October 14, 2021

To: Forest Practices Board's Water Typing Rule Committee

From: Anadromous Fish Floor Project Team

Subject: Anadromous Fish Floor Analysis

Attached is the Anadromous Fish Floor Spatial Analysis Preliminary Draft Findings Report. Ash Roorbach will provide an overview of the findings at your October 18 meeting.

paa/
Attachment

Anadromous Fish Floor Spatial Analysis

Preliminary Draft Findings Report

Prepared for

Washington State Forest Practices Board Water Typing Rule Committee

By

Anadromous Fish Floor Project Team

October 14, 2021

Contents

Executive Summary

Introduction

This report presents the findings of the Anadromous Fish Floor Workgroup. The Workgroup was established in response to a request by Washington's Forest Practices Board for stakeholders engaged in the state's forest practices adaptive management program to collaboratively analyze and evaluate physical stream characteristics downstream from which all waters can be assumed to be anadromous fish habitat. The function of this 'anadromous fish floor' (AFF) in the permanent forest practices water typing rule will be to establish the location on the landscape where fish surveys may begin, thereby reducing electrofishing in waters that are likely to support fish use in all or some times of the year. The tasks of the workgroup included compiling currently available data on fish distributions from multiple western Washington watersheds and assessing those distributions against available and modeled channel attribute metrics, along with an assessment of the performance of these metrics. Metrics evaluated included channel gradient, changes in channel gradient, channel width, changes in channel width, and vertical and non-vertical anadromous fish migration barriers and obstacles. While the workgroup lacked data on the upper extent of anadromous fish distribution, the group evaluated four different board-selected AFF alternatives to describe their effectiveness at capturing the distribution of known anadromous fish presence. The Forest Practices Board also charged the workgroup with developing recommendations on potential future field studies, as needed, to address technical uncertainties.

The balance of risk between underestimating known anadromous stream length and overshooting the fish-non fish habitat break point locations is the subject of the policy and recommendations sections of this report.

The results presented in this report focus on the spatial analysis findings presented at the September 24, 2021 Spatial Analysis Workshop held with the Forest Practices Board Water Typing Committee.

Workgroup Organization and Deliberations

Membership of the Project Team and Workgroup included representatives from tribal, state, landowner and conservation stakeholders. Dan Miller, Kevin Andras and Lee Benda from TerrainWorks were also part of the Project Team and took the lead in doing the GIS modelling, mapping, and conducting the analyses.

The process included regular meetings of the Project Team and Workgroup, which used a consensus-based decision-making process modeled after the Washington State Adaptive Management Program. The work of the AFF Project Team and Workgroup was overseen and guided by the Forest Practices Board Water Typing Committee.

Key Findings

Relation of the AFF to channel gradients

- The total lengths of stream channels covered by each AFF alternative varied in predictable ways. Alternatives that used a 10% gradient threshold to terminate the AFF tended to extend farthest upstream; alternatives that used smaller gradient thresholds (7% and 5%) tended to extend lower in watersheds. The alternative that did not use a gradient threshold but instead a change in gradient criteria (Alternative D) tended to extend the shortest distance upstream.

- Alternatives that used a 10% gradient threshold tended to capture a higher percentage of anadromous and resident fish data points within the AFF than alternatives that used lower gradient thresholds or that used changes in gradient (Alternative D).
- Alternatives that used lower gradient thresholds or that used changes in gradient (Alternative D) had higher percentages of anadromous and resident fish data points that fell upstream of the modeled AFF.
- Many of the overall observed anadromous fish data points were located in low gradient streams (<2% gradient). ~90% of the anadromous data points had downstream sustained gradients of 10% or less. ~60% of the anadromous data points had downstream sustained gradients of 5% or less.

Relation of the AFF alternatives to Anadromy

- All the evaluated AFF alternatives captured most of the known anadromous stream length in the study basins. Channel lengths where the modeled AFF alternatives fell short of the known anadromy basins studied were a small percentage of the overall length of the AFF for each alternative.
- Alternatives that used lower gradient thresholds (Alternatives C and E at 5% or 7%) or that used changes in gradient (Alternative D) tended to fall short of the anadromous data more than the other alternatives.

Relation of the AFF alternatives to concurred F/N Breaks

- None of the alternatives captured all the known anadromous channel lengths without extending above some of the F/N break point locations. Alternatives that used a 10% gradient threshold tended to extend beyond F/N break point locations more than those that used lower gradient thresholds or changes in gradient.

Relations of the AFF alternatives to barriers

- The inclusion of natural barriers as AFF termination points (Alternative A) reduced the overall lengths of the AFF when compared to similar alternatives that relied solely on gradient thresholds (Alternatives C and E).

Consensus Recommendations

Formally adopt Alternatives A3 and A4 as AFF alternatives for consideration by the FP Water Typing Rule Committee. The workgroup recognized that implementation of Alternative A could be greatly facilitated if its stopping criteria (10% sustained gradient or permanent natural barrier) is identified upstream from known anadromy, as represented in SWIFD, instead of from salt water. This approach, analyzed as A3 and A4, also enables a more meaningful comparison of performance between Alternatives A and D.

If adopted into rule, include an AFF alternative as part of the water typing Fish Habitat Assessment Methodology currently under rule consideration by the FP Board, with implementation to be covered in Board Manual section 23.

Background

The Anadromous Fish Floor and Anadromous Overlay Proposals

Two different sets of AFF criteria were proposed to the Washington State Forest Practices Board in May 2019. Participants recognize that a collaborative effort to analyze available and current anadromous and resident fish distribution data and stream characteristics would assist the Board in making a final determination on which alternative to adopt as part of finalizing the Forest Practices water typing system. Eventually a total of four alternatives were spatially analyzed by the Workgroup (Table 1).

Table 1. Anadromous fish floor alternatives included in the analyses.

Alternative A [1]	Alternative C [1]	Alternative D [3]	Alternative E [4]
Tribal proposal Gradient threshold + permanent natural barrier	Gradient threshold + Potential Habitat Breaks	**Landowner proposal** SWIFD + Potential Habitat Breaks	Gradient threshold without barrier
Waters within the anadromous fish floor. These are waters connected to saltwater and extending upstream to a *sustained* [2] *10% gradient* or a permanent natural barrier, whichever comes first. These waters contain main stem stream segments and associated tributaries.	Waters within the anadromous fish floor. These are waters connected to saltwater that have a *sustained gradient of 5% [or 7% or 10%]* or less, and include associated *tributaries lacking a 5% gradient increase* or permanent natural obstacle at the junction with the main stem.	Waters within the anadromous fish floor. These are waters connected to saltwater that are included in widely available GIS datasets of known and presumed anadromous use (such as SWIFD or StreamNet), and include associated *tributaries lacking a 5% gradient increase* or permanent natural obstacle at the junction with the main stem.	Waters within the anadromous fish floor. These are waters connected to saltwater and extending to a *sustained 5% or [7% or 10%] gradient*. These waters contain main stem stream segments and associated tributaries.

Table taken from an April 14, 2021 memo from the Anadromous Fish Floor Project Team to the Forest Practices Board's Water Typing Rule Committee.

[1] Language accepted by the FP Board at the May 2019 Board meeting.

[2] Sustained in this definition means a minimum gradient that is maintained over the full length of the reach, and doesn't at any point fall below that gradient.

[3] Language crafted by AFF Project Team to reflect the AFF proposal as explained by the large landowner caucus in April 2021.

[4] Language crafted by the project team. This alternative includes the 5%, 7%, or 10% component of Alternative C, but does not include the natural barrier component of Alternative A or the 5% gradient increase component of Alternative D.

Additional Alternatives A3 and A4:

In addition to the AFF alternatives approved by the water typing subcommittee (Table 1), the AFF Project Team analyzed two alternatives that combine aspects of Alternatives A and D. Specifically, the new alternatives incorporated the 10% gradient threshold from Alternative A and used the concept of an 'anadromous core' from Alternative D as a starting point to define anadromous waters. Alternative 'A3' is defined as all waters included in the SWIFD GIS database of documented and presumed anadromy, plus associated waters downstream of a sustained gradient of 10% or a permanent natural barrier, whichever comes first. For the purposes of Alternative A3, permanent natural barrier is defined using the WDFW definition (explained earlier for Alternative A). Alternative A4 is identical to A3, except it uses a channel-width-based natural barrier definition (See below - Synthetic Stream Layer/Channel features of interest in the spatial analysis).

Questions addressed in this report

The Anadromous Fish Floor workgroup collaboratively developed questions of interest to guide the spatial analysis. The workgroup prioritized the following specific questions from the questions of interest to be addressed in this report:

a. What is the distribution of stream lengths (both positive and negative) between anadromous fish presence points, concurred F/N breaks [1] and the proposed tribal and landowner proposals (including 5%, 7% and 10% AFF gradient thresholds)?
b. What is the distribution of maximum channel downstream from known anadromous fish distribution points and concurred F/N breaks?
c. What proportion of anadromous fish distribution points and concurred F/N breaks points are observed above and below the proposed AFF overlays?

Methods

Fish distribution data

The Workgroup compiled available fish distribution data from a variety of sources and integrated them into a single geodatabase to use in the analyses using GIS tools. These data included:

1. Statewide Integrated Fish Distribution (SWIFD). These data are jointly managed by the western Washington treaty tribes and WDFW. They were originally developed as part a ‘limiting factors analysis’ project which brought together knowledgeable fish biologists from tribes, state agencies and other interested parties to map known fish distribution based on observations of fish presence. As such, these data represent anadromous presence, not the delineation between downstream anadromous presence and upstream anadromous absence. In fish biologist jargon, these are ‘presence’ data, not ‘presence-absence’ data. Moreover, there are possible mapping errors apparent in some of the data where anadromous fish points were placed far from actual stream channel locations due to the small scale of the maps used in the original mapping efforts. Other likely mapping errors may be seen where anadromous fish presence is indicated above 100+ foot vertical waterfalls. Due to these considerations, we regard the SWIFD data to approximate anadromous habitat but to not necessarily demarcate the end of habitat. While the mapping errors have not been analyzed in detail, they appear to minimally affect the results. Only documented and presumed anadromous fish presence data were included; all other labels regarding data origin were deemed to be suspect. We have SWIFD data for all of the analyzed basins.
2. Skagit-LFA. These data came from a similar source as the original SWIFD dataset, but were vetted, snapped to the stream channel network by hand (visually, using lidar topographic data), and classified into points lying directly downstream from permanent natural barriers and points

[1] F/N break is the current regulatory point that divides fish habitat from non-fish habitat.

indicating the end of anadromous habitat due to the upstream end of streamflow. These data are limited to the Skagit and Samish River basins.

3. U.S. Forest Service. These data came from a study conducted by the U.S. Forest Service in the Olympic Peninsula region. They followed a similar protocol as the forest practices water typing protocol survey. The data contain information on fish species; therefore, we were able to use this dataset to inform anadromous presence and resident fish presence.
4. Squaxin Island Tribe. This dataset primarily represents juvenile coho presence data in Skookum Creek and Mill Creek watersheds.
5. Water Type Modification Forms. These data represent breaks between water types (fish-non fish) in all of our analyzed watersheds. Many errors exist in this database, and there were spatial errors introduced into the locations of these data during the development of the spatial analysis model. Therefore, we vetted a random selection of these points and retained 95 points that were assessed to be true field-based concurred fish habitat type breaks, and that were correctly located in the GIS system. Additionally, we added 448 F/N break points that had been similarly vetted during a previous analysis completed for the Stillman Creek and Kalama River basins. Therefore, these data are located throughout our study watersheds but are heavily represented in the southwest Washington region. These data represent our best approximation of the end of fish habitat.

Multiple watersheds and basins in western Washington are represented by these data, including Skagit/Sauk Rivers, Sol Duc/Calawah/Bogachiel Rivers, Wynoochee/Humptulips Rivers, North Fork Skokomish, Mill Creek/Skookum Creeks, Kalama River, and Stillman Creek (Figure 1).

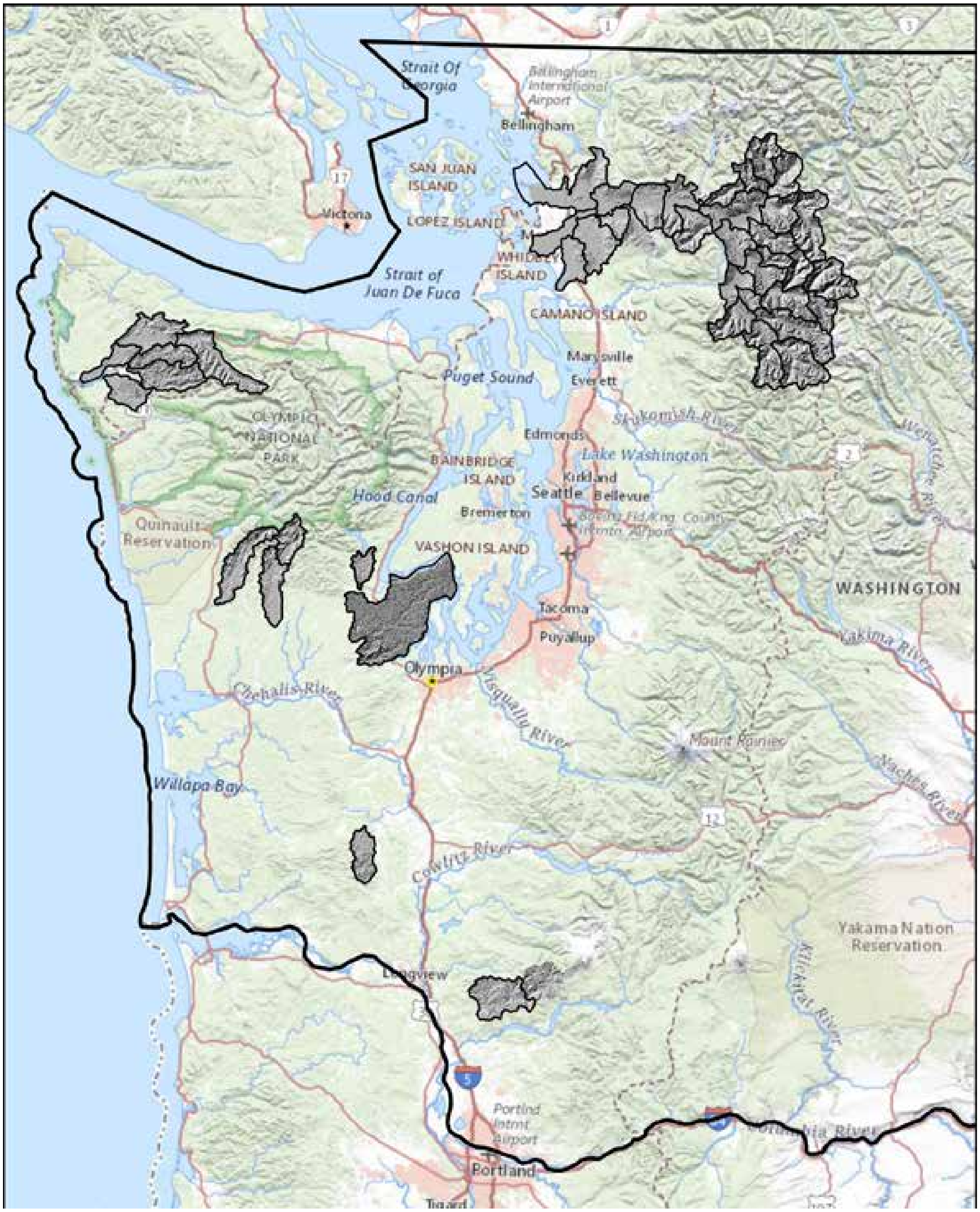

Figure 1. Fish distribution data were compiled from shaded areas of the map and used in the sensitivity and spatial analysis.

Fish Types. Integrating the fish data from these diverse datasets included categorizing each fish point into one of four types:

1. SWIFD_Anadromy: Point data from the Statewide Integrated Fish Distribution (SWIFD) database indicating presence of anadromous fish. These fish points are treated as presence only, not the upstream extent of anadromous fish use.

2. Other_Anadromy: Point data other than SWIFD indicating presence of anadromous fish. These fish points treated as presence only, not the upstream extent of anadromous fish.
3. Resident & Unknown_Life_History: Point data indicating locations of fish of resident or unknown life history type. These fish points treated as presence only, not the upstream extent of anadromous fish.
4. Concurred_FN: Concurred F (fish bearing) to N (non-fish-bearing) water type break location. These data represent the best estimates of the end of fish points.

The compiled fish distribution data were projected and digitized onto the synthetic stream layer. Stream flow paths on the original hydro-layers from which the fish data were drawn (National Hydrography Dataset and Washington State DNR Hydrography) do not generally align exactly with those determined by tracing flow paths through a lidar DEM (see synthetic stream layer, below), with discrepancies in places of tens of meters. As a result, the fish data points were moved ("snapped") from their original locations to fall on the flow paths in the synthetic channel network.

Synthetic Stream Layer

Terrainworks used high resolution lidar to develop digital elevation models and delineate synthetic stream layers for each selected watershed. Additionally, Terrainworks built a GIS model based on the synthetic stream layer, where each network channel in the layer was represented as a series of nodes at 1-meter intervals along the stream channel. Each node was associated with a DEM grid point with a set of attributes that describe the conditions at that node location (elevation, upstream and downstream gradient, modeled channel width, etc.). Each node was linked to the adjacent upstream and downstream nodes, so that flow paths were traced through the network both up and downstream. The attribute information at each node was used to estimate channel gradients and to identify features along the channel profile such as water falls and steep channel sections chutes. For each node, contributing area and mean annual precipitation over that contributing area was also determined, and used in regional regression equations to estimate the channel width and depth at each node.

Channel features of interest in the spatial analysis

The primary channel features used in the spatial analyses that were modeled using the Terrainworks GIS model included:

<u>Channel width:</u> All AFF alternatives relied on estimates of channel widths to determine minimum stream lengths when identifying sustained gradients or gradient breaks. See sustained gradient below.

<u>Sustained gradient:</u> Alternatives A, C, and E use a threshold in a sustained gradient as one criterion for determining the upstream extent of the modeled AFF. Alternatives A uses a threshold gradient of 10%; Alternatives C and E include three gradient thresholds, 5%, 7%, and 10%.

<u>Barriers:</u> For Alternative A, along with a 10% sustained gradient threshold, permanent natural barriers are used to identify the upstream extent of the AFF where they are encountered downstream of the sustained gradient threshold. Alternative A relies on the Washington Fish and Wildlife Fish Passage Inventory, Assessment and Prioritization Manual (2019) to define these barriers, which includes two types of permanent natural barriers:

1. Gradient, defined as a reach with sustained gradient ≥ 20% for ≥ 160 meters without resting areas.
2. Waterfall, defined as a single, near vertical drop > 3.7 meters in height.

Channel-width-dependent barriers. The WDFW definitions do not incorporate channel size into these barrier definitions. It seems plausible that the ability of fish to ascend a potential barrier might vary with channel size, so the AFF-project team devised and tested an alternative channel-width-dependent set of barrier criteria (Barrier Definition for Anadromous Fish Floor GIS Analysis, memo dated 03/29/2021):

1. Gradient:
   a. Channels < 5 feet in width: sustained gradient ≥ 20% for ≥ 100 feet (30 meters) without resting areas.
   b. Channels 5 – 10 feet in width: sustained gradient ≥ 20% for ≥ 250 feet (76 meters) without resting areas.
   c. Channels > 10 feet in width: sustained gradient ≥ 20% for ≥ 515 feet (160 meters) without resting areas.
2. Waterfall (permanent natural features):
   a. Channels < 5 feet in width: near vertical drop ≥ 5 feet in height (1.5 meters)
   b. Channels 5 – 10 feet in width: near vertical drop ≥ 8 feet in height (2.5 meters)
   c. Channels > 10 feet in width: near vertical drop ≥ 12 feet in height (3.7 meters)

These along with the 10% sustained gradient threshold are referred to as Alternative A2.

<u>Potential Habitat Breaks:</u> Two alternatives (C and D) use Potential Habitat Breaks (PHBs) to help define the AFF. Both alternatives identify a core anadromy area -- Alternatives C uses gradient thresholds to define the anadromous core whereas Alternative D uses known documented anadromy based on existing data (e.g., SWIFD) to define the anadromous core. In both alternatives the AFF extends upstream on tributaries to the anadromous core until a PHB is encountered, ignoring the width-based potential habitat break at the junction of the tributary with the mainstem. The PHBs include two types of obstacles, a gradient break, and a change in channel width:

1. Vertical step ≥ 3 feet (0.9 meters)
2. A sustained gradient of ≥ 20% that persists for a sufficient length so that the elevation increase along the segment is ≥ one channel width equivalent. These are referred to as nonvertical obstacles (NVO).
3. A gradient break, identified as a point along the channel profile where the upstream-looking gradient exceeds the downstream-looking gradient by 5% or more for at least 20 channel widths.
4. A decrease in channel size at tributary junctions of 20% or more. We use the modeled channel width as an indicator of channel size (not used at confluences of tributaries to anadromous core)

Web-Based Map

To aid with ongoing project-team review of the data products and analyses, Terrainworks uploaded the synthetic channel networks and AFF fish distribution database points to a web-based map. Different symbols and colors were used to distinguish different types of data points and lines. These included observations of fish presence, concurred F/N break points, and barriers. The upstream-most fish points were flagged (virtually speaking). Channels in the synthetic network were divided into reaches based on modeled channel gradient and color coded to indicate extent of the modeled AFF. Points indicating modeled barriers and potential habitat breaks were also displayed. The map interface allowed users to move around the map and to zoom in or out and to toggle each layer on and off.

With this map, AFF-project-team members reviewed data products and identified errors in the database and synthetic networks, reviewing nearly 12,000 data points. Corrections included: correcting the location of some data points, removing some data points, adding channels to the synthetic network, repositioning some channels, and removing some traced channels.

Link to AFF WebMap

The WebMap can be viewed through this link: ***https://arcg.is/1Sfeim0***

Spatial Analyses

The performance of each alternative was evaluated by sorting stream reaches into different categories defined by the spatial relationships between the most upstream occurrence of each fish point, by type of fish, and the modeled AFF locations. The fish types of interest in the spatial analysis included:

- Highest_SWIFD_Anadromy
- Highest_Other_Anadromy
- Highest_All_Anadromy
- Highest Concurred_F/N_Break

Stream Categories

The spatial relationships between these fish distribution points on each unique stream and the locations of the AFF alternatives as predicted by the model can create eight possible stream categories. For the spatial analysis, there were four primary categories of interest the AFF workgroup identified as useful to addressing the spatial analysis questions. These categories describe whether the AFF alternative places the stream upstream or downstream of the fish reference point. These categories included: True Positive, False Negative, Uncertain Interpretation, and False Positive (described below). Additionally, the Workgroup identified the length of stream within the AFF for each alternative on streams with no fish data (a potentially important category relevant to policy decision making).

True Positive, False Negative, Uncertain Interpretation, False Positive

1. **True Positive** – Stream reaches downstream of SWIFD or Other Anadromy, and within the AFF (Figure 2).
2. **False Negative** – Stream reaches downstream of SWIFD or Other Anadromy, and upstream of the AFF (Figure 2).

To the extent that the documented anadromy points accurately reflect anadromous fish use, the stream lengths that terminate at the 'End of the AFF point' represent either a 'True Positive' or 'False Negative' depending on whether the reach is located above or below the **highest documented known anadromous fish use point** (Figure 2).

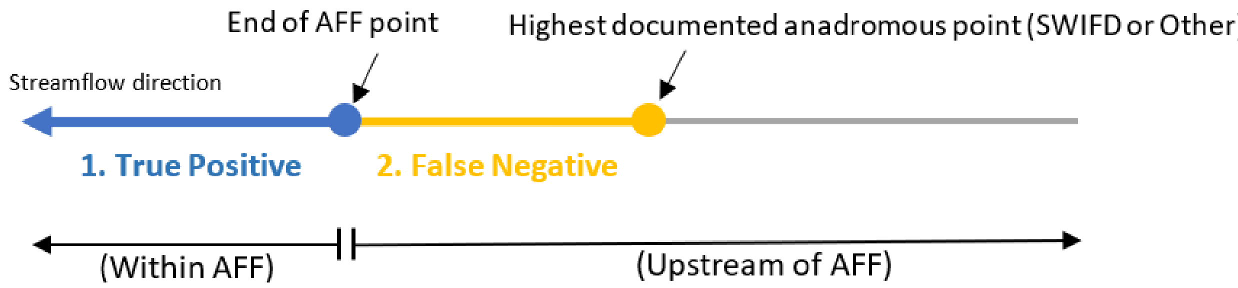

Figure 2. Stream reach schematic illustrating "True Positive" and "False Negative" stream categories.

3. **Uncertain Interpretation** – Stream reaches upstream of documented anadromy points and within the AFF (Figure 3). These reaches have no documented anadromy but could potentially contain anadromous species, hence the uncertainty.
4. **False Positive** – Stream reaches upstream of concurred F/N break points and within the AFF (Figure 3).

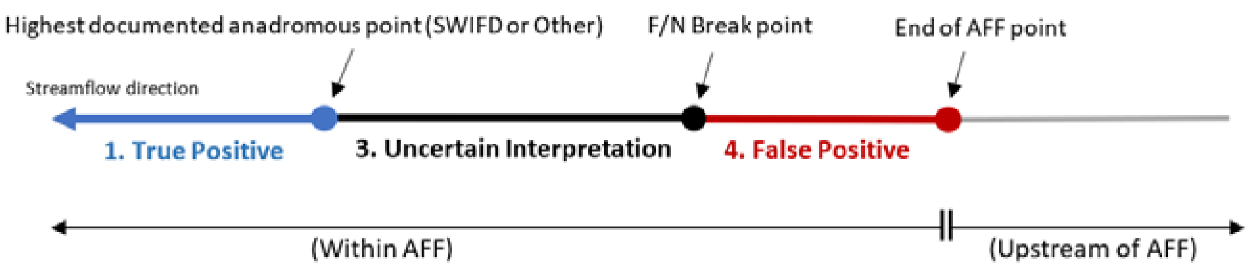

Figure 3. Stream reach schematic illustrating "Uncertain Interpretation" and "False Positive" stream categories.

The "Uncertain Interpretation" and "False Positive" categories include streams where anadromous fish data or concurred F/N Break data suggest the end of the **AFF is located *upstream* of the F/N break or known highest documented fish point** (Figure 3). Streams categorized as "Uncertain Interpretation" are within the AFF but located upstream of a SWIFD or Other Anadromy (known) point. Unlike concurred F/N breaks, the anadromous distribution data represent presence documented up to these points, but do not necessarily represent demonstrated absence upstream from the point. The upstream limits of anadromy and anadromous access in most cases have not been determined. "False Positive" streams are also within the AFF but located upstream of a concurred F/N Break point.

Once the streams were assigned to categories, the cumulative lengths were calculated for each stream category and compared across the different AFF alternatives (Figure 4).

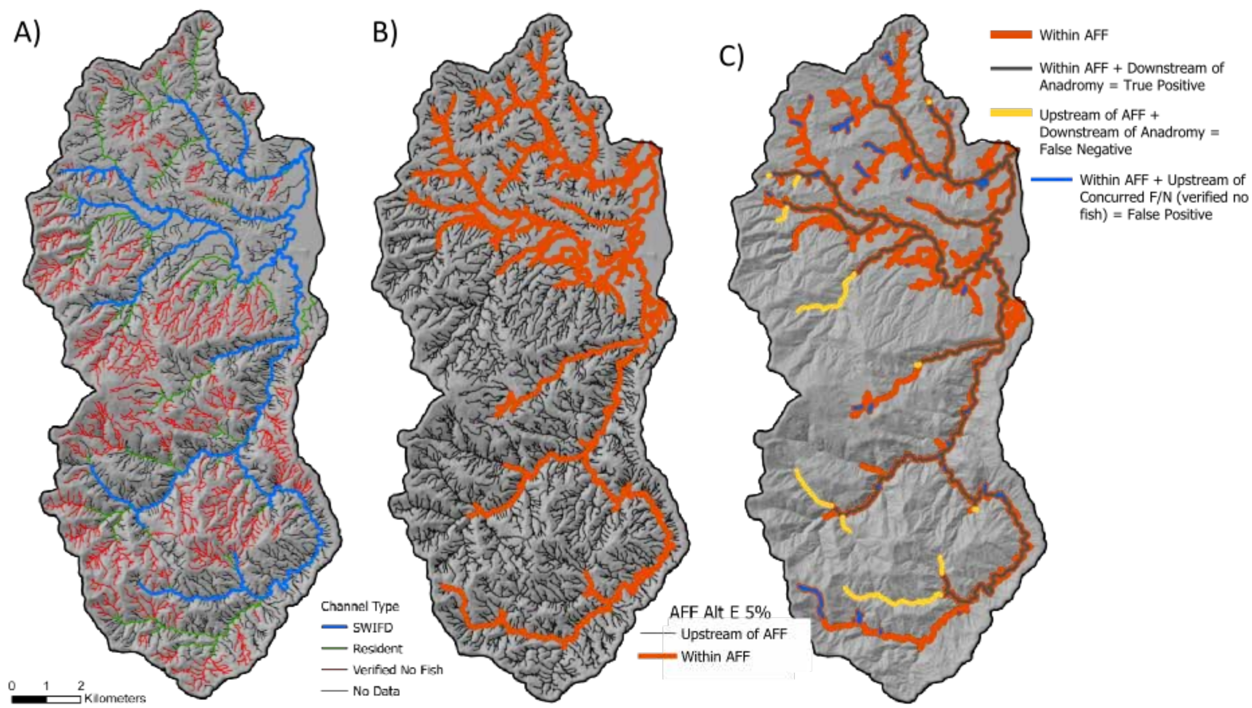

Figure 4. Channel classification for the Stillman Creek basin in southwest Washington. The colored lines represent the different channel classifications used in the spatial analysis. A) channel classes based on documented fish presence. This basin lacks data for 'other anadromy' and 'unknown life history', so there are fewer total channel classes. B) Modeled AFF for Alternative E5% (as an example). C) Overlay of the modeled AFF on the channel classes based on the available fish data.

Additional analyses

Data were also sorted and analyzed to address questions about (1) the proportion of fish points (anadromous and F/N break) upstream and downstream of the different AFF alternatives, and (2) patterns in the steepest sustained channel gradients observed downstream from the highest documented anadromous and F/N break points.

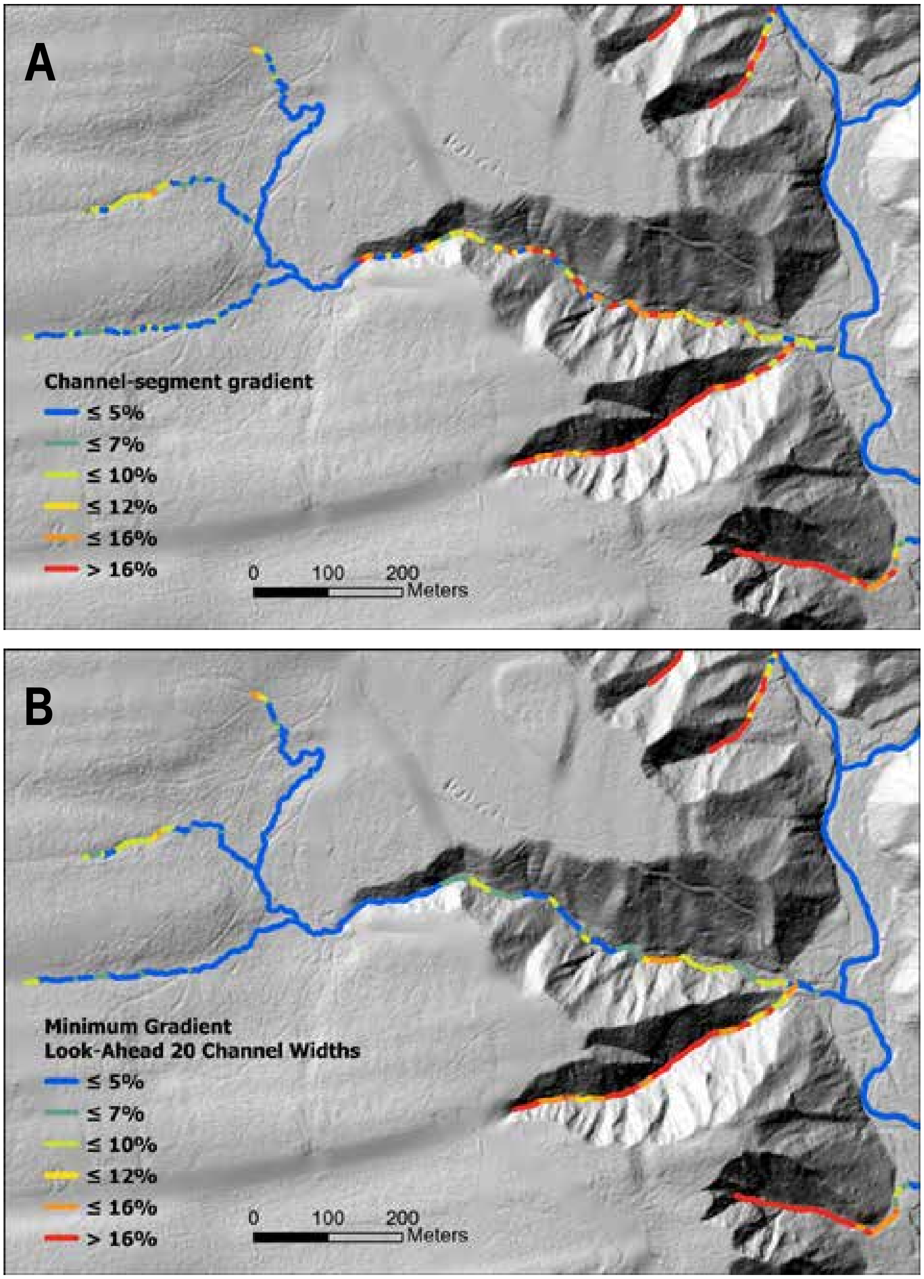

Figure 5. The upper panel (A) shows channel gradients inferred from piece-wise linear profiles fit to the DEM-traced channels with a maximum elevation deviation of 0.2 meters. The lower panel (B) shows the minimum segment gradient over a 20-channel-width look-ahead distance. This was used as a measure of sustained gradient.

Figure 5 illustrates how the ‘sustained’ channel gradients are estimated using the synthetic stream network. The stream channel was initially delineated into segments based on gradient (Figure 5A). Then the lowest gradient encountered along the channel profile within an upstream look-ahead distance equal to 20 channel widths in length defines the sustained gradient for that stream reach (Figure 5B).

Results of the Spatial Analysis

Total AFF length by alternative

Alternative C10% and Alternative E10% had the greatest overall length, and Alternative D had the shortest length (Figure 6). As expected, the total length of the AFF shortened as the gradient threshold values decreased. Alternative A had a similar total length to C7% and E7%, due to the addition of natural barriers in the definition of Alternative A.

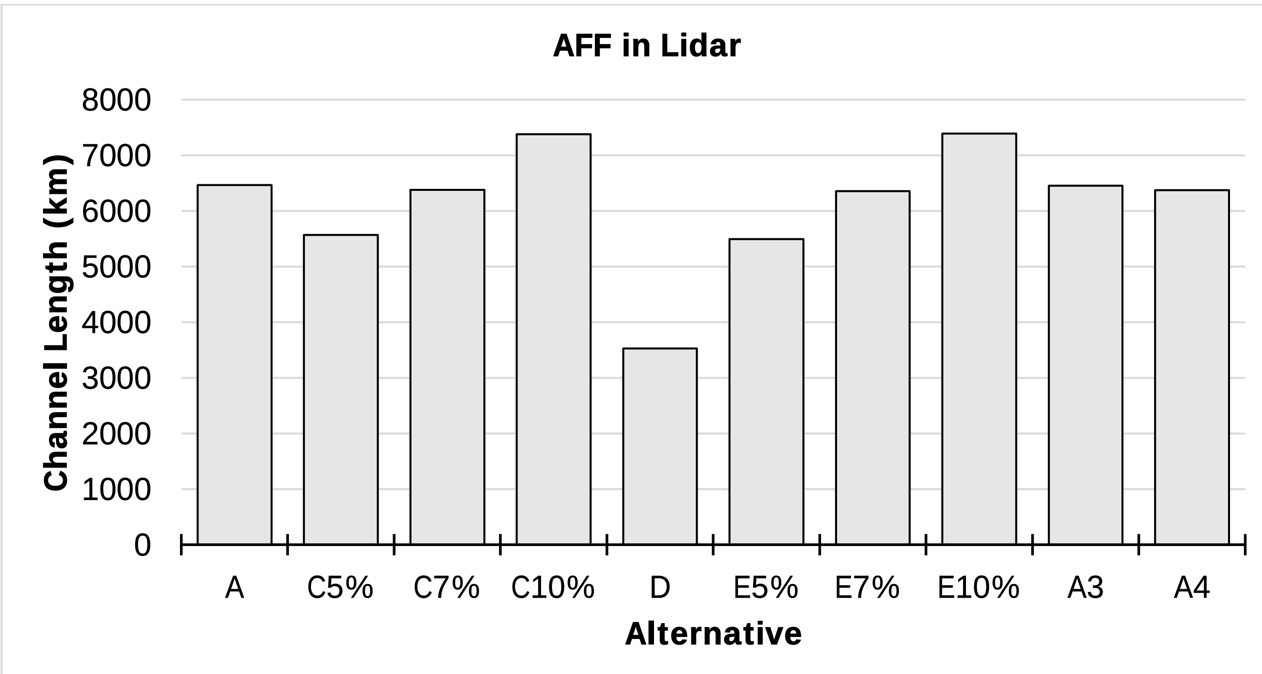

Figure 6. Modeled AFF length within portions of the analyzed watersheds covered by lidar topographic data. The length of the AFF that fell outside of lidar coverage was a small percentage of the total length for each alternative.

Distribution of stream lengths by categories

Question of Interest: What is the distribution of stream lengths (both positive and negative) between anadromous fish distribution points, concurred F/N breaks and the proposed tribal and landowner proposals), including 5%, 7% and 10% AFF gradient thresholds?

True positives

The alternatives that used a 10% gradient threshold had the greatest length of channel in which there was overlap between the modeled AFF and the anadromy data (true positives, Figure 7, Figure 8). Lower gradient thresho between anadromous streams and the modeled AFF alternatives. This follows directly from the channel length results (alternatives with the longest total length will overshoot the anadromy data in places, but will tend to have greater lengths in the true positive category).

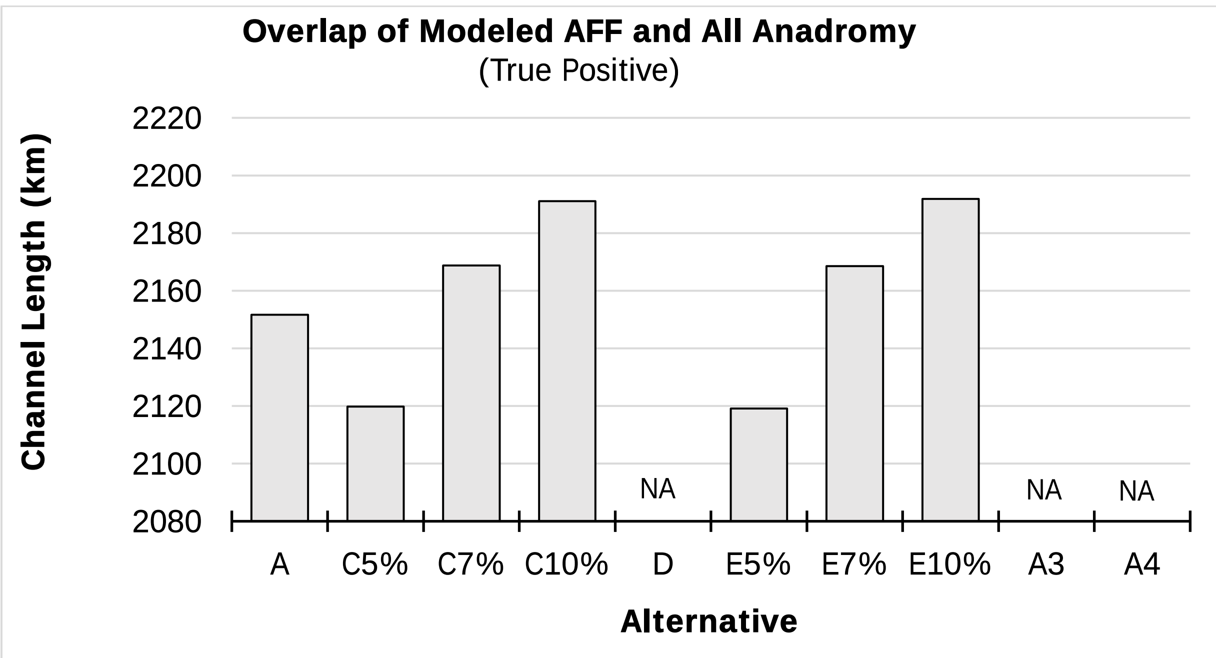

Figure 7. Bar chart showing length of channel with all anadromous data included (SWIFD + Other) and modeled AFF overlap for each alternative (the True Positive stream reach category). Alternatives D, A3 and A4 are excluded from this plot because they are defined by the SWIFD stream extent; therefore, comparison against SWIFD data is not valid (see methods). Note the y-axis shows only the tops of the bars (i.e. does not span the full range down to zero) to emphasize differences between the alternatives for the sake of comparison.

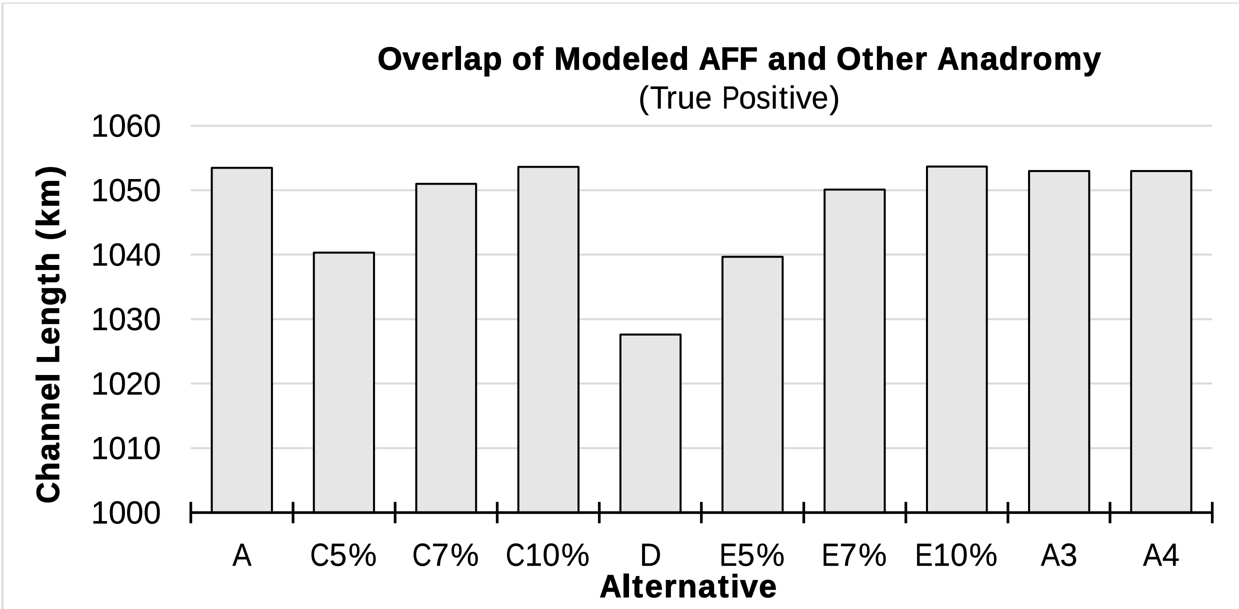

Figure 8. Similar to Figure 7 but using ‘other anadromy’ data (excluding SWIFD).

False Negative

Cumulatively the stream lengths above the end of AFF but below known anadromous waters (False Negative) were much shorter than stream lengths within the AFF and below known anadromous waters (True Positive) (compare Figures 8 and 9). Alternatives with lower gradient thresholds tended to have greater length of underestimation of known anadromous waters (Figure 9). Alternative D had the greatest length of False Negative (underestimating documented fish use). The alternatives with the larger gradient thresholds (A, C10%, E10%) had the least AFF stream length ending downstream of the 'Other Anadromy' data. This is consistent with the total AFF length results: alternatives that extend higher into the watersheds (A, C10%, E10%) tend to have less length that falls short of the documented known anadromous data.

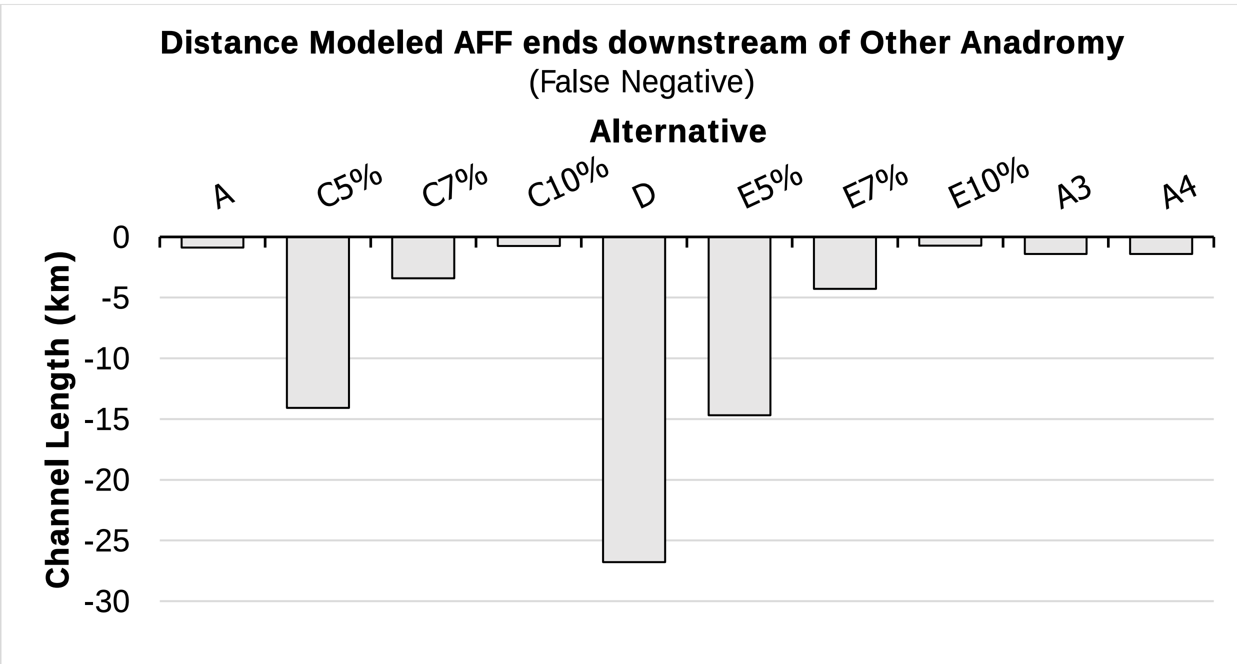

Figure 9. Bar chart showing the length of stream in which the modeled AFF ends downstream of the 'other anadromy' data (False Negatives).

Generally, a similar pattern can be seen when using SWIFD points as the reference to evaluate the alternative performances, recognizing that Alternatives D, A3 and A4 cannot be used in that analysis because these alternatives include SWIFD in its definition (Figure 10). One difference between Figures 9 and 10 is the performance of Alternative A – when measured against SWIFD this alternative tends to underestimate anadromy to a greater extent than when measured against Other Anadromy. This might suggest that permanent natural barriers are not as prominent a feature in watersheds where Other Anadromy data predominate than where SWIFD points are located when determining the extent of the AFF.

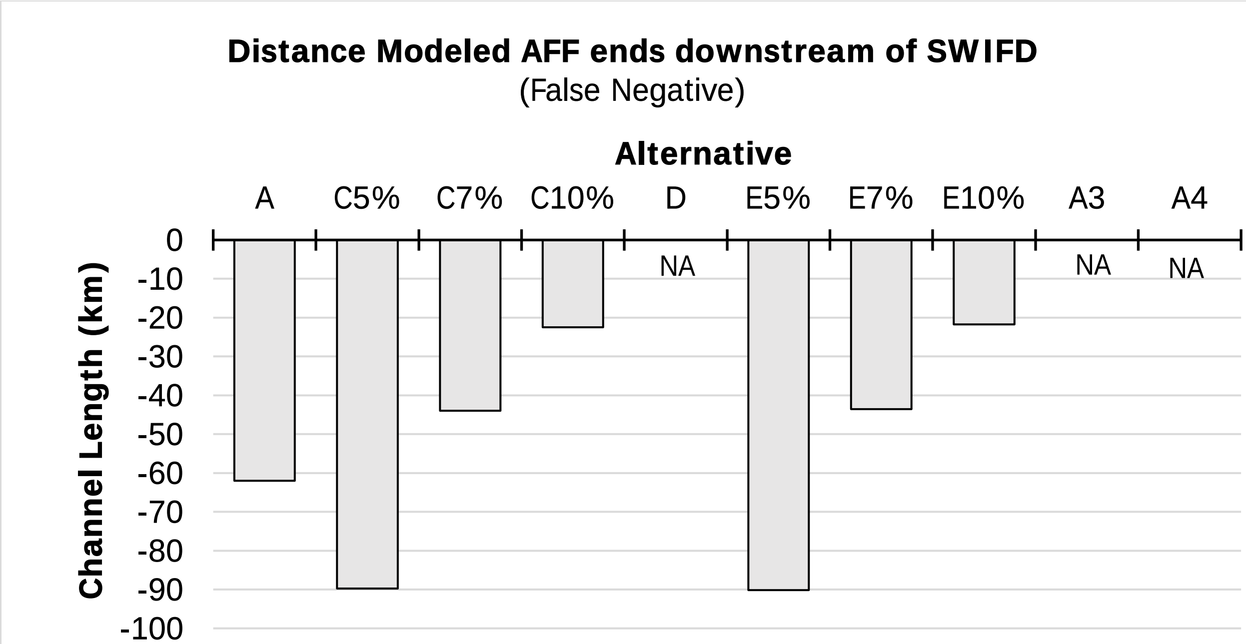

Figure 10. Similar to Figure 9 but using the SWIFD anadromy data only as the reference dataset. Alternatives D, A3 and A4 are excluded from this plot because they are defined by the SWIFD stream extent; therefore, comparison against SWIFD data is circular and not informative.

Uncertain Interpretation

Extending the AFF up lateral streams under Alternative D added approximately 1,400 kilometers of stream length to the AFF in lateral streams connected to known anadromous waters (Figure 11). Alternatives A3 and A4 added approximately 4,100 km to the AFF above SWIFD streams, including the terminal SWIFD streams (in Alternative D there is no extension of the AFF above the terminal SWIFD points). The other alternatives followed predictable patterns – as the gradient threshold increased, the distance of modeled AFF increased upstream of SWIFD. The barriers included in Alternative A reduced this distance when compared to the other alternatives that used a 10% gradient (C10% and E10%).

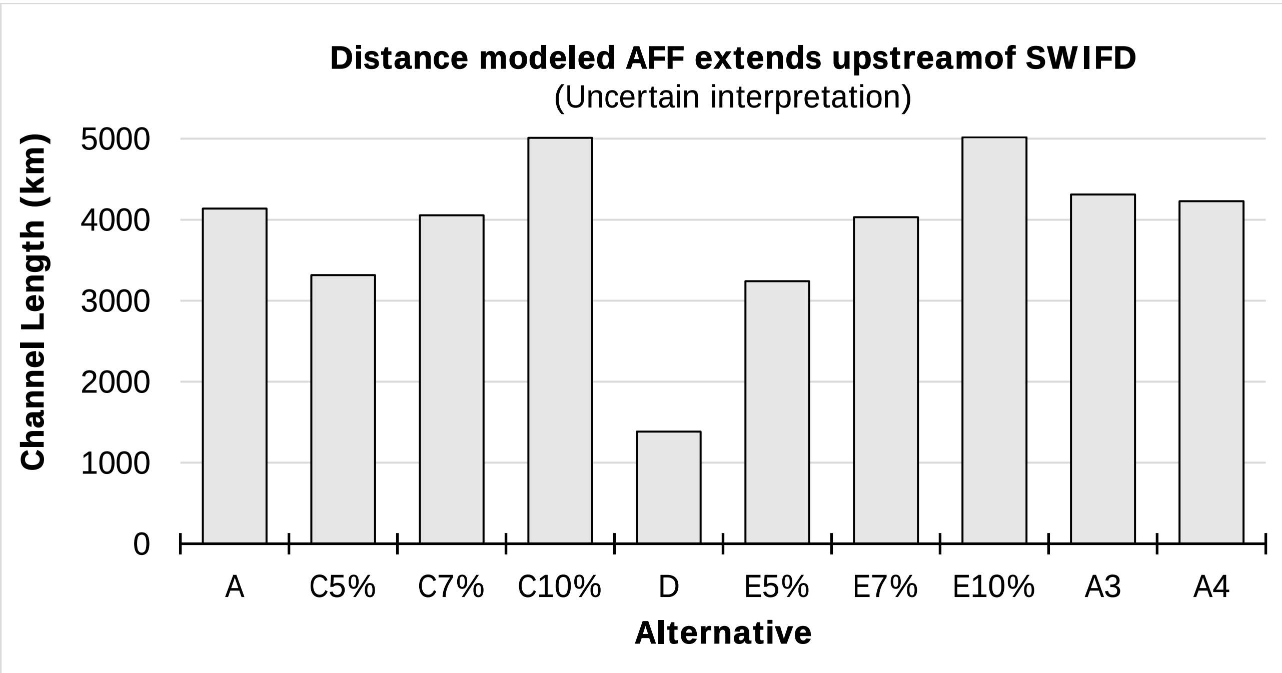

Figure 11. Bar chart showing the length of stream in which the modeled AFF extends upstream of the highest anadromous SWIFD points (Uncertain Interpretation).

False Positive

As expected, the alternatives that extend highest into the stream network (e.g. Alternatives C10%, E10% and A) also extend the farthest above F/N break points (Figure 12). Reducing the gradient threshold for Alternatives C and E reduces the length of stream in the False Positive category. The inclusion of barriers in Alternative A accounts for the shorter cumulative length of False Positive streams than either C10% or E10%, despite having the same gradient threshold (10%). Alternative D, which has the shortest total AFF length, also has the shortest length above F/N break points. The channel width-based barrier definitions in Alternative A4 reduced the false positive rate by ~20% below Alternative A3 (which used the WDFW barrier definitions).

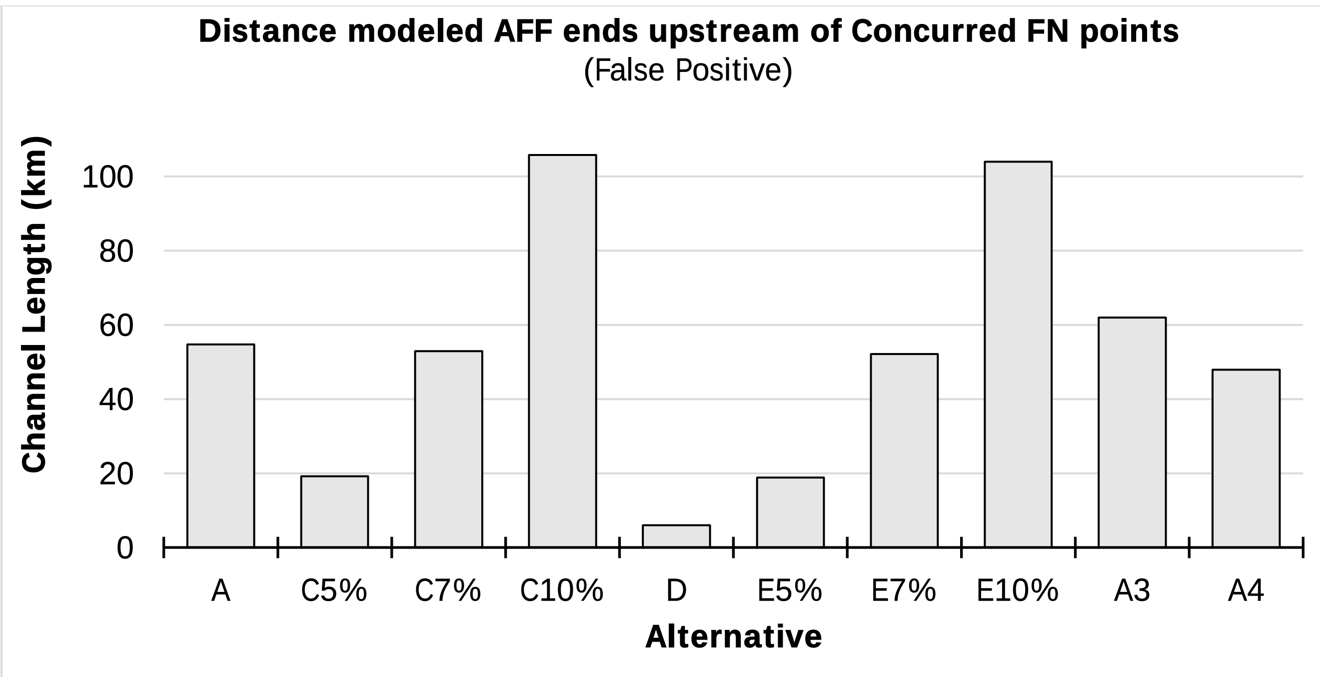

Figure 12. Bar chart showing the distance each modeled AFF alternative extends upstream of concurred F/N break points (false positives).

<u>No Data – streams without a concurred FN break point or Anadromy data</u>

Streams for which there were no fish data followed similar patterns as the overall AFF length results: Alternatives that used a 10% gradient threshold had the greatest length within their proposed AFFs, while alternatives that used lower gradient thresholds and Alternative D had the least length within their AFFs (Figure 13). Alternative D had the shortest length within its AFF for streams with no fish data – the area where any selected approach would actually be implemented as part of FHAM

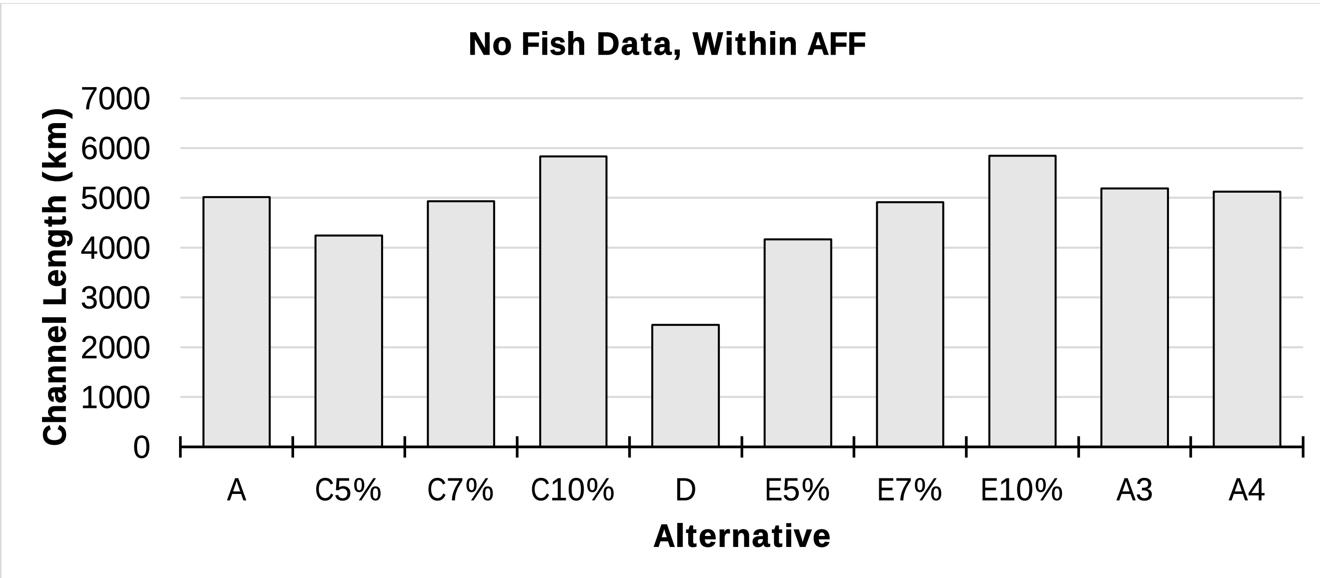

Figure 13. Stream lengths in the data set with no SWIFD, Other Anadromy or concurred F/N break point data.

Proportion of AFF and FN points above and below each alternative

Question of Interest: What proportion of anadromous fish distribution points and concurred F/N breaks points are observed above and below the proposed AFF overlays?

Alternatives using larger gradient thresholds had a larger proportion of anadromous and F/N break points within their modeled extent; the opposite was true for the proportion of points upstream of the AFF (Figure 14 - A). The exception to this rule was Alternative D, which had a high proportion of anadromous fish points coincident with the end of the AFF due to the use of the SWIFD data in the definition.

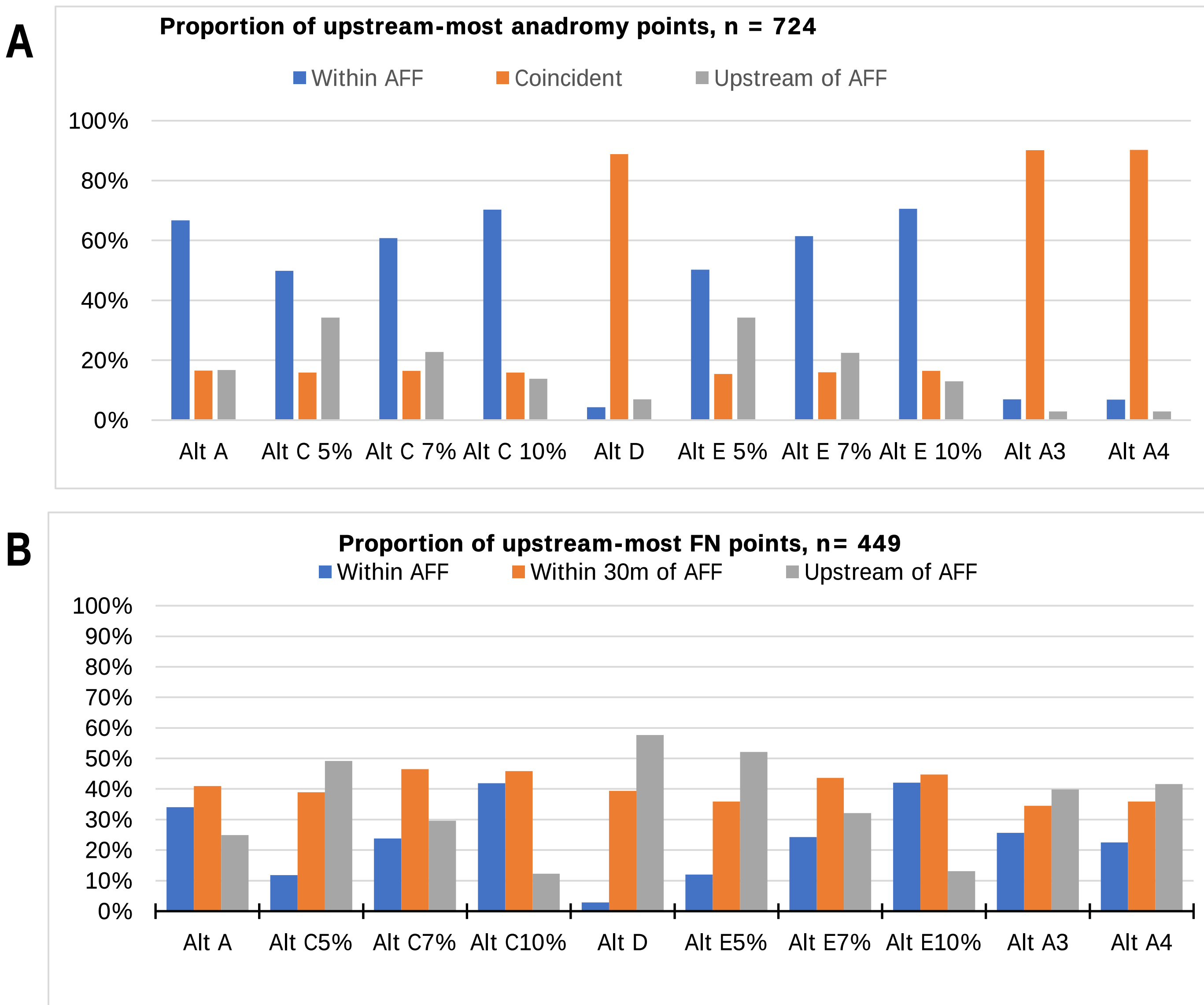

Figure 14. Proportion of anadromous and F/NN break points observed above, below and coincident with the upper extent of each AFF alternative, for anadromy points (A) and F/N Break points (B). 'Coincident' refers to fish data points located within 30m of channel distance to the AFF termination points. This distance was found to be effectively coincident during the GIS data 'snapping' exercise.

Not surprisingly a relatively higher proportion of F/N break points were observed upstream of the AFF proposals than the anadromous points (Figure 14 - B). These points are typically based on resident fish observations which tend to occupy higher portions of watersheds than anadromous fish.

Downstream Gradients

Question of Interest: What is the distribution of maximum channel gradients downstream from known anadromous fish distribution points and concurred F/N breaks?

Three of the four alternatives use a threshold in sustained gradient as at least one factor in determining the upstream extent of the modeled AFF. The appropriate choice of sustained-gradient threshold for identifying an anadromous floor is informed by the maximum sustained gradient values encountered downstream of documented anadromy in the synthetic channel networks. The distribution of maximum sustained gradient values within channels with documented anadromy and downstream of concurred F/N break points are shown in Figure 15. For anadromy, 63% of the maximum values are at 5% sustained gradient or less; 75% have maximum values of 7% or less; and 88% have maximum values of 10% or less. Values above 17% are potential outliers; these are typically associated with poorly placed anadromy points and have been removed from this analysis. For example, some data points on channels near the edge of a flood plain were digitized such that they fell on the valley slope rather than within the floodplain and were then incorrectly snapped to steep channels above the floodplain [2]. Other points were placed on road prisms when they should have been placed in the channel below. The edge of the road prism became an extremely steep channel reach. In total 650 anadromous points were used in this analysis.

The concurred F/N break points are typically upstream of the top-most anadromy points and, as expected, have a distinctly steeper distribution of maximum downstream sustained gradient values (Figure 15). A total of 420 concurred F/N break points were used in this analysis.

While informative, the steepest downstream gradient results should be interpreted with caution, because the documented anadromy points used in this analysis do not necessarily represent the upstream extent of anadromy (anadromy likely extends further upstream, and above steeper sustained gradients) and do not capture the full range of anadromy. Conversely, many of the anadromous points were also observed in channel segmented with less than 2% gradient (169 of 650), steepening the curve at lower elevations (Figure 15).

[2] Unique ID 4449 provides an example. The site is at the edge of the floodplain at the foot of a steep valley side slope. The original point location is on the side slope and it was snapped to a channel descending the slope rather downslope a bit after it flowed onto the floodplain.

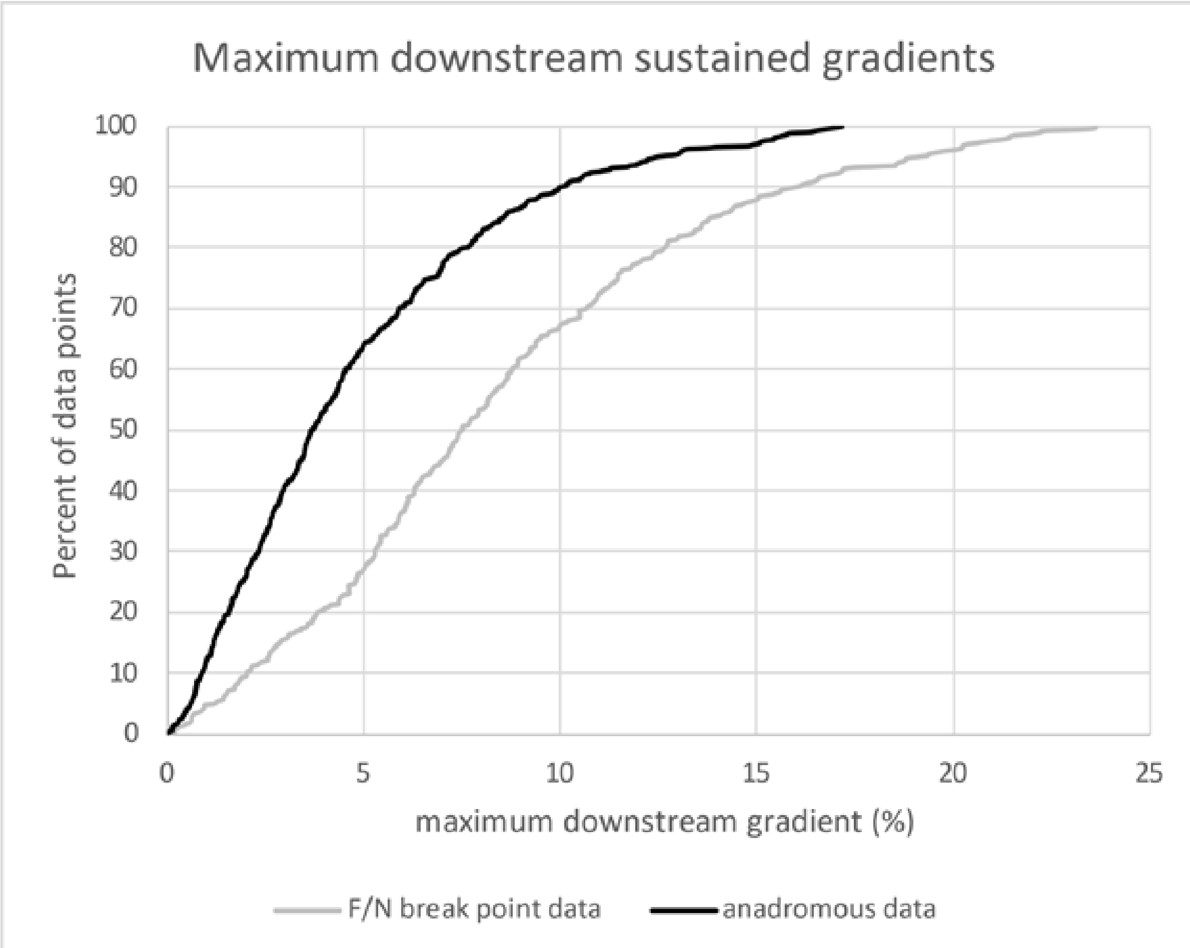

Figure 15. Cumulative distribution of maximum sustained downstream gradient below the anadromous fish distribution and F/N break data points. Outliers were removed from the plot using the 'Tukey's Fences' metric. In many cases, we discovered these outliers were mis-mapped data points on top of road prisms or other unnaturally steep channel sections.

The steepest downstream gradient from the highest known anadromy points averaged 4.7% gradient (median 3.7%; Figure 16). Not surprisingly, when measured from the highest concurred F/N break points, the steepest downstream gradient tended to be higher than when measured from the anadromy points (mean 8.4%, median 7.5%). As with Figure 15 the distribution of steepest downstream reaches from highest anadromy is weighted by many data points in streams with gradients less than 2%.

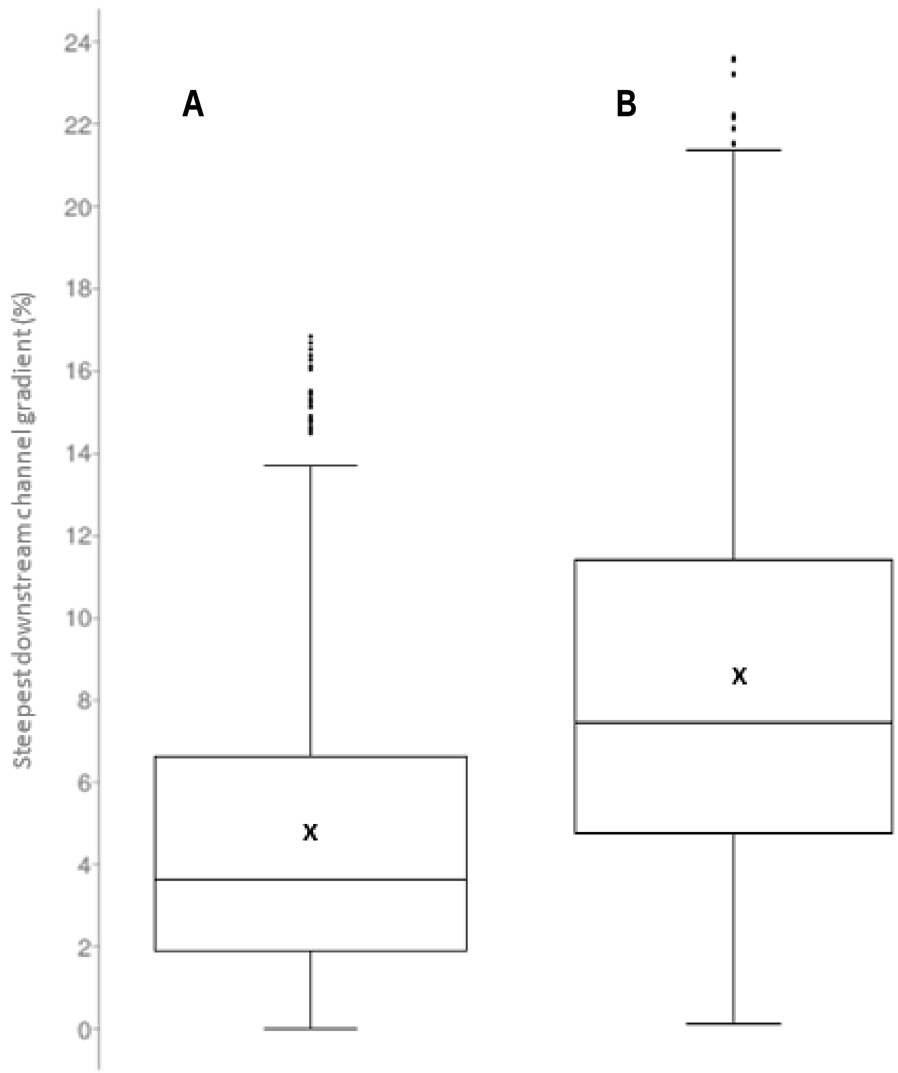

Figure 16. Box and whisker plots displaying the spread of steepest downstream gradients below highest anadromous points (A) and the highest concurred F/N break points (B). These are the same data as displayed in Figure 15. The median is indicated by the line in the box, mean is indicated by the 'X'.

Performance of Alternative Summary

Table 2 summarizes the channel lengths by stream category associated with each AFF alternative.

Table 2. Cumulative channel lengths (kilometers) for each AFF alternative and stream categories. The source of the reference points used to calculate channel lengths are identified in parenthesis.

	AFF Alternative									
Stream category (reference data)	**A**	**C5%**	**C7%**	**C10%**	**D**	**E5%**	**E7%**	**E10%**	**A3**	**A4**
Total stream length	6,468	5,568	6,378	7,381	3,527	5,495	6,356	7,391	6,455	6,371
True Positive (Other Anadromy)	1,053	1,040	1,051	1,054	1,028	1,040	1,050	1,054	1,053	1,053
False Negative (Other Anadromy)	1	14	3	1	27	15	4	1	1	1
Uncertain Interpretation (SWIFD)	4,138	3,315	4,054	5,008	1,384	3,240	4,030	5,017	4,312	4,228
False Positive (F/N break)	55	19	53	106	6	19	52	104	62	48
No Fish or F/N Break Data	5,014	4,241	4,935	5,831	2,451	4,169	4,913	5,842	5,189	5,125

The AFF alternative that resulted in the greatest length of stream presumed anadromous is E10% (7,391 km; Table 2). The AFF alternative accounting for the shortest distance of presumed anadromy is Alternative D (3,527 km).

Alternatives that extend highest into the watersheds (A, C10%, E10%) have the least length of streams that fall short of the anadromous data, and the most length of streams that extend upstream of F/N break points (Table 2).

Because Alternatives D, A3 and A4 start from known anadromous waters (SWIFD) they avoid potential modeling errors downstream of those points (Table 2). However, the stream lengths presumed anadromous under these proposals differed. Total stream lengths based on Alternatives A3 and A4 were notably greater than total stream lengths under Alternative D (6,455 km & 6,371 km vs 3,527 km). The difference is explained by how the AFF is applied relative to known anadromous waters under the alternatives, along with the use by the alternatives of different channel features that indicate the end of the AFF. The AFF only extends up lateral streams connected to known anadromous waters under Alternative D, whereas the AFF under Alternatives A3 and A4 can extend up terminal streams as well (Figure 17). Alternative D uses a 5% change in gradient criteria or a PHB obstacle at the tributary junctions with known anadromous waters; Alternatives A3 and A4 rely on larger features to indicate the end of anadromy -- 10% gradient threshold or a permanent natural barrier.

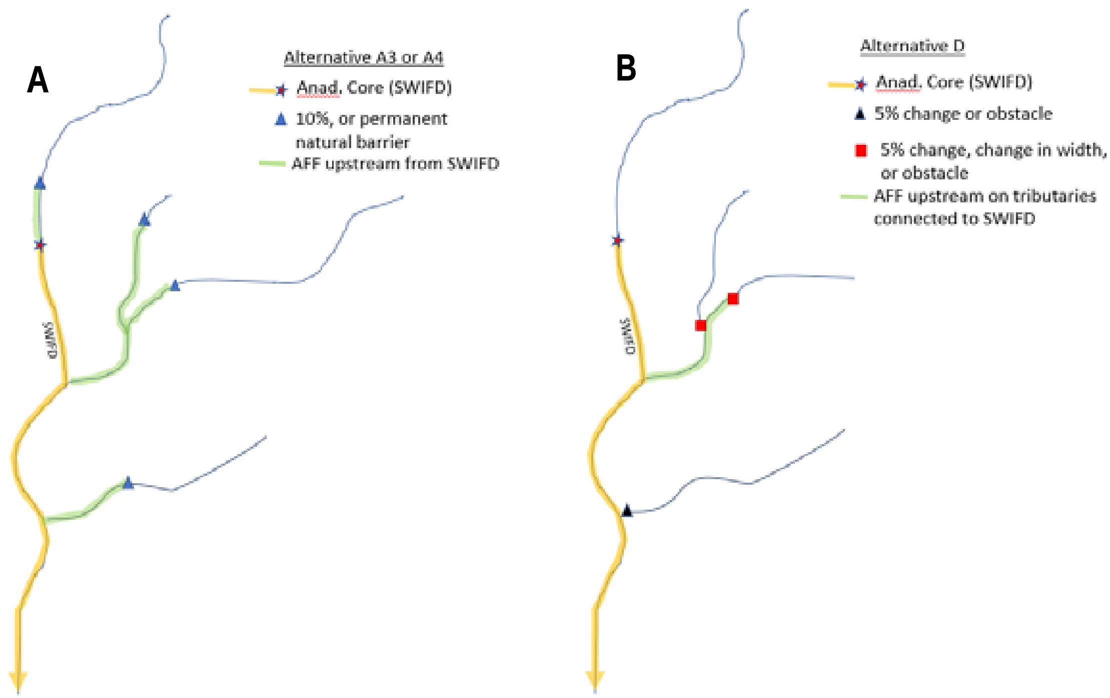

Figure 17. Stream schematic illustrating the difference between Alternatives A3 and A4 (A), and Alternative D (B).

The criteria used to define stream sized based barriers (Alternative A4) generally resulted in slight decreases in the extent of the AFF when compared to Alternative A4, which uses WDFW barrier definition, Table 2).

Alternative A better captures anadromous fish presence than Alternative D, but Alternative D does a better job of not extending beyond the mapped F/N breaks. The cumulative distance of stream lengths in the False Positives category under option Alternative A was 55 km vs 6 km of stream lengths in the False Positive category under Alternative D (Table 2). Including SWIFD and the stream sized based definition of barriers to Alternative A (Alternative A4) reduced the length of streams categorized as False Positive from 55 km to 48 km.

In streams that currently have yet to be water typed or where there is currently no anadromous fish data, applying Alternative D results in the most amount of stream length open to future protocol surveying in the water typing process (Table 2). Under Alternative A, slightly more than twice the stream length would be presumed anadromous than under Alternative D (5,014 km versus 2,451). Applying Alternative E10% results in the greatest distance of stream length presumed anadromous - 5,842 km.

Implementation

Alternatives A, C and E could be implemented a couple of ways. (1) Develop a statewide map identifying the (a) first occurrence of gradient thresholds upstream from saltwater and (b) the location of permanent natural barriers. This map likely would need to be created based on a modeling exercise similar to the work done on this project. Actual final placement of the AFF would be based on field verification as part of the FHAM process. (2) Make the assumption, absent any other information or access to downstream reaches, there are no permanent natural barriers downstream and/or channel gradients downstream that are lower than the gradient at the downstream edge of the property line. Field identification of the AFF would then proceed upstream from that downstream property line.

For alternatives incorporating SWIFD (A3, A4, D) implementation involves conducting field surveys working upstream from SWIFD (laterals only for Alternative D) to identify the gradient, obstacle, or barrier features associated with the upper extent of anadromous fish habitat, as defined in each alternative.

Alternative A3, A4, and D rely on formally incorporating known anadromy, such as SWIFD or StreamNet, into the Forest Practices water typing process. If any of these alternatives are adopted into the water typing process, DNR will need to add these anadromous fish data to its hydro layer, which will require a significant amount of work. In the interim, a field-based implementation protocol will need to be developed.

Whichever AFF criteria are applied, there will be some situations where ID Teams will be appropriate to address site-specific conditions.

DRAFT Recommendations

Consensus recommendations

Formally adopt Alternatives A3 and A4 as AFF alternatives for consideration by the FP Water Typing Rule Committee. The workgroup recognized that implementation of alternative A would be facilitated through field identification of its stopping criteria (10% sustained gradient or permanent natural barrier) upstream from known anadromy as represented in SWIFD. This approach, analyzed as A3 and A4, also enables a more meaningful comparison of performance between alternatives A and D.

If adopted into rule, include an AFF alternative as part of the water typing Fish Habitat Assessment Methodology currently under rule consideration by the FP Board, with implementation to be covered in Board Manual section 23.

Non-consensus recommendations

Add AFF to the FHAM/default physicals study currently being developed in CMER.