Slope stability and class IV-Special forest practices in the Skagit and Samish watersheds since the Forests and Fish Report

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SKAGIT RIVER SYSTEM COOPERATIVE

Introduction

In Washington State, strengthening mitigation measures for sediment supply impacts from forestry was a central component of the 1999 Forests and Fish Report (USFWS et al., 1999) due to the many prior decades of high sediment yield and resulting impacts to aquatic resources in the managed forest landscape (Beechie et al., 2001; Montgomery et al., 2000). Since the recommendations from the Forests and Fish Report were enacted into law in 2001, the Washington forest practices rules (Washington Administrative Code Chapter 222) have increased regulatory scrutiny for timber harvest and associated activities within potentially unstable slopes and landforms ('class IV-Special' activities). Therefore, there is now a greater than two-decades long record of regulated forestry activities within potentially unstable landforms that may be used to assess the efficacy of this aspect of Forests and Fish regulation. Moreover, recent work has quantified a large drop in managed forest landsliding and linked the reduction to hazard avoidance and road engineering strategies adopted by State and private timber companies to comply with the Forests and Fish Report and related Habitat Conservation Plans (Seixas and Veldhuisen, 2023). That research was conducted at a watershed scale, limiting the conclusions to general trends. Site-scale evaluations to test the efficacy of forest practices rule implementation were not possible. The objectives of this report are to:

1. Assess temporal trends in class IV-Special FPA approval and spatial trends in class IV-S activities.
2. Assess which landforms are most commonly proposed for forestry activities, and what mitigation strategies are most commonly employed.
3. Evaluate evidence for the success or failure of the proposed mitigation solutions at the site scale.

To accomplish these objectives, I conducted a retrospective analysis of an extensive database of forest practices applications and supplemented the analysis using a combination of GIS and field methods, detailed below. I conclude the report with a discussion of the findings and some recommendations.

Background and regulatory context

The first forest practices rules did not regulate forestry activities on unstable slopes (WFPB, 1976). Slope stability was added to the list of activities triggering class IV-S classification in 1982, yet the new rules only regulated road construction (not timber harvest) and the criteria for triggering class IV-S classification were subjective and poorly defined (WFPB, 1982). Since 2001, the Washington Administrative Code (WAC 222-16-050(1)(d)) has classified forestry activities within 'rule identified landforms' as class IV-Special (IV-S) FPAs. The rule identified landforms are:

A. Inner gorges, convergent headwalls, or bedrock hollows with slopes steeper than thirty-five degrees (seventy percent).
B. Toes of deep-seated landslides, with slopes steeper than thirty-three degrees (sixty-five percent).
C. Groundwater recharge areas for glacial deep-seated landslides.
D. Outer edges of meander bends along valley walls or high terraces of an unconfined meandering stream.
E. Any areas containing features indicating the presence of potential slope instability which cumulatively indicate the presence of unstable slopes.

Within these landforms, forestry activities are precluded unless a 'qualified expert' (a licensed engineering geologist or hydrogeologist with substantial relevant experience) determines the proposed activities will result in a low risk to public resources or public safety and/or proposes an adequate mitigation strategy Additionally, the landowner must complete a State Environmental Policy Act checklist. An interdisciplinary team assembled by the Department of Natural Resources assesses the potential risks and proposed mitigation and offers recommendations prior to FPA approval. Therefore, unstable slopes risk assessments are part of a multi-stakeholder collaborative process focused on technical solutions to forestry and aquatic resource protection challenges.

Methods

I used the FPA database maintained by the Skagit River System Cooperative Forests and Fish staff to identify all class IV-S FPAs submitted between 2001 and 2022 within the Skagit and Samish River watersheds (Fig. 1). Because FPAs were entered into this database as they were submitted, and because it is common for proposals to be resubmitted more than once (for example, if additional information is needed late in the FPA review period or adverse conditions delay field review), I removed withdrawn or disapproved FPAs from the dataset without regard to the reason for the disapproval or withdrawal. Additionally, WAC 222-16-050 uses the class IV-S mechanism for potentially sensitive forestry activities not related to unstable slopes (e.g. timber harvest in a public park or near the habitat of endangered wildlife); I further refined the dataset to exclude non-slopes-related class IV-S FPAs.

The FPA database contains fields for year of submission, watershed administrative unit (WAU), and landowner. To supplement the data contained in the database, I reviewed each FPA in the reduced dataset and recorded information on class IV-S trigger (i.e. timber harvest, road building), rule-identified landform proposed for the activity, and proposed mitigation. I gathered this information from notes by DNR staff on the FPA cover page, from information included in the FPA itself, and from information in the geotechnical reports included with most unstable slopes class IV-S FPAs.

Additionally, I located each proposal on aerial photographs and lidar-derived hillshades in ArcGIS Pro using maps included in the FPAs and geotechnical reports. At each site, I determined the locations of the specific activities that triggered the class IV-S classification and reviewed the subsequent aerial photograph record to try to identify evidence of failure of the proposed mitigation. For example, at inner gorge road crossings I evaluated the crossing location and downstream reaches for evidence of road failure and debris flow. I reviewed aerial orthophotographs from 2003, 2004, 2006, 2009, 2011, 2013, 2015, 2017, 2019, 2021 and 2022. Additionally, I reviewed a sample of sites in the field to confirm the aerial photo observations and to better understand site-scale conditions.

Results

FPA database overview and spatial and ownership representation

There were 163 approved class IV-S FPAs in our dataset between 2001 and 2022. Of these, 72 (44%) were classified as class IV-S due to proposing forestry activities within rule identified landforms (the remaining 91 contained forestry activities within parks or close to critical wildlife habitat, among other issues). Hereafter, I use the term 'class IV-S' to refer only to proposals that were classified that way due to slope stability concerns.

Class IV-S FPAs were well represented throughout the state and private managed forest land base (hatched portions of Fig. 1).

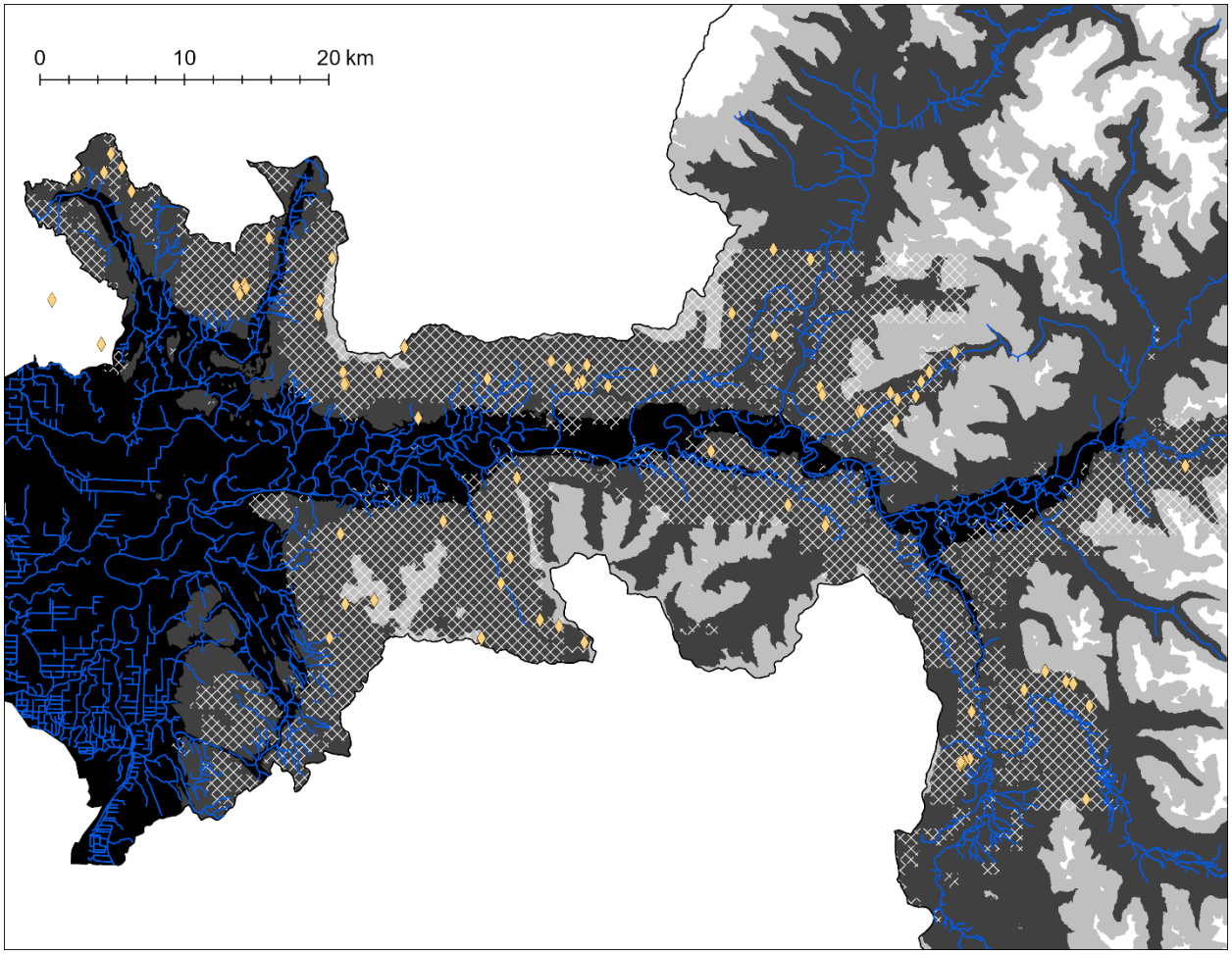

Figure 1. Map of the lower Skagit and Samish River watersheds showing anadromous waters (blue lines) and the extent of industrial and state forestry (white hatch marks) where the forest practices rules apply. Class IV-S FPA locations are shown as yellow diamonds. The FPAs off the far western edge of the map are adjacent to streams draining directly to Puget Sound. Elevations are shown in bins (black: 0-100m; dark gray: 100-1000m; light gray: 1000-1500m; white: >1500m).

The Department of Natural Resources submitted the most class IV-S FPAs of any ownership, followed by Longview/Weyerhaeuser, Crown Pacific/Sierra Pacific Industries, and then a host of small industrial and small landowners (Fig. 2).

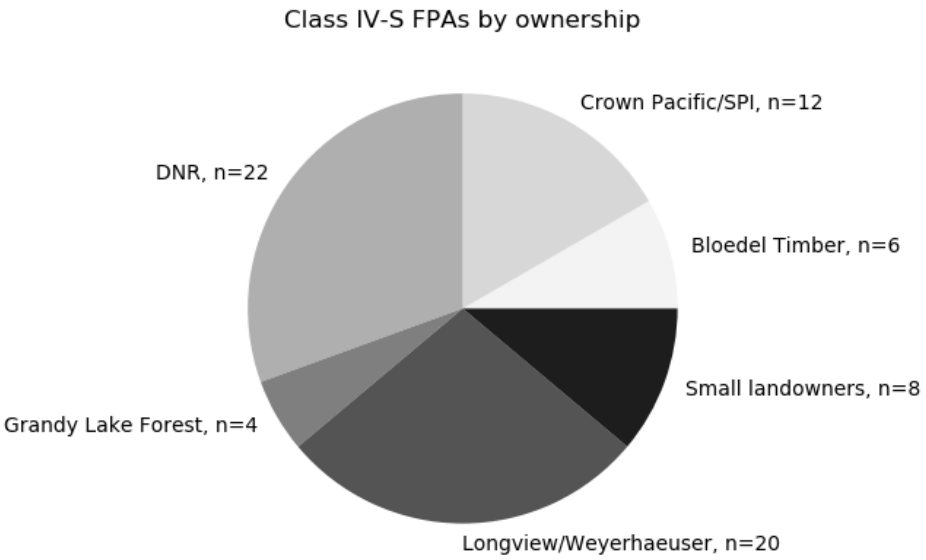

Figure 2. Class IV-S FPAs by ownership. For this figure, ownerships have been combined where tree farms were sold to a new owner (i.e. Crown Pacific/SPI represents the same forest land base managed under two successive owners). DNR: Department of Natural Resources. SPI: Sierra Pacific Industries.

Using parcel data from Skagit, Whatcom and Snohomish counties, I determined the area of each of the large land ownerships presented in figure 2 (Crown Pacific/SPI, DNR State Lands, Longview/Weyerhaeuser, Grandy Lake Forest Associates and Bloedel Timber). Using these data, I determined that Bloedel Timber and Longview/Weyerhaeuser (which is now owned by Mid Valley Resources) have submitted the greatest number of class IV-S FPAs on a per-area basis (Table 1). The Crown Pacific/SPI ownership has submitted the lowest number on a per-area basis.

Table 1. Ownership area and area-normalized class IV-S FPAs for the largest ownerships in the database.

Ownership	Area (acres)	# Class IV-S FPAs/10km^2
Bloedel Timber	7091.924	0.85
Longview/Weyerhaeuser	38869.68	0.51
DNR	93727.07	0.23
Grandy Lake Forest	19817.85	0.20
Crown Pacific/SPI	69683.72	0.17

Temporal variability, forestry activity type, landform and mitigation strategy

Road crossings through rule identified landforms were by far the most common class IV-S trigger (62%), followed by harvest on RIL (30%), harvest near RIL (4%) and yarding corridor through RIL (3%) (Fig. 3). The mean rate of class IV-S FPA approval was 3.6 FPAs/year. Prior to 2010, most years only recorded one or two class IV-S FPAs; starting in 2010, most years recorded at least four class IV-S FPAs. The greatest number of class IV-S FPAs in a year occurred in 2015, when seven were approved (Fig. 3).

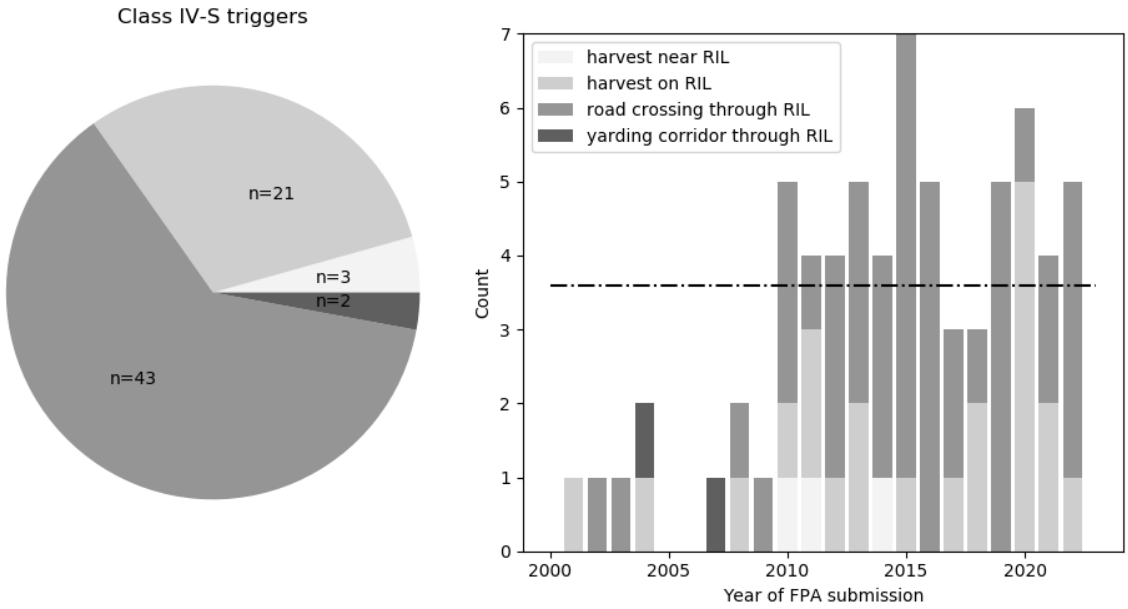

Figure 3. Class IV-S triggers shown as a pie chart (left) and as a bar chart (right), which also serves to demonstrate the temporal progression. The horizontal dashed black line in the right chart signifies the mean annual class IV-S approval rate (3.6). RIL: rule identified landform.

The inner gorge landform (category A; see regulatory background section above) was by far the landform most commonly proposed for forestry activities (road building), followed by groundwater recharge areas of glacial deep-seated landslides, deep-seated landslides, and then other more unusual landforms (Fig. 4). I was not able to determine the triggering landform for class IV-S status in three FPAs due to poor or incomplete descriptions.

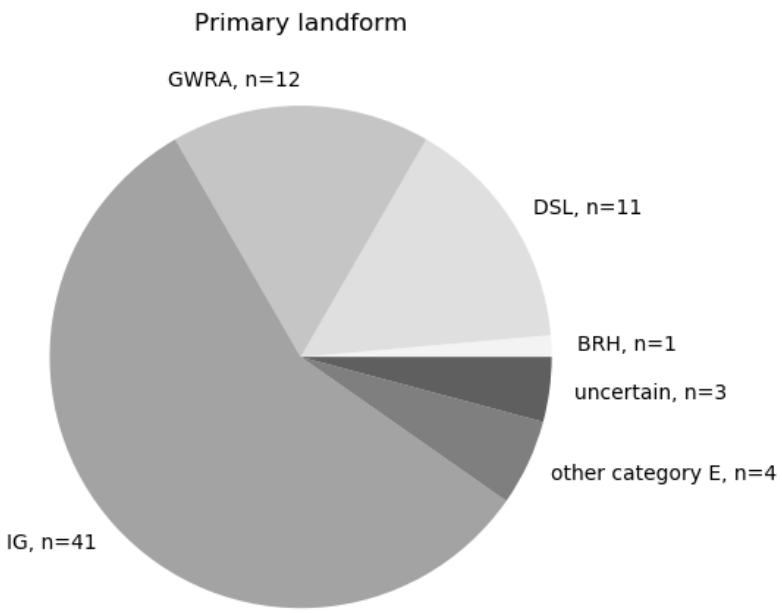

Figure 4. Class IV-S FPAs by primary landform, i.e. the landform in which forestry activities were proposed that triggered class IV-S status. GWRA: ground water recharge area (glacial deep-seated landslides only). DSL: deep-seated landslide. IG: inner gorge. BRH: bedrock hollow. 'Other category E' refers to landforms that were difficult to classify but were nonetheless deemed to be potentially unstable.

A wide array of mitigation strategies were prescribed for FPAs proposing road crossings within rule identified landforms (Fig. 5, left side). Shot rock fill was the most common primary mitigation strategy, followed by rock armored native fill and then a range of strategies designed to strengthen the crossing structure, minimize disturbances, repair previous structures, or abandon the structure following harvest (Fig. 5, left side). In contrast, proposed harvest on rule identified landforms tended to elicit only four possible prescriptions: minimize disturbance, avoid the landform, avoid the activity during the wet season, or justify the activity due to the low likelihood of response following harvest (Fig. 5, right side). My 'minimize' category refers to a variety of techniques to minimize disturbance of the activity such as selective harvest (thinning).

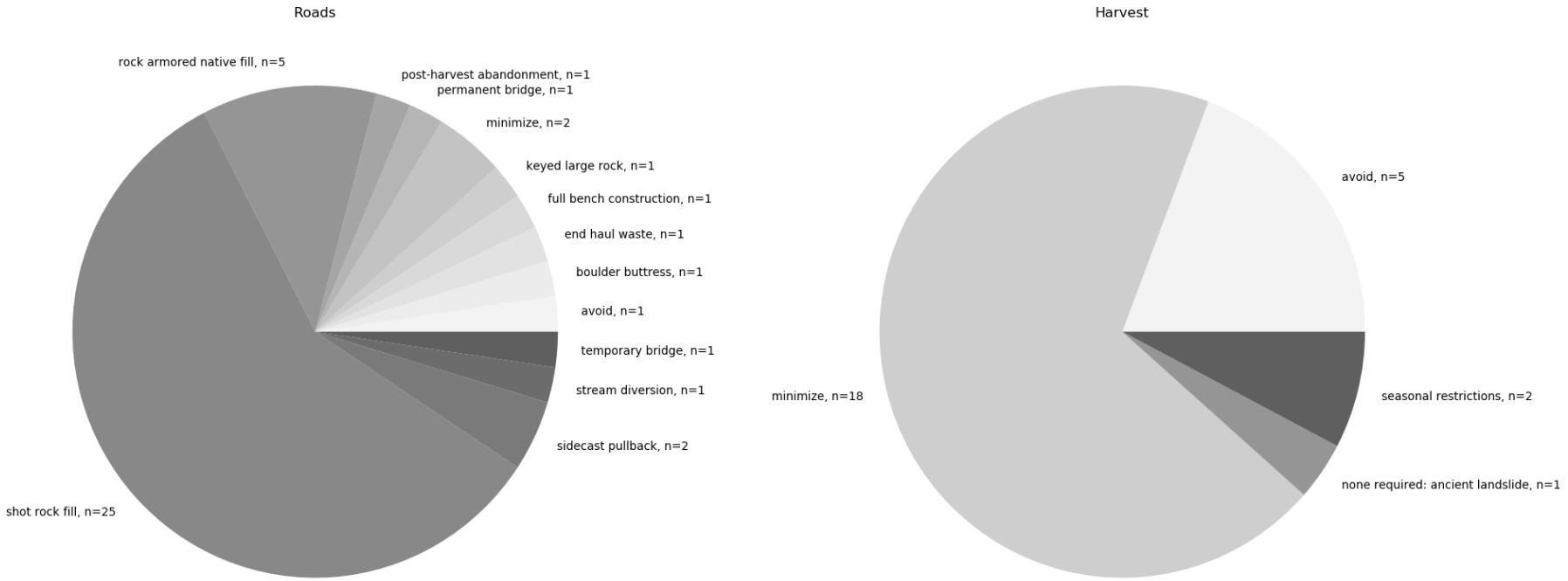

Figure 5. Class IV-S FPAs by primary mitigation. Left: road crossings. Right: timber harvest.

Evidence for success of class IV-S mitigation strategies

I found no evidence for mass wasting at or nearby class IV-S trigger sites in the available aerial photograph record. I field reviewed 14 class IV-S trigger sites (all water crossings) spread across 10 class IV-S FPAs (13.9% of the FPAs in the dataset), where I confirmed the stability of the built structures and mitigation strategies. I found no evidence for failure or sediment delivery issues at any of the sites. One site had evidence of minor windthrow (2-3 trees) in the inner gorge possibly caused by exposure following road building, but no sediment appeared to have delivered to the nearby stream.

Discussion

This summary of class IV-S FPAs demonstrates the ubiquity of inner gorge crossings and the commonality of the primary mitigation strategy used for these crossings (shot rock fills). Most shot rock fills were accompanied by additional mitigation measures such as dips in the road cross-section, large rock armoring, and/or full bench construction where roads 'side hill' into large inner gorges. The commonality of these approaches, as well as the complete lack of evidence for problems associated with these crossings, suggests that many inner gorges and associated streams could be successfully crossed with minor input from a geological engineer. Indeed, many of the geotechnical evaluations I reviewed were long, cumbersome documents burdened by geological details that were irrelevant for what was in essence a very simple proposal. These observations suggest that a 'standard prescription' could be developed for inner gorge road crossings, similar to the prescriptions in many watershed analyses (Collins and Pess, 1997). Qualified experts could be used to confirm whether a proposed stream crossing location presents unusual challenges requiring additional mitigation measures. Deviations from the standard prescription could be dealt with by the interdisciplinary team or, in more challenging settings, by a qualified expert hired by the landowner.

Harvest *near* a rule identified landform is not a class IV-S trigger because mitigation by avoidance is thought to be one of the most effective strategies to avoid land management-related hazards (Stewart et al., 2013). However, two FPAs were classified as class IV-S but had geotechnical evaluations appearing to support a mitigation by avoidance strategy. One possible explanation for the classification is the history of FPA submission and review, which may have changed the original proposal following reviewer feedback. For example, FPA 2817960 was originally classified as class IV-S due to proposed harvest on an active deep-seated landslide. During review, the interdisciplinary team did not accept the justification for harvest provided by the landowner's geotechnical expert; the landowner elected to remove the deep-seated landslide harvest from the proposal, effectively eliminating the class IV-S trigger. The FPA maintained its original classification, but I coded the mitigation strategy as 'avoid' in the database.

Interestingly, the rate of class IV-S FPA approval was significantly different before and after 2010 (Fig. 3). The increase in FPA approval following 2010 is likely a real phenomenon and not a data completeness issue. Anecdotally, many landowners avoided activities within rule-identified landforms in the first years following 2001 primarily to defer the higher costs of class IV-S activities while more accessible timber was available (Curt Veldhuisen, personal communication, October 2023). The abrupt uptick in class IV-S FPAs starting in 2010 (Fig. 3) may also be related to changing landowner strategies as ownerships changed hands. For example, Weyerhaeuser bought the Longview tree farm around 2010; in-house Weyerhaeuser geotechnical experts (as well as corporate managers) may have had more comfort with the class IV-S process. Similarly, Sierra Pacific Industries bought the Crown Pacific tree farm in 2008. Further, the decade following 2010 saw a strong uptick in harvest in portions of the state and private

forest land base due to stands in those areas aging into merchantability (Seixas and Veldhuisen, 2023). These areas included very steep terrain owned by Weyerhaeuser in Jackman Creek and Nookachamps Creek, among others, that likely contained a higher concentration of rule identified landforms and therefore a higher rate of class IV-S activities.

Previous work has demonstrated that landslide sediment yield was 24 $m^3/km^2/yr$ between 1999 and 2019 in the managed forest landscape of select Skagit River tributary basins; this represents significant sediment volumes but is far less than the historical average of 98 $m^3/km^2/yr$ (Seixas and Veldhuisen, 2023). Road related landsliding represented approximately one third of that volume in the 2000s but fell to almost zero following 2010. Therefore, this study extends previous work by demonstrating that the forestry related landslides documented by Seixas and Veldhuisen (2023) after 2001 seldom occurred on rule identified landforms. In the case of road crossing class IV-S FPAs, it is possible small failures occurred that did not lead to disturbance of downstream vegetation and that were quickly repaired by the landowner such that evidence of the failure was not detected during field checks. Even if this had occurred at a few sites, the fact that downstream damage was not visible in the aerial photo record suggests impacts to aquatic habitat would have been minimal. Therefore, the findings of this report support the conclusion of Seixas and Veldhuisen (2023) that the Forests and Fish rules have had positive outcomes for slope stability mitigation.

Conclusions

1. *What are the temporal trends in class IV-Special FPA approval and spatial trends in class IV-S activities?*

   Class IV-S FPAs were approved at a mean rate of 3.6/year between 2001 and 2022. There was a significant uptick following 2010, after which at least 4 class IV-S FPAs were submitted in most years. Class IV-S FPAs were well distributed throughout the managed forest landscape.

2. *Which landforms are most commonly proposed for forestry activities, and what mitigation strategies are most commonly employed?*

   Inner gorges were most commonly proposed for road crossings (no inner gorges were proposed for timber harvest). Groundwater recharge areas were also commonly proposed for harvest (usually thinning). Common mitigation measures included shot rock fills, dips, large rock armoring, and selective harvest or avoidance. Mitigation strategies for roads were more varied than for harvest.

3. *What was the evidence for the success or failure of the proposed mitigation solutions?*
   I found no evidence for failure of any of the proposed mitigation solutions, suggesting a positive outcome from the class IV-S regulatory process since the Forests and Fish Report. Several proposals in the database had few or no aerial photos following construction/harvest; I recommend revisiting this analysis in five years to assess possible future impacts.

Acknowledgements

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References

Beechie TJ, Collins BD, Pess GR. 2001. Holocene and Recent Geomorphic Processes, Land Use, and Salmonid Habitat in two North Puget Sound River Basins. In Geomorphic Processes and Riverine Habitat, Water Science and Application , . American Geophysical Union; 37–54.

Collins BD, Pess GR. 1997. Evaluation of forest practices prescriptions from Washington's watershed analysis program. Journal of the American Water Resources Association **33** : 969–996. DOI: 10.1111/j.1752-1688.1997.tb04118.x

Montgomery DR, Schmidt KM, Greenberg HM, Dietrich WE. 2000. Forest clearing and regional landsliding. Geology **28** : 311–314.

Seixas GB, Veldhuisen CN. 2023. Forest management history influences eight decades of shallow landsliding in the northwest Cascade Mountains, USA. Earth Surface Processes and Landforms **48** : 2716–2736. DOI: 10.1002/esp.5656 [online] Available from: https://onlinelibrary.wiley.com/doi/10.1002/esp.5656

Stewart G, Dieu J, Phillips J, O'Connor M, Veldhuisen C. 2013. The Mass Wasting Effectiveness Monitoring Project: An examination of the landslide response to the December 2007 storm in Southwestern Washington . Olympia, WA

U.S. Fish and Wildlife Service, along with other federal and state agencies, Native American Tribes, and forest landowner associations. 1999. Forests and Fish Report . Olympia, WA [online] Available from: https://www.dnr.wa.gov/publications/fp_rules_forestsandfish.pdf (Accessed 8 August 2023)

Washington Forest Practice Board. 1976. Washington Forest Practice Rules and Regulations . Washington Department of Natural Resources: Olympia, WA

Washington State Forest Practices Board. 1982. Washington Forest Practices Rules and Regulations . Washington Department of Natural Resources: Olympia, WA