Economic Analysis of Proposed Changes to Minnesota's Forest Management Guidelines

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Executive Summary

The Minnesota Forest Resources Council (MFRC) revises the voluntary forest management guidelines in response to new information, changing technology, and evolving social factors. Following a thorough evaluation, the MFRC has identified and initially approved several changes to the guidelines which will improve protection of forest resources during management activities and increase operational efficiency. The Sustainable Forest Resources Act (§ 89A.05) requires analysis of the costs and benefits of these new recommended site-level practices prior to implementation. The MFRC determined that costs and benefits of the recommended changes could only be quantified for those related to allowable infrastructure, riparian management zones, and leave tree retention. Other recommended changes not addressed in this analysis are more nuanced in their effect on costs and benefits, but will generally result in improved operational efficiency during timber harvesting operations and greater flexibility in application.

This report presents a relatively detailed assessment of the 1) potential marginal foregone stumpage value associated with increases in riparian management zone (RMZ) width and residual basal area (RBA), the 2) stumpage value associated with allowing RMZ area to count towards leave tree area, and 3) forestland area and productivity impacted by increases in allowable infrastructure for small harvest sizes. It is not a cost-benefit analysis, nor do we quantify ecosystem services such as water quality, wildlife habitat, or aesthetics. 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 assign market value to them in a comprehensive and defensible manner. Our analysis determined that:

- Less than 20% of harvest sites in Minnesota have riparian areas with RMZ's. Of these, mean harvest size is 32 acres and RMZ's under the new guidelines would compose 11% of total harvest area (2.2% more area than under the old guidelines).
- Marginal foregone stumpage revenue associated with increased RMZ widths and RBA averaged 10.4 $ ac.$^{-1}$ at sites with RMZ's present, representing an annual statewide foregone revenue of $240,000 (<0.4 % of current stumpage removals).
- Per acre foregone stumpage revenue varied by site conditions, ranging from 0.3 to 73.8 $ ac.$^{-1}$. Sites with highest per acre foregone stumpage were those with streams 3-10 feet wide and lakes 1-10 ac. in size because these water features had the greatest increase in recommended RMZ widths (70 ft. compared to 15-20 ft. for other sizes). Mean marginal foregone stumpage for these streams and lakes was 23.7 $ ac.$^{-1}$ compared to less than 8.4 $ ac.$^{-1}$ for other size classes.
- RMZ area was equal to or greater than the 5% leave tree area recommendation at 65% of sites. Across all sites, additional stumpage that may be removed due to changes in the

leave tree accounting was more than sufficient to offset foregone stumpage revenue associated with changes in RMZ's.

- On average, the net value between the marginal foregone stumpage of RMZ's and the additional stumpage from leave tree area resulted in a net revenue gain of 6.6 $ ac.$^{-1}$ harvested. However when calculated for sites with streams 3-10 ft. wide or lakes 1-10 ac. in size, there was a net loss of 5.1 $ ac.$^{-1}$ harvested.
- Under the old guideline, infrastructure should have occupied about 2.8% of annual harvest area, but actually occupied 3.8% of harvest area because the guideline was commonly not achieved. Under the new guideline total allowable infrastructure would increase to 4.4% of annual harvest area.
- Estimated reduction in stumpage value of maximum allowable infrastructure area under the new guideline was $90,000, $180,000, and $360,000 annually for scenarios of 25%, 50%, and 100% reduction in productivity, respectively. However, it is unclear whether or not operators will increase infrastructure amount in response to the new guideline.
- Adherence to the infrastructure guideline would increase by 47% in sites < 20 acres in size, and by 25% in sites 20-30 acres in size under the new guideline without any change in operational practices currently employed.

Given the above, we conclude that changes to the RMZ guidelines are unlikely to have adverse economic impacts at the statewide scale and at most harvest sites, partly because marginal costs are offset by additional stumpage which may be harvested from leave tree areas. However, at harvest sites with streams 3-10 ft. wide or lakes 1-10 acres in size, or at sites with a high ratio of RMZ length to total harvest area, additional costs may accrue to landowners. It is possible that these costs may result in adverse economic effects (e.g., no harvesting), and exploration of options to offset these effects is warranted.

The potential for changes to the infrastructure guideline to have adverse economic impacts is less clear, as there is much uncertainty on the extent to which infrastructure will increase following adoption of these changes, as well as uncertainty on the magnitude and duration of impacts to soil and forest productivity. Implementation monitoring conducted by the Department of Natural Resources will determine whether total infrastructure increases in response to this guideline change. Research utilizing controlled manipulation or retrospective approaches would more accurately quantify impacts to soil and forest productivity and help determine the true economic impact of these changes

Background

The Sustainable Forest Resources Act (SFRA, 1995) established the Minnesota Forest Resources Council (MFRC) to provide recommendations and guidance to achieve sustainable forestry. The SFRA charged the MFRC with development of comprehensive voluntary timber harvesting and forest management guidelines to mitigate impacts of management activities on forest resources. First published in 1999, the guidelines are a set of recommended forest management practices designed to mitigate impacts to soil and water quality, wetlands, wildlife habitat, historic and cultural sites, and visual quality during activities such as timber harvesting. The guidelines combine the best scientific information with flexibility considerations to provide options for managing forestland sustainably and are analogous to best management practices (BMP's). Guidelines are written for loggers, resource managers, and landowners. Since their inception the guidelines have been revised twice as required in statutes; a comprehensive revision in 2003-05 and again in 2007 when biomass harvesting guidelines were added.

In 2004, the MFRC convened a Riparian Science Technical Committee (RSTC) composed of technical experts in aquatic and wildlife biology, water quality, forest ecology, soils, and silviculture to provide information and guidance to the Council on riparian-related guidelines. A 2007 RSTC report provided recommendations on minimum widths and residual basal area in RMZ's for maintenance of important riparian functions (MFRC 2007). Following completion of the RSTC report, MFRC staff conducted an economic analysis of potential changes to riparian guidelines so that the costs and benefits could be evaluated during revision (MFRC 2010).

Although the focus of this most recent revision was on riparian guidelines, all other topical areas were also considered for revision and new areas were evaluated for inclusion. Following a scoping process, a subset of MFRC members made recommendations to the full Council after evaluating monitoring data, existing research, and other information. Topics considered for revision included those related to erosion control, rutting, invasive species, infrastructure, leave trees, biomass harvest, seasonal ponds, and riparian management zones.

Preliminary decisions on changes to the forest management guidelines were completed by the MFRC in March 2012, followed by a peer review and public comment period completed in early June 2012. The MFRC is required under the SFRA to analyze the costs and benefits of new

recommended site-level practices prior to implementation (§ 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 (Brown et al. 2012) and the time and motion study (Goychuk et al. 2011), added to our knowledge of the economic outcomes of site-level practices. Additionally in 2005, the MFRC commissioned a literature review to examine the valuation of non-market benefits emanating from forest riparian areas.

Table 1. Recommended changes in riparian management zone (RMZ) width and residual basal area (RBA).

Water feature	Old guidelines		New guidelines	
	RMZ Width (ft)	RBA (sq.ft/ac)	RMZ Width (ft)	RBA (sq.ft/ac)
Designated trout streams, tributaries, and lakes	150	60	165	60
Non-trout streams > 10 ft. wide	100	25-80	120	60
Non-trout streams 3-10 ft wide	50	25-80	120	60
Non-trout streams <3 ft. wide	50	25-80	50	60
Non-trout lakes/OWW[1] > 10 acres	100	25-80	120	60
Non-trout lakes/OWW 1-10 acres	50	25-80	120	60
Non-trout lakes/OWW < 1 acre	50	25-80	50	60

[1] OWW = open water wetland.

This analysis is limited to quantifiable market costs and benefits, including stumpage value of foregone or additional harvest, and the amount of land area potentially impacted. Specifically, we quantify the marginal foregone stumpage value associated with increases in RMZ width and residual basal area (Table 1), and the potential loss of productive forest land associated with

increases in infrastructure at small harvest sizes (Table 2). We also quantify the additional stumpage that could result from allowing RMZ area to count towards the recommended 5% leave tree area in harvest blocks. The previous guideline did not allow RMZ area to count as leave trees, resulting in greater overall foregone stumpage compared to the new recommendation.

Table 2. Recommended changes in allowable infrastructure (roads and landings) by harvest size

Harvest area	Old allowable infrastructure area	New allowable Infrastructure area
< 20 acres	1-3% of harvest area	<1 acre
20-30 acres	1-3% of harvest area	<5% of harvest area
>30 acres	1-3% of harvest area	<3% of harvest area

Non-Market Costs and Benefits

A comprehensive economic analysis should not only include goods and services that are well defined in a competitive marketplace with easily identifiable monetary values, but also those which can be equally or more important such as indirect use and non-use values. Benefits not well defined in the marketplace often accrue to society as a whole rather than individuals. In addition, many benefits and costs, such as those associated with water quality protection, erosion control, recreation, and wildlife habitat are very difficult to quantify.

We firmly believe that consideration of these non-market goods is essential for making sound policy and management decisions. However, quantifying the value of these goods and services is difficult due to their complexity and interdependent nature, and the tremendous room for error and interpretation in their accounting. Traditional forest product values have an existing market

in which prices are well defined and we have included these values in this analysis. In contrast, recreational values are less defined in the marketplace, and often do not reflect full values of the considered resource. There are a host of other values which are even more difficult to determine, and assigning monetary values to marginal changes in relation to these values becomes even more difficult.

Recognizing the complexity in assigning values to non-market goods and services, and the dangers of additive and interdependent values and our limited ability to transfer or extrapolate values among geographies, we concluded that assignment of value to non-market goods was beyond the scope of this analysis. Because of this, we chose to include in this analysis only those values which were reasonably well defined in the marketplace (stumpage values). We strongly encourage further examination of non-market values associated with the forest management guidelines.

Methods for estimation of market costs and benefits

We used guideline implementation monitoring data collected by the DNR from 2004-2011 (Dahlman 2008; Dahlman and Rossman 2010; Rossman 2012) to help quantify the costs and benefits of recommended changes to the forest management guidelines. This data is well-suited for these analyses. Monitoring sites were randomly selected and provide an unbiased assessment of the statewide harvest given that the sample size was relatively large (~90 sites each year). Harvest characteristics germane to this analysis (i.e., total harvest area, RMZ length and area, total infrastructure) were measured at each site. This data reflects operational settings and provide realistic estimates of additional costs and benefits associated with changes in recommended practices. In addition to the monitoring data, we used data from the Department of Natural Resources (DNR) – Resource Assessment Unit, the USDA Forest Inventory and Analysis (FIA) program, and stumpage price reports prepared by DNR-Division of Forestry.

Forest characteristics. FIA data from 2003 - 2011 was used to estimate species composition and mean volume across all forest area, and for riparian and upland areas separately. We used the all forest estimate to assess impacts of increased infrastructure on forest productivity, the riparian estimate to assess foregone stumpage associated with increased RMZ width and residual BA, and the upland estimate for leave tree stumpage that might become available given the allowance to count RMZ area towards leave tree area. FIA plots were separated into upland and riparian plots with use of a spatially referenced 200 foot buffer around known water features maintained by DNR-Resource Assessment. Plots within this buffer were assumed to be riparian and those outside were assumed to be upland.

FIA plots were further segregated into the northern (includes MFRC northern, north central, and northeast landscape regions) and central (includes east and west central MFRC landscapes) regions. We chose to develop estimates for each of these regions because of the differences in species composition and annual harvest removals between them. We did not develop estimates for the southeast landscape region because the annual harvest from this region is small, and there was insufficient monitoring data to calculate costs with any accuracy. FIA plots within a region and area (upland or riparian) were averaged to estimate mean total per acre volume by species, annual volume removals by species, and the ratio of volume to basal area by species in riparian areas only (Table 3). For the all forest estimate, we averaged characteristics across all plots in riparian and upland areas within the central and northern regions (data not shown). A weighted mean volume per acre was then calculated for each region and area using the volumes of species that comprised greater than 75% of removals.

Stumpage values. Species which comprised the majority of annual harvest removals (representing >75% of the total) were identified to develop a weighted cord price within riparian areas, upland areas, and all forest area. Cord price for each species was estimated from annual stumpage price reports produced by the DNR for 2011 and the proportion of harvest intended for various products (e.g., pulpwood or sawtimber). These individual cord prices were weighted according to the percent contribution that each species made to the annual harvest, and then summed across species to estimate a weighted cord price. Since RMZ guidelines use residual

BA in the recommendations, we also calculated the cost per unit BA in riparian areas for conversion to a total per acre cost associated with retention of 60 ft^2 BA in RMZ's.

Table 3. Forest characteristics and weighted cord prices for riparian and upland areas in the northern and central regions of Minnesota.

	Central Region		Northern Region	
Characteristic	**Riparian area**	**Upland area**	**Riparian area**	**Upland area**
Primary species harvested (% of harvest in parenthesis)	Aspen (71.4) R. maple (16.8) Bur oak (11.8)	Aspen (54.2) R. pine (14.8) R. maple (13.0) R. oak (10.3) P. birch (7.7)	Aspen (50.8) R. Oak (7.8) P. Birch (7.4) B. Fir (7.2) R/W Pine (12.9)	Aspen (55.5) P. Birch (13.4) J. pine (12.8) B. fir (9.5) B. spruce (8.9)
Weighted volume (ft^3)	1564	1578	1265	1413
Volume:basal area	11.9	NA	12.9	NA
Weighted cord value ($)	22.9	24.6	26.0	22.7

Area calculations for RMZs, leave trees, and infrastructure.

RMZs associated with streams and lakes. Field contractors recorded the area of RMZs 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 estimated the new additional RMZ area as the difference between the original area and the product of the estimated length and the new recommended RMZ widths (Table 4).

Leave tree area accounted for in RMZ's. Field contractors delineated harvest boundaries and calculated total harvest area. Note that total harvest area includes the area of any RMZ area when present. For RMZ's where the "new" RMZ area was equal to or greater than 5%, we calculated the amount of leave tree area that could be harvested under the new recommendation as 5% of the total harvest area. For RMZ's where the "new" RMZ area was less than 5%, we calculated the amount of leave tree area that could be harvested under the new recommendation as the product of the percent "new" RMZ area and the total harvest area. This accounts for leave tree area that would still have to be retained if the RMZ is less than the 5% of total harvest area leave tree recommendation.

Existing and potential infrastructure area. All road and landing areas were measured by field contractors to determine total infrastructure area at each monitored site. We used total harvest area to calculate the maximum recommended amount of total infrastructure under the old and new infrastructure guidelines, and also report the amount that was actually measured during field monitoring (Table 5).

Stumpage estimates.

Foregone stumpage in RMZs. Marginal foregone stumpage revenue associated with increases in RMZ width and RBA were calculated for each monitoring site as the product of the: 1) new additional RMZ area, and 2) the per unit riparian area BA cost multiplied by 60. For RMZ's associated with non-trout lakes and streams, additional foregone revenue associated with increased RBA in the "old" RMZ area were also calculated. In these calculations, we used a RBA of 50 in the "old" RMZ area (the approximate midpoint of the RBA range currently recommended in the guidelines), resulting in a net increase of 10 ft^2 RBA in "old" RMZ area. Difference in foregone revenue associated with "new" and "old" RMZ area were then calculated to determine the total marginal foregone timber revenue for a given site. A statewide per acre marginal foregone revenue estimate was calculated for each year of monitoring data by summing the total marginal value of foregone revenue across all sites with RMZ's present, and dividing that amount by the total harvest area monitored within a year. Foregone revenue was also expressed on a per acre basis for comparison among sites that had RMZ's present.

Table 4. Change in RMZ area under new guidelines for RMZ width calculated for harvest sites by monitoring year

Monitoring year	Total sites monitored	Sites with RMZ's (%)	Mean area of sites with RMZ's (ac.)	Old amount of site in RMZ area (%)*	New amount of site in RMZ area (%)	Sites with > 5% harvest area in RMZ (%)
2004	100	18	33.9 (6.5)#	8.6 (2.1)	12.0 (2.5)	61.1
2005	89	22	21.9 (2.3)	8.5 (1.9)	11.5 (2.3)	54.5
2006	90	9	64.7 (18.0)	5.4 (1.1)	8.1 (1.8)	55.5
2009	88	17	25.7 (4.7)	6.4 (1.3)	8.4 (1.5)	76.4
2011	84	18	34.7 (5.2)	9.3 (1.5)	14.0 (2.9)	77.8
Mean	**NA**	**NA**	**32.4 (3.1)**	**7.9 (0.8)**	**11.1 (1.1)**	**65.1**

* Old RMZ area refers to area with pre-existing RMZ widths; New RMZ area was calculated using the proposed RMZ widths approved in 2012

Standard error of the mean in parenthesis

Table 5. Infrastructure acres at monitoring sites by harvest size category, percent of total annual harvest under the old and new guidelines, and infrastructure measured during field monitoring after harvesting

Monitoring year and category	Site < 20 acres	Sites 20-30 acres	Sites > 30 acres	Percent of total harvest[1]
2004				
Old guideline	18.1	11.4	49.3	2.8
Actual observed	19.9	12.3	58.1	3.2
New guideline	54.8	21.1	49.3	4.4
2005				
Old guideline	16.7	16.9	29.6	2.7
Actual observed	21.9	24.6	39.4	3.7
New guideline	46.5	32.4	29.6	4.7
2006				
Old guideline	16.6	11.9	43.7	2.7
Actual observed	23.2	19.4	70.8	4.2
New guideline	49.4	24.3	43.7	4.3
2009				
Old guideline	13.4	11.8	31.1	2.6
Actual observed	22.3	15.8	47.1	4.0
New guideline	17.5	7.9	31.1	4.4
2011				
Old guideline	12.6	12.8	59.7	3.0
Actual observed	18.6	16.7	69.5	3.7
New guideline	35.5	24.4	59.7	4.2

[1] calculated as the sum of total infrastructure area divided by total area monitored during monitoring

Additional stumpage in leave trees. Potential additional stumpage revenue associated with allowing RMZ area to count towards leave tree area was calculated as the product of area in RMZ which accounted for leave tree area (either 5% or the amount of RMZ if less than 5% of harvest area) and the per acre weighted value of stumpage in upland areas. Per acre upland stumpage value was calculated from weighted FIA volume estimates (where 1 cord = 79.2 cubic feet) and the weighted per cord stumpage value described above.

Reduction in stumpage associated with infrastructure. Potential impacts of increased allowable infrastructure on future stumpage was calculated as the product of total allowable infrastructure (under old and new guidelines) and the weighted value of stumpage in all forest areas under three

scenarios of reduced productivity (25%, 50%, and 100% reduction). We choose to present a range of scenarios because long-term (i.e., rotation length) impacts of infrastructure on growth and productivity are unclear and dependent on infrastructure type (i.e., road vs. landing impact). Further, impacts are likely to vary depending on season of harvest, equipment mix, and soil type.

Results

Foregone stumpage associated with changes in RMZ width and RBA

Using the weighted values developed for the northern region as an example, mean marginal foregone stumpage revenue in RMZ's ranged from $7.7 per acre to $14.1 per acre, averaging $10.4 per acre across all monitoring years (Table 6). When averaged across all harvests including those without RMZ's, mean statewide total marginal foregone stumpage revenue of the proposed changes was approximately $240,000 annually (assuming annual harvest of 140,000 acres, T. Aunan, pers. Comm.). This foregone stumpage revenue is less than 0.4% of current stumpage harvested in the state (~2.7 million cords, MN DNR 2011) and less than 0.3% of historic levels (~3.7 million cords, Schwalm 2009).

At individual sites where RMZ's were present, marginal foregone revenue ranged from a low of $0.3 per acre harvested to a high of $73.8 per acre harvested. Individual sites with the highest per acre foregone revenues were generally those with a high ratio of RMZ length to total harvest area (data not shown). The amount of foregone revenue was also dependent on the type of water feature present, because the magnitude of proposed changes in RMZ width and RBA varied by water feature type (Table 1.). Estimated marginal foregone revenues are significantly higher at sites with streams 3-10 feet wide and lakes 1-10 acres in size compared to sites with other water features, averaging $23.7 per acre harvested compared to $2.4-8.4 per acre for other water feature types (Table 7).

Table 6. Marginal foregone stumpage revenue of increased RMZ widths, stumpage value of counting RMZ area as leave tree area, and net value of the combined changes by monitoring year. Negative values indicate net increase in value of stumpage removal

		----------Sites with riparian management zones present----------				
Monitoring year	**Total statewide foregone stumpage value**	**Mean foregone revenue per acre**	**Minimum foregone revenue per acre**	**Maximum foregone revenue per acre**	**Value of 5% leave tree area per acre**	**Net value of changes per acre***
2004	286,000	11.0	0.3	40.6	16.6	-5.6
2005	225,000	10.5	0.5	34.7	15.7	-5.2
2006	285,000	8.8	0.5	23.7	16.3	-7.4
2009	133,000	7.7	0.6	19.3	18.0	-10.4
2011	274,000	14.1	0.9	73.8	18.3	-4.2
Mean	**241,000 (29,000)#**	**10.4 (1.1)**	**NA**	**NA**	**17.0 (0.5)**	**-6.6 (1.1)**

*negative value indicates net reduction in foregone stumpage
Values in parenthesis is the standard error of the mean calculated across monitoring years

Table 7. Marginal foregone stumpage revenue of increased RMZ widths, stumpage value of counting RMZ area as leave tree area, and net value of the combined changes by water feature type across all monitoring years.

Water Feature	Marginal foregone revenue ($ acre^{-1})	Value of 5% leave tree area ($ acre^{-1})	Net value of changes ($ acre^{-1})*
Streams <3 feet wide and lakes < 1 acre	2.4 (0.5)	15.2 (1.8)	-12.8 (1.4)
Streams 3-10 feet wide and lakes 1-10 acres	23.7 (4.5)	18.6 (0.9)	5.1 (4.1)
Streams > 10 feet wide and lakes > 10 acres	8.4 (1.2)	16.1 (1.0)	-7.6 (0.9)
All designated trout streams and lakes	4.4 (1.5)	19.2 (0.9)	-14.8 (1.4)

* Negative value indicates net reduction in foregone stumpage

Additional stumpage value arising from counting RMZ area as leave tree area

Under the new recommendations for RMZ width and RBA, RMZ area was equal to or greater than 5% of total harvest area at 65% of harvest sites across all monitoring years (Table 4). Across all sites and monitoring years, the mean value of additional stumpage which could be removed from the general harvest area when RMZ area is allowed to count towards leave tree area more than offset foregone stumpage revenue (Table 6). Note that this estimate assumes that leave trees are left as clumps in 5% of the harvest area under the old recommendations. In practice, scattered individual trees are more often retained than clumps, which would have less total value than 5% of harvest area.

Similarly to the foregone revenue estimates described above, total net value of foregone RMZ stumpage and additional stumpage from leave trees differed among water feature types (Table 7). Additional stumpage removal with leave tree harvest was sufficient to offset foregone revenue at

most harvest sites, but sites with streams 3-10 feet wide and lakes 1-10 acres in size had on average a net revenue loss of $5.1 per acre harvested. This net loss is largely due to the high marginal foregone stumpage value associated with these water features relative to others (Table 7).

Reductions in stumpage associated with increased infrastructure

Across all monitoring years, the total amount of infrastructure allowable under the old guideline was 2.8% of the annual harvest area. However, allowable amounts were commonly exceeded, and the observed mean was 3.8%, causing an estimated net stumpage value loss of 0.56, 1.12, and 2.24 million in today's dollars annually at the end of rotation under the 25%, 50%, and 100% reduced productivity scenarios (Table 8). If infrastructure increases to the maximum allowable under the new guideline, these reduced statewide stumpage values would increase by 0.09, 0.18, and 0.36 million in today's dollars annually at the end of rotation under the 25%, 50%, and 100% reduced productivity scenarios.

Stumpage losses associated with potential reductions in productivity at landing and road areas are costs that largely accrue to the landowner. Clearly, infrastructure is a necessary component of timber harvesting and to some extent these costs are fixed, but infrastructure also provides market benefits which we have not quantified here. In particular, increased total landing area is likely to increase operational efficiency during harvesting, because it can allow for more efficient processing and also decrease skidding distance which is a primary factor controlling operational productivity (Goychuk et al. 2011). Given this, the net overall value of the change to the forest economy is likely less than the stumpage estimates reported in Table 8.

One of the primary reasons in changing the recommended allowable infrastructure amount was that the old guideline was difficult to achieve at small harvests since it was expressed as a relative amount that did not vary with harvest size. Harvests of less than 30 acres typically comprise >60% of total harvests in the state (Dahlman and Rossman, 2010). Under the old guidelines, only 42% of the sites less than 20 acres in size adhered to recommended amounts.

Table 8. Estimated total cost of old and new infrastructure guidelines at end of rotation under current market conditions and a range of reduced productivity scenarios.

Monitoring year and category	Percent of[1] total harvest	100% reduction in productivity[2]	50% reduction in productivity	25% reduction in productivity
2004				
Old guideline	2.8	1,652,651	826,325	413,163
Actual observed	3.2	2,035,136	1,017,568	508,784
New guideline	4.4	2,625,785	1,312,893	656,446
2005				
Old guideline	2.7	1,604,554	802,277	401,138
Actual observed	3.7	2,180,873	1,090,436	545,218
New guideline	4.7	2,754,653	1,377,327	688,663
2006				
Old guideline	2.7	1,570,993	785,497	392,748
Actual observed	4.2	2,467,461	1,233,730	616,865
New guideline	4.3	2,554,496	1,277,248	638,624
2009				
Old guideline	2.6	1,553,261	776,630	388,315
Actual observed	4.0	2,350,583	1,175,292	587,646
New guideline	4.4	2,609,920	1,304,960	652,480
2011				
Old guideline	3.0	1,777,224	888,612	444,306
Actual observed	3.7	2,188,638	1,094,319	547,160
New guideline	4.2	2,497,720	1,248,860	624,430
Mean				
Old guideline	2.8	1,631,737	815,868	407,934
Actual observed	3.8	2,244,538	1,122,269	561,135
New guideline	4.4	2,608,515	1,304,257	652,129

[1] total infrastructure area divided by total harvest area observed in a given monitoring year

[2] assumes an annual harvest of 140,000 acres, weighted mean volume of 18.5 cords, and weighted mean cord value of $22.8. Weighted values calculated from FIA data and DNR stumpage reports.

This increases to almost 90% under the new guideline (Table 9). For sites 20-30 acres in size, adherence would increase by almost 25% under the new guideline. It appears that the new guidelines will be achievable at most small harvest sites without any change in operational practices.

Table 9. Adherence to recommended allowable infrastructure (road and landings) amount under the old and new guidelines by monitoring year. Values are the percentage of all monitored sites with equal to or less than the maximum allowable infrastructure.

Monitoring year	Sites < 20 acres	Sites 20-30 acres	Sites > 30 acres
2004			
Old adherence	49	56	62
New adherence	95	81	
2005			
Old adherence	45	33	57
New adherence	84	54	
2006			
Old adherence	44	31	50
New adherence	88	63	
2007			
Old adherence	34	50	55
New adherence	84	69	
2008			
Old adherence	35	47	52
New adherence	91	76	
Mean			
Old adherence	42	43	55
New adherence	89	67	

Conclusions

A key goal of this analysis was to determine if the proposed changes in forest management guidelines would result in *adverse* economic effects (SFRA, § 89A.05). For changes in RMZ guidelines at the statewide scale, it seems unlikely that significant adverse impacts would occur. Foregone revenue estimates are less than 0.3% of the long-term annual stumpage value and are mostly offset with additional stumpage that can be harvested when allowing RMZ area to count as leave tree area. However, at individual sites, significant adverse impacts may occur. In particular, on sites with streams 3-10 feet wide or lakes 1-10 acres in size, foregone stumpage revenue will be highest with recommended RMZ widths (Table 1.). Further, regardless of the water feature type, sites with a high RMZ length to total harvest area ratio may also accrue

additional costs. The combination of these two conditions may very well result in adverse economic effects to landowners, and exploration of options to offset these effects is warranted.

Under the assumption of 5% leave tree area retention (rather than scattered trees), the guideline change to allow RMZ area to count towards leave tree area will result in net increase in stumpage value removed at greater than 65% of harvest sites, offsetting the marginal costs of increased RMZ width and residual basal area. Without this provision, RMZ costs at some sites would likely have been prohibitive for timber harvesting to occur, including harvesting and management in riparian zones to achieved desired conditions associated with longer-lived cover types and more complex forest structure.

Under the new infrastructure guidelines, costs associated with reduced stumpage value at the end of rotation could increase by $90,000, $180,000, and $360,000 annually for scenarios of 25%, 50%, and 100% reduction in productivity compared to estimated costs that currently occur. However, the actual maximum statewide value of these changes is likely less, as we did not quantify the benefit to operational productivity associated with greater infrastructure (e.g., reduced skidding distance). Further, the primary reason in making the change to the infrastructure guideline was so that small harvest sizes (< 30 acres) could readily achieve the recommended amounts, and it is unclear whether or not actual infrastructure amounts will increase in response to this change above what currently occurs in practice. Continued evaluation of infrastructure amounts during implementation monitoring will be critical to determine if total infrastructure changes in operational settings following adoption of the change.

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