The Role and Function of Forest Buffers in the Chesapeake Bay Basin for Nonpoint Source Management

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FOREWORD

The Forestry Work Group has recognized the enormous value of streamside forests in providing quality aquatic habitat, a measure of water quality, and in enhancement of other living resources of the Bay. We equally acknowledge the important role that forest buffers play in planning for and achieving greater control over nonpoint source pollutants reaching the Chesapeake Bay and its many tributary rivers and streams. With this in mind, a discussion of riparian forest buffers is timely.

This position paper provides useful information for consideration in current planning efforts. The recommendations offer a focus for discussion of remaining issues related to use of forest buffers and a guide for further work and study.

INTRODUCTION

When colonists first arrived in the Chesapeake Bay they found vast forests covering over 95% of the watershed. As the natural ecosystem, these forests provided a biological and physical system which yielded high quality waters and a productive Chesapeake Bay. Unfortunately much of the historic forest, especially along streamsides, has been lost or altered by human activities. Farmers found streamside soils to be highly fertile and many were cleared for agriculture. Uncontrolled access to streams and rivers by livestock also destroyed riparian forests. And increasingly, urban and suburban development is contributing to the permanent loss of forests. Although today's forests have been reduced to less than 60% of their original extent, they are just as important in maintaining the purity of water and quality of life in the Chesapeake Bay watershed as they were in the 1600's.

THE ROLE OF FOREST BUFFERS

The problems of the Chesapeake Bay are largely the result of non-point source (NPS) pollutants. It is unquestionable that the conversion of forests to other land uses throughout the watershed and particularly adjacent to streams and rivers, has adversely affected the vitality of our water resources. Now, there is an increasing recognition of the role that forests can play to help reduce pollution when combined with other management practices. Research results from a variety of sources have documented the effectiveness of the riparian forest in reducing NPS loading from runoff and groundwater. Most of this research has been done in agricultural watersheds or in connection with silvicultural activities. Forests have many uses within systems of best management practices (BMP's) in agriculture, silviculture, land use planning, and stormwater management. Most attention is now, however, focussed on the use of riparian forest buffer strips as a management practice. However, forest buffers are difficult to address in the same context as other common best management practices. Forest buffers are also recognized for their high value in wildlife and fish habitat and maintaining ecosystem integrity. This paper primarily discusses elements of the relationship between forests and water quality in the context of the forest buffer.

Definitions

A Riparian Ecosystem is a complex assemblage of plants and other organisms in an environment adjacent to and near flowing water. Without definitive boundaries, it may include streambanks, floodplains, and wetlands as well as sub-irrigated sites forming a transitional zone between upland and aquatic. Mainly linear in shape and extent, they are characterized by laterally flowing water that rises and falls at least once within a growing season (Lowrance, Leonard and Sheridan, 1985).

A Forest Buffer is an area of trees, shrubs, and other vegetation designed to intercept surface runoff, wastewater, subsurface flow and deeper groundwater flows from upland sources for the purpose of removing or buffering the effects of associated nutrients, sediment, organic matter, pesticides, or other pollutants prior to entry into surface waters and groundwater recharge areas. Forest buffers can also be designed to accomplish specific objectives for terrestrial and aquatic habitat (Welsch, 1991).

Components of a Forest Buffer

All forest buffers are not created equal. A forest buffer has three basic components whose characteristics determine its effectiveness in terms of NPS pollution control: soil structure and composition, the extent of surface litter/organic layer, and the species, diversity, and age of forest vegetation.

1. <u>Soil Structure</u>. Forest soils are generally regarded as highly effective in nutrient removal however their degree of efficiency can be variable. The ability of a forest soil to function in removing nutrients in surface and groundwater is partially dependent upon its depth and position in the landscape, relationship to geologic structure, permeability, presence of subsurface clay and gravel layers, extent and duration of shallow water table, and function as a groundwater discharge zone (Pionke and Lowrance, 1991).

2. <u>Organic Litter Layer</u>. The organic litter layer in a forest buffer provides a physical barrier to sediments, maintains surface porosity and high infiltration rates, increases populations of soil mycorrhizae, and provides a rich source of carbon essential for denitrification. The organic soil provides a reservoir for storage of nutrients to be later converted to woody biomass. A mature forest can absorb as much as 14 times more water than an equivalent area of grass (NCASI, 1992). The absorptive ability of the forest floor develops over time. Trees release stored moisture to the atmosphere through transpiration while soluble nutrients are used for growth.

3. <u>Vegetation</u>. Trees have several advantages over other vegetation in improving water quality. Trees aggressively convert nutrients into biomass. They are not easily smothered by sediment deposition or inundation during periods of high water level. Their deep spreading root systems resist erosion, stimulate biological and chemical soil processes, and draw water and nutrients from deep within the soil profile. Trees produce high amounts of carbon needed as an energy source for bacteria involved in the denitrification process. All species do not perform equally, but hardwoods are generally considered essential to maximum efficiency. Perkey (1990) summarized the effectiveness of tree species in biological uptake of nutrients. A forests' effectiveness in NPS pollution control will vary with the age, structural attributes and species diversity of its trees, shrubs and understory vegetation.

PHYSICAL AND BIOLOGICAL FUNCTIONS

<u>Sediment Filtering</u>. The forest floor is composed of decaying leaves, twigs and branches forming highly permeable layers of organic material. Large pore spaces in these layers catch, absorb, and store large volumes of water. With buffers of adequate size, 50% to 100% of sediment and its adsorbed nutrients has been shown to settle out in the streamside forest as the speed of runoff is reduced by the many obstructions encountered. Suspended sediment is further removed as runoff and sediments are readily incorporated into the forest floor. With a well developed litter layer, infiltration capacities of forest soils generally exceed rainfall and can absorb overland flows from adjacent lands. Grass stands may have only 1/10th this capacity and may actually be smothered by sediment deposition (Cooper, et al., 1987).

Nitrogen and Phosphorus Removal. Forest ecosystems and forest buffers function similar to wetlands by serving as filters, sinks, and transformers of suspended and dissolved nutrients (Richardson, 1989). The forest ecosystem retains or removes nutrients by rapid incorporation and long term storage in biomass, improvement of soil nutrient holding capacity by adding organic matter to the soil, reduction in leaching of dissolved nutrients in subsurface flow from uplands by evapotranspiration, bacterial denitrification in soils and groundwater, and protection of the soil during heavy rains and runoff events.

Studies of forest buffer performance by Peterjohn and Correll (1984) on the coastal plain of Maryland showed reductions of up to 88% of nitrate and 76% of phosphorus after agricultural runoff passed through a forest buffer. On the coastal plains of Georgia, Lowrance and others (1984) credited riparian forests with removing 80-90% of nitrate, 50% of phosphorus and 99% of sediments generated from adjacent agricultural fields. Cooper, Gilliam and others (1985,1987) studied the role of riparian forests in sediment and nutrient reduction on the middle coastal plain of North Carolina and found reductions of as much as 93% of nitrate and 50% of phosphorus over a 20 year period. Each of these studies was conducted using a water balance approach incorporating surface and groundwater components.

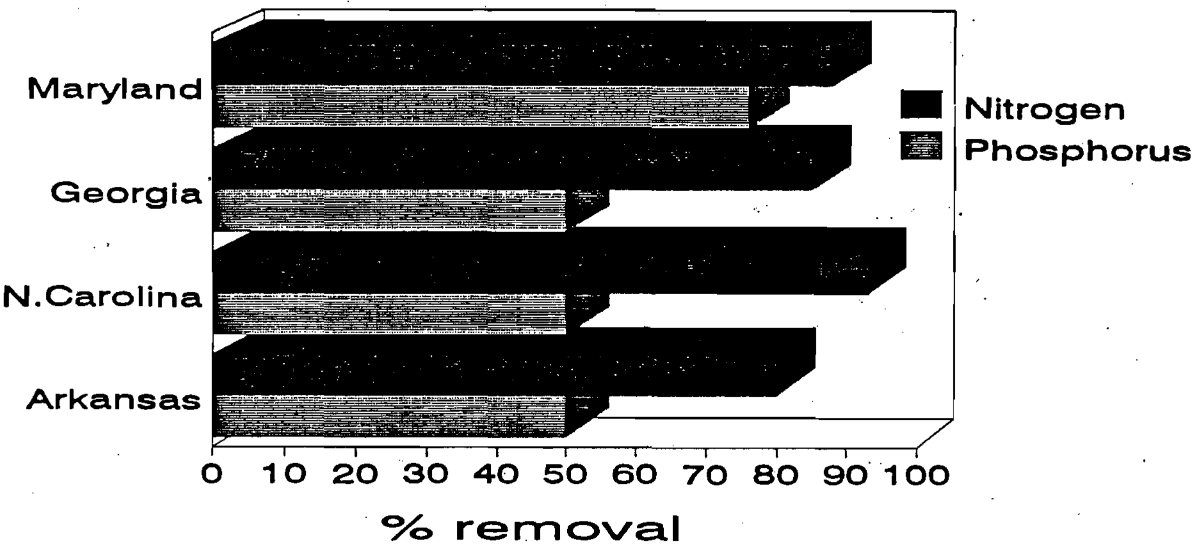

Figure 1. Summary of studies in various states regarding nutrient removal efficiency of riparian forests.

Additional studies conducted in Indiana (Karr and Gorman, 1975), by the Corps of Engineers on the Cache River in Arkansas, and in France (Piney, et.al., 1988) support these findings. In general, a third or more of nitrogen was accumulated in woody biomass while denitrification and other processes accounted for the remainder of the reduction. Phosphorus was removed with the particulate matter. No studies directly represented urban runoff situations, although potential exists for nutrient removal in developed settings. The above figures reflect the nutrient removal potential of riparian forests primarily based in the coastal plain. Preliminary results from research studies currently in progress in the piedmont and hill/valley terrain characteristic of uplands in the Bay watershed generally support these findings.

Stream Channel Stability. Streams and rivers are highly dynamic systems that are prone to change even without human interference. In-channel stream stability and streambank erosion at a given point are heavily influenced by the land use and condition in the upstream watershed (Heede, 1980). However, vegetation is essential for stabilizing stream banks, especially woody vegetation (Karr, J. R. and I. J. Schlosser, 1978). Forest buffers alone can rarely be expected to control existing stream erosion problems but forests have an indirect effect on streambank stability by providing deep root systems which hold the soil in place more effectively than grasses and by providing a degree of roughness capable of slowing runoff velocities and spreading flows during large storm events. Karr and Gorman (1975) explained, that while slowing velocities of flood heights may increase headwater flood height, downstream flood crest and flood damage is dramatically reduced. These processes are also critical for building floodplain soils.

Shade and Temperature. The shade provided by a riparian forest buffer moderates stream temperatures and levels of dissolved oxygen. These factors are critical for fisheries and submerged aquatic vegetation, but also have water quality implications. Temperature increases the rate at which nutrients attached to suspended solids are converted to readily available (soluble) forms. As stream temperature increases above 60° F significant increases in phosphorus release from sediments occurs (Karr and Schlosser, 1978). In this way, the loss of forest shade may exaggerate nonpoint pollutant effects by reducing the streams ability to assimilate organic wastes and inducing algae blooms and low oxygen levels.

Habitat. A great variety of habitats are found in structurally diverse riparian woodlands. In many cases, their value to wildlife and fish alone may be substantial enough to justify forest buffers. Forested corridors function as connectors between isolated blocks of habitat and provide shelter for insects beneficial to control of agricultural pests. Fallen and submerged logs and the root systems of woody vegetation provide cover for fish and invertebrates while forest detritus is the basis of the food web for the stream. Energy cycles in the aquatic system are often critically dependent on interaction with streamside woody vegetation. As such, fish and habitat are important indicators of good water quality. In many agricultural and urbanized areas, even narrow forest buffers can be essential to the survival for many important species. Human habitat is also important. Forest buffers in urban areas provide a unique linkage between people and their environment. Forests can enhance quality of life and increase community involvement and activism by planting and caring for urban forests.

THE PRACTICAL USE OF FOREST BUFFERS

Forest buffers present an emerging challenge. Opportunities exist for preserving, enhancing and restoring riparian forest ecosystems. Improved land use planning can preserve forest buffers and greenbelts during development and land clearing. Narrow or intermittent forest buffers along streams and rivers can be expanded and connected through planting and better management. Thousands of miles of riparian forest, now lost, can be restored. Restoring forests along our streams and rivers, however, will not be an easy task. Compatibility with historic farm and pasture management, potential loss of cropland, small farm sizes, long term protection of buffers, and social acceptance may be difficult barriers to overcome in parts of the farming community. Stormwater engineering needs, high land values, and vandalism or other physical damage in urban areas can make urban reforestation challenging.

Agricultural Lands. Cropping practices, fertilization, pesticide application, field drainage and livestock grazing and confinement all have the potential to seriously degrade water quality. Forest buffers can be used as a linear break in the pattern of row crops and pastures to manage sediment, wind and runoff problems. Riparian forests form a buffer between agricultural uses and streams and can control nonpoint source pollution while producing numerous additional benefits. In some situations, non-riparian forests safely removed from areas of high water table can be used for disposal of manure or in treatment of leach field effluent. When properly protected from livestock use, forests can help protect streambanks. Forests and forest buffers are used in conjunction with other nutrient and erosion control practices. For example, a best management system for a farm may combine conservation tillage, fencing, grass waterways, forest buffers, and a nutrient management plan.

Urban and Suburban Development. Forests should be retained as greenbelts along streams and drainageways during development. Forests and forested wetlands can also be used as part of treatment systems for urban runoff, where design requirements can be met. Forests can be used as infiltration zones. Urban forest buffers filter runoff, air pollutants, and noise. Forests cool the air and provide corridors for movement of birds and other wildlife. In urban areas, these buffers may provide the only available habitat for many organisms.

Silvicultural Activities. Much like their use on agricultural lands, forest buffers are used during timber harvest operations to prevent sediment from logging roads, skid trails, and site preparation activities from reaching streams and rivers.

Specifications for Establishment. The USDA Forest Service and Soil Conservation Service jointly established guidelines and practice specifications for use in establishing forest buffers (Welsch, 1991). Although implementation is flexible, these specifications discuss components and uses of the forest buffer that should be taken into consideration by field consultants and landowners prior to buffer establishment. Location, width, placement, fencing option, management objectives (such as water quality improvements, wildlife habitat, wood products, recreation, etc.), species selection and more will be taken into consideration during forest buffer design. The SCS NE Regional Technical Center has issued interim standards and specifications on forest buffers for states in the northeast region.

MANAGEMENT OF FOREST BUFFERS

Although maintenance-free for most of their existence, forest buffers may be designed and managed to accomplish many different resource objectives. Once established, management options for the riparian forest ecosystem range from strict preservation to the complete removal of streamside trees. However, neither of these extremes represents the optimum management of these areas to enhance water quality. With proper management, riparian forest buffers can be more productive and provide better NPS pollution control (Lowrance, 1985). Studies have shown that both old growth and young growth forests alone have less potential to remove nutrients than a vigorous forest of mixed ages. Hardwood species must be predominent enough to perpetuate developed organic litter layers. Wildlife habitat concerns, such as those for old growth trees, must be integrated with water quality needs.

A challenge exists for forestry professionals. Current silvicultural systems for evenage or unevenaged management are designed primarily to provide a sustained yield of wood products. Systems which focus on a variety of landowner desires while protecting riparian values are more appropriate. Pionke and Lowrance (1991), have recommended that unevenaged silvicultural systems should be employed in forest buffers to maximize water quality benefits. However, trees should be periodically harvested to sustain this growth and diversity and remove nutrients sequestered in tree stems and branches. In this way, forests can benefit both the landowner and the environment (Welsch, 1991).

NEEDED RESEARCH

A general conclusion can be made that forested riparian buffer strips are effective in reducing nutrient, temperature and sediment levels in runoff and that riparian ecosystems can exert major control on NO_3-N concentrations in riparian zone groundwater, especially when subjected to shallow water tables (Pinoke and Lowrance, 1991). However, it is generally accepted that nitrate removal efficiency varies in different geographic provinces. Research should continue to document forest buffer effectiveness in mountain, hill and valley, piedmont and coastal plains and to compare performance of various forest types, and with other practices such as grass filters. In each case additional quantification of expected performance is needed.

The age and degree of development of the forest buffer and its attendant litter layer is also likely to have an effect on buffer efficiency. This comparison is important in relating forest buffers to grass filters over time. Although grass filters in the riparian zones contain less organic matter in their surface soils, no data is currently available to determine the levels necessary for optimal denitrification. The role of organic carbon in this process needs further study.

Studies of the minimum width of riparian forest necessary to achieve effective nutrient reductions has not been done. In addition, management prescriptions for forest buffers to improve their nutrient removal effectiveness over the long term need additional study and development. Information is also needed on species mix and nutrient uptake and the time necessary to establish a functioning forest buffer.

SUMMARY AND CONCLUSIONS

Streams and rivers are the focal point of increasing public interest. Their quality affects most residents of the Bay watershed. Riparian forests play a significant and demonstrable role in protecting and improving these ecosystems' quality. The restoration of a healthy aquatic ecosystem from the tributary streams to the Chesapeake Bay will require the reestablishment of significant amounts of riparian forest. It will also require the enhancement and repair of many existing forest buffers. Although additional research and study is necessary to better quantify the effectiveness of forest buffers in a variety of field conditions, and provide a comparison with other vegetation types, sufficient studies currently exist to document the value of this practice in nonpoint source control.