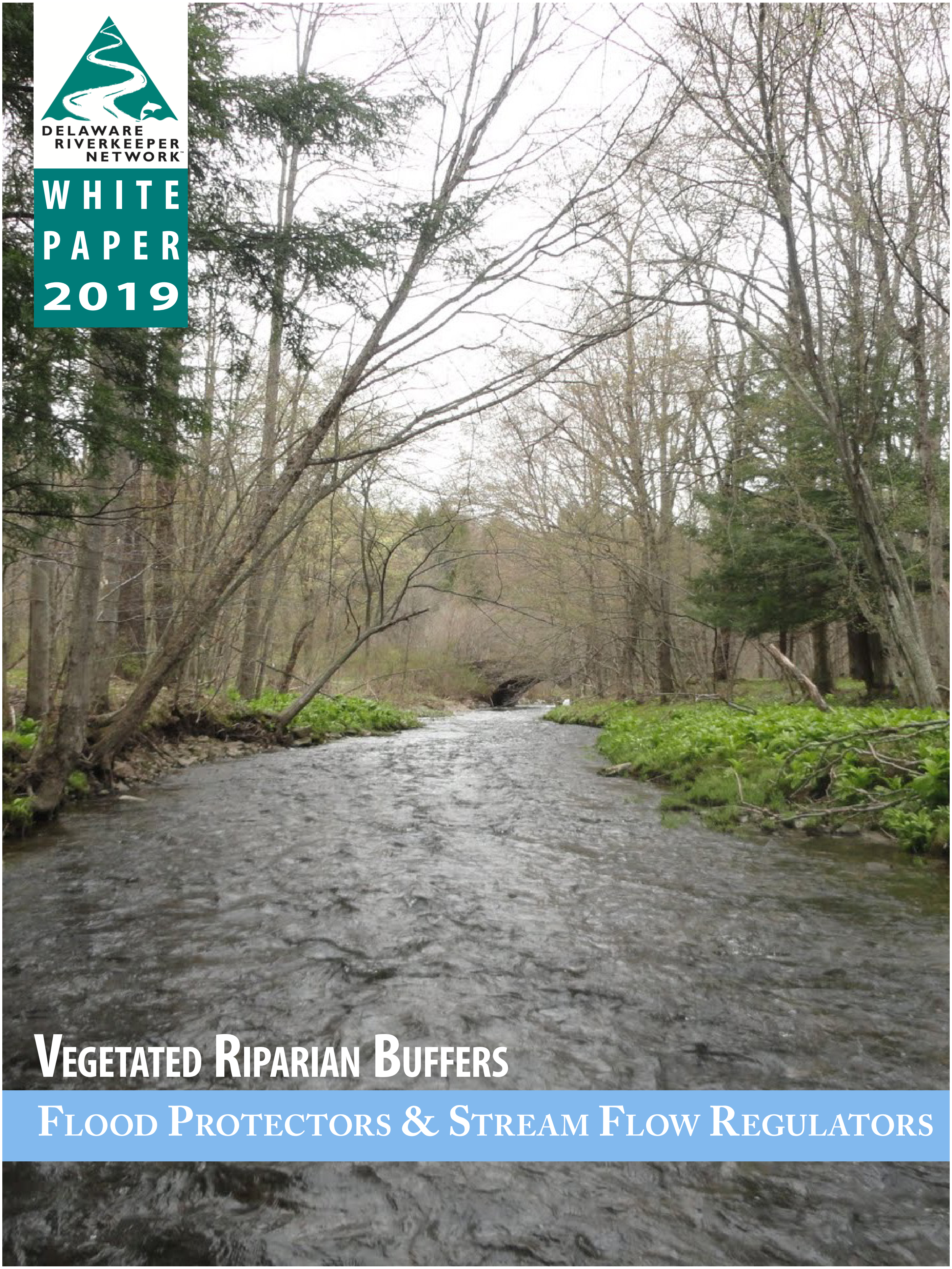


DELAWARE RIVERKEEPER NETWORK™

WHITE PAPER 2019

Vegetated Riparian Buffers

Flood Protectors & Stream Flow Regulators

Vegetated Riparian Buffers

WHAT - Lands next to bodies of water that are planted with trees, shrubs, and other vegetation

WHERE - Can be planted along rivers, streams, ponds, estuaries, and wetlands

WHY - Because buffers at least 100 feet wide on each side of a waterway provide flood protection benefits

Riparian Buffers Provide Drought, Flow, and Flood Protections

In addition to water quality benefits,[1] vegetated buffers also have water quantity benefits. Vegetated buffers influence the volume, rate, and timing of floodwaters. Vegetated buffers allow water to be taken up by vegetation, encourage infiltration through the soil, slow the velocity of runoff, reduce flood peaks, and provide flood storage.[2] Vegetated buffers also allow for groundwater to be replenished and aquifers to be recharged, keys to the long-term sustainability of groundwater supplies and stream flow.[3]

Understanding the water cycle is important for achieving successful stormwater management. Water is always moving; the natural water cycle, also known as the hydrologic cycle, describes the continuous movement of water on, above, and below the ground surface.[4] This cycle includes various components and is a closed loop where impacts on one part of the cycle create comparable impacts elsewhere in the cycle. This action/reaction system is sensitive to any attempts to manipulate and manage elements within the water cycle.[5] For example, land development which results in significant changes in one part of the cycle (such as increased surface runoff), translates into decreases in another part of the cycle (such asdecreased infiltration and groundwater recharge). Effective stormwater management integrates all aspects of the water cycle into a comprehensive

1 Delaware Riverkeeper Network. (2015). Vegetated Buffers: Water Quality Protectors.

2 Wenger, S. (1999). A review of the scientific literature on riparian buffer width, extent and vegetation.; Matteo et al. (2006). Watershed-scale impacts of forest buffers on water quality and runoff in urbanizing environment. Journal of water resources planning and management, 132(3), 144-152.; Tourbier, J.T. (1994). Open space through stormwater management: Helping to structure growth on the urban fringe. J. Soil Water Conservation. 1994. vol. 49, no. 1, pp. 14-21.

3 Patten, D. T. (1998). Riparian ecosystems of semi-arid North America: Diversity and human impacts. Wetlands, 18(4), 498-512.; Palone, R. S., & Todd, A. H. (Eds.). (1998). Chesapeake Bay riparian handbook: a guide for establishing and maintaining riparian forest buffers. US Department of Agriculture, Forest Service, Northeastern Area State and Private Forestry.

4 http://water.usgs.gov/edu/watercycle.html

5 DNREC and Brandywine Conservancy. (1997) Conservation Design for Stormwater Management: A Design Approach to Reduce Stormwater Impacts from Land Development and Achieve Multiple Objectives Related to Land Use, September, 1997.

program that sustains water resources, both groundwater and surface water, while attenuating floodwaters.

An average of 45 inches of rain falls every year in the Piedmont and Upland portions of the Delaware Valley. Historically, about 8 inches ran off the land prior to development – the other 37 inches was returned to the sky as evapotranspiration (ET) (about 22 inches) or soaked into the ground (about 15 inches). After land development, these numbers are dramatically altered, and the bulk of the rainfall is lost as runoff – 40 inches or more. In the estuary portion of the watershed, 2.5 inches of pre-development runoff increases to 40 inches annually when land is developed.[6] Other studies have shown that ET from agricultural watersheds is also significantly reduced (compared to natural landscapes) with threefold to fourfold increases in total runoff.[7] Despite the high water demand of crops, the lower leaf area, rooting depth, and shorter growing season (compared to forests) combine to decrease ET enough to influence the amount of water that runs off agricultural landscapes.

Transpiration: The movement of water within a plant from roots to leaves where it changes to vapor and is released into the air.
Evapotranspiration: The combination of evaporation and transpiration.

Effective stormwater management sustains water resources, both groundwater and surface water, while reducing flood flows and flood peaks.

Riparian Buffers Reduce Flood Peaks, Damages

Vegetated buffers perform an irreplaceable function in the hydrologic/water cycle for flood, drought, and stream protection. Streamside lands may frequently be inundated by floodwaters. These lands also can often contain wetlands. Development on floodplains and wetlands—including removal of vegetation, introduction of fill, building of structures, and the compaction of soils—has cumulative effects on flooding by increasing the volume of water that is passed into the stream, reducing the space available for floodwaters to spread out, and lessening the ability of streamside lands to absorb and slow down floodwaters.

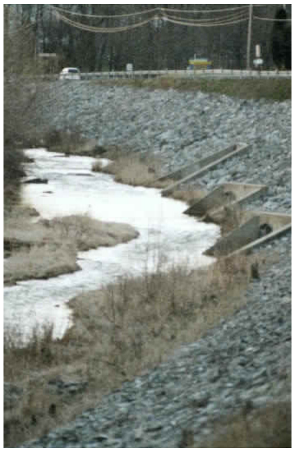
Expert opinion supports the benefits of vegetated buffers for addressing non-natural flood flows and peaks.[8] Streams without vegetated buffers have higher peak flow volumes and faster flow rates during periods

Streams without buffers have higher peak flow volumes and faster flow rates during periods of high flows.

6 Personal communications with Cahill Associates, West Chester, PA, 1999-2000

7 Neill et al. (2013). Watershed responses to Amazon soya bean cropland expansion and intensification. Philosophical Transactions of the Royal Society B: Biological Sciences, 368(1619), 20120425.; Bonell M. (2005) Runoff generation in tropical forests. In Forests, water and people in the humid tropics (eds M Bonell, LA Bruijnzeel), pp. 314–406. Cambridge, UK: Cambridge University Press.; Brown et al. (2005) A review of paired catchment studies for determining changes in water yield resulting from alterations in vegetation. J. Hydrol: 310, 28–61.

8 Palone, R. S., & Todd, A. H. (Eds.). (1998). Chesapeake Bay riparian handbook: a guide for establishing and maintaining riparian forest buffers. US Department of Agriculture, Forest Service, Northeastern Area State and Private Forestry.



of high flows, i.e., during floods.[9] For example, forest vegetation was shown to lower stream water elevations from 9.9 m (32.3 ft) to 5.3 m (17.3 ft) for a 100-year flood.[10] Moreover, forested streams have wider channels resulting in higher bed roughness and lower average water velocities than adjacent deforested channels.[11] In combination, the reduced flow volume and decreased runoff velocity impacts the timing of floodwaters and flood peaks and can minimize flood damages.[12] Streamside trees are well recognized for their ability to reduce flooding and flood damages and are generally more effective at providing flood protection than either grass or shrubs.[13]

Riparian Buffers Reduce Floodwater Volume

The water demand of riparian buffer vegetation reduces the amount of runoff that is delivered to stream channels through ET. Runoff from upland areas is intercepted by streamside vegetation before it reaches the channel. The portion of runoff that is not removed through ET is either released into the channel as streamflow or infiltrates into the soil contributing to groundwater recharge. Consequently, the volume of water released into the channel is reduced.[14] ET is a substantial element of the water cycle. In temperate deciduous forests, more than 50% of annual precipitation is returned to the atmosphere through ET.[15] In the Mid-Atlantic Region, ET returns approximately two-thirds of all the precipitation to the atmosphere.[16] Removal of buffer vegetation eliminates the ET component of the natural water cycle the

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9 Wengelgass, B. , & B. Sweeney. (2009) "The importance and benefits of forested buffers," Presentation to the DRBC Floodplain regulations evaluation subcommittee (FRES) March 17, 2009. ; DRBC FAC (2009) Recommendations of the floodplain regulations evaluation subcommittee. May 19, 2009; Vidon, P. (2012) Towards a better understanding of riparian zone water table response to precipitation: surface water infiltration, hillslope contribution or pressure wave processes?. Hydrological Processes, 26(21): 3207-3215.

10 Castelle et al. (1994) Wetland and stream buffer size requirements- a review. Journal of Environmental Quality, 23(5): 878-882.

11 Sweeney et al. (2004). Riparian deforestation, stream narrowing, and loss of stream ecosystem services. Proceedings of the National Academy of Sciences of the United States of America, 101(39), 14132-14137.

12 The Task Force on the Natural and Beneficial Functions of the Floodplain. (2002). The Natural and Beneficial Functions of Floodplains: Reducing Flood losses by Protecting and Restoring the Floodplain Environment. A Report for Congress, June 2002.

13 See for example PA CREP Fact Sheet: Streamside Magicians, How Trees Help Streams, 2006, in which this powerful benefit of trees is affirmatively stated by the State program's fact sheet.

14 Connor et al. (2013). Hydrology of a forested riparian zone in an agricultural landscape of the humid tropics. Agriculture, Ecosystems & Environment, 180: 111-122.

15 Tsang et al. (2014), A variable source area for groundwater evapotranspiration: impacts on modeling stream flow. Hydrol. Process., 28: 2439–2450.

16 Neff et al. (2000). Impact of climate variation and change on Mid-Atlantic Region hydrology and water resources. Climate Research, 14(3), 207-218.

forested buffer would otherwise provide resulting in greater runoff volumes and increases in flood peaks.

Riparian vegetation also encourages infiltration which further reduces the total runoff of water that is exported to stream channels.[17] For example, measurements to determine a soil's ability to infiltrate found that infiltration rates for land under intensive cropland agriculture was close to half that measured for riparian forests; pasture infiltration rates were 15% to 20% of that of forests.[18] The presence of trees results in higher soil porosity because of the presence of roots, the high turnover of roots, and the high concentrations of organic matter. In reforested areas, open soil pores occur as roots grow and subsequently die.[19] In pasture areas, grasses have shallow, non-woody roots compared to trees which have a higher diversity of root sizes ranging from fine roots to large woody roots that leave large conduits in the soil.[20] High soil organic matter is also responsible for providing low-density mass to the soil and improving soil structure which increases soil aeration.[21] In combination, these characteristics of vegetated areas result in higher porosity and more open soil pores that act as conduits to transport water into the soil instead of over the land as runoff. This increased infiltration provides flood storage by reducing the volume of water delivered to waterways during rain events.

Streamside trees are well recognized for their ability to reduce flooding and flood damages .

Deforestation and removal of riparian vegetation reduces infiltration and increases discharge to creeks through increased stormwater runoff. For example, the destruction of heavy forest canopy in the Delaware Valley

Removal of buffer vegetation results in greater runoff volumes and increases in flood peaks.

17 Gregory et al. (1991). An ecosystem perspective of riparian zones. BioScience, 540-551.; Gageler et al. (2014) Early response of soil properties and function to riparian rainforest restoration. Retrieved from: http://www.lbccg.org.au/wp-content/uploads/2014/02/Gageler-soil-response-to-reforestation.pdf

18 Gageler et al. (2014) Early response of soil properties and function to riparian rainforest restoration. Retrieved from: http://www.lbccg.org.au/wp-content/uploads/2014/02/Gageler-soil-response-to-reforestation.pdf.; Neill et al. (2013). Watershed responses to Amazon soya bean cropland expansion and intensification. Philosophical Transactions of the Royal Society B: Biological Sciences, 368(1619), 20120425.; Cristina Penuela, M., & Drew, A. P. (2004). A model to assess restoration of abandoned pasture in Costa Rica based on soil hydrologic features and forest structure. Restoration Ecology, 12(4), 516-524.

19 Beven, K., & Germann, P. (1982). Macropores and water flow in soils. Water Resources Research, 18, 1311-1325.

20 Jimenez et al. (2009). Fine root dynamics for forests on contrasting soils in the Colombian Amazon. Biogeosciencee, 6, 2809-2827; Finer et al. (2011). Factors causing variation in fine root biomass in forest ecosystems. Forest Ecology and Management, 261, 265-277; Powers, J. S., & Perez-Aviles, D. (2012). Edaphic factors are a more important control on surface fine roots than stand age in secondary tropical dry forests. Biotropica, 45, 1-9.

21 Murty et al. (2002). Does conversion of forest to agricultural land change soil carbon and nitrogen? a review of the literature. Global Change Biology, 8, 105-123; Penuela, M. C., & Drew, A. P. (2004). A model to assess restoration of abandoned pasture in Costa Rica based on soil hydrologic features and forest structure. Restoration Ecology, 12, 516-524; Laub et al. (2013). Comparison of designed channel restoration and riparian buffer restoration effects on riparian soils. Restoration Ecology, 1-9.

region of southeastern Pennsylvania has resulted in an annual loss of up to 400 million gallons of stormwater retention.[22] Furthermore, increased discharge from small headwater streams leads to impacts that extend to larger river networks. For instance, the more than 82,000-km^2 watershed of the Araguaia river in east-central Brazil has had a 25% increase in discharge over a 20-year period induced to a large degree by deforestation and conversion to agriculture in the headwater regions.[23] The results of this analysis suggest that similar and significant changes in the surface water budget of both small and large rivers is occurring due to deforestation. Conversely, the flow attenuation benefit of riparian buffers has a cumulative effect as multiple small streams converge to form larger rivers, and therefore, reductions in flow becoming greater further downstream.[24]

Mandating forested buffers along all natural water courses ensures a vegetated buffer that is able to provide these quantity reduction benefits that protect communities from the adverse impacts of floods. Additionally, vegetated buffers help ensure that there are not structures placed in such close proximity to streams and rivers thereby reducing the quantity of structures present and subject to flood damage.[25]

Riparian Buffers Reduce Flow Rates

In addition to reducing the volume of flow, above ground vegetation in riparian buffer zones reduces the velocity of flow. The combination of vegetation, dead foliage, branches from trees which have fallen onto the ground surface, and the layer of organic leaf litter on the soil surface create perturbations that increases flow resistance slowing stormwater that moves across the landscape as overland flow.[26] The level of flow velocity reduction depends on plant structure and stiffness, the distribution of plants, and the area occupied by vegetation.[27]

22 American Forests. (2003). Urban ecosystem analysis: Delaware valley region. Special publication of American Forests and the U. S. Department of Agriculture Forest Service. Washington, DC.

23 Coe et al. (2011). The effects of deforestation and climate variability on the streamflow of the Araguaia River, Brazil. Biogeochemistry, 105(1-3), 119-131.

24 Scott, M. A. (2012). An Analysis of Flow Attenuation Provided by Stream-Buffer Ordinances in Johnson County, Kansas. M.S. Thesis, University of Kansas.

25 Vegetated riparian buffers and buffer ordinances, NOAA and South Carolina Dept of Health and Environmental Control.

26 Correll, D.L. (1997). Buffer zones and water quality protection: General Principles, pp. 7-20. In: N.E. Haycock, T.P. Burt, K.W.T. Goulding and G. Pinay (ed.) Buffer zones: Their processes and potential water protection. Quest Environmental, Harpenden, Herts, UK.

27 Luhar et al. (2008). Interaction between flow, transport and vegetation spatial structure. Environmental Fluid Mechanics 8.5-6: 423-439.

Table 1 lists the roughness coefficients for different types of ground cover with higher values representing greater retardation of flow. Riparian buffers are most effective at reducing flow velocities when surface flow is distributed evenly across the land surface since channelization of flow through scouring, artificial swales, and across paved roads encourages high runoff velocities.[28] Increased hydraulic roughness associated with woodland plantings compared to grasslands can reduce water velocity by 50%.[29] In addition to the hydraulic roughness associated with riparian trees, the presence of flow obstructions created by large woody debris within forested stream channels acts to reduce in-stream flow velocity and increase flood storage.

Mandating forested riparian buffers would help protect communities from floods.

Table 1[a]: Roughness Coefficients for Typical Ground Cover Types of Floodplains	
Pasture with No Brush	0.030- 0.035
Cultivated Areas with Mature Row or Mature Field Crops	0.035 – 0.040
Brush	0.050 – 0.100
Trees	0.100 – 0.150
Trees with little undergrowth and flood stage below branches	0.100
Trees with little undergrowth and flood stage reaching branches	0.120
Dense willows, summer, straight	0.150
[a] Adapted from Table 2-3, DNREC and Brandywine Conservancy, Conservation Design for Stormwater Management: A Design Approach to Reduce Stormwater Impacts from Land Development and Achieve Multiple Objectives Related to Land Use, September, 1997	

Riparian vegetation not only slows the flow of runoff from the landscape but also affects the flow of floodwaters during overbank flow. Modeling results show that floodwater velocities can be up to 41% greater for channelized streams compared to natural channels with vegetated riparian zones.[30] The drag exerted by submerged vegetation determines the rate of the water current such that higher drag results in reduced flow rates.[31] Generally, the flow impacts under submerged and non-submerged conditions are different indicating that vegetation height is important.[32] However, the flow

Floodwater velocities can be up to 41% greater for channelized streams compared to natural channels with vegetated riparian zones.

28 Newham et al. (2005). A conceptual model of particulate trapping in riparian buffers. CSIRO Land and Water; Hairsine et al. (2001). Stock tracks and the delivery of pollutants to streams by overland flow', In I. Rutherford, F. Sheldon, G. Brierley and C. Kenyon. (eds), Third Australian; Dosskey et al. (2002). Assessment of concentrated flow through riparian buffers. Journal of Soil and Water Conservation, 57(6), 336-343. tream Management Conference, Brisbane, August 2001.

29 Thomas, H., & Nisbet, T.R. (2006). An assessment of the impact of floodplain woodland on flood flows. Water and Environment Journal, 21: 114-126.

30 Keesstra et al. (2012). Assessing riparian zone impacts on water and sediment movement: a new approach. Netherlands Journal of Geosciences, 91(1-2), 245-255.

31 Luhar et al. (2008). Interaction between flow, transport and vegetation spatial structure. Environmental Fluid Mechanics 8.5-6: 423-439.

32 Stone, B.M., & Shen, H.T., (2002). Hydraulic resistance of flow in channels with cylindrical roughness. J. Hydraulic Eng. 128 (5), 500–506.

Requiring forested buffers along all natural water courses can protect both stream ecosystems and communities from the adverse impacts of high flows and flooding.

The preservation and restoration of buffers can reduce the need for and the size of stormwater infrastructure, such as detention basins.

Waterways that have lost their forested banks suffer an increase in the degree and duration of low flow conditions.

resistance of submerged vegetation is also determined by plant morphology, stiffness, and the distribution of plants.

Since flood damages are influenced in part by flow velocity,[33] the dissipating effect of riparian buffers can reduce flood damages. Reductions in flow volume typically benefits downstream communities, but lower stream flow rates is a direct local benefit. The importance of flow velocity was shown in an analysis of damages from hurricane Katrina on New Orleans that showed that high velocities in addition to flood depth caused more substantial damages than flood depth alone or at lower velocities.[34] Due to the substantial costs associated with flood damage, flood risk management should require the preservation and restoration of riparian buffers for reducing floodwater velocities.

Requiring forested buffers along all natural water courses affords the velocity reduction benefits that protect both stream ecosystems and communities from the adverse impacts of high flows and flooding.

In addition, the longer it takes runoff to reach the stream the longer runoff water spends in the riparian buffer area further encouraging volume reduction mechanisms (i.e. infiltration and uptake) and delaying the delivery of water to the stream channel and to downstream communities.

Riparian Buffers Change the Timing of Floodwaters

In addition to absorbing storm flows, riparian buffers delay flood flows by holding floodwater and gently releasing it over time which reduces downstream flooding during storms and recharges groundwater supplies.[35] Due to increased development and associated increases in the percentage of land covered by impervious surfaces (including pavement, buildings, compacted soils and lawnscapes) the amount of runoff flowing directly into waterways has increased significantly. Buffers slow this

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33 Kelman, I., & R. Spence (2004), An overview of flood actions on buildings, Eng. Geol., 73, 297–309.; Merz B, Kreibich H, Thieken A, Schmidtke R (2004) Estimation uncertainty of direct monetary flood damage to buildings. Nat Hazards Earth Syst Sci 4:153–163.

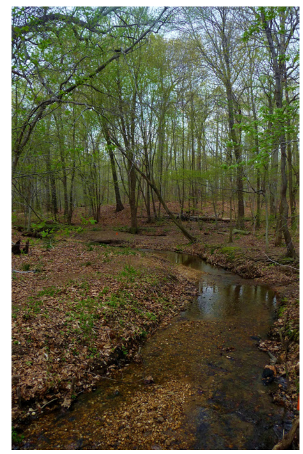
34 Pistrika, A.K., & Jonkman, S.N. (2010). Damage to residential buildings due to flooding of New Orleans after Hurricane Katrina. Nat Hazards 54: 413-434.

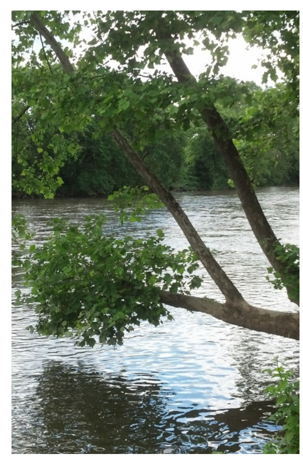
35 O'Connell et al. (2007). Is there a link between agricultural land use management and flooding? Hydrology and Earth System Sciences, 11: 96-107.; Xavier et al. (2007). Restored Floodplain Woodland on the River Laver, North Yorkshire: A benefit or drawback to flooding in Ripon. Conference proceedings from The River Restoration Centre's 8th annual network conference River restoration as a measure to deliver sustainable Flood Risk Management (FRM) and Water Framework Directive (WFD) objectives Wednesday 18th April – Thursday 19th APRIL 2007 on line at: http://www.therrc.co.uk/pdf/conferences/Session%202%202007.pdf; Tourbier, J.T. (1994). Open space through stormwater management: Helping to structure growth on the urban fringe. Journal of Soil and Water Conservation 49(1): 14-21.

runoff and allow some of this excess water to be absorbed back into the soil. Stored stormwater is then released evenly over time,[36] unlike detention basins which become direct conduits of runoff, and alter timing in an unnatural way.

This delay in runoff reduces flood peaks downstream by staggering the flood contributions of multiple tributaries. In arid and semi-arid areas, infiltration in the riparian zones also helps sustain "baseflow," the continuous seepage of groundwater to stream channels, by acting as a storage zone in between high flow periods.[37]

Increased infiltration delays the time between when a storm starts and when surface runoff begins. Additionally the decreased velocity increases the lag time of a flood (the time between the middle of the rainfall and the flood peak) which can minimize the magnitude of flooding.[38] Flood water can be stored in the floodplain for varying time periods and subsequently flows back to the channel gradually. For example, a wooded riparian buffer was shown to delay downstream progression of a flood peak by 140 minutes resulting in a 71% increase in flood water retention within the upstream reach.[39] Conversely, less absorption of rainwater (i.e. less infiltration into the ground) results in increased frequency of flooding.[40] For example, an increase of 20% imperviousness would result in 3 times as many days of extremely high flows (greater than 30 m^3/s) and an even more pronounced effect on the frequency of moderate flows (greater than 3 m^3/s) with 5 times as many days relative to an undeveloped watershed.[41] Research has consistently concluded that because of the hydrological impacts of buffers, those areas which preserve and restore such systems may require less or smaller sized stormwater infrastructure, such as detention basins.[42]





36 Penn. DEP. (2010). Riparian Forest Buffer Guidance, Document #394-5600-001, November 27, 2010.

37 Ponce, V. M., & Lindquist, D. S. (1990). MANAGEMENT OF BASEFLOW AUGMENTATION: A REVIEW. JAWRA 26(2): 259-268.

38 The Task Force on the Natural and Beneficial Functions of the Floodplain. (2002). The Natural and Beneficial Functions of Floodplains: Reducing Flood losses by Protecting and Restoring the Floodplain Environment. A Report for Congress, June 2002.

39 Thomas, H., & Nisbet, T.R. (2006). An assessment of the impact of floodplain woodland on flood flows. Water and Environment Journal, 21: 114-126.

40 Cressler, W. (2014). Water in the Piedmont Watersheds–The Vital Flow.; Eng, K., Wolock, D. M., & Carlisle, D. M. (2013). River flow changes related to land and water management practices across the conterminous United States. Science of the Total Environment, 463, 414-422.

41 Hawley, R. J., & Bledsoe, B. P. (2011). How do flow peaks and durations change in suburbanizing semi-arid watersheds? A southern California case study. Journal of Hydrology, 405(1), 69-82.

42 Miller, A.E., & A. Sutherland. (1999). Reducing the Impacts of Storm Water Runoff through Alternative Development Practices. Office of Public Service & Outreach, Institute of Ecology, University of Georgia, Athens, GA

Reduced infiltration where buffers have been removed can lower the water table causing baseflow declines and even the drying up of formerly perennial streams.

Riparian vegetation also affects streamflow on a seasonal, monthly, and daily basis. Waterways that have lost their forested banks suffer an increase in the degree and duration of low flow conditions that occur between storms. The quantity of water in rivers, streams and wetlands during periods between storms is integrally linked with groundwater.[43] Groundwater supplies both drinking water and baseflow to streams.[44] Most of the annual flow of perennial streams and rivers is attributable to "baseflow." Significant loss of groundwater recharge due to less infiltration in deforested reaches can lower the water table causing baseflow declines and even the drying up of formerly perennial streams.[45] For example, field measurements indicate a correlation between increased impervious cover and subsequent decrease in infiltration in the White Clay Creek watershed near Newark, Delaware and decreased stream baseflows.[46] Infiltration plays a critical role in maintaining low flow conditions although the effect of deforestation will depend on the distribution of rainfall and the extent to which quickflow develops.[47]

A minimum buffer of 100 feet on both sides of a waterway is needed to provide essential flood protection benefits.

Changes in the hydrologic regime of streamflow can have far-reaching effects on both stream organisms and communities that rely on consistent drinking water sources. Increased variability in flow also exacerbates flooding making it difficult to control storm flows and prevent flood damages. Without riparian buffers, water flows more rapidly downstream merely relocating the flooding problem from one spot to another. Proper management of streamflow is important to preserve both the function of the stream ecosystem and to prevent non-natural flooding and flood damages.

Riparian areas also prevent storm damage by keeping the area adjacent to waterways free of development.

43 Striz, E. A., & Mayer, P. M. (2008). Assessment of near-stream ground water-surface water interaction (GSI) of a degraded stream before restoration. EPA/600/R-07/058. USEPA, Washington, DC.

44 Fischer, R. A. (2001). "Technical and Scientific Considerations for Upland and Riparian Buffer Strips in the Section 404 Permit Process," ERDC TN-WRAP-01-06, U.S. Army Research and Development Center, Vicksburg, MS.

45 Leopold, L.B., (1968). Hydrology for Urban Planning – A Guidebook on the Hydrologic Effects of Urban Land Use. U.S. Geological Survey Circular 554, Washington, D.C.

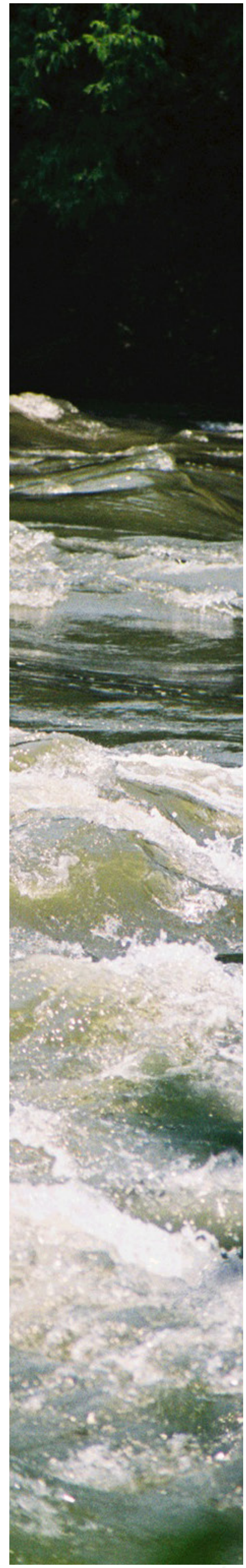
46 Kauffman et al. (2009). Link between impervious cover and base flow in the White Clay Creek Wild and Scenic watershed in Delaware. Journal of hydrologic engineering, 14(4), 324-334.

47 Brown et al. (2005). A review of paired catchment studies for determining changes in water yield resulting from alterations in vegetation. Journal of hydrology, 310(1), 28-61.

Wider Riparian Buffers Provide Better Flood Protection

Flood damages are expensive with costs in the U.S. from insurance claims and aid exceeding four billion dollars annually.[48] Forests and riparian vegetation play an important role in ensuring stormflows are stored and released gradually rather than immediately surging downstream in large flood pulses. The dissipation of flood energy will vary with the width of the riparian buffer in comparison with the channel width.[49] It is essential to have riparian buffers that are wide enough to provide adequate flood control, damage reduction, erosion prevention, and the many other non-flood related benefits. Scientific evidence suggests that a minimum buffer of 100 feet on both sides of a waterway is needed to provide essential flood protection benefits.[50] Smaller widths do not adequately maintain most of the beneficial functions of riparian buffers and, therefore, are of much more limited value.

One literature review found that for flood attenuation the science pointed to a range of widths from 65 feet to 492 feet.[51] This review demonstrates that for flood attenuation a mandatory 100-foot minimum width along each bank is actually on the smaller side of the range – a more conservative approach would actually mandate a larger buffer requirement closer to 250 feet along each bank. For example, modeled overbank flow widths for watersheds in Kansas indicate that a stream-buffer ordinance requiring a 100-foot buffer would not provide the maximum peak-flow attenuation for storms greater than the 10-year return interval, but 250-foot width buffers on both sides of a waterway would contain the average overbank top width for up to the 500-year storm.[52]



48 Costanza et al. (2006). The value of New Jersey's ecosystem services and natural capital. New Jersey Department of Environmental Protection.

49 Tabacchi et al. (2000). Impacts of riparian vegetation on hydrological processes. Hydrological processes, 14(16-17), 2959-2976.

50 Sweeney, B. W., & Newbold, J. D. (2014). Streamside Forest Buffer Width Needed to Protect Stream Water Quality, Habitat, and Organisms: A Literature Review. JAWRA Journal of the American Water Resources Association, 50(3), 560-584.; Johnson, A.W., & D. M. Ryba. 1992. A literature review of recommended buffer widths to maintain various functions of stream riparian areas. Prepared for King County Surface Water Management Division, as cited in Buffer Strip Function and Design, An Annotated Bibliography, Compiled for Region III Forest Practices Riparian Management Committee. Aquatic Resource Consultants, Renton, WA.

51 Fischer, R. A., & Fischenich, J. C. (2000). Design recommendations for riparian corridors and vegetated buffer strips (No. ERDC-TN-EMRRP-SR-24). Army Engineer Waterways Experiment Station Vicksburg ms Engineer Research and Development Center.

52 Scott, M. A. (2012). An Analysis of Flow Attenuation Provided by Stream-Buffer Ordinances in Johnson County, Kansas. M.S. Thesis, University of Kansas.

Natural Riparian Buffers Provide Effective Stormwater Management

Riparian areas also prevent storm damage by keeping the area adjacent to waterways free of buildings, roadways and other man-made structures and activities vulnerable to storm-related damage. Rivers naturally increase in size and change shape within the floodplain in response to storms. Locating structures or other vulnerable land uses within these areas makes them susceptible to flooding and increases flood risk. Avoidance is the best and most cost-effective way to prevent flood damage.

Riparian areas should be covered in native vegetation and contain no structures. When the streamside area is built on or deforested, its ability to provide flood control is diminished. Only by keeping floodplains in their natural state can they function as nature intended.

Riparian buffers offer an effective and less expensive alternative to structural measures for managing stormwater runoff, for flood protection, and for sustainable stream flow during periods between storms. A 100-foot minimum buffer on each side of a waterway is needed to provide essential flood protection benefits – a more conservative approach would mandate a buffer requirement closer to 250 feet.

A condensed version of this white paper is available from the Delaware Riverkeeper Network. Contact the Delaware Riverkeeper Network to request *Quick Facts: Vegetated Riparian Buffers - Flood Protectors & Stream Flow Regulators*. When you contact us, be sure to ask about our other resources on riparian buffers.

DELAWARE RIVERKEEPER NETWORK

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