DELAWARE RIVERKEEPER NETWORK™

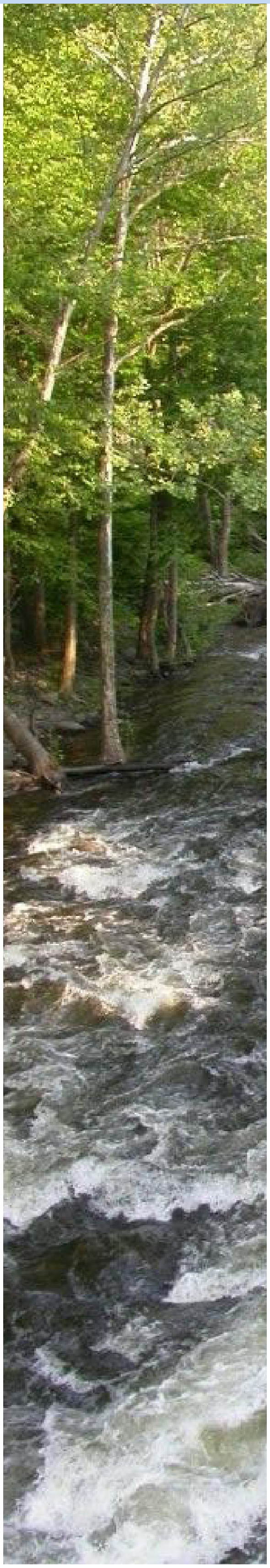
WHITE PAPER 2019

Vegetated Riparian Buffers

Economic Service Providers

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 diverse economic benefits



Riparian Buffers Provide Economic Benefits

Riparian buffers are typically protected or restored with a goal of improving environmental conditions and habitats. However, riparian buffers also provide economic benefits that are often overlooked or ignored. The health of the economy is inextricably linked with the health of the natural environment, and healthy riparian buffers provide ecosystem services such as natural purification of water; regulation of water supply for municipal, industrial, and agricultural users; storm and flood protection; erosion control; recreational opportunities; and habitat for fish and wildlife. These goods and services translate directly into economic benefits including goods and services associated with high quality water. We also receive economic benefits when we can avoid the costs of responding to the many harms that result when healthy buffers are absent. Riparian buffers can reduce drinking water treatment costs, limit flood damage expenses, provide stormwater management and infrastructure savings, substantially enhance property values, support creation of high quality products for sale such as craft beer, and boost state revenues by providing recreational areas and attracting tourism. The many economic benefits derived from well-functioning and healthy riparian buffers deserve greater recognition.

Table 1: Goods and services provided by healthy streams with riparian buffers.
Water Supplies for agricultural, industrial, and domestic uses
Water Filtration/Purification
Flow Regulation
Flood Control
Erosion and Sedimentation Control
Recreation/Aesthetic
Fisheries/Habitat
Carbon Storage

Riparian Buffers Reduce Costs Associated with Providing Clean Drinking Water

Surface water sources such as lakes and streams supply two-thirds of public water supplies for domestic, commercial, and industrial purposes in the U.S.[1] Most large cities and towns in the U.S. get their drinking water from surface waters such as lakes and rivers. Before water taken from a lake or river can be provided to users as drinking water, it is treated to

1 Kenny et al. (2009). Estimated use of water in the United States in 2005 (p. 52). Reston, VA: US Geological Survey.

make it potable, or safe for consumption. To be considered potable, treated water must meet federal and state standards. Since water may travel long distances from headwater streams through the landscape and downstream before being withdrawn for drinking water supply, activities many miles away from a public water supply can affect the quality and availability of drinking water delivered to homes. Scientific research has documented that riparian buffers improve water quality by filtering runoff water. The healthier streams that exist because of riparian buffers have an increased ability to assimilate nonpoint sources of pollution.[2] Forested streams are healthier with wider channels, greater stream bottom surface area, and higher capacity to remove pollutants through in-stream processing.[3] Additionally, surface waters that are shaded by streamside trees are generally cooler and consequently have higher dissolved oxygen concentrations. The higher oxygen concentrations of streams with riparian forest buffers are better able to assimilate the organic wastes from sewage plant discharges.[4] Improving the water quality of rivers reduces treatment costs for public water supply and results in direct health benefits to those drinking the water.

Water quality protection should be the first step in a multi-barrier approach to safeguard clean drinking water. The use of watershed protection programs that include riparian buffer requirements to achieve drinking water quality standards often cost less than human engineered treatment, with savings on capital, operation, and maintenance costs. For example, in the U.S., the treatment cost for drinking water drawn from watersheds with at least 60% forest cover was half the cost of treating water from watersheds with 30% forest cover, and one-third the cost of treating water from watersheds with just 10% forest cover.[5] Protecting upstream sources can be complementary to the use of

Riparian buffers provide economic benefits that are often overlooked or ignored.

Riparian buffers improve water quality by filtering runoff water.

Drinking water standards can be achieved at lower cost through the use of riparian buffers than through human engineered treatment.

2 Sweeney, B.W., (1992). Streamside Forests and the Physical, Chemical and Trophic Characteristics of Piedmont Streams in Eastern North America. Water Science and Technology 26:2653-2673.; 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.; Backer et al. (2006). Water management practices, rain-fed cropland. In: Environmental Benefits of Conservation on Cropland: The status of Our knowledge, M. Schnepf and C. Cox (editors). Soil and Water Conservation Society. Ankeny, Iowa, pp. 89-130.; Dosskey et al. (2010). The role of riparian vegetation in protecting and improving chemical water quality in streams. JAWRA 46(2): 261-277.

3 Bernhardt et al. (2005). Can't see the forest for the stream? In-stream processing and terrestrial nitrogen exports. Bioscience, 55(3), 219-230.; 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.

4 Pennsylvania Department of Environmental Protection (2010). Riparian Forest Buffer Guidance. November 27, 2010. Document # 394-5600-001. Available at: http://www.elibrary.dep.state.pa.us/dsweb/Get/Document-82308/394-5600-001.pdf

5 Postel, S. L., & Thompson, B. H. (2005, May). Watershed protection: Capturing the benefits of nature's water supply services. In Natural Resources Forum (Vol. 29, No. 2, pp. 98-108). Blackwell Publishing, Ltd..

drinking water filtration and treatment, but can also be used in lieu of engineered filtration technology. Protecting the source of drinking water supply before it reaches the intake of a drinking water system can limit the amount of contaminants entering the system. A number of U.S. cities have avoided millions of dollars in annual operating costs, as well as the capital costs of constructing expensive filtration plants, by investing in watershed protection and allowing healthy watersheds to do the work of purifying drinking water supplies.[6] For example, New York City has implemented a watershed protection program as the main strategy to achieving drinking water quality standards, and as a result has reduced phosphorus loadings, chlorophyll a concentrations, and microbial pathogens.[7] By spending $1.5 billion on watershed protections, New York City has avoided spending at least $6 billion in capital costs for the construction of a water filtration plant, as well as the $300 million it would cost every year to operate that plant.[8]

Water quality protection programs can also reduce the health risk associated with contaminated drinking water. Although typically associated with problems in developing countries, waterborne disease outbreaks also occur in developed countries.[9] For example, the drinking water for over 400,000 people in Toledo, Ohio, was declared unsafe in July 2014 due to a toxin released by algae in Lake Erie, the source of the city's water supply. The toxin could not be removed by the local treatment plant.[10]

Poor source water quality intrinsically has greater associated health risks. Contamination of drinking water supplies can have serious health consequences for consumers. Drinking water contaminants have the potential to cause both acute and chronic health effects. Acute or sudden health problems are usually a result of microbial pathogen

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6 Gazzo, K. J., "Watershed Protection as the Primary Tool to Achieve High Quality Drinking Water" (2014).Master's Projects. Paper 11.; Postel, S. L., & Thompson, B. H. (2005, May). Watershed protection: Capturing the benefits of nature's water supply services. In Natural Resources Forum (Vol. 29, No. 2, pp. 98-108). Blackwell Publishing, Ltd..

7 National Research Council. (2000). Watershed Management for Potable Water Supply: Assessing the New York City Strategy (p. 545). Washington DC. Retrieved from http://www.nap.edu

8 Postel, S. L., & Thompson, B. H. (2005, May). Watershed protection: Capturing the benefits of nature's water supply services. In Natural Resources Forum (Vol. 29, No. 2, pp. 98-108). Blackwell Publishing, Ltd..

9 Krewski et al. (2004). Managing the microbiological risks of drinking water. Journal of Toxicology and Environmental Health, Part A, 67(20-22), 1591-1617.; Hrudey et al. (2003). A fatal waterborne disease epidemic in Walkerton, Ontario: comparison with other waterborne outbreaks in the developed world. Water science & technology, 47(3), 7-14.; Medema et al. (2003). Safe drinking water: an ongoing challenge. In: Assessing Microbial Safety of Drinking Water. WHO/ OEDC, London.

10 Bechman, D.S. (Aug 6, 2014) The Threats to Our Drinking water. The New York Times. The Opinion Pages. Retreived from: http://www.nytimes.com/2014/08/07/opinion/the-threats-to-our-drinking-water.html?_r=1

contamination.[11] Conversely, exposure to small amounts of chemicals such as metals, pesticides, and nutrients over long periods of time can lead to chronic or long-term health implications.[12] For example, long-term exposure to arsenic in drinking water can lead to lung cancer and nervous system toxicity.[13] Furthermore, newer manufactured synthetic pesticides and pharmaceuticals are some of the most difficult chemicals to remove from drinking water supplies, and little is known about how these chemicals interact with the products commonly used to disinfect a water supply.[14] Ensuring a safe source water supply is a more effective option than treating a contaminated water supply to render it suitable for consumption. Furthermore, sources with higher water quality can easily be made potable with the addition of fewer disinfectants which reduces the risk from potentially harmful disinfection byproducts.[15] Therefore, the economic benefits of riparian buffers can be measured in terms of high water quality protected and the resulting lives saved, health costs reduced, sick days avoided and money saved for a community on treatment technology.

The economic benefits of high water quality as a result of riparian buffers can be measured in terms of lives saved, health costs reduced, sick days avoided and money saved.

Riparian Buffers Reduce Costs Associated with Reliable Drinking Water

In addition to providing high quality water, riparian buffers also provide a level of reliability of supply. Riparian buffers play a critical role in maintaining stream flows including during periods of low flow. Protecting the quantity of water flow helps to ensure the reliability of drinking water sources. Having a dependable supply of surface water for public use, as well as a safe source of water, is crucial to healthy communities and a healthy economy.

Furthermore, since precipitation is not typically spread evenly over time, sudden influxes of surface runoff during heavy rain events can render a water supply unusable or even hazardous. Riparian buffers do not create water, but they can modify the amount and the timing of water moving

In addition to providing high quality water, riparian buffers also help to ensure the reliability of a water supply.

11 Davies, J. M., & Mazumder, A. (2003). Health and environmental policy issues in Canada: the role of watershed management in sustaining clean drinking water quality at surface sources. Journal of Environmental Management, 68(3), 273-286.; Medema et al. (2003). Safe drinking water: an ongoing challenge. In: Assessing Microbial Safety of Drinking Water. WHO/ OEDC, London.

12 Ward et al. (2005). Workgroup report: Drinking-water nitrate and health-recent findings and research needs. Environmental health perspectives, pp. 1607-1614.

13 National Research Council. (2000). Watershed Management for Potable Water Supply: Assessing the New York City Strategy (p. 545). Washington DC. Retrieved from http://www.nap.edu.

14 Gazzo, K. J., "Watershed Protection as the Primary Tool to Achieve High Quality Drinking Water" (2014). Master's Projects. Paper 11.; Ernst et al. (2004). Conserving forests to protect water. Am. Water W. Assoc, 30, 1-7.

15 Krewski et al. (2004). Managing the microbiological risks of drinking water. Journal of Toxicology and Environmental Health, Part A, 67(20-22), 1591-1617.; Medema et al. (2003). Safe drinking water: an ongoing challenge. In: Assessing Microbial Safety of Drinking Water. WHO/ OEDC, London.

through the landscape.[16] By promoting infiltration, buffers increase the transfer of runoff water to groundwater.[17] This means the water is available more consistently over time, as opposed to being lost in a sudden rush after it rains.

The world's increasing population will continue to place pressure on the availability of clean and reliable water supply.[18] Alterations to rainfall/runoff patterns associated with climate change may also exacerbate water scarcity and unpredictable flow regimes.[19] Therefore, buffers are important for long-term sustainability of stream flow, and changes in the hydrologic regime as a result of land use alterations can have far-reaching effects on local communities that rely on consistent drinking water sources.

Riparian Buffers Reduce Costs Associated with Flood Protection

Floods are the most expensive natural disasters affecting the U.S., and billions of tax dollars are spent annually on flood preparedness, stormwater control infrastructure, construction and operation of structural flood controls, flood insurance claims and aid, and crop loss payments.[20] Riparian buffers reduce the cost of flooding by decreasing the frequency of flooding through storage and infiltration, by eliminating the need for expensive stormwater infrastructure, and by reducing the damage caused by flooding through flow attenuation and avoidance. Requiring appropriate buffer widths also ensures we are not building too close to our streams so that homes and businesses are not located in floodprone areas.

16 Brauman et al. (2007). The nature and value of ecosystem services: an overview highlighting hydrologic services. Annu. Rev. Environ. Resour., 32, 67-98.; Ward JV. (1989). The 4-dimensional nature of lotic ecosystems. J. North Am. Benthol. Soc. 8:2–8.

17 Water et al. (2008) EPA 600/R-07/058, www. epa. gov/ada United States Environmental Protection Agency Assessment of Near-Stream.; Millenn. Ecosyst. Assess., ed. (2005). Ecosystems and Human Well-Being: Current State and Trends. Vol. 1. Washington, DC: Island; Smakhtin VU. (2001). Low flow hydrology: a review. J. Hydrol. 240:147–86.; 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.

18 Vörösmarty et al. (2010). Global threats to human water security and river biodiversity. Nature, 467(7315), 555-561.; Vörösmarty et al. (2004). Humans transforming the global water system. Eos, Transactions American Geophysical Union, 85(48), 509-514.

19 Vörösmarty et al. (2010). Global threats to human water security and river biodiversity. Nature, 467(7315), 555-561.

20 Conrad, D. R. (1998). Higher Ground: A Report on Voluntary Property Buyouts in the Nation's Floodplains: a Common Ground Solution Serving People at Risk, Taxpayers and the Environment. National Wildlife Federation.

Conventional development alters stormflow by causing higher surface runoff and lowering infiltration.[21] For example, modeling results show that conventional development can increase the runoff depth of a 2-year storm by 55% compared to pre-development (natural) conditions.[22] Consequently, the frequency of flood events will increase. After conventional development, the occurrence of the runoff depth expected with a 25-year storm increases from 4% to 10%.[23] Riparian buffers in conjunction with Low Impact Development (LID) utilize natural processes to reduce the volume of runoff as well as reducing flood peaks.[24]

Vegetated buffers intercept runoff, infiltrate a portion of the runoff into the soil, and evaporation a portion into the air. By keeping the water onsite as part of the natural system, the runoff is detained until the peak of the storm is past, and then released slowly back into the channel, but at a rate at which the ecosystem can absorb it without overflowing. Particularly when coupled with modern stormwater practices focused on reducing the volume of runoff and enhancing natural conditions, buffers reduce surface runoff by maximizing runoff losses through infiltration, evapotranspiration, and groundwater recharge.

Since riparian vegetation plays an important role in ensuring storm flows are stored, developed areas with preserved and restored buffers may require less or smaller-sized stormwater infrastructure.[25] This fact is widely recognized, and many state and local stormwater management programs, including Pennsylvania's, allow for the "crediting" of stormwater that is discharged to intact riparian buffers. Furthermore, riparian buffers are less expensive to construct than storm drainage systems. Stormwater drainage infrastructure includes drains, pipes, inlet structures, curbs, gutters, sanitary sewers, water

Riparian buffers reduce the cost of flooding by decreasing flood frequency, by eliminating the need for expensive stormwater infrastructure, and by reducing flood damages.

Riparian buffers reduce surface runoff by maximizing runoff losses through infiltration, evapotranspiration, and groundwater recharge.

Riparian buffers are less expensive to construct than storm drainage systems.

21 Konrad, C. P., & Booth, D. B. (2005). Hydrologic changes in urban streams and their ecological significance. In American Fisheries Society Symposium (Vol. 47, pp. 157-177).; Booth, D. B. (2005). Challenges and prospects for restoring urban streams: a perspective from the Pacific Northwest of North America: BRIDGES Journal of the North American Benthological Society, 24(3), 724-737.

22 Wang et al. (2010). Low Impact Development Design—Integrating Suitability Analysis and Site Planning for Reduction of Post-Development Stormwater Quantity. Sustainability, 2(8), 2467-2482.

23 Wang et al. (2010). Low Impact Development Design—Integrating Suitability Analysis and Site Planning for Reduction of Post-Development Stormwater Quantity. Sustainability, 2(8), 2467-2482.; Booth, D. B., & Jackson, C. R. (1997). URBANIZATION OF AQUATIC SYSTEMS: DEGRADATION THRESHOLDS, STORMWATER DETECTION, AND THE LIMITS OF MITIGATION1.

24 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.

25 Miller, A.E. and 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; 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.

mains, and detention basins. The costs associated with traditional stormwater infrastructure range from $500 to $10,000 per acre with similar amounts in maintenance costs over 20 years.[26] Alternatively, existing riparian buffers provide these services for free, and the cost of establishing new buffers is approximately $500 per acre with the cost of maintenance approximately 10% of that.[27] For example, Fairfax County, Virginia was able to avoid $57 million in stormwater management costs by retaining forested riparian buffers. Therefore, buffers provide economic benefits in the form of cost savings and cost avoidance as a result of reducing the length of infrastructure needed and the maintenance required.

Riparian buffers also have the economic benefit of reducing flood-related damage by avoidance. The dissipative effect of streamside vegetation reduces flood damages since high velocity floodwaters are associated with substantial flood damages.[28] In addition to reducing the impact of floodwaters, the protection of riparian buffers prevents storm damage by deterring the placement of buildings, roadways, and other man-made structures vulnerable to storm-related damage in areas adjacent to waterways where they can be damaged by flooding. Since the federal government assumes a primary role in disaster relief, the public essentially subsidizes those harmed by flooding. Avoidance is the best and most cost-effective way to prevent flood damage costs.

Riparian Buffers Reduce Costs Associated with Erosion and Soil Loss

Vegetated riparian buffers protect and support stream banks by resisting erosive forces and helping to stabilize the soil. Increased runoff volume from development increases the risk of erosion which subsequently causes channel incision and sediment transport downstream. Erosion is costly - it is a literal washing away of the landscape, and it causes degradation of aquatic ecosystems, as well as problems associated with sediment accumulation downstream.[29] Sedimentation poses economic concerns by contributing to

26 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.

27 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.

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

29 Telles et al. (2013). Valuation and assessment of soil erosion costs. Scientia Agricola, 70(3), 209-216.; Pimentel et al. (1995). Environmental and economic costs of soil erosion and conservation benefits. SCIENCE-NEW YORK THEN WASHINGTON-, 1117-1117.

increased water treatment costs, reduced reservoir storage capacity, decreased efficiency of hydroelectric power plants, damages associated with siltation of roadways, sewers, and basements, and loss of water availability for navigation. The U.S. spends approximately $5 billion annually on soil conservation practices to limit soil losses from agricultural fields,[30] and damage costs associated with soil erosion have been estimated to be as high as $40 billion annually.[31] Vegetated buffers reduce erosion and therefore prevent public and private lands from being washed away, reduce the costs associated with erosion control, and minimize the harms associated with sedimentation downstream.

Riparian buffers provide economic benefits in the form of cost savings and cost avoidance.

The root systems of vegetation in buffers hold riparian lands in place, while at the same time maintaining the hydraulic roughness of the bank and slowing flow velocities in the stream near the bank.[32] The root systems of woody shrubs and trees, compared to turf grass, do a better job of anchoring soils, and rates of erosion are less for reaches bordered by forests compared to reaches without trees.[33] The loss of riparian trees results in higher rates of erosion and channel migration.[34] Major bank erosion is 30 times more prevalent on non-vegetated streamside land as on vegetated banks.[35]

Erosion washes away both public and private lands. Severe erosion and bank instability can cause an entire slope to fall downward, eliminating acres of hillside land. Stabilizing

Riparian buffers reduce erosion, reducing the costs associated with erosion control, and minimizing the harms associated with sedimentation downstream.

30 Heathcote et al. (2013). Watershed sediment losses to lakes accelerating despite agricultural soil conservation efforts. PloS one, 8(1), e53554

31 Telles et al. (2011). The costs of soil erosion. Revista Brasileira de Ciência do Solo, 35(2), 287-298.; Uri, N. D. (2001). The environmental implications of soil erosion in the United States. Environmental monitoring and assessment, 66(3), 293-312.

32 Gurnell, A. (2014). Plants as river system engineers. Earth Surface Processes and Landforms, 39(1), 4-25. ; Gumiere et al. (2011). Vegetated filter effects on sedimentological connectivity of agricultural catchments in erosion modelling: a review. Earth Surface Processes and Landforms, 36(1), 3-19.; Allmendinger et al. (2005). The influence of riparian vegetation on stream width, eastern Pennsylvania, USA. Geological Society of America Bulletin, 117(1-2), 229-243.; Zaimes et al. (2004). Stream bank erosion adjacent to riparian forest buffers, row-crop fields, and continuously-grazed pastures along Bear Creek in central Iowa. Journal of Soil and Water Conservation, 59(1), 19-27.

33 Allmendinger et al. (2005). The influence of riparian vegetation on stream width, eastern Pennsylvania, USA. Geological Society of America Bulletin, 117(1-2), 229-24; Micheli et al. (2004). Quantifying the effect of riparian forest versus agricultural vegetation on river meander migration rates, Central Sacramento River, California, USA. River Research and Applications, 20(5), 537-548.; National Research Council, Water, Science, and Technology Board, Board of Environmental Studies and Technology, "Riparian Areas: Functions and Strategies for Management". 2002.

34 Allmendinger, N.E. (1999). Changes in the Sediment Budget and Stream Channel Geometry as a Result of Suburban Development of the Good Hope Tributary Watershed, Colesville, Maryland 1951-1996. M.S. Thesis, University of Delaware, Newark, Delaware, 92 pp.; Beeson, C. E., & Doyle, P. F. (1995), COMPARISON OF BANK EROSION AT VEGETATED AND NON-VEGETATED CHANNEL BENDS. JAWRA Journal of the American Water Resources Association, 31: 983–990. doi: 10.1111/j.1752-1688.1995.tb03414.x

35 Beeson, C. E., & Doyle, P. F. (1995), COMPARISON OF BANK EROSION AT VEGETATED AND NON-VEGETATED CHANNEL BENDS. JAWRA Journal of the American Water Resources Association, 31: 983–990. doi: 10.1111/j.1752-1688.1995.tb03414.x

hillside land can be expensive to property owners.[36] Mere land loss is not eligible for government assistance. As land washes away, buildings and critical infrastructure can also be damaged or threatened.[37] Houses and roads can be washed away, bridge foundations can be undermined, utilities can be damaged, and communities can be isolated.

Because of increased erosion, streambanks without buffers are more likely to be the source of suspended sediments which degrades water quality.[38] Too much sediment in the water column can also fill stream bottom habitats, smother aquatic invertebrates at the base of the food chain, and resulting in cascading impacts on dependent species such as fish. An analysis of a Maryland watershed showed that upland erosion and channel enlargement produced 70% to 80% of the stream's total sediment yield.[39]

Additionally, erosion from croplands results in over 900 million tons of soil loss in the U.S. which reduces soil fertility and negatively affects agricultural productivity.[40] Losses to farm income as a result of soil erosion have been conservatively estimated to be at least $100 million per year.[41] Farmers can use riparian buffers to help control soil erosion, reduce wind erosion of topsoil, reduce noise and odors, and improve the aesthetic appearance of the landscape.[42]

In addition to land loss, sediment that is eroded into streams and rivers cause significant off-site and downstream impacts due to sedimentation. Siltation of waterways and navigational channels reduces reservoir storage capacity, reduces hydroelectric production efficiency, shortens the life and increases the maintenance costs of dams, and results

36 See Vermont's NPR news Source, "Few Options for Homeowners after Irene washed away land" July 15, 2013. Retrieved from: http://digital.vpr.net/post/few-options-homeowners-after-irene-washed-away-land

37 Swanson et al; Center for Watershed Protection, "Impacts of Impervious Cover on Aquatic Systems", Watershed Protection Research Monograph No. 1, March 2003.

38 Allmendinger et al. (2007). A Sediment Budget for an Urbanizing Watershed, 1951-1996, Montgomery County, Maryland, USA 1. JAWRA Journal of the American Water Resources Association, 43(6), 1483-1498.; Wilson et al. (2008). Quantifying relative contributions from sediment sources in Conservation Effects Assessment Project watersheds. Journal of Soil and Water Conservation, 63(6), 523-532.

39 Allmendinger et al. (2007). A Sediment Budget for an Urbanizing Watershed, 1951-1996, Montgomery County, Maryland, USA 1. JAWRA Journal of the American Water Resources Association, 43(6), 1483-1498.

40 Tegtmeier, E. M., & Duffy, M. D. (2004). External costs of agricultural production in the United States. International Journal of agricultural sustainability, 2(1), 1-20.; Pimentel et al. (1995). Environmental and economic costs of soil erosion and conservation benefits. SCIENCE-NEW YORK THEN WASHINGTON-, 1117-1117.

41 CROSSON, P. (2007) Soil quality and agricultural development. In: EVENSON, R. & PINGALI, P., eds. Handbook of agricultural economics. Agricultural development: Farmers, farm production and farm markets. Amsterdam, North-Holland. v.3. p.2911-2932.

42 Lovell, S. T., & Sullivan, W. C. (2006). Environmental benefits of conservation buffers in the United States: evidence, promise, and open questions. Agriculture, ecosystems & environment, 112(4), 249-260.; USDA. National Conservation Buffer Initiative Question and Answers. Retrieved from: http://www.creppa.org/pdf/home/National%20Conservation%20Buffer%20Initiative.pdf

in commercial shipping damages due to inland grounds, delays and engine problems. Dredging is very expensive, and the financial burden falls on the public. For example, 130 million m^3 of sediments are dredged annually from ports and channels in the U.S.[43] at a cost of over $520 million.[44] Furthermore, estimated reservoir siltation costs range from $274 to $851 million.[45] The most significant factor affecting annual sedimentation of reservoirs is the quantity of sediments that flow into reservoirs which is directly linked to the rate of erosion upstream. Analysis shows that it would be more economical to fund management practices that reduce erosion and sedimentation than to rely on continual dredging.[46] For example, a one-ton reduction in soil erosion can conserve up to $1.38 in reservoir benefits which equates to up to $154 million saved over a 15 year period.[47]

Major bank erosion is 30 times more prevalent on non-vegetated streamside land as on vegetated banks.

Riparian buffers protect soils and stabilize stream banks. This service provided by buffers reduces the risks associated with increased runoff from development and the damages caused by sediments from upstream erosion. Sedimentation has economic impacts through increased costs associated with damages. Conversely, soil conservation practices have an overall net economic benefit, not only by saving these damage costs, but also by increasing agriculture productivity and preventing land loss. Riparian buffers are literally the glue that holds together nature's design.

Riparian buffers help control soil erosion, reduce wind erosion of topsoil, reduce noise and odors, and improve the aesthetic appearance of the landscape.

Riparian Buffers Increase Aesthetic Value

Riparian buffers also have aesthetic value that enhances quality of life and itself can translate into economic benefit. The aesthetic value of buffers can have a direct economic impact through increased property values, increased business sales, and increased livability, as well as indirect economic impact through increased health due to pollution-reduction benefits, reduced crime rates, enhanced recreational opportunities, and higher visitor satisfaction.

Riparian buffers can also increase property values. For example, Philadelphia's Pennypack Park is comprised of approximately 1,600 acres of woodlands, meadows, and wetlands. The central feature of this linear park is the Pennypack Creek and its vegetated riparian buffers.

Riparian buffers reduces the risks associated with increased runoff from development and the damages caused by sediments from upstream erosion.

43 Lewis et al. (2001). Dredging impact on an urbanized Florida bayou: effects on benthos and algal-periphyton. Environmental Pollution, 115(2), 161-171.

44 Pimentel et al. (1995). Environmental and economic costs of soil erosion and conservation benefits. SCIENCE-NEW YORK THEN WASHINGTON-, 1117-1117.

45 Tegtmeier, E. M., & Duffy, M. D. (2004). External costs of agricultural production in the United States. International Journal of agricultural sustainability, 2(1), 1-20.

46 Williams, J. R., & Smith, C.M. (2008) Economic Issues of Watershed Protection and Rehabilitation. In Hargrove, W.L., Editor. Sedimentation in Our Reservoirs: Causes and Solutions. Kansas State University Agricultural Experiment Station and Cooperative Extension Service, Manhattan, KS.

47 Hansen, L., & Hellerstein, D. (2007). The value of the reservoir services gained with soil conservation. Land economics, 83(3), 285-301.

The aesthetic value of riparian buffers can have a direct economic impact through increased property values, increased business sales, and increased livability.

The stream buffer network in the Pennypack park area of Philadelphia accounted for 33% of the land value of properties located within 40 feet of the park and 9% of the value of those located within 1,000 feet.[48]

Conserving forests and planting trees on residential and commercial sites enhances property values up to 37%.[49] Properties adjacent to water bodies command a price premium, but a buffer design incorporating a view corridor could potentially enhance the aesthetics by framing the water view, resulting in an even higher sales price. Furthermore, water quality has a significant effect on property values.[50] Riparian habitat increases property values more so than just planting trees because homebuyers differentiate between the healthy riparian buffers and manmade "green" areas such as golf courses.[51] Any increase in property value results in an increase in property tax revenue which therefore benefits the community as a whole.

Studies of the effects of riparian buffer protection regulations on property values are limited, but current research suggests property values are not affected by riparian buffer ordinances.[52] Despite being a restriction on land use, the water quality benefits that accrue from buffer protections may even have a positive effect on property values.[53]

Riparian habitat increases property values more so than just planting trees.

Landowners can also gain some non-market amenities from riparian buffers. For example, under its Long-Term Watershed Protection Program, New York City has invested $1.5 billion to protect and restore the watershed of its drinking water supply – reservoirs in the Upper Delaware. Participating watershed land owners, who curb streambank erosion and riparian habitat degradation, are paid for the water quality services they provide.[54] In addition to the benefit of healthy streams, residents in the Watershed Protection Program area

Riparian buffers can reduce heating and cooling costs for buildings and homes by providing shade, windbreaks, and winter cover.

48 Hammer et al. (1974). The effect of a large urban park on real estate value. Journal of the American Institute of Planners, 40(4), 274-277.).

49 Foster et al. (2011) The value of green infrastructure for urban climate adaptation. Rep. Center for Clean Air Policy. Retrieved from: http://dev.cakex.org/sites/default/files/Green_Infrastructure_FINAL.pdf

50 Liu et al. (2014). Estimating the impact of water quality on surrounding property values in Upper Big Walnut Creek Watershed in Ohio for dynamic optimal control. AAEA Annual Meeting, Minneapolis, MN, July 27-29, 2014; Leggett, C. G., & Bockstael, N. E. (2000). Evidence of the effects of water quality on residential land prices. Journal of Environmental Economics and Management, 39(2), 121-144.

51 Bark et al. (2009). Habitat preservation and restoration: Do homebuyers have preferences for quality habitat?. Ecological economics, 68(5), 1465-1475.

52 Maurer, K., & Soldavini, S. (2013). The Influence of Riparian Setbacks On Private Property Values: Hedonic Price Analysis of Riparian Properties in Jackson County, Oregon. Department of Economics, University of Oregon.

53 Bin et al.(2009). Riparian buffers and hedonic prices: a quasi-experimental analysis of residential property values in the Neuse River basin. American Journal of Agricultural Economics, 91(4), 1067-1079.

54 Postel, S. L., & Thompson, B. H. (2005, May). Watershed protection: Capturing the benefits of nature's water supply services. In Natural Resources Forum (Vol. 29, No. 2, pp. 98-108). Blackwell Publishing, Ltd..

receive economic benefits through loans and grants for environmentally sustainable economic development.[55]

In agriculturally dominated areas, forested riparian buffers increase the diversity of views and heterogeneity of the landscape.[56] Buffers can reduce heating and cooling costs for buildings and homes by providing shade, windbreaks, and winter cover.[57]

In addition to individual landowner benefits, there are many business benefits to riparian buffers through perceived higher quality livability which translates into increased sales and higher rental rates. Rivers and greenways in the form of riparian buffers contribute to quality of life. People prefer natural environments with a preference for trees[58] and clean water,[59] characteristics of healthy and functioning riparian areas. Quality of life is a major factor in corporate and business location decisions and retention rates since the use of adjacent greenways is a benefit to employees for exercise and relaxation.[60] Office locations adjacent to rivers are more attractive to prospective tenants, therefore commanding higher rental rates. Additionally, waterfront development which uses green infrastructure can preserve, improve, or restore the environmental services of a healthy watershed,[61] resulting in a return of monetary investment through an increase in business and greater worker productivity. For example, shoppers will travel further, stay longer, and be willing to pay higher prices for goods in green communities.[62] Furthermore, green

55 Postel, S. L., & Thompson, B. H. (2005, May). Watershed protection: Capturing the benefits of nature's water supply services. In Natural Resources Forum (Vol. 29, No. 2, pp. 98-108). Blackwell Publishing, Ltd..

56 Kenwick et al. (2009). Preferences for riparian buffers. Landscape and Urban Planning, 91(2), 88-96.; Hoover et al. (1985). A wilderness riparian environment: visitor satisfaction, perceptions, reality, and management. Riparian ecosystems and their management: reconciling conflicting uses. USDA Forest Service General Technical Report RM-120. USDA, Fort Collins, CO.; Alliance for Community Trees. Benefits of Trees and Urban Forests. Retrieved from: www.actrees.org/files/Research/benefits_of_trees.pdf

57 Klapproth, J. C., & Johnson, J. E. (2001). Understanding the science behind riparian forest buffers: benefits to communities and landowners. Virginia Cooperative Extension.

58 Sullivan W.C. (1994) 'Perceptions of the rural-urban fringe: citizen preferences for natural and developed settings' Landscape and Urban Planning Vol. 29, pp. 85-101.

59 Sullivan et al. (2004) 'Agricultural buffers at the rural-urban fringe: an examination of approval by farmers, residents, and academics in the Midwestern United States' Landscape and Urban Planning Vol. 69, pp. 299-313.

60 Rivers, T., & Assistance, C. (1995). Economic Impacts of Protecting Rivers, Trails, and Greenway Corridors. Retrieved from: http://www.nps.gov/pwro/rtca/econ_index.htm

61 Aerts, J. C., & Wouter Botzen, W. J. (2011). Flood-resilient waterfront development in New York City: Bridging flood insurance, building codes, and flood zoning. Annals of the New York Academy of Sciences, 1227(1), 1-82.

62 Wolf, K. L. (2007). The environmental psychology of shopping. Research Review, 14(3), 39.; Wolf, K. L. (2005). Business district streetscapes, trees, and consumer response. Journal of Forestry, 103(8), 396-400.; Wolf, K. L. (2003). Public response to the urban forest in inner-city business districts. Journal of Arboriculture, 29(3), 117-126.

Both residents and planners prefer riparian buffers in both suburban and rural landscapes.

Riparian buffers provide air pollution-reduction benefits.

Riparian buffers are ideal locations for hiking, birding, camping, fishing, boating, hunting, picnicking, swimming, and wildlife viewing.

infrastructure and exposure to natural areas can enhance worker productivity[63] and promote community well-being and participation.[64] Both residents and planners prefer riparian buffers in both suburban and rural landscapes.[65] However, the preference is for ecologically-functional riparian habitat and not arbitrary "green" open space.[66]

In addition to these direct benefits, indirect economic benefits result from riparian buffers from improvements in health and the prevention of health hazards. There is a growing trend to increase the amount of naturalized open spaces including riparian buffers because of the social-economic benefits which include stress reduction and mitigation,[67] recovery from fatigue and attention deficit symptoms in both adults and children,[68] and increased public safety.[69] Furthermore, vegetated open spaces appear to increase and foster social networks and relationships, factors which can result in less crime.[70] For example, in Philadelphia, substantially lower rates of assault, robbery, and burglary were associated with communities with higher vegetative abundance.[71]

The water quality benefits provided by riparian buffers prevent adverse effects on human health through the reduction of pollution of drinking water and the indirect health hazards associated with nitrogen, algal toxins, and

63 Kaplan, R. (1992) Urban forestry and the workplace. In Gobster, P.H. (Ed.). Managing Urban and High-Use Recreation Settings. USDA Forest Service, General Technical Report NC-163. North Central Forest Experiment Station, Chicago, IL.

64 Newton, J. L., & Sullivan, W. C., 2005. Nature, culture, and civil society. J. Civ. Soc. 1 (3), 195–209.

65 Kenwick et al. (2009) 'Preferences for riparian buffers' Landscape and Urban Planning Vol. 91, pp. 88-96.

66 Bark et al.(2009) 'Habitat preservation and restoration: Do homebuyers have preferences for quality habitat?' Ecological Economics Vol. 5, pp. 1465-1475.

67 Ulrich et al. (1991). Stress recovery during exposure to natural and urban environments. Journal of environmental psychology, 11(3), 201-230.; Ulrich, R. S. & Simons, R. F. (1986). Recovery from stress during exposure to everyday outdoor environments. In J. Wineman, R. Barnes & C. Zimring, Eds., Proceedings of the Seventeenth Annual Conference of the Environmental Design Research Association. Washington, D.C.: EDRA, pp 115 122.

68 Taylor et al. (2001). Coping with ADD The surprising connection to green play settings. Environment and Behavior, 33(1), 54-77.; Cimprich, B. (1993). Development of an intervention to restore attention in cancer patients. Cancer nursing, 16(2), 83-92.; Kaplan, R., & Kaplan, S. (1989). The experience of nature: A psychological perspective. CUP Archive.

69 Troy et al. (2012). The relationship between tree canopy and crime rates across an urban–rural gradient in the greater Baltimore region. Landscape and Urban Planning, 106(3), 262-270.; Wolfe, M. K., & Mennis, J. (2012). Does vegetation encourage or suppress urban crime? Evidence from Philadelphia, PA. Landscape and Urban Planning, 108(2), 112-122.; Kuo, F. E., & Sullivan, W. C. (2001). Environment and crime in the inner city does vegetation reduce crime?. Environment and Behavior, 33(3), 343-367.

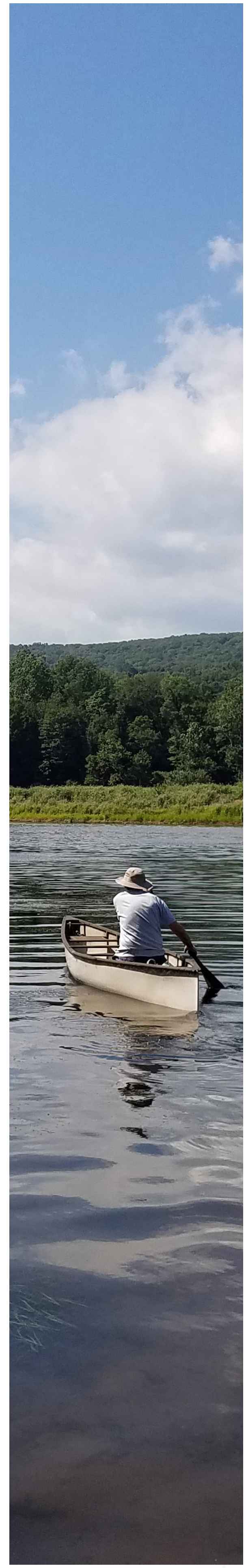
70 Kuo, F. E. (2003). The role of arboriculture in a healthy social ecology. Journal of Arboriculture, 29(Part 3), 148L 155.; Sullivan, W. C., & Kuo, F. E. (1996). Do trees strengthen urban communities, reduce domestic violence? (Vol. 4). Northeastern Area State and Private Forestry, Urban Forestry Center for the Midwestern States.

71 Wolfe, M. K., & Mennis, J. (2012). Does vegetation encourage or suppress urban crime? Evidence from Philadelphia, PA. Landscape and Urban Planning, 108(2), 112-122.

other water pollutants.[72] In addition to providing clean water, trees and vegetation in riparian buffers provide air pollution-reduction benefits. For example, computer simulations show that trees and forests in the U.S. prevent approximately 850 deaths and 670,000 incidences of acute respiratory symptoms.[73] Human sickness caused by environmental pollution results in lost wages and work days and increased medical treatment costs. This scientific evidence confirms that exposure to natural and healthy ecosystems is associated with indirect economic impact through psychosocial and human health benefits that are shared by both communities and individuals.

Riparian Buffers Provide Tourism Revenue and Recreational Opportunities

Healthy riparian areas with forested buffers are characterized by a combination of diverse wildlife, a mixture of land and water with movement, reflections and color, and features such as rapids, scenic vistas, and sinuous topography. These attributes, generally prevalent in areas characterized by healthy riparian buffers, are given the highest desirability rates by recreational users[74] and make these locations ideal for numerous recreational activities including hiking, birding, camping, fishing, boating, hunting, picnicking, swimming, and wildlife viewing. The outdoor recreation economy in the U.S. supports 6.1 million jobs and generates $646 billion in direct spending each year.[75] Ecotourism is on the increase worldwide, and predictions suggest that it will continue to increase.[76] According to the Outdoor Industry Foundation, "more Americans paddle (canoe, kayak, raft) than play soccer," and "more Americans camp than play basketball."[77] Recreation and tourism provide revenue to local economies as well as support for both scientific research and protection of ecologically important habitats.



72 Camargo, J. A., & Alonso, Á. (2006). Ecological and toxicological effects of inorganic nitrogen pollution in aquatic ecosystems: a global assessment. Environment international, 32(6), 831-849.; Wolfe, A. H., & Patz, J. A. (2002). Reactive nitrogen and human health: acute and long-term implications. AMBIO: A Journal of the Human Environment, 31(2), 120-125.

73 Nowak et al. (2014) Tree and forest effects on air quality and human health in the United States. Environmental Pollution. 193: 119-129.

74 Klapproth, J. C., & Johnson, J. E. (2001). Understanding the science behind riparian forest buffers: benefits to communities and landowners. Virginia Cooperative Extension.; Hoover et al. (1985). A wilderness riparian environment: visitor satisfaction, perceptions, reality, and management. Riparian ecosystems and their management: reconciling conflicting uses. USDA Forest Service General Technical Report RM-120. USDA, Fort Collins, CO.

75 The White House Blog. "The Land and Water Conservation Fund and the Wilderness Act Turn 50." Retrieved from: http://www.whitehouse.gov/blog/2014/09/03/land-and-water-conservation-fund-and-wilderness-act-turn-50

76 Burger, J. (2000). Landscapes, tourism, and conservation. Science of the total environment, 249(1), 39-49.

77 The Outdoor Industry Foundation. (2006) The Active Outdoor Recreation Economy: A $730 Billion Annual Contribution to the U.S. Economy. Available at: https://outdoorindustry.org/images/researchfiles/RecEconomypublic.pdf?26

Riparian buffers provide for public recreational uses that are compatible with all of the other water quality and flood protection benefits they provide.

Riparian buffers provide for public recreational uses that are compatible with all of the other water quality and flood protection benefits they provide. The most popular river activities include fishing, boating, and bird watching, all activities which provide tourism revenue (see Figure 1). The total economic contribution of fishing in Pennsylvania, New York, and New Jersey exceeds $3 million, and another $2.5 million is supplied from paddle based recreation.[78] An additional $2 million is spent on the gear to support these industries, and $3 million more is generated from related travel.[79] Furthermore, nearly $750,000 is generated in state and federal taxes on all of these water recreation income streams.[80]

Healthy riparian buffers are important for supporting healthy fish populations – providing the food, habitat, pollution protection, and temperature control fish need for sustainable lives. Therefore, the benefit of buffers for fishing-based recreation and ecotourism is closely connected

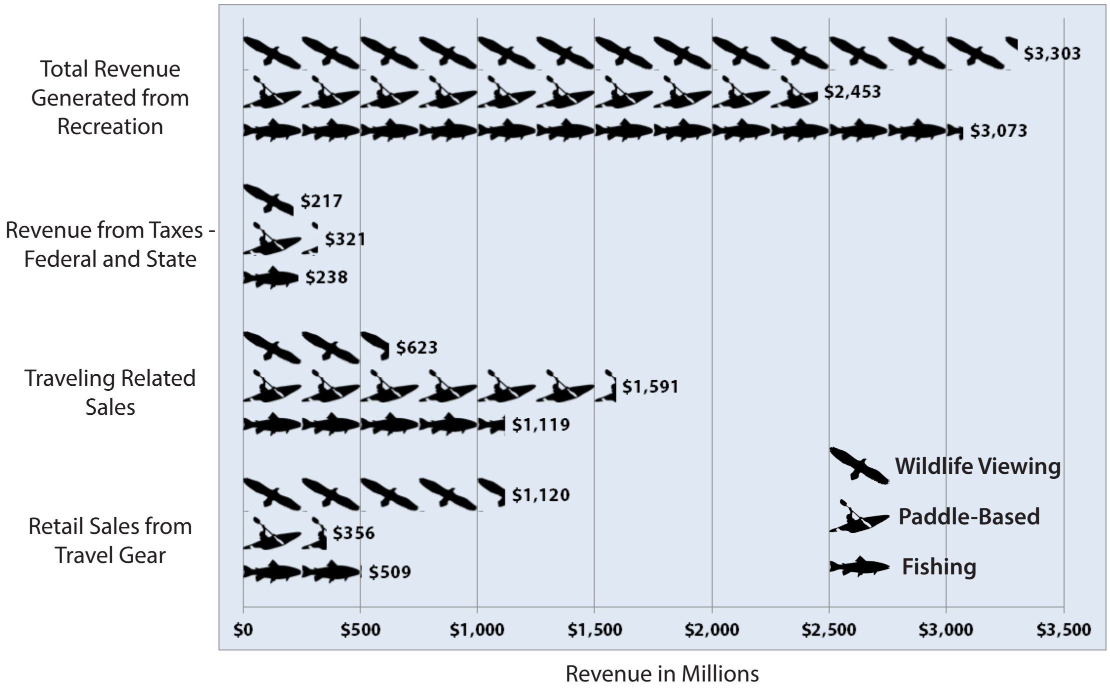


Figure 1: The amount of money spent on recreation purposes in the tristate area and how it breaks down by recreational category.

Adapted from a chart published in *River values: The value of a clean and healthy Delaware River*, Delaware Riverkeeper Network, April 2010.

The scenic beauty that buffers provide also plays an important role in attracting and supporting paddle based recreation.

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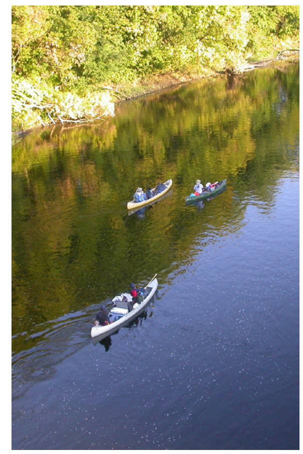
78 Pawelko et al. (1995). Examining the nature of river recreation visitors and their recreational experiences on the Delaware River. In Proceedings of the 1995 Northeastern recreation research symposium. USDA Forest Service GTR-NE-218 (pp. 43-49).

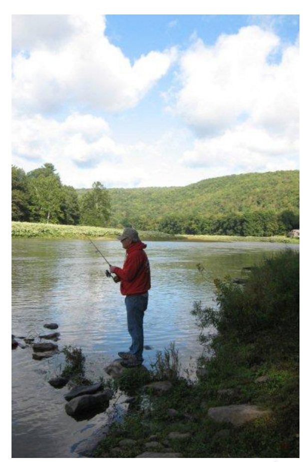
79 Pawelko et al. (1995). Examining the nature of river recreation visitors and their recreational experiences on the Delaware River. In Proceedings of the 1995 Northeastern recreation research symposium. USDA Forest Service GTR-NE-218 (pp. 43-49).

80 Pawelko et al. (1995). Examining the nature of river recreation visitors and their recreational experiences on the Delaware River. In Proceedings of the 1995 Northeastern recreation research symposium. USDA Forest Service GTR-NE-218 (pp. 43-49).

with the economic benefits of this favored American past time. In 2006, the U.S. Fish & Wildlife Service reported that fishing was the "favorite recreational activity in the United States" with 13% of those 16 and older (nearly 30 million anglers) spending an average of 17 days fishing a year and more than $40 billion on trips, equipment, licenses, and other items to support their fishing activities.[81] Forty-four percent of that money ($17.8 billion), was spent on items related to their trips, including food, lodging and transportation.[82] In the Upper Delaware River, wild trout fishing resulted in over $17 million for local business revenue in 1996, and $7.25 million (41%) of this spending by anglers remained in the local communities surrounding the tail water fisheries area (Hancock, Deposit, Walton, and the Village of Downsville).[83] Angler expenditures in these communities ultimately resulted in nearly $30 million in local economic activity which supported 348 jobs with total wages of $3.65 million; and provided $719,350 in local taxes.[84] Furthermore, nearby towns benefited from the clean water and resulting healthy fish populations found in tributary streams. For example, the Beaverkill and Willowemoc Rivers were credited with providing towns such as Roscoe and Livingston Manor with $10 million in annual expenditures from their sport fishery.[85]



More recently, the famous Upper Delaware fishery was conservatively estimated to generate a minimum of $21 million in non-property value impacts annually.[86] Property value impacts of the fishery for the study area (a market area five to 10 miles in width along 77.9 miles of the Delaware River and its East and West Branches, taking in land in two states and four counties in the Upper Delaware region) were placed at $109 million.[87]



81 US Fish and Wildlife Service. (2006). National Survey of Fishing, Hunting, and Wildlife-Associated Recreation, National Overview. (Preliminary Findings) May 2007. p. 5.

82 US Fish and Wildlife Service. (2006). National Survey of Fishing, Hunting, and Wildlife-Associated Recreation, National Overview." (Preliminary Findings) May 2007. p. 5.

83 Maharaj et al. (1998). The economic impact of trout fishing on the Delaware River Tailwaters in New York. Alexandria (VA): American Sportfishing Association and Trout Unlimited..

84 Maharaj et al. (1998). The economic impact of trout fishing on the Delaware River Tailwaters in New York. Alexandria (VA): American Sportfishing Association and Trout Unlimited..

85 Maharaj et al. (1998). The economic impact of trout fishing on the Delaware River Tailwaters in New York. Alexandria (VA): American Sportfishing Association and Trout Unlimited..

86 Shepstone Management Company, Inc. (2014). Upper Delaware River Cold Water Fishing & Boating. Delaware County Department of Economic Development and Friends of the Upper Delaware River.

87 Shepstone Management Company, Inc. (2014). Upper Delaware River Cold Water Fishing & Boating. Delaware County Department of Economic Development and Friends of the Upper Delaware River.

Riparian buffers are ideal locations for connective corridors to mitigate fragmentation and increase biodiversity.

For some of the services provided by riparian buffers, there are no direct price mechanisms to quantify the benefits we receive.

The scenic beauty that vegetated buffers provide also plays an important role in attracting and supporting paddle based recreation. Canoeing and kayaking are significant economic drivers in the communities in which they are pursued, which tend to be along the well vegetated and beautiful creeks of a region. There are numerous canoe liveries along the Delaware River which combined employ over 200 people.[88] Individual liveries report annual attendances of approximately 60,000 to 70,000 people.[89] Rates for tubing at one livery (Bucks County River Country) range from $25 to $29 a trip in 2018; a family of four could go rafting for $140 to $172. Canoe and kayak rentals range from $35 to $58.[90] With an estimated 225,000 annual trips,[91] the estimated gross revenue from liveries ranges from$4.2 million to $11.2 million. Canoe liveries cater to family fun, and afford families a full day on the water together—relaxing, fishing, reading, and sunbathing—experiences that engender greater appreciation for rivers.

In addition to generating revenue, recreational opportunities generate jobs. According to the New Jersey Department of Fish and Wildlife, New Jersey state parks received 12 million visits in one year (1994), with wildlife recreation, fishing and hunting responsible for 75,000 jobs and $5 billion in retail sales.[92] Valley Forge National Historical Park, through which the Schuylkill River and tributary streams flow, created 1.23 million recreation visits in 2001 with park visitors spending "$33.3 million dollars within an hour's driving distance of the park, generating $10.4 million in direct personal income (wages and salaries) for local residents and supporting 713 jobs in the area."[93]

Increased tourism also generates revenue through new business development and visitor expenditures. New businesses are created in response to user demand, and concessionaires can cater to the many users of riparian buffer trails and river amenities. Tourists will then purchase additional goods and services from other

88 Kauffman, G. J. (2011). Socioeconomic Value of the Delaware River Basin in Delaware, New Jersey, New York, and Pennsylvania. Delaware River Basin Commission, West Trenton, NJ.

89 Jones, D. (Kittatinny Canoes). Telephone Interview. 14 November 2006; Breen, D. (Bucks County River Country). Telephone Interview. 21 February 2007.

90 http://www.rivercountry.net/Prices_ep_40.html

91 Kauffman, G. J. (2011). Socioeconomic Value of the Delaware River Basin in Delaware, New Jersey, New York, and Pennsylvania. Delaware River Basin Commission, West Trenton, NJ.

92 Eubanks, T., & Stoll, P. K. (2000). Wildlife-associated Recreation on the New Jersey Delaware Bayshore, The Economic Impact of Tourism Based on the Horseshoe Crab-Shorebird Migration in New Jersey. 16 February 2000. Prepared for the New Jersey Department of Environmental Protection.

93 Michigan State University. (2003). Impacts of Visitor Spending on the Local Economy: Valley Forge National Historical Park, 2001. Prepared for National Park Service Social Science Program and Department of Parks, Recreation and Tourism Resources.

local businesses. For example, for every dollar paid to a canoe livery, customers will also spend money on gas, food, and lodging. New recreation focused businesses and their employees purchase goods and services from other businesses.[94] Tourism therefore stimulates the local economy creating jobs and increasing household incomes.

The large economic benefits of ecotourism can also provide monetary and community support for enhanced and continued habitat protection and maintenance of biodiversity. Since habitat fragmentation is a major problem for conservation and preservation of biodiversity throughout the world, riparian buffers are ideal locations for connective corridors to mitigate fragmentation and increase biodiversity. In this way, recreation and tourism in riparian buffers can serve to garner support for preservation and restoration, and such recreational activity is typically compatible with preserving ecosystem structure and function. The protection and restoration of riparian buffers can increase biodiversity which will draw additional tourists from further away and provide an impetus for further protection and overall ecosystem management.

Riparian Buffers Provide Substantial Carbon Storage

Forested riparian buffers can play a critical role in our overall response to the threat from climate change. These benefits accrue in two ways. First, the forests and soils within protected riparian corridors become a major location for carbon capture and sequestration. Second, the protection of these forests from conversion to other land uses such as residential or commercial development or agriculture prevents the release of the stored carbon within both the forest vegetation and the soils themselves.

Recent efforts to quantify the magnitude of these carbon storage benefit has shown it to be among the most important economic valuations of riparian forests within the Delaware River watershed.[95] Using current market valuations for carbon storage, riparian forests can lead to benefits of $5,000 or more for a single acre every year. As the threats from climate change become increasingly dire, and as human societies struggle to find ways to prevent carbon release and store the high concentrations of carbon in the atmosphere, forested riparian buffers can be seen as a clear means to economically and sustainably provide for high local benefits while likewise providing benefits for society more broadly.

94 Rivers, T., & Assistance, C. (1995). Economic Impacts of Protecting Rivers, Trails, and Greenway Corridors. Retrieved from: http://www.nps.gov/pwro/rtca/econ_index.htm

95 Rempel, A., & Buckley, M. (2018). The Economic Value of Riparian Buffers in the Delaware River Basin. ECONorthwest, Portland, OR.

The Value of Buffers is Often Priceless

It is critical to understand the many ways in which the environmental benefits of buffers interact with economic factors and stakeholder preferences. One acre of riparian buffer provides monetized benefits of over $10,000 per acre per year.[96] Many of the services provided by buffers are non-marketable benefits making them difficult to assess monetarily.[97] Some services that healthy riparian ecosystems provide are free with no market value because no market exists in which they can be exchanged. Therefore, there are no direct price mechanisms to illustrate the degradation of these services until they fail. However, failing to incorporate both the market and non-market value of riparian buffers into decision-making about the management of watershed lands diminishes opportunities for societies to reap the full extent of benefits that can be derived from watersheds.

With their numerous potential economic impacts, vegetated riparian buffers should be recognized as vital to the well-being of both communities and the economy. The optimal buffer width may vary from site to site, but a policy calling for minimum 100-foot fixed-width buffers on both sides of a waterway is scientifically supported.

96 Rempel, A., & Buckley, M. (2018). The Economic Value of Riparian Buffers in the Delaware River Basin. ECONorthwest, Portland, OR.

97 Meyerson et al. (2005). Aggregate measures of ecosystem services: Can we take the pulse of nature? Front. Ecol. Environ. 3:56–59.

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 - Economic Service Providers. When you contact us, be sure to ask about our other resources on riparian buffers.

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