Economic Analysis of Potential Changes to the Riparian Forest Management Guidelines

Potential Costs and Benefits of the Riparian Science Technical Committee Findings

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Executive Summary

The Minnesota Forest Resources Council (MFRC) convened the Riparian Science Technical Committee (RSTC) in 2004 to compile and evaluate scientific information on harvest-related impacts in riparian areas, and evaluate the suitability of riparian area buffers at mitigating any impacts. The purpose in convening this committee was to provide information and analysis to be used as part of the basis for the second revision of the Forest Management Guidelines. Members of the RSTC suggested several changes regarding buffer area width and residual basal area (RBA), generally calling for an increase in these variables to protect certain riparian functions. The MFRC is required under the Sustainable Forest Resources Act to analyze the costs and benefits of new site-level practices prior to implementation (§ 89A.05). The MFRC directed staff to conduct an economic analysis of potential changes to the riparian guidelines based on the RSTC recommendations prior to the revision process. The RSTC recommendations will be fully evaluated and considered for adoption starting in 2010.

This report presents a relatively detailed assessment of the potential marginal foregone stumpage value associated with RSTC-recommended changes in riparian management zone width and RBA. It is not a cost-benefit analysis, nor do we quantify non-market services such as water quality or wildlife habitat. We fully recognize that these services have substantial value which need to be fully considered, but their complexity, additive nature, spatial heterogeneity, and other confounding factors severely constrain our ability to quantify them in a comprehensive and defensible manner. Marginal foregone stumpage value associated with greater buffer area and a range of RBA's (25, 50, 75, and 100 ft^2 $ac.^{-1}$) was estimated for streams and lakes, and seasonal ponds separately. Our analysis determined that:

- Non-market benefits emanating from forest riparian areas are extremely important and should be an integral part of making decisions regarding riparian buffer widths and recommended residual basal areas.
- Existing stream and lake riparian area characteristics (species composition and volume) differ among regions of the state. Estimated annual riparian harvest removals from 2003-2007 were 1.8% (200,000 cords), 1.1% (47,500 cords), and 1.0% (18,300 cords) of the total standing riparian volume for the northern, central, and southeast regions, respectively. Aspen comprised the majority of riparian harvest (>45%) in all regions despite making up only 24%, 20%, and 4% of the total riparian volume in the northern, central, and southeast regions, respectively.

- At the RSTC-recommended RBA of 75 ft^2 $ac.^{-1}$, total annual statewide marginal cost of timber revenue foregone was estimated to be $280,000 for streams and lakes, and $150,000 for seasonal ponds.
- Approximately 20% of landowners who harvest will bear the majority of the total statewide cost (i.e., owners of land that have water features in the sale area). Median costs to these landowners were estimated to be $4.84 and $5.85 $ac.^{-1}$ harvested for lakes and streams, and seasonal ponds, respectively. However, costs to individuals within this group will vary widely depending on length and type of water features present at a given ownership.
- The potential for these costs to cause "….significant adverse economic effects" (SFRA, § 89A.05, Subd.2) is dependent on the scale of assessment.
- Total statewide costs are likely to have minimal impact, as they would account for only 0.4% of the annual stumpage sold. Recognizing the recent volatility of stumpage markets, however, this small percentage could be significant in absolute dollars.
- At the scale of individual ownership, it is likely that there is potential for significant adverse impacts to occur at some sites with a high amount of water feature edge. Additional site-level economic impacts are also possible if the spatial configuration of water features increases logger operating costs (e.g., skidding distance).
- Analysis indicated that 5% leave tree requirements are more than sufficient to fulfill the recommended seasonal pond buffer requirement at harvests greater than 10 acres in size.

We are confident that the above findings are accurate, but significant uncertainty exists in applying these estimates to the southeast region of the state as we have relatively poor information on riparian areas in forests compared to the central and northern portions of the state. Although forest harvest in this region makes up less than 1% of the statewide total, costs and benefits could be disproportionate to the level of harvest given the unique hydrology, geology and cultural influence in this region. This uncertainty should be considered when using the results from this analysis in the forest management guideline revision process.

Background

The Minnesota Forest Resources Council (MFRC) is required under the Sustainable Forest Resources Act (SFRA) to analyze the costs and benefits of new recommended site-level practices (§ 89A.05). This type of analysis was carried out during development of the original timber harvesting and forest management guidelines in the late 1990s. Other complimentary analyses, such as the UMN timber sale bidding study and the ongoing time and motion study, continue to add to our knowledge base regarding economic outcomes of site-level practice implementation. Additionally in 2005, the MFRC commissioned a literature review to examine the valuation of non-market benefits emanating from forest riparian areas.

The original site-level guidelines were revised in 2005 as statutorily required. At that time, revision of the riparian portion of the guidelines was deferred until new and existing information on forested riparian functions could be compiled and evaluated. In 2004, the MFRC convened a Riparian Science Technical Committee (RSTC) to bring forth the best applicable scientific knowledge to assist the MFRC in resolving outstanding riparian guideline questions. The RSTC was composed of nine interdisciplinary scientists with regional expertise in their chosen fields related to riparian functions and processes (MFRC 2007). Three functional areas associated with riparian zones were evaluated by the RSTC: (1) geochemistry, (2) hydrology, and (3) habitat. The RSTC spent extensive time reviewing existing literature and utilizing members' expertise to determine the potential for forest harvesting to alter these functional areas, and evaluate alternative management practices designed to ameliorate any negative effects (MFRC 2007). Following that analysis, the RSTC made a number of judgments regarding the adequacy of the current riparian guidelines and potential changes to be considered. Potential changes identified by the RSTC include 1) modified width of riparian management zones (RMZ), 2) modified amount of residual basal area (RBA) within RMZ's, and 3) changes in the water bodies to be considered for RMZ application (Table 1).

After the work of the RSTC was completed, the MFRC created an ad hoc committee to provide direction to staff on conducting an economic analysis of the RSTC findings. Following the committee's direction, MFRC staff convened a panel of forest resource data experts from the University of Minnesota-Department of Forest Resources, USDA-FS FIA staff, and DNR-

Table 1. Current and potentially modified guidelines for riparian management zone (RMZ) width and residual basal area (RBA) based on RSTC findings.

Guideline	Current		RSTC Potential	
	RMZ Width (ft)	RBA (sq.ft/ac)	RMZ Width (ft)	RBA (sq.ft/ac)
Designated trout streams/lakes				
Even-aged management	150	60	165	75
Uneven-aged management	200	80	165	75
Non-trout streams > 10 ft. wide				
Even-aged management	100	25-80	110	75
Uneven-aged management	200	80	110	75
Non-trout streams 3-10 ft wide				
Even-aged management	50	25-80	110	75
Uneven-aged management	100	80	110	75
Non-trout streams <3 ft. wide				
Even-aged management	50	25-80	50	25-80
Uneven-aged management	50	80	50	80
Non-trout lakes/OWW[2] > 10 acres				
Even-aged management	100	25-80	110	75
Uneven-aged management	200	80	110	75
Non-trout lakes/OWW 1-10 acres				
Even-aged management	50	25-80	110	75
Uneven-aged management	50	80	110	75
Non-trout lakes/OWW < 1 acre				
Even-aged management	50	25-80	50	75
Uneven-aged management	50	80	50	75
Seasonal ponds[3]				
Even-aged management	Filter Strip	Filter Strip	50	75
Uneven-aged management	Filter Strip	Filter Strip	50	75

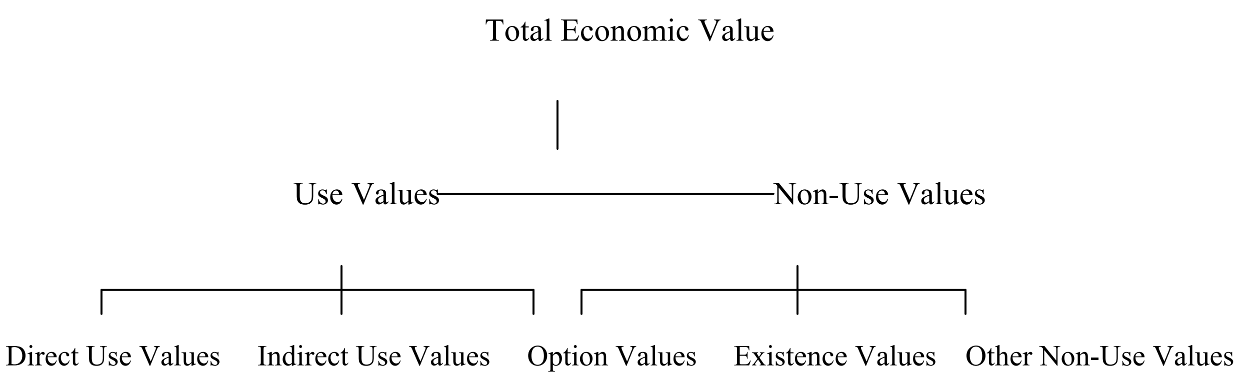
[1] applies to perennial streams only; all others apply to perennial and intermittent
[2] OWW = open water wetland.
[3] note that the RSTC did not reach consensus on RMZ width or RBA in relation to seasonal ponds

Division of Forestry (including DNR-Resource Assessment) to aid in the acquisition and analysis of these data. MFRC staff then developed estimates regarding the identified information needs as well as other pertinent data. The following analysis utilizes information developed by staff and the above panel to estimate the marginal cost of foregone timber revenue if the potential changes identified by the RSTC were implemented. It is important to note that this analysis is not evaluating new site-level practices, but does serve as a preliminary assessment of the economic impacts of potential changes in the riparian guidelines as supported by the scientific outcomes of the RSTC process.

Economic Analysis

There are a number of types of values to be considered in identifying and quantifying the full costs and benefits of forest riparian areas. These values may simply be the price a good or service brings on the open market or may be much more difficult to determine. Benefits related to forest riparian areas, captured in these various values, may include forest products, flood control services, erosion control benefits, water quality protection services, groundwater purification services, ecosystem protection services, recreational services, cultural services, income possibilities, property values, future option values, as well as existence and bequest values. Costs may include opportunity costs (timber harvest or other forgone activities), property value reductions (loss of flexibility, aesthetics, increased likelihood of the property being subject to future regulation) and potential establishment costs.

Economists often divide these values into use and non-use values, as diagrammed below:



Those direct use values relating to forest riparian areas in Minnesota might include traditional forest products, woody biomass for energy generation and recreational use. Indirect use values might include wildlife habitat, erosion control, water quality and flood control. Values related to carbon sequestration may fall in a grey area between the two. These benefits can be placed on a continuum reflecting our ability to place solid monetary values on the various costs and benefits. For instance, traditional forest products have an existing, competitive market in which prices are well defined, making valuation a simple task. Valuing recreational experiences is more difficult, as limited markets exist and generally do not reflect full values. The indirect use values are much more difficult to determine with no existing markets to determine prices. The non-use values, on the right hand side of the above graphic, are even more difficult to quantify in generating values for analysis.

Non-Market Values. This economic analysis initially was intended to identify and value the market and non-market costs and benefits which emanate from forest riparian areas and vary depending on changes in buffer width and/or residual basal area. Most of these values are those that are indirect in nature, as defined above. As demonstrated by the RSTC analysis, quantifying changes in these non-market goods and services, including ecosystem processes and conditions, is difficult, and assigning monetary values to those changes is even more difficult. As noted above, this difficulty stems from the fact that most of the economic benefits we attribute to forest riparian areas are not traded in markets with some limited exceptions, including wetland banking programs, specific air emission cap-and-trade programs, and the Chicago Climate Exchange (which does not exhibit characteristics of a truly functioning market). Therefore, most of these benefits accrue to society and not the individual, exhibiting characteristics of public goods, such as non-exclusivity and non-rivalrous consumption. Despite the difficulties in quantifying and valuing many of these goods and services, they are important considerations in making informed decisions regarding the management of forest riparian areas. Ignoring or over-valuing these attributes could have serious detrimental effects, such as the under-provision of ecosystem services or substantial financial impacts to local businesses and communities.

There are a number of techniques that have been used to approximate many of the values of non-market goods and services related to forest riparian areas. These techniques, which include contingent valuation and other stated preference techniques, hedonic pricing methods (utilizing statistical analysis of property values), travel cost methodologies, and replacement or substitution cost methods, among others, have various advantages and shortcomings in their applications.
In this particular case, the analysis is to value the changes in goods and services related to changes in riparian buffer width and corresponding residual basal areas. In order to conduct an economic analysis, beyond a simpler financial analysis (cash in – cash out), we must be able to quantify the change in conditions (e.g., abundance of invasive plants, macroinvertebrate populations, turbidity and dissolved solids, water temperature, number of snags) identified within

the RSTC work. After these changes are quantified, we need to attach monetary values in order to conduct an economic analysis that employs non-market valuation techniques.

In addition to the complexity and uncertainties associated with quantifying and valuing many of the goods and services provided by forest riparian areas by any of the above mentioned techniques, it is very difficult to provide a single value for a resource (forest riparian buffers), as the suite of services provided are mostly interdependent, and can be either complimentary or competing in nature, meaning many of these benefits exhibit complex dynamics and are additive or partially additive, while others are not. Complicated by substitution effects and income constraints, these factors can lead to double counting and the overestimation of total economic value.

Non-Market Valuation Literature Review. The MFRC commissioned a literature review to identify studies which attempted to value one aspect or another of riparian areas. None of these studies attempted to quantify the entire suite of benefits from forest riparian areas. The MFRC directed the contractors (Industrial Economics) to only look at revealed preference valuation studies. These valuation studies, looking at various benefits, included:

- Changes in property values with riparian buffers
- Changes in property values due to proximity to wetlands
- Willingness to forego riparian harvesting for varying levels of tax incentive payments
- Valuation of additional water flow by looking at downstream uses
- Changes in recreational property values due to turbidity
- Increase water treatment costs due to sediment loads
- Recreation demand and reduced tree density
- Travel cost evaluation with reduced salmon populations
- Water quality and recreation value
- Relationship between fish abundance and catch rate
- Value of foregone timber

Examples of the results of these studies most applicable to Minnesota and the forest management guidelines include:

- 1 ft increase in buffer width = .06% decrease in property value (OR)
- 1 point change in pH = 6% change in property value (PA)
- $200+ increase in lake lot value = 1 foot in Secchi disk depth (MN)

- 30% loss in tree density in riparian area = 24% decrease in recreational value (CO)

Those studies indentified in the literature review that were most pertinent to our work included hedonic studies of water quality, specifically the influence of water quality on property values, and aquatic-based recreational demand studies, such as the relationship of lake clarity to fishing benefits.

Scope of Analysis. It is important to remember that the valuation of non-market goods and services is an important tool that can provide decision-makers with useful information for deciding among policy alternatives or upon preferred combinations of alternatives. At the same time, non-market valuation of these goods and services, on its own, does not provide a full basis for making decisions. These decisions need to be based on available market values *and* non-market values as well as other political, cultural, and social values. Noting that the valuation of non-market goods is limited by its complexity, additive nature, and transferability from one geography to another (spatial heterogeneity), the ad hoc committee decided to limit the energy and resources expended on this part of the economic analysis, as these methods are highly prone to errors and vulnerable to criticism. In addition, the committee, in consultation with other experts including UMN economists, determined that convening a panel of economists (as originally envisioned) would be of limited value in improving the decision making process regarding riparian buffer widths and residual basal areas. The Ad Hoc committee and staff fully recognize the importance of non-market benefits in informing decisions regarding the forest management and timber harvesting guidelines, but believe that quantification of these benefits in a comprehensive and defensible manner is not possible. Given the above, the balance of this analysis is purely financial in nature, limited to estimation of the marginal foregone timber revenue associated with increased RMZ width and RBA. Further study regarding the valuation of non-market benefits and their inclusion in future analyses would be of great benefit to the state in making forthcoming natural resource management decisions.

Methodology for cost estimates

This analysis is limited to the estimation of the marginal foregone timber revenue associated with increased RMZ width and RBA (stumpage costs), and does not include additional benefits or costs along the supply chain or value-added products, quantitative assessment of potential environmental benefits of the recommended changes (e.g., improved water quality, increased wildlife habitat, etc.), costs associated with timber-sale layout (e.g., seasonal pond delineation), or the potential for increased RMZ area to fulfill other state forest management goals (e.g., reserves, extended rotation, etc.). Two approaches were developed and used to assess foregone timber revenue associated with the RSTC recommendations (Figure 1). Both of the approaches were largely based on data collected by the DNR during guideline implementation monitoring from 2004-06 (Dahlman 2008). The first approach estimated the statewide marginal cost per acre by calculating the total potential costs across all monitored sites (see below), and then dividing that cost by the total number of acres monitored in a given year. The second approach focused on the probability of encountering a seasonal pond or RMZ on a harvest site, and the distribution of cost estimates among sites with those features present (see below). In addition to the monitoring data, both of these approaches were based on data from the Department of Natural Resources (DNR) – Resource Assessment Unit, the USDA Forest Inventory and Analysis (FIA) program, and the annual stumpage price reports prepared by DNR-Division of Forestry.

Riparian forest characteristics. A spatially referenced 200 ft riparian buffer around identified water features was used to identify FIA plots within riparian areas. The riparian area within this 200 ft buffer is approximately 1.63 million acres. A total of 624 FIA plots, measured over the period 2003-2007, were identified within the buffer areas and assigned to one of three landscape regions for this analysis: northern (includes MFRC northern, north central, and northeast landscape regions), central (includes east and west central MFRC landscapes), and southeast (includes southeast MFRC landscape). We chose to develop estimates for each of these three regions because of the differences in species composition and annual harvest removals among them (Table 2). For all calculations, we assumed that characteristics within the 200 ft buffer were uniform. FIA plots within a region were averaged to estimate mean species composition,

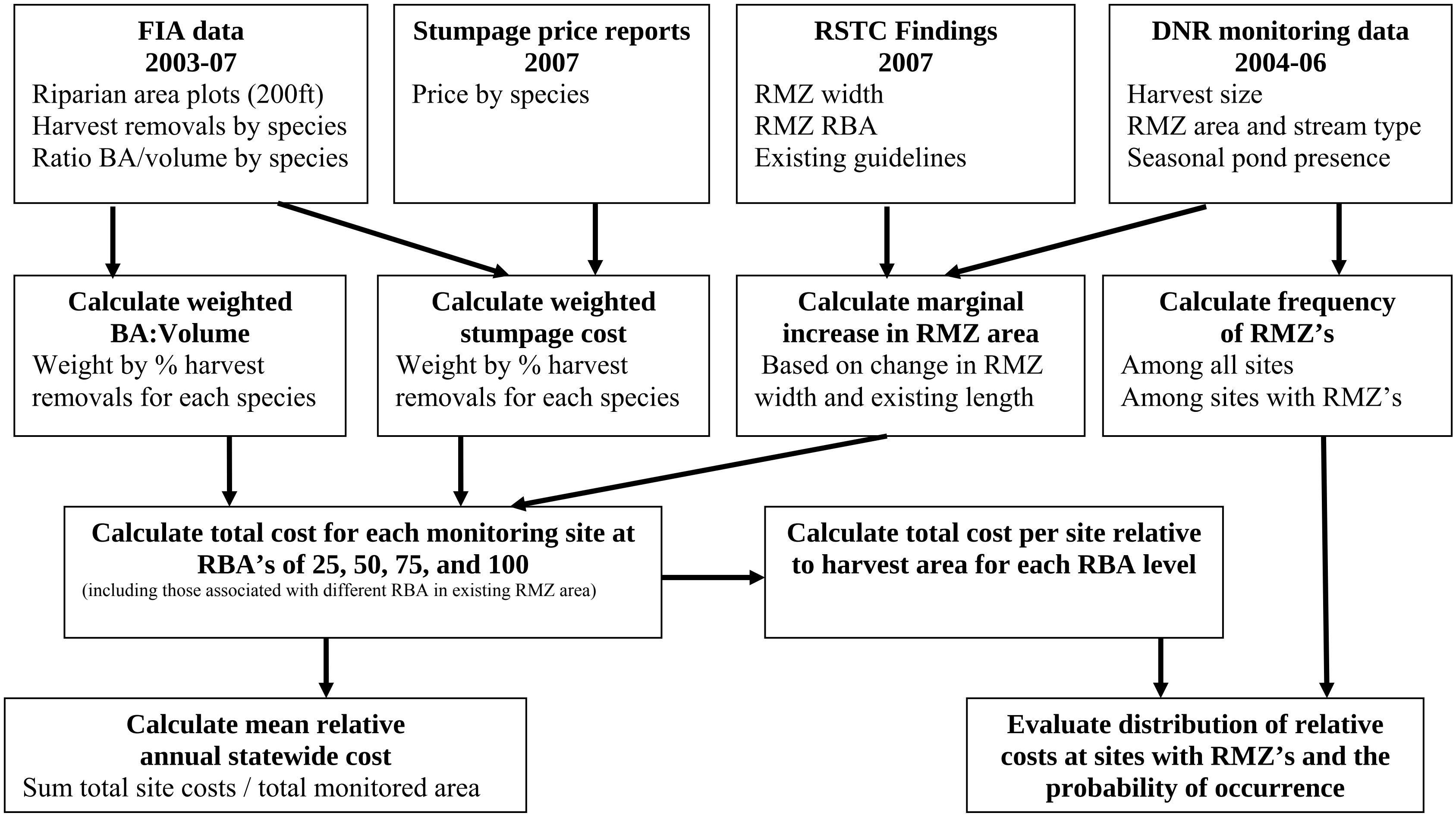


Figure 1. Flow diagram showing the general approach used to estimate costs of foregone stumpage value if the findings from the Riparian Science Technical Committee (RSTC) regarding riparian management zones (RMZ's) were adopted. FIA = USDA Forest Inventory and Analysis program; RBA = residual basal area (BA).

Table 2. Species composition in 200-ft riparian buffer area by landscape region. Species in bold are the dominant species harvested within riparian areas. Values in parenthesis are the percent of total volume; underlined values when shown are the corresponding percent of total removal for that species and region.

Northern Region	Central Region	Southeast Region
aspen (23.72/50.8)	**aspen (19.66/64.6)**	**n. red oak (17.04/8.0)**
paper birch (8.81/7.4)	**bur oak (14.04/10.7)**	bur oak (13.17)
n. white-cedar (8.22)	**n. red oak (12.68/4.0)**	A. basswood (8.16)
black spruce (6.73)	A. basswood (11.33)	A. elm (7.74)
red pine (6.48/6.3)	black ash (5.35)	sugar maple (5.63)
black ash (6.02)	**red maple (4.85/15.2)**	e. cottonwood (5.58)
balsam fir (5.08/7.2)	green ash (4.78)	silver maple (5.50)
tamarack (4.93)	bigtooth aspen (4.69)	white oak (5.25)
sugar maple (3.73)	sugar maple (4.35)	boxelder (4.95)
e. white pine (3.64/6.7)	red pine (3.53)	green ash (3.12)
A. basswood (3.50)	paper birch (3.30)	black walnut (2.85)
red maple (3.29)	n. pin oak (2.22)	slippery elm (2.46)
jack pine (3.28)	silver maple (1.98)	**aspen (3.57/44.8)**
n. red oak (2.81/7.8)	A. elm (1.81)	black cherry (1.84)
balsam poplar (2.49)	e. white pine 91.27)	**paper birch (1.75/5.5)**
white spruce (2.46)	tamarack (1.20)	shagbark hickory (1.71)
bur oak (2.43)	jack pine (1.15)	n. pin oak (1.31)
green ash (0.98)	boxelder (0.98)	black oak (1.20)
yellow birch (0.42)	white oak (0.66)	hackberry (1.10)
A. elm (0.36)	black willow (0.58)	**e. white pine (1.06/5.9)**
silver maple (0.27)	balsam poplar (0.48)	bitternut hickory (0.91)
boxelder (0.10)	black spruce (0.48)	e. redcedar (0.89)
	e. hophornbeam (0.43)	e. hophornbeam
	e. redcedar (0.42)	rock elm (0.51)
	balsam fir (0.34)	white ash (0.39)
	white spruce (0.34)	**red pine (0.38/4.6)**
	black cherry (0.29)	black willow (0.33)
	slippery elm (0.27)	butternut (0.24)
	e. cottonwood (0.26)	black ash (0.20)
	Scotch pine (0.21)	elm spp. (0.15)
	yellow birch (0.14)	black maple (0.10)

Table 3. Total volume, ratio of volume to basal area (BA), weighted price per cord, and relative cost per unit BA by region.

Region	Volume† (cubic ft. acre^{-1})	Weighted ratio volume to BA§	Weighted cost per cord* ($ cord^{-1})	Cost per unit BA# ($ sq.ft.$^{-1}$ acre^{-1})
Northern	1265	12.88	28.07	2.82
Central	1564	11.88	24.49	2.27
Southeast	1390	12.81	34.01	3.40

† note that volume is the mean across the entire 200 ft riparian area. Monitoring data has indicated that volumes generally increase from water body edge to the forest interior.
§ individual species ratio weighted by percent harvest removal and then summed within a region
* individual species cord price weighted by harvest percentage, and then summed within a region
# calculated based on cord = 128 ft^3

total per acre volume, annual volume removals by species, and the ratio of volume to basal area by species for each region (Table 3). Total harvest volume from the 200 ft riparian area differed among regions, with mean annual removals of 200, 47.5, and 18.3 thousand cords for the northern, central, and southeast regions, respectively. Annual harvest accounts for 1.8%, 1.1%, and 1.0% of the total standing riparian volume in the northern, central, and southeast regions, respectively.

Riparian area stumpage costs. For each region, species which comprised the majority of annual harvest removals (representing >75% of the total) (Table 2) were identified to develop a weighted cord price applicable to that region. Cord price for each species was estimated from annual stumpage price reports produced by the DNR for 2007 and the proportion of harvest intended for various products (e.g., pulpwood or sawtimber). These individual cord prices were weighted according to the percentage of annual harvest that the species contributed within each region, and then summed across species within a region to estimate a weighted cord price for wood harvested in riparian areas. Since the RSTC findings and existing riparian guidelines use residual BA in the recommendations, we calculated the cost per unit BA by region so that a variety of RBA's could be evaluated in the analysis (Table 3).

Frequency and area calculations for RMZ's and seasonal ponds. Forest management guideline monitoring data from 2004-06 was used to estimate the frequency of seasonal pond and RMZ occurrence on harvest units in Minnesota, and to develop estimates of the potential change in buffer area if the RSTC recommendations were adopted. Monitoring sites were randomly selected from the population of harvest sites for a given year, providing an unbiased assessment of the statewide population given that the sample size was relatively large (~90 sites each year). (Note: Given that most harvesting occurs in the northern portion of the state, very few sites were randomly selected from the southern portion of the state). Monitoring occurred in early spring, making it likely that most seasonal ponds were included in the assessment (i.e. monitoring occurred during the likely time of seasonal pond hydroperiod). Effort was also made to identify and record "adjacent" RMZ's to account for those RMZ's which may have been outside of the marked sale, but otherwise considered in the harvest planning. Monitoring over the 2004-06 period was performed by the same contractors who received calibration training prior to monitoring, limiting the potential for operator sample error common in qualitative assessments. Given the above, we have relatively high confidence that the monitoring results accurately reflect site conditions associated with harvest operations.

Seasonal ponds. For each of the three monitoring years, all identified seasonal ponds were summed and divided by the total acreage of monitored harvest sites to estimate the number of seasonal ponds per acre (Table 4). These frequency estimates across all sites are similar to those estimated in several research studies conducted in northern Minnesota (0.015 and 0.027 ponds/ac., B Palik, pers. com.). Monitoring data indicated that almost all ponds are less than 0.1 ac in size, and several studies have estimated mean pond size to be between 0.02-0.03 acres in size (Palik et al. 2001, B. Palik pers. com.). We assumed that seasonal ponds were circular, and used a mean estimate of 0.025 acres in pond size (corresponding to 0.31 buffer acres) from Palik et al. (2001). Based on the assumed pond size and the mean frequency of occurrence (Table 4), seasonal ponds cover approximately 6,200 acres of forest in Minnesota.

Table 4. Seasonal pond frequency and related measures calculated from the DNR implementation monitoring program data for years 2004, 2005, and 2006.

Variable	Monitoring Year			
	2004	**2005**	**2006**	**Mean**
Total sites	100	89	90	NA
Sites with ponds	14	22	16	NA
Total ponds	39	49	33	NA
Pond freq. at sites with ponds (#/ac.)	0.089	0.133	0.125	0.116 (0.014)[1]
Pond freq. across all sites (#/ac.)	0.015	0.022	0.013	0.017 (0.003)
Annual pond buffer area (%)[2]	0.47	0.68	0.40	0.52 (0.08)
Annual pond buffer area (ac.)[3]	650	950	550	700

[1] standard error among years in parenthesis
[2] calculated as (∑pond buffer area / total monitored acres) * 100
[3] assumes 140,000 acre annual harvest (T. Aunan, pers. comm.)

RMZ's associated with streams and lakes. Field contractors recorded the area of RMZs associated with a given water body at each monitoring site, but not the dimensions. We estimated the RMZ length by dividing the recorded area by the recommended RMZ width (from the existing guidelines) for the associated water body type. This approach assumes that RMZ's within a harvest unit are linear in shape, which is valid for stream segments and short distances along the perimeter of non-linear water features (e.g. lake which abuts the harvest boundary). We then calculated the new additional RMZ area as the difference between the original area and the product of the estimated length and the RSTC-recommended width (Table 5).

Table 5. Existing and RSTC-recommended RMZ area at lakes and streams for sites with RMZ's present during implementation monitoring for years 2004, 2005, and 2006.

Variable	Monitoring Year 2004	2005	2006	Mean
Total sites monitored	100	89	90	NA
Sites with RMZ's	18	23	9	NA
Existing RMZ area per site (%)	8.6 (2.1)[1]	8.0 (1.8)	5.4 (1.1)	7.7 (1.1)
RSTC RMZ area per site (%)	11.4 (2.4)	9.9 (2.1)	7.6 (1.7)	10.0 (1.3)
Increase in RMZ area per site (%)	2.7 (0.9)	2.0 (0.6)	2.2 (0.9)	2.3 (0.4)
Increase in annual statewide RMZ area (%; acres in parenthesis)[2]	0.55 (770)	0.46 (640)	0.59 (830)	0.53 (0.04) (740)

[1] standard error in parenthesis; n=number of sites per year or across all years for the mean
[2] Percent estimate calculated as Total RMZ area increase / Total harvest area monitored; acre estimate assumes annual harvest of 140,000 acres

Statewide and individual cost estimates. Marginal foregone stumpage costs associated with the RSTC recommendations were calculated for each site as the product of the: 1) new additional RMZ area, 2) per unit BA cost (Table 2) and 3) the values 25, 50, 75, and 100 (representing a range of potential RBA's). For RMZ's associated with lakes and streams, additional costs associated with a change in RBA in the existing RMZ area were also calculated. In these calculations, we used an existing RBA of 60 for trout streams and lakes (the current recommended amount), and a RBA of 50 for all others (the approximate midpoint of the RBA range currently recommended in the guidelines). Costs associated with "new" and "old" RMZ area were then summed to determine the total amount of foregone timber revenue for a given site. We did not conduct any estimation of the change in cost for uneven-aged management RMZ guidelines because monitoring results have consistently shown that only a small portion of harvests (<2% statewide) are conducted in that manner.

A statewide relative marginal cost estimate was calculated for each year of monitoring data by summing the total marginal increase in cost across all sites with RMZ's present, and dividing that amount by the total harvest area monitored within a year. Similarly, the distribution of costs among sites with RMZ's present were examined by calculating the marginal cost relative to that sites harvest area, and then plotting the values on a histogram. For both approaches, estimates were presented both individually (for RMZ's associated with streams and lakes, and those for seasonal ponds) and in combined form. Probability of encountering these sites during harvesting operations was calculated for each year and across monitoring years by dividing the number of sites with RMZ's or seasonal ponds with the total number of monitored sites. In most instances, there was little difference in harvest size between sites with no water body present and those with either a RMZ or seasonal pond present (Table 6), indicating that harvest size had small influence on the probability of encountering these water features during the 2004-06 monitoring period.

Table 6. Mean harvest size at sites with no water bodies present ("none"), sites with RMZ's at lakes and streams present, and sites with seasonal ponds present by monitoring year.

Year	None (ac.)	RMZ (ac.)	Seasonal pond (ac.)
2004	24.9 (3.6)[1]	28.4 (3.5)	28.6 (3.3)
2005	25.5 (2.4)	21.6 (2.2)	25.5 (3.4)
2006	24.9 (2.8)	64.7 (18.0)	29.3 (6.7)

[1] standard error in parenthesis, n=number of sites, Tables 4 and 5

Results

Statewide and regional estimates Using the weighted values developed for the northern region as an example, relative marginal foregone stumpage costs in RMZ's ranged from a low absolute net gain of $0.54 at the lowest RBA considered, to a high loss of $3.34 per acre harvested. Gains are associated with reductions in RBA in the existing RMZ area, as the lowest RBA considered in this analysis was 25 ft^2 lower than the average recommended for non-trout streams and lakes in the current guidelines. These gains were more than sufficient to offset costs associated with seasonal pond buffers at the lowest RBA, but not at greater RBA's (Table 7). At the RSTC-recommended RBA of 75, RMZ relative costs are almost two times higher than those estimated for seasonal ponds, mostly due to the additional 25 ft^2 of RBA (on average) in the existing RMZ area required under the RSTC recommendation. Estimated relative marginal costs in the central and southeast regions are 20% lower and higher, respectively, relative to those estimated for the northern region (data not shown).

Table 7. Harvest area estimates of costs of RSTC-recommended changes to the riparian guidelines in the northern region.

Residual basal area (ft^2)	Lake and stream cost ($/acre)	Seasonal pond cost ($/acre)	Total annual relative cost ($/acre)
25	-0.54[§]	0.37	-0.17
50	0.75	0.74	1.49
75	2.05	1.11	3.16
100	3.34	1.47	4.81

§ negative numbers indicate gains in stumpage

Based on regional annual harvest estimates (T. Aunan, pers. comm.) and the estimated relative costs for each region (Table 7), total annual statewide costs of the RSTC recommendations were estimated for a range of RBA's (Table 8). Note that these estimates are weighted heavily towards conditions in the northern region as over 88% of the harvest area in the state occurs in that region. Annual statewide stumpage value was estimated using the 10-year mean statewide harvest volume estimate (3.69 mil cd yr^{-1}, Schwalm 2009) and the weighted cost per cord for the northern region (Table 3). At the RSTC-recommended RBA of 75, estimated total annual marginal cost of RMZ's and seasonal ponds is approximately 0.41% of the annual stumpage value sold in the state (~104 million).

Table 8. Total statewide costs weighted by region of foregone stumpage value associated with RSTC recommendations to the riparian guidelines at various levels of residual basal area (RBA).

Residual basal area (ft^2 $ac.^{-1}$)	Annual RMZ cost ($)[1]	Annual seasonal pond cost ($)	Total annual cost ($)
25	-75,000[2]	50,000	-25,000
50	100,000	100,000	205,000
75	280,000	150,000	430,000
100	455,000	200,000	655,000

[1] estimated costs based on percentage annual harvest area for each region during the 2001-07 period (northern=88%; central=11%; southeast= 0.5%) and a mean annual harvest area of 140,000 acres (T. Aunan, pers. comm.)
[2] estimates rounded to the nearest 5,000

Individual site estimates. Mean probabilities calculated across monitoring years indicate that approximately 20% of harvests will involve either a RMZ or a seasonal pond, and 5% will encounter both (Table 9). Probability of encountering a seasonal pond or stream is dependent on sample area size, with probability generally increasing with size assuming that the features are well-distributed across the landscape and do not influence placement of the sample area space. In forest operations, water features influence harvest boundaries and sale design directly given their influence on machine trail layout, stand volumes, site access, and logger operating costs. Probably of greater influence is recognition by managers of the general perception regarding potential impacts of forest management on water quality, perhaps leading to avoidance of water features when setting up sales. For these reasons, it is likely that the probability of water features being present on (or included in the design of) a given harvest site is dependent on the individual managing the harvest and site-specific conditions. This influence appears to override that associated with harvest size.

Table 9. Probability of a RMZ associated with lakes and streams, seasonal pond, or both being present at a site by monitoring year.

Year	RMZ	Seasonal pond	Both
2004	0.18	0.14	0.06
2005	0.26	0.25	0.07
2006	0.10	0.18	0.02
All years	0.18	0.19	0.05

For comparison purposes, total costs at individual sites are presented relative to harvest site area at a standard RBA of 75. Median marginal cost of RSTC-recommendations for sites with water features present during the 2004-06 monitoring period was estimated as \$4.84 $ac.^{-1}$, \$5.85 $ac.^{-1}$, and \$13.16 $ac.^{-1}$ for RMZ's associated with lakes and streams, seasonal ponds, and both, respectively. Based on cumulative distributions, 90% of the sites with seasonal ponds, 70% of the sites with RMZ's associated with lakes and streams, and 65% of sites with both water features had marginal relative costs less than \$15.00 $ac.^{-1}$ (Figure 2). Across all sites, maximum relative marginal costs were \$34.30 $ac.^{-1}$, \$31.00 $ac.^{-1}$, and \$47.46 $ac.^{-1}$ for sites that had RMZ's, seasonal ponds, or both present, respectively. The harvest site with maximum cost for seasonal ponds was a 4 ac. area with 2 ponds on NIPF land. The harvest site with maximum cost for RMZ's was a 30 ac. area with 1 open water wetland and 1 lake (total RMZ length of 3180 ft.) on NIPF land. The harvest site with maximum cost for both water features was an 18 ac. site with 7 seasonal ponds and 2 streams (total RMZ length of 1400 ft.) on county land. Note that neither of the above sites with RMZ's associated with lakes and streams followed the current recommended guidelines at time of harvest.

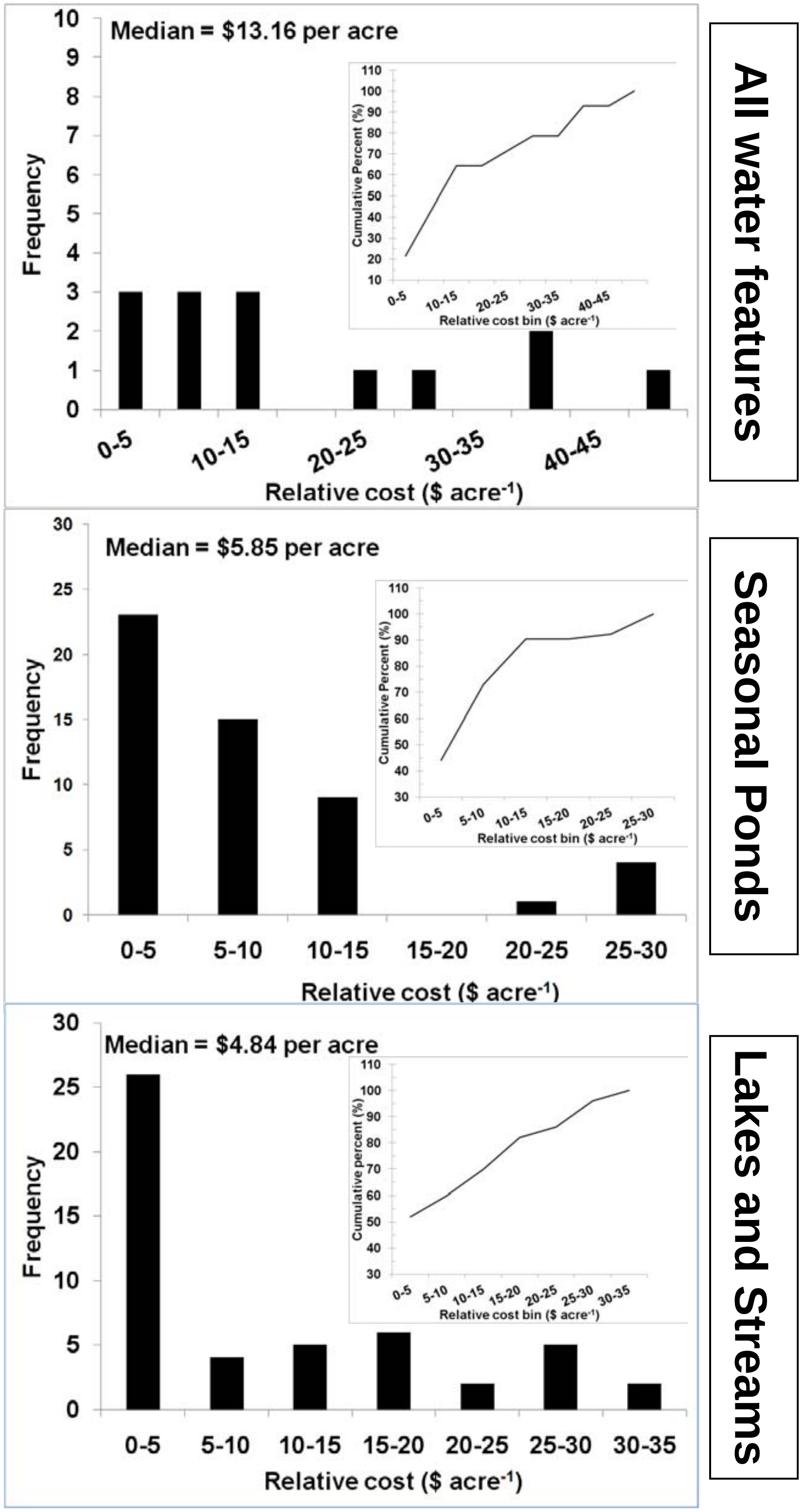


Figure 2. Distribution and median relative marginal costs of foregone timber revenue if RSTC recommendations were implemented at monitoring sites with water features.

The current guidelines recommend that 5% of the harvest area be retained as clumps, or that 6-12 individual trees be retained following harvesting for wildlife considerations and aesthetics. A power function relating pond frequency to harvest area was used to estimate pond buffer area for a range of harvest sizes (assume pond size of 0.025 ac) to examine if 5% leave tree requirements could fulfill the recommended buffer requirements for seasonal ponds (Figure 3). Although specific conditions will influence outcomes at individual sites, it appears that on average, sites greater than 10 acres have leave tree requirements that are in excess of those needed to fulfill the RSTC recommendations for seasonal ponds (Figure 3). Given the mean harvest size calculated from monitoring data (Table 6), it appears that most harvest sites could meet the RSTC recommendations relating to seasonal ponds without any additional foregone timber revenue than that already required under the current guidelines.

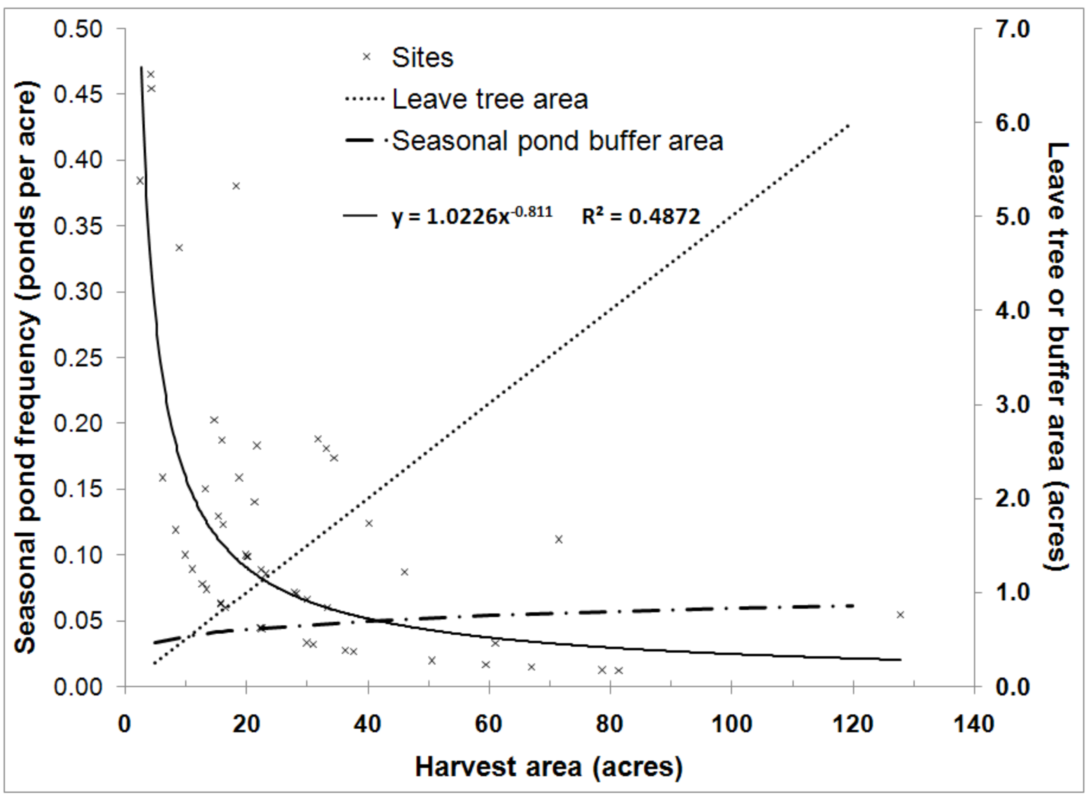


Figure 3. Seasonal pond frequency, buffer area, and leave tree area as related to harvest size. Buffer area calculations assumes a pond size of 0.025 ac.

Conclusions

A key goal in conducting this analysis was to determine if the potential changes in riparian guidelines would result in adverse economic effects (SFRA, § 89A.05). At the statewide level, it seems unlikely that significant adverse impacts would occur given that estimated costs are only 0.4% of the total stumpage value. Even if these costs are somewhat adverse, Minnesota citizens have indicated that additional costs are warranted for protection of water quality and wildlife habitat when they voted overwhelmingly in 2008 in support of a sales tax increase to protect these values. However, at the scale of the individual ownership, it is likely that there is potential for significant adverse impacts to occur at some sites with a high amount of water feature edge, or at sites where logging operation costs are increased due to constraints associated with the riparian areas. If the recommended practices are adopted during the next guideline revision, effort will need to be made to identify ways to offset the prohibitive costs at these unique sites. One possible means to offset costs is to modify the guidelines to recommend that leave tree clumps be placed around seasonal ponds to fulfill buffer requirements for those areas. Analysis indicated that leave tree requirements are more than sufficient to fulfill the buffer requirement at harvests greater than 10 acres in size.

Use of monitoring data as the basis for this analysis provided a reasonably accurate assessment of potential costs given the “real life” harvest conditions that the monitoring data reflects. The lack of any relationship between harvest size and probability of water feature occurrence supports this contention, as it is likely that managers actively avoid these areas during sale design. However, there is potential for estimates from this approach to be inaccurate at the regional scale, particularly as related to the southeast, given that only a few sites were monitored in that region during the 2004-2006 period. Probability of encountering a water feature at harvest sites in that region, and the characteristics of that feature, could differ compared to the rest of the state given differences in hydrology, geology and cultural influence between the regions. Although the southeast contributes less than 1% of the statewide annual harvest volume, forest riparian areas in this region may play a more important role to local water quality and wildlife habitat than in other regions, especially considering the steep topography, limited forest cover, and higher level of biodiversity in that region than in other regions.

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