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STREAMSIDE MANAGEMENT ZONES AND THEIR IMPORTANCE FOR WATER QUALITY AND WILDLIFE IN FORESTED WATERSHEDS

Ferhat KARA*

*Auburn University, School of Forestry and Wildlife Sciences, Auburn, AL, USA

Abstract

Due to increasing impact of human activities such as land conversion, urbanization, and forest management on water quality, protection of water sources has become very important to the public. High quality water is generally provided by forested watersheds. Since forested watersheds are often subject to intensive forest operations, water quality and wildlife can be negatively affected by these operations. However, the adverse effects of silvicultural treatments on water quality can be mitigated by the implementation of best management practices (BMPs) such as streamside management zones (SMZs). In addition to water quality, SMZs also provide many benefits to wildlife and aquatic systems during silvicultural operations near water sources. In this study, the importance of SMZs was investigated by presenting its definition, effectiveness in protecting water quality, and importance for wildlife.

Key words: Streamside Management Zone, Water Quality, Wildlife

1. Introduction

One of nature's most important gifts to living beings is water. It is a vital resource that we rely on every day. With increasing human pollution, and global warming, clean water is becoming one of the most precious natural resources for the future generations. Thus, in the last two decades, there has been increasing concern over the impact of human activities such as land conversion, deforestation, urbanization, and forest management on water quality [1].

Forested watersheds are generally associated with high quality water compared to watersheds with other major land use/cover types [2]. Because surface runoff and erosion are negligible in undisturbed forests, they generate relatively low sediment yields [3]. In addition to low sediment yield, amount of dissolved nutrients and stream temperature are also low; and oxygen content is high in streams draining undisturbed forests [4]. Erosion rates in undisturbed forest lands are actually less than the background rate of soil formation caused by geological processes [5]. Both trees and understory provide effective surface cover in undisturbed forests. Minimal erosion and sedimentation occurs because this cover protects the soil surface from damaging storm energy [6]. In addition to protecting water quality, forests provide many other benefits such as oxygen production, wind control, animal habitat, aesthetics, recreation, and timber production. To ensure the sustainability of these benefits, some management practices may be required. But these operations can affect Nonpoint Source Pollution (NPS) such as sediment leaving a forested watershed [7]. In addition, these operations can negatively affect wildlife and aquatic organisms by destroying their habitats and decreasing water quality as well.

Over the past 30 years, the need to protect water quality has gained recognition, and Best Management Practices (BMPs) such as streamside management zones (SMZs) were developed. These practices are designed to be at or above the minimum standards necessary to protect and maintain water quality during forestry activities [8]. Many studies have shown that without BMPs, forest management practices can have negative effects on water quality [9, 10, 11, and 12]. These negative effects can be reduced by the

Corresponded Author; ferhatom@hotmail.com

implementation of BMPs as part of forest management [13], and BMPs have proven to be a cost effective means for controlling NPS pollution in forested watersheds [12]. Streamside Management Zones are one of the most effective BMPs to protect water quality and wildlife habitats.

2. Streamside Management Zones

SMZs are one of the most commonly employed nonstructural BMP types. A SMZ is a strip of land immediately adjacent to a water body where soils, organic matter and vegetation are managed to protect the physical, chemical and biological integrity of the surface water adjacent to and downstream from forestry operations [8] (Figure 1). Streamside management zones with greater canopy cover may increase the ability of trees to reduce the effects of direct rainfall on erosion. A SMZ consists mostly of riparian habitat area and provides a variety of functions and values such as [14];

- Reducing surface runoff
- Filtering sediment and nutrients from runoff
- Stabilizing streambanks
- Maintaining stream temperature
- Allowing water to soak into the ground
- Providing food and shelter for wildlife.

Figure 1. A streamside management zone [8]

There are many factors that influence the effectiveness of streamside buffers to trap sediment including slope, hydrology, type and density of riparian vegetation, surface litter layer, soil structure, and frequency and force of storm events [15]. These factors should be taken into account when designing SMZs.

3. SMZs and water quality

The most important function of SMZs is maintaining water quality. Stream buffers minimize the effect of different activities including timber harvesting, agricultural uses, grazing, use of prescribed fire, and urban activity [16]. Trees and other vegetations within SMZs keep sediment out of a stream. Cooper et al. (1987) have shown that a riparian buffer can trap 84 to 90 percent of the sediment loading [17]. In addition to sediment, they also trap the materials attached to sediment, such as phosphorus and heavy metals and pesticides. SMZs are effective to reduce the velocity of surface runoff that causes deposition of sediment in streams. As runoff water moves through a buffer zone, it slows and drops sediment before it reaches the stream.

A stream buffer zone is comprised of three zones; undisturbed zone, managed zone, and upland zone [18] (Figure 2). In Zone 1, harvesting is not generally allowed while Zone 2 can be managed if necessary. Upland zone consists of herbaceous vegetation that mitigates effects of runoff by reducing velocity of flow [18].

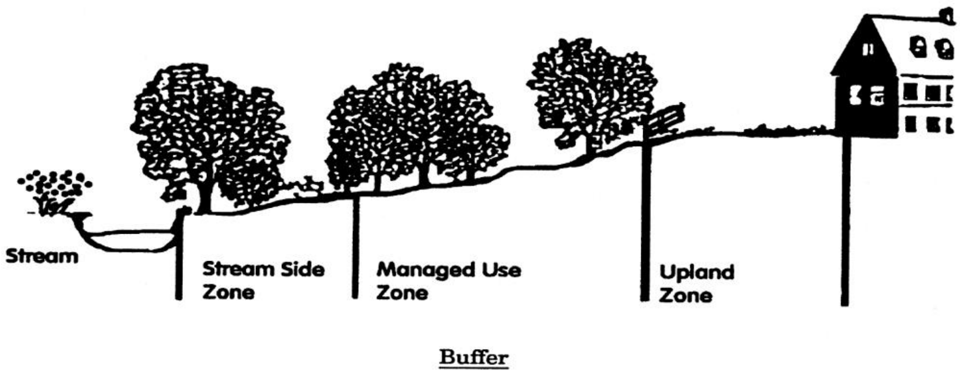

Figure 2. The three-zone of a SMS [18]

3.1. Forest operations near SMZs

Water quality in streams is related to upland disturbances or management activities. Productive forests are often exposed to intensive management practices [19]. To increase site productivity and reduce rotation time, silvicultural prescriptions often include site preparation, fertilization, and thinning, as well as harvesting. These intensive management practices may affect NPS pollution because they disturb the natural environment. However, these effects may be mitigated by BMPs. Grace (2005) concluded that forestry BMPs help protect and maintain water quality following forest operations after he investigated the effects of forestry operations on water quality in the 13 southern states of the USA [19].

The greatest impact of forest operations on water quality occurs in first year following harvest [20]. As the vegetation reestablishes following harvest, the evapotranspiration rate will eventually return to previous conditions, and all treatment effects will reduce over entire watershed because of revegetation [20]. Arthur et al. (1998) state that a strip buffer is effective in reducing the effects of clearcutting on water yield and sediment rate, and the effect of treatments on water quality decreases after first year following treatments [11].

Clearcutting in particular, causes a large decrease in evapotranspiration and a large increase in streamflow [21]. Although clearcutting is considered to have the biggest impact on water quality, silvicultural systems that include more frequent entries into the forest may actually cause greater impact than clearcutting [22]. Some studies have shown that SMZs are effective at protecting water quality from clearcutting as well. Lakel et al. (2006) observed the effects of clearcutting on water quality [23]. Their results indicated that harvesting did not damage water quality and SMZs were effective at protecting water quality from clearcut operations [23]. In another study that observed the effects of clearcutting on water quality, Patric (1980) found a slight increase in concentration of sediment, nitrate, calcium, magnesium, potassium, and sodium thanks to 40 m buffer zone and well-managed logging roads [20].

3.2. Forest operations within SMZs

Although silvicultural activities need not be excluded from SMZ's, any silvicultural activity within them must be closely supervised and managed. However, regardless of the width, the first 5 meter should be treated as an undisturbed strip because this undisturbed strip is very efficient in filtering sediment from surface runoff [14]. Careful management within a SMZ may increase its effectiveness. Timber harvesting within a SMZ must be done using selection, and with special care [8]. In order to reduce fire and insect hazards, to provide some economic return, and to improve the effectiveness of SMZs, forested SMZs are often thinned [12]. Complete removal of the streamside or riparian vegetation during harvesting might increase: sediment and slash delivery to the stream, sediment accumulation in the streambed, stream temperature, and nutrient concentration [24]. Thus, approximately half of the pre-harvest vegetative canopy cover should be maintained, and amount of bare soil surface shouldn't be more than 20 percent within a SMZ. Higher roughness with many small stems within a SMZ increases infiltration and decreases runoff, thus reducing transport of detached soil particles [6]. Trees shouldn't be removed from banks, beds or steep slopes if it will destabilize the soil [8]. As long as careful logging practices are followed within SMZs, logging can be conducted without increasing risk of sediment input to streams [25]. Kreutzweiser et al. (2009) examined the effects of a partial harvest within a SMZ, and concluded that careful logging practices, including winter harvesting, in riparian areas mitigated logging impacts on fine sedimentation in streams [25].

4. Wildlife Benefits

A wildlife habitat consists of a complex mixture of food, cover, water, and space requirements [26]. These major requirements of many wildlife species are provided by forests. Forest operations including logging, site preparations, and road construction near or within riparian areas may negatively affect wildlife habitat, aquatic life, biodiversity, recreation, and aesthetics. Removal of trees and other vegetations within a SMZ may destroy both wildlife habitat and aquatic habitat, deplete food and shelter for fishes, change water temperature, and impair water quality [26]. The effects of these operations on wildlife and aquatic life can be minimized by the implementation of SMZs.

Stream buffers provide food and shelter for many wildlife species and aquatic organisms. Shade of trees and other plants within SMZs keep the water cool for aquatic life in the summer. Fallen leaves, twigs, and other organic debris are foods for aquatic organisms. Aquatic invertebrates shred these materials, and then they are eaten by fishes which are in return eaten by other wildlife species [14]. In addition, large woody debris is used as hiding cover by fishes in streams. SMZs provide high quality water for wildlife and aquatic species by trapping sediment and other heavy metals carried by surface runoff.

One of the biggest threats to wildlife species is habitat fragmentation. In addition to providing food and shelter, SMZs are also used by some species of wildlife as travel corridors that counter habitat fragmentation (Figure 1). These corridors can link areas of more mature forest habitat that are needed by some wildlife species, and for this purpose, wider SMZs are required [27]. Cavity and den trees within SMZs can meet habitat requirements for certain wildlife species. If fish and wildlife habitats are improved within riparian areas, it can also enhance aesthetic, and provide recreational benefits to the public such as fishing.

Forest should not be disturbed within 30 m of these habitats if possible [26]. Understory and midstory vegetation should be kept intact within SMZs so that these areas can be utilized by wildlife animals for nesting or foraging. Since SMZs are serving as nesting places for some wildlife species, harvest operations during breeding period of these species should be avoided. Some cavity and dead trees are also left on the forest floor within riparian areas for nesting and sheltering. Some SMZs are managed for wildlife benefits so that desired large trees will fall into the stream when they die to create crucial fish habitat [28]. In addition, SMZs can be managed to promote certain tree species such as oaks, hickories, or beech that produce nuts or berries which are food sources for many wildlife species.

5. Designing SMZs

5.1. SMZ Width

A SMZ should be wide enough to protect water quality, but SMZs with excessive widths may cause economic loss of valuable timber resources [29]. Even though the width of a SMZ is determined according to type of stream, management objectives, risk of erosion, soil type, slope, or width of stream, it should not be less than 10 meters from a definable bank [8]. SMZs are established on each side of the stream. Width of SMZ is measured from the top of each bank.

Wider streams generally require wider SMZs. Thus, as the width of stream increases, width of buffer zone should be extended as well (Table 2). SMZs on perennial streams are wider than SMZs on intermittent streams. Slope is another important factor considered to define the width of a buffer zone. Steeper slopes require wider stream buffer zones (Table 1). Soil type affects SMZ width as well. For example, wider SMZs are needed if the soil is highly erodible. In addition to slope, soil type, stream type, and stream width [30], management objectives should be taken into account as well. For example, if wildlife is major objective, a minimum buffer of 15 meter is recommended [8]. Width of buffer zone should be increased if there is a wetland (such as a seep, spring, wallow, marsh or bog) adjacent to a stream channel [14].

Table 1. Recommended stream widths for different slope percents [14].

Slope (%)	Recommended width of filter strip (m)
<10	10-15
10-35	15-30
>35	30<

Table 2. Recommended stream width for different stream widths [30].

Width of stream (m)	Recommended width of filter strip (m)
>100	100
20-100	70
5-20	50
1.5-5	40
<1.5	30

The width of a SMZ is important for its effectiveness at protecting water quality. While too narrow buffers may not be effective to protect water quality, unnecessarily wide SMZs may cause economic loss of timber resources. Significantly higher levels of suspended solids may be measured; even though an uncut buffer zone is left streamside. For example, Ensign and Mallin (2001) determined that a 10 m buffer zone was not sufficient to prevent impacts from a clearcut on water quality in the Goshen Swamp, NC, USA [31]. Corner and Bassman (1993) suggest that width of a buffer zone should be determined as a function of physical parameters (e.g. slope, soil permeability, soil erodibility) and intensity of management practices [32]. Benefits from a SMZ are associated with the SMZ width [33]. Table 3 shows that a wider SMZ provides more benefits than narrower ones.

Table 3. Benefits of a SMZ based on width of buffer [33]

SMZ width	Benefits
5 m	Stabilizing stream bank, reducing algae
7.5 m	Stabilizing stream bank, water quality, some wildlife habitat
15 m	Stabilizing stream bank, water quality, wildlife and fish habitat
30-45 m	Stabilizing stream bank, water quality, wildlife and fish habitat, some timber production

5.2. Stream Crossings

Sediment from forest roads, skid trails, firebreaks, and log landings has been a major factor affecting water quality [22] since the most of sediment yield is contributed by forest roads and skid trails [6, 34]. They have the greatest impact of any forestry activities within a SMZ [14] because they cause a break in the canopy and filtration strip provided by an SMZ [8]. Forest roads should be located outside of the SMZ if possible. If not, the number of roads and other stream crossing points should be minimized, and crossings should be installed at right angles if possible [8]. Crossings should be located where the bank and SMZ will be least disturbed [8]. Forest roads within SMZs should be properly drained, and these roads shouldn’t cut channels across the SMZ [14]. In order to minimize the effects of stream crossings on water quality, culverts, bridges, or log crossings are recommended. All temporary crossings should be promptly removed within riparian areas after harvesting is completed.

6. Conclusion

Forested watersheds and forested areas on a watershed play important roles in protecting and maintaining both water quality and quantity. However, any silvicultural operations in forested watersheds must be carefully managed and supervised in order to protect and maintain water quality. When a forested watershed is exposed to minimal soil disturbance by these careful logging practices, the watershed will generally continue to provide high water quality. Riparian vegetation is very important for the water quality because it creates roughness on the ground, decreases water velocity and allows water to infiltrate the soil, and trap sediments. It has been shown that SMZs are very effective in protecting and maintaining water quality and quantity. They are important for wildlife as well. Riparian vegetation also protects the surface of the soil from wind and water erosion that cause sedimentation.

In order to protect and maintain water quality and wildlife habitat, the following recommendations may be considered before, during and after forest management practices within riparian areas [14]. When constructing forest roads and stream crossing, particular attention should be paid.

- The best SMZ width should be designated,
- Roads and stream crossings should be wisely and carefully constructed,
- A diversity of tree species and age classes should be retained in SMZs
- A SMZ must not be clearcut, and sufficient trees should be left to protect stream bank,
- Soil disturbances should be minimized,
- Use of heavy equipment should be avoided near streams,
- Sufficient ground cover should be maintained within SMZs,
- Logging debris should be kept out of the SMZs,
- Hazardous or toxic materials, pesticides or herbicidies shouldn't be stored and used in or near streams and SMZs,
- Site preparation should be restricted in the SMZs.
- Broadcast application of any pesticide should be avoid within SMZs.

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