An Overview of the DFC Model and an Analysis of Westside Type F Riparian Prescriptions and Projected Stand Basal Area per Acre

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WASHINGTON STATE DEPARTMENT OF
Natural Resources
Peter Goldmark - Commissioner of Public Lands

Cooperative Monitoring
Evaluation & Research

May 2010

CMER 10-1002

Washington State Forest Practices Adaptive Management Program
Cooperative Monitoring, Evaluation, and Research Committee (CMER)
Report

An Overview of the DFC Model and an Analysis of Westside Type F Riparian Prescriptions and Projected Stand Basal Area per Acre

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Washington State Forest Practices Board
Adaptive Management Program
Washington State Department of Natural Resources
Olympia, Washington

May 2010 **CMER 10-1002**

Forest Practices Adaptive Management Program

The Washington Forest Practices Board (FPB) has adopted an adaptive management program in concurrence with the Forests and Fish Report (FFR) and subsequent legislation. The purpose of this program is to:

> Provide science-based recommendations and technical information to assist the board in determining if and when it is necessary or advisable to adjust rules and guidance for aquatic resources to achieve resource goals and objectives. (Forest Practices Rules, WAC 222-12-045)

To provide the science needed to support adaptive management, the FPB made the Cooperative Monitoring, Evaluation and Research Committee (CMER) a participant in the program. The FPB empowered CMER to conduct research, effectiveness monitoring, and validation monitoring in accordance with guidelines recommended in the FFR.

Disclaimer

This exploratory report was prepared for the Cooperative Monitoring, Evaluation and Research Committee (CMER) and contains scientific information, which was intended to improve or focus the science underlying the Forest and Fish Adaptive Management program. The project is part of the Type F Riparian Prescriptions Rule Group DFC Validation Program, and was conducted under the oversight of the Riparian Scientific Advisory Committee.

This document was reviewed by CMER and was assessed through the Adaptive Management Program's independent scientific peer review process. CMER has approved this document for distribution as an official CMER document. As a CMER document, CMER is in consensus on the scientific merit of the document. However, any conclusions, interpretations, or recommendations contained within this document are those of the authors and may not reflect the views of all CMER members.

The original report of the same name, CMER 07-701, was completed and approved by CMER in June 2007. A decision was subsequently made to submit the report for Independent Scientific Peer Review (ISPR) in January 2009. This new report is a revised version of CMER 07-701 based on ISPR review comments and responses.

Proprietary Statement

This work was developed with public funding including contracts: PSC 07-22 and IAA Agreement #10-86. As such it is within the public use domain. However, the concept of this work originated with the Washington Department of Natural Resources (WDNR) and the authors; permission must be obtained from the originators to use the results in the way developed herein. Use of results without permission of WDNR and the authors may be deemed a violation of federal statures under preview of the Office of Research Integrity. As a public resource document, this work should be given proper attribution and be properly cited.

Full Reference

McConnell, S.P. 2010. An overview of the DFC model and an analysis of Westside type F riparian prescriptions and projected stand basal area per acre. Cooperative Monitoring Evaluation and Research Report CMER 10-1002. Washington Department of Natural Resources, Olympia, WA.

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ABSTRACT

New Forest Practices Rules (Rules) that took effect in July, 2001, introduced a Desired Future Condition (DFC) concept for managing riparian forests. The intent of rules (WAC 222-30-021) was to allow for timber harvest from riparian forests while protecting and improving water quality and habitat for fish and selected amphibians (WDNR 1999). DFC rules use a systematic approach for making site-specific prescriptions that consider site attributes and current and projected future stand conditions. For riparian forests along Type F streams in western Washington, timber harvest is allowed only in riparian stands that are projected, using the DFC Model, a stand growth Model developed to implement Rules, to "meet" a rule-prescribed target condition when stands are mature. For DFC rules, "mature" stands are 140-yrs old, and the target condition stand growth is measured against is basal area per acre (bapa). For riparian stands that meet DFC, two riparian prescriptions allowing for some timber harvest were developed; thinning from below (Option 1) and leave trees closest to the water (Option 2). The DFC Model determines if stands meet requirements to be eligible for timber harvest and provides stand-specific prescription details and projected stand-age-140 bapa for each stand modeled.

There was little information available to determine appropriate target bapa for Rules, thus validating these targets was a high priority for the Adaptive Management Program (AMP). It was commonly assumed that the Rule criterion that determined stand eligibility for inner zone timber harvest would also be the primary constraint to timber harvest and that managing by DFC Rules would put stands on a trajectory towards the DFC Target bapa at stand-age-140. The purpose of this study was to address this uncertainty and: 1) determine the rule component that most constrains timber harvest, and 2) quantify stand-age-140 bapa projected for each sample stand for both "active management" riparian prescriptions and a no-cut treatment.

DFC Model outputs were analyzed using data from 150 randomly selected, approved Forest Practices Applications (FPAs) in which inner zone timber harvest was proposed along west-side Type F streams. These analyses showed that for Option 1, bapa was the primary constraint to timber harvest on only 7 FPAs (4.6%) while the required 57 inner zone leave tpa was the primary constraint to timber harvest on 142 FPAs (94.6%). One FPA (0.7%) was constrained equally by bapa and the required number of leave trees. One-hundred and eight of the 150 stands were eligible for Option 2. Of these, the bapa target constrained timber harvest on 40 FPAs (37%), while the required minimum no cut floor widths constrained timber harvest on 68 FPAs (63%).

Stand-age-140-bapa (average and the 95th percentile confidence interval around the mean) for each prescription, for all FPAs, across all Site Classes, stream sizes and other possible covariates was: no-cut, 364.1 ±7.1, Option 1, 335.5 ± 7.4, and Option 2, 301.1 ± 5.4 with the trees in the outer part of the inner zone excluded and 333.0 ± 6.0 with the trees in the outer part of the inner zone included.

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ACKNOWLEDGEMENTS

I would like to thank the following individuals and organizations for their contribution to this project: Bonnie Thompson, Department of Natural Resources, entered data from Forest Practices Applications into DFC Model compatible files. Chris Mendoza (Aquatic Resource Consultants) and Pete Heide (Washington Forest Protection Association) engaged often and provided many valuable suggestions that added to the content, context and utility of this report. Other CMER reviewers also provided useful comments ranging from minor editorial to substantive and involved. These reviewers were: Dick Miller (Washington Farm Forestry Association), Todd Baldwin (Kalispel Tribe of Indians), Ash Roorbach (CMER staff), Jim Van Der Ploeg (Hancock Forest Management), Jeff Madsen (Timber Industry) and Lyle Almond (Makah Tribe). Jeff Welty (Weyerhaeuser) provided valuable assistance in understanding the origins, design and outputs of the DFC Model in addition to providing direct contributions to analyses of trees not accounted for (by rule design) in the DFC Model. Cynthia Piez (University of Idaho, Department of Mathematics) reviewed equations used in spreadsheet analyses to ensure their accuracy. Dawn Pucci-Spilsbury helped create Figures and Tables and helped with editing and formatting the final draft of this report. Much of the early work on this project was done while I was an employee of the Northwest Indian Fisheries Commission and then with the Upper Columbia United Tribes. I appreciate the time both entities allowed me to develop this work.

INTRODUCTION

REPORT TYPE AND CONTEXT

1. Report Type

The Forest Practices Application (FPA) Desktop Analysis is a model-based exploratory examination of "standard-prescription"[1] rules for riparian forests along Type F streams in western Washington (WAC 222-30-021). The intent of an exploratory report is to provide scientific or technical information that will improve understanding of the science underlying the Forest and Fish AMP and/or to provide better focus to questions/hypotheses that might be addressed in future studies. There is no field component to this study. A simple random sample of 150 approved FPAs, 75 each from 2003 and 2004, from across western Washington, along Type F streams that had inner zone timber harvest proposed was used for this analysis.

2. Purpose

One of the FPA Desktop Analysis is to provide quantitative information to Forest and Fish Report (FFR) / Timber Fish and Wildlife (TFW) stakeholders on the effect riparian rule prescription components have in determining Desired Future Condition (DFC) Model[2] generated, harvest-age prescriptions and stand-age-140 basal area per acre (bapa) projected values. Another purpose is to identify assumptions that are embedded in the DFC Model and DFC Rules, many of which have not yet been validated, and describe how the model assumptions used affect model outcomes. Suggestions for ways to address some uncertainties in DFC Model and DFC rule assumptions are provided in "Recommendations".

3. Adaptive Management Context

The FPA Desktop Analysis project was implemented at the request of FFR Policy[3] (Policy). Policy requested this project because results from a stakeholder[4]-initiated DFC Model analysis of FPAs appeared likely to be relevant to Policy discussion and, potentially, Forest Practices Board decision-making on DFC rules. No formal study plan was prepared for the FPA Desktop Analysis, nor were Scientific Advisory Groups (SAGs) or the Cooperative Monitoring, Evaluation and Research (CMER) committee consulted to provide input into the study design[5]. The Riparian Scientific Advisory

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[1] For this report, "standard" prescriptions are those contained in WAC 222-30-021(1)(ii) and include: a) no-cut, b) thinning from below (Option 1) and leaving trees closest to the water (Option 2). This definition excludes hardwood conversions and alternate plans.

[2] Available on-line at: http://www.dnr.wa.gov/forestpractices/dfc/

[3] The CMER Protocols and Standards Manual (Pleus and Rowton 2005) does not identify Policy request as one of the means by which projects may be introduced into CMER.

[4] Steve McConnell, then (Autumn, 2004) an employee of the Northwest Indian Fisheries Commission

[5] I did not participate in RSAG or CMER from Nov. 2005 to October 2006 and did not participate in the May 2006 DFC Workshop sponsored by RSAG so I do not know for certain whether there was discussion of the study design for the Desktop Analysis by RSAG and/or CMER. There was, obviously, ample opportunity for such discussion, and a draft report submitted to RSAG on Nov. 12, 2005, that could serve to focus discussion on possible methodological problems. However, no such concerns were communicated to me prior to my taking this on as contractor with a contract finally signed in August, 2006.

Group (RSAG) and CMER reviewed report drafts[6] and ultimately approved final drafts of the report in 2007. In 2009, Policy directed the Adaptive Management Program Administrator (AMPA) to initiate Independent Scientific Peer Review (ISPR) review of the Desktop Analysis and Field Check reports. These reports were sent to ISPR in spring of 2009 and this final report dated 2010 reflects inclusion of ISPR review comments into these reports. Both RSAG and CMER will be given the opportunity to approve reports that include ISPR comments and that draft will then be declared final and replace the report currently available on the DNR Adaptive Management website.

4. Related Reports

The reports described in this section are part of a "package" of reports that began with the FPA Desktop Analysis. These reports are the "Field Check" report (McConnell and Heimburg, 2010), the "Sensitivity Analysis" (Roorbach et al. 2006), the "Model and Manual" report (McConnell and Heimburg 2010) the "Synthesis" report (McConnell 2010) and an "Overview" report (McConnell 2010). The follow-on reports provide analyses that give context to the results of the FPA Desktop Analysis e.g. the "Field Check" report (McConnell and Heimburg 2010) project and the "Sensitivity Analysis" (Roorbach et al., 2006), convey information and insights that were gained while conducting the work required to implement these studies ("Model and Manual" report), or introduce or synthesize, the body of work and important findings contained in these reports.The Overview report introduces the other reports and describes how they are related while the Synthesis report summarizes key findings from these reports. Additionally, an overview of site attributes and stand characteristics of the riparian stands used in the Desktop Analysis is provided in Appendix A of this (Desktop Analysis) report.

OVERVIEW OF DFC RULES

1. West-side Type F Riparian Zone DFC Rules: a Synopsis

New Forest Practices Rules (Rules) based on a Desired Future Conditions (DFC) concept for managing riparian forests became effective in Washington State in July, 2001. The intent of rules was to allow for timber harvest from riparian forests while protecting and improving water quality and habitat for fish and selected amphibians. The Rules are designed to provide a systematic approach for implementing site-specific management across a range of site and stand conditions to provide riparian functions (shade and wood input in particular). Forest structure is presumed to provide function. Timber harvest is allowed only if a riparian forest is suitably stocked with conifers and on trajectory towards a desirable structure. The spatial location from which structure (and hence functions) originate is incorporated into rules. More timber harvest is allowed as distance from stream increases because most riparian functions are provided by near-stream trees. Timber harvest is restricted for a greater distance perpendicular to stream edge along large streams as compared to small streams because input of more and larger wood is required to provide riparian functions in large streams.

2. RMZ Widths: Systematically Determined, Based on Site Attributes

[6] The first draft was dated December 12, 2005 and the second draft was dated November 26, 2006.

Riparian forests provide shade, organic material and stability to forest streams and, in general contributions from riparian forests are greater from stream-adjacent trees and decrease as distance from stream increases (FEMAT,1993, p. V-27). For management simplicity, discrete units, riparian management zones (RMZs) of core, inner and outer zones are designated and for Option 2, the inner zone is further divided into a no-cut "floor" on the inner portion of the zone and a harvest entry area in the outer part of the inner zone. The management applied within each riparian zone/subzone is the same regardless of where a tree or micro-site is located within each zone/subzone. Similarly, although a stream's need for LWD input varies along a theoretical continuum of stream size, the stream width set as the threshold amount at which function was presumed to differ, measured by bankfull width, is ≤ 10' wide (small streams) and >10' wide (large streams). The total width of the RMZ, including core, inner and outer zones, was set in Rules to equal site potential tree height (SPTH) for 100-yr old Douglas-fir trees. So, for each of Site Classes 1-5, total RMZ widths are, respectively, in feet, 200, 170, 140, 110 and 90. The Site Class used to represent stands is obtained from maps available via internet from the DNR. Data used to develop these maps was from soil maps. The resulting site class maps are accurate at a coarse scale; actual site productivity likely varies at fine scales but management simplicity is enhanced by using an easily obtainable, coarse-scale measure of productivity.

The core zone is always 50' wide and begins at the outer edge of bankfull width or the channel migration zone (CMZ) and extends 50' perpendicular to the stream. The inner zone adjoins both the core and outer zones, lying between these. The outer zone extends from the outer edge of the inner zone to the full extent of SPTH for a given Site Class. Inner and outer zone widths vary by Site Class, stream size and the riparian prescription landowners choose. Inner zone widths are greater where site productivity, measured by Site Class is higher, and where streams are large. Since total RMZ and core zone widths are constant, where inner zone widths are wider, the corresponding outer zone width is narrower.

Riparian zone widths also vary by the management choice made by landowners. Only two standard prescriptions involving timber harvest in the inner zones are available to landowners for Type F streams in western Washington (described in more detail in subsequent sections of this report). These are: 1) thinning from below (Option 1) or 2) leaving trees closest to the water (Option 2). Landowners can also opt to use a "no-cut" prescription in the inner zone but cut in the outer zone. For Option 1 the outer limit of inner zone widths were negotiated to be a percentage of SPTH; 2/3 for small streams and 3/4 for large streams (Fairweather 2001). These dimensions are also used for the no-cut prescription. For Option 2, inner and outer zone widths were negotiated and do not vary formulaically (Fairweather 2001).

The relationship between RMZ widths for all three zones, by Site Class, stream size, and management choice are presented graphically for Option 1 (Figure 1) and Option 2 (Figure 2). Inner zone widths are greater for large streams than for small streams for all Site Classes in Option 1 (Figure 1) and the difference, large stream to small, is a maximum of 17' on Site Class 1 and a minimum of 8' on Site Class 5. For Option 2

(Figure 2), inner zone widths are the same (84’) for both large and small streams for Site Class 1 and differ by only 6’ for Site Class 2, e.g. they are 70’ wide for large streams and 64’ wide for small streams.

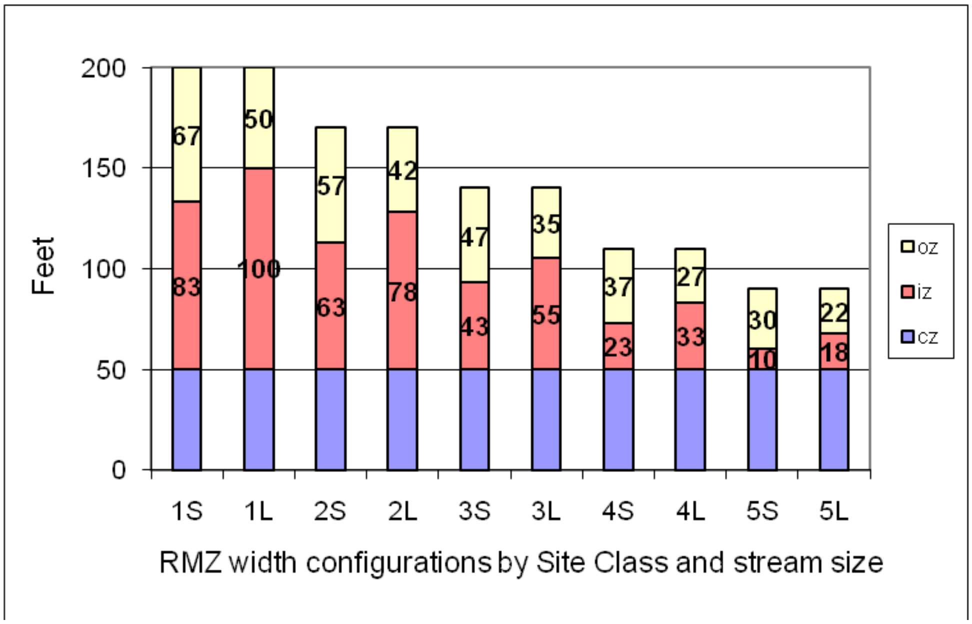

Figure 1 – Riparian Management Zone widths by Site Class, and stream size for Option 1 or for no inner zone timber harvest. The zones, cz, iz and oz denote, respectively, the core, inner and outer zones. The numbers on the x axis are Site Class (1-5) and the letters denote stream size: Small (≤ 10’ wide), and Large (> 10’ wide). The numbers overlaid on zones are widths in feet (the core zone is always 50’). Bars extend to Site Potential Tree Height for each Site Class: 1) 200’, 2) 170’, 3) 140’, 4) 110’ and 5) 90’.

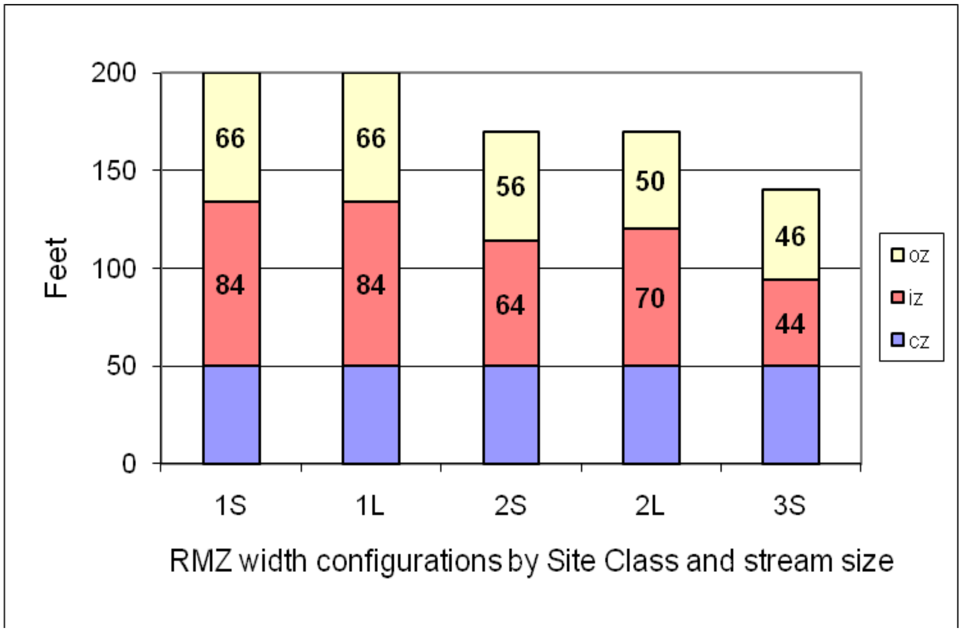

Figure 2 – Riparian Management Zone widths by Site Class, and stream size for Option 2. The zones, cz, iz and oz denote, respectively, the core, inner and outer zones. The numbers on the x axis are Site Class (1-3) and the letters denote stream size: Small (≤ 10' wide), and Large (> 10' wide). The numbers overlaid on zones are widths in feet (the core zone is always 50'). Bars extend to Site Potential Tree Height for each Site Class: 1) 200', 2) 170', 3) 140'. Option 2 is not allowed on Site Classes 4 and 5, or on Site Class 3 along large streams.

3. Activities Allowed by Riparian Management Zone

No timber harvest is allowed in the core zone. Some timber harvest is allowed in the inner zone subject to the stand meeting eligibility requirements (see next section). More timber harvest is allowed in the outer zone. Timber harvest in the outer zone is not restricted by a riparian stand meeting eligibility requirements for inner zone harvest, but more outer zone timber harvest is permitted in some circumstances in stands that do (WAC 222-30-021(B)(II)).

4. Determining Eligibility for Timber Harvest in the Inner Zone

Stand eligibility for timber harvest in the inner zone is based on forest growth model (DFC Model) projections of a complete inventory of core and inner zone trees and site attribute data that it is required for landowners to collect and submit with FPAs (see section B. f.). Stands eligible for timber harvest must have a projected stand-age-140 bapa that meets or exceeds basal area targets in Rules (DFC Targets) which, for Site Classes 1-5 respectively are, in ft^2/acre, 285, 275, 258, 224, 190. Stand-age-140 was agreed by rule negotiators to represent a mature stand and was therefore used as the target age against which to judge basal area growth (Fairweather 2001). No stand inventory data is collected for outer zone trees. The outer zone is not considered in determining whether the inner zone of a stand is eligible for timber harvest.

5. Riparian Prescriptions

There are two prescriptions that allow for timber harvest in the inner zone of riparian stands along Type F streams in western Washington that meet eligibility requirements and other qualifying criteria. These prescriptions are: 1) a thinning from below (Option 1) and 2) leaving trees closest to the water (Option 2). Option 2 is only allowed on Site Classes 1 and 2 and Site Class 3 along small streams. The stand-age-140 bapa DFC Target used to determine whether the stand is eligible to have inner zone harvest is a constraint common to both prescriptions that excludes some stands from being entered for timber harvest in the inner zone. Both prescriptions have one other rule component that also may serve to limit inner zone timber harvest although unlike the DFC Target, these components do not of themselves exclude the possibility of inner zone timber harvest in riparian stands. For Option 1, inner zone timber harvest must leave the 57 largest conifer trees un-cut. For Option 2, no cutting is allowed in a portion of the inner zone that lies adjacent to the core zone. Called the "floor", the minimum width of the no-cut inner zone adjacent to the core zone along small streams is 30' and along large streams it is 50'.

6. Data used to run the DFC Model

The DFC Model runs on site attribute and stand inventory data (Table 1) that landowners are required to collect. Landowners' report these data on DFC Worksheets that are included as part of the FPA they submit to the Washington Department of Natural Resources (WDNR). Site class, species type and the stand inventory data are used to "grow" the stand by the DFC Model. Other site attribute data, for example RMZ length, provide inputs used to calculate the area of the core and inner zones, tpa and current and future bapa. Site Class is also used by the DFC Model, along with stream size to determine whether Option 2 is allowed. Stand inventory and site attribute data are used to calculate specific quantitative elements of prescriptions for landowners, for example the basal area credit and/or required floor width (Option 2) and the specific number of inner zone leave tpa and the maximum diameter of trees that can be cut so that the thinning implemented is from below (Option 1).

7. DFC Model Characteristics and use

The DFC Model consists of three pages (Figures 3-5). These are labeled, respectively, from page one to page three as, "Worksheet" (Figure 3), "Option 1 –Thinning from below" (Figure 4), and "Option 2 –Leaving trees closest to stream" (Figure 5). DFC Model calculations of core and inner zone area, tpa, bapa, % conifer (on a basal area basis) and projected stand-age-140 bapa for the core and inner zones are obtained on the "Worksheet" page. The prescribed number of leave trees or the leave "floor" width for the two active management prescriptions are calculated on, respectively. page 2 (Option 1) or page 3 (Option 2) of the DFC Model.

Table 1 – Data required to run the DFC Model, data attributes, and data source.

Data Attribute	Units or Characteristics	Source of Data
Stream Size	Large (> 10' wide) or Small (≤ 10'wide)	Landowner
Site Class	1-5	Landowner - from maps available on the WDNR website using the Forest Practices Application Review System
Major Species	Douglas-fir or western hemlock	Landowner - determines which species has a majority or plurality of total stand basal area
RMZ Length	Feet	Landowner – no specific method is prescribed for making this measurement.
Stand Age	Years	Landowner – using stand inventory records and/or coring trees
Number of trees in dbh class	Number	Landowner – a simple count of the number of 2" dbh classes populated
Stand Inventory Data	Number of trees by 2" dbh class and species type – conifer and hardwood. Smallest diameter class is 6" (trees 5.0" to 6.9").	Landowner – must collect tree data from the core and inner zones, using widest possible width for the given Site Class, stream size and prescription.

8. The Worksheet Page of the DFC Model (Version 1.1.12)

The "Worksheet" page of the DFC Model is where stand inventory and site attribute data are entered. Site attributes required by the DFC Model include stream size, Site Class, major species (Douglas-fir or western hemlock), and RMZ length (ft). Stand inventory data includes stand (entered separately for the core and inner zone) age (yrs) and the number of trees by species type (conifer or hardwood), by two-inch diameter class.

Once site and stand inventory information is entered, pushing the "Calc" function key on the right side of the boxes titled "core zone stand table" and "inner zone stand table" causes the DFC Model to calculate (separately) inner and outer zone stand area, tpa, bapa, % conifer and projected stand-age-140 bapa (as a percent of the DFC Target).

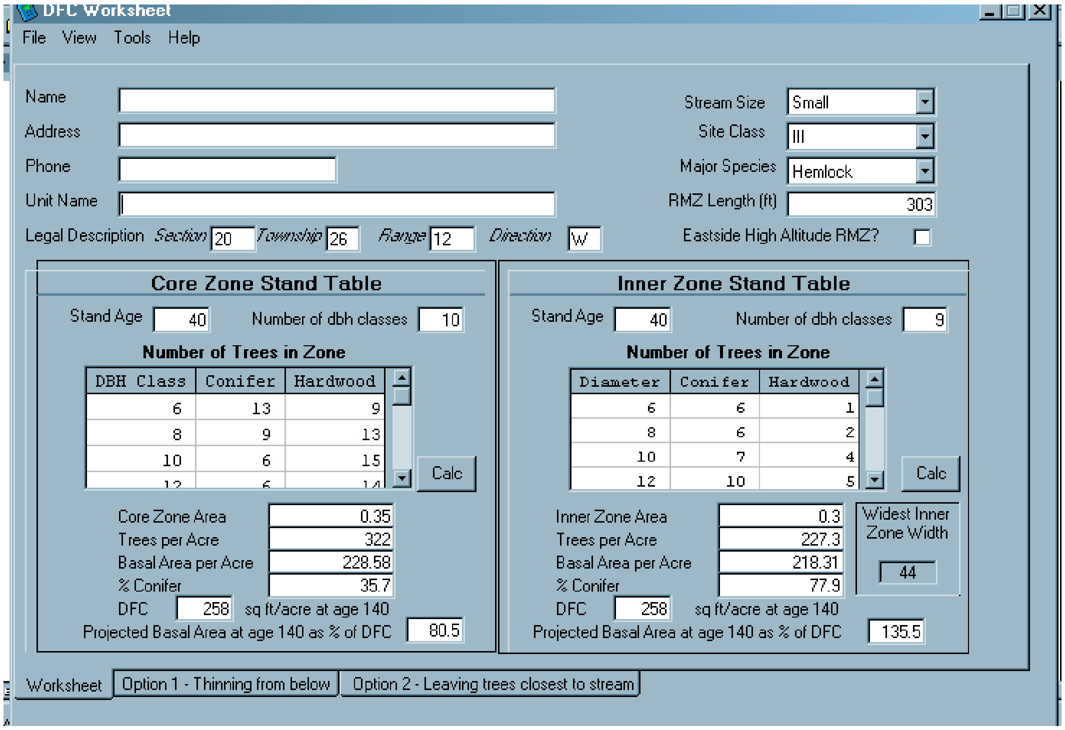

Figure 3 – The "Worksheet" page of the DFC Model.

9. The "Option 1 – Thinning from below" Page of the DFC Model

The DFC Model provides outputs of "projected basal area" and "required basal area" on the "Option 1 – thinning from below" page of the DFC Model. These numbers refer to (only) the inner zone bapa projected to stand-age-140 (although core zone bapa is part of the calculation used to determine the required or projected, respectively, stand-age-140 bapa). "Projected basal area" must be equal to or greater than "required basal area" in order for DFC to be met. Projected bapa changes after pushing the "suggest thinning" toggle on this page as the Model calculates a new projected basal area for the trees remaining after thinning from below, along with a positive growth response to thinning incorporated into the Model.

The Model user will be provided prescription information on the graphic that includes the width of the inner and outer zones for that Site Class / stream size configuration, the number of trees that must be left in the inner zone (absolute number, not per acre) and the size of the largest tree that can be cut (by scrolling down in the spreadsheet below the graphic to find the diameter of the smallest tree left after thinning). The other information contained on this worksheet is not required by the user to implement prescriptions. This information includes the post-thinning projected bapa, the required bapa, and, on the Table to the right, the number of inner zone trees left (expressed as tpa) and the post-thinning stand basal area per acre.

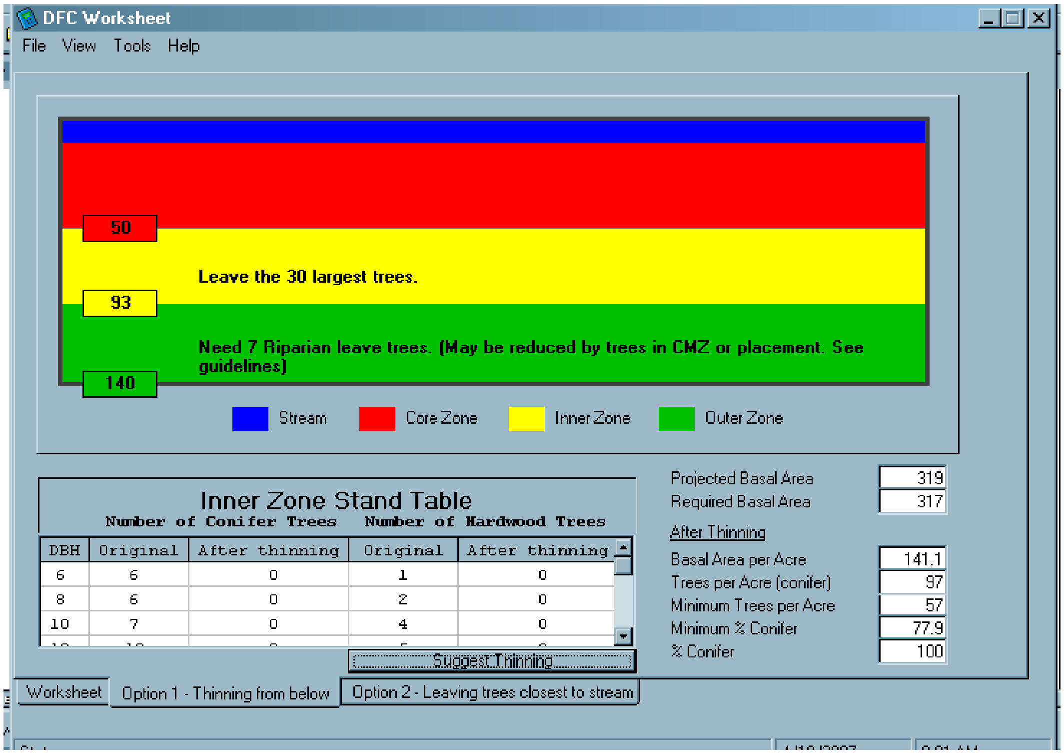

Figure 4 – The "Option 1 – Thinning from below" page of the DFC Model

10. The "Option 2 – Leaving trees closest to stream" Page of the DFC Model
DFC Model outcomes for Option 2 are obtained from the page labeled "Option 2 – Leaving trees closest to the stream". Information available to the user on this page include the width of the inner zone, the width of the no-cut portion of the inner zone required for each stand and the number of trees that must be left in the outer part of the inner zone and in the outer zone. Unlike as for Option 1, no interaction with the Model is required to obtain Option 2 outcomes once the "calc" buttons on the Worksheet page of the Model are toggled. The outputs for Option 2 are more limited than for Option 1 in that estimates of stand basal area acre at age 140 are not provided, nor are there estimates of inner zone stand density or post-harvest stand bapa. Instead, outputs are limited to those required to implement the DFC Rules.

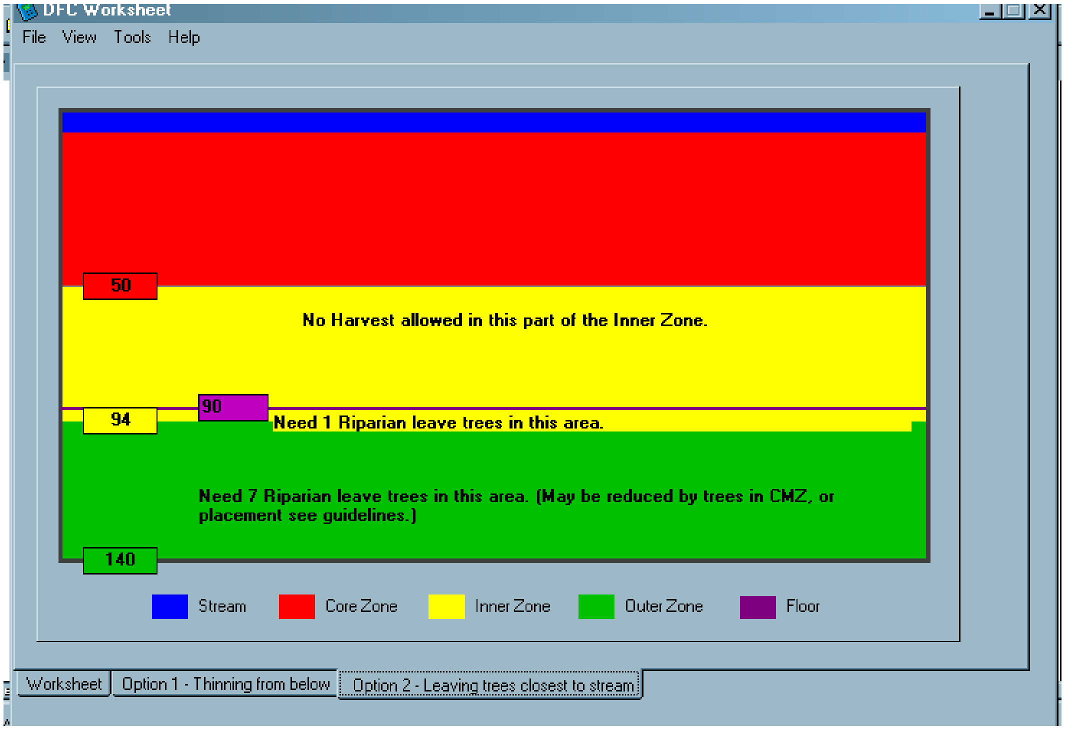

Figure 5 – The “Option 2 – leaving trees closest to stream” page of the DFC Model

11. Calculating Basal Area Per Acre in the DFC Model

The bapa used by the DFC Model to determine if a stand meets DFC, and is therefore eligible for inner zone timber harvest, is calculated by projecting the bapa of each of the core and inner zones and then calculating an area-adjusted average value for the core and inner zones combined. For example, for a riparian stand that is on Site Class 2, along a large stream, the core zone is 50’ wide and the inner zone is 78’ wide[7]. The area of each of the core and inner zones is the product of RMZ length times zone width. Since RMZ length is the same for both zones, width can be used as a surrogate for area to simplify calculations. For this example, the DFC Model projected basal area for the core zone at stand-age-140 is 424.6 and for the inner zone (with no timber harvest) it is 411.1. The DFC Model projected stand-age-140 bapa is calculated using the equation below. For this equation cz = core zone width in ft and iz = inner zone width in ft.

((cz/(cz+iz) * cz bapa 140)	+	((iz/(cz+iz) * iz bapa 140))	=	DFC Model projected, area-adjusted, stand-age-140 bapa

Using the numbers from the randomly selected stand used for this example, these calculations are:

$$((50/128) * 424.6) + ((78/128) * 411.1) = 416.4$$

[7] This example uses a stand from this analysis that was selected at random.

In the example above, each of the values were weighted proportionally to their area, the core zone at 39% (50/128) and the inner zone at 61% (78/128). Inner zone width varies by Site Class, stream size and management option selected from as small as 10' wide on Site Class 5 small streams to as much as 100' wide on Site Class 1 large streams while the core zone is constant at 50' wide. Because the size of the inner zone varies, the relative importance of the core and inner zones towards meeting the basal area target varies. The core zone may account for as little as 33% or as much as 83% of the projected bapa used to calculate core + inner zone stand-age-140 bapa

12. Riparian Zone Width as a Factor in Meeting DFC Targets

The variable width of the inner zone of riparian stands has a potentially important effect on whether or not stands meet DFC. As noted above, projected stand basal area is calculated for the core and inner zones and it is the area-adjusted combined basal area from these zones, projected to stand-age-140 that determines whether a stand will meet DFC. Because inner zone widths vary, the relative importance of the core zone relative to the inner zone also varies across Site Class, stream size and management option configurations (Figures 3 and 4). Calculating the ratio of core to inner zone area (or width, as they have a common length) indicates the relative importance of each zone. If the ratio is 1.0, then the core and inner zones are equally important in DFC (stand-age-140 bapa) calculations. If the ratio is less than 1.0, the inner zone has more influence. Where the ratio is greater than 1.0, the core zone has more influence.

For Option 1 (Figure 6), the core zone is more influential than the inner zone on DFC Model calculated stand-age-140 bapa for less productive sites (Site Classes 4 and 5, and Site Class 3 along small streams). The inner zone is more influential than the core zone on Site Classes 1 and 2 and Site Class 3 along large streams (Figure 6). For all Site Classes, the core zone is relatively more influential than the inner zone on small streams because the core zone is wider than the inner zone; the inner zone is more influential on large streams,on which the inner zone is wider than the core zone (Figure 6).

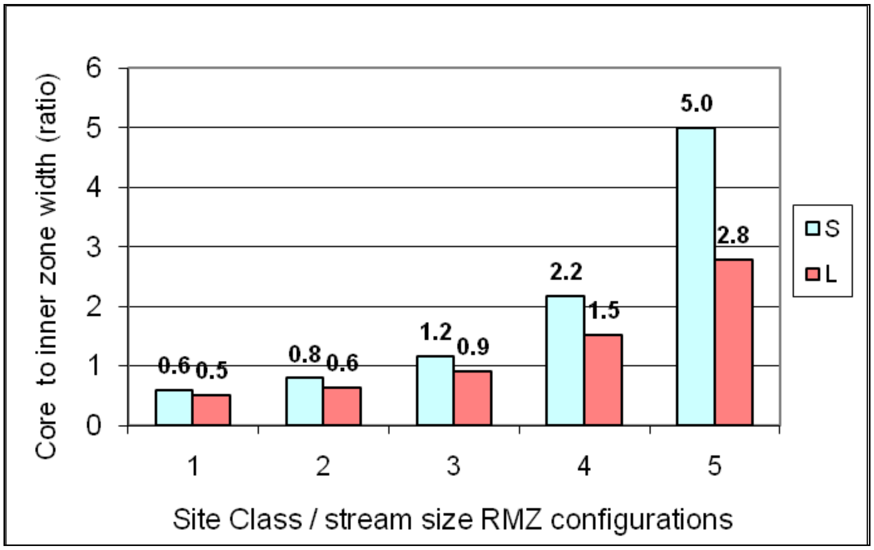

Figure 6 – Option 1, core over inner zone stand area (or width as both zones have a common length) ratios. Site Class (1-5) is on the x axis. Ratio values (unit-less) are on the y axis. "S" and "L" represent "small" (≤ 10' wide) and "large" (> 10' wide) streams, respectively.

For Option 2, Site Class 1, the core and inner zone widths are the same for both large and small streams, thus the core over inner zone ratio is the same (Figure 7). For both large and small streams, the inner zone is more influential than the core zone in DFC target calculations. For Site Class 2 also, the core zone is less influential than the inner zone in DFC target calculations. The core zone, however, is more important on small streams than on large streams (Figure 7). Option 2 can only be used along small streams on Site Class 3 and for this configuration the core zone has more influence than the inner zone on DFC target calculations (Figure 7).

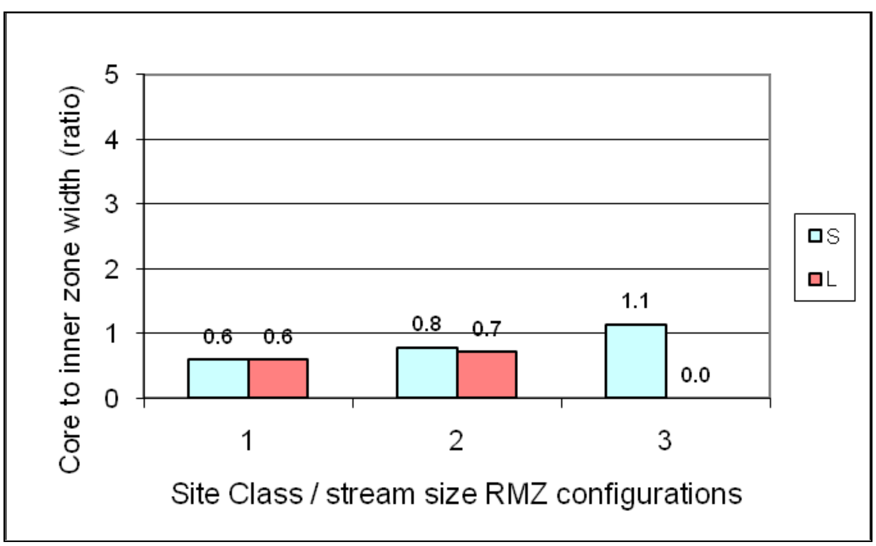

Figure 7 – Option 2, core over inner zone stand area (or width as both zones have a common length) ratios. Site Class (1-5) is on the x axis. Ratio values (unit-less) are on the y axis . "S" and "L" represent "small" (≤ 10' wide) and "large" (> 10' wide) streams, respectively.

13. Characteristics of Option 1

The Option 1 prescription can be implemented on all Site Classes on both small and large streams. According to the Rules (WAC 222-30-021(2)(B)(I)) "The objective of thinning is to distribute stand requirement trees in such a way as to shorten the time required to meet large wood, fish habitat and water quality needs. This is achieved by increasing the potential for leave trees to grow larger than they otherwise would without thinning." Option 1 requires that the "Residual trees left in the combined core and inner zones must meet stand requirements necessary to be on a trajectory to desired future conditions." This is therefore, the component of the rule that establishes the eligibility requirement for inner zone timber harvest, e.g. that the residual stand must meet DFC. The other component of the Rule for Option 1 is that the treatment applied must be a thinning from below and that there must be at least 57 residual tpa after thinning[8]. DFC Model outputs calculate the largest inner zone tree (dbh) that may be harvested, and the number of trees in this diameter class that must be left.

14. Characteristics of Option 2

The Option 2 prescription is allowed only on sites mapped as Site Class 1 and 2 and on Site Class 3 with streams that are less than or equal to 10' wide. Option 2 results in a no-cut zone adjacent to the core zone. On small streams this no-cut portion of the inner zone is 30' and on large streams it is 50' wide. Timber harvest is implemented by "Trees are selected for harvest starting from the outer most portion of the inner zone first, then progressively closer to the stream" (WAC 222-30-021(ii)(B)(II)", remembering that "A minimum of 20 conifers per acre with a minimum 12" dbh, will be retained in any portion of the inner zone where harvest occurs." Option 2, therefore, provides a wider no-cut riparian buffer adjacent to the stream than does Option 1.

The ecological basis for Option 2 is that wood recruitment to streams is directly related to the distance from streams at which trees grow[9]. Option 2 is designed to retain more trees near the stream. Timber harvest is constrained to the portion of the inner zone furthest from water where trees provide proportionally much lower amounts to riparian functions as compared to trees nearer to the water. The rationale for leaving 20 conifer tpa that are at least 12" dbh in the outer part of the inner zone is not provided[10]. Depending on the quality of trees left, however, and how affected by windthrow they are, there could be a thinning release effect to these trees similar to that for Option 1. A response to more

[8] I've found through experimentation that if 57 conifer trees are not available but the stand meets DFC, the DFC Model prescribes leaving the largest hardwood trees present after all conifer are accounted for if still short of 57 tpa. This occurred on only one of the 150 stands analyzed for this report.

[9] Other important riparian functions, shade, nutrients, etc. are affected by distance from stream. The negotiations leading to Rules, however, primarily centered on wood recruitment (Fairweather 2001, p. 9)

[10] Not discussed in any of: 1) Forest Practices Rules WAC 222-30-021 (WDNR, 2001), 2) Forest Practices Board Manual, Section 7 (WDNR, 2001), or 3) Fairweather (2001)

growing space would hasten the growth of the trees furthest from the water, lessening the time for inner zone trees furthest from the water to provide functions.

Another distinguishing characteristic of Option 2 is the division of the inner zone into different portions, e.g. the "floor" and the outer part of the inner zone, to which different rules apply. For Option 1, in contrast, the entire inner zone is treated as a single unit with the same rules applied throughout.

The DFC Model makes some different calculations for Option 2 than it does for Option 1. The calculation common to both options is using the full stand inventory data from the core and inner zones to calculate stand-age-140 bapa to determine whether the stand meets the DFC Target for the given Site Class and is therefore eligible for inner zone timber harvest. Like as for Option 1, the DFC Model does this by weighting projected core and inner zone contribution to bapa from each zone, in proportion to the area of each zone.

For Option 2, the DFC Model then makes some additional area-based calculations. First, the area-adjusted, projected stand-age-140 bapa that would result from the core zone and the floor portion of the inner zone are calculated. If this amount exceeds the DFC target, then the entire outer part of the inner zone (the part further from the stream than the floor out to where the outer zone begins) can be harvested, leaving 20 tpa of conifers greater than or equal to 12" dbh. If there is bapa from the core + floor that is in excess of the DFC Target, then up to half of the normally required outer zone trees (20 per acre) can be cut (down to a minimum of 10 per acre), on a basal area for basal area basis. "Basal area for basal area" means that if the credit basal area is, for example, 3.3 ft^2/acre, then only 3.3 ft^2/acre could be harvested from the 10 outer zone leave trees that are potentially available for cutting. A 12" tree has about 0.78 ft^2/acre basal area, so for this example, only four 12" inch tpa could be cut (4 trees * 0.78 ft^2/tree = 3.12 ft^2). [11].

If the DFC Target will not be met from the area-adjusted combined core and floor portion of the inner zone, then the DFC Model makes calculations that extend the no-cut area into the outer part of the inner zone until a width, measured in feet, is reached at which the DFC Target is reached. Extending the width of the no cut portion of the inner zone adds basal area because the calculation is made over the entire inner zone and any part of the inner zone that is outside the no-cut portion is considered by the DFC Model to have no basal area. As you add more basal area by adding width, you increase the numerator without changing the denominator and may eventually get a high enough basal area within the inner zone to meet the DFC Target.

[11] Note that there are problems with how the DFC Model reports outer zone trees available for harvest. In brief, where the DFC Model lists the number of outer zone trees that must remain, it infers that up to half may be removed if there is a basal area credit but fails to note that this is supposed to be on a "basal area for basal area basis". Thus the number of outer zone trees that can be removed is over-reported when the basal area credit is less than the basal area of trees potentially removed.

For example, a Site Class 2 stand along a large stream has a 50' core zone width and a 70' inner zone width, with 50' of the inner zone being in the no-cut floor. For a stand with DFC Model projected stand-age-140 bapa of 280 and 349 in the core zone and inner zones, respectively, calculations to determine the floor width are as follows, where cz = core zone width (ft), iz = inner zone width (ft), :

((cz/(total cz+iz) * cz bapa 140)	+	((floor / total cz+iz) * iz bapa 140))	+	((opiz / total cz+iz) * iz bapa 140)	=	Total DFC Model projected, area-adjusted, cz+iz combined bapa 140

((50/120)*280) + ((50/120)*349) + ((20/120)*349) = 336.2

To calculate the width from the outer part of the inner zone required to obtain a stand-age-140 bapa that meets or exceeds the DFC Target of 275, requires solving for **X** in the following equation:

((50/120)*280) + ((50/120)*349.0) + ((**X**/120)*349) = 275 or (more)

The equations for doing this are algebraic and not included here. The result, however, is:

116.7 + 145.4 + ((**5**/120)*349) = 276.6

Thus the floor width for this example from one of the stands used in this analysis is 50' core zone + 50' floor width + 5' from the outer part of the inner zone = a total no-cut width of 105'.

If the width at which a stand meets DFC is equal to the combined width of the core + inner zone, the stand technically "meets DFC" but no cutting is permitted because this would reduce projected stand-age-140 bapa to below the DFC Target. Stands on which this occurs, however, may still be entered for inner zone harvest using Option 1. And, because all or most hardwood trees can be cut and, for the conifers cut, the thinning is from below for which a "release" (post-harvest accelerated growth) response is programmed in to the DFC Model. So, stands on which no cutting is allowed using Option 2 can allow for timber harvest using Option 1[12].

Because the core width, the floor widths and the DFC Target by Site Class are fixed, the bapa required from the core + floor zones to meet the DFC Target from each Site Class, stream size configuration can be calculated (Table 2). The required core+floor stand-age-

[12] The one stand in this analysis on which DFC was met at the total width of the core+inner zones, meaning that no timber harvest was allowed for Option 2 allowed for, using Option 1, cutting 43.4 ft^2/acre (6.3 conifer and 37.1 hardwood) distributed between 76.8 tpa (25.3 conifers and 51.5 hardwoods).

140 bapa decreases with Site Class (Table 2) and is lower on Large streams than it is on Small streams within the same Site Class.

The core + floor required stand-age-140 bapa targets change by Site Class and stream size for several reasons. First the required DFC Targets decrease with Site Class (Site Classes 1-3 respectively are, in ft^2/acre, 285, 275 and 258) meaning stands must have less projected basal area to meet targets. Second, because inner zone widths are wider on more productive sites, the core + floor combined, area-adjusted bapa account for proportionally less of the core + inner zone width. Therefore, more bapa is required for the core + floor for stands to meet the DFC Target across a larger area (wider inner zone). Third, for small streams, the core zone + floor width is 20’ less than for large streams because the floor minimums for small and large streams are, respectively, 30’ and 50’. . Therefore, the basal area in the core + floor zone has to be higher in order to meet DFC across the full core + inner zone combined, area-adjusted bapa. .

Table 2 – Minimum stand-age-140 basal area per acre required from the combined core zone + floor in order for the DFC Target to be met at the minimum floor width (e.g. without extending the no-cut portion of the inner zone beyond the minimum no-cut width required), by Site Class (1-3) and stream size (small ≤.10’ wide, large > 10’ wide).

Site Class	Small	Large
1	477.4	381.9
2	391.9	330.0
3	303.2	

More details of the riparian prescriptions used in FFR rules are provided in the Forest Practices Rules, WAC 222-30-021 (WDNR, 2001). Implementation guidelines are located in the Forest Practices Board Manual, Section 7 (WDNR, 2001). Background information on how and why rules were devised, alternatives to the rules adopted that were considered and rejected, and a description of how the DFC Model was constructed was prepared by Fairweather (2001).

15. Model and Guidance Problems to Implementing DFC Rules

I found that the information provided for implementing “DFC” rules in these documents have at least the following set of problems: 1) lack of specified methodologies for collecting some of the data required to implement rules, 2) conflicting information presented, 3) undefined terminology leading to confusion over how to implement rules, and 4) a disorganized and incongruous presentation of information – particularly in the Board Manual, making rule implementation based on these materials difficult and providing no resolution to landowner questions about how to implement rules correctly.

Additionally, there were some errors found in DFC Model calculation, incomplete and inadequate guidance for entering stand and site attribute data into the DFC Model and a number of ”user interface” problems identified that make interpreting rule prescriptions difficult and misinterpretation of prescription directions likely for landowners. Problems associated with collecting data consistently and accurately for implementing DFC Model problems are identified and discussed in the "Model and Manual" report (McConnell and Heimburg 2010b). Problems that derive from direction for collecting and reporting required stand and site attribute data, undefined terms or inconsistent or poorly organized and presented direction for implementing rules are presented in both the Model and Manual report (McConnell and Heimburg 2010b) and the "Field Check" report (McConnell and Heimburg, 2010a).

OBJECTIVES

The objective of this study was to quantify DFC Model calculated (current stand age) and projected (standage-140) outputs from a random sample of approved FPAs for west-side Type F streams on which inner zone timber harvest was proposed in order to:

1) Quantify the effect of rule components on constraining timber harvest for each of the three standard riparian prescriptions using DFC Model outputs[13].

   The prescriptions are:
   a. no-cut,
   a. Option 1 (thinning from below) and,
   b. Option 2 (Leaving trees closest to the stream).

   The Rule constraints are:
   a. the stand-age-140 bapa "DFC" target,
   b. the required 57 inner zone leave tpa required for Option 1, and
   c. the required minimum no-cut inner zone "floor" required for Option 2.

2) Quantify the projected bapa for riparian stands at stand-age-140 for the three standard prescriptions permitted in current rules: 1) no-cut, 2) Option 1 and 3) Option 2.

METHODS

1. Overview

The Forest Practices Application Review System (FPARS) available on the WDNR website was used to identify DNR-approved FPAs reporting inner zone timber harvest in west-side forests along Type F streams. From the FPAs that qualified, one-hundred and fifty were randomly selected for use in this analysis using an unstratified random selection without replacement.[14] An equal distribution was selected for each of two years, 2003 and 2004, with seventy-five FPAs selected from each year.
The sample was drawn by identifying all qualifying FPAs for each year. Qualifying FPAs were those that stated that timber harvest in the inner zone would occur as part of that application. For 2003, there were 391 qualifying FPAs listed and for 2004 there

[13] This report is entirely a modeling exercise and operational constraints, field conditions or other rationale which may cause landowners to make different decisions than those that result from the DFC Model outputs are not considered.
[14] http://www3.wadnr.gov/dnrapp4/fparsweb/login.aspx?RedirectURL=FPASearch.aspx

were 445. The full list of FPAs was sorted separately for each year, using a computer driven randomization program and the sorted lists were numbered by selection order. Beginning with 1, each FPA was reviewed and either accepted or rejected. Rationale for rejecting an FPA included, for example, no DFC Worksheet included (not required at that time), FPA is in an HCP not governed by DFC rules, the FPA was for an Alternate Plan, the stream segment did not meet DFC, or there were data entry problems. If an FPA was rejected the next FPA from the randomized list was selected (Appendix C). There were three approved FPAs encountered that met DFC **only** if Option 1 (thinning from below) were implemented[15]. These three FPAs were included in the sample.

Some FPAs had multiple stream segments submitted in one FPA. For each FPA sampled, only the first stream segment encountered in the FPA was reviewed. If this segment had to be rejected, the entire FPA was set aside and an entirely new FPA drawn.[16]

DFC Worksheet data from the FPAs selected were entered into the DFC Model and the model was then run to get projected DFC Model bapa outcomes. Projections were obtained from all three prescriptions available to landowners (no-cut, Option 1 and Option 2) not just the prescription selected by landowners for a given FPA. Analyses were then made of projections from all three scenarios to determine if rule components within each of Options 1 (stand-age-140 bapa target and the requirement to leave the 57 largest inner zone conifer trees) and Options 2 (stand-age-140 bapa target and the required no-cut “floor”) constrained timber harvest equally or if there were differences in the constraining effect exerted by each rule component. DFC Model projected stand-age-140 bapa outcome from each prescription, for each FPA were summarized using descriptive statistics and compared graphically.

2. Data Acquisition and Data Entry

Pdf. Files of the FPAs selected were accessed electronically using the public domain “Adobe Reader” program. Reading each FPA from front to back, the first DFC Worksheet encountered (some FPAs had multiple stream segments in a given FPA, each with a different Worksheet), was selected and data from this Worksheet entered into the DFC Model and saved as a .dcf file with a unique name for each stand. Data from .pdf files cannot be transferred electronically to spreadsheets and .dcf files were not available from landowners, so .dcf files used in this analysis were re-created by re-entering data manually[17].

[15] A description of DFC Model behavior for these stands is provided in the “Model and Manual Report”.

[16] The FPA selection process used was intended to provide a representative sample of stand conditions and configurations implemented under DFC rules. Another possible approach to obtaining a sample might have been to identify attributes of interest, for example stream size, dominant tree species (DF or WH), site class or location (DNR Region). This sample approach would have been useful for more carefully evaluating model outcomes by specific factors. However, that was not the objective of this study and this approach to selecting sample stands would not have been a better approach for obtaining a representative sample of FPAs that reflected the variability of situations that occur amongst approved FPAs.

[17] Bonnie Thompson from WDNR did much of the data entry for this project.

The DFC Model must be "run" to obtain most of the data required by this analysis. Running the model consists simply of opening the file and pressing some toggles that cause the model to make calculations and generate outputs. The data used in this analysis, by DFC Model action required are: 1) site attribute data (no interactive component to obtaining these other than opening the .dcf file), 2) stand attribute data (need to push calc buttons on the "Worksheet" page to generate outputs), 3) Option 2 data (need to push calc buttons on first page, then turn to the third page), and 4) DFC Model pre- and post-harvest outputs for the Option 1 option (need to push the "suggest thinning" toggle to generate post-harvest data).

The DFC Model provides outputs that are keyed to its primary use as a regulatory tool for implementing Forest Practices Rules so it is not possible to obtain from it many outputs that are common to other growth and yield models. For example, ORGANON (Hann et al. 1997)[18] and FVS (Dixon 2003)[19] allow for simulations of different user-specified time periods while the DFC Model allows only for simulations to stand-age-140. Similarly, using ORGANON or FVS, different cutting prescriptions can be evaluated, different outputs (besides stand bapa) can be obtained, among other factors for which other models offer more flexibility. To work around this, spreadsheets were used extensively to make calculations not provided directly by DFC Model outputs.

Because the DFC Model has not previously been rigorously tested, calculated attributes were compared against DFC Model outputs to ensure that calculations were made correctly. Some errors in DFC Model calculations were in fact identified by checking calculations.[20] The spreadsheets used in these analyses, including equations used to derive each outcome or analysis variable are provided to the DNR and will be retained in the project file for this work along with a "data dictionary" for each spreadsheet (available upon request from either the DNR or the report author). The services of a qualified mathematician were secured to ensure that all calculations made for this analysis are correct.[21]

3. Quantifying Constraints to Timber Harvest for Option 1

If the basal area target is not met, the DFC Model will provide a message on p. 2 of the DFC Model in the inner zone portion of the graphic that says "No harvesting allowed". Returning to p. 1, a message will appear that says "DFC not met, TPA too low, or % conf reduced." However, for stands that meet the DFC target, the DFC Model does not identify which constraint, the required stand-age-140 bapa or the required 57 inner zone leave trees serves as the primary constraint to timber harvest.

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[18] Available on-line at: http://www.cof.orst.edu/cof/fr/research/organon/downld.htm
[19] Available on-line at: http://www.fs.fed.us/fmsc/fvs/index.shtml
[20] Two errors in DFC Model calculations were identified. These are described in the "Model and Manual" report (in prep). One error was the use of the wrong inner zone width for small streams in site classes 1, 2, and 3 on the DFC Worksheet. The other error was in calculating and reporting the number of inner zone trees to leave after thinning for the thin-from-below prescription on the "Option 1 – Thinning from below" page of the DFC Model. The first error has only a minor effect (quantified in the Model and Manual" report), and the second error has no effect on the analyses conducted in this report.
[21] Cynthia Piez, Department of Mathematics, University of Idaho

To distinguish the effect of rule components and determine which was the primary constraint, the effect to current tpa and stand-age-140 bapa of removing one additional tree (Table 5) was calculated for stands that were near threshold values for basal area or required leave tree number. If taking away one additional tree reduced tpa to less than 57 and bapa was not limiting, then tpa is the primary constraint to timber harvest. Conversely, if taking away one additional tree put projected stand-age-140 bapa too low while more than 57 tpa remained, then the DFC bapa target was the primary constraint.

The effect of removing one tree was evaluated using both external calculations with data obtained from stand yield tables (McArdle 1961, Figure 4) and the DFC Model itself. A yield table was used because the DFC Model does not provide a tree list (number and size of trees) for stand-age-140, only a projected stand basal area. Therefore, to calculate the effect to stand basal area of subtracting one additional tree I estimated, by Site Class, tree diameter growth of the smallest dbh tree remaining in the inner zone after thinning from its starting age and size (dbh) to stand-age-140. The starting diameter is obtained from the Stand Table on the "Option 1" page of the DFC Model after pushing the "suggest thinning" toggle. Basal area is calculated from the final (stand-age-140 basal area) using the equation: basal area = .005454 * $(dbh)^2$ (Husch et al. 1972).

This method provided an approximate but repeatable basis for evaluating the effect of cutting (from below) one more tree in each stand and estimating the effect of doing so to stand age-140 bapa for the few stands for which both bapa and tpa were possible constraints to timber harvest. This method was also used because the DFC Model has been found to contain some errors (McConnell and Heimburg, 2007b), thus should not be relied on exclusively to quantify results when other methods are available.

To estimate the effect to stand-age-140 bapa of removing one additional tree using the DFC Model, the data using the full stand inventory was run first. The stand was "thinned" using the "suggest thinning" toggle, and the inner zone tree inventory reduced on the DFC Worksheet to the number and size of inner zone trees left after the thinning suggested and then one additional tree taken beyond that. The "calc" button was then pressed, re-setting the inner zone characteristics quantified by the Model and outputs evaluated to determine what happens to current tpa and projected bapa after removing one additional tree. If taking one additional tree set the inner zone below the 57 tpa and "projected bapa" still exceeds "required bapa", then it is tpa that is the primary constraint. Conversely, if the stand has inner zone trees in excess of 57 tpa but projected bapa does not meet required bapa, it is bapa that is the primary constraint to additional timber harvest.

4. Calculating Basal Area for Trees Not Considered by the DFC Model for Option 2

Rules require that for Option 2 timber harvest 20 conifer tpa with a minimum dbh of 12" be left in the outer part of the inner zone. These trees are not counted towards the DFC Targets, thus are not considered by the DFC Model. To make calculations comparable across prescriptions, the basal area of these trees was calculated. The equation used for this was obtained from Jeff Welty (Weyerhaeuser) who developed it from ORGANON outputs specifically for this analysis. The equation is:

Contribution to stand bapa from trees in the outer part of the inner zone	=	initial bapa (ft^2/acre)	+	(-1.0599 + Site Class – 0.00004563* Site Class^2 + 0.0142 * starting dbh)	*	(140 – current stand age)

The values used for Site Class are: 1) 139', 2) 119' and 3) 98'

Initial bapa = 15.71 because this is the bapa of 20 trees, 12" in diameter, calculated as follows: 20 * .005454 * $(dbh)^2$ = 20 * .005454 * $(12)^2$ = 15.71.

A sample calculation for a Site Class 2 stand that is 55 yrs old is as follows:.

=15.71 + (-1.0599 +0.0311*119 -0.00004563*119*119+0.0142*12)*(140-55)

= 199.8' ft^2/acre

CAVEATS AND ASSUMPTIONS

The following assumptions and caveats must be kept in mind to thoughtfully interpret results presented.

CAVEATS

1. I did not evaluate other rule attributes that might apply in the course of implementing prescriptions or that could be considered in a field study, for example:
    1) Whether a thinning from below decreased the proportion of conifer in the stand. The DFC Model will not propose a prescription, and landowners presumably would not implement a timber harvest that had that effect.
    2) The shade rule may override the Option 1 prescription for timber harvest occurring within 75' of any Type S or F water. The data required to consider this are not available for this model analysis so possible shade rule effects were not considered.

2. The DFC Model has not been comprehensively compared against other common growth and yield models used in the Pacific Northwest, for example, ORGANON or FVS. The extent that DFC Model outputs differ from these more standard tools is not known.

3. The DFC Model does not consider ingrowth - growth of trees that establish after timber harvest occurs or that are less than 5" dbh at the time the stand inventory is collected. The basal area modeled, therefore, accrues only on trees that were part of the stand inventory at the time the FPA was submitted. Stand-age-140 basal

area might be higher if the basal area from trees established after timber harvest were included.

4. Leave trees in the outer part of the inner zone under Option 2 are not included in stand-age-140 bapa projections made by the DFC Model as per rule intent. I account for these trees (20 tpa with a 12" minimum dbh) in some of the analyses reported using calculations made outside of the DFC Model. It is not known how different the outputs I calculated are from what would result had growth of these trees been included in the model. It is not known what the actual growth of these trees would be as compared to the growth I attribute to them.[22]

5. The DFC Model assumes that all trees in the core and inner zones left after timber harvest will survive and contribute to stand basal area at age 140. Negotiators recognized that there would be windthrow mortality (Welty 1999, included as Appendix A in Fairweather 2001) and rules were written with this in mind. Windthrow is highly variable in its effect causing high mortality in some stands while leaving others intact (Grizzel and Wolff, 1998). The rules are designed around average expected mortality rather than the range of possible effects. It is not known how much stand outcomes will differ from DFC Model projected stand-age-140 outputs because of windthrow-driven tree mortality. Windthrow may affect the accuracy of DFC Model projections but we do not know the extent to which accuracy might be affected. This report is not directed at understanding or analyzing windthrow although this work is going on elsewhere. In addition there are a number of completed studies, for example Reeves et al. (2004), Martin and Grotefendt (2007), Liquori (2006) and Reid and Hilton (1998) among others, that provide some indication of how much windthrow may occur in riparian buffers and how site attributes and cutting patterns may affect a buffer's susceptibility to windthrow.

ASSUMPTIONS

1. Implementation of Rules through the DFC Model process assumes that stands are relatively homogeneous throughout the core and inner zones, respectively. The composition and structure of forest trees throughout stands may in fact vary with distance from the stream because of changing ecological conditions and along the length of the riparian stands because of different management history. Other

[22] The equation I used to calculate growth of trees in the outer part of the inner zone (opiz) was provided to me by Jeff Welty, Weyerhaeuser. This equation was the product of a relatively quick analysis and should not be considered definitive. Jeff and I considered this equation to be adequate to illustrate the point that there is additional basal area that is unaccounted for by the DFC Model in these trees because the rules and hence the DFC Model do not account for these trees. Ash Roorbach (personal communication) used the DFC Model to project the basal area contribution of trees in the outer part of the inner zone and got values that were about half those obtained from the "Welty equation". However, the 20 tpa in the outer part of the inner zone are substantially less than the smallest tpa parameter used in developing the DFC Model. Using age values that were less than the minimum from which the Model was programmed resulted in inaccurate results. Using tpa values that are outside the parameters used to program the DFC Model may also not be reliable. The equations developed by Welty were at least developed specifically for this question using ORGANON model outputs for the number of trees being evaluated (20 tpa). Neither method can account accurately for windthrow or the possible effects of other disturbance agents.

factors may also cause stand heterogeneity. Heterogeneity could affect management outcomes. If for example:

a. trees on one end of a riparian stand are uniformly large and uniformly small on the other, following the size guidelines for Option 1 would result in heavy cutting in one area and little or no cutting in another and post-harvest tree growth would likely be different from the tree spacing assumptions incorporated into the DFC Model.
b. large trees are unevenly distributed and Option 2 is used, stand basal area could be substantially lower or higher than growth modeled from stands on which tree diameter variations were evenly distributed throughout the stand.
c. for Option 2, conifer trees are concentrated towards the inner part of the inner zone and there are hardwood trees throughout the outer part of the inner zone, the 20 conifers per acre it is required to leave in the outer part of the inner zone may not exist.

2. All of the required leave trees in the outer part of the inner zone (Option 2) are 12" diameter, the minimum required by rules.

3. All models are presumed to have error associated with their predictions and this error is often assumed to be normally distributed. The DFC Model, however, is constructed so that it has a specific critical value that signals the opportunity to harvest timber. This essentially means that there is an assumption of no error in model predictions and rules do not incorporate provisions for the possibility that the model under- or over-predicts stand basal area.

RESULTS

The objectives of this study again are to: 1) Quantify the effect of rule components on constraining timber harvest for the three standard riparian prescriptions (no-cut, Option 1 - thinning from below and, Option 2 - leaving trees closest to the stream) for rule components that act as constraints (stand-age-140- bapa-"DFC"-target, the 57 inner zone leave tpa after thinning from below (Option 1), and c) the required minimum no-cut inner zone "floor" required for Option 2, and 2) Quantify the projected bapa for riparian stands at stand-age-140 for the three standard prescriptions permitted in current rules: 1) no-cut, 2) Option 1 and 3) Option 2.

RULE COMPONENT EFFECTS TO TIMBER HARVEST ALLOWED

1. The No-Cut Riparian Prescription

Three of the 150 stands included in this analysis were projected by the DFC Model to have a combined core + inner zone basal area that would not meet the stand-age-140 bapa Target unless Option 1 is implemented (Table 3). Two of these stands were mapped as Site Class 3 and one as Site Class 2; all occurred along large streams. Without thinning these stands were projected by the DFC Model to be short of meeting the DFC Target by 27, 57 and 58 ft^2/acre, respectively. With a thinning from below harvest, these stands were projected to make up this basal area and meet the DFC Target according to DFC Model projections.

Table 3 – Projected stand-age-140 inner zone bapa (ft^2/acre) with no thinning and with thinning from below in the inner zone. With thinning, stands meet DFC, with no thinning, stands do not meet DFC.

Stand #	Site Class	Inner Zone No Thin Projected bapa	Inner Zone Required bapa	Difference With No Thinning	Inner Zone After Thin Projected BA	Difference With Thinning
24	3	272	330	-58	333	3
104	3	207	264	-57	265	1
22	2	320	347	-27	348	1
Average		266	314	-47	315	1

This DFC Model projected response to thinning from below is not typical to all stands (McConnell, unpublished data). The large thinning response of these stands is attributable to characteristics of the trees on these stands (Table 4). The stands that did not meet DFC under a no-cut prescription according to DFC Model projections, but did meet DFC using Option 1, have less conifer basal area as a percent of total basal area than most stands in this analysis. The average % conifer across all stands for the core and inner zones, respectively is 80.3% and 90.1% (Appendix A) as compared to an average of 37.0 and 56.0, respectively, for these three stands (Table 4).

Table 4 – Attribute data for stands that are projected by the DFC Model to meet current DFC targets only if an Option 1 (thinning from below) timber harvest is implemented

Stand #	Site Class	Stream Size	Major Species	Core Zone % Conifer	Inner Zone % Conifer
24	3	L	D	35.8	55.3
104	3	L	H	45.6	38.6
22	2	L	D	29.2	74.7
Average				37	56

Stand # 22, on Site Class 2 (Table 3) also did not meet the DFC Target for Option 2 although, by virtue of Site Class and stream size it would be eligible for harvest using Option 2 if it qualified based on projected stand-age-140 bapa. There were Model interactions that occurred with these stands, in particular Stand #22, that were not encountered in other stands, presumably because projected stand basal area is so near to the stand-age-140 bapa targets for these stands. This DFC Model response is a model implementation result so is described here.

2. Option 1

The requirement for 57 inner zone leave tpa was the primary constraint on 142 of 150 (94.7%) stands, meaning that leaving the required 57 tpa resulted in projected stand-age-140 bapa that exceeded the bapa that would have been required if the basal area target were the only rule component in effect. The DFC Target was the primary constraint to timber harvest on 7 (4.7%) stands, meaning that more than 57 tpa were left after thinning because additional trees were needed to meet the minimum DFC basal area target. On 1 (0.7%) stand, the leave tree requirement and the DFC Target constrained timber harvest equally (Table 5).

The first 7 stands in Table 5 have less basal area than is required to meet the DFC Target but still have more than 57 tpa even after one additional tree is removed. By the eighth stand (# 192) there is a substantial excess of basal area, and slightly more than 57 tpa calculated[23]. Stand # 199 was constrained by both basal area and the required number of leave tpa as both of these will be less than required if one additional tree were removed[24].

[23] The DFC Model prescription for this stand should have removed one more tree than it did. The number of tpa does not drop below 57 until two additional trees are removed beyond what the DFC Model reported. It is unclear why this error occurs and how often it may occur as the limits of DFC Model prescriptions were evaluated to this level of detail only on these 8 stands.

[24] Using the alternative method of using the DFC Model to evaluate stand response, tpa went below 57 while projected basal area just equaled required basal area. The projected basal area result does not have any decimal points so it is not known if this number was rounded. The DFC Model is designed to round "up", thus, using only the DFC Model the conclusion would be that tpa alone was the primary constraint.

Table 5 – DFC Model projected stand-age-140 basal area (no-cut, required, and after thinning); harvest age leave tpa and the number of tpa and BA-140 that would be left if one more tree were cut; and the difference between projected BA-140 from BA-140 less one tree. The * indicates 55 stands in column 6 that have tpas of between 56.97 and 56.75. The ** indicates 83 stands with column 6 tpa values of between 56.73 and 52.47.

1 #	2 Inner Zone No-Cut Projected BA-140	3 Inner Zone Required BA-140	4 Inner Zone After Thin Projected BA-140	5 After Thin TPA	6 After Thin TPA if One More Tree is Cut	7 BA-140 if One More Tree is Cut at Harvest Age	8 Difference BA-140 with One Less Tree from Required BA-140 (Column 7 minus Column 3)
180	349	317	319	97.0	93.67	315.3	-1.7
263	207	264	265	73.1	72.98	263.9	-0.1
251	357	302	302	72.8	72.43	297.7	-4.3
195	353	288	289	71.5	70.66	286.6	-1.4
164	320	347	348	70.9	69.93	345.8	-1.2
295	306	254	254	64.9	64.35	250.9	-3.1
154	358	347	347	58.6	58.04	343.3	-3.7
192	386	160	255	58.0	57.04	250.4	90.4
173	355	144	252	58.0	57.04	247.7	103.7
228	414	125	394	57.2	57.02	389.4	264.4
166	370	260	327	57.5	57.01	321.8	61.8
299	373	198	269	57.2	56.98	263.8	65.8
*							
199	349	272	274	57.6	56.74	270.0	-2.0
**							

For almost all stands there was excess bapa even after cutting one additional tree and only a few stands required more than the required minimum number of trees in order to meet DFC targets (Figure 8). The stands that dip below 0 bapa in Figure 8 are the stands for which removing one more trees causes stands to fail to meet the DFC target because of lack of basal area. And, except for these few stands, the number of trees per acre remains constant while excess basal area amounts increase to the right, indicating that if the basal area target were the only constraint, additional trees could be cut if not limited by the minimum number of leave tpa required.

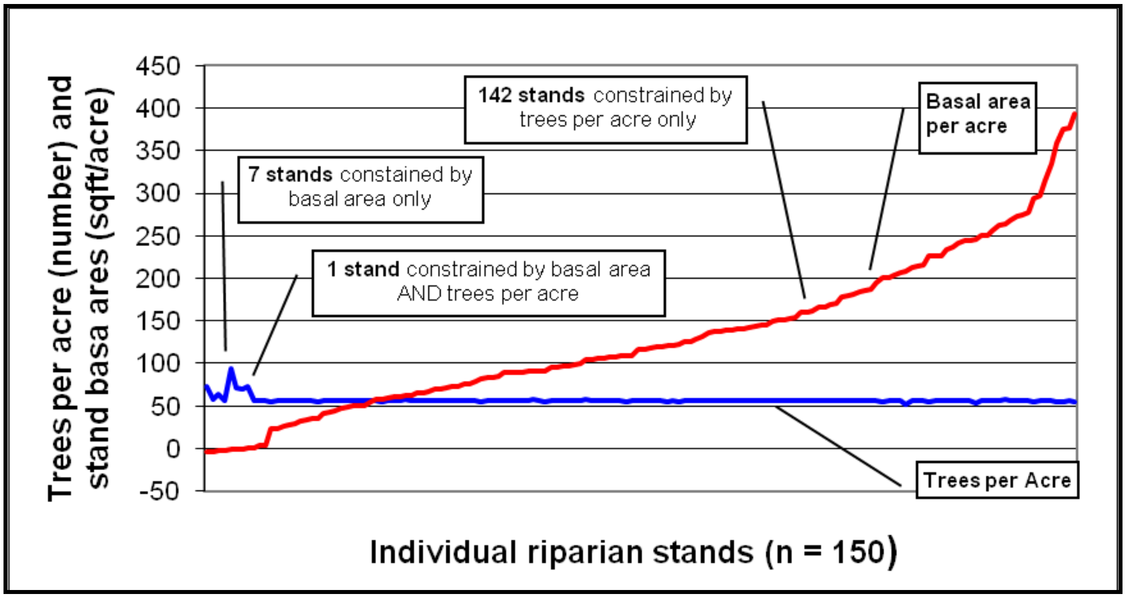


Figure 8 – The number of inner zone leave trees per acre vs. the difference between DFC Model inner zone "projected basal area" and "required basal area" at stand-age-140, after removing one additional tree from the point at which DFC was met. Across the x axis are the 150 stands represented as point values (they appear as lines rather than points because of their number). Stand values for tpa and bapa match up by "stacking" points vertically. The y axis is, for trees per acre, in individual trees; for basal area per acre, it is in ft^2/acre. Stands are sorted by ascending basal area.

3.Option 2

For the Option 2 Prescription, the no-cut portion of the inner zone or "floor" that it is required to leave adjacent to the core zone was the dominant constraint to timber harvest on 63% of FPAs evaluated (68 of 108). The proportion of stands constrained by each factor, the required minimum floor width or the basal area target varied by Site Class and stream size (Table 6). The average floor width also varied by Site Class and stream size. The average floor width for Site Class 1 small streams exceeded the widths for Site Class 1 large streams, despite the required minimum being 20' less. No Site Class 1 small stream stands had enough basal area to limit timber harvest by minimum floor width; wider widths up to the basal area target were required for each of these stands. The stand with the highest core zone to inner zone ratio, Site Class 3 small stream, had the lowest percentage of stands constrained by the basal area target. Almost all Site Class 3 small stream stands had excess basal area (a basal area credit) and timber harvest was constrained to the minimum width in 38 of 40 (95%) of these stands.

Table 6 – Rule component constraints to timber harvest for the leave-trees-closest-to-the-stream prescription, by Site Class and stream size.

Site Class	Steam Size	Floor Width	Average floor width plus and minus one standard deviation	Number of Stands Constrained by Floor Width	Number of Stands Constrained by Basal Area Target	Total
1	Small	80’	103.0 ± 12.6	0	5	5
1	Large	100’	102.0 ± 4.0	3	1	4
2	Small	80’	87.4 ± 7.1	7	25	32
2	Large	100’	102.6 ± 5.7	20	7	27
3	Small	80’	80.4 ± 1.8	38	2	40

Unlike the Option 1 prescription, it is not difficult to determine the factor constraining timber harvest on stands on which the Option 2 is used. Stands that are constrained by basal area have a wider inner zone than the minimum required and no basal area credit. Stands that are constrained by the minimum floor width will have a basal area credit and the floor width generated by the DFC Model will be the minimum allowed. Figures 9 through 13 show the distribution of floor widths and their accompanying basal area credits, by Site Class and stream size from which constraining factors were determined. For each figure, the number in the boxes marked as being in feet are, from left to right, the maximum and minimum widths. The boxes with no units are the basal area credit in ft^2/acre.

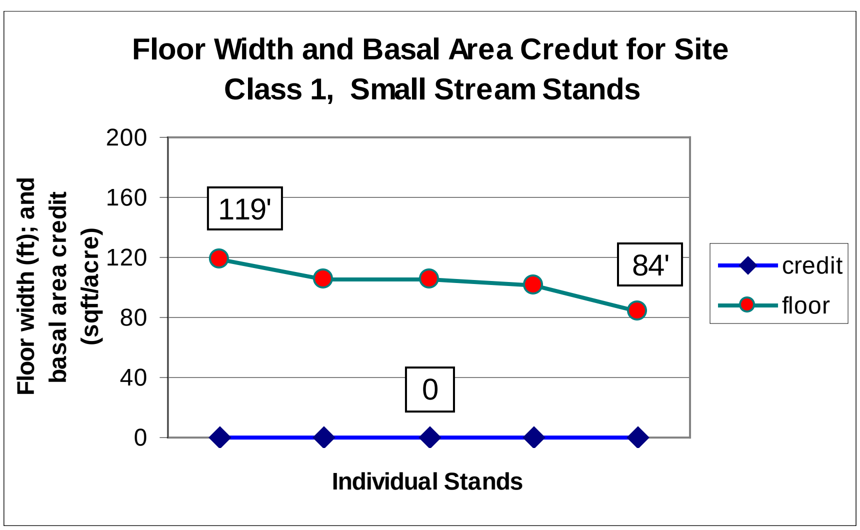


Figure 9 – Distribution of floor widths (feet) and basal area credits (ft^2/acre) for Site Class 1, small stream stands. Minimum floor width for small stream stands is 80’. Numbers in boxes marked in feet are, from left to right, the maximum and minimum

floor widths. The numbers that have no units are the basal area credit in ft^2/acre. "n" = 5 for this Site Class, stream size configuration.

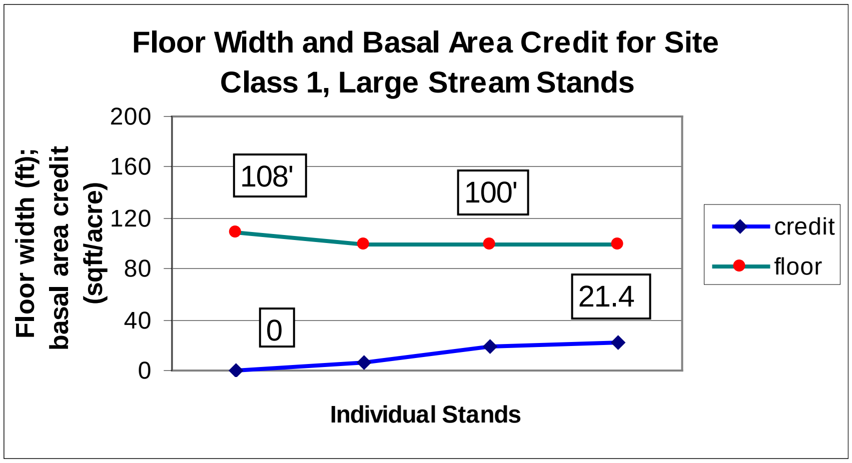


Figure 10 - Distribution of floor widths (feet) and basal area credits (ft^2/acre) for Site Class 1, large stream stands. Minimum floor width for large stream stands is 100'. Numbers in boxes marked in feet are, from left to right, the maximum and minimum floor widths. The numbers that have no units are the basal area credit in ft^2/acre, with minimum values on the left and maximum values on the right. "n" = 4 for this Site Class, stream size configuration.

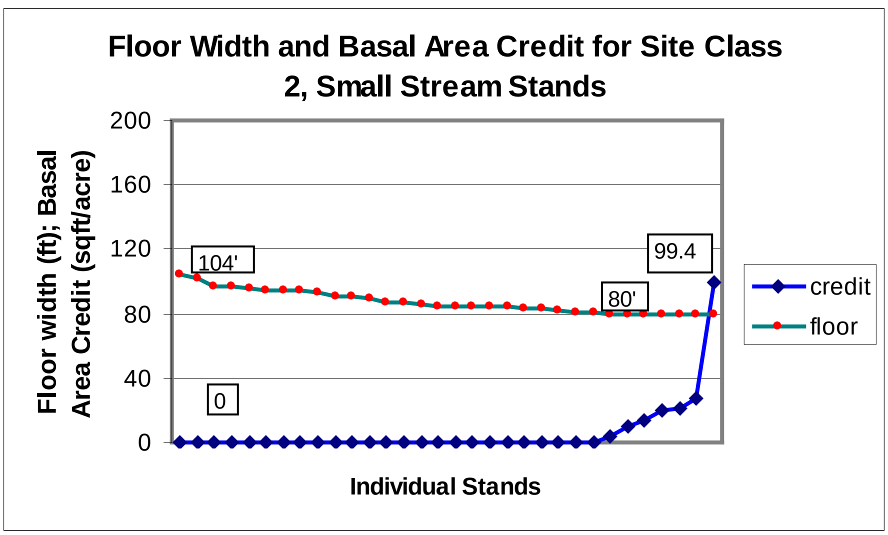


Figure 11 - Distribution of floor widths (feet) and basal area credits (ft^2/acre) for Site Class 2, small stream stands. Minimum floor width for small stream stands is 80'. Numbers in boxes marked in feet are, from left to right, the maximum and minimum floor widths. The numbers that have no units are the basal area credit in ft^2/acre, with minimum values on the left and maximum values on the right. "n" = 32 for this Site Class, stream size configuration.

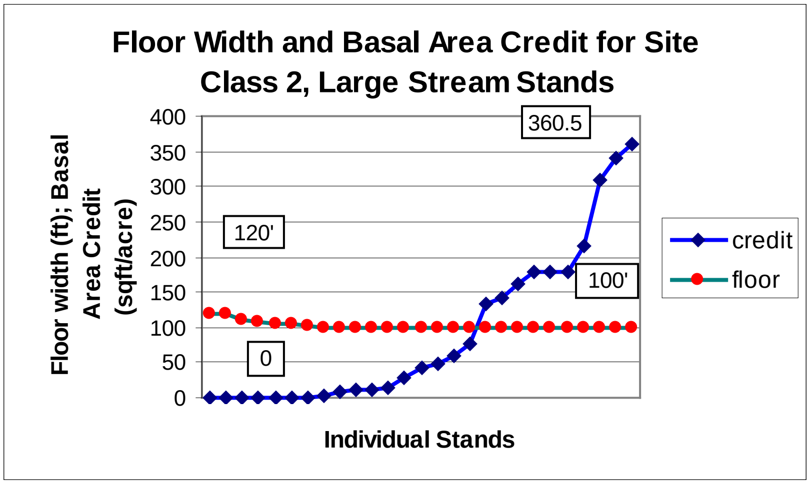


Figure 12 - Distribution of floor widths (feet) and basal area credits (ft^2/acre) for Site Class 2, large stream stands. Minimum floor width for large stream stands is 100'. Numbers in boxes marked in feet are, from left to right, the maximum and minimum floor widths. The numbers that have no units are the basal area credit in ft^2/acre, with minimum values on the left and maximum values on the right. "n" = 27 for this Site Class, stream size configuration.

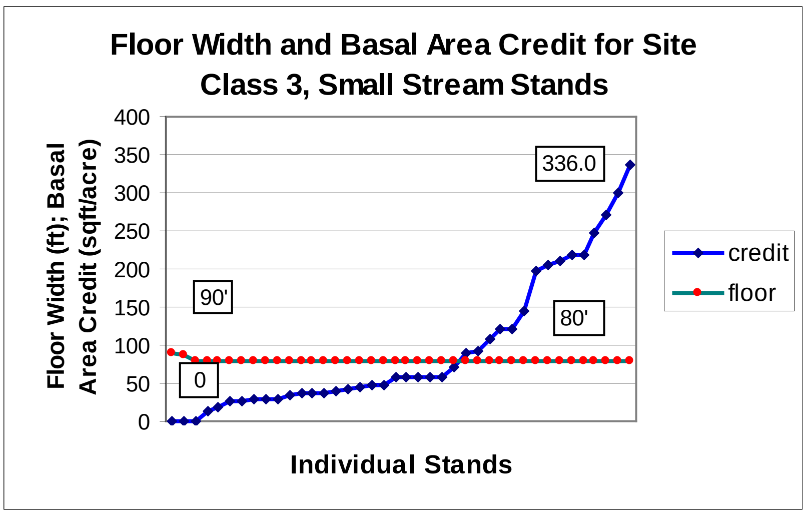


Figure 13 - Distribution of floor widths (feet) and basal area credits (ft^2/acre) for Site Class 3, small stream stands. Minimum floor width for small stream stands is 80'. Numbers in boxes marked in feet are, from left to right, the maximum and minimum floor widths. The numbers that have no units are the basal area credit in ft^2/acre, with minimum values on the left and maximum values on the right. "n" = 40 for this Site Class, stream size configuration.

PROJECTED STAND-AGE-140 BASAL AREA PER ACRE

1. Stand-Age-140 bapa Distribution Across Site Classes, by Prescription

The DFC Model projected mean bapa at stand-age-140, for all 150 FPAs for the no-cut and Option 1 prescriptions are respectively, 364.1 and 335.5, with 95% Confidence Intervals of 7.4 and 5.4 (Figures 14, 15, 16 and Table 7). The mean bapa for the 108 FPAs meeting the Site Class and stream size criteria for the Option 2 prescription was 301.1 (Figures 14, 15 and Table 7). The value for Option 2 considers only the core + no-cut "floor" portion of the inner zone. If the basal area of the 20 leave tpa (12" minimum dbh) in the outer part of the inner zone are included, mean bapa and 95% Confidence Interval for Option 2 is 334.6 ± 5.8 (Figure 16).

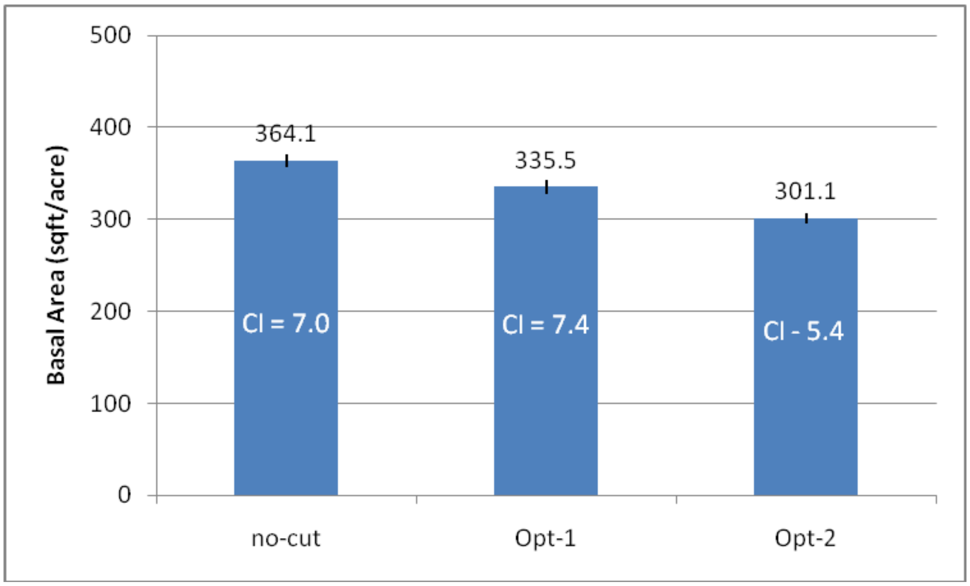


Figure 14 – DFC Model projected mean basal area per acre (bapa) at stand-age-140 for, from left to right, the no-cut, Option 1 (Opt 1) and Option 2 (Opt 2) riparian prescriptions, across all Site Classes. The 95th percentile Confidence Intervals (CI) are shown graphically and the CI value provided on data bars. The values above bars are DFC Model projected stand-age-140 mean basal area per acre. For the no-cut and Option 1 prescriptions, n = 150; for Option 2, n = 108 and trees in the outer part of the inner zone are NOT included

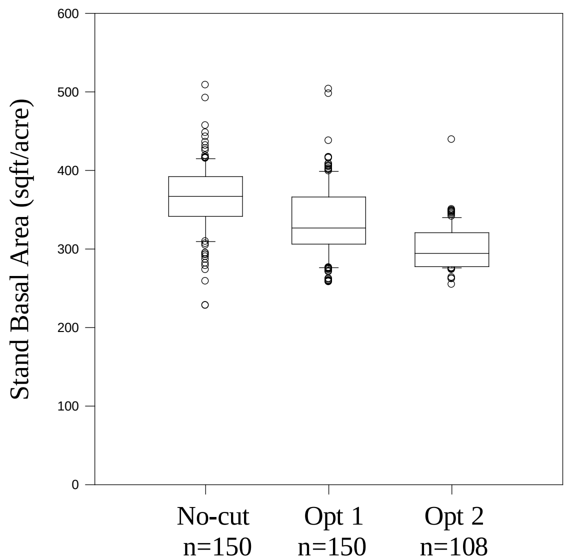


Figure 15a - Box plot distributions of stand-age-140 basal area per acre values projected by the DFC Model. Box plots show the median and 25th, 75th and 90th percentiles. From left to right, the distributions are from the No-cut prescription, Option 1 and Option 2 (with trees in the outer part of the inner zone NOT included). The "y axis" extends from 0 to 600 square feet of basal area per acre.

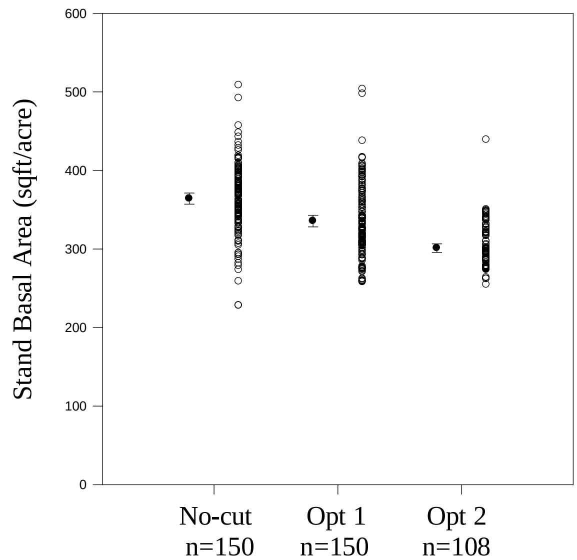


Figure 15b – Point distribution of stand-age-140 basal area per acre values with 95% confidence interval shown to the left of each data distribution. From left to right, distributions are from the no-cut prescription, Option 1, and Option 2 (with trees in the outer part of the inner zone NOT included). The "y axis" extends from 0 to 600 square feet of basal area per acre.

Table 7 – Descriptive statistics for stand-age-140 basal area per acre by riparian prescriptions allowed under "DFC Rules". For the no-cut prescription and Option 1, n=150, for option 2, n=108.

	No Cut	Option 1	Option 2
Mean	364.1	335.5	301.1
Std Dev	43.7	45.9	28.4
CI of Mean	7.0	7.4	5.4
Median	367.0	326.7	294.5
25th percentile	341.9	306.6	277.6
75th percentile	391.9	356.6	320.7
Range	280.6	245.5	184.4
Maximum	508.4	503.3	439.0
Minimum	227.8	257.8	254.6

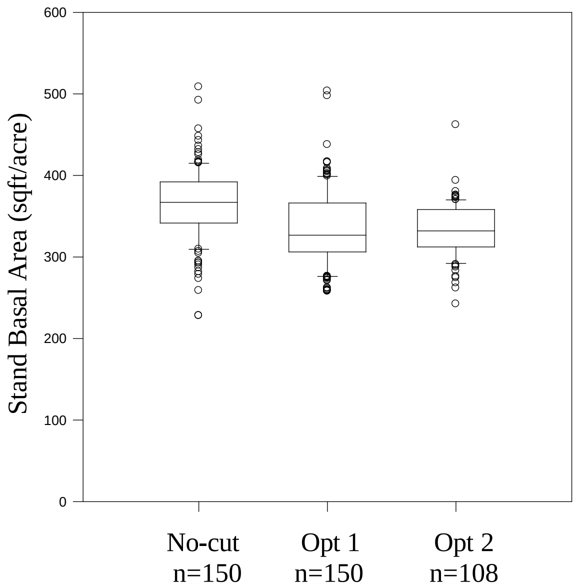


Figure 16a - Box plot distributions of stand-age-140 basal area per acre values projected by the DFC Model. Box plots show the median, 25th and 75th percentiles. From left to right, the distributions are from the No-cut prescription, Option 1 and Option 2 (with trees in the outer part of the inner zone **included**). The "y axis" extends from 0 to 600 square feet of basal area per acre.

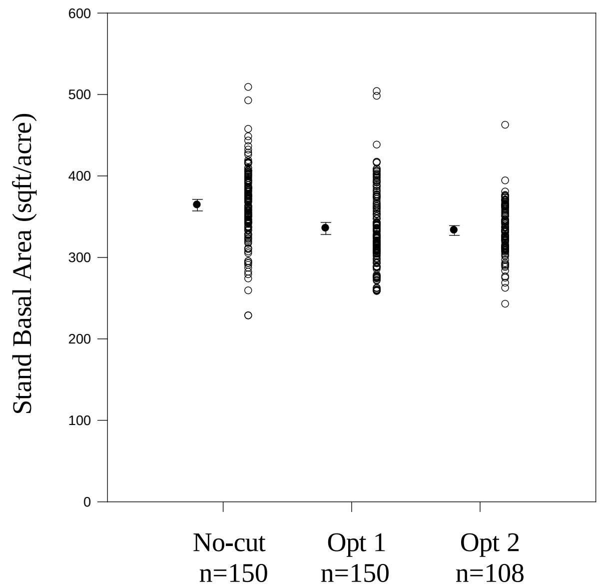
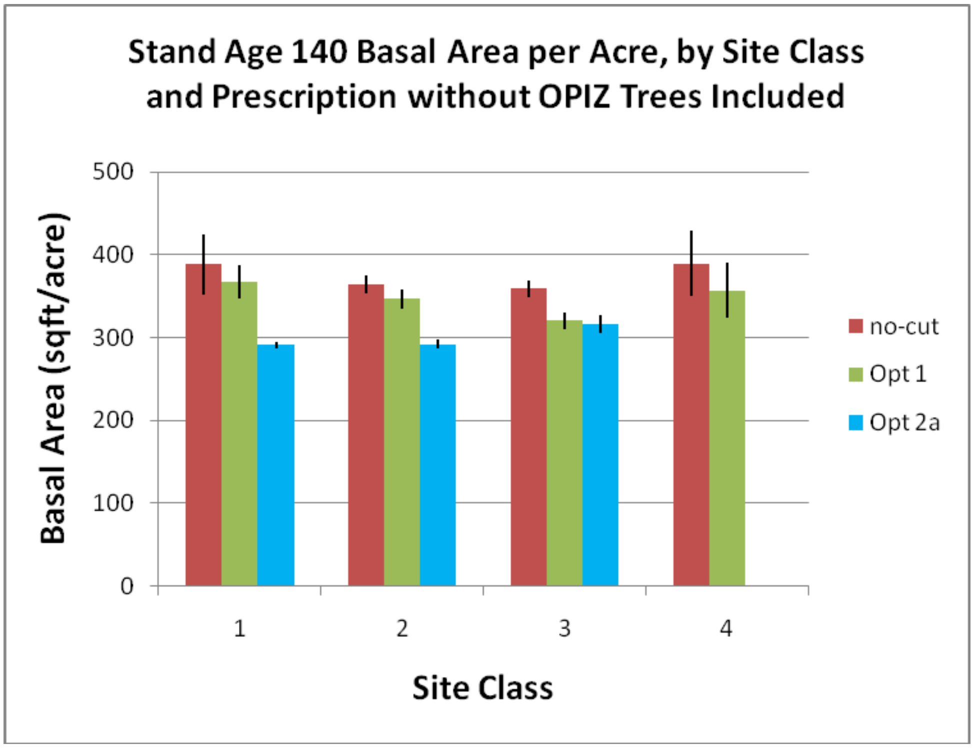


Figure 16b – Point distribution of stand-age-140 basal area per acre values with 95% confidence interval shown to the left of each data distribution. From left to right, distributions are from the no-cut prescription, Option 1, and Option 2 (with trees in the outer part of the inner zone **included**). The "y axis" extends from 0 to 600 square feet of basal area per acre.

2. Mean bapa by Site Class and Prescription

Mean values and a 95% Confidence Interval for all three prescriptions are presented in Figure 17 with the trees for the outer part of the inner zone (Option 2) excluded and in Figure 18 with these trees included (thus the only difference between figures is amounts for Option 2). There is no basal area reported for Option 2 on Site Class 4 as this prescription is not used on this Site Class. No statistical analysis was conducted to determine whether differences observed between means by prescription are statistically meaningful.



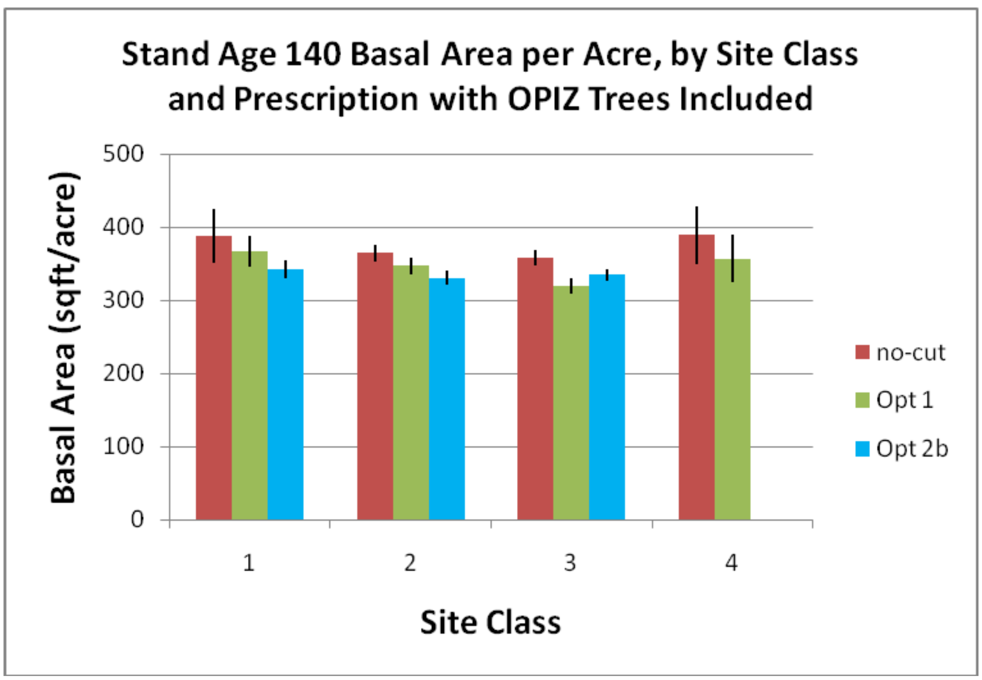
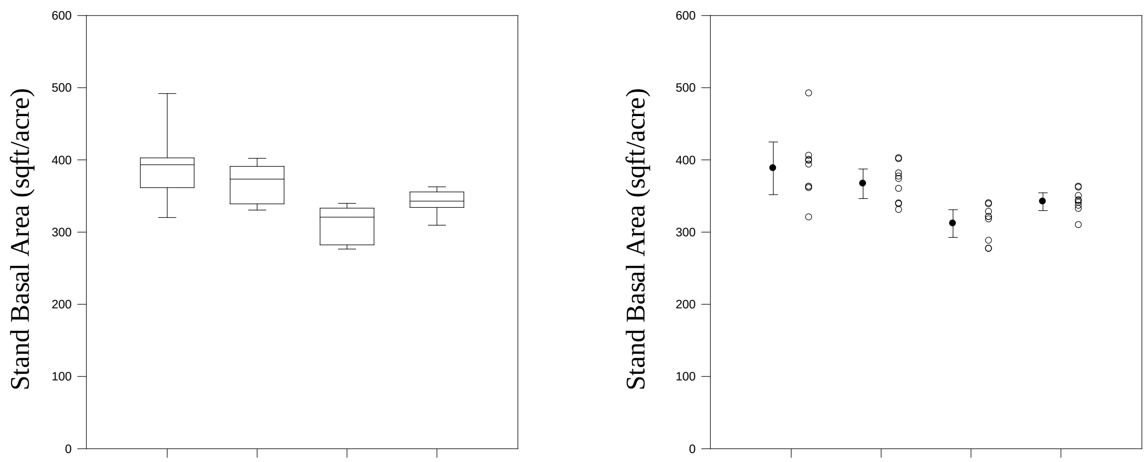


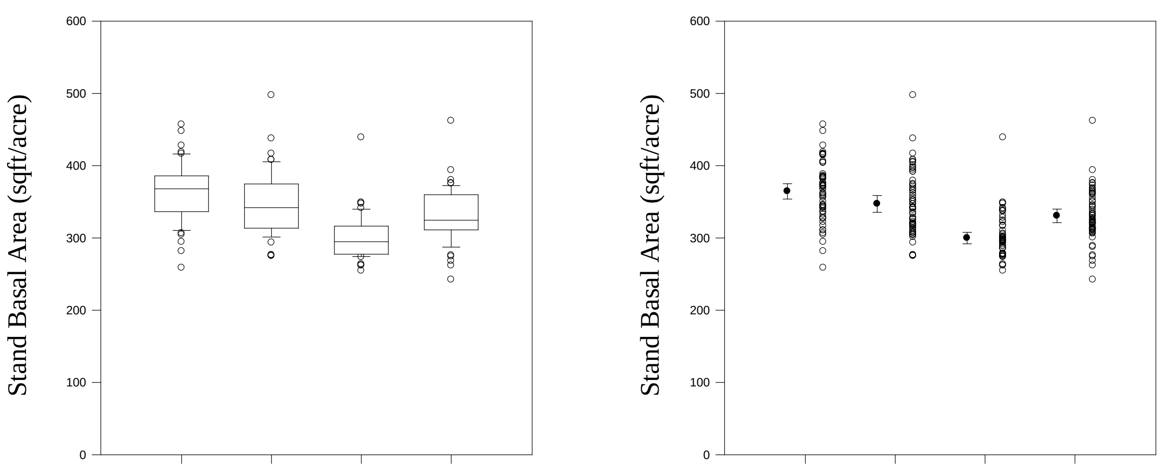
Figure 17 (top) and Figure 18 (bottom) - DFC Model projected mean basal area per acre (ft^2) at stand-age-140 for the no-cut, and Option 1and 2) prescriptions, by Site Class. Error bars show 95% Confidence Interval. n by Site Class are 1 (9), 2 (59), 3 for the no-cut and Option 1 prescriptions (74), and for the Option 2 prescription (40), and 4 (4).

The highest mean bapa projected (388.4) and the highest variability in mean bapa projected (±36.5 95 % Confidence Interval) was for the no-cut prescription on Site Class (Figures 19a and b). When trees from the outer part of the inner zone are added in, stand-age-140 bapa values for Options 1 and 2 are very similar.



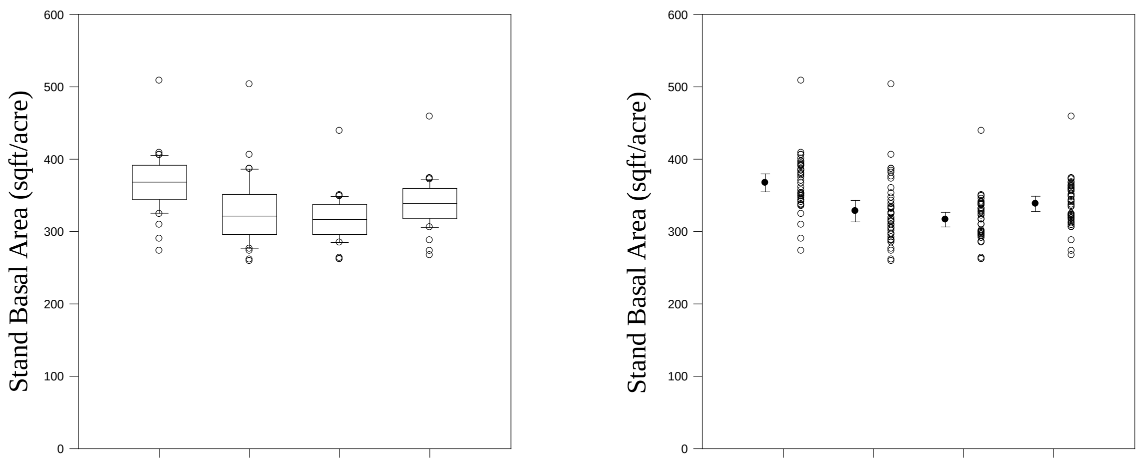
Figures 19a (left) and b (right) – Stand-age-140 basal area per for Site Class1 by DFC rule prescription. n =9. Treatments are from left to right for both a and b: 1) no-cut, 2) Option 1, 3) Option 2 with trees from the outer part of the inner zone NOT included, and 4) Option 2 with trees from the outer part of the inner zone INCLUDED. Box plots show the median, 25th and 75th percentiles. The point distribution figures are of individual stand age-140 basal area per acre values with a 95% confidence interval shown to the left of each data distribution.

The lowest mean bapa projected was 299.9 ± 7.9 (95% CI) on Site Class 2 for Option 2 with trees in the outer part of the inner zone not included (Figures 20a and b). Where trees from the outer part of the inner zone are included in Option 2, stand-age-140 bapa values for Options 1 and 2 are similar.



Figures 20a (left) and b (right) – Stand-age-140 basal area per for Site Class 2 by DFC rule prescription. n = 59. Treatments are from left to right for both a and b: 1) no-cut, 2) Option 1, 3) Option 2 with trees from the outer part of the inner zone NOT included, and 4) Option 2 with trees from the outer part of the inner zone INCLUDED. Box plots show the median, 25th and 75th percentiles. The point distribution figures are of individual stand age-140 basal area per acre values with a 95% confidence interval shown to the left of each data distribution.

Different from Site Class 1 and 2, for Site Class 3/small stream stands, stand-age-140 bapa values projected from the DFC Model are higher than they are for the no-cut treatment than for either Options 1 or 2. For this Site Class/stream size configuration, projected stand-age-140 bapa values were similar for Options 1 and 2. When trees from the outer part of the inner zone were added in, stand-age-140 bapa values were higher than for either Options 1 or 2.



Figures 21a (left) and b (right) – Stand-age-140 basal area per for Site Class 3 by DFC rule prescription. n = 40. Treatments are from left to right for both a and b: 1) no-cut, 2) Option 1, 3) Option 2 with trees from the outer part of the inner zone NOT included, and 4) Option 2 with trees from the outer part of the inner zone INCLUDED. Box plots show the median, 25th and 75th percentiles. The point distribution figures are of individual stand age-140 basal area per acre values with a 95% confidence interval shown to the left of each data distribution.

Option 2 is not available for Site Class 3/ large stream stands and on this configuration the no-cut prescription is projected to have a higher stand-age-140 bapa (Figures 22a and b) than for Option 1.

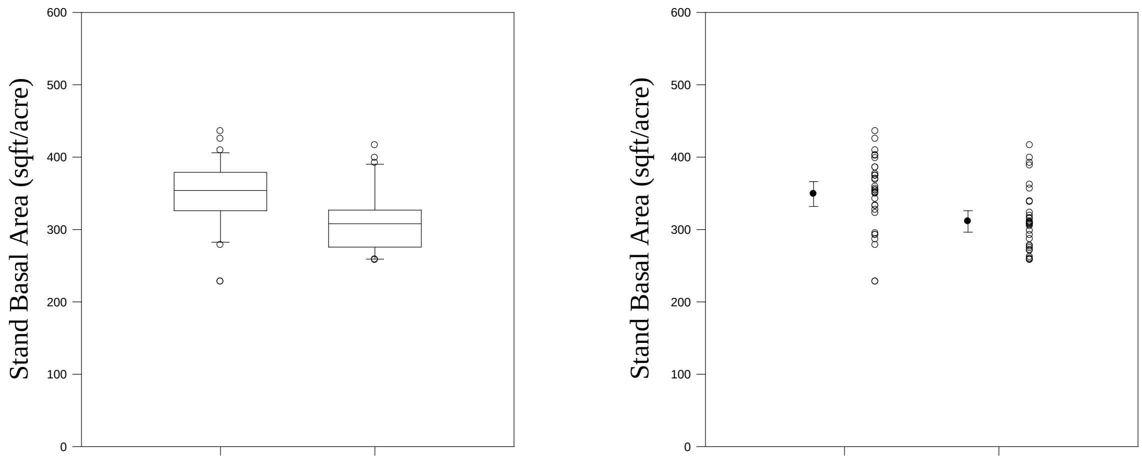


Figure 22a (left) and b (right) – Stand-age-140 basal area per for Site Class 3 / large stream by DFC rule prescription. n = 34. Treatments are for both a and b: 1) no-cut (left), and 2) Option 1 (right). Box plots show the median, 25th and 75th percentiles. The point distribution figures are of individual stand age-140 basal area per acre values with a 95% confidence interval shown to the left of each data distribution.

For Site Class 4, there was a low sample size (n=7), reflected by the large variability thus no means to evaluate differences between the no-cut treatment and Option 1 (Figures 23a and b).

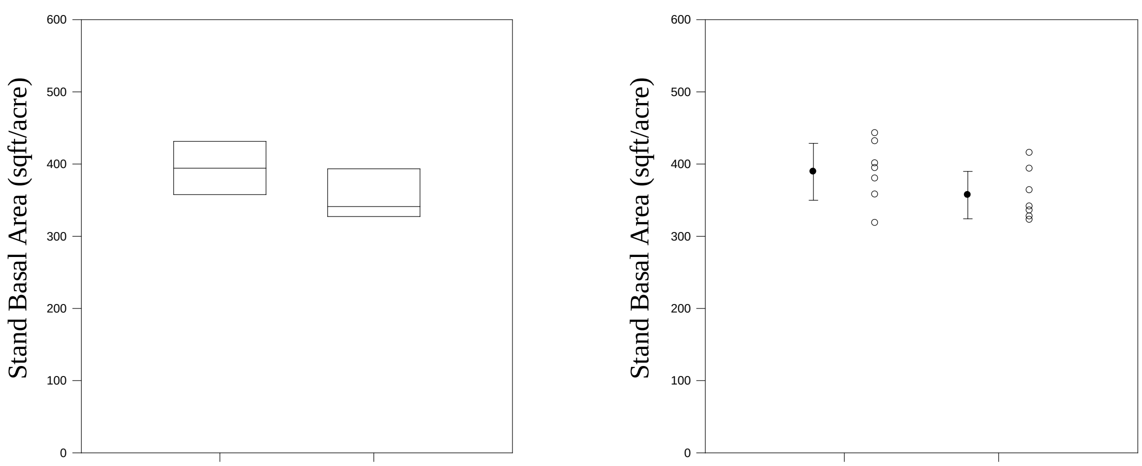


Figure 23a (left) and b (right) – Stand-age-140 basal area per for Site Class 4 DFC rule prescriptions. n = 7. Treatments are for both a and b: 1) no-cut (left), and 2) Option 1 (right). Box plots show the median, 25th and 75th percentiles. The point distribution figures are of individual stand age-140 basal area per acre values with a 95% confidence interval shown to the left of each data distribution.

3. Distribution of Stand-age-140 Basal Area by Site Class and Stream Size

There are apparent differences in DFC Model projected stand-age-140 bapa values by prescription, Site Class and stream size (Figure 24) for stands that are on Site Classes 1, 2 and 3, small stream, with trees in the outer part of the inner zone included. The no-cut prescription has a higher projected stand-age-140 bapa than does Option 1 or Option 2 for Site Classes 1 and 2 (large stream) and Site Class 3 (small stream). Option 1 stand-age-140 bapa is most variable across all Site Class/stream size combinations. Option 1 and Option 2 stand-age-140 bapa values track closely on Site Class 2 (large stream) and Site Class 3 (small stream). The no-cut prescription and Option 1 track more closely on Site Class 2 (small stream).

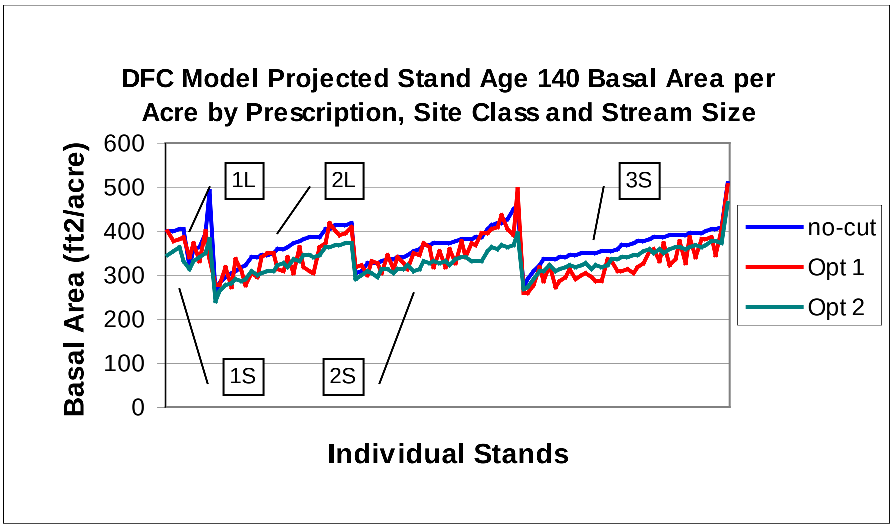


Figure 24 – Stand-age-140 basal area per acre (ft^2/acre) for the no-cut, thin from below (Option 1) and leave trees closest to the stream (Option 2) riparian prescriptions, by Site Class and stream size. Boxes show Site Class as a numeric value and stream size (L = large or S = small); the arrows point to the region on the figure where stands for each Site Class, stream size combination reside. Stands are sorted by Site Class, stream size and ascending basal area per acre for the no-cut prescription. Sample size (n) are as follows, by Site Class and stream size: 1L (4); 1 S (5), 2L (27); 2S (32), 3S (40). The Option 2 Prescription is not permitted on Site Class 4, 5 and 3-large stream. The Option 2 results include the core + floor portion of the inner zone and trees in the outer part of the inner zone.

DISCUSSION

The Discussion is focused on the Objectives of this study which are:

1) <u>Quantify the effect of rule components on constraining timber harvest</u> for the three standard riparian prescriptions (no-cut, Option 1 - thinning from below and, Option 2 - leaving trees closest to the stream). The rule components that constrain timber harvest are: 1) the stand-age-140- bapa-“DFC”-targets, 2) the 57 inner zone leave tpa after thinning from below, and 3), for Option 2, the minimum no-cut inner zone “floor”, and,

2) Quantify the projected bapa for riparian stands at stand-age-140 for the three standard prescriptions permitted in current rules: 1) no-cut, 2) Option 1 and 3) Option 2.

OBJECTIVE 1 – QUANTIFY THE EFFECT OF RULE COMPONENTS TO TIMBER HARVEST ALLOWED

For all prescriptions, the growth to stand-age-140 projected by the DFC, measured in bapa, appears to be reasonably represent forest stand growth in western Washington, a determination also made by Fairweather (2001) in his review of the DFC Model.

1. The no-cut riparian prescription

The DFC Model responds to the site attribute and stand inventory data it is provided and the treatment (silvicultural prescription) simulated. The no-cut description for this prescription is something of a misnomer because for this prescription, the DFC Model simulates growth that has a built in mortality function for red alder senescence and diminution of hardwood tree basal area over time (described in Welty (date unknown) in Fairweather (2001), Appendix B, p. 6), This factor was built into the model as red alder trees typically senesce and die at around 80-yrs of age while conifers typical of riparian stands in western Washington live and continue to grow to the 140-yr target age and beyond. The senescence of red alder and its removal from the DFC Model stand table over time have an effect similar to that of a thinning except that it is: 1) implemented more gradually and later in a stands life than the Option 1 thinning, 2) the thinning is not necessarily from below (it is not stated how the thinning is implemented), and, 3) it results in thinning only red alder trees, not associated conifers.

In most cases, stand growth without timber harvest will be higher at 140-yrs than if trees were cut from the stand as occurs for the other prescriptions (Option 1 and 2). In some cases, however, for example in stands that are overly dense or in stands that have a high component of hardwoods, a thinning from below (Option 1) will create stand conditions that favor rapid growth of the remaining conifer trees such that by stand-age-140, the basal area from thinned stands will exceed that of the same stand with no thinning. The three stands used in this analysis that met DFC **only** if a thinning from below were implemented are examples of stands that responded with accelerated growth on residual trees after thinning, sufficiently so in the case of these stands to put them over the threshold bapa required for meeting the DFC Target[25].

While basal area growth can be high on stands that are not cut and usually a higher stand-age 140 bapa will occur without cutting, slow or even negative growth can also occur in stands on which no timber harvest occurs, depending on initial stand conditions. Trees

[25] These stands also pose an interesting Policy question. Since DFC is met on these stands ONLY if a thinning from below is implemented, does that mean that a treatment that does not result in meeting DFC should not be allowed? In this case, the no-cut treatment is not projected to meet DFC so, is inner zone thinning required?

respond to the availability of resources which is in part determined by the relative dominance of a tree relative to the rest of the population of the stand (D'amato and Puettmann, 2004). Without thinning, tree and stand basal area growth can be slow because no tree has access to enough resources to thrive. Overtopped shade-intolerant conifers (Douglas-fir) might even suffer mortality due to light deprivation, resulting in negative growth if not released by thinning. Thinning the same stand, however, can result in high stand-age-140 bapa values, very high compared to values obtained with no silvicultural treatment. This is apparently the basis for the DFC Model being set to identify stands that do not meet DFC with no thinning but will meet DFC if thinned (See Model and Manual Report, McConnell and Heimburg, 2010).

The stands used in this (Desktop Analysis) report were mainly conifer-dominated (Appendix A) but included some stands with a high initial composition of red alder. Stand growth from these initial conditions explains why the no-cut treatment had both the highest average stand-age-140-bapa, e.g. usually growth was highest where no trees were removed, and high variability as compared to the other treatments, e.g. tree harvest imposes more similarity in stand conditions, in particular bringing slow or negative growth stands towards the mean while under a no-cut scenario slow or negative growth is unconstrained.

The effect of having some stands meet DFC only if a thinning from below is implemented is a credible finding and fits with existing silvicultural knowledge. The DFC Model has not been validated against the actual growth of riparian stands and has not been rigorously compared against other commonly used stand growth models used in western Washington so there remains uncertainty in terms of bapa projections it provides.

2. Option 1

The problem of quantifying what factor, basal area target or the required leave trees were the primary constraint on timber harvest was made difficult because DFC Model outputs are narrowly structured to provide landowners only the information they need to implement DFC Rules; they are not, however, broadly informative for other uses. For example, the DFC Model reports the number of inner zone trees that must be left after pressing the "suggest thinning" toggle in two places on the "Option 1" page. One is on the graphic where the number reported is in absolute numbers, not on a per acre basis. This number is always rounded up[26], thus with any fraction above an integer for a tpa calculation, the number of required inner zone trees was rounded to the next highest integer. The other place the required number of leave trees is reported is in the Table on the right side of the "Option 1" page of the Worksheet, where it is reported on a per acre basis.

[26] It was found that the number reported in the graphic was inaccurate almost half the time (49.3%) and did not accurately reflect the number of inner zone leave trees that were reported in the spreadsheet below the graphic. When there was an error, the error amount was always 1, and the result was that more trees than should have been were reported. The effect of the error would have been to cause landowners to leave more, not less, trees than were required to meet the prescription. This error is described in more detail in the "Model and Manual" report (McConnell, in review).

In both places, the number of required trees is not very useful to a limiting constraints analysis. The absolute (as opposed to per acre) number of trees reported on the graphic having been rounded up, are already an over-estimate of tpa. Further, for both numbers, the size of stands can have a profound effect on the number of trees reported. For example, one tree on the DFC Model graphic can represent as many as 9.2 tpa[27] in very small stands or as few as 0.11 tpa in large stands. Thus, depending on the size of the stand, calculations made for inner zone post-harvest tpa could exceed 57 by as much as 9.2 trees while the constraining element in rules may in fact be tpa (that is, if one more tree were removed, the stand would fall below 57 tpa), even for stands on which the reported per acre trees exceeds 60.

Further, the relationship between the "Projected Basal Area at age 140 as % of DFC" for the core and inner zones on the Worksheet page of the DFC Model to the "Projected" and "Required", respectively, Basal Area for the inner zone only on the Option 1 page of the DFC Model is confusing at best. Even if understood, in instances where projected basal area was at or near required basal area such that it was possible to determine that basal area was limiting, it was not possible to determine if the constraint had been the basal area target or if the tpa value reported exceeded 57 in order for DFC to be met.

These problems were solved by working outside the Model to calculate the effect of removing one additional tree and determining the effect of that to bapa and tpa in regards to which of these targets first dropped below the required target value. Using this approach, it was possible to discern which was the primary constraint to timber harvest.

3. Option 2

Determining which rule component was the primary constraint to timber harvest was much easier for Option 2 than for Option 1. Where there was a basal area credit and the inner zone width was limited to the no-cut floor width, the primary constraint to timber harvest was the required floor width. Where the no-cut portion of the inner zone extended beyond the required minimum floor width and there was no basal area credit, the DFC target constrained timber harvest.

The outcome of this analysis demonstrates characteristics of Rules for Option 2 that may have been unintended, for example, the effect of the core to inner zone ratios to the likelihood of a stand meeting the DFC Target. Where the no-cut portion of the inner zone is large as compared to the core + floor portion of the stand as in for example Site Classes 1 and 2 small stream configurations, more stand area (wider no-cut portion of the inner zone) must be added in order for the DFC Target to be met. Where the no-cut portion of the stand is small as compared to the core + floor portion of the stand as in, for example, Site Class 2, large stream and (especially) Site Class 3, small stream, timber harvest is almost always constrained by the floor width rather than the need to add width to increase basal area up to the target level.

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[27] Using the data from the 150 stands used in this analysis. Obviously, the tpa represented by one tree can be still higher if stand sizes are smaller than the 87' RMZ length that was the minimum for this data set.

OBJECTIVE 2 – QUANTIFY PROJECTED STAND-AGE-140 BASAL AREA PER ACRE BY PRESCRIPTION

There were no statistical analyses done to compare DFC Model projected results for each prescription to each other, to DFC Targets or to the results of other studies. Outcomes are instead reported graphically, with error bars marking the 95% CI where applicable.

Recognizing that statistical certainty is lacking, there are some trends that it may be useful to investigate further. For example, DFC Model stand-age-140 bapa projected values by Site Class exceed the DFC Target values set in Rules. For Options 1 and 2, this effect is caused by the constraint imposed by rule components other than the basal area target for each prescription.

Predicted average stand basal areas by Site Class at age 140 are similar to the basal area values that were measured in the DFC Target Validation study (Schuett-Hames et al., 2005). The DFC Target Validation study was a field study in which data was collected from mature, unmanaged, conifer-dominated riparian stands along Type F streams in western Washington. In the DFC Target Validation Study, a bapa mean value of 333.8 ft^2/acre was measured for Site Class 2 stands. In the present study, the DFC Model projected mean bapa values for Site Class 2 stands were 364.4 for the no-cut prescription, 347.2 for Option 1 and 330.3 for Option 2 (with trees in the outer part of the inner zone included). For Site Class 3, the DFC Target Validation study mean bapa value was 307.7 ft^2/acre, while for the Desktop Analysis values were 362.6 for the no-cut prescription, 320.8 for Option 1 and 339.8 for Option 2 (the Option 2 value is only for stands along small streams and includes trees in the outer part of the inner zone). For Site Class 4, the DFC Target Validation study mean bapa value was 353.1 ft^2/acre while for the Desktop Analysis, the values were, for the no-cut prescription 389.3 and for Option 1 357.0 (Option 2 is not allowed on Site Class 4). The DFC Target Validation Study had only one site for Site Class 1 and there was only one Site Class 5 site in the Desktop Analysis so values for these Site Classes are not presented.

It is important to recognize the differences between the DFC Target Validation Study and the Desktop Analysis. First and foremost, the DFC Target Validation study collected field data while the Desktop Analysis uses a Model of uncertain reliability to project stand growth. Additionally, there are a number of uncertainties as to whether DFC Model projected outcomes are reliable. The most important of these is that the effect of windthrow on abruptly opened riparian stands is not known; windthrow can account for significant mortality in riparian buffer stands. No commonly used stand growth model was calibrated using data that were highly prone to windthrow, thus even if it is found that DFC Model results compare favorably to other models, it will remain uncertain how riparian buffers grow in comparison to the intact, interior stands from which other commonly used growth models were developed. It is also uncertain how closely landowners implement timber harvest in comparison to DFC Model prescriptions. Differences in treatment can affect stand trajectory. Lastly, it is not known how much ingrowth there may be in riparian stands from newly regenerated trees or from trees with dbh's less than 5.0" at the time riparian stands were inventoried. Careful review of the

Caveats and Assumptions in this report is important to interpreting the results of this study, in particular the comparison made against DFC Targets in Rules and the results of the DFC Target Validation Study (Schuett-Hames et al. 2005).

Other trends are apparent from a graphic analysis but of unknown reliability statistically. For example, the no-cut prescription usually has the highest stand-age-140 bapa, but sometimes Option 1 values surpass the no-cut prescription values. Option 2 consistently has the lowest stand-age-140 bapa values although if the trees in the outer part of inner zone are left in a dispersed pattern, the difference between this prescription and the others is less, and it is greater than the Option 1 prescription on Site Class 3.

Projected stand-age-140 bapa values are influenced by a number of factors including different Site Class/stream size configuration core to inner zone ratios, DFC Targets that change with Site Class in addition to differences in stand composition and structure. The differences in Option 2 core zone, inner zone and floor width ratios appears to affect projected stand-age-140 bapa and therefore prescriptions for current stands. For example, on both Site Class 1 and Site Class 2 small streams, most stands managed under Option 2 need to expand the no-cut portion of the inner zone in order to meet the DFC Target. The result of this is that for most stands with these configurations, the projected stand bapa will just equal the stand-age-140 bapa target, exceeding it slightly in instances where there are enough trees in the outer part of the inner zone to make a difference in projected stand-age-140 bapa.

For Option 1, the high residual basal area that comes from leaving the 57 largest trees on the site and the release effect from thinning from below keep projected stand-age-140 bapa in the same range of values for most stands, as for the no-cut prescription. For Option 2 Site Class, stream size configurations, for example Site Class 2 / large stream and Site Class 3 / small stream, that have a high proportion of the stand in the no-cut (core and minimum floor) portions of the stand, the difference in DFC Model projected stand-age-140 bapa between Option 2 and the other prescriptions is less (see Figure 17). This result occurs because the core + floor bapa values are a greater proportion of stand area and these stands will often have excess basal area on to which the Model projects additional growth (and will have growth on trees in the outer part of the inner zone where this is included in calculations).

CONCLUSIONS

The Conclusions are focused to the Objectives of this study which are:

1) <u>Quantify the effect of rule components on constraining timber harvest</u> for the three standard riparian prescriptions (no-cut, Option 1 - thinning from below and, Option 2 - leaving trees closest to the stream). The rule components that constrain timber harvest are: 1) the stand-age-140- bapa-“DFC”-targets, 2) the 57 inner zone leave tpa after thinning from below, and 3), for Option 2, the minimum no-cut inner zone “floor”, and,

2) <u>Quantify the projected bapa for riparian stands at stand-age-140 for the three standard prescriptions permitted in current rules: 1) no-cut, 2) Option 1 and 3) Option 2.</u>

Quantify the effect of rule components on constraining timber harvest – Objective 1

These analyses demonstrated that the DFC Basal Area Target was a less consequential constraint on timber harvest amount than other rule components. For Option 1, the 57 required inner zone leave trees per acre that result from a thinning from below was usually the primary constraint to timber harvest amount. For Option 2, the required minimum floor widths were also more often the primary constraint, although its effect varied by Site Class and stream size. The higher Site Class stands have higher DFC Target values and lower core + floor ratios in relation to core + inner zone widths and are thus more often constrained by the DFC (basal area) Target as wider no-cut inner zone widths are required to increase area-adjusted basal area to the Target required. This is especially true along small streams with smaller floor to inner zone width ratios. Stands with lower Site Class (Site Class 3) have more favorable core + floor ratios in relation to the core + inner zone as well as having a lower DFC (basal area) Target. Site Class 3 stands therefore almost always are constrained by the minimum required floor width and will almost always have excess basal area, expressed as a basal area credit.

The result of the constraints to timber harvest amount was that, on average, more trees are left using both Option 1 and Option 2 than are required to meet the DFC basal area Targets. The DFC Model projected stand-age-140 bapa values that result, therefore, on average exceed the DFC Targets and were similar to the measured values obtained for Site Classes 2, 3, and 4 from the DFC Target Validation Study (Schuett-Hames et al., 2005). The no-cut prescription almost always (147 out of 150 stands, 98%) resulted in stands that met DFC but a few stands required a thinning from below (Option 1) in order to meet the DFC basal area Target.

There remain uncertainties about the reliability of the DFC Model, how it compares against other growth and yield models and how well any model performs in stands that can reasonably be expected to be subject to high mortality from the effects of windthrow. This report concludes with some bullet conclusions that may be useful for considering some of the details of this report followed by recommendations for future studies that could address some of the uncertainty that remain for DFC rules.

1) The current rule basal area targets are rarely the limiting factor in determining how much timber can be harvested from the inner zone for Option 1. Only 5.3% of stands evaluated required that more than the minimum number of trees be left in order for basal area targets to be met.
2) The basal area target constrained inner zone timber harvest on 40 of 108 Option 2 stands (37%). On these stands, there was no basal area credit and the no-cut portion of the inner zone had to be increased in order for the DFC Target to be met.
3) For the Option 2 Prescription, the minimum inner zone "floor" width constrained timber harvest on 68 of the 108 (63%) stream segments evaluated.

4) For Option 2, high Site Class, small stream stands are more likely to require extending the no-cut portion of the inner zone above the minimum required than are low Site Class, large streams stands.
5) Of the 150 FPAs evaluated, 108 (72%) could be managed using the Option 2 Prescription.
6) The 57 leave trees required in the inner zone (Option 1) and the floor widths (Option 2) constrain harvest such that the DFC Model projected growth stand-age-140 bapa values exceed DFC Targets.
7) In general, the highest mean stand-age-140 bapa projected by prescription was from the no-cut prescription, intermediate was Option 1 and the lowest stand-age-140 bapa was projected for Option 2.
8) There was little difference in DFC Model projected stand-age-140 bapa by Site Class for any of the prescriptions.
9) The projected results from the Desktop Analysis for Site Classes 2, 3 and 4 were similar to the results measured in the DFC Target Validation Study (Schuett-Hames et al. 2005).
10) There is a long list of caveats and assumptions that need to be considered carefully in interpreting the results of this report.

RECOMMENDATIONS

CMER's purview for recommendations are those that are limited to technical work that could reduce uncertainty and improve the quality of information that can be provided to Policy makers so that they have the best possible information available to them to consider in context of possible rule changes that could occur as a result of information developed in the Adaptive Management Program. With that in mind, the recommendations made focus primarily on studies that could be implemented that would reduce uncertainty in the validity of DFC Model assumptions.

One: Model Comparisons
Make a rigorous comparison of DFC Model outputs to outcomes of other stand growth models that are commonly used in western Washington. Rationale: this would provide at least a theoretical validation that the DFC Model provides reasonable estimates of stand growth. As Fairweather (2001) notes, "It would be unreasonable to expect an exact match, but the values should be close".

Two: Windthrow
Windthrow remains a major uncertainty to the ultimate outcome of buffers left following DFC Rules. The follow-up Field Check study that was a part of the package of reports that developed out of the current Desktop Analysis study provides an opportunity to get useful data on windthrow. For the Field Check study, data were collected from 15 stands, 12 that had had the adjacent upslope timber harvest implemented within the previous 2 years and 3 others that had not been cut. The data collected from these stands recorded trees by status of live, dead and windthrown. Re-sampling these stands would provide information from a robust, if unplanned, BACI experimental design from randomly samples stands. While there would be limitations on what these data could be used for,

the effect of windthrow that is currently incorporated into the DFC Model is entirely from the study done be Grizzel (1998) and these data are entirely from the NW Region and sampled stands treated according to Watershed Analysis treatments, not FFR treatments. There is an opportunity to acquire a more robust and credible data set. Additionally, the NW Region has by far the least amount of timber harvest activity in riparian forests as measured by the number of FPAs processed, while the stands sampled in the Field Check Report are representative of the distribution of stands being treated by DFC Rules.

Three: Thinning response
A number of reviewers with expertise in forest management have expressed the opinion that the thinning response, the increase in stand basal area growth after a thinning from below is implemented (simulated) is high. It would not be difficult to compare thinning response from other commonly used models (ORGANON and FVS) to those generated by the DFC Model and to empirical data from thinning studies. There are limitations to both approaches and neither will be definitive but a better understanding of the bounds and extent of uncertainty could be developed with little cost, in a short period of time, by making this modeling comparison.

Four: Simulated senescence of red alder
The growth modeled by the no-cut option includes a function to account for natural senescence of red alder. The function used is coarse and its validity based on unverified assumptions. The simulated effect of the natural senescence of red alder included affects final basal area outcomes but the amount of this effect is unknown. Better understanding of red alder senescence rates in riparian buffers would be helpful to validating the assumptions used in the DFC Model.

Five: Harvest amount, stand characteristics and proximity values
It is not uncommon for there to be substantial timber harvest opportunity on stands that barely meet DFC (McConnell, unpublished data), because, for example, there may be an abundance of red alder or a stand may be very densely stocked. In either situation, timber harvest, allows for the harvest of what could be a substantial volume of timber and its harvest enables the residual trees to grow rapidly towards the DFC target. It is also not uncommon for stands that exceed the basal area target by a substantial amount to offer very little timber harvest activity, for example in the case of stands with few, large trees such that there are few that can be cut after accounting for the required number of trees for the thinning from below, or have a site class / stream size configuration that allows for harvest from a narrow outer part of the inner zone allowable cut area despite a large excess of basal area as compared to the target. Where there is opportunity for both timber harvest and improvement of forest stands based on rule objectives, there is a missed opportunity from not treating these stands. Similarly, some stands that meet DFC but offer little in the way of harvestable timber, represent a missed opportunity for focusing management to achieving habitat goals of forest rules. I suggest focused attention to better understanding the relationship between rules and stand characteristics and look for opportunities to improve management.

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GLOSSARY

AMP – Adaptive Management Program, specifically the program defined in Washington State's Forest Practices Rules, WAC 222-12-045 and supporting documents, in particular Forest Practices Board Manual Section 22.

bapa – Basal Area per Acre in ft^2

CMER – Cooperative Monitoring, Evaluation and Research Committee

Core Zone – One of three Riparian Management Zones designated by Rules. Closest to the stream. Always 50' wide. No timber harvest is allowed in the core zone.

DFC – Desired Future Condition

DFC Model – A computerized growth and yield model that projects stand basal area growth to age 140 (negotiated age of a "mature" forest) to determine whether a given stand may be entered for timber harvest and, if so, analyzes site and stand data to provide landowners harvest prescription details

FFR – Forest and Fish Report

FPAs – Forest Practices Applications

FPARS – Forest Practices Application Review System. Section on DNR's website used to obtain information about Forest Practices Applications. Contains Site Class maps landowners need to fill out their FPAs. Provides a means to search for FPAs of interest and review them in .pdf files.

Floor – The minimum no-cut portion of the inner zone. Defined by width, it extends either 30' (small stream) or 50' (large stream) from the outer edge of the core zone into the inner zone. The width of the no-cut floor can exceed these minimum distances as per rules and DFC Model outputs, but they cannot be less than these minimum amounts under current rules.

Inner Zone – The zone that lies between the core zone (next to water) and the outer zone (next to the upslope timber harvest area). The characteristics of the inner zone, along with the core zone, are considered in the DFC Model calculations that determine whether inner zone timber harvest can occur and the specific requirements of that harvest if allowed.

Large Stream - > 10' bankfull width

Option 1 – A riparian stand timber harvest prescription that allows for thinning from below in inner zone trees.

Option 2 - A riparian stand timber harvest prescription that mandates leaving inner zone trees that are closest to the water and cutting trees in the outer part of the inner zone down to a density of 20 tpa

Outer Zone – The outermost (furthest from the stream) of the three designated riparian management zones. Outer zone width varies with Site Class and stream size. More activity is allowed in the outer zone than in core and inner zones.

RMZ – Riparian Management Zone

SAG – Scientific Advisory Group

Site Potential Tree Height – The expected height of a tree at stand age 100 for a given Site Class. For Forest Practices Rules on the west-side, Douglas-fir growth was used to determine SPTH.

Small Stream - ≤ 10’ bankfull width

SPTH – Site Potential Tree Height

Stream size – Determined by measuring the bankfull width of a stream and determining if it is less than or equal to 10’ (small stream) or greater than 10’ (large stream)

TFW – Timber Fish and Wildlife

TPA – trees per acre

Type F – A fish-bearing stream in Washington Forest Practices Rules

West-side – western Washington as defined by Forest Practices Rules

APPENDIX A - Selected riparian stand and site attribute data from the FPA's used in the Desktop Analysis report

INTRODUCTION

The "Desktop Analysis" Report is narrowly directed at understanding which rule component constrains inner zone timber harvest and quantifying Desired Future Condition (DFC) Model stand age 140 basal area per acre (bapa) projected values are that result from current rules. DFC Worksheets, however, also provide data on current stand conditions. Some site and stand attributes are presented below to provide an indication of what additional management and research-related information may be obtainable from these data.

These data were collected by individual landowners and are required information on Forest Practice Applications (FPAs) on which inner zone timber harvest will occur. Rigorous quality control over data collection is lacking as compared to studies that utilize trained crews to collect data. In the "Field Check" study (McConnell and Heimburg, 2010), site visits were made to 10% of the stands used in the Desktop Analysis (randomly selected) and landowner collected data were compared to data collected by a Cooperative, Monitoring, Evaluation, and Research (CMER) crew. The landowner-collected data were judged to be suitable for using in the Desktop Analysis but that was in part because the objectives of the Desktop Analysis were very narrowly focused and having an error in a given stand attribute did not matter for that study as the data collected, even if wrong on one or more attribute (for example, stream size or major species) still provided a configuration of data that made for a useful comparison for the Desktop Analysis.

The comparison of landowner vs. CMER-collected data used in the Field Check report did raise some cautions about using site and stand attribute data for other purposes, however. In particular, we did not agree with four of the stream width (LE or GT 10') calls made by landowners but did not feel qualified to overturn decisions made by trained foresters and approved by Department of Natural Resources Forest Practices foresters (DNR FPF). We also found one stand on which the major species reported by landowners was incorrect (reported as DF (Douglas-fir), was actually WH (western hemlock)) and, although we did not have enough data on any one attribute collected, we noticed that across all attributes, if there was an error or a possibility of interpreting a measurement in different ways, the outcome invariably favored the landowner and supported an opportunity to harvest more, not less, timber.

Despite that caution, these data provide insight into stand- and site-attribute conditions from a randomly selected sample of FPA's being managed according to DFC Rules.

OBJECTIVES

Provide an overview of site attributes and stand conditions using the data used in the Desktop Analysis Report to:

1) Allow reviewers to understand the range of site and stand conditions evaluated in the Desktop Analysis,
2) Identify characteristics of data that may merit further investigation from a rule implementation perspective,
3) Identify characteristics of data that may merit further investigation from a research or Adaptive Management perspective.

RESULTS

Location

The FPAs analyzed were located in four different DNR Regions, and distributed between 16 counties in western Washington (Table 1). Six counties accounted for 83% of the FPAs analyzed. These are, in decreasing number of FPAs, Grays Harbor (38), Clallam (26), Lewis (24), Jefferson (13), Pierce (12) and Cowlitz (11).

Table 1 – Distribution of FPAs analyzed for the desktop analysis study by DNR Region and County, by number and percent.

DNR REGION	County	Number of FPAs	Percentage
Northwest	Skagit	1	
Northwest	Snohomish	3	
	Total	**4**	**2.7%**
Olympic	Clallam	26	
Olympic	Grays Harbor	7	
Olympic	Jefferson	13	
	Total	**46**	**30.7%**
Pacific Cascades	Clark	1	
Pacific Cascades	Cowlitz	11	
Pacific Cascades	Grays Harbor	31	
Pacific Cascades	Lewis	24	
Pacific Cascades	Pacific	8	
Pacific Cascades	Skamania	1	
Pacific Cascades	Thurston	2	
Pacific Cascades	Wahkiakum	3	
	Total	**81**	**54%**
S. Puget Sound	King	4	
S. Puget Sound	Kitsap	2	
S. Puget Sound	Mason	1	
S. Puget Sound	Pierce	12	
	Total	**19**	**12.7%**

Site Attributes by DNR Region

Stream Size (Figure 1)

Key Points:

1. In the Pacific Cascades Region, there were twice as many FPAs selected along small streams (54) as along large streams (27).
2. In the South Puget Sound Region, there were nearly four times as many FPAs from alongside large streams (15) as from small streams (4).
3. FPAs along small streams in the Pacific Cascade Region accounted for 36% (54 out of 150) of all FPAs evaluated.
4. Across all regions, there were 69 FPAs (46%) selected that were alongside small streams and 81 (54%) from alongside large streams.

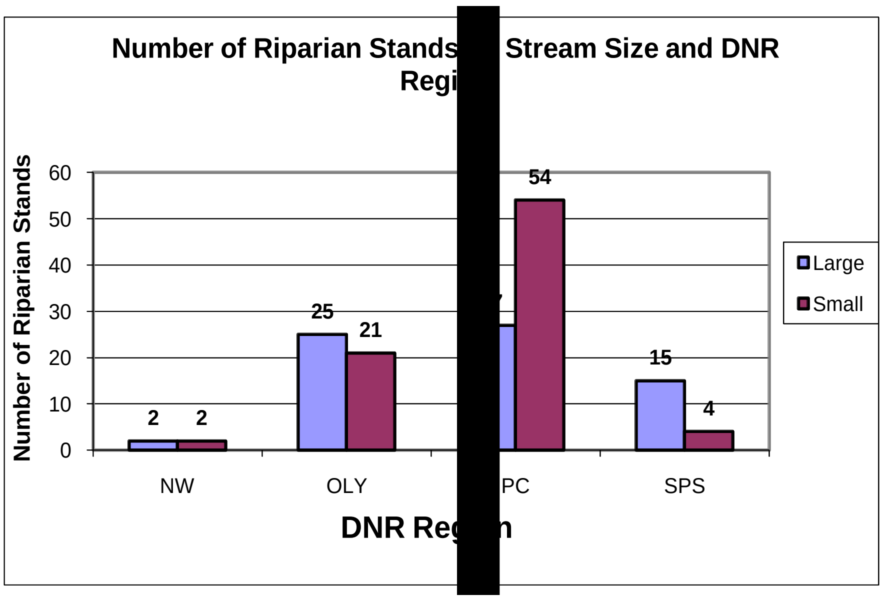

Figure 1 – Number of riparian stands evaluated by DNR Region and stream size; large streams are > 10' wide, small streams are ≤ 10' wide.

Site Class (Figure 2)

Key Points:

1. One-hundred and thirty-three riparian stands evaluated (88.7%) were on Site Classes 2 and 3 (Figure 2).
2. Only 17 riparian stands (11.3%) were on Site Classes 1, 4, and 5 with 9, 7 and 1, stands in each Site Class, respectively.
3. The distribution of Site Classes varied by DNR Region.
   a. All 9 Site Class 1 stands were from the Pacific Cascades Region.
   b. In the Olympic Region 39 of 46 riparian stands (84.5%) were Site Class 3, 4 in Site Class 2 (8.7%) and 3 in Site Class 4 (6.5%).
4. In the Pacific Cascades Region, most stands were Site Class 2 (45 of 81 (55.6%).
5. The South Puget Sound Region was the only Region with a riparian stand on Site Class 5. There were nearly equal numbers of stands on Site Classes 2 (9) and 3

(8) in the South Puget Sound Region, accounting for 89.5% of the stands selected in this region.

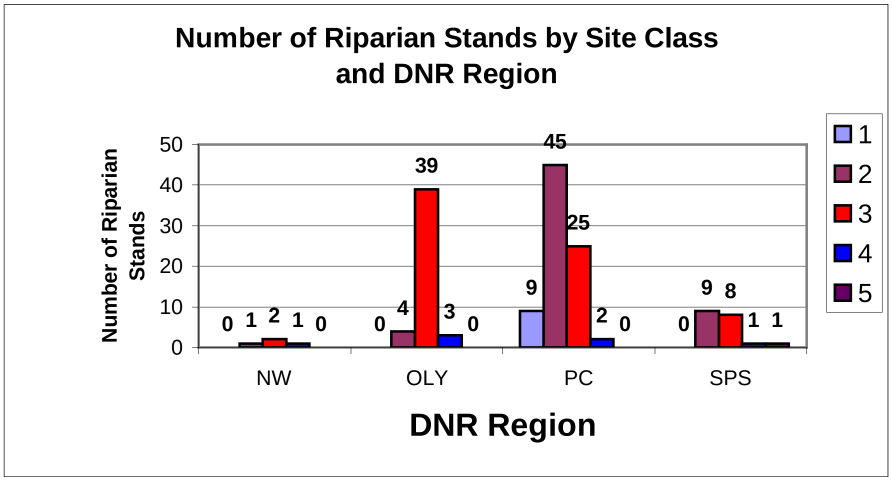

Figure 2 – The number of riparian stands evaluated by Site Class and Washington Department of Natural Resources (DNR) Region. The legend indicates Site Classes 1-5. DNR Regions are: NW (Northwest), OLY (Olympic), PC (Pacific Cascades) and SPS (South Puget Sound).

<u>Major Species</u> (Figure 3)

Key Points:

1. Across all DNR Regions, there were nearly an equal number of riparian stands evaluated in each of the two "major species"- Douglas-fir (74) and western hemlock (76).
2. Major species were not evenly distributed across DNR Regions.
3. In the Olympic Region, 38 of 46 riparian stands (82.6%) were western hemlock
4. In the Pacific Cascades Region 55 of 81 riparian stands (67.9%) were dominated by Douglas-fir.
5. In the South Puget Sound Region Douglas-fir and western hemlock were nearly equal with 10 and 9 stands each.

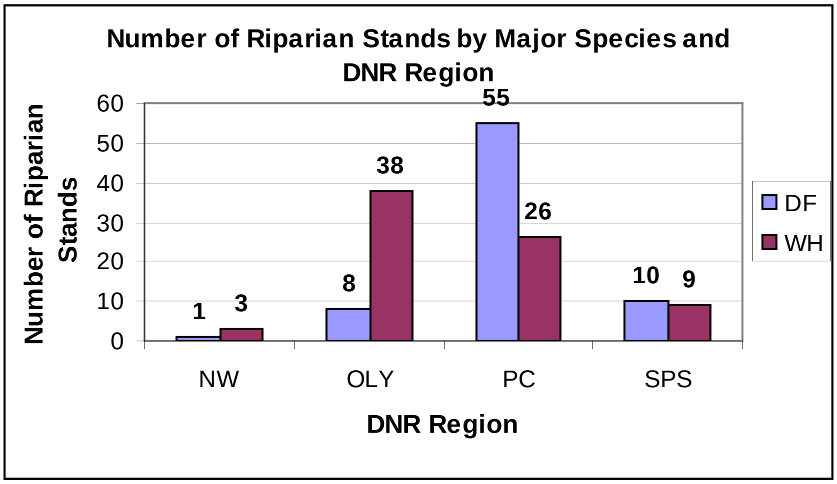

Figure 3 - The number of riparian stands evaluated by major species and Washington Department of Natural Resources (DNR) Region. DF is Douglas-fir. WH is western hemlock. DNR Regions are: NW (Northwest), OLY (Olympic), PC (Pacific Cascades) and SPS (South Puget Sound).

RMZ Length (Figure 4)
Key Points:
The average RMZ Length across all 150 riparian stands was 1394' with a standard deviation of 1312'.

1. There were some differences in average length by DNR Region but for all Regions, variability was high.

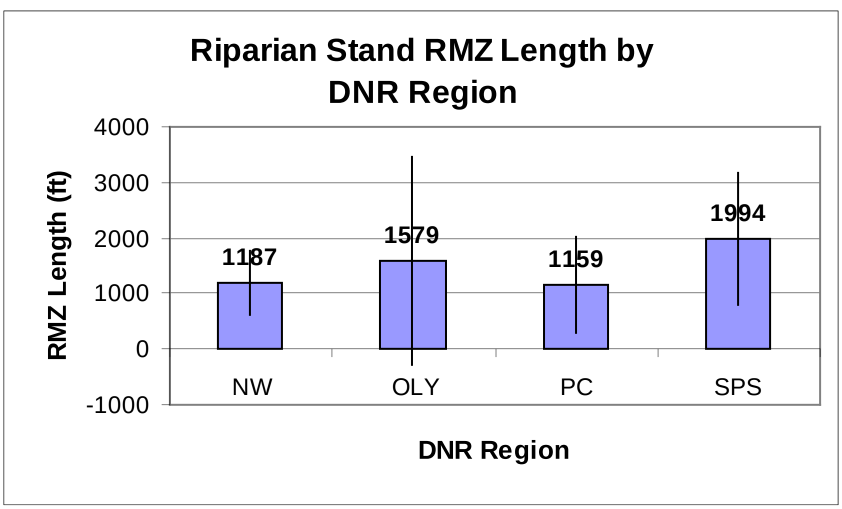

Figure 4 – Average RMZ Length and standard deviation, by DNR Region of riparian stands evaluated. The bold number above bars indicates average stream length. The lines through bars are one standard deviation, showing both plus and minus. Washington Department of Natural Resources (DNR) Regions are: NW (Northwest), OLY (Olympic), PC (Pacific Cascades) and SPS (South Puget Sound). The number of riparian stands (n) for each region are: NW (4), OLY (46), PC (81), and SPS (19).

2. RMZ Lengths are skewed to the right. There are some very long riparian stands accounting for the high variability in mean values (Figure 5).

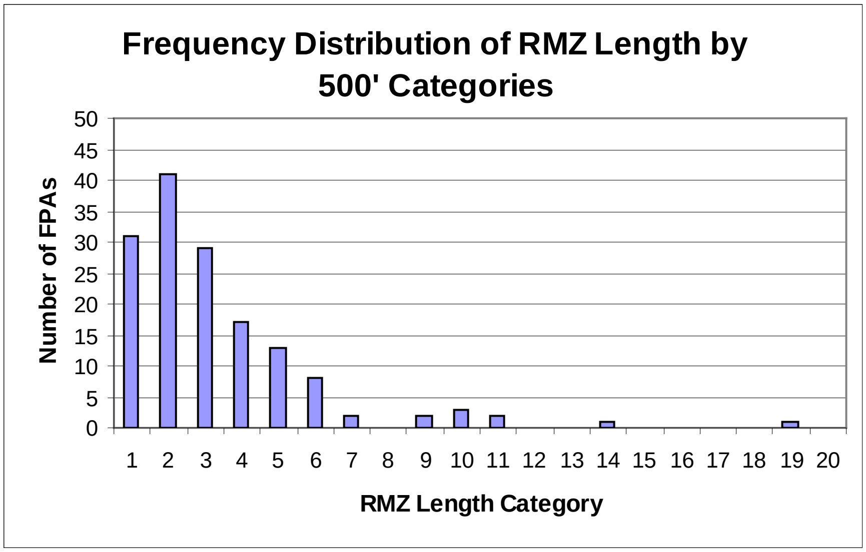

Figure 5 – Frequency distribution of riparian stand RMZ Lengths for all sample riparian stands. RMZ Length categories are set at 500' intervals. So, for example, category includes RMZ Lengths that are from 0 to 499 feet long, category 2 is inclusive of RMZ Lengths 500 to 999 feet long etc. Category 19, the last category populated by these data represents stream lengths from 9000 to 9499 feet long.

3. There are differences in the distribution of RMZ Lengths by Region (Figure 6)
    a. There is nearly an equal distribution of riparian stands by length categories in the South Puget Sound Region
    b. The number of riparian stands decreases as RMZ Length increases in the Olympic and Pacific Cascades Regions except for an increase from category 3 to 4 in the Olympic Region.

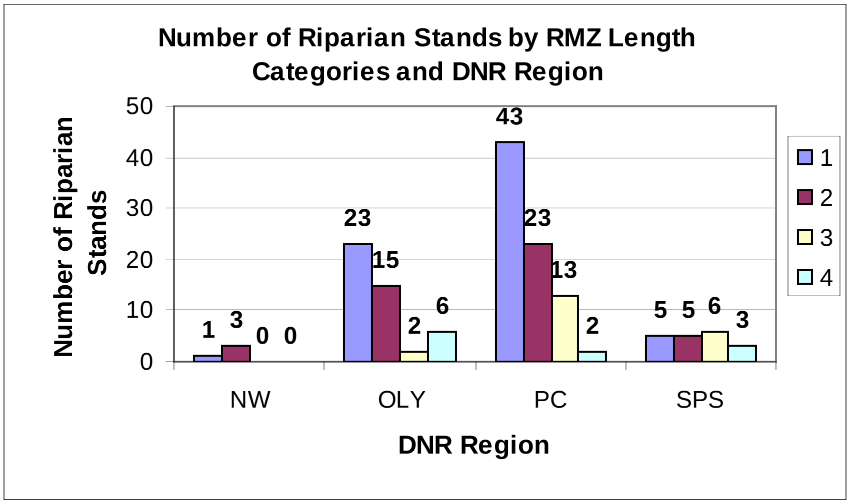

Figure 6 – Frequency distribution of riparian stand RMZ Lengths by Department of Natural Resources (DNR) Region. DNR Regions are: NW (Northwest), OLY (Olympic), PC (Pacific Cascades) and SPS (South Puget Sound). RMZ Length categories are set at 1000' intervals. RMZ Lengths are, by category: 1) 0 to 999', 2) 1000 to 1999', 3) 2000 to 2999', and 4) > 3000'.

4. Average RMZ Lengths within Categories are very similar across DNR Regions except there are some very long (Category 4; > 3000') riparian stands in the Olympic Region (Figure 7).
5. The six riparian stands in Category 4 in the Olympic Region range from 4350 to 9400'; four of these stands are longer than 5000'.
6. The longest RMZ Lengths in the Pacific Cascades Region is 4540' and in the South Puget Sound Region it is 4789'.

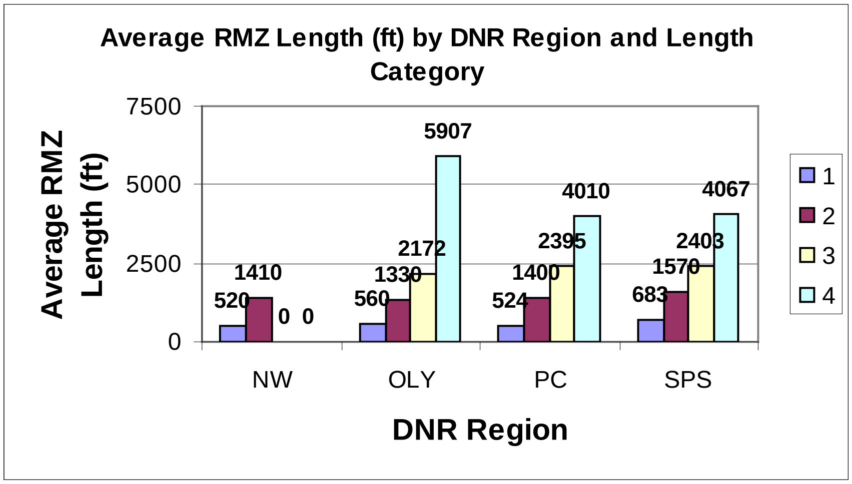

Figure 7 – Average RMZ lengths by RMZ Length categories and Department of Natural Resources (DNR) Region. DNR Regions are: NW (Northwest), OLY (Olympic), PC (Pacific Cascades) and SPS (South Puget Sound). RMZ Length categories are set at 1000' intervals. RMZ Lengths are, by category: 1) 0 to 999', 2) 1000 to 1999', 3) 2000 to 2999', and 4) > 3000'.

7. The total cumulative RMZ Length of riparian areas evaluated by the riparian stands used in this analysis is 209,135' (39.61 miles).

Stand Age (Figure 8)
Key Points:
1. The average age of all riparian stands in this analysis was 51.6.
2. The oldest stand was 100-yrs old and the youngest was 31-yrs.
3. Average age varied very little between Regions ranging from 49.5 in the Northwest Region to 54.8 in the South Puget Sound Region. Variation around the mean was similar across all Regions.

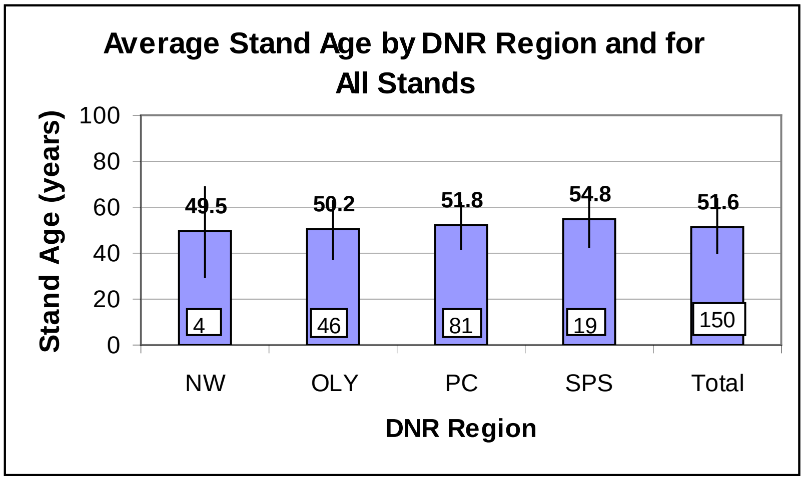

Figure 8 – Average age of riparian stands by Department of Natural Resources (DNR) Region and for all stands combined. DNR Regions are: NW (Northwest), OLY (Olympic), PC (Pacific Cascades) and SPS (South Puget Sound) and "Total" is all riparian stands. The lines through bars indicate plus and minus one standard deviation. The number above bar is the mean stand age. The number at the base of each bar is "n"; the number of stands.

4. Most riparian stands in this analysis (123 out of 150, 82.0%) were 36 to 60-yrs old (Figure 9).
5. Twenty-three stands (15.3%) are between 61 and 100-yrs old.

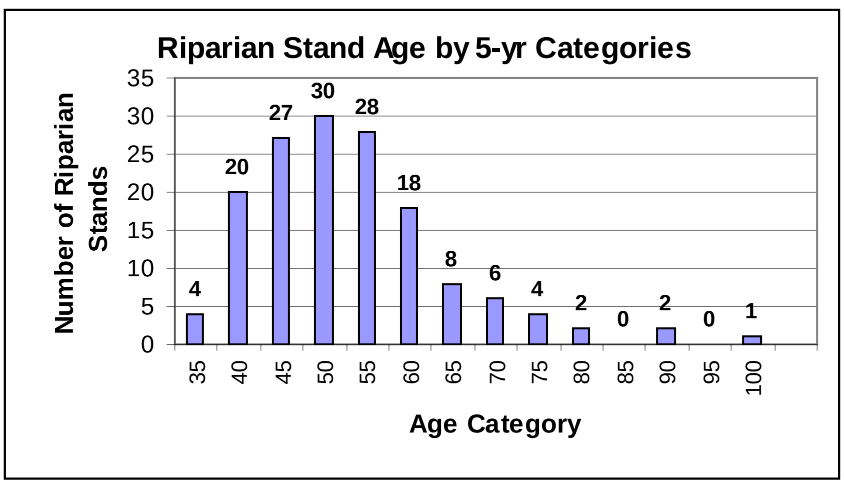

Figure 9 – Number of riparian stands by age categories. Age categories are in 5-yr increments. The age reported for each category is the upper end of each age grouping. For example, stands reported as 35 include all stands from 31 to 35 yrs-old. Stands included in the age 40 category include all stands from 36 to 40-yrs old.

6. The cumulative curve depicting ages of all riparian stands (Figure 10) indicate that landowners often round to the nearest 5-yr intervals as there are peaks at

these intervals throughout the age range represented by these stands. There are three stands less than 35-yrs old and one stand that is 100-yrs old.

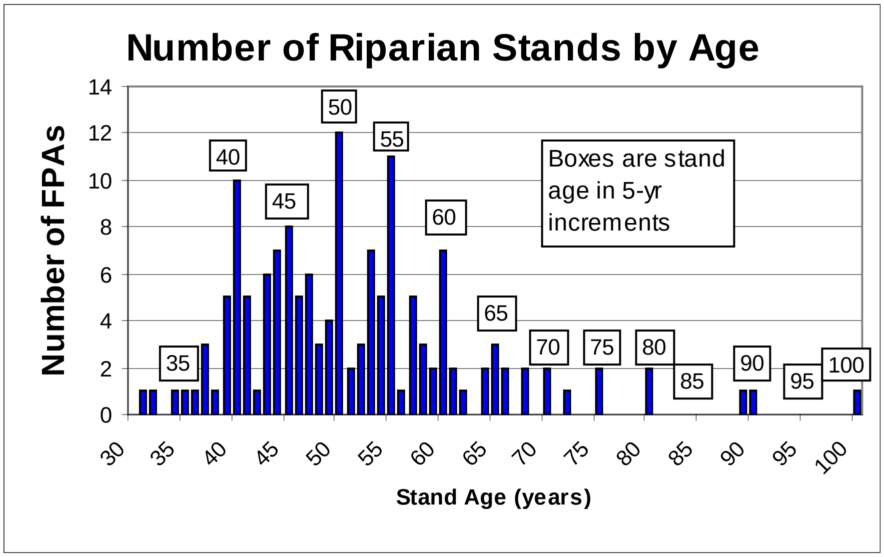

Figure 10 – Number of riparian stands by age.

Stand Basal Area (Figure 11)
Key Points:

1. The average harvest age stand basal area per acre (bapa) in ft^2/acre for the core and inner zones, across all stands were, respectively 246.9 and 232.5.
2. The area-adjusted[28] core + inner zone mean value was 238.8 ft^2/acre (Figure 11). Core zone basal area was higher than inner zone basal area in each of the DNR Regions except the Northwest Region.

[28] Inner zone widths vary by Site Class and stream size while the core zone width is always 50'.

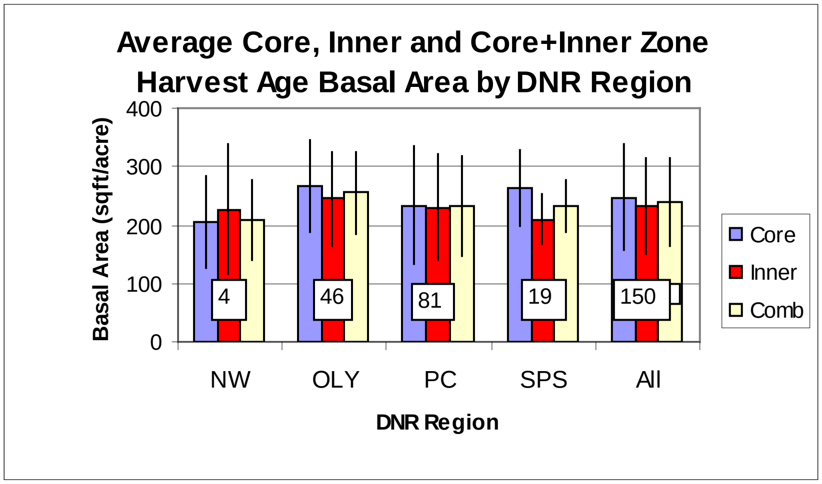

Figure 11- Average basal area per acre (ft^2) of the core, inner, and area-adjusted core + inner zone for riparian stands. The line through bars indicates one standard deviation. The number in the box is the sample size (n) for each region. DNR Regions are: NW (Northwest), OLY (Olympic), PC (Pacific Cascades) SPS (South Puget Sound); "All" uses data from all of the DNR Regions.

3. On an individual stand level, the core and inner zones can be quite dissimilar (Figure 12). Core zone bapa was as little as 36% and as much as 223% that of inner zone bapa.
4. In only 108 of 150 stands were core zone and inner zone bapa within plus or minus 30% of each other.
5. Core zone bapa was greater than inner zone bapa on 86 of 150 stands (57.3%).

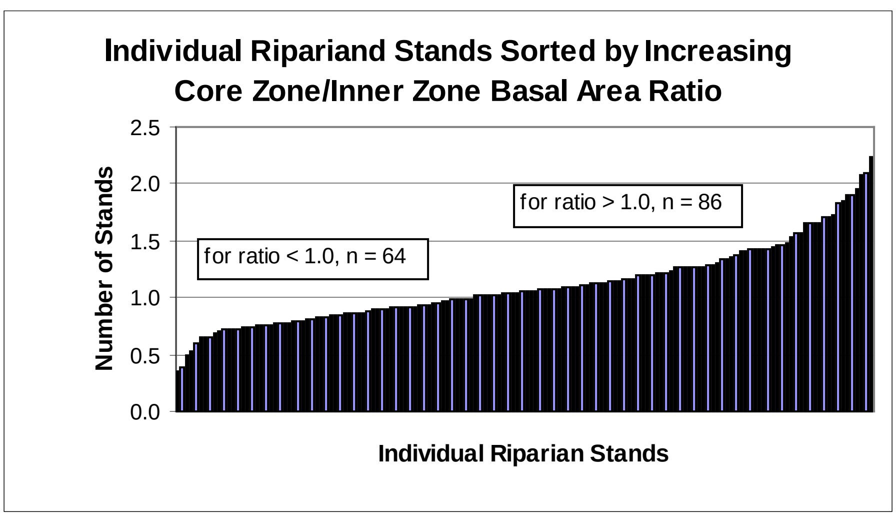

Figure 12 – Ratio of core zone to inner zone basal area per acre (ft^2/acre) for individual timber harvest age riparian stands sorted by ascending ratio value from left to right.

6. For both the core and inner zones, there was more bapa on stands on which western hemlock was the major species than for Douglas-fir stands, although variability in bapa values was high for both species (Figure 13).

7. Mean core zone bapa was greater than mean inner zone basal area for both Douglas-fir (230.0 and 225.4, respectively) and western hemlock (263.6 and 239.9, respectively), but variability was high.

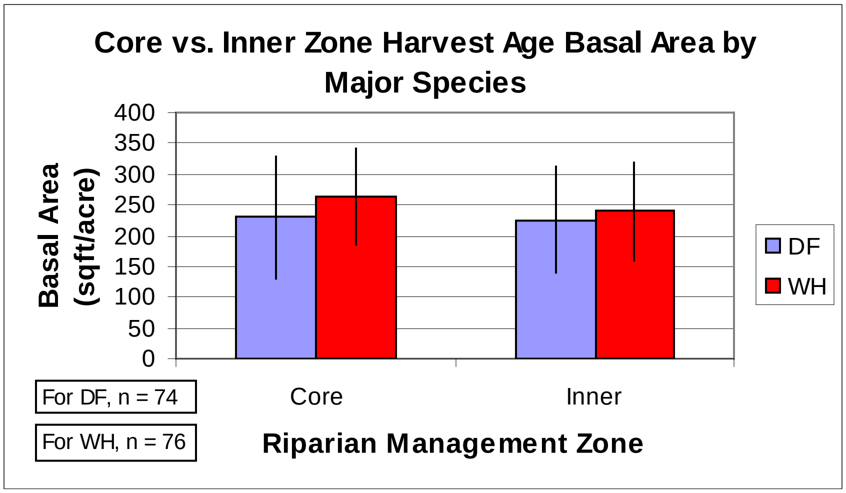

Figure 13 – Mean basal area by major species (DF = Douglas-fir, WH = western hemlock) and riparian management zone (core and inner). The line through bars shows plus and minus one standard deviation.

Trees per Acre (Figure 14)
Key Points:

1. There were more trees per acre (tpa) in the core zones of harvest age stands (225.0 ± 93.0) than in the inner zone 208.1 ± 78.4). There were more stands (87 of 150) in which the number of inner zone tpa exceeded the number of core zone tpa (Figure 20).

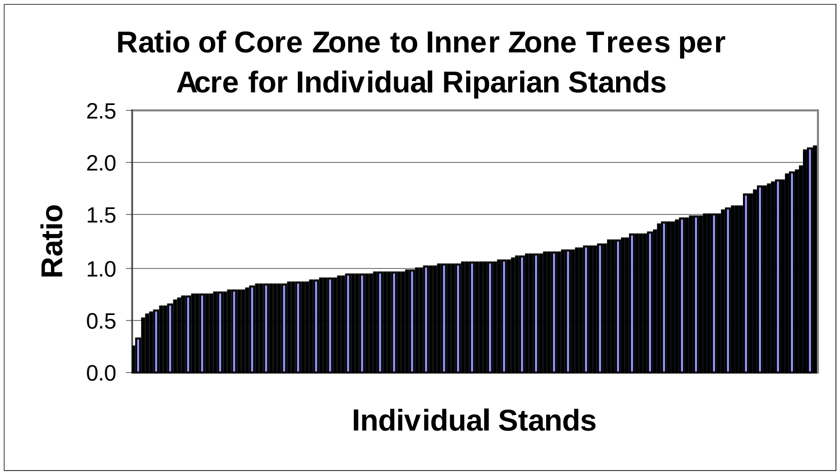

Figure 14 – Ratio of core zone to inner zone trees per acre for individual harvest age riparian stands sorted by ascending ratio value from left to right. The range of values is 0.24 to 2.16. There is one stand with a value of 1.0, 63 stands with a value of less than 1.0 (core zone tpa < inner zone tpa), and 86 stands with a ratio of greater than 1.0 (core zone tpa > inner zone tpa).

2. There were more tpa on sites on which western hemlock was identified as the major species than where Douglas-fir was the declared major species (Fig 15), but variability is high.

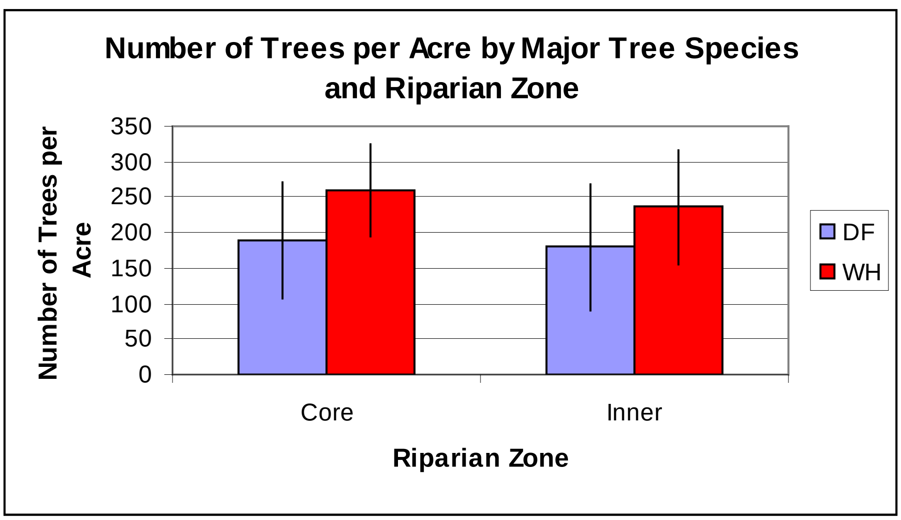

Figure 15 – Harvest age trees per acre by major species (DF = Douglas-fir, WH = western hemlock) by riparian zone (cz = core zone, iz = inner zone). The lines through bars indicate plus and minus one standard deviation.

3. Mean tpa increased from Site Class 1 to Site Class 4 but there was high variability (Figure 16).

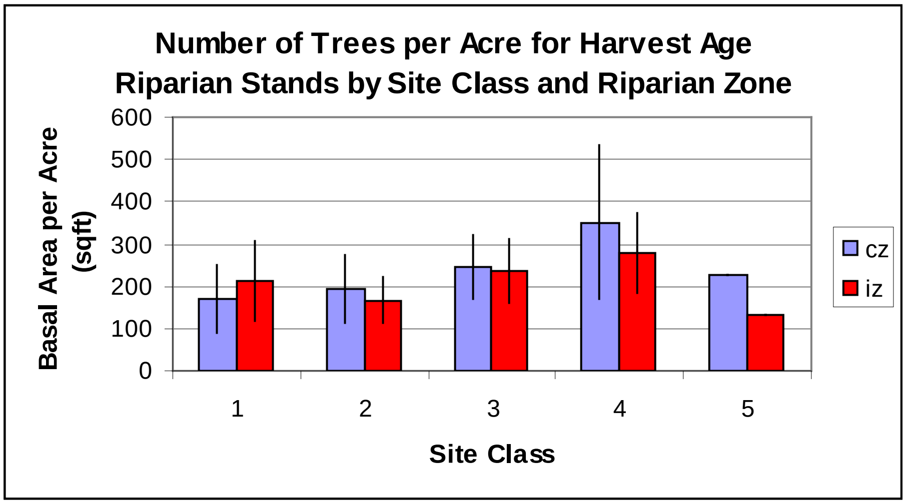

Figure 16 – Harvest age trees per acre by Site Class and riparian zone (cz = core zone, iz = inner zone). The lines through bars indicate plus and minus one standard deviation. By Site Class, the number of stands ("n") are: 1 (9), 2 (59), 3 (74), 4 (7) and 5 (1).

<u>Quadratic Mean Diameter</u> (Figure 17)

Key Points:

1. Average core and inner zone quadratic mean diameter (qmd) were 14.6 and 14.7, respectively. QMD's were similar across DNR Regions (Figure 17).

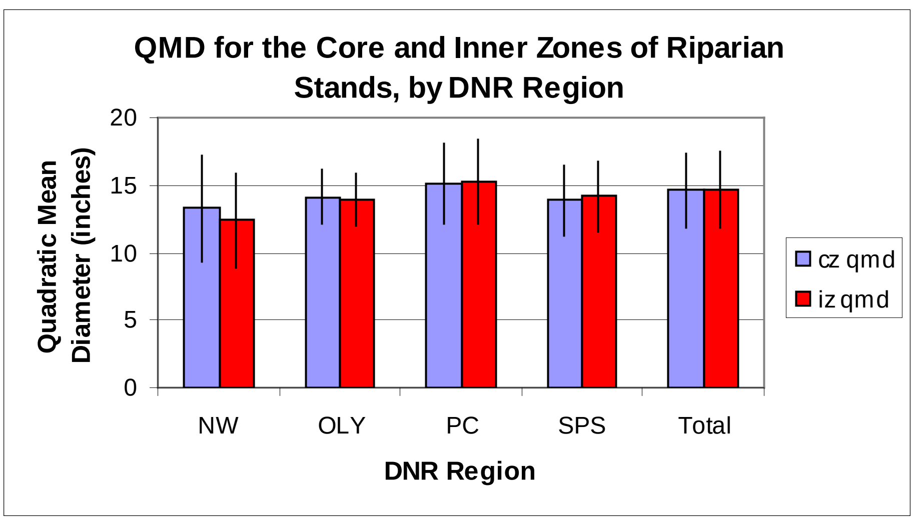

Figure 17 - Harvest age average quadratic mean diameter by riparian zone (cz qmd = core zone, iz qmd = inner zone) and DNR Region. The line through bars indicates plus and minus one standard deviation. DNR Regions are: NW (Northwest), OLY (Olympic), PC (Pacific Cascades) SPS (South Puget Sound); "Total" uses data from all of the DNR Regions. By DNR Region, the number of stands ("n") are: NW (4), OLY (46), PC (81), and SPS (19).

2. The average qmd by major species was higher for both core and inner zones for Douglas-fir then for western hemlock (Figure 18).
3. The average qmd for harvest age western hemlock stands was 13.9” for both core and inner zones.
4. Douglas-fir average core zone qmd was 15.3 and inner zone qmd was 15.5.
5. Variability was less for western hemlock than for Douglas-fir.

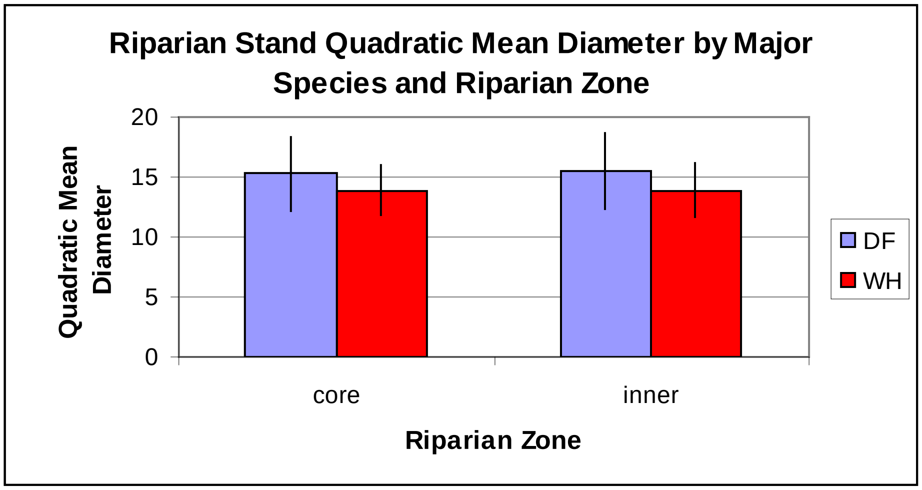

Figure 18 - Harvest age average quadratic mean diameter by “major species” and riparian zone (core and inner). “Major species” are: DF = Douglas-fir and WH = western hemlock. The line through the bars indicates plus and minus one standard deviation. By “major species”, the number of stands (“n”) are: DF (74) and WH (76).

6. There were progressively lower qmd values in the core zones of riparian stands from Site Class 1 to Site Class 4 (Figure 19) and in the inner zone in Site Classes 1-3.

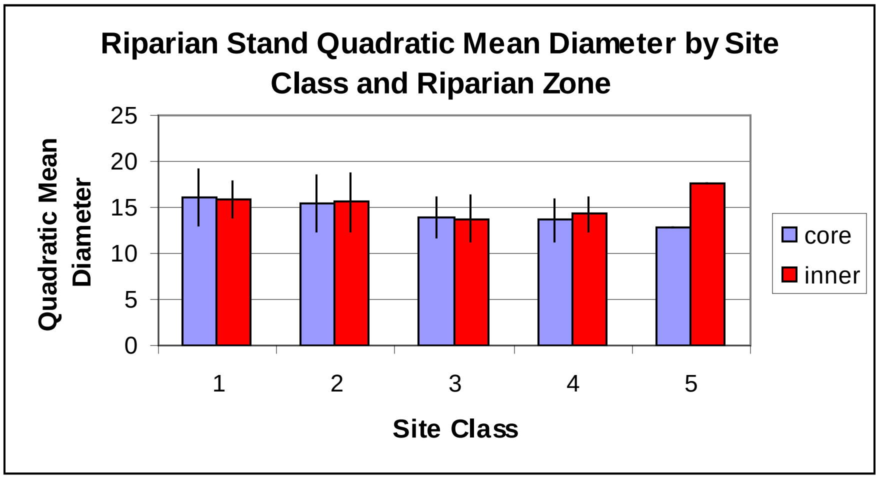

Figure 18 - Harvest age average quadratic mean diameter by Site Class and riparian zone (core and inner). The line through the bars indicates plus and minus one standard deviation. By Site Class, the number of stands ("n") are: 1 (9), 2 (59), 3 (74), 4 (7) and 5 (1).

7. Core zone inner zone qmd values varied within individual stands but across all sites, the pattern was for values to increase and decrease together (Figure 19).

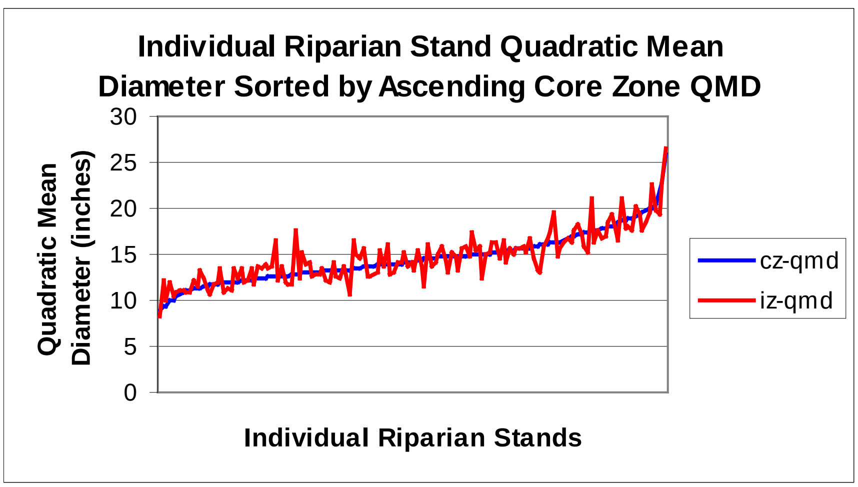

Figure 19– Core and inner zone quadratic mean diameter (qmd) values for individual stands, sorted by increasing core zone qmd. cz-qmd = core zone qmd and iz-qmd = inner zone qmd.

Relative Density (Figure 20)
Key Points:

1. Average relative density across all sites was 64.8 for core and 60.7 for inner zones, respectively (Figure 20), but there was high variability.

2. Average relative density was higher in the core than the inner zone in the Olympic and South Puget Sound Regions and nearly equal in the Pacific Cascades Region, but there was high variability.

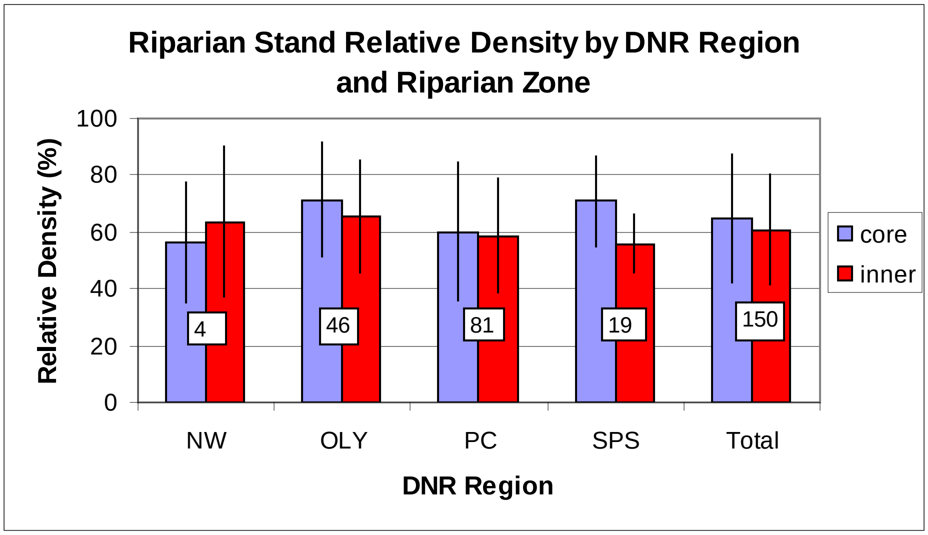

Figure 20 - Harvest age relative density by riparian zone (core and inner) and DNR Region. The line through bars indicates plus and minus one standard deviation. DNR Regions are: NW (Northwest), OLY (Olympic), PC (Pacific Cascades) SPS (South Puget Sound); “Total” uses data from all of the DNR Regions. The boxes on each bar pair indicate the number of stands “n” for each DNR Region.

3. Relative density for harvest age riparian stands was higher for western hemlock stands than for Douglas-fir stands, for both the core and inner zones, but variability, measured by standard deviation, was high (Figure 21).

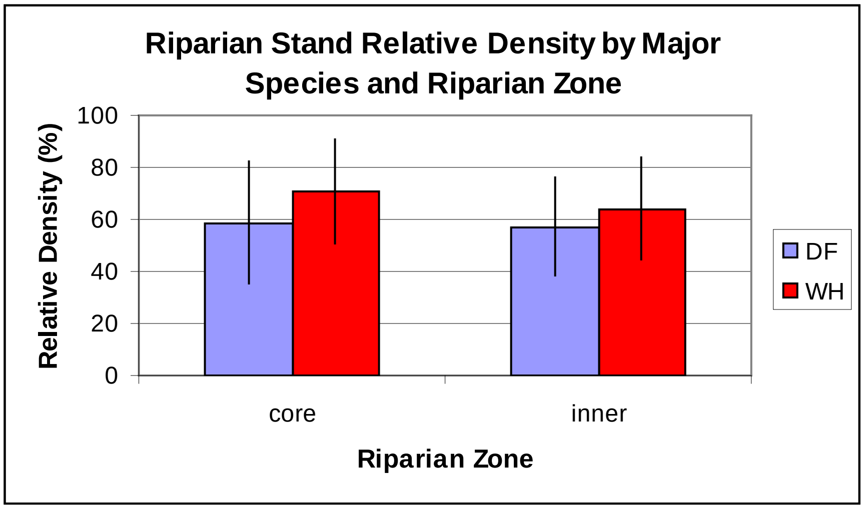

Figure 21 - Harvest age relative density by “major species” and riparian zone (core and inner). “Major species” are: DF = Douglas-fir and WH = western hemlock. The line through the bars indicates plus and minus one standard deviation. By “major species”, the number of stands (“n”) are: DF (74) and WH (76).

Percent Conifer (Figure 22)
Key Points:

1. The mean conifer basal area percentage in harvest age riparian stands was higher in the inner zone than the core zone in the Olympic, Pacific Cascades and South Puget Sound Regions (Figure 22) and averaged across all Regions, but variability is high.

2. Across all stands, mean percentage conifer basal area in the core zone was 81.3 % compared to 90.1% in the inner zone +/- 17.0 and 12.3 %, respectively.

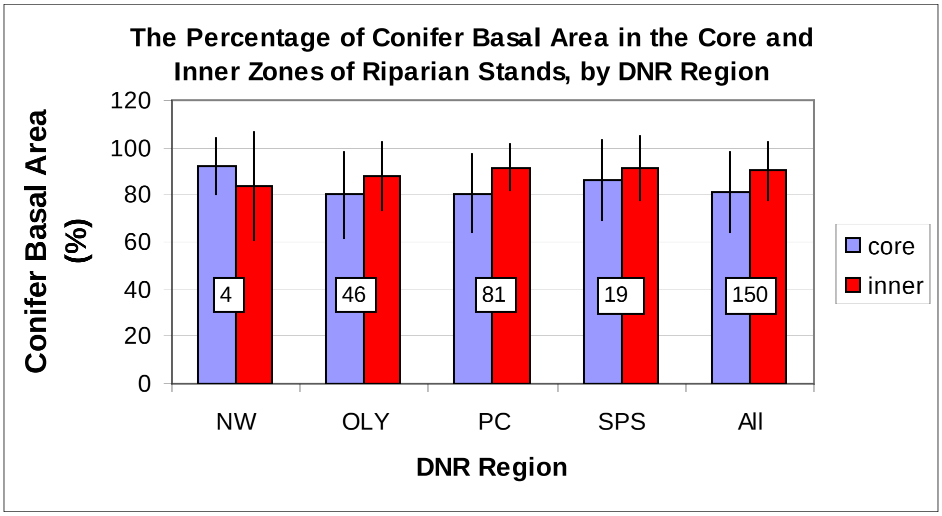

Figure 22 - Harvest age conifer percentage (measured as a proportion of total stand basal area) by riparian zone (core and inner) and DNR Region. The line through bars indicates plus and minus one standard deviation. DNR Regions are: NW (Northwest), OLY (Olympic), PC (Pacific Cascades) SPS (South Puget Sound); "Total" uses data from all of the DNR Regions. The boxes on each bar pair indicate the number of stands "n" for each DNR Region.

3. There were 111 stands in which the percentage of conifer was less in the core zone than in the inner zone (Figure 23).
4. On 21 stands, core and inner zone conifer percent were equal.
5. There were 19 stands in which the percentage of conifer in the inner zone was less than for the core zone.

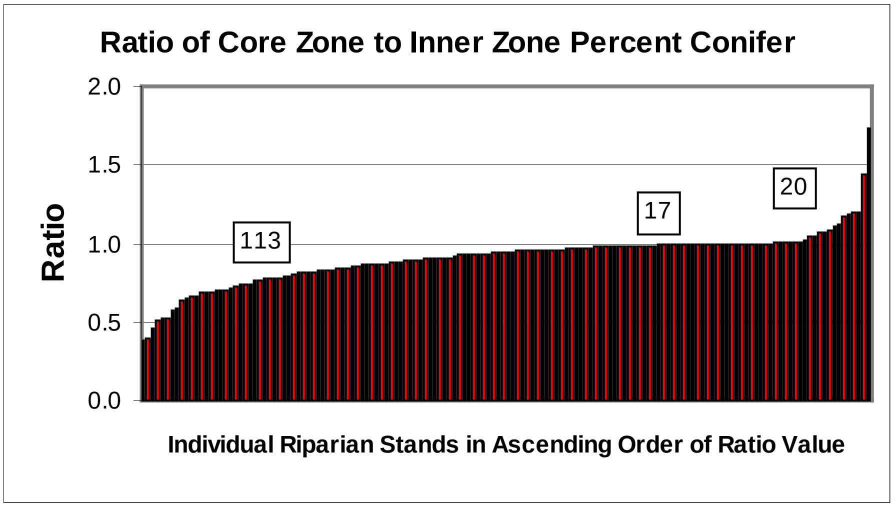

Figure 23 – Ratio of core zone over inner zone percent conifer for individual harvest age riparian stands sorted by ascending ratio value from left to right. The range of values is 0.38 to 1.73. The values in the boxes are, from left to right, the number of stands in which core to inner zone percent conifer is: 1) < 1.0, 2) = 1.0, and 3) > 1.0.

KEY FINDINGS

1. Most of the FPAs selected by random sample were on Site Class 2 and 3, 59 and 74 stands, respectively, representing 88.7% of the riparian stands analyzed. Only 1 FPA on Site Class 5 (0.7%) was selected.

2. Most (81- 54.0 %) of the FPAs selected that had inner zone timber harvest were from the Pacific Cascades Region, followed by the Olympic Region with 46 (30.7 %). There is little inner zone timber harvest occurring in the Northwest Region (4 – 2.7%).

3. There were twice as many riparian stands selected along small streams (54) in the Pacific Cascades Region as for large streams (27). In the South Puget Sound Region, there were almost four times more riparian stands selected along large streams (15) than along small streams (4).

4. In the Pacific Cascades Region, most (45 of 81) riparian stands were on Site Class 2, while in the Olympic Region most (39 of 46) were on Site Class 3. For most stands in the Pacific Cascades Region (55 of 81) Douglas-fir was the "major species". For most (38 of 46) stands in the Olympic Region western hemlock was the "major species".

5. RMZ length was highly variable across all DNR Regions, ranging from 87' to 9400' with an average length of 1394' with a standard deviation of 1312'. The Olympic Region had some very long RMZ Lengths; 6 stands had RMZ lengths that were more than 3000' long.

6. Stand age varied little between regions. The average age across all stands was 51.6 years and the frequency distribution of stand age centered around this age as well. Landowners appear to round stand age to the nearest five-year interval. The range of stand ages was 31-yrs to 100-yrs.

7. Average stand basal area for the core and inner zones respectively was 246.9 and 232.5 ft^2/acre, respectively. On average core zone basal area was higher than inner zone. The percentage of conifer of inner zones on average was higher in the inner than in the core zone.

8. There was an almost a 50:50 split in the number of stands classed by "major species", with 74 Douglas-fir stands and 76 western hemlock stands.

9. Basal area by species type was highly variable but there was a trend for western hemlock stands to have higher basal area than Douglas-fir stands in both the core and inner zones.

10. There was also a trend for there to be more trees per acre on western hemlock than on Douglas-fir stands in both the core and inner zones.

11. There was a trend for higher quadratic mean diameters, lower relative densities, and lower percent conifer on Douglas-fir stands as compared to western hemlock stands.

DISCUSSION

The Sensitivity Analysis (Roorbach et al.2006) showed that DFC Model projections for western hemlock are lower than for Douglas-fir and that this is one of the largest sources of difference in projected outcomes. The growth incorporated into the DFC Model is based on the simple assumption that the stand basal area growth is slower on western hemlock stands than on Douglas-fir stands. With more than half of FPAs coming on western hemlock stands, a productive next step in the Adaptive Management process might be to look more carefully at modeled results of western hemlock stands.

There are distinct differences in stand conditions between western hemlock and Douglas-fir stands, for example in number of trees per acre, basal area, qmds, relative density and abundance of intermingled hardwood trees. Given these differences, it might be useful to consider whether different rules could apply by species type that might better meet FFR Objectives than is accomplished by managing these two different species under the same rules.

CONCLUSIONS

These analyses were done primarily to supplement the Desktop Analysis report by providing insights on some of the characteristics of the data used for that study.

This analysis also provides some insight on characteristics of the riparian stands managed using DFC rules. This information can provide insights useful to the adaptive management process to help it be better equipped to design studies and pose research questions with information in hand.

There are other site stand stand attribute “by” comparisons that could be made but differences by region and major species were thought to be the most useful for preliminary analyses for purposes of both rule implementation and developing ideas or hypotheses for possible future studies. The Field Check study cast some doubt on the reliability of some site attribute conditions identified by the landowner collected data, including stream size, RMZ length, major species and stand age, and this uncertainty must be kept in mind as these data are considered. Additionally, none of the trends identified above were tested for statistical significance and, in addition, most attributes analyzed had high variability associated with it. Both the lack of statistical certainty and high variability need be remembered as these data are considered.

REFERENCES

McConnell, S. and J. Heimburg. 2010. A field analysis of riparian site attributes and stand inventory data from approved forest practices applications along west-side Type F streams. Contract # PSC 07-22 and IAA Agreement #10-86

Roorbach, A., S. McConnell and D. Schuett-Hames. 2006. DFC Model sensitivity analysis. Unnumbered report prepared by CMER staff. On file at NWIFC, Olympia, WA 23 p.

APPENDIX B – Number of FPAs reviewed, accepted and rejected. Rejected FPAs are categorized by reason they were removed from the sample pool.

Year	Valid	Alt Plan	No DFC input	DFC not met	Other	Total
2003	75	7	36	3	4	125
Percent	60	5.6	28.8	2.4	3.2	100
	Valid	Alt Plan	No DFC input	DFC not met	Other	
2004	75	5	29	4	2	115
Percent	65.2	4.3	25.2	3.5	1.7	100