APPENDIX G

Effectiveness of Riparian Buffers on Water Quality:
A Brief Summary of Literature
DNREC, DWR, Watershed Assessment Section
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Riparian buffer zones have received considerable attention across the United States for their ability to provide habitat, mitigate floodwaters, and improve water quality. The effectiveness of buffers at achieving these goals, however, is often dependent on the type of vegetation utilized, the width of the buffer employed, and other factors such as the local hydrology and soils. Also of importance is the location of a stream within the watershed landscape, as headwater streams make up a large portion of total stream length and collectively influence downstream water quality conditions. There are hundreds of published research papers that address these issues and support the implementation of riparian buffers for water quality improvements. In addition, many literature reviews have been conducted, which summarize the findings and provide ranges of suitable buffer widths for removing various pollutants of concern.

Buffers are known to efficiently reduce particulate and dissolved nutrients like nitrogen and phosphorus in runoff and groundwater (Desbonnet et al., 1994; Wenger, 1999; Lowrance and Sheridan, 2005). The majority of the nutrients that enter a riparian buffer zone from upland agricultural and developed lands either become trapped in the soils, taken up by vegetation, or transformed by other processes, so that the actual amount of pollutants that reach receiving waters is greatly reduced.

Both nitrogen and phosphorus can adsorb onto sediment particles and be transported in surface runoff. This is the primary form of transport for phosphorus due to its chemical characteristics (Novak et al., 2002). Therefore, particulate P and N can be effectively removed through a buffer's sediment trapping mechanisms. Several studies have examined the effectiveness of buffers at removing sediment from surface runoff, with the general agreement that as buffer width increases, sediment removal increases (Cooper et al., 1987; Castelle et al. 1994; Wenger, 1999; Dosskey, 2001). Sediment, and the attached nutrients, can be trapped within a buffer by forest or grassy vegetation. The deep root structures of trees stabilize soils and promote further sedimentation. Grasses, on the other hand, are effective at minimizing runoff velocity and trapping sediment by maintaining sheet flow through the riparian zone. In high sedimentation environments, grassed buffers may become covered over time, which rapidly decreases their efficiency.

Nitrogen is primarily transported in the dissolved form, and within a buffer, it can be taken up by vegetation or permanently removed from the system through denitrification, a process through which microbial organisms in the soils and streambed reduce nitrate-N to nitrogen gas. Denitrification is likely the more significant mechanism of nitrate-N removal, however, several factors influence where the greatest amount of denitrification will occur (Peterjohn and Correll, 1984; Spruill, 2000). Denitrification rates are often greatest when the ground water table is near the surface and when carbon and nitrate-N are in good supply. These zones of high denitrification can be highly spatially variable and in order to capture as many zones as possible, and hence remove as much nitrate-N as possible, buffer width should be maximized (Jacobs and Gilliam, 1985; Lowrance, 1992).

Grass and forest buffers are both effective at removing N and P from runoff, however forests are more efficient at removing dissolved nutrients from groundwater (Osborn and Kovacic, 1993). Several studies have found that buffers that include both grass and forest zones have increased nutrient removal capacities (Dillaha et al., 1989; Lowrance et al., 2000 and 2005; Novak et al., 2002; Lee et al., 2003). Lee et al. (2003) studied three plots, one with no buffer, one with a grass buffer, and one with a grass buffer in conjunction with a woody buffer. The grass buffer was effective at removing sediment and sediment bound nutrients, but the combined grass-woody buffer reduced 20% more N and P than the grass buffer alone because the woody zone increased removal of soluble nutrients. Lowrance et al. (2005) studied the USDA recommended three zone buffer systems, where zone 1 is composed of grasses, zone 2 consists of a mixture of grass and woody species, and zone 3, closest to the stream, contains hardwood trees. They concluded that managed three zone buffers can reduce most of the nutrient loads entering streams.

Several recent studies have examined the importance of forest buffers on a larger, watershed scale (Spruill, 2000 and 2004; Sweeney et al., 2004). These researchers have found links between the extent of riparian forests in a watershed and the extent of pollutant removal occurring within buffers, as well as in the streambed and water column. This line of reasoning suggests that forest buffers not only act to prevent nonpoint source pollution from entering streams, but that they also enhance the processing of pollutants as they travel downstream.

This is possible for several reasons. First, forest buffers help to slow water flow, creating longer residence times so that more nutrients are processed out of the water column prior to reaching downstream rivers and estuaries. Secondly, streams with forested buffers tend to have wider channels due to stabilized banks, which are often not found when streams are buffered by only herbaceous grasses. Wider streams have a greater benthic surface area, so that removal of dissolved nutrients by sorption onto bottom sediments or uptake by the microbial communities on and in the streambed is increased. Finally, natural forest systems provide suitable amounts of woody debris to streams and this organic matter acts as food and energy for the ecosystem. The increased productivity increases nitrogen removal through denitrification and microbial uptake. These properties, which significantly enhance nutrient removal within bottom sediments and the water column, are especially important to create and preserve in streams that drain to sensitive ecosystems, like estuaries (Sweeney et al., 2004).

In addition to the improved in-stream processing of nutrients as a result of watershed-wide buffers, several researches have found that headwater streams are especially important to downstream water quality (Nadeau and Rains, 2007).

Headwater streams, although smaller in size, are typically more prevalent and make up a large portion of the total stream length. These waterways are closely connected to their catchment areas and the hydrologic and chemical nature of these streams are highly sensitive to changes in upland land use. Since water flows downhill, the processes that occur in headwater areas impact downstream conditions. Changes in the hydrological and biogeochemical processes in headwater regions may alter stream and groundwater flow paths, residence times, and the chemical nature of these waters (Alexander et al., 2007). Triska et al. (2007) found that dissolved nitrogen can efficiently be removed in headwater streams that have natural hydrology. Therefore, it is important to protect the hydrologic and biogeochemical nature headwater streams in order to protect the quality of downstream rivers and estuaries, which can be done by providing riparian buffers.

The water quality benefits of buffers as discussed above apply to buffers on both agricultural and urban lands. Buffers in urban settings can remove not only sediment and nutrients, but also other contaminates, such as hydrocarbons and metals, (Herson-Jones et al., 1995 as cited in Wenger, 1999). A common problem for urban buffers, though, is that water becomes concentrated and fast flowing over impervious surfaces, so that there is not adequate time for the effective removal of pollutants in the actual buffer. It is also common for urban buffers to be bypassed by water conveyance structures like stormwater discharge pipes. These concerns can be mitigated through the implementation of a pre-planning process before commencement of any construction activities (Palone and Todd, 1997; Schueler and Holland, 2000).

For example, in Delaware, a permanent sediment and stormwater management plan must be created when a proposed development project of a certain size reaches the conceptual stormwater plan process. These plans, when designed and implemented, should include green technologies to further reduce nutrient contributions from runoff in order to improve the quality of impaired receiving waters. Green technologies intercept runoff from rooftops, parking lots, roads, and other impervious surfaces and directs it into vegetative areas. Since vegetation is known to extract a fairly high percentage of pollutants, especially nutrients, from water, the stormwater is effectively cleaned before entering a stream or soaking into the ground. Examples of green technologies include rain gardens, bioretention facilities, and buffers (DNREC 2006).

Due to little pre-planning in the past, many urban streams now require restoration. Restorative projects are primarily done to improve water quantity problems, like flooding, that are the result of high levels of impervious surfaces and altered stream and groundwater flow paths. A study by Kaushal et al. (2008) found that stream restoration, which often involves hydrologically reconnecting a stream to its floodplain and planting vegetation, also has positive effects on water quality. Water quality is believed to improve in restored streams because more locations for denitrification are available at the riparian-zone-stream interface, which is limited or not present in degraded streams. The engineering and construction involved in planning and implementing stream restoration projects are far more expensive than protecting streams with buffers that naturally provide water quantity and water quality benefits.

In summary, a number of studies have shown that riparian buffers effectively trap sediment and dissolved and particulate nutrients in the surface and groundwater flowing from uplands, and thus improve the quality of receiving waters (Castelle et al. 1994; Desbonnet et al. 1994; Wenger, 1999; Dosskey, 2001). Results of buffer studies, especially those that examine the relationship between nutrient reductions and buffer width, may appear to be quite variable. Indeed, based on the available scientific literature, recommended buffer widths for optimum nutrient removal range from 15 to 300 feet (Castelle et al., 1994; Desbonnet et al., 1994; Palone and Todd, 1997; ELI, 2003). The wide range of widths reported in the literature is due to differences in site specific conditions (such as hydrology, soils, and upland activities) and experimental designs (such as measuring nutrient reductions in runoff versus reductions in groundwater or reporting reductions in individual nutrient species, like nitrate or phosphate, versus total nitrogen or total phosphorus). Based on the research, there is no ideal buffer width applicable to all situations; however, it is quite apparent that streams with vegetated riparian corridors have better water quality than streams without these features.

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