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ABSTRACT

Vegetative filter strips (VFS) on 33 Virginia farms were visited and observed over a 13-month period to evaluate their long-term effectiveness for water quality improvement. Operational problems observed during the site visits were documented and design or maintenance procedures to alleviate the problems were evaluated. Of the VFS observed, 36% were judged to be totally ineffective, were no longer in existence, or were simply extensions of pastures — although all were, or had been, part of the state cost-share program.

Most of the sites visited had topographic limitations which severely limited VFS performance. Accumulation of surface runoff in natural drainageways within fields before it reached the VFS was the most common and critical problem. Runoff from the drainageways crossed the VFS in a few narrow areas, totally inundating the filters and rendering them ineffective for sediment and nutrient reduction. This situation is difficult to control and VFS are probably not appropriate for fields with extensive internal drainageways unless the VFS extend up into the fields and parallel the drainageways forming wide grassed waterways.

Vegetative filter strips were judged to be beneficial even when they could not filter sediment and nutrients from runoff because they provided localized erosion protection in critical areas along streambanks. They did not act as filters, however, and should therefore be referred to as vegetative buffer strips or critical area plantings.

KEY WORDS: Vegetative Filter Strips, Buffer Strips, Vegetative Filters, Sediment Transport and Deposition, Nutrient Removal, Water Quality, Nonpoint Source Pollution

INTRODUCTION

Sediments and nutrients associated with runoff from agricultural areas were identified as primary causes of eutrophication and declining water quality in the Chesapeake Bay Program Study (U.S. Environmental Protection Agency, 1983). According to the EPA study, croplands were estimated to contribute between 27% and 53% of the phosphorus (P) load and 60% to 70% of the nitrogen (N) load in average and wet years, respectively. Cropland was also identified as the primary source of sediments.

While much progress has been made towards the control of agricultural nonpoint source (NPS) pollution through the use of best management practices (BMPs), much work remains to reduce sediment and nutrient loadings to the Bay system. The Commonwealth of Virginia has long been a leader in the development and implementation of BMPs with a higher percentage of cropland in conservation tillage than any other state. In spite of this, however, water quality in the Chesapeake Bay and Virginia's streams, lakes and estuaries continues to decline and it is apparent that without further efforts, this trend will continue.

I. VEGETATIVE FILTER STRIPS

One BMP that is receiving considerable interest in Virginia for removing sediment and nutrients from the surface runoff of cropland and areas of livestock activity is the vegetative filter strip (VFS). Although VFS have not traditionally been part of state and federal agricultural cost-sharing programs, they are now being promoted with funds from Virginia's Chesapeake Bay Agricultural BMP Cost-Sharing Program.

Vegetative filter strips — also referred to as grass filters, vegetative buffer strips, filter strips or buffer strips — are bands of planted or indigenous vegetation used to remove sediment and nutrients from surface runoff. They reduce sediments and nutrients in runoff by filtering large solid particles from the runoff (hence the name filter strips) and by reducing the velocity of surface runoff which decreases sediment transport capacity and induces sediment deposition. The effectiveness of VFS is related to factors such as the incoming sediment and nutrient load, the flow rate per unit length, vegetal height and density, and filter slope and width.

Considerable research has been conducted in Kentucky, Virginia, and Maryland concerning the design of VFS and their effectiveness under controlled experimental plot conditions. However, little work is available documenting the effectiveness of on-farm VFS and the maintenance procedures required to overcome operational problems to sustain high rates of nutrient and sediment removal. Additional research in these areas is necessary if VFS are to achieve their full potential as a reliable and cost-effective BMP for controlling agricultural NPS pollution.

II. PROJECT GOALS

The goals of this research were to 1) evaluate the long-term effectiveness of on-farm VFS, 2) to document the management practices required for them to remain effective in removing sediment and nutrients from cropland runoff, and 3) to develop instructional materials promoting the proper installation and maintenance of VFS in Virginia. To achieve these goals, these specific objectives were undertaken:

1. Observe on-farm VFS to evaluate filter strip effectiveness over time and determine whether the movement of surface runoff through VFS is in the form of shallow sheet flow or deeper channel flow and the relative proportions of each;

2. Interview farm owners/operators and local conservation officials to document existing installation and maintenance practices, identify operational problems, and assess attitudes towards VFS and their effectiveness;

3. Document appropriate and inappropriate practices observed and develop a list of recommended installation and maintenance procedures; and

4. Develop an educational slide set for promoting the effective use of VFS.

LITERATURE REVIEW

Sediment, nitrogen, and phosphorus are three of the primary pollutants associated with surface runoff from cropland. One technique for removing these pollutants that is receiving increased interest is the use of VFS. The major pollutant removal mechanisms associated with VFS are thought to involve changes in flow hydraulics which enhance the opportunity for the infiltration of runoff and pollutants into the soil profile, deposition of total suspended solids (TSS), filtration of suspended sediment by vegetation, adsorption on soil and plant surfaces, and absorption of soluble pollutants by plants.

Infiltration is one of the most significant removal mechanisms affecting VFS performance because many pollutants associated with surface runoff from cropland enter the soil profile as infiltration takes place. Once in the soil profile, most of these pollutants are removed by a combination of physical, chemical, and biological processes. Infiltration is important also because it decreases the amount of surface runoff which reduces the ability of runoff to transport pollutants. Since infiltration is one of the more easily quantifiable mechanisms affecting VFS performance, many filter strips have been designed to allow all runoff from a design storm to infiltrate the filter area.

Vegetative filter strips also purify runoff through the process of deposition. Because VFS are usually composed of grasses and other types of dense vegetation which offer high resistance to shallow overland flow, they decrease the velocity of overland flow immediately upslope of and within the filter causing significant decreases in sediment transport capacity. If the transport capacity is less than the incoming load of suspended solids, the excess suspended solids may be deposited and trapped within or upslope of the VFS. Presumably, sediment-bound pollutants will also be removed during this deposition process.

The filtration of solid particles by vegetation during overland flow and the absorption process are not as well understood as the infiltration and deposition processes. Filtration is probably more significant for the larger soil particles, aggregates, and manure particles while absorption is probably more significant with respect to the removal of soluble pollutants.

The use of VFS for removing pollutants from cropland runoff is a relatively new practice. Historically, pollution control efforts on cropland were intended to minimize off-site pollution by reducing erosion and surface runoff within the field. Vegetative filter strips, however, are designed to remove pollutants from runoff once they have left the field and reached the filter area on the boundary of the field.

I. SEDIMENT TRANSPORT

Wilson (1967) presented the results of a sediment trapping study which gave optimum distances required to trap sand, silt, and clay in flood waters on flat slopes. He concluded that filter width, sediment load, flow rate, slope, grass height and density, and degree of submergence all affect sediment removal. A method for estimating the relationship between these parameters and filter performance was not presented. Neibling and Alberts (1979) used experimental field studies to show that grass filters reduced total sediment discharge under shallow sheet flow conditions by more than 90%. Significant deposition of solids was observed to occur just upslope of the leading edge of the VFS and 91% of the incoming sediment load was removed within the first 0.6 m of the filter. Sediment discharge of clay-sized particles was reduced 37% by a 0.6-m strip.

The most comprehensive research to date on sediment transport in VFS has been conducted by a group of researchers at the University of Kentucky working on erosion control in surface mining areas (Barfield et al. 1977, 1979; Kao and Barfield 1978; Tollner et al. 1976, 1978, 1982; Hayes and Hairston 1979; Hayes et al. 1979, 1983). Tollner et al. (1976) presented design equations relating the fraction of sediment trapped in simulated vegetal media to the mean flow velocity, flow depth, particle fall velocity, filter length, and the spacing hydraulic radius (a parameter similar to the hydraulic radius in open channel flow which is used to account for the effect of media spacing on flow hydraulics). Barfield et al. (1979) developed a steady state model, the Kentucky filter strip model, for determining the sediment filtration capacity of grass media as a function of flow, sediment load, particle size, flow duration, slope, and media density. Outflow concentrations were primarily a function of slope and media spacing for a given flow condition. The Kentucky filter strip model was extended for unsteady flow and non-homogeneous sediment by Hayes et al. (1979). These investigators presented methods for determining the values of the hydraulic parameters required by the Kentucky model for real grasses. Using three different types of grasses, model predictions were reported to be in close agreement with laboratory data. Hayes and Hairston (1983) used field data to evaluate the Kentucky model for multiple storm events. Eroded material from fallow cropland was used as a sediment source. 'Kentucky 31' (*Festuca arundinacea*) tall fescue trimmed to 10 cm was used and the model predictions agreed well with the measured sediment discharge values. The Kentucky researchers, like Neibling and Alberts (1979), observed that the majority of sediment deposition occurred just upslope and within the first meter of the filter, until the upper portions of the filter were buried in sediment. Subsequent flow of sediment into the filter resulted in the advance of a wedge-shaped deposit of sediment down through the filter. The Kentucky research reported high trapping efficiencies as long as the vegetal media was not submerged, but trapping efficiency decreased dramatically at higher runoff rates which inundated the media.

Kao et al. (1975) proposed a VFS arrangement in which grass strips were alternated with strips of bare ground to solve the problems associated with sediment inundation of the filter and the killing of vegetation. They indicated that with the proper VFS to bare ground strip width ratio, most of the trapped sediment would be retained in the bare area just upslope of the filter. This maintained high filter efficiencies and allowed the sediment trapped in the bare strips to be removed periodically without damaging the VFS. The results were based upon laboratory studies with artificial media and have not been tested in the field.

II. NUTRIENT TRANSPORT

Doyle et al. (1977) applied dairy manure to 7 x 5-m fescue plots on a Chester silt loam soil (fine-loamy, mixed thermic, Typic Hapludult) with a 10% slope. Soluble nutrient concentrations were measured after passing through 0.5 m, 1.5 m, and 4.0 m of fescue filter strips. Soluble P was reduced by 9% after passage through the 0.5-m strip; 8% in the 1.5-m strip; and 62% in the 4.0-m filter. Soluble NO_3 decreased by 0% in the 0.5-m strip; 57% in the 1.5-m strip; and 68% in the 4.0-m filter. However, NH_4 concentrations increased with increasing filter length — presumably due to the release of NH_4 from decomposing organic N, which had been trapped in the filter previously.

Young et al. (1980) used a rainfall simulator to study the ability of VFS to control pollution from feedlot runoff. Field plots were constructed on a 4% slope with the upper 13.7 m in an active feedlot and the lower 27.4 m planted in either corn (*Zea mays*), oats (*Auena sativa*), orchardgrass, (*Dactylis glomerata*) or a sorghum-(*Sorghum vulgare*) sudangrass (*Sorghum sudanensis*) mixture. Water was applied to the plots to simulate a 25-year, 24-hour duration storm. Total runoff was reduced by 81%, sediment by 66%, total P (T-P) by 88%, and total nitrogen (T-N) by 87% with the orchardgrass and by 61%, 82%, 81%, and 84%, respectively, with the sorghum-sudangrass mixture. The authors concluded that VFS were a promising treatment alternative. Thompson et al. (1978) studied the effectiveness of orchardgrass filter strips on a sandy loam soil in reducing nutrient loss from the application of dairy manure to frozen or snow covered orchardgrass plots. Fresh dairy manure was applied to 24-m orchardgrass plots and runoff quality determined after traveling through 12 m and 30 m of additional orchardgrass during natural runoff events. Total P was reduced by an average of 55%, NO_3 by 46%, total Kjeldahl nitrogen (TKN) by 41%, and T-N by 45% after passing through 12 m of filter. A 36-m filter resulted in reductions in T-P of 61%, NO_3 of 62%, TKN of 57%, and T-N of 69%. Nutrient concentrations in the runoff from the 36-m filters approached that from control plots to which no manure had been added.

Bingham et al. (1978) applied poultry manure to 13-m long fescue grass plots on an eroded Cecil clay loam (clayey, kaolinitic, thermic Typic Hapludult) with 6-8% slopes and reported that filter strip length/waste area length ratios of about 1.0 reduced pollutant loads to near background concentrations. Total P was reduced by 25%, TKN by 6%, NO_3 by 28%, and T-N by 28%.

Edwards et al. (1983) monitored storm runoff for 3 years from a paved feedlot. Storm runoff was measured and sampled as it left the feedlot, after passing through a shallow concrete settling basin, and then after two consecutive 30.5-m long fescue filter strips. Runoff was reduced by -2%, total suspended solids (TSS) by 50%, T-P by 49%, and T-N by 48% after passing through the first filter and by an additional -6%, 45%, 52%, and 49%, respectively, after passing through the second filter. Total runoff from the filters was greater than the incoming runoff because rainfall rates during runoff events exceeded the infiltration capacity of the filters. This rainfall excess coupled with the added area of the filters resulted in increased runoff.

Patterson et al. (1977) applied liquid dairy waste via a gated pipe to fescue on Hosmer silt loam (fine-silty, mixed, mesic, fragiudalf) with a 3.4% slope. After applying dairy waste to the filter for one year, pollutant reductions averaged 42% for 5-day biological oxygen demand, 38% for NH_4, 7% for Ortho-Phosphorus (O-P), and 71% for TSS after passage through a 35-m fescue VFS. Nitrate loss increased after passage through the filter, presumably due to mineralization of organic-N and nitrification of NH_4 which had been trapped in the filter previously. Paterson et al. (1977) noted problems with maintaining a good grass cover on the filter area. They recommended that several filter areas should be utilized and rotated on a weekly basis to maintain good grass cover.

Procedures for the design of VFS with respect to organics removal have been presented by Norman et al. (1978) and Young et al. (1982). However, these design procedures were based primarily on infiltration or limited organics removal data. Regression type design equations for P reduction were presented by Young et al. (1982), but details of their development were not presented and have not been verified.

III. VEGETATIVE FILTER STRIP RESEARCH IN VIRGINIA

Dillaha et al. (1986a, 1986b) used a rainfall simulator to evaluate the effectiveness of VFS for controlling sediment and nutrient losses from feedlots and cropland. Simulated rainfall was applied to a series of 5.5-m by 18.3-m bare soil plots with 4.6-m and 9.1-m vegetative filter strips located at the lower end of the plots. For the feedlot simulations, fresh dairy manure was applied to the bare portions of the plots at rates of 7,500 and 15,000 kg/ha and compacted with rollers to simulate feedlot conditions. For the cropland simulations, commercial fertilizers, 112 kg/ha of granular P_2O_5 and K_2O and 222 kg-N/ha of non-pressurized N solution were applied to bare tilled plots. Water samples were collected from H-flumes at the base of each plot to evaluate the effectiveness of VFS in removing sediment and nutrients from the feedlot or cropland runoff.

The VFS were found to be effective for the removal of sediment and other suspended solids from surface runoff if flow was shallow and uniform and if the VFS had not been previously inundated with sediment. The 9.1-m VFS on the shallow sheet flow plots removed 91% of the incoming sediment during the feedlot simulations and 78% during the cropland simulations. The 4.6-m VFS removed 81% of the incoming sediment during the feedlot simulations and 63% during the cropland simulations.

Vegetative filter strip effectiveness for sediment removal appeared to decrease with time as sediment accumulated within the filters. One set of the filters was almost totally inundated with sediment during the cropland simulations and filter effectiveness dropped 30-60% between the first and second set of runs. This may not be a problem in "real world" VFS because filter strip vegetation may be able to grow through most sediment accumulations.

Total N and P in runoff from the simulated feedlots were not removed by VFS as effectively as sediment. Presumably, much of the N and P in feedlot runoff was soluble or associated with very fine sediment which the 4.6-m and 9.1-m VFS could not remove efficiently because of high runoff rates from the bare portions of the plots. The long and short filters of the sheet flow feedlot plots removed 69% and 58% of the applied P, respectively, and 74% and 64%, respectively, of the applied N. The filter strips below simulated cropland were much more effective and removed T-P almost as effectively as sediment.

The VFS lengths used in this research were not effective in removing soluble N and P present in the runoff from simulated feedlots and cropland. Soluble P and N in the outflow from the filters were often higher than that in the inflow. This was thought to be due to the release of P and N which had been trapped in the filters previously.

Vegetative filter strips characterized by concentrated or deeper channel type flow were found to be much less effective for sediment, N, and P removal than filters with shallow sheet flow. Filters with concentrated flow were 40-60%, 70-95%, and 61-70% less effective with respect to sediment, P, and N removal than the sheet flow filter strips.

Dillaha et al. (1986b) concluded that the effectiveness of the experimental filter strips should not be used as a direct indicator of real world VFS effectiveness because concentrated flow effects in real situations would have been orders of magnitude greater than those measured during the experimental field studies.

A simplified procedure for the design and evaluation of VFS which considers the effects of natural drainageways and concentrated flow was presented by Dillaha et al. (1986b). They developed the following series of regression equations which may be used to describe VFS performance with respect to sediment, N and P removal:

$$RTSS=71.41-29.23Q^2+2.55W \qquad r^2=0.87 \qquad (1)$$

$$RTN=70.38+88.26Q-110.26Q^2 \qquad r^2=0.91 \qquad (2)$$

$$RTP=74.03+74.47Q-97.96Q^2 \qquad r^2=0.90 \qquad (3)$$

where: RTSS, RTN, and RTP are the percent reductions in TSS, T-N, and T-P, respectively; Q is the flow rate into the filter per unit length, L/s-m (liters/sec/min); and W is the filter width, m. Filter slope was not statistically significant in the regressed equations.

Equation 1 describing the percent reduction in sediment is appropriate for filters less than 11.2 m in width and for flow rates less than 1.8 L/s-m. At higher flow rates, RTSS was assumed negligible.

Equations 2 and 3, describing the percent reductions in T-N and T-P, are appropriate for flow rates between 0.4 and 1.3 L/s-m. At higher flows, RTN and RTP were assumed to be negligible. For flows less than 0.4 L/s-m, RTN, and RTP were assumed to be 90%.

Using these regression equations, the following design/evaluation procedure was developed:

1. Obtain topographic map of area proposed for protection by VFS;
2. Delineate subwatersheds within the field from a topographic map which will drain through the VFS and determine the drainage area for each subwatershed;
3. Estimate the total volume of runoff which will be discharged from each subwatershed using the SCS total runoff volume method or other appropriate method for the desired design storm;
4. Estimate the VFS length through which flow will pass for each subwatershed, VFS longitudinal length in areas with shallow sheet flow or channel width through VFS in subwatersheds with developed drainageways;

5. Determine flow rate per unit length through the VFS for each subwatershed;

6. Estimate percent reduction in desired pollutant for each subwatershed using the regression equations; and

7. Weight percent reductions on an areal basis to determine if VFS are appropriate for the field under investigation.

Additional details concerning the simplified design procedure are given in Dillaha et al. (1986b). They recommend that the design equations be used with caution because of the limited database from which they were derived.

A new process-oriented design model, based on the Kentucky filter strip model, which considers phosphorus transport in VFS, is currently under development at Virginia Tech. A report describing this model and its development will be available in early 1987.

IV. VIRGINIA FILTER STRIP PROGRAM

The Virginia cost-share program for VFS was initiated in 1983 as part of the Commonwealth's Chesapeake Bay Program to encourage farmers to install permanent VFS along the banks of streams to filter runoff, stabilize soil, and to protect stream banks against scour and erosion. During the first year of the program, only fields enrolled in the Agricultural Stabilization and Conservation Service (ASCS) Acreage Reduction and Payment-In-Kind (PIK) programs located within the Chesapeake Bay and Chowan River Basins were allowed to participate in the VFS program. In subsequent years, the requirement for participation in the Acreage Reduction and PIK programs was dropped. The program was and is administered by the ASCS and Soil and Water Conservation Districts (SWCDs) for the Virginia Division of Soil and Water Conservation (VDSWC).

Farmers participating in the program were originally eligible to receive 10 cents per linear foot, or approximately $218/acre of VFS installed. In 1983 and 1984, five cents per linear foot was paid the first year after filter strip establishment and two and one-half cents per year per linear foot in the subsequent two years if the VFS were maintained adequately. From 1985 on, farmers received 10 cents per linear foot as soon as the VFS was established, but were required to refund this amount if the VFS were not maintained in subsequent years. Minimum VFS eligibility requirements for the 1987 VFS program (VDSWC, 1986) include:

1. The VFS must be installed within 100 feet of a live or intermittent waterway.

2. The VFS width must average 20 feet with a minimum width of 12 feet.

3. A 10-ft VFS is acceptable if the land slope is less than 2%.

4. The VFS must be planted in a permanent vegetative cover according to the seeding specifications shown in Table 1 and the VFS maintained for a minimum of 5 years (3 years for VFS installed before 1987).

5. State cost-share will be provided only once per VFS while the land is under the same ownership (not a requirement prior to 1987).

6. Grass filter strips will be designed and installed to filter sheet flow rather than concentrated flow. If concentrated flow occurs, grading and shaping or the use of other BMPs such as sod waterways or drop structures, may be required (not a requirement prior to 1987).

Guidelines quoted from the VDSWC Grass Filter Strip Specifications (VDSWC 1986) for VFS establishment and maintenance include:

1. All trees, stumps, brush, rock and similar materials that could interfere with the installation or maintenance of VFS should be removed.

2. No-till planting is preferable. If necessary, the site should be graded so that conventional equipment can be used for seedbed preparation, seeding, fertilization, and maintenance.

3. Select a seed mixture of permanent vegetation that satisfies the state minimum specifications and is appropriate for the time of planting.

4. Lime and fertilizers should be applied according to soil test recommendations at the time of establistment.

5. Hayland is considered cropland if used in rotation with row crops during the 5-year life span of the VFS (not specified prior to 1987).

6. Soil loss rates must be computed for all applications for use in establishing priority considerations, however, soil loss rates in excess of the soil loss tolerance are not required (new requirement 1987).

7. Filter strips planned for runoff from concentrated livestock activity areas or controlled overland flow for the treatment of liquid wastes are subject to SCS specification 393 (new requirement 1987).

8. VFS should be maintained on each side of the stream.

9. Protect the VFS from damage by livestock.

10. Do not use the VFS as a roadway.

11. Avoid operations which leave tillage or wheel marks.

12. Woody stems within the strip should not be allowed to exceed 2 inches in diameter.

13. Avoid damaging VFS with herbicides.

14. Lime and fertilize at the same time as adjacent fields or as needed.

15. Hay may be harvested from VFS except when using the wildlife option.

Additional details concerning the Virginia VFS program may be found in the publications *Grass Filter Strips in Virginia* (VDSWC 1983), *Dollars for Soil and Water Conservation Practices* (VDSWC 1984), and *Grass Filter Strips, VDSWC Specification No. WQ-1* (VDSWC 1985, 1986, and 1987).

During the spring of 1984, VDSWC field representatives conducted a survey of VFS installed during the 1983 VFS program (VDSWC, 1984) along with personnel from the USDA-SCS and SWCDs. Approximately 30% of the VFS participating in the cost-share program were inspected. Almost half of the VFS observed had poor to fair vegetative cover. The surveyors reported that this was the result of not seeding according to specifications in the *Grass Filter Strips in Virginia* brochure or not reseeding strips which had been damaged. Almost 75% of the VFS observed were within 100 feet of a stream. One filter strip was recorded as being nowhere near a stream. A majority of the VFS were reported to be effectively located below land where potential erosion was evident. Nineteen percent of the fields above the VFS were judged to have substantial erosion. Some filter strips were noted to be at a higher elevation than the fields they were supposedly protecting. The surveyors recommended that good judgment be used when selecting sites eligible for VFS cost-sharing to insure that the VFS were not located too far from streams or higher than the fields they were to protect. Problems due to vehicular traffic also were noted. The surveyors reported that use of the VFS as roadways and turn rows caused considerable VFS damage.

The field representatives recommended that the local SWCDs accept responsibility for monitoring cost-shared VFS to insure that they are properly installed and maintained. They also recommended that strips which "do not comply with plans, guidelines, and specifications should *not* receive funding."

No mention was made concerning the effects of natural drainageways and concentrated flow on VFS performance. Accumulations of sediment within the VFS were not reported, indicating that concentrated flow effects may have been significant.

The Virginia VFS cost-share program was most popular during 1983 when 155 miles of VFS were certified for payment. An additional 12, 56, and 125 miles of VFS were certified for payment in 1984, 1985, and 1986, respectively. Not all of the VFS which have been certified for first year cost-sharing have remained in the program. Many VFS were dropped from the program during the second and third years of the program because they had been taken out of use.

V. RECOMMENDED DESIGN, PLANTING, AND MAINTENANCE PROCEDURES

Little information is currently available concerning the design, planting and maintenance of VFS because they are a relatively new best management practice (BMP). One of the better sources of information on VFS is the Virginia *Best Management Practices Handbook: Agriculture* (VWCB 1979). This publication describes the purpose, conditions where the practice can be applied, planning considerations, and establishment and maintenance procedures. It describes the usefulness of VFS in removing sediment from surface runoff and suggests that the practice is applicable only when soil is transported primarily by sheet flow. The use of VFS for nutrient removal and recommendations concerning the effects of concentrated flow on filter performance are not discussed.

The Handbook states that VFS design, with respect to VFS width, is a largely judgmental factor that is based primarily on local experience. The Handbook lists the following factors which should be considered in determining required VFS width: land use and management above the strip; land slope above the strip; length of slope above the strip; soil erodibility above the strip; slope across the strip; type of strip vegetation; and anticipated degree of strip maintenance. However, no details are given as to what weight or how these factors should be considered. Suggested VFS widths for effective sediment removal were said to vary from a few feet in relatively well drained flat areas to as much as several hundred feet in steeper areas with more impermeable soils. A minimum width of 12 feet was recommended for herbaceous strips.

Recommendations for VFS establishment and maintenance are similar to those given in the *Grass Filter Strips in Virginia* publication (VDSWC 1983). The Handbook states, however, that care must be exercised when applying herbicides near VFS and that periodic herbicide application for weed control and mowing may be required for efficient VFS operation. The Handbook recommends that VFS be planted and maintained in accordance with established procedures developed for grassed waterways.

Almost no information is available concerning operational problems associated with VFS and their long-term effectiveness in the field. Barfield et al. (1981), Hayes et al. (1981), and Dillaha et al. (1986a, 1986b) reported that the most serious problems affecting VFS performance were caused by flow inundation. Barfield et al. (1981) reported that VFS vegetation must remain erect and non-submerged for optimum effectiveness. Hayes et al. (1981) determined that VFS grasses such as fescue and rye require periodic mowing to maintain their rigidity and resist bending over during flow events. A maximum grass height of approximately 15 cm was suggested to maintain rigidity and promote thick growth. Dillaha et al. (1986a, 1986b) also recommended mowing and reported that VFS which had been mowed regularly were much thicker and appeared healthier than those which had not.

Vanderholm et al. (1979) recommended that VFS vegetation be harvested regularly for nutrient removal and to maintain a thick grass cover. He also suggested that livestock should be excluded from VFS to minimize compaction and damage problems.

Dillaha et al. (1986b) noted problems in VFS which had filled with sediment. In some cases, the VFS had accumulated sufficient sediment that they were at a higher elevation than that of the adjacent field. In these cases, the VFS resembled a terrace and runoff tended to flow parallel to the VFS until it reached a low point where it crossed as concentrated flow. Problems were also noted on several farms with moldboard plowing. When soil was turn plowed parallel and away from the VFS, a large furrow was formed between the field and the VFS which caused runoff to flow parallel to the field. If this furrow was not removed later by careful disking, runoff concentrated, a gully was formed, and the flow crossed the VFS in a few low areas rendering the filter ineffective for sediment and nutrient removal.

VI. SUMMARY AND CONCLUSIONS

As indicated in the literature review, little information is currently available concerning the effectiveness of VFS in practice. Considerable research has been conducted under experimental conditions to evaluate VFS under a variety of situations for both sediment and nutrient removal. Progress has been made in the development of design procedures but no procedures have been developed which have received widespread acceptance and verification. Recommendations for VFS establishment and maintenance have been based largely on recommendations developed for forage production or similar practices such as grassed waterways.

Additional research is needed to evaluate the long-term effectiveness, maintenance, and operational problems associated with VFS in the field. Without this research, VFS cannot be used cost effectively for water quality improvement because they will be installed in areas for which they are inappropriate and because maintenance and operational problems will reduce their effectiveness. The purpose of the present study was to observe existing VFS in the field to identify design, planting, and maintenance procedures which will alleviate operational problems and increase long-term VFS effectiveness.

FILTER STRIP EVALUATION PROCEDURES

With the assistance of individuals from the U.S. Soil Conservation Service, a number of existing vegetated filter strips of differing ages were selected for detailed inspection and evaluation. The strips were located either in the Chesapeake Bay or Chowan River Basin watersheds. Filter strips evaluated in the Chesapeake Bay Basin were located in Culpeper, Green, Lancaster, Madison, Northumberland, Prince George, and Richmond counties. The remainder of the VFS were located in the Chowan River Basin in the City of Suffolk and in Southampton and Sussex counties.

Two methods were used to evaluate the effectiveness of on-farm filter strips. These included quarterly inspections over a one-year time period and a mail survey to ascertain the opinions and attitudes of landowners, farm operators, and SCS professionals concerning VFS. Detailed procedures followed for each method of evaluation are summarized below.

I. FIELD EVALUATIONS

A large majority of the filter strips surveyed were inspected a total of five times over the study period. The initial visit occurred in March 1985 and was followed by inspections every three months concluding in April 1986. Some of the filter strips were visited only once. In these instances, it was clear that the strips were not serving their intended purpose, had never been planted, or had been taken out of service.

Each filter strip was inspected in detail by walking the length of the strip and noting any problems as well as characteristics which seemed to enhance or detract from VFS effectiveness. This was accompanied by measurement of strip width, slope of adjacent land, observation of land use above the VFS, estimation of the percentage of flow entering the VFS as concentrated flow, cover evaluation, maintenance needs, owner attitudes, and other factors. A copy of the evaluation form, which was completed at the site during each visit, is presented in Figure 1.

II. OWNER AND SCS EVALUATIONS

After the last site visits were made in April 1986, a questionnaire was mailed to SCS and VDSWC officials and owners of VFS to assess their opinions and attitudes regarding VFS in general, the effectiveness of VFS in controlling erosion and improving water quality, and their recommendations for improving VFS effectiveness. Sixteen questionnaires were returned from the 26 mailed. The questionnaire used is shown in Figure 2. The primary purpose of the survey was to obtain information on:

1. Source of initial information regarding the filter strip program;
2. Reason for installing filter strips;
3. Type of filter strip vegetation;
4. Recommended strip vegetation;
5. Width of strip when planted;
6. Land use above strip;
7. Installation and maintenance problems;
8. Recommended maintenance procedures to preserve VFS;
9. Effectiveness for water quality improvement and erosion prevention;
10. Need for cost-sharing money as an incentive to install strips; and
11. Plans for VFS after the cost-share program ends.

RESULTS AND DISCUSSION

I. FIELD EVALUATIONS

On-farm VFS were surveyed on a quarterly basis from March 1985 to April 1986. Filter strips on 33 farms with a total length of approximately 142,000 feet were visited and evaluated. The following is a summary of significant finding obtained from the on-farm visits:

1. Of the 33 farms visited, 6 (18%) had no VFS and on an additional 6 farms (18%) the VFS were simply the border areas of existing or new pastures. All 12 of these VFS had received first-year cost-share funds and at least two were known to have withdrawn or been removed from the program after the first year. One VFS was withdrawn because it was killed when herbicides were mistakenly applied to the entire VFS and another was withdrawn because the site was too wet for good growth. Filter strips at several sites participating in the cost-sharing program could not be found. Several others either never existed or were plowed out within the first year after establishment.

2. Approximately 50% of the VFS observed were judged to have excellent vegetative cover which would have been adequate for effective VFS performance assuming that shallow sheet flow conditions existed. Many of these VFS had fair to poor cover during the first two site visits because they had been planted within the previous 6 months and because of drought conditions in Virginia during that period. By the end of the project, 59% of the VFS had good to excellent cover; 14% had fair cover (thin stand with some bare areas); and 27% had poor cover (sparce ground cover, usually a lot of weeds; not suitable for VFS).

3. Tall fescue was the dominant vegetation in all but two of the VFS surveyed. Some orchardgrass, clover and Lespedeza were present in most VFS, but fescue was clearly dominant. One strip was predominantly Timothy which formed a good cover but this strip was damaged repeatedly by cattle. One wildlife habitat strip contained a mixture of millet, fescue and cabbage. This VFS was never very thick at ground level, although it appeared adequate from a distance, and did not perform effectively as a filter strip. By the end of the project, this VFS had a sparce cover which was predominantly weeds. This VFS was never mowed and this fact may have contributed to excessive weed growth and its failure.

4. Almost all (88%) of the VFS observed were within 100 feet of a stream or pond. Most, or at least a portion, of each VFS was within 20 feet of a stream. A stream could not be found within 1000 feet of one VFS.

5. Most of the strips observed needed maintenance during one or more of the surveys. Mowing was the most often needed maintenance practice. About 20% of the VFS had severe erosion and gully problems in localized areas. Only one owner was observed to have repaired and reseeded areas with severe erosion problems. In most cases, grass and weeds became established in the gullies within the first year or two after establishment. However, the stabilized gullies still permitted runoff to pass through the VFS as channel flow which reduced VFS effectiveness. Excessive weed growth was judged to be a significant problem in 29% of the VFS visited. The taller weeds tended to shade desirable grasses and reduced cover at ground level. Mowing, use of herbicides, and/or reseeding could have greatly helped these VFS. Nineteen percent of the VFS had poor cover and/or severe damage due to their use as roadways or turn rows. Tire tracks 3 to 12 inches deep were observed in some VFS and those with heavy traffic were generally bare and compacted. Two VFS were observed which had been damaged by cattle. Grazing itself did not appear to be a problem but there was considerable hoof damage. Vehicular and cattle damage was usually most severe in lower areas close to streams and channels. This was unfortunate as flow naturally concentrated in these areas where good cover was needed the most.

6. The majority of the VFS observed were judged to be ineffective for water quality improvement because most of the flow through the filters was concentrated rather than shallow and uniform. Runoff entering the VFS as concentrated flow averaged an estimated 60%. Larger fields in hilly areas, such as in the Piedmont region, generally had well developed natural drainageways within the fields and had the most concentrated flow. Flatter fields with more uniform slopes had less concentrated flow but as field size increased so did drainageways and concentrated flow. Filter strips appeared to be most effective in smaller fields where runoff did not have a chance to concentrate before reaching the VFS. Strips located parallel to grassed waterways and other drainageways within fields would help overcome the concentrated flow problem by removing runoff sediment and nutrients before it concentrated.

7. Of the VFS observed, 62% were located at lower elevations than their adjacent cropland, but 15% were so much higher than adjacent cropland that runoff could not flow through them except during flood flow conditions. The remaining 23% had significant portions which were higher, but most of the strips were lower than the adjacent cropland. Problems were most pronounced along some larger streams where natural levees had built up in the stream's floodplain. Filter

strips constructed on these elevated levees were judged to be effective only for streambank and localized erosion protection. They were judged to be totally ineffective as VFS. Strips located between levees or other obstructions and the fields also had problems because the levees caused water to back up in the VFS, concentrate, and then flow parallel to the levee until a low point in the levee was reached. Filter strips with this problem acted more like grassed waterways and many had significant gullying.

8. The individual VFS inspected ranged from 9 feet to 30 feet in width and averaged about 19 feet. Most new VFS were about 20 feet wide but there was a definite trend for width to decrease with time due to encroachment into the VFS each time the fields were tilled. Some VFS lost as much as 10 feet of width over the course of the study but 2- to 5-foot decreases were more common. Filter strip widths tended to be much narrower in areas where valleys, woods, and natural drainageways projected into the fields. This is where they should be the widest because these are areas where flow tends to concentrate.

9. Tillage also caused problems on several flatter fields where moldboard plowing was practiced. If the soil was turn plowed parallel to and away from the VFS, a gully or deep furrow was formed next to the strip. If this furrow was not removed by careful disking later, surface runoff tended to collect in the furrow and flow parallel to the VFS until a low point was reached where it crossed the VFS as concentrated flow. One way to alleviate this problem would be to turn plow perpendicular to the VFS to minimize concentrated flow and distribute flow uniformly across the VFS, but this requires using the VFS as a turn row which might cause damage to the strip. An alternative is to not plow within a foot or two of the VFS or to turn plow the soil towards the filter and then follow with disking. A furrow would not be formed immediately adjacent to the VFS in this case and subsequent disking would be easier and more effective.

II. OWNER AND SCS EVALUATIONS

Based on the quality of the responses obtained from the questionnaire it was evident that filter strip owners and SCS officials had taken great care in completing the mail survey.

Respondents listed 27 primary reasons for installing filter strips. Twenty-one of the reasons can be combined into the goals of the filter strip program: erosion control and water quality improvement. The remaining reasons VFS were installed included: a) economic incentive due to state cost-share program; b) wildlife habitat enhancement; c) use as field borders; and d) extra hay production.

Age of the filter strips varied from 1 year to more than 6 years. The majority were between 2-4 years old during the study period. Half of the respondents claimed they used filter strips prior to initiation of VFS cost-sharing programs.

Many different types of vegetation were installed in the filter strips. Fescue, orchardgrass, and clover were the predominant types of vegetation reported.

Nine of the sixteen respondents were satisfied with recommended seed mixes and planting practices. Dissatisfied owners recommended use of higher fescue seeding rates, switchgrass, fungus-free fescue, tall grasses, and more wildlife forage mixes.

Vegetative filter strip widths were reported to vary from 10 feet to 300 feet. The majority were in the 20-foot wide range and most respondents believed that a 20-foot width was satisfactory. Fourteen of the sixteen landowners reported having cropland adjacent to the filters and two had adjacent land in pasture.

Most respondents felt that mowing and proper fertilization were the principal management practices needed to maintain the filters to ensure long-term VFS effectiveness. Annual reseeding, avoiding the use of VFS as roadways, and care in applying herbicides on adjacent fields also were recommended.

Five respondents indicated they had no problems with their VFS and that performance was satisfactory. Ten landowners reported problems, including:

1. Poor establishment due to drought at time of initial planting;

2. Weed and Johnson grass invasion;

3. Plowing adjacent land reduced VFS width;

4. Sedimentation and silt build-up in VFS with recommendations to control this problem including use of waterways and terraces within adjacent fields and disking to rework land;

5. VFS width too narrow, — when used as roadway, repeated passage over the same area caused damage;

6. Gullies in VFS due to concentrated flow;

7. Installation too narrow, (12 feet);

8. Drift and/or misapplication of herbicides on adjacent land killed cover;

9. Excessive weed growth resulted in a need for replanting.

All respondents indicated that they believed VFS were effective for erosion control and water quality improvement. In addition, all respondents reported that they would continue to maintain their VFS after the cost-sharing program terminates.

When asked if they would install new VFS without cost-sharing 33% said yes, 40% said no, and 27% were not sure.

The majority of filter strip owners learned about the filter strip program through the SCS, ASCS, and newsletters. Several landowners reported that they became involved through their extension agents or friends.

Queried about their neighbors' opinion of filter strips, owners responded equally with 'no interest,' 'liked them,' and 'unknown.'

Final general responses, recommendations, and comments included:

1. VFS are a good practice for both erosion control and water quality improvement.

2. The Virginia VFS cost-sharing program should continue.

3. Use of wildlife plantings should be encouraged.

4. More research is needed concerning VFS design, maintenance and effectiveness.

5. Education is needed to make people more aware of VFS benefits.

6. The cost-share program is a good way to get people interested in VFS.

7. VFS should also be used on farmland adjacent to ephemeral streams.

8. More planning is needed to insure that VFS are installed properly and planted during favorable times of the year.

9. The VFS program is very good for runoff control and wildlife propagation.

10. The VFS program is a good practice and all farmers should install filters without cost-sharing.

11. Ten-foot VFS should be used rather than 20-foot strips.

12. Farmers who planted strips have no regrets.

RECOMMENDATIONS

I. RECOMMENDATIONS FOR IMPROVED VFS PERFORMANCE

As discussed in this report, many problems were observed during the course of this study. To alleviate these problems and to increase the cost-effectiveness of the program with respect to water quality, the following specifications and recommendations should be incorporated into Virginia's VFS cost-sharing program. This list of recommendations should be used as a guide with final decisions concerning the appropriateness of VFS at specific sites being made by qualified local conservation officials.

A. Site Eligibility

1. Vegetative filter strips are effective for water quality improvement only if the flow across the VFS is shallow and the VFS is not submerged. Vegetative filter strips should therefore not be cost-shared on fields with significant concentrated flow across the proposed VFS areas. The suitability of a site for VFS cost-sharing funds should be determined by an on-site inspection of the site by an SCS, SWCDs or other designated conservation official who has been trained in VFS site selection and evaluation before VFS are installed. On-site visits are not currently required to assess site suitability.

2. Vegetative filter strips should be located only within areas characterized by shallow sheet flow which are upslope of natural or man-made channels. Current state VFS regulations require that VFS be located within 100 feet of natural or man-made waterways. This restriction should be relaxed to "within 500 feet of a natural or man-made waterway unless a natural VFS characterized by shallow sheet flow exists between the proposed VFS site and the drainageways." This change should allow the placement of VFS in areas which are more appropriate for their use and should improve their effectiveness.

3. Vegetative filter strips should not be installed in areas higher than the fields they are intended to protect.

4. Large fields with significant natural drainageways or grassed waterways are acceptable for VFS only if the VFS are installed on both sides of internal field drainageways. This will allow pollutants to be trapped before they can enter the drainageways.

5. Vegetative filter strips are inappropriate for fields in continuous forage or pasture because the field is already protected from excessive sediment and nutrient loss.

B. Vegetative Filter Strip Establishment

1. The type(s) of vegetation and seeding rates used in VFS should be appropriate for local soil and climatic conditions and approved for use in the designated area. Grasses and legumes or combinations thereof are the most effective for erosion control and water quality improvement because of their dense growth, resistance to overland flow and filtering ability. Shrub and wildlife strips should not be permitted because they are relatively ineffective for water quality improvement when compared to grass and legume VFS.

2. Trees, stumps, brush and similar materials should be removed from the proposed filter strip to avoid interference with proper VFS operation and maintenance.

3. The VFS area should be limed and fertilized according to soil test recommendations with subsequent incorporation into the top 3 to 6 inches of soil as part of seedbed preparation.

4. Vegetation should be planted during optimum seeding times with cyclone seeders, hydroseeders, drill or cultipacker seeders on firm, moist seedbeds. If site conditions are unfavorable at planting, mulch material should be applied immediately after seeding. Mulching is recommended to minimize rill development during VFS establishment.

5. Some sites may require limited grading to correct slope problems within the strip such as gullies or high areas within or immediately downslope of the filter. This is not economically feasible for sites with severe topographic limitations.

6. At sites where there may be significant flow along or parallel to the filter, shallow berms or terraces may need to be constructed perpendicular to the filter at 50-foot to 100-foot intervals to intercept runoff and force it to flow through the VFS before it can concentrate further.

7. Vegetative filter strips should be a minimum of 20 feet in width at the time of establishment. In steeper areas with poorly drained soils, minimum VFS width should be determined with design equations or according to approved local specifications.

C. Maintenance Practices

1. Vegetative filter strips should be mowed and the residue harvested a minimum of 2 to 3 times per year to promote a thick vegetation with optimum pollutant-removal capabilities.

2. Vegetative filter strips should be limed and fertilized annually along with the rest of the field according to soil test recommendations.

3. Caution should be used when applying herbicides to VFS or adjacent fields for weed control. If herbicides are applied to fields, sprayers should be turned off before crossing VFS or using them for turn rows.

4. Vegetative filter strips should not be used for roadways because roadways change flow patterns which can lead to concentrated flow problems. If a VFS must be used for a roadway then the VFS should be 8 to 10 feet wider than normal and the roadway should be located on the downslope side of the filter so that field runoff will be filtered before it can concentrate in the disturbed roadway area.

5. Cattle should be excluded from VFS at all times but especially during periods when soils are moist and VFS are most susceptible to damage from hooves.

6. VFS should be inspected for stand establishment after planting and if stand is inadequate, the area should be re-fertilized and overseeded.

7. Vegetative filter strips should be inspected regularly for damage caused by tillage operations, misapplication of herbicides, gully erosion, sediment inundation, etc and repaired as soon as possible.

8. Vegetative filter strips that have accumulated sufficient sediment so that they are higher than adjacent fields should be plowed out, disked and graded if necessary before reseeding. This is necessary to re-establish flow conditions favorable for optimum VFS performance.

9. Care must be taken during all tillage operations to avoid tilling into the VFS and reducing its effective width. If moldboard plowing is practiced, the last plow pass should turn soil towards the filter and the disturbed area next to the filter should be carefully disked to minimize gully formation and other flow problems.

D. Cost-Share Eligibility

1. Vegetative filter strips should be inspected by a conservation official after establishment before approving payment of cost-share funds and once a year thereafter to insure that the filter strip meets the minimum state standards. The official should notify the operator if the VFS does not meet state standards and allow him a reasonable amount of time to correct deficiencies. All cost-share funds should be withheld or returned if the deficiencies are not corrected.

2. Vegetative filter strips which are less than 75% of their original width or less than 15 feet in width one or more years after establishment should be removed from the cost-share program.

II. RECOMMENDATIONS FOR FUTURE RESEARCH

1. Reliable VFS design procedures must be developed if VFS are to be used cost-effectively. Deterministic or process-oriented models are desirable because of the varied site conditions and types of vegetation which must be considered.

2. Research needs to be conducted on the long-term fate of accumulating nutrients in VFS. If VFS only trap nutrients for the first few years and then release them during extreme runoff events, they may not be as effective as currently assumed. This is probably not a problem in VFS where vegetation is harvested regularly.

3. The effects of sediment inundation on the growth and health of different types of VFS vegetation should be investigated to identify types of vegetation which recover quickly after inundation.

4. Better methods need to be developed to rapidly estimate flow regimes within fields to assess the suitability of prospective fields for VFS.

SUMMARY AND CONCLUSIONS

A study was conducted to evaluate the long-term effectiveness and operational problems associated with vegetative filter strips. Filter strips were observed on 33 farms in the Chesapeake Bay and Chowan River Basins. Most of the VFS were visited five times at 3-month intervals between March 1985 and April 1986. Twelve sites were visited only once because the VFS no longer existed or because they were so poor that they were not worth observing.

The most significant factor affecting VFS performance was the flow regime of runoff. For runoff flowing shallowly and uniformly distributed across the VFS, the strips were highly effective for sediment removal and presumably moderately effective for nutrient removal. Under concentrated flow conditions, however, deeper flows tended to inundate the VFS, bending the vegetation over and greatly reducing VFS effectiveness. It was estimated from the fields observed that 60% of the runoff concentrated in natural and man-made drainageways within the fields before reaching the VFS at the edges of the fields. The water concentrated in the drainageways, then flowed across the VFS at a few narrow points and only minor pollutant reduction was achieved.

Since it is difficult to economically change flow patterns in fields to improve VFS performance, it is suggested that cost-shared VFS be limited to topographic situations for which they are suited, namely, fields with fairly uniform slopes and poorly developed drainage patterns.

Overall, the observed VFS had adequate cover but many had weed problems which reduced grass thickness and cover. Mowing for weed control and to promote thicker grass growth is highly recommended (2 to 3 mowings per year). Wildlife habitat filter strips were judged to be totally ineffective as filter strips. They may provide valuable food and habitat for wildlife, but cover and vegetative conditions at ground level are too sparce for effective filtering or flow retardance.

Because the factors controlling VFS effectiveness are highly site specific, it is recommended that a conservation professional with a knowledge of VFS and hydrology visit each field before it is approved for VFS cost-sharing to determine if the site is acceptable. Sites in which more than 40% to 50% of the runoff crosses the VFS as concentrated flow should probably be excluded. Other BMPs, such as reduced tillage, would be much more effective for these fields unless the VFS extend up into the field and filter the runoff before it concentrates in the natural drainageways.

Owners of VFS which do not meet minimum state standards after establishment and in subsequent years of the cost-sharing program, should not receive cost-share funds unless all deficiencies are corrected.

Overall, the VFS program has been beneficial. Even in areas where the VFS were ineffective for filtering sediment and nutrients from runoff, they have provided localized erosion protection in border areas and along streambanks where erosion is often most critical. Farmers interviewed were all positive about their VFS and believed them effective for water quality improvement. Almost all the farmers interviewed indicated that they would continue to maintain their existing VFS after cost-sharing ended, but most said they would not install new VFS without cost-sharing. It is hoped that this attitude will change and more farmers will accept their responsibilities as stewards of our most valuable natural resources — our air, land, and water.

FIGURES

FIGURE 1
Vegetative Filter Strip Evaluation Form

VFS code: __________ Date: __________ Evaluated by: ____________________

District: ____________________ County: ____________________

Participant's name: ____

Field number(s): ____________________ Adjacent stream: ____________________

Length certified for payment (ft): ________________________________

Average width (ft): ________ Minimum: ________ Maximum: ____________

Estimated age (yrs): ________________ Distance to stream: ________________

Cover condition: Excellent Good Fair Poor No visible VFS
(circle appropriate response and describe below)

____

Type of Vegetation: ____

Is VFS damaged or in need of maintenance? ____________ (describe) __________

____

Land use, crops, etc., above VFS: ________________________________

____

Slope of field above VFS, % ____________ Slope across VFS, % ____________

Estimated percentage of field drainage entering VFS as concentrated flow,

%: ________________ Describe field drainage system: ________________

____

Elevation of VFS with respect to field: ________________________________

____

Owner's attitude concerning VFS (good, bad?): ____________________________

____

Owner's opinion of effectiveness of VFS for water quality improvement:

____

Would owner install VFS without cost sharing? ____________________________

FIGURE 2
Filter Strip Owner's Survey

1. What are the primary reasons that you installed filter strips?

____

2. Estimated age of your filter strips: ____________________

3. Did you have any filter strips before the cost-sharing programs were initiated?

____

4. What types of vegetation are in your filter strips? ____________________

____

5. Would you recommend other vegetation or different planting practices? ______
If so, what? ____________________

____

6. How wide are your filter strips? ____________________

7. How wide do you think they should be? ____________________

____

8. What land use do you have above your filter strips (cropland, pasture, etc.)?

____

9. How do you think filter strips can best be maintained to ensure their long-term effectiveness ____________________

10. Have you noticed any problems with your filter strips? ____________________
If yes, describe problems. ____________________

____

What practices could you recommend to overcome any problems you mentioned above? ____________________

11. Do you think your filter strips are effective for erosion control? ____________

12. Do you think your filter strips are effective for water quality improvement (removing sediment and fertilizer from runoff)? ____________________

13. Will you continue to use and/or maintain your filter strips when cost-sharing expires? ____________________

14. Will you install new filter strips without cost-sharing? ____________________

15. How did you learn about the state filter strip program? ______________________

____

16. What do your neighbors think of your filter strips? ______________________

____

17. Do you have additional comments concerning the filter strip cost-sharing program, recommendations for future programs or recommendations to improve filter strip performance?

____

If additional space is needed for any responses, please use the space below:

TABLES

TABLE 1
Minimum Seeding Specifications

Non-Wildlife Option[1]	Seeding Rate (lbs/acre)
a. Tall Fescue	20
Ladino Clover	1
Korean Lespedeza	10
Red Clover	2
or	
b. Orchardgrass	15
Ladino Clover	1
Korean Lespedeza	10
Red Clover	2
or	
c. Reed Canarygrass	20
Alsike Clover	6
(for poorly drained areas	
or	
d. Weeping Lovegrass	3 PLS*
Sericea Lespedeza	30
(primarily for warm season planting between 4/1 and 8/15)	

Wildlife Option[2]

Persons wishing to enhance wildlife habitat can plant the above Orchardgrass or Weeping Lovegrass mixture or the following:

a. Switchgrass	8 PLS* (broadcast)
or	
	5 PLS* (No-Till)
Korean Lespedeza	10
Ladino Clover	2
or	
b. Atlantic Coastal Panicgrass	20 PLS*
Sericea Lespedeza	10

[1] for plantings between 4/15 and 8/1, add 10 lbs/acre of Foxtail Millet.

[2] For wildlife options mow only every three or four years or mow only one-third of the filter strip each year. All mowing should be completed before April 15 and/or after September 1.

* PLS — Pure Live Seed

TABLE 2
Vegetative Filter Strips Surveyed

SWCD	No. of VFS Surveyed	Total VFS Length, ft
Culpeper	9	37,455
Northern Neck	9	60,421
Peanut	8	23,980
James River	2	6,000
J.R. Horsley	5	14,572
Total	33	142,428

BIBLIOGRAPHY

Barfield, B. J., E. W. Tollner and J. C. Hayes. 1977. "Prediction of Sediment Transport in Grassed Media." ASAE Paper No. 77-2023. ASAE, St. Joseph, MI.

Barfield, B. J., E. W. Tollner and J. C. Hayes. 1979. "Filtration of Sediment by Simulated Vegetation, I. Steady-State Flow with Homogeneous Sediment." *TRANSACTIONS of the ASAE,* 22 (3): 540-545, 548.

Bingham, S. C., M. R. Overcash, and P. W. Westerman, 1978. "Effectiveness of Grass Buffer Zones in Eliminating Pollutants in Runoff from Waste Application Sites." ASAE Paper No. 78-2571. ASAE, St. Joseph, MI.

Dillaha, T. A., J. H. Sherrard, D. Lee, V. O. Shanholtz, S. Mostaghimi, and W. L. Magette, 1986a. *Use of Vegetative Filter Strips to Minimize Sediment and Phosphorus Loss from Feedlots, Phase I, Experimental Plot Studies.* VWRRC Research Bulletin 151, Virginia Water Resources Research Center, Virginia Polytechnic Institute & State University, Blacksburg.

Dillaha, T. A., R. B. Reneau, S. Mostaghimi, V. O. Shanholtz, and W. L. Magette, 1986b. *Evaluating Nutrient and Sediment Losses from Agricultural Lands: Vegetative Filter Strips.* U. S. Environmental Protection Agency, Washington, D.C. (in press).

Doyle, R. C., G. C. Stanton and D. C. Wolf. 1977. "Effectiveness of Forest and Grass Buffer Filters in Improving the Water Quality of Manure Polluted Runoff." ASAE Paper No. 77-2501. ASAE, St. Joseph, MI.

Edwards, W. M., L. B. Owens, and R. K. White. 1983. "Managing Runoff from a Small, Paved Beef Feedlot." *J. Environ. Qual.* 12: 281-286.

Hayes, J. C., B. J. Barfield, and R. I. Barnhisel. 1979. "Filtration of Sediment by Simulated Vegetation II. Unsteady Flow with Non-homogeneous Sediment." *TRANSACTIONS of the ASAE,* 22 (5), 1063-1067.

Hayes, J. C., B. J. Barfield, and R. I. Barnhisel. 1979. "Performance of Grass Filters under Laboratory and Field Conditions." ASAE Paper No. 79-2530. ASAE, St. Joseph, MI.

Hayes, J. C. and J. E. Hairston. 1983. "Modeling the Long-term Effectiveness of Vegetative Filters on On-site Sediment Controls." ASAE Paper No. 83-2081. ASAE, St. Joseph, MI.

Kao, T. Y., B. J. Barfield, and R. I. Barnhisel, 1975. "On-site Sediment Filtration Using Grass Strips." In *Proceedings 1975 National Sumposium on Urban Hydrology and Erosion Control,* University of Kentucky, Lexington, 73-82.

Kao, T. Y. and B. J. Barfield. 1978. "Predictions of Flow Hydraulics of Vegetated Channels." *TRANSACTIONS of the ASAE,* 21 (3): 489-494.

Neibling, W. H. and E. E. Alberts. 1979. "Composition and Yield of Soil Particles Transported through Sod Strips." ASAE Paper No. 79-2065. ASAE, St. Joseph, MI.

Norman, D. A., W. M. Edwards and L. B. Owens. 1978. "Design Criteria for Grass Filter Areas." ASAE Paper No. 78-2573. ASAE, St. Joseph, MI.

Paterson, J. J., J. H. Jones, F. J. Olsen, G. C. McCoy, 1977. "Dairy Waste Distribution in an Overland Flow Vegetative-Soil Filter System." ASAE Paper No. 77-4582. ASAE, St. Joseph, MI.

Thompson, D. B., T. L. Loudon, and J. B. Gerrish, 1978. "Winter and Spring Runoff from Manure Application Plots." ASAE Paper No. 78-2032. ASAE, St. Joseph, MI.

Tollner, E. W., B. J. Barfield, C. T. Haan and T. Y. Kao. 1976. "Suspended Sediment Filtration Capacity of Simulated Vegetation." *TRANSACTIONS of the ASAE,* 20 (4): 940-944.

Tollner, E. W., J. C. Hayes, and B. J. Barfield. 1978. *The Use of Grass Filters for Sediment Control in Strip Mine Drainage, Vol. 1. Theoretical Studies on Artificial Media.* IMMR 35-RRR2-78, Institute for Mining and Minerals Research, University of Kentucky, Lexington.

Tollner, E. W., B. J. Barfield, and J. C. Hayes. 1982. "Sedimentology of Erect Vegetal Filters." *Proceedings of the Hydraulics Division,* ASCE, Vol. 108, HY 12, 1518-1531.

U. S. Environmental Protection Agency, 1983. *Chesapeake Bay: A Framework for Action.* U. S. Environmental Protection Agency, Chesapeake Bay Program, Annapolis.

VDSWC, 1983. *Grass Filter Strips in Virginia.* Virginia Division of Soil and Water Conservation, Richmond.

VDSWC, 1984. *Dollars for Soil and Water Conservation Practices.* Virginia Division of Soil and Water Conservation, Richmond.

VDSWC, 1984. *The 1983 Virginia Grass Filter Strip Incentive Program Evaluation Report.* Virginia Soil and Water Conservation Commission, Richmond.

VDSWC, 1985, 1986. *Grass Filter Strips — VDSWC Specification No. WQ-1.* Virginia Soil and Water Conservation Commission, Richmond.

VSWCB, 1979. *Best Management Practices Handbook: Agriculture.* VSWCB Planning Bulletin 316. Virginia State Water Control Board, Richmond.

Wilson, L. G. 1967. "Sediment Removal from Flood Water by Grass Filtration." *TRANSACTIONS of the ASAE,* 19 (1): 35-37.

Young, R. A., T. Huntrods, and W. Anderson. 1980. "Effectiveness of Vegetative Buffer Strips in Controlling Pollution from Feedlot Runoff." *J. Environ. Qual.* 9: 483-487.

Young, R. A., M. A. Otterby, and A. Roos. 1982. *An Evaluation System to Rate Feedlot Pollution Potential.* ARM-NC-17, USDA-ARS, Washington, D.C.

The Virginia Water Resources Research Center is a federal-state partnership agency attempting to find solutions to the state's water resources problems through careful research and analysis. Established at Virginia Polytechnic Institute and State University under provisions of the Water Research and Development Act of 1978 (P.L. 95-467), the Center serves six primary functions.

- It studies the state's water and related land-use problems, including their ecological, political, economic, institutional, legal and social implications.
- It sponsors, coordinates, and administers research investigations of these problems.
- It collects and disseminates information about water resources and water resources research.
- It provides training opportunities in research for future water scientists enrolled at the state's colleges and universities.
- It provides other public services to the state in a wide variety of forms.
- It facilitates coordinated actions among universities, state agencies, and other institutions.

More information on programs and activities may be obtained by writing or telephoning the Water Center.

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