"Stewards of the land... for generations to come."
Washington FARM FORESTRY ASSOCIATION
P.O. Box 1010
Chehalis, WA 98532
Phone (360) 388-7074
info@wafarmforestry.com
www.wafarmforestry.com

January 21, 2015

Forest Practices Board
c/o Department of Natural Resources
Forest Practices Division
PO Box 47012
Olympia WA 98504-7012

(via electronic transmittal to forestpracticesboard@dnr.wa.gov)

Dear Board Members:

The Washington Farm Forestry Association (WFFA) is a membership based non-profit organization that represents approximately 1300 tree farming families that collectively own about 150,000 acres of forest land in Washington State. Our objectives include educating small landowners about improved management of forest land, representing small forest landowners in the legislative process and by participation in Adaptive Management through CMER, science, and Policy, and educating the public on the contribution of small forest landowners to the environment and rural economies in Washington.

WFFA respectfully requests inclusion of an agenda item for the February 10, 2015 Forest Practices Board meeting. For the last year, WFFA has been working within the forest landowner community and with external scientists to develop an alternate plan template for RMZs along typed waters. WFFA requests that the Board initiate the Adaptive Management process and direct CMER and Policy to review the proposed alternate template.

In order to facilitate the Board's understanding of our request and the role of the Adaptive Management program, WFFA requests 15 minutes to present a summary of the template and answer any questions the Board members may have.

As the Board members are aware, the Adaptive Management Program is an integral part of the Forest Practices Habitat Conservation Plan (FP HCP) and the Forest Practices Rules. Adaptive Management is the method agreed on by the stakeholders to examine alternative strategies for meeting measurable biological goals and objectives. (FP HCP at 173; WAC 222-12-045(1)). The Implementation Agreement for the FP HCP requires the stakeholders to use the Adaptive Management Program to determine if and when it is necessary or advisable to adjust rules and guidance to achieve the goals of the Forests & Fish Report. (IA at §10.1; WAC 222-10-045(1)). The Board may also use the Adaptive Management Program to adjust rules and guidance to further the purpose of the Forest Practices Act. (WAC 222-08-160(2)).

The template is appropriate for review by the Adaptive Management Program because it is a modification to improve forest practices management and aquatic resource protection. (Board Manual, Section 22 at M22-8). Templates are discussed in both Forests & Fish and in rule. Forests & Fish anticipated that generic templates, such as the proposal developed by WFFA, would be developed for planning situations of differing levels of complexity. (Forests & Fish Report, Appendix H at p. 59 (h); WAC 222-12-0403(3)). As a participating representative for small forest landowners, WFFA believes existing science supports the proposed template and as a participant, requests the Board initiate Adaptive Management review of the proposal. *See* Board Manual at M22-8; WAC 222-12-045(2)(d)(i).

WFFA is not requesting a Board vote to approve the template, but is asking the Board to forward the attached proposal initiation document, template, and supporting documentation to the Adaptive Management Administrator to initiate the process required by Part 3 of Board Manual Section 22 (August 2013) and Appendix L of the Forests & Fish Report (Appendix B to the Forest Practices HCP). *See* RCW 76.09.370(3), (6); WAC 222-12-045(2).

Under the Adaptive Management process, the Board sets priorities for action. (WAC 222-12-045(2)(b)(iv); Appendix L at L.2.(a); Board Manual at M22-8). If the Board accepts Adaptive Management review of the template, it will first be evaluated for the need for scientific review by CMER. (WAC 222-12-045(2)(b)(i), (d)(ii)-(v); L.2.(b); M22-10). CMER will report its results to Policy, which will use the CMER findings to make specific recommendations to the Board. (WAC 222-12-045(2)(b)(ii), (d)(vi); L.4(a); M22-10). The Board then makes a final determination. (WAC 222-12-045(2)(d)(vii); L.2.(a); M22-14).

WFFA acknowledges that CMER and Policy continue to have full agendas, and in recognition of this, requests that the Board direct evaluation of the template proposal within nine months. If workload priorities prevent CMER and Policy from completing the Adaptive Management process within nine months, WFFA requests that the timeline be reviewed and an alternate timeline proposed at the November Board meeting.

The Legislature recognized the value of alternate plans to balance its objectives of sustainable forestry and to protect the environment. (RCW 76.09.010, 76.09.368, 76.13.100). It required the Board to consult with the small forest landowner office to develop alternate approaches that meet the public resource protection standard while lowering the overall cost of regulation. (RCW 76.09.368). Alternate plans are permitted where the proposed activity has a relatively low impact on aquatic resources, meets the resource protection standards, and lowers the cost of regulation for small forest landowners. (RCW 76.09.368, 76.13.100).

Our proposed Alternate Plan template responds to this legislative intent by proposing alternate harvest restrictions for riparian management zones (RMZs) along typed waters. The template is designed to provide protection of RMZ functions at least equal in effectiveness to those in existing rules, meet current performance standards, and support economic viability of small forest landowners. WAC 222-12-0401(6).

Although small forest landowners can propose alternate plans for any proposed forest practices, (WAC 222-12-040 through -0404 and Section 21 of the Board Manual), the Department of Natural Resources, through its Small Forest Landowner Office, has identified certain situations where more management flexibility is appropriate. Currently, there are two alternate plan templates and five scenarios where site specific management flexibility may be needed, including riparian hardwood management, overstocked stands, forest health, and seasonal streams. These template alternate plans ensure consistency and compliance with best available science in forest practices on small forest landowner property. They also provide regulatory certainty and minimize the regulatory costs which disproportionately impact small forest landowners. After careful consideration and development, WFFA proposes this template to fulfill an additional area where management flexibility is appropriate to meet protection standards but reduce regulatory impact.

WFFA developed the template in consultation with Dr. Douglas Martin, a fish biologist with Martin Environmental and an active member of the adaptive management scientific committee. Dr. Martin used the best available science to develop a template that meets or exceeds the standards in existing rules while decreasing the regulatory burden on small forest landowners. His scientific justification is documented in the accompanying Attachment 3 for the Board members' reference.

In order to ensure our template was based on sound science, we solicited technical review of Dr. Martin's scientific justification by Dr. Peter Bisson, a retired USFS fish biologist. We included Dr. Bisson's commentary in its entirety in Attachment 4. As Dr. Bisson indicates, templates are best addressed through application of the adaptive management process. Dr. Bisson suggests "a dedicated monitoring program that would yield data for various functions from a variety of sites, over an extended time period." His recommendations, as well as Dr. Martin's, are included in the Proposal Initiation document.

WFFA is confident that the proposed template is based on the current best-available science *and* addresses the uncertainties associated with implementation of any adaptive management protocols through monitoring. However, our objective in the adaptive management process is to gain more insights from the variety of stakeholder perspectives and expertise, suggest appropriate changes, and improve the template to ensure it meets the Legislative objectives and the Forest Practices HCP. Following completion of the review by CMER and Policy and any appropriate revisions to the template, WFFA anticipates the template will be brought back to the Board for review and adoption, based on Policy's recommendation.

Our goal in developing this template is to provide more options for ensuring the long-term economic viability of small forest landowners, thereby improving their ability to remain on the land and keep trees growing in Washington. Consistent with the balance inherent in the Forest Practices Act, the template also protects habitat and water quality consistent with our long- term view of forest management and its role in supporting rural community stability and quality of life for all Washingtonians. WFFA believes this proposal meets these goals, and looks forward to working with the members of CMER and Policy to improve the template to meet all stakeholder needs. Moreover, we hope the pending process will serve as a testament to the cooperative spirit that led our predecessors to include adaptive management as part of the original TFW and FFR agreements.

Thank you in advance for your consideration of our request to initiate Adaptive Management review of our proposed alternate plan template.

Sincerely,

Elaine Oneil, PhD
Executive Director
Washington Farm Forestry Association

Encl:
Attachment 1:Proposal Initiation Document
Attachment 2: Template including riparian function assessment
Attachment 3: Scientific Justification
Attachment 4: Peer Review Comments

P.O. Box 1010
Chehalis, WA 98532
Phone (360) 388-7074
info@wafarmforestry.com
www.wafarmforestry.com

Attachment 1:

Proposal Initiation Document, WFFA request to the Forest Practices Board, February 10, 2015

The Washington Farm Forestry Association (WFFA) Alternate Plan Template proposal (Attachment 2) details alternative harvesting restrictions/prescriptions for Westside riparian management zones (RMZs) based on best available science. Consistent with "Proposal Initiation" requirements in the Forest Practices Board Manual Section 22, part 3.1, we have highlighted the five elements of import for our request to the Forest Practices Board, including: 1) specifics on the affected sections of forest practices board manual, 2) our assessment of level of urgency based on scientific uncertainty and resource risk, 3) a summary of outstanding TFW, FFR, and Policy agreements supporting the proposal, 4) how results of the proposal could address Adaptive Management Program key questions and objectives, or other rule, guidance, or DNR product, and 5) extensive detail on the best available science and more broad scale details in support of advancing the template proposal through the adaptive management process.

1. The affected forest practices rule, guidance, or DNR product:

The WFFA Alternate Plan template proposal would affect Board Manual Section 21, Guidelines for Alternate Plans by adding a new template in addition to those that now exist: Template #1 (Overstocked Stands) and Template # 2 (Fixed Width Buffers). It is possible that the proposed template could substitute for a previously drafted, but not ratified, Hardwood Conversion template, and WFFA hopes to utilize the Adaptive Management process to discuss the merits of this approach.

Utilizing the "template" process provides the Board, the DNR, and stakeholders greater assurance that future changes to prescriptions and guidance in these templates can be readily made by DNR as, and when, changes are warranted based on long term monitoring projects.

2. The urgency based on scientific uncertainty and resource risk:

For nearly a decade, the Northwest Environmental Forum has been convening to discuss how to keep forests as forests. Efforts such as the 2007 Future of Washington's Forests demonstrated that the risk of land conversion was substantial, especially in the lowlands of Puget Sound. Data from the then Small Forest Landowner Database (now Washington State Parcel Database) show that forest land moves from industrial to small private ownership and then to development in an ongoing trend. Since 2007 additional NW Environmental Fora have been convened that examine a range of solutions aimed at keeping forests as forests. Most revealing was the October 2013 challenge from a long time participant

(Ecotrust) that asserted that as a state we had not moved the needle very far in our efforts to keep forests as forests - if at all. The trend toward conversion and development continues particularly in the interface where small landowners easily succumb to development pressure. Once converted, the lands rarely return to forest land that provides a high level of protection to public resources.

Like Ecotrust, WFFA believes that retaining working forests is important to citizens and communities in Washington State. We also believe the needle hasn't moved all that far in support of retaining small forest landowners as a viable part of the continuum of forestry ownerships. WFFA has been an active small landowner education organization for over 60 years. Our members come from all walks of life and represent a continuum of small landowner views. Like the NW Environmental Forum, our internal discussions focus on the very issues of maintaining the family tree farm in the face of development pressure and an aging cohort of owners. What we hear from our members is that while alternate harvest prescriptions that are equal in overall effectiveness are unlikely to prevent conversion in all cases, they are a move in the right direction to incentivize forest land ownership. Incentives are especially critical for those that would like to maintain their forest as forest but have financial challenges, or would like to pass it to their heirs if they can show demonstrable benefits of forest land ownership.

The proposed template (Attachment 2) seeks to address these disincentives for keeping forestland forested by reducing regulatory complexity and cost and increasing financial returns while still maintaining a residual stand the meets the effectiveness standards identified in rule (see Attachment 3 Table 3) and addresses cumulative effects via monitoring and modification as needed. It reflects the views of a dedicated, committed group of small forest landowners who, with the input of scientists, were able to develop a package that both honors current legislative language regarding resource protection and the original intent of Forest and Fish Regulations (FFR) (1999), which SFLOs helped pass.

3. Any outstanding TFW, FFR, or Policy agreements supporting the proposal:

The Legislature recognized the value of alternate plans to small forest landowners in the Forest Practices Rules. Alternate plan templates provide even greater value to small forest landowners for situations warranting greater management flexibility where resource protection can be met or exceeded. The proposal is consistent with and could provide valuable information for the following CMER projects due to its inclusion of a monitoring element: Westside buffer, DFC validation, Westside riparian effectiveness, hardwood conversion, and riparian status and trends. For more details *see* CMER Fiscal Year 2015 Work Plan, §§ 6.2.3, 6.3.1, 6.3.4, 6.3.6, 6.3.7 at:
http://www.dnr.wa.gov/Publications/bc_cmer_workplan.pdf

According to RCW 19.85.030 requirements for the Small Business Economic Impact Statement (SBEIS) that was completed when the Forest and Fish Agreement was adopted by rule, there are identified methods that the agency must consider, *without limitation*, for reducing the impact of the proposed rule on small businesses. These methods include:

a) *"Reducing, modifying, or eliminating substantive regulatory requirement:"*
    a. The WFFA proposal would modify the board manual to include the template for SFLO in Western Washington, based on science that is expected to ensure equal overall effectiveness.
b) *"Simplifying, reducing, or eliminating recordkeeping and reporting requirements:"*
    a. The WFFA template simplifies the assessment procedure for riparian stands.
c) *"Reducing the frequency of inspections";*
    a. Not part of this proposal.
d) *"Delaying compliance timetables";*
    a. Not part of this proposal
e) *"Reducing or modifying fine schedules for noncompliance";*
    a. Not part of this proposal
f) *"Any other mitigation techniques including those suggested by small businesses or small business advocates".*
    a. WFFA support additional monitoring and evaluation in support of long term adaptive management needs.

Because of the findings of the SBEIS, alternate plans were included in RCW 76.09.368 which states that small forest landowners (SFLO) "have access to alternate plan processes or alternate harvest restrictions, or both if necessary, that meet the public resource protection standard set forth in RCW 76.09.370(3), but which also lowers the overall cost of regulation to small forest landowners including, but not limited to, timber value forgone, layout costs, and operating costs". WFFA asserts that the proposed template is consistent with this language and also with the language on alternate plans as documented in WAC 222-12-040, 0401,& 0403 and in similar RCW's 76.09, 76.13, and 77.85.180(4). These assertions about fulfilling statutes and rules are based on science-based evidence provided below in item 5, which also describes meeting standards of all alternate plans.

4. How the results of this proposal could address Adaptive Management Program key questions and resource objectives or other rule, guidance, or DNR product:

The proposed template supplements Board Manual guidance by offering optional harvesting prescriptions along with useful guidelines for selecting a prescription that best fits reach-specific conditions and landowners' objectives. Implementation of the prescriptions in these templates will provide equal effectiveness to current rule for protecting riparian functions, yet provide opportunity to harvest more trees by landowners who desire increased economic viability to help justify retention of forest ownership. Further, as addressed above, the monitoring element could provide valuable data for CMER work plan projects.

Justification for including these templates in Board Manual section 21 is based on interpretation of the literature as noted in item 5 below, Appendix 1 of the template, and attachment 3. In summary the review indicates that depending on width of associated fish-bearing streams, all five riparian functions can be protected by 25 to 75 ft – wide, no-cut core buffers. In addition to providing full long-term riparian function, these buffers will also allow greater harvest within the typical mosaic of species and stocking in riparian stands, thus addressing the disproportionate effect of riparian rules on SFLOs as expressed in WAC 222-12-040(1) and (2).

Alternate plans (APs) without templates lower some costs and can better fit harvest plans to site-specific or reach-specific conditions than harvesting per default rules. However, APs without templates fail to fully address the disproportionate impact of Forest and Fish legislation on SFLOs. Because small forest landowners generally own acreage in the lower portion of watersheds, their land often has more acreage in streams and wetlands. Because their holdings are small, the percentage of acreage affected by RMZ regulation is greater. Moreover, most SFLOs do not have personal knowledge or resources to deal with complex regulations designed to protect water quality and associated fish and amphibians. Hence, cost of professionals to complete these tasks reduces income from harvesting.

Because of both location and greater operating costs, small landowners or their heirs are more likely to convert their forest to other uses. To retain these private tracts in forestry, more simplicity and flexibility are needed in harvest restrictions. This would fulfill the legislature's intent and may improve compliance as monitored by the DNR.

Templates are simpler to implement by landowners than alternate plans and have additional advantages. In contrast to the considerable time and effort required to change forest practice rules or legislation, unanticipated problems with a template can be corrected promptly and simply within the board manual by the Forest Practices Division of DNR. Thus, when cumulative field experience or monitoring results demonstrate that template corrections will better meet the objectives of the Forest Practices Rules, these are easier to make than rule changes, allowing fine tuning that better fits all four goals of Forest and Fish, including economic viability.

This template differs from rule-based harvest prescriptions within the RMZ by utilizing thinning and small patch-cuts that integrate elements of economic viability, improved forest health, and RMZ functionality, and to begin a DFC trajectory to historical species composition and stocking levels.

5. Available literature, data and other information supporting the proposal:

Science-based opinions to support WFFA's template (Attachment 2) were prepared by Dr. Douglas Martin, a fish biologist with more than a decade of association with Washington State's Adaptive Management Program. Dr. Martin's prescription proposal and riparian function assessment are found in Attachment 3. As noted in the introductory letter, Dr. Martin's scientific assessment was reviewed by Dr. Peter Bisson, a fish biologist most recently employed by the USFS, Pacific Northwest Research Station. Dr. Bisson's assessment is found in Attachment 4. Dr. Bisson raises policy and monitoring questions WFFA looks forward to addressing in Adaptive Management.

Reviews and commentary on best available science do not determine how much risk to riparian functions is acceptable and on whom the burden of proof should fall. For guidance in working with Dr. Martin's recommendations we relied heavily on the findings and reports of Dr. Tom Hruby, Washington State Department of Ecology. In particular Dr. Hruby makes reference to risks as they pertain to riparian resources and decision making that were used in the decision matrix. Pertinent quotes from Hruby, T., 2010, *Setting Buffers for Wetlands When the Science is Not Specific*, Washington Department of Ecology, Oct, 8,2010 are included here (**our emphasis in bold**):

> *"**Laws and regulations have not specified a minimum threshold at which the risk is considered to be acceptable**. Some will argue therefore that the slightest indication that an activity will damage streams justifies its rejection. On the other hand, the "absolute scientific proof" required by some proponents of the "innocent until proven guilty" philosophy can never be achieved. The cost of collecting data at each individual site is too costly and time consuming, and the results are never absolute. We still have to decide how much risk of being wrong we will accept.*
>
> *The laws require us to protect the functions and values of wetlands. The question facing decision makers becomes will not be protected for a given buffer width? Conversely, how certain are we that the buffers are adequate? Dealing with uncertainty and the risk of being wrong, however, is not new to our culture. **In fact, our legal system has formalized three qualitative levels of certainty used in making legal decisions that can also be applied to other types of decisions**. These are:*
>
> *• "**Beyond a reasonable doubt**" is the highest standard of proof that must be met to ensure that a decision is correct. In this case the risk of being wrong and having a buffer that does not protect wetland functions is very small. Buffers have to be large enough so there is no reasonable doubt that all functions of the wetland will be protected. "Beyond a reasonable doubt" in scientific studies usually means that the probability a decision will be wrong is less than 5%, and there is a 95% chance it is correct.*
>
> *• "**Clear and Convincing Proof**" is evidence that establishes a high probability that the fact sought to be proved is true. The standard for evidence needed to meet this criterion is less than that needed for "beyond a reasonable doubt," but higher than that needed for "preponderance of evidence" described below. It means decision makers must be persuaded by the evidence that it is highly probable that any buffer widths chosen will protect the functions of wetlands in a jurisdiction. Conversely, the probability that the buffers will not be adequate is relatively low but higher than 5%. If the risk of being wrong and not protecting wetland functions is "low" for the previous criterion, it can be considered "moderate" in this case.*

•*"**<u>A preponderance of the evidence</u>**" simply means that one side has more evidence in its favor than the other, even by the smallest degree. A preponderance of evidence has been described as just enough evidence to make it more likely than not that the fact the claimant seeks to prove is true. From a scientific perspective this means that the probability the decision is correct, and a buffer will protect the functions of a wetland is only 50% or more. This level of evidence results in much weaker decisions.* ***The chance that a buffer is too small is as high as 50% rather than the 5% needed to meet the "beyond a reasonable doubt" criterion****. If buffers are established based on this criterion, there is a much higher risk that the buffer is not wide enough to protect the resource."*

WFFA used the second level of certainty: "clear and convincing proof" as a guide, which implies risk of not adequately protecting functions and values of riparian stands is more than 5%, but not as high as 50%. With these criteria in mind, WFFA, working in conjunction with Dr. Martin to confirm that there is scientific justification for the proposed metrics included in the template, recommends the buffer widths as documented in Attachment 2.

Alternate Harvest Prescriptions for Small Forest Landowners in Western Washington

Background

In Forest and Fish Legislation, legislators stated their intent that small forest landowners (SFLOs) have access to alternate plans or alternate harvest restrictions, or both if necessary, to lower costs of regulation including, but not limited to, timber value forgone, layout costs, and operating costs (RCW76.09.368). These alternatives must meet the public resource protection standard set forth in RCW 76.09.370(3).

This template applies to small forest landowners (SFO) defined in WAC 222-21-010(13) and RCW 76.13.120(2)(c) as landowners who have harvested from their own lands in the state of Washington less than 2 million board feet per year for the three years prior to the year of application, and who certify at the time of application that they do not expect to harvest more than 2 million board feet per year during the ten years following application.

This template contains 13 optional prescriptions that landowners may use to harvest and manage stands near fish-bearing and non-fish-bearing streams in western Washington. Landowners can select the prescription that best fits their management objectives and the stand and site conditions near their streams. Optional prescriptions are useful because individual Westside RMZs usually are a mosaic of species composition ranging from pure hardwoods to pure conifers. Moreover, stand age and stocking, by tree numbers or basal area per acre, can also differ among stands composing this mosaic.

Purpose

The purpose of this Westside template is to provide optional prescriptions for harvesting trees near Types S/ F, Np, and Ns streams. Landowner choice depends on landowner objectives and on reach-specific stream, stand, and site conditions. To improve efficiency of harvesting permitted by a Forest Practices Application (FPA), these RMZ prescriptions can be combined concurrently with upland harvests proposed in the same FPA. Objectives of this template are to increase economic viability of small forest landowners and protect riparian functions to achieve the goal of WAC 222-30-010(2): ". . . to protect aquatic resources and related habitat to achieve restoration of riparian function; and the maintenance of these resources once they are restored." Meeting performance standards for stream shade and recruitment of large wood into streams is emphasized in these template prescriptions.

Optional harvest prescriptions in this template differ mostly in width of the RMZ and the no-cut streamside buffer or "core" zone. Both widths are based on local reach and site conditions. Contrary to rule, site quality based on soils maps is not considered. Outside the no-cut core zone is the harvest zone where commercial thinning to harvest overstocked portions can be combined with small gap clearings to regenerate new coniferous stands or to reduce shade that can result in some increase in water temperature, but increase instream productivity.

Process

Adherence to prescriptions within this template will meet riparian function requirements for approval of an alternate plan as described in WAC 222-12-0401(6): "An alternate plan must provide protection for public resources at least equal in overall effectiveness to the protection provided in the act and rules." An alternate plan must include the template form, available through the DNR. The form must be included with the Forest Practices Application (FPA). This template form provides the technical justification as required in WAC 222-12-0401(3) (b), (c), and (d), identifying how the alternate plan addresses the various functional requirements of the RMZ. Information in APPENDIX A will be useful for completing this form.

As for any proposed alternate plan, an Interdisciplinary (ID) Team may be called to review an application using this template (see WAC 222-12-0401(5)). However, by following provisions in this template, an ID team may only be necessary if site-specific issues arise.

Qualifying Stands

Qualifying stands are adjacent to Type S, F, or Np waters. These riparian stands often are a mosaic of hardwoods and conifers at varying combinations of species, age, and stocking. Because of stand conditions and the small riparian acreage available (**Table 1**) some riparian stands may not have sufficient merchantable volume to justify commercial harvest. Combining harvests in riparian with upland harvest can be a viable option.

Landowners planning to harvest a qualifying stand within an RMZ protected by the Shoreline Management Act (RCW 76.09.910) must consult with the county of jurisdiction and include written documentation from the county stating that the operation complies with the Shoreline Management Act. This documentation must be included with the Forest Practices Application.

Riparian Management Zones

This template separates the RMZ into two management zones: no-harvest and harvest by thinning to reduce stocking and/or patch cuts for regenerating conifers.

This template differs from standard rules by:

- Not requiring a before-harvest, Desired Future Condition (DFC) - type inventory of core and inner zones. Within the proposed harvest zone, trees designated for retention after thinning will be identified by spot or band of paint to assist loggers, ID and monitoring teams.
- Re-defining widths of RMZ and no-harvest core along typed streams within the FPA ***(Table 2***), RMZ width varies between 75 and 25 feet, depending on stream width of F-streams, and width and seasonal flow in Np streams. Site quality is not considered. To accommodate on-site topography and vegetative conditions, landowners will have the alternative that these widths are either fixed or variable. Specifically:

Table 1. Area of RMZ Harvest and Its Percentage of Total FPA Acreage by Length of RMZ and, where width for thinning, A = a two-sided harvest and B = one- sided.

Total of FPA (acres)	Length of RMZ and Option					
	500 Feet		1000 Feet		1500 Feet	
	A	B	A	B	A	B
	RMZ harvest acreage					
	0.57	0.29	1.15	0.57	1.71	0.86
	Percent of total FPA					
20	2.8	1.4	5.8	2.8	8.6	4.3
30	1.9	1	3.8	2	5.7	2.9
40	1.4	0.7	2.9	1.4	4.3	2.2

Note: Depending on the total acreage of the FPA (including both upland and 75- foot RMZ areas), length of the RMZ, and the no-cut buffer width, 0.7 to 8.6 percent of total FPA harvest area will be within the RMZ.

For Type S and F Waters with bankfull width of five feet or more, width of no-cut buffers is 25 to 75 ft where harvest is by thinning or a minimum of 25 feet where harvest is by patch- regeneration cuts. Within 50 or 75 ft- wide no-cut buffers along F- streams, individual tree may be marked for harvest and felled after approval of the DNR forester.

For Type S and F Waters with bankfull widths less than five feet, width of the RMZ is reduced to 25 feet and the no-cut core width is 25 feet. Outside this core buffer, thinning or patch-cut harvesting are part of the upland harvest. Within the 25 ft- wide no-cut buffers along F- streams, individual tree may be marked for harvest and felled after approval of the DNR forester.

For Type Np Waters, the RMZ has a continuous 25 feet- wide, no-cut buffer on both sides of the stream for the first 300 feet above the Np/F junction. Current rule specifies a 50 ft-wide buffer for 300 or more feet above this junction, depending on the total length of the Np stream below the upper-most point of perennial flow (UMPPF). Determining total Np length can problematic, because the UMPPF is often located on another ownership. Above the 300 ft long no-cut buffer, the 25-ft-wide buffer is retained, but may be thinned from above by removing merchantable trees and leaving smaller trees and shrubs to provide shade and small wood to these narrow reaches. Isolated intermittent reaches that are seasonally dry and are not connected downstream to F-streams by perennially flowing water may be thinned or patch cut.

Table 2. Decision-Logic for Westside Template

Table 2. Riparian Prescriptions by Stream Type and Bankfull Width

Decision Logic

If Water Type is:	And bankfull width is:	And flow is:	And seasonal reach is connected to F-stream:	Then the two-sided RMZ is:	Then the two-sided No-Cut Zone is:	And area for Thinning: (mostly conifers)		And area for Regeneration Harvest: (mostly hardwoods)		Prescription Option Number
	in feet			*in feet*						
S or F	>15	all seasons or seasonal	- -	75	50	50 - 75	*(7)*	50 - 75		1
				75	75	beyond 75	*(1)*	40% of F	**(9)*	2
	5 - 15	"	- -	50	25	25 - 50	*(8)*	50% of F	**(10)*	3
				50	50	beyond 50	*(2)*	beyond 50		4
				50	50	beyond 50	*(11)*	beyond 50		5
	<5	"	- -	25	25	beyond 25	*(3)*	beyond 25		6
Np	> or = 5	all seasons	yes	25	25 x 300	beyond 300**	*(4)*	"		7
		seasonal	yes	25	25 x 300	"		"		8
		"	no	0	0	beyond 0		beyond 0		9
	<5	all seasons	yes	25	0	beyond 0**	*(5)*	beyond 25		10
		seasonal	yes	25	0	"		"		11
		"	no	0	0	beyond 0		beyond 0		12
Ns	- -	seasonal	no	0	0	beyond 0	*(6)*	beyond 0		13

*Maximum length of individual patches is 500 ft; minimum thinnable width between patch cuts is 100 ft ; Cumulative total length of patch cuts along Type F streams within FPA: 40% (>15ft), 50% (<15ft)

**Remove larger trees (thin-from-above)

(Numbers in Italics) reference "situation numbers" in Table 2, Attachment 3 - Technical Assessment by Dr. Douglas Martin.

<u>This template is the same as standard rules, as follows:</u>

- Outside the RMZ, upland harvest rules apply.
- RMZ widths on all typed waters are measured horizontally from the outer edge of bankfull width (BFW) or the channel migration zone (CMZ), whichever is wider (see Board Manual Section 2).
- In situations where type S and F streams have stream-adjacent wetlands, RMZ measurement will start from the vegetation line change separating wetland and upland plant communities.

- No equipment is permitted to operate within 30 feet from edge of bankfull width or the CMZ.
- Minimum number and size of leave trees after thinning are same as required by rule; however residual trees must have live crown in 30 or more percent of total height to ensure survival and rapid growth.

Harvest Prescriptions

In this template, harvest prescriptions differ, depending on stream type, stream width, and seasonal flow. Table 3 provides considerations to guide landowners' decisions. For all typed waters within an FPA, average stream width is calculated from 10 equally spaced measurements of BFW. Landowners are advised to flag measurement locations to enable subsequent checking by regulatory personnel.

Type S and F Streams Averaging Five Feet or More in Width (RMZ = 75 or 50 ft)

Six harvest options are available within the RMZ of Type S and F waters. Width of no-cut core or stream-side buffers is 25, 50, or 75 feet. ***(Table 2)***. Choice of option depends largely on the need for stream shading and wood recruitment in site-specific reaches. Corresponding widths of the harvest zone within the RMZ for thinning or regeneration harvest is 25 ft. Within the core zone, some individual or groups of trees designated by landowners may be removed if approved by the DNR forester. Both patch cuts to regenerate new stands of conifers and thinning overstocked conifers must be at least 25 feet from BFW or CMZ. Regeneration cuts may merge with upland harvests.

Type S and F Streams Averaging Less than Five Feet (RMZ =25 ft)

Width of the no-cut core is 25 feet, the full width of the RMZ. Area outside the RMZ is considered upland harvest. Within the core zone, some individual or groups of trees designated by landowners may be removed if approved by the DNR forester.

Table 3. Fish-Bearing Streams: Guidance for Choosing among Prescription Options based on Landowner Objectives and On-Site Conditions

Objective and Conditions
<u>Provide more shade, where</u>: • No tall stand or blocking ridges to south • Stream is wide (> 20 ft) and oriented N-S • Few tall, dense shrubs near stream • Stand stocking in RMZ is sparse (< RD 20) • No reverse break in slope within RMZ
<u>Provide less shade at short intervals , where:</u> • Warming of stream is likely to increase food for fish
<u>Provide more channel wood recruitment, where:</u> • No or few boulder-caused pools in stream reach • No evidence of wood recruitment by natural bank erosion, especially near wide streams
<u>Provide wider no-cut buffer, where:</u> • Hazard of blow-down from wind storms is high • Concurrent harvest outside RMZ is clearcutting • A road is within the RMZ

<u>Harvesting guidelines for the thinning zone are:</u>
RMZ harvest prescriptions using this template have two general objectives: limit thinning intensity to avoid over-cutting and meet residual tree metrics to provide long-term riparian functions, especially shade to moderate stream temperature and recruitment of large wood into streams. Meeting rule-based performance standards for these RMZ functions is critical. To attain these thinning objectives:

- Limit harvest of trees 4 inches DBH and larger to about 50 % of before-harvest basal area per acre or about 60% of before-harvest trees. Maintain a minimum of 57 large conifer trees per acre (28 ft average spacing) after harvest. These residuals must have at least 30 % of their total height in live crown.
- Thin-from-below by harvesting mostly intermediate and weak co-dominant crown classes.

In general, harvest most hardwoods and lower crown classes of conifers. Retain dominant and co-dominant conifers about 28 feet apart (57 trees / acre). To leave more canopy cover or to reduce thinning intensity, retain additional conifer trees with live crowns at least 30 % of their total height. After harvest, residual stands could have a relative density of about 20 or more or a Stand Density index (SDI) of about 400 (***Table 4***).

Table 4. Rule-Based Minimum Number of After-Harvest Leave Trees per Acre and Corresponding Basal Area per Acre and Relative Density (RD)

Mean DBH	**57 Trees per Acre – 28 Ft Spacing (Westside)**	
	Basal Area per Acre	**RD****
8	20	7
10	31	10
12	45	13
14	61	16
16	80	20
18	101	24
20	124	28
22	145	31
24	180	37

*** RD= (basal area per acre) / square root of (basal area per acre / trees per acre). Do not count suppressed trees; counting small trees inflates calculated RD. Therefore, count only trees 4 inches DBH and larger.*

<u>*Harvesting guidelines for patch cuts are:*</u>
Limit individual patch harvests for regeneration to not exceed 500 feet of the type F stream reach, and additionally constrain that:

- Patches are no closer to BFW than 25 feet on perennially flowing Type Np waters;
- Combined lengths of patch-harvests do not exceed 40 or 50% of the F stream within the FPA (Table 2).
- Individual small regeneration/patch-harvests are separated by at least 100 feet of thinned or non-thinned areas;
- Where patch-cuts are on both sides of the stream, attempt to offset these small patch-cuts so that they are not directly across the stream from one another;
- Where large wood is needed in adjacent streams, the DNR may specify directional falling instructions and provide any applicable permits. See Template 1 (Overstocked Stand) for further details.
- Until effectiveness of these template prescriptions is assessed, limiting length of individual regeneration/patch harvests to generally less than 500 feet and a maximum cumulative length of 40 or 50% of the total stream reach in the FPAs is a precautionary restriction.
- Additional regeneration/patch harvest entries proposed in future FPAs for this stream reach are not permitted until the area of an earlier regeneration harvest by the landowner is well stocked with an average height of dominant and co-dominant trees equal to or greater in height to

bankfull width plus 6 feet. On streams that average wider than 34 feet, the average height of dominant and co-dominant trees does not need to exceed 40 ft.

Type Np Waters Harvest Prescriptions

Six alternative prescriptions may be applied along Type Np waters (Table 2). Choice depends on stream width and whether a given reach flows above-ground in all seasons or is seasonally dry. Reaches with above-ground flow in all seasons shall have a 25 foot- wide RMZ. Where the Np stream is 5 ft or wider, then the first 300 ft above the F/Np junction has a no-cut buffer that is continuous on both sides of perennially flowing reaches. Thinning or clearcutting to within 25 feet of BFW may be implemented. Above that 300-ft distance, larger trees may be removed (thinning from above), because smaller trees and shrubs are likely to provide adequate shade and because small streams lack power to transport bole wood downstream.

Np streams narrower than 5 ft need not be fully buffered (Table 2). Merchantable trees may be harvested. Shrubs and small trees are likely to provide sufficient shade and organic debris.

Complying with standard rules for S/F Type waters, harvesting near Np water types also must not occur within any sensitive site buffers. Sensitive sites include the 56-foot radius buffer patch centered on the point of intersection of two or more Type Np waters, headwall seeps, sidewall seeps, headwater springs or the points at the upper-most extent of Type Np waters, or within an alluvial fan. See WAC 222-30-021(2)(b)(i) through (vi).

Where a landowner objective is to supplement natural wood recruitment through time, consider the Large Woody Debris Placement Strategy detailed in Template 1 (Overstocked stand template). Risk of downstream damage from displaced long logs or boles is less likely in narrow streams with low power.

Summary

Appling this template will allow small forest landowners to submit an alternate plan for harvesting within riparian stands in western Washington as part of a completed forest practices application (FPA). The FPA will be processed as an alternate plan as outlined in WAC 222-12-0401. The template form must be included with the FPA, and is available through DNR. This form provides the technical justifications, as required in WAC 222-12-0401 (3) (b), (c), and (d), identifying how the alternate plan addresses the various functional requirements of the RMZ. Information in APPENDIX A will be useful for completing this form.

An Interdisciplinary (ID) team may be called to review the proposed harvest (see WAC 222-12-0401(5)). However, by adhering to the guidelines in this template, the need for an ID Team will be minimal and only necessary if specific issues arise.

WFFA Note: Appendix A is the riparian function assessment from the Martin Environmental Scientific Justification (Attachment 3 of the proposal; page 10-26). It is included here for ease in using the template as a stand-alone document.

Appendix A: Riparian Function Assessment

Shade

The primary function of riparian vegetation in controlling water temperature is to block incoming solar radiation (direct and diffuse). Direct solar radiation on the water's surface is the dominant source of heat energy that may be absorbed by the water column and streambed. Absorption of solar energy is greatest when the solar angle is greater than 30° (i.e., 90 to 95 % of energy is absorbed as heat) and decreases as the solar angle declines due to the reflection of radiation off the water surface. Therefore, riparian vegetation that blocks direct solar radiation along the sun's pathway across the sky is the most effective for reducing radiant energy available for stream heating (Moore et al. 2005). Research shows that the attenuation of direct beam radiation by riparian vegetation is a function of canopy height, vegetation density, and buffer width (Beschta et al., 1987, Sridhar et al. 2004, DeWalle 2010). Light attenuation increases with increasing canopy height and increasing buffer density as a result of the increased solar path and extinction of energy. Buffer width has a variable influence on light attenuation depending on stream azimuth (e.g., effective buffer widths for E-W streams may be narrower than for N-S streams due to shifts in solar beam pathway from the sides to the tops of the buffers; Dewalle 2010). Riparian buffer width is important for a given stand type and age, but is not a good predictor of stream shading among different stands because of differences in the shade-controlling variables. For example, Beschta et al. (1987) showed that shade levels[1] similar to old-growth forests (i.e., range 75% to 90%) varied from 65 ft. to 100 ft. depending on stand types in western Oregon. Similarly, Sridhar et al. demonstrated the most effective shading for temperature control in eastern and western Washington Cascade conifer stands was predicted for mature (high leaf-area-index) canopies close to the stream (i.e., within 33 ft. of the stream bank) and overall buffers of about 100 ft.

High levels of shading can be provided by buffers ranging from 25 ft. to 75 ft. wide, because most shade is provided by trees directly adjacent to the stream (Table A-1). For example, Teply et al. (2013) demonstrated that thinning the outer portion of a buffer with a 25-ft. no-harvest core in a grand fir-western red cedar stand reduces the overall potential shade by 6% to 15% depending on the width and level of thinning in the outer zone. Also, they indicated that similar buffer treatments in the western hemlock-subalpine fir and Douglas-fir stands of western Idaho could provide relatively high shade levels.

Predictions of effective shade (i.e., percentage of potential daily solar radiation blocked by vegetation and topography) were simulated with the Ecology shade model (http://www.ecy.wa.gov/programs/eap/models.html) to demonstrate how stand height, composition, buffer width, and stream aspect influence shade. Effective shade was simulated for a hypothetical low-gradient (2 - 3%) stream, with no topographic shading, located in Olympia vicinity, and having conifer/deciduous riparian stands that are typical of western Washington (Table 2). The simulation results are consistent with the findings described by others and show that effective shade is mostly provided by trees within 15-25 ft. of the stream regardless of stand height, composition, and aspect (Figure A-1, Appendix B). Trees beyond 25 ft. only contribute a small amount of shade. Shade is correlated with tree height as high shade levels (i.e., exceeding 75%) are provided by small trees along 5-ft. streams, and by

[1] Based on measure of angular canopy density (ACD) which is a projection of the canopy at the angle above the horizon at which direct-beam solar radiation passes through the canopy (Beschta et al 1987).

medium to large size trees along streams up to 25 ft. wide. Shade potential declines with increasing stream width and is lowest for the wider streams with a N-S aspect. Note, the mixed-medium and mixed-large stands provide slightly more shade than the conifer stands of similar size (Appendix B). The latter is partly due to the greater overhang which blocks direct beam radiation. Similarly, high shade levels can be maintained along E-W streams (aspects 270º and 225º) with dense stands on the south side and sparse stands on the north side because most radiation is blocked by the south side stand (Figure A-2).

Shade levels in headwater streams without buffer strips are typically greater than zero initially following timber harvest as a result of cover from logging slash. Even though BMPs (e.g., 30-ft ELZ) are intended to minimize slash input, studies show that slash is relatively common in seasonal streams (Type Ns). For example, shade levels in four headwater streams bordered by clearcut units in southern Oregon averaged 66% after harvest (i.e., average 20% reduction from pre-harvest levels) (Kibler et al. 2013) and similarly, Ehinger et al. (unpub.) observed a mean decreased in canopy cover at the water surface from 91% pre-harvest to 52% as a result of logging slash in headwater streams in western Washington. In both studies the longitudinal distribution of slash cover was patchy and associated shade was highly variable. The effectiveness of slash to provide shade is likely to decline over time with decay and debris export.

Shade from riparian vegetation is not the only factor influencing stream temperature. Research shows that temperature response from timber harvest is variable and is highly dependent on the volume of stream flow, substrate type, groundwater inflow, and surface/subsurface water exchange (i.e., hyporheic exchange) (Moore et al. 2005). Stream size is a key driver with sensitivity decreasing in relation to increasing depth, velocity, and discharge (Moore et al. 2005). Velocity influences exposure duration which decreases with increasing velocity in steeper channels (cascade channels). Stream depth has significant influence because it affects both the magnitude of the stream temperature fluctuations and the response time of the stream to changes in environmental condition (Adam and Sullivan 1989). The temperature response to heat input is dampened by hyporheic exchange rate which is a function of bed composition. Streams with alluvial gravel/cobble bed material (pool riffle, alluvial fan channels) enables increased hydraulic retention (promotes conductive cooling) and are less sensitive to shade loss compared to streams with less-permeable boulder/bedrock substrate (e.g., cascade, bedrock channels) (Johnson 2004, Dent et al. 2008). In general, stream sensitivity to shade loss is a function of reach-scale physical characteristics. For example, streams at lower elevations (i.e., warmer air temperature), or with no topographic shading, or with shallow-wide channels (i.e., high width-to-depth ratio), or with bedrock substrate (i.e., hyporheic exchange limited) are more sensitive to heating from shade loss than are streams with the following conditions: at higher elevations, or with topographic shading, or with deep-narrow channels, or with alluvial substrate.

Table A-1 Summary of stream shade provided by different buffer treatments similar to proposed template.

Location	Stand type	Buffer treatment	metric	Post-harvest amount	Post-harvest change	Reference
western WA	df, hem, 35-50 yrs	50-ft. no-harvest	canopy cover	81%	-10%	Schuett-Hames et al. 2011
western WA	df, hem, 60-110 yrs	33 to 50-ft. no-harvest	canopy density[a]	86%	-8%	Janisch et al. 2012
coastal OR	df, alder, 50-70 yrs	50 to 70-ft.; inner 20 ft. no-harvest, outer thinned	shade	78%	-7%	Groom et al. 2011
western ID	grand fir-redcedar	50-ft. no-harvest	effective shade	82%	-8%	Teply et al. 2013
western ID	grand fir-redcedar	75-ft. no-harvest	effective shade	87%	-3%	Teply et al. 2013
western ID	grand fir-redcedar	50-ft.; inner 25 ft. no-harv., outer 25 ft. thinned	effective shade	75%	-15%	Teply et al. 2013
western ID	grand fir-redcedar	75-ft.; inner 25 ft. no-harv., outer 50 ft. thinned	effective shade	84%	-6%	Teply et al. 2013

[a]includes topographic shading

Table A-2. Description of riparian stand characteristics used for modeling. Data derived from riparian shade study in Stillaguamish River by Ecology (http://www.ecy.wa.gov/programs/eap/models.html). **Note, canopy density of 75% approximates levels found in unmanaged stands.**

Stand description	Height (ft)	Canopy density (%)	Overhang (ft)
css - conifer, small, sparse	49	25	5
csd - conifer, small, dense	49	75	5
cms - conifer, medium, sparse	148	25	15
cmd - conifer, medium, dense	148	75	15
cls - conifer, large, sparse	174	25	17
cld - conifer, large, dense	174	75	17
msd - mixed, small, dense	49	75	6
mms - mixed, medium, sparse	66	25	7
mmd - mixed, medium, dense	121	75	15
mld - mixed, large, dense	148	75	18
clearcut	0	0	0

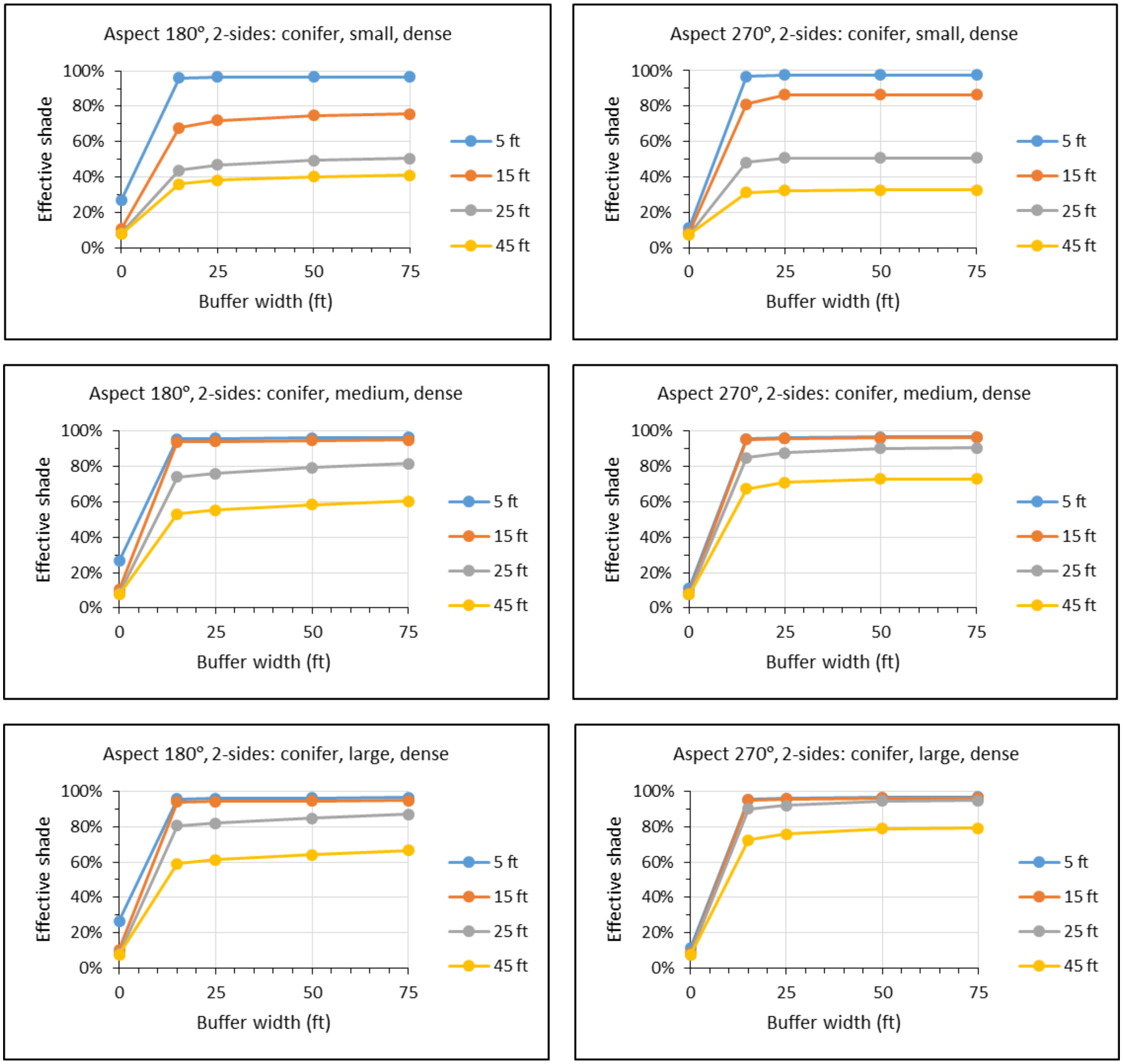

Figure A-1. Predicted effective shade in relation to buffer width, channel width, and aspect for riparian stands with different tree heights and composition. Shade simulated for streams with N-S and E-W aspects, and with dense conifer stands on two sides. Stand specifications are listed in Table A-2.

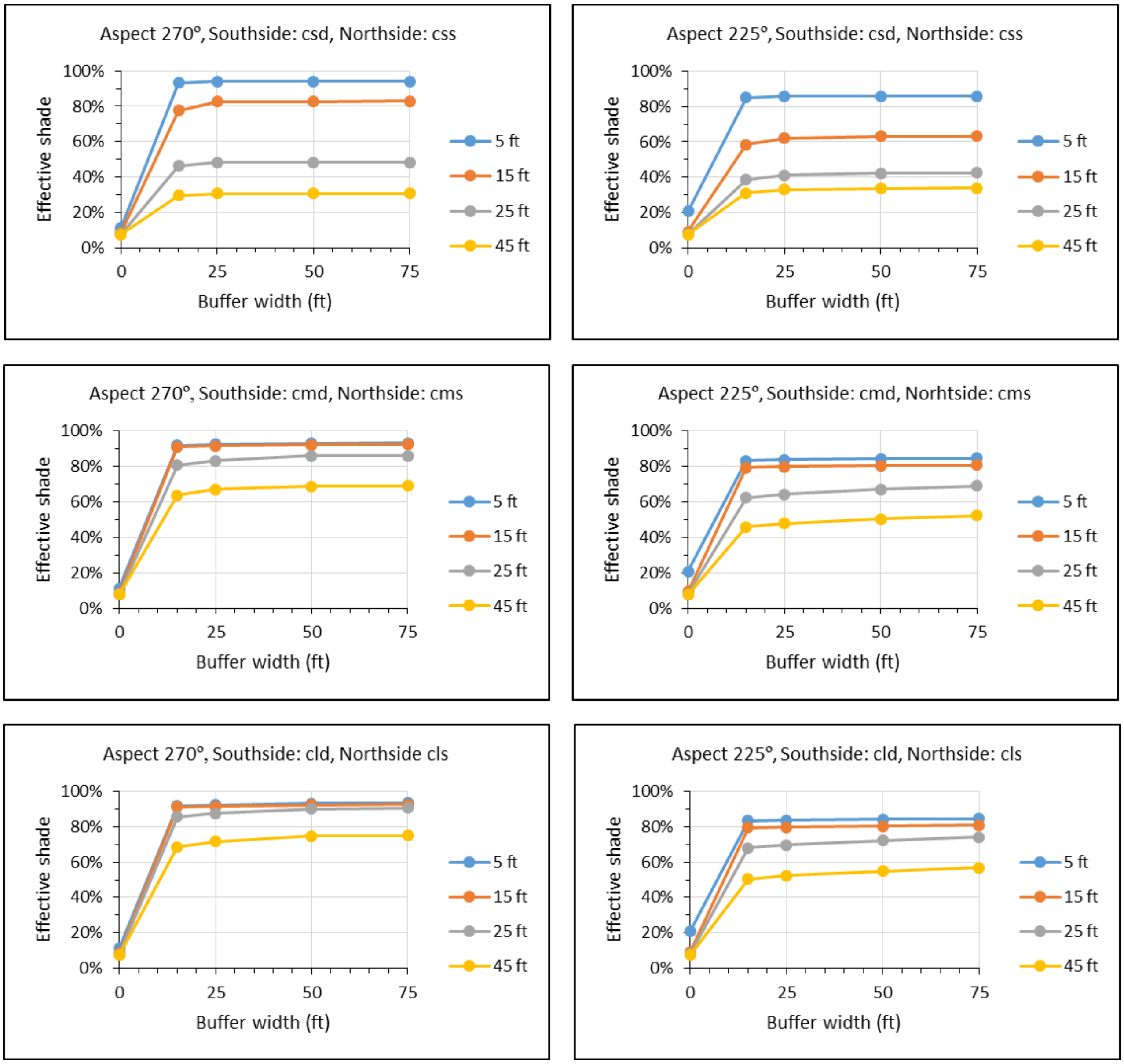

Figure A-2. Predicted effective shade in relation to buffer width, channel width, and stream aspect for riparian stands with different tree heights and composition. Shade simulated for streams with dense conifer stands on south side and sparse conifer stands on north side. Stand specifications are listed in Table 2.

Large Wood

The primary factors controlling large wood (LW) recruitment to streams are tree height and stand mortality processes. In general the distances to sources of stream wood increase with increasing tree height. For example, the source distances for tall old growth Douglas fir or coastal redwoods of California may extend out to 200 ft., but recruitment of shorter Sitka spruce in Southeast Alaska may only extend to 125 ft. (Benda & Bigelow 2014, Martin & Grotefendt 2007, McDade et al. 1990). Similarly, smaller trees in second-growth stands will have shorter source distances than trees from old-growth stands. However, the tree height source distance relationship is modified by site-specific factors (i.e., valley morphology, stream width, and wind exposure) that can have a strong influence on stand mortality. For example, LW recruitment by bank erosion is the dominant wood input process for low- to moderate-gradient channels in unconfined valleys and bank erosion recruitment increases with increasing stream width (Benda & Bigelow 2014, Johnston 2011, Martin & Benda 2001). Most of the LW in erosion prone channels is derived from the stream banks (e.g., 86% to 98% may be recruited from within 25 ft.; Table A-3, Figure A-3). Recruitment by stand mortality (e.g., stem suppression) is generally dominant where bank erosion is limited, such as in riparian stands adjacent to smaller streams and streams of any width that are confined by bedrock or hillslopes. Also, there is a strong tendency for dead trees to fall towards the channel on steeper hillslopes (i.e., >40%) that may increase recruitment by 1.5 to 2.4 times over levels from lower-gradient landforms (Sobota et al. 2006). In areas where stand mortality dominates, the source distance distribution shifts away from the stream bank and most recruits are derived from within 50 to 75 ft. (Table A-3, Figure A-3). Note, the far right shift of source distances for the McDade (1990) data (Figure A-3) are due, in part, to significant recruitment from trees and tree pieces that slid down steep side slopes (50% of study sites were located on slopes > 40%). Windthrow can extend the source distance by increasing recruitment from trees along the outer edge of buffer strips (Rollerson et al. 2009, Martin & Grotefendt 2007, Liquori 2006). Local landslides can extend the source distances even farther from the channel up the hillslopes (Benda & Bigelow 2014). The rank ordering of source distances for all mortality processes are bank erosion < tree mortality < windthrow < local landslides.

Table A-3. Summary of large wood inputs to streams by riparian source distance and dominant recruitment process (recruitment by landslides excluded).

			Percentage input by source distance				
Location	**Stand type**	**Dom. recruit process**	**25 ft.**	**50 ft.**	**75 ft.**	**100 ft.**	**Reference**
Southeast AK	old-growth	bank erosion	86	93	96	98	Martin & Grotefendt (2007)
South-Central BC	old-growth/mat. conif.	bank erosion	98	99	100	100	Johnston (2011)
South-Central BC	old-growth/mat. conif.	mortality	81	95	98	100	Johnston (2011)
Cascade, WA,OR	mature conif.	mortality	40	71	85	94	McDade et al. (1990)[a]
Cascade, WA,OR	old-growth	mortality	33	62	76	84	McDade et al. (1990)[a]
Southeast AK	Old-growth	mixed	75	91	97	99	Murphy & Koski (1989)
Cascade, WA	conifer (50-80 yrs)	mixed	82	96	98	100	Mckinley (1997)
Cascade, CA	Unmanaged	mixed	75	97	99	100	Benda & Bigelow (2014)

[a]Data include trees and tree pieces from given distance.

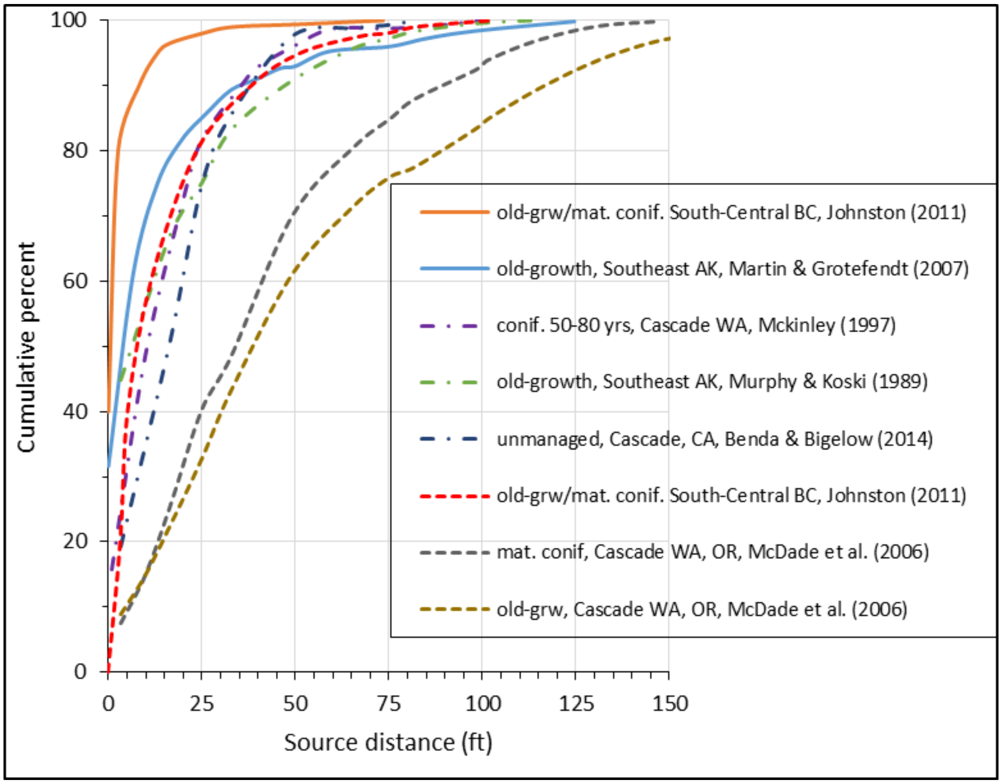

Figure A-3. Large wood source distance curves for riparian forests similar to stands typical of western Washington. Dominant recruit processes are bank erosion (solid line), stand mortality (dashed line), mixed (dash-dot line). Note, the far right shift of source distances for the McDade (1990) data are due, in part, to significant recruitment from trees and tree pieces that slid down steep side slopes (50% of study sites were located on slopes > 40%).

Windthrow can increase the probability of LW recruitment from buffer strips over the short-term and can influence the long-term supply at locations prone to wind damage. At the landscape scale, windthrow mortality is highly variable; having a skewed mortality distribution (i.e., most sites have low mortality and a few have high mortality (Grizzel and Wolff 1998, Martin and Grotefendt 2007, Rollerson et al. 2009). Wind damage is strongly associated with buffer orientation relative to the predominant storm direction (i.e., southeast, south, southwest in the Pacific Northwest) and local conditions including wind fetch length resulting from the size of clearcut units (Kramer et al. 2001, Mitchell et al. 2001, Rollerson et al. 2009). At the scale of individual trees, windthrow mortality is associated with low percent live crowns (< 40%) and high height-diameter ratios (>60%) (Scott 2005). Reductions in windthrow mortality are feasible when site and landscape factors are considered in harvest unit plans (Kramer et al. 2001; Mitchell et al. 2001)

The transport of LW in streams provides connectivity between upstream sources areas and downstream processes that create channel complexity and form aquatic habitat. Debris flows that result from channelize landslides are an important mechanism for delivery of LW from steep headwaters to larger fish bearing streams (May and Gresswell 2003, Reeves et al. 2003). Debris flows can transport wood in small streams that lack the capacity for fluvial transport of wood, and for transporting wood that is longer than the bank-full width of the channel. In the absence of debris flows, drainage area (i.e., stream size) is the primary factor controlling the fluvial transport of LW in streams. Studies by Martin & Benda (2001) in Southeast Alaska and by Benda and Bigelow (2014) in four regions of northern California (Coast, Klamath, Cascade, and western Sierra ranges) show that fluvial transport of LW increases with increasing stream size. In both studies the predicted wood transport distance (over the lifetime of wood in streams varied from a few hundred ft. to ten thousand ft. in channels with drainage areas of 250 ac to 18,000 ac, with transport distance increasing with drainage area. For example, in the smallest channel (10-15 ft. wide), Martin and Benda (2001) estimated there was a 90% probability that LW would be transported at least 150 ft. and only a 10% probability that transport could exceed 1000 ft. Also, the length of nearly all mobile LW is less than or equal to the bank-full width of the channel. Therefore, only a small proportion of LW is exported by fluvial processes in smaller headwater streams and only the lower-larger portions of headwater channels are likely transport LW to larger streams. Correspondingly, the residence time of LW accumulations in streams is inversely related to channel size (Martin & Benda 2001, Benda and Bigelow 2014).

The size of LW (diameter and length of wood pieces) required to form habitat increases with increasing stream width (Bilby and Ward 1989). For example, Bilby and Ward (1989) found that functional size pieces ranged from 25 to 65 cm in diameter and 5 to 12 m in length in streams 13 to 65 ft wide. Beechie and Sibley (1997) regressed wood diameter with channel width and showed the minimum diameter for forming pools ranged from 5 inches to 10 inches for streams 15 ft. and 30-ft. wide, respectively. In small headwater streams (range 3 - 12 ft wide), Jackson and Sturm (2002) found that wood smaller than 8 inches diameter is more likely to function than is larger wood and that smaller wood along with inorganic material and organic debris (< 4 inches diameter) were major step-forming agents.

The formation of fish habitat in streams is not only a function of LW supply and size, but on reach-scale physical characteristics (channel width, morphology, substrate composition) that influence the channel response to wood loading. For example, research shows that large wood has a stronger influence on the formation of pools and gravel bars in moderate gradient, unconfined channels (e.g., plan bed, pool riffle, alluvial fan channel types) compared to either high-gradient-confined channels or low-gradient channels (Montgomery et al. 1995, Beechie and Sibley 1997, Martin 2001). The cobble-boulder-bedrock substrate typical of steeper high-energy channels controls bedform (e.g., step pool, cascade) and pool formation is independent of LW; although LW may function to trap sediment in step-pool channels (Montgomery and Buffington 1997, Benda and Bigelow 2014). In very low-gradient meandering channels (e.g., dune ripple) the dependency on LW is limited as free-formed pools are common (Beechie and Sibley 1997).

Sediment

Timber harvest in or adjacent to riparian management zones can influence surface erosion and sediment input to streams as a result of ground disturbances from yarding activities (e.g., skid trails, yarding ruts), or to increases in root-pit formation from windthrow. Sediment retention within a riparian forest is controlled by vegetative ground cover, hillslope gradient, and soil erodibility (WFPB 1997). Ground cover including roots, stems, and debris (logs, slash) bind soils and create roughness elements minimizes surface runoff and traps soil particles (Liquori et al. 2008, Litschert and MacDonald 2009). Sediment delivery potential increases with slope. Therefore, the sediment retention function of riparian ground cover is most important in steeper terrain

Research shows that current harvest procedures and BMPs are largely effective in reducing erosion and sediment delivery to streams. Post-harvest evaluations of erosion features across a wide range of sites indicates that buffers and the prevention of ground disturbances within 30-ft of streams effectively prevented sediment inputs in most cases (Rashin et al. 2006, Litschert and MacDonald 2009). For example, Schuett-Hames et al. 2011 found that implementation of a 30-ft equipment exclusion zone (ELZ) in clearcut units met the performance targets for sediment control at seven of eight clear-cut reaches. In a related study of buffer and ELZ effectiveness in headwater streams Stuart et al. (unpub.)

reported the area of bank erosion (or lack thereof) was similar among reference and treatment sites suggesting the absence of a treatment effect. Root-pit formation is increased as result of post-harvest windthrow. However, the density of root-pits with sediment delivery were no different among reference and buffer treatment sites in two separate studies of BMP effectiveness (Schuett-Hames et al. 2011, Stuart et al. unpub). In both studies the mean distance to stream for root-pits that delivered sediment was less than 9 ft.

Biotic Productivity/Litter

Research shows that algal biomass and invertebrate prey biomass generally increase with increasing canopy openness and/or increasing densities of deciduous vegetation. Autotrophic (algal) production responds most with an open canopy and heterotrophic (detrital) production responds most to a full canopy consisting of red alder. Light is the primary factor limiting primary productivity in temperate-forest streams (Gregory 1980, Kiffney et al. 2004) and is strongly associated with productivity at higher trophic levels (Wilzbach et al. 2005, Kiffney and Roni 2007). For example, biotic responses to moderate light levels or to deciduous vegetation ingrowth is detectable in buffers that range from 33 ft to 66 ft wide, in defoliated or thinned buffers (e.g., Danehy et al. 2007, Hoover et al. 2007), and in regenerated riparian stands (12 to 27 years old; Moldenke & Ver Linden 2007). Also, the longitudinal variation in light levels and chlorophyll *a* concentrations are significantly correlated with canopy gaps that occur along streams in late-successional (multi-structured) stands (Stovall et al. 2009). In contrast, biotic productivity in streams with conifer-dominated buffer strips that are wider than 100 ft (i.e., low quality detritus, low light levels) is similar to that observed in an unlogged forest (Newbold et al. 1980, Castelle and Johnson 2000, Moldenke & Ver Linden 2007).

The literature is consistent in showing that aquatic invertebrate assemblages are closely associated with litter composition (deciduous and conifer) and that alder is an important contributor of readily available and nutritious litter. For example, Wipfli & Musselwhite (2004) found (in SE Alaska) that small fishless headwater streams dominated by red alder contributed more detritus and more aquatic invertebrates to downstream fish habitat than did tributaries not dominated by alder. In Oregon coastal streams, Romero et al. (2005) showed that invertebrate drift under deciduous and mixed canopies was about 30% more abundant than under conifer due to a higher biomass of terrestrial macroinvertebrates.
Allan et al. (2003), using insect fallout traps near streams in Southeast Alaska, captured a greater biomass of terrestrial macroinvertebrates beneath red alder compared to that beneath conifers (western hemlock, Sitka spruce). The quality of litter from red alder is the most nutritious and available for biological processing compared to other deciduous species and conifer; the latter being generally less available and more difficult to process (Allan, 1995; Cummins 2002).

There are no quantitative studies of source distances for litter and terrestrial subsidies. The FEMAT (1993) team, using profession judgment, estimated that most litter input comes within 0.5 tree heights. Streambank erosion and flooding of the adjacent forest floor in flood plain areas is also known to be a significant source of litter and invertebrates (White and Harvey 2007). Therefore, by inference, stream adjacent trees and shrubs, especially overhanging vegetation, are considered the most important contributors of litter and terrestrial insect fallout. Riparian management for high quality litter and terrestrial macroinvertebrate inputs would be most effective by maintaining stream adjacent (e.g., one tree crown width or about 30 ft) deciduous overstory and understory vegetation, especially near streams with moderately confined or unconfined channels (i.e., locations susceptible to bank erosion and flooding). Small streams are more tightly connected to riparian biotic inputs as a result of the closed canopy and the high edge-to-area ratio (Richardson et al. 2005).

The retention and subsequent biological processing of organic litter is dependent on channel morphology and flow regime (Richardson et al. 2009). Retention of detrital particles increases with increasing channel roughness which is associated with complex channels consisting of an intermingling of rock and debris (stones, twigs, logs; pool riffle, step pool, alluvial fan). Channel types with low roughness (plane-bed, cascade, bedrock) would have low retention of litter. Litter transport increases rapidly with discharge as particles become entrained and are transported downstream (Richardson et al. 2009).

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Proposed Riparian Prescriptions
and
Technical Assessment for Small Forest Landowners

Prepared by Douglas Martin
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Proposed Riparian Prescriptions

Management Objectives

The riparian prescription (Rx) are formulated to address landowner's desired management objectives and the resource potential of a given site and stand condition (Table 1). The intent is provide prescription options that range from simple to more complex in terms of effort and expertise needed for design and permitting.

Table 1. Prescription options, landowner riparian management objectives and associated stand conditions.

Landowner Objective	Riparian Objective	Stand Condition	Rx Options
Implement prescription that is easy to lay-out with the least effort and cost for permitting.	Provide overall function effectiveness at or near FPR levels	None specified	Standard
Optimize ecological and economic benefits of resource protection and timber utilization	Implement treatments to balance protections and harvest	Well-stocked (70% conifer), harvestable age	Thinning
Restore/improve desired riparian conditions, where appropriate, for long-term benefit to functions and aquatic resources, and facilitate harvest to offset costs of proactive management.	Implement riparian silviculture treatments to alter stand structure and composition that will restore/improve desired ecological functions, biotic productivity, and stand quality	Overstocked conifer or dominated by hardwoods, high fire-fuel loads or disease-prone species	Patch harvest

The riparian prescriptions vary by stream type and bankfull width (BFW) (Table 2). Prescriptions for Type F are focused on maintaining habitat and water quality for fish. Those for Type Np focus more on limiting export of heat and sediment while promoting biotic productivity (e.g., invertebrates, smaller wood, organic litter) and amphibian habitat. Both lateral and longitudinal source distance functions are addressed by breaking stream types into large and small stream-width categories. The width break at 15 ft. for Type F separates larger channels with a higher potential for fluvial transport of large wood (LW) from smaller channels where there is little or no potential for fluvial transport[a] (e.g., probability of LW

[a] Streams with a high probability for debris flows are not included in the proposed Type F or N prescriptions and require buffers for unstable slopes as specified in the state Forest Practices Act.

movement is less than 1000 ft. in a 15-ft channel over life of wood, see Appendix A). The <5-ft break for Type F and Np streams delineates smaller, low-energy fish-bearing and non-fish streams where seasonal flows (e.g., spatially intermittent) are likely to influence vertebrate occupancy, small trees and shrubs are capable of providing shade, and small wood including tree limbs effectively contribute habitat and create retention structures for sediment storage/biological processing. The 5 to 15-ft wide Type F streams are more likely to be perennial and would be sensitive to shade loss during low summer flows. Also, streams in this category have an increasing dependency on LW to form habitat and retention structures with increasing BFW.

Table 2. Riparian prescription options by stream type and bankfull width (BFW) category. The prescription is coded with a number followed by a slash and letters; where the number is the outer buffer distance (ft) and letters identify the treatment for that distance. If there is an "x" in between two numbers, the second number/percentage (%) indicates the length of the prescription or applicable portion of reach. The riparian management zone (RMZ) starts at the stream bank or outer edge of Channel Migration Zone whichever is greater distance from stream. Buffers for unstable slope are applicable as defined by WAC and the 30-ft equipment limitation zone (ELZ) is applicable for all RMZ's less than 30-ft wide.

Prescription group	Stream Type	BFW (ft)	RMZ (ft)	Prescription options[a]	Situation No.
Standard	F	>15	75	75/nc	1
Standard	F	5-15	50	50/nc	2
Standard	F	<5	25	25/nc	3
Standard	Np	>5 ft	25	25x300/nc[b] 25/tha	4
Standard	Np	<5 ft	25	25/tha	5
Standard	Ns	NA	NA	30/elz	6
Thinning	F	>15	75	50/nc, 75/hth	7
Thinning	F	5-15	50	25/nc, 50/mth	8
HC Regen. Harvest	F	>15	75	40%/ph[c] 75x60%/nc	9
HC Regen. Harvest	F	<15	50	50%/ph 50x50%/nc	10
Biotic Regen. Harvest	F	<15	50	50%/hth 50x50%/nc	11

[a]Prescription codes: nc = no-cut, tha = thin from above, hth = heavy thin from below, mth = moderate thin from below, ph = patch harvest, elz = equipment limitation zone
[b]There are two prescriptions in this cell for Np; top one is for lower 300-ft of reach and lower one is for upper remaining portion of reach.
[c]The percentages (%) for prescriptions in Situations 9-11 refer to the proportion of total FPA reach where each prescription (e.g., 40%/ph = 40% of FPA reach has patch harvest) is applicable; see text for details.

Description of Prescriptions

Standard Prescription

The standard group of prescriptions are applicable for most riparian stands where the landowner wants to minimize effort/cost for unit layout and has a management objective is to protect existing ecological functions, at or near, levels provided by the FPR. Prescription options consist of simple no-cut buffers and thinned buffers that vary in width and application depending on stream type and BFW. For F streams, large wood supply and shade are the primary and secondary factors, respectively, that set buffer widths. Therefore, the no-cut buffer width for F streams increases with increasing BFW in keeping with the increasing dependence on LW and the reduced function of small wood (SM) as streams become larger. Because LW residence time also decreases with increasing channel size, the needed LW supply varies accordingly. Similarly, buffers widths affect shade potential that also varies in relation to stream BFW. Sediment filtering and biotic subsidies (i.e., litter, invertebrates) are influenced most by near-stream undisturbed soil and vegetation that are maintained by minimum 25-ft no-cut or thinned buffers for all prescriptions.

The prescription for Np > 5 ft. includes a 25-ft wide continuous no-cut buffer for 300 ft. upstream of the N/F break and a 25-ft radius no-cut buffer around all tributary junctions within the Np network. The remaining upstream Np reach has a 25-ft continuous buffer that may be thinned to a canopy cover of 25%. In the thinned reach, all seeps and springs including the perennial initiation point (PIP) would receive the thinning prescription to minimize surface disturbances and to maintain the unique vegetation at these locations. Thinning of merchantable trees (i.e., thinning from above; tha) is permitted where ground disturbance is controlled (i.e., subject to ELZ rules) and includes the removal of windthrow-prone trees (i.e., small crown ratio) within 10 ft. of the stream to minimize the potential for sediment delivery from windthrow-root-pits. In the lower-wider portion of the Np stream where perennial flows are probable, the no-cut buffer will provide LW and shade for habitat and temperature protection. Upstream, the thinning prescription addresses longitudinal connectivity of sediment and biotic processes in the extensive upstream network (i.e., headwaters account for 60-80% of total stream length, Benda 2005). The thinned stand will maintain sediment filtering, reduce slash and heat loading, and supply wood retention structures for sediment storage and biological processing. Also, the thinned stand will increase light and associated biotic subsidies over the short-term, and with appropriate silviculture facilitate the development of a multi-aged (structured) riparian stand over the long-term.

The prescription for Np < 5-ft is identical to the thinning prescription for Np > 5 and includes the 25-ft radius no-cut buffer around all tributary junctions within the Np network. This prescription is focused on sediment filtering, slash control, and longitudinal functions for sediment storage and biological processing.

Thinning

The objective for the thinning prescriptions group on Type F streams is to implement active management schemes that are designed to optimize the trade-offs between protecting ecological functions and providing economic benefits from timber harvest. The prescriptions (Table 2) consist of a no-cut buffer adjacent to the stream and heavy or moderate thinning intensity in the outer 25-ft portion of the RMZ. For large Type F (i.e., > 15-ft wide, Situation 7), the no-cut buffer is 50-ft wide and the outer zone (50 to 75 ft) may be thinned to a minimum 57 large (dominant crown class) trees per acre (i.e., heavy thin, [hth]). For narrower Type F (5-15 ft wide, Situation 8) the no-cut buffer is 25-ft wide and the outer zone (25 to 50 ft) may be thinned to a minimum 100 large trees per acre (i.e., moderate thin,

[mth]). Thinning is focused on removing the smaller trees and trees with short crowns that are more susceptible to windthrow than are trees with long crowns. Also, thinning should avoid removing trees leaning toward the stream and trees located on slopes > 40% in order to retain future mortality trees that are likely to fall towards the stream.

The thinning prescriptions are designed to increase diameter growth of residual trees, while minimizing losses of future large dead trees that could potentially contribute LW to the stream. Therefore, intensity of thinning increases with distance from the stream where function is increasingly dependent on tree size and where LW recruitment potential is inversely proportional to distance. The moderate thinning intensity within 25 to 50 ft for Situation 8 will result in more large trees (i.e., > 20” dbh) in trade for a small reduction in the potential supply of LW from dead trees following the thinning treatment than would result if no thinning had occurred (see Function Evaluation for explanation). The heavier thinning within 50 to 75 ft for Situation 7 reduces production of LW from dead trees, compared to the moderate thin, but this has a minor effect on the potential LW supply, because only a small proportion of trees are recruited to the stream from this distance. Also, heavier intensity thinning will promote faster production of large (>20”) and very large (> 40”) trees which benefits both ecological and economic resources.

Regeneration Harvest

The landowner objective of the regeneration harvest prescriptions is restore or improve desired riparian conditions, where appropriate, for the long-term benefit to riparian functions and aquatic resources. Also, these prescriptions facilitate timber harvest in the RMZ that may help offset the costs of permitting and implementation of a project. The riparian management objective is accomplished through active manipulation of stand structure and composition near or adjacent to streams. This approach is more effective than either the standard or thinning prescriptions because the effectiveness to influence buffer functions diminishes with distance.

The situations where regeneration harvest may be applied are limited to two common stand conditions; riparian areas dominated by hardwoods, where conditions are suitable to restore a conifer stand (i.e., subject to same requirement as WAC 222-30-021); and, riparian areas with overstocked single-age confer where heavy thinning would increase light, promote biotic productivity, and a diverse stand structure. Other stand conditions that could likely benefit from active management are not addressed because they typically require a site-specific evaluation that goes beyond a template approach (e.g., see VTAC 2012).

The hardwood (HC) regeneration harvest prescriptions are comprised of alternating riparian segments with patch harvest and intervening no-cut zones. On larger streams (Situation 9), the total length of patch harvest is limited to 40% of the stream length within the FPA and 50% on smaller streams (Situation 10). The 40% restriction on larger streams is intended to minimize the reduction in existing LW supply, whereas the 50% limit is allowed on the smaller streams because both large and small wood effectively contribute to function. The intervening no-cut reaches are a minimum of 100-ft long and should be located, where feasible, along segments with the highest potential for maintaining shade (e.g., south side of streams oriented east-west), and/or where there is high potential for LW recruitment (e.g., reaches with active bank erosion). The patch-cut segments should be located where conditions are suited for conifer regeneration. All trees within the regeneration patches may be harvested except for conifers and trees that occur within 25 ft. of the stream. The latter will provide some shade, LW, and bank stability in the patch-cut reaches during the period of stand regeneration.

The biotic regeneration prescription (Situation 11) is intended to improve ecological diversity by developing canopy openings along smaller streams to emulate natural disturbances. Openings would be created by heavy intensity thinning (57 tpa, thin from below) up to the stream edge within riparian segments no greater than 150-ft long and cumulatively no more than 50% of the project reach. Canopy opening segments alternate with intervening no-cut segments that are a minimum of 150-ft long. Precautions to minimize ground disturbance and ELZ rules are applicable. Small, especially lower gradient) streams are better suited for the biotic regeneration prescription than larger streams because shade is typically limiting (e.g., > 90%) both instream and riparian (deciduous) productivity and there is lower dependence on LW supply.

Function Evaluation

Standard Prescription

This effectiveness evaluation assesses the potential of the riparian forest to provide LW, shade, sediment filtering, and biotic processes both on-site and downstream (i.e., considers both lateral and longitudinal connectivity of ecological functions). Given the large variability in riparian stands and site characteristics, a number of assumptions, as described below, are necessary to facilitate the evaluation. Therefore, this assessment provides a relative index of prescription effectiveness to provide riparian functions.

Information from the literature and modeling (Appendix A and B) are used to quantify or qualify function effectiveness. Both modeling and empirical source- distance data from fish-bearing streams are used to quantitatively evaluate shade and LW effectiveness; and, best professional judgment based on literature is used to assign qualitative rankings to other functions. The Department of Ecology model (Appendix A Figures A-1, A-2) is used to assess potential shade for a conifer stand with mean height 148 ft. and canopy densities of either 25% (sparse) or 75% (dense) depending on the prescription. Large wood source-distance curves based on empirical data from the Northwest and Southeast AK (Appendix Figure A-3) are used to evaluate LW supply potential. One dataset (McDade et al. 1990) was excluded from this evaluation because these data include both tree pieces and trees unlike the other datasets that were based on counts of recruited trees (i.e., data not comparable because source-distances for trees and pieces likely differ).

Sediment filtering is ranked as H (high), M (moderate), or L (low) based on following conditions: a minimum 25-ft RMZ with 25% stand density within a 30-ft. ELZ = H; a clearcut with 30-ft ELZ = M; and, a clearcut with no ELZ = L. Biotic subsidies are based on the potential to provide litter and invertebrates. Litter potential is ranked as H if riparian stand is at least 25-ft wide or L if clearcut. Invertebrate potential is based on the availability of light and presence of diverse understory and overstory riparian vegetation (e.g., shurbs, deciduous) which promotes both aquatic macroinvertebrate and terrestrial insect productivity. Therefore, thinned riparian stands within 25-ft of stream that retains trees and understory vegetation = H, clearcuts = M, and no-cut riparian stands at least 25-ft wide = L. Longitudinal connectivity is ranked as Y (yes) if riparian prescription for stream type F and N RMZ's are contiguous or N (no), if not (i.e., clearcut, no contiguous RMZ).

Function effectiveness for the standard prescription are compared to that for the FPR prescriptions in Table 3. The effectiveness for both groups of prescriptions is based on the BFW's listed for the proposed prescriptions. In stream type F, function effectiveness is evaluated for both the "no inner zone" and "thin from below" options for Site Class 3. Effectiveness for shade is based on the width (distance at outer edge) of the no-cut or thinned buffer that is located adjacent to the stream. Effectiveness for LW supply is based on the widths of the no-cut buffer and the thinned buffer. The LW supply potential for the thinned zone is reduced by tree harvest. Therefore the post-thinning LW supply potential is adjusted as follows. First the LW supply potential for the no-cut width and the width at the outer edge of the thinning zone (i.e., outer edge of "inner zone" for FPR rules) are derived from the source distance curves (Appendix A). Second, the difference in LW supply between the no-cut and thinned zone widths, is adjusted based on the predicted loss in dead tree production due to thinning as shown in modeling by Pollock and Beechie (2014). The reduction in dead tree production for trees > 20" (i.e., 50 cm dbh) at 50 years post-treatment for thinning levels of 57 tpa and 100 tpa (i.e., 150 tph and 250 tph, respectively) are based on results presented in Figure 5b of Pollock and Beechie (2014). Using these results, the relative production of dead trees for thinning treatments of 57 (heavy thin) and 100 tpa (moderate thin) are 45% and 73%, respectively, of the potential production for an un-thinned stand at 50 years. For example, LW supply potential after heavy thinning (retain 57 tpa) in Situation 8 (50/nc, 75/hth) is > 93%. This estimate is based on LW supply potential of 91% and 96%, respectively for the no-cut buffer distance at 50 ft and thinning distance at 75 ft respectively; with difference of 5% and relative dead tree production of 45%; results in LW potential of 93% (i.e., 0.91 + (0.05 x 0.45) = 0.93).

The increased growth of residual trees as a result of thinning are based on live tree production estimates from Figure 6 of Pollock and Beechie (2014).

Table 3. Comparison of riparian function potential between proposed and Forest Practices Rule (FPR) prescriptions. In FPR type F streams, function effectiveness is evaluated for both the "no inner zone" and "thin from below" options for Site Class 3, respectively. See Table 2 caption for description of prescription codes.

		Riparian function potential									Riparian function potential							
Prescription No.	**Stream Type**	**BFW (ft)**	**RMZ (ft)**	**Prescript.**	**Shade**	**LW**	**Sed.**	**Litter**	**Invert**	**Long. Cont.**	**BFW (ft)**	**Prescript.**	**Shade**	**LW**	**Sed.**	**Litter**	**Invert**	**Long. Cont.**
		Standard Prescription									**FPR Prescriptions**							
1	F	>15	75	75/nc	max	> 96%	H	H	L	Y	>10	105/nc[c]	max	> 98%	H	H	L	Y
											>10	50/nc, 105/hth	> 94%	> 94%	H	H	L	Y
2	F	5-15	50	50/nc	> 94%	> 91%	H	H	L	Y	<10	93/nc	max	> 97%	H	H	L	Y
											<10	50/nc, 93/hth	> 94%	> 93%	H	H	L	Y
3	F	<5	25	25/nc	> 95%	> 75%	H	H	L	Y	<10	93/nc	max	> 97%	H	H	L	Y
											<10	50/nc, 93/hth	> 96%	> 93%	H	H	L	Y
				25x300/nc	> 94%	> 75%	H	H	L	Y		50x50%/nc	> 94%	> 91%	H	H	L	Y
4	Np	>5 ft	25	25/tha	43%[a]	> 19%[b]	H	H	H	Y	NA	50%/cc	>0	slash	M	L	M	N
												50x50%/nc	> 96%	> 91%	H	H	L	Y
5	Np	<5 ft	25	25/tha	43%[a]	> 19%	H	H	H	Y	NA	50%/cc	59%[d]	slash	M	L	M	N
6	Ns	NA	0	30/elz	>0	slash	M	L	M	N	NA	30/elz	>0	slash	M	L	M	N
		Thinning Prescription									**FPR Prescriptions**							
7	F	>15	75	50/nc, 75/hth	> 94%	> 93%	H	H	L	Y	>10	50/nc, 105/hth	> 94%	> 94%	H	H	L	Y
8	F	5-15	50	25/nc, 50/mth	> 95%	> 87%	H	H	L	Y	<10	50/nc, 93/hth	> 94%	> 93%	H	H	L	Y

[a]Shade in upper portion of Np reach based on cms stands (i.e., 25% density)

[b]Assume 75% supply potential for a 25-ft buffer which is reduced by 25% stand density (i.e., 0.25 x 0.75 = 0.19)

[c]Top and bottom cell Rx's are no-inner-zone-harvest and thin-from-below, respectively

[d]Base on mean canopy cover for headwater streams with slash (see Appendix A).

The comparison of riparian function potential between the proposed and FPR prescriptions (Table 3) shows there are similarities in effectiveness, particularly for the wider F streams, and unique differences, particularly for the Np streams. Function effectiveness for F streams 5-15 ft and F >15 ft wide are nearly identical to that for the FPR prescription options in the same BFW categories. Differences in effectiveness between prescription groups are small, because most function potential is provided within 50-ft of the stream. Therefore, increases in buffer width beyond 50 ft provide relatively small gains in effectiveness of riparian functions. The effectiveness for F Type < 5-ft is also similar to the FPR prescription options for all functions except LW supply which is reduced to 75% by the narrower buffer. The effect of this small reduction in LW supply potential on habitat is a lesser concern for small steams considering that smaller wood from limbs and tree pieces are effective habitat formers and fluvial export of LW is limited.

Prescription effectiveness for Np streams depends on differences in treatments for the lower (i.e., adjacent to F/N break) and upper portions of the stream. Effectiveness for the lower reach of Np Type > 5-ft (Situation 4) is similar to the FPR prescription for all functions except for potential LW supply which is reduced by about 20% (Table 3). However, there are large differences in overall effectiveness between prescription groups because the FPR prescription stops at 50% of the stream length, but the proposed prescription has a continuous 25-ft buffer up to the end of the Np reach. This continuous vegetated buffer is more effective at reducing the potential negative effects of clearcutting (e.g., erosion, sediment transport, heat loading, excessive slash) by providing longitudinal connectivity for key functions (sediment filtering, shade, biotic inputs) along the entire channel including all adjacent seeps and wetlands. In contrast, the FPR prescription does not provide longitudinal connectivity of functions and is less likely to mitigate the negative effects that are exported from upstream clearcut areas.

The function effectiveness for Np steams < 5 ft (Situation 5) is similar to that described for Situation 4. In these small low-energy streams, a continuous 25-ft wide buffer provides longitudinal connectivity of functions that minimizes the negative effects from clearcutting on-site. Increases in function effectiveness along the entire stream reduces the need for a wider "mitigation" buffer in the lower reach of the Np stream.

Thinning Prescriptions

Effectiveness of the proposed thinning prescriptions are similar to the FPR thinning prescriptions for all functions with small difference for LW supply (Table 3). The LW supply in Situation 8 is reduced partly by the narrower RMZ and by the small reduction in dead tree production after the thinning treatment. However, at 50 years post treatment the moderate thinning for Situation 8 will result in about 45 large (> 20" dbh) live trees per acre in the thinned zone compared to about 34 large live trees per acre in the inner zone of the FPR prescription (from Figure 6 of Pollock and Beechie, 2014). This difference is a result of heavy thinning within the inner zone for the FPR prescription.

Regeneration Harvest Prescriptions

Function effectiveness for the regeneration harvest prescriptions is based on the future potential conditions and functions resulting from the treatment including planting; not the immediate post-treatment condition as evaluated in Table 3. The hardwood conversion and biotic regeneration harvest prescriptions are designed to minimize short-term reductions in riparian functions in trade for rapidly improving ecological functions that have a long-term benefit to instream habitat and aquatic biota. The hardwood conversion is focused on restoring conifer stands to improve the LW supply potential for streams where instream wood loading and associated LW dependent habitat is limited. The alternating patch-cut and no-cut segments not only minimize negative effects from treatment, but will promote longitudinal diversity in stand structure/composition when the conifer stands are re-established. Similarly, the 25-ft tree retention buffer in the patch-cuts reaches contributes to stream protection. Allowing flexibility in size and location of conifer regeneration patches is recommended and is likely to improve regeneration success (Roorbach et al. unpublished).

The biotic regeneration harvest prescription will be applied to overstocked single-age conifer stands with dense canopies that significantly limit light and reduces litter quality in small streams. Maintaining a fixed-width buffer under these conditions may protect some functions (e.g., temperature and LW), but restricts other functions (primary productivity, invertebrates, food production) that are beneficial to aquatic biota (Liquori et al. 2008). Research shows that canopy openings and multi-structured riparian stands with deciduous litter improves biotic productivity (see Appendix A). Further, there is growing support for active management of riparian stands (e.g., create canopy openings) to facilitate riparian structural diversity and associated biotic productivity by emulating natural disturbances (Kreutzweiser et al. 2012, Moore and Richardson 2012). For example, MacCracken et al. (unpublished) demonstrated with experimental canopy openings that moderate increases of light along stream reaches 150-ft long resulted in small temperature increases (< 1^{o} C), benefited amphibian taxa, and had no negative effects on benthic macroinvertebrates.

Spatial Context for Prescriptions

The overall effectiveness of the proposed prescriptions to provide functions is not only due to their site-specific effectiveness, but also related to the frequency of implementation across the landscape.
One way to assess the relative rate of implementation is to compare the prescription width categories to channel width data from the CMER extensive temperature studies (Peter and Engeness 2014). The distribution of channel widths (Figure 1) are based on a random sample from all streams on private forestlands in western Washington. The cumulative frequency distribution for Type F indicates that the > 15, 5-15, and < 5-ft. width categories would occur on 48%, 41%, and 11% of the network length, respectively. The Type Np streams > 5 ft and < 5 ft width categories would occur on 51% and 49% of the network length, respectively. Therefore, in F streams, the F >15 and F 5-15 standard prescriptions which have similarly high function effectiveness are likely to be applied on streams that are typical for 89% of the F network. Whereas, the F <5 prescription may only occur on streams typical for 11% of the F network.

The two Np prescriptions are likely to be applied equally across all Np streams because the 5-ft break between small and large is equivalent to the 50th percentile (Figure 1). However, the Np prescriptions will probably occur on more streams than the F prescriptions because headwater streams occupy from 60% to 80% of the total length of streams in the hydrographic network (Benda 2005).

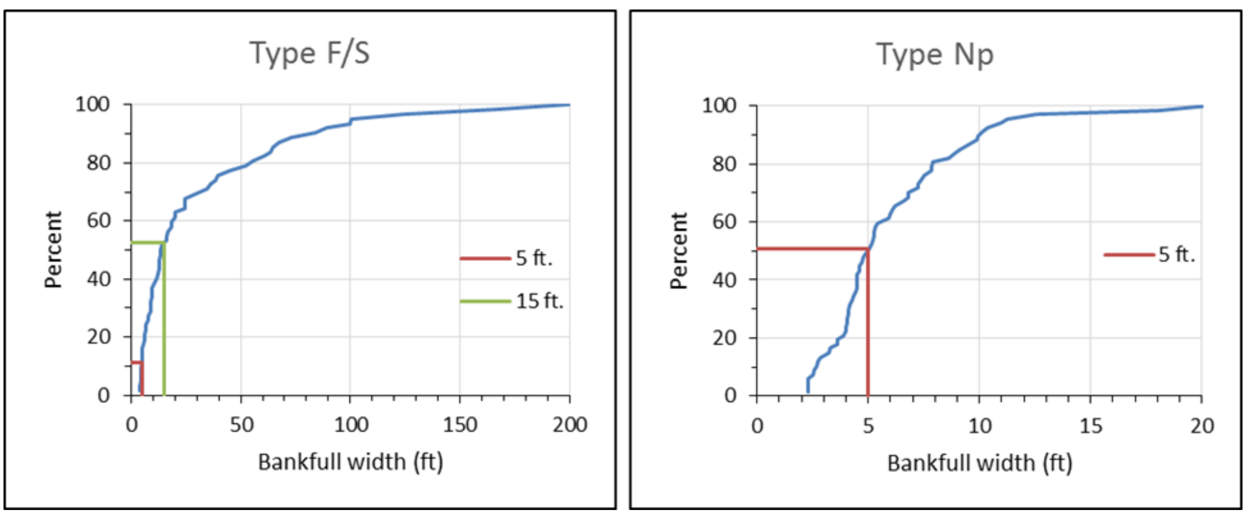

Figure 1. Cumulative frequency distributions of channel bankfull widths for Type F/S (n = 62) and Np (n = 67) streams. Data based on random sample from all streams on private forestlands in western Washington. Data from W. Ehinger, WDOE, personal communication.

Appendix A: Riparian Function Assessment

Shade

The primary function of riparian vegetation in controlling water temperature is to block incoming solar radiation (direct and diffuse). Direct solar radiation on the water's surface is the dominant source of heat energy that may be absorbed by the water column and streambed. Absorption of solar energy is greatest when the solar angle is greater than 30° (i.e., 90 to 95 % of energy is absorbed as heat) and decreases as the solar angle declines due to the reflection of radiation off the water surface. Therefore, riparian vegetation that blocks direct solar radiation along the sun's pathway across the sky is the most effective for reducing radiant energy available for stream heating (Moore et al. 2005). Research shows that the attenuation of direct beam radiation by riparian vegetation is a function of canopy height, vegetation density, and buffer width (Beschta et al., 1987, Sridhar et al. 2004, DeWalle 2010). Light attenuation increases with increasing canopy height and increasing buffer density as a result of the increased solar path and extinction of energy. Buffer width has a variable influence on light attenuation depending on stream azimuth (e.g., effective buffer widths for E-W streams may be narrower than for N-S streams due to shifts in solar beam pathway from the sides to the tops of the buffers; Dewalle 2010). Riparian buffer width is important for a given stand type and age, but is not a good predictor of stream shading among different stands because of differences in the shade-controlling variables. For example, Beschta et al. (1987) showed that shade levels[b] similar to old-growth forests (i.e., range 75% to 90%) varied from 65 ft. to 100 ft. depending on stand types in western Oregon. Similarly, Sridhar et al. demonstrated the most effective shading for temperature control in eastern and western Washington Cascade conifer stands was predicted for mature (high leaf-area-index) canopies close to the stream (i.e., within 33 ft. of the stream bank) and overall buffers of about 100 ft.

High levels of shading can be provided by buffers ranging from 25 ft. to 75 ft. wide, because most shade is provided by trees directly adjacent to the stream (Table A-1). For example, Teply et al. (2013) demonstrated that thinning the outer portion of a buffer with a 25-ft. no-harvest core in a grand fir-western red cedar stand reduces the overall potential shade by 6% to 15% depending on the width and level of thinning in the outer zone. Also, they indicated that similar buffer treatments in the western hemlock-subalpine fir and Douglas-fir stands of western Idaho could provide relatively high shade levels.

Predictions of effective shade (i.e., percentage of potential daily solar radiation blocked by vegetation and topography) were simulated with the Ecology shade model (http://www.ecy.wa.gov/programs/eap/models.html) to demonstrate how stand height, composition, buffer width, and stream aspect influence shade. Effective shade was simulated for a hypothetical low-gradient (2 - 3%) stream, with no topographic shading, located in Olympia vicinity, and having conifer/deciduous riparian stands that are typical of western Washington (Table 2). The simulation results are consistent with the findings described by others and shows that effective shade is mostly provided by trees within 15-25 ft. of the stream regardless of stand height, composition, and aspect (Figure A-1, Appendix B). Trees beyond 25 ft. only contribute a small amount of shade. Shade is correlated with tree height as high shade levels (i.e., exceeding 75%) are provided by small trees along 5-ft. streams, and by medium to large size trees along streams up to 25 ft. wide. Shade potential declines with increasing stream width and is lowest for the wider streams with a N-S aspect. Note, the mixed-medium and mixed-large stands provide slightly more shade than the conifer stands of similar

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[b] Based on measure of angular canopy density (ACD) which is a projection of the canopy at the angle above the horizon at which direct-beam solar radiation passes through the canopy (Beschta et al 1987).

size (Appendix B). The latter is partly due to the greater overhang which blocks direct beam radiation. Similarly, high shade levels can be maintained along E-W streams (aspects 270^o and 225^o) with dense stands on the south side and sparse stands on the north side because most radiation is blocked by the south side stand (Figure A-2).

Shade levels in headwater streams without buffer strips are typically greater than zero initially following timber harvest as a result of cover from logging slash. Even though BMPs (e.g., 30-ft ELZ) are intended to minimize slash input, studies show that slash is relatively common in seasonal streams (Type Ns). For example, shade levels in four headwater streams bordered by clearcut units in southern Oregon averaged 66% after harvest (i.e., average 20% reduction from pre-harvest levels) (Kibler et al. 2013) and similarly, Ehinger et al. (unpub.) observed a mean decreased in canopy cover at the water surface from 91% pre-harvest to 52% as a result of logging slash in headwater streams in western Washington. In both studies the longitudinal distribution of slash cover was patchy and associated shade was highly variable. The effectiveness of slash to provide shade is likely to decline over time with decay and debris export.

Shade from riparian vegetation is not the only factor influencing stream temperature. Research shows that temperature response from timber harvest is variable and is highly dependent on the volume of stream flow, substrate type, groundwater inflow, and surface/subsurface water exchange (i.e., hyporheic exchange) (Moore et al. 2005). Stream size is a key driver with sensitivity decreasing in relation to increasing depth, velocity, and discharge (Moore et al. 2005). Velocity influences exposure duration which decreases with increasing velocity in steeper channels (cascade channels). Stream depth has significant influence because it affects both the magnitude of the stream temperature fluctuations and the response time of the stream to changes in environmental condition (Adam and Sullivan 1989). The temperature response to heat input is dampened by hyporheic exchange rate which is a function of bed composition. Streams with alluvial gravel/cobble bed material (pool riffle, alluvial fan channels) enables increased hydraulic retention (promotes conductive cooling) and are less sensitive to shade loss compared to streams with less-permeable boulder/bedrock substrate (e.g., cascade, bedrock channels) (Johnson 2004, Dent et al. 2008). In general, stream sensitivity to shade loss is a function of reach-scale physical characteristics. For example, streams at lower elevations (i.e, warmer air temperature), or with no topographic shading, or with shallow-wide channels (i.e., high width-to-depth ratio), or with bedrock substrate (i.e., hyporheic exchange limited) are more sensitive to heating from shade loss than are streams with the following conditions: at higher elevations, or with topographic shading, or with deep-narrow channels, or with alluvial substrate.

Table A-1 Summary of stream shade provided by different buffer treatments similar to proposed template.

Location	Stand type	Buffer treatment	metric	Post-harvest amount	Post-harvest change	Reference
western WA	df, hem, 35-50 yrs	50-ft. no-harvest	canopy cover	81%	-10%	Schuett-Hames et al. 2011
western WA	df, hem, 60-110 yrs	33 to 50-ft. no-harvest	canopy density[a]	86%	-8%	Janisch et al. 2012
coastal OR	df, alder, 50-70 yrs	50 to 70-ft.; inner 20 ft. no-harvest, outer thinned	shade	78%	-7%	Groom et al. 2011
western ID	grand fir-redcedar	50-ft. no-harvest	effective shade	82%	-8%	Teply et al. 2013
western ID	grand fir-redcedar	75-ft. no-harvest	effective shade	87%	-3%	Teply et al. 2013
western ID	grand fir-redcedar	50-ft.; inner 25 ft. no-harv., outer 25 ft. thinned	effective shade	75%	-15%	Teply et al. 2013
western ID	grand fir-redcedar	75-ft.; inner 25 ft. no-harv., outer 50 ft. thinned	effective shade	84%	-6%	Teply et al. 2013

[a]includes topographic shading

Table A-2. Description of riparian stand characteristics used for modeling. Data derived from riparian shade study in Stillaguamish River by Ecology (http://www.ecy.wa.gov/programs/eap/models.html). **Note, canopy density of 75% approximates levels found in unmanaged stands (Beschta et al. 1987).**

Stand descrption	Height (ft)	Canopy density (%)	Overhang (ft)
css - conifer, small, sparse	49	25	5
csd - conifer, small, dense	49	75	5
cms - conifer, medium, sparse	148	25	15
cmd - conifer, medium, dense	148	75	15
cls - conifer, large, sparse	174	25	17
cld - conifer, large, dense	174	75	17
msd - mixed, small, dense	49	75	6
mms - mixed, medium, sparse	66	25	7
mmd - mixed, medium, dense	121	75	15
mld - mixed, large, dense	148	75	18
clearcut	0	0	0

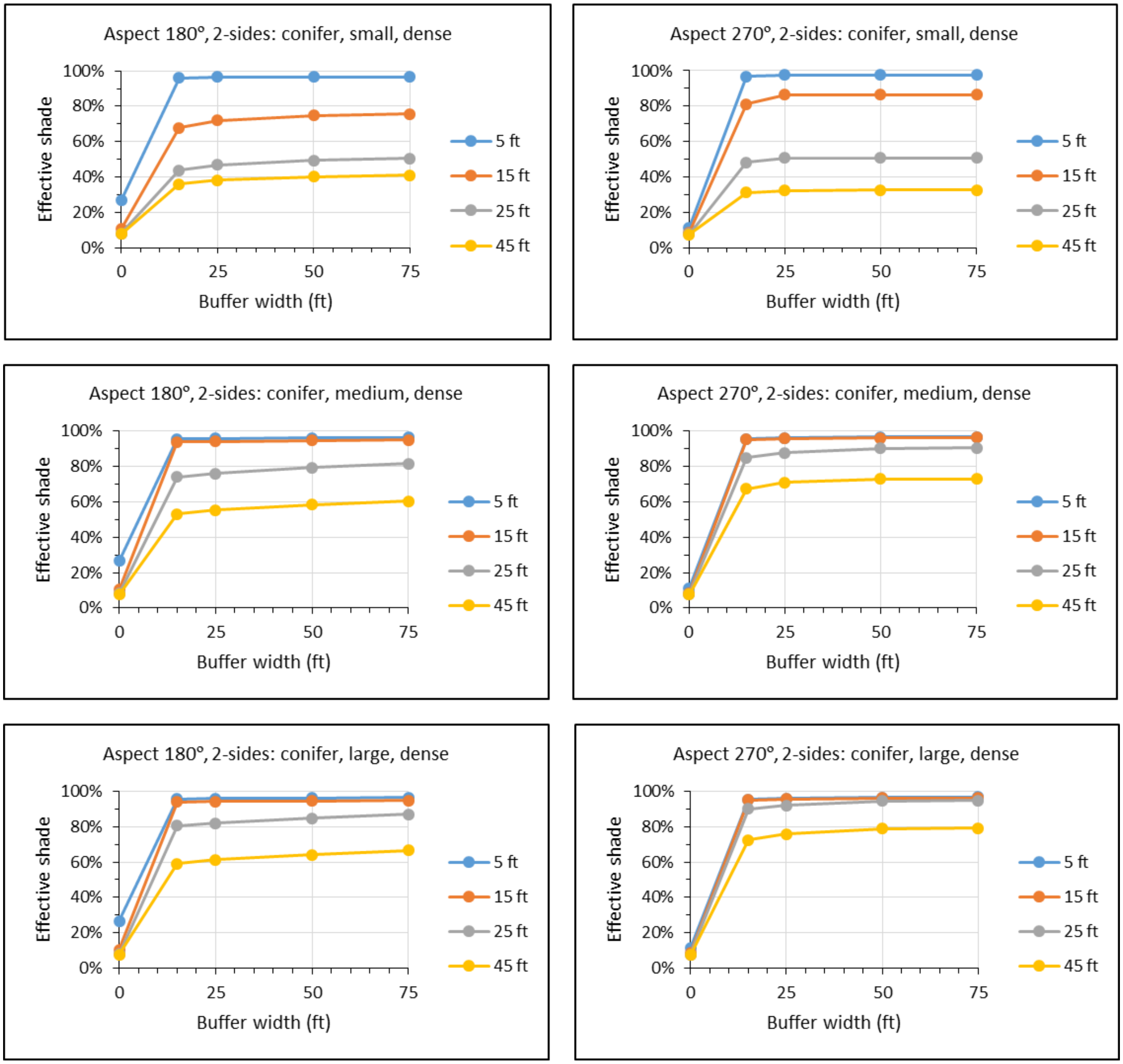

Figure A-1. Predicted effective shade in relation to buffer width, channel width, and aspect for riparian stands with different tree heights and composition. Shade simulated for streams with N-S and E-W aspects, and with dense conifer stands on two sides. Stand specifications are listed in Table A-2.

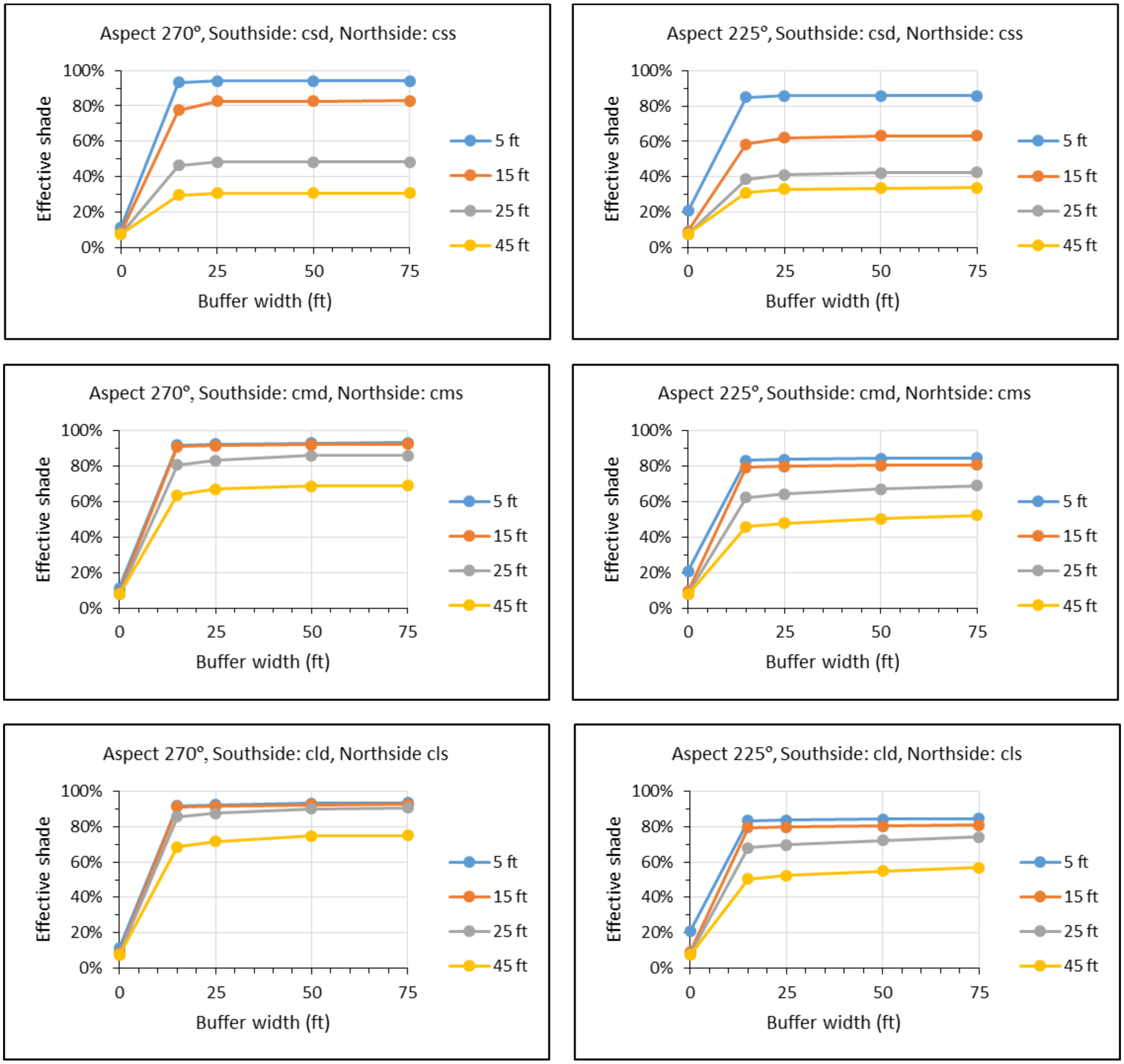

Figure A-2. Predicted effective shade in relation to buffer width, channel width, and stream aspect for riparian stands with different tree heights and composition. Shade simulated for streams with dense conifer stands on south side and sparse conifer stands on north side. Stand specifications are listed in Table 2.

Large Wood

The primary factors controlling large wood (LW) recruitment to streams are tree height and stand mortality processes. In general the distances to sources of stream wood increase with increasing tree height. For example, the source distances for tall old growth Douglas fir or coastal redwoods of California may extend out to 200 ft., but recruitment of shorter Sitka spruce in Southeast Alaska may only extend to 125 ft. (Benda & Bigelow 2014, Martin & Grotefendt 2007, McDade et al. 1990). Similarly, smaller trees in second-growth stands will have shorter source distances than trees from old-growth stands. However, the tree height source distance relationship is modified by site-specific factors (i.e., valley morphology, stream width, and wind exposure) that can have a strong influence on stand mortality. For example, LW recruitment by bank erosion is the dominant wood input process for low- to moderate-gradient channels in unconfined valleys and bank erosion recruitment increases with increasing stream width (Benda & Bigelow 2014, Johnston 2011, Martin & Benda 2001). Most of the LW in erosion prone channels is derived from the stream banks (e.g., 86% to 98% may be recruited from within 25 ft.; Table A-3, Figure A-3). Recruitment by stand mortality (e.g., stem suppression) is generally dominant where bank erosion is limited, such as in riparian stands adjacent to smaller streams and streams of any width that are confined by bedrock or hillslopes. Also, there is a strong tendency for dead trees to fall towards the channel on steeper hillslopes (i.e., >40%) that may increase recruitment by 1.5 to 2.4 times over levels from lower-gradient landforms (Sobota et al. 2006). In areas where stand mortality dominates, the source distance distribution shifts away from the stream bank and most recruits are derived from within 50 to 75 ft. (Table A-3, Figure A-3). Note, the far right shift of source distances for the McDade (1990) data (Figure A-3) are due, in part, to significant recruitment from trees and tree pieces that slid down steep side slopes (50% of study sites were located on slopes > 40%). Windthrow can extend the source distance by increasing recruitment from trees along the outer edge of buffer strips (Rollerson et al. 2009, Martin & Grotefendt 2007, Liquori 2006). Local landslides can extend the source distances even farther from the channel up the hillslopes (Benda & Bigelow 2014). The rank ordering of source distances for all mortality processes are bank erosion < tree mortality < windthrow < local landslides.

Table A-3. Summary of large wood inputs to streams by riparian source distance and dominant recruitment process (recruitment by landslides excluded).

			Percentage input by source distance				
Location	**Stand type**	**Dom. recruit process**	**25 ft.**	**50 ft.**	**75 ft.**	**100 ft.**	**Reference**
Southeast AK	old-growth	bank erosion	86	93	96	98	Martin & Grotefendt (2007)
South-Central BC	old-growth/mat. conif.	bank erosion	98	99	100	100	Johnston (2011)
South-Central BC	old-growth/mat. conif.	mortality	81	95	98	100	Johnston (2011)
Cascade, WA,OR	mature conif.	mortality	40	71	85	94	McDade et al. (1990)[a]
Cascade, WA,OR	old-growth	mortality	33	62	76	84	McDade et al. (1990)[a]
Southeast AK	Old-growth	mixed	75	91	97	99	Murphy & Koski (1989)
Cascade, WA	conifer (50-80 yrs)	mixed	82	96	98	100	Mckinley (1997)
Cascade, CA	Unmanaged	mixed	75	97	99	100	Benda & Bigelow (2014)

[a]Data include trees and tree pieces from given distance.

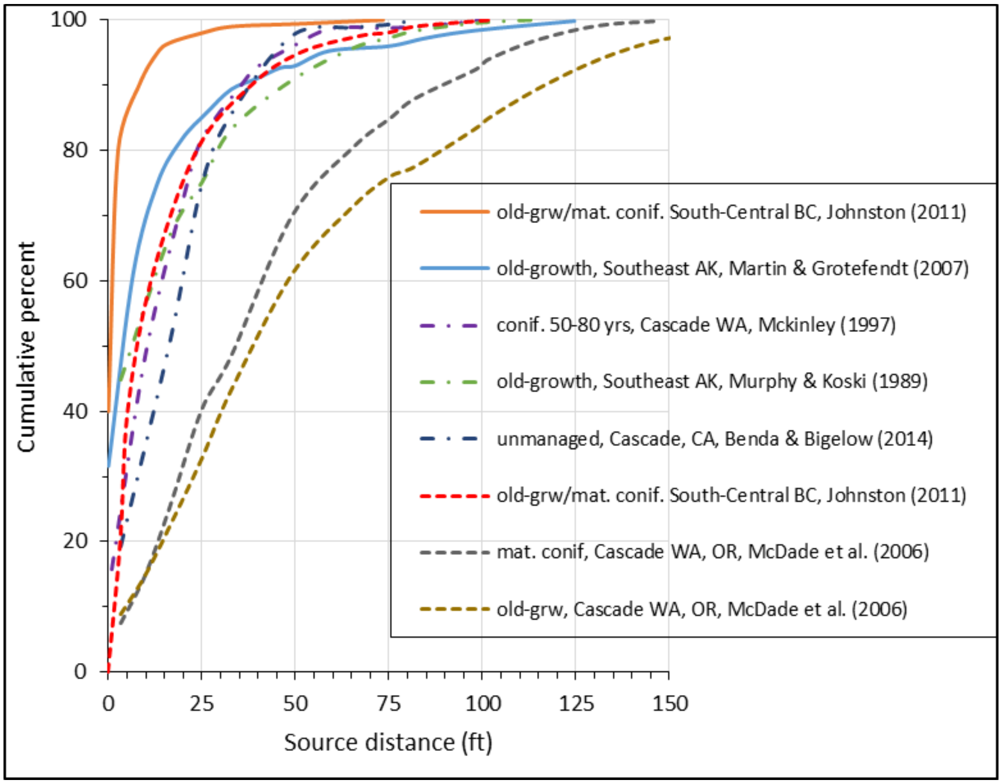

Figure A-3. Large wood source distance curves for riparian forests similar to stands typical of western Washington. Dominant recruit processes are bank erosion (solid line), stand mortality (dashed line), mixed (dash-dot line). Note, the far right shift of source distances for the McDade (1990) data are due, in part, to significant recruitment from trees and tree pieces that slid down steep side slopes (50% of study sites were located on slopes > 40%).

Windthrow can increase the probability of LW recruitment from buffer strips over the short-term and can influence the long-term supply at locations prone to wind damage. At the landscape scale, windthrow mortality is highly variable; having a skewed mortality distribution (i.e., most sites have low mortality and a few have high mortality (Grizzel and Wolff 1998, Martin and Grotefendt 2007, Rollerson et al. 2009). Wind damage is strongly associated with buffer orientation relative to the predominant storm direction (i.e., southeast, south, southwest in the Pacific Northwest) and local conditions including wind fetch length resulting from the size of clearcut units (Kramer et al. 2001, Mitchell et al. 2001, Rollerson et al. 2009). At the scale of individual trees, windthrow mortality is associated with low percent live crowns (< 40%) and high height-diameter ratios (>60%) (Scott 2005). Reductions in windthrow mortality are feasible when site and landscape factors are considered in harvest unit plans (Kramer et al. 2001; Mitchell et al. 2001)

The transport of LW in streams provides connectivity between upstream sources areas and downstream processes that create channel complexity and form aquatic habitat. Debris flows that result from channelize landslides are an important mechanism for delivery of LW from steep headwaters to larger fish bearing streams (May and Gresswell 2003, Reeves et al. 2003). Debris flows can transport wood in small streams that lack the capacity for fluvial transport of wood, and for transporting wood that is longer than the bank-full width of the channel. In the absence of debris flows, drainage area (i.e., stream size) is the primary factor controlling the fluvial transport of LW in streams. Studies by Martin & Benda

(2001) in Southeast Alaska and by Benda and Bigelow (2014) in four regions of northern California (Coast, Klamath, Cascade, and western Sierra ranges) show that fluvial transport of LW increases with increasing stream size. In both studies the predicted wood transport distance (over the lifetime of wood in streams varied from a few hundred ft. to ten thousand ft. in channels with drainage areas of 250 ac to 18,000 ac, with transport distance increasing with drainage area. For example, in the smallest channel (10-15 ft. wide), Martin and Benda (2001) estimated there was a 90% probability that LW would be transported at least 150 ft. and only a 10% probability that transport could exceed 1000 ft. Also, the length of nearly all mobile LW is less than or equal to the bank-full width of the channel. Therefore, only a small proportion of LW is exported by fluvial processes in smaller headwater streams and only the lower-larger portions of headwater channels are likely transport LW to larger streams. Correspondingly, the residence time of LW accumulations in streams is inversely related to channel size (Martin & Benda 2001, Benda and Bigelow 2014).

The size of LW (diameter and length of wood pieces) required to form habitat increases with increasing stream width (Bilby and Ward 1989). For example, Bilby and Ward (1989) found that functional size pieces ranged from 25 to 65 cm in diameter and 5 to 12 m in length in streams 13 to 65 ft wide. Beechie and Sibley (1997) regressed wood diameter with channel width and showed the minimum diameter for forming pools ranged from 5 inches to 10 inches for streams 15 ft. and 30-ft. wide, respectively. In small headwater streams (range 3 - 12 ft wide), Jackson and Sturm (2002) found that wood smaller than 8 inches diameter is more likely to function than is larger wood and that smaller wood along with inorganic material and organic debris (< 4 inches diameter) were major step-forming agents.

The formation of fish habitat in streams is not only a function of LW supply and size, but on reach-scale physical characteristics (channel width, morphology, substrate composition) that influence the channel response to wood loading. For example, research shows that large wood has a stronger influence on the formation of pools and gravel bars in moderate gradient, unconfined channels (e.g., plan bed, pool riffle, alluvial fan channel types) compared to either high-gradient-confined channels or low-gradient channels (Montgomery et al. 1995, Beechie and Sibley 1997, Martin 2001). The cobble-boulder-bedrock substrate typical of steeper high-energy channels controls bedform (e.g, step pool, cascade) and pool formation is independent of LW; although LW may function to trap sediment in step-pool channels (Montgomery and Buffington 1997, Benda and Bigelow 2014). In very low-gradient meandering channels (e.g., dune ripple) the dependency on LW is limited as free-formed pools are common (Beechie and Sibley 1997).

Sediment

Timber harvest in or adjacent to riparian management zones can influence surface erosion and sediment input to streams as a result of ground disturbances from yarding activities (e.g., skid trails, yarding ruts), or to increases in root-pit formation from windthrow. Sediment retention within a riparian forest is controlled by vegetative ground cover, hillslope gradient, and soil erodibility (WFPB 1997). Ground cover including roots, stems, and debris (logs, slash) bind soils and create roughness elements minimizes surface runoff and traps soil particles (Liquori et al. 2008, Litschert and MacDonald 2009). Sediment delivery potential increases with slope. Therefore, the sediment retention function of riparian ground cover is most important in steeper terrain

Research shows that current harvest procedures and BMPs are largely effective in reducing erosion and and sediment delivery to streams. Post-harvest evaluations of erosion features across a wide range of sites indicates that buffers and the prevention of ground disturbances within 30-ft of streams effectively prevented sediment inputs in most cases (Rashin et al. 2006, Litschert and MacDonald 2009). For example, Schuett-Hames et al. 2011 found that implementation of a 30-ft equipment exclusion zone (ELZ) in clearcut units met the performance targets for sediment control at seven of eight clear-cut reaches. In a related study of buffer and ELZ effectiveness in headwater streams Stewart et al. (unpup.) reported the area of bank erosion (or lack thereof) was similar among reference and treatment sites suggesting the absence of a treatment effect. Root-pit formation is increased as result of post-harvest windthrow. However, the density of root-pits with sediment delivery were no different among reference and buffer treatment sites in two separate studies of BMP effectiveness (Schuett-Hames et al. 2011, Stewart et al. unpub). In both studies the mean distance to stream for root-pits that delivered sediment was less than 9 ft.

Biotic Productivity/Litter

Research shows that algal biomass and invertebrate prey biomass generally increase with increasing canopy openness and/or increasing densities of deciduous vegetation. Autotrophic (algal) production responds most with an open canopy and heterotrophic (detrital) production responds most to a full canopy consisting of red alder. Light is the primary factor limiting primary productivity in temperate-forest streams (Gregory 1980, Kiffney et al. 2004) and is strongly associated with productivity at higher trophic levels (Wilzbach et al. 2005, Kiffney and Roni 2007). For example, biotic responses to moderate light levels or to deciduous vegetation ingrowth is detectable in buffers that range from 33 ft to 66 ft wide, in defoliated or thinned buffers (e.g., Danehy et al. 2007, Hoover et al. 2007), and in regenerated riparian stands (12 to 27 years old; Moldenke & Ver Linden 2007). Also, the longitudinal variation in light levels and chlorophyll *a* concentrations are significantly correlated with canopy gaps that occur along streams in late-successional (multi-structured) stands (Stovall et al. 2009). In contrast, biotic productivity in streams with conifer-dominated buffer strips that are wider than 100 ft (i.e., low quality detritus, low light levels) is similar to that observed in an unlogged forest (Newbold et al. 1980, Castelle and Johnson 2000, Moldenke & Ver Linden 2007).

The literature is consistent in showing that aquatic invertebrate assemblages are closely associated with litter composition (deciduous and conifer) and that alder is an important contributor of readily available and nutritious litter. For example, Wipfli & Musselwhite (2004) found (in SE Alaska) that small fishless headwater streams dominated by red alder contributed more detritus and more aquatic invertebrates to downstream fish habitat than did tributaries not dominated by alder. In Oregon coastal streams, Romero et al. (2005) showed that invertebrate drift under deciduous and mixed canopies was about 30% more abundant than under conifer due to a higher biomass of terrestrial macroinvertebrates. Allan et al. (2003), using insect fallout traps near streams in Southeast Alaska, captured a greater biomass of terrestrial macroinvertebrates beneath red alder compared to that beneath conifers (western hemlock, Sitka spruce). The quality of litter from red alder is the most nutritious and available for biological processing compared to other deciduous species and conifer; the latter being generally less available and more difficult to process (Allan, 1995; Cummins 2002).

There are no quantitative studies of source distances for litter and terrestrial subsidies. The FEMAT (1993) team, using profession judgment, estimated that most litter input comes within 0.5 tree heights. Streambank erosion and flooding of the adjacent forest floor in flood plain areas is also known to be a significant source of litter and invertebrates (White and Harvey 2007). Therefore, by inference, stream adjacent trees and shrubs, especially overhanging vegetation, are considered the most important contributors of litter and terrestrial insect fallout. Riparian management for high quality litter and terrestrial macroinvertebrate inputs would be most effective by maintaining stream adjacent (e.g., one tree crown width or about 30 ft) deciduous overstory and understory vegetation, especially near streams with moderately confined or unconfined channels (i.e., locations susceptible to bank erosion and flooding). Small streams are more tightly connected to riparian biotic inputs as a result of the closed canopy and the high edge-to-area ratio (Richardson et al. 2005).

The retention and subsequent biological processing of organic litter is dependent on channel morphology and flow regime (Richardson et al. 2009). Retention of detrital particles increases with increasing channel roughness which is associated with complex channels consisting of an intermingling of rock and debris (stones, twigs, logs; pool riffle, step pool, alluvial fan). Channel types with low roughness (plane-bed, cascade, bedrock) would have low retention of litter. Litter transport increases rapidly with discharge as particles become entrained and are transported downstream (Richardson et al. 2009).

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Appendix B. Predicted effective shade in relation to buffer width, channel width, and stream aspect for riparian stands with different tree heights and composition. Shade simulated WDOE model for two conditions: streams with dense conifer stands on two sides, and streams with dense stands on south side with sparse conifer stands on north side. Stand specifications are listed in Table A-2.

	Buffer	Effective shade (%)			Effective shade (%)		
BFW (ft)	width (ft)	two sides	aspect 180°	aspect 270°	Sside/Nside	aspect 270°	aspect 225°
5	0	cc	26.7	11.3	cc/cc	11.3	20.7
5	15	csd	96.1	96.8	csd/css	93.2	85.0
5	25	csd	96.6	97.6	csd/css	94.2	85.7
5	50	csd	96.7	97.6	csd/css	94.2	85.8
5	75	csd	96.7	97.6	csd/css	94.2	85.8
5	0	cc	26.7	11.3	cc/cc	11.3	20.7
5	15	cmd	95.6	95.5	cmd/cms	91.9	83.4
5	25	cmd	95.9	96.0	cmd/cms	92.5	84.0
5	50	cmd	96.2	96.6	cmd/cms	93.2	84.4
5	75	cmd	96.4	96.7	cmd/cms	93.3	84.8
5	0	cc	26.7	11.3	cc/cc	11.3	20.7
5	15	cld	95.5	95.4	cld/cls	91.8	83.3
5	25	cld	95.8	95.9	cld/cls	92.3	83.7
5	50	cld	96.1	96.5	cld/cls	93.0	84.2
5	75	cld	96.3	96.8	cld/cls	93.4	84.6
5	0	cc	26.7	11.3	cc/cc	11.3	20.7
5	15	msd	96.2	96.9	msd/mss	93.4	85.0
5	25	msd	96.7	97.7	msd/mss	94.4	85.7
5	50	msd	96.8	97.7	msd/mss	94.4	86.0
5	75	msd	96.8	97.7	msd/mss	94.4	86.0
5	0	cc	26.7	11.3	cc/cc	11.3	20.7
5	15	mmd	95.8	95.9	mmd/mms	92.4	84.4
5	25	mmd	96.2	96.5	mmd/mms	93.1	85.0
5	50	mmd	96.5	96.8	mmd/mms	93.4	85.4
5	75	mmd	96.7	96.8	mmd/mms	93.4	85.6
5	0	cc	26.7	11.3	cc/cc	11.3	20.7
5	15	mld	95.8	95.8	mld/mls	92.2	83.8
5	25	mld	96.1	96.3	mld/mls	92.8	84.3
5	50	mld	96.4	96.9	mld/mls	93.5	84.8
5	75	mld	96.6	97.0	mld/mls	93.6	85.2
15	0	cc	10.5	8.5	cc/cc	8.5	9.2
15	15	csd	67.8	81.1	csd/css	77.5	58.3
15	25	csd	71.9	86.4	csd/css	82.7	62.0
15	50	csd	74.6	86.5	csd/css	82.8	63.1
15	75	csd	75.6	86.5	csd/css	82.8	63.2
15	0	cc	10.5	8.5	cc/cc	8.5	9.2
15	15	cmd	93.9	95.2	cmd/cms	91.2	79.5
15	25	cmd	94.2	95.7	cmd/cms	91.8	80.0
15	50	cmd	94.6	96.2	cmd/cms	92.4	80.5
15	75	cmd	94.8	96.2	cmd/cms	92.5	80.9
15	0	cc	10.5	8.5	cc/cc	8.5	9.2
15	15	cld	93.9	95.1	cld/cls	91.1	79.3
15	25	cld	94.2	95.5	cld/cls	91.6	79.8
15	50	cld	94.5	96.1	cld/cls	92.2	80.3
15	75	cld	94.8	96.3	cld/cls	92.5	80.7
15	0	cc	10.5	8.5	cc/cc	8.5	9.2
15	15	msd	77.9	90.7	msd/mss	87.3	68.2
15	25	msd	81.1	92.2	msd/mss	89.0	71.4
15	50	msd	83.4	92.2	msd/mss	89.0	72.1
15	75	msd	83.7	92.2	msd/mss	89.1	72.2
15	0	cc	10.5	8.5	cc/cc	8.5	9.2
15	15	mmd	94.0	95.7	mmd/mms	90.3	76.4
15	25	mmd	94.4	96.2	mmd/mms	91.0	77.0
15	50	mmd	94.7	96.5	mmd/mms	91.2	77.5
15	75	mmd	95.0	96.5	mmd/mms	91.3	77.8
15	0	cc	10.5	8.5	cc/cc	8.5	9.2
15	15	mld	94.1	95.5	mld/mls	91.5	79.9
15	25	mld	94.5	96.0	mld/mls	92.1	80.4
15	50	mld	94.8	96.5	mld/mls	92.7	81.0
15	75	mld	95.1	96.5	mld/mls	92.8	81.4

Appendix B continued.

	Buffer	Effective shade (%)			Effective shade (%)		
BFW (ft)	width (ft)	two sides	aspect 180º	aspect 270º	Sside/Nside	aspect 270º	aspect 225º
25	0	cc	8.1	7.8	cc/cc	7.8	7.9
25	15	csd	43.7	48.4	csd/css	46.2	38.5
25	25	csd	46.9	50.7	csd/css	48.3	41.2
25	50	csd	49.3	50.8	csd/css	48.3	42.2
25	75	csd	50.3	50.8	csd/css	48.4	42.4
25	0	cc	8.1	7.8	cc/cc	7.8	7.9
25	15	cmd	73.9	85.0	cmd/cms	80.7	62.4
25	25	cmd	76.0	87.6	cmd/cms	83.3	64.3
25	50	cmd	79.2	90.3	cmd/cms	86.1	67.1
25	75	cmd	81.6	90.4	cmd/cms	86.2	69.1
25	0	cc	8.1	7.8	cc/cc	7.8	7.9
25	15	cld	80.5	90.0	cld/cls	85.7	68.1
25	25	cld	82.0	91.8	cld/cls	87.5	69.6
25	50	cld	84.8	94.4	cld/cls	90.1	72.1
25	75	cld	87.0	94.7	cld/cls	90.5	74.1
25	0	cc	8.1	7.8	cc/cc	7.8	7.9
25	15	msd	46.1	50.7	msd/mss	49.0	41.4
25	25	msd	49.3	53.0	msd/mss	51.1	44.1
25	50	msd	51.5	53.1	msd/mss	51.1	45.0
25	75	msd	52.5	53.1	msd/mss	51.2	45.2
25	0	cc	8.1	7.8	cc/cc	7.8	7.9
25	15	mmd	77.7	89.3	mmd/mms	83.9	63.0
25	25	mmd	79.7	91.6	mmd/mms	86.2	64.9
25	50	mmd	82.8	92.3	mmd/mms	86.9	67.5
25	75	mmd	85.1	92.3	mmd/mms	87.0	69.1
25	0	cc	8.1	7.8	cc/cc	7.8	7.9
25	15	mld	85.4	93.9	mld/mls	89.7	72.5
25	25	mld	86.7	94.4	mld/mls	90.2	73.8
25	50	mld	88.9	94.8	mld/mls	90.6	75.7
25	75	mld	90.4	94.8	mld/mls	90.7	76.5
45	0	cc	7.6	7.5	cc/cc	7.5	7.6
45	15	csd	35.8	31.3	csd/css	29.7	31.1
45	25	csd	38.2	32.4	csd/css	30.6	33.0
45	50	csd	40.2	32.5	csd/css	30.6	33.7
45	75	csd	41.1	32.5	csd/css	30.6	33.8
45	0	cc	7.6	7.5	cc/cc	7.5	7.6
45	15	cmd	53.0	67.3	cmd/cms	63.8	46.0
45	25	cmd	55.3	71.0	cmd/cms	67.2	48.0
45	50	cmd	58.3	72.8	cmd/cms	68.9	50.5
45	75	cmd	60.5	72.8	cmd/cms	69.0	52.2
45	0	cc	7.6	7.5	cc/cc	7.5	7.6
45	15	cld	59.1	72.5	cld/cls	68.6	50.6
45	25	cld	61.2	75.7	cld/cls	71.6	52.4
45	50	cld	64.2	78.8	cld/cls	74.7	54.9
45	75	cld	66.5	79.2	cld/cls	75.1	56.9
45	0	cc	7.6	7.5	cc/cc	7.5	7.6
45	15	msd	36.9	32.1	msd/mss	30.8	32.2
45	25	msd	39.3	33.1	msd/mss	31.6	34.1
45	50	msd	41.2	33.2	msd/mss	31.7	34.8
45	75	msd	42.0	33.2	msd/mss	31.7	35.0
45	0	cc	7.6	7.5	cc/cc	7.5	7.6
45	15	mmd	56.0	70.7	mmd/mms	66.4	46.8
45	25	mmd	58.4	74.5	mmd/mms	70.0	48.8
45	50	mmd	61.2	74.8	mmd/mms	70.2	51.1
45	75	mmd	63.3	74.9	mmd/mms	70.3	52.6
45	0	cc	7.6	7.5	cc/cc	7.5	7.6
45	15	mld	64.0	78.6	mld/mls	74.7	55.1
45	25	mld	66.3	81.8	mld/mls	77.8	57.1
45	50	mld	69.2	83.5	mld/mls	79.5	59.6
45	75	mld	71.5	83.5	mld/mls	79.6	61.3

Attachment 4: Commentary on Dr. Doug Martin's science documentation in support of the WFFA Alternate Plan Template

By: Dr. Pete Bisson

I'd like to make a couple of general observations about the buffer proposals, as I think WFFA would like me to comment on the prescriptions from a broad scale perspective. My overall impression from reviewing the November 2014 template and from reading this draft is that the proposed prescriptions represent a fairly significant reduction in the width of buffers required on small tree farms relative to current state buffer requirements for small streams. As pointed out in the draft, these reductions may not translate into a linear corresponding reduction in various ecological functions. I agree with the conclusion that the trees closest to the channel will have the greatest influence on the aquatic ecosystem, but my personal opinion is that not enough studies have been conducted under a variety of conditions and forest types to allow us to predict function impairment at different distances from the channel with much accuracy at this time. I've always felt that the FEMAT curves were a useful starting point for testing hypotheses, but that more field verification is needed and it will require a lot of case studies before it is possible to develop quantitative predictions of function vs. distance from channel. Therefore, I think any document that includes graphs of function vs. distance from channel for purposes of justifying buffer widths should be careful to note that such graphs are based on fairly limited field evidence or on expert opinion-based models. For this reason I would suggest that if the Forest Practices Board were to accept the proposal that it would be accompanied by a dedicated monitoring program that would yield data for various functions from a variety of sites, over an extended time period. I know that's asking a lot, but I'm convinced that without a well-organized riparian status and trends monitoring program on managed forests we will continued to be plagued with uncertainty about the effectiveness of different buffer strategies. I can see value in monitoring sites on federal lands (most conservative buffers), state and large private industrial lands, and small landowners (least conservative buffers) as a spectrum of conservation approaches that could be tested. Perhaps the point doesn't need to be made in this document, but I hope it finds its way into policy discussions. For more details on this reasoning please see a paper John Richardson, Bob Naiman, and I wrote on fixed-width buffers a couple of years ago [http://www.bioone.org/doi/full/10.1899/11-031.1].

My second observation is that the report doesn't deal with how the proposed alternative buffers address the issue of resiliency. Most of the proposed widths on the smallest streams are only 1-2 standing trees wide, which means that they will need to remain standing until the surrounding forest has regenerated to the point that it provides sufficient replacement ecological functions. If those buffer trees die, some functions will be impaired until the adjacent forest recovers. The notion of "buffering the buffer" has been examined in several studies (e.g., http://citeseerx.ist.psu.edu/viewdoc/summary?doi=10.1.1.164.1291) and seems to be a part of many policy deliberations. This is another topic that may be deferred until later, but I'd be surprised if it didn't come up at some point.

I think the draft report is an effective document to present to the policy folks. I'll be interested to see what the response is.