Skagit County Riparian Buffer Evaluation

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Introduction

Reducing riparian canopy cover impairs ecological function and ecosystem integrity (Quinn et al. 2020). The Washington Department of Fish and Wildlife has adopted a set of science-based management recommendations for riparian buffer widths in land use planning that are intended to minimize this impairment (Rentz et al. 2020). Specifically, a lateral distance set by "site potential tree height" (SPTH) at age 200 can provide "full riparian function" (i.e., the height of the tallest mature trees defines the buffer width). Riparian functions include bank stabilization, shade, pollution removal, large wood delivery, nutrient inputs, climate mitigation, stormwater attenuation, and wildlife habitat (among others). These functions help ameliorate the impacts of upland land uses and management practices on aquatic systems.

The goal of this technical analysis is to demonstrate the spatial implications of the buffer width framework proposed by Skagit County as a part of the county's periodic update to its critical areas ordinance (CAO) under Washington State's Growth Management Act. We evaluated three alternative buffer scenarios: the site potential tree height at age 200 (SPTH), the current Skagit County proposed amendments (SKA2025), and the current Skagit County buffer requirements (SKA2006, Table 1). Within each of these three scenarios we report the raw acreages as well as the area of past riparian tree loss and existing riparian forest using land cover change detection data and land cover, respectively. We also examine these forest cover metrics across different stream types and land use designations.

Our focus is on relevant relative differences at the scale of countywide jurisdiction, not site-scale geospatial precision. This analysis was scripted from publicly available datasets released by Skagit County and other state and federal agencies, emphasizing transparency and reproducibility. While this is not a regulatory document and should not be read or interpreted as bearing on any particular parcel land use considerations, it does provide a new source of best available science for the county to include in its CAO update.[3] While type S waterbodies, by definition, fall within shoreline jurisdiction, they are currently covered under the county's CAO until its Shoreline Master Program update is complete.

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Methods

The analysis area of interest was where the county's stream buffers apply. We defined this as the county's jurisdictional area by excluding tribal, federal, state, and other non-county land use regimes (Figure 1) from further analysis. We also used the zoning designations in the Skagit County "Comprehensive Plan and Zoning Districts" GIS dataset to further constrain the analysis to the relevant jurisdictional area.[4] Specifically, "Incorporated Areas," "Secondary Forest," "Industrial Forest," and "Public Open Space of Regional/Statewide Importance" were excluded.

Table 1. Areas and parameters of the three riparian buffer width scenarios evaluated. Two scenarios (SKA2006 and SKA2025) were based on stream type, and one scenario was based on site potential tree height at age 200 (SPTH).

Buffer Scenario	Acres	Percent SPTH	Type S Width	Type F Width	Type Np/Ns Width
SKA2006	20,993	75.78%	200	150	50
SKA2025	22,823	82.39%	200	150	100
SPTH	27,701	100.00%	Site potential tree height		

The DNR Watercourses[5] and Water Bodies[6] datasets were used as the primary hydrography for this analysis because they are used by the county. Water types S (Shorelines of the State), F (Fish Habitat), and N (Non-fish Habitat) were included. Type U (Unknown) was treated as type N, and type X (Non-typed) was excluded. Because the scope of this analysis is limited to stream buffers and not lakes or wetlands, only water bodies labeled as stream were included, and watercourse streamlines within lakes and channel migration zones (i.e., around riverine islands) were removed. Watercourse ditches were also excluded. To further refine the accuracy of the mapped river boundaries, the Extent of Observed Water polygons from WDFW's Riparian Management Zone dataset[7] were incorporated wherever they overlapped the selected DNR water bodies, and the DNR water type attribute was transferred to them.

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[4] https://www.skagitcounty.net/Departments/GIS/Digital/compplan.htm

[5] https://data-wadnr.opendata.arcgis.com/datasets/wadnr::dnr-hydrography-watercourses-forest-practices-regulation/about

[6] https://data-wadnr.opendata.arcgis.com/datasets/wadnr::dnr-hydrography-water-bodies-forest-practices-regulation/about

[7] https://fortress.wa.gov/dfw/public/PublicDownload/Habitat/PHSRMZInformation/index.htm

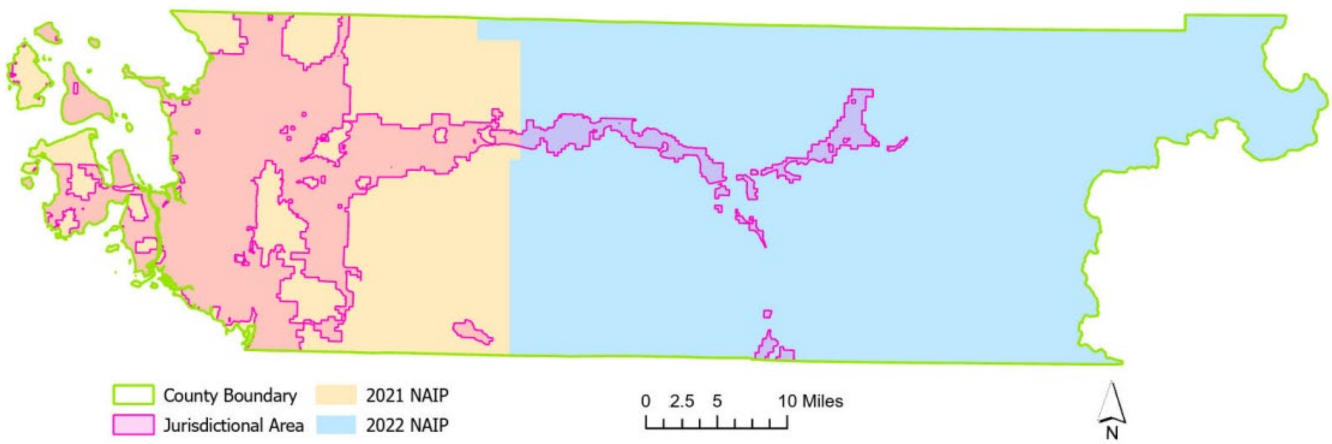

Figure 1. Most of the county's jurisdictional area (pink) is covered by 2021 National Agriculture Imagery Program (NAIP) imagery[8] (tan), but some was not flown until 2022 (blue). These are also the dates of the Ecopia land cover dataset.

We generated buffers for SKA2006 and SKA2025 based on DNR water type according to the widths in Table 1. For the SPTH scenario, we intersected WDFW's 200-year SPTH dataset[7] with the DNR hydrography to generate the buffer widths and applied a minimum 100-foot width where the SPTH was less than 100 or missing data, consistent with WDFW recommendations (stream length-weighted mean = 175 feet; stream length-weighted median = 204 feet). For each scenario, buffers were dissolved by water type, erased from within water bodies, and clipped to the jurisdictional area. In terms of the raw acreage, the SKA2006 buffers captured >75% of the area of SPTH buffers, and the SKA2025 buffers captured ~82% of the area of SPTH buffers (Table 1).

We then intersected the buffers with the comprehensive plan zoning dataset after filling gaps in the non-zone areas along rivers with the closest zone (i.e., where buffers meandered). We used the same four comprehensive plan zoning designation categories of "Natural Resource Lands," "Rural Lands," "Commercial/Industrial Lands," and "Urban Growth Areas (UGA)"; ("Public Open Space of Regional/Statewide Importance" was excluded).[9] Within "Natural Resource Lands" we only included "Agricultural" in this analysis for comparison purposes acknowledging the county's participation in the Voluntary Stewardship Program (VSP) as an alternative to regulation under the CAO. An additional "no-data" category represents a trace amount of acreage and was not shown in results.

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8 https://naip-usdaonline.hub.arcgis.com/

9 https://www.skagitcounty.net/PlanningAndPermit/Documents/CompPlan2016/comp-plan-2016-adopted-text-only.pdf (see Table 1)

Next, we evaluated land cover data within the buffer scenario features as an indicator of riparian function (Figure 2). First, we estimated past riparian tree loss from the WDFW High Resolution Change Detection (HRCD) dataset.[10] Then, we estimated existing riparian forest from the Ecopia high resolution land cover vector dataset (the most recent data available).[11] As a result, each feature contains information about the type and acres of land cover change that occurred within two- or three-year intervals between 2006 and 2019 (HRCD) and the total number of acres by land cover class in 2021-2022 (Ecopia).

HRCD data exists for the full jurisdictional area for the timeframe of 2006-2019 (Figure 2). Because HRCD changes are detected using NAIP imagery, data are available for the six intervals of 2006-2009, 2009-2011, 2011-2013, 2013-2015, 2015-2017, and 2017-2019. Land cover change acres were calculated by multiplying the change percentage for a polygon by the acres of that polygon that fall within the given buffer. Annualized change acres were calculated for each interval by dividing the total change acres by three for the 2006-2009 interval or by two for the other intervals. HRCD records tree loss, impervious surface increase, semipervious surface increase, and total change, and assigns a change agent attribute to each change. We limited our evaluation to human caused, or anthropogenic, change agents which include "Development," "Forestry," "Other Anthropogenic," "Redevelopment," "Retention Pond," and "Tree Removal" and did not evaluate the natural change agents ("Stream" and "Other Natural"). Because we excluded forestry-related land use categories from the county's jurisdiction area, we assume the land cover change our analysis attributed to Forestry was for tree harvest permitted under the CAO (i.e., conversion to development) as opposed to tree harvest permitted under the Forest Practices Rules (Class III, non-conversion).

Please note that HRCD data are an estimate, not an exact measurement, of land cover change. While analyst review of predicted change polygons eliminates commission error, some changes are missed; therefore, change acres predicted by HRCD can be considered an approximate *lower* bound estimate of the true acres of change. There also may be spatial uncertainty about the exact location of a change whenever less than 100% of a polygon has changed.[12]

The Ecopia land cover dataset includes two forest classes: "forest," which is a more conservative (lower) estimate of the ground area occupied by forest and "forest_canopy_overlap," which includes the area mapped as "forest" plus areas where the tree canopy overlaps other land classes such as "grass" or "pavement." Both are included in this report because they provide a range for assessing riparian ecological functions. The Ecopia dataset was created using NAIP imagery, which for this jurisdictional area was flown mostly in 2021, but there is a portion (~12%) in the eastern part of the area that was not flown until 2022 (Figure 1).

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[10] https://hrcd-wdfw.hub.arcgis.com

[11] https://www.ecopiatech.com/products/3d-nationwide-landcover

[12] https://hrcd-wdfw.hub.arcgis.com/pages/tutorials

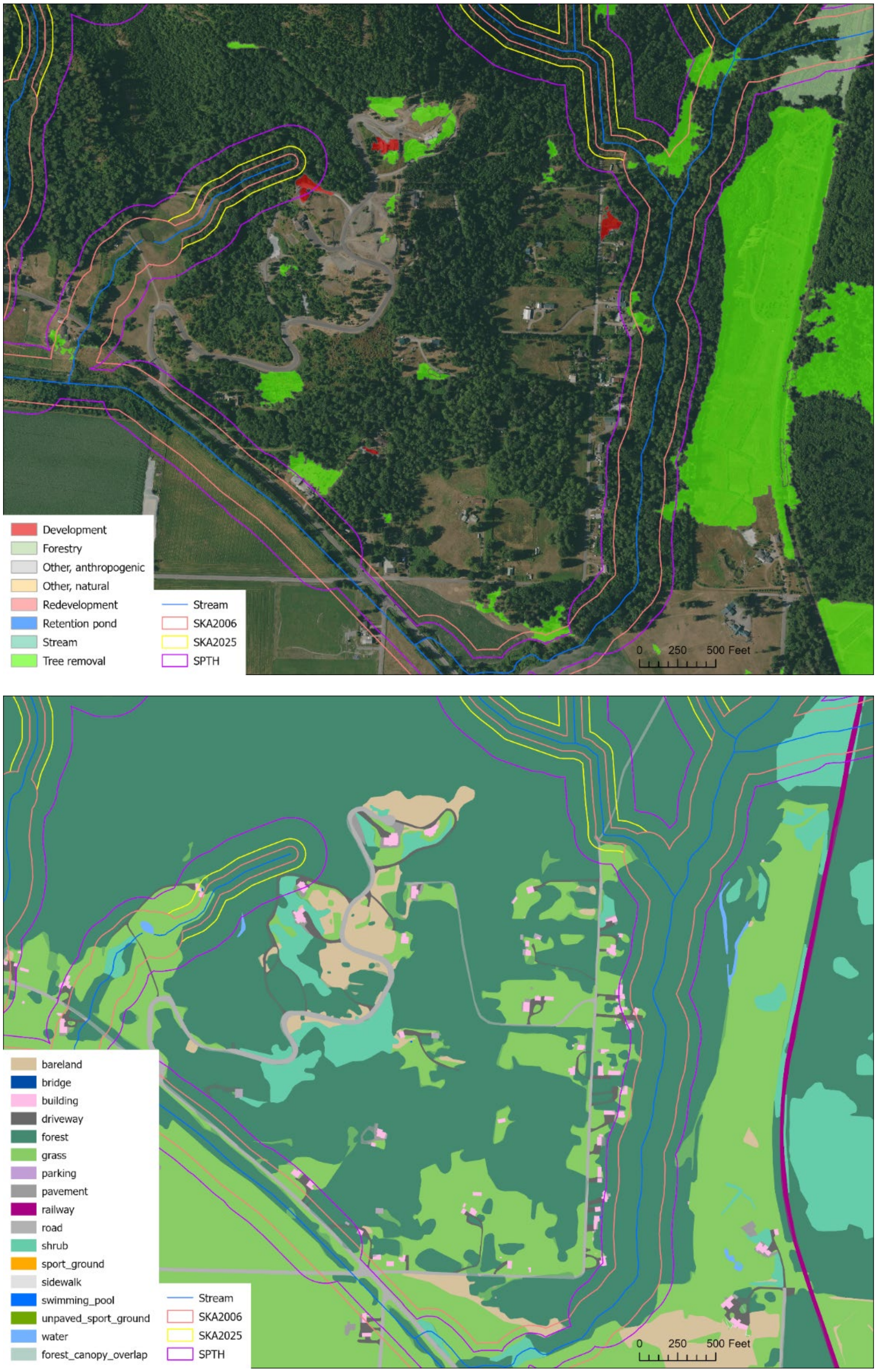

Figure 2. The three fully dissolved buffer scenarios shown with the 2006-2019 HRCD dataset (top) and the 2021-2022 Ecopia land cover classes (bottom) in the Rural Lands land use category. SKA2006 is the same as (i.e., lines overlap) SKA2025 for stream types F & S.

Results

Past Riparian Tree Loss

Most riparian tree loss in the riparian buffer scenarios was due to Tree Removal and Forestry, which both fall in the anthropogenic category (Figure 3). "Tree Removal" is a catch-all for any trees that are removed by humans but that are not part of forestry operations or development/redevelopment and often includes small-scale clearing of land on established properties. A lesser amount of tree loss also occurred due to stream movement, but this along with Other Natural were not included in sums of anthropogenic tree loss.

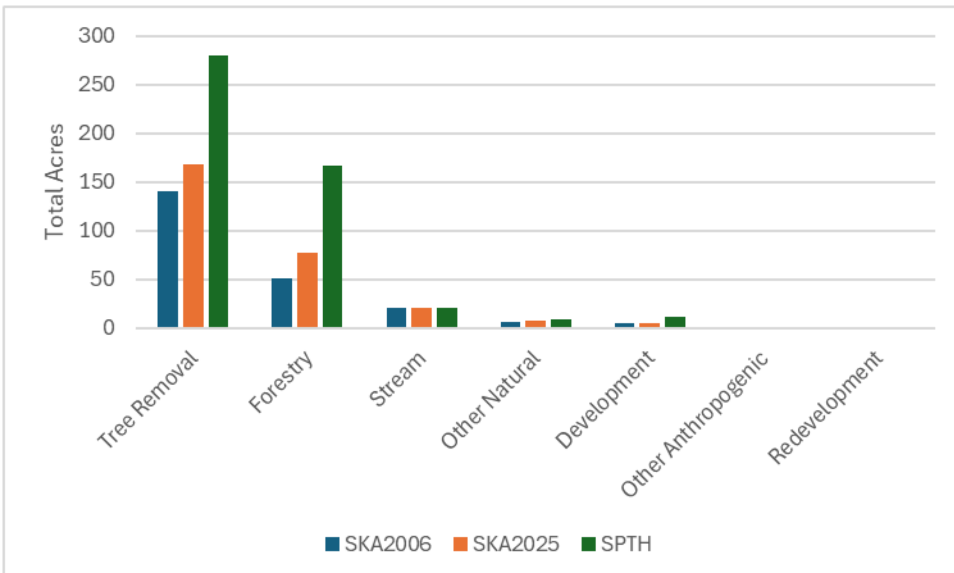

Figure 3. Total acres of riparian tree loss by change agent from 2006 to 2019.

The area and rate of anthropogenic tree loss between 2006 and 2019 was greater in wider buffer scenarios (Table 2). This pattern may be due to the buffer rules in place during this time period that only protected areas closest to streams (SKA2006 buffers). SPTH buffers had the greatest loss of forest (460 acres), and SKA2006 buffers had the least loss of forest (197 acres). Similarly, SPTH buffers had the greatest rate of forest loss (35 acres/year), and SKA2006 buffers had the lowest rate of forest loss (15 acres/year).

Table 2. Acres of anthropogenic riparian tree loss between 2006 and 2019 and percent of the buffer affected by that loss, across all water types and land use categories. Total acres are the sum across the 13-year timespan, and annualized acres are the per-year averages.

Buffer Scenario	Total Acres	Total Tree Loss Acres	Total Tree Loss Percent	Annualized Tree Loss Acres	Annualized Tree Loss Percent
SKA2006	20,993	197	0.94%	15	0.07%
SKA2025	22,823	252	1.10%	19	0.08%
SPTH	27,701	460	1.66%	35	0.13%

Anthropogenic tree loss occurred at variable rates over time within all buffer scenarios (Figure 4). The county's CAO (SCC 14.24) was last updated in 2006, coinciding with the year of the earliest available HRCD data, so there were no changes in the CAO's riparian buffer widths (SKA2006) during this period of analysis. The area of anthropogenic tree loss per year in the buffer scenarios declined sharply between 2009/2011 and 2011/2013 and then rebounded partially between 2011/2013 and beyond. Outside of SKA2006, the wider the buffer scenario, the greater the area of anthropogenic tree loss per year.

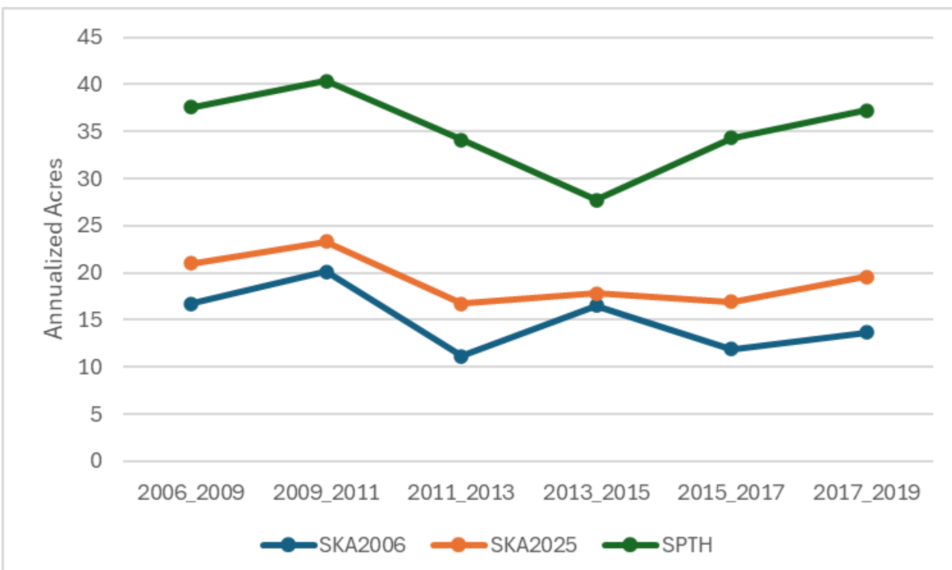

Figure 4. Annualized acres of anthropogenic tree loss for each HRCD interval.

Across *water types*, the average annual riparian tree loss by *percentage* of buffer area was lowest for shorelines (type S) and highest for non-fish bearing (type N) streams (Figure 5). The percent loss was greatest for SPTH buffers across all water types. Non-fish bearing stream buffers showed substantially higher rates of tree loss than fish bearing (type S and F) stream buffers across all buffer scenarios. When interpreting any *percent*-based results, please note that they can be misleading without also considering the associated raw values, in this case, the *acres* of tree loss.

The average annual *acres* of tree loss in riparian buffers by *water type* was lowest for type S across all buffer scenarios (Figure 6). The acres of tree loss per year was considerably higher for types F and N streams, especially within SPTH buffers. The highest rates of anthropogenic riparian tree loss occurred within SPTH buffers of type N streams at more than 19 acres per year (Table 3).

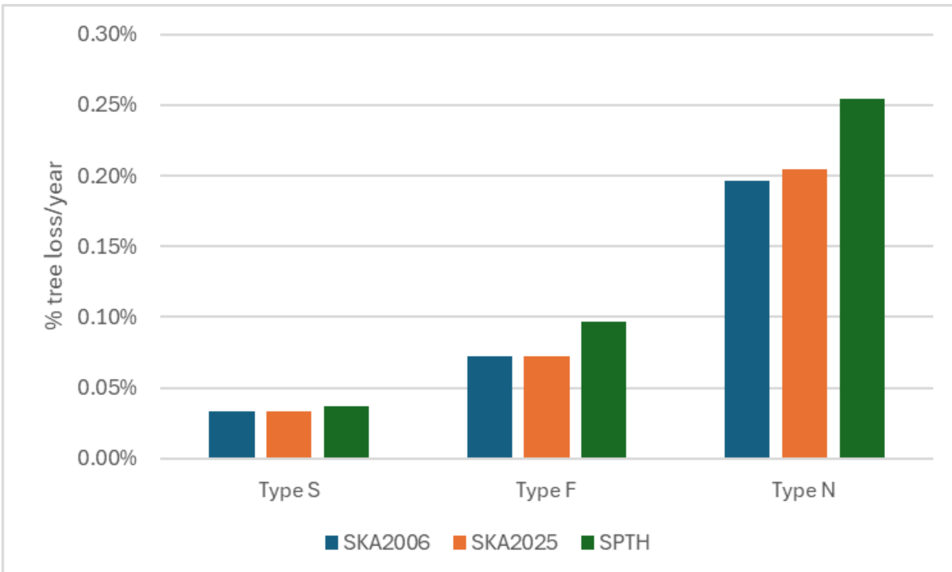

Figure 5. Average annual anthropogenic tree loss as a percentage of buffer area between 2006 and 2019 by water type and riparian buffer scenario.

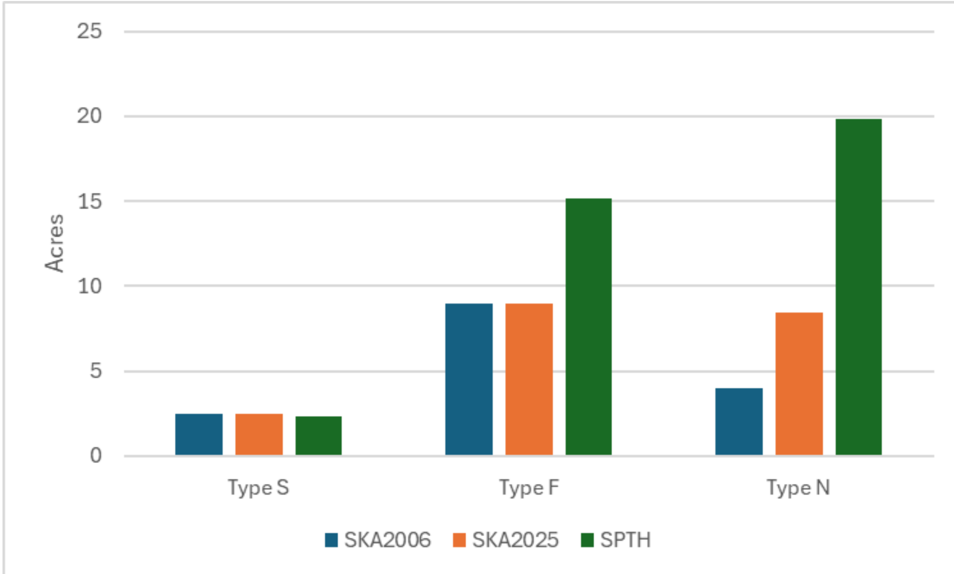

Figure 6. Average annual acres of anthropogenic tree loss between 2006 and 2019 by water type and riparian buffer scenario.

The average annual riparian tree loss by *percentage* of buffer area and *land use category* was lowest within UGA, intermediate within Agricultural and Commercial/Industrial Lands, and highest within Rural Lands (Figure 7). Within each land use category except UGA, the percent tree loss per year increased with buffer scenario width.

Similarly, the average annual *acres* of riparian tree loss in buffers by *land use category* was highest in Rural Lands followed closely by Agricultural Lands (Figure 8). Within these two land use categories, the annual acres of tree loss increased with stream buffer scenario width, with Rural Lands losing >19 acres of riparian trees per year and Agricultural Lands losing ~17 acres of riparian trees per year (Table 3).

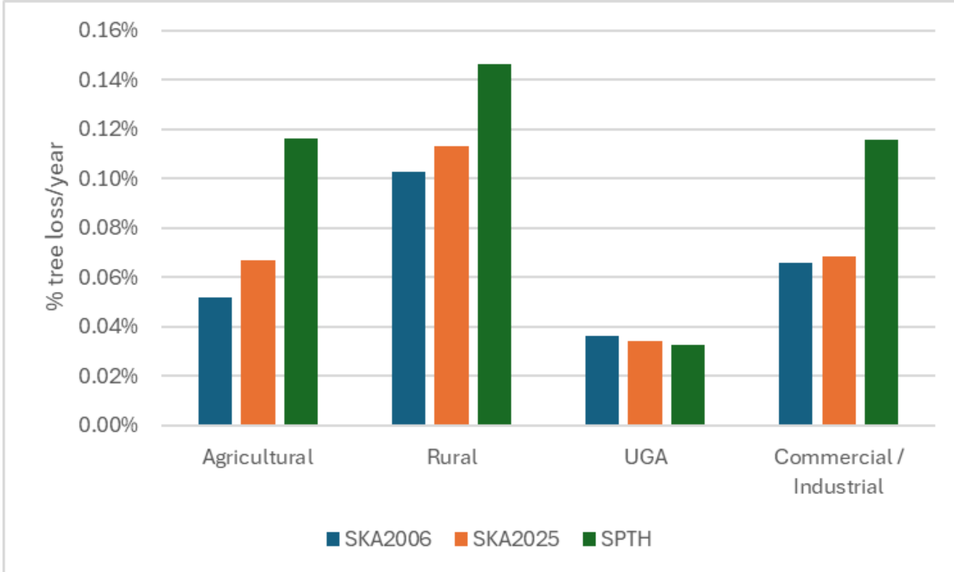

Figure 7. Average annual anthropogenic riparian tree loss as a percentage of buffer area between 2006 and 2019 by land use category and buffer scenario.

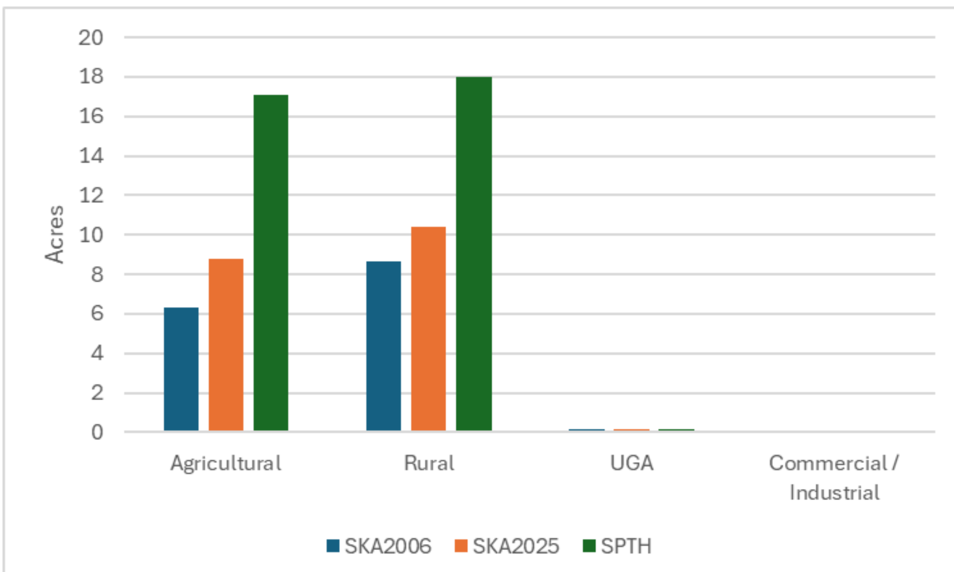

Figure 8. Average annual acres of anthropogenic riparian tree loss between 2006 and 2019 by land use category and buffer scenario.

Among stream types *and* land use categories, SPTH buffers on type N streams in Agriculture had the highest tree loss *proportionally* (0.29%/year) and the highest total *area* of tree loss at ~11 acres/year (Table 3). SPTH buffers of type F streams in Rural Lands showed the next highest rate of tree loss at ~9 acres/year.

Table 3. Average annual acres of anthropogenic riparian tree loss between 2006 and 2019 by water type and zoning category.

	SKA2006		SKA2025		SPTH	
	Tree Loss Acres	Tree Loss Percent	Tree Loss Acres	Tree Loss Percent	Tree Loss Acres	Tree Loss Percent
Type S						
Agricultural	1.31	0.03%	1.31	0.03%	0.97	0.02%
Rural	1.15	0.05%	1.15	0.05%	1.31	0.06%
UGA	0.03	0.13%	0.03	0.13%	0.03	0.11%
Commercial/Industrial	0.00	0.00%	0.00	0.00%	0.00	0.03%
Type F						
Agricultural	2.92	0.04%	2.92	0.04%	5.47	0.07%
Rural	5.88	0.11%	5.88	0.11%	9.40	0.13%
UGA	0.11	0.03%	0.11	0.03%	0.17	0.03%
Commercial/Industrial	0.04	0.10%	0.04	0.10%	0.09	0.14%
Type N						
Agricultural	2.12	0.19%	4.64	0.20%	11.04	0.29%
Rural	1.84	0.21%	3.78	0.21%	8.79	0.23%
UGA	0.00	0.00%	0.00	0.00%	0.00	0.00%
Commercial/Industrial	0.00	0.10%	0.01	0.10%	0.02	0.08%

Existing Riparian Forest

More than half of the area in each of the riparian buffer scenarios was forested in 2021-2022 (Table 4). On average the "forest_canopy_overlap" class covers 2.5% more buffer acreage than the "forest" class. The difference between the most forested buffer scenario (SPTH) and the least forested buffer scenario (SKA2006) was 4,074 acres of forest or 4,221 acres of forest canopy. For simplicity, we report only the "forest" class for the remainder of this report.

Table 4. Acres of forest and percent of the buffer that is forested for the three buffer scenarios across all water types and land uses.

Buffer Scenario	Total Acres	Forest Acres	Forest Canopy Overlap Acres	Forest Percent	Forest Canopy Overlap Percent
SKA2006	20,993	11,950	12,486	56.92%	59.48%
SKA2025	22,823	12,851	13,418	56.31%	58.79%
SPTH	27,701	16,024	16,707	57.85%	60.31%

Among *stream types*, type N buffers have the least *percent* of existing riparian forest (Figure 9). The SPTH buffer scenario has the highest percentage of forest on type S streams. When interpreting any *percent*-based results, please note that they can be misleading without also considering the associated raw values, in this case, the *acres* of riparian forest.

Among *stream types* and by *acres*, type F riparian buffers have considerably greater forested area than the other stream types under all buffer scenarios (Figure 10). SPTH buffers have the most acres of existing forest for type F streams (9,092 ac), and SKA2006 buffers have the least acres of existing forest for type N streams (1,077 ac; Table 5). There is a notable difference (6,247 acres) in the area of riparian forest between type F and type N buffers under SKA2006.

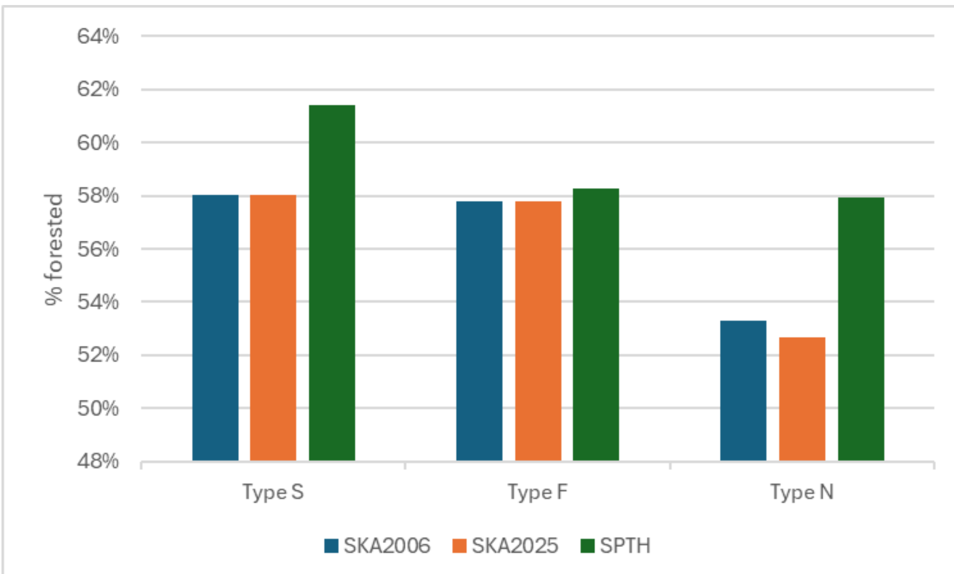

Figure 9. Percent of riparian buffer that is forested ("forest" class) by water type and buffer scenario.

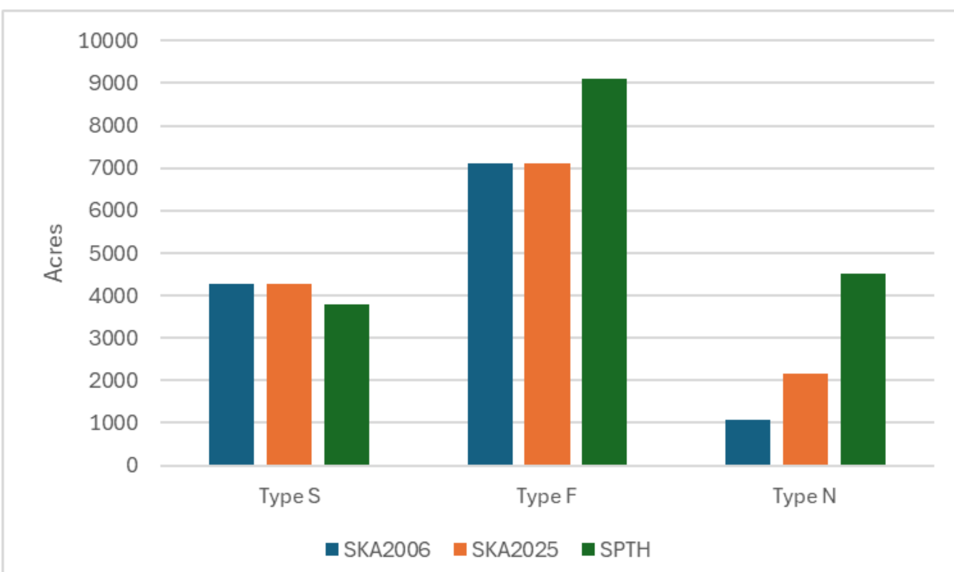

Figure 10. Acres of forest ("forest" class) by water type and buffer scenario.

Among *land use categories*, riparian buffers in Agriculture have the lowest *percent* forest, and Rural Lands have the highest percent forest (Figure 11). The percent of existing riparian forest is roughly equal among buffer scenarios except for SPTH buffers in the commercial/industrial land use category.

Among *land use categories,* the existing *acres* of riparian forest was highest in Rural Lands followed closely by Agricultural Lands (Figure 12). Within these two land use categories, the acres of riparian forest increased with stream buffer scenario width, with Rural Lands having 9,413 acres of riparian forest and Agricultural Lands having 7,599 acres of riparian forest under the SPTH buffer scenario (Table 5). The total acres of existing riparian forest varies the most within Rural Lands, from 6,358 acres in SKA2006 buffers to 9,413 acres in SPTH buffers, a 3,055 acre difference in riparian function (across all stream types).

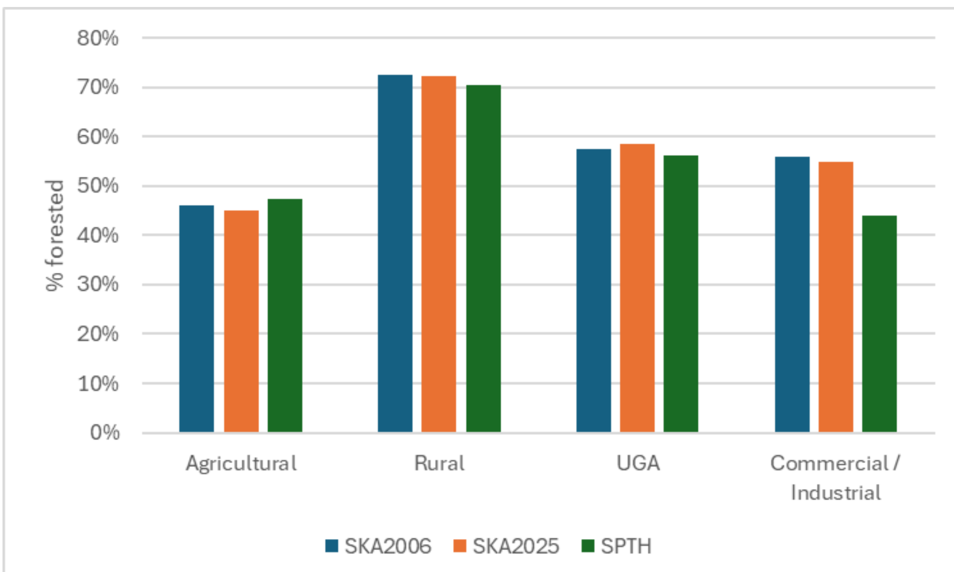

Figure 11. Percent of buffer that is forested ("forest" class) by land use category and buffer scenario.

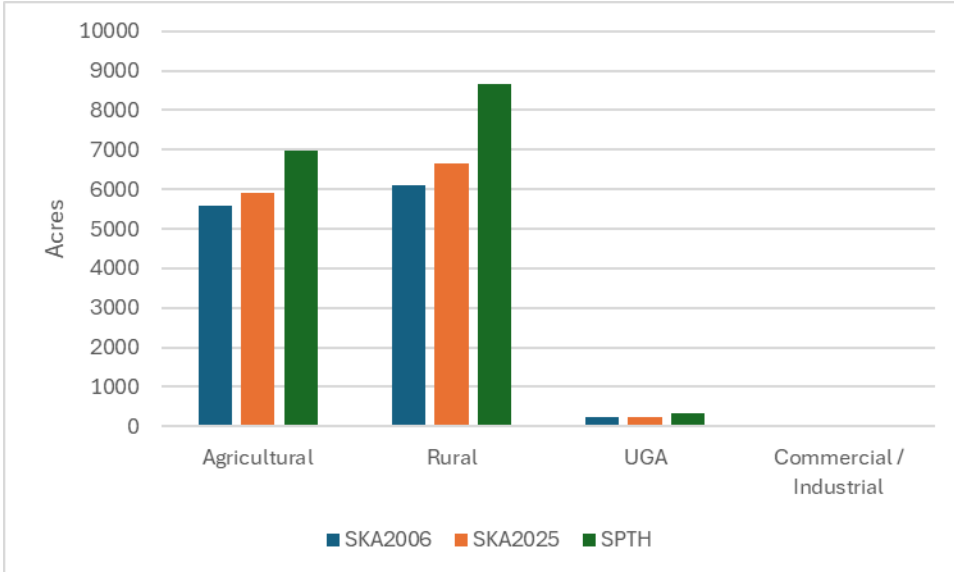

Figure 12. Acres of forest ("forest" class) by land use category and buffer scenario.

Among all combinations of stream type *and* land use, the percent of existing riparian forest ranges widely from 19% for type S SPTH buffers in UGA to >79% for type N SKA2006 buffers in UGA (Table 5). However, both of these combinations have far fewer forested acres than most other combinations. The highest single combination was in SPTH buffers on type F streams in Rural Lands (5,033 acres), and the second highest combination was in SKA 2006 and SKA2025 buffers on type F streams in Rural Lands (3,832 acres).

Table 5. Forested acres and percent of buffer that is forested ("forest" class) by water type and land use category.

	SKA2006		SKA2025		SPTH	
	Forest Acres	Forest Percent	Forest Acres	Forest Percent	Forest Acres	Forest Percent
Type S						
Agricultural	2,380	49.11%	2,380	49.11%	2,083	53.25%
Rural	1,883	75.53%	1,883	75.53%	1,695	76.13%
UGA	5	19.84%	5	19.84%	5	19.52%
Commercial/Industrial	22	79.09%	22	79.09%	13	76.10%
Type F						
Agricultural	3,066	46.77%	3,066	46.77%	3,775	47.88%
Rural	3,832	71.30%	3,832	71.30%	5,033	70.08%
UGA	207	58.66%	207	58.66%	260	54.72%
Commercial/Industrial	19	43.44%	19	43.44%	24	36.72%
Type N						
Agricultural	413	37.02%	833	36.82%	1,741	45.79%
Rural	643	73.47%	1,297	71.83%	2,685	69.56%
UGA	19	79.75%	40	77.50%	85	73.11%
Commercial/Industrial	2	40.19%	3	38.30%	7	35.81%

Discussion

Past Riparian Tree Loss

We evaluated past trends in riparian tree cover as potential indicators of future trends in riparian tree cover in Skagit County with a focus on anthropogenic/human causes of change. The county's current riparian buffer regulations (SKA2006) date back to at least 2006, roughly equal to the earliest HRCD Change Detection data available to analyze. Between 2006 and 2019, we found SPTH buffers had 2.34 times the area of loss and 1.77 times the rate of loss of riparian forest than SKA2006 buffers. While these patterns are not unexpected based on the regulatory buffer protections in place during this period that only protected areas closest to streams (SKA2006), they also illustrate the full extent and range of loss of riparian function within the county's jurisdiction over this 13-year period (SPTH) under this regulatory framework.

Comparing trends among *stream types*, the average annual acres of riparian tree loss per year was considerably higher for types F and N streams (compared with type S streams), with the highest rates of loss within SPTH buffers of type N streams (>19 acres per year). Across *land use categories,* the average annual acres of riparian tree loss was highest in Rural Lands (>19 acres/year) followed by Agricultural Lands (~17 acres/year). Among stream types *and* land use categories, SPTH buffers on type N streams in Agriculture had the highest rate and area of riparian tree loss (~11 acres/year), and SPTH buffers of type F streams in Rural Lands showed the next highest rate of tree riparian tree loss (~9 acres/year). These findings underscore the important role the county's CAO can play in minimizing future losses of riparian forest within lands with Rural land use designations. These findings also illustrate the important role the county's VSP workplan implementation plays in minimizing future losses of riparian forest within Agricultural Lands.

Existing Riparian Forest

We estimated the area of existing riparian forest within the county's jurisdictional area to illustrate the extent of riparian function that may be at risk of loss under different buffer scenarios. There was >4,000-acre difference between the most forested buffer scenario (SPTH) and the least forested buffer scenario (SKA2006), and SKA2025 buffers have an intermediate amount of riparian forest. Type F buffers have considerably more riparian forest than the other stream types under all buffer scenarios, with the most existing forest occurring within SPTH buffers. The sizeable difference (>6,000 acres) in the area of riparian forest between type F and type N buffers under SKA2006 likely reflects their relative levels of protection under the CAO since at least 2006.

Among *land use categories*, the most riparian forest exists on Rural Lands and Agricultural Lands under the SPTH buffer scenario. Similarly, the two highest combinations of stream type *and* land use were in SPTH buffers on type F streams in Rural Lands and Agricultural Lands. Within Rural Lands, there is a >3,000-acre difference in the area of riparian forest between SKA2006 buffers and SPTH buffers (across all stream types).

Conclusions

This analysis examined the extents of past riparian tree losses and existing riparian forest between alternative buffer scenarios, with past trends serving as potential indicators of future risks to existing riparian functions. We found the greatest riparian tree losses occurred in type F stream buffers within Rural Lands and type N streams within Agricultural Lands. We also found that type F stream buffers in Rural Lands have the most existing acres of riparian forest, especially in the SPTH buffer scenario. We estimate a total of ~4,000 acres of existing forest providing riparian functions within SPTH buffers could be at risk of loss if the county's future CAO retains SKA2006 buffers. Most (~3,000 acres) of this existing riparian function occurs on lands with Rural land use designations.

The county is responsible for achieving no net loss of critical area functions and values, including within its Fish and Wildlife Habitat Conservation Areas.[13] The results presented here document consistent losses of riparian function both within the regulated buffers (SKA2006)

[13] WAC 365-196-830(4)

and outside of them (SPTH) as well as key opportunities for the county to better protect riparian functions in greater alignment with best available science. As land use pressures continue to grow, the health and resilience of the county's rivers and streams and communities will depend in part on the extent that riparian forest is protected and restored now and into the future.

Appendix

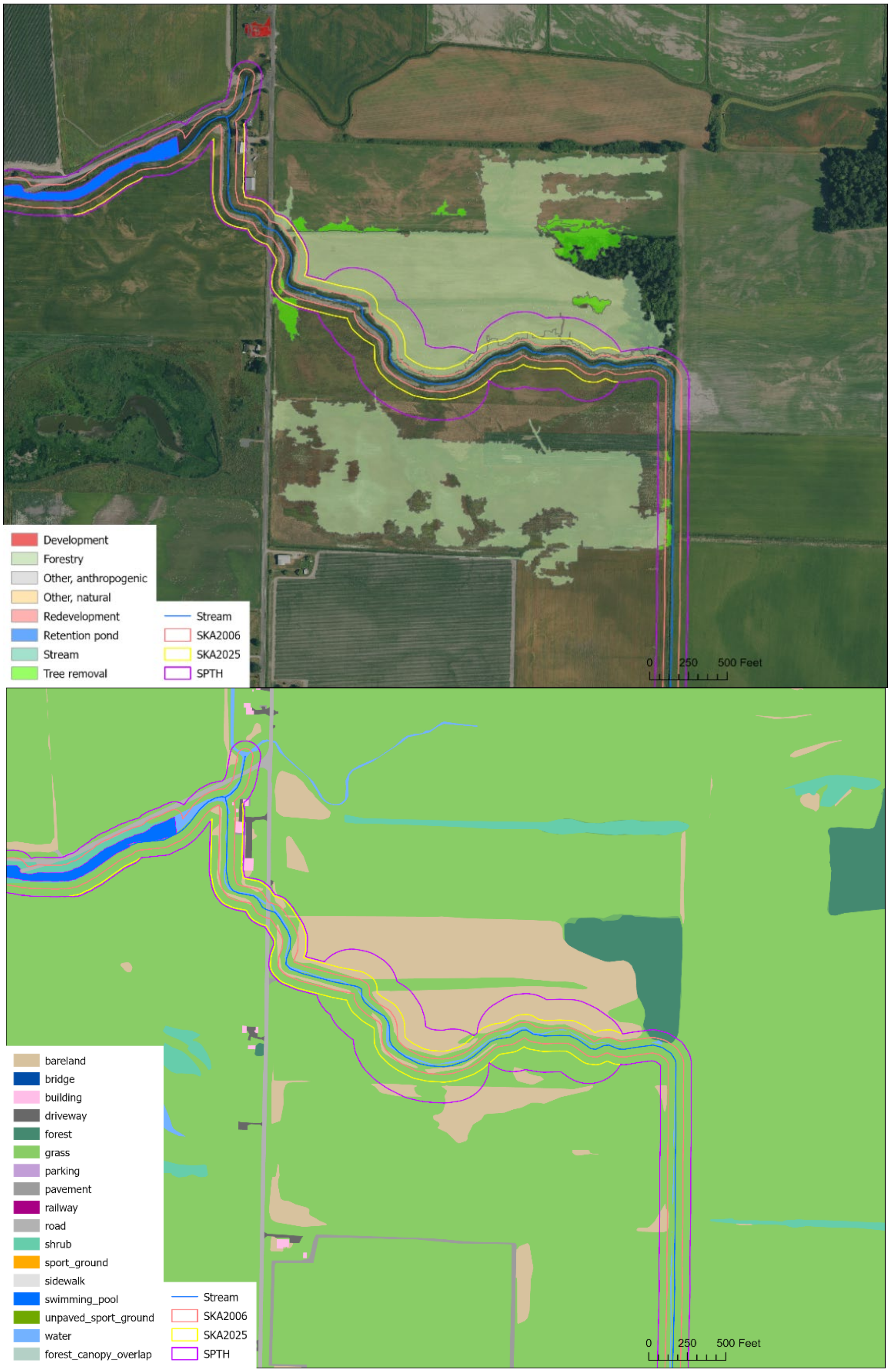

Figure 13. Agricultural land use category: the three fully dissolved buffer scenarios shown with the 2006-2019 HRCD dataset (top) and the 2021-2022 Ecopia land cover classes (bottom). SKA2006 is the same as (i.e., lines overlap) SKA2025 for stream types F & S.

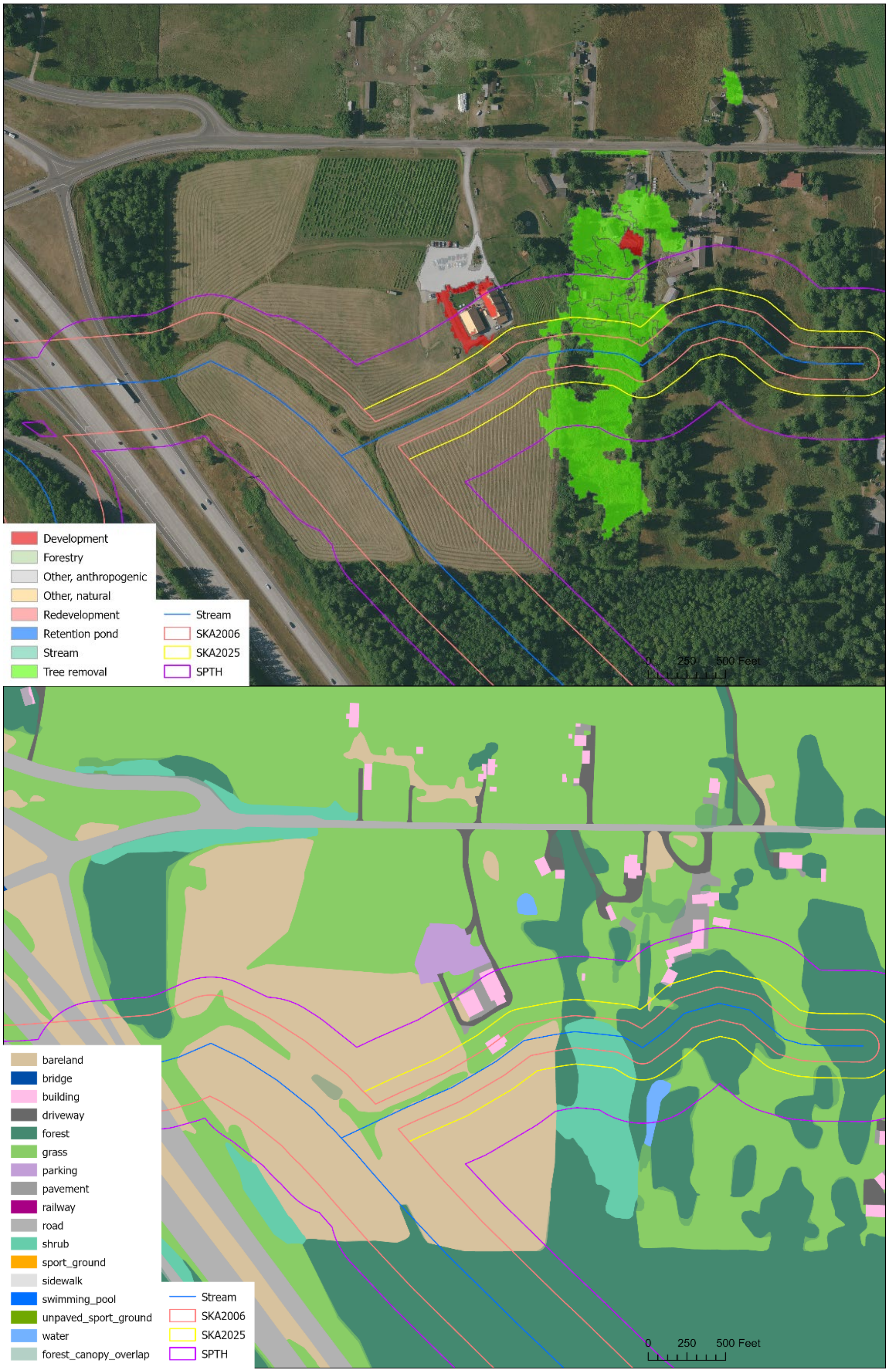

Figure 14. Commercial/Industrial land use category: the three fully dissolved buffer scenarios shown with the 2006-2019 HRCD dataset (top) and the 2021-2022 Ecopia land cover classes (bottom). SKA2006 is the same as (i.e., lines overlap) SKA2025 for stream types F & S.

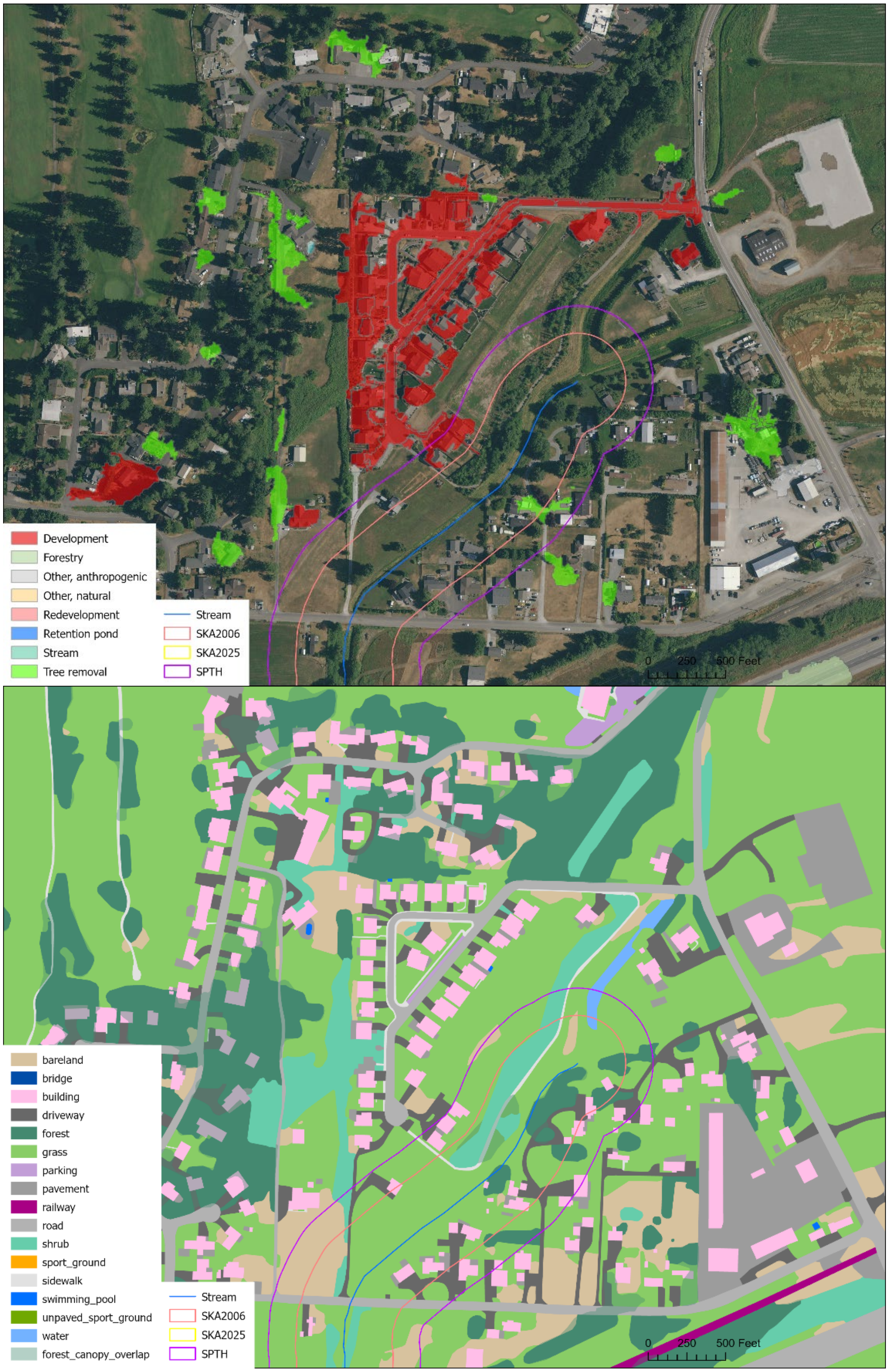

Figure 15. UGA land use category: the three fully dissolved buffer scenarios shown with the 2006-2019 HRCD dataset (top) and the 2021-2022 Ecopia land cover classes (bottom). SKA2006 is the same as (i.e., lines overlap) SKA2025 for stream types F & S.