WHITE PAPER

ALLIANCE for the CHESAPEAKE BAY

White papers are published by the Alliance's Public Policy Program and are intended to provide objective, up-to-date information about policy issues affecting Chesapeake Bay.

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Riparian Forest Buffers

Prologue:

A Watershed Dependent on Trees

Since the glaciers withdrew from Pennsylvania about 10,000 years ago, forests have dominated the land which today makes up the 64,000-square-mile Chesapeake Bay drainage basin. Prior to the Colonial era, it has been said, the forest blanket was so complete that a squirrel could have traveled from the Atlantic Coast to the Mississippi River without touching the ground. That may not be much of an overstatement, though forest fires and Native Americans certainly cleared openings in that blanket from time to time.

As the dominant vegetation, trees exerted important environmental controls over the flow of water and nutrients from the headwaters of the region's rivers to the Chesapeake Bay. A complex food web evolved, intimately connected to the forest. Leaves and twigs that fell into the streams provided food for algae species that thrived in the shaded waterways. Many insects, in turn, became adapted to feeding on those types of algae. The forest canopy moderated temperatures, allowing many sensitive species, such as trout, to survive. But in a relatively short time after colonial settlement, massive forest clearing would dramatically change the conditions to which many living things had adapted over thousands of years.

Introduction:

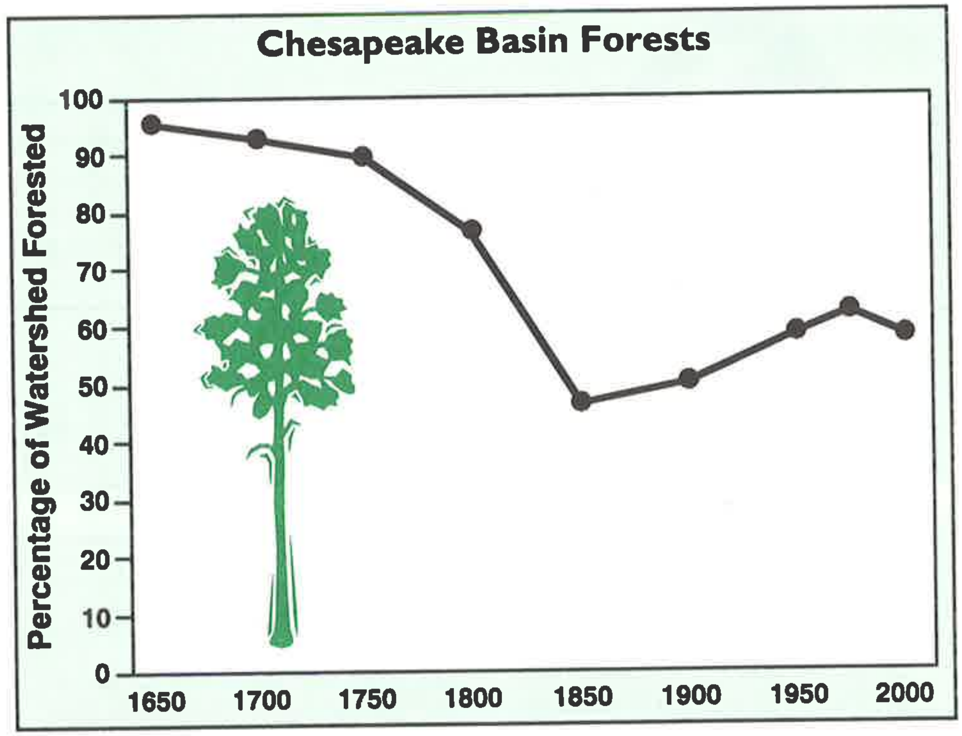
Four Centuries of Landscape Change

In the early 1600s, William Strachey, secretary of the Jamestown colony, observed, "the land we see around us is overgrown with trees and woods, being a plain wilderness, as God first ordained it." It is no wonder that the region seemed so strange to Europeans who had cleared most of their large forests centuries before. Also, Europe had only about 25 prominent tree species, while the New World had more than 500.

Lumber quickly became one of the first exports from the colony; the first ship returning to England carried a cargo of oak and cedar. Soon, the colony became an important supplier of ship masts and hardwood lumber. Land was quickly cleared for farming, settlements and fuel.

The rate of land clearing increased rapidly through the 1800s as demand for wood — primarily as fuel for industry — grew. By the early 1900s, only about 30-40 percent of the watershed was still covered by forest. After the early part of the century, forests gradually reclaimed some land, particularly as previously harvested areas regrew and farmland was allowed to return to forest. By the late 1970s, forest land made up 60 percent of the Chesapeake Bay watershed. Since then, the amount has declined, largely because of development and suburban sprawl.

As a result, today's forests are not evenly distributed in the watershed. Much of the remaining forest land is far inland, covering the mountains of Pennsylvania, Maryland and Virginia. By contrast, most of the forests have vanished in agricultural areas and rapidly developing urban centers nearest the Bay, where deforestation in some counties approaches 80 percent.



For the Chesapeake Bay, that change has major ramifications. Acre for acre, forests contribute less sediment and nutrient runoff pollution than any other land use; its ability to filter water is comparable to wetlands. The loss of forests is therefore correlated with declining water quality in both the Bay and the rivers and streams that supply it with fresh water. In recent years, studies have suggested that streamside forests can serve as highly effective filters that control both surface runoff and — in many landscapes — groundwater flow into streams. In addition, they provide shade, temperature control and food required by many aquatic species.

Streamside forests, as a result, are being viewed as a way to partially mitigate the loss of forests over much of the remaining landscape. This recognition has come after many streamside forests were cleared for other uses. The Chesapeake Basin has roughly 100,000 miles of rivers and streams, but it has been estimated that as much as 50 percent of the streamside forests have been removed or severely impaired.

Bay Restoration Goals

Responding to widespread concern that the Bay's water quality was dramatically worsening, the Environmental Protection Agency financed a seven-year study of the estuary which concluded, in 1983, that excess nutrients were a key problem in the Bay. That same year, the Chesapeake Bay Program was created as a cooperative, consensus-based effort to restore the nation's largest estuary. Policy is set by the Chesapeake Executive Council, consisting of the governors of Maryland, Virginia and Pennsylvania; the mayor of the District of Columbia; the administrator of the EPA; and the chairman of the Chesapeake Bay Commission, which represents the legislatures of the three states.

The Executive Council set the direction for the cleanup effort in the 1987 Chesapeake Bay Agreement. It set restoration of the Bay's "living resources" — its fish, shellfish, waterfowl and other water-dependent species — as the primary goal of the cleanup. To achieve that goal, it called for a number of actions to improve water quality. The cornerstone was a commitment to reduce the amount of the nutrients nitrogen and phosphorus entering the Bay 40 percent by the turn of the century.

That goal was based on research and computer modeling that indicated such a reduction would result in a significant water quality improvement. Excessive amounts of nutrients spur algae blooms which cloud the Bay's water. This prevents sunlight from reaching grass beds that provide important habitat for fish, blue crabs and other species. When the algae dies, it sinks to the bottom of the Bay and decomposes in a process that depletes the water of the oxygen needed by most aquatic dwellers. During the summer, large amounts of the Bay's water becomes totally, or largely, depleted of oxygen, forcing species to move elsewhere. Many of those that cannot move die.

Into the Tributaries

After a multiyear review that verified the need for a 40 percent nutrient reduction, the Executive Council in 1992 determined that the goal should be met by setting specific nutrient reduction targets for each of the Bay's major tributaries. That led to the development of "tributary strategies" by each of the Bay states to offer details of how those reductions will be achieved.

Generally, it is thought that achieving the goal will push the envelope of technology for many nutrient control practices, both for controlling "nonpoint source" runoff from fields, lawns and streets, as well as for "point source" discharges, primarily from sewage treatment plants.

As a result, the past few years have seen a surge in interest for the use of "riparian forest buffers" to control runoff. Though not viewed as a pollution control technique until recently, research indicates that in many landscapes, forest buffers can be highly effective in controlling phosphorus and nitrogen. And because forests are the natural landscape for the Bay watershed, forest buffers also help to re-create the water quality conditions needed for native aquatic species to thrive — from the algae at the bottom of the food chain to the fish at the top.

Recognizing that riparian forests "deliver the greatest range of environmental benefits of any type of stream buffer," the Executive Council in 1994 called for the creation of a policy to guide the maintenance and restoration of forested riparian buffers in the Bay watershed. Not only would forest buffers help improve water quality, the Council said, but they would help fulfill other goals, such as creating the water quality conditions in river and streams that will be needed to support migrating shad, herring and striped bass as fish passages are constructed.

Forested riparian buffers will also play a key role in the Bay Program's long-range goal of capping nutrient inputs at the 40 percent reduction levels after the turn of the century despite the increased growth and development expected in the watershed. "Maintaining long-term caps on nutrients in the tributaries will require approaches that maintain ecosystem or watershed-scale functions, like those provided by healthy riparian forests," the Council said in its directive.

"We now recognize that forests along waterways, also known as 'riparian forests,' are an important resource that protects water quality and provides habitat and food necessary to support fish survival and reproduction. Used as buffers, riparian forests provide a means of helping us achieve our restoration goals in the tributaries."

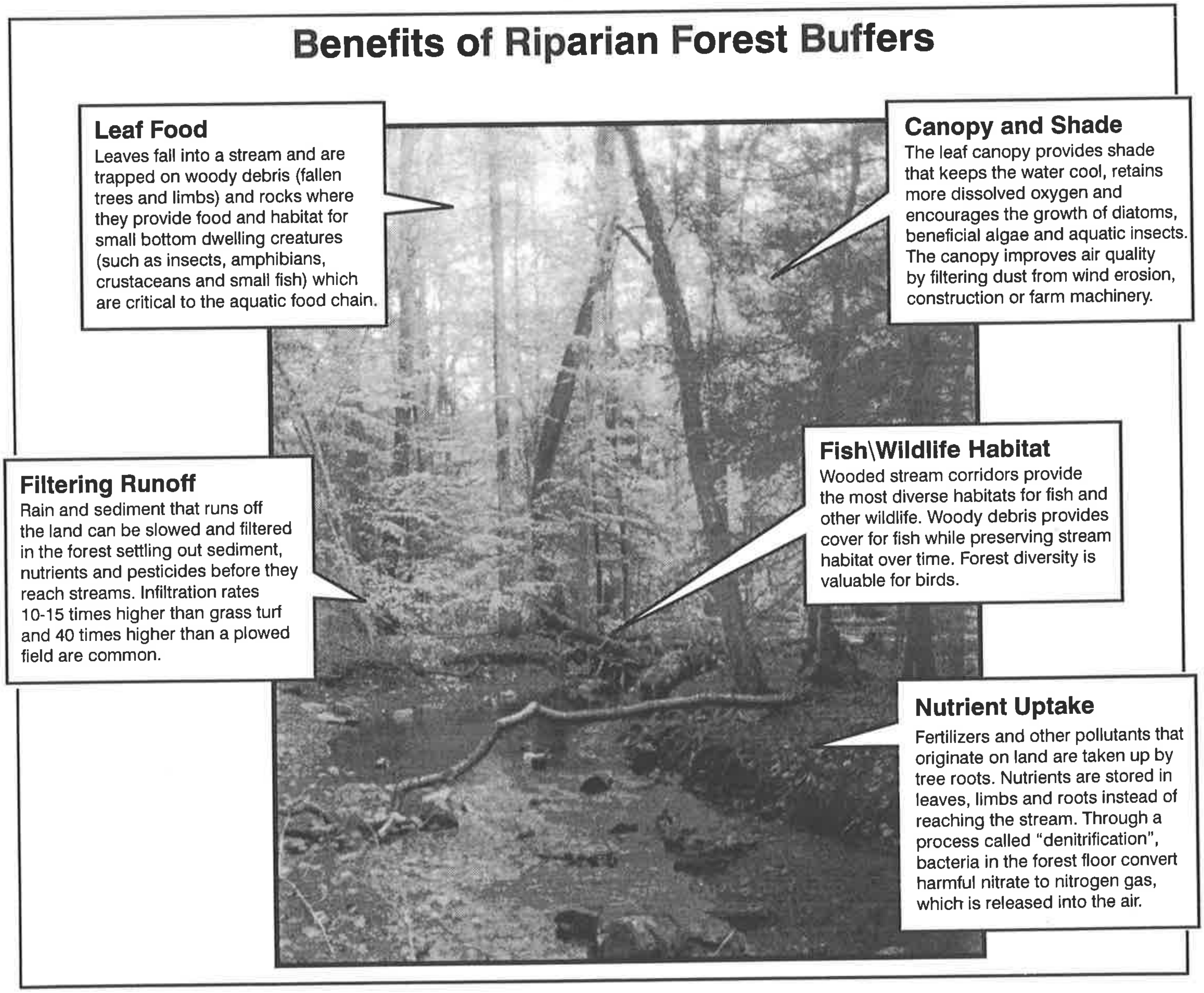
— *from the 1993 Chesapeake Executive Council directive on Riparian Forest Buffers*

Forested Riparian Buffers

Exactly what constitutes a riparian forest buffer will vary from landscape to landscape. The term itself is still evolving, but it is based on two definitions. The phrase "riparian area" refers to the land adjacent to streams, rivers or water bodies that directly affects — or is affected by — the water. The area serves as a transition between aquatic and upland environments. A "buffer," meanwhile, is an area managed to reduce the impacts of an adjacent land use.

A "forest riparian buffer" is a combination of the two. It refers to a forested area situated between a stream and the adjacent land use which is managed to help maintain the hydrologic and ecological integrity of stream channels and shorelines; prevent upland sources of pollution from reaching surface waters by trapping, filtering and converting sediments, nutrients and chemicals; and protect fish and other wildlife by supplying food, cover and temperature control.

With more than 100,000 miles of widely differing streams winding through the Bay watershed, there is



no "one size fits all" description of an ideal riparian forest buffer. Instead, a three-zone buffer concept has been developed to help technical professionals and landowners customize buffer planning for widely varying landscapes. The three-zone buffer provides a framework in which water quality, habitat and landowner objectives can be accomplished. The three zones consist of:

❑ Zone 1, a permanent tree buffer immediately adjacent to the stream bank which exerts the most control over the stream environment.

❑ Zone 2, a managed forest immediately upslope from Zone 1 which is the primary area for the removal of pollutants carried in surface runoff and shallow groundwater.

❑ Zone 3, a herbaceous or grass filter strip, or other control measure, upslope from Zone 2 which helps to protect the forested buffer and slow runoff to improve the sediment trapping ability in Zone 2.

This highly flexible system can be adapted to maximize environmental benefits for a wide variety of geologic and geographic conditions while taking landowner objectives into account. Zone 3, for example, is compatible with uses that range from suburban lawns to stormwater management to pasture. Zone 2 may shrink or expand to reduce pollution runoff and to meet landowner objectives such as improving wildlife habitat or providing recreational opportunities such as bike paths. Managed timber harvests could take place in Zone 2, and may even be desirable as growing trees will uptake more nutrients than mature ones.

This mix of techniques helps compress a number of habitat and pollution-control functions into a relatively narrow strip of land. Conceptually, planners generally consider a buffer width of 75 to 100 feet on each side of the stream adequate to achieve all of those functions. The width of each zone may vary from landscape to landscape. In general, wider buffers will help increase runoff control, particularly on steep slopes. In areas where wide buffers are not practical, even narrow wooded buffers — perhaps only 25 feet — can provide some habitat benefits such as streambank stabilization, food supply for aquatic organisms, and shading. On the narrowest headwater streams, the overall buffer width needed for water quality may also be narrower.

Applying the System

To help assess the effectiveness of riparian forest buffers in various settings, the Chesapeake Bay Program formed a special team of scientists in 1994 to review available research about forest buffers and their impact on habitat and water quality. In August 1995, their work resulted in a consensus document, "Water Quality Functions of Riparian Forest Buffer Systems in the Chesapeake Bay Watershed."

The team concluded that in almost all settings, the forest buffer system will help control the stream environment and substantially improve habitat for aquatic species. In most places, buffers will prove to be an effective means to control surface runoff and many types of runoff-borne pollutants as well, though effectiveness will vary from landscape to landscape. Controlling groundwater pollutants varies widely, depending on the geologic setting.

The scientists rated the four major functions performed by riparian forest buffers from their most common and widespread role, to their least effective function. Those were, in descending order of effectiveness:

❑ Control of the stream environment. This includes controlling stream temperatures and the amount of light reaching the stream; expanding habitat diversity; stabilizing the streambank against the effects of erosion; and enhancing the food web.

❑ Control of sediment and sediment-borne pollutants. Forests are highly effective at trapping and filtering sediments and any accompanying pollutants (such as particulate phosphorus or nitrate) that are contained in the runoff. Debris on the forest floor slows the water, allowing sediment to settle. Slope and soil permeability are the greatest factor in determining effectiveness of sediment trapping; areas with steep slopes may require wider buffers. Buffers can trap 80-90 percent of the sediment as long as management actions are taken to disperse concentrated runoff flowing into the forested area.

❑ Control of nitrate in shallow groundwater. In areas where groundwater moves in short, shallow paths to the stream, passing through the root zone of the riparian forest buffer system, nitrate removal can be extremely high, on the order of 90 percent. In areas where groundwater flows in longer, deeper paths to larger streams, the root zone will be bypassed and nitrate removal may be minimal. Of all the forest buffer functions, this one is most sensitive to the geographic, geologic and land use settings.

❑ Control of dissolved phosphorus. While buffers are effective at controlling particulate phosphorus linked to the sediment, they are less effective at controlling dissolved phosphorus. Most dissolved phosphorus is immediately available to organisms when it reaches the water. To increase dissolved phosphorus retention, efforts to trap fine sediments need to be coupled with the use of vegetation that increases phosphorus uptake into plant tissue. Fortunately, dissolved phosphorus makes up a very small portion of the Bay's pollution problem.

The scientists reviewed forest buffer effectiveness for pollution control within each of the major physiographic regions found in the Chesapeake Bay watershed, and offered their best professional judgments of how riparian forest buffer systems would perform.

Riparian Forest Buffers:
% Reduction of Nutrients and Sediment*

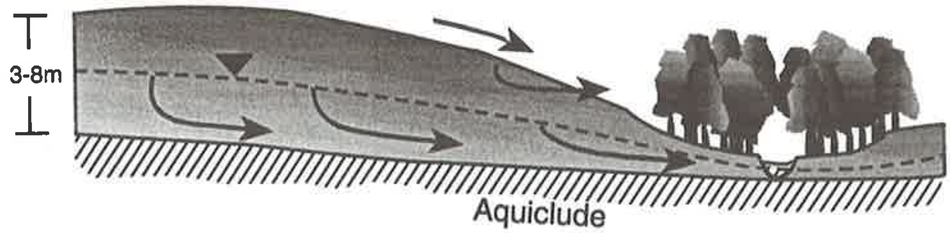
Level	Sediment	Nitrogen	Phosphorus
High	85-95	68-92	70-81
Medium	65-85	45-68	50-70
Low	40-65	15-45	24-50

* General approximations for 100-foot forest buffer system. Actual levels will vary by land use and site conditions. Based on loadings from agricultural lands, performance in field studies rated as high removed total N in the range of 23-66 #/acre/year and total P in the range of 1-3 #/acre/year from adjacent fields. Expected level of function is based on mature forest in Zone 1 & 2.

Inner Coastal Plain

Of all physiographic regions, the inner coastal plain probably represents the maximum potential for nonpoint source control in riparian forest buffer systems. Most excess rainfall enters streams through subsurface runoff or shallow groundwater and therefore moves in or near the forest buffer root zone where nutrient removal is very high. Forest buffers will be highly effective in controlling most particulate surface runoff as well, though dissolved phosphorus removal takes place at a lower rate. Because this region is often flat, many agricultural areas have drainage systems. For forest buffers to be effective, those systems must be modified to encourage flow through the buffer.

INNER COASTAL PLAIN

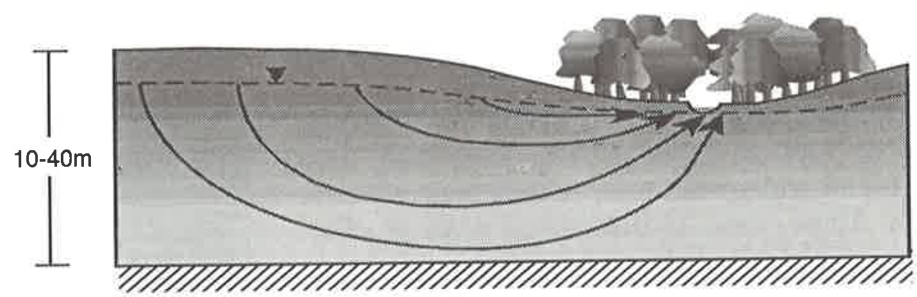


Water Quality Function	Expected Level	Critical Constraints	Restoration/ Enhancement
Removal of nitrate from groundwater	High, most water moves in or near root zone.	Bypass due to artificial subsurface drains. Organics in Zone 2.	Important on all streams. Rapid restoration of dentrification function. Ground cover in Zone 3.
Removal of sediment and sediment-borne pollutants	High/Medium	Convert concentrated flow to sheet flow.	Restore in all areas. Enhance existing forest with Zone 3 speaders.
Removal of dissolved phosphorus	Medium/Low	Control of dissolved **P** in surface runoff and groundwater is limited.	Restore in areas with major P load in surface runoff. Enhance existing forest with Zone 3.

Outer Coastal Plain

Well drained upland: Aside from lands immediately adjacent to streams, excess rainfall sinks farther into the ground and therefore enters the streams through their bottoms, never coming into contact with the root zone. As a result, there is little nitrate removal from groundwater. In this area, Zone 1 vegetation is particularly important because trees immediately adjacent to small streams offer the most potential for root systems to intercept the deeper groundwater before entering small streams. Management actions in this area might include the selection of trees that would have roots most likely to make that connection. If the roots can reach the groundwater, ni-

OUTER COASTAL PLAIN FLOW SYSTEM
Well-Drained Upland



Water Quality Function	Expected Level	Critical Constraints	Restoration/ Enhancement
Removal of nitrate from groundwater	Low, primarily removal from shorter flow paths.	Bypass flow due to deeper aquifers. Long flow paths surface in stream channels.	Concentration on headwater areas. Zone 1 important for nitrate removal.
Removal of sediment and sediment-borne pollutants	High/Medium	Concentrated flow must be converted to sheet flow.	On larger streams, focus on filtering eroded sediment. Enhance functions of Zones 2 & 3.
Removal of dissolved phosphorus	Medium/Low	Dissolved **P** control is limited. Focus on **P** load in surface runoff.	Increase vegetation uptake and accretion. Enhance existing forest and grass strips.

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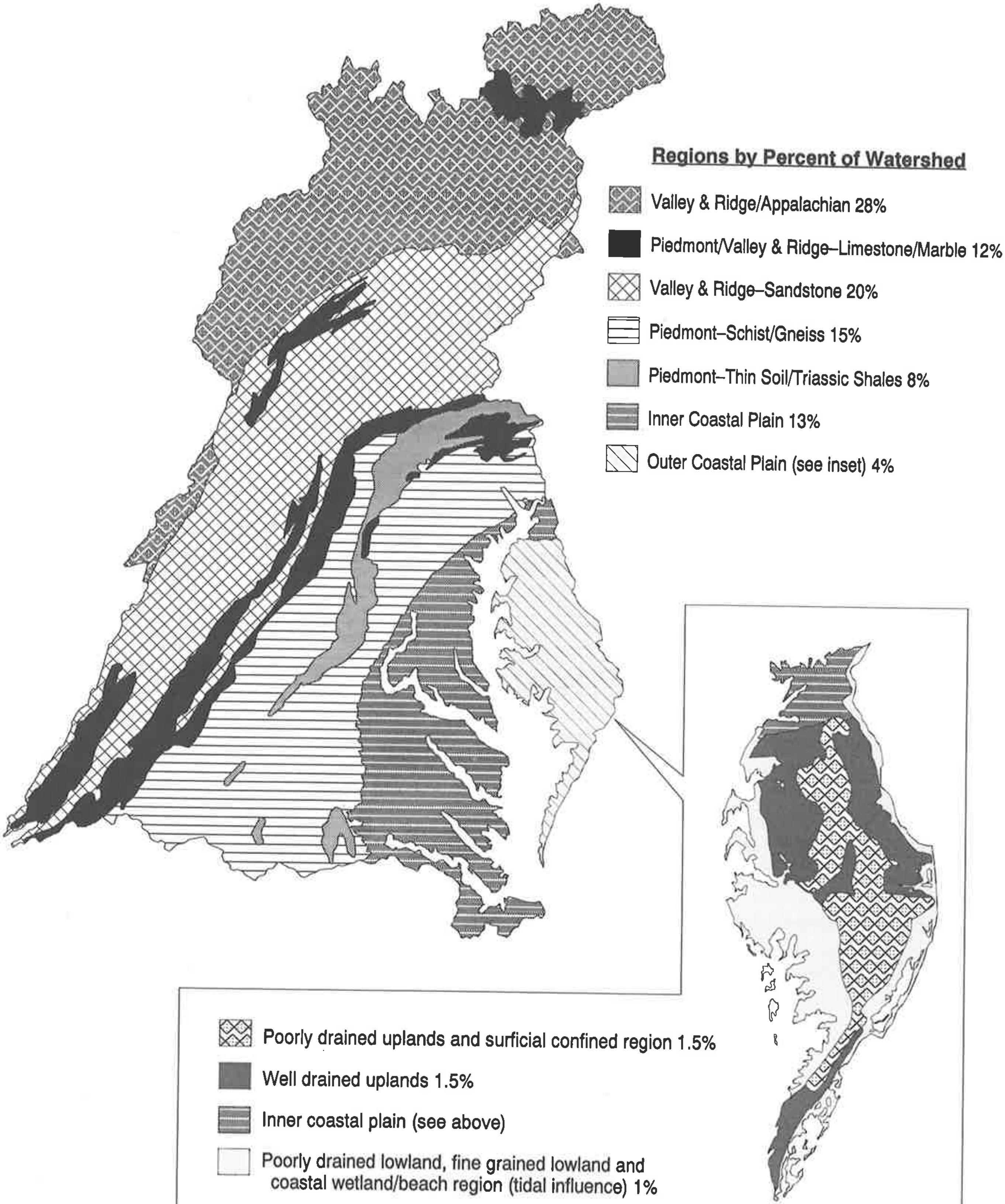
Major Hydro-Physiographic Regions in the Chesapeake Watershed



The Three-Zone Concept: A Tool tc

A three-zone system has been developed to help plan riparian forest buffers. This three-zone concept is intended to be highly flexible in order to achieve both water quality and landowner objectives.

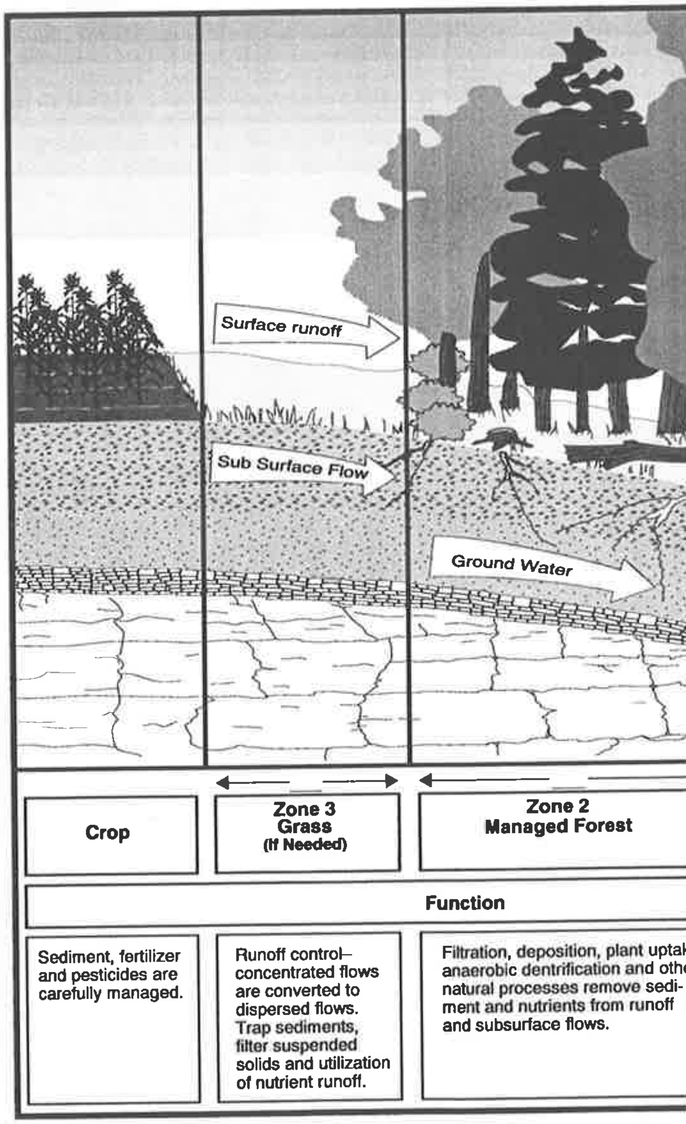
Zone 1: This represents the inner core of the buffer, stretching upland from the edge of the stream. Its primary purpose is to stabilize the streambank and provide habitat for aquatic organisms. The roots of trees in Zone 1 hold together the soil to resist the erosive force of flowing water. This also keeps sediment, and any nutrients bound to it, out of the stream.

Roots and fallen logs slow stream flow. This not only provides additional protection against erosion, but also creates pools that form unique "microenvironments." Pools support species of macroinvertebrates different from those in riffles only a few feet away. As a result, the presence of trees is directly related to greater biodiversity in the stream ecosystem.

Roots and submerged tree limbs also provide important habitats for macroinvertebrates, supporting even greater densities of the insects than can be found on the rocky stream bottom. This fallen debris also traps leaves, twigs, fruit seeds and other material in the stream, allowing it to decay and be used by stream-dwelling organisms. As the canopy is removed, there is not only less material, but the litter that remains breaks down more rapidly. Litter seems to be trapped and consumed in a relatively small area, so an upstream forested area does little to "subsidize" an unforested area downstream. This supports the need for a continuous streamside forest where possible.

The leafy canopy of the trees provides shade that helps to control water temperature. Maximum summer temperatures in a deforested stream may be 10-20 degrees warmer than in a forested stream. That is significant as temperature changes of only 4-10 degrees usually alter the life-history characteristics of macroinvertebrates that form an important part of the food web.

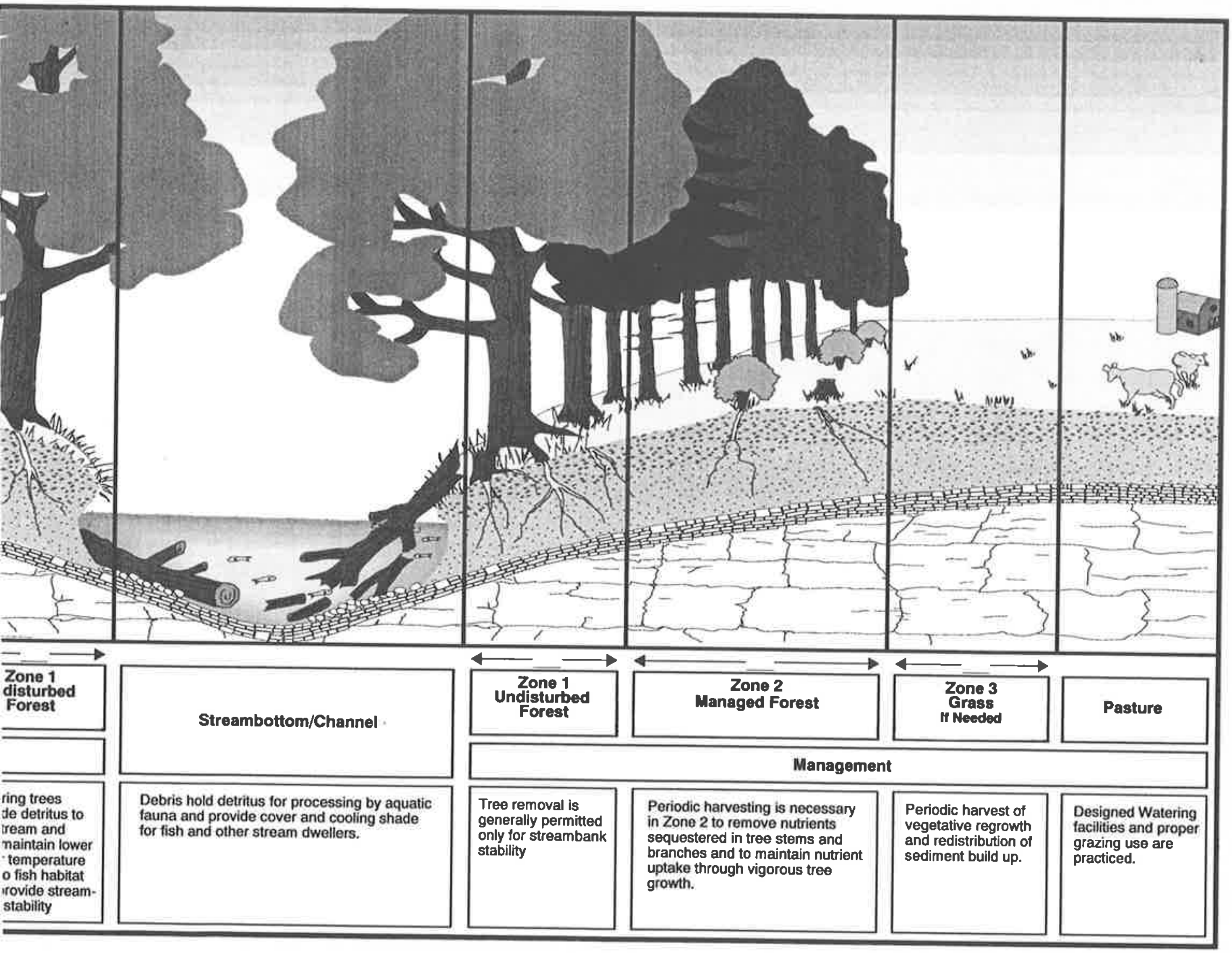
In addition, shaded streams support algae communities dominated by diatoms — a type of algae favored by many species — throughout the year while areas getting more direct sunlight are dominated by filamentous algae. This change, at the very bottom of



the food web, is critically important. While crayfisl and a few insect species will consume filamentous al gae, most macroinvertebrate species cannot becaus they have evolved as specialists for scraping diatom from the bottom.

While Zone 1 will improve habitat along a streams, its greatest impact will be along smalle streams where the canopy completely covers the wa ter surface, providing maximum control over ligh and temperature conditions. Trees in Zone 1 will ai in filtering surface runoff and, in some landscape can help remove nutrients carried in the groundwater

Guide Forest Buffer Planning



Zone 2: Located immediately upslope from Zone 1, the primary function of Zone 2 is to remove, transform, or store nutrients, sediments and other pollutants flowing over the surface and through the groundwater. Widths of Zone 2 can vary.

In areas where shallow groundwater flows through the root zones of trees, large amounts of nitrate can be removed before the water enters a stream. This results primarily from plant uptake and denitrification in the soils. Nitrate removal in these areas can be high — on the order of 90 percent. In areas where the groundwater flows deeper, much of this benefit will be lost as most of the water bypasses the root zone and enters the stream directly through the sediment.

Regardless of whether shallow groundwater flows through the root zones, all Zone 2 forest buffers will remove surface-borne pollutants. Debris from the trees slows and traps sediments in the runoff, giving the nutrients they carry time to infiltrate into the ground where they may be stored or removed through natural processes. Studies have found that Zone 2 can remove 50-80 percent of the sediment in runoff from upland fields. Generally, the upland edge of the Zone

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2 forest traps the largest share of coarse sediments while finer sediments will drop out as the water flows through the remainder of the buffer. Fine sediments carry larger amounts of nutrients and pollutants, so their concentrations are distributed over a wider area. This makes the width of Zone 2 critical.

Whether they are pulled from shallow groundwater or infiltrate into the soils from surface runoff, nutrients are removed in zone 2 through a variety of mechanisms. The most obvious process is plant uptake, as all plants must absorb nutrients to grow. In addition, forests provide large amount of decaying organic material that is necessary to fuel the microbial processes in Zone 2 soils that remove nutrients. There are three main ways those processes work:

- ❑ Microbes in the soil can take up nutrients and store them until they die, at which time the nutrients are released in a mineralized form that is less biologically available to other organisms and more readily stored in the soil. If managed to foster accumulation of this material, Zone 2 may support significant long-term nutrient storage.
- ❑ Denitrification takes place under the proper conditions when certain denitrifying bacteria convert nitrate to nitrogen gases. Denitrification is carried out by anaerobic microbes, organisms which survive in water or soils — usually wetlands — without oxygen. The large amount of decaying organic material on the ground in forested buffers depletes oxygen in the soils, and there is usually enough moisture in riparian areas to support the microbes needed for denitrification. Even drier forest soils commonly have small pockets which support these bacteria. Denitrification rates will vary depending on site conditions.
- ❑ Microbes use organic compounds as food and, though various reactions, change them so they are degraded to simpler compounds or synthesized into microbial biomass. Riparian forests appear to support a variety of microbial degradation mechanisms, though the management strategies that would promote them are not understood at this point.

Several factors will affect Zone 2 effectiveness at controlling surface runoff. Runoff must be managed to encourage "sheet" flows across the buffer. Buffers must also be wide enough to trap and hold sediments coming from adjacent land uses; if the buffer becomes overloaded with sediment, the excess will no longer be trapped and will simply wash into the stream. And the ability of Zone 2 forests to remove nutrients in groundwater will vary dramatically from landscape to landscape, depending on whether the groundwater comes into contact with the root zone.

Most Zone 2 studies have been made in existing or "natural" riparian forests. Scientists believe that even greater nutrient removal can be achieved in riparian buffers that are specifically managed for this function. Such management could include planting trees, such as bottomland hardwoods, which grow well in "well-watered" conditions and absorb large amounts of nutrients, or, through management techniques that promote soil conditions conducive to microbes that promote denitrification or nutrient storage.

Zone 3: Located immediately upslope of Zone 2, Zone 3 contains grass filter strips or other control measures which help slow runoff, filter sediment and its associated chemicals, and allow water to infiltrate into the ground. Grass filter strips help to protect the wooded areas and sets the stage so the forest buffer can perform at its maximum potential. Effective sediment trapping in Zone 2 requires that runoff entering that portion of the buffer be in the form of sheet flow. Zone 3, therefore, acts to spread out the flow and prevent runoff from adjacent land uses from eroding channels into the buffer.

Several studies show that grass filter strips are highly effective at reducing sediment runoff, with removal rates of 50 percent or more. Also, the filter strips are highly effective at removing sediment-bound nutrients such as phosphorus, but less effective at removing dissolved nutrients. Over time, the removal efficiency decreases as grass is smothered by deposited sediment. Generally, the narrower the filter strip, the shorter its effective life. As a result, grass filter strips require periodic maintenance which includes the removal of sediment, reestablishment of vegetation, and removal of channels. In urban areas, infiltration trenches and stormwater control measures may be common in Zone 3.

trate removal could be about as effective as buffer systems in other landscapes. Regardless of the groundwater situation, buffer systems in this area would still provide sediment control capacity similar to the Inner Coastal Plain. Because of the lower water tables, well-drained uplands may have more capacity to store dissolved chemicals in groundwater.

Poorly drained upland/ surficial confined: Groundwater is slightly higher here than in the well-drained upland but lower than the inner coastal plain. As a result, the effectiveness of nitrate removal from the groundwater is between those two extremes. Surface runoff control would still be effective, but removal of dissolved chemicals would probably be less than in the well-drained upland because the higher groundwater level limits storage. Agriculture in this region is commonly associated with artificial drainage, which requires integration into the buffer system.

Shorelines: Tidally influenced areas are unique because groundwater discharges are affected by tidal movements. Also, unlike most of the Bay watershed, marshes are the natural shore vegetation in many of these areas. At sites where marshes are not the natural shoreline, forest buffers can help stabilize the banks. Shorelines and cliffs are unique areas where special management may be needed. In most areas, the water table will be completely under the root zone, minimizing its im-

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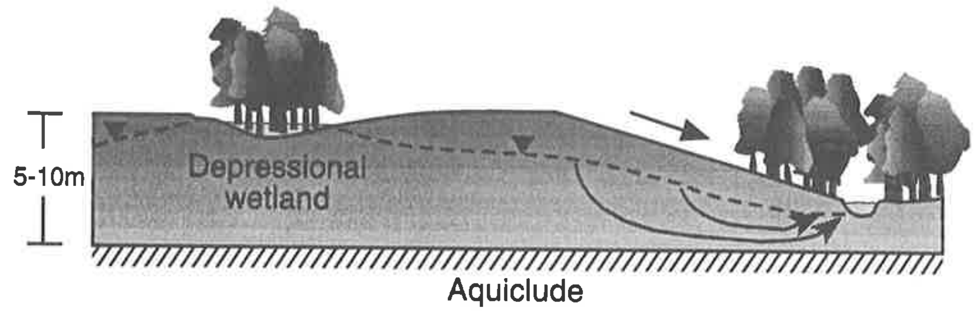
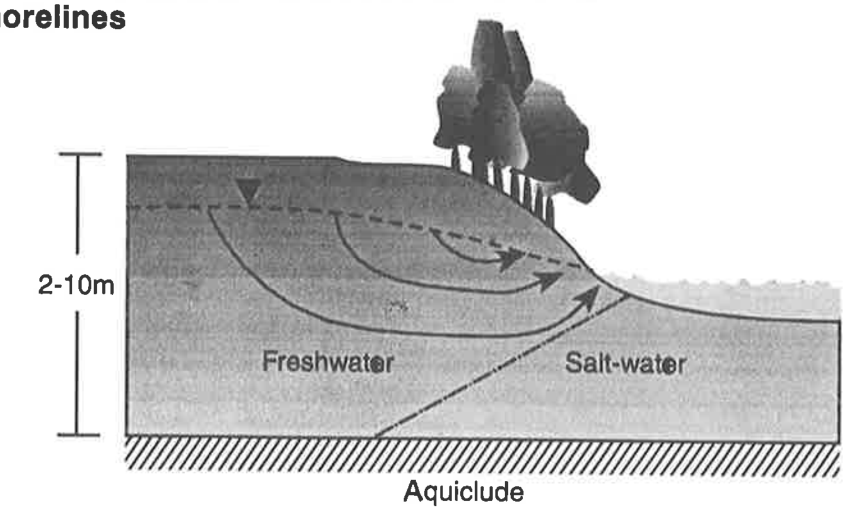
OUTER COASTAL PLAIN FLOW SYSTEM
Poorly Drained Upland/Surficial Confined



Water Quality Function	Expected Level	Critical Constraints	Restoration/ Enhancement
Removal of nitrate from groundwater	Medium/High	Lower loadings. Lower rates of removal in head-water areas.	Restore first in headwaters then larger streams. Rapid restoration of dentrification function.
Removal of sediment and sediment-borne pollutants	High/Medium	Less surface runoff but similiar efficiencies as in other C P systems.	Enhance vegetation in broad existing areas. Restore in headwaters.
Removal of dissolved phosphorus	Medium/Low	Dissolved **P** control is limited. Focus on **P** load in surface runoff.	Increase vegetation uptake and accretion. Enhance existing forest and grass strips.

OUTER COASTAL PLAIN FLOW SYSTEM
Shorelines



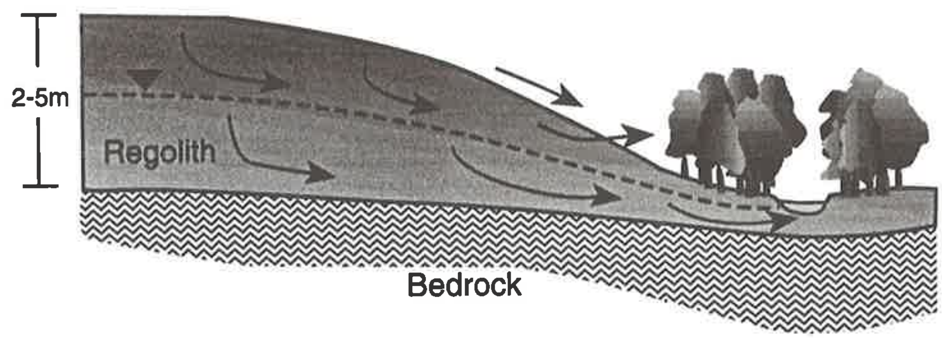
Water Quality Function	Expected Level	Critical Constraints	Restoration/ Enhancement
Removal of nitrate from groundwater	Low/Medium	Depth to water-tables. Bank erosion due to unstable soils.	Limit practice to areas without marsh wetlands down slope. Enhance vegetation uptake.
Removal of sediment and sediment-borne pollutants	High/Medium	Convert concentrated flow to sheet flow. Bank stability limits usefulness in some areas.	Restore/enhance in all areas. Limit to wider Zone 3 in some areas. Enhance Zone 3.
Removal of dissolved phosphorus	Medium/Low	Dissolved **P** control is limited. Focus on **P** load in surface runoff.	Increase vegetation uptake and accretion. Enhance existing forest and grass strips.

Piedmont

The Piedmont contains rich soils which can be quite deep. The effectiveness of a riparian forest buffer's ability to remove nitrate from the groundwater hinges on the depth of those soils and the underlying bedrock. In areas with thin or finely textured soils and short flow paths to streams through shallow groundwater or surface seepage — characteristics common in the Virginia Piedmont — nitrate removal would be high, as in the inner coastal plain.

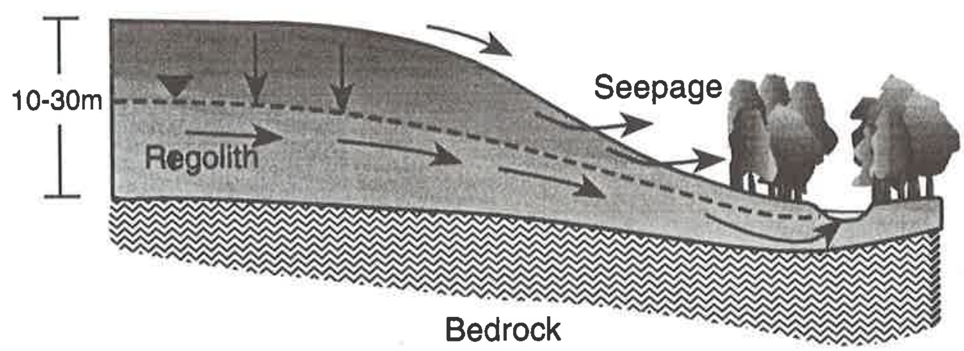
Piedmont areas with deeper soils are likely to have longer flow paths which allow water to sink deeper into the ground before entering the stream, in some cases bypassing the forest buffer. These areas are characterized by two different types of bedrock: gneiss/shist and marble. Areas with primarily shist bedrock would achieve moderate nitrate removal as groundwater would be forced to move laterally toward small streams. Some groundwater would either seep up toward the surface before reaching the stream or would pass through the root zone of the buffer, while some flowing more deeply would bypass the buffer. In areas with deep soils underlaid by marble, nitrate removal would be minimal as much of the groundwater would move through the porous marble layer and into regional aquifers. Riparian forests are most valuable here in floodplains and valley bottoms.

PIEDMONT FLOW SYSTEM
Thin Soils/Triassic Shales



Water Quality Function	Expected Level	Critical Constraints	Restoration/ Enhancement
Removal of nitrate from groundwater	High	Lower loadings than ICP Valley shapes control local flow paths.	Select deeply rooted vegetation, restore small and large streams, seepage areas.
Removal of sediment and sediment-borne pollutants	High/Medium	Slope of non-floodplain areas. Volumes of surface runoff.	Restore in areas. Function dependent on Zone 3 in first few years. Enhance Zone 3.
Removal of dissolved phosphorus	Medium/Low	Control of dissolved **P** in surface runoff.	Restore in areas with large surface runoff P loads. Increase infiltration.

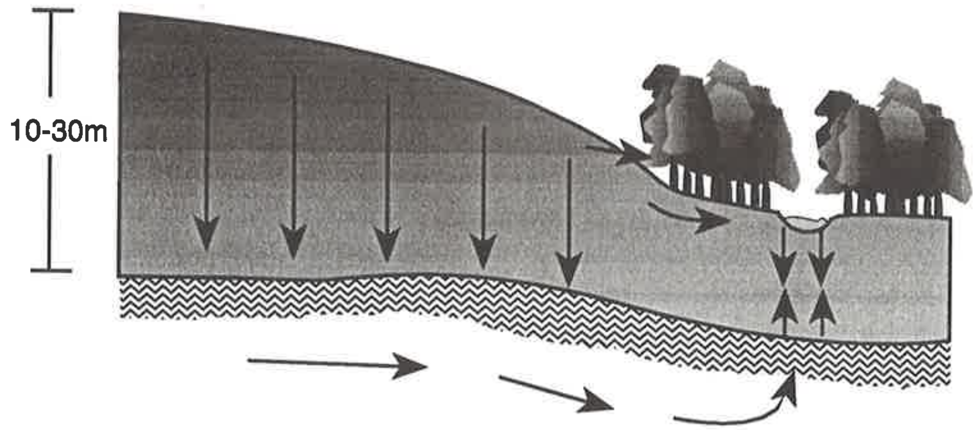
PIEDMONT FLOW SYSTEM
Schist/Gneiss Bedrock



Water Quality Function	Expected Level	Critical Constraints	Restoration/ Enhancement
Removal of nitrate from groundwater	Medium	More flow into regional aquifers, bypassing riparian zone.	Select deeply rooted vegetation. Restore in seepage areas.
Removal of sediment and sediment-borne pollutants	High/Medium	Slope of non-floodplain areas. Sediment loads in stream flow from valley sides.	Restore in areas with erosion impacting streams. Enhance existing forests with Zone 3.
Removal of dissolved phosphorus	Medium/Low	Control of dissolved **P** in surface runoff.	Restore in areas with large surface runoff **P** loads. Increase infiltration.

Sediment control in areas characterized by thin soils and flatter terrain would be similar to that of the inner coastal plain, with the removal of sediment and particulate nutrients being fairly high, while control of dissolved phosphorus would be fairly low. In hillier areas of the Piedmont, sediment control will depend on how effectively Zone 3 is managed to spread out the runoff and prevent it from cutting channels into the forest, allowing water to pass rapidly through the buffer. Steeper slopes in riparian areas may limit both the sediment filtering capacity and the retention time of water, possibly requiring expansion of Zone 3 and/or Zone 2.

PIEDMONT/VALLEY & RIDGE FLOW SYSTEM
Marble/Limestone Bedrock



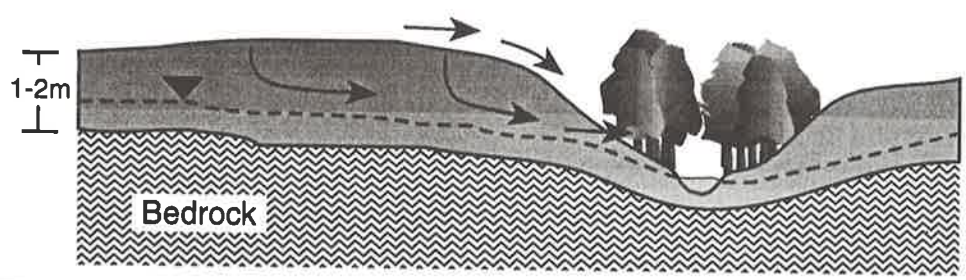
Water Quality Function	Expected Level	Critical Constraints	Restoration/ Enhancement
Removal of nitrate from groundwater	Low	Most flow into regional aquifers and into large rivers.	Dentrification focus. Select deeply rooted vegetation. Restore in seepage areas.
Removal of sediment and sediment-borne pollutants	High/Medium	Slope of non-floodplain areas. Sediment loads in stream flow from valley sides.	Restore in all areas with erosion impacting streams. Enhance existing forests with Zone 3.
Removal of dissolved phosphorus	Medium/Low	Control of dissolved **P** in surface runoff.	Restore in areas with large surface runoff **P** loads. Increase infiltration and fine sediment filter.

Valley and Ridge/Appalachian

The Valley and Ridge province is characterized by folds in topography. Ridges of harder, more resistant rock lie parallel to softer rock worn down over time to form the lowlands. Streams are intimately connected to this topography, flowing on belts of soft rock which rarely cross mountain ridges. Where they do, they cross at right angles, forming a distinctive "trellised" drainage pattern. Springs and seepage areas are common and the water table is often close to the surface in near-stream areas.

This area is characterized by larger streams that drain the main valleys, with smaller, and often steeper, streams draining the ridges. Forested riparian buffers have proven highly effective in controlling water

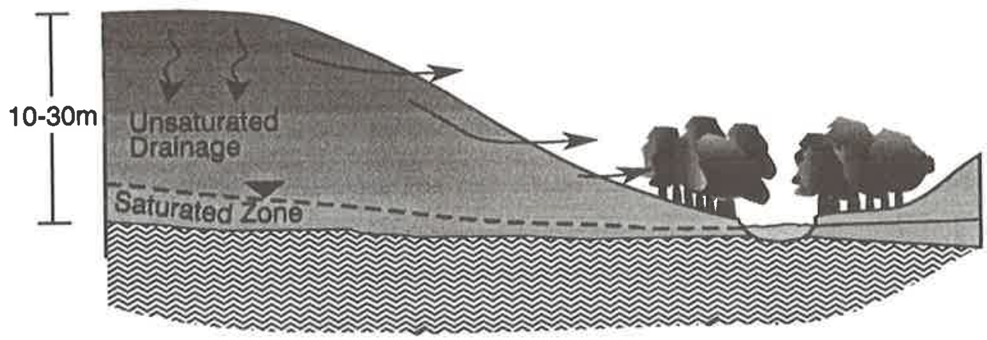
VALLEY & RIDGE FLOW SYSTEM
Sandstone/Shale Bedrock



Water Quality Function	Expected Level	Critical Constraints	Restoration/ Enhancement
Removal of nitrate from groundwater	Medium/High	Presence of seeps and floodplains. Valley configurations.	Select for vegetation uptake especially early in growing season. Deeply rooted.
Removal of sediment and sediment-borne pollutants	High/Medium	Sediment loads in stream flow from valley walls. Slopes of non-floodplains.	Restore in all areas with stream erosion. Enhance Zone 3 to control sediment.
Removal of dissolved phosphorus	Medium/Low	Control of dissolved **P** in surface runoff.	Restore in areas with large surface runoff **P** loads. Increase infiltration.

temperature and sediment delivery to streams in forest and agricultural settings in the Valley and Ridge, but knowledge of the removal of nutrients from groundwater is less certain. This is primarily because of differences in geology. Water flow in Valley and Ridge areas with limestone bedrock is complicated and quite variable over time. There is often little potential for removing nitrate from groundwater as water will flow through cavernous openings in the rock to deep aquifers. From there, groundwater will eventually flow into the bottom of larger streams or rivers, bypassing riparian buffer zones altogether. Valley and Ridge areas with sandstone/shale bedrock have greater potential for groundwater nitrate removal as the hard bedrock keeps water moving laterally in the shallow soils toward the streams. Seepage and near-stream areas provide opportunities for substantial nitrate removal, while valley floodplains where groundwater discharge occurs will likely be areas for forest buffers to influence water quality. Surface runoff control would face the same issues as in hilly portions of the Piedmont.

VALLEY & RIDGE/APPALACHIAN FLOW SYSTEM
Low Order Streams



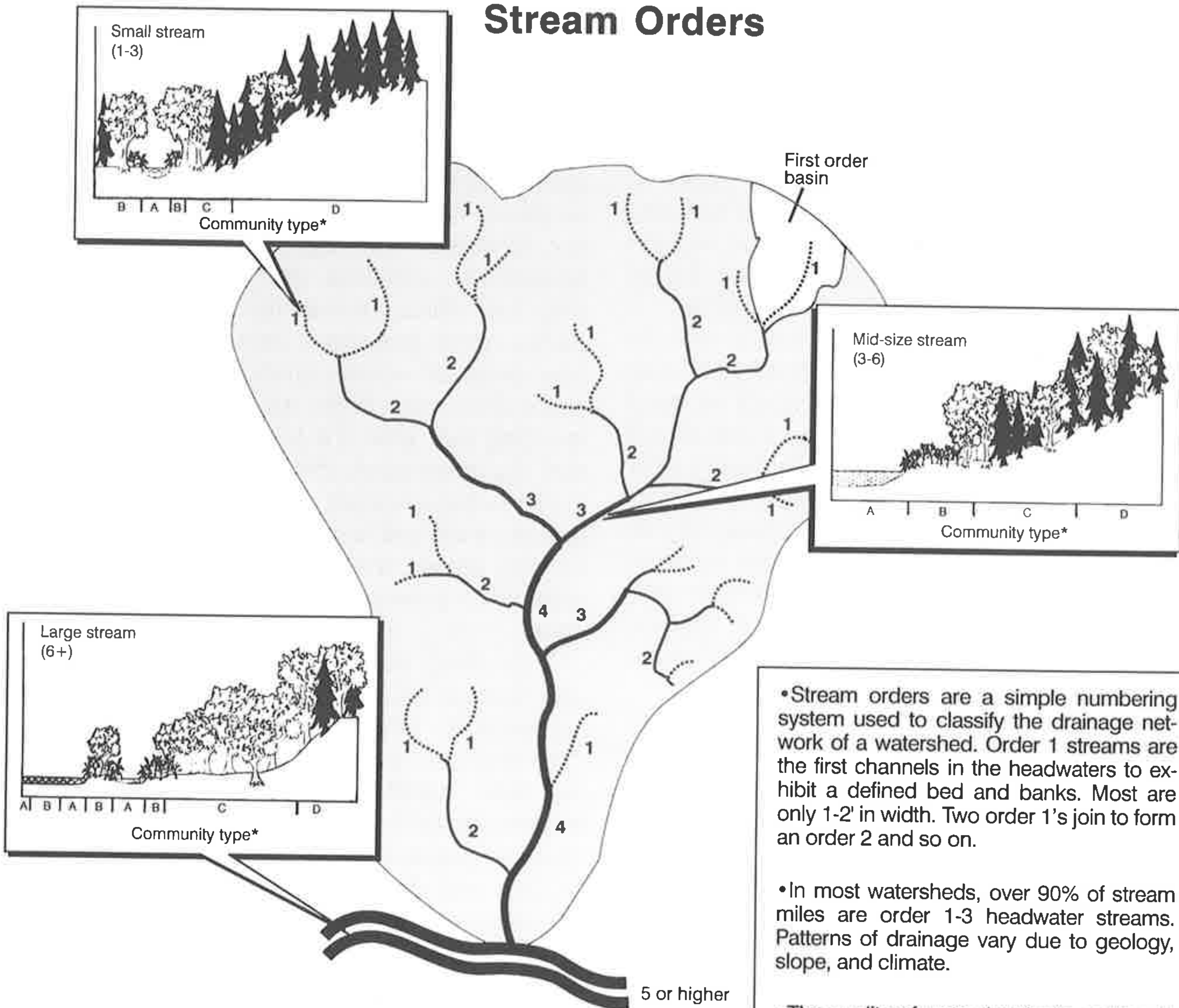
Water Quality Function	Expected Level	Critical Constraints	Restoration/ Enhancement
Removal of nitrate from groundwater	Medium/High	Residence time of water. Presence of seeps and floodplains.	Select deeply rooted vegetation for uptake. Zone 1 is important for removal.
Removal of sediment and sediment-borne pollutants	High/Medium	Sediment loads in stream flow from valley walls. Slopes of non-floodplains.	Restore in all areas with stream erosion. Enhance Zone 3 to control sediment.
Removal of dissolved phosphorus	Medium/Low	Control of dissolved **P** in surface runoff.	Restore in areas with large surface runoff P loads. Increase infiltration.

Management considerations

To be most effective, riparian forest buffers need to be planned and implemented on a watershed scale. This allows for a continuous forested buffer linking the headwaters with downstream areas. Protecting headwaters is particularly important because forest buffers affect water quality primarily as water moves *toward* the stream; downstream buffers will have proportionally less impact on polluted water already in the stream. Watersheds that have the highest stream densities — the number of streams relative to the size of the watershed — will get the greatest water quality benefits as most surface and groundwater will flow through the buffer before reaching the stream.

Riparian forest buffers exert the greatest control over small streams (Order 1-3). Not only will much of the water entering the stream pass through the buffer, but the tree canopy also covers the entire waterway, providing shade and litter inputs. As the stream widens and the canopy no longer shades the entire surface, the buffer can still filter nutrients flowing toward the stream. Forest buffers along wider streams will also provide such benefits as streambank stabilization; mitigation of flood damage; provision of coarse

Stream Orders



***Key**

A–Active channel or water body
B–Stream banks and adjacent area flooded on an annual basis
C–Riparian zone of influence-zone of vegetation directing affecting or affected by the stream or water body
D–Uplands

(Note that A, B and C make up the complete riparian zone. In some cases, portions of D may be included in a riparian buffer.)

- Stream orders are a simple numbering system used to classify the drainage network of a watershed. Order 1 streams are the first channels in the headwaters to exhibit a defined bed and banks. Most are only 1-2' in width. Two order 1's join to form an order 2 and so on.

- In most watersheds, over 90% of stream miles are order 1-3 headwater streams. Patterns of drainage vary due to geology, slope, and climate.

- The quality of water (nutrients, sediment, and temperature) is affected most by the condition of headwater streams (order 1-4). Riparian forest buffers may exert their greatest influence here as the majority of water flows through the shaded riparian zone.

- Riparian forests may provide the greatest opportunities to enhance fish habitat on mid-order streams (3-6) and shorelines where there is sufficient large woody debris, stream structure and flow to support fish and other aquatic life.

- Larger streams and rivers (order 6+) are often characterized by well-defined floodplains or adjacent wetlands. Wider buffers may be needed here to allow meandering, as well as improve channel stability, water quality, and wildlife corridors.

woody debris and leaf detritus, habitat and stream structure; and shading to cool a portion of the channel and the groundwater recharging the streams. These functions will occur regardless of stream size. Providing a continuous stream corridor is therefore desirable.

It's unclear how quickly newly established riparian forest buffers impact water quality. Based on the coastal plain, which has received the most intensive research, newly planted buffers would have a substantial impact within 5 to 10 years in areas where wetland soils existed in the past. Within 15 to 20 years, buffer systems would provide their full range of benefits.

Once established, a forest buffer should provide water quality and habitat benefits indefinitely but may require maintenance. In areas — particularly on steep slopes — actions will be needed to assure that runoff does not carve gullies that allow water to rapidly flow through the buffer. In some areas, primarily buffers with older trees, periodic selective harvesting may be required as growing trees will absorb more nutrients than mature ones. Efforts may also be needed to control invasive plants, particularly nonnative species, which can limit tree growth and diminish the habitat quality for aquatic species.

For best results, the three zones should be integrated. The width of the buffer will vary depending on the site conditions and landowner objectives. As a minimum, establishing contiguous forest buffers of even narrow (Zone 1) width to link existing forested areas or buffers should be considered a high priority to provide continuous streamside habitat. If only a minimal forest buffer is possible, efforts should be made to ensure it is wide enough to sustain a forest community and forest soil conditions over the long term.

Conclusion

In the Chesapeake Bay watershed, riparian forest buffers will enhance or restore stream habitat in any setting, and will improve water quality in the vast majority of areas. For fish, wildlife and people, they are one of the most valuable investments landowners, and the public, can make for the Bay.

In recognition of their significant role in Bay restoration efforts, the Chesapeake Executive Council asked that recommendations for a riparian forest buffer policy be developed for its 1996 meeting. The policy, developed with input from government agencies, landowners, scientists, nonprofit organizations, business, and others, ensures that the improvements in riparian forest protection, restoration and stewardship take place by setting quantifiable goals for riparian forest restoration in the watershed and a timetable for reaching that goal. To promote forest buffer protection and restoration, the policy explores ways to improve communication and build partnerships among federal, state and local government agencies, as well as with private landowners and the public to coordinate existing programs and provide additional incentives.

Ultimately, success in enhancing riparian forests and buffers will depend as much on cultivating a stewardship ethic among landowners and other "stakeholders" as it will on planting trees. Determining how policies that will promote riparian forest buffers should be incorporated into local government land use plans, how to integrate economic values of buffers into decision-making, and the development of incentive and educational programs needed to promote riparian forest buffer maintenance and restoration throughout the watershed will be the challenge. With such cooperation, the tributaries will carry cleaner water into the Chesapeake — and provide an avenue for many of the Bay's fish species to travel upstream and thrive — for generations to come.

ALLIANCE for the CHESAPEAKE BAY

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For more information about riparian forest buffers in the Bay watershed, contact: 1-800-YOUR-BAY

The Alliance for the Chesapeake Bay is a nonpartisan, nonprofit group of citizens, scientists, corporations, trade groups, environmental groups and others from throughout the Chesapeake Bay watershed: from Owego, N.Y., through Lancaster, Pa., to Williamsburg, Va., and from Harpers Ferry, W.Va., beyond Washington, D.C., to the Eastern Shore of Maryland.

The Alliance does not lobby. It is committed to hands-on restoration, public policy research, and education and information services. It puts the collective talents and resources of its diverse membership to work directly on watershed restoration.

For more information about the Alliance, call the Chesapeake Regional Information Service, 1-800-662-CRIS.