Figure 1). One suggested design criterion is that the combined width of VFSs for a field should be at least as great as the width of the runoff-contributing area, though this may in fact be an impractical standard.
- **Vegetation.** Sturdy, tall perennial grasses do the best job of trapping sediment. Generally, hardy perennial native grass species that are capable of withstanding summer drought conditions are preferred, though it is important to consider local conditions and cultural practices. Short, flexible grasses are much less effective. Legumes are less effective than grasses at trapping sediment, but they work well when mixed with grasses because they boost nitrogen levels in the soil. Filter strips can also include other vegetation planted parallel to the grass strips, such as poplar, walnut, or shrubs. Note that soils that are subject to prolonged saturated conditions may require special wetland plant species. The USDA–NRCS "VegSpec" Web site (http://ironwood.itc.nrcs.usda.gov/Netdynamics/Vegspec/pages/HomeVegspec.htm) is an excellent Web-based support system that can help you select appropriate plant species for filter strips and other vegetative establishment practices.

Table 1. Minimum width for vegetative filter strips

Slope	Minimum width of buffer strip
1–3%	25 ft
4–7%	35 ft
8–10%	50 ft

Source: Standards and Specifications No. 393, USDA–NRCS Field Office Technical Guide, 2004.

Table 2. Examples of pollutant removal efficiency for vegetative filter strips

Filter type	Nutrient source	Plot length	Pollutant	Removal efficiency %	Reference
Bermudagrass buffer strip	cropland runoff	16 ft (4.8 m)	chlorpyrifos dicamba 2,4-D mecroprop	62–99 90–100 89–98 89–95	Cole et al., 1997
Bermudagrass-crabgrass mixture	cropland runoff	14–17 ft (4.3–5.3 m)	P (total) N (total)	26 50	Parsons et al., 1991
Bluegrass and fescue sod (9% slope)	cropland runoff	15 ft (4.6 m) 30 ft (9.1 m) 45 ft (13.7 m)	NH_4-N atrazine NH_4-N atrazine NH_4-N atrazine	92 93 100 100 97 98	Barfield et al., 1992
Corn-oat or orchardgrass mixture (4% slope)	feedlot	45 ft (13.7 m)	P (total) N (total)	88 87	Young et al., 1980
Fescue (10% slope)	dairy waste on silt loam soil	5 ft (1.5 m) 13 ft (4.0 m)	P dissolved NO_3 P dissolved NO_3	8 57 62 68	Doyle et al., 1977
Orchardgrass (5–16% slope)	simulated feedlot	15 ft (4.6 m) 30 ft (9.1 m)	P (total) N (total) P (total) N (total)	39 43 52 52	Dillaha et al., 1988
Orchardgrass (5–16% slope)	cropland runoff	15 ft (4.6 m) 30 ft (9.1 m)	P (total) N (total) P (total) N (total)	75 61 87 61	Dillaha et al., 1989
Ryegrass	cropland runoff	20, 40, & 60 ft (6, 12, & 18 m)	suspended solids atrazine isoproturon diflufenican NO_3 P (soluble)	87–100 44–100 99 97 47–100 22–89	Patty et al., 1997
Sorghum-Sudan-grass mix (4% slope)	feedlot	45 ft (13.7 m)	P (total) N (total)	81 84	Young et al., 1980
Vegetated drainage ditch	simulated runoff	13 ft (4 m)	atrazine pyrethroid	98 100	Moore et al., 2001

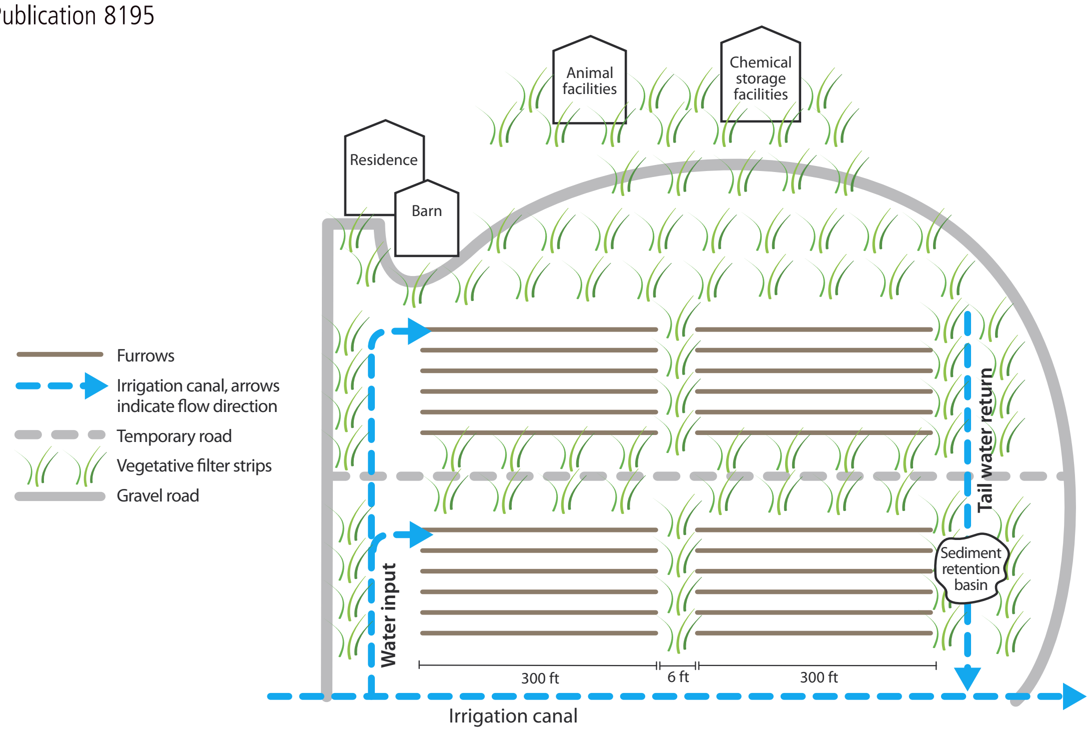

Figure 1. Farm plan indicating potential locations for vegetative filter strips.

- **Placement.** It is best to place the filter strips strategically so as to maximize the efficiency of contaminant removal. As a land manager, you have to identify where water flows on the property in order to identify the locations where VFSs will have the best chance of intercepting runoff. For instance, filter strips along stream banks are helpful since these areas can be subject to concentrated surface runoff from the surrounding landscape, but if you move the filter strips further up-slope within fields or orchards they can do their work before concentrated runoff occurs and that will yield better results. In irrigated row crop systems, wide filter strips along field boundaries would be most practical. A sample layout for VFS placement is illustrated in Figure 1. There are several critical placement areas: along roads, ditches, and animal confinement facilities, interspaced with the crop within the field, and at the field boundaries. Vegetated irrigation ditches can also be an effective strategy to trap pollutants.
- **Maintenance.** Vegetative filter strips require minimal maintenance, but you should consider the following operations:
  - Inspect the strips regularly for bare spots and other signs of erosion, especially after intense rain or runoff events.
  - Shallow, sheetlike flow of water must be maintained. If you find any evidence of channels and rills, repair it and reseed those areas.
  - Remove excess sediment buildup to keep water from diverting to a new, easier drainage route. If sediment accumulation is high (more than 6 inches deep), you will need to cultivate and reseed the affected areas.
  - Irrigate occasionally in summer if the vegetation that you plant requires it.
  - Mow the strips occasionally to a height of 4 to 10 inches to deter noxious weeds.
  - If pathogens such as bacteria are present in runoff water, mow the strips short to introduce sunlight and air that will desiccate the bacteria.
  - Noxious weeds must be controlled in and around the filter strips. You

may have to apply spot treatments of herbicide to control perennial noxious weeds.
- Limit traffic within filter strips.
- Occasionally harvest the filter strip vegetation and remove the cut biomass to prevent nutrient buildup.

- **Monitoring.** Some thought and effort should be given to monitoring the performance of the filter strips after installation. That way it will be possible for you to gauge your success and make later adaptations (such as redesign or replanting) to ensure regulatory compliance.

OBSERVED NONPOINT SOURCE POLLUTION CONTROL USING VEGETATIVE FILTER STRIPS

The effectiveness of VFSs for control of several NPS pollutants from cropland and feedlot runoff has been the subject of study, as has their effectiveness on sediment removal from surface mining and urban runoff (see Table 2). Based on empirical studies, trapping or removal efficiency frequently exceeded 90 percent of sediments, 50 to 80 percent of nutrients, and 44 to 100 percent of the herbicide atrazine. The ability of VFSs to trap pesticides varies depending on the nature of the compound and the design and maintenance of the filter strip. Vegetative filter strips are better at removing pesticides such as pyrethroids that bind to soil particles.

POLLUTANT-FILTERING MECHANISMS OF VEGETATIVE FILTER STRIPS

A vegetative filter strip functionally consists of three distinct layers—surface vegetation, root zone, and subsoil horizon—and as a result, the flow of water and pollutants through the filter strip can be a complex process. Once surface flow enters a VFS, infiltration is followed by saturation of the shallow subsurface. When the inflow rate exceeds the strip's infiltration capacity, overland flow occurs. In the root zone, some water infiltrates deeper into the subsoil while the remainder becomes lateral subsurface flow or *interflow* (Figure 2).

Runoff is less from hill slopes that have VFSs than from those that have none, a result of increased infiltration rates in the vegetated area. The vegetative strip's root zone allows high infiltration rates via macropores that arise with the generally

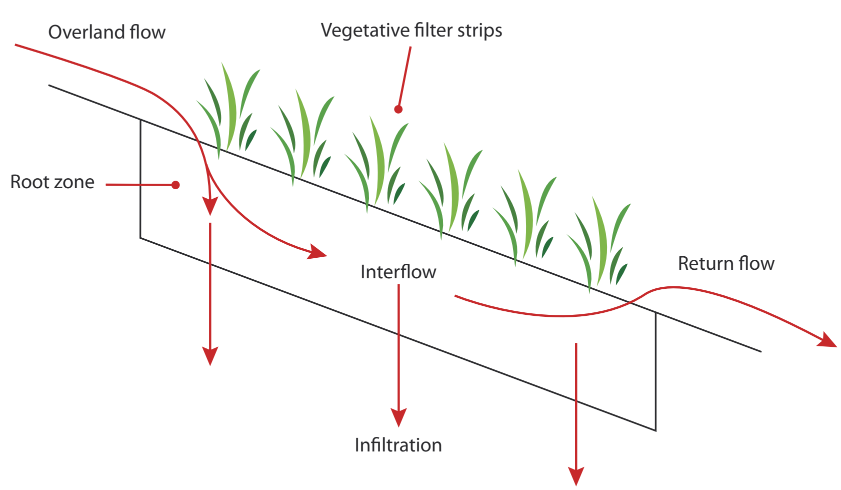

Figure 2. Cross-section of the patterns of water flow through hillside vegetative filter strips.

improved soil structure created by plant roots and other biological activities. The most important pollutant-trapping mechanism of VFSs is infiltration, followed by storage in the surface layer.

The soil constituent with the greatest influence on pesticide transport or pollutant retention and degradation is organic matter in the root zone and overlying surface litter layer. Greater biological activity in a soil improves its ability to effectively deal with pesticides and pollutants, and that kind of activity is more prevalent in a soil rich in plant roots, soil micro- and macro-fauna, and bacteria than in a soil without those organisms. Soil microorganisms play an essential role in the degradation of contaminants and soil organic matter is chemically reactive with the contaminants. For these reasons, you can expect degradation and adsorption of herbicides and pesticides to be greater in the filter strip's root zone than in adjacent fallow soils.

Vegetative filter strips on sloping land are subject to horizontal interflow within the root zone, in which case some pesticides may be filtered out, adsorbing onto soil organic matter. When the interflow water reappears on the surface as return flow it may have a lower pesticide concentration than the water that has flowed above ground. When infiltration is high in a VFS, the microbial- and plant-uptake processes cause denitrification, degradation of chemicals, and reduction of chemical concentrations in the surface layer between runoff events.

The effectiveness of VFSs depends on field conditions such as soil type, rainfall intensity, slope, micro-topography (surface soil roughness), the infiltration capacity of the vegetated area, the width of the strip, and the height of its plants. Slope and micro-topography affect overland flow velocity and uniformity and also appear to have an effect on the ability of VFSs to retain sediment and pollutants in runoff. Of course, the steeper the slope, the greater the sediment yield, all other factors being equal. Infiltration capacity and interflow within the VFSs influence the fate and path of dissolved nutrients and chemicals. The width of VFSs determines the strips' sediment-removing capacity and the amount of time the pollutant can be expected to remain in soil layers where adsorption and degradation processes are active.

You can find additional information at USDA–NRCS's "Buffer Strips Common Sense Conservation" Web site (http://www.nrcs.usda.gov/feature/buffers/). For more information on vegetative filter strips and incentive programs for land managers, contact your local UC Cooperative Extension office, Natural Resources Conservation Service office, Resource Conservation District, or Farm Service Agency office.

GLOSSARY

Absorption: the uptake of matter by a substance (such as a sponge) or living tissue (such as a plant).

Adsorption: a process whereby contaminants in water are drawn to and retained on the surfaces of soil solids by a chemical or physical binding mechanism.

Decomposition: a process whereby complex chemical compounds such as pesticides or organic materials are transformed into simpler compounds such as carbon dioxide gas.

Denitrification: the anaerobic conversion of nitrate-nitrogen into nitrogen gas by microbes.

Deposition: the retention of a transported material (such as waterborne chemicals) in a new, stationary position.

Infiltration: the entry of water into soil.

Interflow: water that moves through a filter strip as subsurface flow.

Volatilization: the transformation of a compound from liquid phase to gas phase.

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