Westside Type F Riparian Management Zone Exploratory Study, Study Design

Jenelle Black, Emily Davis, Dave Schuett-Hames,
Gregory Stewart, Christopher Mendoza

WASHINGTON DEPARTMENT OF NATURAL RESOURCES

Cooperative Monitoring
Evaluation & Research

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Washington State
Cooperative Monitoring, Evaluation, and Research Committee (CMER)
Report

Westside Type F Riparian Management Zone Exploratory Study Design

Prepared by
Jenelle Black[1], Emily Davis[1,2], Dave Schuett-Hames[1,3],
Gregory Stewart[1,4], Christopher Mendoza[5]

Prepared for the
Riparian Scientific Advisory Group (RSAG)
Westside Type F Riparian Rules Effectiveness Monitoring Program.

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

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[1] CMER Staff Scientist, Northwest Indian Fisheries Commission, Olympia, Washington, USA
[2] Currently at King County, Department of Natural Resources
[3] Retired
[4] Currently at Anchor Environmental
[5] Mendoza Environmental, LLC

Washington State 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.

Report Type and 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 Westside Type F Riparian Effectiveness Program, and was conducted under the oversight of the Riparian Scientific Advisory Group (RSAG).

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.

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Project Manager Contact Information
Alexander Prescott
Washington Department of Natural Resources
Alexander.Prescott@dnr.wa.gov
546 200 2956

Westside Type F Riparian Prescription Monitoring Project- Exploratory Field Study

Draft Study Plan-December 4, 2017

Definition of acronyms used in the Westside Type F Study Design Discussion:

CMER- Cooperative Monitoring, Evaluation and Research Committee. The Cooperative Monitoring, Evaluation, and Research (CMER) Committee is a monitoring, evaluation, and research program established by the Forest Practices Board. Its purpose is to ensure effective implementation of the recommendations contained in the Forests and Fish Report.

FPA- Forest Practice Application. A permit required to conduct most forest practices activities on state or private forest land in Washington State.

DFC- Desired Future Condition. Refers to the condition of a forest at 140 years, with respect to age of trees, canopy cover, downed logs, etc. The goal of the Forests & Fish riparian management strategy is to leave the riparian area in a condition today that is on a trajectory to replicate the conditions of natural stands of forest at age 140.

FPHCP- Forest Practices Habitat Conservation Plan. The purpose of the FPHCP is to provide programmatic "coverage" under the Washington Department of Natural Resources (WDNR) forest practices division regulating private forestlands, and eastern WA state lands. Landowners who conduct forest practices activities that are in compliance with the Forest Practices Act and rules will meet the requirements of the Federal Endangered Species Act for "listed" species under the FPHCP (i.e., certain freshwater fish species and some stream associated amphibians). The HCP seeks to provide for the protection and long-term conservation of aquatic designated species, meet Clean Water Act requirements, and support the restoration and conservation of riparian habitat. The FPHCP is also supposed to provide for the restoration of harvestable levels of salmon while maintaining an economically viable timber industry.

LTCW-Leave trees closest to the water. An inner zone harvest strategy that involves of harvesting trees furthest from the water and leaving those closest to the water.

RMZ- Riparian Management Zone. An area protected on each side of a Type F or S Water.

TBF- Thin from below. An inner zone harvest strategy of harvesting smaller diameter trees and leaving the larger trees.

Type F Water- Segments of natural waters that contain fish habitat (other than Type S waters).

Type S Water- All waters inventoried as shorelines of the state under the state Shorelines Management Act; also waters containing fish habitat.

Background

Westside Type F and S Prescriptions

The westside Type F and S riparian prescriptions are an important component of the Riparian Conservation strategy of the Washington Forest Practices Habitat Conservation Plan (FPHCP) (WDNR 2005). The Riparian Conservation Strategy of the FPHCP focuses on protection of riparian habitat and processes to meet water quality standards and support recovery of aquatic and riparian dependent species such as fish and stream-associated amphibians. Riparian forests covered by these prescriptions are adjacent to waters fish use for spawning, incubation, and rearing. Habitat for fishes is directly affected by the functions, processes, and inputs provided by these forests including litter fall, shade, long-term wood recruitment, bank protection, and sediment filtering.

The FPHCP identifies Resource Objectives, which are key aquatic conditions and processes affected by forest practices (http://www.dnr.wa.gov/Publications/fp_hcp_31appn.pdf). The Westside Type F and S riparian prescriptions help achieve the resource objectives for heat/water temperature, large wood/organic inputs, and sediment by providing shade to maintain cool water temperatures and a source of large wood and organic material to create aquatic habitat, and by preventing input of sediment from timber harvest operations.

The Westside Type F and S riparian prescriptions establish riparian management zones (RMZs) adjacent to the stream (Washington Forest Practices Board 2012). The RMZ consists of three zones oriented parallel to the edge of the bankfull channel (Figure 1). Closest to the stream is the 50 ft wide core zone where no harvest is allowed. Beyond the core zone lies the inner zone, which varies in width depending on site class and stream width category. Some harvest is allowed within the inner zone if stocking is adequate to meet the desired future condition (DFC) performance target (WFPB 2012, WAC 222-30-021). Inventory data from the core and inner zone are used to run a stand growth model that predicts whether the stand will achieve the DSC target of 325 sq ft of basal area per acre at 140 years of age (McConnell 2007). If basal area is sufficient, the model identifies excess trees that can be harvested from the inner zone. In cases where inner zone harvest is allowed, landowners can use harvest option 1, thin from below, or in some cases use option 2, leave trees closest to the water. Where the DFC target will not be met, or where inner zone harvest is not economically or logistically feasible, no inner zone harvest occurs. Beyond the inner zone lies the outer zone. Landowners are required to leave 20 trees/acre in the outer zone and can choose whether to clump or disperse the leave trees.

The prescribed width of RMZs for westside Type F and S streams varies according to five site class categories, two channel bankfull width categories and three harvest options (Table 1). Given the possible combinations there are 25 potential variations of the westside Type F standard rules, hereafter referred to as prescription variants.

Table 1. Description of site class categories, stream width categories and harvest options used in the western Washington Type F and S riparian prescriptions (WFPB 2016).

Site Class Categories	50-year site index range (tree height in feet)
I	137+
II	119–136
III	97–118
IV	76–96
V	<75
Stream width categories	**Description**
Large stream	>10 feet bankfull width
Small stream	≤10 feet bankfull width
Harvest options	**Description**
Option 1	Thin from below (TFB)
Option 2	Leave trees closest to water (LTCW)
No-inner-zone-harvest	Leave all trees

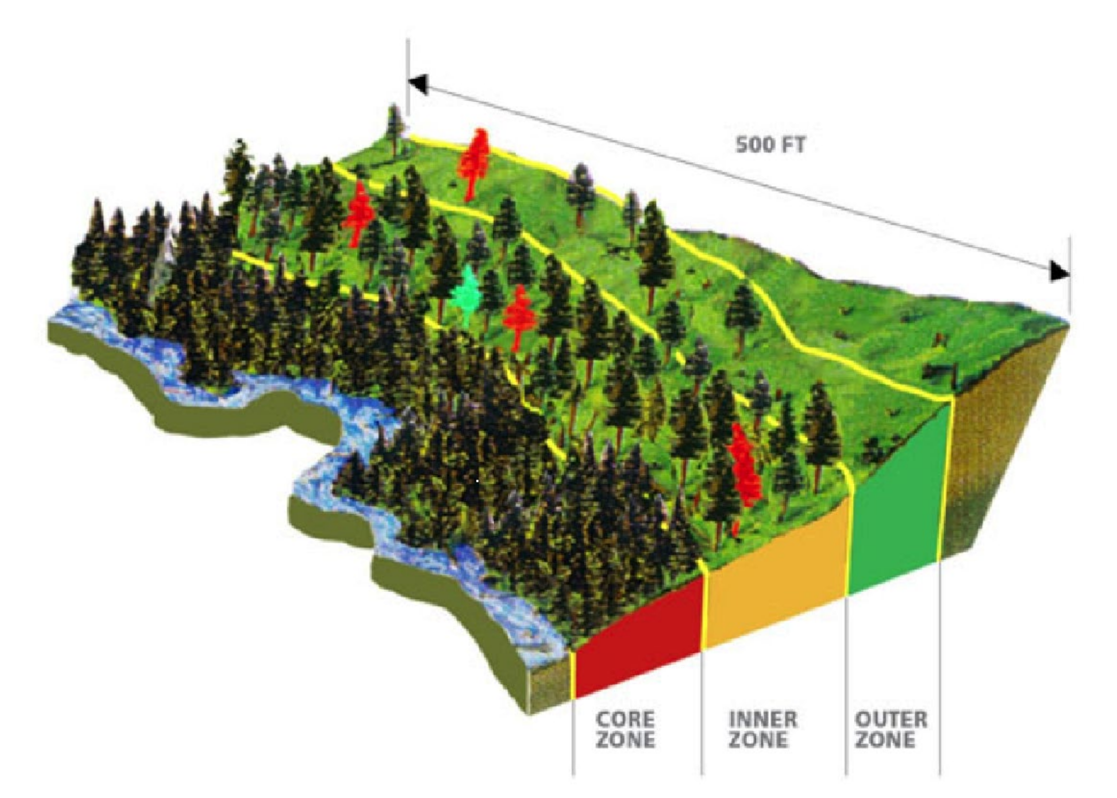

Figure 1. Diagram of the western Washington Type F Riparian Management Zone layout, showing the core, inner and outer zone. Colored trees indicate trees retained for wildlife.

Westside Type F Riparian Prescription Monitoring Project

The effectiveness of the Westside riparian prescriptions for F and S streams in achieving the FPHCP resource objectives and performance targets has not been evaluated. The CMER Workplan (CMER 2015; http://www.dnr.wa.gov/publication/bc_cmer_workplan_2015.pdf) identified the need for research to examine the effectiveness of RMZ rules and to provide information that is necessary to inform the FPHCP adaptive management program. In 2015, CMER established a Technical Writing and Implementation Group (TWIG) to conduct scoping and develop a research approach for assessing Type F riparian prescription effectiveness (Schuett-Hames et al. 2015).

The TWIG identified an intensive before-after-control-impact (BACI) study as our preferred approach to answer questions about causal linkages between the prescriptions, changes in riparian stand structure and inputs/functions, and the responses of stream habitat, water quality, and aquatic biota (Schuett-Hames et al. 2015). Due to the large number of different prescription variants and uncertainty about how frequently they were used and how the prescriptions influence post-harvest riparian stand structure and functions, we determined that more information was needed to develop an effective, focused, and efficient design for the intensive BACI study. Consequently, we proposed to conduct two preliminary information gathering steps prior to designing the intensive study: 1) an analysis of approved forest practice applications and GIS data (the FPA/GIS analysis) to determine the implementation frequency of different prescription variants and the size and spatial distribution of riparian harvest units on the landscape, and 2) an exploratory field study to examine post-harvest stand characteristics and riparian functions associated with various prescription variants. The FPA/GIS analysis (step 1) has been completed. The results are presented in Appendix A and have been used to design the exploratory study. This document contains the proposed study design for the exploratory field study.

The exploratory study is intended reduce uncertainties associated with the relative sensitivity of post-harvest riparian stand conditions and riparian functions to potential disturbances associated with the prescription variants and to provide an estimate of effect size for some metrics. Information on the magnitude of differences between prescription variants will be used to inform and guide the design of the intensive BACI study. In addition, stand structure data and soil disturbance data will be used to provide an estimate of the proportion of sites meeting FPHCP performance targets.

Exploratory Field Study Design

The exploratory field study will assess riparian stand conditions and selected riparian functions across a wide range of prescription variants and site conditions. It will provide a coarse-level assessment of current riparian conditions that focuses on addressing scientific uncertainty surrounding their sensitivity to current forest practices expressed as prescription variants. This is not a designed experiment but an exercise in collecting pilot data for riparian prescriptions that are already distributed across the landscape. With adequate funding, we estimate this exploratory study will be completed in approximately three years. At the conclusion, we will have information for most of the westside Type F prescription variants including:

- the level of riparian functions associated with the prescriptions, including data on post-harvest large wood recruitment, shade, and sediment delivery,
- riparian stand conditions associated with the prescriptions, including stand mortality, density, basal area, and the proportion of sites currently on trajectory to meet DFC target of 325 ft^2/acre of basal area at 140 years,
- the frequency, magnitude and distribution of windthrow and its effects on stand structure, buffer tree mortality rates and riparian functions,
- the relative influence of differences in site conditions and geographic location on the above.

Goal and objectives of the Exploratory Study

The overall goal of the exploratory study is to produce information needed to focus and design the BACI study.

The objectives of the exploratory study are:

1. To evaluate post-harvest riparian stand conditions and riparian ecological functions across prescription variants with and without inner zone harvest.
2. To evaluate the extent to which post-harvest riparian forest stands are on trajectory to achieve DFC targets at sites with and without inner zone harvest.

Exploratory Study Approach

The exploratory study will collect data after impact (AI) to provide a landscape-scale, coarse-level assessment of post-harvest riparian stand structure and riparian functions, and to evaluate whether stands are on trajectory to meet DFC targets three years after harvest. We considered using an after-control-impact (ACI) approach, but rejected it because it requires a substantial effort to obtain and sample an appropriate reference population. The proposed AI approach enables us to maximize the number of treatment sites that can be sampled, which will improve our ability to detect, distinguish and assess measurable patterns in post-harvest conditions across treated sites. While a reference population and/or pre-treatment data would be essential for attributing observed conditions to treatments, e.g., attributing causation, that is not our goal and these data will not be used to compare harvested versus unharvested areas.

Population of Interest

The population of interest consists of riparian stands in the core and inner zones of RMZs adjacent to fish-bearing streams harvested according to the current standard riparian prescriptions for western Washington Type F and S streams (Figure 2 and Table 2). Because the minimum basal area thresholds controlling harvest under the forest practices rules and regulations were changed in 2006, the population of interest only includes activities approved under the new rules (WAC 222-30-021; http://file.dnr.wa.gov/publications/fp_rules_ch222-30wac.pdf). The population of interest excludes stands harvested using alternative riparian prescriptions, such as practices covered under hardwood conversion rules, 20-acre exempt parcel rules, alternate plans, and landowner-specific habitat conservation plans (HCPs). Riparian stands with channel migration zones (CMZs) or stream adjacent roads are excluded because they are regulated under separate provisions of the forest practice rules.

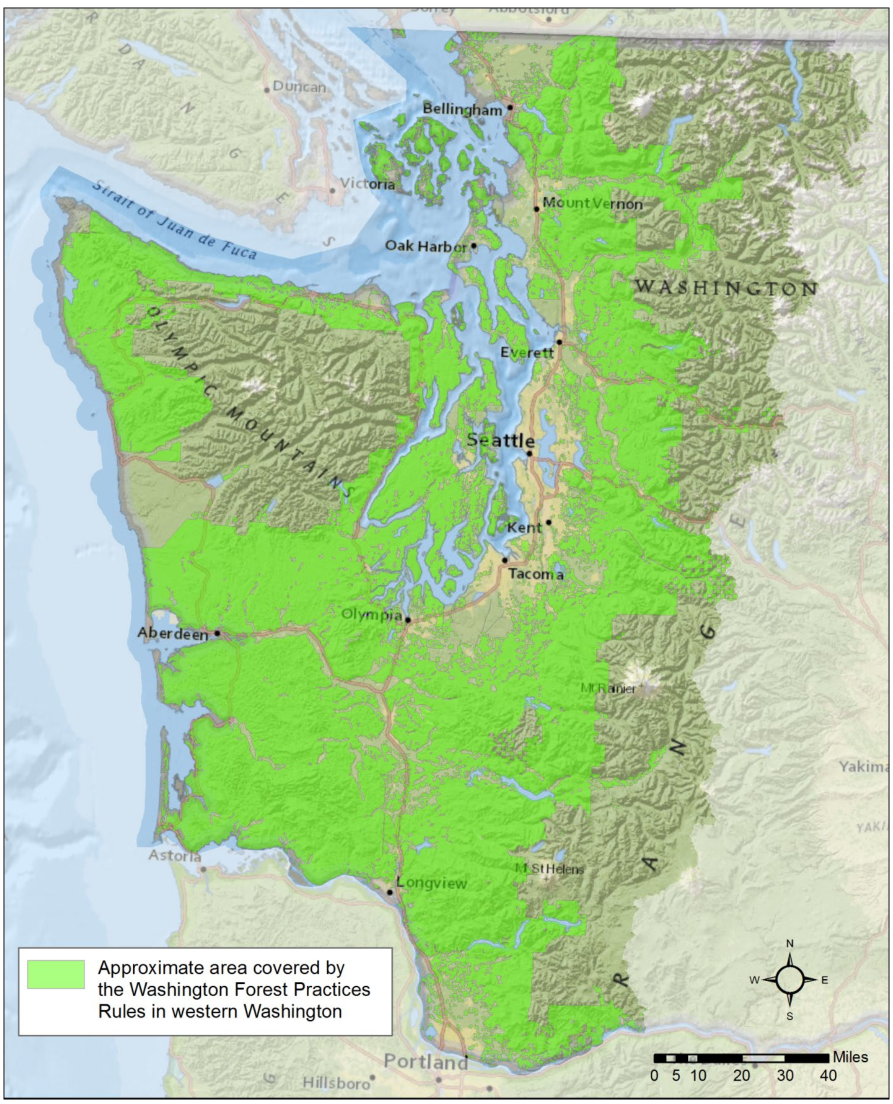

Figure 2. Approximate area covered by the Forest Practices rules in western Washington.

Table 2. Frequency distribution of stream segments with RMZs harvested according to Westside Type F prescription variants. Based on random sample of 170 FPAs and 590 associated stream segments with effective dates between July 2008 and June 2013 (see Appendix A for details).

Prescription Variant			Core & Inner Zone No Harvest Width (ft)	Minimum Basal Area (ft^2/acre)	Stream Segment Count	Percent*
Site Class	Stream Width Category	Harvest Treatment				
I	large	No inner zone harvest	150	No Minimum	8	1.4%
I	large	Option 1- TFB	150	325	0	0.0%
I	large	Option 2- LTCW	100+	325	11	1.9%
I	small	No inner zone harvest	133	No Minimum	6	1.0%
I	small	Option 1- TFB[1]	133	325	0	0.0%
I	small	Option 2- LTCW[2]	80+	325	7	1.2%
II	large	No inner zone harvest	128	No Minimum	52	9.0%
II	large	Option 1- TFB[1]	128	325	0	0.0%
II	large	Option 2- LTCW[2]	100+	325	24	4.1%
II	small	No inner zone harvest	113	No Minimum	59	10.2%
II	small	Option 1- TFB[1]	113	325	4	0.7%
II	small	Option 2- LTCW[2]	80+	325	13	2.2%
III	large	No inner zone harvest	105	No Minimum	86	14.8%
III	large	Option 1- TFB[1]	105	325	31	5.3%
III	small	No inner zone harvest	93	No Minimum	107	18.4%
III	small	Option 1- TFB[1]	93	325	8	1.4%
III	small	Option 2- LTCW[2]	80+	325	94	16.2%
IV	large	No inner zone harvest	83	No Minimum	15	2.6%
IV	large	Option 1- TFB[1]	83	325	0	0.0%
IV	small	No inner zone harvest	73	No Minimum	6	1.0%
IV	small	Option 1- TFB[1]	73	325	0	0.0%
V	large	No inner zone harvest	68	No Minimum	19	3.3%
V	large	Option 1- TFB[1]	68	325	0	0.0%
V	small	No inner zone harvest	60	No Minimum	30	5.2%
V	small	Option 1- TFB[1]	60	325	0	0.0%

[1] Thin from below [2] Leave trees closest to the water

Experimental Unit

A single FPA can have several Type F or S streams with multiple segments based on site class and stream width category, each with different prescriptions. The landowner can choose to break streams into separate segments with different harvest strategies based on stand characteristics and operational considerations. Consequently, the experimental unit is a Type F or S RMZ segment with a consistent DNR site class (I, II, III, IV or V), stream width category and harvest option.

Stratification and Sample Size

We propose to stratify sampling by prescription variant, which differ in buffer width and leave tree requirements according to site class (tree growth potential), stream size category and harvest treatment (Table 3). These differences are expected to influence riparian stands and riparian functions post-harvest. Since one goal of the pilot project is to help focus the BACI study on prescription variants where there is evidence of a response to treatment, we want to survey as many prescription variants as possible. However, due to the budget constraints, we propose limiting sampling to the eleven prescription variants that are present in substantial amounts across the landscape (Table 3). We eliminated seven variants that did not occur in our sample and another seven which each represented <2% of the total. Together, the excluded prescription variants represented <10% of the population.

Table 3. Eleven prescription variants (strata) to be sampled with proposed sample allocation.

Prescription Variant			Core & Inner Zone Width (ft)	Minimum Basal Area (ft^2/acre)	Stream Segment Count	% total stream segments*	Proposed Sample Allocation
Site Class	Stream Width Category	Harvest Treatment					
II	large	No inner zone harvest	128	No Minimum	52	9.0%	10
II	large	Option 2- LTCW[1]	100+	325	24	4.1%	10
II	small	No inner zone harvest	113	No Minimum	59	10.2%	10
II	small	Option 2- LTCW[1]	80+	325	13	2.2%	10
III	large	No inner zone harvest	105	No Minimum	86	14.8%	10
III	large	Option 1- TFB[2]	105	325	31	5.3%	10
III	small	No inner zone harvest	93	No Minimum	107	18.4%	10
III	small	Option 2- LTCW[1]	80+	325	94	16.2%	10
IV	large	No inner zone harvest	83	No Minimum	15	2.6%	10
V	large	No inner zone harvest	68	No Minimum	19	3.3%	10
V	small	No inner zone harvest	60	No Minimum	30	5.2%	10

[1] Thin from below, [2] Leave trees closest to the water, * Data from the FPA-GIS analysis (Appendix A).

For practical reasons, we propose limiting our sample size to approximately 110 samples. To enable statistical analyses and provide even information across the prescription variants, we propose to sample the same number (n = 10) of RMZ segments in each prescription variant (Table 3). Given that some prescription variants are relatively rare and others are relatively common, a simple random sample would run the risk of creating too much or too little information about one particular treatment variant. The proposed stratified scheme will collect equal information across the selected set of treatment variants (Table 3).

A power analysis was conducted using data from the Westside Type N BCIF study (Schuett-Hames et al., 2012) which compared unharvested and harvested stands with 50ft no-cut buffers on headwater streams (See Appendix B). While this exploratory study will not be focusing on statistical testing, a power analysis can inform whether we have an unreasonably high or low sample size and can also serve as a reminder to avoid certain types of statistical testing. The results showed that the power to detect differences varies depending on the variable of interest and that a sample of N = 10 may be weak for comparing between two prescription variants. While a sample size of 10 per strata is not ideal for every variable (mortality in particular, see Appendix B), this sample size is likely to provide reasonable estimates across treatments for other variables of interest such as basal area/acre or shade in this or future studies.

The selected sampling strategy has two clear benefits: 1) less common prescription variants will be equally represented in the analysis across strata, and 2) fine-scale analysis at the strata-scale will be possible. Clearly, a larger sample size per strata would be preferable (see Appendix B). However, the goals of the pilot project are not specifically related to strata (e.g., site class and stream width divisions), but to broader definitions of harvest prescriptions (e.g., inner-zone-harvest, no-inner-zone-harvest). Therefore, this approach will allow for representation of less common, but potentially more sensitive, harvest prescriptions in the sample set used for comparison. Additionally, we recognize the results of the power analysis (Appendix B) are only a general indication of how data may look as there is no guarantee that the data we observe in the proposed study will be similar in terms of distribution as the test data. Therefore, the proposed sampling strategy is viewed as a starting point for quantifying and comparing the prescription variants commonly applied on Type F and S streams in western Washington and will be essential for conducting refined power analyses to inform the BACI design for the full study.

Sampling Strategy

Site Selection and Screening

We identified five site selection criteria which will be used to include or eliminate RMZ segments from the study due to their potential to confound our ability to detect treatment effects. These include time since harvest, stream length, presence of channel migration zones (CMZs), stream-adjacent parallel roads, and one- or two-sided buffers. Factors that only affect a portion of a RMZ segment, such as the presence of road crossings or unharvested areas with mass wasting or wetlands buffers, were not used to exclude sites. In these cases, the affected portion of the RMZ segment will not be surveyed, but the remainder will be included in the study, as long as it meets the minimum stream length criterion.

Site selection criteria

Time since harvest. We propose to sample sites that were harvested three winters prior to sampling. We propose this time frame because research shows that post-harvest windthrow in newly harvested buffer strips generally peaks within a few years after logging (Harris 1989, Bahuguna et al. 2010, Schuett-Hames et al. 2012). Over time, windthrow mortality generally declines as the surviving trees grow more wind firm (Ruel et al. 2001, Bahuguna et al. 2010, Mitchell 2013). However, buffer strips remain vulnerable to impacts from severe storm events which can also cause high mortality in unharvested stands (Ruel et al. 2001, Schuett-Hames et al. 2012). Therefore, the post-harvest sampling schedule is designed to allow time for the newly established buffers to be exposed to natural wind disturbances. Also, the three year delay is soon enough after harvest to enable differentiation of pre- versus. post-harvest tree mortality and recent wood recruitment (see “Fallen trees and large wood recruitment” section). We recognize the short post-harvest time frame limits our assessment of mortality and changes in stand structure that affect stand trajectory to meet the DFC target over longer timeframes and a greater range of natural disturbance. However, the study time frame will provide a useful assessment of the initial impacts of post-harvest mortality which can affect long-term trends in riparian functions (e.g., Martin and Shelly 2017) and change in the ability of stands to achieve the DFC target at year three post-harvest.

Segment length. There is substantial variation in the length of RMZ segments for a given prescription variant (Figure 3). Because response variables such as canopy closure and wood recruitment may be heavily influenced by adjacent unharvested stands we propose to locate study reaches in harvested segments ≥150 m in length. This minimum length will eliminate about 15% of harvested segments in the study population. See below for more details about study site layout.

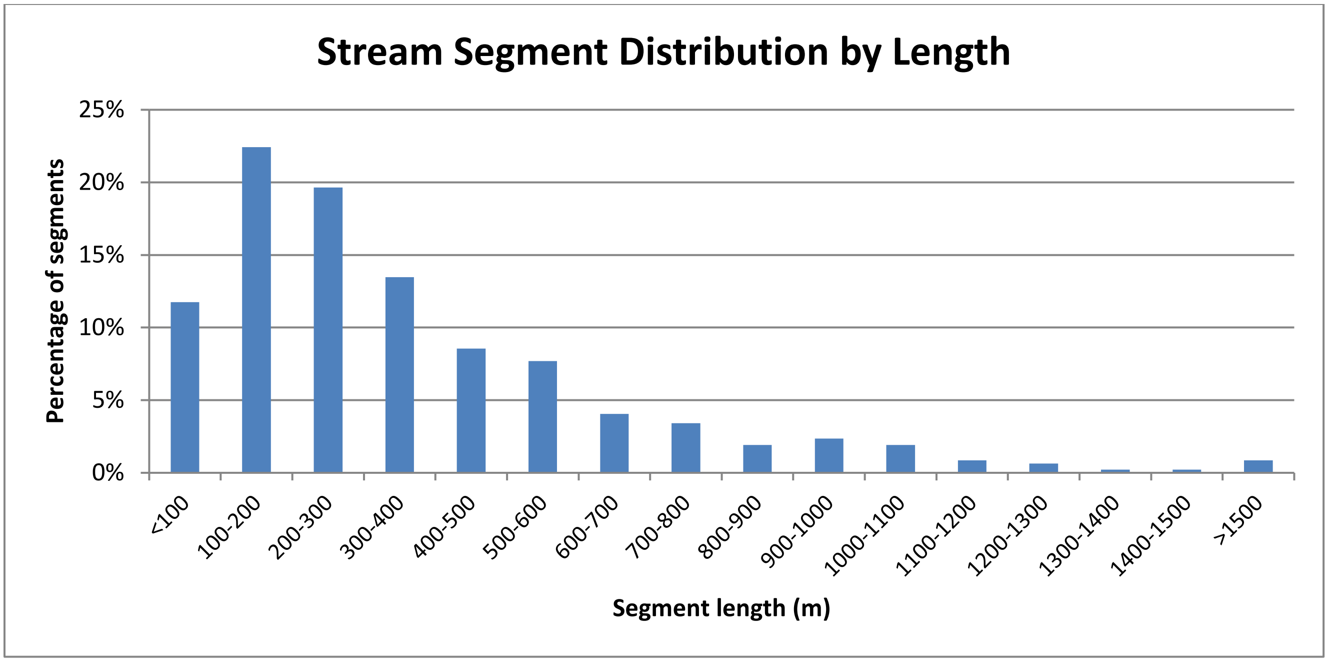

Figure 3. Distribution of stream segments from the FPA-GIS analysis by segment length (m).

Channel migration zones. RMZ segments with channel migration zones (CMZs) will be eliminated from the study. CMZs are areas adjacent to the stream where the active channel is prone to move, which are identified using criteria in the Forest Practices Board manual. The presence of a CMZ is noted on the FPA, and a separate no-harvest prescription is applied to the entire CMZ. The RMZ begins at the outer edge of the CMZ, so in effect, streams with CMZs receive a variable width buffer that exceeds the standard RMZ buffer. Approximately 2% of RMZ segments had CMZs.

Stream-adjacent parallel roads. RMZ segments with stream-adjacent parallel roads will be eliminated from the study. These are roads that go through the core or inner zones in a direction parallel to the alignment of the stream. In these cases, separate site-specific rules apply. Approximately 2% of the FPAs had stream-adjacent roads.

One- vs. two-sided harvest. Many harvest units are laid out with larger Type F or S streams as harvest unit boundaries. In these cases the stand on one side of the stream receives the riparian prescription and the stand on the other side does not. However, when a Type F stream lies within the harvest unit, harvest with a prescription buffer occurs on both sides of the stream. We surveyed 346 Type F or S segments from the FPA-GIS analysis to determine the proportion with one- and two-sided harvest for each of 10 stream width and site class combinations (Table 4). Two-sided harvest occurred less frequently than one-sided harvest, ranging from 8.3% to 50% of the segments. Less than 30% of the segments had two-sided harvest in 7 of the 10 stream width/site class categories. Two-sided harvest tended to occur more frequently in small stream categories.

This poses a sampling dilemma because some response variables, such as canopy closure are influenced by stands on both sides of the stream. Where the harvest prescriptions are done on only one side of the stream, these variables could be affected by riparian stand conditions on the opposite side which were likely harvested at various times under different prescriptions. This variability could confound our ability to associate riparian functions with the current prescription. On the other hand, it may be difficult to find an adequate sample of stream RMZ segments with two-sided harvest for some prescription variants.

Table 4. Proportion of Type F RMZ segments with one- vs. two-side harvest by stream width and site class grouping.

Stream Width	Site Class	Number of Segments	% with 2 sided harvest
	I	12	8.3%
	II	52	28.8%
>10ft	III	72	16.7%
	IV	6	16.7%
	V	9	33.3%
	I	9	11.1%
	II	40	37.5%
≤10ft	III	132	36.4%
	IV	4	25.0%
	V	10	50.0%
All combined	-	346	29.5%

After careful consideration, we designate only one side of a stream as the sample unit. We will include RMZ segments with both one- and two-sided treatments in the sample frame, but if a segment with a two-sided treatment is selected, one side will be chosen at random. Our rationale includes the following:

- including both one- and two-sided segments provides the largest sample frame with eligible sample units;
- the larger sample frame is more representative of the wide range of physiographic conditions on the landscape;
- there is variability in site conditions on the opposite bank, such as slope, aspect, or wind exposure, that have the potential to complicate or confound a two-sided analysis; and
- one-sided sample units facilitate more efficient allocation of field effort and allowing inclusion of more sample units for budget because a two-sided buffer requires double the effort per sample unit.

Where possible, we have attempted to structure the data collection to minimize confounding effects due to stand conditions on the opposite side of the stream (see Methods).

The presence of yarding corridors and the outer zone harvest strategy will not be used to exclude sites but will be treated as covariates. Yarding corridors consist of strips where trees are removed to allow logs to be transported across the stream. They are considered to be part of the RMZ harvest prescription and will be included when they occur in a study reach. The outer zone is the next band beyond the inner zone (Figure 1). Landowners are required to leave 20 trees/acre in the outer zone and can choose whether to clump or disperse the leave trees. We anticipate that the outer zone leave tree configuration will have little effect on the response variables, due to the small number of trees and the distance from the stream.

Randomized Sampling Procedure

The sampling frame for each prescription variant in Table 3 will be assembled from approved forest practice applications (FPAs) in the WDNR Forest Practices Application Review System (FPARS) database using the procedures described in detail in Appendix C. Each entry in the sampling frame will be a single RMZ segment that has been treated with a single prescription variant and is at least 150 m in length. To minimize the potential for spatial autocorrelation, only one FPA/RMZ segment will be accepted in each USGS Hydrologic Unit.

Prior to acceptance of a site in the sample frame, the landowner will be contacted to verify the harvest timing and obtain permission to visit the site. Next, a field visit will be conducted to verify that the harvest occurred as specified on the FPA, there is no CMZ or stream adjacent roads, and the RMZ segment is long enough to support a study reach.

Study Reach Layout

We propose a fixed study reach length of 100 m with each portion of the RMZ segment having an equal probability of being sampled. As such, we propose a random starting location at 25m increments. A schematic of study reach layout from different starting points are shown in Figure 4, with study reaches highlighted in yellow and an aerial photo with an example of the sample reach layout is shown in Appendix D). The first and last 25 m intervals at the end of the RMZ segment would be excluded from sampling (highlighted in orange in Figure 4). If the full length of the study reach cannot be accommodated before the end of the segment is reached, the remaining portion of the study reach would be continued at the opposite end of the segment on the same side of the stream. While logistically cumbersome, such an approach ensures that all areas along the length of the RMZ segment have an equal probability of being sampled. We proposed using the 100 m long sample unit instead of using multiple smaller plots because of the extra cost and logistical challenges of implementing a multiple plot design.

Unharvested areas. Some RMZs include areas where the harvest treatments are not applied due to other constraints, such as areas that receive no-harvest buffers due to unstable slopes, wetlands, or tributary junctions, or areas where harvest is not economically or operationally feasible. If an unharvested area is <25 m in length it will be skipped (not sampled) and the study reach layout will continue on the far side (Figure 4, bottom row). If the unharvested area is >25 m in length, the study reach starting point will be relocated to a new random start point that meets the 150 m minimum length criterion for a study reach.

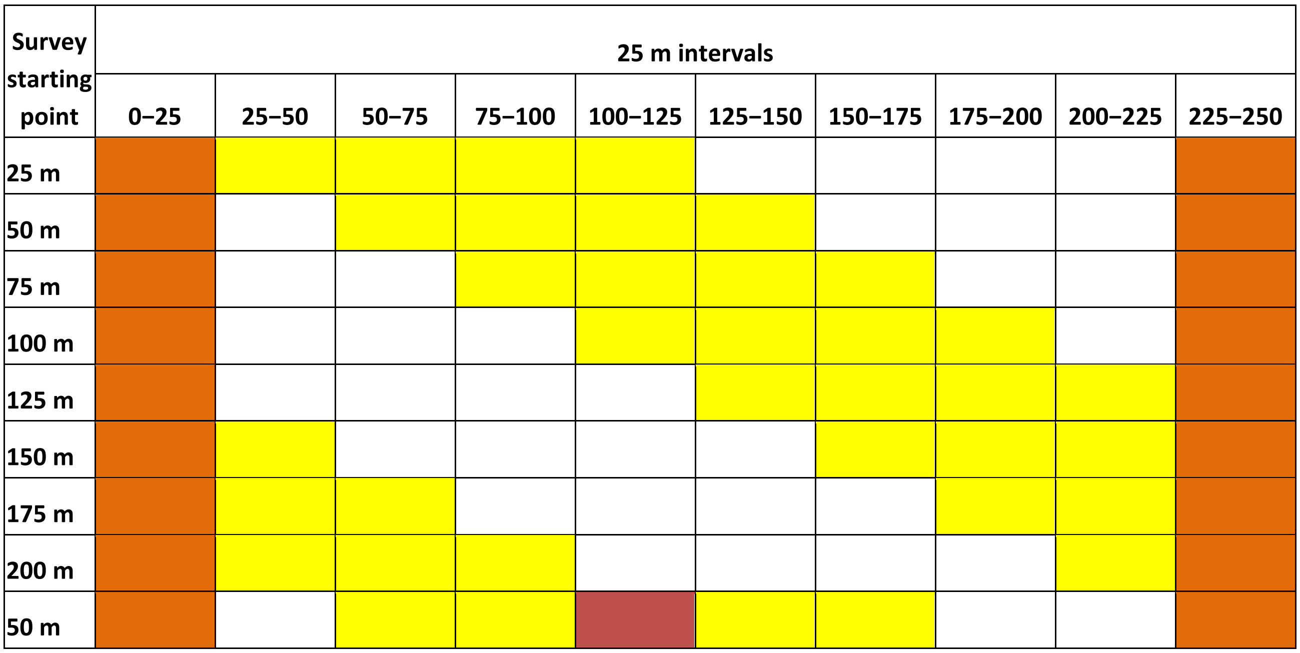

Figure 4. Example of layout options for 100 m long study reaches beginning at different possible starting points within a 250 m long RMZ segment. The study reaches are highlighted in yellow. The 25 m areas at the edge of the segment that would not be sampled are highlighted in orange. The bottom row shows an unharvested area within the study reach (highlighted in red) that would not be sampled.

Road crossings. Approximately 2% of the segments in the FPA/GIS analysis had perpendicular road crossings through the RMZ and over the stream. Segments with perpendicular road crossings will be disqualified and study reach layout will be handled as described above for unharvested areas >25 m in length.

Methods

Layout

Layout will begin by locating the downstream end of each selected RMZ segment. The crew will then walk the segment measuring the length in meters. The starting point of the study reach will be randomly selected and the starting and end points of the survey reach will be monumented with a permanent stake and flagging. The core, inner and outer zone boundaries along the study reach will be delineated using the methods described in McConnell and Heimburg (2010). All boundaries will be documented with a GPS.

Data Collection

Stand structure

Data will be collected on all standing live and dead trees with diameters ≥4 inches at breast height [4.5 ft (1.37 m) above ground] that are within the core or inner zone of the RMZ. Data recorded for each tree include the condition (live or dead), species, diameter at breast height (DBH) and regulatory zone (core or inner). The canopy class (overstory, understory, or open) is recorded for live trees. Data recorded for dead trees includes decay characteristics (Table 5) and mortality agent (e.g. wind, bank erosion, suppression, fire, insects, disease, and physical damage) when it was possible to determine. All stumps within the inner zone boundary will be counted and their diameter and height above ground will be measured.

Fallen trees and large wood recruitment

The RMZ will be surveyed to identify fallen trees that originate from within the core and inner zones of the study reach that recruited to the channel (i.e. a portion crossed the plane of the bankfull channel) during the post-harvest period. Pre- versus post-harvest downed trees will be differentiated using decay data collected on each down tree using the attributes and descriptors in Table 5. The species, DBH, source distance, zone (core or inner), and agent (e.g., bank erosion, windthrow) that caused the tree to fall will be recorded. Decay class has been successfully used in post-harvest studies to differentiate pre- versus post-harvest riparian stand mortality in Pacific coastal forests (Liquori 2006, Martin and Grotefendt 2007, Bahuguna et al. 2010, Schuett-Hames et al. 2012).

Recruited large wood (LW) includes pieces originate from trees that were growing within the core and inner zone of the study reach. Each piece must be at least 10 cm in diameter (small end of log) and 1 m in length, and a portion of the piece must extend across the plane of the bankfull channel edge, coming to rest either within or above the bankfull channel. Data will be collected on each recruited LW piece, including species, recruitment class, and in-channel functions. Separate lengths and midpoint diameters for the within- and above-bankfull portions will be used to calculate in-channel and over-channel recruited volume (Schuett-Hames et al. 1999).

Table 5. Decay attributes and descriptors that will be used to define pre- vs. post-harvest mortality from Robinson and Beschta (1990), Washington Dept. of Natural Resources (1996), Martin and Grotefendt (2007), Bahuguna et al. (2010).

Feature	Category
Leaves/needles	Green, Red, Brown, Absent
Bark	Intact, Partial (sloughing), Trace, Absent
Twigs (<3cm)	Present (many); Few–absent
Branches	Secondary branches present, Primary branches only, No branches
Wood texture	Intact, Smooth, Abrasion (some holes and openings), Vesicular (many holes/openings)
Shape	Round, Oval, Irregular
Color	Original (bright), Darkening (inc. gray weathering), Dark

Canopy closure/cover

Canopy closure data will be collected at systematic intervals along the study reach. The first measurement station will be located at the study reach boundary and additional measurements are taken at 25m intervals, with the last station at the far study reach boundary (for a total of five measurements). Two procedures will be used to collect canopy closure measurements at each station using a concave spherical densiometer.

The first procedure is described in the Forest Practices Board manual for evaluating canopy closure. Measurements will be taken at the center of the stream with the densiometer held one meter above the water surface. Four readings are made at each station viewing a reflected image of the stand in the densiometer facing upstream, downstream, left bank, and right bank, counting the number of points (from a total of 96) with obstructed view to sky (Pleus and Schuett-Hames 1998). Percent canopy closure is calculated for each station by averaging the four readings and multiplying by 1.04 (Strickler 1959).

The second procedure consists of a single reading taken at the channel edge facing towards the RMZ being sampled (Platts e t al. 1987, Mills and Stevenson 1999). This procedure has the advantage of measuring canopy density for the stand being surveyed by eliminating variability from the trees on the other side of the stream and by taking measurements at a consistent distance from the RMZ regardless of stream width. The reading is taken using 17 dots in a wedge-shaped portion of concave spherical densiometer (Strickler 1959; Platts et al. 1987). The percentage canopy closure for each station is calculated by multiplying the total number of obstructed dots by 5.88 and the average will be computed from all stations within the study reach

Soil disturbance

Surface erosion within the core and inner zone, and potential sediment delivery to the stream will be assessed by examining the stream bank and RMZ using methods based on Litschert and MacDonald (2009). Data will be collected on the length, average width, distance to edge of the bankfull channel and channel delivery (yes, no) for each erosion feature. The type of disturbance (e.g. root-pit, yarding, bank erosion, mass wasting) will be noted.

Metrics

Table 6 identifies the metrics that will be used in the analyses and describes how they will be computed. The procedures to calculate tree mortality and trajectory to DFC are described in more detail in the following section.

Tree mortality

The number and basal area of trees that died since harvest will be estimated from the decay class of dead and fallen trees. Annual post-harvest mortality rates will be calculated using the formula in Table 6. To use decay class to estimate mortality, we will create a list of all dead and fallen trees that exhibit recent mortality that occurred since timber harvest). Recent mortality will be estimated from the relationship between decay attributes and time since mortality for each dead tree. Table 7 shows examples of how decay data and time since mortality relationships have been successfully used in studies of snag mortality and for estimating rates of riparian large wood recruitment (Martin and Benda 2001, Benda et al. 2002, Hennon et al. 2002; Liquori 2006, Bahuguna et al. 2010, Schuett-Hames et al. 2012).

Table 6. Description of methods used to calculate metrics used in the analysis.

Metric	Calculation	Description
Stand structure		
Stem density (post-harvest)	Live stem count divided by acreage (by core and inner zone)	trees/acre
Basal area (post-harvest)	Calculate basal area for each live tree using the formula: *basal area (ft^2) = 0.005454*dbh^2 (inches).* Sum live tree basal area for each segment and divide by acreage (by core and inner zone).	ft^2/acre
Mortality		
Mortality rate as percent of initial live stem count	Calculated as an annualized rate: *%count/yr = ([ending live tree count/immediate post harvest live tree count]^[1/number of years in period])-1*	%stems/yr
Mortality rate as percent of initial live basal area	Calculated as an annualized rate: *%basal area/yr = ([ending live tree basal area/beginning live tree basal area]^[1/number of years in period])-1*	%basal area/yr
Large wood recruitment		
LW recruitment rate by piece count	Calculated as a rate: LW pieces recruited/100m/yr = ([LW pieces/reach length in m]*100)/years in period	pieces/100 m/yr
LW recruitment rate by volume	Calculated as a rate: ([LW volume in m^3/reach length in m]*100)/years in period	m^3/100 m/yr
Canopy closure/cover		
Percent canopy closure- 4 directions	Sum the counts of obstructed points for each of the 4 readings at each station. Divide by 4 and multiply by 1.04. Average the station values to calculate the mean for each study reach.	% 4d canopy closure
Percent canopy closure-towards RMZ	Count the number of obstructed points (out of 17 possible) and multiply by 5.88. Average the station values to calculate the mean for each study reach.	% RMZ canopy closure
Soil disturbance		
Erosion surface area	Sum the surface area (m^2) of sediment delivering erosion features, divide by study reach length in m and multiply by 100.	m^2/100 m
Trajectory to DFC		
DFC target performance target	Run DFC worksheet using live tree list for each study reach to determine if basal area meets or exceeds DFC target (325 ft^2/acre at age 140). Calculate the proportion of segments in each strata projected to meet the target. For sites with <325 ft^2, divide projected basal area by 325 to determine percent difference.	Proportion of site projected to meet target % of target DFC

We recognize that the published relationships for decay class and time since mortality may need to be calibrated for the species and climate applicable for our study area. Therefore, we will use tree mortality data from a field survey of marked dead trees in the CMER Type N "soft rock" study (Ehinger et al., 2011) to establish decay class relationships for species common to the proposed study area.

Table 7. Examples of published estimates for time since death for snags, down trees, and large wood recruits by decay class for two Pacific coastal regions.

		Mean time since death (yrs)		
Category	**Description**	**Martin & Benda 2001 conifer, Southeast AK**	**Benda et al. 2002 conifer, coastal CA**	**Benda et al. 2002 deciduous, coastal CA**
1	Foliage (live/dead leaves and needles) present	--	2.7	1
2	Twigs present	7.6	4.1	4.1
3	Secondary branches present	10.1	5	4.7
4	Primary branches present	18.7	14.3	8.8
5	No branches remaining (nubs may be present)	30.3	24.3	19.3

Analysis

The goals of data analyses are to:

- identify and assess the relative magnitude of differences in riparian stand conditions and functions among the prescriptions variants,
- estimate the proportion of stands that are projected to achieve the DFC performance target and erosion performance target,
- evaluate the post-harvest riparian stand conditions and riparian ecological functions across prescription variants, and
- summarize pilot study results to inform the more intensive BACI follow-up study once BACI study objectives and budgets have been finalized.

The analyses will consist of a combination of approaches including: 1) comparing and contrasting post-harvest study variables among RMZ treatments using parameter estimates and associated estimates of uncertainty, and 2) comparing post-harvest conditions to the FPHCP resource objectives and performance targets. The approach, or combination of approaches, will vary depending on the question of interest.

Estimating means and confidence intervals for response variables and comparison of post–harvest response variables among prescription variants

A mean with confidence intervals, as well as box plots of the observed range of values will be calculated for each response variable for each prescription variant. The 90% confidence intervals and distribution of values will be examined to assess the variability in the metrics measured for each prescription variant, and to identify particular instances where unusually large differences occurred.

We intend for the results to be primarily these estimates, associated confidence intervals, graphical comparisons, pilot data, and the understanding that comes with them. These results will be able to answer questions such as:

- How variable is large wood recruitment within prescription variants?
- Do we see that mean large wood recruitment is very different from one prescription variant to another?
- Which prescription variants have the largest values for large wood recruitment and which the smallest?
- Can we see any patterns in which differences in mean large wood recruitment or differences in variability of large wood recruitment occur systematically such as between prescription variants with inner zone harvest and without or between prescription variants on large versus small streams or along spatial gradients in where prescriptions exist along the landscape?

Because there is a general interest in understanding how response to prescription variants might differ across the landscape or in response to specific conditions that we do not have adequate sample size to control for, we may be able to create models. These models are a byproduct of the study and not the main purpose of the study.

Factors, e.g., covariates, that might be investigated with models include the following:

- All covariates inherent in the prescription variants such as stream size, site index, harvest in the inner core;
- Essential ecological factors that may vary by site such as exact stream width (note that only large and small are included above), elevation, aspect, longitude, and latitude;
- A set of variables to explore wind exposure including aspect (also included above because aspect might also relate to solar energy inputs and potential growth rates), buffer orientation / exposure, and fetch. These three variables will also be combined into a categorical (1−5) ranking of wind exposure (Rollerson et al. 2009).
- A small set of harvest features that we cannot capture with additional stratification but which we would like to understand better before designing the BACI study. These include presence of harvest on the opposite bank, total length of stream treated, presence/absence of yarding corridors, outer zone harvest strategy.

Models would generally take the following form. We note that, given sample size constraints, there would likely be at most only one factor and an interaction or two factors with no interaction but the full model form is described for completeness. All models would be exploratory rather than confirmatory. We are looking for patterns that might help us build a better BACI design or that might lead to further testing with additional data. We are not testing hypotheses or attributing causation:

$$\text{Response (Table 6)} \sim \text{Prescription} + \text{Factor1} + \text{Factor 2} + \text{Prescription:Factor1} + \text{Prescription:Factor2} + e$$

Such models might be simple linear models if all factors were fixed and the distribution of the residuals could be assumed to be normal. Such models might be as complicated as generalized linear mixed effects models if one of the factors were considered a random effect and the residuals were likely from a non-normal distribution. Models could be used to quantify differences in response among the prescription variants, to determine whether harvest on the opposite bank, presence of yarding corridors or outer zone harvest strategy needs to be accounted for in the full BACI study, and to estimate where specific responses can be pooled across prescription variants. For example, in an analysis of windthrow mortality it may be possible to combine the Site Class V large and small stream strata (60−66 ft buffers) for a comparison with much wider buffers (e.g. Site Class III small and large stream strata;93−105 ft buffers). In no case would strata with inner zone harvest be combined with strata with no-inner-zone-harvest.

Spatial autocorrelation between sites may be an issue but we have minimized it to the degree possible. First, we are restricting the sampling design to allow only one study site per USGS HU. This will maximize spatial spread given our stratified random sampling plan. We will also explore whether latitude and longitude describe trends in the data for each response metric. If there are, for example, East-West trends in stand structure after harvest, this will be essential to incorporate in the BACI design and in our descriptive assessment of on-the-ground conditions in this pilot study. Lastly, we will incorporate factors that describe wind exposure. There are three possible variables (aspect, orientation of buffer, and fetch) which can be explored one by one and as a combined 1−5 categorical ranking of wind exposure (Rollerson et al. 2009). Lastly, we can plot residuals from our descriptive models above in space to visually explore whether there is spatial pattern remaining. Spatial covariance would likely lead to confidence intervals on our effects that are slightly smaller than they should be if the data were independent. If we find evidence of residual spatial covariance, we can note this potential impact in our findings.

Comparison with existing performance targets

We will determine the percentage of RMZ segments in each prescription variant grouping that meet or exceed the performance targets for stream bank/equipment limitation zone disturbance and the DFC target for riparian condition in Appendix N of the FPHCP.

Erosion data from each segment will be compared used to determine the percentage of segments in each prescription variant that meet the stream bank/equipment limitation zone disturbance target of no stream bank disturbance outside of road crossings.

The DFC worksheet (https://fortress.wa.gov/dnr/protection/dfc/DfcRun.aspx) uses stand inventory data in conjunction with a stand growth model to project basal area per acre in the combined core and inner zone at a stand age of 140 years. We will run the DFC worksheet with stand data from each RMZ segment to predict basal area at age 140 for each segment. The results will be used to: 1) estimate the change in projected trajectory for each site, 2) determine if the site meets the target of 325 sq ft of basal area at 140 years, and the percent deviation above or below the target, and 3) estimate percentage of sites on target for each prescription variant.

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Appendix A. Forest Practice Application-Geographic Information System (FPA-GIS) Analysis

Purpose

This document describes an office review and analysis of forest practice applications (FPAs) to supply information to inform the design of the Western Washington Type F Prescription Monitoring Project pilot study. The purpose of this analysis is to determine how frequently different variations of the western Washington prescriptions for Type F (fish-bearing) and Type S (shorelines of the state) riparian management zones (RMZs) are being implemented, regional distribution patterns, and provide information on the characteristics of sites where the prescriptions are being applied.

Methods

Data were collected on Type F and S stream segments in harvest units contained in a random sample of Forest Practices Applications (FPAs) selected from the Washington Department of Natural Resources (WDNR) Forest Practices Application Review System (FPARS) database. The information used in this process came from:

1. archived PDFs in the DNRs Forest Practice Application Review System (FPARS) https://fortress.wa.gov/dnr/protection/fparssearch/, and
2. DNRs FPARs Geographic Information System (GIS) database http://www.dnr.wa.gov/GIS

To be included in the survey, each FPA had to meet the following criteria:

- timber harvest along a Type F water within the area of the proposed FPA (this criterion excludes FPAs where harvest is restricted to salvage or road right-of-ways)
- harvest under the "standard" westside Type F forest practices rules (this criterion excludes Alternate Plans, Habitat Conservation Plans, conversions to other land uses, 20 acre exempt parcels, and hardwood conversions)
- an effective date between 2008 and 2013
- within the Northwest, Olympic, Pacific Cascade, or South Puget Sound DNR regions

Sample selection and data collection procedures

The process used to screen FPAs included four steps:

Step 1. Select potential FPAR data for analysis

Download the FPARs data (GIS unit boundary shapefile and associated attribute table) and select those FPA/units with the desired characteristics.

EFFECTIVE_DT (Effective date): select for dates between July 1, 2008 and June 30, 2013 (dates likely to have been harvested within our harvest window (June 2011-July 2013).

REGION_NM (DNR region): select for Northwest, Olympic, Pacific-Cascade or South Puget Sound (excludes eastside regions).

DECISION (Status of Application): select for APPROVED or RENEWAL (excludes applications that are not approved for harvest).

ALTERNATE_PLAN_FLG (Alternative Plan Submitted): exclude Y (excludes activities conducted under an alternative plan).

HABITAT_CONSERVATION_FLG (Application covered by Habitat Conservation Plan): select for blanks- (excludes activities conducted under a Habitat Conservation Plan).

CUTTING_OR_REMOVING_TIMBER_FLG (Involves cutting or removing timber): select for Y (excludes FPAs without timber harvest, e.g. road construction, chemical application).

EXEMPT_20_ACRE_RMZ_FLG (Application qualifies for less than 20 acre parcel RMZ prescription): exclude Y (excludes FPAs with RMZ harvest under special 20 acre parcel exemption).

HARDWOOD_CONVERSION_FLG (Hardwood conversion applications): exclude Y (excludes hardwood conversion applications).

TIMHARV_FP_TY_LABEL_NM (harvest type): select for EVEN AGE, UNEVEN AGE, EVEN/SALVAGE, UN/SALVAGE, EVEN R/W, UNEVEN R/W (excludes FPAs limited to right-of-way, salvage, or no harvest).

CMZ_PRESENT_FLG (channel migration zone): exclude Y (excludes RMZs with channel migration zone buffer present)

Step 2. Identify FPAs within 200 ft of a Type F or S stream.

Using WDNR statewide hydrography (downloaded 16 January 2016 from www.dnr.wa.gov/GIS), restrict the hydro layer to F and S segments and use the ArcGIS Near function to identify those FPAs from Step 1 that are within 200 ft of a Type F or S stream.

Step 3. Put list of selected potential FPARs units in random order.

Use an ArcGIS script to assign a random integer between 1 and 1000000 to each FPA, sort on the random number, and work systematically through the sorted list.

Step 4. Screen the FPAs in assigned order to verify there is a Type F or S stream in or adjacent to the harvest unit.

Working thru the randomized list of FPA numbers from the top, ArcGIS was used to overlay the FPARs unit boundary polygon on the 2013 NAIP imagery and the WDNR hydrography to verify that there was a Type S or F stream in the unit and to determine if the unit was harvested prior to 2013. If no type F or S stream was present in the unit the FPA was rejected. The data were manually screened to remove duplicate records, or FPAs with HCPs or Alternative Plans that were missed in Step 1.

Step 5. Collect data on attributes of interest for each of the selected FPAs.

Using the FPARs database, the pdf file for each FPA, the FPARs unit boundary polygons, and other GIS information (hydrolayer, NAIP imagery, DEM, SSHIAP) extract and record the data on each Type F or S stream segments identified in each FPA. Table 1 (next page) shows the data attributes and provides a brief description of the procedures to obtain the information.

Table 1. FPA-GIS analysis data attributes and procedures.

Field	**Description**	**Source**	Procedures
FPA Number	FP_ID, unique identifier for each FPA.	FPARs database	Copy data field in FPARs database
DNR region	REGION_NM, DNR region	FPARs database	Copy data field in FPARs database
Landowner Name	Name of legal landowner	FPA pdf	Manually extract from FPA pdf and type in spreadsheet
Project name	Landowner name of project/unit	FPA pdf	Manually extract from FPA pdf and type in spreadsheet
County	County FPA is located in	FPA pdf	Manually extract from FPA pdf and type in spreadsheet
WAU	WAU FPA is located in	FPA pdf	Manually extract from FPA pdf and type in spreadsheet
WRIA	WRIA FPA is located in	FPA pdf	Manually extract from FPA pdf and type in spreadsheet
Harvest Type	Type of harvest (even, uneven age, salvage)	FPA pdf	Copy data field in FPARs database
Effective Date	EFFECTIVE_DT, month/day/yr activities may begin.	FPARs database	Copy data field in FPARs database
Harvested by 2013?	Unit harvested on 2013 NAIP photography	2013 NAIP imagery	Overlay FPAR harvest unit polygon with 2013 NAIP imagery
Stream segment	Individual Type F segment identifier	Table 21 in FPA pdf file	Manually extract from FPA pdf and type in spreadsheet
Water type	Water Type classification	Table 21 in FPA pdf file	Manually extract from FPA pdf and type in spreadsheet
site class	DNR site class	Table 21 in FPA pdf file	Manually extract from FPA pdf and type in spreadsheet
stream width	Average stream width	Table 21 in FPA pdf file	Manually extract from FPA pdf and type in spreadsheet
stream width cat	Greater than or less than 10 ft	Table 21 in FPA pdf file	Calculate based on stream width in FPA table
Inner zone harvest	Yes or No, If yes, record code for inner zone harvest	Table 21 in FPA pdf file	Manually extract from FPA pdf and type in spreadsheet
Outer zone harvest	Yes or No, If yes, record code for outer zone harvest	Table 21 in FPA pdf file	Manually extract from FPA pdf and type in spreadsheet
CMZ present	Channel migration zone present	Table 21 in FPA pdf file	Manually extract from FPA pdf and type in spreadsheet
Total RMZ width	Width of total RMZ (core+inner+outer)	Table 21 in FPA pdf file	Manually extract from FPA pdf and type in spreadsheet
DFC worksheet?	Yes if DFC worksheet included in FPA	DFC worksheets in FPA pdf.	Look for DFC worksheet in FPA (RMZ harvest codes D ore E)
Usable FPA map	Yes if activity map in FPA is legible and identifies location of stream segments in table	map in FPA pdf.	Examine FPA map provides useful information
RMZ length	Length of stream segment	DFC worksheet or NAIP	In DFC worksheet when present, otherwise GIS stream layer
1 or 2 sided RMZ	Harvest proposed on 1 or both sides of Type F stream?	FPA map, NAIP imagery	Examine FPA map and NAIP imagery
Stream Adjacent Road	Stream adjacent road present in RMZ	FPA Table 21, map, NAIP	Examine FPA map, NAIP imagery, RMZ harvest code G
Road stream crossing	Road stream crossing present in RMZ	FPA Table 21, map, NAIP	Examine FPA map, NAIP imagery, RMZ harvest code H
Yarding corridors	Yarding corridors present in RMZ	FPA Table 21, map, NAIP	Examine FPA map, NAIP imagery, RMZ harvest code J
Elevation	elevation of stream segment (lower, mid, upper)?	GIS-DEM	Extract from DEM
Gradient	channel gradient	GIS- SSHIAP	Extract from SSHIAP
Confinement	channel confinement	GIS- SSHIAP	Extract from SSHIAP
Basin Area	drainage area above segment	GIS-DEM	Calculate from DEM
Aspect	Stream aspect thru segment in downstream direction	GIS-NAIP imagery	Snap line from upper to lower segment boundary

Results

A total of 170 FPAs with harvest adjacent Type F and S streams were included in the analysis. These FPAs included 590 unique stream segments (an average of 3.5 per FPA) which varied in their classification by site class, stream width category, and the harvest option applied. The following results are based on analysis at the stream segment scale.

Geographic distribution

The western Washington Type F prescriptions are applied in four WDNR administrative regions. Half of the segments were located in the Pacific Cascade Region, which includes the Willapa Hills and the southwest slopes of the Cascade Range. Another 35% were in the Olympic Region, which includes the Olympic Peninsula outside of Olympic National Park. The remaining 15% occurred in the South Puget Sound and Northwest Regions (Table 2).

Table 2. Distribution of Type F and S stream segments by WDNR administrative region.

WDNR region	Count	Percent
Northwest	28	4.7%
Olympic	205	34.7%
Pacific-Cascade	295	50.0%
South Puget Sound	62	10.5%

Eighteen western Washington counties were represented in the sample (Table 3). Three counties, Grays Harbor, Pacific and Jefferson, accounted for 60% of the stream segments.

Table 3. Distribution of Type F and S stream segments by WDNR administrative region.

County	Count	Percent
Clallam	42	7.1%
Clark	2	0.3%
Cowlitz	31	5.3%
Grays Harbor	137	23.2%
Jefferson	105	17.8%
King	25	4.2%
Kitsap	2	0.3%
Lewis	30	5.1%
Mason	8	1.4%
Pacific	108	18.3%
Pierce	17	2.9%
San Juan	4	0.7%
Skagit	1	0.2%
Skamania	18	3.1%
Snohomish	14	2.4%
Thurston	21	3.6%
Wahkiakum	18	3.1%
Whatcom	7	1.2%

RMZ harvest options

The vast majority of the stream segments (92.9%) were on streams classified as Type F waters (fish-bearing). The remaining 7% were classified as Type S (shorelines of the state, also fish bearing). The same RMZ requirements apply to both classifications.

Prescription variants

The combination of site class and stream width determines the leave tree and RMZ width requirements in the Type F and S riparian prescriptions, so we examined the distribution of stream segments by both factors. Site class is typically determined from maps provided by WDNR, while stream width is determined from field measurements as described in the Forest Practices Board Manual.

Site class

Site class III (57%) and Site Class II (26%) together accounted for over 80% of the stream segments (Table 4). Site Classes I, IV and V each accounted for <10% of the segments, and only 17% when combined.

Table 4. Distribution of stream segments by site class.

Site class	Count	Percent
I	32	5.4%
II	152	25.8%
III	336	56.9%
IV	21	3.6%
V	49	8.3%

Stream width

Both the greater than 10 ft (large stream) and less than 10 ft (small stream) width categories were well represented in the sample, with a higher proportion classified as small streams (58%).

Table 5. Distribution of stream segments by stream width category.

Stream width category	Count	Percent
Greater than 10 ft	248	42.0%
Less than 10 ft	342	58.0%

Since site classes II and III comprised such a large proportion of the stream segments, it is not surprising that the site class III small and large stream categories had the greatest number of stream segments (37% and 20%, respectively), followed by the site class II large and small stream categories (both 13%). The remaining categories had ≤5% of the stream segments (Table 6).

Table 6. Distribution of stream segments by combined site class/stream width category.

Combined site class and stream width category	Count	Percent
Site Class I- large stream >10 ft	19	3.2%
Site Class I- small stream <10 ft	13	2.2%
Site Class II- large stream >10 ft	76	12.9%
Site Class II- small stream <10 ft	76	12.9%
Site Class III- large stream >10 ft	119	20.2%
Site Class III- small stream <10 ft	217	36.8%
Site Class IV- large stream >10 ft	15	2.5%
Site Class IV- small stream <10 ft	6	1.0%
Site Class V- large stream >10 ft	19	3.2%
Site Class V- small stream <10 ft	30	5.1%

The western Washington Type F and S riparian prescriptions regulate harvest in RMZs. If stocking is not adequate to meet the DFC performance target, no harvest is allowed in the inner zone. When stocking is adequate, landowners can use harvest Option 1 (thin from below) in any site class/stream width category. Option 2 (leave trees closest to the water) is allowed in Site Class I or II and the small stream category of

Site Class III. Two thirds of stream segments had no inner zone harvest (Table 7). Option 2 was done in 25% of the segments and Option 1 occurred less than 7% of the time, although it is the only option for removing timber in 5 of 10 site class/stream width categories. DFC worksheets are required for segments where inner zone harvest is proposed, so this information was available for about 30% of the stream segments.

Table 7. Distribution of stream segments by harvest option.

Harvest option	Count	Percent
No inner zone harvest	399	67.6%
Option 1- Thin from below	39	6.6%
Option 2- Leave Trees Closest to the Water (LTCW)	150	25.4%
Yarding corridor only	2	0.3%

Since the harvest characteristics (buffer width, leave tree requirements, and harvest configuration) will vary by site class, stream width category and harvest option, the distribution of stream segments in this framework of 25 potential categories (prescription variants) provides an indication of the likely distribution of the population of stream segments that could be sampled in the pilot study (Table 8).

Table 8. Distribution of stream segments by prescription variant.

Site class	Stream width category	Harvest option	Count**	Percent
I	large stream	No harvest	8	1.4%
I	large stream	Option 1	0	0.0%
I	large stream	Option 2	11	1.9%
I	small stream	No harvest	6	1.0%
I	small stream	Option 1	0	0.0%
I	small stream	Option 2	7	1.2%
II	large stream	No harvest	52	8.9%
II	large stream	Option 1	0	0.0%
II	large stream	Option 2	24	4.1%
II	small stream	No harvest	63	10.7%
II	small stream	Option 1	0	0.0%
II	small stream	Option 2	13	2.2%
III	large stream	No harvest	85	14.5%
III	large stream	Option 1	31	5.3%
III	small stream	No harvest	115	19.6%
III	small stream	Option 1	8	1.4%
III	small stream	Option 2	94	16.0%
IV	large stream	No harvest	15	2.6%
IV	large stream	Option 1	0	0.0%
IV	small stream	No harvest	6	1.0%
IV	small stream	Option 1	0	0.0%
V	large stream	No harvest	19	3.2%
V	large stream	Option 1	0	0.0%
V	small stream	No harvest	30	5.1%
V	small stream	Option 1	0	0.0%

* Opt 2 not allowed in SCIV, SCV, or SCIII>10ft

**1 segment listing an option 2 harvest on a SCIII >10 ft segment was not included, nor were 2 segments with yarding corridors only.

Together, five of the 25 prescription variants contained over 70% of the stream segments. Not surprisingly, three were from SC III and the other two were from SC II. The three SCIII variants included the small stream, no harvest option (20%), small stream, Option 2 (16%) and the large stream, no harvest option (14.5%). The two SCII categories included the small stream, no harvest option (11%) and the large stream, no harvest option (9%). Twelve other prescription variants had from 1 to 5 % of the stream segments each, and together comprised about 30% of the segments. The remaining eight prescription variants each had no stream segments in the sample. All eight were harvest option 1, thin from below, indicating that thin from below was not typically used, even when it is the only harvest method available to remove timber from the inner zone. These findings are also consistent with the CMER Desktop Analysis Report (McConnell 2007) results indicating that when given the choice, landowners choose Option 2 the vast majority of the time, or choose not to harvest under Option 1 based on leave tree and other stand requirements.

Other factors affecting RMZ harvest

Several other factors affect RMZ layout and stand conditions.

Road crossings

Perpendicular road crossings occurred in about 2% of the stream segments. In these cases, the RMZs were divided by a road right-of-way and crossing structure.

Stream-adjacent roads

In other cases, roads run parallel to the stream (stream-adjacent roads), occupy portions of the RMZ along the length of the stream. In these cases, special prescriptions are applied to compensate for trees harvested during construction of the road right-of-way. Stream-adjacent roads occurred in about 2% of the stream segments sampled, indicating that they are not widespread.

Channel migration zones

A special situation occurs when there is a channel migration zone (CMZ) between the stream and the RMZ. No harvest is allowed within the CMZ boundary, so in effect the width of no-harvest buffer is increased by the width of the CMZ, which can vary greatly. CMZs occurred in only 2% of the stream segments sampled.

Yarding corridors

Yarding corridors are cleared strips running through the RMZ that allow logs to be transported across the RMZ. Yarding corridors were proposed for 2% of the stream segments sampled.

One- and two-sided harvest

In some cases, larger Type F streams are used as the boundary between units, so the harvest (and buffer) is applied to only one side of the stream, while in other cases harvest (with a buffer) occurs on both sides of the stream. The FPA does not explicitly identify whether harvest (and hence the buffer) is applied on one or both sides of the stream, so we examined the harvest unit maps for a subset of stream segments (346) to determine the proportion of one- and two-sided harvests.

In total, about 30% of the stream segment had two-sided harvest. The proportion of segments with two sided harvest ranged from 8-50% among site class-stream width groupings. Two-sided harvest occurred somewhat more frequently in small streams than for large streams in the same site class category.

Table 9. Proportion of stream segments with one- and two-sided harvest by site class and stream width.

Stream width category	Site class	Segment count	1 sided harvest count	2 sided harvest count	% of two-sided harvest
large	I	12	11	1	8.3%
large	II	52	37	15	28.8%
large	III	72	60	12	16.7%
large	IV	6	5	1	16.7%
large	V	9	6	3	33.3%
small	I	9	8	1	11.1%
small	II	40	25	15	37.5%
small	III	132	84	48	36.4%
small	IV	4	3	1	25.0%
small	V	10	5	5	50.0%
All combined		346	244	102	29.5%

Outer zone harvest

In the outer zone, the outermost portion of the RMZ, landowners have the option of clumping or dispersing required leave trees. The dispersal option was most common, selected in 65% of the stream segments, followed by clumping (17%) and mixed dispersal/clumping (16%).

Physical site characteristics.

A limited amount of information was collected on the physical stream characteristics and the setting in which they occurred, using available GIS data.

Channel gradient and confinement

Information on channel gradient and confinement was obtained from the Salmon and Steelhead Inventory and Assessment (SSHIAP) database at the Northwest Indian Fisheries Commission for a subset of sites (210) located within the SSHIAP project area (Water Resource Inventory Areas (WRIAs) 1-23.

Channel gradient varied greatly, with stream segments occurring in all channel gradient categories (Table 10). The greatest proportion of stream segments occurred in the 4-8% category (26%), followed by the <1% category (22%) and the 8-20% category (19%).

Table 10. Distribution of stream segment by channel gradient category.

Channel gradient category	Count	Percent
<1%	46	21.9%
1-2%	16	7.6%
2-4%	27	12.9%
4-8%	55	26.2%
8-20%	40	19.0%
>20%	26	12.4%

The majority of stream segments were classified as confined (69%), followed by unconfined (19%), and moderately confined (12%) (Table 11).

Table 11. Distribution of stream segment by channel gradient category.

Channel confinement category	Count	Percent

Confined	144	68.6%
Moderately Confined	26	12.4%
Unconfined	40	19.0%

The overall distribution of stream segments according to the gradient/confinement categories used in Washington's Watershed Analysis Process (Table 12) indicates that segments with confined channels occurred most frequently in higher gradient reaches (>2%), while Unconfined and moderately confined segments occurred more frequently in lower gradient reaches (<2%).

Table 12. Distribution of stream segments by channel gradient/confinement category.

Channel gradient-confinement category	Count	Percent
<1%, Confined	3	1.4%
<1%, Moderately Confined	10	4.8%
<1%, Unconfined	33	15.7%
1-2%, Confined	4	1.9%
1-2%, Moderately Confined	6	2.9%
1-2%, Unconfined	6	2.9%
2-4%, Confined	18	8.6%
2-4%, Moderately Confined	8	3.8%
2-4%, Unconfined	1	0.5%
4-8%, Confined	53	25.2%
4-8%, Moderately Confined	2	1.0%
4-8%, Unconfined	0	0.0%
8-20%, Confined	40	19.0%
8-20%, Moderately Confined	0	0.0%
8-20%, Unconfined	0	0.0%
>20%, Confined	26	12.4%
>20%, Moderately Confined	0	0.0%
>20%, Unconfined	0	0.0%

Basin area

Basin area upstream of the upper end of the segment was calculated using a routed digital elevation model (DEM). Basin area varied by 5 orders of magnitude (Table 13), however the majority of stream segments (83%) were between 1 and 100 acres in size.

Table 13. Distribution of stream segments by basin area.

Basin area	Count	Percent
< 1 acre	44	9.8%
1-10 acres	138	30.7%
10-100 acres	193	42.9%
100-1,000 acres	62	13.8%
1,000-10,000 acres	12	2.7%
> 10,000 acres	1	0.2%

Stream aspect

Distribution of stream segments by aspect category (measured on a line from the upstream to downstream unit boundary) was somewhat uniform among the eight categories, ranging from 9%-17%, with the highest proportions in the south, southwest and west categories.

Table 14. Distribution of stream segments by stream aspect.

Aspect Category	Count	Percent
N	53	11.4%
NE	47	10.1%
E	42	9.1%
SE	52	11.2%
S	80	17.2%
SW	71	15.3%
W	70	15.1%
NW	49	10.6%

Appendix B. Statistical “Power “Analysis for Exploratory Pilot Study

As in any pilot study, sample sizes are not as high as might be ideal. Never-the-less, it is important to consider how well the study design will perform using pilot data. Although we are not focusing on statistical testing, we call this a “power” analysis in that it explores the value of our data collection efforts in creating the information we need.

In the pilot study, we are not trying to detect a causal relationship but rather to get estimates of on-the-ground conditions and to assess whether and to what degree these conditions differ across prescription variants.

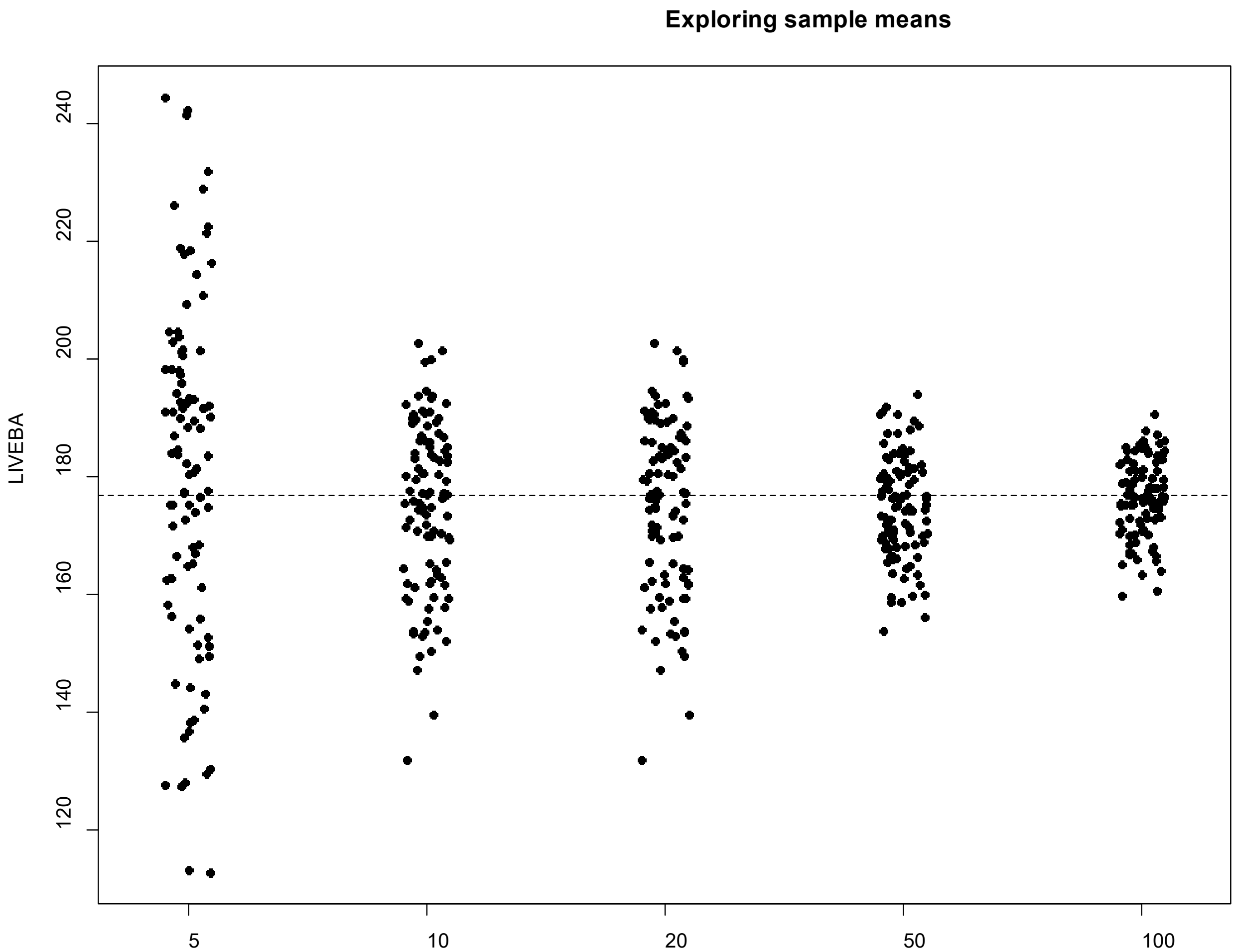
Using data from non-fish-bearing streams in western Washington that were harvested with 50 ft no-cut buffers from the Westside Type N Buffer Characteristics, Integrity and Function study, we conducted a simulation-based “power analysis” to explore two things.

First, we explored how much our estimates of the mean might vary for sample sizes of 5, 10, 20, 50, and 100. We know that we will take just one sample of a particular size, proposed size = 10. It is therefore useful to see how frequently samples of this size have a mean that is far from the truth (estimated by the dashed horizontal line). It is also useful to see how samples of other sizes might compare. These analyses were conducted using a simple Monte Carlo analysis with 100 draws (with replacement) of each sample size from the pilot data.

Second, we explored how the standard error of the mean varied by sample size. This was also conducted using a Monte Carlo simulation. The standard errors of the mean depicted here are the average standard errors over 100 simulations. These should be very close to what would be calculated through simple formulas for variables that are distributed normally but not all responses in the pilot data were distributed normally. Error bars describe a 90% confidence around the estimated mean.

There are limitations to these analyses in that we don’t know whether treated data might have altered variance structures; a sample of size n=100 drawn with replacement from a sample of size n=27 likely has somewhat reduced variability as compared to a true sample of size n=96; and, data are pooled from treated and untreated areas which may provide an increased estimate of variance. As well, there is no guarantee that the data we observe in this study will be similar in terms of distribution as these test data. However, as a general indication of how results may look with our proposed sample size of 10 sites per strata, these analyses are valuable.

The overall conclusions from this exploration is that we will have a reasonable estimate of the mean with a sample of size 10. Smaller samples fairly frequently yield estimates that are far from the truth. Samples that are even twice as big (n=20) are fairly similar in the frequency with which sample means are inaccurate. The se of the mean, of course, goes down in proportion to the square root of n for all variables. The projected 90% confidence interval seems reasonable for a pilot study in all cases.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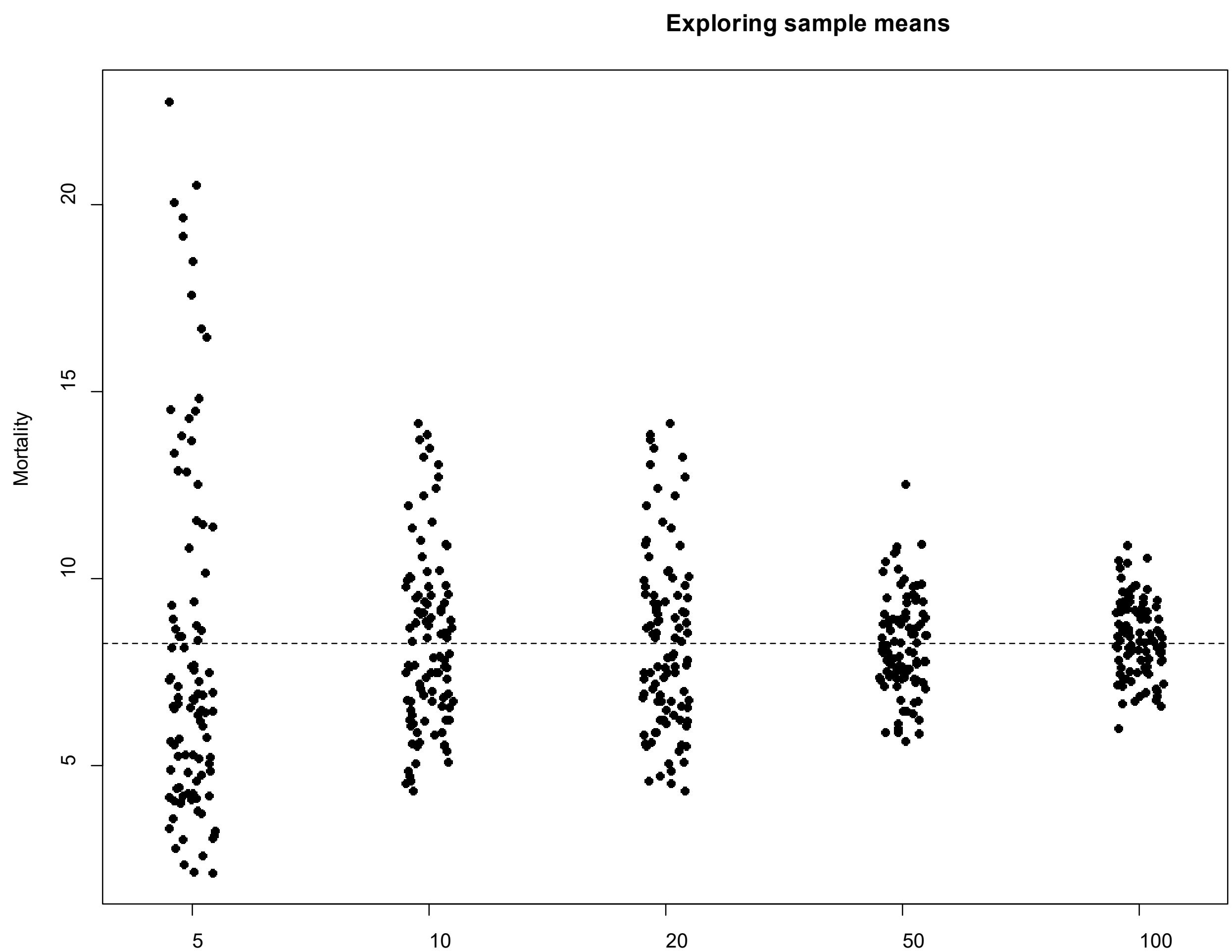
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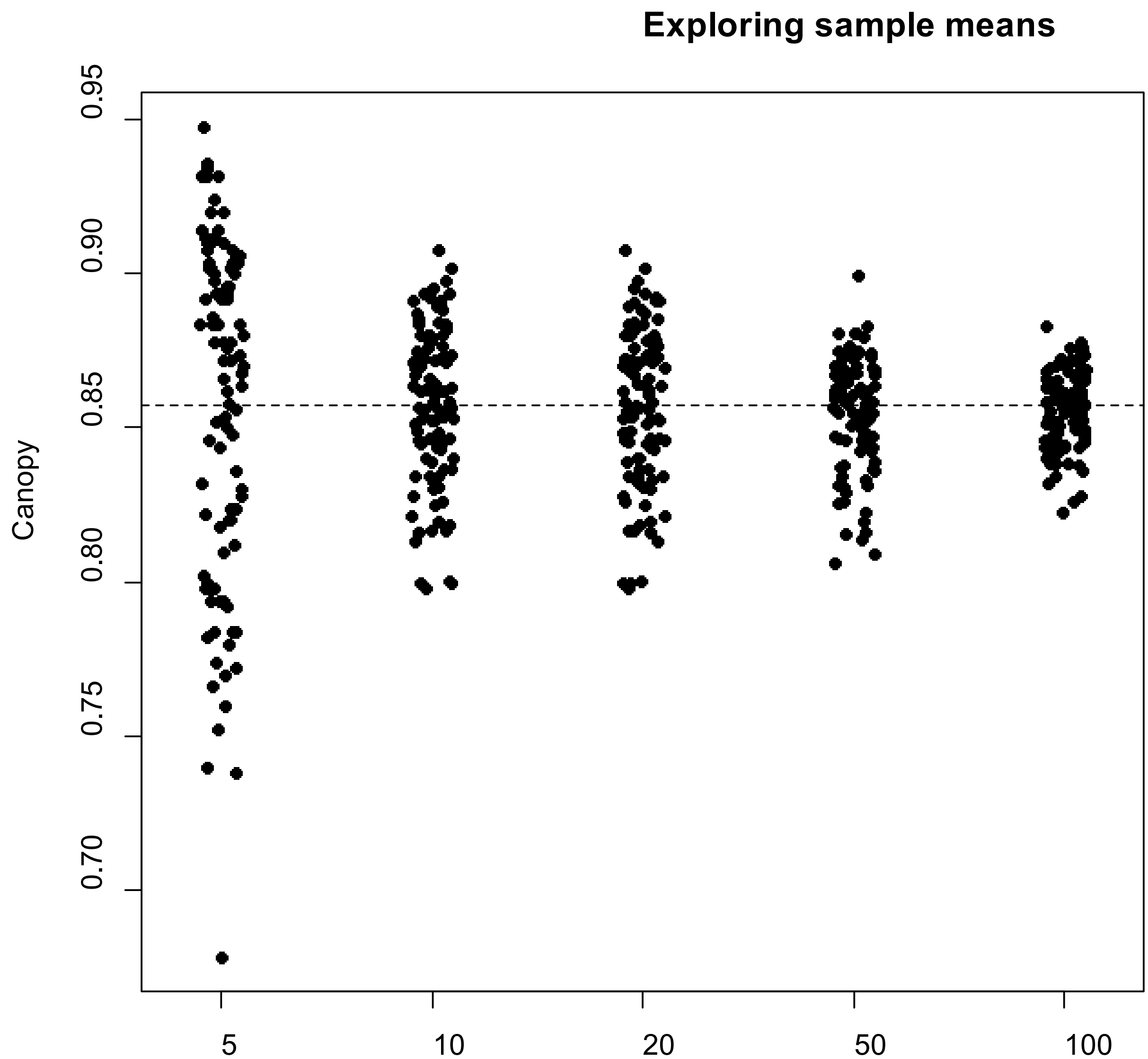
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5
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20
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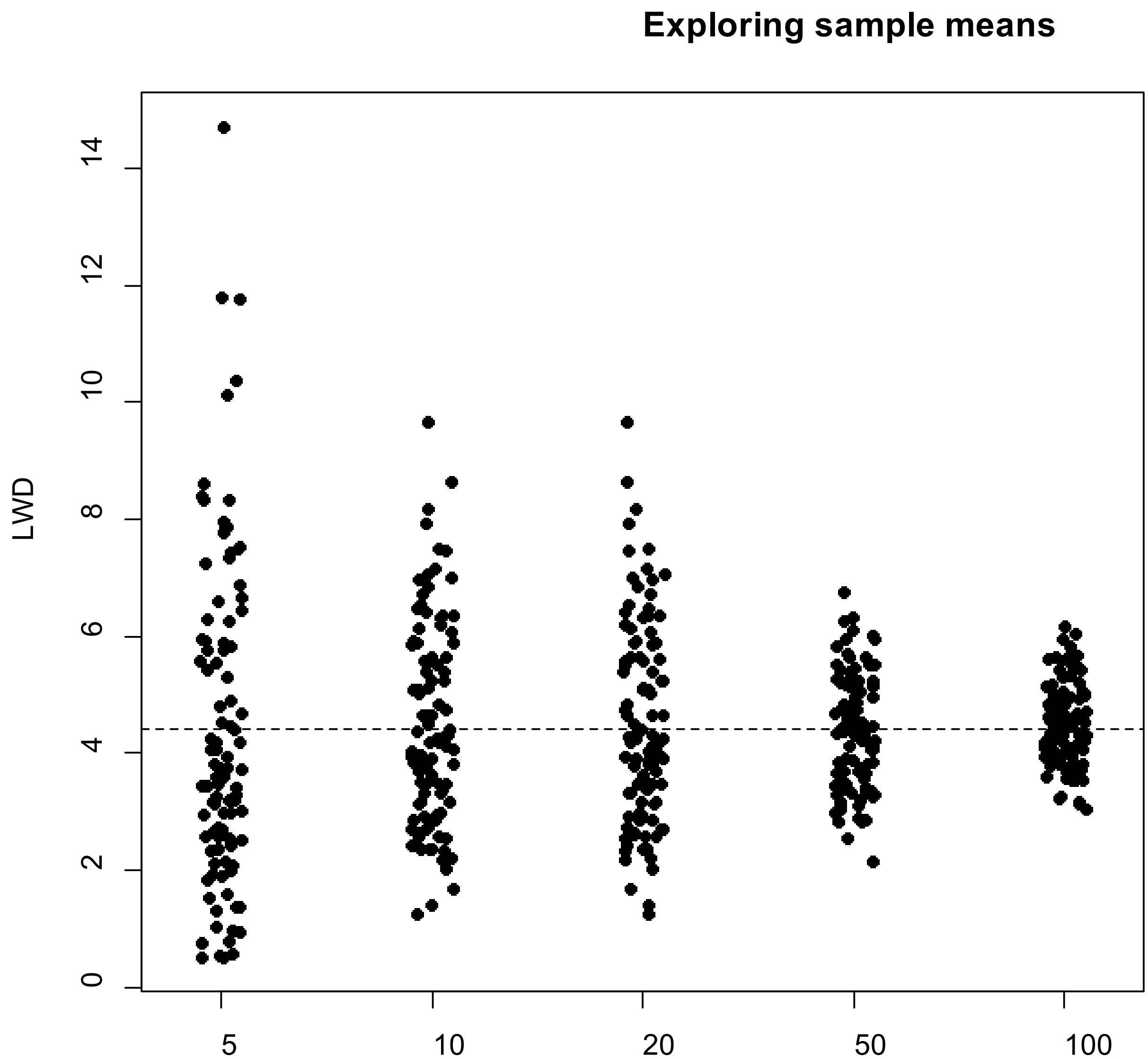
100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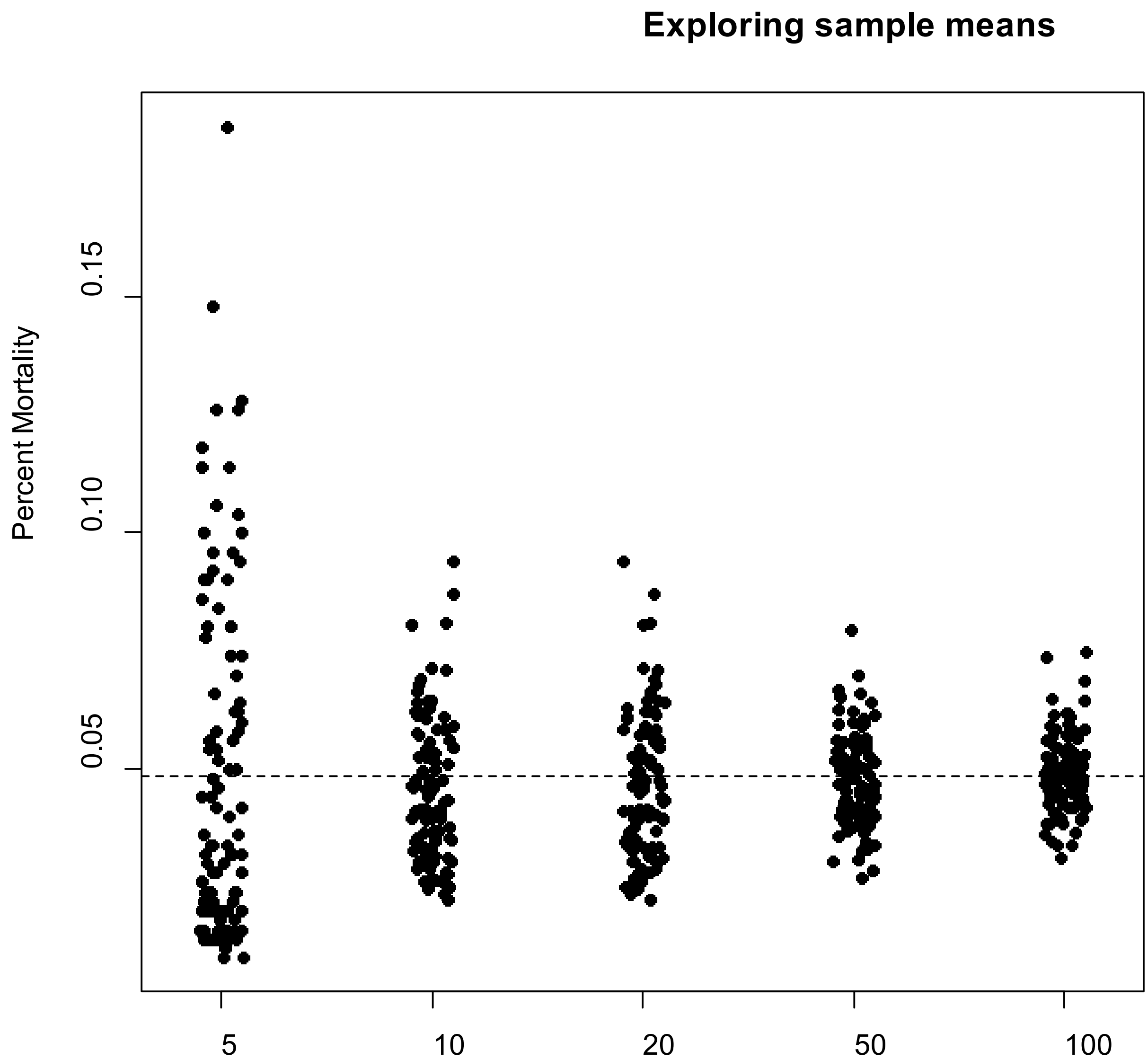
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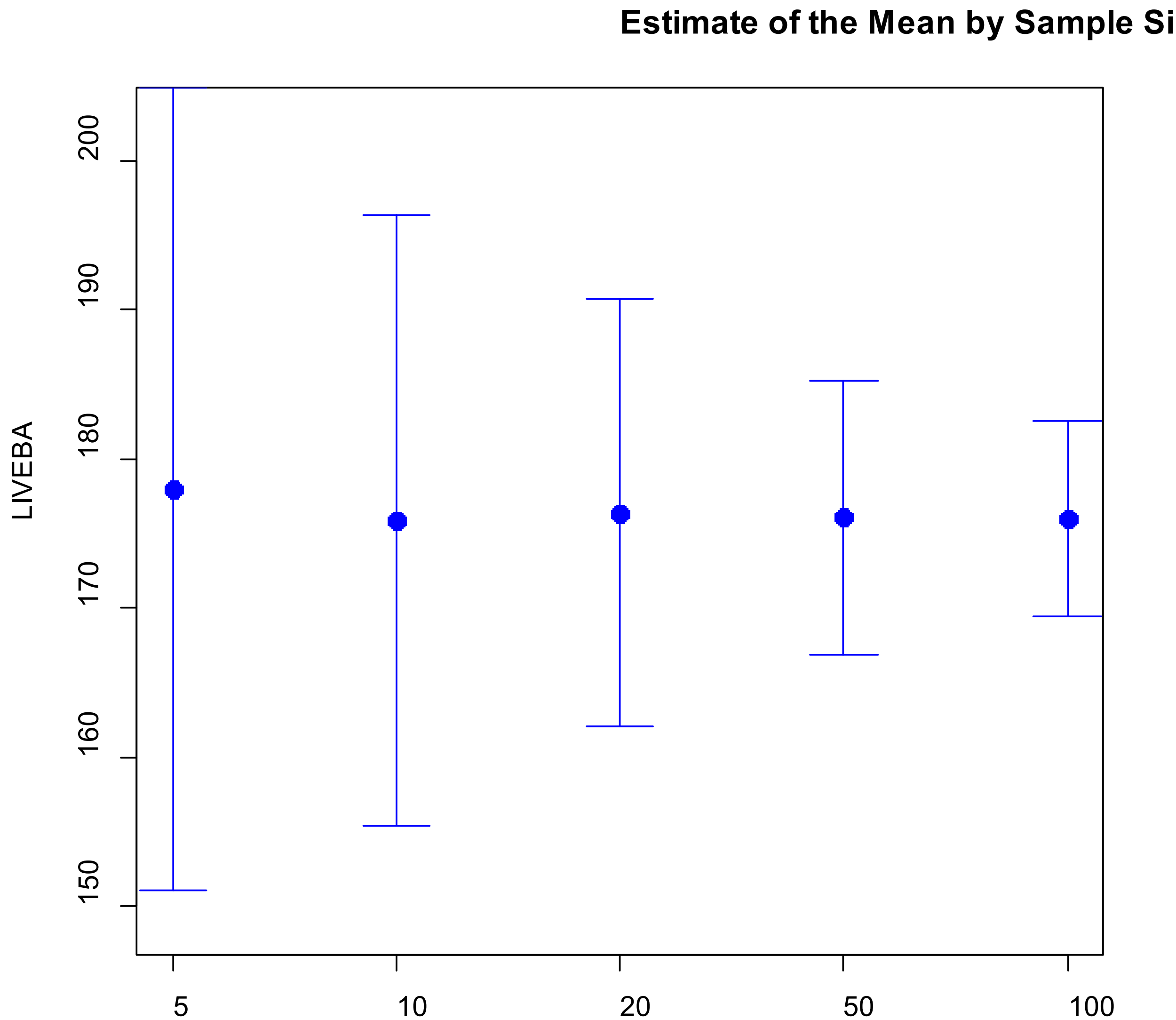
0.10
0.15
5
10
20
50
100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160
170
180
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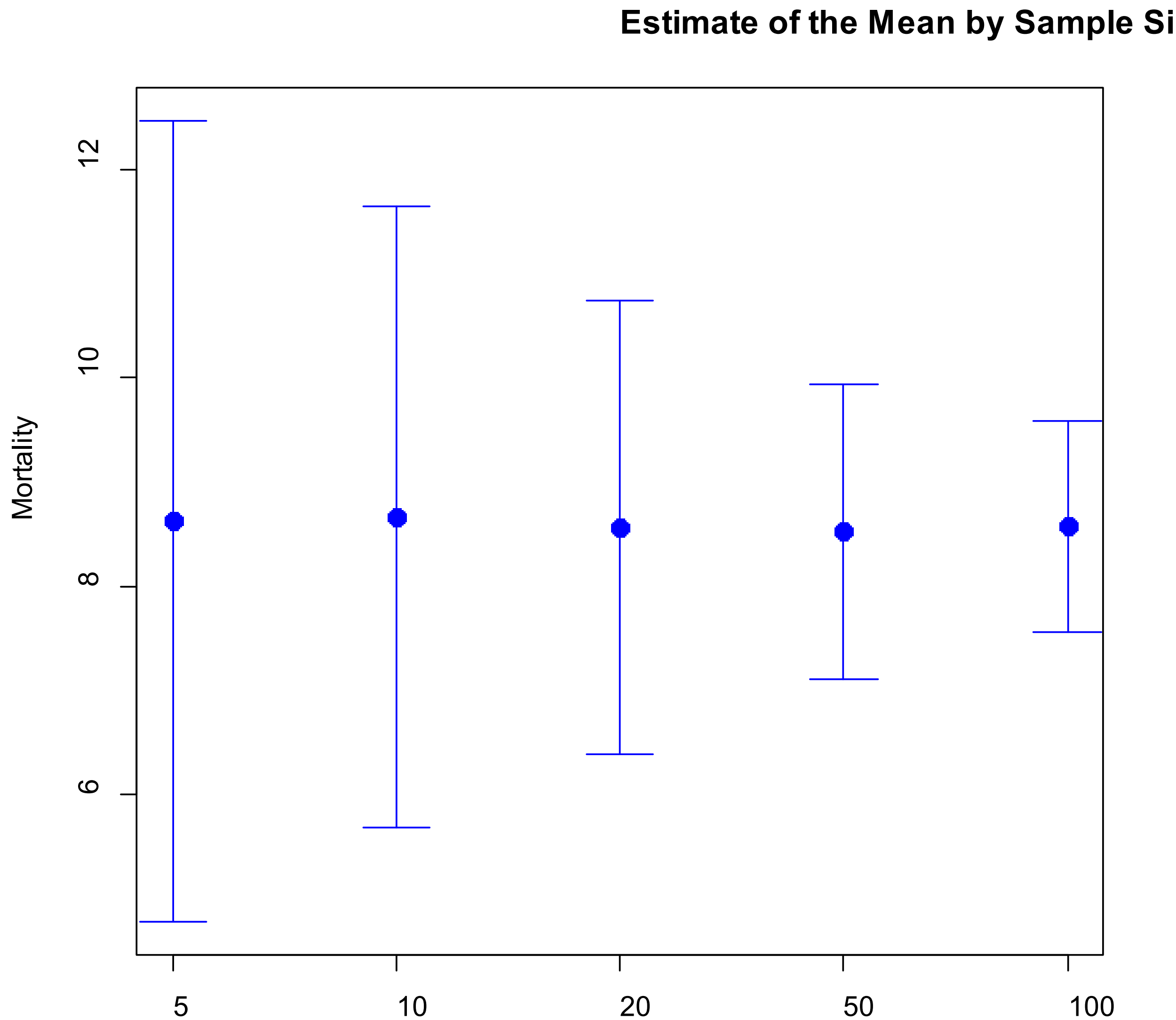
200
5
10
20
50
100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Mortality
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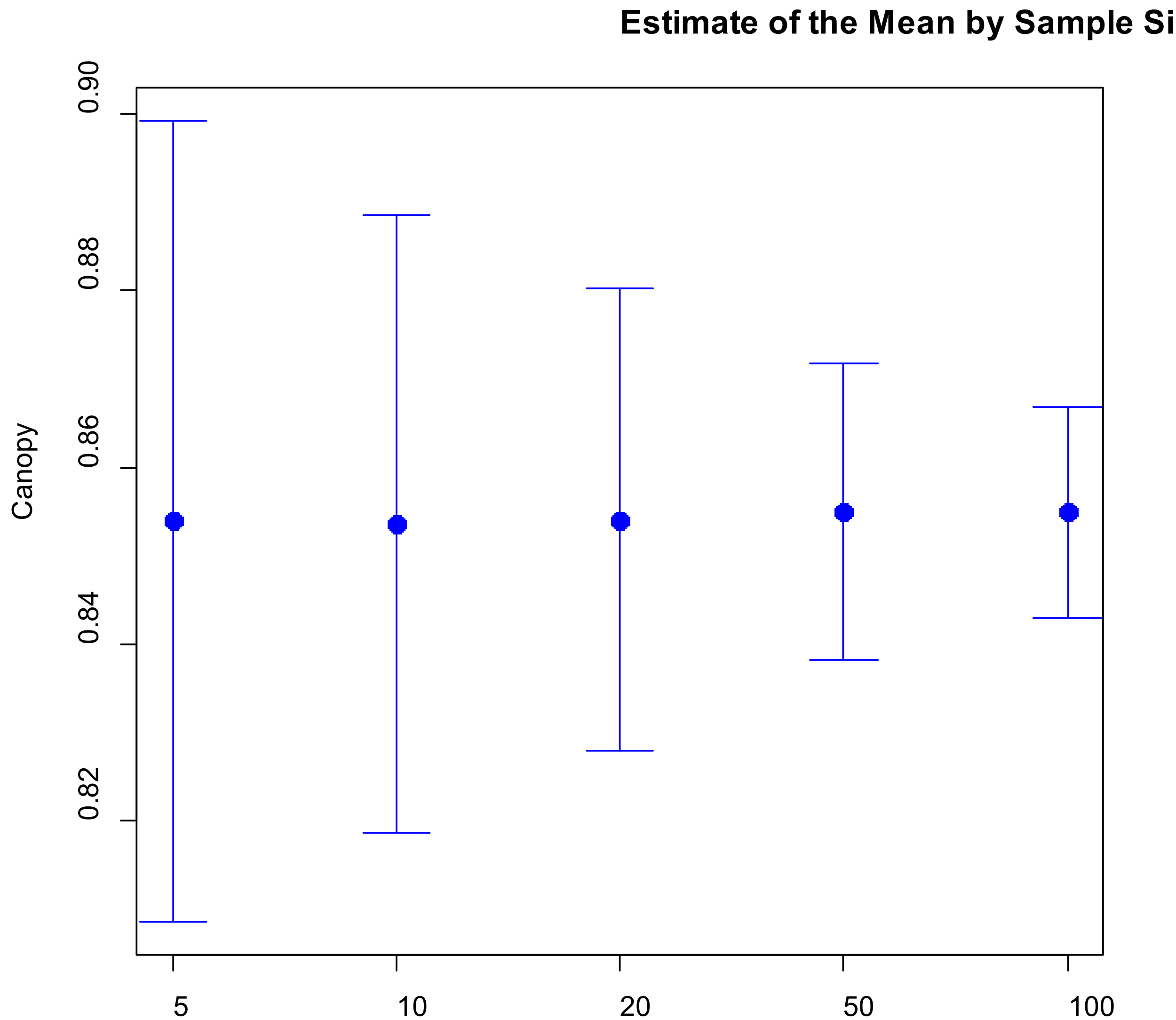
20
50
100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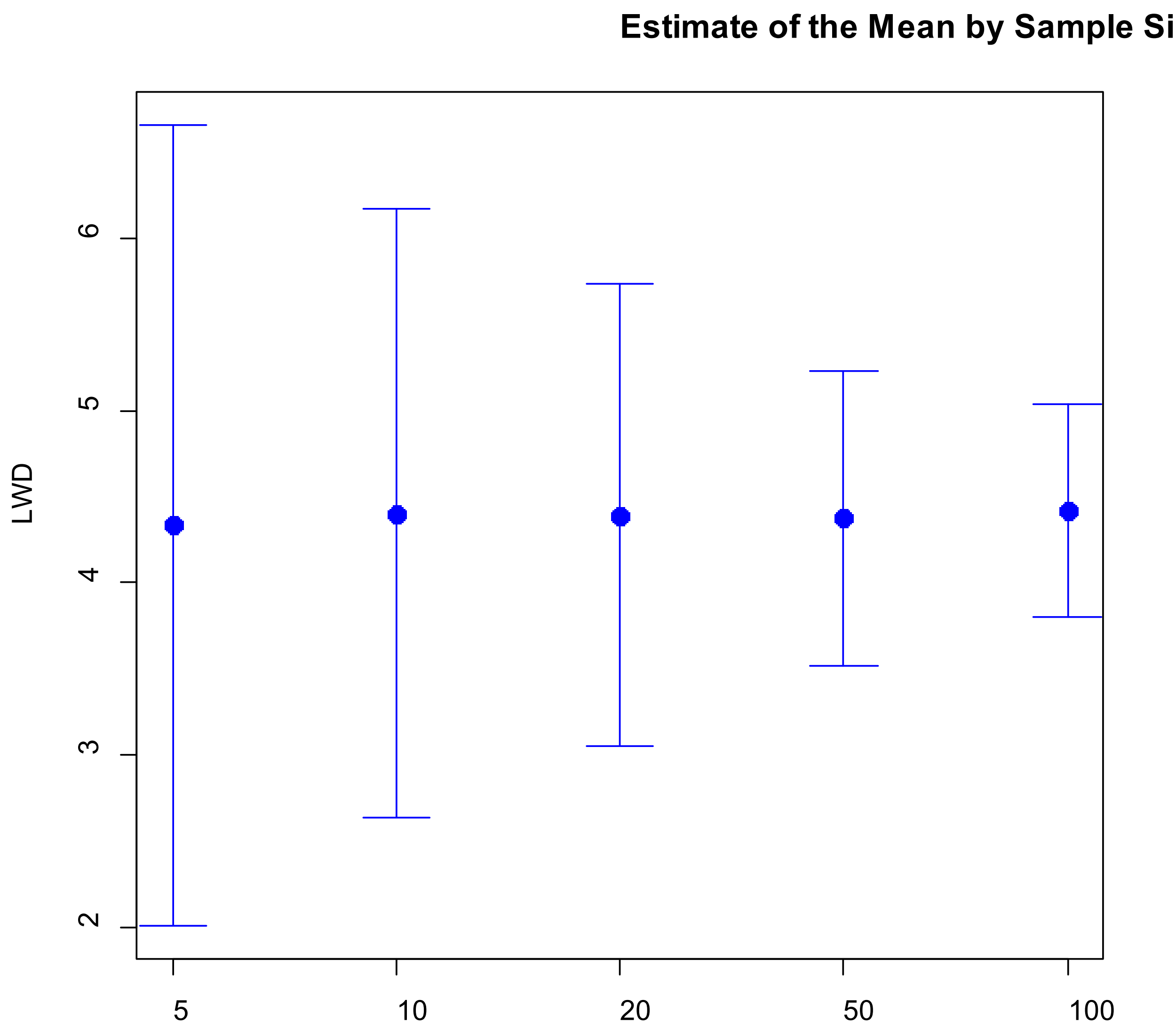
100


Estimate of the Mean by Sample Si
LWD
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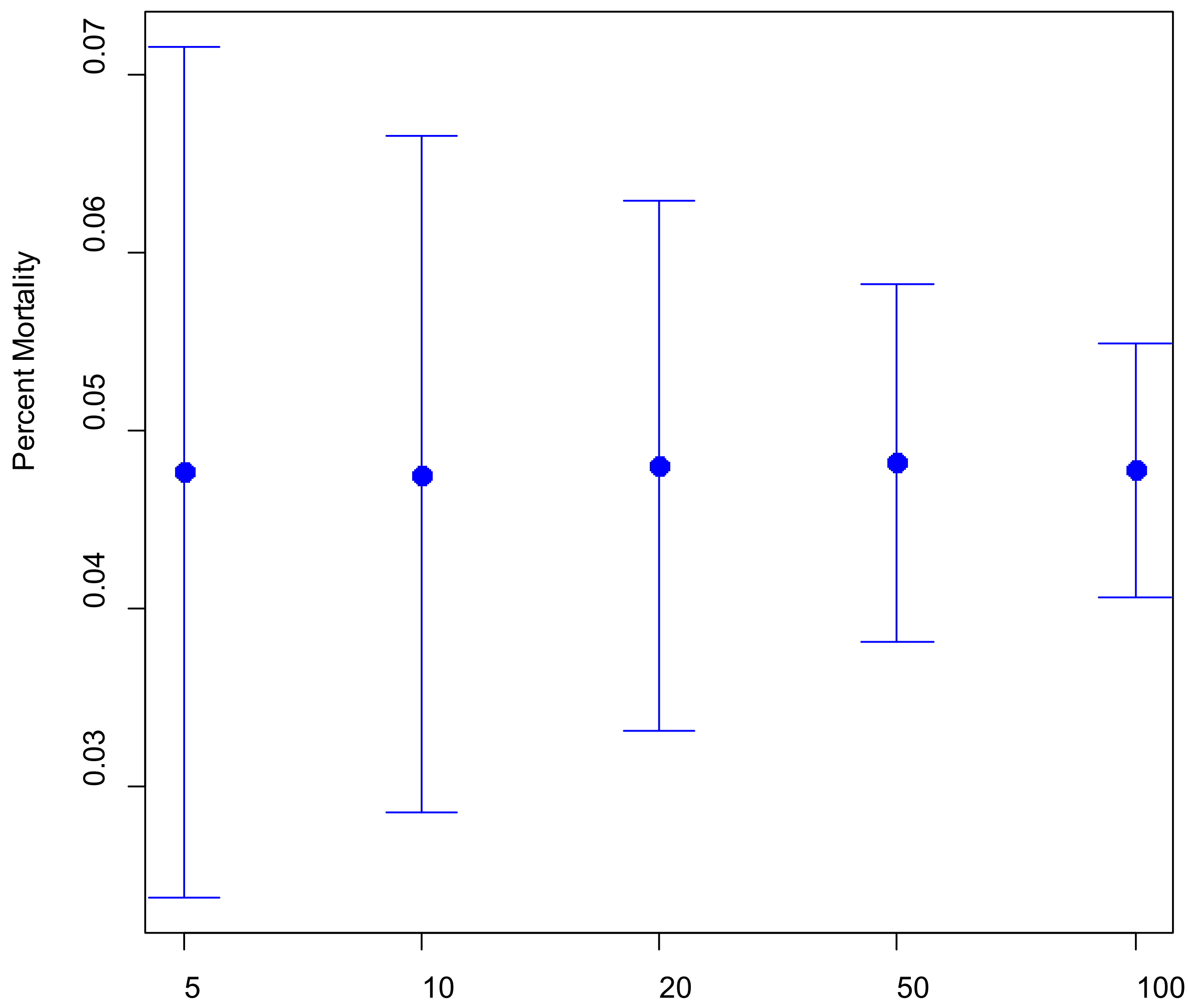
5
6
5
10
20
50
100

Estimate of the Mean by Sample Si



Appendix C. Site Selection Procedure

Following is a detailed description of the site selection procedures.

Materials

- FPARs GIS layer with FPA polygons and associated attribute table
- pdf files for each FPA
- 2015 NAIP photography in GIS format (collected between Aug. 1 and Sept. 15)
- GIS layers for WDNR hydrography and site class
- GIS layer for USGS Hydrologic Unit Maps

The process used to select stream segments include the following steps:

Step 1. Initial screening to select potential FPAs for further evaluation

1. Download FPARs GIS data from the on-line DNR FPARs website, i.e. the GIS unit boundary shapefile and associated attribute table) and query the attribute table to screen and select potential FPAs based on the following characteristics:

EFFECTIVE_DT (Effective date): select for dates between Jan. 1, 2014 and February 28, 2015 (dates most likely to have been harvested within our harvest window (March 2015-October 2015).

REGION_NM (DNR region): select for Northwest, Olympic, Pacific-Cascade or South Puget Sound (excludes eastside regions).

DECISION (Status of Application): select for APPROVED or RENEWAL (excludes applications that are not approved for harvest).

ALTERNATE_PLAN_FLG (Alternative Plan Submitted): exclude Y (excludes activities conducted under an alternative plan).

HABITAT_CONSERVATION_FLG (Application covered by Habitat Conservation Plan): select for blanks-(excludes activities conducted under a Habitat Conservation Plan).

CUTTING_OR_REMOVING_TIMBER_FLG (Involves cutting or removing timber): select for Y (excludes FPAs without timber harvest, e.g. road construction, chemical application).

EXEMPT_20_ACRE_RMZ_FLG (Application qualifies for less than 20 acre parcel RMZ prescription): exclude Y (excludes FPAs with RMZ harvest under special 20 acre parcel exemption).

HARDWOOD_CONVERSION_FLG (Hardwood conversion applications): exclude Y (excludes hardwood conversion applications).

TIMHARV_FP_TY_LABEL_NM (harvest type): select for EVEN AGE, UNEVEN AGE, EVEN/SALVAGE, UN/SALVAGE, EVEN R/W, UNEVEN R/W (excludes FPAs limited to right-of-way, salvage, or no harvest).

CMZ_PRESENT_FLG (channel migration zone): exclude Y (excludes RMZs with channel migration zone buffer present)

Step 2. GIS screening to select FPAs within 200 ft of a Type F or S stream.

Using WDNR GIS hydrography layer (from www.dnr.wa.gov/GIS), restrict the hydro layer to F and S segments and use the ArcGIS Near function to select the subset of FPAs from Step 1 with harvest within 200 ft of a Type F or S stream.

Step 3. Put list of selected potential FPARs units in random order.

Use an ArcGIS script to assign a random integer between 1 and 1000000 to each FPA from Step 2, sort on the random number.

Step 4. Examine FPAs in assigned order to identify potentially suitable segments.

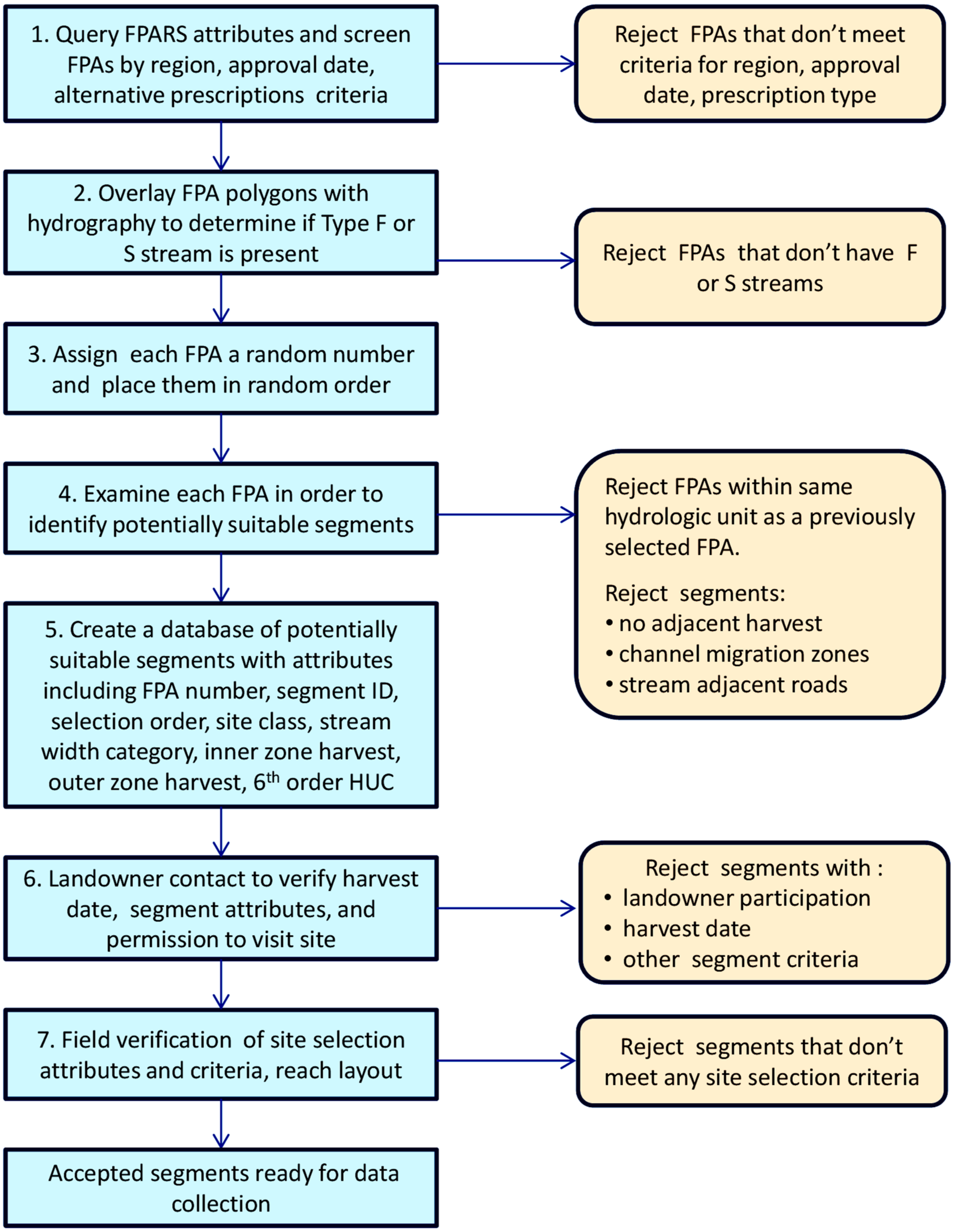
Working thru the randomized list of FPA numbers from the top, do the following:

- Overlay the FPARs unit boundary polygons on the WDNR hydrography to verify that there is a Type S or F stream in or immediately adjacent to the unit. Verify by examining the map included with the FPA pdf file. If no type F or S stream is present, reject the FPA.
- If F or S streams are present, overlay the 2015 NAIP imagery to verify that there is evidence of harvest. If not, reject the FPA.
- Overlay FPA polygon with GIS layer of USGS Hydrologic Units. Reject any FPAs that are within the same Hydrologic Unit as a previously selected FPA to ensure spatial dispersion and minimize potential for spatial autocorrelation.
- Use data in the FPA pdf file to reject FPAs for Habitat Conservation Plans, Alternative Plans or 20-acre exempt parcels that were missed in Step 1.
- If an F or S stream is present and there is evidence of harvest, use data in FPA pdf file (Table 21 and the attached DFC worksheets) to identify the stream segments with adjacent harvest. Reject any segments with Channel Migration Zones.
- Examine each segment using the map in the FPA pdf file and the NAIP photography to determine if there is a stream adjacent road through the Core or Inner Zones of the segment. Reject segments with stream adjacent roads.
- Using NAIP photography in GIS, measure the length of the segment. Overlay the segment with the USGS Hydrologic Unit (HU) layer to identify the 6th level HU.
- Create a database record for each remaining potential segment with the following attributes: FPA number, segment identifier, selection order, site class, stream width category, inner zone harvest type, outer zone harvest strategy, one-or two sided buffer, 6th order HU code.
- Assign segments to prescription variants.

Step 5. Collect data on attributes of interest for each of the selected FPAs.

Using the FPARs database, the pdf file for each FPA, the FPARs unit boundary polygons, and other GIS information (hydrolayer, NAIP imagery, DEM, SSHIAP) extract and record the data on each Type F or S stream segments identified in each FPA. Table 1 (next page) shows the data attributes and provides a brief description of the procedures to obtain the information.

Appendix Table C-1. Graphical depiction of the site selection process.



Appendix D. Example of RMZ Segment Layout