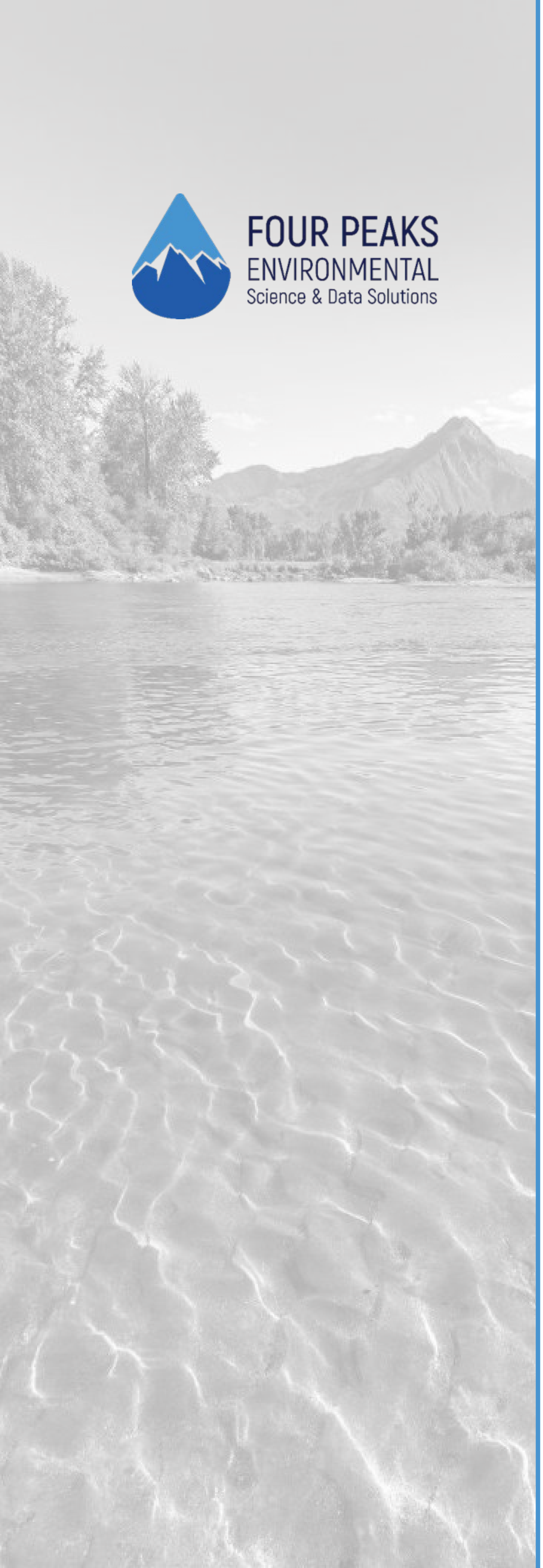

SPATIAL ANALYSIS OF THE WATER TYPING SYSTEM RULE SYNTHETIC STREAM DEVELOPMENT, COMPARISON OF ALTERNATIVES, AND BUFFER ANALYSIS

DNR Contract No. 93-105525

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Abbreviations

Abbreviation	Definition
AFF	anadromous fish floor
BFF	bankfull flow
BFW	bankfull width
Board	Forest Practices Board
DEM	Digital Elevation Model
DNR	Washington Department of Natural Resources
DPC	default physical characteristics
DTM	digital terrain model
F/N Break	fish/no-fish water type break
FHAM	fish habitat assessment methodology
Four Peaks	Four Peaks Environmental Science & Data Solutions
GNN	Gradient Nearest Neighbor
HUC	hydrologic unit code
Last Fish	Last observed fish (field data from WTMF or otherwise provided with water type break location)
PHB	potential habitat barrier
RMZ	riparian management zone
S/N	shoreline of the state/no-fish water type break
SSN	synthetic stream network
SVA	Stumpage Value Area
SWIFD	Statewide Washington Integrated Fish Distribution
Type F water	watercourse that provides fish habitat
Type N water	watercourse that does not provide fish habitat
Type Np water	perennial watercourse that does not provide fish habitat
Type S water	streams and waterbodies that are designated “shorelines of the state”
WAC	Washington Administrative Code
WTMF	Water Type Modification Forms

Executive Summary

The Washington Department of Natural Resources (DNR) is conducting ongoing evaluations of proposed rule changes to regulatory water typing and their implications for forest practices in Washington state. To support DNR's evaluations, Four Peaks Environmental Science & Data Solutions conducted a series of analyses using a remote sensing framework to compare environmental and economic effects of proposed rule change options with those of the existing regulatory landscape. These analyses consisted of a review of the relative placement of potential habitat breaks (PHBs), anadromous fish floors (AFF), and default physical characteristics (DPC), and involved the following tasks:

- Creation of high-resolution synthetic stream networks using 1-meter resolution LiDAR
- Evaluation of these synthetic stream networks to locate PHBs under three proposed options, AFF for two proposed alternatives, and breaks in DPC
- Evaluation of the relative position of all of these against the DNR-concurred (i.e., current rule) water break and corresponding location of last fish observed during water typing surveys (last fish) in each network
- Calculation of buffer attributes (buffer area, timber volume, and timber value) associated with existing and proposed rules for water typing statewide
- Calculation of buffer attributes around perennial waters that do not provide fish habitat (Type Np) waters on the westside of Washington

Patterns varied across ecoregions and on both sides of the state in the relative positions of the DNR-concurred fish habitat/non-fish habitat (F/N) water type breaks, last fish, PHB-based water type breaks, AFF, and DPC breaks. Within individual subwatersheds, relative positions of PHB-based water type breaks, AFF, and DPC breaks were often driven by differences in gradient criteria: criteria based on a gradient threshold (e.g., DPC) tended to be met downstream of criteria based on a change in gradient or on a gradient being sustained (PHB, AFF A4). When calculating PHBs using a 5x Bankfull Width (BFW) reach to calculate gradient, PHBs for all three options moved downstream closer to the last fish point when compared to a 20x BFW reach. However, the overall patterns between the three PHB options remained consistent other than PHB Option A remaining closer to Option B and the concurred break statewide under 5x BFW (but still moving downstream roughly as much as Option C on the west side alone).

When evaluating differences between applying existing riparian management zone buffers to the concurred break and the PHB-based water type breaks, the net change in riparian buffer area, timber volume, and value of timber within riparian buffers across all streams (fish habitat watercourses [Type F] and Type Np combined) varied under each PHB option and on each side of the state. On average, when compared to the current rule, riparian buffer area decreased in all ecoregions on both sides of the state and statewide under all PHB options. Statewide, the n-weighted average riparian timber volume and value protected by riparian buffers decreased under all three PHB Options, with volume and values for Option B consistently the closest to the concurred break.

This report also evaluated the differences between applying buffers to Type Np waters defined by the concurred break using buffer widths and extents defined under the current rule to buffer widths and extents defined by the proposed west side Type Np buffer rule. The n-weighted west side average of timber volume and value protected by Option 1a and Option 1b were within 3% of one another for both metrics, and both represented a substantial increase in the amount of timber protected within Type Np riparian buffers.

The analyses in this report were limited by the resolution of LiDAR data, the fact that these LiDAR data were only available for terrestrial topography (i.e., not instream bathymetry), and a limited ability to field-verify the results. Higher-resolution LiDAR data—ideally of the kind that can penetrate water to collect bathymetry data—would improve the ability to detect small changes in stream width and gradient, increasing accuracy of the positions based on these remotely sensed data. Current LiDAR precision is the primary source of uncertainty constraining the remotely sensed approach. Field verification of stream locations, stream network densities, location of AFF and PHBs, and extent of Type Np waters, would provide an empirical quality control step that is not possible with remote sensing only. This would ensure study-wide accuracy regarding the existence, location, seasonality, geometry, and flow of streams included in the analyses.

1 Introduction

1.1 Regulatory Context

In Washington, forest practices are primarily regulated by the Washington Department of Natural Resources (DNR) and the Forest Practices Board (Board). The Board[1] has established the water typing classification system based on the implementation of the interim water typing system rule, which identifies fish use and seasonality of flow within streams and other water bodies ("waters") to determine riparian buffer protections required during forest practices activities.[2] The Board is responsible for adopting rules that set standards for forest practices. All forest practices rules adopted by the Board are implemented and enforced by the DNR Forest Regulation program.

Currently, the Board is engaged in two major rulemaking efforts related to regulatory water typing (DNR 2022): 1) the Permanent Water Typing System Rule, and 2) the Type Np Water Buffer Rule.

The Permanent Water Typing System Rule aims to establish a new methodology for determining how to classify waters of Washington State, including how to identify the water type break between segments of streams that contain fish habitat (Type F waters) and those that do not (Type N waters). Part of this new system includes determining the location of an anadromous fish floor (AFF), below which occupancy by anadromous salmonids can be reasonably presumed, to eliminate the need for electrofishing in those areas (DNR 2022). Above the AFF, the fish habitat assessment methodology (FHAM) would be implemented to conduct water typing surveys, which would include electrofishing above potential habitat breaks (PHBs) (Walter et al. 2022). Three PHB options (Section 2.2.1) and two AFF alternatives (Section 2.2.2) have been approved by the Board for additional analysis to determine which criteria will be used to identify PHBs and the AFF in the final water typing system rule (DNR 2022).

The Type Np Buffer Rule would amend WAC 222-30-021 and add a new rule for riparian buffers around Type Np Waters in western Washington. This proposed rule change would protect sensitive sites and change the extent and width of buffers along Type Np Waters. The goal of the analysis of the Type Np Buffer Rule is to compare two Board-approved options, which differ based on the size of the affected stream basin and the intensity of planned harvest (see Section 2.4.2 for additional detail), to the buffers under the current rule, to determine which option best meets the objective of the rule making while being the least burdensome for those required to comply with it.

As part of DNR's ongoing evaluation of these proposed rule changes, DNR engaged Four Peaks Environmental Science & Data Solutions (Four Peaks) to conduct a series of analyses that compares the environmental and economic effects associated with the proposed options for each rule change with those of the existing regulatory framework. This framework includes previous determinations of water type and guidelines in place for establishing water type. Under current guidelines, default physical characteristics (DPC) for Type 3 Water under the Interim Water Typing system (Washington Administrative Code [WAC] 222-16-031(3)(b)(i)) imply presumed fish use. In the absence of a complete water typing survey, these DPC can be used when submitting a forest practices application to establish

[1] https://www.dnr.wa.gov/about/boards-and-councils/forest-practices-board
[2] https://www.dnr.wa.gov/forest-practices-water-typing

buffer requirements. DPC alone do not establish the regulatory water type break, but they contribute to forest management in the absence of a field-based protocol survey (DNR 2002).

1.2 Study Goals and Objectives

The purpose of this study was to provide information that would support decision-making surrounding ongoing development of the proposed forest practices rule changes. The study individually focused on each of these rule changes with the following primary goals:

- Permanent Water Typing System Rule
  - Estimate regional and statewide values for the following metrics, and for each, compute the change from the current rule to each of the three Board-approved PHB options that would be used in the application of FHAM:
    - Relative extent of Type F and N Waters,
    - Area of associated Type F and Np buffers,
    - Corresponding volume and value of timber protected within those buffers.
- Type Np Water Buffer Rule
  - Estimate regional and state side (e.g., the west side of Washington state) change in the following metrics that would result from replacing the current rule with proposed alternatives:
    - Area of Type Np buffer,
    - Corresponding volume and value of timber protected within those buffers.

The following specific objectives supported achieving these study goals:

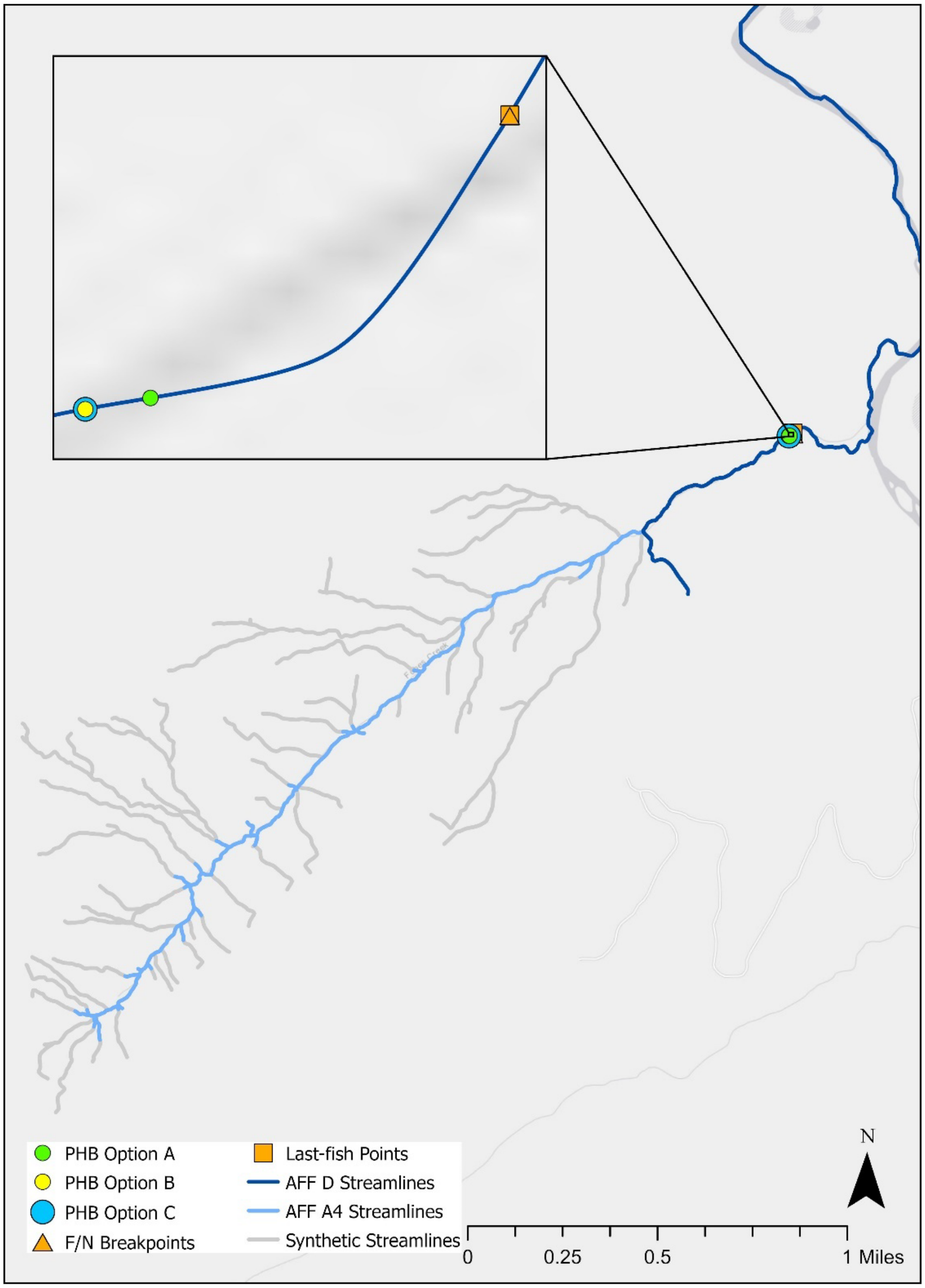
- **Build synthetic hydrographic stream networks**. Generate a synthetic stream network (SSN) associated with DNR-concurred (i.e., the current ruleset) F/N breaks throughout Washington state to support analyses that evaluate the effects of proposed forest practices rule changes.
- **Identify key locations under current and proposed rulesets**. Use Board-approved field data to locate the points where fish were last observed (last fish points) and where the existing F/N break exists within each SSN, and then identify the following for each network:
  - **The PHB locations based on each option.** Calculate potential PHBs based on the three approved PHB options and identify the first PHB locations upstream of the last fish point for each option, and the FHAM-identified F/N break point (first PHB on the mainstem) for each of these PHB options.
  - **The AFF associated with each alternative**. Determine the AFF locations under Alternatives A4 (7%) and D to each stream within the SSN based on the different gradient (sustained 7% gradient or change in gradient), vertical barrier, and proximity to presumed or documented anadromy criteria for each alternative.
  - **The end of presumed fish habitat using existing DPC**. Within the SSN, apply DPC to each stream to locate the end of presumed fish habitat, then calculate the location of the break in DPC.
- **Conduct distance analyses**. For each ecoregion, compute averages for distance within each stream within the SSN from the metrics outlined below, and extrapolate those averages

statewide and for each side of the state weighted by the number of breaks (n-weighted) in the DNR watercourses (wchydro) dataset that do not have DNR-concurred breaks.

  - Distance from last fish to DNR-concurred F/N break under current rule
  - Distance from last fish to the calculated mainstem break (FHAM) for each PHB option
  - Distance from DNR-concurred break to the calculated mainstem break (FHAM) for each PHB option
  - Distance from last fish downstream to, or extent upstream of:
    - Type F waters as determined by first PHB upstream of last fish point on each branch
    - Extent of AFF under Alternatives A4 (7%) and D
    - DPC extent downstream of first break in DPC
  - Distance from DNR-concurred break downstream to, or extents upstream of:
    - Type F waters as determined by first PHB upstream of last fish point on each branch
    - Extent of AFF under Alternatives A4 (7%) and D
    - DPC extent downstream of first break in DPC

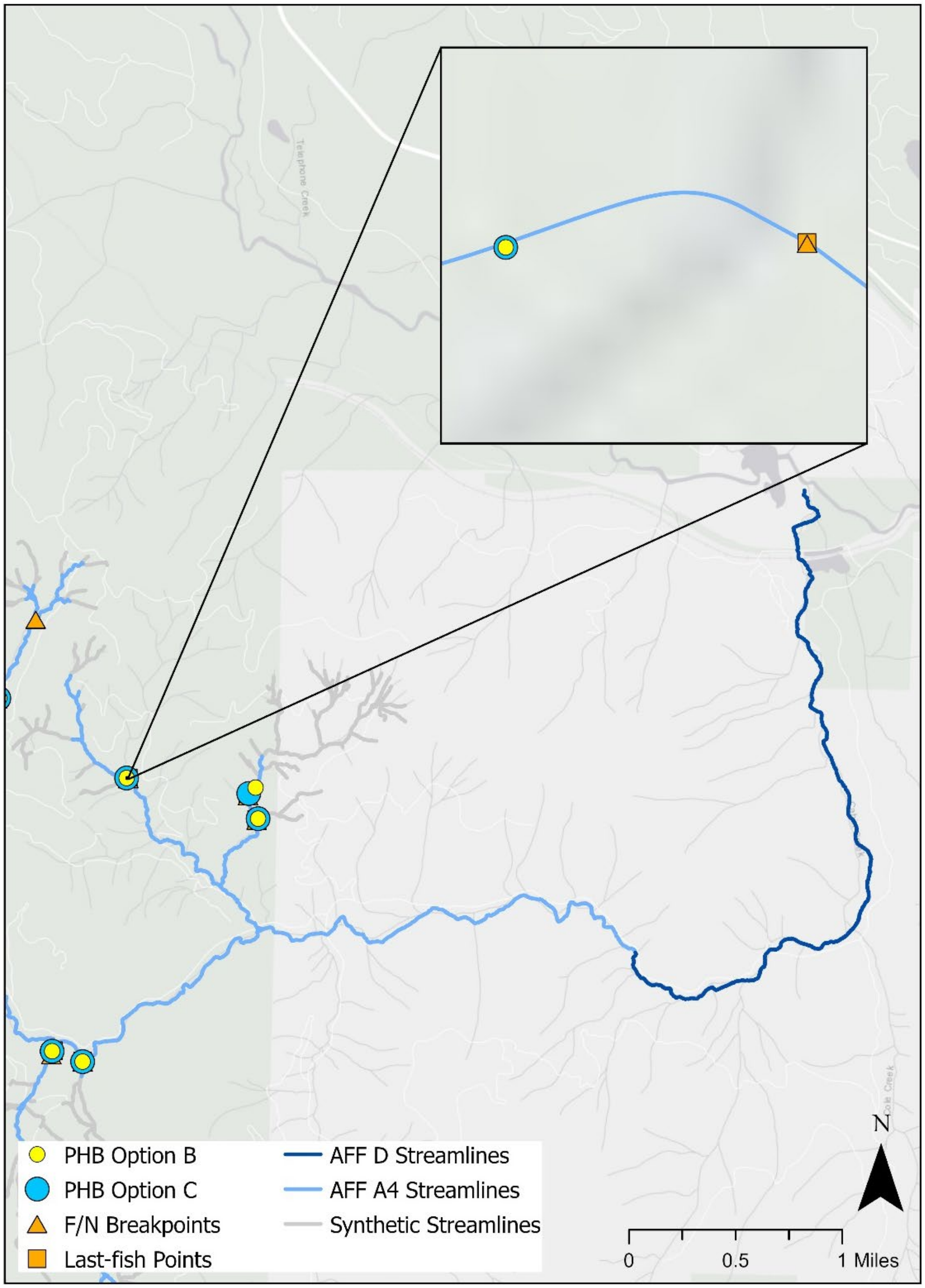
- **Determine changes in buffers and associated implications for timber harvest**. Based on the extent of Type F and Type Np waters associated with FHAM water breaks under each PHB option, compare the buffer area and associated timber volume and value among each of the proposed PHB options and between each option and the current rule within each ecoregion, and then extrapolate to streams statewide that do not have DNR-concurred breaks.
- **On the west side, determine the change in Type Np water buffers under proposed options**. Based on the current water typing, determine the change in buffer area, timber volume, and timber value that would result from implementing each of the proposed options for Type Np water buffers on the west side within each ecoregion, and then extrapolate to streams statewide that do not have DNR-concurred breaks.

Figure 1 and Figure 2 provide visual examples of synthetic streamlines, AFF A4 and D streamlines, and PHBs for Options A-C on the west side and Options B-C on the east side of Washington state, respectively.



Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community, Esri, HERE, County of Skagit, Bureau of Land Management, Esri, HERE, Garmin, GeoTechnologies, Inc., USGS, EPA

Figure 1. Example synthetic streamlines, AFF A4 and D streamlines, and PHBs (gradient calculated over a reach of 5x BFW) for Options A-C on the west side of Washington state



County of King, County of Kittitas, Bureau of Land Management, Esri, HERE, Garmin, GeoTechnologies, Inc., USGS, EPA, Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community, County of Kittitas, Bureau of Land Management, Esri, HERE, Garmin, USGS, EPA, NPS, Esri, HERE, NPS

Figure 2. Example synthetic streamlines, AFF A4 and D streamlines and PHBs (gradient calculated over a reach of 5x BFW) for Options B-C on the east side of Washington state

2 Methods

Using the following process, Four Peaks combined DNR-provided datasets, external datasets, and LiDAR-derived digital terrain model (DTM) rasters:

1. Process and perform quality assurance/quality control on input of DNR-concurred break and last fish datasets, and use them to create SSNs
2. Calculate PHB, AFF, and DPC locations and extents for each network
3. Compare the extents of waters in each network meeting the criteria for each PHB option, each AFF alternative, and DPC
4. Compare the changes in riparian buffer area, timber volume, and timber value for water type buffers around SSNs

This process enabled the comparison of the different aspects of current and proposed water typing rules under a single, remote-sensing based framework. An overview of these methods is presented in Sections 2.1 through 2.4. APPENDIX A provides more detailed methods, including tools and workflows used in the analyses, as well as study-specific examples.

2.1 Create Synthetic Stream Networks

2.1.1 Data Sources and Processing

The locations of DNR-concurred F/N breaks (between Type F and Type N waters) and S/N breaks (between shorelines of the state and Type N waters) were provided by DNR in the form of Board-approved point datasets. The locations of the last fish observed during water typing surveys (last fish) were recorded in the dataset as one of the following two data point types:

- A distance from the F/N break to the last observed fish
- A coordinate, for surveys on the east side that recorded last fish as a GPS point

The F/N break points were separated out into a single dataset and were evaluated for accuracy; points were dropped if any of the following criteria were met:

- They did not correspond to locations on a streamline
- The point was a duplicate of another point already in the dataset
- The location of last fish for that F/N break was upstream of another last fish location due to conflicting last fish locations on Water Type Modification Forms (WTMFs) covering overlapping streams

This process resulted in a total of 365 F/N breaks across the state.

2.1.2 Create Synthetic Stream Networks

2.1.2.1 Create LiDAR-Derived Streamlines

To build SSNs, DTM datasets were downloaded from the DNR LiDAR portal for all areas within 12-digit hydrologic units (subwatersheds) that contained a representative sample of DNR-concurred F/N break points. Individual rasters were mosaicked and clipped to the extent of each subwatershed. Multiple LiDAR rasters were generally required to cover the extent of one subwatershed. Each raster was then smoothed to remove LiDAR artifacts before using the ArcHydro toolbox (version 3.1.14) in ArcGIS Pro (version 3.1.2) to create streamlines and associated point and catchment polygon datasets. The output layers were checked for missing features or ID columns.

If the streamline density did not match (1) the streamline density of the wchydro layer at the hydrologic unit code (HUC)12 subwatershed scale, and (2) visible channels in high-resolution aerial imagery (ESRI imagery basemap), then the flow accumulation threshold was adjusted in the ArcHydro tool. The density was adjusted by changing the Ncell count parameter within the ArcHydro tool, which controls the threshold number of upslope cells required to designate a stream. The Ncell count value is inversely related to streamline density: lower Ncell count values lead to a greater stream density within a network. This threshold was assessed at the subwatershed scale to ensure that the Digital Elevation Model (DEM)-derived streamlines reflected the length and density of streamlines in the wchydro network and visible channels or other evidence of near-surface water in the aerial imagery, without creating artifact streamlines (such as along road berms without an upslope channel). In cases where a decision between under- and over-predicting the presence of streams was necessary, this threshold was set so that the SSN extended slightly beyond the extent of the wchydro layer. Final Ncell counts ranged from 5,000 to 175,000, with almost half of subwatersheds between 75,000 and 100,000. Ncell values were lower on the west side than on the east side of the state, reflecting broad differences in geology and climate between the two sides of the state.

Additionally, the streamlines around and upstream of the F/N break points were checked to see whether road berms or LiDAR artifacts were diverting flow in ways not reflected on the ground (e.g., road berms with presumed culverts on the ground). In some cases, road berms artificially diverted the course of the streamline in a way that impacted the amount of upstream network running through a DNR-concurred break, or changed the course of the streamlines in a way that impacted how much area would be upstream of the DNR-concurred break or stream segments immediately downstream of the DNR-concurred break. In those cases, a channel was manually “burned” through the road berm to replicate the effects of the culverts that were assumed to be present in the field but not visible in the LiDAR data (APPENDIX B).

Using the DNR-concurred F/N break point, SSNs were created by selecting all segments upstream and downstream of each point using the R (version 4.2.3) package sfnetworks[3] (version 0.6.3). Each resulting network was smoothed using the kernel smoothing method (n = 5) to smooth out the artifacts resulting from generating lines from raster pixels. DNR-concurred F/N break points were then snapped to the resulting smoothed streamlines.

2.1.2.2 Assign Attributes to Synthetic Streams

After the SSN lines were created, the following attributes were calculated at the level of the stream segment (the reach between two stream junctions):

- **Upstream basin area** was calculated using the area of catchment polygons generated during the stream creation process.

[3] sfnetworks package - RDocumentation

- **Bankfull width (BFW)** was calculated by applying the Beechie and Imaki (2014) formula based on basin area and modeled precipitation data (Parameter-elevation Regressions on Independent Slopes Model [PRISM] dataset, Daly et al. 2015).[4]
- **Bankfull flow (BFF)**, or the 2-year return interval flood flow, was calculated for each segment using a region-specific formula (Mastin et al. 2016) based on a combination of catchment precipitation, catchment canopy cover (NLCD 2021), and catchment area.
- **Minimum elevation** was calculated using the DTM data used to create the synthetic stream.
- **Stream segment length** was the automatically-calculated Shape_Length field; when stream segments were subset for specific analyses, length was explicitly calculated manually.
- **Water Type** was designated by characterizing segments downstream of the F/N break as Type F and segments upstream of the F/N break as Type N (Figure 3).
- **Seasonality** was determined from wchydro, by designating "unknown" segments as
  - Perennial if they were downstream of a perennial segment
  - Seasonal if they were upstream of a seasonal segment
  - Perennial for all remaining unknown stream segments in wchydro for which no information about seasonality was availability
- **Anadromous zone** inference was determined by designating stream segments as being within the extent of presumed or documented anadromy based on the corresponding extent of "Documented" and "Presumed" anadromy in the Statewide Washington Integrated Fish Distribution (SWIFD) dataset (SWIFD 2023).

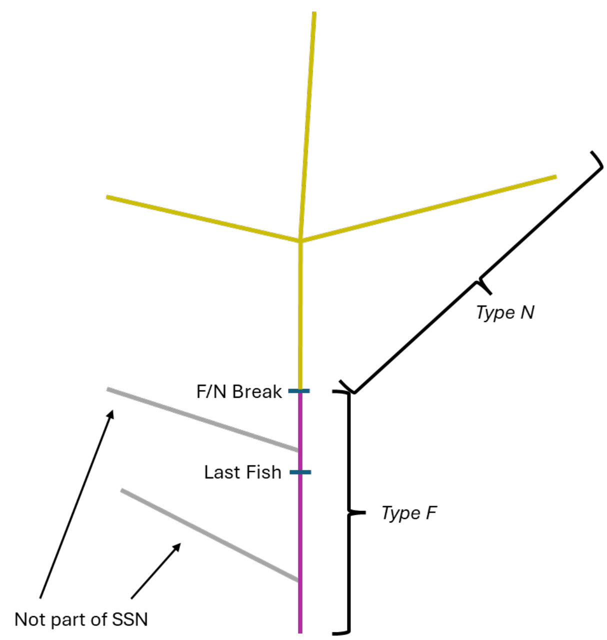


Figure 3. Line segments directly upstream (yellow) and downstream (purple) of each F/N break were subset to create the SSNs, excluding lines that were not directly downstream (gray) of the break

[4] Beechie and Imaki's (2014) formula for BFW presumes that bankfull flow represents a 2-year return interval flood.

2.2 Calculate Potential Habitat Breaks, Anadromous Fish Floor, and Default Physical Characteristics

For the PHB, AFF, and DPC analyses (Sections 2.2.1, 2.2.2, and 2.2.3), a dataset consisting of points created at 1-foot intervals was generated for each SSN.

- For the PHB and DPC analyses, these points were generated starting at 2,000 feet below the last fish location.
- For the AFF analysis, if the points created for the PHB and DPC analyses did not include waters containing presumed or documented anadromy in SWIFD in a given SSN, points were generated starting from stream segments with SWIFD or from the downstream-most extent of the network (to the outlet of the network's HUC12 subwatershed). If the points did include waters containing presumed or documented anadromy in SWIFD, the points from the PHB and DPC dataset were used for that SSN. Data from the StreamNet portal were also downloaded and evaluated for use in calculating AFF Alternative D. The only relevant data that did not originally come from SWIFD were documentation of resident populations of Cutthroat Trout, which are not anadromous and were therefore not used in the analysis. For each point, several metrics were calculated for that location. In particular, the relative distance along the network of each point was calculated, and elevation was extracted from LiDAR data downloaded from the DNR LiDAR portal. Segment-level characteristics such as BFW and seasonality were taken from the streamlines used to generate the points.

2.2.1 Potential Habitat Breaks

For each option, PHBs were calculated based on the criteria for that option (Table 1), using the point dataset described above. The first PHB points upstream of the last fish location on each branch were used to define the upper extent of Type F waters under each option. If no PHB was calculated between the last fish point and the upper extent of the branch, the upstream extent of that branch was categorized as Type F water. To provide an illustrative estimate of the linear change in the location of the F/N break under each option, the first PHB upstream of the last fish observation on the mainstem was identified.[5]

Table 1. Criteria for stream physical features associated with each PHB option

Option	Regional Application	Width or Flow Criterion	Gradient Criterion	Permanent Obstacle Criteria
A	Western Washington	≤2 feet BFW	≥5% Increase	Vertical: ≥BFW & ≥3 feet
B	Statewide	≤2 feet BFW	≥10% Increase	Vertical: ≥BFW & ≥3 feet Non-vertical: ≥20% & elevation change > upstream BFW
C	Statewide	Decrease ≥20% BFF	≥5% Increase	Vertical: ≥3 feet Non-vertical: ≥20% & elevation change > US BFW

Note:
Increase in gradient as measured over a reach with length at least 20x BFW. BFF comparison as measured at the tributary junction.

[5] For this and other analyses, the "mainstem" within the network was defined as the upstream branch with the largest BFW.

2.2.2 Anadromous Fish Floor

The criteria used to determine the upstream end of the AFF are described in Table 2. The resolution of the LiDAR data was too coarse to detect resting areas small enough to impact the sustained gradient calculations; therefore, the non-vertical permanent natural barrier criteria of a sustained gradient of 20% for Alternative A4 was not considered. This is because a sustained gradient of 7% would be reached before a sustained gradient of 20%.

Table 2. Physical criteria of the AFF for Alternatives A4 and D

Alternative	AFF Criteria	Permanent Natural Barrier Subcriteria
A4 (7%)	• Waters with presumed or documented anadromy in SWIFD, OR • Waters directly upstream of waters with SWIFD presumed or documented anadromy AND below a sustained channel gradient of 7% or a permanent natural barrier	• Near vertical drop greater than ○ 5 feet for streams with BFW < 5 feet, ○ 8 feet for streams with BFW of 5-10 feet, or ○ 12 feet for streams with BFW > 10 feet.
D	• Waters within presumed or documented anadromy in SWIFD, or comparable records in other GIS databases e.g., StreamNet, OR • Waters directly upstream of waters with SWIFD presumed or documented anadromy WITHOUT a 5% gradient change or permanent natural barrier at the tributary junction	• A near-instantaneous vertical step ≥ BFW and ≥ 3 feet, OR • A step pool ≥ 20% gradient with elevation increase ≥ upstream BFW

Note:
Sustained channel gradient indicates that the gradient criteria had to be met for the average slope from each point to the point 5 feet upstream of it for all starting points within the indicated distance (for AFF A4, proscribed distances of 100, 250, and 525 feet for streams with BFW < 5 feet, BFW 5-10 feet, and BFW > 10 feet, respectively). As for permanent natural barriers, at each confluence, each possible tributary path was considered separately as an upstream continuation of the indicated window, and the point was marked as a permanent natural barrier only if all possibilities met the criteria. At each confluence, the downstream end of each possible tributary path was examined separately as the next point upstream of the confluence.

Several subwatersheds did not include any waters with documented or presumed anadromy in SWIFD. Those subwatersheds were dropped from the Alternative D analysis, as no streams in those subwatersheds met the criteria for Alternative D. For subwatersheds that contained populations with documented or presumed fluvial life histories that migrated to rivers with documented or presumed anadromy, the upper extent of the AFF under Alternative A4 was placed at the subwatershed outlet. If a subwatershed had no anadromy or fluvial connection to anadromy in SWIFD, or there was a gap in LiDAR data in a location that impacted the ability to calculate BFW, and therefore accurately assess end of AFF, networks in that subwatershed were not included for either alternative.

The outlet of the subwatershed tended to be far downstream of the DNR-concurred F/N break. Because the upstream extent of the AFF was located at the outlet of the HUC12 subwatershed for Alternative A4 but dropped them from Alternative D distance calculations, these long downstream distances (or proportions of zero when calculating the proportion of AFF extent relative to the full SSN extent) influenced the ecoregion averages, particularly in those ecoregions with a high proportion of such subwatersheds (e.g., Northern Rockies).

2.2.3 Default Physical Characteristics

The DPC for presumed fish occupancy differ between the east and west sides of the state and include gradient thresholds that vary depending on the size of the contributing basin (Table 3). Each point along the SSN was evaluated to determine if the stream channel at that location met the appropriate BFW threshold and exhibited an upstream gradient less than or equal to 16% over a reach of 20x BFW. If the contributing basin of the stream met the state side basin threshold, the upstream gradient threshold was less than or equal to 20%.

Table 3. Bankfull width and basin size thresholds for DPC criteria

State Side	DPC for BFW	DPC for Gradient
East	≥3 ft	• Upstream Basin ≤175 ac ○ ≤16% • Upstream Basin >175 ac ○ ≤20%
West	≥2 ft	• Upstream Basin ≤ 50 ac ○ ≤16% • Upstream Basin >50 ac ○ ≤20%

In order to be consistent with the methods for establishing PHBs and calculating the extent of Type F waters downstream of PHBs, breaks in DPC were evaluated upstream of the last fish point on each network, and water break points were established immediately downstream of reaches longer than 3 feet that did not meet DPC. The extent of DPC was then established as all waters downstream from the first water break point to the network outlet.

2.3 Compare the Extent of Type F Waters, Anadromous Fish Floor, and Default Physical Characteristics in Each Network

2.3.1 Computing Distances and Extents

The distances between last fish and DNR-concurred F/N break points were calculated based on the distance data provided by DNR.[6] If no distance was provided, the last fish distance was calculated using the provided last fish point on the SSN. These locations were also compared to the PHB, AFF, and DPC metrics described in Section 2.2.

For the AFF and DPC analyses, the extent of each metric (AFF, DPC) was compared to the last fish and F/N break points by calculating the distance downstream from last fish or the F/N break to the relevant metric break point (i.e., the end of AFF or DPC) or the total upstream extent of the relevant metric.

For the PHB analysis, the extent of Type F was compared to the last observed fish and F/N breaks for each network in the same way as for AFF and DPC, but the linear distance to the first PHB on the mainstem also was calculated relative to the last fish and F/N break points.[7]

[6] This information ultimately derived from water typing survey data captured in WTMFs.
[7] Defined as in Footnote 5: the first PHB upstream of the last fish point on the branch with the greatest BFW.

To compare the extents of each metric within each network, Four Peaks calculated the total extent of Type F under each PHB option, the extent of AFF for each alternative, the extent of DPC in each network, and the proportion of each relative to the total extent of the SSN (Figure 4).

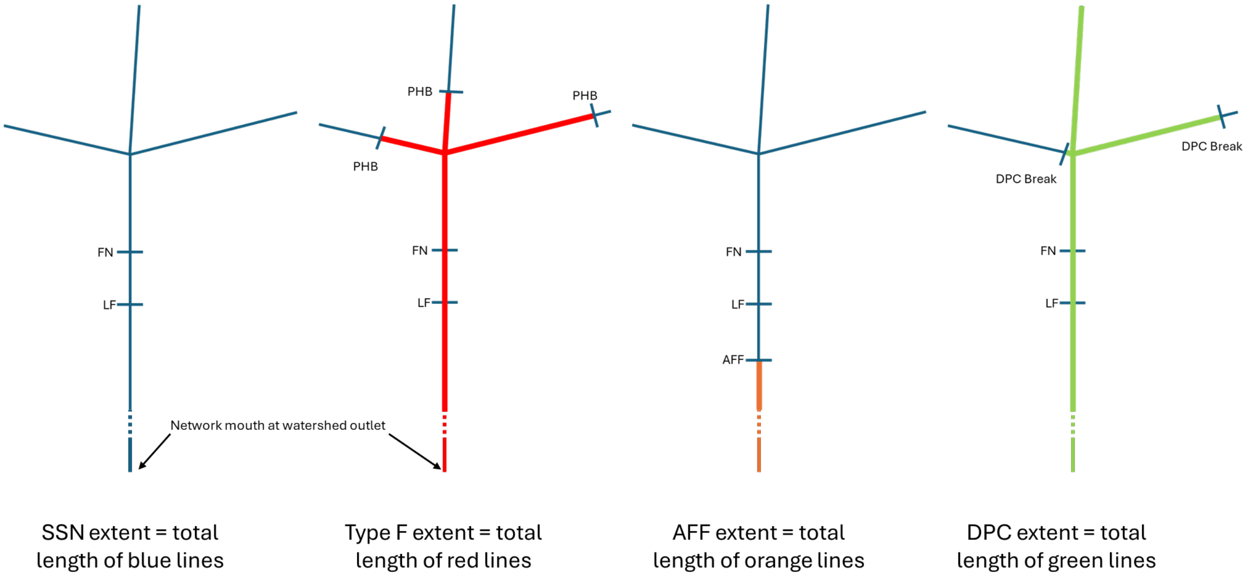


Figure 4. Points (blue lines perpendicular to blue streamlines) were used to designate the stopping point for the extent of Type F waters, AFF, and DPC

2.3.2 Averaging

For each distance calculation, Four Peaks computed average distances per network, by ecoregion. Networks were assigned to an ecoregion based on the location of the DNR-concurred F/N break.[8] Four Peaks calculated weights based on the relative proportion of water breaks within each ecoregion. Relative proportions were defined as the total number of F/N and S/N breaks (S/N break refers to a break between waters designated as "shoreline of the state" and those designated "not fish habitat") documented in wchydro within a given ecoregion, relative to either

1. The total number of F/N and S/N breaks in wchydro statewide in the relevant ecoregion
2. The total number of breaks within each ecoregion on each side of the state relative to the total number of waters on that side of the state

Four Peaks then applied those weights to the ecoregion averages for each metric to generate statewide and state-side summaries of each metric.

[8] The single network that fell within the Columbia Plateau ecoregion was moved into the Eastern Cascades Slopes and Foothills (E. Cascades Foothills) ecoregion, which contains the rest of the points in that subwatershed.

2.4 Water Type Buffer and Riparian Timber Comparisons

2.4.1 Riparian Buffer Area, Current Rule

Riparian buffers were created around Type F and Type Np waters from the synthetic streamlines generated using the F/N break points, as well as the Type F and Type Np extents calculated using the PHBs calculated in Section 2.2. Buffer widths were assigned based on water type and side of state, as outlined in WAC Chapter 222-30.

2.4.1.1 Buffers for Type F Waters

On the west side, buffer widths around Type F waters represented the combined inner and core zones for each site class and BFW (as calculated during the SSN creation process described in Section 2.1.2).[9] On the east side, because the combined zones did not vary by site class, buffer widths were based on BFW alone. Type F buffers were created based on the buffer distances assigned (Section 2.3) using the Pairwise Buffer Geoprocessing tool in ArcGIS Pro. Buffers were created separately for Type F waters designated by the DNR-concurred break (i.e., the current ruleset), for PHB Options A through C for the west side of Washington state, and for the DNR-concurred break and PHB Options B and C for the east side of Washington state.

2.4.1.2 Buffers for Type Np Waters

Within each network, a buffer of 50 feet was applied to at least 50% of the extent of Type Np streams, using an automated, spatially referenced process.[10] The Np buffers were created using a custom ArcPy script that applied 50-foot buffers along 50% of the Type Np streams in each network. Due to the length of the line segments within stream networks, it was not always possible to buffer precisely 50% of the network. All stream segments were split in half before running the script, to improve the precision of this process and get closer to 50%. The ArcPy script prioritized continuity and buffering downstream areas while also buffering as close to 50% of the stream network as possible.

Additional areas were buffered and combined with streamline buffers for Type Np streams, including sensitive site buffers and waterbodies from the DNR waterbodies (wbhydro) layer that intersected the Type Np streamlines.[11] The sensitive sites were buffered to 56 feet as specified in the WAC, and the waterbodies were buffered to 50 feet. Only the buffer area was included in the final buffered layers (not the full waterbody area). The final streamline buffers had flat end caps (end of buffer perpendicular to the end of the streamline rather than a rounded end extending from the end of the streamline with a radius of the buffer distance) and were created for the same combination of state side and PHB options

[9] For example, for FHAM option C Type F streams on the west side, if the site class was 2, the buffer width was 113 feet for streams less than 10-feet BFW or 128 feet for streams greater than 10-feet BFW.

[10] Though not following the way buffers are to be applied to Type Np Waters in practice, a calculation resulting in slightly more than 50% of the extent of Np Water in a network being buffered reflects real-world application under the current rule. A remote analysis cannot accurately calculate the amount of additional buffer due to unstable slopes.

[11] Sensitive features are defined within WAC Chapter 222-30 to include seeps and springs, alluvial fans, the upper most extent of a Type Np water, and intersections (confluences) of Type Np waters. Because most of these features are not catalogued within wchydro, only the junction between two Type Np streams and the upper most point of perennial flow were treated as sensitive and preferentially buffered.

as the Type F buffers. Buffer area was calculated for the full extent of Type F, Type Np, and combined riparian buffers based on the proposed break for each PHB option as well as the DNR-concurred break before calculating the differences between each proposed option and the DNR-concurred break.

2.4.2 Type Np Riparian Buffer Area, Proposed Type Np Rule

For the proposed west side Type Np buffer rule, riparian buffers around Type Np waters were created for Board-approved Type Np buffer alternatives. For the purposes of this analysis, these options will be identified as Option 1 (with sub-options 1a and 1b), and Option 2.

Table 4. Proposed Type Np buffer rule criteria for Option 1 (sub-options 1a and 2a) and Option 2

Option	Application	First 600 Feet Upstream of Break	Beyond 600 Feet Upstream of Break: Streams ≥ 3 Feet	Beyond 600 Feet Upstream of Break: Streams < 3 Feet
1a	All Basins	75-foot no-harvest buffer	50-foot inner no-harvest plus outer 25-foot 50% harvest buffer	50-foot no-harvest buffer
1b	All Basins	75-foot no-harvest buffer	65-foot no-harvest buffer	50-foot no-harvest buffer
2	Basins > 30 ac at F/N break that will be harvested ≥ 85%, for the five years before	75-foot no-harvest buffer	75-foot no-harvest buffer	75-foot no-harvest buffer

For Option 1, the first 600 feet of all Type Np streams above the water type break were buffered by a 75-foot no-harvest buffer (Table 4). Upstream of the first 600 feet, stream segments with a bankfull width (BFW) less than 3 feet were buffered by a 50-foot no-harvest buffer. For streams greater than 3 feet, the buffer width varied by sub-option:

- For Option 1a, separate inner 50-foot (no-harvest) buffer and outer 25-foot (50% harvest) buffers were created.
- For Option 1b streamlines greater than 3 feet were buffered using a uniform 65-foot buffer.

Option 2 only applies to networks in which the basin above the fish/no-fish water type (F/N) break is greater than 30 acres and for which at least 85% of the basin area will be harvested within 5 years. Therefore, Option 2 cannot be directly compared with Option 1 and the current rule with respect to available timber. Instead, Option 2 was compared to the current rule separately from Option 1, and changes in buffer metrics were summarized by ecoregion but not extrapolated to all water breaks on the west side of the state.

Additional areas were buffered and combined with streamline buffers for Type Np streams, including sensitive site buffers (see footnote 11) and waterbodies from the wchydro layer that intersected the Type Np streamlines. The sensitive sites were buffered to 56 feet as specified in WAC 222-30-021, and the waterbodies were buffered to 50 feet. Only the buffer area was included in the final buffered layers (not the full waterbody area). The final streamline buffers had flat end caps. For each option, buffer area was compared to the Type Np buffer area in the same networks calculated under the current rule using the DNR-concurred F/N break. The total buffer area was used for Option 1a, including areas with a 50% harvest limit.

2.4.3 Tree Volume Calculation

DNR provided a point layer of vegetation data, produced by the Landscape Ecology, Modeling, Mapping and Analysis (LEMMA) team at Oregon State University, using Gradient Nearest Neighbor (GNN) models. The data are provided as 30-meter-resolution ArcGIS grids, where the grid value is a unique plot number that links to a plot database containing vegetation information, such as tree species and density, with density provided as the volume of timber per unit area, reported in terms of m^3/ha. Prior to providing the GNN data, DNR clipped it to the state of Washington for ease of use. DNR also provided the tree species volume cross-tabulation table from the plot database, which provides the densities of 116 species common to the Pacific Northwest and California. The buffers created (Section 2.4.1) were used to clip the GNN point layer and evaluate the timber in the riparian zone. Species and timber volume data were then joined using the associated timber volume table (grid_code in the GNN layer matches the SPPS_ATTR_LIVE_FCID column in the timber volume table). The total timber volume of all species within the riparian buffer and the total volume (presented in thousands of board feet [MBF]) of each species within the buffer (Section 2.4.1) were calculated for each network and summarized by ecoregion.

For the proposed west side Type Np rule, the timber volume was calculated for all tree species and for each tree species within the buffers for each network was calculated the same way as under the current rule except for Option 1a. For that option, the volume of timber within outer zone buffers for Option 1a was divided in half to represent the 50% harvest limit before being combined with the rest of the volume of timber within riparian buffers for each network (calculated the same as described above for the current rule). Species-specific and total timber volume were calculated for each network, and then averaged by ecoregion.

2.4.4 Timber Value Calculation

2.4.4.1 Current Rule

To calculate the value (in USD) of the timber within the buffers, the buffers were spatially joined with a Stumpage Value Area (SVA) polygon layer provided by DNR. The state of Washington contains eight SVAs; every 6 months, updated stumpage value tables are provided for these SVAs by the Washington Department of Revenue. These tables provide a monetary value based on the species, the SVA in which the trees are located, and the side of the state (i.e., west or east). Once the buffers were joined with the SVA layer, the value of specific species of tree were assigned based on SVA, using stumpage value tables for January 1 through June 30, 2024. Stumpage values were then combined with the tree species and volume data based on species and SVA. Because there are not existing stumpage values for Red Alder and Black Cottonwood for most of the eastern side of the state, The Red Alder stumpage values from SVA 5 and all western SVA areas except 9 ($511 for the tables valid Jan-June 2024) were used for SVA 6 and 7. Black Cottonwood was dropped for those areas and the east side summaries. The total value of riparian timber within the buffers (Section 2.4.1) was calculated for each network and averaged by ecoregion.

2.4.4.2 Proposed West Side Type Np Rule

For the proposed west side Type Np rule, the value (in USD) of timber that would be contained within Type Np buffers under the proposed alternative scenarios was calculated for all tree species. For Option 1a, the timber value within outer zone Np buffers of each network were first divided in half to represent the 50% harvest limit. These outer zone buffer values were then combined with the value for the rest of the riparian timber within that Type Np buffers, which were calculated as described above for the current rule. Species-specific and total timber values were calculated for each network, and then averaged by ecoregion.

2.4.5 Statewide and State-Side Summaries

Within each ecoregion, the average value of each buffer metric (buffer area, timber volume, and timber value) was calculated for all networks within that ecoregion. These averages were then used to calculate n-weighted averages for the full state of Washington, as well as separately for the east and west sides of the state. Weights were calculated based on the proportion of waters (defined as the total number of F/N and S/N breaks in wchydro without DNR-concurred breaks) within each ecoregion relative to 1) the total number of F/N and S/N breaks without DNR-concurred breaks in wchydro statewide in the relevant ecoregion, and 2) the total number of breaks without DNR-concurred breaks within each ecoregion on each side of the state relative to the total number of waters on that side of the state. Those weights were then applied to the ecoregion averages for each metric to generate statewide and state-side summaries.

For the proposed west side Type Np rule, buffer area, timber volume, and value were only extrapolated to west side waters without DNR-concurred breaks in wchydro, and only for Option 1. N-weighted averages and totals were not calculated for Option 2 because it is applied only when 85% or more of the basin will be harvested within 5 years, and therefore does not represent a direct comparison of available timber.

3 Results

3.1 Create Synthetic Stream Networks

A total of 365 unique locations representing DNR-concurred F/N break points or equivalent points representing the end of fish habitat in eastern Washington were used in this analysis (Figure 5).[12] These points were used to generate SSNs spanning seven Level III ecoregions, with between 12 and 76 networks in each ecoregion (Table 5). Unless otherwise specified, metrics presented below (e.g., distance, buffer area) were calculated for each network and then summarized at the ecoregion level.

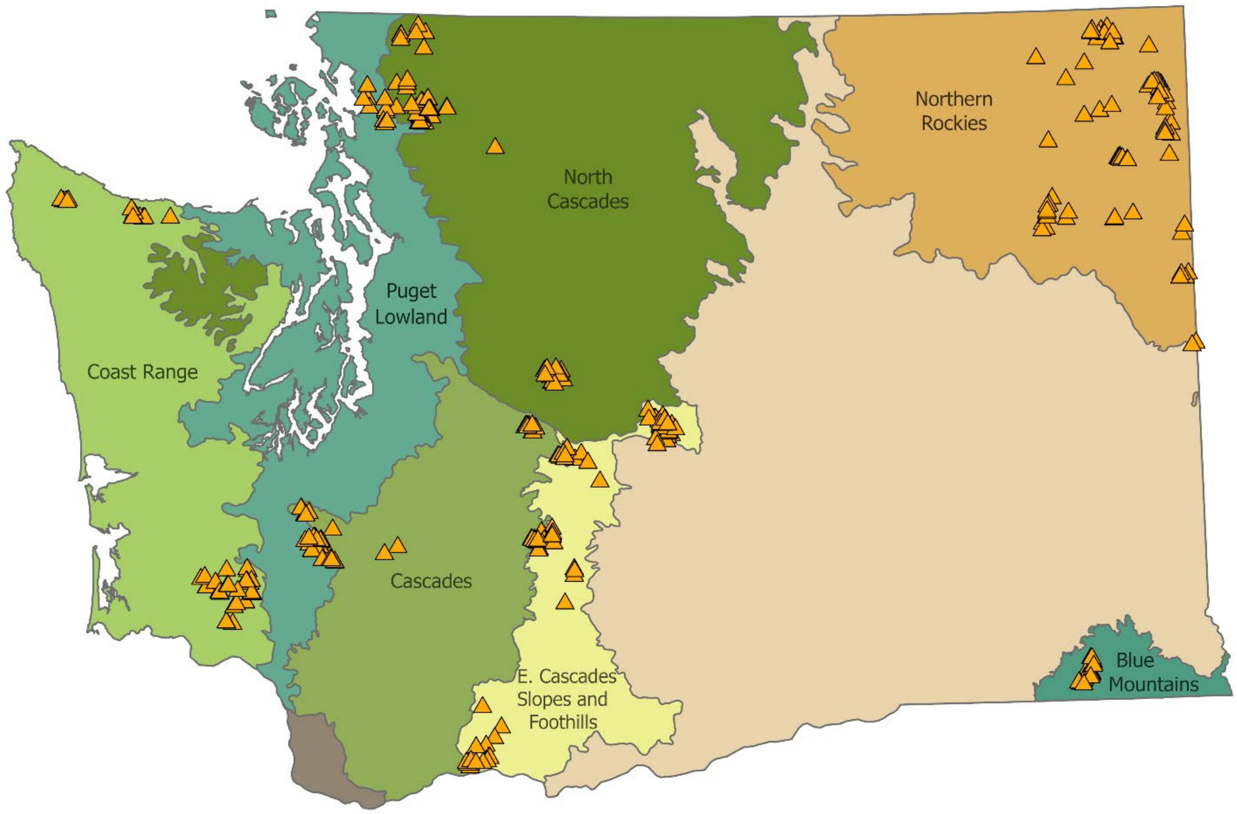


Figure 5. Map of DNR-concurred F/N breaks or equivalent locations (orange triangles) by Washington ecoregion

Table 5. Number of SSNs and average distance between DNR- concurred F/N break and last fish location on those networks

Ecoregion	No. of Synthetic Streams	Distance from Last Fish to DNR-Concurred Break (ft)		
		Mean (SE)	Range	Coincident Points
Puget Lowland	12	494 (144)	0 to 1,660	8.3%
Coast Range	54	196 (49)	0 to 1,668	59.3%
North Cascades	56	343 (71)	0 to 1,891	41.1%
Cascades	76	135 (49)	0 to 2,389	77.6%
E. Cascades Foothills	76	361 (82)	0 to 3,197	59.2%

[12] This group of points is hereafter referred to collectively as DNR-concurred F/N break points.

Ecoregion	No. of Synthetic Streams	Distance from Last Fish to DNR-Concurred Break (ft)		
		Mean (SE)	Range	Coincident Points
Northern Rockies	73	338 (102)	0 to 5,381	67.1%
Blue Mountains	18	677 (319)	0 to 3,988	72.2%

Note:
Positive numbers indicate that the F/N break point is upstream of the last fish point. Coincident percentages represent the percentages of networks in each ecoregion where the last fish and concurred breaks are the same.

After generating the SSNs, the distance between last fish and the DNR-concurred F/N break was summarized to provide a high-level QC check and additional context for comparisons against the last fish and concurred break. Across the state, the n-weighted average distance between the DNR-concurred F/N break point and the last observed fish was 280 feet when weighting the ecoregion averages (Table 5) by the number of water breaks on wchydro within each ecoregion. When weighting the ecoregion averages by the number of water breaks on wchydro on each side of the state, the average distance between the DNR-concurred F/N break and the last fish observation was 354 feet on the east side and 249 feet on the west side. Other than in the Puget Lowland ecoregion, the last fish and concurred break points were identical. This reflects a combination of field observations and last fish points that were manually placed at the same location as the concurred break in a previous analysis (Walter et al. 2022).

3.2 Calculate Potential Habitat Breaks, Anadromous Fish Floor, and Default Physical Characteristics

3.2.1 Potential Habitat Breaks

The following sections represent the PHB analysis using a reach distance of 5x BFW to calculate gradient-based criteria. For PHBs and subsequent distance, Type F, and buffer analyses calculated using a reach length using 20x BFW, see APPENDIX B; for a comparison of PHBs calculated using five different reach lengths, see Section 4.3.

Potential habitat breaks (PHBs) were calculated for 143 networks for Option A (out of a total of 150 networks on the West side of the state), 353 networks for Option B, and all 365 networks for Option C (Table 6). This represents three additional points for Option B and four additional points for Option C relative to PHBs calculated using a 20x Bankfull Width (BFW) reach.

Table 6. Number of networks with at least one PHB calculated by ecoregion

Ecoregion	No. Networks Option A	No. Networks Option B	No. Networks Option C
Puget Lowland	12	12	12
Coast Range	50	50	54
Cascades	39	72	75
North Cascades	41	53	56
E. Cascades Foothills		75	75
Northern Rockies		71	73
Blue Mountains		17	17

For all three PHB options, the first PHB upstream of the last fish point was upstream of the DNR-concurred F/N break more often than it was downstream of the break (Figure 6). However, for Option A the first PHB upstream of the last fish point was downstream of the DNR-concurred F/N break almost as often as it was upstream of the break.

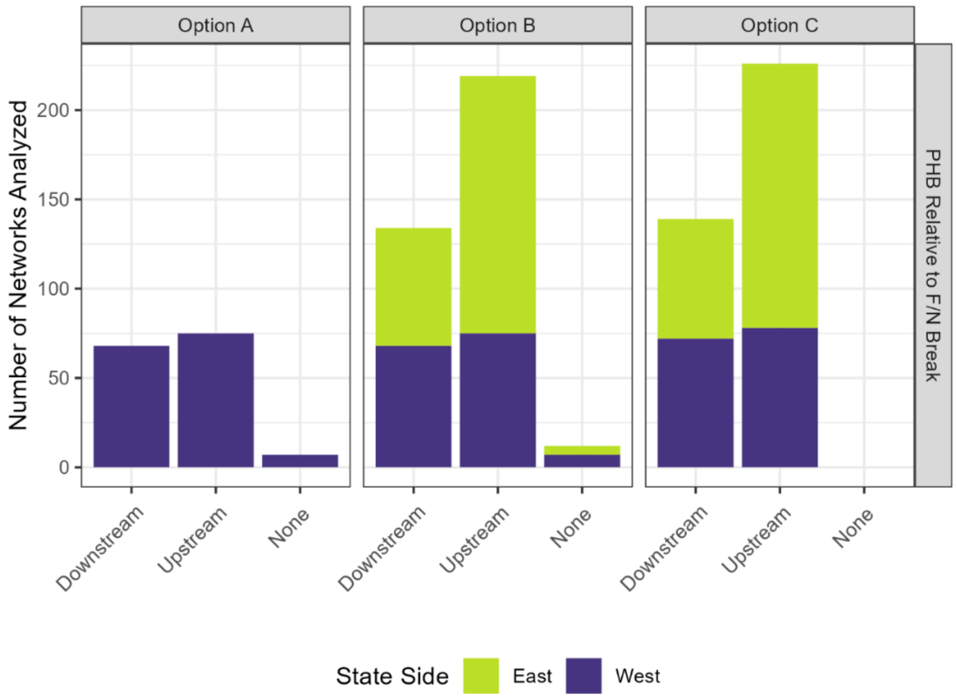


Figure 6. The number of networks with the first upstream potential habitat break upstream or downstream of the DNR-concurred F/N break

3.2.2 Mainstem Fish Habitat Assessment Methodology Point Comparisons

On average, the first PHB above the last fish point on the mainstem[13] was 33 to 693 feet below the DNR-concurred F/N break and 13 to 333 feet above the last fish point (Table 7). The first PHB above last fish was relatively close to the last fish point for most options across all ecoregions, except for Option B in the E. Cascades Foothills and Blue Mountains, where this distance averaged more than 100 feet.

Table 7. Network distance (ft) between the first mainstem PHB (FHAM) point and the DNR-concurred break and last fish points, summarized by ecoregion

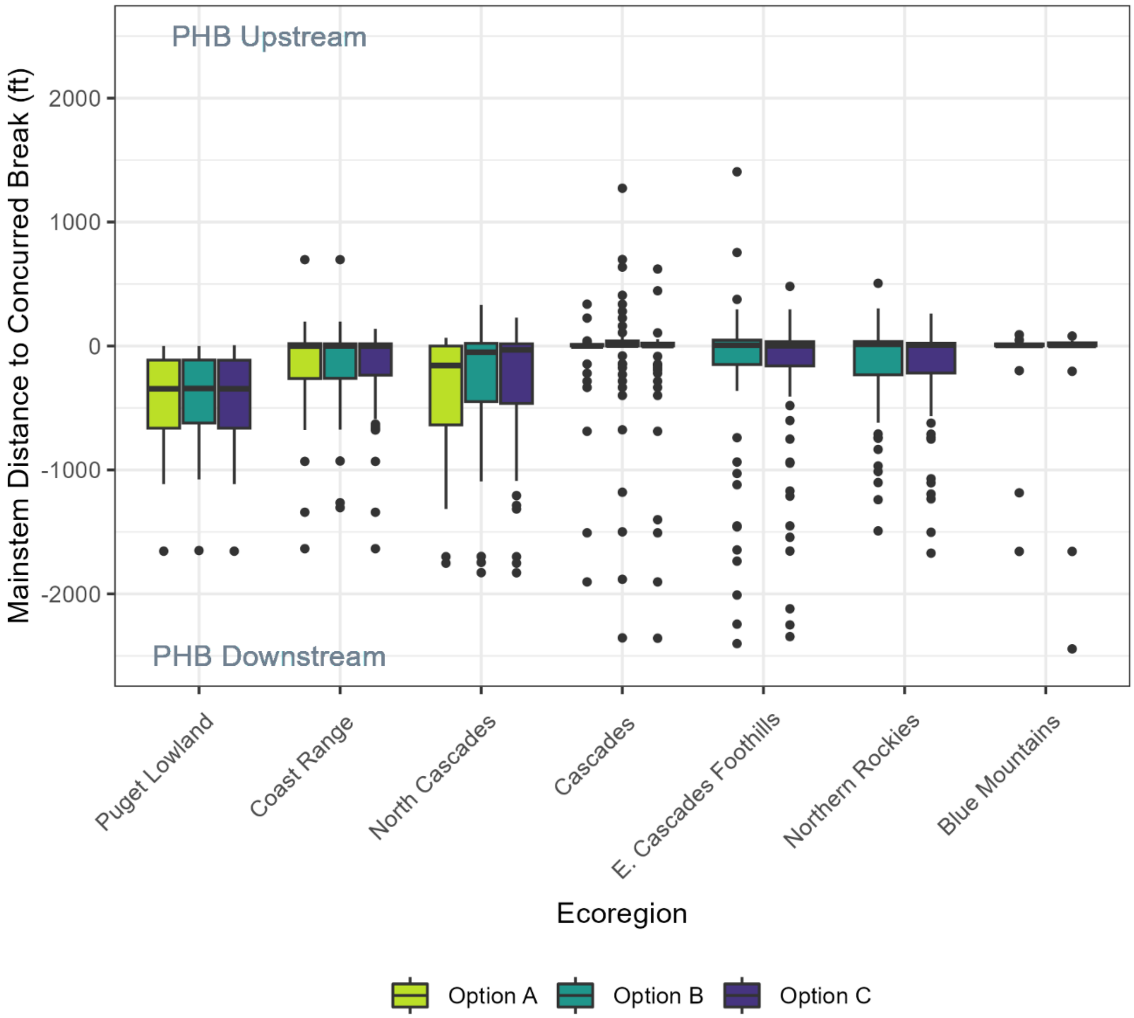
Ecoregion	PHB Option	Distance (ft) FHAM to DNR-concurred Break		Distance (ft) FHAM to Last Fish	
		Mean (SE)	Range	Mean (SE)	Range
Puget Lowland	A	-481 (144)	-1655 to 0	13 (3)	0 to 30
Puget Lowland	B	-469 (143)	-1650 to 0	25 (7)	0 to 86
Puget Lowland	C	-481 (144)	-1655 to 6	13 (3)	0 to 30
Coast Range	A	-177 (55)	-1635 to 697	34 (14)	0 to 697
Coast Range	B	-156 (52)	-1304 to 697	55 (16)	0 to 697
Coast Range	C	-178 (49)	-1635 to 138	18 (3)	0 to 138
Cascades	A	-109 (65)	-1903 to 337	30 (14)	0 to 452
Cascades	B	-60 (57)	-2355 to 1273	82 (23)	0 to 1273

[13] Here, first PHB on the mainstem refers to the first PHB identified upstream of the last fish point.

Ecoregion	PHB Option	Distance (ft) FHAM to DNR-concurred Break		Distance (ft) FHAM to Last Fish	
		Mean (SE)	Range	Mean (SE)	Range
Cascades	C	-105 (51)	-2358 to 621	32 (10)	0 to 621
North Cascades	A	-369 (80)	-1752 to 66	34 (6)	0 to 191
North Cascades	B	-286 (69)	-1828 to 331	76 (20)	0 to 982
North Cascades	C	-308 (69)	-1829 to 229	35 (6)	0 to 229
E. Cascades Foothills	B	-33 (156)	-3063 to 8630	333 (128)	0 to 8630
E. Cascades Foothills	C	-309 (84)	-3176 to 481	57 (10)	0 to 481
Northern Rockies	B	-275 (102)	-5309 to 506	73 (19)	0 to 1158
Northern Rockies	C	-307 (101)	-5358 to 262	31 (7)	0 to 455
Blue Mountains	B	-587 (299)	-3877 to 91	130 (81)	1 to 1354
Blue Mountains	C	-693 (334)	-3973 to 80	24 (7)	1 to 95

Note:
Distance minimum and/or maximum distances may be the same in cases where the FN and LF points are the same

Although mean distance from the first PHB above last fish to the DNR-concurred break was on the order of tens to hundreds of feet (below the break), median distance between these two points was close to 0 for all three PHB options across all ecoregions other than the Puget Lowlands and the North Cascades (Figure 7). Note that all boxplots in this report show the median as the metric of central tendency, in contrast to the means reported in tables. A mismatch in the sign of the median and mean of distance between two points indicates a skewed underlying distribution, which can be seen in the distribution plots, many of which have long “right tails” (Figure 8).



Note: Limits of -4,000 to 2,500 cut out 3 E Cascades and foothills (max) and 4 N Rockies (min). Limits of -2,500 cut out an additional 2 E Cascades and foothills and 4 Blue mountains (each split evenly between Options B and C).

Figure 7. Distance between the first potential habitat break upstream of the last fish on the mainstem and the DNR-concurred F/N break

When considering all PHBs upstream of the last fish location, the distributions of distance from the DNR-concurred F/N break to each PHB were similar for all three options in most ecoregions (Figure 8). The greatest range in distance was observed within the E. Cascades Foothills for all three PHB options. The range in distances between the concurred break and PHBs under Option A was notably smaller relative to the other two options in the Cascades ecoregion.

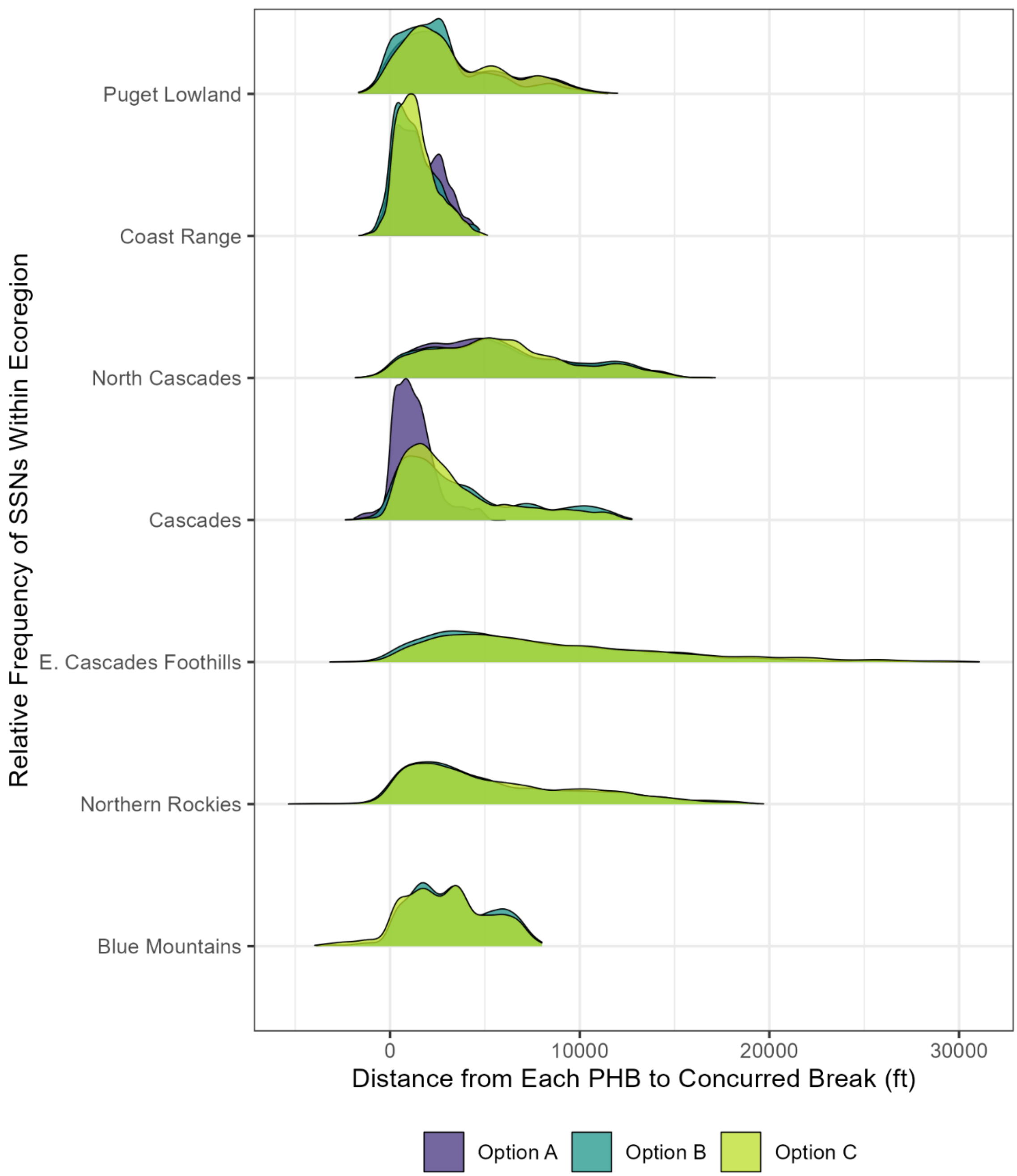
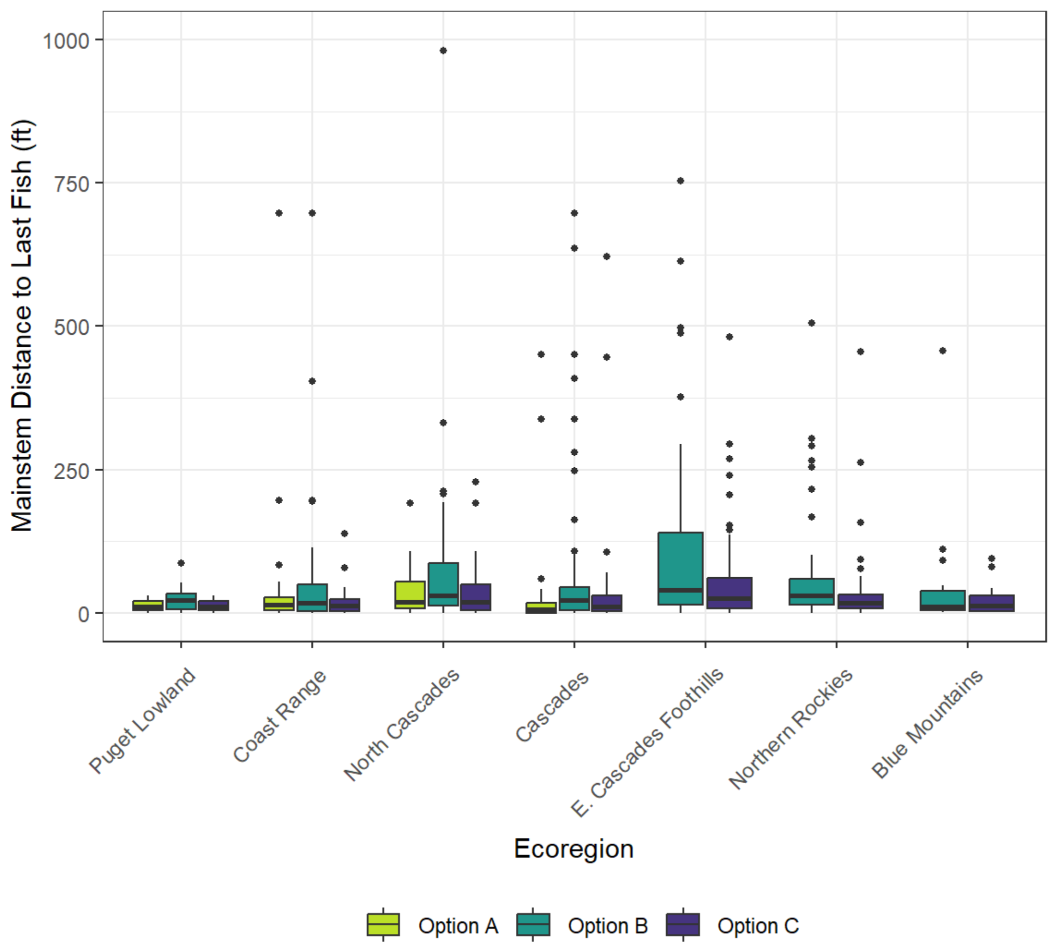


Figure 8. The distance between each PHB upstream of the last fish point to the DNR-concurred break for that network.

Across the state, the distance between the last fish point and the first PHB upstream of last fish was greatest and most variable for Option B (Table 8, Figure 9). Patterns in the distributions of distance between the last fish location and each PHB upstream of the last fish location were similar to those for the distance between the first PHB upstream of last fish and the DNR-concurred break (Figure 10). Distance ranges tended to be similar for all three options in most ecoregions, with the biggest range in distance within the E. Cascades Foothills for all three PHB options. The range in distances between the last fish location and PHBs under Option A was notably smaller relative to the other two options in the Cascades ecoregion and slightly wider in the coast range. The Blue Mountains and Northern Rockies had more PHBs downstream of the concurred break for all three options.

Table 8. N-weighted average summaries of average distances between the first mainstem PHB (FHAM) point and the DNR-concurred break and last fish points

State Side	PHB Option	N-Weighted Average Distance (ft), DNR-Concurred Break to FHAM	N-Weighted Average Distance (ft), Last Fish to FHAM
Statewide	Option A	-204	25
	Option B	-217	75
	Option C	-254	26
East	Option B	-254	115
	Option C	-322	35
West	Option A	-236	30
	Option B	-202	59
	Option C	-227	23



Note: Upper limit 1,000 cuts out 8 outliers (option B only), 5 in E Cascades Foothills, 1 in Cascades, 1 in NR, and 1 in Blue Mtns

Figure 9. Distance between the last fish location and the first potential habitat break upstream of the last fish on the mainstem within each network

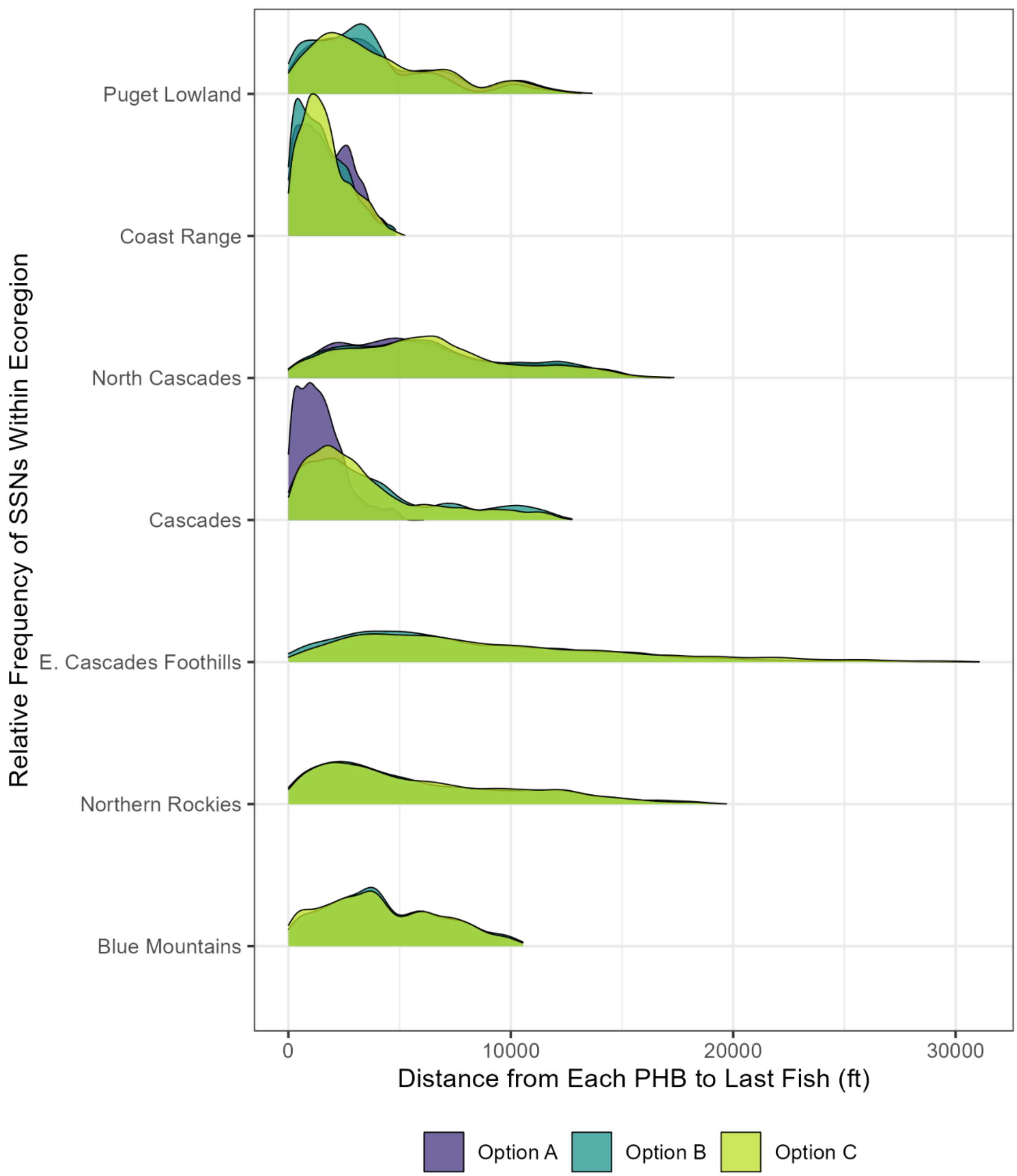


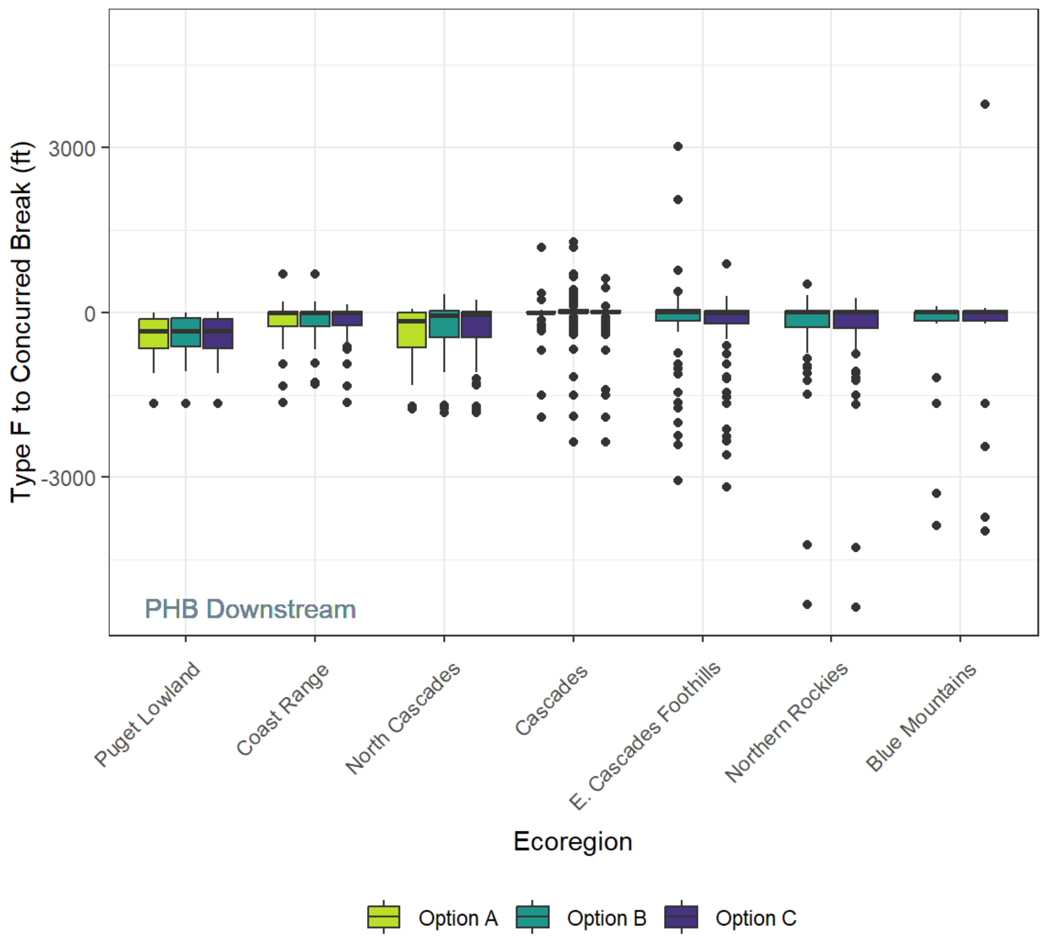
Figure 10. The distance between each PHB upstream of the last fish point to the last fish point

3.2.3 Extent of Type F Waters

Patterns in the distance downstream to or extent of Type F upstream of the last fish point were largely consistent with the mainstem PHB patterns, with Type F overall not extending very far upstream of the last fish point for most options across ecoregions (Table 9), adding Option C in the Blue mountains to Option B in the E. Cascades Foothills and Blue Mountains as the only options averaging more than 100 feet upstream of the last fish point. In addition, the median distance downstream to Type F waters was close to zero for all PHB options across all ecoregions with the exception of all three options in the Puget Lowlands and Option A in the North Cascades (Figure 11). Across the state (and on both sides when considered separately), as with the mainstem PHBs, the extent of Type F waters above the last fish point was greatest (and most variable) for Option B (Table 10, Figure 12).

Table 9. Summary (mean, standard error, and range) of distances (ft) downstream to, or extent upstream of, Type F waters relative to the DNR-concurred break and last fish points

Ecoregion	PHB Option	Number of Networks	N-Weighted Average Distance, DNR-Concurred Break (ft)		N-Weighted Average Distance, Last Fish (ft)	
			Mean (SE)	Range	Mean (SE)	Range
Puget Lowland	Option A	12	-481 (144)	-1655 to 0	13 (3)	0 to 30
Puget Lowland	Option B	12	-469 (143)	-1650 to 0	25 (7)	0 to 86
Puget Lowland	Option C	12	-481 (144)	-1655 to 6	13 (3)	0 to 30
Coast Range	Option A	50	-177 (55)	-1635 to 698	34 (14)	0 to 698
Coast Range	Option B	50	-156 (52)	-1304 to 698	55 (16)	0 to 698
Coast Range	Option C	54	-178 (49)	-1635 to 138	18 (3)	0 to 138
Cascades	Option A	39	-109 (65)	-1903 to 338	30 (14)	0 to 454
Cascades	Option B	72	-59 (57)	-2355 to 1273	83 (23)	0 to 1273
Cascades	Option C	75	-105 (51)	-2358 to 621	32 (10)	0 to 621
North Cascades	Option A	41	-369 (80)	-1752 to 66	34 (6)	0 to 191
North Cascades	Option B	53	-286 (69)	-1828 to 331	77 (20)	0 to 982
North Cascades	Option C	56	-308 (69)	-1829 to 229	35 (6)	0 to 229
E. Cascades Foothills	Option B	75	164 (274)	-3063 to 16777	530 (255)	0 to 16777
E. Cascades Foothills	Option C	75	-303 (85)	-3176 to 882	63 (14)	0 to 882
Northern Rockies	Option B	71	-275 (102)	-5309 to 509	73 (19)	0 to 1156
Northern Rockies	Option C	73	-307 (101)	-5358 to 262	32 (7)	0 to 454
Blue Mountains	Option B	17	-585 (299)	-3877 to 106	131 (81)	1 to 1354
Blue Mountains	Option C	17	-692 (334)	-3973 to 80	25 (7)	1 to 95

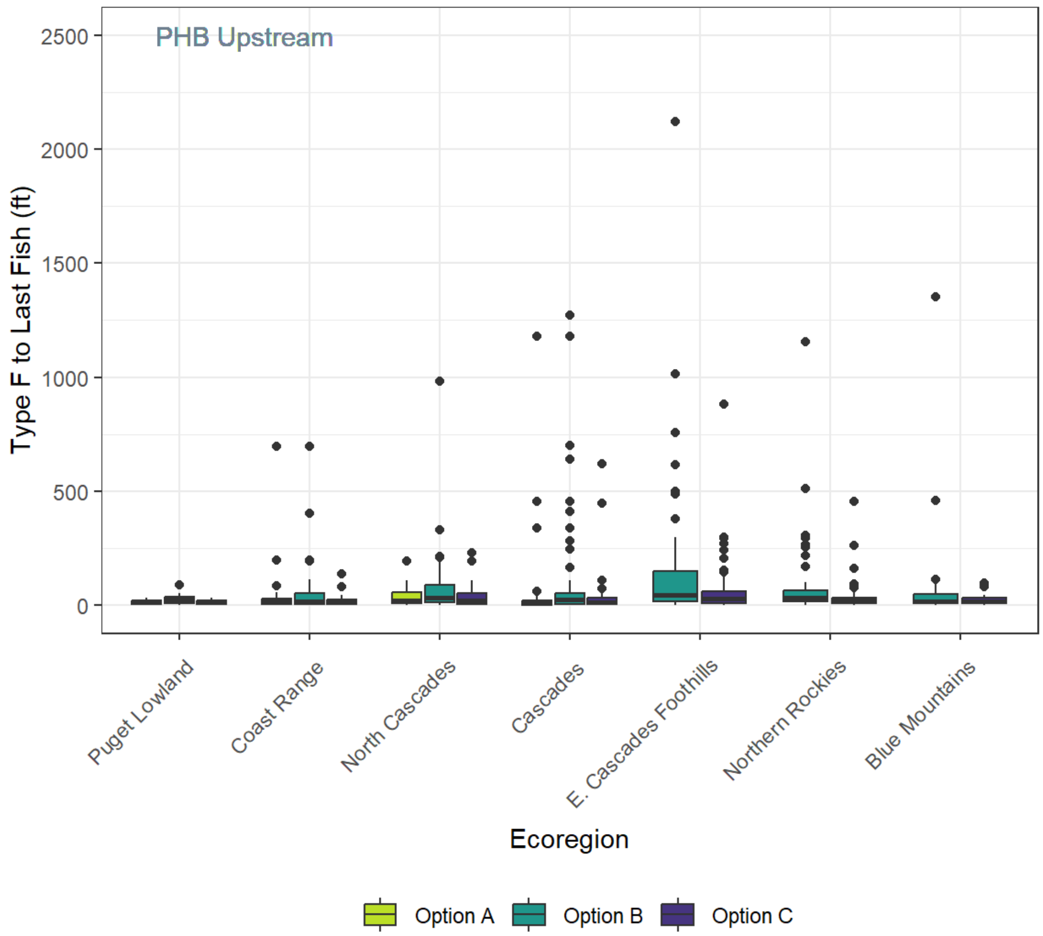


Note: setting upper limit of 5,000 removes 2 outliers from E. Cascades Slopes and Foothills Option B

Figure 11. Total extent upstream of or downstream distance to the uppermost extent of Type F waters to the DNR-concurred F/N break point

Table 10. N-weighted average distance downstream to, or upstream extent of, Type F waters relative to the DNR-concurred break and last fish points

State Side	PHB Option	Extent Upstream of, or Distance Downstream From DNR-concurred Break to, Type F (ft)	Extent Upstream of, or Distance Downstream From Last Fish to, Type F (ft)
Statewide	Option A	-204	25
	Option B	-209	84
	Option C	-254	27
East	Option B	-226	142
	Option C	-321	37
West	Option A	-236	30
	Option B	-202	60
	Option C	-227	23



Note: setting upper limit of 2500 removes 3 outliers from E. Cascades Slopes and Foothills Option B and 1 from Blue Mountains Option C

Figure 12. Total extent of Type F waters upstream of the last observed fish for each SSN

3.2.4 Anadromous Fish Floor

For the AFF analyses, the number of networks (each corresponding to a DNR-concurred break) included in the distance analyses varied by AFF alternative (Table 11). Under Alternative A4, the AFF tended to extend upstream of the DNR-concurred break and last fish locations more often than it was placed downstream, especially on the west side of the state (Figure 13). In contrast, under Alternative D, the AFF extended to a point downstream of the DNR-concurred break and last fish points more often than it extended upstream. Most occurrences of AFF Alternative D extending upstream of the F/N break were because the upper extent of anadromy recorded in SWIFD extended above the break.

Table 11. The number of networks analyzed for each AFF alternative

Ecoregion	No. Networks Analyzed for AFF Alternative A4	No. Networks Analyzed for AFF Alternative D
Puget Lowland	11	11
Coast Range	53	53
North Cascades	56	56

Ecoregion	No. Networks Analyzed for AFF Alternative A4	No. Networks Analyzed for AFF Alternative D
Cascades	71	71
E. Cascades Foothills	71	49
Northern Rockies	49	5
Blue Mountains	18	18

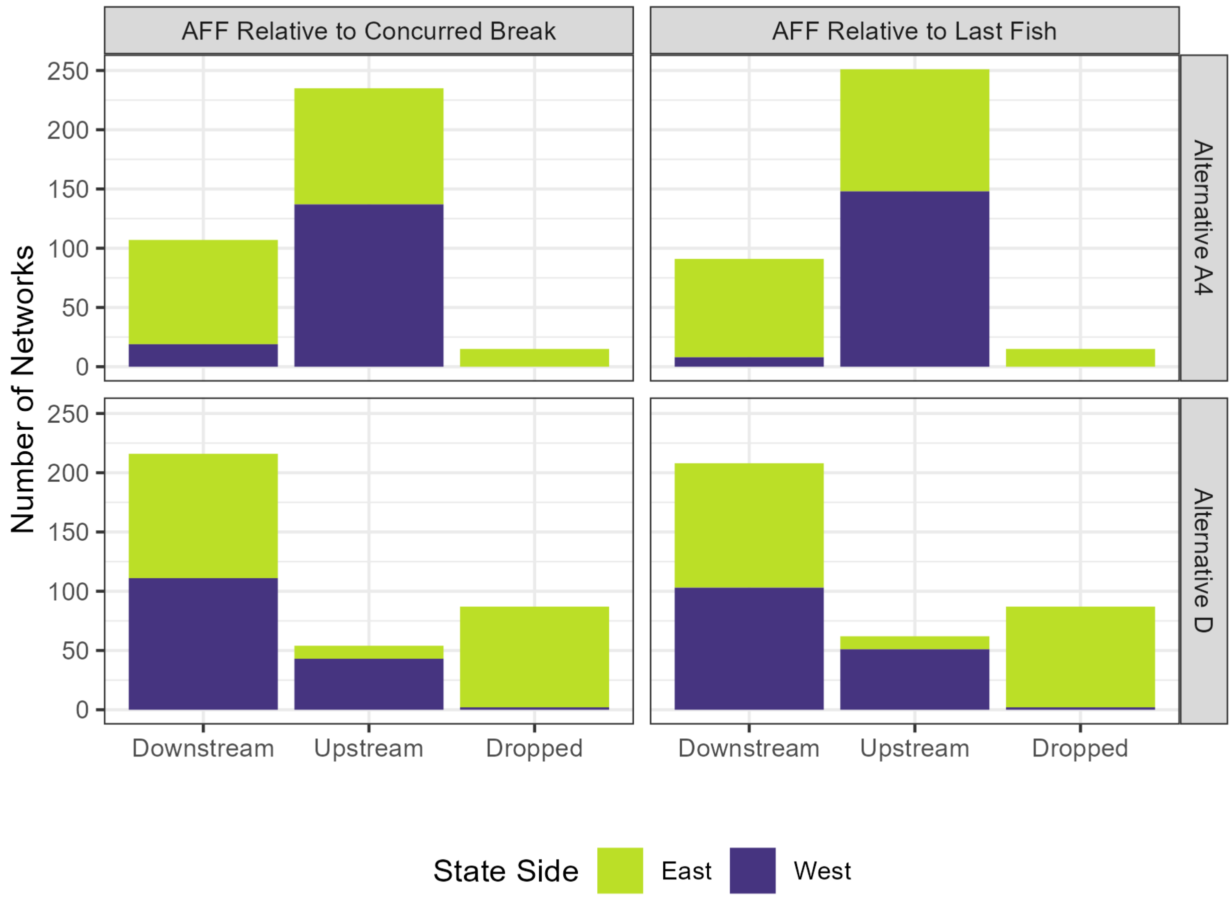
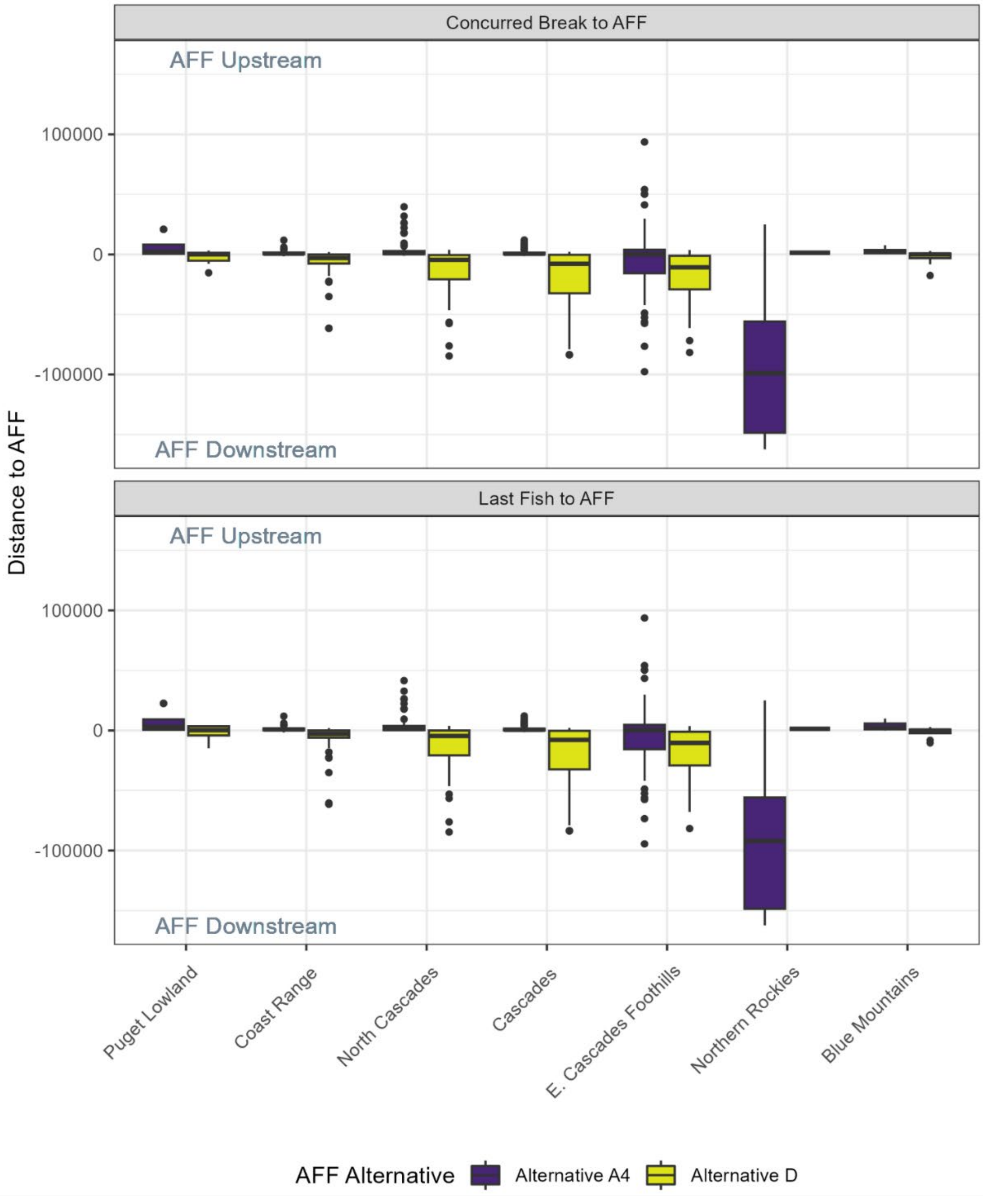


Figure 13. The number of networks whose anadromous fish floor is downstream of or extends upstream above the last fish and DNR-concurred F/N break points

Across the state, the AFF under Alternative A4 extended farther upstream than under Alternative D (Figure 14). The extent of both alternatives was very close to the DNR-concurred break in the Blue Mountains, and close to the break in the Puget Lowlands as well. The greatest variation in distance between AFF extent and the DNR-concurred F/N break was observed in the Cascade and North Cascades ecoregions, especially for Alternative D.



Note: Negative distances indicate that the uppermost extent of the AFF under the given alternative was downstream of the last fish or DNR-concurred break point, while positive numbers represent the extent of AFF upstream of the last fish or DNR-concurred break point.

Figure 14. Distance downstream to, or the extent of anadromous fish floor upstream of, the last fish location and DNR-concurred F/N break point for Alternatives A4 (7%) and D

In most ecoregions, the AFF extended farther upstream on the east side than the west side (Table 12). This was not the case for the Northern Rockies ecoregion (Table 13), where most of the subwatersheds in the region only had a fluvial connection to anadromy and therefore the AFF stopped at the subwatershed outlet well downstream of the last fish and F/N break points.

Table 12. N-weighted average of ecoregion-average network distances (ft) between the last fish and upper extent of the AFF, and between the F/N break and upper extent of the AFF, by state side and statewide

State Side	AFF Alternative	N-Weighted Average AFF Extent Above or Distance Downstream from F/N Break (ft)	N-Weighted Average AFF Extent Above or Distance Downstream from Last Fish (ft)
Statewide	Alternative A4 (7%)	-3,611	-3,336
	Alternative D	-9,117	-8,885
East	Alternative A4 (7%)	-17,891	-17,527
	Alternative D	-16,837	-16,626
West	Alternative A4 (7%)	2,219	2,457
	Alternative D	-5,965	-5,726

Note:
Negative numbers indicate that the upper extent of AFF was downstream of the last fish or F/N break point. Values are expressed in terms of distance per SSN.

Table 13. Network distances between the last fish and upper extent of anadromous fish floor, and between the F/N break and upper extent of AFF, summarized by ecoregion

Alternative	Ecoregion	Extent of AFF Upstream of or Distance Downstream to DNR-Concurred Break (ft)		Extent of AFF Upstream of or Distance Downstream to Last Fish (ft)	
		Mean (SE)	Range	Mean (SE)	Range
Alternative A4	Puget Lowland	3,683 (1,853)	-95 to 20,866	4,219 (1,989)	49 to 22,526
	Coast Range	1,301 (274)	-1,677 to 11,802	1,467 (276)	-1,677 to 11,899
	North Cascades	4,887 (1,197)	-1,217 to 39,641	5,230 (1,209)	-261 to 41,501
	Cascades	1,444 (296)	-1,488 to 11,954	1,571 (299)	-1,412 to 12,072
	E. Cascades Foothills	1,033 (2,502)	-48,946 to 93,660	1,362 (2,497)	-47,289 to 93,660
	Northern Rockies	-47,859 (3,555)	-81,381 to 24,992	-47,487 (3,540)	-81,381 to 24,992
	Blue Mountains	2,570 (564)	-77 to 7,653	3,247 (757)	-77 to 9,873
Alternative D	Puget Lowland	-2,030 (1,192)	-7,964 to 3,159	-1,495 (1,238)	-7,677 to 3,965
	Coast Range	-4,892 (937)	-30,954 to 2,013	-4,723 (931)	-30,367 to 2,013
	North Cascades	-7,704 (1,412)	-42,326 to 3,883	-7,361 (1,403)	-42,326 to 3,883
	Cascades	-10,385 (1,508)	-42,050 to 2,189	-10,257 (1,503)	-42,050 to 2,189
	E. Cascades Foothills	-10,134 (1,254)	-41,126 to 3,715	-9,785 (1,236)	-41,126 to 3,715
	Northern Rockies	-29,582 (2,362)	-47,320 to 1,378	-29,582 (2,362)	-47,320 to 1,378
	Blue Mountains	-1,196 (746)	-9,169 to 2,819	-518 (506)	-5,180 to 2,819

Note:
Negative numbers indicate that the upper extent of AFF was downstream of the last fish or F/N break point. Values are expressed in terms of distance per SSN.

3.2.5 Default Physical Characteristics

Across the state, the upper end of waters meeting the DPC were located downstream of the DNR-concurred F/N break more often than upstream (Figure 15). The average distance between the upper extent of waters meeting the DPC was closer to the DNR-concurred F/N break point than the last fish point (Figure 16). However, waters meeting the DPC tended to extend farther upstream relative to the last fish and DNR-concurred F/N break points on the east side of the state than on the west side (Table 14) when weighting the ecoregion averages (Table 15) by the number of water breaks on wchydro within each ecoregion.

When beginning to look for breaks in DPC within approximately 2,000 feet downstream of the last fish point, fixed-gradient thresholds for DPC frequently placed the end of DPC downstream of the last fish point (Figure 15). By contrast, when breaks in DPC were only evaluated upstream of the last fish point, the extent of DPC extended above the F/N break most of the time (Figure 17). However, there could be substantial stretches of stream meeting the DPC criteria upstream of the first break (Figure 18; for additional example maps, see APPENDIX C). Overall, these results are meant for comparison purposes and do not represent changes in how DPC is currently applied in the field or part of current or proposed water type rules.

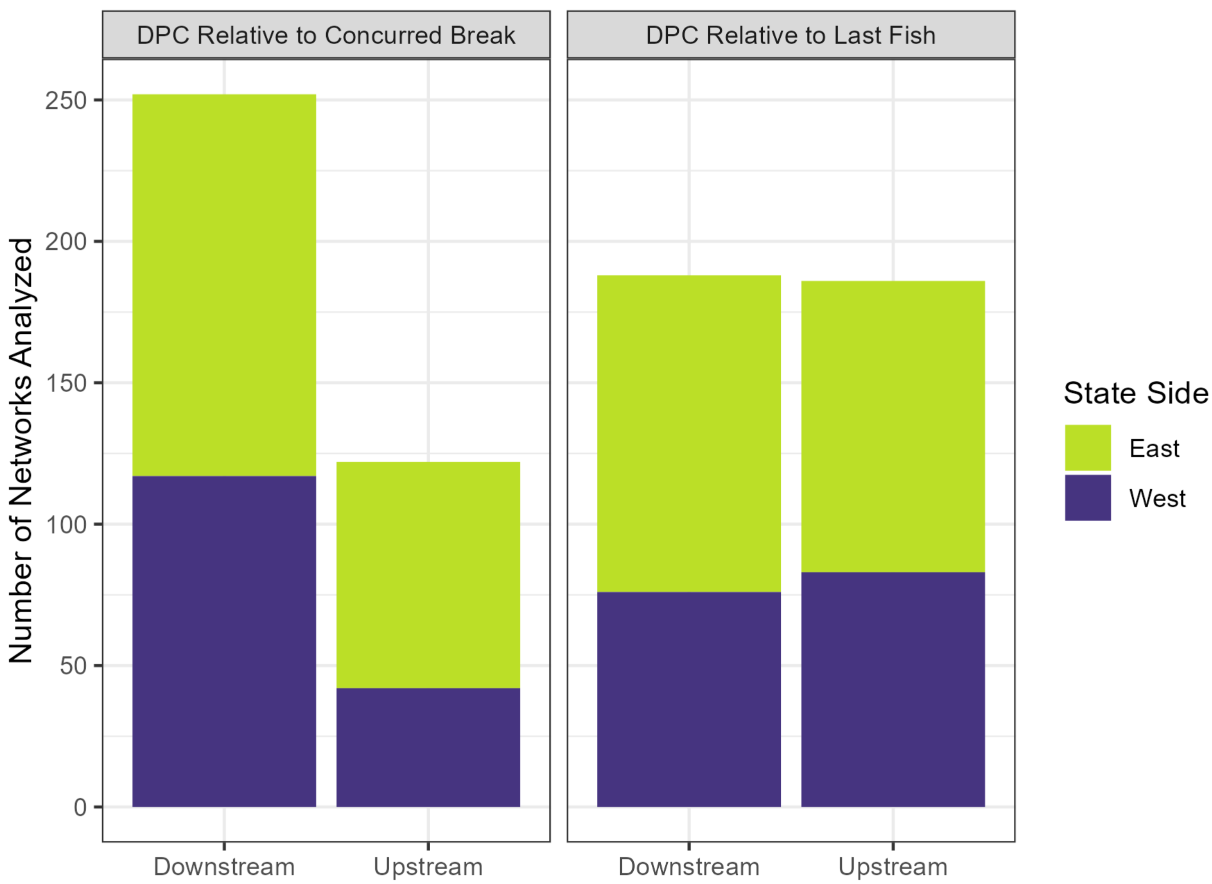
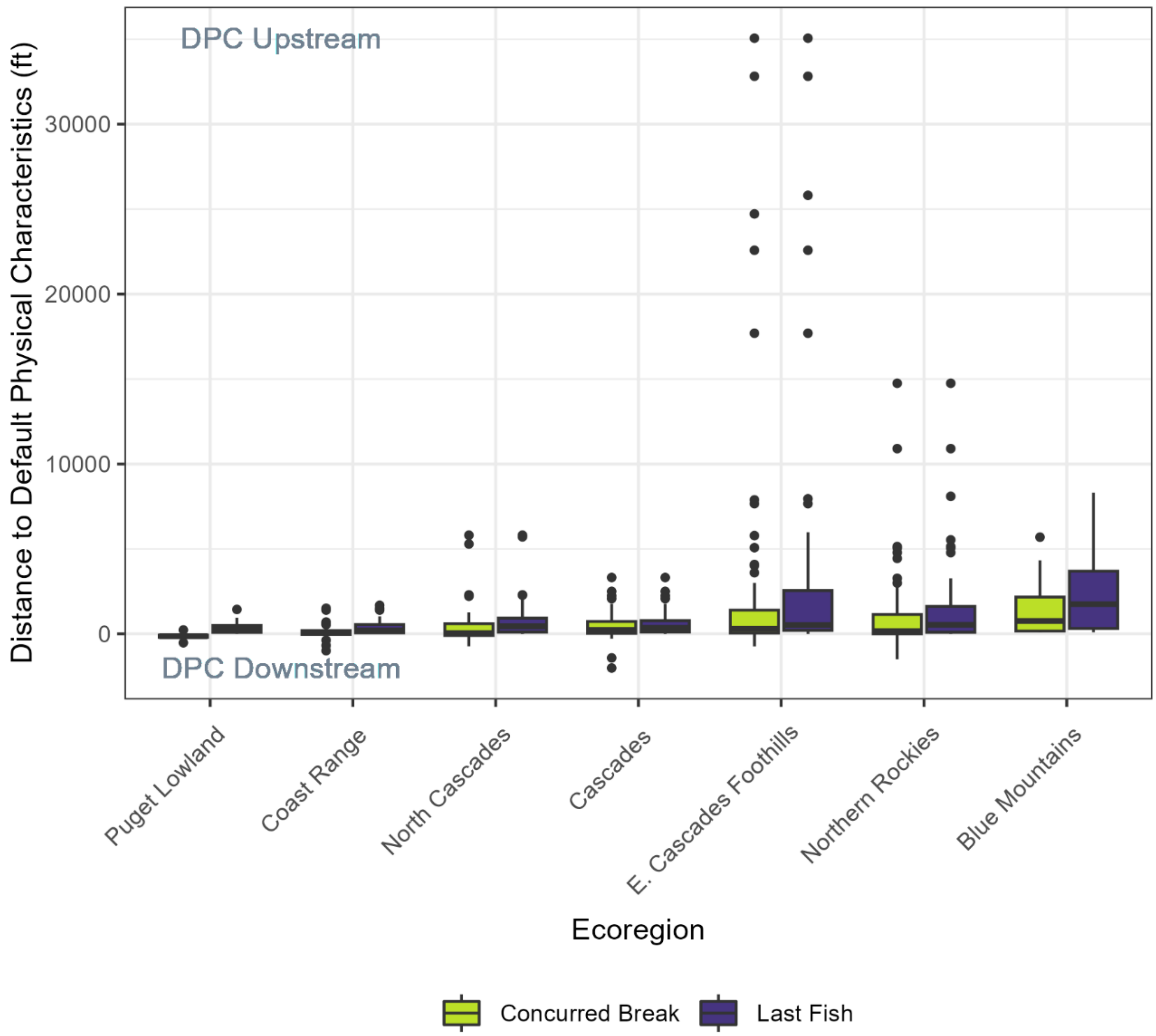


Figure 15. The number of networks with the upstream extent of waters meeting unbroken default physical characteristics downstream of or extending upstream of the last fish and DNR-concurred F/N break points when DPC is considered downstream of the first break in DPC within approximately 2,000 feet downstream of the last fish point



Note: Negative distances indicate that the uppermost extent of DPC was downstream of the last fish or DNR-concurred break point, while positive numbers represent the extent of DPC upstream of the last fish or DNR-concurred break point.

Figure 16. Total extent upstream of or downstream distance to the uppermost extent of waters that meet the DPC

Table 14. N-weighted average distances (weighted mean of ecoregion-averaged network distance) between the last fish and upper extent of stream segments meeting the DPC, and between the DNR-concurred F/N break and the upper extent of stream segments meeting the DPC, by state side and statewide

State Side	N-Weighted Average DPC Extent Upstream of or Distance Downstream from	
	DNR-Concurred Break (ft)	Last Fish (ft)
Statewide	464	774
East	1,101	1,495
West	204	479

Note:
Negative numbers indicate that the upper extent of DPC was downstream of the last fish or F/N break point. Breaks in DPC were evaluated beginning upstream of the last fish point. Values are expressed in terms of distance per SSN.

Table 15. Network distances between the last fish and F/N break and upper extent of stream segments meeting the DPC, summarized by ecoregion

Ecoregion	DPC Extent Upstream of or Distance Downstream to DNR-Concurred Break (ft)		DPC Extent Upstream of or Distance Downstream to Last Fish (ft)	
	Mean (SE)	Range	Mean (SE)	Range
Puget Lowland	-137 (56)	-521 to 230	402 (134)	6 to 1,439
Coast Range	133 (58)	-989 to 1,509	349 (57)	1 to 1,683
North Cascades	438 (170)	-735 to 5,809	814 (168)	1 to 5,809
Cascades	457 (104)	-2,008 to 3,319	617 (88)	1 to 3,319
E. Cascades Foothills	2,687 (802)	-740 to 35,062	3,058 (799)	3 to 35,062
Northern Rockies	1,110 (316)	-1,489 to 14,751	1,490 (324)	2 to 14,751
Blue Mountains	1,474 (436)	94 to 5,694	2,287 (660)	94 to 8,317

Note:
Negative numbers indicate that the upper extent of DPC was downstream of the last fish or F/N break point. Breaks in DPC were evaluated beginning upstream of the last fish point. Values are expressed in terms of distance per SSN.

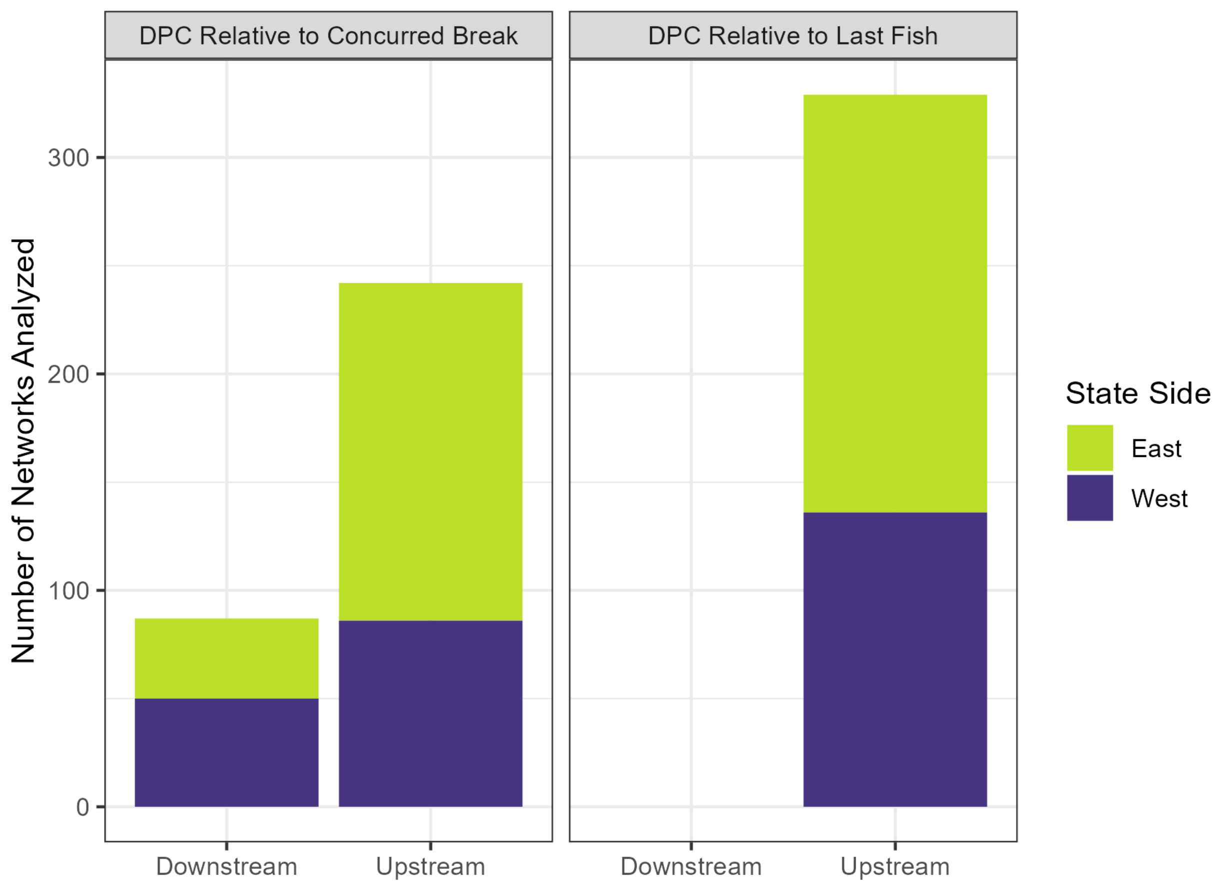


Figure 17. The number of networks with the upstream extent of waters meeting unbroken DPC downstream of or extending upstream of the last fish and DNR-concurred F/N break points when DPC is considered downstream of the first break above the last fish point

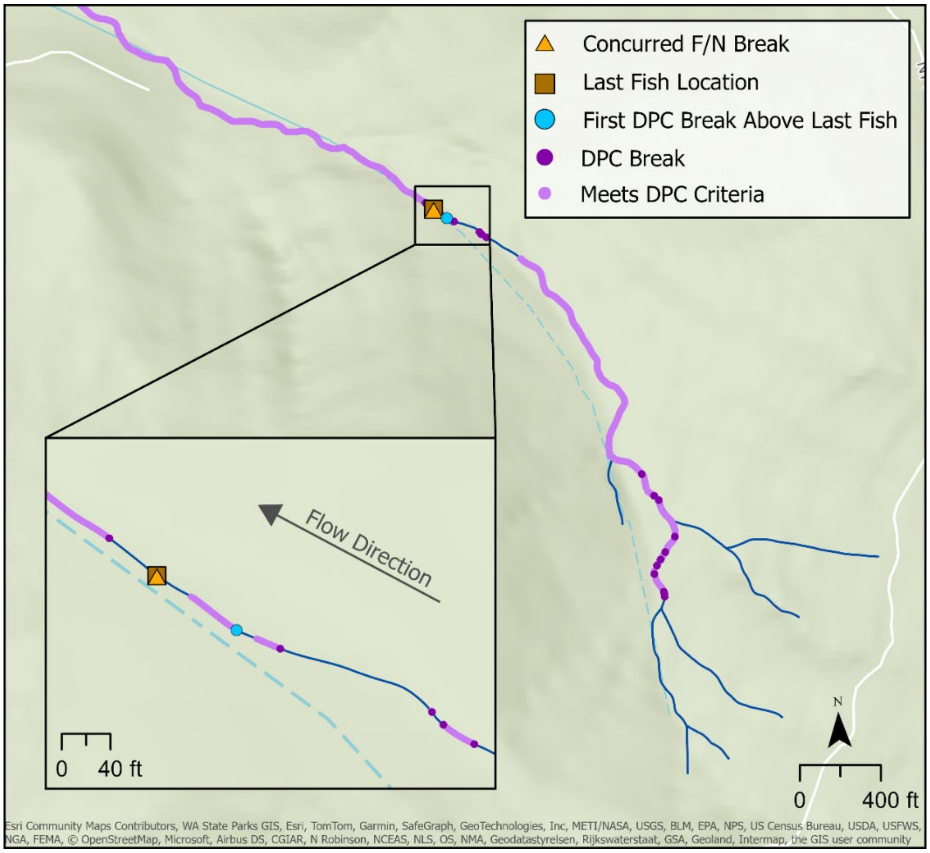


Figure 18. Example of stream reaches meeting DPC criteria throughout a SSN, with the first break in DPC just upstream of the last fish and DNR-concurred F/N break

When the first break in waters meeting the DPC was identified upstream of the last fish point, DPC waters extended above the DNR-concurred F/N break point, on average, in most ecoregions (Table 15). The break in waters meeting DPC was farthest upstream in the E. Cascades Foothills ecoregion; in the Puget Lowlands, the break in waters meeting DPC was on average 137 feet downstream of the F/N break. The n-weighted average extent of DPC was upstream of the F/N break statewide and on both sides of the state and extended farther upstream on the east side than on the west side. Among all ecoregions, when measuring from the last fish location, waters meeting DPC criteria extended between 349 and 3,058 feet upstream.

3.3 Compare the Extent of Type F Waters, Anadromous Fish Floor, and Default Physical Characteristics

Within each network, there was substantial variation in the proportion of an SSN that would be considered Type F waters under each PHB option, the extent of AFF for each alternative, and the extent of waters meeting the DPC (Table 16). The proportion of SSN covered by a given metric in the Puget Sound and E. Cascades Foothills ecoregions tended to be lower and had a wider range across metrics when compared to other ecoregions. In contrast, the Coast Range and Cascades ecoregion west of the Cascades tended to have a relatively high proportion of all metrics relative to the total length of the networks in that ecoregion. The proportions of Type F waters, the extent of both AFF options, and DPC relative to network extent were all higher on the west side than on the east side of the state when weighting ecoregion averages by the number of water breaks on wchydro (Table 17).

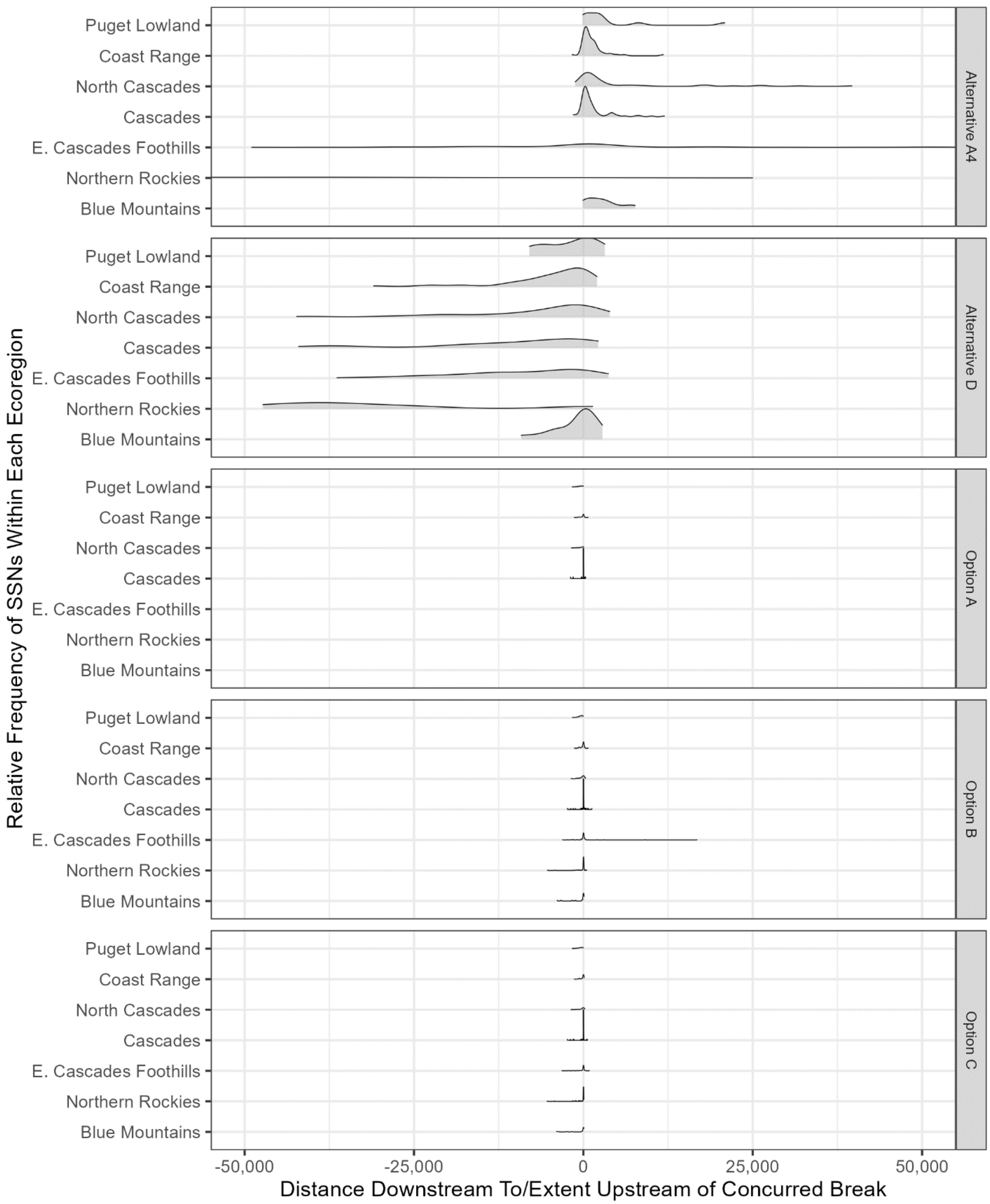
Table 16. Extent of Type F waters for each PHB option, extent of AFF within the network for both alternatives, and extent of DPC in the synthetic stream networks, expressed as proportions of total network length, for each ecoregion

Ecoregion	Proportion Type F for PHB Option A	Proportion Type F for PHB Option B	Proportion Type F for PHB Option C	Proportion Within AFF for Alternative A4	Proportion Within AFF for Alternative D	Proportion Meeting DPC
Puget Lowland	0.72	0.73	0.72	0.86	0.70	0.71
Coast Range	0.89	0.90	0.90	0.93	0.81	0.90
North Cascades	0.74	0.74	0.75	0.82	0.62	0.74
Cascades	0.91	0.87	0.87	0.90	0.73	0.86
E. Cascades Foothills		0.62	0.59	0.51	0.45	0.61
Northern Rockies		0.82	0.81	0.08	0.23	0.81
Blue Mountains		0.80	0.77	0.85	0.76	0.80

Table 17. N-weighted averages of the proportion of each metric (within-network extent of Type F waters for each PHB option, extent of AFF for each alternative, and extent of DPC) relative to the full network extent, by state side and statewide

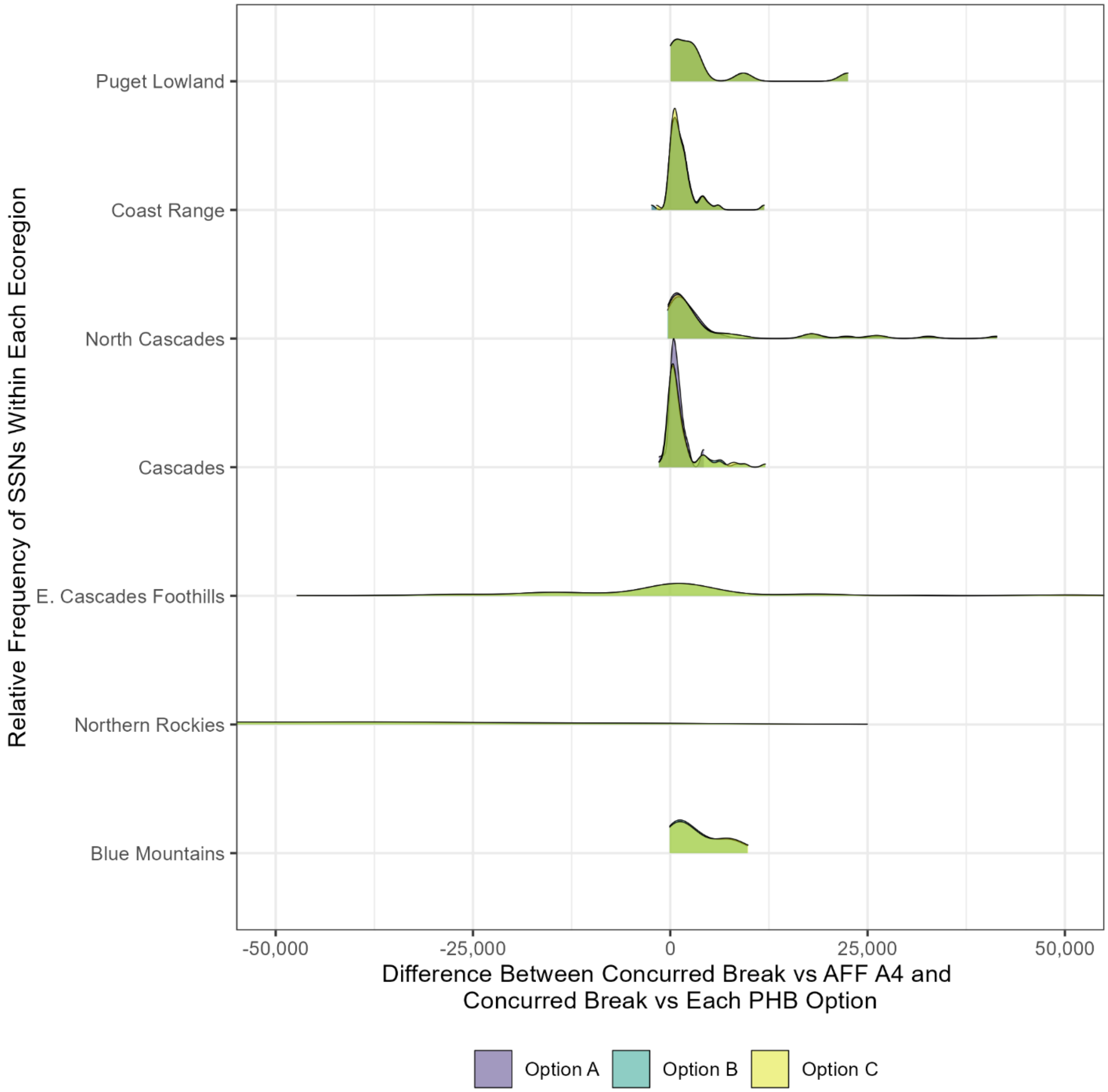
State Side	Proportion Type F for PHB Option A	Proportion Type F for PHB Option B	Proportion Type F for PHB Option C	Proportion Within AFF for Alternative A4	Proportion Within AFF for Alternative D	Proportion Meeting DPC
Statewide	0.69	0.82	0.82	0.78	0.66	0.82
East	-	0.77	0.76	0.48	0.45	0.76
West	0.85	0.85	0.85	0.90	0.75	0.84

Overall, the range in the relative position of both AFF alternatives to the DNR-concurred break was much more variable across networks and ecoregions than across PHB options (Figure 19). While Alternative A4 placed the AFF relatively close but upstream of the concurred break, it was usually upstream of all three PHB options (Figure 20). When Alternative A4 was placed substantially downstream of the break and all three PHB options, that was usually a network in which the AFF was placed at the outlet of the watershed due to a lack of SWIFD in the watershed, most of which were located in the Northern Rockies ecoregion.



Note: This figure only includes distances downstream to or extent upstream of Type F waters for networks analyzed for at least one AFF Alternative. Values < -50,000 and > 50,000 were excluded from this figure to increase figure legibility.

Figure 19. Distance downstream to, or extent upstream of, AFF alternatives or PHB-derived Type F waters relative to the concurred break



Note: Values < -50,000 and > 50,000 were excluded from this figure to increase figure legibility.

Figure 20. The difference between the extent upstream of, or distance downstream to, AFF Alternative A4 and the concurred break, and the extent upstream of, or distance downstream to, Type F waters under each PHB option.

3.4 Water Type Buffer and Riparian Timber Comparisons

3.4.1 Total Riparian Buffer Area

When PHBs were calculated using a reach length of 5x BFW for gradient criteria, total riparian buffer area was greatest in the Cascades or North Cascades ecoregion for all three options and the concurred break (Table 18, Figure 21). Total buffer area did not change substantially for most networks across all three options (Figure 22), and on average decreased by a half to two acres in almost all ecoregions for all three PHB options relative to the DNR-concurred break (Table 19).

Table 18. Total (combined Type F and Type N) riparian buffer area (ac) per SSN for each PHB option, summarized by ecoregion

Ecoregion	Total Buffer Area (ac) per SSN							
	DNR-Concurred F/N Break		PHB Option A		PHB Option B		PHB Option C	
	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range
Puget Lowland	141.2 (26.4)	54.2 to 342.6	139.4 (26.4)	50.8 to 342.4	139.4 (26.4)	50.8 to 342.4	139.4 (26.4)	50.8 to 342.4
Coast Range	243.7 (21.5)	56.2 to 975.6	240.0 (22.8)	50.4 to 972.5	240.1 (22.8)	50.9 to 972.5	243.0 (21.5)	50.6 to 972.5
North Cascades	230.7 (13.3)	43.3 to 467.8	244.4 (15.4)	64.2 to 461.6	231.8 (13.6)	43.4 to 467	229.6 (13.2)	43.4 to 461.6
Cascades	286.9 (10.4)	44.2 to 540.4	314.5 (17.8)	43.4 to 540.5	287.7 (10.8)	43.4 to 540.6	286.5 (10.4)	43.4 to 540.5
E. Cascades Foothills	165.8 (10.4)	30.7 to 492.7			166.1 (10.4)	30.7 to 493.1	165.3 (10.4)	30.7 to 492.7
Northern Rockies	228.1 (11.0)	31.2 to 391.4			229.6 (11.2)	32.2 to 390.1	227.5 (11.0)	31.2 to 391.4
Blue Mountains	145.4 (16.0)	44.5 to 251.7			143.9 (15.8)	44.5 to 247.4	143.8 (15.7)	44.5 to 245.2

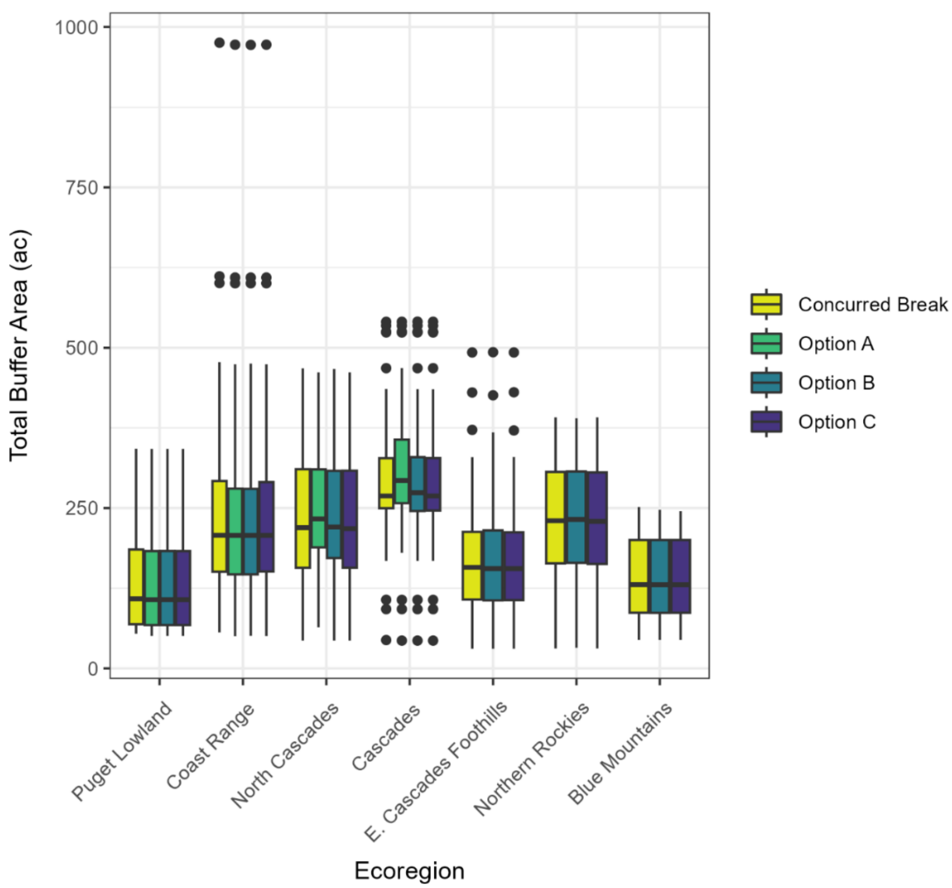
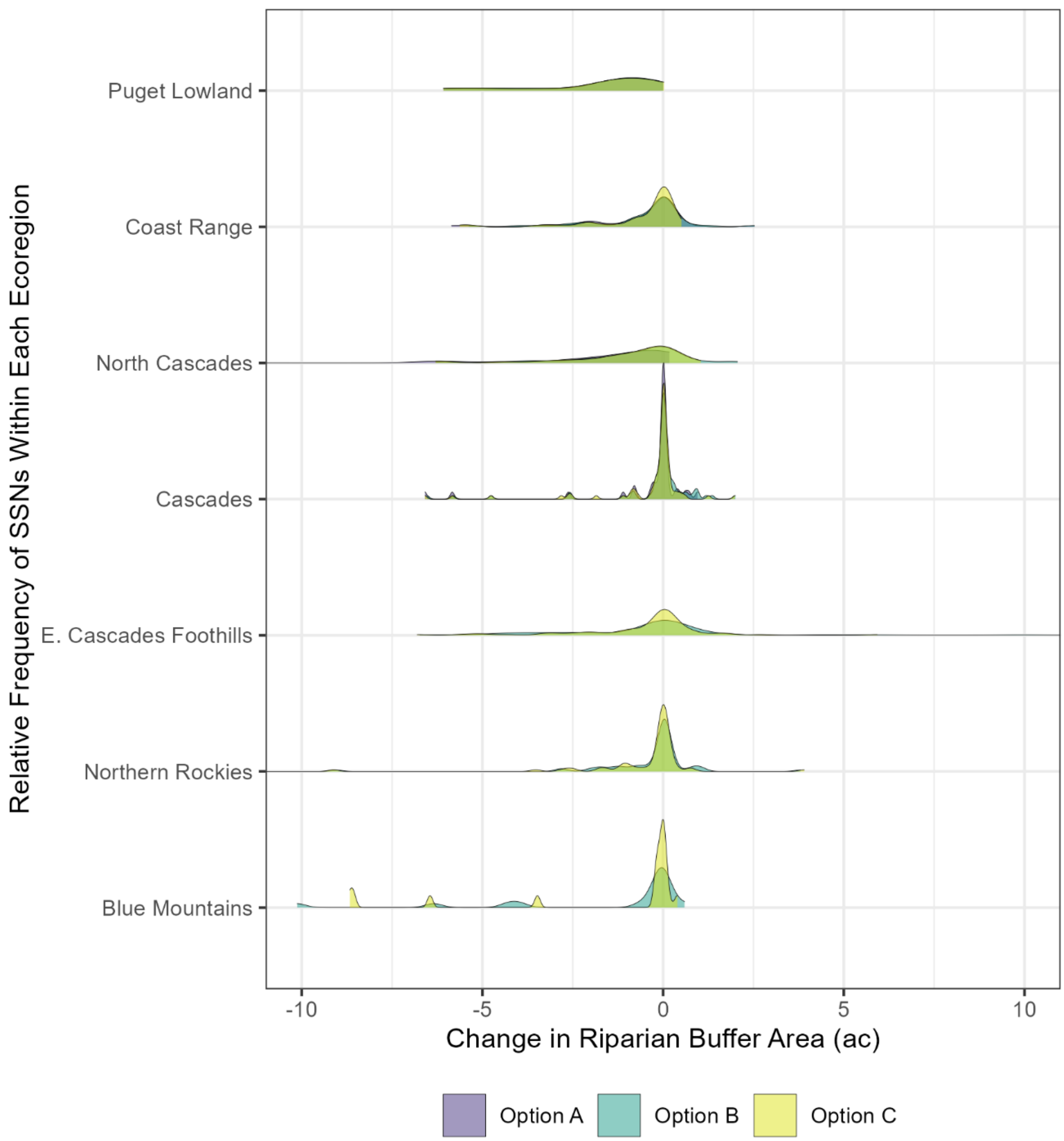


Figure 21. Total riparian (combined Type F and Type N) buffer area (ac) for each network

Table 19. Change in total (combined Type F and Type N) riparian buffer area (ac) per SSN for each PHB option, summarized by ecoregion

Ecoregion	Total Buffer Area Net Change (ac)					
	Option A		Option B		Option C	
	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range
Puget Lowland	-1.9 (0.6)	-6.1 to 0	-1.8 (0.5)	-6.1 to 0	-1.9 (0.6)	-6.1 to 0
Coast Range	-0.7 (0.2)	-5.9 to 2.5	-0.6 (0.2)	-5.4 to 3.7	-0.7 (0.2)	-5.6 to 3.7
North Cascades	-1.7 (0.4)	-12.5 to 1.8	-0.9 (0.2)	-6.3 to 2.1	-1.1 (0.2)	-6.3 to 1.9
Cascades	-0.4 (0.2)	-6.6 to 1	-0.2 (0.2)	-6.5 to 2	-0.4 (0.2)	-6.6 to 2
E. Cascades Foothills			0.2 (0.6)	-6.7 to 35	-0.5 (0.2)	-6.8 to 5.9
Northern Rockies			-0.5 (0.2)	-12.1 to 3.8	-0.6 (0.2)	-12 to 3.9
Blue Mountains			-1.5 (0.7)	-10.1 to 0.6	-1.6 (0.8)	-8.7 to 0.4

Note:
Negative values indicate that buffer area decreased under the relevant PHB option. Changes are calculated within-network before being summarized (averaged). Consequently, the mean of those changes is not always equal to the difference between ecoregion means, because sample sets for the DNR-concurred break scenario may differ among comparisons for the various PHB options and ecoregions. For example, means for Option A are only calculated for west side networks and do not include buffers from the DNR-concurred break on the east side of the North Cascades and Cascades ecoregions.



Note: Values < -10 ac and > 10 ac were excluded from this figure to increase figure legibility.

Figure 22. Within-network net change in riparian buffer area (ac) between buffers calculated under the concurred break and buffers calculated based on each PHB option.

Statewide, buffer area was highest for the DNR-concurred break and lowest under Option A. Within-network changes between PHB options and the concurred break were less than 1% statewide and on both sides of the state (Table 20). Overall, buffer area was lower on the east side than on the west side.

Table 20. N-weighted network riparian (combined Type F and type N) buffer area (ac) and n-weighted average change in buffer area per SSN between the DNR-concurred break and each PHB option

State Side	PHB Option	N-Weighted Average Buffer Area (ac)	N-Weighted Average Change from DNR-concurred Break (ac) [Percent Change]
Statewide	DNR-Concurred	230.5	
	Option A	198.9	-0.8 [-0.35%]
	Option B	229.5	-0.7 [-0.30%]
	Option C	229.6	-0.9 [-0.39%]
East	DNR-Concurred	218.0	
	Option B	219.1	-0.6 [-0.27%]
	Option C	217.2	-0.8 [-0.35%]
West	DNR-Concurred	235.6	
	Option A	240.7	-1.0 [-0.43%]
	Option B	233.8	-0.7 [-0.30%]
	Option C	234.7	-0.9 [-0.39%]

Note:
Weights were calculated based on the number of non-DNR-concurred F/N and S/N breaks in wchydro relative to the total number of F/N and S/N breaks statewide and on each side of the state. Negative values indicate that n-weighted average decreased under the relevant PHB option. Changes are calculated within-network before being summarized (averaged). Due to n-weighting and the fact that sample sets for the DNR-concurred break scenario may differ among comparisons for the various PHB options and ecoregions, the mean of those changes is not always equal to the difference between ecoregion means. For example, means for Option A are only calculated for west side networks and do not include buffers from the DNR-concurred break on the east side of the North Cascades and Cascades ecoregions.

3.4.2 Total Volume of Timber Within Riparian Buffers

As with buffer area, total timber volume within riparian buffers was greatest in the Cascades or North Cascades ecoregion for all three options (Table 21, Figure 23). To provide context, these mean volumes per network can be compared to the mean buffer areas presented above (Table 20) to develop approximate densities of timber volume per acre in each ecoregion.[14]

The magnitude and direction of within-network (per-SSN) changes in the volume of timber that would be protected within riparian buffers as a result of implementing the PHB Options differed among ecoregions (Table 22, Figure 24). Timber volume within buffers tended to decrease under all PHB options, with the largest per-SSN decreases in the Puget Lowlands ecoregion and the smallest in the Cascades. On average, buffered volume of timber under PHB Option B changed the least relative to the concurred break in almost all ecoregions.

[14] These values are not the focus of this analysis, so are not presented comprehensively. As an example, under current conditions, riparian buffers are estimated to contain from 25 MBF per acre in the Northern Rockies, to 54 MBF per acre in the North Cascades.

Table 21.Total network riparian (combined Type F and Type N) timber volume (MBF) per SSN, summarized by ecoregion

Ecoregion	Volume of Timber (MBF) per SSN Within Riparian Buffers							
	DNR-Concurred F/N Break		PHB Option A		PHB Option B		PHB Option C	
	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range
Puget Lowland	6,717 (1,364)	829 to 18,641	6,579 (1,353)	745 to 18,616	6,589 (1,354)	745 to 18,616	6,579 (1,353)	745 to 18,616
Coast Range	9,873 (996)	513 to 30,452	9,778 (999)	305 to 30,363	9,784 (999)	271 to 30,357	9,843 (996)	307 to 30,470
North Cascades	12,417 (755)	2,194 to 26,844	12,314 (804)	2,143 to 19,784	12,600 (787)	2,143 to 26,836	12,350 (756)	2,143 to 26,829
Cascades	11,749 (462)	843 to 23,017	10,514 (616)	824 to 18,604	11,771 (481)	824 to 22,777	11,754 (462)	824 to 22,473
E. Cascades Foothills	7,313 (534)	716 to 26,931			7,313 (532)	700 to 25,898	7,268 (533)	721 to 27,227
Northern Rockies	5,711 (399)	471 to 12,818			5,757 (402)	696 to 12,758	5,698 (398)	488 to 12,758
Blue Mountains	7,725 (1,090)	1,794 to 15,722			7,609 (1,065)	1,800 to 15,169	7,598 (1,060)	1,800 to 15,105

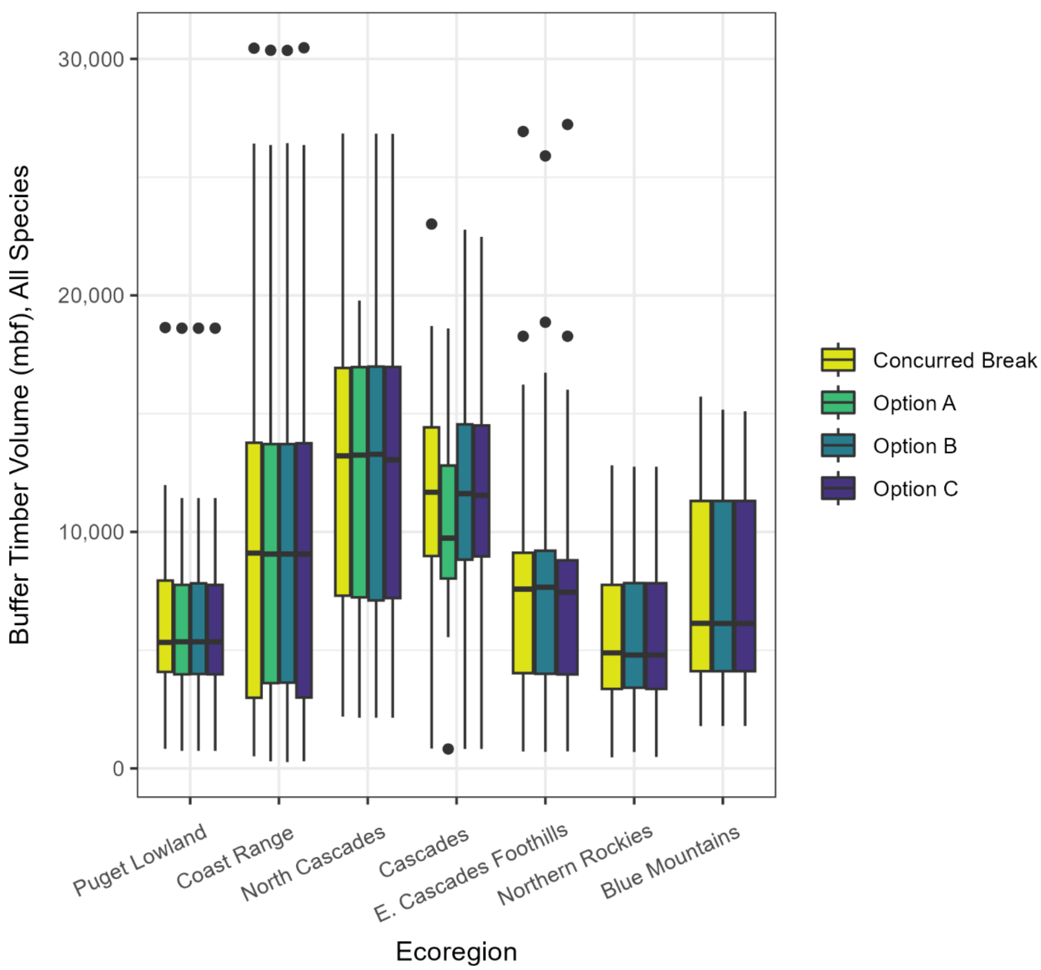
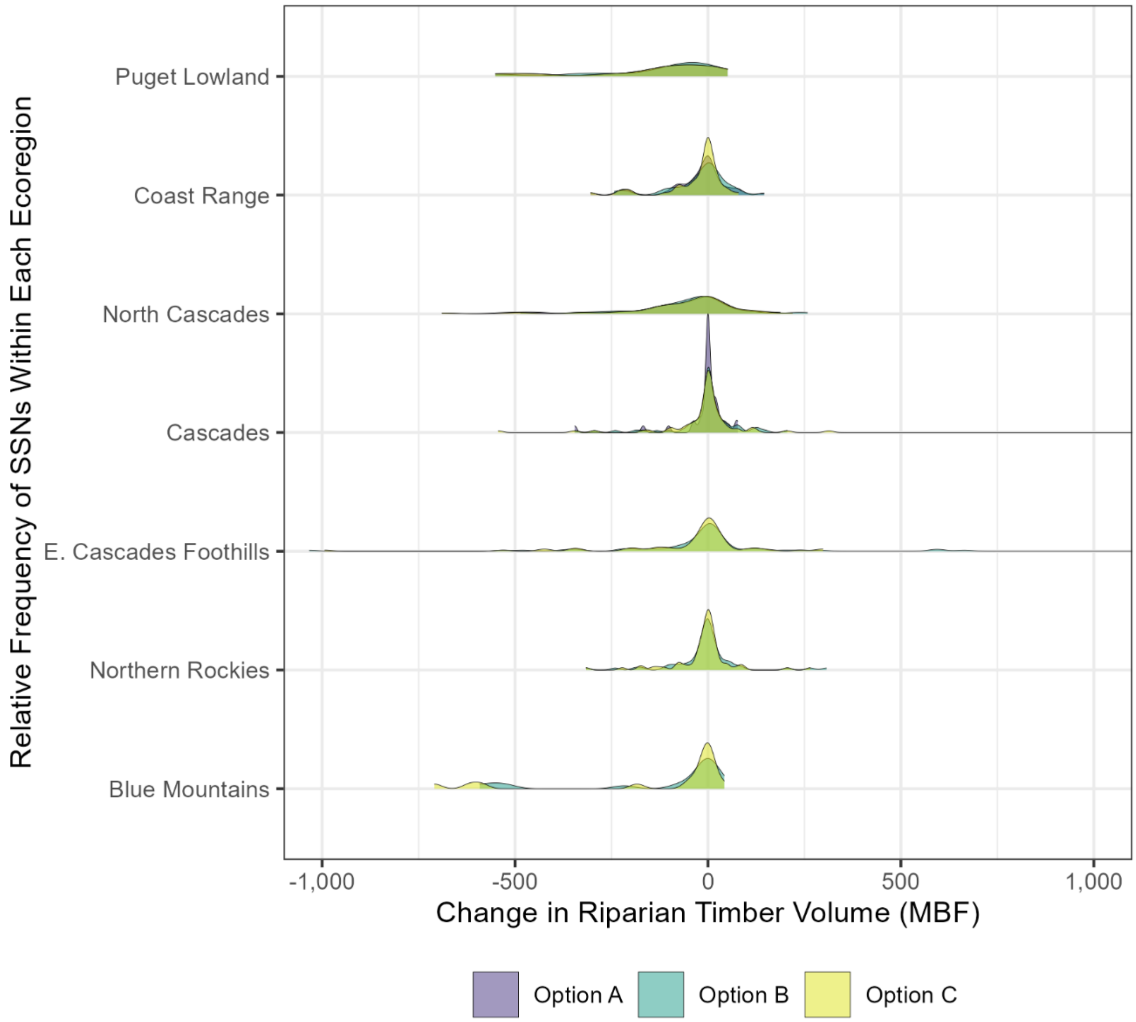


Figure 23. Total timber volume within the riparian buffer for each network

Table 22. Change in total network riparian (combined Type F and Type N) timber volume (MBF) per SSN, summarized by ecoregion

Ecoregion	Change in Volume of Timber (MBF) Within Riparian Buffers per SSN					
	PHB Option A		PHB Option B		PHB Option C	
	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range
Puget Lowland	-138 (55)	-551 to 51	-128 (50)	-551 to 51	-138 (55)	-551 to 51
Coast Range	-29 (12)	-304 to 145	-23 (11)	-243 to 145	-29 (10)	-304 to 79
North Cascades	-85 (28)	-689 to 187	-55 (18)	-485 to 258	-67 (21)	-689 to 219
Cascades	-8 (11)	-345 to 77	-5 (10)	-345 to 205	5 (20)	-544 to 1,171
E. Cascades Foothills			0 (33)	-1,033 to 1,535	-45 (21)	-993 to 298
Northern Rockies			-6 (11)	-316 to 307	-12 (10)	-316 to 265
Blue Mountains			-116 (53)	-591 to 42	-127 (60)	-709 to 42

Note:
Negative values indicate that timber volume within the riparian buffer decreased under the relevant PHB option. Changes are calculated within-network before being summarized (averaged). Consequently, the mean of those changes is not always equal to the difference between ecoregion means, because sample sets for the DNR-concurred break scenario may differ among comparisons for the various PHB options and ecoregions. For example, means for Option A are only calculated for west side networks and do not include buffers from the DNR-concurred break on the east side of the North Cascades and Cascades ecoregions.



Note: Values < -1,000 MBF and > 1,000 MBF were excluded from this figure to increase figure legibility.

Figure 24. Within-network net change in timber volume (MBF) within buffers calculated under the concurred break compared to volume of timber within riparian buffers under each PHB option.

Statewide, the n-weighted average timber volume within riparian decreased across all PHB options except for Option B on the east side (Table 23). N-weighted volume of timber within riparian buffers decreased the most under Option A both statewide and on the west side of the state.

Table 23. N-weighted average of ecoregion-average volume of timber within riparian buffers (MBF) and ecoregion-average change in volume of timber within riparian buffers per SSN between the DNR-concurred network and each PHB option.

State Side	PHB Option	N-Weighted Average Timber Volume (MBF)	N-Weighted Average Timber Volume Change (MBF) [Percent Change]
Statewide	DNR-Concurred	9,717	

State Side	PHB Option	N-Weighted Average Timber Volume (MBF)	N-Weighted Average Timber Volume Change (MBF) [Percent Change]
	Option A	8,330	-254 [-2.61%]
	Option B	9,716	-1 [-0.01%]
	Option C	9,674	-43 [-0.44%]
East	DNR-Concurred	8,571	
	Option B	8,643	72 [+0.74%]
	Option C	8,529	-41 [-0.42%]
West	DNR-Concurred	10,185	
	Option A	9,869	-316 [-3.25%]
	Option B	10,154	-31 [-0.32%]
	Option C	10,141	-44 [-0.45%]

Note:
Weights were calculated based on the number of non-DNR-concurred F/N and S/N breaks in wchydro relative to the total number of F/N and S/N breaks statewide and on each side of the state. Negative values indicate that n-weighted average decreased under the relevant PHB option. Changes are calculated within-network before being summarized (averaged). Due to n-weighting and the fact that sample sets for the DNR-concurred break scenario may differ among comparisons for the various PHB options and ecoregions, the mean of those changes is not always equal to the difference between ecoregion means. For example, means for Option A are only calculated for west side networks and do not include buffers from the DNR-concurred break on the east side of the North Cascades and Cascades ecoregions.

3.4.3 Total Value of Timber Within Riparian Buffers

Total value of timber within riparian buffers (per SSN) was greatest in the North Cascades ecoregion for all three options (Table 24), and decreased in all ecoregions for all three PHB options relative to the DNR-concurred break except for Option C in the Cascades (Table 25).

Ecoregions with networks on the west side of the state (Puget Lowland, Coast Range, Cascades, and North Cascades) tended to have a greater value of timber within riparian buffers per SSN than ecoregions fully on the east side of the state (E. Cascades Slopes and Foothills, Northern Rockies, Blue Mountains [Table 24, Figure 25]). The greatest value of timber within riparian buffers per SSN was in the North Cascades. While the average value of timber within riparian buffers decreased under all three PHB options compared to the concurred break, there were slight increases in the value of timber within riparian buffers within many individual networks (Figure 26).

Table 24. Total network riparian (combined Type F and Type N) timber value (USD) per SSN, summarized by ecoregion

Ecoregion	Value of Timber (USD) per SSN Within Riparian Buffers							
	DNR-Concurred F/N Break		PHB Option A		PHB Option B		PHB Option C	
	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range
Puget Lowland	$3,739,985 ($763,852)	$431,721 to $10,383,345	$3,665,414 ($759,083)	$381,167 to $10,372,155	$3,670,199 ($759,781)	$381,167 to $10,372,155	$3,665,414 ($759,083)	$381,167 to $10,372,155
Coast Range	$4,716,584 ($423,298)	$251,010 to $11,558,160	$4,701,580 ($429,810)	$147,748 to $11,620,270	$4,705,762 ($429,528)	$124,151 to $11,634,353	$4,700,924 ($423,076)	$149,525 to $11,566,632
North Cascades	$6,114,439 ($390,202)	$939,659 to $11,035,086	$6,721,835 ($456,724)	$916,092 to $11,043,330	$6,236,327 ($403,660)	$916,092 to $10,978,025	$6,082,045 ($390,279)	$916,092 to $10,978,025
Cascades	$4,678,657 ($196,653)	$430,423 to $9,167,832	$5,166,116 ($312,209)	$420,916 to $9,198,926	$4,681,467 ($204,749)	$420,916 to $9,198,926	$4,678,167 ($196,632)	$420,916 to $9,198,926

Ecoregion	Value of Timber (USD) per SSN Within Riparian Buffers							
	DNR-Concurred F/N Break		PHB Option A		PHB Option B		PHB Option C	
	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range
E. Cascades Foothills	$2,530,126 ($249,924)	$128,758 to $10,396,153			$2,526,773 ($248,454)	$130,375 to $10,262,238	$2,515,291 ($249,237)	$133,126 to $10,254,734
Northern Rockies	$2,158,058 ($154,216)	$131,487 to $4,503,049			$2,173,349 ($155,465)	$302,717 to $4,496,763	$2,153,976 ($153,958)	$137,266 to $4,496,763
Blue Mountains	$2,060,807 (294,444)	$456,561 to $4,234,555			$2,028,904 ($287,210)	$458,363 to $4,078,256	$2,026,118 ($285,916)	$458,363 to $4,062,090

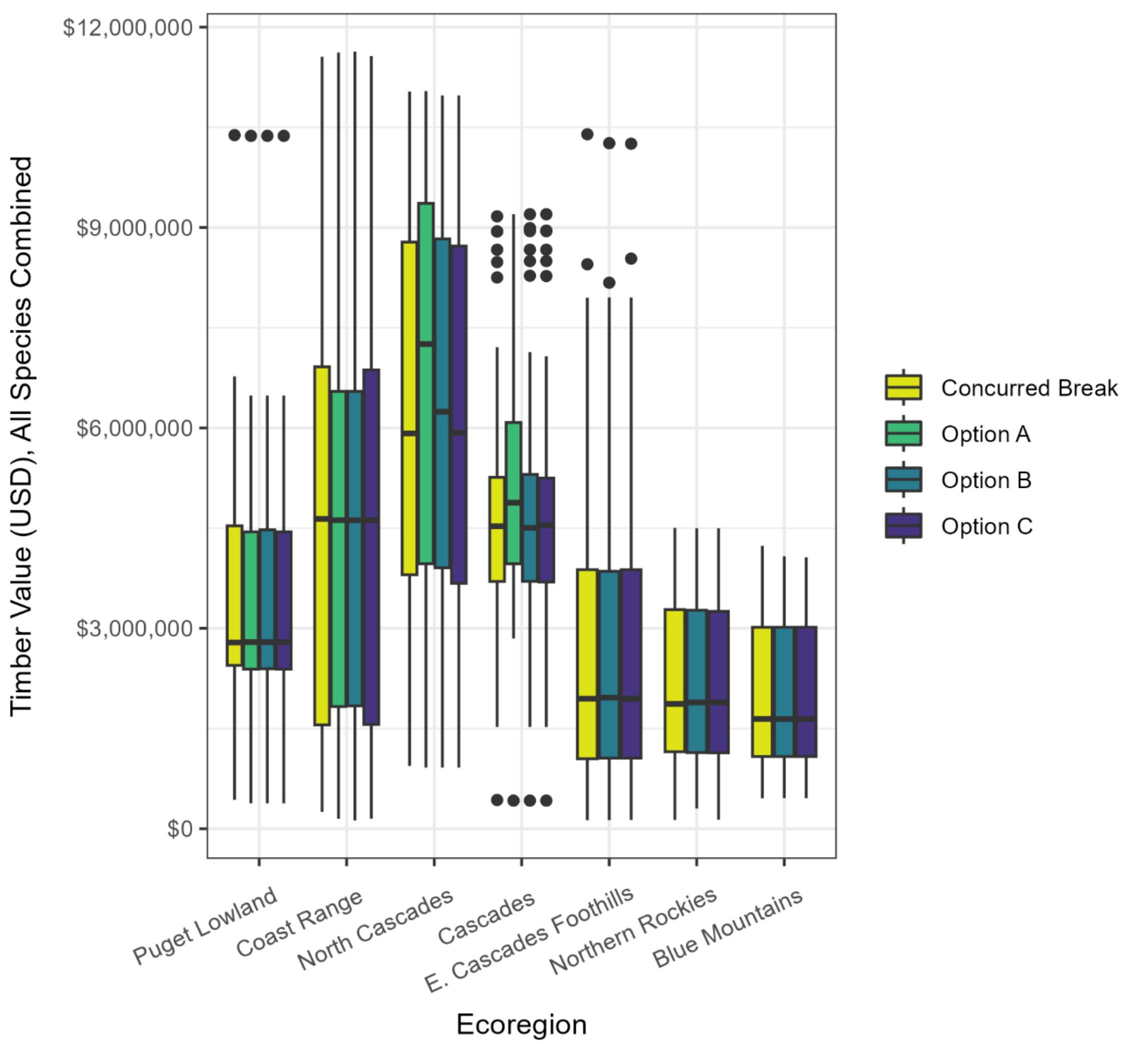
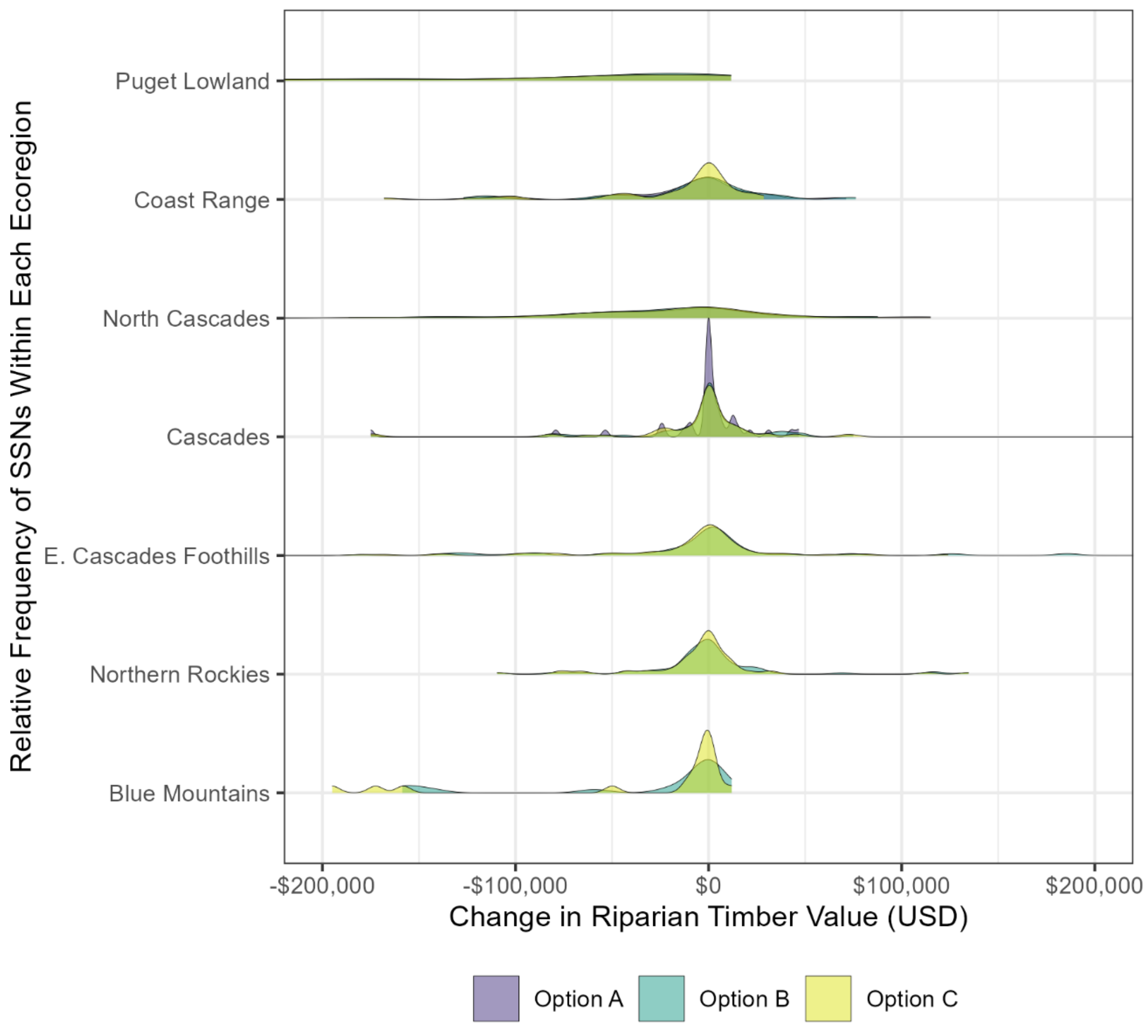


Figure 25 . Total value of timber within the riparian buffer for each network

Table 25. Change in value of total network riparian (combined Type F and Type N) timber value (USD) per SSN, summarized by ecoregion

Ecoregion	Change in Value of Timber (USD) Within Riparian Buffers per SSN					
	PHB Option A		PHB Option B		PHB Option C	
	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range
Puget Lowland	-$74,571 (27,816)	-$286,783 to $11,632	-$69,786 (26,277)	-$286,783 to 11,632	-$74,571 (27,816)	-$286,783 to $11,632
Coast Range	-$13,889 (6,249)	-$167,990 to $71,149	-$9,708 (5,864)	-$126,859 to 76,192	-$15,659 (5,284)	-$167,990 to $28,585
North Cascades	-$41,207 (14,995)	-$366,405 to $114,914	-$25,528 (7,562)	-$186,379 to 87,573	-$32,393 (10,374)	-$352,406 to $114,914
Cascades	-$4,247 (5,624)	-$174,985 to $46,716	-$2,786 (3,962)	-$174,985 to $74,902	-$490 (6,598)	-$174,985 to $370,220
E. Cascades Foothills			-$3,353 (9,531)	-$276,927 to $404,466	-$14,835 (6,730)	-$282,391 to $124,029
Northern Rockies			-$213 (4,534)	-$109,454 to $134,580	-$4,082 (3,989)	-$109,454 to $134,580
Blue Mountains			-$31,903 (14,506)	-$158,648 to 11,966	-$34,690 (16,621)	-$194,961 to $11,966

Note:
Negative values indicate that timber value within the riparian buffer decreased under the relevant PHB option. Changes are calculated within-network before being summarized (averaged). Consequently, the mean of those changes is not always equal to the difference between ecoregion means, because sample sets for the DNR-concurred break scenario may differ among comparisons for the various PHB options and ecoregions. For example, means for Option A are only calculated for west side networks and do not include buffers from the DNR-concurred break on the east side of the North Cascades and Cascades ecoregions.



Note: Values < -$200,000 and > $200,000 were excluded from this figure to increase figure legibility.

Figure 26. Within-network net change in timber value within buffers calculated under the concurred break compared to value of timber within riparian buffers under each PHB option.

Statewide, the value of timber within riparian buffers was greatest under Option B and least under Option A (Table 26). However, within individual networks all three PHB options resulted in lower value of timber within riparian buffers relative to the concurred break both statewide and on both sides of the state. The value of timber within riparian buffers under Option B was more similar to that under the concurred break than the other two options. On average, the value of timber in riparian buffers decreased by less than 1% per SSN across all options.

Table 26. N-weighted average value and n-weighted change in value of riparian timber (USD) per SSN between the DNR-concurred network and each PHB option.

State Side	PHB Option	N-Weighted Average Timber Value (USD)	N-Weighted Average Change in Timber Value (USD) [Percent Change]
Statewide	DNR-Concurred	$4,452,913	
	Option A	$4,235,313	-$21,512 [-0.48%]
	Option B	$4,468,499	-$16,860 [-0.38%]
	Option C	$4,431,351	-$21,562 [-0.48%]
East	DNR-Concurred	$3,620,774	
	Option B	$3,663,974	-$11,081 [-0.25%]
	Option C	$3,604,217	-$16,557 [-0.37%]
West	DNR-Concurred	$4,792,627	
	Option A	$4,960,946	-$24,773 [-0.56%]
	Option B	$4,796,940	-$19,220 [-0.43%]
	Option C	$4,769,022	-$23,605 [-0.53%]

Note:
Weights were calculated based on the number of non-DNR-concurred F/N and S/N breaks in wchydro relative to the total number of F/N and S/N breaks statewide and on each side of the state. Negative values indicate that n-weighted average decreased under the relevant PHB option. Changes are calculated within-network before being summarized (averaged). Due to n-weighting and the fact that sample sets for the DNR-concurred break scenario may differ among comparisons for the various PHB options and ecoregions, the mean of those changes is not always equal to the difference between ecoregion means. For example, means for Option A are only calculated for west side networks and do not include buffers from the DNR-concurred break on the east side of the North Cascades and Cascades ecoregions.

3.5 Current vs. Proposed Type Np Buffer Rule Results

3.5.1 Type Np Riparian Buffer Area, Proposed Option 1

When compared to the current rule, proposed Type Np buffer Options 1a and 1b both increased the area of riparian buffers by similar amounts across all ecoregions on the west side of the state (Table 27, Table 28, Table 29). The North Cascades ecoregion saw the greatest increase (and greatest range in buffer area) for both sub-options (Table 28, Figure 27).

Table 27. Riparian Type Np buffer area (ac) per SSN under the current rule and proposed rule change options, summarized by ecoregion

Ecoregion	Type Np Buffer Area (ac) per SSN					
	Current Rule		Proposed Option 1a		Proposed Option 1b	
	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range
Puget Lowland	11.1 (3.6)	0.7 to 43.5	23.5 (8.1)	1.9 to 99.0	22.3 (7.5)	1.9 to 91.1
Coast Range	6.2 (1.1)	0.4 to 46.8	11.2 (2.0)	1.0 to 83.6	10.9 (1.9)	1.0 to 79.6
North Cascades	27.1 (5.7)	0.5 to 154.4	55.0 (11.4)	1.3 to 282.5	51.8 (10.7)	1.3 to 274.0
Cascades	6.4 (0.8)	0.5 to 21.0	11.1 (1.4)	1.3 to 40.0	11.1 (1.3)	1.3 to 38.8

Table 28. Change in riparian Type Np buffer area (ac) per SSN between the current rule and proposed rule change options, summarized by ecoregion

Ecoregion	Change in Type Np Buffer Area (ac) per SSN			
	Proposed Option 1a		Proposed Option 1b	
	Mean (SE)	Range	Mean (SE)	Range
Puget Lowland	12.4 (4.6)	1.2 to 55.4	11.2 (3.9)	1.2 to 47.6
Coast Range	5.0 (0.9)	0.6 to 36.8	4.7 (0.8)	0.6 to 32.7
North Cascades	27.9 (5.8)	0.8 to 138.6	24.7 (5.1)	0.8 to 121.1
Cascades	4.8 (0.6)	0.8 to 19.0	4.7 (0.6)	0.8 to 17.8

Table 29. N-weighted average and n-weighted average change in riparian Type Np buffer area (ac) for the current and proposed rules for the west side of the state

State Side	Ruleset	N-Weighted Average per SSN Riparian Buffer Area (ac)	N-Weighted Average Change per SSN in Riparian Buffer Area (ac)
West	Current	10.2	-
West	Proposed Option 1a	19.7	9.6 [+94%]
West	Proposed Option 1b	18.9	8.7 [+85%]

Note:
Weights were calculated based on the number of non-DNR-concurred F/N and S/N breaks in wchydro relative to the total number of F/N and S/N breaks on the west side of the state. Changes are calculated within-network before being summarized (averaged).

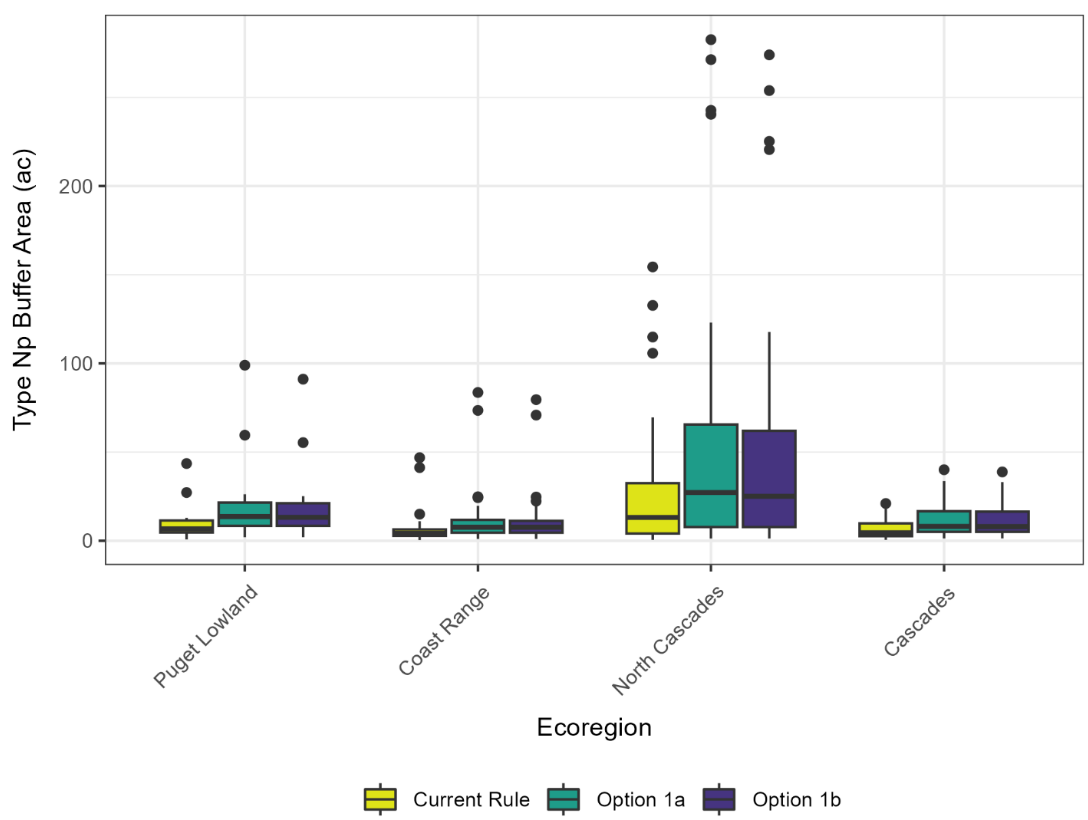


Figure 27. Type Np buffer area for each network under the current rule and Option 1 of the proposed west side Type Np rule

3.5.2 Total Volume of Timber Within Type Np Buffers, Proposed Option 1

The volume of timber in riparian buffers increased for Option 1a and Option 1b across all ecoregions compared to the current rule (Table 30), with only a slightly greater mean volume increase under Option 1b throughout western Washington (Table 31, Table 32). The North Cascades ecoregion saw the greatest increase as well as the greatest range in volume of timber within riparian buffers across networks; this was true for both Options 1a and 1b (Figure 28).

Table 30. Timber volume (MBF) within each Type Np buffer under the current rule and proposed options, summarized by ecoregion

Ecoregion	Volume of Timber (MBF) per SSN Within Riparian Buffers					
	Current Rule		Proposed Option 1a		Proposed Option 1b	
	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range
Puget Lowland	805 (272)	15 to 2,826	1,721 (627)	51 to 6,643	1,747 (639)	51 to 6,727
Coast Range	349 (73)	0 to 3,726	646 (128)	6 to 6,486	649 (128)	6 to 6,460
North Cascades	1,703 (394)	22 to 11,086	3,138 (708)	65 to 19,359	3,185 (720)	65 to 19,459
Cascades	281 (55)	1 to 1,935	470 (94)	3 to 3,348	471 (94)	3 to 3,367

Table 31. Change in timber volume (MBF) within each Type Np buffer between the current rule and proposed options, summarized by ecoregion

Ecoregion	Change in Volume of Timber (MBF) per SSN Within Riparian Buffers for			
	Proposed Option 1a		Proposed Option 1b	
	Mean (SE)	Range	Mean (SE)	Range
Puget Lowland	915 (356)	36 to 3,817	941 (368)	36 to 3,901
Coast Range	297 (57)	6 to 2,760	301 (57)	6 to 2,734
North Cascades	1,435 (316)	28 to 8,274	1,482 (328)	28 to 8,373
Cascades	189 (40)	1 to 1,413	190 (40)	1 to 1,432

Table 32. N-weighted average and average change in volume of timber within riparian buffers (MBF) within the Type Np buffer for the current and proposed Type Np rule for the west side of the state

State Side	Current Rule	N-Weighted Average Volume (MBF)	N-Weighted Average Change in Volume (MBF) [Percent Change]
West	Current	611	-
West	Proposed Option 1a	1,152	541 [+90%]
West	Proposed Option 1b	1,165	554 [+91%]

Note:
Weights were calculated based on the number of non-DNR-concurred F/N and S/N breaks in wchydro relative to the total number of F/N and S/N breaks on the west side of the state. Changes are calculated within-network before being summarized (averaged).

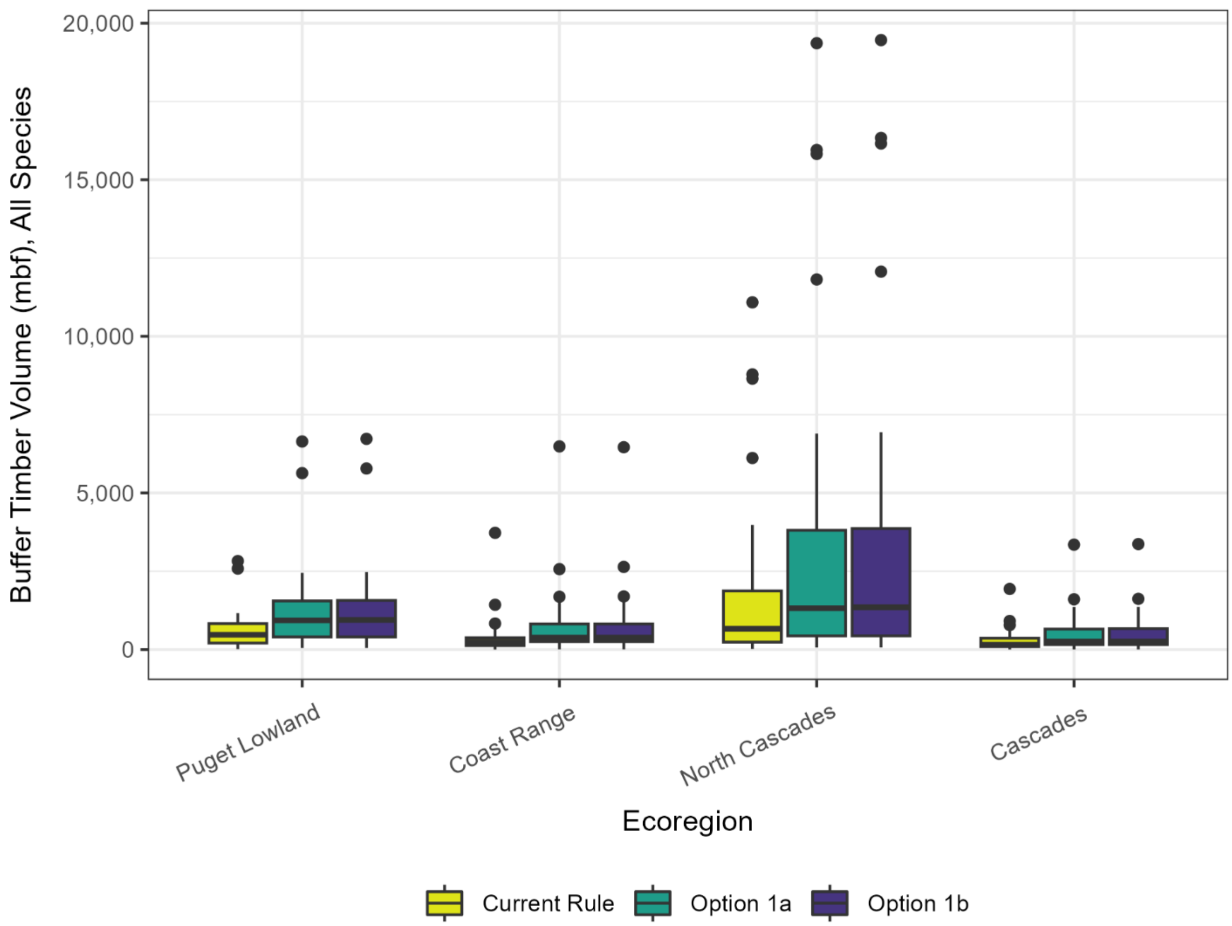


Figure 28. Total timber volume within Type Np buffers under the current rule and Option 1 of the proposed west side Type Np rule

3.5.3 Total Value of Timber Within Type Np Buffers, Proposed Option 1

Compared to the current rule, the per SSN value of timber contained within Type Np riparian buffers increased for Option 1a and Option 1b across all ecoregions in western Washington (Table 33, Table 34, Table 35). When considered across the entire west side of the state, the value of timber within Type Np buffers increased slightly more under Option 1b than 1a (Table 34). The North Cascades ecoregion saw the greatest increase and the greatest range in value of timber within riparian buffers for both sub-options (Table 34, Figure 29).

Table 33. Value of timber (USD) contained within the Type Np buffer for each SSN under the current rule and proposed options, summarized by ecoregion

Ecoregion	Value of Timber (USD) per SSN Within Riparian Buffers					
	Current Rule		Proposed Option 1a		Proposed Option 1b	
	Mean (SE)	Range	Mean (SE)	Mean (SE)	Range	Mean (SE)
Puget Lowland	$407,942 ($134,451)	$10,907 to $1,425,161	$852,041 ($298,961)	$31,024 to $3,246,645	$863,775 ($304,254)	$31,024 to $3,281,276
Coast Range	$164,405 ($29,645)	$0 to $1,449,003	$300,823 ($52,984)	$2,680 to $2,579,026	$302,171 ($52,981)	$2,680 to $2,560,823

Ecoregion	Value of Timber (USD) per SSN Within Riparian Buffers					
	Current Rule		Proposed Option 1a		Proposed Option 1b	
	Mean (SE)	Range	Mean (SE)	Mean (SE)	Range	Mean (SE)
North Cascades	$834,667 ($185,116)	$7,267 to $4,879,531	$1,511,318 ($323,944)	$31,526 to $8,311,785	$1,533,560 ($328,794)	$31,526 to $8,355,389
Cascades	$142,012 ($26,190)	$299 to $847,498	$238,203 ($44,357)	$1,344 to $1,516,667	$238,961 ($44,660)	$1,344 to $1,531,838

Table 34. Change in value of timber (USD) contained within the Type Np buffer for each SSN between the current rule and proposed options, summarized by ecoregion

Ecoregion	Change in Value of Timber (USD) per SSN Within Riparian Buffers for			
	Proposed Option 1a		Proposed Option 1b	
	Mean (SE)	Range	Mean (SE)	Range
Puget Lowland	$444,099 ($165,053)	$20,118 to $1,821,483	$455,832 ($170,239)	$20,118 to $1,856,114
Coast Range	$136,418 ($23,976)	$2,680 to $1,130,023	$137,766 ($24,021)	$2,680 to $1,111,819
North Cascades	$676,651 ($139,731)	$10,444 to $3,432,254	$698,893 ($144,668)	$10,444 to $3,475,858
Cascades	$96,190 ($19,228)	$587 to $669,169	$96,949 ($19,568)	$587 to $684,340

Table 35. N-weighted average and n-weighted average change in value of timber (USD) contained within Type Np riparian buffers (USD) for the current and proposed Type Np rule for the current and proposed rules for the west side of the state

State Side	Current Rule	N-Weighted Average Value of timber within riparian buffers per SSN (USD)	N-Weighted Average Change in Value of timber within riparian buffers per SSN (USD) [Percent Change]
West	Current	$298,835	-
West	Proposed Option 1a	$554,898	$256,063 [+ 86%]
West	Proposed Option 1b	$560,845	$262,010 [+ 88%%]

Note:
Weights were calculated based on the number of non-DNR-concurred F/N and S/N breaks in wchydro relative to the total number of F/N and S/N breaks statewide and on each side of the state. Changes are calculated within-network before being summarized (averaged).

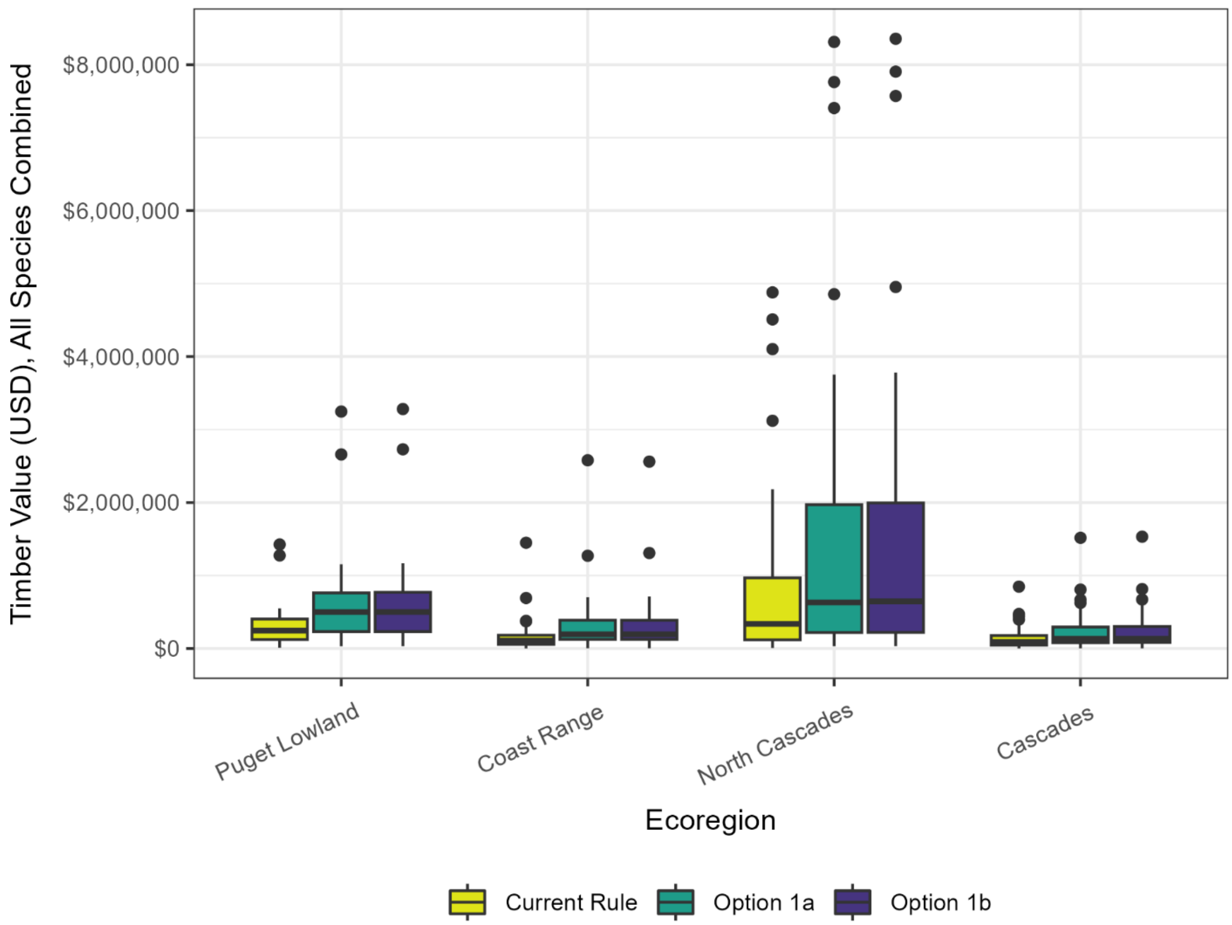


Figure 29. Total timber value within Type Np buffers under the current rule and Option 1 of the proposed west side Type Np rule

3.5.4 Type Np Riparian Buffer Area, Proposed Option 2

Compared to the current rule, the greatest increases (and ranges) in Type Np riparian buffer area under Option 2 occurred in the North Cascades and the Puget Lowland ecoregions (Table 36, Table 37, Figure 30).

Table 36. Type Np buffer area (ac) for each SSN under the current rule and proposed Option 2 for each network, summarized by ecoregion

Ecoregion	Type Np Buffer Area (ac) per SSN for Current Rule		Type Np Buffer Area (ac) per SSN for Proposed Option 2	
	Mean (SE)	Range	Mean (SE)	Range
Puget Lowland	14.1 (4.3)	5.2 to 43.5	36.2 (11.2)	12.3 to 112.7
Coast Range	7.9 (1.4)	2.1 to 41.3	17.9 (3.2)	5.4 to 92.8
North Cascades	32.2 (6.5)	2.6 to 154.4	77.8 (15.6)	7.5 to 359.1
Cascades	9.3 (1.0)	2.3 to 21.0	20.8 (2.2)	6.4 to 52.2

Note:
These comparisons only include networks with basins > 30 acres at the DNR-concurred break.

Table 37. Change in riparian Type Np buffer area (ac) for each SSN between the current rule and proposed rule change Option 2, summarized by ecoregion

Ecoregion	Change in Buffer Area (ac) per SSN for Proposed Option 2	
	Mean (SE)	Range
Puget Lowland	22.1 (6.9)	7.1 to 69.2
Coast Range	9.9 (1.8)	2.5 to 51.6
North Cascades	45.6 (9.1)	4.8 to 204.7
Cascades	11.5 (1.3)	4.1 to 31.2

Note:
These comparisons only include networks with basins > 30 acres at the water type break. Weights were calculated based on the number of non-DNR-concurred F/N and S/N breaks in wchydro relative to the total number of F/N and S/N breaks statewide and on each side of the state. Changes are calculated within-network before being summarized (averaged).

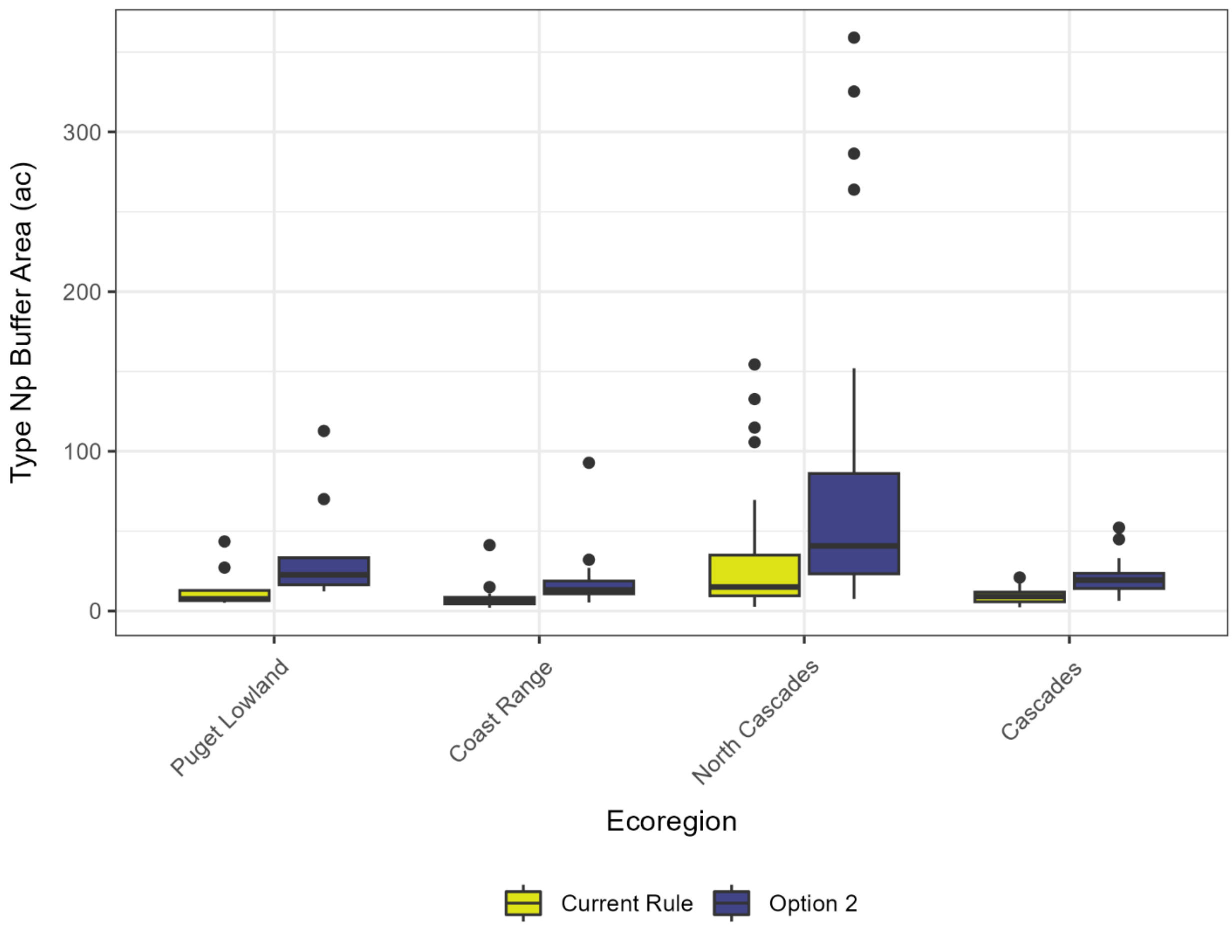


Figure 30. Type Np buffer area under the current rule and Option 2 of the proposed west side Type Np rule

3.5.5 Total Volume of Timber Within Type Np Buffers, Proposed Option 2

Compared to the current rule, the greatest increase (and range) in the volume of timber contained within riparian buffers under Option 2 occurred in the North Cascades ecoregion, followed by the Puget Lowland ecoregions (Table 38, Figure 31, Table 39).

Table 38. Volume of timber (MBF) contained within riparian Type Np buffers per SSN under the current rule and proposed Option 2, summarized by ecoregion

Ecoregion	Volume of Timber (MBF) per SSN Within Riparian Buffers			
	Current Rule		Proposed Option 2	
	Mean (SE)	Range	Mean (SE)	Range
Puget Lowland	1,049 (326)	234 to 2,826	2,940 (973)	556 to 8,577
Coast Range	424 (56)	26 to 1,430	1,012 (135)	51 to 3,124
North Cascades	2,023 (454)	134 to 11,086	4,705 (1,035)	341 to 24,717
Cascades	416 (84)	30 to 1,935	871 (185)	134 to 4,312

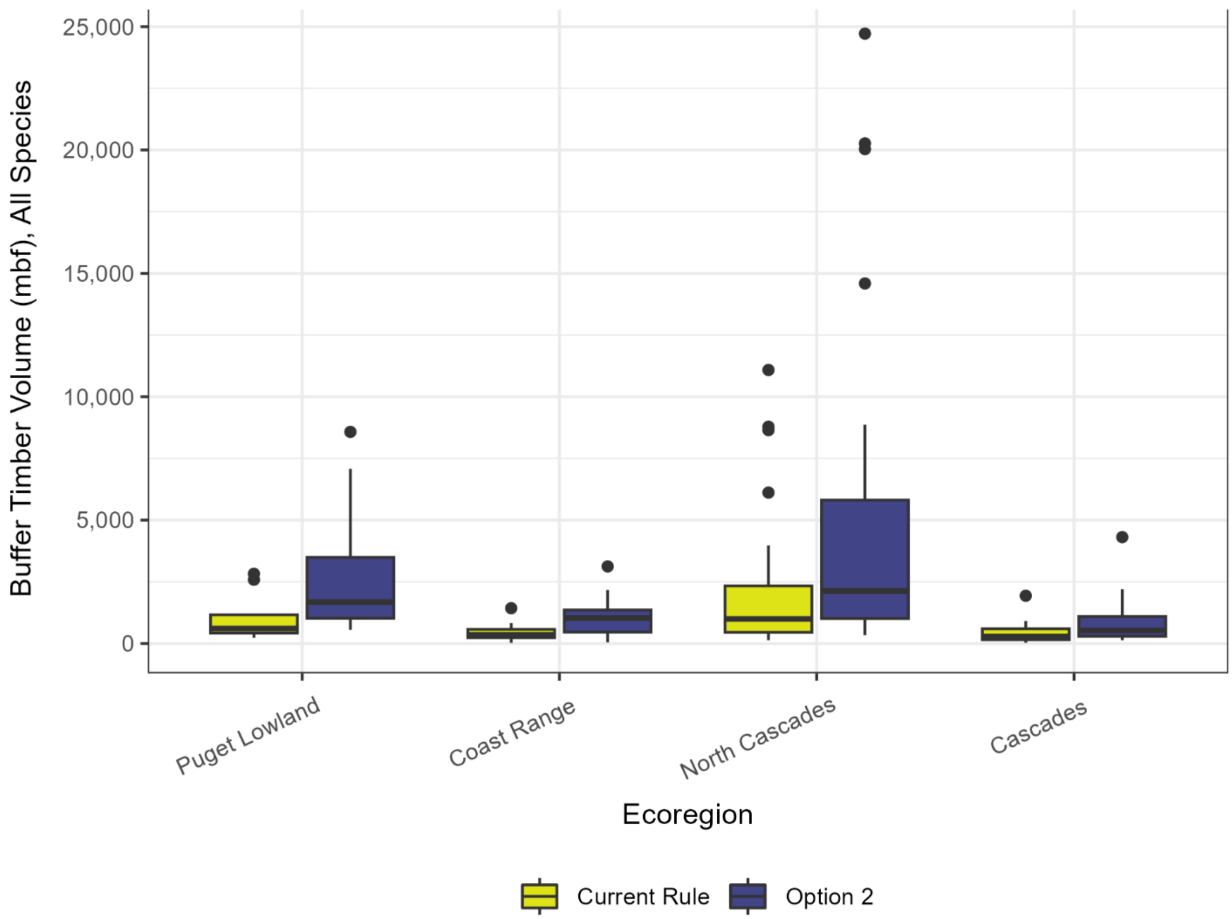


Figure 31. Total timber volume within Type Np buffers under the current rule and Option 2 of the proposed west side Type Np rule

Table 39. Change in volume of timber (MBF) contained within riparian Type Np buffers per SSN under proposed Option 2, summarized by ecoregion

Ecoregion	Change in Volume of Timber (MBF) Contained Within Riparian Type Np Buffers for Proposed Option 2	
	Mean (SE) [and Percent Change]	Range
Puget Lowland	1,891 (649) [+ 180%]	323 to 5,751
Coast Range	588 (84) [+ 139%]	24 to 1,694
North Cascades	2,682 (582) [+ 133%]	188 to 13,631
Cascades	455 (104) [+ 109%]	37 to 2,376

Note:
Weights were calculated based on the number of non-DNR-concurred F/N and S/N breaks in wchydro relative to the total number of F/N and S/N breaks statewide and on each side of the state. Changes are calculated within-network before being summarized (averaged).

3.5.6 Total Value of Timber Within Type Np Buffers, Proposed Option 2

Compared to the current rule, the greatest increase (and range) in the value of timber contained within riparian Type Np buffers under Option 2 occurred in the North Cascades ecoregion, followed by the Puget Lowland ecoregions (Table 40, Table 41, Figure 32).

Table 40. Value of timber (USD) contained within Type Np riparian buffers for each SSN under the current rule and proposed Option 2, summarized by ecoregion

Ecoregion	Value of Timber (USD) per SSN Within Riparian Buffers for Current Rule		Value of Timber (USD) per SSN Within Riparian Buffers for Option 2	
	Mean (SE)	Range	Mean (SE)	Range
Puget Lowland	$530,720 ($159,950)	$142,387 to $1,425,161	$1,445,586 ($456,470)	$327,620 to $4,160,460
Coast Range	$205,474 ($27,336)	$10,316 to $691,416	$480,684 ($63,956)	$18,933 to $1,552,085
North Cascades	$991,052 ($212,759)	$72,065 to $4,879,531	$2,259,613 ($470,447)	$194,611 to $10,644,858
Cascades	$207,905 ($38,889)	$14,632 to $847,498	$436,119 ($87,158)	$71,623 to $1,971,141

Table 41. Change in value of timber (USD) contained within Type Np riparian buffers for each SSN between the current rule and proposed Option 2, summarized by ecoregion

Ecoregion	Change in Value of Timber (USD) per SSN Within Riparian Buffers for Option 2	
	Mean (SE) [Percent Change]	Range
Puget Lowland	$914,866 ($297,410)[+ 172%]	$185,232 to $2,735,299
Coast Range	$275,210 ($38,872)[+ 134%]	$8,617 to $860,669
North Cascades	$1,268,561 ($258,520)[+ 128%]	$82,274 to $5,765,327
Cascades	$228,214 ($49,502)[+ 110%]	$19,627 to $1,123,644

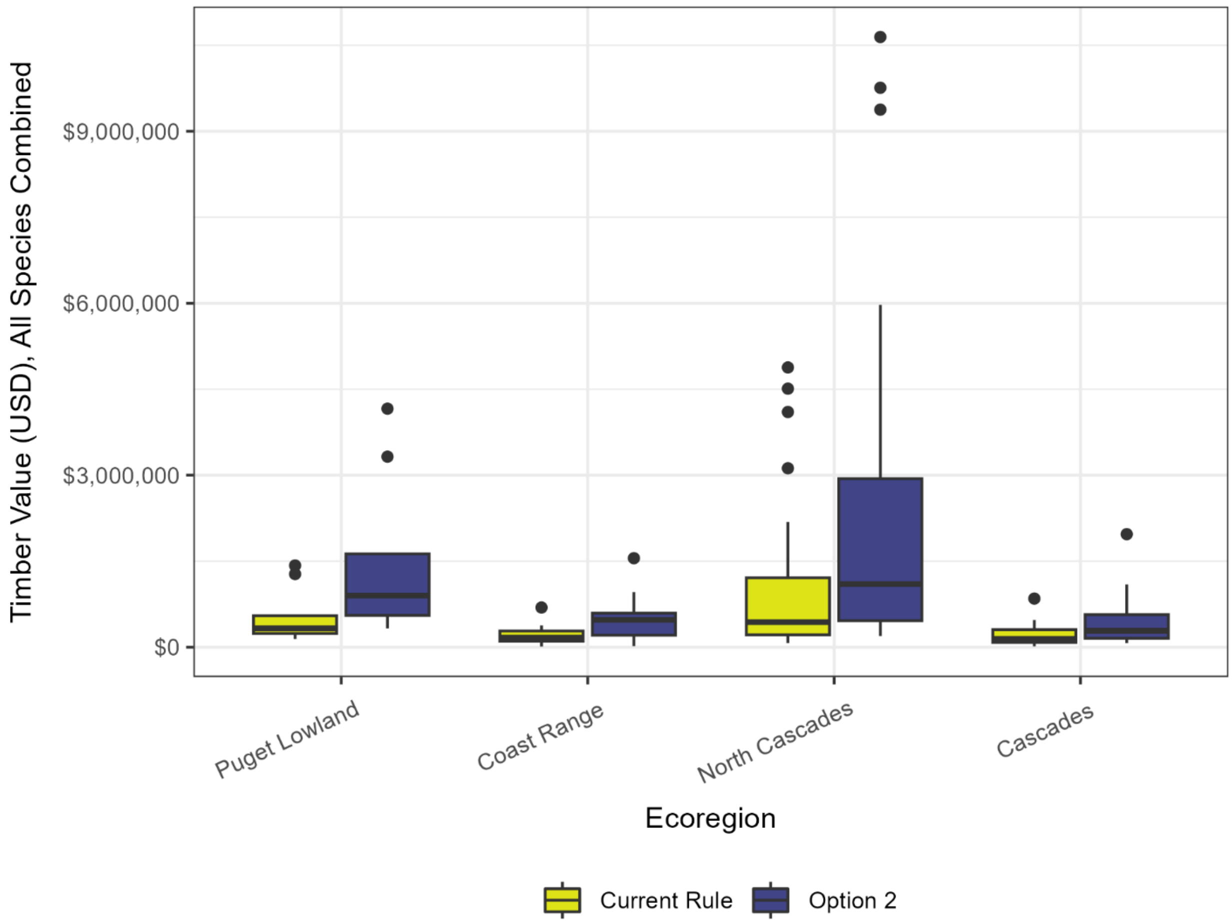


Figure 32. Total timber value within Type Np buffers under the current rule and Option 2 of the proposed west side Type Np rule

4 Sources of Uncertainty and Variance

4.1 LiDAR Data

All analyses in this report are underlain by the LiDAR data available in the DNR LiDAR portal. As a result, uncertainty and data limitations associated with this source data propagate throughout the analyses presented here. The quality of LiDAR data ultimately determine the precision of the DEM, which is the fundamental limitation on the ability to detect terrestrial features. DEM grid size is determined by the spacing of ground returns within the LiDAR data. Within each grid cell, elevation is averaged, meaning that undulations on the earth's surface that are small in area may be obscured by the LiDAR mapping process. Even if a DEM provides very precise and accurate elevations, it still may not be able to detect features that are smaller in area than an individual grid cell (1 meter [3.3 feet] for the current analysis). Consequently, the ability to detect features on the landscape is ultimately limited by the spacing of LiDAR ground returns, which must be closer than the size of the features to be resolved. A general rule of thumb is that DEM grid cell size should be approximately 75% of the size of the smallest features to be detected, which would amount to a 1.33-meter (4.4 feet) feature.

LiDAR data quality and precision depend on the following factors:

- LiDAR transceiver specifications, such as pulse density, laser pulse frequency, pulse length, scanning frequency, swath overlap, and sensor optics
- Elevation of the LiDAR flight
- Environmental conditions at the time of the LiDAR flight, including atmospheric fog, haze, and dust, as well as terrestrial/hydrologic conditions
- Topography over which the LiDAR data are being collected, including ground reflectivity and vegetation type and density

One of the biggest factors in obtaining accurate ground elevation measurements is the vegetation type and density. LiDAR pulse ground return density is highest in open, dry areas and lower in forested areas (where an average of two returns per square meter is considered good). In some cases, dense vegetation such as fireweed or blackberry can prevent ground returns altogether (Abigal Gleason,[15] personal communication, April 30, 2024). Another source of variability in the LiDAR data is the time of year that the flight occurred. Most data in the LiDAR portal was timed to match leaf-off periods, which in WA state is mid-November to mid-April. As this covers periods of baseflow and peak runoff for much of the state, and terrestrial LiDAR does not penetrate water, there is variation in what proportion of the stream channel is visible in the resulting elevation data. LiDAR flown at peak flow could depict a channel that is less prominent than the topographic variation on shore, which could impact modeled flow routing decrease the ability to detect small instream features such as vertical barriers.

4.2 Synthetic Stream Formation

The ArcHydro toolbox for ArcGIS Pro was used in this analysis, as it is an established toolbox, created by an industry leader in the GIS field, and is commonly used for this type of workflow. ArcHydro produced

[15] Abigal Gleason is the LiDAR manager at DNR's Washington Geological Survey.

streamlines that closely matched channels visible in the input LiDAR data and aligned with visual checks of high-resolution aerial imagery.[16]

The biggest factor determining stream density and total network length when creating streamlines from terrain datasets is the parameter that establishes the number of cells that need to flow into a location for it to be considered a streamline (“n-cell threshold”). This threshold must be manually set for individual watersheds, as the amount of upstream basin required to establish seasonal or perennial streamflow differs across the state, based on landscape-level differences in climate and geology. A lower threshold will result in a higher output stream density and longer stream networks, while a higher threshold will result in a lower stream density and shorter stream networks. Lower thresholds decrease the likelihood of underestimating on-the-ground stream density; however, lower thresholds also increase the number of artifacts that appear as artificial streamlines following roadbeds at the upstream extent of the subwatershed (distinct from streamlines diverted by roadside ditches). For this analysis, a priority was ensuring adequate coverage by potentially over-estimating stream density at the HUC12 subwatershed scale, rather than risk omitting tributary streams.

To optimize the parameterization of the n-cell threshold value, coverage was evaluated within each network, using a combination of aerial imagery, LiDAR, and the DNR wchydro layer to cross-check the SSN streamlines (Figure 33, Figure 34). However, it is not always possible to determine the on-the-ground stream density from remotely sensed data alone. Trees obscure streams in aerial imagery, and visualizing the source LiDAR data may show channels, but these data provide no information about whether those channels are ever flooded, versus being historical relicts of historical hydrogeomorphic conditions.

[16] Automating this process to run through multiple subwatersheds at a time was not feasible because it increased the likelihood that output datasets would be missing most if not all features, or that attribute ID fields would be missing from the output dataset. These still happened when the process was run for a single input subwatershed at a time. As a result, if the ultimate goal is to fully automate this process, other stream creation workflows (such as those available in the open source GRASS GIS) might be worth considering instead.

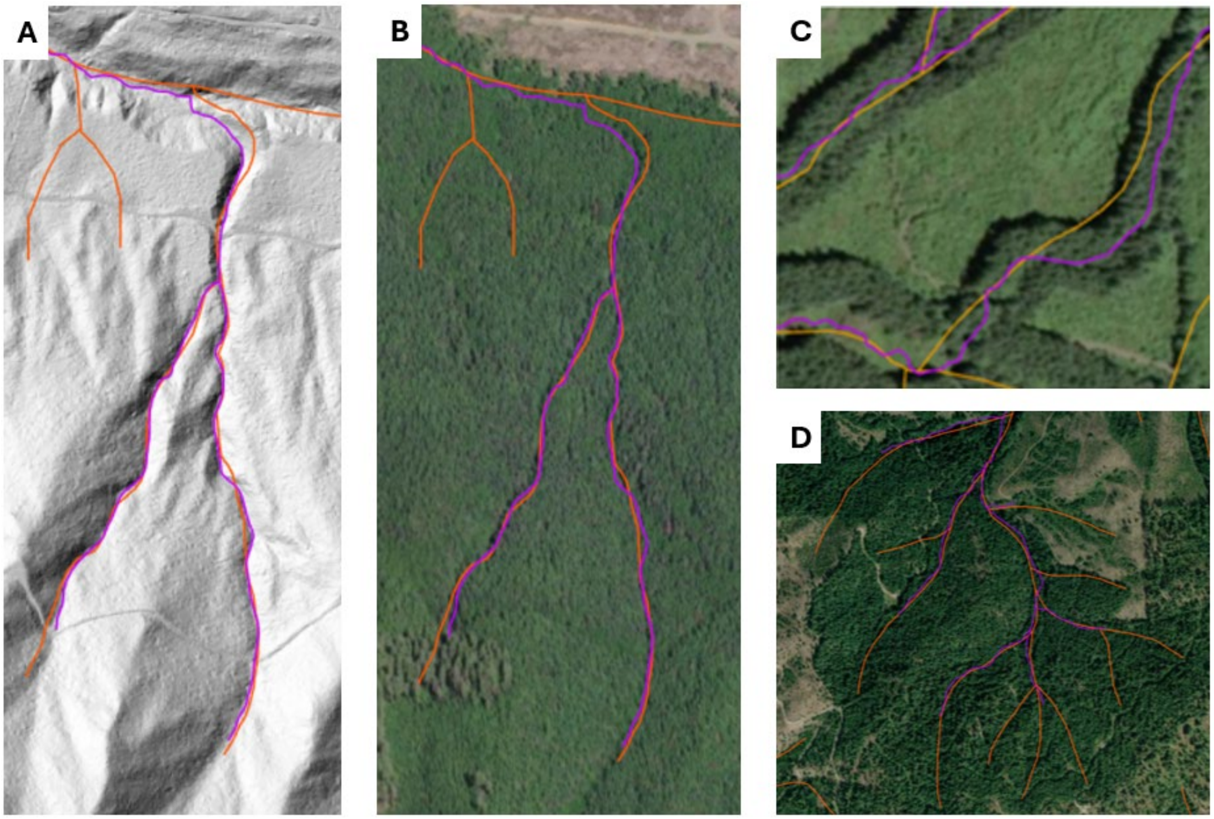


Figure 33. SSN streamlines were compared to LiDAR hillshades (A), and generally followed the terrain more closely than the DNR hydrography layer (orange). Arial imagery was also used to assess flow paths (B and C); in drier areas or clearcuts with riparian buffers it was possible to assess both stream paths and whether or not a channel contained water for long enough to impact the surrounding vegetation (D)

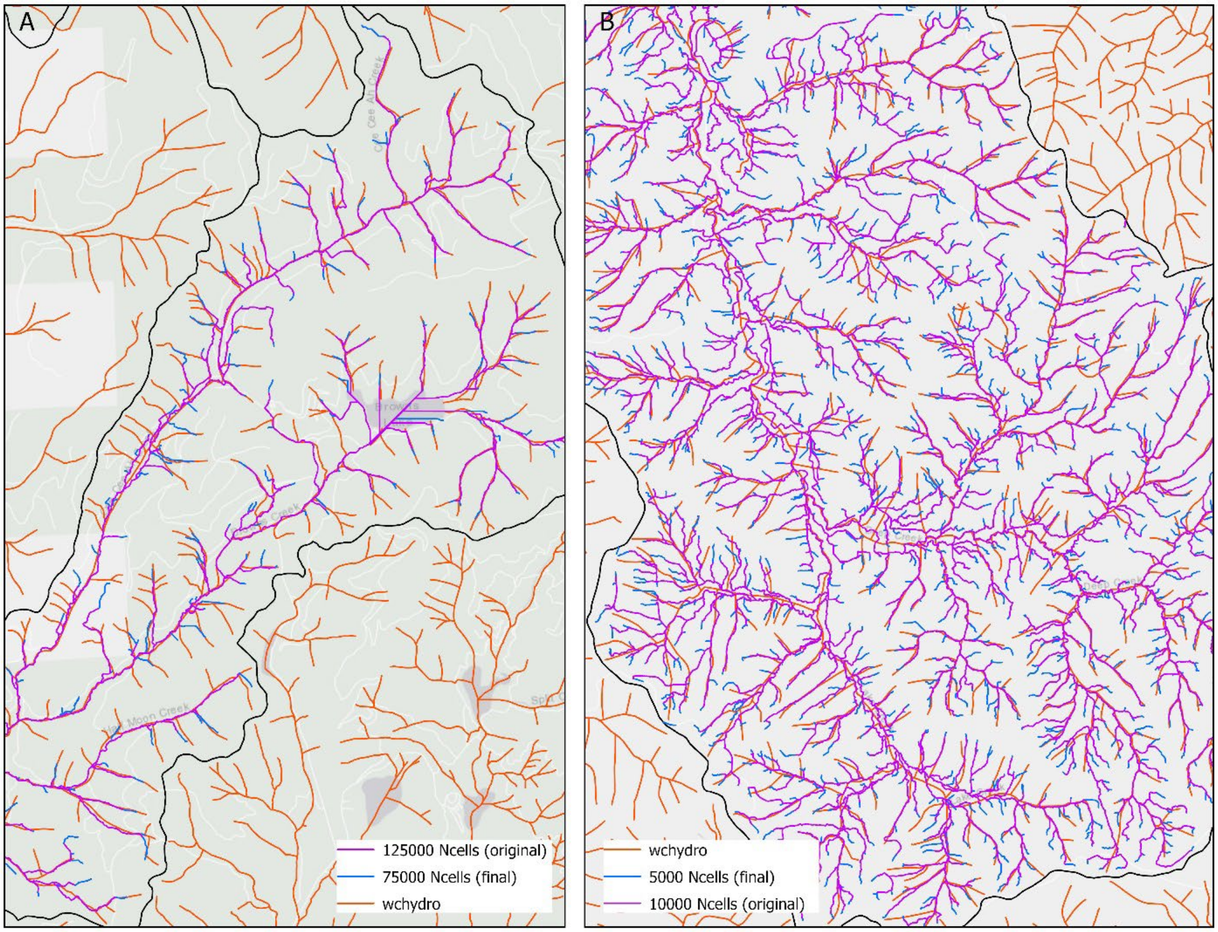
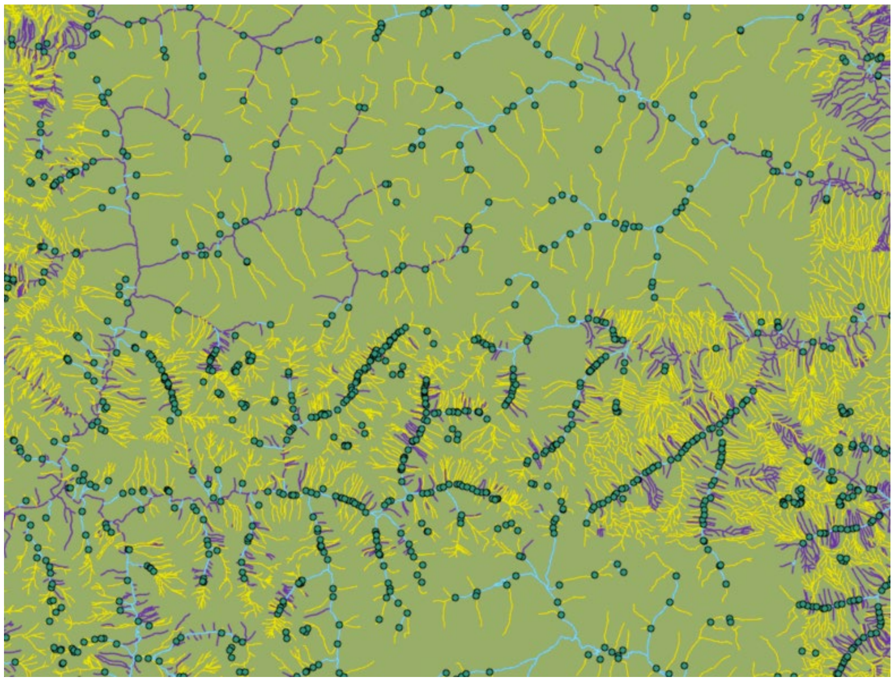


Figure 34. Streamlines were compared to wchydro. (A) Ncells were decreased if the streamlines were not dense enough or long enough. (B) Ncells were increased if the streamlines were too dense or too long

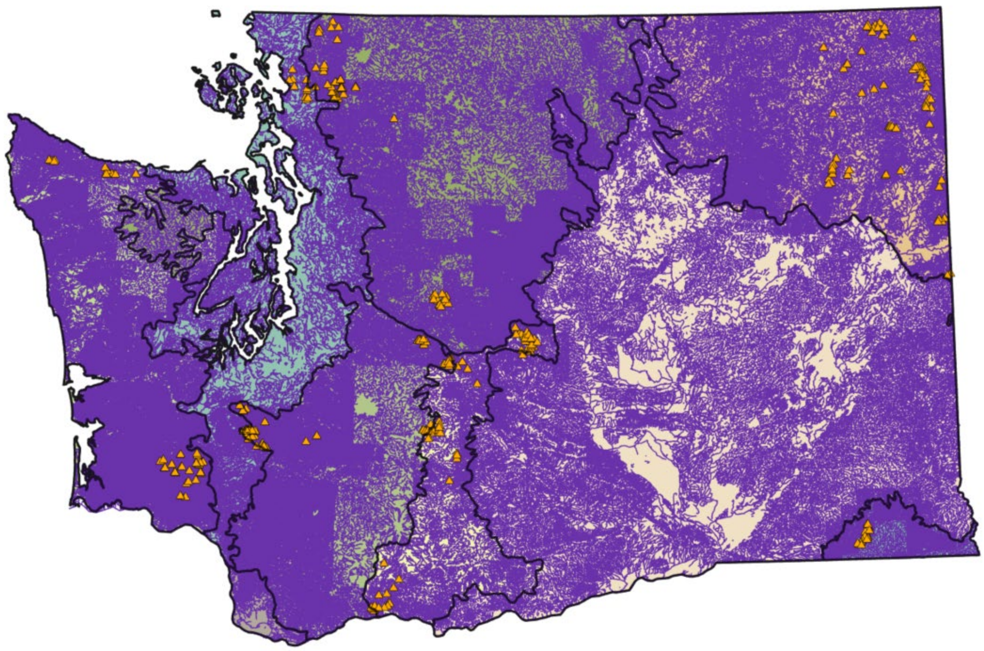
Comparing stream density within SSN to wchydro was informative; however, the variation in streamline density in wchydro could be artificially high within some subwatersheds that were in the process of being updated township by township (Figure 35). The variation in stream density based on township update schedules rather than on-the-ground reality also influenced the statewide and state-side estimates when extrapolating to the number of breaks on wchydro. Overall, however, the statewide representation of relative stream density in wchydro appears to be representative of statewide stream density patterns (Figure 36).

Another portion of this workflow that involved a significant amount of manual editing was manually burning streamlines through road berms where they were presumed to have culverts. While there are spatial datasets documenting culvert locations available for several parts of the state, these datasets rarely went far enough into the headwaters in the subwatersheds in question. Even when they did, they were frequently in locations that the automated stream generation process automatically detected and correctly passed through the roadbed. To address the issue of apparent missing culverts, streamline routing was checked against LiDAR hillshades and aerial imagery (Figure 33), as well as WTMF maps, and road berms were manually addressed where possible. However, this process was not exhaustive, and stream lengths may have been artificially inflated in some locations due to routing around missed culverts. In addition, DEMs were smoothed ahead of the stream generation process to prevent artificially inflating stream lengths due to incorrect routing as a result of LiDAR artifacts, and the streamlines were smoothed again at the end of the generation process to remove the artifacts that arise when lines are generated from a square raster to better reflect real stream channels.



Note: Green points represent water type breaks; streamline color varies by water type (Type F, Type N, state shoreline [Type S], or Unknown).

Figure 35. Stream density variation in wchydro often varied by township within a single HUC12 subwatershed or ecoregion



Note: Orange points represent DNR-concurred breaks used in this analysis; thick black lines represent ecoregion boundaries.

Figure 36. Streamline density variation in wchydro across Washington state

Another area of uncertainty in this analysis and previous similar analyses is the lack of information on stream seasonality in wchydro. This is throughout much of the state, but particularly on the east side, where entire ecoregions had no information on stream seasonality within the SSNs (Table 42).

Table 42. Number of synthetic stream networks and percentage of networks without any seasonality data by ecoregion

Ecoregion	Total Network Count	Networks With No Seasonality Data
Puget Lowland	12	0%
Coast Range	54	0%
North Cascades	56	25%
Cascades	76	45%
E. Cascades Foothills	76	79%
Northern Rockies	73	74%
Blue Mountains	18	100%

Finally, BFW influences the criteria for every metric investigated in this analysis. As a result, the accuracy of the BFW values influences the accuracy of remotely sensed metrics compared to what is on the ground. Because the LiDAR pixel size available at the statewide scale is equal to or coarser than the 2- and 3-foot BFW thresholds that much of this analysis depends on, the LiDAR or LiDAR-derived data was not used to detect stream channels for this analysis. Rather, a model that relied on data that was readily available across the state or that was created as part of the stream creation process was used. However, a model incorporating more parameters or that was derived from Washington-specific field data (such as the BFF model used in this study) would provide a more nuanced BFW estimate for the analyses in this report.

4.3 Reach Length

The analyses presented above rely on calculating gradient over a reach length of 5x BFW, while additional analyses calculating gradient over a distance of 20x BFW are presented in APPENDIX B. The 20x BFW reach length was chosen because it represents a useful scale over which to evaluate stream morphology and habitat (Montgomery and Buffington 1997). Moreover, 20x BFW (or wetted width in some cases) is often used by state and federal agencies for establishing reach length in aquatic habitat field survey protocols (e.g., Minkova and Foster 2022; Roper et al. 2010). An evaluation of how the reach length over which gradient criteria were calculated affects the PHBs identified for each option was performed. To do so, a comparison of the number and relative location of PHBs detected when measuring gradient was conducted over reaches with the following relative lengths:

- 2x BFW
- 5x BFW (presented in more detail in results section)
- 10x BFW
- 20x BFW (presented in more detail in APPENDIX B)
- 40x BFW

It bears noting that the expectation was that the number of PHBs detected would increase as reach length decreases. However, these additional PHBs are hypothesized to contain both true and false positives, with the rate of false positives increasing as reach length approaches zero. Without a validation study—for example, a verification survey or an additional review of available field data—it is not possible to test this hypothesis and determine how many of the PHBs identified under any of the above scenarios are valid. Such a study is required to determine the “optimal” reach length over which to evaluate gradient.

The number of PHBs presented here represent PHBs as calculated using the methods described above and in APPENDIX A to mimic field conditions and eliminate the potential for duplicate PHB identification, as would occur for PHBs extending beyond the 1-foot interval between points along the streamline that were used to calculate gradient. The number of points that met PHB criteria before the filter removing consecutive points (“unfiltered PHBs”) was also calculated, to distinguish between the effect of reach length on identifying PHBs at a given location and the impact of reach length on the number of PHBs as they would be identified in the field. Using these methods, fewer PHBs were identified when using longer reach lengths (Figure 37). However, the number of unfiltered PHBs was more similar for all reach lengths and decreased as reach length increased, with the exception of the 2x BFW reach, which had a lower number of unfiltered PHBs than the 5x BFW reach.

This contrast between PHB counts and the raw, unfiltered PHB counts suggests that smaller reach lengths are more sensitive to small changes in gradient, and at smaller reach lengths, PHBs are calculated in shorter bursts. These patterns persisted when PHB counts were considered on a by-network basis (Figure 38), with the variability in network PHB points per option decreasing as reach length increased. The decrease in PHBs as reach length increases is due at least in part to greater stretches of terminal streamline being counted as “NA”. This is because the distance over which there is no longer an upstream point, and therefore no gradient to calculate, increases as the multiple of BFW increases with the BFW multiplier. In addition, very small reaches with sufficiently steep gradients to trigger PHB criteria may not be over a height greater than BFW, and therefore would not meet all of the PHB criteria.

For a full analysis comparing PHBs calculated using a 20x BFW reach length to the DNR-concurred break, including changes in Type F extent and buffer metrics, see APPENDIX B.

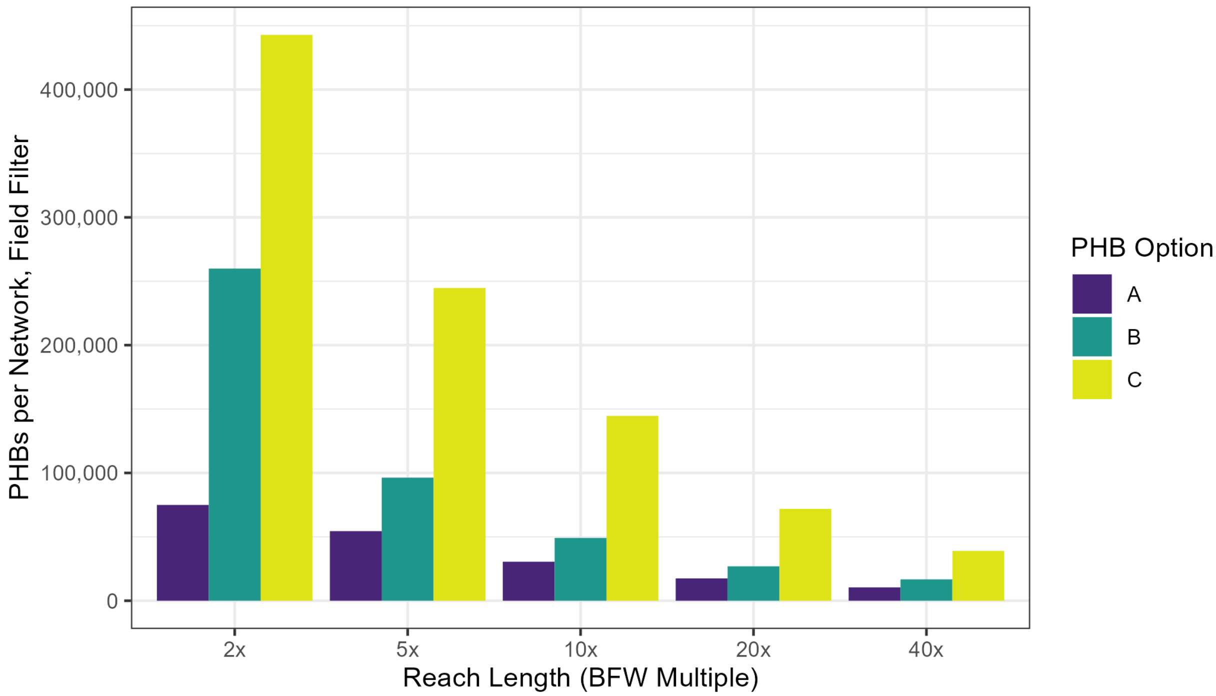
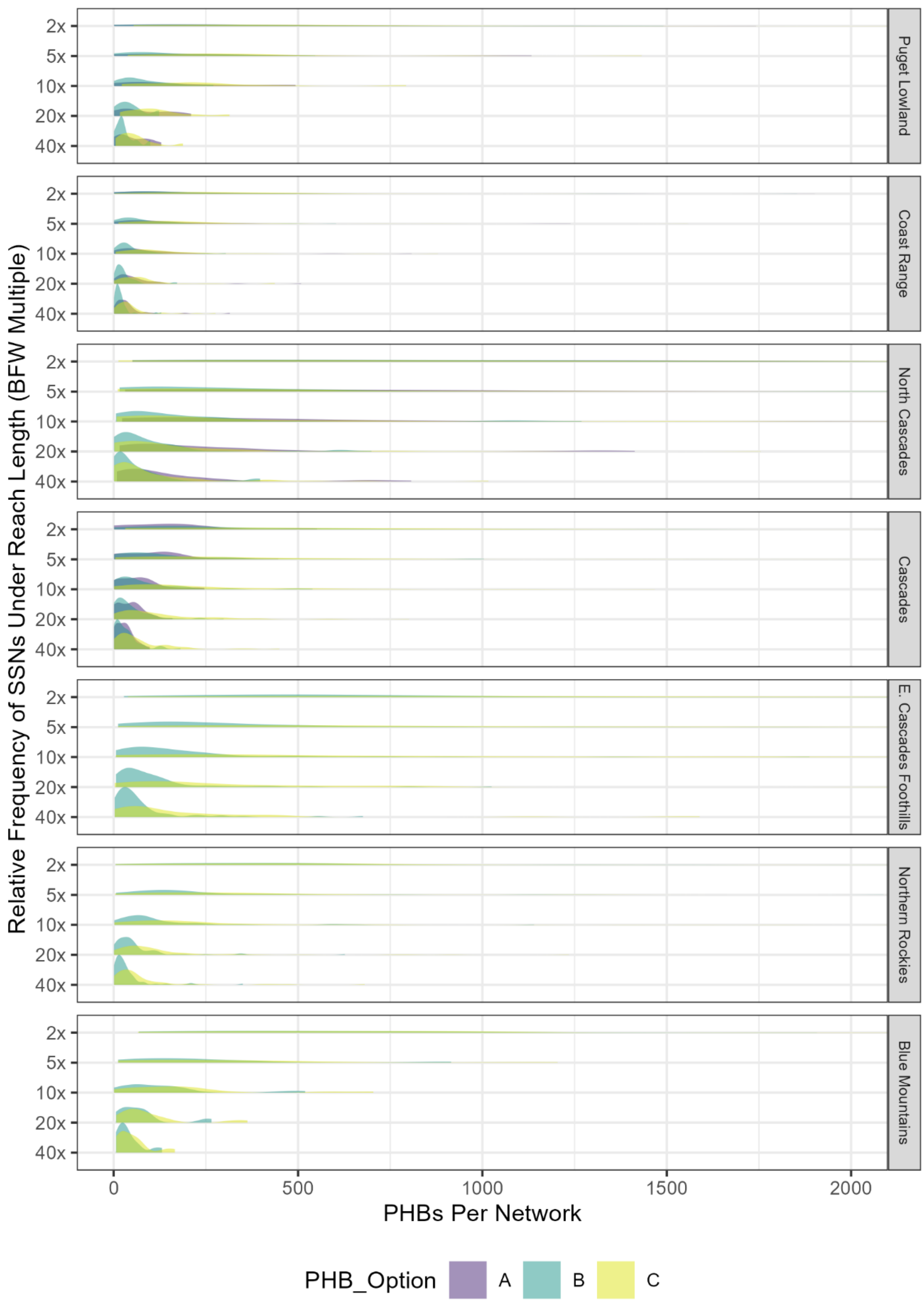


Figure 37. Mean number of filtered PHBs identified across all networks



Note: PHB counts > 2,000 were removed from this figure to increase figure legibility.

Figure 38. Distributions of the number of filtered PHBs identified per network, when evaluated across five alternative reach lengths, by ecoregion

5 Discussion

5.1.1 Potential Habitat Break, Anadromous Fish Floor, and Default Physical Characteristics Comparisons

Patterns in the relative positions of the DNR-concurred water type breaks, last fish, PHB-based water type breaks, AFF, and DPC varied across ecoregions and on both sides of the state. On the west side, all three PHB options tended to place water type breaks closer to and slightly downstream of the DNR-concurred F/N break. On the east side, the range of PHB-based breaks was both greater within ecoregions and farther upstream; this was particularly true for Option B.

The AFF alternatives varied more between alternatives than by ecoregion or side of state. Alternative A4 consistently established the AFF farther upstream than Alternative D, including more frequent AFF breaks established upstream of the DNR-concurred F/N break.

Because of the remote sensing approach, fixed-gradient thresholds for DPC appear to be systematically placing the end of waters meeting DPC downstream of field-observed last fish locations from WTMFs and presumed or detected anadromy in SWIFD. When beginning the evaluation for DPC beginning upstream of the last fish point, the first break in waters meeting DPC was frequently downstream of the DNR-concurred break. However, there were usually multiple stretches of stream upstream of the first break that met DPC.

Any remote sensing or model-based analysis is only as good as the underlying data. The LiDAR data collected and hosted by DNR is very high-resolution at the subwatershed and network scales, but below the reach scale the pixel size is coarse relative to features of interest for these analyses. The point distance for analyzing gradient was kept very small (1 foot) to capture whatever small changes in elevation were apparent in the LiDAR data, although this made the analysis more sensitive to artifacts in the LiDAR data.

The reaches over which gradients were calculated for this analysis were much larger than the pixel size (high-resolution); however, small features that could serve as vertical barriers in smaller streams were much closer in scale to the pixel size (coarse resolution) and were less likely to be detected. In addition, the source LiDAR data did not penetrate water. If the LiDAR flight in a given location was flown during flows at or approaching BFF, vertical barriers within the stream channel would be even less apparent. At such high flows, the stream channel would also be less apparent in the LiDAR data, increasing the chance that the streamlines at that location would flow through the adjacent landscape rather than in the stream channel.

As a result, gradient-based criteria often determined the placement of the PHBs, AFF, and DPC breaks. Because PHB Options A and C shared a gradient criteria (5% gradient change), many of the first PHBs above the last fish locations for those two options were at the same location. The first PHBs for Option A and C were frequently downstream of those for Option B, which had a stricter gradient threshold (10% gradient change). Similarly, the fixed gradient criterion for the DPC (16% or 20%) often placed the break in waters meeting DPC below the AFF under Alternative A4, for which the criteria include a sustained channel gradient of 7%.

The PHB analyses presented here should be understood from the perspective of remote sensing, which, although meant to replicate field surveys, can meaningfully differ from the way a field assessment would be conducted. For example, if a stretch of consecutive PHBs was identified, only the downstream-most PHB was kept. If there was a long series of consecutive PHBs, as often happened around gradient-based PHBs where a steep tributary met a flatter mainstem, the PHBs may have been more widely spaced than they could have appeared in the field or in a remote sensing-based analysis that did not handle consecutive PHBs in the same way.

The reach length over which gradient was calculated was an important factor in determining the number of PHBs calculated for each PHB option, although it is not clear which reach length strikes the most accurate balance between true and false positive identification of PHBs without additional study. Smaller reach lengths resulted in an increased variability in gradients calculated along a given stretch of stream, and therefore increased the frequency of gradient changes detected as well as an overall increase in non-consecutive PHBs being calculated for each SSN. However, without field verification, it cannot be determined how often these inferred PHBs reflect gradient changes on the ground at scales that would affect fish passage, versus LiDAR artifacts (see discussion of LiDAR variation in Section 4.1). In the case of PHBs calculated using a reach length of 5x BFW for gradient criteria, this increase in sensitivity to gradient change and corresponding PHB density resulted in the first PHBs detected above the last fish points moving closer to the last fish point with shorter reach lengths. One effect of this was that, on average, the distance between last fish and the first mainstem PHB identified upstream was less than 100 feet for nearly all ecoregions and options (except two ecoregions on the east side for Option B) and a corresponding downstream shift in Type F waters for all three PHB Options (see APPENDIX C for full results).

The biggest impact of the relatively low-resolution LiDAR (i.e., when considered at the reach scale) was the ability to detect vertical barriers defined in the PHB and AFF criteria. As the size of the vertical barrier approached the LiDAR pixel size, the likelihood detection at that resolution diminished. As a result, PHBs that did not co-occur with sharp changes in gradient were systematically underestimated. This underestimation of vertical barriers likely amplified the differences between AFF alternatives: Alternative D had a set stopping point for each tributary, but in the absence of vertical barriers the AFF could and sometimes did extend all the way to the top of networks with fewer sustained gradients.

Along with the type of gradient threshold, the under-detection of vertical barriers likely contributed to the break in waters meeting DPC frequently and counter-intuitively being placed below the AFF under Alternative A4. This is also the case for the relative location of the break in waters meeting DPC and (in some cases) PHB Options A and C. Because Type F waters based on PHBs by definition use the first PHB above the last fish point, PHBs downstream of the last fish point (and potentially downstream of the first break in waters meeting DPC) were not considered, while DPC breaks were included starting approximately 2,000 feet downstream of the last fish point.

Overall, when calculating the extent of waters meeting DPC as defined by the waters downstream of the first break in DPC, the result depended strongly on the downstream location from which the analysis of water break points began. When calculating breaks in waters meeting DPC, analyses began approximately 2,000 feet downstream of the last fish point, which caused many networks to exhibit breaks in DPC waters that were placed downstream of last fish. This was true even when only considering breaks above the last fish point: most networks had stretches of water that met DPC well upstream of the first break in waters meeting DPC and extending above the location of last fish. Calculating the extent of waters meeting DPC based on the location of the first break in DPC in a remote sensing framework may require adjusted criteria. It bears noting that interpretation of these results regarding application of DPC should be informed by understanding that they are meant for comparison purposes and do not represent changes in how DPC is currently applied in the field or part of current or proposed water type rules.

5.1.2 Riparian Buffer Changes: Current Rule

When comparing total riparian buffer area under each PHB option (gradient criteria calculated over a reach of 5x BFW) to area under the DNR-concurred break, buffer area decreased slightly (up to 1%) statewide and on both sides of the state. The associated timber volume within these buffers was more variable than buffer area on both sides of the state: while buffer area changes also resulted in a net decrease in the volume of riparian timber protected across all three PHB options for both sides of the state and statewide, that decrease was slightly larger under Option A and there was a small increase in timber volume for Option B on the east side. Patterns in value of timber within riparian buffers did not track changes in volume of timber within riparian buffers, likely due to variation in stand densities and composition by ecoregion as well as variation in stumpage values between the east and west side; however, the net value changes were similar to net changes in riparian buffer area. The reach length over which the PHB gradient criteria were evaluated had an impact on the location of the first PHBs upstream of the last fish point. When gradient criteria were calculated over a reach of 20x BFW rather than 5x BFW, the statewide volume and value of timber protected by riparian buffers tended to increase under Option B and decrease under Options A and C. The volume of timber protected within riparian buffers tended to decrease more on the west side than on the east side, although net decreases in riparian timber value were more comparable between Options A and C than volume of timber within riparian buffers. Statewide, the percent change in the volume of timber protected by riparian buffers ranged from a reduction of slightly less than 3% for PHB Option A to an increase of slightly less than 3% for Option B. The corresponding change in value of timber protected by riparian buffers statewide was less than a +/-1% change for all three PHB Options. While PHBs identified using a reach length of 20x BFW to calculate gradient tended to be upstream of those identified using a reach length of 5x BFW, the overall patterns between the PHB options remained similar: there was a decrease in the volume and value of timber within riparian buffers for Options A and C than under the concurred break, and a greater volume and value of timber within riparian buffers for Option B when compared to the other two options.

When considering the relative magnitude of differences between volume changes in Option A compared to the other two options, averaging timber volume between the east and the west side network buffers had a significant effect. On the east side of the Cascades crest in the North Cascades, there were networks that had significant net increases in timber volume for both Options B and C; because Option A only applies to the west side of the state, those networks did not impact the Option A averages for the North Cascades ecoregion. The relatively high proportion of water breaks in the North Cascades ecoregion compared to the total number of breaks on the west side of the state may have also amplified the importance of that ecoregion in the statewide and west side timber volume change averages.

For the proposed Type Np buffer rule change on the west side of the state, the volume and value of timber protected by riparian buffers under Option 1a and Option 1b were similar. In both cases, the proposed rule change would result in an approximately 90% increase in the volume of timber protected in riparian buffers, and a similar (86-88%) increase in the value of timber within those buffers. This suggests that having a 50% harvest limit in the outer portions of a wider overall buffer doesn’t substantially impact the amount of timber protected by a smaller, narrower buffer with a full harvest limit. The volume and value of timber within riparian buffers were both substantially higher under Option 2, but this does not reflect a change in the amount of timber that can be harvested at those locations as Option 2 only represents a temporary no-harvest limit.

6 Conclusion

This study created SSNs from high-resolution LiDAR data across seven ecoregions statewide. The following results were attained when applying the PHB, AFF, and DPC to each network and comparing water type buffers under the current rule:

- Patterns in the relative positions of the DNR-concurred water type breaks, last fish, PHB-based water type breaks, AFF, and DPC varied across ecoregions and on both sides of the state and were mostly driven by gradient-based criteria.
- Limitations in underlying data likely led to under-detection of small features, particularly vertical barriers in streams with small BFW.
- On average, riparian buffer area decreased in all ecoregions under all PHB options.
- The n-weighted average timber volume and value within riparian buffers changed by less than 1% for PHB Options B and C, and less than 3% for Option A.
- When gradient-based PHB criteria were calculated over a 20x BFW reach, the n-weighted average timber volume and value decreased slightly statewide under Options A and C (less than 3% and 0.5%, respectively) and increased slightly (approximately 1%) under Option B but was more variable when considering the east and west sides of Washington separately (up to just over 2.5% on the east side for Option B, but less than 0.5% increase on the west side).
- Using a 5x BFW reach for PHB gradient criteria resulted in a net shift downstream when compared to a reach of 20x BFW, although general patterns among PHB options on the east, west, and state side were similar.
- Under the proposed west side Type Np buffer rule, the timber volume and value protected by riparian buffers under Option 1a and Option 1b were very similar.

Future analyses incorporating more nuanced representations of BFW and stream seasonality could help refine this analysis moving forward.

References

Beechie, T., and Imaki, H. 2014. Predicting natural channel patterns based on landscape and geomorphic controls in the Columbia River basin, USA. *Water Resources Research* 50(1):39-57.

Daly, C., Smith, J.I., and Olson, K.V. 2015. Mapping atmospheric moisture climatologies across the conterminous United States. *PloS ONE* 10(10):e0141140. doi:10.1371/journal.pone.0141140. Downloaded July 2023.

DNR (Washington Department of Natural Resources). 2002. Section 13: Guidelines for Determining Fish Use for the Purpose of Typing Waters, Forest Practices Board Manual. Washington Department of Natural Resources, Forest Practices Board, Olympia, WA.

DNR. 2022. *Forest Practices Board Stream Related Rulemaking and Board Manual Development.* Prepared by Washington State Department of Natural Resources, Olympia, WA.

Mastin, M.C., Konrad, C.P., Veilleux, A.G., and Tecca, A.E. 2016. *Magnitude, frequency, and trends of floods at gaged and ungaged sites in Washington, based on data through water year 2014* (ver 1.2, November 2017). U.S. Geological Survey Scientific Investigations Report 2016–5118. http://dx.doi.org/10.3133/sir20165118

Minkova, T., and Foster, A. 2022. *Status and Trends Monitoring of Riparian and Aquatic Habitat in the Olympic Experimental State Forest*. Washington State Department of Natural Resources, Olympia, WA.

Montgomery, D.R., and Buffington, J.M. 1997. Channel-reach morphology in mountain drainage basins. *GSA Bulletin* 109(5):596-611.

NLCD (National Land Cover Dataset). 2021. Canopy Cover Conterminous United States. U.S. Geological Survey. https://doi.org/10.5066/P9JZ7AO3. Downloaded July 2023.

Roper, B.B., Buffington, J.M., Bennett, S., Lanigan, S.H., Archer, E., Downie, S.T., Faustini, J., Hillman, T.W., Hubler, S., Jones, K., Jordan, C., Kaufmann, P.R., Merritt, G., Moyer, C., and Pleus, A. 2010. A comparison of the performance and compatibility of protocols used by seven monitoring groups to measure stream habitat in the Pacific Northwest. *North American Journal of Fisheries Management* 30(2):565-587.

SWIFD (Statewide Washington Integrated Fish Distribution). 2023. WA DNR. Updated 4/27/2023. Downloaded 6/30/2023.

Walter, J., Heimburg, J., Martin, D., Mendoza, C., Thomas, C., Nauer, D., Black, J., and Toledo, A. 2022. *Evaluation of potential habitat breaks (PHBs) for use in delineating end of fish habitat in forested landscapes in Washington State: Study Design prepared for the Washington Forest Practices Board (Revised from PHB Science Panel Draft 2019).* Washington State Forest Practices Cooperative Monitoring, Evaluation, and Research (CMER) Committee, Olympia, WA.

APPENDIX A Detailed GIS Methodology

Overall Methods Approach

Datasets and Overall Structure

The analyses in this study were conducted on a combination of Washington Department of Natural Resources (DNR)-provided data and publicly available datasets such as the National Land Cover Database (NLCD) and the Statewide Washington Integrated Fish Distribution (SWIFD) dataset. The methods described below are broken into the following five parts:

1. An initial description of the DNR-provided data and quality assurance/quality control process
2. Creating synthetic stream networks (SSNs) using cleaned and compiled DNR-provided data and high-resolution, LiDAR-derived digital terrain (DTM) rasters
3. Calculating potential habitat breaks (PHBs), the anadromous fish floor (AFF), and default physical characteristics (DPC) on the SSNs
4. Calculating the distances between the field-based, DNR-concurred water type breaks and last fish points to the PHB, AFF, and DPC locations and extents
5. Calculating and comparing riparian buffers under the current rules based on water types designated by the DNR-concurred break and each PHB option, as well as the volume and value of the timber within those buffers

Unless otherwise indicated, analyses were conducted in R (version 4.2.3) using tidyverse functions, the R package sf[1] (version 1.0-15), and other sf-compliant spatial packages. ArcGIS Pro (version 3.1.2) was primarily used for the stream creation workflow and portions of the buffer analysis workflow.

Create Synthetic Stream Networks

Compile F/N Break and Last Fish Datasets

Washington Department of Natural Resources-Provided Datasets

DNR provided point feature class data of Last Fish and End of Fish Habitat points, which were created using water type survey data submitted by forest landowners. The point data were split into east side and west side data points. The west side data were provided as one point feature class, while the east side data were provided in four separate point feature classes: Kalispell, Terrapin, Eastside original, and Yakama.

The attribute tables of these data had varying levels of information, but all had the latitude and longitude of the point at which fish habitat ends in the stream, which is referred to as the F/N break. The Terrapin and the Yakama data also had the latitude and longitude of the point at which the last fish was detected during the survey. The rest of the data had a column ("FN_minus_EOF”) of the distance measured downstream from the location of the F/N break to the location of the last fish detection. Some of these data had associated Water Type Modification Forms (WTMFs), while others did not; the west side data had a WTMF linked for each point, while only the east side points from the Kalispell and the Eastside original points dataset had WTMFs linked.

[1] Simple Features for R • sf (r-spatial.github.io)

Processing and Analysis

The east side data were joined into one point layer, and then separated into two feature classes—one with last fish points, and one with fish/non-fish water type (F/N) break points. The Last Fish dataset comprised only points that had associated latitude and longitudes. In each of these datasets, a column called FN_LF_DIST was created, which stored the distance between the F/N break and the associated Last Fish point. For the west side data, this value was pulled from the FN_minus_EOF column. For the east side data, if there was a value in the FN_minus_EOF column then it was pulled from this column. If there was no value in the FN_minus_EOF column, there were two approaches taken; if the F/N break point and the Last Fish point were the same, this value was 0. If there was a corresponding Last Fish point in the Last Fish point dataset (meaning there are recorded GPS coordinates for this point), but the distance downstream from the F/N break point was unknown, this value is <Null>.

The final compiled data (prior to snapping to the SSNs, described below), comprised three sets:

1. East side Last Fish points 'Eastside_All_20231215_LF_Flood'
2. East side F/N break points 'Eastside_All_20231215_FN_Flood'
3. West side Last Fish/F/N break points 'Westside_All_Points_20230824'

Each of these datasets had the original columns in the attribute tables provided by DNR, along with additional data, including the FN_LF_DIST column, unique ID for each point (LF_ID in 'Eastside_All_20231215_LF_Flood' data, FN_ID in 'Eastside_All_20231215_FN_Flood', and FNID_W in 'Westside_All_Points_20230824' data). Lastly, these points were spatially joined with the DNR provided USGS Washington Flood Regions polygon layer 'Ecoregions_WA_State_L3', resulting in the addition of a Flood_Region column. The resulting datasets contained a combined total of 377 F/N break points with associated last fish locations across the state. Additional networks were dropped from all analyses in the analysis code downstream due to conflicting last fish information or LiDAR artifacts that impacted all analyses, bringing the total networks analyzed to 365.

Create LiDAR-Derived Streamlines

Raster Preparation

Digital Terrain Model (DTM) datasets were downloaded from the DNR LiDAR portal (https://lidarportal.dnr.wa.gov) for all areas within hydrologic unit code (HUC) 12 units containing DNR-concurred F/N break points. The individual rasters were combined into larger rasters using the Mosaic to New Raster geoprocessing tool (unless otherwise specified, the geoprocessing tools described in this section refer to built-in tools in ArcGIS Pro version 3.1.2) and clipped to the extent of the HUC 12 or HUC 12 cluster polygon with the Extract by Mask geoprocessing tool using the Spatial Analyst license. The metadata was recorded within the LiDAR download using an Excel tracking spreadsheet. A single polygon was then selected from the dataset WDNR_HUC12. The mosaic of choice for the raster input was selected and named the output raster DTM_c[HUC12_code].tif (with the "_c" indicating that the raster was clipped). For the environments tab, the mosaic raster was entered as both the Snap Raster and the Coordinate Reference System entry. Additionally, the size of each raster was reduced by trimming the extent of each raster (removed all columns and rows that were entirely NA) and decreasing the amount of data stored per pixel (bit depth) for all rasters in R. This method did not change the elevation values encoded in each pixel.

Create Streamlines and Associated Catchment Polygons

Streamlines and associated point and polygon data were created in an ArcGIS notebook script run in ArcGIS Pro that combined tools from built-in toolboxes and the ArcHydro toolbox (https://downloads.esri.com/archydro/archydro/Setup/Pro/3.1/3.1.14/setup/). First, the DTM rasters were smoothed to remove LiDAR artifacts using the focal statistics geoprocessing tool (statistics type = mean, neighborhood size was 3x3 to balance maintaining raster resolution with cleaning up LiDAR artifacts). The following tools from the ArcHydro toolbox were then used:

- Fill Sinks
- Flow Directions
- Flow Accumulation
- Stream Definition
- Stream Segmentation
- Drainage Line Processing
- Catchment Grid Delineation
- Catchment Polygon Processing
- Adjoint Catchment Processing
- Drainage Point Processing
- Append Coastal Catchment

Four layers were created for each subwatershed using the DTM created in Task 1:

1. A drainage point layer created using the drainage point processing tool
2. A drainage line layer created using the drainage line processing tool
3. A catchment layer created by the catchment polygon processing tool
4. An adjoint catchment layer created with the adjoint catchment processing tool

The density of streamlines was determined by an n-cells threshold for flow accumulation, with low values (~5,000) creating denser networks than higher values (~150,000). The flow accumulation threshold was adjusted as needed, based on cross-checking the density of the Washington watercourses (wchydro) layer at the HUC12 subwatershed scale and comparing to aerial imagery (ESRI imagery basemap) as well as the LiDAR. For example, the subwatershed with HUC12 ID 170102160202 was originally run with an Ncell density of 150,000. However, after comparing the synthetic stream density against wchydro, it was clear that the streams were not dense enough. So, the Ncell count was adjusted to 100,000, and the stream densities were a better match. Additional checks were performed to make sure the adjoint catchments did not have empty polygons, to see if any columns had missing IDs, and to check streamlines around F/N points to determine whether burning through road berms was necessary for any of the input Digital Elevation Models (DEMs) (described in the following section).

Burn Culverts into the Digital Elevation Model

The SSNs were checked for accuracy against the wchydro layer. Occasionally, the synthetic streamlines would not follow the wchydro streamlines. If it was determined that the synthetic streamlines needed to be manually moved to accommodate what could confidently be inferred to be missing culverts, the DTM was manually modified so that the stream would pass through the presumed culvert rather than along the road. For example, a road berm in the subwatershed with HUC12 ID 171100070107 re-routed streamlines so that upstream flow that should have gone through the DNR-concurred breakpoint

(FN89_W) was diverted downstream of the point; therefore, one channel was "burned" through the road berm where there appeared to be a culvert and the streamlines connected as expected upstream of the point rather than downstream.

To burn through the road berm, a line feature layer was created consisting of line segments that connected streamlines through culverts that were not picked up by LiDAR but could be seen in aerial imagery. This line layer was buffered by 3 feet using the Buffer geoprocessing tool to ensure the culvert would be large enough to change the water flow. The buffered lines were used as the input for the Zonal Statistics geoprocessing tool (type minimum) to lower the elevation where the "culverts" were created. The Input raster was the buffered line layer, and the input value raster was the DEM. The output from this tool was a new DEM with a change in the elevation where the new "culverts" were drawn. A final DEM was created using the Mosaic to New Raster geoprocessing tool using the output from the Zonal Statistics tool as the first input raster and the original DEM as the second input raster. The pixel type was set at 32-bit float (to maintain decimal precision) and Mosaic Operators was first. The final DEM was used to generate drainage lines, points, catchments, and adjoint catchments using the methods previously discussed.

Create Synthetic Stream Networks

Generate Networks

Using the DNR-concurred F/N break point, SSNs were created by selecting all segments upstream and downstream of each point using the R package sfnetworks (version 0.6.3). Each synthetic stream dataset was converted into a network framework (line segments as edges, the junction of each line segment a node) using sfnetworks::as_sfnetwork, and the corresponding F/N break point was blended (snapped to the streamline and added as an additional node into the network, which also split the line segment) into that network using sfnetworks::st_network_blend. All nodes (confluences or stream segment endpoints) upstream and downstream of the F/N break were selected (main text Figure 3) and their corresponding edges (stream segments) were designated "upstream" and "downstream", respectively, before converting the network back into a simple features (sf) object.

Each resulting network was smoothed using the kernel smoothing method (n = 5, smoothr::smooth, package[2] version 1.0.1) This method adds extra vertices to each line segment and then uses Gaussian kernel regression to generate a smoother and more generalized curve in order to remove artifacts resulting from generating lines from raster pixels. DNR-concurred break points were then snapped to the nearest location on the resulting smoothed streamlines using a customized version of the sf::st_snap function (incorporating snapping distance limits and maintaining a feature ID). Last Fish locations that were provided as points rather than distances were also snapped to the streamlines. Points were visually assessed to ensure that they snapped to the correct location on the SSN by Four Peaks and confirmed by DNR; if the snapped point looked like it was in the same, or comparable, location on the SSN as the original point on wchydro, no edits were made. If the snapped point looked like it was in a different location, e.g., further downstream or upstream, or on a different stream entirely, the location was cross-checked with the WTMF and verified in discussion with DNR. From there, the point was either manually placed on the SSN in the verified location or removed from all subsequent analyses. Points that

[2] smoothr package - RDocumentation

snapped to the incorrect location were separated into a dataset called 'FN_LikelySnapError_20231215_Flood' and manually moved close to the location on the synthetic streamlines that corresponded to their location on wchydro. These points were then combined with the rest of the F/N break points to create the 'FN_All_Points_snapped_20231228' dataset.

For last fish locations provided as points, the distance along the SSN was calculated by converting the SSN into a network object, blending the snapped Last Fish point and corresponding DNR-concurred break snapped point into the network, and then calculating the distance between the two points using sfnetworks::st_network_cost. These distances were then added to the FN_LF_DIST field in the 'FN_All_Points_snapped_20231228' dataset.

Assign Attributes to Synthetic Streams

After the SSN lines were created, attributes at the stream segment level were calculated. Stream segment length was calculated automatically as part of the attribute in ArcGIS (although it was often explicitly calculated in subsequent analyses using sf::st_length to ensure that analyses that involved splitting line segment were appropriately characterized). Upstream basin area was calculated using the area of catchment polygons generated during the stream creation process (adjoint catchment polygons for stream segments with at least one upstream stream segment, segment-level catchment polygons for the uppermost stream segments). Bankfull width (BFW) was calculated at the stream segment (defined by the junctions in the line layer) scale by applying the Beechie and Imaki (2014) formula based on basin area and mean annual basin precipitation using PRISM data (Daly et al. 2015). Bankfull flow, or the 2-year flood flow, was calculated at the stream segment scale using a region-specific formula (Mastin et al. 2016) based on a combination of catchment precipitation, catchment canopy cover (NLCD 2021), and catchment area. Minimum elevation was calculated using the DTM data that were used to create the synthetic stream. Water type of each segment was designated relative to the location of the F/N break: waters downstream of the F/N break were designated fish habitat type water (Type F), and waters upstream of the break were designated non-fish habitat type water (Type N). Perennial and seasonal designations were taken from wchydro; segments labelled unknown were designated perennial if they were downstream of a perennial segment, seasonal if they were upstream of a seasonal segment, and then all remaining unknown stream segments were designated perennial. Finally, stream segments were designated as being within the extent of anadromy based on the corresponding extent of "Presumed" or "Documented" anadromous waters (including the "Artificial-", "Historic-", and "Transported-" subcategories for each) in the Statewide Washington Integrated Fish Distribution (SWIFD) dataset (SWIFD 2023).

Create Datasets for Potential Habitat Break, Default Physical Characteristics, and Anadromous Fish Floor Analyses

Underlying Point Datasets

For the PHB and DPC analyses, a dataset consisting of points created at 1-foot intervals was generated starting at least 2,000 feet below the last fish location for each network. To create this dataset, first, an additional version of the SSN streamlines was created by generating a point 2,000 feet downstream of the last fish point. That point was then used to generate a network of all of the streamlines upstream of that location using the subsetting method described in the Generate Networks section for creating the original SSN using the F/N break point (in this case, only the stream segment intersecting with the newly generated point and segments upstream rather than streamlines upstream and downstream of the point). This additional version of the SSN was created to 1) ensure that there was only one unique HydroID per line segment rather than having a line segment split at the F/N break, and 2) to attempt to get all of the line segments in some kind of downstream-upstream order. This dataset was then filtered to only include stream segments in the original synthetic streams network.

While still in the network framework, the distance from the "mouth" of the network to the downstream end of each line segment was calculated (mouth_dist), and segment-level attributes including anadromous waters from SWIFD and BFW were transferred from the original SSN by the original line segment ID (HydroID). Points were then generated at 1-foot intervals using sf::st_line_sample. These 1-foot intervals allowed us to maintain the high resolution of the LiDAR dataset and provided a flexible way to calculate distances and assign point IDs for stream segments with highly variable lengths. Unique point IDs were generated at the network level and within segments; the segment-level ID (in order along the streamline) was used in combination with the segment-level distance-to-mouth to calculate the distance from the "mouth" to each point (mouth_dist_pt). The elevation for each point was extracted from the DTM (each point was assigned the value of the raster pixel that it overlapped) used to create the stream network using terra::extract (package[3] version 1.7-29).

For the AFF analysis, if the point dataset above did not contain anadromous waters from SWIFD, points were generated starting from stream segments with anadromy farther downstream of the initial point dataset or from the downstream-most extent of the network (to the outlet of the network's HUC12 subwatershed) using the process described in the Generate Networks section.

In order to determine the relative position (upstream or downstream, flow-connected or not) of points and line segments in a network, two types of unique identifiers were assigned to each segment essentially describing how to get there from the mouth of the network. The BinaryID calculation assumed that no more than two tributaries joined at each confluence. The unique string for a given segment is constructed recursively, with the most-downstream segment assigned a base case of "1". At each confluence, the two upstream segments' BinaryIDs are the combination of the downstream segment's BinaryID appended with either a "0" or a "1" arbitrarily to the two tributaries. For example, one might use "0" to indicate a right turn and "1" to indicate a left turn, such that "100110" indicates the segment found by starting at the mouth segment, heading upstream in the network, and making two right turns, then two left turns, and then a right turn (although the assignment of "0" and "1" was not explicitly applied to one direction or the other). Segments in this dataset sometimes had up to four tributaries apparently meeting at a single confluence, so instead the digits 1 through 9 were used in the same fashion, and the result was called a NonaryID. Because the NonaryID is recursive, it was straightforward to filter for all segments upstream of a given confluence: they shared a unique initial substring, which was the full NonaryID of the segment downstream of the confluence. In combination with relative point position within a given line segment, these NonaryIDs were used in the analyses described below to filter PHB, AFF, and DPC points (for example, if there was a PHB on each of line segments 1211, 12110, and 12211, the PHB on the 12110 line segment would be dropped because the NonaryID begins with 1211, meaning it was upstream of the PHB on 1211; however, the PHB on 12211 would be kept because it was on separate branch and not upstream of any other PHBs).

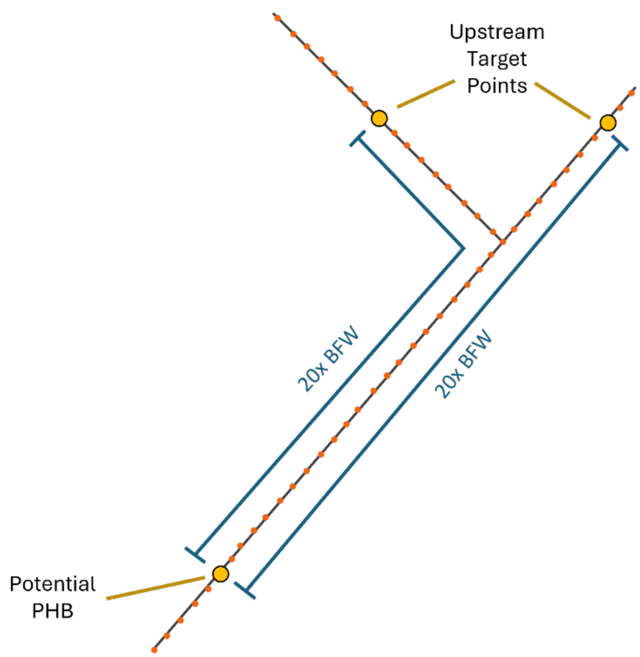
[3] terra package - RDocumentation

Calculate Potential Habitat Breaks and Water Type Extents

Calculate Potential Habitat Breaks

PHB were calculated for each PHB option (main text Table 1) using the point dataset generated for the PHB and DPC analyses based on the criteria for each option. Using the point dataset described in the previous section, the change in gradient was calculated between the upstream and downstream gradients of each point, each point was evaluated as a potential permanent barrier, and change in flow was calculated at each stream segment junction.

To calculate the change in gradient, the gradient was calculated over the interval 20x BFW upstream and downstream of each point. First, the 20x BFW interval was calculated for each point. Next, the upstream and downstream mouth_dist_pt values of points upstream and downstream of each point by the 20x BFW interval (rounded to the nearest foot) were added to the same row in the data frame. The elevations of all target points upstream of the potential PHB by the 20x BFW interval were joined to each row, and the gradients calculated for each row. In order to account for upstream gradients that spanned junctions, the minimum upstream gradient was assessed to avoid calculating a PHB downstream of a tributary junction based on the elevation of the tributary when the gradient on the mainstem (likely a more gradual gradient than the gradient calculated upstream of the potential point on the tributary) would not inhibit fish passage. In other words, in order to meet the gradient criteria, the gradient change threshold had to be met upstream of a given point on all upstream tributaries (Appendix Figure A-1); if it did not exceed the threshold on all upstream tributaries (e.g., it met the threshold going up a tributary but not on the mainstem), the point was not considered a PHB. The difference in the gradient upstream and downstream of each point was calculated, and points that met the gradient change criteria for each option were flagged as PHBs. Points within less than 20x BFW distance from the upstream or downstream ends of the network did not have enough information to calculate the gradient across the full reach.



Appendix Figure A-1. Diagram of an example point being assessed for PHB status and the target points upstream of the example point by 20x BFW

To evaluate for vertical barriers, points were arranged by mouth_dist_pt within a given segment. If the change in elevation between a given point and the point immediately upstream of that point on a given line segment met the vertical barrier criteria for that option (e.g., if the BFW of the downstream point was 3 feet and the elevation change between the two points was 4 feet, it would meet the vertical barrier criteria for all three PHB options), the point was flagged as a PHB. Points were also flagged as PHBs if they met the BFW threshold for that option. The upstream gradient calculated for the gradient change criteria was used for the non-vertical barrier criterion for Option B, which also specified that the change in elevation between the downstream and upstream ends of the gradient window (between the point and the point 20x BFW upstream) had to be greater than the BFW at the downstream point. Points were flagged as PHBs under that non-vertical barrier criterion if both exceeded the gradient threshold and if the change in elevation between the point and the point 20x BFW was greater than the BFW at the downstream point. The change in flow calculations for Option C were calculated by joining the flow values for all stream segments upstream to a given point using the HydroID and NextDownID fields. If the change in criteria were met, the lowermost point on the segment downstream of the junction was flagged as a PHB for Option C.

All points in each network were evaluated against the PHB criteria for each network. In order to better simulate conditions in the field, consecutive points on a single line segment were filtered out (in other words, if the point downstream of a given point also met the criteria for that option, the upstream point was not included in the dataset and only the downstream-most point in the series was kept). A separate dataset containing all points upstream of (points whose mouth_dist_pt attribute was greater than) the last fish point was created for each option, as well as a dataset only including the first PHB upstream of the last fish point (on each branch, if there were multiple branches). To calculate the first PHB on each branch, each line segment (keeping only the downstream-most point or the point with the lowest mouth_dist_pt value) was filtered by mouth_dist_pt then by all points whose NonaryID began with the NonaryID of another point. A dataset was also created for each option that included only the first PHB upstream of the last fish point on the mainstem. Because information on which streamlines should be considered the mainstem was not available, the first upstream PHB on the stream segment with the largest BFW was used.

In order to investigate the impact of reach length over which the gradient was calculated, the above process was repeated using a reach length of 5x BFW instead of 20x BFW (see APPENDIX C for results).

Calculating Extent of Type F

For each PHB option, the first PHB point upstream of the last fish location on each branch was used to define the upper extent of Type F waters (main text Figure 4). For each option, SSN streamlines were converted into network objects (sfnetworks::as_sfntework) and PHB points were blended into the network (sfnetworks::st_network_blend). All stream segments upstream of points were selected and exported back into a simple features object; these lines represented Type N waters. Streamlines representing Type F waters were created by calculating the difference between the original SSN streamlines and the Type N streamlines (a custom st_erase function combining sf::st_union and sf::st_difference). To keep the analysis focused on the changes that would result from proposed rule changes, SSNs and their associated points and characteristics were considered independently of one another even if parts of the networks overlapped on the ground (e.g., networks around F/N breaks on different tributaries of the same river).

If no PHB was calculated between the last fish point and the upper extent of the branch, Type F waters were assumed to continue upstream to the terminus of that branch. In addition, the first PHB upstream of the last fish observation on the mainstem (as defined by the upstream branch with the largest BFW was identified in order to describe the linear change in F/N break under each option and the DNR-concurred F/N break point. If no PHB was calculated for the entire network under a given option, no Type F or Type N streamlines were created for use in the distance calculations or buffer analysis.

Calculate Anadromous Fish Floor Breaks and Extent

Anadromous Fish Floor Alternative A4 (7%)

Calculating the AFF required knowing which tributaries in the dataset were upstream of a given stream segment. It was decided to borrow from a known, scripted method that assigns a unique string to each segment essentially describing how to get there from the mouth of the network. This existing method assumed that no more than two tributaries joined at each confluence. The unique string for a given segment is constructed recursively, with the most-downstream segment assigned a base case of "1". At each confluence, the downstream segment's BinaryID is appended with each an "0" and a "1", and these new BinaryIDs are handed out arbitrarily to the two tributaries. For example, one might use "0" to indicate a right turn and "1" to indicate a left turn, such that "100110" indicates the segment found by starting at the mouth segment, heading upstream in the network, and making two right turns, then two left turns, and then a right turn. Segments in this dataset sometimes had more than two tributaries apparently meeting at a single confluence, so a BinaryID wasn't sufficient to describe all of the branches upstream of that confluence. Instead, a "NonaryID" was calculated using the digits 1 through 9 in the same way that the BinaryID was calculated using 0 and 1; this enabled the NonaryID to account for up to 9 branches coming together (although the maximum observed in this dataset was four tributaries in a single confluence). Because the NonaryID is recursive, it was straightforward to filter for all segments upstream of a given confluence: they shared a unique initial substring, which was the full NonaryID of the segment downstream of the confluence (e.g., a segment with the NonaryID 1211 is downstream of the segments 12111, 12112, 121111, etc.; 121111 is upstream of 12111 but not 12112).

The AFF is defined by criteria for elevation differences and gradients across a series of consecutive upstream points in the stream network. The bulk of the analysis for this step involved classifying each point as either an AFF break or not an AFF break, according to each criterion. Specifically, a point was determined to be an AFF break if (1) there was a sustained gradient of at least 7% for an indicated distance upstream of the point, or (2) there was a vertical barrier of at least an indicated height just upstream of the point (main text Table 2). The non-vertical barrier criterion was not calculated because the resolution of the data was insufficient to detect step pools, and as a result the criteria for a sustained 7% gradient would always be met before a sustained 20% gradient. The indicated distances and heights depended on the BFW (main text Table 2).

For points at or just downstream of each confluence, the criteria would depend on the elevation and gradient of upstream tributaries, which created an ambiguity because some tributaries met the criterion and others did not. It was decided that the downstream point would qualify as an AFF break of a given type only if the criteria were met for all possible upstream paths. If even one path did not meet the criteria, anadromous fish would be able to continue upstream via that path (e.g., if a 7% gradient upstream of a given point was sustained up a tributary but not the mainstem, the point would not meet the criteria for AFF).

An algorithm was written in Python to check these criteria for each point in every network. The two criteria were structurally similar enough that a single algorithm could be written for both, accepting the specific criterion as a parameter. The algorithm checked the criterion on a rolling window of the appropriate length, assigning a True or False value to each point for each type of AFF break. For a point to qualify for the sustained gradient criterion, the average slope from each point in the rolling window to the point 5 feet (a subdivision that balanced being greater than the underlying LiDAR pixel size, small enough to have multiple replicates within a window, and divisible by each of the moving window sizes) upstream of that point had to meet or exceed the 7% threshold. Where the window included a confluence, the NonaryID field was used to identify all possible paths through upstream tributaries and check whether all of them satisfied the criterion. Points at the upstream end of the network could not be checked because there was an insufficiently long window, so they were marked as NA and treated as True, on the assumption that it's not possible for an anadromous fish to swim past the upstream end of a stream network. After checking both criteria on the whole network, the most-downstream AFF break was identified within each stream segment.

Subwatersheds that had no presumed or documented anadromy recorded in SWIFD were dropped from the analysis for Alternative D because no stream segments would meet the criteria. Data from the StreamNet[4] portal were also downloaded and evaluated, but the only relevant data that did not originally come from SWIFD documented resident populations of Cutthroat Trout and therefore not used in the analysis. Subwatersheds that were connected by fluvial behavior in SWIFD to anadromy were included to account for the fact that the criteria for Alternative A4 did not restrict the streams able to be considered for calculating the end of AFF and otherwise a large portion of the subwatersheds and SSNs on the east side would have been excluded. Assuming that the AFF was located somewhere downstream of the subwatershed outlet, the upstream extent of AFF Alternative A4 was considered to be at the subwatershed outlet in order to provide a minimum estimate of the distance to the last fish and DNR-concurred F/N breaks for each network in the subwatershed.

Anadromous Fish Floor Alternative D

Under AFF Alternative D, only tributaries directly upstream of presumed or documented anadromy could be included in the AFF. For each point, the downstream stream segment's SWIFD attributes were joined the point using the relationship between HydroID and NextDownID, and filtered out all points not within presumed or documented anadromy or whose downstream segment wasn't within presumed or documented anadromy.

Within this subset, points on stream segments upstream of documented anadromy were evaluated against the gradient criterion. The change between upstream and downstream gradients for the downstream-most point on the segment was calculated over 20x BFW using the same methods as the change-in-gradient calculations for the PHB alternatives, and flagged as an AFF stopping point if the change in gradient met the criteria in Table 2 (main text). Vertical barriers were evaluated by comparing the change in elevation between a given point and the point immediately upstream, and flagged as an AFF

[4] https://www.streamnet.org/home/data-maps/sn-mapper/

stopping point if it met the criteria in Table 2 (main text). Due to the resolution of the LiDAR data, step pools were unlikely to be detected; the step pool gradient criteria were based on the gradient between the point and the point 20x BFW upstream of that point if the change in elevation criteria were met.

The AFF stopping points for all Alternative D criteria were combined, and points that were upstream of another point on the same segment (had a greater mouth_dist_pt distance) were filtered out of the final dataset.

Calculating Anadromous Fish Floor Extent

Once AFF points were calculated for both options and filtered to the downstream-most point on each segment, points were further filtered to the first point on each branch by removing all points whose NonaryIDs began with a NonaryID of another point. The extent of anadromy was treated as the network extending upstream from the outlet of the subwatershed to all of those points (main text Figure 4). For branches where no points were calculated, the AFF continued to the end of the branch (Alternative A4) or the end of the stream segment upstream of SWIFD (Alternative D).

AFF extents were calculated using the same methods used to determine the extent of Type F waters for each PHB option. For AFF Alternative A4, the full SSN was used as the network; for Alternative D, only stream segments with SWIFD anadromy or directly upstream of anadromy were converted into a network object and processed as described above in the Generate Networks section.

Calculate Default Physical Characteristics Breaks and Extent

Points that met the criteria for DPC had BFW greater than the BFW threshold described in Table 3 (main text) and an upstream gradient less than or equal to 16%. If the contributing basin of the stream met the state side basin threshold, the upstream gradient threshold was less than or equal to 20%. The upstream gradient was calculated using the same upstream gradient method for the PHB analysis, and the basin area and BFW were calculated as part of calculating attributes at the stream segment level for the SSNs described in the Assign Attributes to Synthetic Streams section.

In order to be consistent with the methods for establishing PHBs and calculating the extent of Type F waters downstream of PHBs, breaks in DPC were evaluated upstream of the last fish point on each network, with water break points established just downstream of reaches longer than 3 feet (greater than underlying LiDAR pixel size) that did not meet DPC. To accomplish this, points were arranged by relative distance from the mouth of the network; if a point meeting the DPC criteria had three consecutive points upstream of it that did not meet the DPC criteria, it was flagged as a water break point. Water break points were filtered to the first point on each branch by isolating the downstream-most break on each line segment and then removing all points whose NonaryIDs began with a NonaryID of another point.

Calculating Default Physical Characteristics Extent

The extent of DPC was considered to be the extent of the SSN downstream of the first water break point(s) on each branch above the last fish point (main text Figure 4), and was calculated by combining the first water break point(s) with the SSN streamlines using the same methods used to for determine the extent of Type F waters for each PHB option.

Distance Analyses

Last Fish to Washington Department of Natural Resources-Concurred Break

The distance between the DNR-concurred F/N break and the last observed fish was either taken from the WTMF or calculated using the provided last fish point as described in the Compile F/N Break and Last Fish Datasets section. These distances were averaged by ecoregion (the ecoregion of the F/N point was used for all of the below analyses). The ecoregion-weighted average distance between the last fish and DNR-concurred break was then calculated by multiplying the average ecoregion distance by the number of F/N and S/N breaks in that ecoregion statewide (Appendix Table A-1. The number of non-DNR-concurred water type breaks statewide and within each ecoregion) or on the relevant side of the state within that ecoregion(Appendix Table A-2. The number of non-DNR-concurred water type breaks on each side of the state and within each ecoregion on the relevant side of the state), dividing by the total number of water breaks on wchydro statewide or on the relevant side of the state, and summing the weighted ecoregion averages.

Appendix Table A-1. The number of non-DNR-concurred water type breaks statewide and within each ecoregion

Ecoregion	Total Breaks (#)	Breaks By Ecoregion (#)
Puget Lowland	120,047	11,827
Coast Range		44,098
North Cascades		24,555
Cascades		17,944
E. Cascades Foothills		4,847
Northern Rockies		14,444
Blue Mountains		2,332

Appendix Table A-2. The number of non-DNR-concurred water type breaks on each side of the state and within each ecoregion on the relevant side of the state

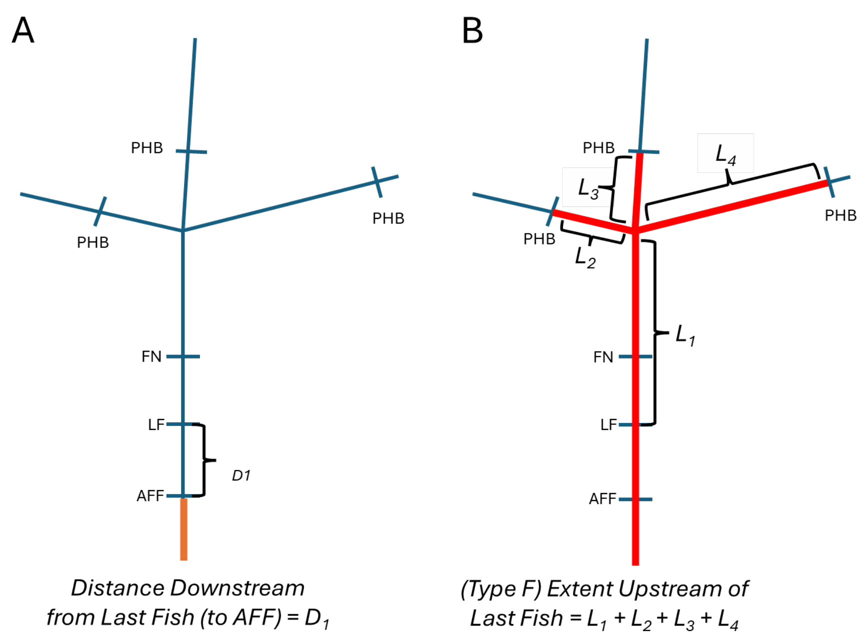
Ecoregion	State Side	Total Breaks (#)	Breaks By Ecoregion (#)
Puget Lowland	West	85,246	11,827
Coast Range			44,098
North Cascades			13,334
Cascades			15,987
North Cascades	East	34,801	11,221
Cascades			1,957
E. Cascades Foothills			4,847
Northern Rockies			14,444
Blue Mountains			2,332

In order to facilitate calculating linear distances between the last fish and DNR-concurred break points and the various PHB, AFF, and DPC points, the mouth_dist_pt values of the nearest point in the point dataset created for the PHB and DPC analyses (lf_md_pt) and the dataset created for the AFF analysis (lf_md_pt_aff) were assigned the last fish point dataset. The corresponding value for the DNR-concurred break was the relevant last fish mouth distance plus the distance between the last fish and DNR-concurred break in that dataset (FN_LF_DIST).

Potential Habitat Break Options to Washington Department of Natural Resources-Concurred Break, Last Fish

To calculate the distances between the mainstem PHB for each option and the last fish and DNR-concurred break points, the relative distance along the network of the last fish (lf_mdp) or DNR-concurred break (lf_mdp + FN_LF_DIST) was subtracted from the value for the mainstem PHB (mouth_dist_pt). As a result, positive distances between the DNR-concurred break and the first PHB upstream of the last fish point indicated that the latter was upstream of the DNR-concurred break, while negative values indicated that it was downstream.

When comparing the extent of Type F waters for each PHB option to the DNR-concurred break and last fish points, the method depended on the relative position of the upper extent of Type F to the metric in question (Appendix Figure A-2). Where the upper extent of Type F was downstream of the last fish or DNR-concurred break, the distance was calculated using the mouth_dist_pt attribute of the PHB point as described for the mainstem PHB (similar to diagram A). If the Type F waters extended above the last fish or DNR-concurred break point, the PHB streamlines for that network were converted to a network object (sfnetworks::as_sfnetwork) and the last fish or DNR-concurred break point was blended into the network (sfnetworks::st_network_blend). The total length of the downstream segment was subtracted from the total length of the original PHB streamlines (the red lines in diagram B), which was computationally less intensive than selecting the upstream segments in the network framework. The resulting streamlines were added together to equal the total extent upstream of the last fish or DNR-concurred break point. This process was conducted on a network-by-network basis for both the last fish and DNR-concurred break points under each PHB option.



Appendix Figure A-2. Diagram representing how (A) the distance downstream to the relevant metric (Type F, AFF, or DPC) was calculated when the F/N break or last fish point was upstream of the upstream extent of the relevant metric, and (B) the extent upstream of the relevant metric was calculated when it extended upstream of the F/N break or last fish point

Once all distances or upstream extents were calculated, each network-level value was averaged by ecoregion (assigned to the entire SSN based on the location of the DNR-concurred break). The ecoregion-weighted statewide and state-side averages were then calculated by multiplying the ecoregion averages by the number of F/N and S/N breaks in that ecoregion (total number for the statewide average, total number on the relevant side of the state within that ecoregion for the state-side average) and dividing by the total number of water breaks on wchydro statewide or on the relevant side of the state.

Anadromous Fish Floor Alternatives to Washington Department of Natural Resources-Concurred Break, Last Fish

As with the PHB analysis, the method used to compare the location of the AFF relative to the last fish and DNR-concurred break points depended on their relative positions. Where the upper extent of the AFF was downstream of the last fish or F/N break (diagram A in Appendix Figure A-2), the distance was calculated using the mouth_dist_pt attribute of the AFF point and the lf_md_pt_aff attribute of the last fish point (lf_md_pt_aff value of the last fish point + FN_LF_DIST for the DNR-concurred break). If the AFF extended upstream of the last fish or DNR-concurred break point (diagram B in Appendix Figure A-2), if the red lines represented extent of AFF rather than Type F), the AFF streamlines for that network were converted to a network object (sfnetworks::as_sfnetwork) and the last fish or DNR-concurred break point was blended into the network (sfnetworks::st_network_blend). The total length of the downstream segment was subtracted from the total length of the original AFF streamlines.

Networks located in subwatersheds without any presumed or documented anadromy and no fluvial connection to anadromy were dropped from this analysis. Networks in subwatersheds with a fluvial connection to anadromy were still dropped from the analysis for Alternative D; for Alternative A4, the AFF was assigned to the HUC12 subwatershed outlet to calculate a minimum distance to the AFF. For these networks, the distance between the last fish or DNR-concurred break to the outlet was calculated by converting the original SSN streamlines into a network object, blending that point into the network, and subsetting all of the streamlines downstream of that point to be converted back into a simple features object. The total length of all stream segments in that object was calculated and multiplied by -1 to indicate that the distance was downstream. For Alternative D, if the AFF was downstream of the relevant point but there was no AFF point calculated, the difference between the SSN and the AFF streamlines was determined using the st_erase function, and then converted into a network object. The last fish or DNR-concurred break point was then blended into that network, and the subset downstream of the point was exported into a simple features object whose total length was multiplied by -1.

The ecoregion-weighted statewide and state-side averages for each alternative were then calculated by multiplying the ecoregion averages by the number of F/N and S/N breaks in that ecoregion (total number for the statewide average, total number on the relevant side of the state within that ecoregion for the state-side average) and dividing by the total number of water breaks on wchydro statewide or on the relevant side of the state.

Default Physical Characteristics Alternatives to Washington Department of Natural Resources-Concurred Break, Last Fish

As with the PHB analysis, the method used to compare the location of the DPC relative to the last fish and DNR-concurred break points depended on their relative positions (Appendix Figure A-2). Where the upper extent of DPC was downstream of the last fish or DNR-concurred break, the distance was calculated using the mouth_dist_pt attribute of the DPC water break point and the lf_md_pt attribute of the last fish point (lf_md_pt value of the last fish point + FN_LF_DIST for the DNR-concurred break). If the DPC extended upstream of the last fish or DNR-concurred break point, the DPC streamlines for that network were converted to a network object (sfnetworks::as_sfnetwork) and the last fish or DNR-concurred break point was blended into the network (sfnetworks::st_network_blend). The total length of the downstream segment was subtracted from the total length of the original DPC streamlines.

Extent of All Metrics as Proportion of Synthetic Stream Networks

In order to more directly compare the frequently non-linear extents of Type F waters, AFF, and DPC, the proportion of each SSN that fell under those metrics was calculated and summarized by ecoregion. The total length of the line segments for Type F waters under each PHB option, both AFF alternatives, and the DPC was calculated for the line features calculated above and divided by the total length of the line segments in the corresponding SSN. The total extent of each metric and the corresponding proportions were then averaged by ecoregion. The ecoregion-weighted statewide and state-side averages were then calculated by multiplying the ecoregion averages by the number of F/N and S/N breaks in that ecoregion (total number for the statewide average, total number on the relevant side of the state within that ecoregion for the state-side average) and dividing by the total number of water breaks on wchydro statewide or on the relevant side of the state.

Buffer Analysis: Current Rule

Riparian buffers were created around the Type F and perennial Type N (Type Np) streamlines from the synthetic streamlines generated using the F/N break points, as well as the Type F and Np extents calculated using the PHBs calculated above. Buffer widths were assigned to Type F and Type Np streamlines based on water type and side of state outlined in the WAC. For Type F buffers on the west side of the state, buffer widths represented the combined inner and core zones for each site class and BFW; in eastern WA, because the combined zones did not vary by site class, buffer widths were based on BFW alone.

The Type F streamlines created for the PHB analysis were combined into layers combining all networks within each PHB option (or DNR-concurred break) and side of the state. A buffer width field (“buff_dist”) was populated based on site class and BFW according to WAC 222-30-021. The layers representing streamlines on the east side of the state were assigned buffer widths based on BFW according to WAC 222-30-022. On the east side, these buffer widths were determined by whether the BFW of the stream was less than or equal to 15 feet, or greater than 15 feet. The layers representing streamlines on the west side of the state were assigned site classes based on the site class forest practices regulation layer provided by DNR using a spatial join (sf::st_join or using the Pairwise Intersect tool in ArcGIS). Stream segments with site class 8, site class 9, or segments that did not have a site class (due to gaps in the site class data representing water) were assigned to site class 5 on the west side, and buffer widths were then assigned based on-site class and BFW. Adjacent stream segments with the same buffer distance were combined within individual networks.

For Type N streams, all Type Np streamlines were assigned a buffer width of 50 feet (field named “buff_dist”). Each line segment was split in half by generating a point at the midpoint of each line segment, buffering it by 0.001 feet, and splitting the original line segment with the buffered point (lwgeom::st_split). New segment lengths were calculated and assigned to the attribute table, and segments were sorted and assigned unique values in the “frequency” field (1:n for each individual network). In order to prioritize buffering the downstream end of Type Np waters where possible, the downstream 25% of segments was identified for each network (1 through n/4) and assigned 1 in the “keep” field.

For Type F streams, buffers were created using the Pairwise Buffer Geoprocessing tool in ArcGIS Pro (version 3.1.2). The inputs were the synthetic streamlines created for each network that were classified as Type F using the DNR-concurred F/N break point or using PHBs for each PHB Option (calculated in Task 2). Buffers were created separately for Type F waters designated by the DNR-concurred break, for PHB options A through C for the west side of Washington state, and for the DNR-concurred break and PHB options B and C for the east side of Washington state. There was a total of seven Type F buffer layers. Round-endcap buffers were used for Type F buffers to avoid the artifacts and gaps that occur when flat-endcap buffers are used (this is an underlying issue in the ESRI algorithm as well as all JTS and GEOS-based open-source geospatial software, which includes the R spatial packages, QGIS, JTS, and Python spatial packages) occur in particular where buffer distances change and streams are going around curves, as well as at the end of a network).

For Type N streams, buffers were created using a python (version 3.8.18) script developed to buffer 50% of Type Np streams in an individual network. The script was run using the IDE Visual Studio Code (VSC) (version 1.87.0) and utilized the ArcPy[5] (version 2.2.0), pandas[6] (version 1.4.4), and NumPy[7] (version 1.20.1) packages. The script prioritizes continuity and buffering downstream areas while also buffering as close to 50% of the stream network as possible. Stream networks consisted of line segments rather than one continuous line. Due to the size disparities between line segments within stream networks, individual line segments were subset to attempt to approach 50% more closely; however, there were tradeoffs between the number of times an individual line segment could be subset and the ability to successfully process the dataset. Therefore, it was not always possible to buffer precisely 50% of the network. The attribute table for the Type Np streams contained columns “keep” and “frequency”. The “keep” column contained values 0 and 1, with 1 indicating stream segments that would always be buffered and 0 indicating stream segments that could be dropped. The downstream 25% of the network (or the downstream half of the segment for networks with only two Type Np segments) was marked with 1’s and the script would add segments marked with 0’s until as close to 50% of the network was selected. The script cycled through line segments using the frequency column which labeled segments 1-n per stream network from downstream to upstream. This allowed the script to prioritize continuity and downstream segments. The script calculated 50% of the length of each network relative to the total number of Np segments in the network.

The buffer width was set to 50 feet for all buffered Type Np stream segments identified in the previous step. The streamlines were buffered with flat end caps within the script using the Pairwise Buffer Geoprocessing tool with the GIS Professional Advanced license. Flat endcaps were used for Type Np because there were many fewer artifacts around the edges of buffers when all buffers were the same width, and the artifacts occurring at the downstream end of Type Np were smaller in area than the amount of extra buffer from a round endcap would have been. Additional areas were buffered and

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[5] What is ArcPy?—ArcGIS Pro | Documentation
[6] pandas · PyPI
[7] NumPy -

included for Type Np streams including sensitive site buffers (for the purposes of this analysis, only the junction between two Type Np streams and the upstream extent of Type N streams), and waterbodies from the DNR waterbodies (wbhydro) layer that intersected the Type Np streamlines.

The sensitive site buffers were generated using an R script that created a point layer from points at the junction of two Type Np streams and at the upstream extent of the Type Np streams. The points were extracted using lwgeom::st_startpoint (package[8] version 0.2-13) from the streamline layers for the same combination of state side and PHB options described in the type F section. Waterbody buffers were created in ArcGIS Pro by selecting the waterbodies in wbhydro that intersected any Type N waters (based on the DNR-concurred break or any of the PHB options) and buffering them by 50 feet. Buffers of long linear features were manually split upstream of stream junctions to avoid artificially including large areas of buffers well outside of the networks.

The sensitive sites were buffered to 56 feet as specified in the Washington Administrative Code (WAC) chapter 222-30-021 and the waterbodies were buffered to 50 feet and only the buffer area was included in the final buffered layers (the waterbody itself was excluded to avoid artificially inflating the buffer area by including an area without trees). The sensitive sites and wbhydro buffer layers were appended to the streamline buffers within the script using the Append geoprocessing tool and then dissolved using the Pairwise Dissolve geoprocessing tool by the column containing the unique ID given to each F/N breakpoint (FN_ID). The final streamline buffers were created for the same combination of state side and PHB options described in the Type F section. As an example, for the Type Np streams in the east side of the state, the inputs used were the streamlines layer, the sensitive site buffers layer, and the waterbody buffers layer. The final output was a buffer polygon layer dissolved by FN ID into a single continuous buffer.

The buffers created for the previous steps were then used to clip the Gradient Nearest Neighbor (GNN) layer of points to generate a spatially associated reference sample of tree species statewide using the Intersect tool in ArcGIS Pro. To reference and associate the timber volumes with the tree species from the clipped GNN buffer, a table join was performed between the clipped GNN layers and the timber volume table; this combined the timber volume tables with the timber species in the buffers (grid_code in the GNN layer matches the SPPS_ATTR_LIVE_FCID column in the timber volume table).

Timber volumes provided in the GNN dataset are reported in m^3/ha. In conversations with Matthew Gregory at Oregon State University, the manager of the data, he explained that when these volumes were used in GNN, the area used became the pixels themselves. Each pixel represented an area of 900 m^2 (30m resolution 0.09 ha); therefore, if there was a point with a species volume of 300 m^3/ha, the actual volume represented by that point (and corresponding raster pixel) would be 27 m^3 (300 m^3/ha multiplied by 0.09 ha). Thus, in order to convert these volumes to board feet, the unit in which the stumpage values are reported, the volumes were multiplied by 0.09 and again by 423.667 to convert the values from m^3 to board feet. The timber volume (now reported in MBF) was then calculated for each tree species within each network and summarized by ecoregion. All 116 tree species in the timber volume table were assessed during this calculation, but if the volume was 0 it was not shown.

[8] lwgeom package - RDocumentation

In order to calculate the value of the timber within the buffers, the buffers were spatially joined with the Stumpage Value Area (SVA) polygon layer, provided by DNR. The value of specific species of tree were assigned based on SVA (these tables are available on the Washington State Department of Revenue's website – "TAX REPORTING INSTRUCTIONS AND STUMPAGE VALUE DETERMINATION TABLES Jan 1 through Jun 30, 2024"). To reference and associate the timber values with the tree species/volumes calculated in the previous step, a table join was performed between the GNN layers and the stumpage value tables; this combined the timber volumes by tree species with the corresponding tree species and stumpage values. Per communication with DNR, it was determined that though there are no stumpage values for Red Alder in SVA 6 and 7, there is a consistent market for Red Alder on the east side of the state. Therefore, the Red Alder stumpage values from SVA 5/all western SVA areas except 9 were used for SVA 6 and 7 ($511 for the tables valid Jan-June 2024). Alternatively, it was determined that there is not a consistent market for Black Cottonwood on the east side of the state, so Black Cottonwood was dropped for SVA 6 and 7 and the total east side calculations. The total value of riparian timber for each network was then averaged by ecoregion, as described next.

Within each ecoregion, the average value of each metric (buffer area, timber volume, and timber value) was calculated for all of the networks within that ecoregion using the same methods described at the end of the previous section to achieve weighted average distances. These averages were then extrapolated to all waters in wchydro by calculating n-weighted averages and totals for the full state of Washington, as well as separately for the east and west sides of the state. Weights were calculated based on the proportion of waters (defined as the total number of F/N and S/N breaks in wchydro) within each ecoregion relative to 1) the total number of F/N and S/N breaks in wchydro statewide in the relevant ecoregion, and 2) the total number of breaks within each ecoregion on each side of the state relative to the total number of waters on that side of the state. Those weights were then applied to the ecoregion averages for each metric to generate statewide and state-side summaries of each metric. DNR-concurred water breaks were removed from this layer before weights were calculated. Each ecoregion average was multiplied by the total number of total number of F/N and S/N breaks in wchydro in that ecoregion (for the state-side summaries, the total number of breaks in that ecoregion on the relevant side of the state) and then divided by the total number of breaks statewide or on that side of the state to obtain the n-weighted average values statewide and on each side of the state. For example, average total riparian buffer area of all SSNs in the Puget Lowland ecoregion under PHB Option B was 140 ac, which was then multiplied by the number of breaks in wchydro within that ecoregion (11,827) and divided by the total number of water breaks statewide (120,047). The weighted averages for each ecoregion were then summed to calculate the weighted average area statewide. The process was repeated to calculate the weighted average for each side of the state. The number of wchydro breaks on the east and west sides of the state within ecoregions spanning both sides of the state (Cascades and North Cascades) were considered separately when calculating the weighted statewide averages. The average riparian buffer area in the Cascades ecoregion (289 ac for PHB Option B) was multiplied by the total number of streams on the west side of the ecoregion (15,987) and divided by the total number of streams on the west side of the state (85,246); the weighted averages of all ecoregions on the west side were summed to get the weighted west side average riparian buffer area.

Buffer Analysis: Proposed Type Np Rule (West Side)

Riparian buffers were created for Options 1a, 1b, and 2 under the proposed rule for Type Np waters on the west side of the state. Buffer widths were assigned in R using a network analysis framework. Within each network, the input streamlines were filtered to only include Type Np waters. From there, a point was created 600-feet upstream of the DNR-concurred F/N break on each upstream branch. The line segments downstream of those points were combined into a single object, and all stream segments in that object were assigned a 75-foot buffer. The Type Np streamlines upstream of the points created were isolated using the st_erase function described in the Calculate Potential Habitat Breaks and Water Type Extents section on the input Type Np lines and the 600-foot dataset. These streamlines were assigned a 50-, 65-, and 75-foot buffer attribute on all stream segments with a BFW above 3 feet and a 50-foot attribute for all stream segments with a BFW below 3 feet.

Once buffer width values were assigned to the relevant stream segments, the datasets were imported into ArcGIS Pro. The streamlines were buffered with flat end caps using the Pairwise Buffer Geoprocessing tool. Flat endcaps were used for Type Np because there were many fewer artifacts around the edges of buffers when all buffers were the same width, and the artifacts occurring at the downstream end of Type Np were smaller in area than the amount of extra buffer from a round endcap would have been. No-harvest zone buffers were created by combining the sensitive site buffers (for the purposes of this analysis, only the junction between two Type Np streams and the upstream extent of Type N streams), waterbody buffers (created using the process described in the Buffer Analysis: Current Rule section), and the following buffer distances:

- Option 1a: 75-foot buffers for the first 600 feet, 50-foot buffers for all Type Np streamlines above 600 feet
- Option 1b: 75-foot buffers for the first 600 feet, 65-foot buffers for all Type Np streamlines above 600 feet with BFW above 3 feet, 50-foot buffers with BFW below 3 feet
- Option 2: 75-foot buffers for all Type Np streamlines with basins greater than 30 acres

The above buffers were combined into a single dataset for each option and dissolved into single features for each network (dissolved by the FN_ID field in the attribute table).

An additional outer buffer representing the 50% harvest zone for Option 1a was created by taking the inner buffer created in the previous step and using the Erase tool in ArcGIS Pro on 75-foot buffers on all stream segments above 600 feet with a BFW of greater than 3 feet. These buffers were dissolved by FN_ID and kept as a separate layer for subsequent steps.

The buffers created for each proposed option were used to clip the GNN point layer and evaluate the timber volume and value in the Type Np riparian zone using the process described for calculating the timber value and volume for the current rule in Four Peaks (2024). The GNN points contained within inner and outer zones for Option 1a were extracted separately, and the volume and value of timber within the outer zones were divided in half before being combined with the inner zone values.

Within each ecoregion, the average value of each metric (buffer area, timber volume, and timber value) was calculated for all networks within that ecoregion under the current rule and proposed Option 1. These averages were then extrapolated to all waters in wchydro on the west side of the state by calculating n-weighted averages. Weights were calculated based on the proportion of waters (defined as the total number of F/N and S/N breaks in wchydro without DNR-concurred breaks) within each ecoregion relative to the total number of F/N and S/N breaks without DNR-concurred breaks in wchydro within each ecoregion on the west side of the state. Those weights were then applied to the ecoregion averages for each metric to generate average and total values across the west side of the state. N-weighted averages and totals were not calculated for Option 2 because this option is applied only when at least 85% of basins greater than 30 acres above the F/N break will be harvested within the next 5 years; as a result, comparing this option to the current rule or Option 1 does not result in a direct comparison of available timber. For additional details and examples, see the Distance Analyses and Buffer Analysis: Current Rule sections.

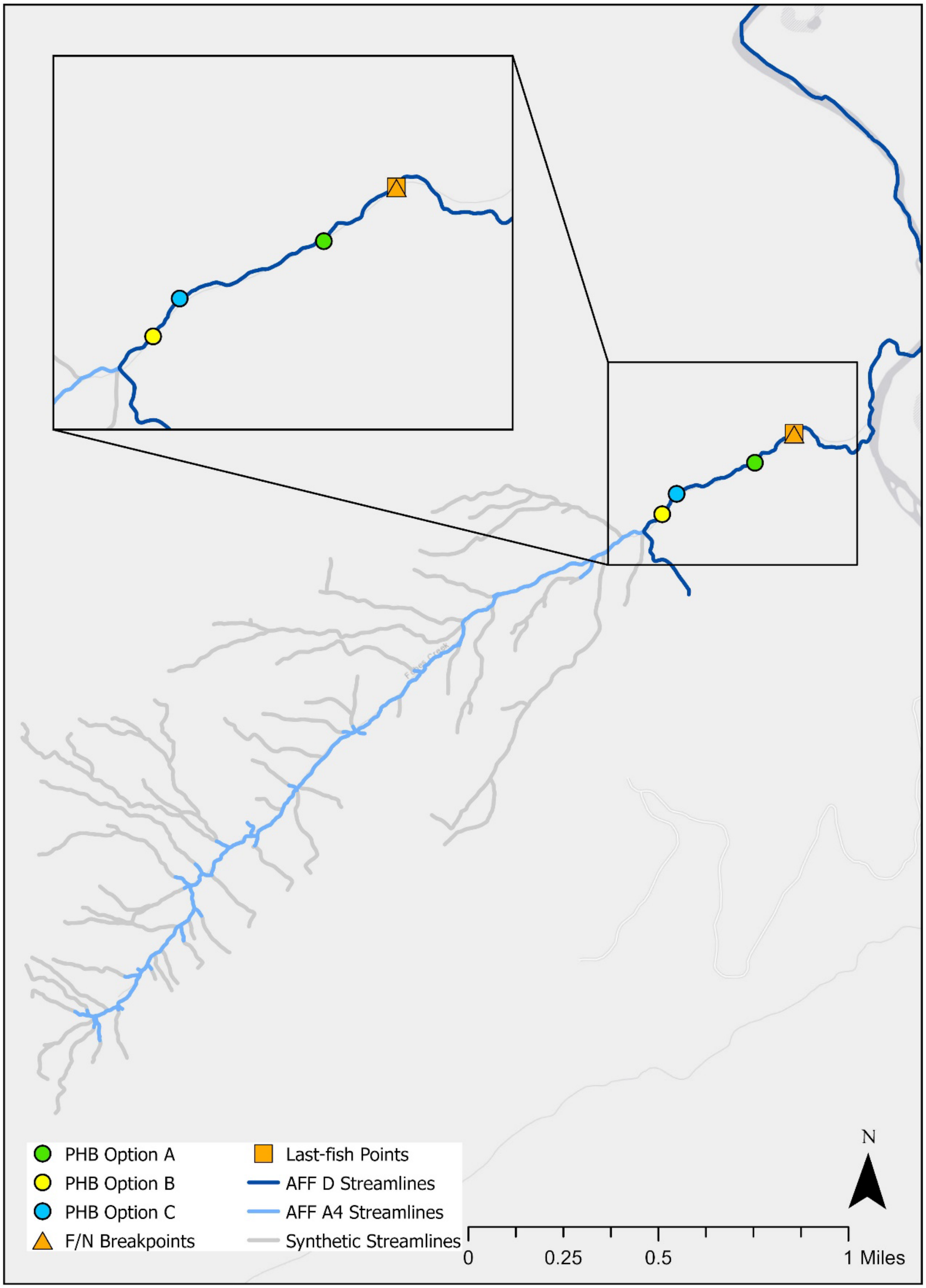
APPENDIX B Potential Habitat Breaks – 20x BFW

The following sections represent the Potential Habitat Break (PHB) analysis using a reach distance of 20x BFW to calculate gradient-based criteria. For PHBs and subsequent distance, Type F, and buffer analyses calculated using a reach length using 5x bankfull width (BFW), see main report Sections 3.2 through 3.4 and APPENDIX C; for a comparison of PHBs calculated using five different reach lengths, see Section 4.3.

PHB points were identified within:

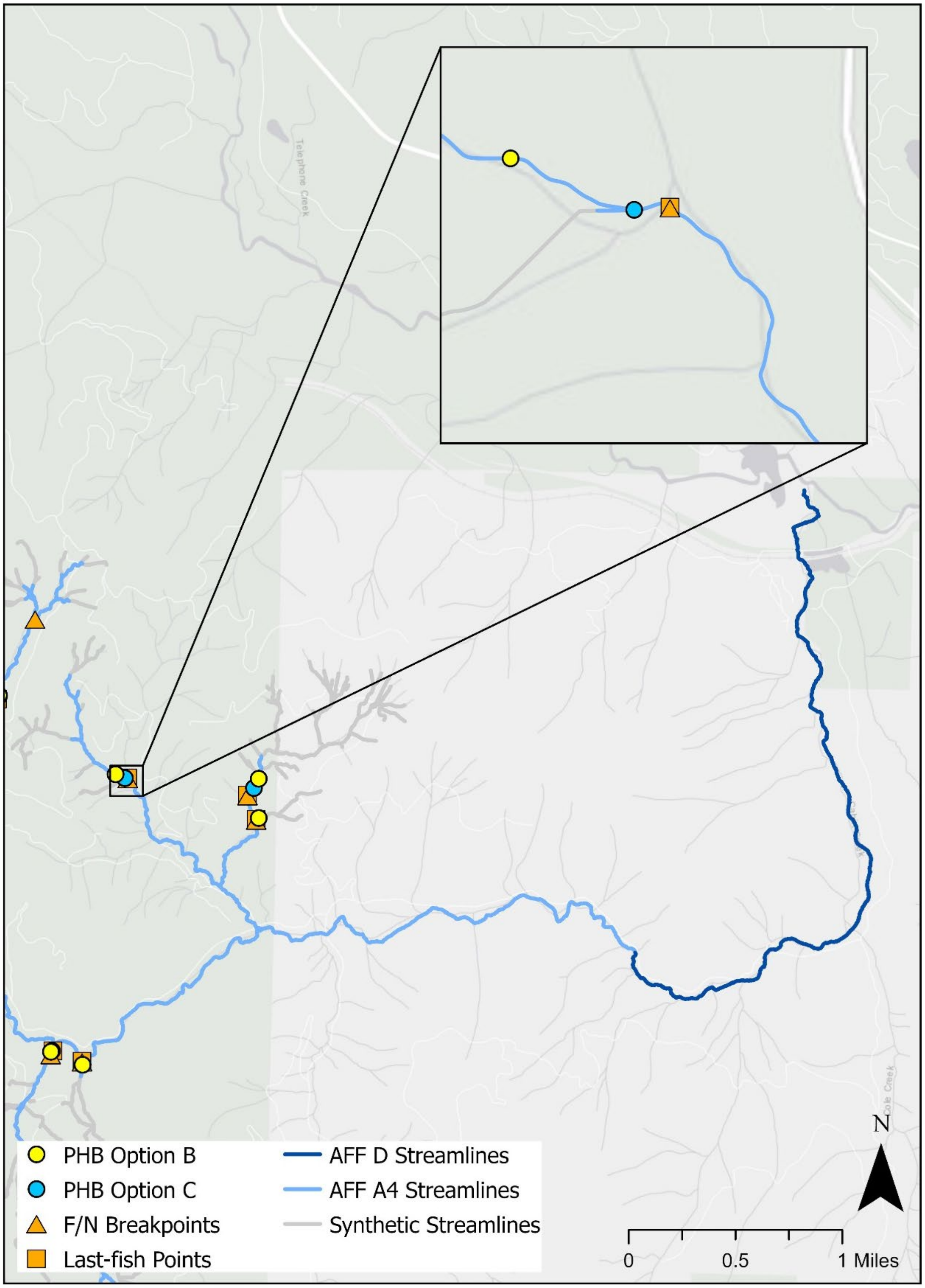
- 143 out of 150 networks for Option A (west side only)
- 350 out of 365 networks for Option B
- 361 out of 365 networks for Option C

Appendix Figure B-1 and Appendix Figure B-2 provide visual examples of synthetic streamlines, AFF A4 and D streamlines, and PHBs for Options A-C on the west side and Options B-C on the east side of Washington state, respectively.



Esri, HERE, County of Skagit, Bureau of Land Management, Esri, HERE, Garmin, GeoTechnologies, Inc., USGS, EPA

Appendix Figure B-1. Example synthetic streamlines, AFF A4 and D streamlines, and PHBs (gradient calculated over a reach of 5x BFW) for Options A-C on the west side of Washington State

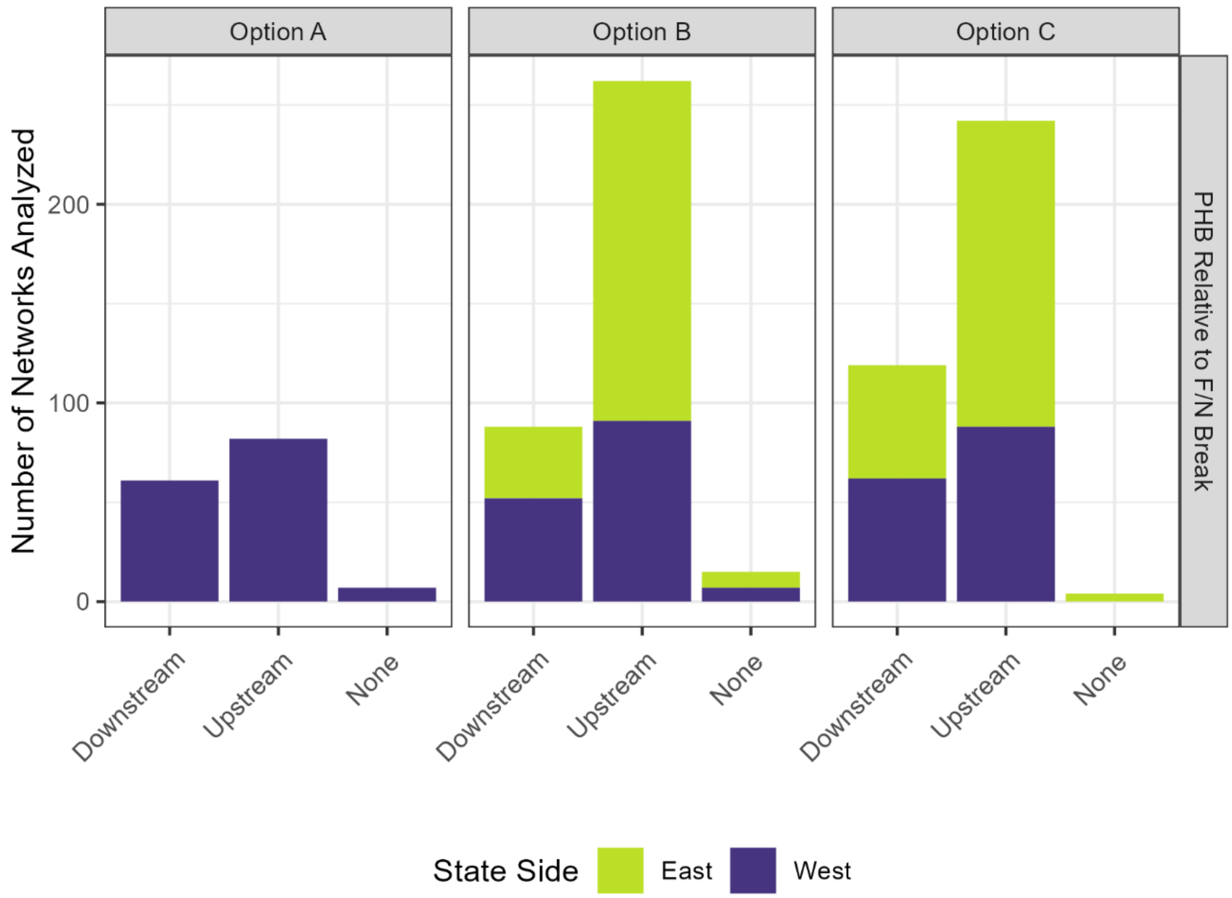


County of King, Esri, HERE, County of King, County of Kittitas, Bureau of Land Management, Esri, HERE, Garmin, GeoTechnologies, Inc., Intermap, USGS, EPA, County of Kittitas, Bureau of Land Management, Esri, HERE, Garmin, USGS, EPA, NPS, Esri, HERE, NPS

Appendix Figure B-2. Example synthetic streamlines, AFF A4 and D streamlines, and PHBs (gradient calculated over a reach of 20x BFW) for Options B-C on the east side of Washington State

Networks with no PHBs identified for a given option were not included in the analyses related to that PHB option. If a network did not have any PHB comparisons, the network was not included in the buffer analyses.

For all three PHB options, the first PHB upstream of the last fish point was also upstream of the DNR-concurred F/N break more often than it was downstream of the break (Appendix Figure B-3). This relative positioning of the first PHB upstream of last fish being located above the DNR-concurred break was more common for Option B than the other two PHB options.

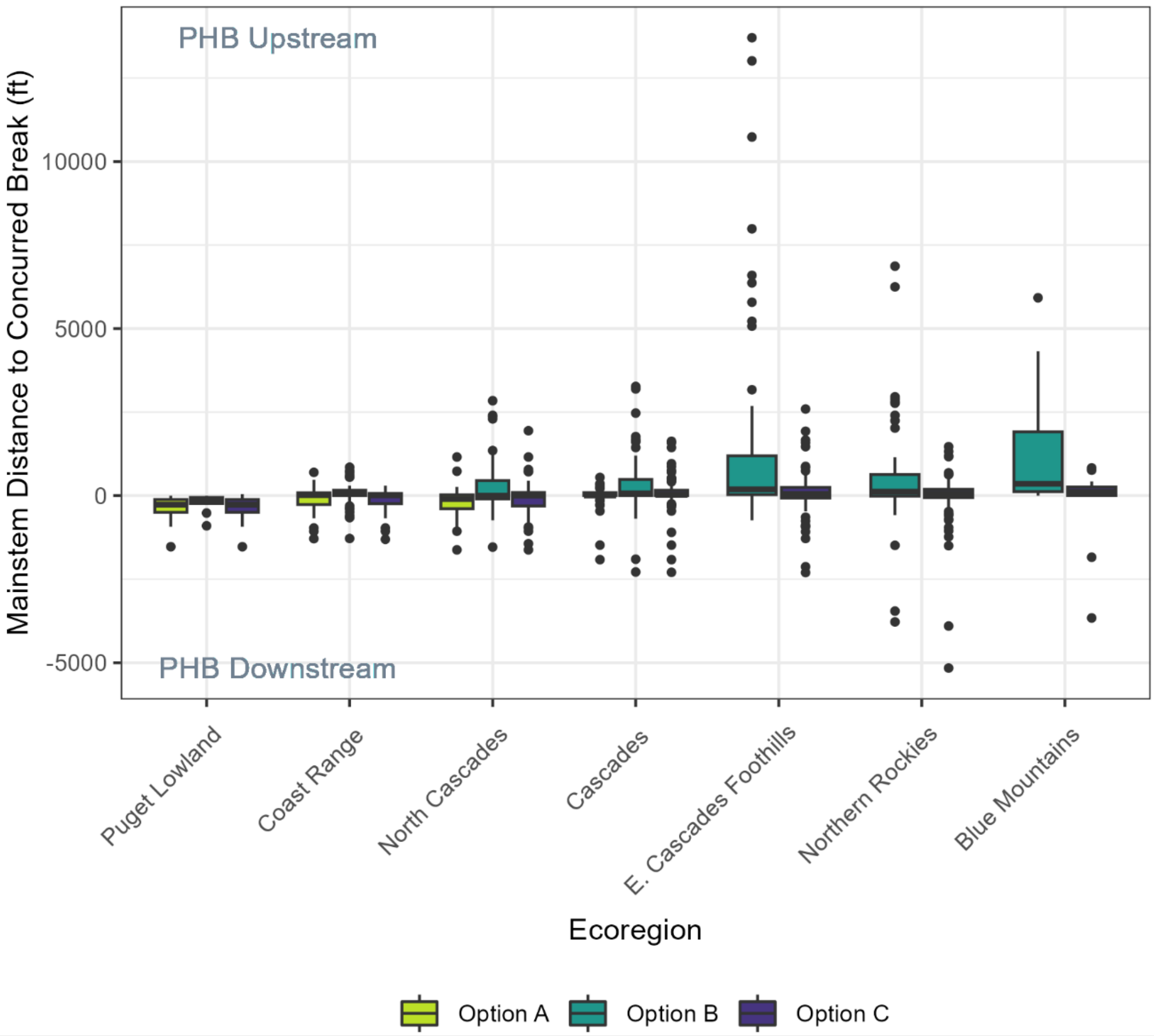


Note: PHB points were not generated for every network for every option.

Appendix Figure B-3. The number of networks with the first upstream potential habitat break upstream or downstream of the DNR-concurred F/N break

Mainstem Fish Habitat Assessment Methodology Point Comparisons

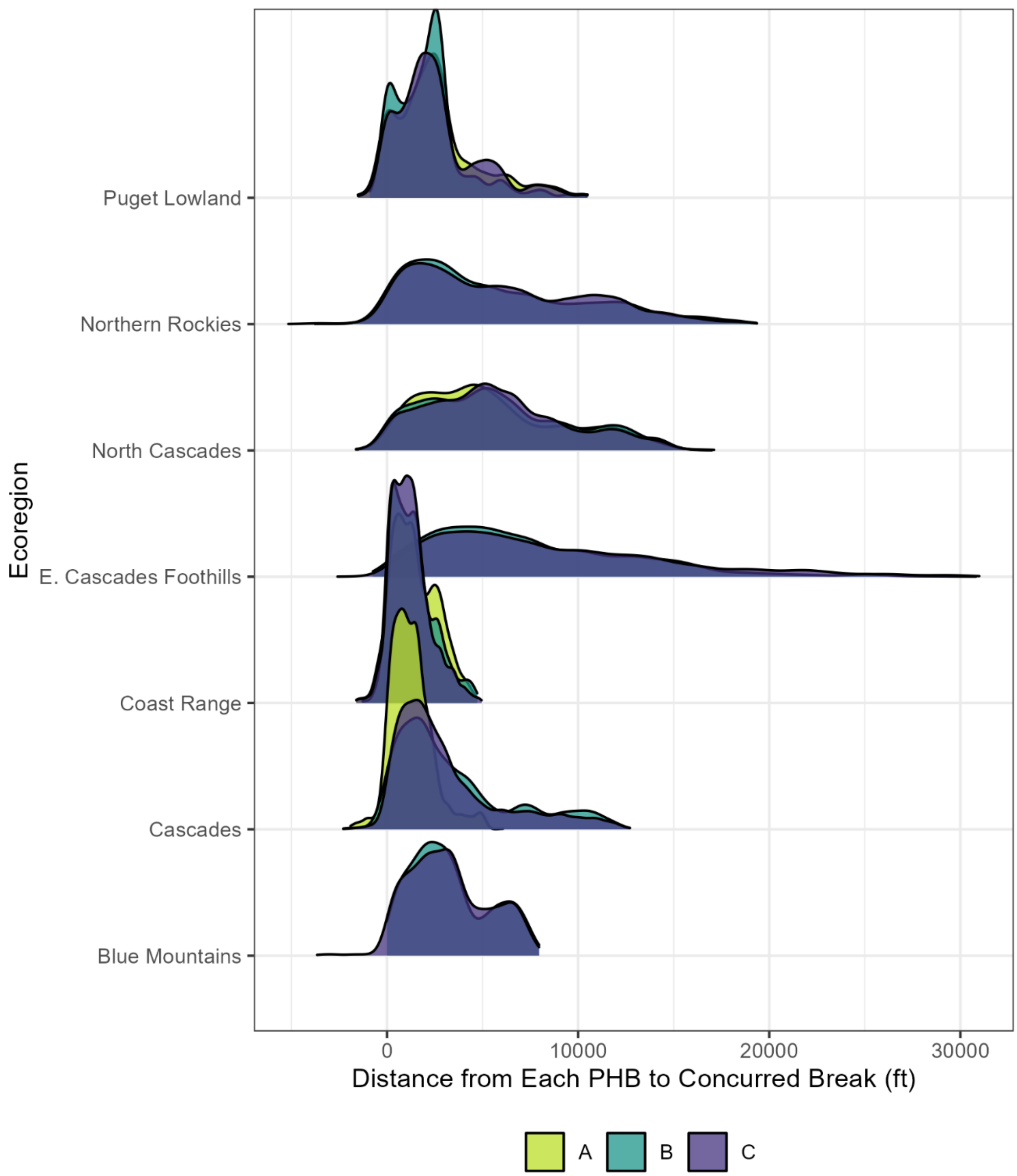
For each PHB option, the median distance between the first PHB identified on the mainstem[25] and both the F/N break tended to cluster around 0, and often negative in the Puget Lowlands and the Coast Range ecoregions, with PHB Option B exhibiting the highest variation and extending farthest upstream in the E. Cascades Foothills and Blue Mountains (Appendix Figure B-4). Note that all of the boxplots in this report show the median as the metric of central tendency, in contrast to the means reported in tables. In some cases, this results in a mismatch in the direction of effect, which reflects a skewed underlying distribution.



Note: Negative distances indicate that the PHB was downstream of the DNR-concurred F/N break.

Appendix Figure B-4. Distance between the first potential habitat break upstream of the last fish on the mainstem and the DNR-concurred F/N break

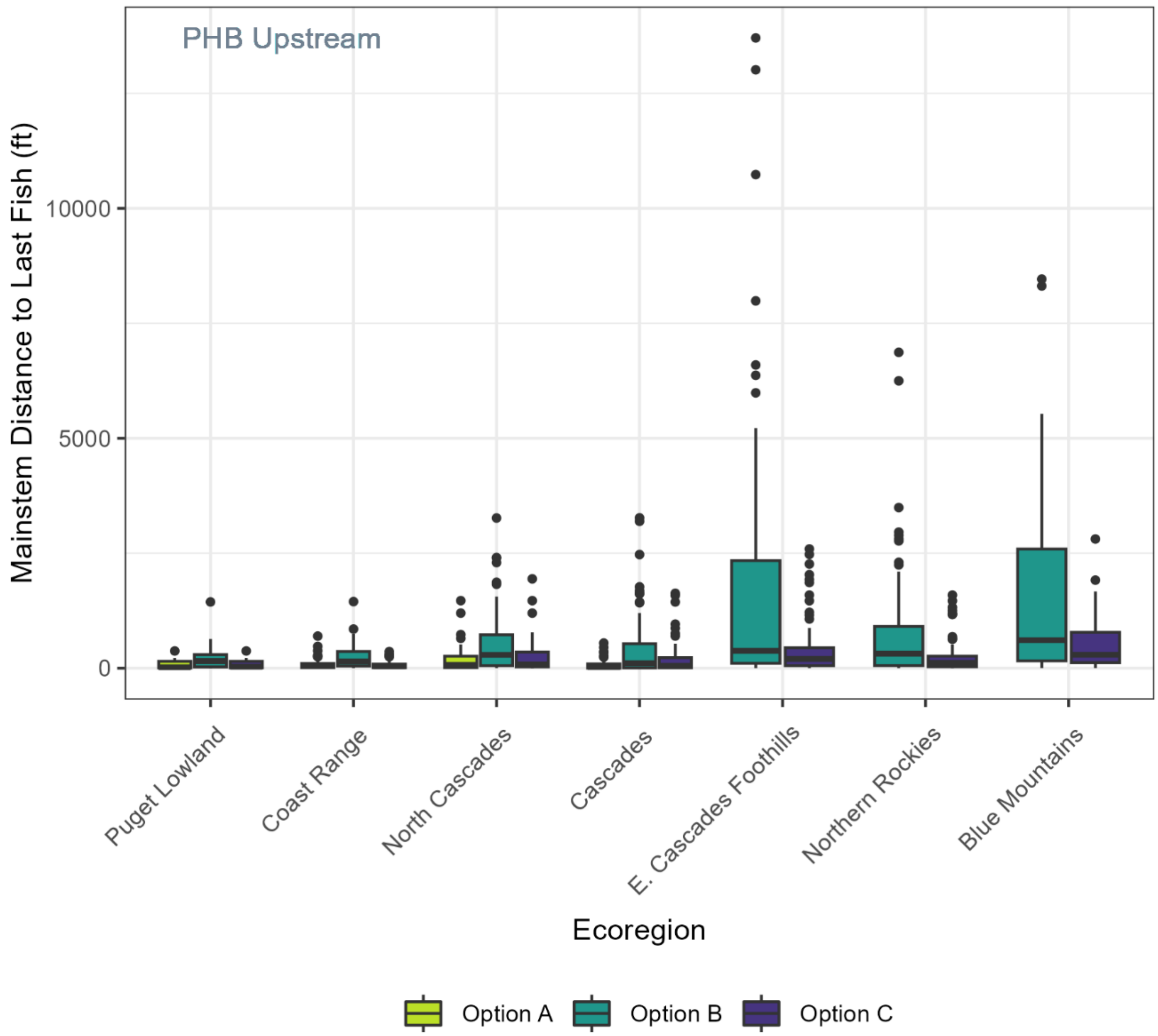
[25] Here, first PHB on the mainstem refers to the first PHB identified upstream of the last fish point.



Appendix Figure B-5. The distance between each PHB upstream of the last fish point to the DNR-concurred break for that network.

When considering the distance between the concurred break and each PHBs upstream of the last fish location, distance ranges tended to be similar for all three options in most ecoregions, with the biggest range in distance within the E. Cascades Foothills for all three PHB options (Appendix Figure B-5). The range in distances between the concurred break and PHBs under Option A was notably smaller relative to the other two options in the Cascades ecoregion.

The first PHB detected above last fish on the mainstem was generally within 1,000 feet of last fish, with few exceptions (Appendix Figure B-6, Appendix Table B-1). Mean distances along the mainstem from last fish to the first PHB were smallest for the Puget Lowland ecoregion (56, 277, and 93 feet for Options A, B, and C, respectively), with the greatest distances and highest variation in the E. Cascade Foothills (1,759 and 366 feet for Options B and C) and Blue Mountains (2,039 and 535 feet for Options B and C) ecoregions for Option B in particular**.**

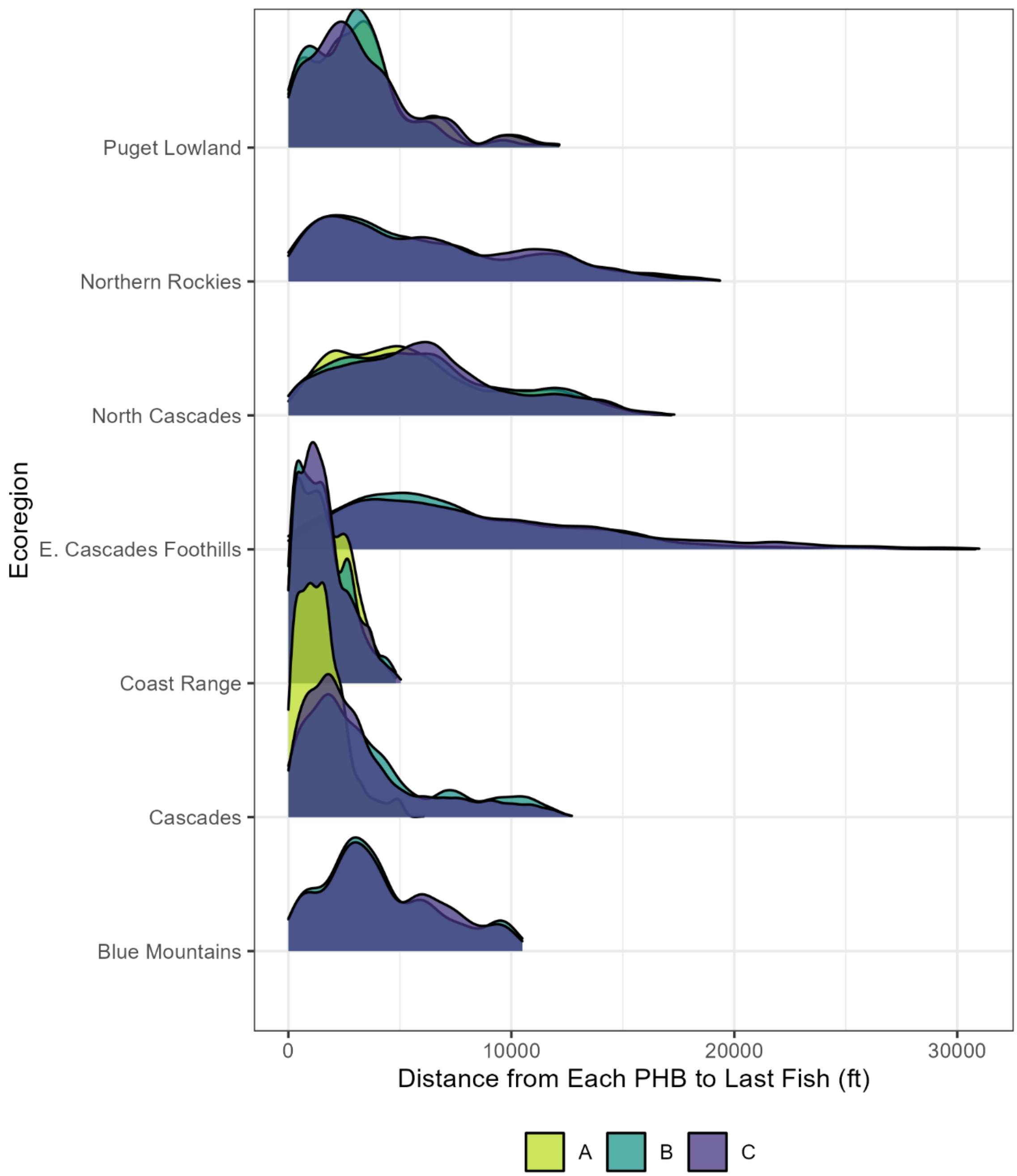


Appendix Figure B-6. Distance between the last fish location and the first potential habitat break upstream of the last fish on the mainstem within each network

Appendix Table B-1. Within-network distances between the last fish and first mainstem PHB, and between the F/N break and the first mainstem PHB, averaged by ecoregion

Ecoregion	PHB Option	FHAM Distance to DNR-Concurred Break (ft)		FHAM Distance to Last Fish (ft)	
		Mean (SE)	Range	Mean (SE)	Range
Puget Lowland	A	-401 (127)	-1,529 to 0	93 (35)	0 to 374
	B	-216 (75)	-903 to 0	277 (119)	0 to 1,440
	C	-438 (131)	-1,521 to 43	56 (19)	0 to 199
Coast Range	A	-117 (54)	-1,289 to 697	94 (19)	0 to 697
	B	36 (53)	-1,283 to 850	247 (40)	0 to 1,447
	C	-135 (49)	-1,523 to 301	61 (9)	0 to 301
North Cascades	A	-185 (75)	-1,623 to 1,156	218 (50)	0 to 1,468
	B	238 (112)	-1,540 to 2,841	600 (106)	0 to 3,265
	C	-112 (78)	-1,623 to 1,942	231 (49)	0 to 1,942
Cascades	A	-47 (69)	-1,916 to 545	92 (22)	0 to 545
	B	301 (98)	-2,286 to 3,268	442 (83)	0 to 3,268
	C	52 (64)	-2,295 to 1,628	188 (37)	0 to 1,628
E. Cascades Foothills	B	1,412 (338)	-739 to 13,705	1,783 (339)	0 to 13,705
	C	-16 (87)	-2,594 to 2,592	355 (59)	0 to 2,592
Northern Rockies	B	472 (178)	-3,779 to 6,868	820 (154)	0 to 6,868
	C	-141 (102)	-5,160 to 1,167	202 (35)	0 to 1,589
Blue Mountains	B	1,208 (471)	0 to 5,921	2,020 (774)	1 to 8,460
	C	-242 (294)	-3,661 to 831	571 (173)	1 to 1,851

Note:
Negative numbers indicate that the PHB is downstream of the last fish or F/N break point. Values are expressed in terms of distance per SSN.



Appendix Figure B-7. The distance between each PHB upstream of the last observed fish to the last observed fish for that network.

When considering the distance between the last fish location and each PHBs upstream of the last fish location (Appendix Figure B-7), patterns were similar when comparing all PHBs to the concurred break (Appendix Figure B-5). Distance ranges tended to be similar for all three options in most ecoregions, with the biggest range in distance within the E. Cascades Foothills for all three PHB options. The range in distances between the last fish location and PHBs under Option A was notably smaller relative to the other two options in the Cascades ecoregion and slightly wider in the coast range.

When considered at both the state side and statewide scale, on average, PHBs were identified below the DNR-concurred F/N break for Options A and C, and above the break for Option B (Appendix Table B-2). For PHB Option B, the first PHB identified on the mainstem was closer to the DNR-concurred F/N break on the west side (weighted average of 83 feet upstream) compared to the east side (weighted average of 223 feet upstream). For Options A and C, the distance between the DNR-concurred F/N break and the first mainstem PHB was similar among networks on the east and west side of the state. The distance from last fish to the first PHB upstream on the mainstem was greatest for Option B, particularly on the east side of the state.

Appendix Table B-2. N-weighted average distances between the F/N break and the first mainstem PHB and between the last fish and first mainstem PHB, by state side and for statewide

State Side	PHB Option	Distance from F/N Break to Mainstem PHB	Distance from Last Fish to Mainstem PHB
Statewide	Option A	-127	102
	Option B	223	517
	Option C	-130	153
East	Option B	567	943
	Option C	-110	257
West	Option A	-154	113
	Option B	83	344
	Option C	-138	111

Note:
Negative numbers indicate that the PHB is downstream of the last fish or F/N break point. Values are expressed in terms of distance per SSN.

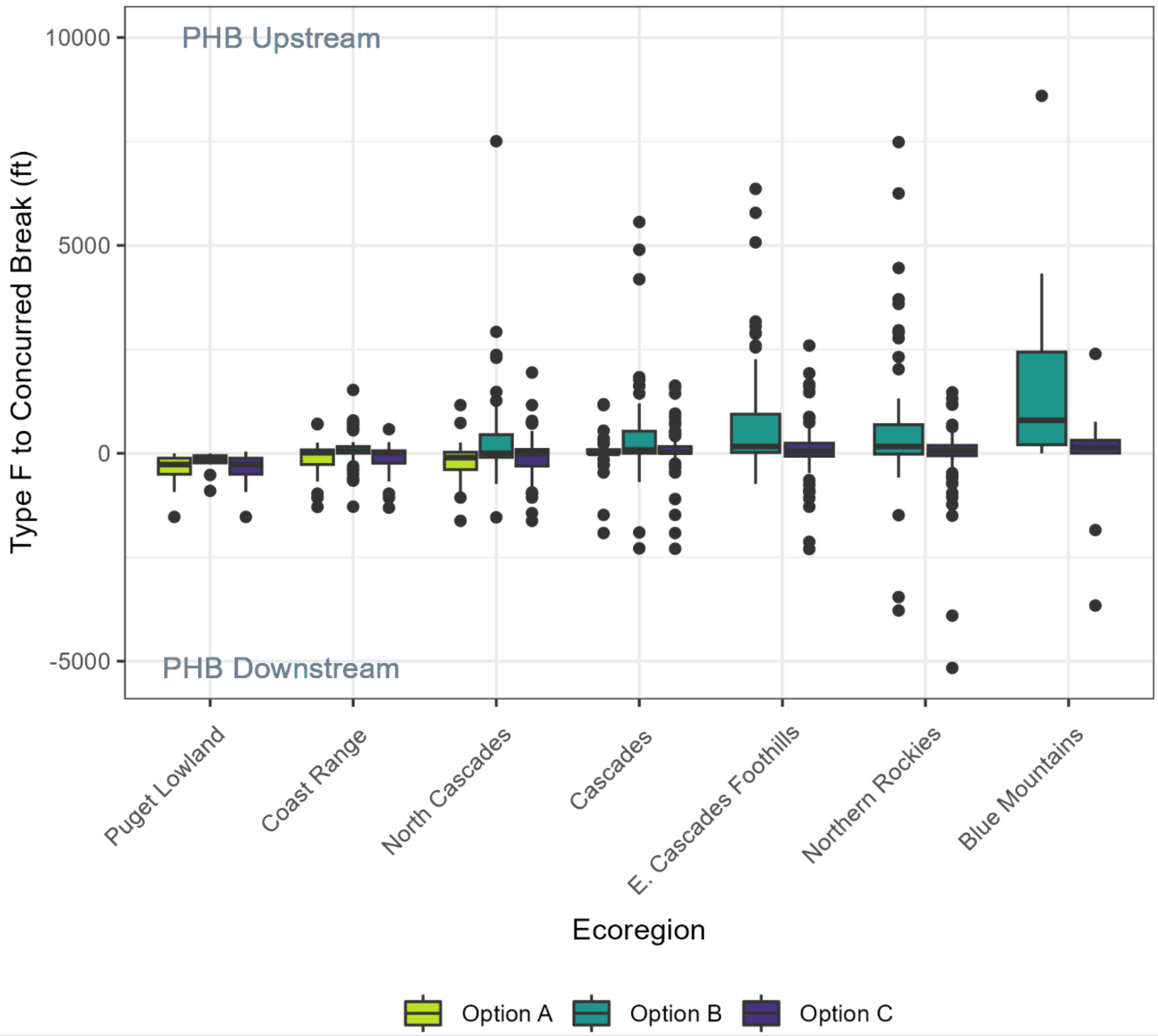
Extent of Type F Waters

The extent of PHB-determined Type F waters upstream, or distance downstream of the F/N break within a network extended the farthest upstream on the east side of the state than on the west side, and farther upstream for PHB Option C compared to other PHB options and the current break (Appendix Table B-3, Appendix Figure B-8, Appendix Figure B-9). The greatest extent (and range) of PHB-determined Type F waters upstream of the DNR-concurred break occurred in the E. Cascades Foothills and Blue Mountains Ecoregions under Option B. Within a given network, the extent Type F waters upstream of the last observed fish was greatest for Option B for all ecoregions (Appendix Table B-4, Appendix Figure B-10, Appendix Figure B-11).

Appendix Table B-3. N-weighted average distances between last fish and upper extent of Type F waters, and between F/N break and upper extent of the Type F waters, by state side and statewide

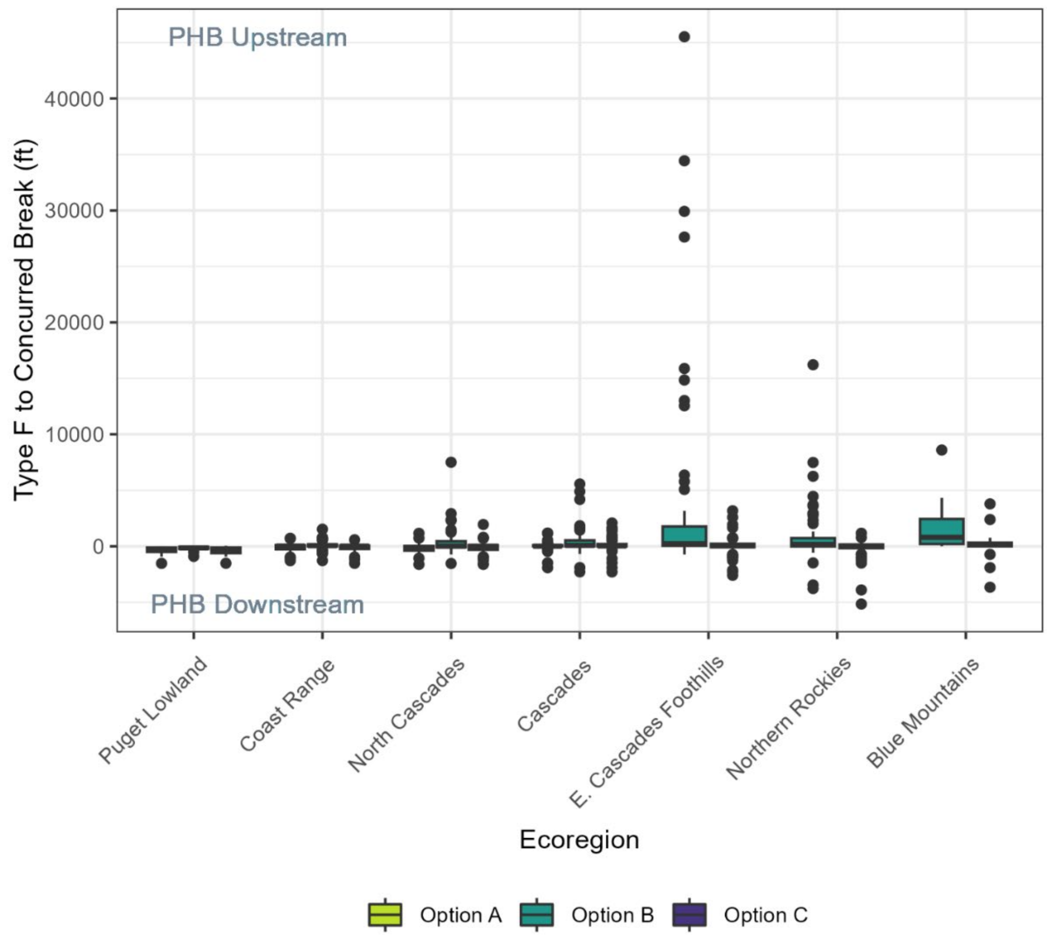
State Side	PHB Option	N-weighted average Distance (ft) From F/N Break vs to Type F	N-weighted average Distance (ft) From Last Fish to Upper Extent of Type F
Statewide	Option A	-122	107
	Option B	397	691
	Option C	-113	170
East	Option B	1,038	1,414
	Option C	-89	278
West	Option A	-147	120
	Option B	135	395
	Option C	-122	127

Note:
Extent of Type F waters is based on the first PHB upstream of last fish (on each branch where there are multiple branches upstream of the last fish point). Negative numbers indicate distance downstream from last fish or F/N break locations, positive numbers represent extent of Type F waters above last fish or F/N break locations. Values are expressed in terms of distance per SSN.



Note: This figure excludes networks with an upstream extent greater than 10,000 feet to better display overall patterns; those networks were still included in subsequent analyses. Negative distances indicate that the uppermost extent of Type F under the given PHB option was downstream of the DNR-concurred break, while positive numbers represent extent of Type F waters above the DNR-concurred break.

Appendix Figure B-8. Total extent upstream of, or downstream distance to, the uppermost extent of Type F waters to the DNR-concurred F/N break point



Note: Negative distances indicate that the uppermost extent of Type F under the given PHB option was downstream of the DNR-concurred break, while positive numbers represent extent of Type F waters above the DNR-concurred break. This figure includes networks that were excluded from the previous figure to increase legibility.

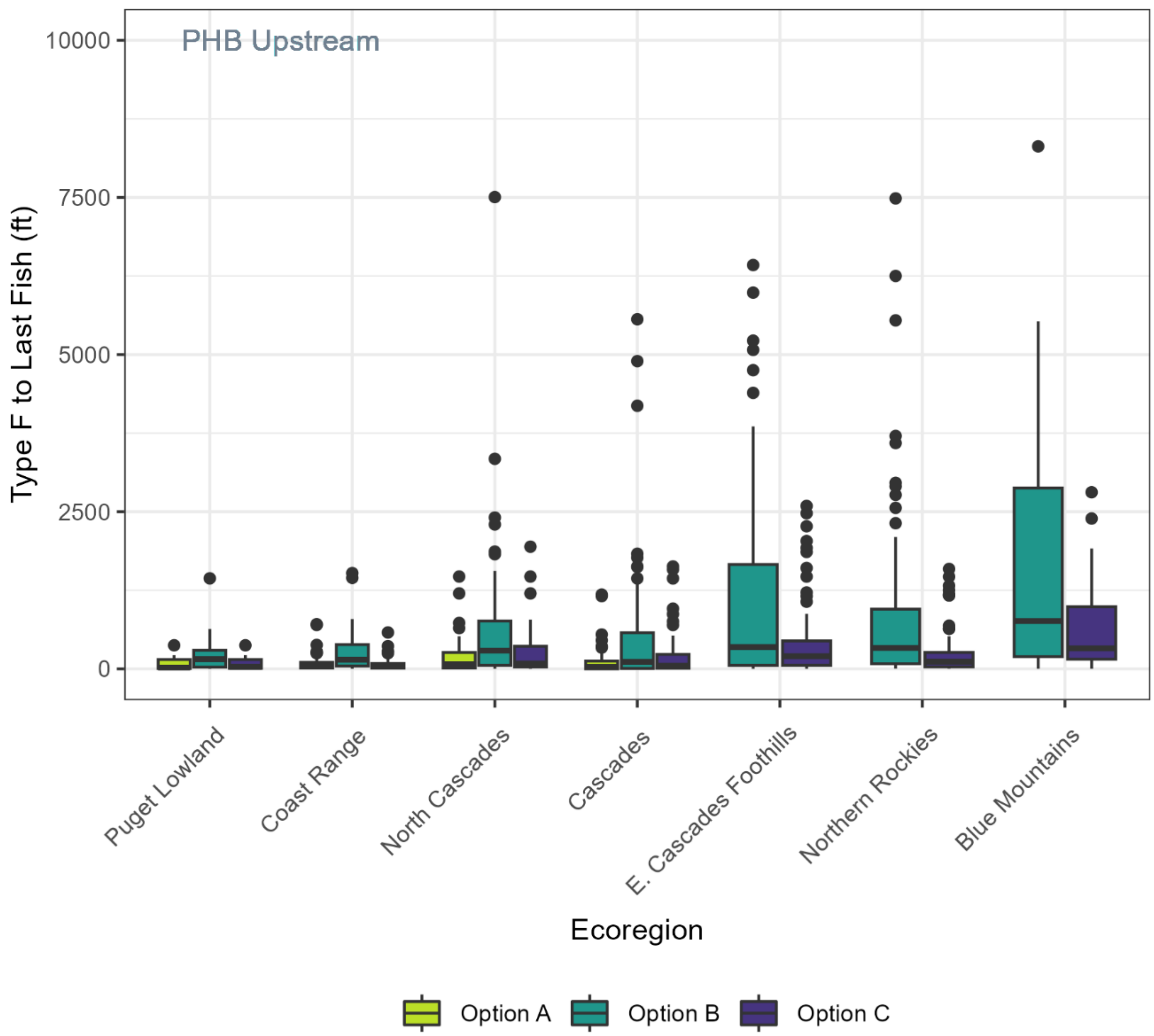
Appendix Figure B-9. Total extent upstream of, or downstream distance to, the uppermost extent of Type F waters to the DNR-concurred F/N break point

Appendix Table B-4. Network distances between the last fish and upper extent of the Type F waters, and between F/N break and upper extent of the Type F waters, summarized by ecoregion

Ecoregion	PHB Option	Extent of Type F Upstream of or Distance to DNR-concurred Break (ft)		Extent of Type F Upstream of or Distance to Last Fish (ft)	
		Mean (SE)	Range	Mean (SE)	Range
Puget Lowland	Option A	-401 (127)	-1,529 to 0	93 (35)	0 to 374
Puget Lowland	Option B	-216 (75)	-903 to 0	277 (119)	0 to 1,440
Puget Lowland	Option C	-438 (131)	-1,521 to 43	56 (19)	0 to 199
Coast Range	Option A	-112 (55)	-1,289 to 710	99 (21)	0 to 710
Coast Range	Option B	68 (61)	-1,283 to 1,523	279 (48)	0 to 1,523
Coast Range	Option C	-129 (50)	-1,523 to 578	67 (13)	0 to 578
North Cascades	Option A	-185 (75)	-1,623 to 1,159	218 (50)	0 to 1,468
North Cascades	Option B	347 (174)	-1,540 to 7,506	709 (166)	0 to 7,506

Ecoregion	PHB Option	Extent of Type F Upstream of or Distance to DNR-concurred Break (ft)		Extent of Type F Upstream of or Distance to Last Fish (ft)	
		Mean (SE)	Range	Mean (SE)	Range
North Cascades	Option C	-108 (78)	-1,623 to 1,943	235 (49)	0 to 1,943
Cascades	Option A	-23 (75)	-1,916 to 1,157	116 (35)	0 to 1,157
Cascades	Option B	401 (135)	-2,286 to 5,562	543 (122)	0 to 5,562
Cascades	Option C	117 (75)	-2,295 to 2,081	253 (51)	0 to 2,081
E. Cascades Foothills	Option B	3,290 (970)	-739 to 45,520	3,661 (962)	0 to 45,520
E. Cascades Foothills	Option C	26 (97)	-2,594 to 3,170	397 (70)	0 to 3,170
Northern Rockies	Option B	806 (295)	-3,779 to 16,218	1,154 (277)	2 to 16,218
Northern Rockies	Option C	-139 (102)	-5,160 to 1,168	205 (35)	0 to 1,589
Blue Mountains	Option B	1,661 (595)	1 to 8,597	2,473 (820)	1 to 11,140
Blue Mountains	Option C	106 (339)	-3,661 to 2,391	706 (207)	1 to 2,391

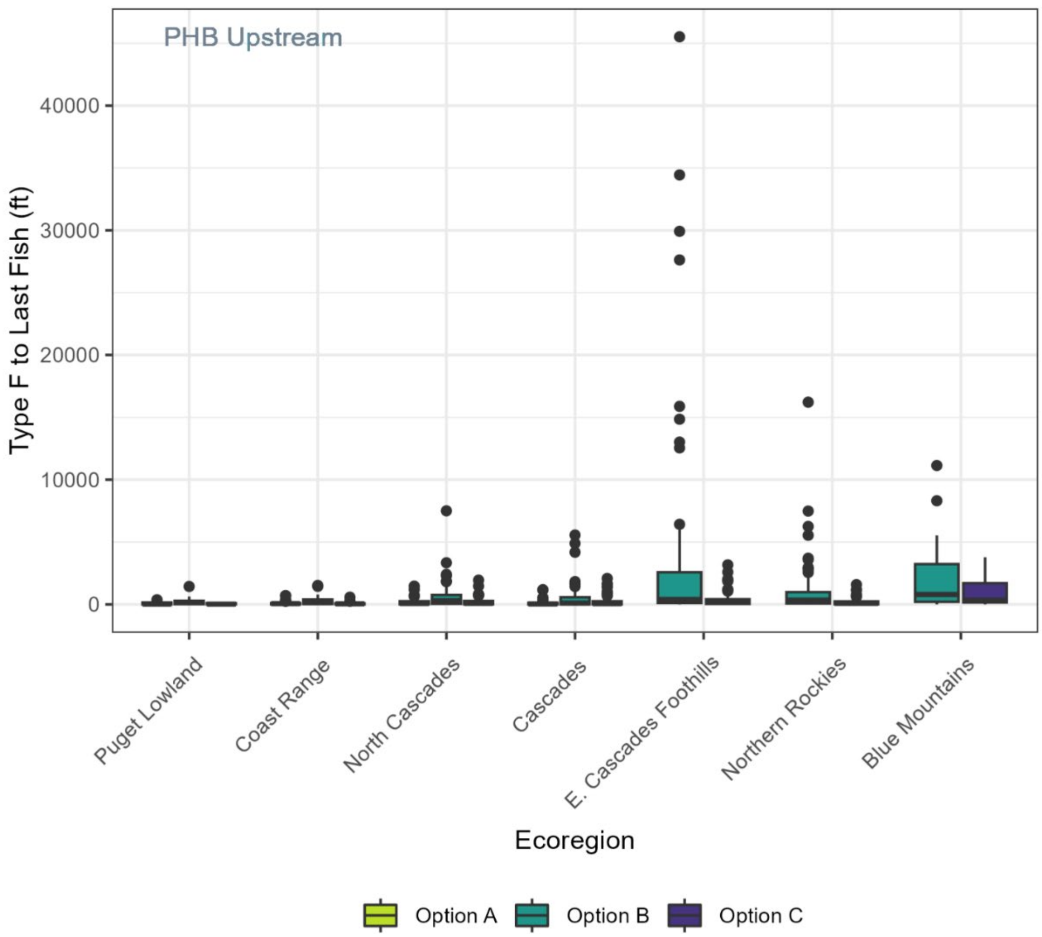
Note:
Extent of Type F waters is based on the first PHB upstream of last fish (on each branch where there are multiple branches upstream of the last fish point). Negative numbers indicate distance downstream from last fish or F/N break locations, positive numbers represent extent of Type F waters above last fish or F/N break locations. Values are expressed in terms of distance per SSN.



Note: This figure excludes networks with an upstream extent greater than 10,000 feet to better display overall patterns; those networks were still included in subsequent analyses. A version that contains these outlier data is presented as Appendix Figure B-11

Appendix Figure B-10. Total extent of Type F waters upstream of the last observed fish for each SSN

Within a given network, the extent of Type F waters upstream of the last observed fish was greatest for Option B for all ecoregions (Appendix Figure B-11).



Note: This figure includes networks that were excluded from Appendix Figure B-10. to increase the legibility of that figure.

Appendix Figure B-11. Total extent of Type F waters above the last observed fish for each SSN

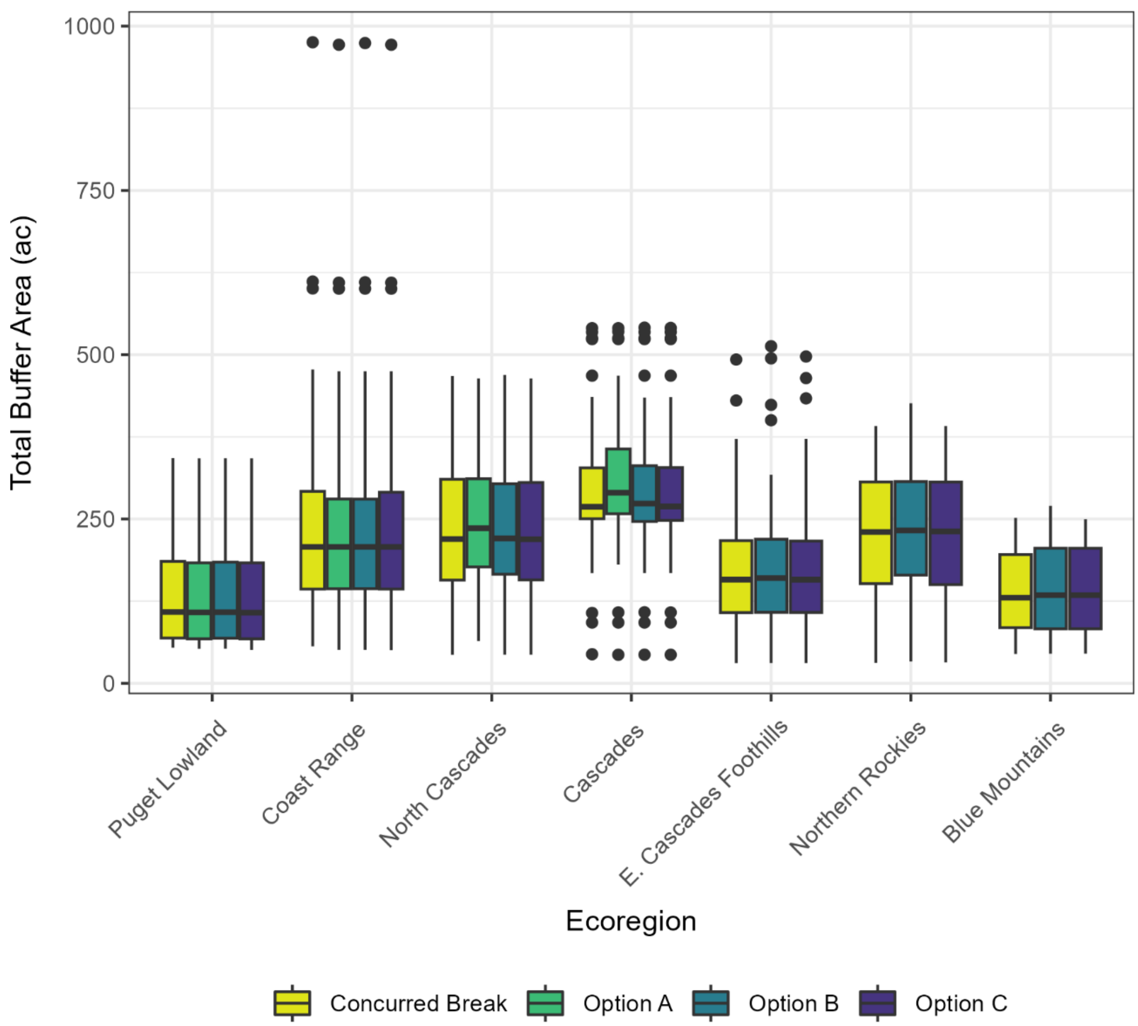
Total Riparian Buffer Area

The total (combined Type F and Type N) riparian buffer area and within-network change in buffer area were calculated across all riparian buffers for each network and averaged by ecoregion (Appendix Table B-5, Appendix Figure B-12).

Appendix Table B-5. Total (combined Type F and Type N)riparian buffer area (ac) in each network under the current rule and under each potential habitat break option, summarized by ecoregion

Ecoregion	Total Buffer Area (ac) per SSN							
	DNR-Concurred F/N Break		PHB Option A		PHB Option B		PHB Option C	
	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range
Puget Lowland	141.2 (26.4)	54.2 to 342.6	140.0 (26.3)	52.5 to 342.4	140.5 (26.4)	52.7 to 342.5	139.7 (26.4)	50.8 to 342.4
Coast Range	243.7 (21.5)	56.2 to 975.6	240.3 (22.8)	50.9 to 971.8	240.8 (22.8)	50.9 to 974.3	243.2 (21.4)	50.4 to 971.8
North Cascades	230.7 (13.3)	43.3 to 467.8	243.5 (15.5)	64.4 to 464.0	232.0 (13.7)	43.4 to 469.1	228.9(13.3)	43.4 to 464.0
Cascades	286.9 (10.4)	44.2 to 540.4	314.8 (17.8)	43.4 to 540.4	288.9 (10.8)	43.5 to 541.2	287.1 (10.4)	43.4 to 540.8

Ecoregion	Total Buffer Area (ac) per SSN							
	DNR-Concurred F/N Break		PHB Option A		PHB Option B		PHB Option C	
	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range
E. Cascades Foothills	165.8 (10.4)	30.7 to 492.7			175.1 (11.3)	30.9 to 512.9	167.8 (10.4)	30.8 to 497.3
Northern Rockies	228.1 (11.0)	31.2 to 391.4			232.3 (11.3)	33.1 to 426.1	228.7 (11.1)	31.8 to 391.4
Blue Mountains	145.4 (16.0)	44.5 to 251.7			151.7 (18.6)	45.0 to 269.9	147.8 (18.0)	45.1 to 249.7



Appendix Figure B-12. Total riparian buffer area (combined Type F and Type N buffer area) per network in each ecoregion

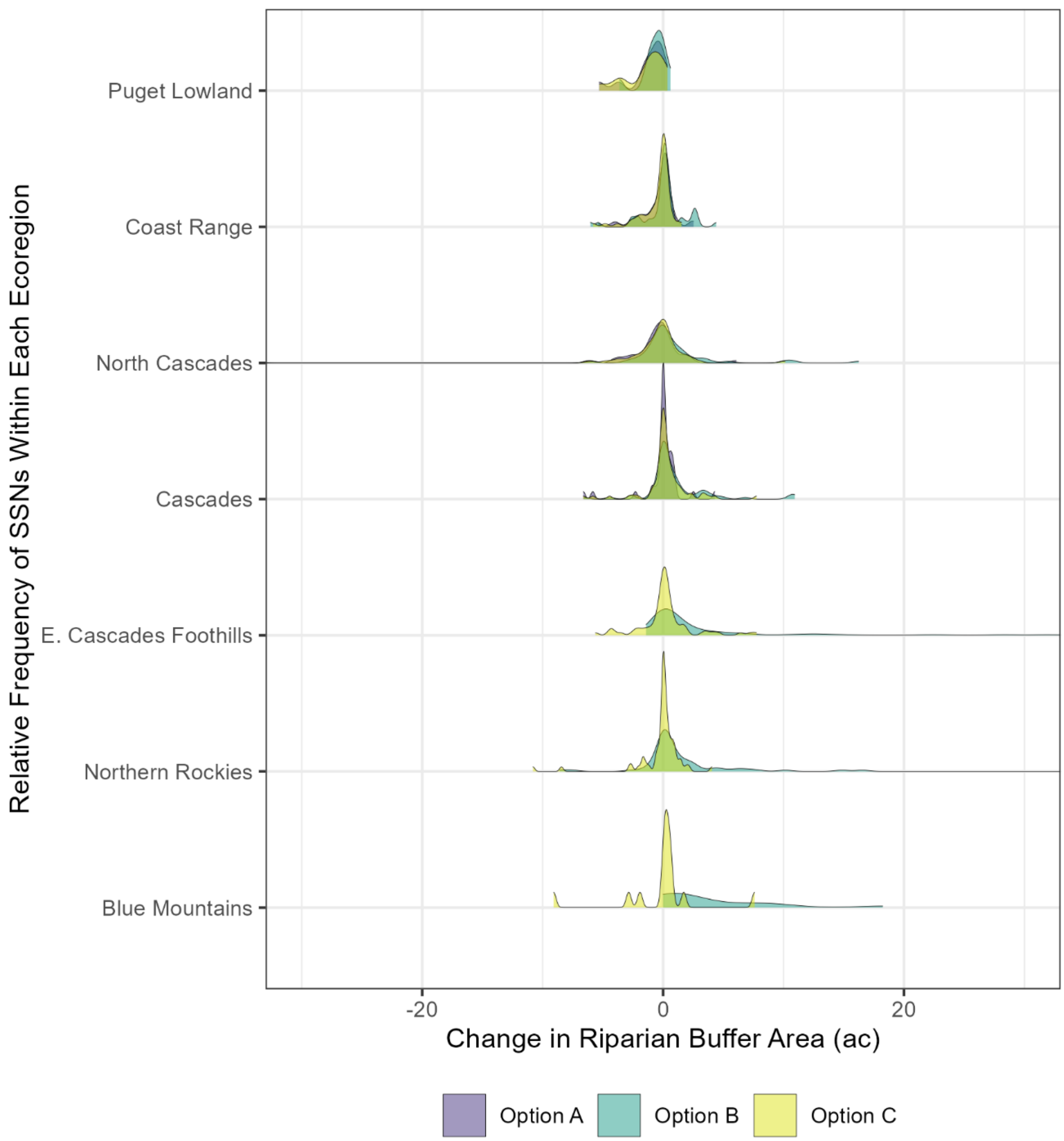
Appendix Table B-6. Net change in buffer area (ac) per network, between riparian buffers based on the DNR-concurred F/N break and those based on each PHB option, summarized by ecoregion

Ecoregion	Change in Total Buffer Area (ac) per SSN from DNR-concurred Break to					
	PHB Option A		PHB Option B		PHB Option C	
	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range
Puget Lowland	-1.3 (0.5)	-5.3 to 0.0	-0.7 (0.3)	-3.6 to 0.2	-1.5 (0.5)	-5.3 to 0.2

Ecoregion	Change in Total Buffer Area (ac) per SSN from DNR-concurred Break to					
	PHB Option A		PHB Option B		PHB Option C	
	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range
Coast Range	-0.4 (0.2)	-5.4 to 3.9	0.0 (0.3)	-6.0 to 4.4	-0.5 (0.2)	-5.8 to 3.9
North Cascades	-2.6 (1.5)	-53.4 to 6.1	-0.8 (1.3)	-52.2 to 16.2	-1.8 (1.2)	-53.5 to 10.1
Cascades	-0.1 (0.3)	-6.6 to 4.3	1.0 (0.3)	-6.6 to 10.9	0.2 (0.2)	-6.6 to 7.8
E. Cascades Foothills			7.5 (2.2)	-2.2 to 99.1	0.2 (2.0)	-5.6 to 7.8
Northern Rockies			1.8 (0.7)	-8.6 to 34.8	-0.2 (0.2)	-10.8 to 4.1
Blue Mountains			3.8 (1.3)	0.0 to 18.2	-0.1 (0.9)	-9.1 to 7.6

Note: Negative values indicate that buffer area decreased under the relevant PHB option. Changes are calculated within-network before being summarized (averaged). Consequently, the mean of those changes is not always equal to the difference between ecoregion means, because sample sets for the DNR-concurred break scenario may differ among comparisons for the various PHB options and ecoregions. For example, means for Option A are only calculated for west side networks and do not include buffers from the DNR-concurred break on the east side of the North Cascades and Cascades ecoregions.

When compared to the DNR-concurred F/N break, on average all three PHBs would result in very small changes in the total area of riparian buffer per SSN (Appendix Table B-6), with some within-network increases particularly on the east side for PHB Option B (Appendix Figure B-13). Average changes were approximately the same within all ecoregions except the Cascades and North Cascades: in those two ecoregions, PHB Option A resulted in increased median buffer area, even though the mean buffer area reduced or was unchanged under PHB Option A in those ecoregions (Appendix Figure B-12).



Note: Values < -20 and > 20 were excluded from this figure to increase figure legibility.

Appendix Figure B-13. Within-network net change in riparian buffer area (ac) between buffers calculated under the concurred break and buffers calculated based on each PHB option

Statewide, the n-weighted average riparian buffer area changed very little, with buffer area for Options A and C decreasing slightly and Option B increasing slightly (Appendix Table B-7). Buffer area for Option B increased more on the east side than on the west side.

Appendix Table B-7. N-weighted average and average change in total riparian buffer (combined Type F and Type N) area (ac) under current rule and for each PHB option, by state side and statewide

State Side	Option	N-weighted Average of Riparian Buffer Area (ac)	N-weighted Average Net Change in Riparian Buffer Area (ac) [Percent Change]
Statewide	DNR-Concurred Break	230.5	
	Option A	198.9	-0.8 [-0.37%]
	Option B	230.9	0.5 [+0.23%]
	Option C	230.0	-0.7 [-0.32%]
East	DNR-Concurred Break	218.0	
	Option B	222.0	1.8 [+0.92%]
	Option C	218.2	-0.6 [-0.31%]
West	DNR-Concurred Break	235.6	
	Option A	240.8	-0.8 [-0.36%]
	Option B	234.5	0.0 [+0.0%]
	Option C	234.8	-0.7 [-0.31%]

Note:
Weights were calculated based on the number of non-DNR-concurred F/N and S/N breaks in wchydro relative to the total number of F/N and S/N breaks statewide and on each side of the state. Negative values indicate that n-weighted average decreased under the relevant PHB option. Changes are calculated within-network before being summarized (averaged). Due to n-weighting and the fact that sample sets for the DNR-concurred break scenario may differ among comparisons for the various PHB options and ecoregions, the mean of those changes is not always equal to the difference between ecoregion means. For example, means for Option A are only calculated for west side networks and do not include buffers from the DNR-concurred break on the east side of the North Cascades and Cascades ecoregions.

Total Volume of Timber Within Riparian Buffers

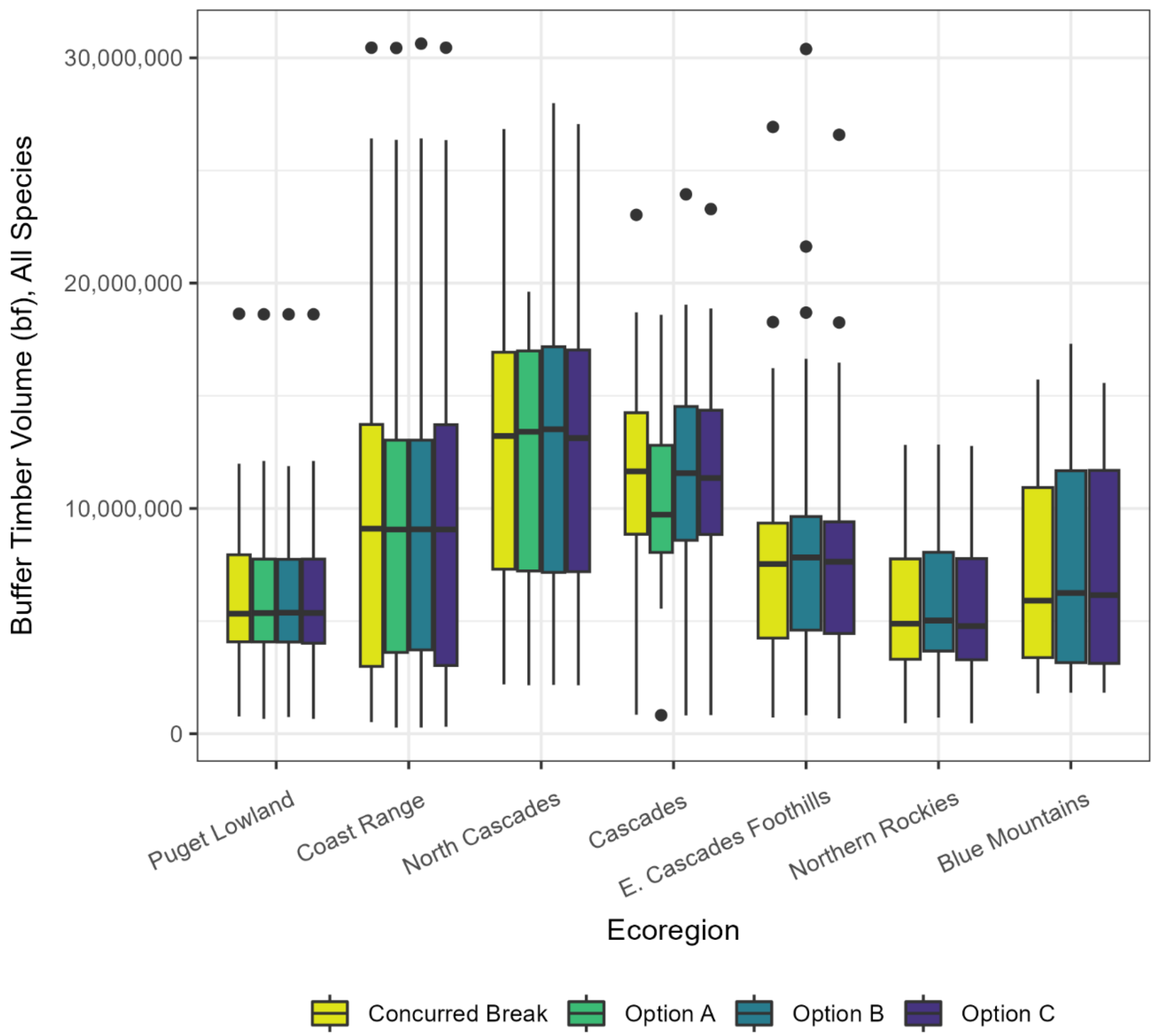
The total timber volume (MBF) across all tree species within all riparian buffers for each network and averaged by ecoregion is presented in Appendix Table B-8 and Appendix Figure B-14. Total timber volume within the riparian buffer for each network. To provide context, these mean volumes per network can be compared to the mean buffer areas presented above (Appendix Table B-5) to develop approximate densities of timber volume per acre in each ecoregion.[26]

Appendix Table B-8. Timber volume (MBF) per synthetic stream network, combining all tree species within the riparian buffers (Type F and Type N) under the current rule and each PHB option, summarized by ecoregion

Ecoregion	Volume of Timber (MBF) per SSN Within Riparian Buffers							
	DNR-Concurred F/N Break		PHB Option A		PHB Option B		PHB Option C	
	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range
Puget Lowland	6,717 (1,364)	829 to 18,641	6,666 (1,365)	813 to 18,616	6,644 (1,358)	820 to 18,616	6,648 (1,369)	813 to 18,616

[26] These values are not the focus of this analysis, so are not presented comprehensively. As an example, under current conditions, riparian buffers are estimated to contain from 25 MBF per acre in the Northern Rockies, to 54 MBF per acre in the North Cascades.

Ecoregion	Volume of Timber (MBF) per SSN Within Riparian Buffers							
	DNR-Concurred F/N Break		PHB Option A		PHB Option B		PHB Option C	
	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range
Coast Range	9,873 (996)	513 to 30,452	9,797 (1,000)	273 to 30,438	9,827 (1,000)	273 to 30,631	9,854 (996)	310 to 30,452
North Cascades	12,417 (755)	2,194 to 26,844	12,411 (806)	2,152 to 19,619	12,712 (796)	2,172 to 27,989	12,435 (760)	2,152 to 27,062
Cascades	11,749 (462)	843 to 23,017	10,520 (616)	824 to 18,596	11,835 (488)	813 to 23,931	11,754 (465)	824 to 23,288
E. Cascades Foothills	7,313 (534)	716 to 26,931			7,721 (592)	818 to 30,391	7,384 (531)	682 to 26,585
Northern Rockies	5,711 (399)	471 to 12,818			5,846 (401)	714 to 12,832	5,689 (403)	469 to 12,776
Blue Mountains	7,725 (1,090)	1,794 to 15,722			8,221 (1,283)	1,822 to 17,311	7,924 (1,213)	1,822 to 15,573



Appendix Figure B-14. Total timber volume within the riparian buffer for each network

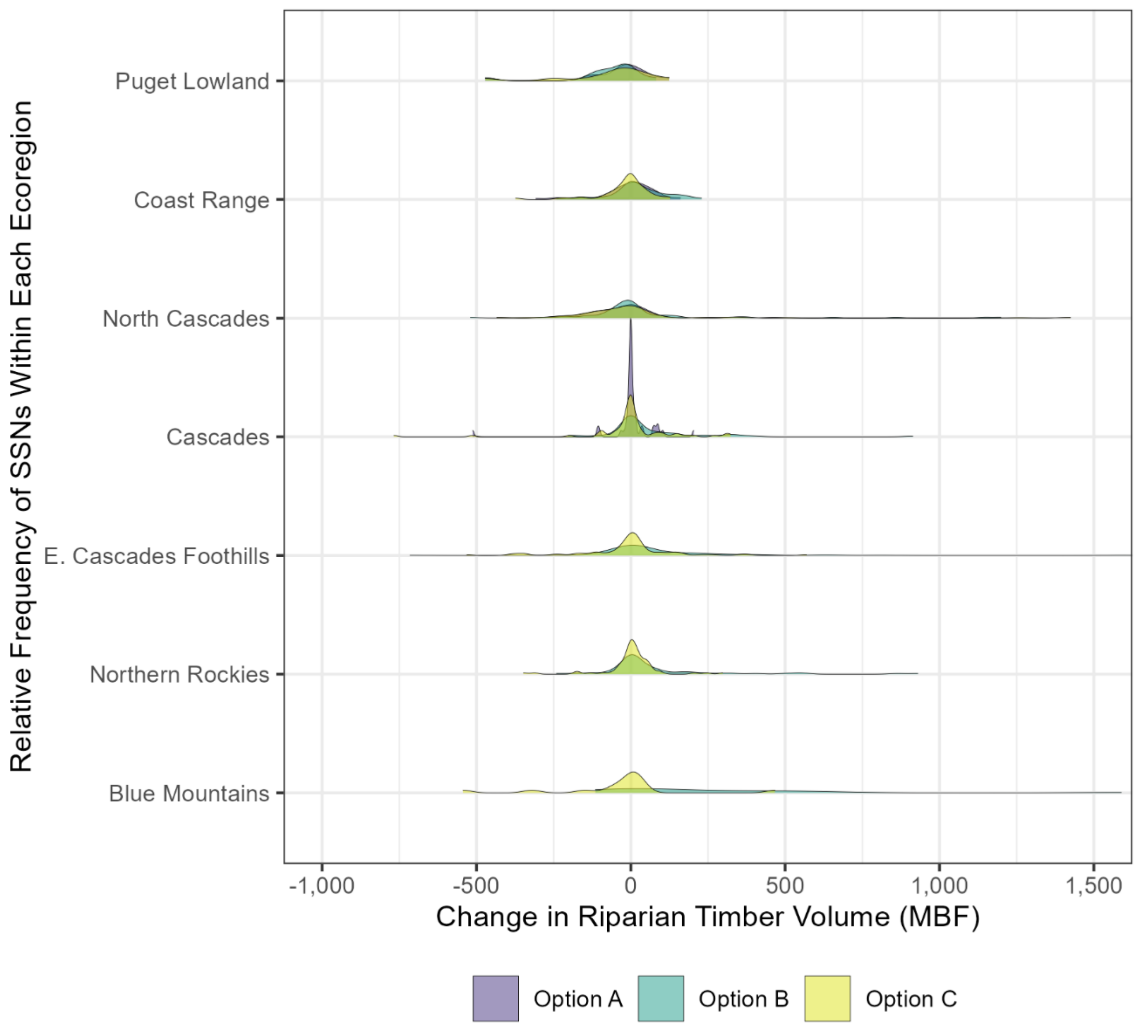
The mean change in total MBF per network between the DNR-concurred break and each PHB option is presented for each ecoregion in Appendix Table B-9.

Appendix Table B-9. Net change in timber volume contained within riparian buffers for each network under each PHB option, summarized by ecoregion

Ecoregion	Change in Volume of Timber (MBF) Within Riparian Buffers per SSN					
	PHB Option A		PHB Option B		PHB Option C	
	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range
Puget Lowland	-52 (43)	-472 to 124	-74 (40)	-472 to 81	-69 (46)	-472 to 124
Coast Range	-10 (13)	-308 to 161	20 (13)	-240 to 229	-19 (12)	-373 to 127
North Cascades	12 (42)	-434 to 1,424	57 (41)	-520 to 1,199	19 (40)	-434 to 1,424
Cascades	-1 (16)	-512 to 204	59 (19)	-204 to 914	5 (17)	-768 to 323
E. Cascades Foothills			331 (115)	-715 to 5,917	-7 (19)	-531 to 569
Northern Rockies			82 (25)	-240 to 930	3 (11)	-348 to 298
Blue Mountains			258 (112)	-115 to 1,589	-39 (55)	-544 to 467

Note:
Negative values indicate that timber volume within the riparian buffer decreased under the relevant PHB option. Changes are calculated within-network before being summarized (averaged). Consequently, the mean of those changes is not always equal to the difference between ecoregion means, because sample sets for the DNR-concurred break scenario may differ among comparisons for the various PHB options and ecoregions. For example, means for Option A are only calculated for west side networks and do not include buffers from the DNR-concurred break on the east side of the North Cascades and Cascades ecoregions.

The magnitude and direction of changes in the volume of timber per SSN that would be protected within riparian buffers as a result of implementing the PHB Options differed among ecoregions (Appendix Figure B-15, Appendix Table B-9). Per SSN, timber volume within buffers tended to decrease under PHB Options A and C: the largest per SSN decrease was for all three PHB options in the Puget Lowlands ecoregion. However, both Option A and C led to per SSN increases in the volume of timber within buffers within Cascades, and Option C also led to increases in the Cascades and E. Cascades foothills. PHB Option B tended to increase per SSN timber volume within buffers, although this was not the case for the Puget Lowlands, where timber volume per SSN decreased.



Note: Values < -1,000 and > 1,500 were excluded from this figure to increase figure legibility.

Appendix Figure B-15. Within-network net change in timber volume (MBF) within buffers calculated under the concurred break compared to volume of timber within riparian buffers under each PHB option

Statewide, the n-weighted average timber volume within riparian buffers increased under Option B and decreased under Options A and C (Appendix Table B-10), with the greatest decrease under Option A. On the east side of the state, n-weighted average timber volumes increased under Option B and decreased under Option C, and on the west side of the state, n-weighted timber volumes increased under Option B and decreased under Options A and C, with the greatest decrease under Option A.

Appendix Table B-10. N-weighted average and average change in timber volume (MBF) across all species within network riparian buffers (combined Type F and Type N), by state side and statewide

State Side	Option	N-Weighted Average Volume of Timber (MBF) Within Riparian Buffers	N-Weighted Average Change in Volume of Timber (MBF) Within Riparian Buffers (and Percentage Change)
Statewide	DNR-Concurred Break	9,717	
	Option A	8,367	-218 [-2.24%]
	Option B	9,808	92 [0.95%]
	Option C	9,712	-5 [-0.05%]
East	DNR-Concurred Break	8,571	
	Option B	8,817	246 [2.87%]
	Option C	8,591	21 [0.25%]
West	DNR-Concurred Break	10,185	
	Option A	9,907	-278 [-2.73%]
	Option B	10,213	29 [0.28%]
	Option C	10,169	-16 [-0.16%]

Note:
Weights were calculated based on the number of non-DNR-concurred F/N and S/N breaks in wchydro relative to the total number of F/N and S/N breaks statewide and on each side of the state. Negative values indicate that n-weighted average decreased under the relevant PHB option. Changes are calculated within-network before being summarized (averaged). Due to n-weighting and the fact that sample sets for the DNR-concurred break scenario may differ among comparisons for the various PHB options and ecoregions, the mean of those changes is not always equal to the difference between ecoregion means. For example, means for Option A are only calculated for west side networks and do not include buffers from the DNR-concurred break on the east side of the North Cascades and Cascades ecoregions.

Total Value of Timber Within Riparian Buffers

The total value of timber within riparian buffers (USD) across all tree species within all riparian buffers for each network and averaged by ecoregion is presented in Appendix Table B-11. The mean change in value per network between the DNR-concurred break and each PHB option is also presented by ecoregion in Appendix Table B-12.

Appendix Table B-11. Value of timber within riparian buffers (USD) per SSN for all species within the total network buffer under the current rule and each PHB option, summarized by ecoregion

Ecoregion	Value (USD) Of Timber per SSN in Riparian Buffers							
	DNR-Concurred F/N Break		PHB Option A		PHB Option B		PHB Option C	
	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range
Puget Lowland	$3,739,985 ($763,852)	$431,721 to $10,383,345	$3,705,389 ($763,563)	$406,166 to $10,372,155	$3,703,569 ($761,878)	$420,011 to $10,372,155	$3,694,981 ($765,748)	$406,166 to $10,372,155
Coast Range	$4,716,584 ($423,298)	$251,010 to $11,558,160	$4,711,241 ($430,441)	$125,929 to $11,666,233	$4,727,901 ($429,976)	$125,929 to $11,772,230	$4,706,480 ($423,240)	$150,138 to $11,558,160
North Cascades	$6,114,439 ($390,202)	$939,659 to $11,035,086	$6,775,136 ($456,820)	$918,553 to $10,973,479	$6,284,010 ($404,549)	$919,736 to $11,013,933	$6,126,648 ($392,455)	$918,553 to $11,033,265
Cascades	$4,678,657 ($196,653)	$430,423 to $9,167,832	$5,170,894 ($312,206)	$420,916 to $9,165,862	$4,705,324 ($205,931)	$416,695 to $9,240,826	$4,682,118 ($197,662)	$420,916 to $9,165,862

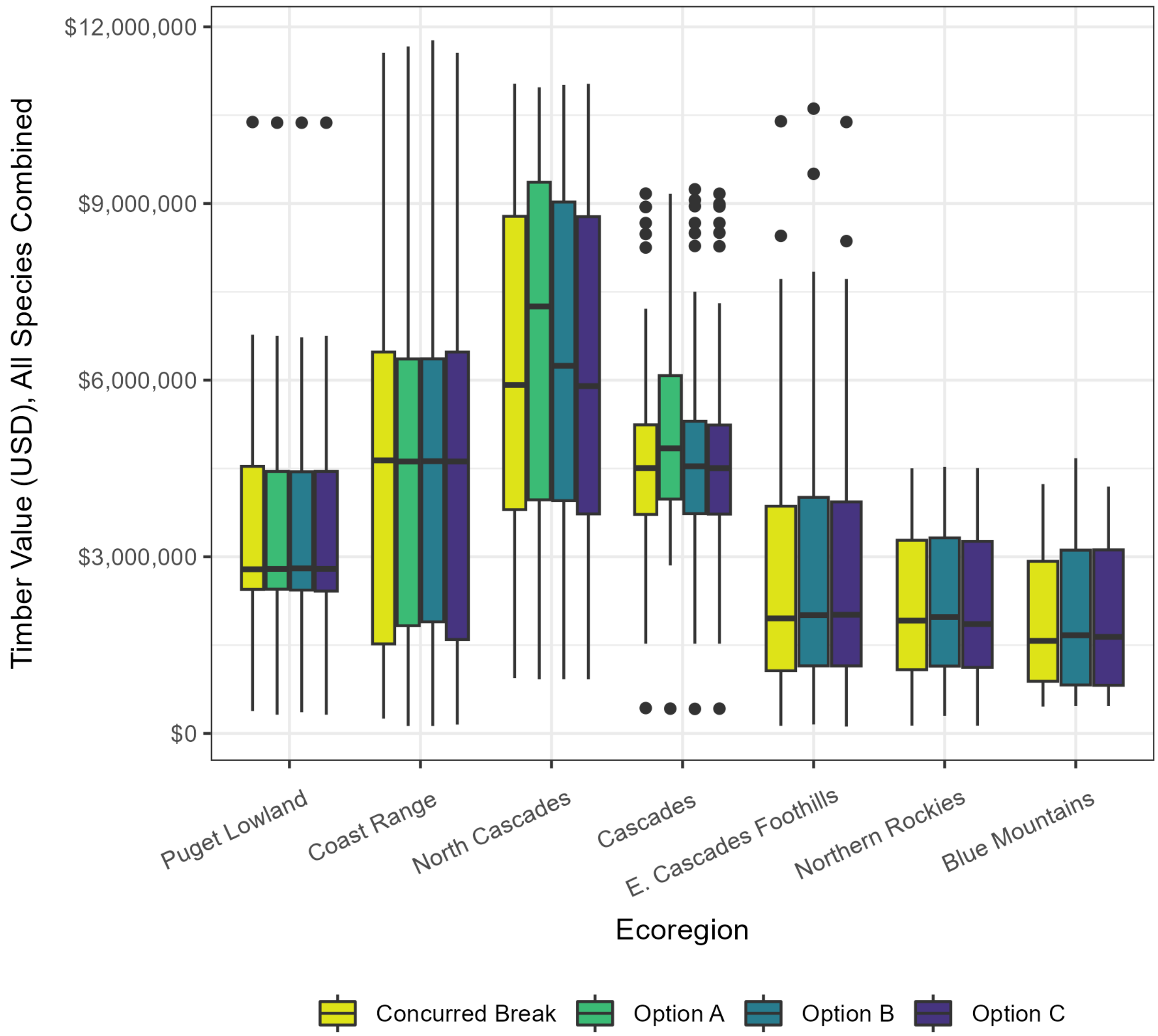
Ecoregion	Value (USD) Of Timber per SSN in Riparian Buffers							
	DNR-Concurred F/N Break		PHB Option A		PHB Option B		PHB Option C	
	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range
E. Cascades Foothills	$2,530,126 ($249,924)	$128,758 to $10,396,153			$2,664,734 ($264,494)	$152,092 to $10,611,155	$2,554,580 ($250,959)	$116,678 to $10,383,856
Northern Rockies	$2,158,058 ($154,216)	$131,487 to $4,503,049			$2,203,973 ($154,949)	$297,727 to $4,526,636	$2,149,518 ($156,037)	$130,740 to $4,506,965
Blue Mountains	$2,060,807 ($294,444)	$456,561 to $4,234,555			$2,195,717 ($347,236)	$464,011 to $4,674,413	$2,113,056 ($327,745)	$464,011 to $4,191,170

Appendix Table B-12. Net change per SSN in value of timber within riparian buffers (USD) between riparian buffers based on the DNR-concurred F/N break and each PHB option, summarized by ecoregion

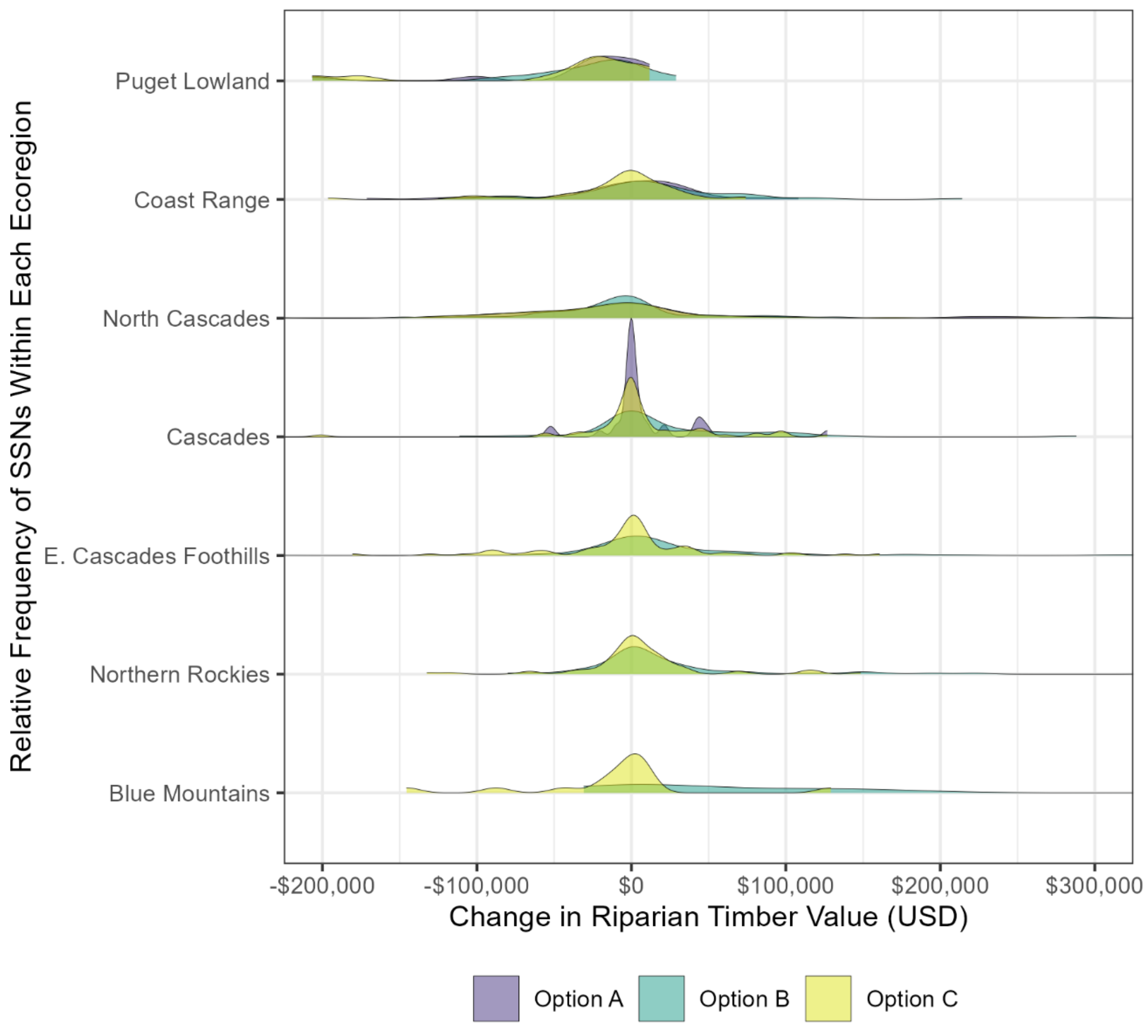
Ecoregion	Change in Value of Timber (USD) in Riparian Buffers per SSN					
	PHB Option A		PHB Option B		PHB Option C	
	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range
Puget Lowland	-$34,596 ($17,818)	-$206,524 to $11,632	-$36,416 ($17,564)	-$206,524 to $28,901	-$45,004 ($20,463)	-$206,524 to $11,632
Coast Range	-$4,228 ($7,186)	-$171,164 to $108,073	$12,432 ($7,983)	-$125,081 to $214,070	-$10,103 ($6,127)	-$196,273 to $73,963
North Cascades	$12,094 ($20,604)	-$247,359 to $620,620	$22,155 ($20,049)	-$329,973 to $711,192	$12,209 ($20,632)	-$247,359 to $803,126
Cascades	$531 ($8,194)	-$256,939 to $126,785	$21,071 ($6,423)	-$111,203 to $287,954	$3,461 ($5,921)	-$256,939 to $126,785
E. Cascades Foothills			$107,214 ($36,917)	-$245,206 to $1,696,137	-$2,940 ($6,176)	-$180,445 to $160,577
Northern Rockies			$30,412 ($9,603)	-$79,990 to $361,400	$5,988 ($5,227)	-$132,332 to $148,383
Blue Mountains			$71,952 ($30,908)	-$30,814 to $439,859	-$10,710 ($14,893)	-$145,604 to $129,092

Note:
Negative values indicate that timber value within the riparian buffer decreased under the relevant PHB option. Changes are calculated within-network before being summarized (averaged). Consequently, the mean of those changes is not always equal to the difference between ecoregion means, because sample sets for the DNR-concurred break scenario may differ among comparisons for the various PHB options and ecoregions. For example, means for Option A are only calculated for west side networks and do not include buffers from the DNR-concurred break on the east side of the North Cascades and Cascades ecoregions.

Ecoregions on the west side of the state (Cascades, Puget Lowland, Coast Range, and most of the North Cascades) tended to have greater value of timber within riparian buffers per SSN than ecoregions on the east side of the state (E. Cascades Slopes and Foothills, Northern Rockies, Blue Mountains [Appendix Figure B-16]). The greatest value of timber within riparian buffers per SSN was seen in the North Cascades. Compared to the concurred break, PHB Options A and C resulted in a reduction in the per SSN value of timber contained within riparian buffers in all ecoregions except the Cascades and E. Cascade Slopes and Foothills (Appendix Table B-12, Appendix Figure B-17). PHB Option B resulted in an increase in the per SSN value of timber contained within buffers in all ecoregions.



Appendix Figure B-16. Total timber value within the riparian buffer for each network



Note: Values < -$200,000 and > $300,000 were excluded from this figure to increase figure legibility.

Appendix Figure B-17. Within-network net change in timber value within buffers calculated under the concurred break compared to value of timber within riparian buffers under each PHB option

Statewide, the value of timber within riparian buffers increased under Option B and decreased under Options A and C, with the greatest by-SSN decrease under Option C (Appendix Table B-13). On the east side of the state, n-weighted average value of timber within riparian buffers increased under Option B and decreased under Option C, and on the west side of the state, per-network n-weighted average value of timber within riparian buffers decreased under Options A and C and increased under Option B.

Appendix Table B-13. N-weighted value of timber within riparian buffers (USD) and net change in value of timber within riparian buffers (USD) across all species within riparian buffers, by state side and statewide

Area	Option	N-Weighted Average Value (USD) of Timber Within Riparian Buffers	N-Weighted Average Change in Value (USD) of Timber Within Riparian Buffers (and percent change)
Statewide	Concurred Break	$4,452,913	-
	Option A	$4,254,416	-$2,408 [-0.05%]
	Option B	$4,505,734	$18,046 [+0.41%]
	Option C	$4,448,758	-$4,737 [-0.11%]
East	Concurred Break	$3,620,774	
	Option B	$3,723,794	$40,705 [+1.12%]
	Option C	$3,628,268	$5,489 [+0.15%]
West	Concurred Break	$4,792,627	
	Option A	$4,980,723	-$4,996 [-0.10%]
	Option B	$4,824,955	$8,796 [+0.18%]
	Option C	$4,783,716	-$8,912 [-0.19%]

Note:
Weights were calculated based on the number of non-DNR-concurred F/N and S/N breaks in wchydro relative to the total number of F/N and S/N breaks statewide and on each side of the state. Negative values indicate that n-weighted average decreased under the relevant PHB option. Changes are calculated within-network before being summarized (averaged). Due to n-weighting and the fact that sample sets for the DNR-concurred break scenario may differ among comparisons for the various PHB options and ecoregions, the mean of those changes is not always equal to the difference between ecoregion means. For example, means for Option A are only calculated for west side networks and do not include buffers from the DNR-concurred break on the east side of the North Cascades and Cascades ecoregions.

Type F Riparian Buffer Area

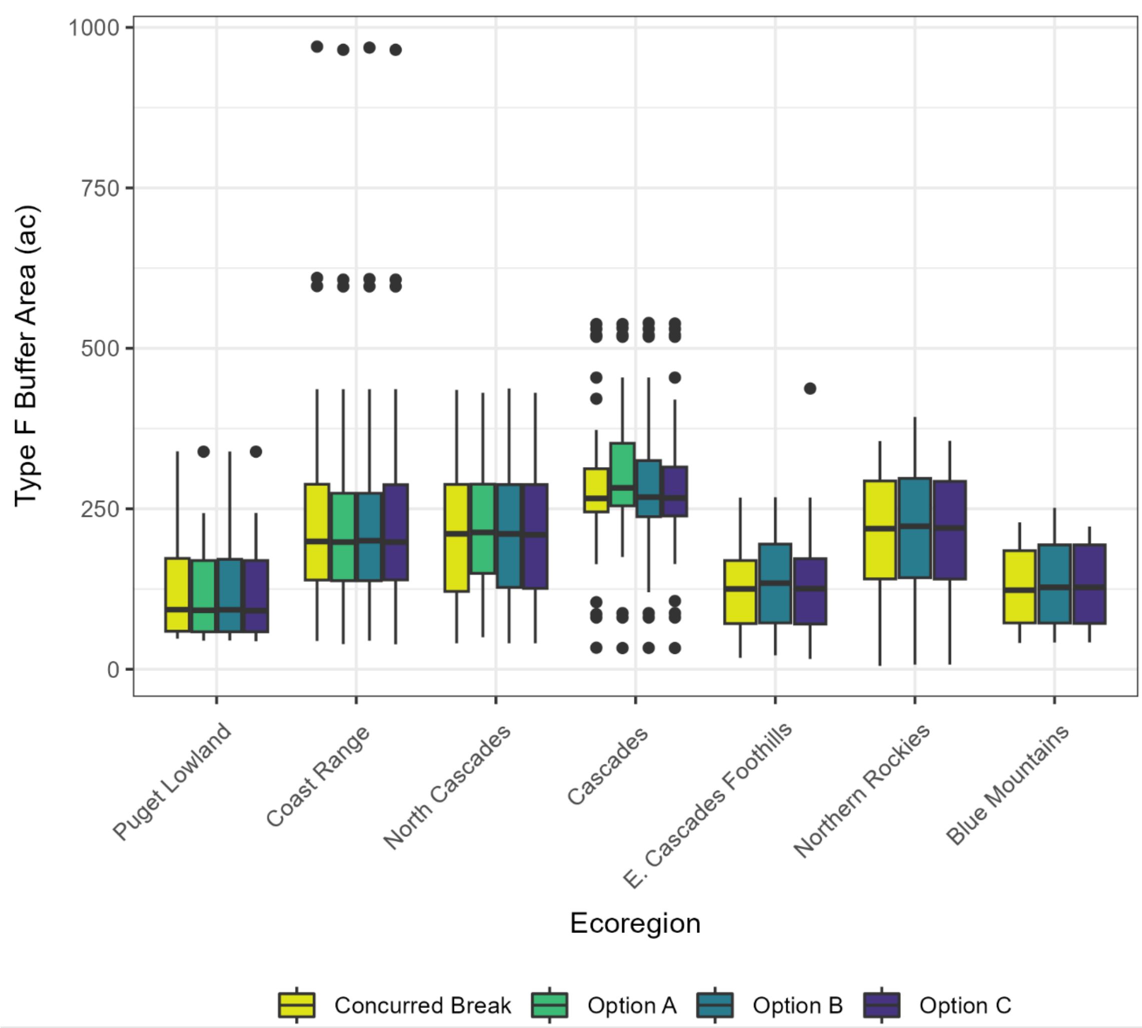
Type F riparian buffer area was greatest in the Cascades ecoregion for all three PHB Options; Type F buffer area was greater in east side than west side ecoregions for PHB Option B (Appendix Table B-14, Appendix Figure B-18). Within-network change was relatively low across all ecoregions, and only increased notably for Option B in the three east side ecoregions (Appendix Table B-15).

Statewide, the n-weighted average area of Type F water buffers changed very little (Appendix Table B-16). Options A and C showed a slight decrease, while Option B showed a slight increase. Option B buffer area increased slightly more on the east side than on the west side.

Appendix Table B-14. Type F riparian buffer area (ac) calculated under the current rule and each PHB option, summarized by ecoregion

Ecoregion	Buffer Area (ac) per SSN							
	DNR-Concurred F/N Break		PHB Option A		PHB Option B		PHB Option C	
	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range
Puget Lowland	130.1 (26.6)	47.7 to 339.5	128.1 (26.6)	44.7 to 339.1	129.0 (26.6)	45.0 to 339.2	127.9 (26.6)	43.6 to 339.1
Coast Range	237.5 (21.3)	44.1 to 970.1	233.6 (22.6)	39.2 to 965.1	234.3 (22.6)	44.7 to 968.5	236.9 (21.3)	38.9 to 965.1
North Cascades	205.2 (13.1)	40.5 to 435.2	215.4 (15.6)	49.9 to 430.9	205.6 (13.5)	40.5 to 437.6	203.2 (13.0)	40.5 to 430.9
Cascades	274.8 (10.7)	33.6 to 537.8	308.0 (18.0)	33.1 to 537.8	276.8 (11.2)	33.3 to 539.5	275.2 (10.7)	33.1 to 538.6

Ecoregion	Buffer Area (ac) per SSN							
	DNR-Concurred F/N Break		PHB Option A		PHB Option B		PHB Option C	
	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range
E. Cascades Foothills	124.4 (7.6)	17.9 to 267.4			136.8 (8.1)	21.7 to 267.9	125.8 (7.6)	16.1 to 267.4
Northern Rockies	212.7 (11.3)	5.2 to 355.7			217.3 (11.6)	7.5 to 393.2	212.9 (11.4)	7.5 to 356.0
Blue Mountains	134.5 (15.0)	41.1 to 228.9			141.4 (17.9)	41.8 to 251.5	135.4 (16.9)	41.9 to 222.4



Appendix Figure B-18. Type F water buffer area (ac) for each network

Appendix Table B-15. Change in Type F riparian buffer area (ac) calculated under the current rule and each PHB option, summarized by ecoregion

Ecoregion	Change in Buffer Area (ac) per SSN					
	PHB Option A		PHB Option B		PHB Option C	
	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range
Puget Lowland	-2.0 (0.7)	-7.9 to 0.0	-1.1 (0.4)	-4.7 to 0.2	-2.2 (0.7)	-7.9 to 0.2
Coast Range	-0.6 (0.3)	-6.8 to 3.6	0.2 (0.3)	-6.8 to 6.2	-0.6 (0.2)	-7.5 to 1.9
North Cascades	-2.9 (1.6)	-53.4 to 4.8	-0.2 (1.4)	-53.1 to 25.3	-2.0 (1.2)	-53.4 to 11.5
Cascades	-0.1 (0.4)	-9.9 to 5.9	1.4 (0.5)	-9.8 to 17.5	0.4 (0.3)	-9.9 to 10.3
E. Cascades Foothills			11.2 (3.3)	-2.5 to 148.8	0.1 (0.3)	-8.9 to 10.4
Northern Rockies			2.7 (1.0)	-13.0 to 52.8	-0.4 (0.4)	-17.7 to 4.0
Blue Mountains			5.7 (2.0)	0.0 to 29.3	-0.4 (1.2)	-12.6 to 8.2

Note:
Negative values indicate that buffer area decreased under the relevant PHB option. Changes are calculated within-network before being summarized (averaged). Consequently, the mean of those changes is not always equal to the difference between ecoregion means, because sample sets for the DNR-concurred break scenario may differ among comparisons for the various PHB options and ecoregions. For example, means for Option A are only calculated for west side networks and do not include buffers from the DNR-concurred break on the east side of the North Cascades and Cascades ecoregions.

Appendix Table B-16. N-weighted average and n-weighted average change in area (ac) of Type F buffers

Area	Option	N-Weighted Average Riparian Buffer Area per SSN (ac)	N-Weighted Average Change in Riparian Buffer Area per SSN (ac) [Percent Change]
Statewide	DNR-Concurred Break	216.4	
	Option A	188.5	-1.0 [-0.46%]
	Option B	216.6	1.0 [+0.46%]
	Option C	215.7	-0.8 [-0.37%]
East	DNR-Concurred Break	196.2	
	Option B	200.6	3.1 [+1.58%]
	Option C	196.0	-0.8 [-0.41%]
West	DNR-Concurred Break	224.6	
	Option A	230.0	-1.1 [-0.45%]
	Option B	223.2	0.2 [+0.09%]
	Option C	223.7	-0.9 [-0.40%]

Note:
Weights were calculated based on the number of non-DNR-concurred F/N and S/N breaks in wchydro relative to the total number of F/N and S/N breaks statewide and on each side of the state. Negative values indicate that n-weighted average decreased under the relevant PHB option. Changes are calculated within-network before being summarized (averaged). Due to n-weighting and the fact that sample sets for the DNR-concurred break scenario may differ among comparisons for the various PHB options and ecoregions, the mean of those changes is not always equal to the difference between ecoregion means. For example, means for Option A are only calculated for west side networks and do not include buffers from the DNR-concurred break on the east side of the North Cascades and Cascades ecoregions.

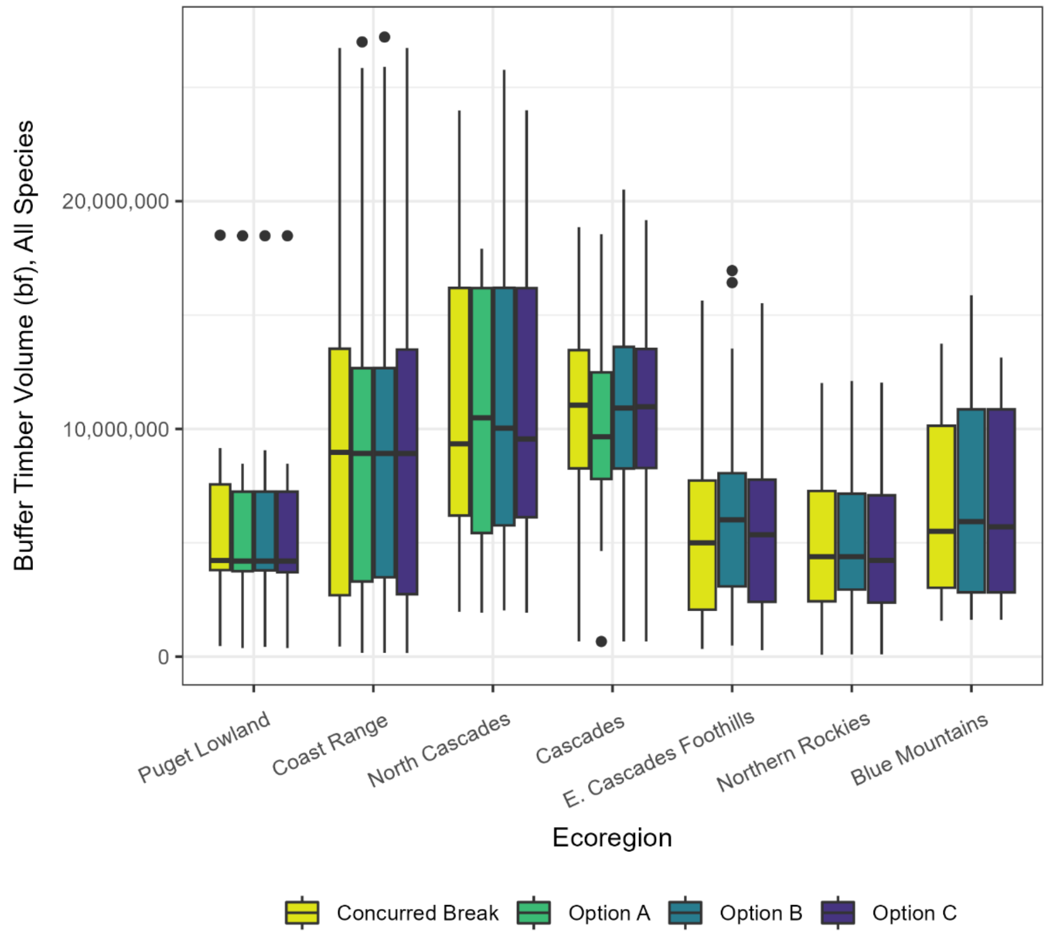
Total Volume of Timber Within Type F Riparian Buffers

The timber volume (MBF) for all tree species within the Type F water buffer for each network was highest in the Cascades and North Cascades ecoregions (Appendix Figure B-19, Appendix Table B-17). The MBF per network between the DNR-concurred break and each PHB option decreased the most in the Puget Lowlands for all three options; all ecoregions had a decrease in mean timber volume under Option A, while Option B had the greatest increase in mean timber volume across ecoregions (Appendix Table B-18).

Statewide, the n-weighted average timber volume within Type F buffers increased under Option B and decreased under Options A and C, with the greatest decreases under Option A (Appendix Table B-19). Though most of the ecoregions had increases in timber volume within Type F buffers under Option C, when combined statewide the decreases outweighed the increases, which led to the slight overall decrease in n-weighted average timber volume in Type F buffers under Option C.

Appendix Table B-17. Volume of timber within riparian buffers (MBF, all species) within the Type F water buffers in each network under the current rule and each potential habitat break option, summarized by ecoregion

Ecoregion	Volume of Timber (MBF) per SSN Within Riparian Buffers							
	DNR-Concurred F/N Break		PHB Option A		PHB Option B		PHB Option C	
	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range
Puget Lowland	5,912 (1,341)	466 to 18,510	5,773 (1,332)	375 to 18,480	5,837 (1,339)	427 to 18,480	5,763 (1,334)	375 to 18,480
Coast Range	9,524 (966)	441 to 26,725	9,413 (967)	173 to 26,995	9,453 (965)	173 to 27,208	9,496 (966)	165 to 26,725
North Cascades	10,754 (751)	1,975 to 23,980	10,597 (836)	1,928 to 17,911	11,003 (797)	2,027 to 25,768	10,731 (752)	1,928 to 23,992
Cascades	11,112 (450)	668 to 18,844	10,219 (623)	665 to 18,546	11,210 (477)	666 to 20,496	11,134 (454)	665 to 19,167
E. Cascades Foothills	5,389 (416)	339 to 15,631			5,970 (450)	490 to 16,952	5,447 (415)	279 to 15,524
Northern Rockies	5,106 (410)	86 to 12,014			5,252 (412)	102 to 12,101	5,062 (415)	102 to 12,034
Blue Mountains	6,973 (1,002)	1,576 to 13,741			7,544 (1,220)	1,613 to 15,865	7,069 (1,113)	1,613 to 13,133



Appendix Figure B-19. Total timber volume within the Type F water buffer for each network

Appendix Table B-18. Change in volume of timber within riparian buffers (MBF, all species) within the Type F water buffers for each network between the current rule and each potential habitat break option, summarized by ecoregion

Ecoregion	Change in Volume of Timber (MBF) Within Riparian Buffers per SSN					
	PHB Option A		PHB Option B		PHB Option C	
	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range
Puget Lowland	-139 (59)	-693 to 0	-75 (31)	-391 to 0	-148 (59)	-693 to 8
Coast Range	-20 (16)	-365 to 270	19 (19)	-300 to 483	-28 (14)	-377 to 153
North Cascades	-58 (30)	-509 to 513	100 (56)	-473 to 1,787	-23 (36)	-509 to 1,517
Cascades	-11 (18)	-555 to 166	93 (37)	-569 to 1,651	22 (18)	-569 to 551
E. Cascades Foothills			527 (178)	-184 to 9,496	4 (18)	-676 to 505
Northern Rockies			111 (36)	-402 to 1,395	-11 (13)	-504 to 309
Blue Mountains			419 (171)	0 to 2,542	-56 (84)	-842 to 501

Note:
Negative values indicate that timber volume within the riparian buffer decreased under the relevant PHB option. Changes are calculated within-network before being summarized (averaged). Consequently, the mean of those changes is not always equal to the difference between ecoregion means, because sample sets for the DNR-concurred break scenario may differ among comparisons for the various PHB options and ecoregions. For example, means for Option A are only calculated for west side networks and do not include buffers from the DNR-concurred break on the east side of the North Cascades and Cascades ecoregions.

Appendix Table B-19. N-weighted average and total timber volume (MBF) across all species within Type F water buffers

Area	Option	N-Weighted Average Volume (MBF) of Timber Within Riparian Buffers	N-Weighted Average Change in Volume (MBF) of Timber Within Riparian Buffers [Percent Change]
Statewide	DNR-Concurred Break	8,909	
	Option A	7,721	-220 [-2.47%]
	Option B	8,993	84 [+0.94%]
	Option C	8,882	-27 [-0.30%]
East	DNR-Concurred Break	7,429	
	Option B	7,695	266 [+3.58%]
	Option C	7,419	-10 [-0.13%]
West	DNR-Concurred Break	9,513	
	Option A	9,244	-269 [-2.83%]
	Option B	9,523	10 [+0.11%]
	Option C	9,479	-34 [-0.36%]

Note:
Weights were calculated based on the number of non-DNR-concurred F/N and S/N breaks in wchydro relative to the total number of F/N and S/N breaks statewide and on each side of the state. Negative values indicate that n-weighted average decreased under the relevant PHB option. Changes are calculated within-network before being summarized (averaged). Due to n-weighting and the fact that sample sets for the DNR-concurred break scenario may differ among comparisons for the various PHB options and ecoregions, the mean of those changes is not always equal to the difference between ecoregion means. For example, means for Option A are only calculated for west side networks and do not include buffers from the DNR-concurred break on the east side of the North Cascades and Cascades ecoregions.

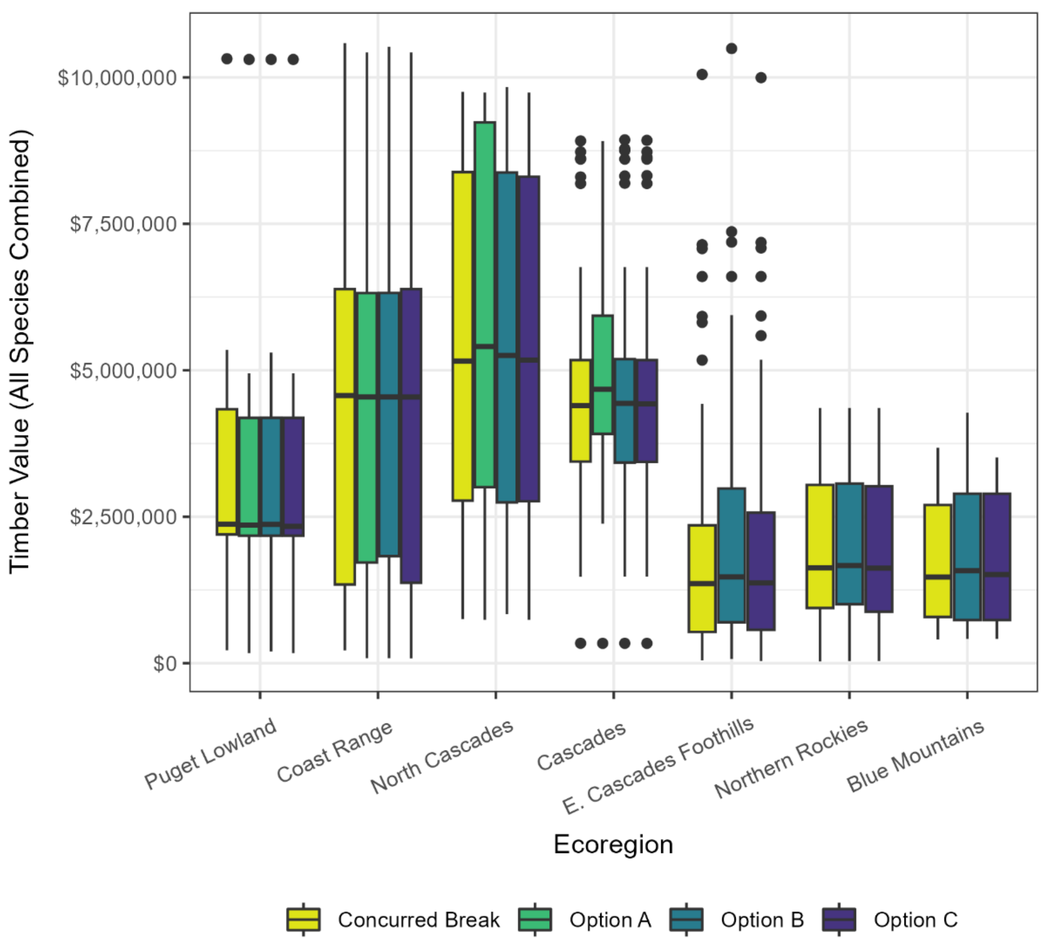
Total Value of Timber Within Type F Riparian Buffers

Ecoregions on the west side of the state tended to have greater mean value of timber within riparian buffers, with the highest values seen in the North Cascades ecoregion (Appendix Table B-20, Appendix Figure B-20). The mean value of timber within riparian buffers within Type F buffers decreased in the Puget Lowland and Coast Range ecoregions across all PHB options, with the greatest decrease seen under Option A. Options B and C had an overall increase in mean value of timber within riparian buffers in all other ecoregions, with the greatest increase seen under Option B (Appendix Table B-21).

Statewide, the n-weighted average value of timber within riparian buffers within Type F buffers increased under Option B and decreased under Options A and C, with the greatest decrease under Option A (Appendix Table B-22). On the east side of the state, n-weighted average value of timber within riparian buffers increased under Option B and decreased slightly under Option C, and on the west side of the state, n-weighted average value of timber within riparian buffers increased under Options A and B, and decreased under Option C.

Appendix Table B-20. Value of timber within riparian buffers (USD, all species) within the Type F water buffers for each network under the current rule and each potential habitat break option, summarized by ecoregion

Ecoregion	Value of Timber (USD) per SSN Within Riparian Buffers							
	DNR-Concurred F/N Break		PHB Option A		PHB Option B		PHB Option C	
	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range
Puget Lowland	3,332,043 (753,577)	220,225 to 10,318,700	3,256,640 (747,557)	170,507 to 10,306,188	3,294,605 (752,507)	199,464 to 10,306,188	3,251,085 (748,492)	170,507 to 10,306,188
Coast Range	4,552,178 (413,411)	218,766 to 10,583,836	4,528,578 (418,599)	84,402 to 10,425,848	4,548,968 (417,168)	84,402 to 10,520,709	4,538,350 (413,369)	80,767 to 10,425,848
North Cascades	5,369,360 (392,725)	751,610 to 9,752,757	5,881,624 (478,013)	740,738 to 9,742,146	5,518,753 (410,434)	837,206 to 9,836,378	5,360,305 (393,540)	740,738 to 9,742,146
Cascades	4,463,705 (200,066)	340,391 to 8,915,459	5,017,779 (312,756)	338,793 to 8,915,459	4,492,485 (209,014)	339,209 to 8,933,923	4,469,855 (200,667)	338,793 to 8,925,331
E. Cascades Foothills	1,964,437 (232,445)	45,823 to 10,051,289			2,152,208 (242,796)	71,226 to 10,492,426	1,986,405 (233,595)	37,894 to 9,995,621
Northern Rockies	1,930,625 (159,168)	31,457 to 4,357,623			1,983,185 (159,784)	37,625 to 4,357,623	1,911,984 (161,139)	37,625 to 4,357,623
Blue Mountains	1,854,615 (269,751)	405,381 to 3,678,095			2,010,402 (329,637)	413,549 to 4,274,498	1,879,154 (299,527)	413,549 to 3,511,044



Appendix Figure B-20. Total timber value within the Type F water buffer for each network

Appendix Table B-21. Change in value of timber within riparian buffers (USD, all species) within the Type F water buffers for each network between the current rule and each potential habitat break option, summarized by ecoregion

Ecoregion	Change in Value of Timber (USD) Within Riparian Buffers per SSN					
	PHB Option A		PHB Option B		PHB Option C	
	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range
Puget Lowland	-75,402 (32,831)	-401,056 to 0	-37,437 (14,317)	-176,818 to 0	-80,958 (32,839)	-401,056 to 2,585
Coast Range	-10,693 (8,157)	-193,553 to 121,330	9,697 (9,463)	-140,023 to 218,417	-13,829 (7,080)	-197,220 to 95,276
North Cascades	-26,908 (15,868)	-281,617 to 309,126	42,702 (26,829)	-260,554 to 1,043,771	-9,056 (19,653)	-281,617 to 911,390
Cascades	-5,582 (9,037)	-279,159 to 80,211	30,175 (11,527)	-171,196 to 502,120	6,150 (6,843)	-279,159 to 169,238
E. Cascades Foothills			167,434 (54,483)	-70,721 to 2,492,263	1,631 (6,250)	-227,396 to 165,393
Northern Rockies			43,723 (14,241)	-136,690 to 537,669	-813 (5,493)	-179,964 to 137,872
Blue Mountains			116,432 (47,745)	0 to 710,667	-14,816 (22,734)	-225,087 to 140,816

Note:
Negative values indicate that timber value within the riparian buffer decreased under the relevant PHB option. Changes are calculated within-network before being summarized (averaged). Consequently, the mean of those changes is not always equal to the difference between ecoregion means, because sample sets for the DNR-concurred break scenario may differ among comparisons for the various PHB options and ecoregions. For example, means for Option A are only calculated for west side networks and do not include buffers from the DNR-concurred break on the east side of the North Cascades and Cascades ecoregions.

Appendix Table B-22. N-weighted average and total timber values across all species within Type F water buffers

Area	Option	N-Weighted Average Value (USD) of Timber Within Riparian Buffers	N-Weighted Average Change in Value (USD) of Timber Within Riparian Buffers [Percent Change]
Statewide	DNR-Concurred Break	$4,113,588	
	Option A	$3,937,456	-$17,695 [-0.42%]
	Option B	$4,160,512	$27,401 [+0.67%]
	Option C	$4,098,720	-$14,309 [-0.35%]
East	DNR-Concurred Break	$3,181,449	
	Option B	$3,289,643	$64,734 [+2.03%]
	Option C	$3,175,842	-$3,677 [-0.12%]
West	DNR-Concurred Break	$4,494,127	
	Option A	$4,655,495	-$21,249 [-0.47%]
	Option B	$4,516,037	$12,161 [+0.28%]
	Option C	$4,475,478	-$12,161 [-0.41%]

Note:
Weights were calculated based on the number of non-DNR-concurred F/N and S/N breaks in wchydro relative to the total number of F/N and S/N breaks statewide and on each side of the state. Negative values indicate that n-weighted average decreased under the relevant PHB option. Changes are calculated within-network before being summarized (averaged). Due to n-weighting and the fact that sample sets for the DNR-concurred break scenario may differ among comparisons for the various PHB options and ecoregions, the mean of those changes is not always equal to the difference between ecoregion means. For example, means for Option A are only calculated for west side networks and do not include buffers from the DNR-concurred break on the east side of the North Cascades and Cascades ecoregions.

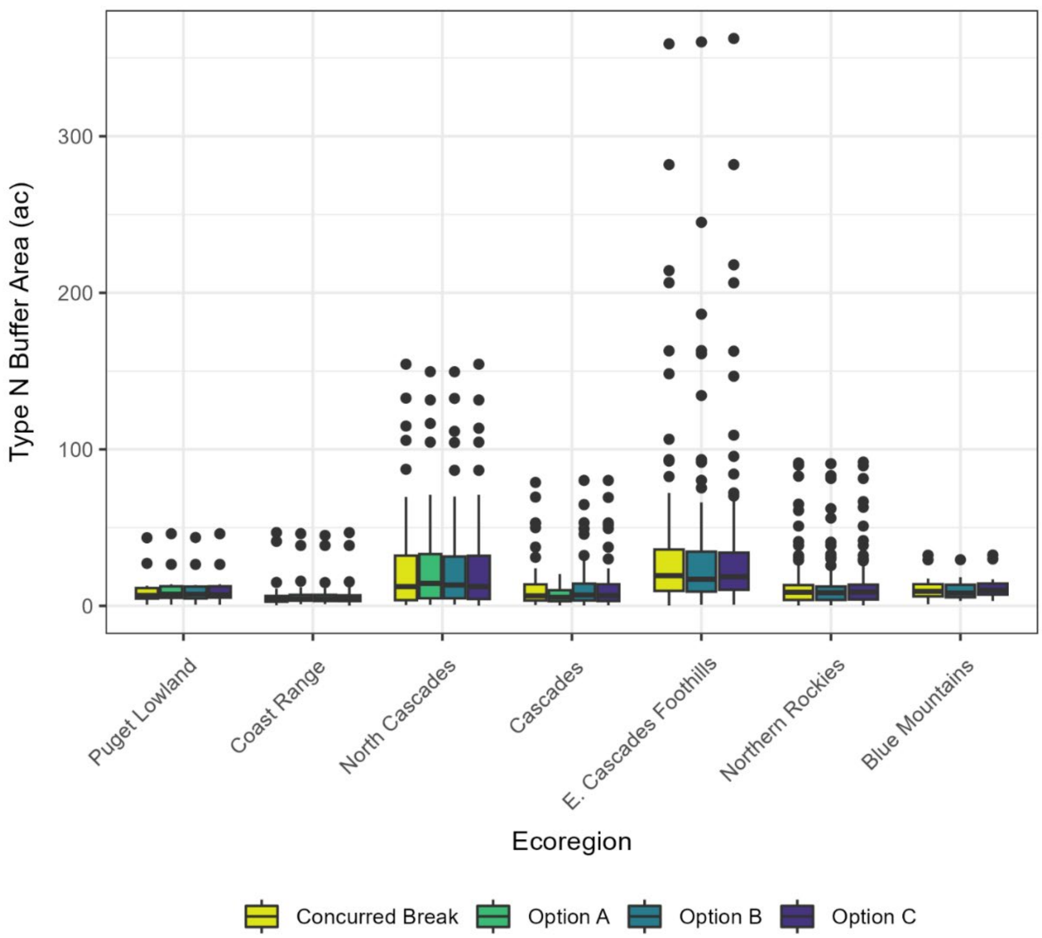
Type Np Riparian Buffer Area

The mean area of Type Np buffer tended to increase or stay approximately the same in ecoregions on the west side of the state and decrease or stay approximately the same on the east side of the state (Appendix Table B-23, Appendix Figure B-21). On the west side, the PHB options had virtually no impact on mean buffer area, with the exception of the Puget Lowland ecoregion, which saw an average increase of 1 acre. On the east side, Option B had a slight decrease in mean buffer area, while Option C had approximately no change in mean buffer area (Appendix Table B-24).

Statewide, the n-weighted average area of Type Np buffer stayed approximately the same under every PHB Option (Appendix Table B-25). On the east side of the state, the n-weighted average buffer area decreased by one acre.

Appendix Table B-23. Type Np riparian buffer area (ac) for each network under the current rule and under each potential habitat break option, summarized by ecoregion

Ecoregion	Buffer Area (ac) per SSN							
	DNR-Concurred F/N Break		PHB Option A		PHB Option B		PHB Option C	
	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range
Puget Lowland	11.1 (3.6)	0.7 to 43.5	11.9 (3.7)	0.7 to 46.1	11.5 (3.5)	0.7 to 43.7	11.8 (3.7)	0.7 to 46.1
Coast Range	6.2 (1.1)	0.4 to 46.8	6.7 (1.1)	1.0 to 46.2	6.5 (1.1)	1.1 to 45.0	6.3 (1.1)	0.2 to 46.8
North Cascades	25.5 (4.6)	0.5 to 154.4	28.1 (5.8)	0.6 to 149.6	26.4 (4.7)	0.8 to 149.6	25.7 (4.5)	0.1 to 154.4
Cascades	12.1 (1.8)	0.5 to 78.9	6.8 (0.8)	0.5 to 20.3	12.1 (1.8)	0.4 to 80.2	11.9 (1.8)	0.4 to 80.2
E. Cascades Foothills	41.4 (7.4)	0.2 to 359.0			38.2 (6.9)	0.7 to 360.3	42.1 (7.5)	0.7 to 362.5
Northern Rockies	15.6 (2.5)	0.2 to 91.3			14.9 (2.4)	0.3 to 90.9	15.8 (2.5)	0.3 to 91.9
Blue Mountains	10.9 (2.1)	1.0 to 32.4			10.3 (1.9)	3.2 to 29.5	12.4 (2.2)	3.2 to 32.5



Appendix Figure B-21. Type Np buffer area for each network

Appendix Table B-24. Change in Type Np riparian buffer area (ac) for each network between the current rule and under each potential habitat break option, summarized by ecoregion

Ecoregion	Change in Buffer Area (ac) per SSN					
	PHB Option A		PHB Option B		PHB Option C	
	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range
Puget Lowland	0.7 (0.3)	-0.7 to 2.6	0.4 (0.1)	-0.7 to 1.4	0.7(0.2)	-0.7 to 2.6
Coast Range	0.1 (0.1)	-2.6 to 1.5	-0.1 (0.1)	-2.6 to 1.4	0.1 (0.1)	-2.7 to 1.7
North Cascades	0.3 (0.2)	-4.8 to 3.0	-0.6 (0.2)	-9.0 to 2.0	0.2 (0.1)	-2.1 to 3.0
Cascades	0.0 (0.1)	-1.6 to 3.3	-0.4 (0.2)	-7.0 to 3.4	-0.2 (0.1)	-2.8 to 3.4
E. Cascades Foothills			-3.7 (1.1)	-49.7 to 3.6	0.1 (0.2)	-6.7 to 5.8
Northern Rockies			-0.9 (0.4)	-18.0 to 4.4	0.2 (0.2)	-2.1 to 6.9
Blue Mountains			-1.8 (0.7)	-11.0 to 0.3	0.3 (0.4)	-1.1 to 3.7

Note:
Negative values indicate that buffer area decreased under the relevant PHB option. Changes are calculated within-network before being summarized (averaged). Consequently, the mean of those changes is not always equal to the difference between ecoregion means, because sample sets for the DNR-concurred break scenario may differ among comparisons for the various PHB options and ecoregions. For example, means for Option A are only calculated for west side networks and do not include buffers from the DNR-concurred break on the east side of the North Cascades and Cascades ecoregions.

Appendix Table B-25. N-weighted average and total area of Type Np buffers

Area	Option	N-Weighted Average Riparian Area per SSN (ac)	N-Weighted Average Change in Riparian Area per SSN (ac) [Percent Change]
Statewide	DNR-Concurred Break	14.2	
	Option A	10.4	0.2 [+0.09%]
	Option B	14.3	-0.5 [-0.23%]
	Option C	14.3	0.2 [+0.09%]
East	DNR-Concurred Break	21.9	
	Option B	21.4	-1.2 [-0.61%]
	Option C	22.1	0.2 [+0.1%]
West	DNR-Concurred Break	11.0	
	Option A	10.8	0.2 [+0.09%]
	Option B	11.3	-0.2 [-0.09%]
	Option C	11.1	0.1 [+0.04%]

Note:
Weights were calculated based on the number of non-DNR-concurred F/N and S/N breaks in wchydro relative to the total number of F/N and S/N breaks statewide and on each side of the state. Negative values indicate that n-weighted average decreased under the relevant PHB option. Changes are calculated within-network before being summarized (averaged). Due to n-weighting and the fact that sample sets for the DNR-concurred break scenario may differ among comparisons for the various PHB options and ecoregions, the mean of those changes is not always equal to the difference between ecoregion means. For example, means for Option A are only calculated for west side networks and do not include buffers from the DNR-concurred break on the east side of the North Cascades and Cascades ecoregions.

Total Volume of Timber Within Type Np Riparian Buffers

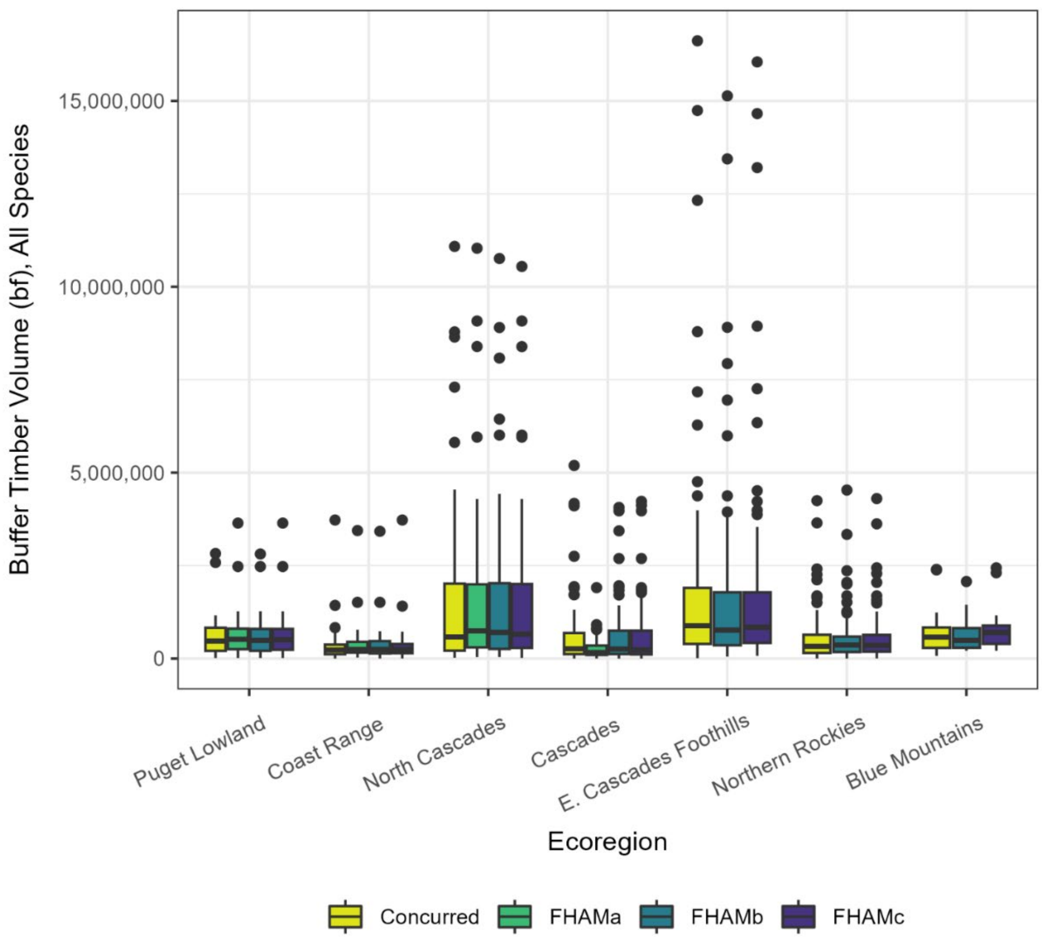
The North Cascades and East Cascades Foothill ecoregions had the greatest overall mean timber volume across PHB options (Appendix Table B-26, Appendix Figure B-22). The mean timber volume within Type Np buffers comparing PHB options to the DNR-concurred break increased under Option A (Appendix Table B-27) but decreased under Option B other than a very slight increase in the Puget Lowland and Coast Range ecoregions. Timber volume increased under Option C in all ecoregions other than within the E. Cascades Foothills and Cascades ecoregions.

Statewide, the n-weighted average timber volume within Type Np buffers increased under all three PHB options, with the greatest increase under Option C (Appendix Table B-28). On the east side of the state, n-weighted average timber volume decreased under Option B and increased under Option C, and on the west side of the state, n-weighted average timber volume decreased under Option A and increased under Options B and C.

Appendix Table B-26. Volume of timber within riparian buffers (MBF, all species) within the Type Np water buffers for each network under the current rule and each potential habitat break option, summarized by ecoregion

Ecoregion	Volume of Timber (MBF) per SSN Within Riparian Buffers							
	DNR-Concurred F/N Break		PHB Option A		PHB Option B		PHB Option C	
	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range
Puget Lowland	805 (272)	15 to 2,826	893 (315)	15 to 3,644	806 (267)	15 to 2,813	884 (316)	15 to 3,644

Ecoregion	Volume of Timber (MBF) per SSN Within Riparian Buffers							
	DNR-Concurred F/N Break		PHB Option A		PHB Option B		PHB Option C	
	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range
Coast Range	349 (73)	0 to 3,726	384 (72)	27 to 3,443	374 (73)	2 to 3,422	357 (72)	2 to 3,726
North Cascades	1,662 (318)	22 to 11,086	1,814 (413)	40 to 11,036	1,709 (325)	40 to 10,760	1,705 (321)	17 to 10,546
Cascades	637 (112)	1 to 5,193	302 (58)	1 to 1,907	625 (102)	0 to 4,065	620 (104)	0 to 4,229
E. Cascades Foothills	1,924 (361)	11 to 16,616			1,751 (321)	52 to 15,134	1,937 (357)	73 to 16,047
Northern Rockies	613 (97)	1 to 4,248			593 (98)	0 to 4,532	628 (99)	4 to 4,303
Blue Mountains	752 (167)	72 to 2,399			677 (136)	209 to 2,072	855 (176)	209 to 2,440



Appendix Figure B-22. Total timber volume within the Type Np buffer for each network

Appendix Table B-27. Change in volume of timber within riparian buffers (MBF, all species) within the Type Np water buffers for each network between the current rule and each potential habitat break option, summarized by ecoregion

Ecoregion	Change in Volume of Timber (MBF) Within Riparian Buffers per SSN					
	PHB Option A		PHB Option B		PHB Option C	
	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range
Puget Lowland	88 (69)	-110 to 818	1 (16)	-110 to 108	79 (70)	-110 to 818
Coast Range	11 (8)	-283 to 129	1 (10)	-304 to 149	9 (6)	-108 to 129
North Cascades	71 (39)	-256 to 1,494	-43 (22)	-643 to 251	42 (34)	-539 to 1,494
Cascades	10 (8)	-77 to 188	-35 (22)	-1,128 to 371	-17 (16)	-963 to 371
E. Cascades Foothills			-197 (70)	-3,580 to 393	-11 (20)	-569 to 572
Northern Rockies			-30 (15)	-465 to 285	14 (8)	-92 to 281
Blue Mountains			-161 (63)	-953 to 0	17 (36)	-183 to 380

Note:
Negative values indicate that timber volume within the riparian buffer decreased under the relevant PHB option. Changes are calculated within-network before being summarized (averaged). Consequently, the mean of those changes is not always equal to the difference between ecoregion means, because sample sets for the DNR-concurred break scenario may differ among comparisons for the various PHB options and ecoregions. For example, means for Option A are only calculated for west side networks and do not include buffers from the DNR-concurred break on the east side of the North Cascades and Cascades ecoregions.

Appendix Table B-28. N-weighted average and total timber volume (MBF) across all species within Type Np buffers

Area	Option	N-Weighted Average Volume (MBF) of Timber Within Riparian Buffers	N-Weighted Average Change in Volume (MBF) of Timber Within Riparian Buffers [Percent Change]
Statewide	DNR-Concurred Break	809	
	Option A	645	3 [+0.37%]
	Option B	815	7 [+0.87%]
	Option C	830	21 [+2.60%]
East	DNR-Concurred Break	1,145	
	Option B	1,122	-23 [-2.01%]
	Option C	1,172	27 [+2.36%]
West	DNR-Concurred Break	672	
	Option A	663	-9 [-1.34%]
	Option B	690	19 [+2.83%]
	Option C	691	19 [+2.83%]

Note:
Weights were calculated based on the number of non-DNR-concurred F/N and S/N breaks in wchydro relative to the total number of F/N and S/N breaks statewide and on each side of the state. Negative values indicate that n-weighted average decreased under the relevant PHB option. Changes are calculated within-network before being summarized (averaged). Due to n-weighting and the fact that sample sets for the DNR-concurred break scenario may differ among comparisons for the various PHB options and ecoregions, the mean of those changes is not always equal to the difference between ecoregion means. For example, means for Option A are only calculated for west side networks and do not include buffers from the DNR-concurred break on the east side of the North Cascades and Cascades ecoregions.

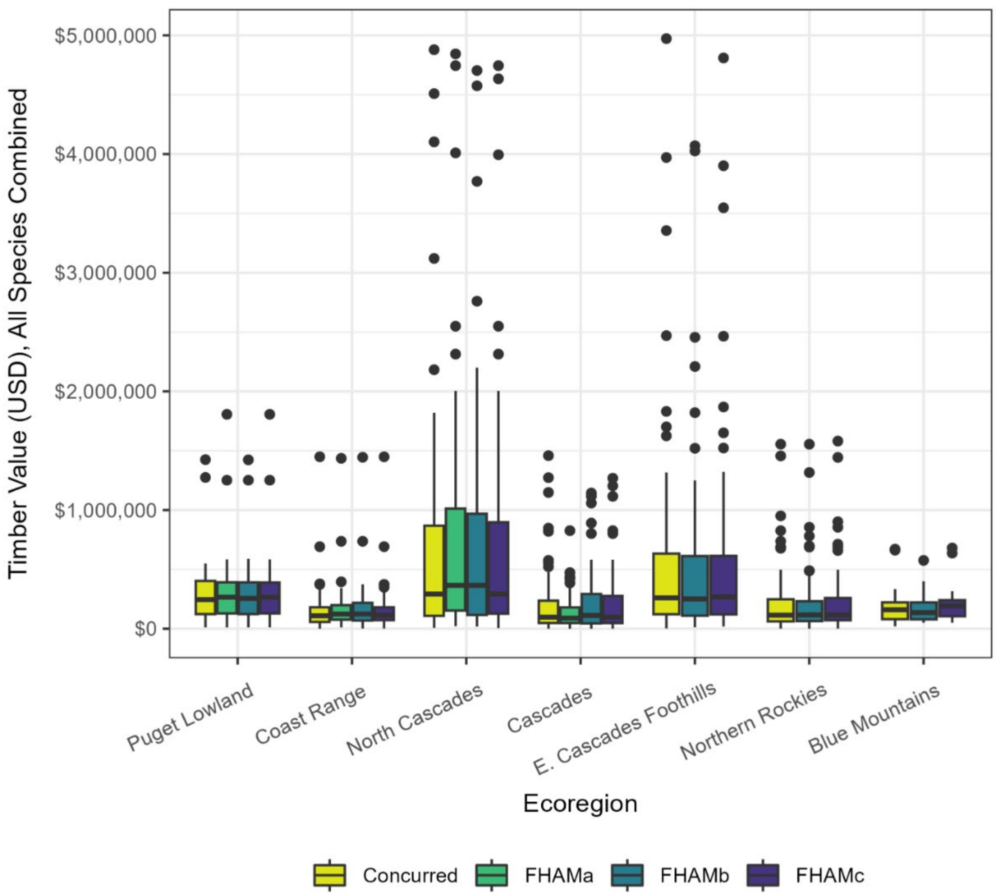
Total Value of Timber Within Type Np Riparian Buffers

The North Cascades and East Cascades Foothill ecoregions had the greatest overall mean Type Np value of timber within riparian buffers across PHB options (Appendix Table B-29, Appendix Figure B-23). The mean value of timber within riparian buffers within Type Np buffers tended to increase in both Options A and C (Appendix Table B-30). Value of timber within riparian buffers under Option B decreased in all ecoregions other than relatively small increases Puget Lowland and Coast Range These changes in timber value reflected the changes in timber volume, as described in Section 3.4.

Statewide, and on both sides of the state, the n-weighted average timber value within Type Np buffers decreased under Option B and increased under Options A and C (Appendix Table B-31).

Appendix Table B-29. Value of timber within riparian buffers (USD, all species) within the Type N water buffers in each network under the current rule and each potential habitat break option, summarized by ecoregion

Ecoregion	Value of Timber (USD) per SSN Within Riparian Buffers							
	DNR-Concurred F/N Break		PHB Option A		PHB Option B		PHB Option C	
	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range
Puget Lowland	$407,942 ($134,451)	$10,907 to $1,425,161	$448,748 ($155,813)	$10,907 to $1,806,818	$408,963 ($133,306)	$10,907 to $1,423,207	$443,897 ($156,293)	$10,907 to $1,806,818
Coast Range	$164,405 ($29,645)	$0 to $1,449,003	$182,663 ($31,307)	$10,746 to $1,435,746	$178,933 ($31,554)	$1,860 to $1,444,656	$168,130 ($29,495)	$1,860 to $1,449,003
North Cascades	$745,079 ($144,571)	$7,267 to $4,879,531	$893,512 ($194,813)	$20,761 to $4,844,435	$765,258 ($147,271)	$17,666 to $4,704,382	$766,343 ($147,216)	$5,763 to $4,745,447
Cascades	$214,952 ($33,154)	$0 to $1,458,554	$153,115 ($27,578)	$248 to $826,326	$212,839 ($30,822)	$0 to $1,143,531	$212,263 ($31,337)	$0 to $1,268,560
E. Cascades Foothills	$565,689 ($101,692)	$2,844 to $4,973,001			$512,526 ($89,455)	$11,933 to $4,070,089	$568,175 ($100,041)	$18,248 to $4,810,075
Northern Rockies	$230,777 ($36,964)	$872 to $1,554,881			$220,787 ($36,051)	$102 to $1,554,675	$237,534 ($37,965)	$996 to $1,581,268
Blue Mountains	$206,193 ($46,637)	$19,381 to $670,724			$185,316 ($37,750)	$50,462 to $575,785	$233,902 ($48,847)	$50,462 to $680,126



Appendix Figure B-23. Total timber value within the Type Np buffer for each network

Appendix Table B-30. Change in value of timber within riparian buffers (USD, all species) within the Type N water buffers in each network between the current rule and each potential habitat break option, summarized by ecoregion

Ecoregion	Change in Value of Timber (USD) Within Riparian Buffers per SSN					
	PHB Option A		PHB Option B		PHB Option C	
	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range
Puget Lowland	40,806 (31,608)	-29,706 to 381,657	1,021 (5,016)	-29,706 to 38,934	35,954 (32,356)	-49,584 to 381,657
Coast Range	6,465 (3,201)	-75,126 to 63,589	2,735 (4,100)	-76,515 to 63,589	3,725 (3,067)	-75,126 to 63,589
North Cascades	39,002 (17,888)	-92,399 to 653,806	-20,547 (10,416)	-332,578 to 95,788	21,265 (14,907)	-245,290 to 653,806
Cascades	6,114 (4,571)	-35,822 to 117,673	-9,103 (6,578)	-315,023 to 114,078	-2,689 (5,141)	-255,087 to 117,673
E. Cascades Foothills			-60,220 (20,339)	-946,907 to 99,030	-4,572 (6,573)	-180,445 to 168,759
Northern Rockies			-13,648 (6,415)	-189,801 to 142,214	6,770 (3,555)	-33,807 to 142,214
Blue Mountains			-44,481 (17,864)	-270,809 to 5,320	4,106 (9,849)	-50,622 to 101,480

Note:
Negative values indicate that timber value within the riparian buffer decreased under the relevant PHB option. Changes are calculated within-network before being summarized (averaged). Consequently, the mean of those changes is not always equal

to the difference between ecoregion means, because sample sets for the DNR-concurred break scenario may differ among comparisons for the various PHB options and ecoregions. For example, means for Option A are only calculated for west side networks and do not include buffers from the DNR-concurred break on the east side of the North Cascades and Cascades ecoregions.

Appendix Table B-31. N-weighted average and change in total timber values across all species within Type Np buffers

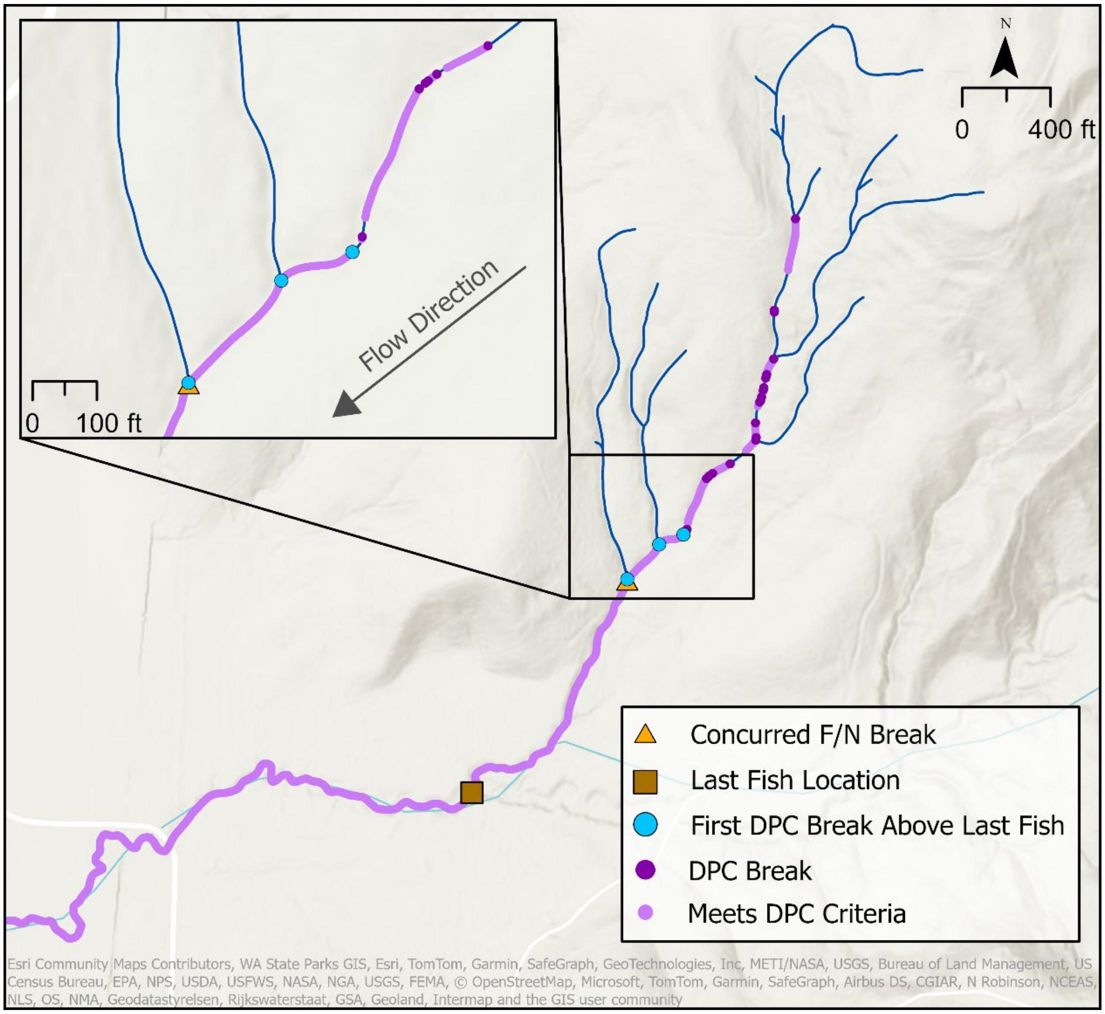
Area	Option	N-Weighted Average Value (USD) of Timber Within Riparian Buffers	N-Weighted Average Change in Value (USD) of Timber Within Riparian Buffers [Percent Change]
Statewide	DNR-Concurred Break	$339,727	
	Option A	$316,960	$15,287 [+4.5%]
	Option B	$345,222	-$9,396 [-2.77%]
	Option C	$350,037	$9,568 [+2.82%]
East	DNR-Concurred Break	$440,714	
	Option B	$434,151	-$24,169 [-5.48%]
	Option C	$452,426	$9,154 [+2.08%]
West	DNR-Concurred Break	$298,501	
	Option A	$325,228	$16,253 [+5.44%]
	Option B	$308,918	-$3,365 [-1.13%]
	Option C	$308,238	$9,737 [+3.26%]

Note:
Weights were calculated based on the number of non-DNR-concurred F/N and S/N breaks in wchydro relative to the total number of F/N and S/N breaks statewide and on each side of the state. Negative values indicate that n-weighted average decreased under the relevant PHB option. Changes are calculated within-network before being summarized (averaged). Due to n-weighting and the fact that sample sets for the DNR-concurred break scenario may differ among comparisons for the various PHB options and ecoregions, the mean of those changes is not always equal to the difference between ecoregion means. For example, means for Option A are only calculated for west side networks and do not include buffers from the DNR-concurred break on the east side of the North Cascades and Cascades ecoregions.

APPENDIX C Additional Results

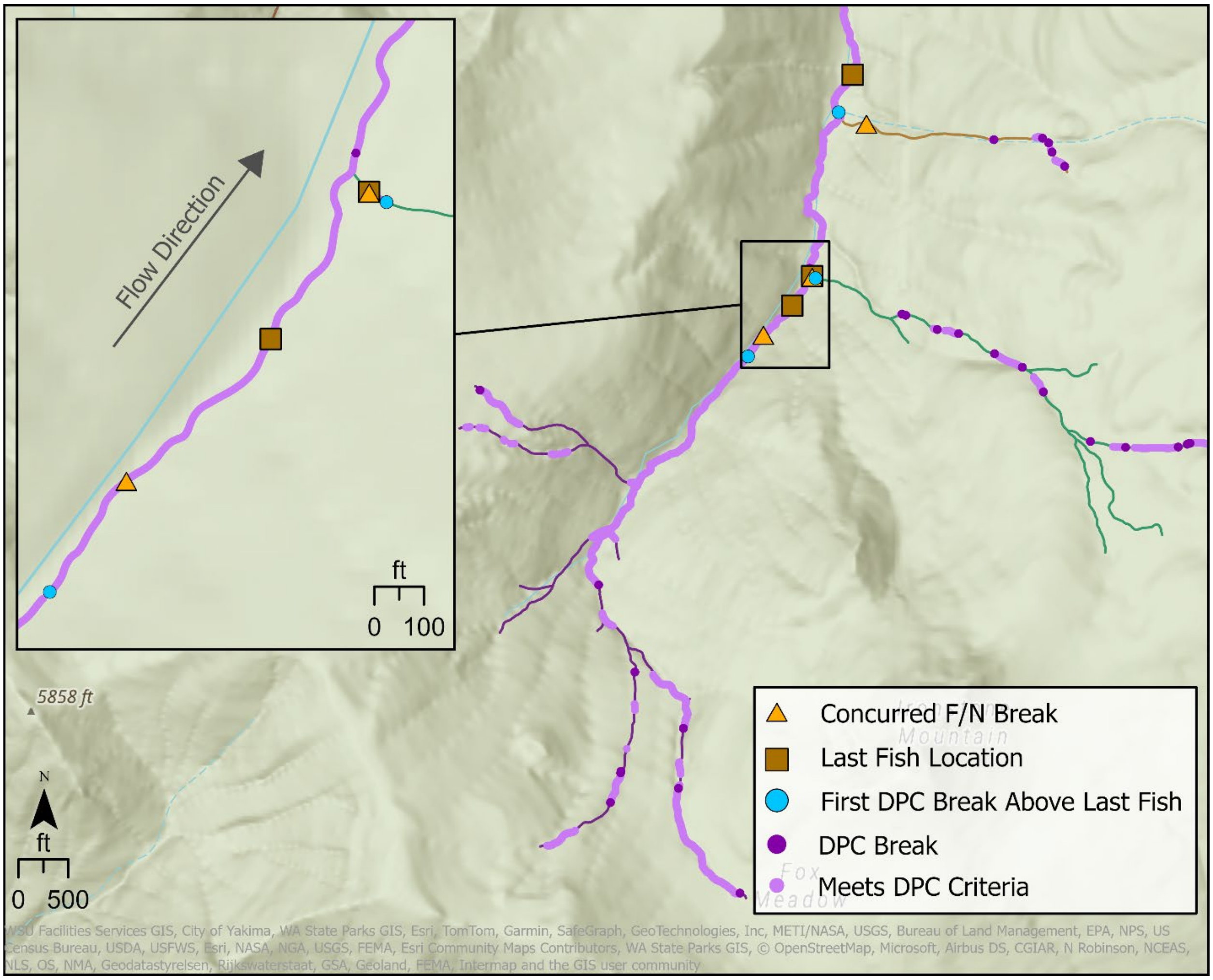
DPC Break Figures

Default Physical Characteristics (DPC) were calculated for all waters upstream of the DNR-concurred F/N break and downstream from the break to the bottom of the subwatershed. Breaks in the extent of water meeting DPC occurred in a variety of positions; most of these breaks did not indicate the upstream extent of water meeting DPC (see Section 3.2.5 for more results). The first break in DPC did occur upstream of the concurred break, and in some cases stretches meeting DPC could extend substantially further upstream of the concurred break on the mainstem (Appendix Figure C-1).

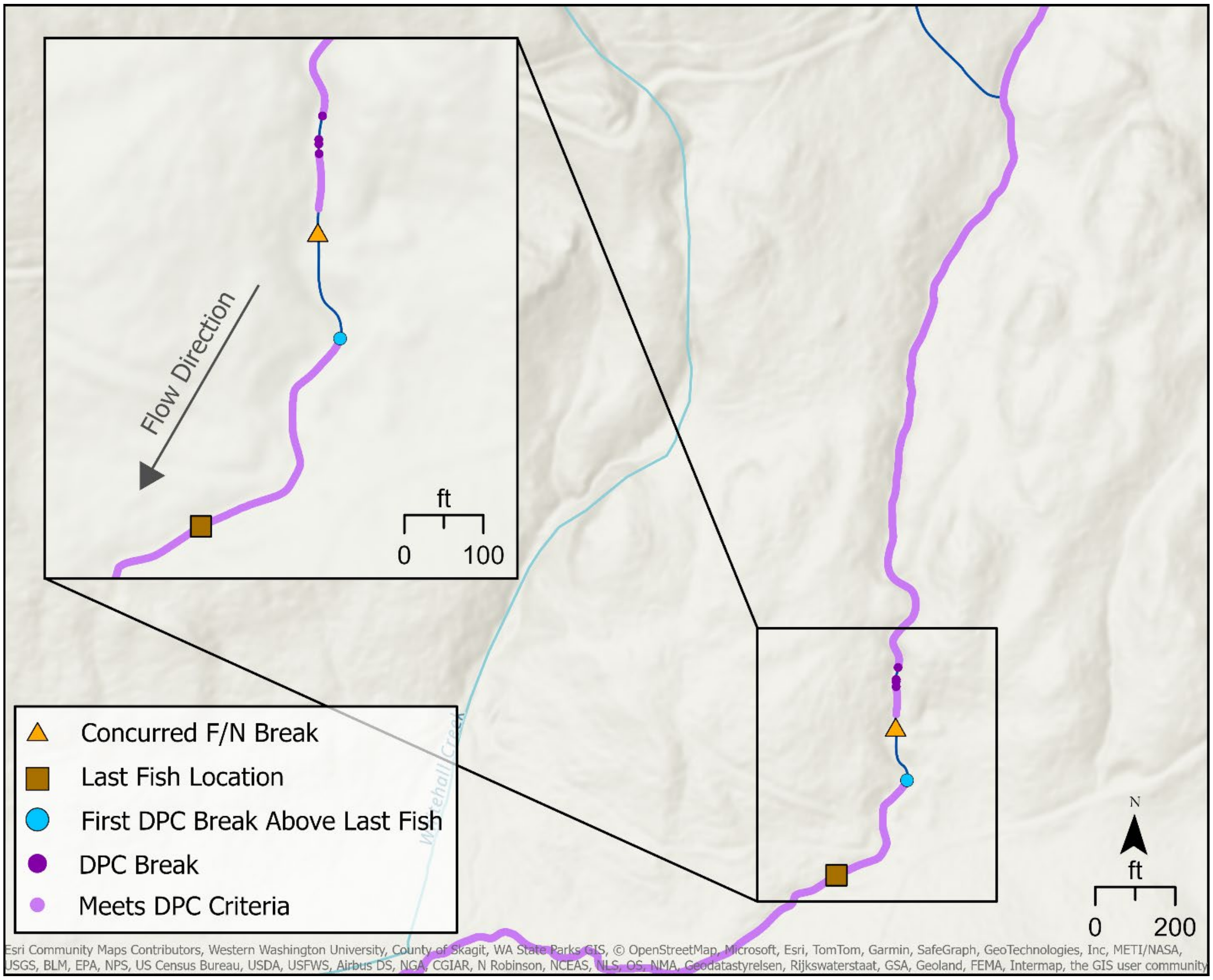


Appendix Figure C-1. Example of stream reaches meeting DPC criteria throughout a SSN, with the first break in DPC upstream of the DNR-concurred F/N break

Streams meeting DPC could occur above the first break in DPC even when that DPC break occurred downstream of the DNR-concurred break. In some cases, extensive reaches meeting DPC occurred upstream of large downstream reaches that did not meet DPC (Appendix Figure C-2, Appendix Figure C-3).

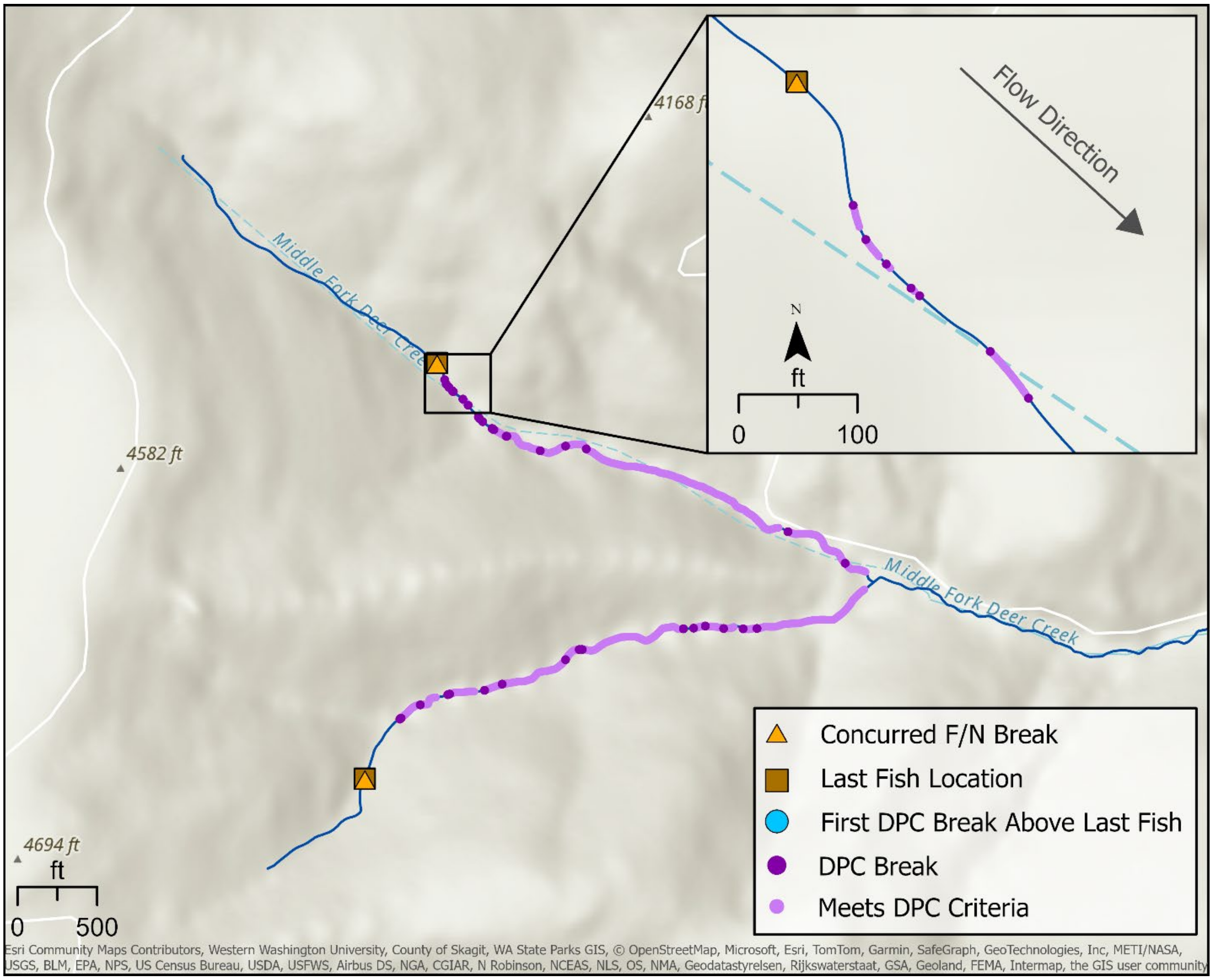


Appendix Figure C-2. Example of stream reaches meeting DPC criteria throughout three overlapping SSNs, regardless of whether the first break in DPC above the last fish for that network is upstream or downstream of its concurred break



Appendix Figure C-3. Example of extensive stream reaches meeting DPC criteria upstream of the first break in DPC above the last fish point

However, only considering breaks in DPC above the last fish point could result in no breaks being detected in a network (Appendix Figure C-4). In some cases, this was because the entire stream above the last fish point did not meet the DPC criteria. In other cases, the upstream extent of stream above last fish was smaller than the reach over which DPC was calculated.



Appendix Figure C-4. Example of SSNs with no stretches of stream meeting DPC criteria upstream of the last fish location

5x BFW Additional Buffer Results

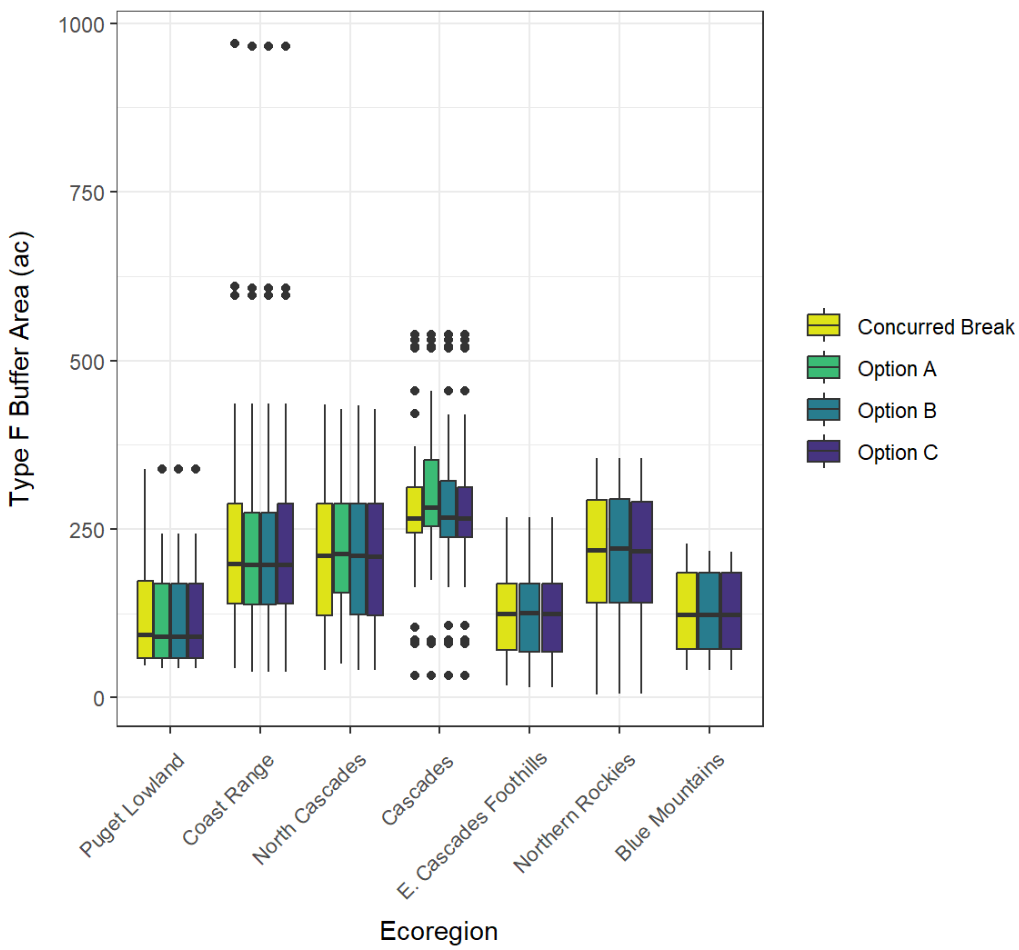
Buffer Analysis: Type F

Type F Riparian Buffer Area

Type F riparian buffer area per SSN was greatest in the Cascades ecoregion for all three options (Appendix Table C-1, Appendix Figure C-5), and decreased somewhat in almost all ecoregions for all three PHB options relative to the DNR-concurred break (Appendix Table C-2). Statewide, buffer area was highest for the DNR-concurred break and lowest under Option A, and buffer area was lower on the east side than on the west side (Appendix Table C-3).

Appendix Table C-1. Total network Type F riparian buffer area (ac) mean, standard error, and range by ecoregion and PHB option

Ecoregion	Buffer Area (ac)							
	DNR-Concurred Break		Option A		Option B		Option C	
	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range
Puget Lowland	130.1 (26.6)	47.7 to 339.5	127.7 (26.6)	43.6 to 339.1	127.7 (26.6)	43.6 to 339.1	127.7 (26.6)	43.6 to 339.1
Coast Range	237.5 (21.3)	44.1 to 970.1	233.3 (22.6)	38.4 to 965.3	233.4 (22.6)	38.5 to 965.3	236.7 (21.5)	38.4 to 965.3
North Cascades	205.2 (13.1)	40.5 to 435.2	216.2 (15.4)	50 to 428.3	204.6 (13.4)	40.5 to 433.3	203.8 (13.0)	40.5 to 428.3
Cascades	274.8 (10.6)	33.6 to 537.8	307.6 (18.0)	33.1 to 538	275.1 (11.2)	33.1 to 538.3	274.4 (10.7)	33.1 to 538
E. Cascades Foothills	124.4 (7.6)	17.9 to 267.4			125.0 (7.5)	16.1 to 267.4	123.4 (7.5)	16.1 to 267.4
Northern Rockies	212.7 (11.3)	5.2 to 355.7			213.7 (11.6)	5.4 to 355.8	211.7 (11.3)	5.4 to 355.8
Blue Mountains	134.5 (15.0)	41.1 to 228.9			132.5 (14.7)	41.1 to 218.2	132.1 (14.6)	41.1 to 216.1



Appendix Figure C-5. Type F riparian buffer area (ac) for each network

Appendix Table C-2. Change in total network Type F riparian buffer area (ac) mean, standard error, and range by ecoregion and PHB option

Ecoregion	Total Buffer Area Change (ac)					
	Option A		Option B		Option C	
	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range
Puget Lowland	-2.4 (0.7)	-8.5 to 0	-2.4 (0.7)	-8.5 to 0	-2.4 (0.7)	-8.5 to 0
Coast Range	-0.8 (0.3)	-7.8 to 3.6	-0.7 (0.3)	-6.8 to 3.6	-0.8 (0.2)	-7.8 to 0.4
North Cascades	-2.0 (0.5)	-12.2 to 0.6	-1.2 (0.3)	-8.7 to 2.4	-1.4 (0.3)	-8.7 to 0.9
Cascades	-0.5 (0.3)	-9.8 to 1.4	-0.3 (0.2)	-9.7 to 4.9	-0.4 (0.2)	-9.8 to 2.1
E. Cascades Foothills			0.6 (0.9)	-10.5 to 56.1	-1.0 (0.3)	-10.9 to 2.1
Northern Rockies			-0.9 (0.4)	-18.2 to 1.7	-1.0 (0.4)	-18.4 to 0.9
Blue Mountains			-2.0 (1)	-13.3 to 0.4	-2.4 (1.1)	-13.7 to 0.3

Note:
Negative values indicate that buffer area decreased under the relevant PHB option. Changes are calculated within-network before being summarized (averaged). Consequently, the mean of those changes is not always equal to the difference between ecoregion means, because sample sets for the DNR-concurred break scenario may differ among comparisons for the various PHB options and ecoregions. For example, means for Option A are only calculated for west side networks and do not include buffers from the DNR-concurred break on the east side of the North Cascades and Cascades ecoregions.

Appendix Table C-3. N-weighted network riparian Type F buffer area (ac) and n-weighted average change in buffer area between the DNR-concurred break and each PHB option

State Side	PHB Option	N-Weighted Average Buffer Area (ac)	N-Weighted Average Change from DNR-concurred Break (ac) [Percent Change]
Statewide	DNR-Concurred	216.4	-
Statewide	Option A	188.5	-1.0 [-0.46%]
Statewide	Option B	214.6	-0.9 [-0.42%]
Statewide	Option C	215.2	-1.1 [-0.51%]
East	DNR-Concurred	196.2	-
East	Option B	196.4	-0.8 [-0.41%]
East	Option C	195.0	-1.2 [-0.61%]
West	DNR-Concurred	224.6	-
West	Option A	229.9	-1.2 [-0.53%]
West	Option B	222.0	-0.9 [-0.40%]
West	Option C	223.5	-1.10 [-0.45%]

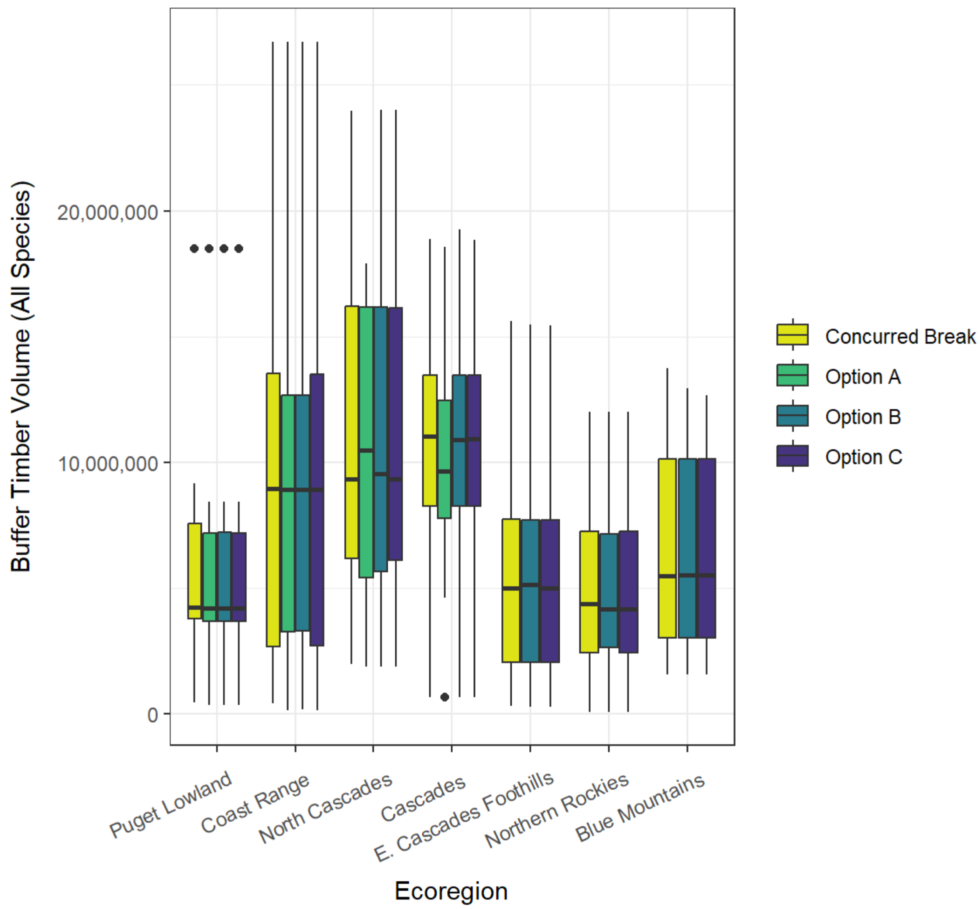
Note:
Weights were calculated based on the number of non-DNR-concurred F/N and S/N breaks in wchydro relative to the total number of F/N and S/N breaks statewide and on each side of the state. Negative values indicate that n-weighted average decreased under the relevant PHB option. Changes are calculated within-network before being summarized (averaged). Due to n-weighting and the fact that sample sets for the DNR-concurred break scenario may differ among comparisons for the various PHB options and ecoregions, the mean of those changes is not always equal to the difference between ecoregion means. For example, means for Option A are only calculated for west side networks and do not include buffers from the DNR-concurred break on the east side of the North Cascades and Cascades ecoregions.

Total Volume of Timber Within Type F Riparian Buffers

Volume of timber within riparian buffers within Type F buffers per SSN was greatest in the Cascades or North Cascades ecoregion for all three options (Appendix Table C-4,Appendix Figure C-6), and decreased in all ecoregions for all three PHB options relative to the DNR-concurred break except for Option B in the E. Cascades Foothills (Appendix Table C-5). Statewide, volume of timber within riparian buffers decreased the most under Option A, and with overall volume lower on the east side than on the west side (Appendix Table C-6).

Appendix Table C-4. Volume of timber within riparian buffers (MBF) within Type F buffers per SSN, summarized by ecoregion

Ecoregion	Volume of Timber (MBF) per SSN Within Riparian Buffers							
	DNR-Concurred F/N Break		PHB Option A		PHB Option B		PHB Option C	
	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range
Puget Lowland	5,912 (1,341)	466 to 18,510	5,751 (1,333)	349 to 18,480	5,754 (1,334)	349 to 18,480	5,751 (1,333)	349 to 18,480
Coast Range	9,524 (966)	441 to 26,725	9,391 (965)	164 to 26,725	9,395 (966)	173 to 26,725	9,480 (967)	164 to 26,725
North Cascades	10,754 (751)	1,975 to 23,980	10,539 (837)	1,903 to 17,911	10,823 (791)	1,903 to 24,020	10,666 (752)	1,903 to 23,992
Cascades	11,112 (450)	668 to 18,844	10,202 (623)	665 to 18,554	11,104 (471)	665 to 19,258	11,087 (451)	665 to 18,844
E. Cascades Foothills	5,389 (416)	339 to 15,631			5,412 (410)	279 to 15,472	5,338 (412)	279 to 15,438
Northern Rockies	5,106 (410)	86 to 12,014			5,110 (415)	86 to 11,998	5,072 (410)	86 to 11,998
Blue Mountains	6,973 (1,002)	1,576 to 13,741			6,820 (972)	1,576 to 12,957	6,788 (961)	1,576 to 12,682



Appendix Figure C-6. Total timber volume within the Type F riparian buffer for each network

Appendix Table C-5. Change in volume of timber within riparian buffers (MBF) within Type F buffers per SSN, summarized by ecoregion

Ecoregion	Change in Volume of Timber (MBF) Within Riparian Buffers per SSN					
	PHB Option A		PHB Option B		PHB Option C	
	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range
Puget Lowland	-160 (63)	-732 to 0	-158 (62)	-732 to 0	-160 (63)	-732 to 0
Coast Range	-43 (14)	-381 to 174	-39 (14)	-379 to 174	-44 (12)	-381 to 32
North Cascades	-116 (25)	-554 to 61	-80 (19)	-509 to 61	-88 (20)	-554 to 61
Cascades	-28 (17)	-555 to 78	-13 (15)	-625 to 414	-25 (13)	-625 to 195
E. Cascades Foothills			23 (41)	-641 to 2,108	-51 (16)	-676 to 147
Northern Rockies			-31 (12)	-560 to 84	-34 (12)	-560 to 65
Blue Mountains			-153 (76)	-948 to 28	-185 (88)	-1,059 to 28

Note:
Negative values indicate that timber volume within the riparian buffer decreased under the relevant PHB option. Changes are calculated within-network before being summarized (averaged). Consequently, the mean of those changes is not always equal to the difference between ecoregion means, because sample sets for the DNR-concurred break scenario may differ among comparisons for the various PHB options and ecoregions. For example, means for Option A are only calculated for west side networks and do not include buffers from the DNR-concurred break on the east side of the North Cascades and Cascades ecoregions.

Appendix Table C-6. N-weighted average of ecoregion-average network Type F volume of timber within riparian buffers (MBF) and ecoregion-average change in Type F volume of timber within riparian buffers between the DNR-concurred network and each PHB option.

State Side	PHB Option	N-Weighted Average Timber Volume (MBF)	N-Weighted Average Timber Volume Change (MBF) [Percent Change]
Statewide	DNR-Concurred	8,909	
Statewide	Option A	7,697	-245 [-0.27]
Statewide	Option B	8,857	-52 [-0.58%]
Statewide	Option C	8,846	-63 [-0.71%]
East	DNR-Concurred	7,429	
East	Option B	7,446	16 [+0.18%]
East	Option C	7,366	-63 [-0.71%]
West	DNR-Concurred	9,513	
West	Option A	9,218	-295 [-3.31%]
West	Option B	9,434	-79 [-0.89%]
West	Option C	9,450	-63 [-0.71%]

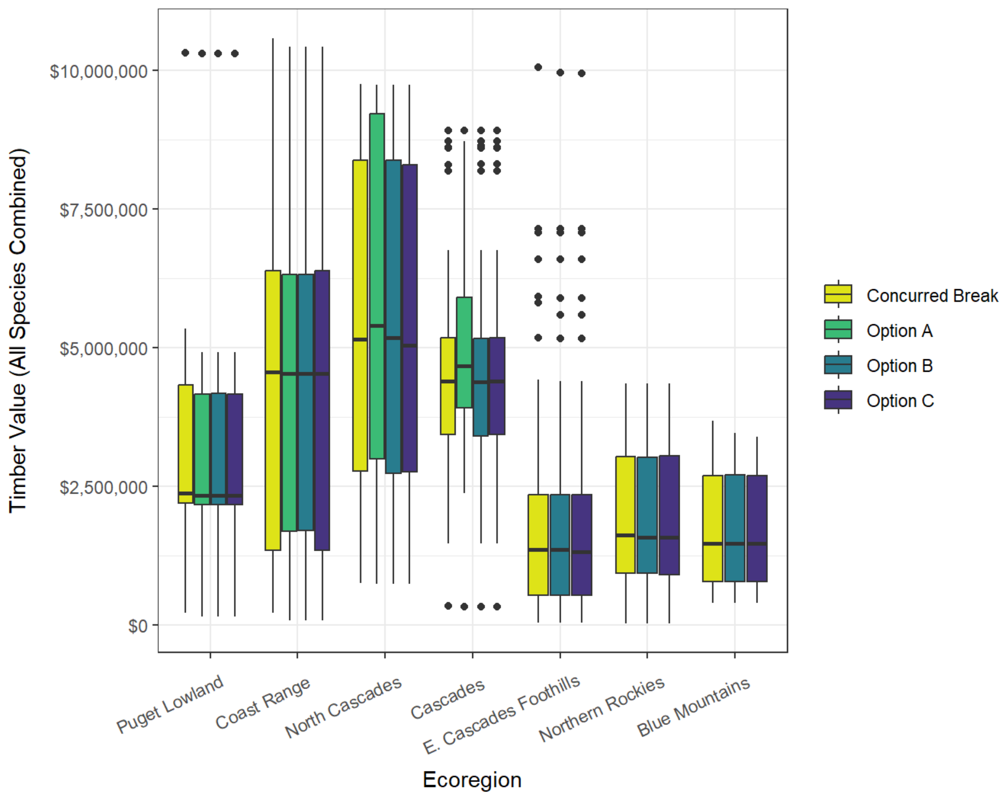
Note:
Weights were calculated based on the number of non-DNR-concurred F/N and S/N breaks in wchydro relative to the total number of F/N and S/N breaks statewide and on each side of the state. Negative values indicate that n-weighted average decreased under the relevant PHB option. Changes are calculated within-network before being summarized (averaged). Due to n-weighting and the fact that sample sets for the DNR-concurred break scenario may differ among comparisons for the various PHB options and ecoregions, the mean of those changes is not always equal to the difference between ecoregion means. For example, means for Option A are only calculated for west side networks and do not include buffers from the DNR-concurred break on the east side of the North Cascades and Cascades ecoregions.

Total Value of Timber Within Type F Riparian Buffers

Total value of timber within riparian buffers per SSN was greatest in the North Cascades ecoregion for all three options (Appendix Table C-7,Appendix Figure C-7), and decreased in all ecoregions for all three PHB options relative to the DNR-concurred break (Appendix Table C-8). Statewide, value of timber within riparian buffers was lowest under Option A, and with overall value lower on the east side than on the west side (Appendix Table C-9).

Appendix Table C-7. Value of timber within riparian buffers (USD) within Type F buffers per SSN, summarized by ecoregion

Ecoregion	Change in Value of Timber (USD) Within Riparian Buffers per SSN							
	DNR-Concurred Break		PHB Option A		PHB Option B		PHB Option C	
	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range
Puget Lowland	$3,332,043 ($753,577)	$220,225 to $10,318,700	$3,245,455 ($748,537)	$152,008 to $10,306,188	$3,246,224 ($748,587)	$152,008 to $10,306,188	$3,245,455 ($748,537)	$152,008 to $10,306,188
Coast Range	$4,552,178 ($413,411)	$218,766 to $10,583,836	$4,517,429 ($418,063)	$79,808 to $10,425,848	$4,519,279 ($418,003)	$84,402 to $10,425,848	$4,529,682 ($413,481)	$79,808 to $10,425,848
North Cascades	$5,369,360 ($392,725)	$751,610 to $9,752,757	$5,851,874 ($479,186)	$742,084 to $9,742,146	$5,439,630 ($411,206)	$742,084 to $9,742,146	$5,328,472 ($393,395)	$742,084 to $9,742,146
Cascades	$4,463,705 ($200,066)	$340,391 to $8,915,459	$5,009,154 ($312,706)	$338,793 to $8,920,178	$4,455,387 ($208,611)	$338,793 to $8,921,597	$4,452,754 ($200,543)	$338,793 to $8,920,178
E. Cascades Foothills	$1,964,437 ($232,445)	$45,823 to $10,051,289			$1,968,341 ($229,997)	$37,894 to $9,963,941	$1,947,570 ($230,761)	$37,894 to $9,940,341
Northern Rockies	$1,930,625 ($159,168)	$31,457 to $4,357,623			$1,931,106 ($161,204)	$31,457 to $4,357,623	$1,918,120 ($159,515)	$31,457 to $4,357,623
Blue Mountains	$1,854,615 ($269,751)	$405,381 to $3,678,095			$1,813,022 ($261,496)	$405,381 to $3,462,656	$1,804,352 ($258,384)	$405,381 to $3,388,363



Appendix Figure C-7. Total price of timber within the Type F riparian buffer for each network

Appendix Table C-8. Change in value of timber within riparian buffers (USD) within Type F buffers per SSN, summarized by ecoregion

Ecoregion	Change in Value of Timber (USD) Within Riparian Buffers per SSN					
	PHB Option A		PHB Option B		PHB Option C	
	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range
Puget Lowland	-$86,588 ($34,760)	-$421,561 to $0	-$85,818 ($34,582)	-$421,561 to $0	-$86,588 ($34,760)	-$421,561 to $0
Coast Range	-$21,842 ($7,191)	-$199,330 to $88,350	-$19,992 ($7,240)	-$197,860 to $88,350	-$22,496 ($6,314)	-$199,330 to $18,176
North Cascades	-$56,658 ($12,292)	-$283,492 to $33,630	-$36,421 ($8,289)	-$222,985 to $33,630	-$40,888 ($9,202)	-$283,492 to $33,630
Cascades	-$14,207 ($8,769)	-$279,159 to $46,504	-$6,924 ($5,975)	-$279,159 to $128,783	-$10,951 ($5,275)	-$279,159 to $53,800
E. Cascades Foothills			$3,903 ($11,689)	-$220,031 to $551,982	-$16,868 ($5,278)	-$227,396 to $41,613
Northern Rockies			-$8,356 ($5,117)	-$196,690 to $124,964	-$12,505 ($4,297)	-$196,690 to $26,361
Blue Mountains			-$41,592 ($20,695)	-$258,460 to $8,183	-$50,263 ($24,048)	-$289,732 to $8,183

Note:
Negative values indicate that timber value within the riparian buffer decreased under the relevant PHB option. Changes are calculated within-network before being summarized (averaged). Consequently, the mean of those changes is not always equal to the difference between ecoregion means, because sample sets for the DNR-concurred break scenario may differ among comparisons for the various PHB options and ecoregions. For example, means for Option A are only calculated for west side networks and do not include buffers from the DNR-concurred break on the east side of the North Cascades and Cascades ecoregions.

Appendix Table C-9. N-weighted average of ecoregion-average network price of Type F riparian timber (USD) and ecoregion-average change in price of riparian timber between the DNR-concurred network and each PHB option.

State Side	PHB Option	N-Weighted Average Timber Value (USD)	N-Weighted Average Change in Timber Value (USD) [Percent Change]
Statewide	DNR-Concurred	$4,113,588	
Statewide	Option A	$3,924,884	-$30,267 [-0.74%]
Statewide	Option B	$4,105,586	-$25,939 [-0.63%]
Statewide	Option C	$4,083,632	-$29,957 [-0.72%]
East	DNR-Concurred	$3,181,449	
East	Option B	$3,201,595	-$17,844 [-0.43%]
East	Option C	$3,156,742	-$24,707 [0.60%]
West	DNR-Concurred	$4,494,127	
West	Option A	$4,641,904	-$34,839 [-0.85%]
West	Option B	$4,474,633	-$29,244 [-0.71%]
West	Option C	$4,462,027	-$32,100 [-0.78%]

Note:
Weights were calculated based on the number of non-DNR-concurred F/N and S/N breaks in wchydro relative to the total number of F/N and S/N breaks statewide and on each side of the state. Negative values indicate that n-weighted average decreased under the relevant PHB option. Changes are calculated within-network before being summarized (averaged). Due to n-weighting and the fact that sample sets for the DNR-concurred break scenario may differ among comparisons for the various PHB options and ecoregions, the mean of those changes is not always equal to the difference between ecoregion means. For example, means for Option A are only calculated for west side networks and do not include buffers from the DNR-concurred break on the east side of the North Cascades and Cascades ecoregions.

Buffer Analysis: Type N

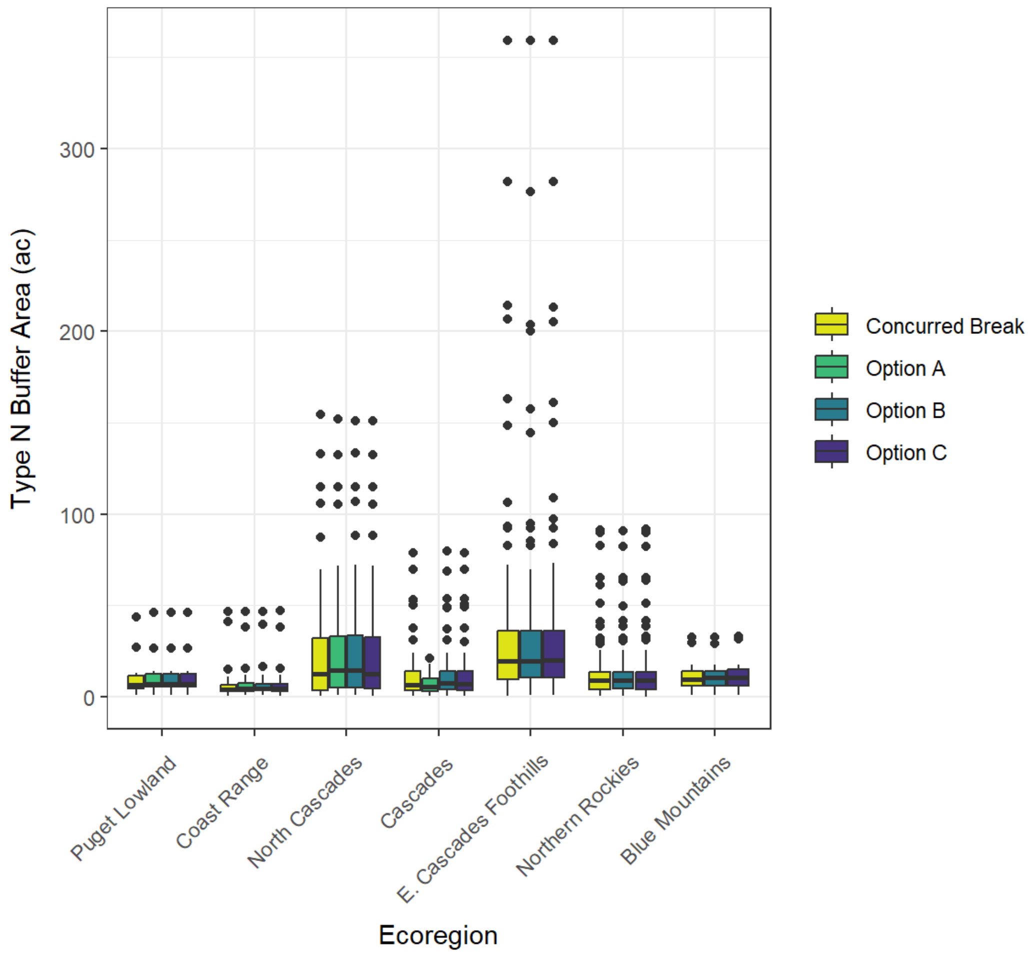
Type Np Riparian Buffer Area

Type Np riparian buffer area per SSN was lowest for the DNR-concurred break among almost all ecoregions, with the highest Type Np buffer areas in the E. Cascades Foothills ecoregion (Appendix Table C-10,Appendix Figure C-8). With the exception of Option B in the E. Cascades Foothills, on average Type Np buffer area increased slightly (by less than an acre) for all PHB options when compared to the DNR-concurred break (Appendix Table C-11). Np buffer areas were higher on the east side of the state than on the west side, but within-network change was low and relatively similar for both sides of the state and statewide (Appendix Table C-12).

Appendix Table C-10. Total network Type N riparian buffer area (ac) mean, standard error, and range by ecoregion and PHB option

Ecoregion	Buffer Area (ac)							
	DNR-Concurred Break		Option A		Option B		Option C	
	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range
Puget Lowland	11.1 (3.6)	0.7 to 43.5	11.7 (3.7)	0.7 to 46	11.7 (3.7)	0.7 to 46	11.7 (3.7)	0.7 to 46
Coast Range	6.2 (1.1)	0.4 to 46.8	6.7 (1.1)	1.1 to 46.6	6.8 (1.1)	1.1 to 46.5	6.4 (1.1)	0.4 to 46.9
North Cascades	25.5 (4.6)	0.5 to 154.4	28.2 (5.8)	0.8 to 152	27.2 (4.7)	0.8 to 151.1	25.8 (4.5)	0.6 to 151.1
Cascades	12.1 (1.8)	0.5 to 78.9	6.9 (0.8)	0.5 to 20.9	12.6 (1.8)	0.2 to 79.7	12.2 (1.7)	0.6 to 78.5

Ecoregion	Buffer Area (ac)							
	DNR-Concurred Break		Option A		Option B		Option C	
	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range
E. Cascades Foothills	41.4 (7.3)	0.2 to 359			41.1 (7.2)	0.8 to 359.3	41.9 (7.3)	0.8 to 359
Northern Rockies	15.6 (2.5)	0.2 to 91.3			16.2 (2.6)	0.2 to 91	15.8 (2.5)	0.2 to 91.9
Blue Mountains	10.9 (2.1)	1 to 32.4			11.4 (2.1)	0.8 to 32.5	11.7 (2.2)	0.8 to 32.9



Appendix Figure C-8. Type Np riparian buffer area (ac) for each network

Appendix Table C-11. Change in total network Type N riparian buffer area (ac) mean, standard error, and range by ecoregion and PHB option

Ecoregion	Total Buffer Area Change (ac)					
	Option A		Option B		Option C	
	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range
Puget Lowland	0.6 (0.2)	-0.7 to 2.5	0.5 (0.2)	-0.7 to 2.4	0.6 (0.2)	-0.7 to 2.5
Coast Range	0.1 (0.1)	-3 to 1.9	0.2 (0.1)	-1.9 to 1.6	0.2 (0.1)	-3 to 2.2
North Cascades	0.4 (0.2)	-2.4 to 3.6	0.3 (0.1)	-3.3 to 3.2	0.3 (0.1)	-3.3 to 3.6

Ecoregion	Total Buffer Area Change (ac)					
	Option A		Option B		Option C	
	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range
Cascades	0.1 (0.1)	-0.5 to 3.2	0.1 (0.1)	-4.2 to 3.3	0.1 (0.1)	-2.8 to 3.3
E. Cascades Foothills			-0.3 (0.4)	-21.1 to 5.9	0.5 (0.2)	-2.8 to 6.1
Northern Rockies			0.4 (0.1)	-1.3 to 6.2	0.4 (0.1)	-0.5 to 6.4
Blue Mountains			0.5 (0.4)	-0.3 to 5	0.8 (0.4)	-0.3 to 5

Note:
Negative values indicate that buffer area decreased under the relevant PHB option. Changes are calculated within-network before being summarized (averaged). Consequently, the mean of those changes is not always equal to the difference between ecoregion means, because sample sets for the DNR-concurred break scenario may differ among comparisons for the various PHB options and ecoregions. For example, means for Option A are only calculated for west side networks and do not include buffers from the DNR-concurred break on the east side of the North Cascades and Cascades ecoregions.

Appendix Table C-12. N-weighted network riparian Type F buffer area (ac) and n-weighted average change in buffer area between the DNR-concurred break and each PHB option

State Side	PHB Option	N-Weighted Average Buffer Area (ac)	N-Weighted Average Change from DNR-concurred Break (ac) [Percent Change]
Statewide	DNR-Concurred	14.0	
Statewide	Option A	10.4	0.2 [+1.43%]
Statewide	Option B	14.9	0.2 [+1.43%]
Statewide	Option C	14.4	0.3 [+2.14%]
East	DNR-Concurred	21.9	
East	Option B	22.7	0.3 [+2.14%]
East	Option C	22.2	0.4 [+1.85%]
West	DNR-Concurred	11.0	
West	Option A	10.8	0.2 [+1.43%]
West	Option B	11.7	0.2 [+1.84%]
West	Option C	11.2	0.3 [+2.76%]

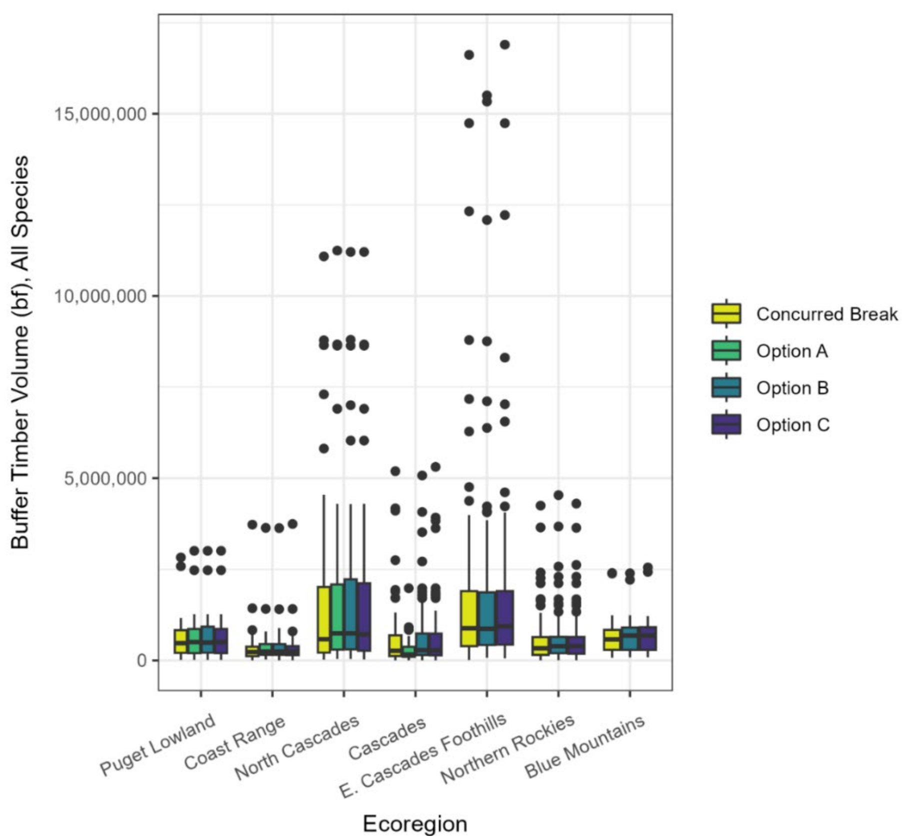
Note:
Weights were calculated based on the number of non-DNR-concurred F/N and S/N breaks in wchydro relative to the total number of F/N and S/N breaks statewide and on each side of the state. Negative values indicate that n-weighted average decreased under the relevant PHB option. Changes are calculated within-network before being summarized (averaged). Due to n-weighting and the fact that sample sets for the DNR-concurred break scenario may differ among comparisons for the various PHB options and ecoregions, the mean of those changes is not always equal to the difference between ecoregion means. For example, means for Option A are only calculated for west side networks and do not include buffers from the DNR-concurred break on the east side of the North Cascades and Cascades ecoregions.

Total Volume of Timber Within Type Np Riparian Buffers

On average, total volume of timber within riparian buffers within Type Np buffers was lowest for the DNR-concurred break when compared to all three PHB options, with the highest volume and variation in volume in the North Cascades and E. Cascades Foothills ecoregions (Appendix Table C-13, Appendix Figure C-9). With the exception of Option B in the E. Cascades Foothills, volume of timber within riparian buffers increased for all PHB options when compared to the DNR-concurred break (Appendix Table C-14). Volume of timber within riparian buffers within Type Np buffers was highest on the east side of the state, and timber volume calculated under Option B increased the most relative to the DNR-concurred break (Appendix Table C-15).

Appendix Table C-13. Volume of timber within riparian buffers (MBF) within Type N buffers per SSN, summarized by ecoregion

Ecoregion	Volume of Timber (MBF) per SSN Within Riparian Buffers							
	DNR-Concurred F/N Break		PHB Option A		PHB Option B		PHB Option C	
	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range
Puget Lowland	805 (272)	15 to 2,826	828 (278)	15 to 3,006	835 (277)	15 to 3,006	828 (278)	15 to 3,006
Coast Range	349 (73)	0 to 3,726	387 (75)	27 to 3,637	389 (76)	2 to 3,631	363 (72)	2 to 3,744
North Cascades	1,662 (318)	22 to 11,086	1,775 (403)	40 to 11,246	1,777 (332)	40 to 11,208	1,684 (318)	29 to 11,208
Cascades	637 (112)	1 to 5,193	312 (58)	1 to 1,980	668 (110)	1 to 5,075	667 (113)	1 to 5,311
E. Cascades Foothills	1,924 (361)	11 to 16,616			1,902 (348)	73 to 15,503	1,930 (357)	55 to 16,897
Northern Rockies	613 (97)	1 to 4,248			657 (103)	4 to 4,536	645 (99)	4 to 4,303
Blue Mountains	752 (167)	72 to 2,399			789 (160)	86 to 2,391	810 (173)	86 to 2,552



Appendix Figure C-9. Total timber volume within the Type N riparian buffer for each network

Appendix Table C-14. Change in volume of timber within riparian buffers (MBF) within Type N buffers per SSN, summarized by ecoregion

Ecoregion	Change in Volume of Timber (MBF) Within Riparian Buffers per SSN					
	PHB Option A		PHB Option B		PHB Option C	
	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range
Puget Lowland	22 (21)	-110 to 180	30 (21)	-110 to 180	22 (21)	-110 to 180
Coast Range	14 (8)	-207 to 207	16 (8)	-207 to 184	15 (7)	-207 to 207
North Cascades	31 (18)	-330 to 414	25 (16)	-356 to 365	22 (17)	-337 to 414
Cascades	20 (8)	-40 to 209	8 (13)	-654 to 331	30 (19)	-544 to 1,171
E. Cascades Foothills			-22 (28)	-1,122 to 593	6 (23)	-993 to 670
Northern Rockies			26 (9)	-76 to 288	23 (9)	-144 to 265
Blue Mountains			37 (34)	-187 to 427	58 (30)	-48 to 350

Note:
Negative values indicate that timber volume within the riparian buffer decreased under the relevant PHB option. Changes are calculated within-network before being summarized (averaged). Consequently, the mean of those changes is not always equal to the difference between ecoregion means, because sample sets for the DNR-concurred break scenario may differ among comparisons for the various PHB options and ecoregions. For example, means for Option A are only calculated for west side networks and do not include buffers from the DNR-concurred break on the east side of the North Cascades and Cascades ecoregions.

Appendix Table C-15. N-weighted average of ecoregion-average network Type N volume of timber within riparian buffers (MBF) and ecoregion-average change in Type N volume of timber within riparian buffers between the DNR-concurred network and each PHB option

State Side	PHB Option	N-Weighted Average Timber Volume (MBF)	N-Weighted Average Timber Volume Change (MBF) [Percent Change]
Statewide	DNR-Concurred	809	-
Statewide	Option A	633	-9 [+1.11%]
Statewide	Option B	860	51 [+6.30%]
Statewide	Option C	830	22 [+2.72%]
East	DNR-Concurred	1,145	-
East	Option B	1,201	56 [+6.92%]
East	Option C	1,171	26 [+3.21%]
West	DNR-Concurred	672	-
West	Option A	651	-21 [-2.60%]
West	Option B	720	49 [+6.10%]
West	Option C	691	20 [+2.47%]

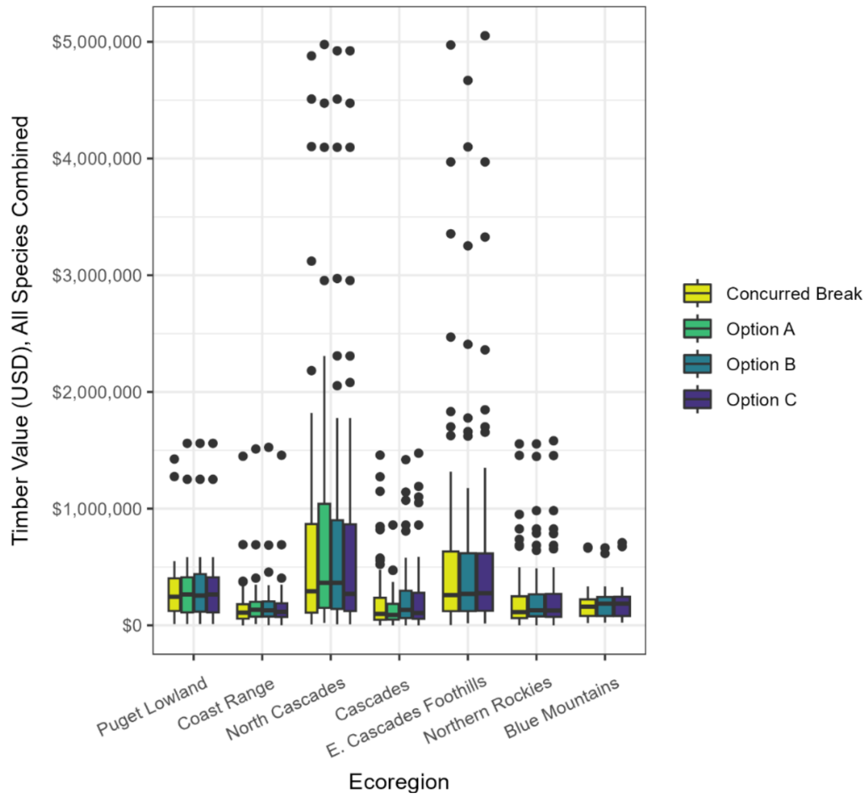
Note:
Weights were calculated based on the number of non-DNR-concurred F/N and S/N breaks in wchydro relative to the total number of F/N and S/N breaks statewide and on each side of the state. Negative values indicate that n-weighted average decreased under the relevant PHB option. Changes are calculated within-network before being summarized (averaged). Due to n-weighting and the fact that sample sets for the DNR-concurred break scenario may differ among comparisons for the various PHB options and ecoregions, the mean of those changes is not always equal to the difference between ecoregion means. For example, means for Option A are only calculated for west side networks and do not include buffers from the DNR-concurred break on the east side of the North Cascades and Cascades ecoregions.

Total Value of Timber Within Type Np Riparian Buffers

Value of timber within riparian buffers within Type Np buffers was lowest for buffers based on the DNR-concurred break for almost all ecoregions, with the highest value and variation in value in the North Cascades ecoregion (Appendix Table C-16, Appendix Figure C-10). With the exception of Option B in the E. Cascades Foothills, value of timber within riparian buffers increased for all PHB options when compared to the DNR-concurred break (Appendix Table C-17). Value of timber within riparian buffers within Type Np buffers was highest on the east side of the state, and timber value calculated under Option B increased the most relative to the DNR-concurred break (Appendix Table C-18).

Appendix Table C-16. Value of timber within riparian buffers (USD) within Type Np buffers per SSN, summarized by ecoregion

Ecoregion	Change in Value of Timber (USD) Within Riparian Buffers per SSN							
	DNR-Concurred F/N Break		PHB Option A		PHB Option B		PHB Option C	
	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range
Puget Lowland	$407,942 ($134,451)	$10,907 to $1,425,161	$419,959 ($141,540)	$10,907 to $1,559,939	$423,974 ($141,011)	$10,907 to $1,559,939	$419,959 ($141,540)	$10,907 to $1,559,939
Coast Range	$164,405 ($29,645)	$0 to $1,449,003	$184,151 ($32,253)	$10,746 to $1,511,113	$186,482 ($32,757)	$1,860 to $1,525,195	$171,242 ($29,636)	$1,860 to $1,457,475
North Cascades	$745,079 ($144,571)	$7,267 to $4,879,531	$869,961 ($190,253)	$20,761 to $4,977,014	$796,697 ($151,460)	$8,175 to $4,923,549	$753,573 ($145,068)	$8,175 to $4,923,549
Cascades	$214,952 ($33,154)	$0 to $1,458,554	$156,962 ($27,394)	$248 to $859,902	$226,080 ($32,555)	$0 to $1,419,734	$225,412 ($33,348)	$0 to $1,474,849
E. Cascades Foothills	$565,689 ($101,692)	$2,844 to $4,973,001			$558,432 ($97,579)	$18,248 to $4,669,445	$567,722 ($100,661)	$16,085 to $5,052,275
Northern Rockies	$230,777 ($36,964)	$872 to $1,554,881			$245,913 ($38,012)	$1,030 to $1,554,645	$242,896 ($37,788)	$1,030 to $1,581,268
Blue Mountains	$206,193 ($46,637)	$19,381 to $670,724			$215,882 ($44,538)	$23,164 to $664,277	$221,766 ($48,152)	$23,164 to $708,871



Appendix Figure C-10. Total price of timber within the Type N riparian buffer for each network

Appendix Table C-17. Change in value of timber within riparian buffers (USD) within Type Np buffers per SSN, summarized by ecoregion

Ecoregion	Change in Value of Timber (USD) Within Riparian Buffers per SSN					
	PHB Option A		PHB Option B		PHB Option C	
	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range
Puget Lowland	$12,017 ($12,991)	-$49,584 to $134,778	$16,032 ($12,973)	-$49,584 to $134,778	$12,017 ($12,991)	-$49,584 to $134,778
Coast Range	$7,953 ($4,159)	-$114,069 to $107,128	$10,284 ($4,340)	-$114,069 to $99,269	$6,837 ($3,619)	-$114,069 to $107,128
North Cascades	$15,451 ($9,513)	-$139,169 to $260,304	$10,892 ($7,299)	-$130,678 to $232,964	$8,495 ($7,597)	-$139,169 to $260,304
Cascades	$9,961 ($4,137)	-$24,235 to $104,175	$4,138 ($4,413)	-$201,625 to $104,175	$10,460 ($6,329)	-$172,882 to $370,220
E. Cascades Foothills			-$7,257 ($8,097)	-$303,556 to $129,486	$2,033 ($7,091)	-$282,391 to $197,721
Northern Rockies			$8,423 ($3,629)	-$35,333 to $134,580	$8,839 ($3,720)	-$77,510 to $134,580
Blue Mountains			$9,689 ($9,275)	-$55,125 to $114,749	$15,573 ($7,945)	-$9,627 to $94,771

Note:
Negative values indicate that timber value within the riparian buffer decreased under the relevant PHB option. Changes are calculated within-network before being summarized (averaged). Consequently, the mean of those changes is not always equal to the difference between ecoregion means, because sample sets for the DNR-concurred break scenario may differ among comparisons for the various PHB options and ecoregions. For example, means for Option A are only calculated for west side networks and do not include buffers from the DNR-concurred break on the east side of the North Cascades and Cascades ecoregions.

Appendix Table C-18. N-weighted average of ecoregion-average network price of Type N riparian timber (USD) and ecoregion-average change in price of riparian timber between the DNR-concurred network and each PHB option

State Side	PHB Option	N-Weighted Average Timber Value (USD)	N-Weighted Average Change in Timber Value (USD) [Percent Change]
Statewide	DNR-Concurred	339,727	
Statewide	Option A	310,428	$8,755 [+2.58%]
Statewide	Option B	363,355	$9,112 [+2.68%]
Statewide	Option C	348,567	$9,062 [+2.67%]
East	DNR-Concurred	440,714	
East	Option B	463,903	$6,879 [+2.02%]
East	Option C	450,397	$8,322 [+2.44%]
West	DNR-Concurred	298,501	
West	Option A	319,041	$10,066 [+2.96%]
West	Option B	322,307	$10,024 [+2.95%]
West	Option C	306,995	$8,494 [+2.50%]

Note:
Weights were calculated based on the number of non-DNR-concurred F/N and S/N breaks in wchydro relative to the total number of F/N and S/N breaks statewide and on each side of the state. Negative values indicate that n-weighted average decreased under the relevant PHB option. Changes are calculated within-network before being summarized (averaged). Due to n-weighting and the fact that sample sets for the DNR-concurred break scenario may differ among comparisons for the various PHB options and ecoregions, the mean of those changes is not always equal to the difference between ecoregion means. For example, means for Option A are only calculated for west side networks and do not include buffers from the DNR-concurred break on the east side of the North Cascades and Cascades ecoregions.