FINAL REPORT

Evaluating Critical Area Ordinance Effectiveness: Mapping Critical Areas

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Evaluating Critical Area Ordinance Effectiveness: Mapping Critical Areas (NTA 2016-0368)

This report fulfills a requirement of the project, providing our grantor and other interested parties an explanation of what was accomplished through this Near-Term Action (NTA), including lessons learned. Further, we offer recommendations about next steps that agencies and local governments can take in their efforts to improve conservation of Puget Sound via better informed land use decisions.

Project Context

We proposed this project at a time (2017-2018) when there was heightened interest in finding ways to improve the effectiveness of land use decision making. Specifically, we and other stakeholders were seeking ways to better protect riparian ecosystems, which, region-wide, already had historical accumulated impacts. Now, the region also faced increasing population and development pressures.

Clear signs indicated that current efforts were not producing desired outcomes. Puget Sound Vital Sign indicators were predominantly moving in the wrong direction – including the land cover indicator for Ecologically Important Lands. Then, in the summer of 2018, a new mother orca carried her dead calf around Puget Sound (hereafter, the Sound) for 17 days as the Southern Resident Killer Whale population was facing dim prospects for their long-term survival.

The Washington Department of Fish and Wildlife (WDFW) was already pursuing several avenues to enable better management of riparian areas. The agency had completed a synthesis of science related to riparian ecosystems for the Priority Habitats and Species (PHS) program ("PHS Riparian Volume 1"). This synthesis concluded that throughout the Sound, most riparian functions are provided from an area within one "site-potential tree height of a 200-year old tree" ($SPTH_{200}$). A draft volume of management recommendations ("PHS Riparian Volume 2"), informed by Volume 1 and thus based on the $SPTH_{200}$ concept was being actively discussed by stakeholders. Additionally, WDFW was working on its fifth round of analyzing land cover change through its High Resolution Change Detection (HRCD) initiative. Finally, WDFW was conducting a multi-year implementation and effectiveness monitoring project to evaluate its efforts to protect fish life through regulatory authority granted to the agency under the state's hydraulic code (RCW 77.55). That monitoring project led WDFW to make several changes to the way it issued permits, focused on improving on-the-ground outcomes.

Beyond WDFW, agricultural stakeholders in 27 of the state's 39 counties were gearing up to do monitoring and adaptive management as required by the Voluntary Stewardship Program, into which those counties had opted-in. HRCD was emerging as a state-sponsored tool in that effort – the only aerial imagery analysis tool to garner such support. The Department of Commerce, with funding provided by the Puget Sound Partnership, had recently sponsored workshops throughout the state on monitoring and adaptive management in which WDFW and the Department of Ecology had been active participants. In those workshops, WDFW staff described ways that HRCD had already been used by Thurston County to evaluate rates of change within shorelands and other critical areas.

Project's Intent

The core of this project's intent has remained the same since the Habitat Strategic Initiative of the Puget Sound Partnership (PSP) awarded this NTA contract in April 2018. However, as the project unfolded, we found it necessary to adjust its specific goals. Below, we indicate how the final objectives were modified from the original objectives using <u>underline</u> to indicate what was <u>added</u> and ~~strikethrough~~ to show what was ~~removed~~:

1. Map riparian areas as defined by <u>twenty-two</u> local jurisdictions' Critical Areas Ordinances (CAOs). ~~Map other critical areas (e.g., channel migration zones, 100-year floodplains) as funds allow.~~
2. Map riparian areas as recommended by WDFW's Priority Habitats and Species (PHS) riparian management recommendations.
3. Create <u>an internal</u> spatial data ~~system~~ <u>intake process</u> that allows for <u>systematically</u> ~~easily~~ incorporating better sources of information.
4. <u>Describe a methodology for using</u> ~~Use~~ High Resolution Change Detection (HRCD) data to evaluate the rates of change (canopy loss and impervious addition) within mapped critical areas by jurisdiction as an indicator of how well each jurisdiction avoided conversion and fragmentation of ecologically important areas. <u>Describe performance indicators useful for tracking CAO's effectiveness at shifting development away from critical areas.</u>
5. Prepare a <u>webinar</u> ~~technical report~~ to share ~~findings~~ with counties, cities, and other partners throughout Puget Sound <u>recommended ways to apply HRCD data and recommended performance indicators against which to evaluate CAO effectiveness. Coordinate with Commerce and Ecology via NTA 2018-0327</u>.
6. Share ~~results~~ with Puget Sound Partnership (PSP) staff~~,~~ <u>and</u> boards <u>recommended next steps for helping jurisdictions use HRCD in their efforts to improve their critical area protections.</u>~~, and at the 2020 Salish Sea Ecosystem Conference.~~
7. <u>Assist staff from PSP's Land Development and Cover Implementation Strategy better define "ecologically important lands with high habitat or biodiversity value."</u>

As the NTA was implemented, its original 2019 due date was extended by one year, to December 31, 2020.

Why were these revisions made?

Of all the revisions, perhaps the largest was our shift from reporting numeric rates of change within individual jurisdictions' riparian areas to reporting (a) the methodology we recommend using to determine such rates of change, and (b) the recommended performance indicators to evaluate such change. This revision was due in part to our discomfort in reporting individual jurisdictions' rates of change based on underlying data that contains known errors which are unquantified.

Specifically, maps of stream buffers created based on "hydro lines" (or "blue lines") are only as good as the spatial data that specifies the stream's location. Through this grant we successfully modeled and mapped WDFW's recommended $SPTH_{200}$-based riparian areas within nearly all of the 124 local jurisdictions in the Puget Sound basin (we were unable to map most SPTH buffers in Seattle and Tacoma because we lack underlying soil data). We also modeled and mapped riparian areas that reflect 22 of those jurisdictions' CAOs. What all these maps of modeled stream buffers have in common is the fact that they are built on top of a GIS depiction of stream locations – in most cases, either hydrography produced by the Department of Natural Resources ("DNR Hydro layer"); or the National Hydrography Dataset (NHD), which in Washington State is maintained by the Department of Ecology. Errors in the hydrography create errors in the location of the modeled buffers, and all these errors are currently unquantified.

For example, we do not know how accurate the blue lines are, but we do know that the accuracy varies throughout the state. We do not know how often a stream exists that is not shown in the blue line network. Likewise, we do not know how often the blue line network shows streams that don't actually exist. No one has yet quantified how far the blue lines are shown from their actual location.

This is not to impugn NHD or DNR Hydro. For the scale and purposes for which they were designed, such unquantified errors may not pose a problem. For example, these datasets do a reasonably good job of flagging the presence of a stream for follow-on site-scale delineation. Local jurisdictions throughout the state routinely rely on NHD or DNR Hydro in this way.

However, the errors can become a bigger problem when analyzing fine-scale features at a site. Although HRCD can appropriately be applied at a parcel scale (we have quantified error rates for HRCD), when HRCD data is used *in conjunction with* unquantified blue line errors, the resulting accuracy is unknown. The analysis is only as good as its weakest link.

If the resulting product was one that was only to be used internally, WDFW leadership may conclude that the uncertainty brought about by the blue line error is less concerning than not having the insights of the analysis. Department leadership faces a different calculus, however, when the analysis describes the activities of our *partners* rather than *ourselves*. When we describe the outcomes of others' conservation efforts our bar for accuracy and reliability is very high. Therefore, WDFW made the decision that this final report should not provide detailed information on — or make evaluations about — individual jurisdictions' efforts to protect critical areas, as we believe this would be unhelpful. Instead, this document focuses on evaluating Puget Sound-wide trends, as well as examining two distinct subsets of Puget Sound: rural areas and urban areas. This analysis has revealed some interesting trends and we believe even more useful results can be obtained when riparian spatial data that is more reliable is brought to bear.

Toward that end, the long-term solution to this problem is to improve the accuracy of the blue line data. Multiple state agencies, including WDFW and the Department of Ecology (through NTA 2018-0436) and in a separate effort, the Department of Natural Resources (DNR), are exploring innovative ways to do this. Once the blue line accuracy is improved and/or quantified, we look forward to revisiting the original intent of this NTA.

In the meantime, we can help local jurisdictions understand how to use HRCD to evaluate CAO effectiveness through outreach and education, which is why we added the webinar element to this NTA. Further, for any Puget Sound county or city that is comfortable with its current depiction of stream buffers (i.e., are not overly concerned about the blue line error) and feels that the benefits of the analysis outweigh the risks, we explain in this report how they can do--at their level--the same analysis we did at the Soundwide scale, which we believe can provide them with useful insights about their own jurisdiction. Specifically, the methods in this paper explain how to determine rates of change[1] and how to calculate and apply five performance indicators.

Project Staff

The work for this NTA was accomplished by staff from WDFW's Habitat Program in Olympia. Information technology specialists Terry Johnson and Rachel Bouchillon took the lead in mapping SPTH buffers and CAO buffers, respectively, with assistance from Ryan Gatchell. Keith Folkerts, project manager, did some GIS mapping and analysis, assembled and interpreted the information, and led the writing of this report. Research scientist George Wilhere and the creator of HRCD, Dr. Ken Pierce, Jr., provided ongoing input and advice for this project. Oversight was provided by Mary Huff (Section Manager), Terra Rentz (former Division Manager), and Dr. Timothy Quinn (Habitat Program Chief Scientist). Project staff for the Puget Sound Partnership included Libby Gier (Project Manager) with DNR, and Sean Williams and Cynthia Harbison from WDFW.

[1] Similar methods are described on WDFW's HRCD Hub; including methods in this factsheet.

Part I: Performance Indicators of CAO Effectiveness

There are no standard definitions to describe ways of measuring and tracking performance. We define the term "performance indicator" as a neutral, quantitative measure of the extent to which something is doing what it is supposed to do. Performance indicators do not judge whether the thing is performing "well" or "poorly" – they simply describe the degree to which it is performing. Ideal indicators provide quantitative, highly reliable, and timely scoring of the most salient aspects of the thing it is reporting on. Some sources refer to this as a "metric" or "measure."

As we define it, a "benchmark" is a target that an indicator is expected to achieve at a specified point in time. It is a value-laden judgment of "how good is good enough?"; it defines what is acceptable and unacceptable. These are also called "targets."

One expectation of this NTA is to create a set of performance indicators that utilize HRCD datasets to describe the effectiveness of CAOs related to riparian areas. To do this, we must first clarify what makes a CAO "effective."

The CAO's Job

The first step of developing performance indicators is to understand the salient aspects of the thing being evaluated. To determine the salient aspects of a CAO we turn to (1) the Growth Management Act (GMA, RCW 36.70A), (2) amplifying provisions (rules) in the Washington Administrative Code (WAC, Chapters 365-190 and 365-196), and (3) relevant science.

The GMA says local governments are required to protect critical areas' functions and values and include the best available science when doing so (RCW 36.70A.172(1)[2]). GMA-defined "critical areas" include the following ecosystems and areas[3] (a) wetlands; (b) critical aquifer recharge areas; (c) fish and wildlife habitat conservation areas (FWHCAs); (d) frequently flooded areas; and (e) geologically hazardous areas. For the purposes of this study we focus our attention primarily on one type of FWHCA: riparian areas.

Commerce's rules clarify that, at a minimum, CAOs (and other development regulations) must provide for **no net loss of ecological functions and values** (WAC 365-196-830(4)[4]). To do this, local jurisdictions are required to utilize mitigation sequencing: avoiding harm, minimizing

[2] "In designating and protecting critical areas under this chapter, counties and cities shall include the best available science in developing policies and development regulations to protect the functions and values of critical areas. In addition, counties and cities shall give special consideration to conservation or protection measures necessary to preserve or enhance anadromous fisheries."

[3] RCW 36.70A.030 (6)

[4] "Although counties and cities may protect critical areas in different ways or may allow some localized impacts to critical areas, or even the potential loss of some critical areas, development regulations must preserve the existing functions and values of critical areas. If development regulations allow harm to critical areas, they must require compensatory mitigation of the harm. Development regulations may not allow a net loss of the functions and values of the ecosystem that includes the impacted or lost critical areas."

unavoidable harm, and providing compensatory mitigation for unavoidable harm[5]. To be clear, while harm is to be avoided, avoiding harm is not the same thing as restoration. The State Supreme Court in its 2007 *Swinomish* case[6] clarified that the requirement to *protect* does not create a duty to *improve* critical areas. That said, local jurisdictions are free to set higher standards within their own land use plans, policies, and regulations.

Science tells us what ecological functions are provided by critical areas. For riparian areas specifically, we turn to PHS Riparian Volume 1, which identified five key ecological functions of riparian areas in the Puget Sound basin:

1. Streambank stability
2. Large wood recruitment
3. Detrital nutrient contributions
4. Shade
5. Pollutant removal

We think of the CAO as having a job to do, which is to avoid, minimize, and offset activities that harm such functions. Examples of common land use activities that can harm these functions include removing trees and adding impervious or semi-pervious surfaces. It is these types of changes that CAOs are supposed to avoid, minimize, and offset. CAOs are not required to preclude all harm, rather they are only required to offset unavoidable harm after it has been minimized to the extent possible.

For the purpose of identifying CAO performance indicators, we defined an "effective" CAO thus:

> *An effective CAO is one that first avoids adverse changes to critical areas, then minimizes adverse change within critical areas, and finally, ensures offsets for unavoidable harm sufficient to achieve no net loss of ecological functions.*

Studying all of these aspects was well beyond the scope of this project. In particular, we do not address the offset. That said, we believe we have taken an important first step in helping identify ways to understand CAO performance related to avoiding and minimizing change in riparian areas.

CAO Effectiveness Performance Indicators

After testing and analyzing a variety of potential performance indicators, we selected five basic indicators of CAO effectiveness: One indicator looks at the current state, three indicators look at recent trends through time, and one indicator looks ahead a decade based on recent trends. Each of these indicators leverages HRCD[7] and associated datasets.

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[5] See WAC 197-11-768: Ecology's rules pursuant the State Environmental Policy Act (SEPA, RCW 43.21C).

[6] *Swinomish Indian Tribal Community v. W. Wash. Growth Management Hearings Board*. 161 Wn.2d 415.

[7] HRCD is a WDFW initiative that measures canopy loss and "total change" (change that involves canopy reduction and/or addition of impervious and/or semi-impervious surfaces). HRCD does not detect tree growth or tree planting projects. For this project, we only consider change *due to development*—HRCD

In this project we only analyzed riparian areas, but we believe this method will work equally well for other mapped FWHCAs, including Priority Habitats (e.g., wetlands, oak woodlands, Biodiversity Areas and Corridors) or mapped Priority Areas for Priority Species (e.g., Great blue heron breeding areas). The methodology also works for other types of critical areas, such as wetlands or frequently flooded areas – especially in forested ecosystems where the historical condition is predominately tree cover.

Five general caveats:

1. As with all performance indicators, the quality and accuracy of these indicators depend upon the quality and accuracy of the inputs. While accuracy of HRCD data have been quantified, the accuracy of the initial maps of riparian area maps has not. The accuracy of the initial maps used in this project are based on the accuracy of the blue line data (discussed earlier), the accuracy of CAO information, and the accuracy of our modeling of CAO stream buffers. Errors contained in the initial maps will impact the quality and accuracy of the performance indicators.
2. These performance indicators address only the outcomes of CAOs that can be seen on the landscape using HRCD datasets; they do not address other ecologically important factors such as bank armoring, water quality, or invasive species.
3. These indicators do not look at the internal processes by which CAOs are implemented. For example, they do not look at the degree to which permits align with the CAO, nor the degree to which permit applicants comply with all permit conditions. These indicators only report *change*, and that change may have been properly permitted.
4. Our estimates about total change based solely on HRCD could be overly pessimistic because HRCD detects *only* loss (not losses *and* gains) of possible habitat. These indicators do not look at restoration projects undertaken to offset unavoidable harm caused by land use actions.
5. No indicator by itself provides the full picture. Even when considering all the performance indicators, it is not possible to provide a nuanced understanding of something as complex as a CAO. However, the indicators will often identify relevant issues that may assist jurisdictions who are on a journey of making improvements to their CAO in identifying areas for additional study.

See the section "Potential Sources of Error" on page 43 for a more robust discussion of potential sources of error and caveats.

The description that follows is intended to fulfill the second half of the NTA's intent #4 (describe performance indicators useful for tracking CAO effectiveness). We present these in the past tense in order to describe what analysis we actually completed on riparian areas specifically as part of this broader NTA effort, but as explained previously, we believe they can be replicated

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can also track changes due to forestry and natural causes such as stream meanders, and landslides. HRCD currently covers five time periods: 2006-2009, 2009-2011, 2011-2013, 2013-2015, and 2015-2017.

for other critical area types.

Indicator #1: Portion of Critical Areas covered by Tree Canopy

What: This indicator reports the proportion (percentage) of riparian areas that have tree canopy[8].

Why: Before we can make sense of *change* within critical areas, we need to know change *from what*? This indicator provided important context to help us understand how things currently *are* before we consider what *changed*. Understanding the amount of tree canopy cover can inform decisions about where and how much restoration may be appropriate for given jurisdiction. Knowing something about the current state of riparian areas is helpful for understanding the urgency of riparian tree loss (Indicator #2). This information could also be useful when jurisdictions consider benchmarks for these performance indicators.

How: To get this indicator, we intersected the latest WDFW high resolution tree canopy dataset (2017) with the CAO-based riparian GIS layers.

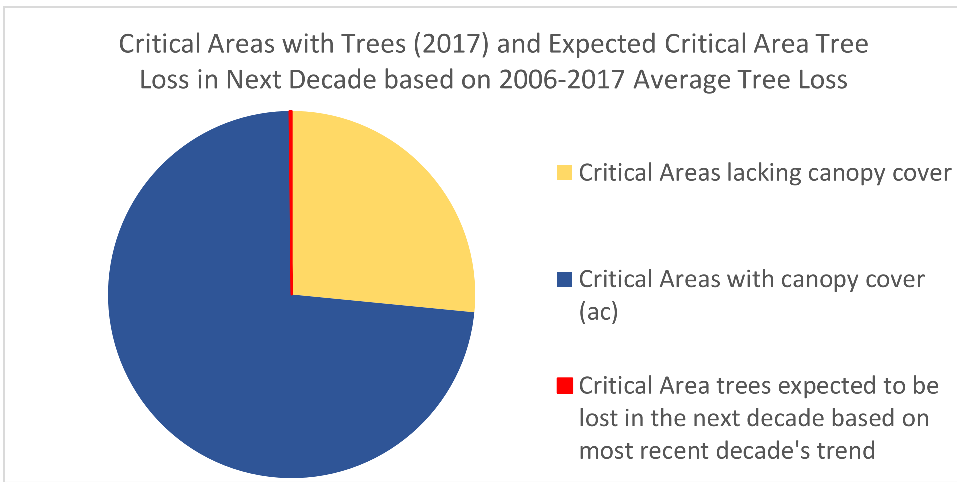


Figure 1: Performance Indicators 1 and 2 (showing the soundwide results for the "CAO Minimum scenario", explained later).

Notes:

(1) When setting benchmarks for this indicator, local jurisdictions should keep in mind that 100% tree canopy cover within all riparian areas is not always ideal. Some riparian areas historically have not had tree cover – in wetlands, for example.

(2) The GIS layer used to calculate this performance indicator (riparian areas that currently lack tree canopy) is valuable information that local governments could use when considering where to conduct restoration projects (e.g., for offsets for unavoidable harm to riparian areas).

Indicator #2: Projected Percentage of Critical Areas Canopy Cover that would be Lost in a Decade (based on the Previous Decade's Rate of Change)

What: This performance indicator reports the proportion (percentage) and amount (acres) of trees within critical areas that would be lost in the next decade if the trends of tree canopy loss

[8] WDFW's high resolution tree canopy dataset identify places with tree canopy as identified by 1-meter aerial imagery and digital photogrammetry techniques that typically identify trees that are taller than about 10 feet.

for the previous decade continue at the same rate. See Figure 1 (red slice).

Why: This indicator provides context for understanding the significance of the rate of canopy cover loss within critical areas. It informs the urgency of taking steps to minimize canopy cover loss.

How: Data inputs: (a) the acreage of trees in critical areas (determined using the high resolution tree canopy dataset) and (b) the average annual rate of canopy loss within critical areas for the previous decade. Output: Projection of the acres and proportion of critical areas trees that would be lost in the next 10 years.

Assumptions: Past performance is predictive of future results (i.e., tree loss within critical areas will continue to be lost at the same rate seen in the past decade).

Note: This indicator relies upon HRCD data which does not detect riparian tree planting restoration projects or the natural regeneration that occurs within tree-less riparian areas where tree growth is not precluded (e.g., by lawns, crops, buildings, roads). WDFW is exploring ways to be able to consistently and accurately detect these types of vegetative “gains”, but such technology is not yet available.

Indicator #3: Acres of Change per Year in Critical Areas

What: This performance indicator reports the amount (acres) of change (both canopy cover loss and total change) within critical areas. This is reported as an absolute number for use by an individual jurisdiction, and as a normalized number (acres of change per 1,000 acres of critical areas) to allow for calculation of regional averages and to allow comparisons across subregions.

Why: Understanding the amount of change and trends in changes that occur within critical areas is fundamental for understanding how effective the CAO has been at *avoiding* and *minimizing* the amount of development within critical areas. Evaluating both total change and canopy cover change can help identify anomalies that warrant further investigation. The values and trends can lead to asking additional questions that help to identify what CAO revisions may be useful.

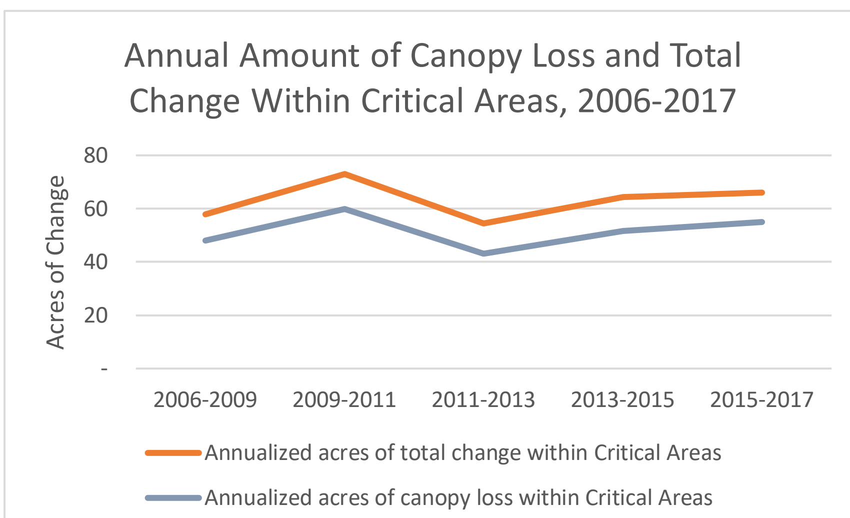


Figure 2: Performance Indicator #3 (showing the soundwide results for the “CAO Minimum scenario,” explained later).

How: To get this indicator, we intersect HRCD polygons with the critical areas. Then we sum the acreages of canopy change and total change within critical areas and divide by the number of years within that time period (typically 2 years; in one instance it was 3). For the normalized number, we convert the *acres of change* to *acres of change per 1,000 acres of critical areas*.

<u>Assumption</u>: Oftentimes, a HRCD polygon is partially within and partially outside of a modeled riparian polygon. In such cases, we assume that the change within the HRCD polygon is evenly spread throughout the HCRD polygon (i.e., across both sides of the split). For example, if the HRCD dataset reported that 100% of a 1.0-acre polygon changed, and if 30% of that polygon was within a critical area, we would reflect 0.3 acres of change occurring in the critical area and 0.7 acres occurring outside of the critical area.

Indicator #4: Relative Change: Change within Critical Areas vs. Change outside of Critical Areas

<u>What</u>: This indicator answers the question, *"For every 10 acres of change outside of critical areas, how much change happened within critical areas?"* See Figure 3.

<u>Why</u>: Since a CAO is supposed to *shift* development out of critical areas, it is helpful to understand and compare the amount of change both within and outside of critical areas. This indicator provides a simple way to simultaneously consider change in both geographies. It also self-adjusts for rapidly developing communities. This indicator is normalized, meaning that in addition to its being useful for an individual jurisdiction to track this number over time, it's also useful for comparisons across jurisdictions.

<u>How</u>: After intersecting HRCD polygons with critical and non-critical areas, we calculate the acres of total change within and outside of critical areas (in our case, riparian areas), multiply the acres of total change within critical areas by 10, and divide by the acres of change outside of critical areas. Results are presented with the time period used. For this indicator, we recommend using the full period of available HRCD data (2006-2017) to reflect the broad trend.

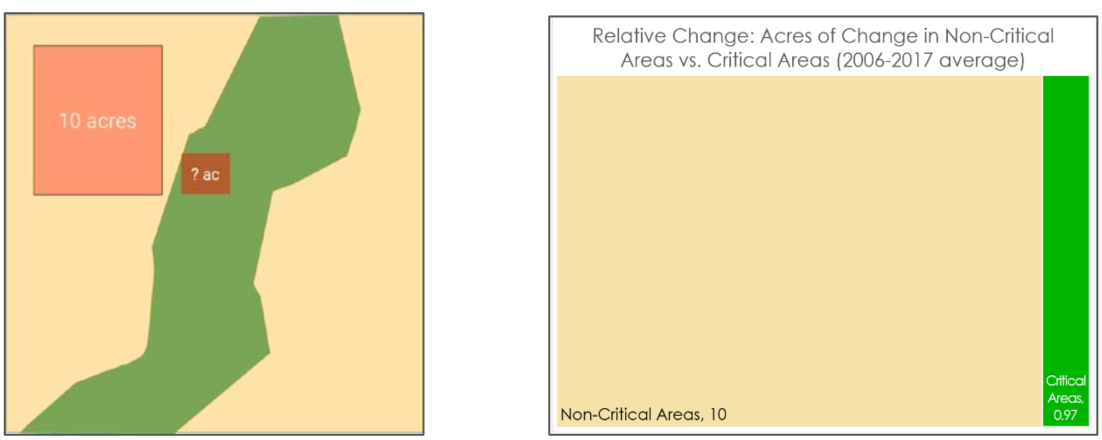


Figure 3: Performance Indicator #4; spatial representation (left) and box chart (right). In the figure on the left, the large red box represents 10 acres of cumulative development outside of riparian areas; the small red box in the green portion represents an unknown amount of cumulative development within riparian areas. This performance indicator solves for the unknown quantity. The box plot on the right shows these quantiles by the size of the box (in this hypothetical example there was 0.97 acres of change in riparian areas for every 10 acres of change outside of riparian areas).

<u>Note</u>: We could have had this indicator answer the question, "*for every acre of change outside of critical areas, how much change occurred within critical areas?*" For that question, the soundwide average would have been 0.015 acres, or 650 square feet. We chose to use an arbitrary scaling factor of 10 so the resulting number is more easily understood without resorting to conversions from acres to square feet or dealing with small fractions of an acre (which people may have difficulty envisioning).

Indicator #5: Ratio of change *outside* of critical areas to change *within* critical areas ("CAO Power Score")

<u>What</u>: Like indicator #4, this indicator helps illustrate how the rate of change within critical areas compares to the rate of change outside critical areas, it just presents the information in a different way, which may be better suited for how some people process information. A higher value represents a situation where CAO-regulated areas show a lower proportion of change compared to non-critical areas. See Figure 4. This indicator answers the question: "*For every acre of change inside critical areas, how many acres of change occur outside of critical areas?*"

<u>Why</u>: Because a CAO is supposed to *shift* development out of critical areas, this performance indicator provides a measure of the relative rate of change between critical areas and non-critical areas. For riparian areas, this can be explained as the number of acres of "upland" development for every acre of riparian area development. This indicator provides a simple way to reflect relative rates of change in both geographies. It self-adjusts for rapidly growing communities. This indicator is normalized; meaning that in addition to its being useful for an individual jurisdiction to track this number over time, it could also be useful for comparisons across jurisdictions.

<u>How</u>: After calculating the annual acres of total change within and outside of critical areas, we divide by the annualized acres of change *outside* of critical areas by the annualized acres of change *within* critical areas. (The result is the same whether the absolute or normalized values are used.)

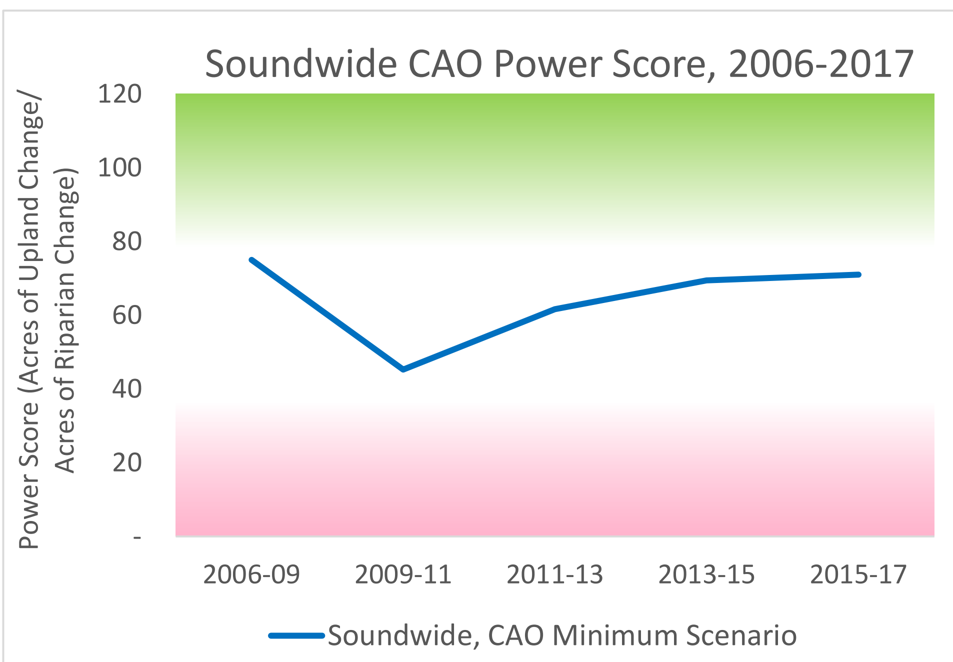


Figure 4 Performance Indicator #5 (showing the soundwide results for the "CAO Minimum scenario," explained later).

Assumption: This indicator (and the previous one) assumes that development that is shifted outside of critical areas will result in change that will be picked up by HRCD. HRCD is effective at identifying new development in previously undeveloped areas, but it is not designed to identify redevelopment within already developed areas – such as conversion of graveled parking lots to buildings. Where redevelopment makes up a larger portion of a community's overall development pattern, the CAO Power Score is likely to be erroneously depressed.

Notes:

(1) To understand this performance indicator, it can be useful to consider a scatter plot, where the graph's *x* axis is the rate of change within critical areas and the *y* axis is rate of change outside of critical areas. See Figure 5. A greater value on the *x* axis (farther to the right) means more acres of change are occurring within critical areas. A greater value on the *y* axis (higher up) means the jurisdiction is seeing a high change rate outside of riparian areas. Using the 2009 point as an example, to calculate the CAO Power Score we divide the change outside of critical areas (*y* axis) which is a value of about 12 by the change inside critical areas (*x* axis) which is a value of 0.26. The result of 45 (12 ÷ 0.26) is seen in Figure 4 as the low point (2009-2011).

(2) This indicator is mathematically related to Performance Indicator #4 - this is simply another way to present the same information. Looking at Indicators #4 and #5 across time or jurisdictions will yield the same patterns and relative performance. Indicator #4 is thought to be more easily visualized and comprehended; Indicator #5 more amenable to displaying changes over time via a line graph.

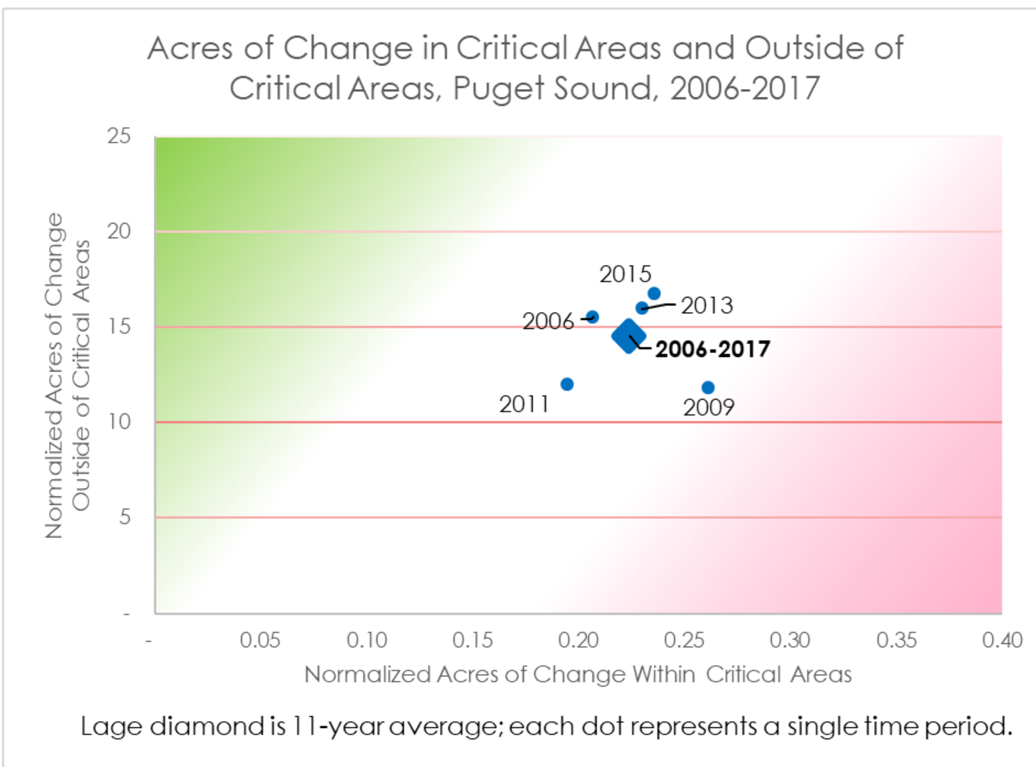


Figure 5 Scatter plot of the components of the CAO Power Score.

Notes regarding all Performance Indicators

When considering performance indicators, we kept these three things in mind:

1. The indicators should only reflect what is under the county's or city's ability to control. Therefore:
    a. We did not lump cities and counties, rather we split counties and cities so that the indicators reflect individual jurisdiction's efforts.
    b. We excluded lands managed by the federal government and tribal governments.
    c. We excluded canopy loss due to rivers meandering, landslides, or wildfires.
2. Indicators should acknowledge and be useful in showing that jurisdictions are very different, including having different contexts. While we have some indicators that use normalized numbers to facilitate cross-jurisdiction comparison, we also have indicators that show where each jurisdiction is starting from. The indictors shed light on the differences (and similarities) among jurisdictions.
3. The indicators should provide factual, quantitative information; they should not be value-laden, normative judgments about how things ought to be. We recommend that policy makers use the indicators to develop their own benchmarks.

Preparing the Initial Study Area Map

The first step in calculating performance indicators is to create an initial map of the study area.

To allow for the calculation of performance indicators the initial map should (a) exclude lands that are not under the jurisdiction's GMA authority (b) exclude surface water, and (c) differentiate critical areas (in this study, riparian areas) from non-critical areas. Care should be taken to create an initial map that is as accurate as reasonably possible.

This NTA created and used three distinct initial maps: one for the CAO Minimum (CAO min) scenario, one for the CAO Maximum (CAO max) scenario, and one for the $SPTH_{200}$ scenario. These initial maps reflect a major undertaking of this NTA: to map, as accurately as possible, CAO- and $SPTH_{200}$-based riparian areas.

In this section we describe how we identified the areas around the Sound subject to GMA, how we identified surface water, and how we mapped riparian areas to reflect CAOs and $SPTH_{200}$.

Study Area

Because of data availability, we differentiated the study areas for the CAO analyses from the study area for the $SPTH_{200}$ analysis.

Similarities: In both cases, we limited our study areas to (a) land within the Puget Sound basin (we excluded the portion of Lewis County that is in the Puget Sound basin), (b) lands that are (primarily) subject to the jurisdiction's GMA decision-making authority (see discussion below), and (c) lands without surface water. We removed visible surface water from the study area because (a) neither tree removal nor development occurs in such places, (b) the HRCD dataset does not evaluate change in these areas, and (c) development rates would be skewed if a jurisdiction included large waterbodies where development cannot take place. We included in the study areas all remaining unincorporated areas (whether inside or outside of a UGA).

Differences: In the SPTH200-based study area we excluded lands without Natural Resources Conservation Service (NRCS) soil data because we were unable to calculate the SPTH200. This resulted in excluding the greater Seattle and Tacoma areas. See Figure 6.

In the CAO-based study areas we excluded all incorporated areas *except for* the 10 cities whose CAOs we analyzed (Auburn, Bainbridge Island, Bellevue, Bellingham, Bremerton, Everett, Kent, Renton, Seattle and Tacoma). See Figure 7.

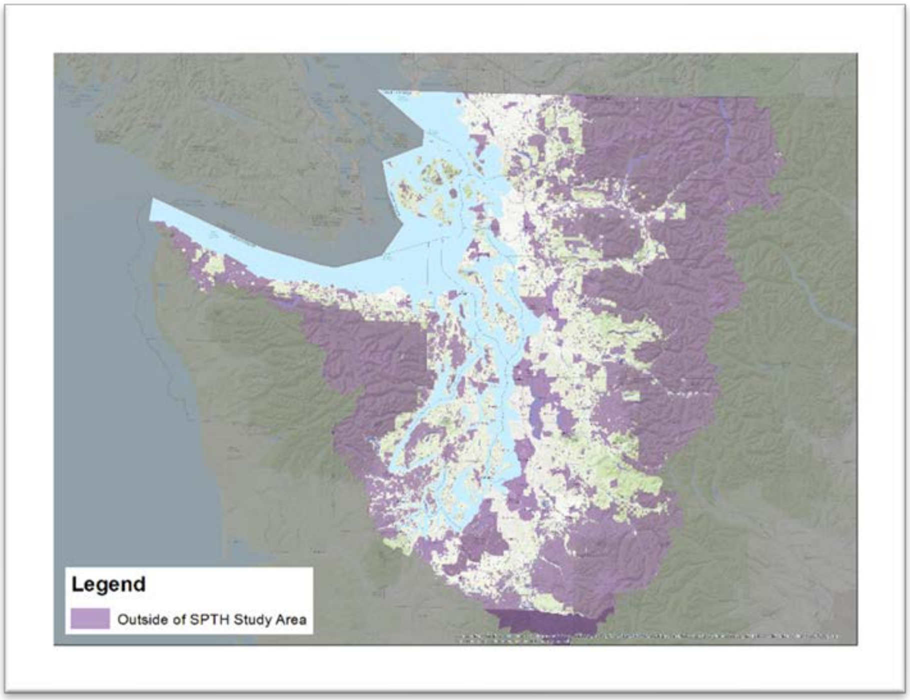


Figure 6 SPTH Study Area: Areas excluded from SPTH200 analysis (purple) include federal, tribal and forestry lands, surface waters, and places that lack NRCS soils data (much of Seattle and Tacoma).

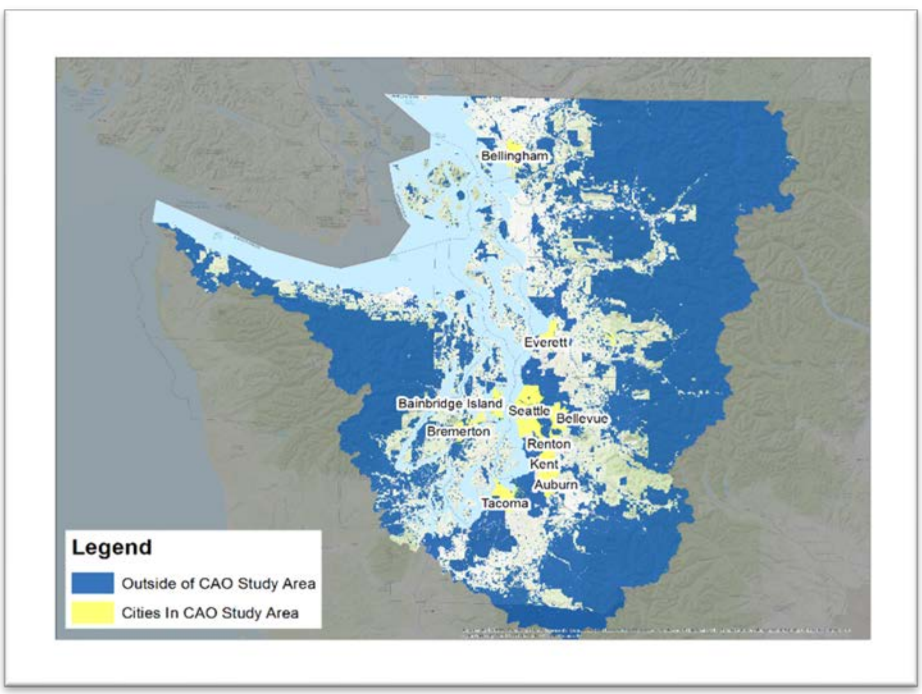


Figure 7 CAO Study Area: The 12 counties and ten cities included in the CAO study area, and areas excluded (dark blue) from the CAO study area. Excluded areas: Federal, tribal and forestry lands; surface water; and incorporated areas outside the 10 identified cities.

Areas Not Subject to GMA

We removed from the study area lands that are not subject to the GMA because the intent of our analysis was to provide feedback to local jurisdictions about how effectively their CAO protections are shifting development out of riparian areas. We would have clouded such understanding if we mixed rates of change from areas where the jurisdiction's

CAO does not impact land use decisions.

Since a local jurisdiction's CAO is not binding on (most) land use actions of the federal government or tribal governments, we excluded these lands from our analyses. Forest practices are regulated by the state's Forest Practices Act and DNR's Forest Practices Rules. While *conversions* from forestry to development *are* covered by the CAO, such conversions are relatively small and infrequent at a jurisdiction scale. So, for our analyses, we assumed that private commercial forestry (places where forestry taxation rates apply) are regulated by Forest Practice Rules, not CAOs. Thus, we excluded these forestry lands from our analyses. (If a jurisdiction were to conduct this analysis, they may be able to accurately identify and include areas that convert from forestry.)

Mapping the CAO Study Area and the $SPTH_{200}$ Study Area

In delineating the study areas, we combined data from the following sources:

- We identified federal and tribal lands to exclude using DNR's Major Public Lands (Owner = Federal Government or Tribal Government)
- We identified forestry lands to exclude using Ecology's 2018 parcel layer (Assessor code = 88 [designated forest land] or 95 [timberland])
- We delineated cities and UGAs using Ecology's CityUGA dataset
- We delineated WRIAs using WDFW's GeoLib standard layer
- We identified visible surface water to exclude using HRCD's 2017 Surface Water
- We identified places to exclude from the $SPTH_{200}$ study area due to non-availability of NRCS data using NRCS' Soil Survey (SSURGO 2.2)

After taking care to ensure all data was in a common projection, we used the ArcGIS *Union* tool to combine datasets. We added appropriate attributes (columns, described below) then dissolved the dataset so that it contained as few records as possible and no spatial overlaps.

This information is conveyed in the geodata files named HRCD_Analysis_CAO_Min_final, HRCD_Analysis_CAO_Max_final and HRCD_Analysis_SPTH_final provided with this report. Specifically:

- The "County", "City" and "UGA_Name" columns specify each record's county, city, and UGA (the 17 records with no identified County are WRIA-based and go across county boundaries; each of these is outside the CAO and $SPTH_{200}$ study areas).
- The "UGA_Name" column specifies the name of the UGA (areas outside of the UGA are labeled as "___ County; outside of UGAs").
- The "UGA_ID" column assigns a number from 1 to 232 for each UGA (areas outside of the UGA ["rural areas"] are given a number from 901 to 912).
- The "Incorporated" column specifies whether the area is within an incorporated area ("yes") or outside ("no").

- The "UGA" column specifies whether the area is within a UGA ("yes") or outside ("no").
- The "WRIA_NR" and "WRIA_NM" specify the WRIA number and name for each record.
- The CAO_StudyArea column specifies if the area is in ("yes") or out ("no") of the CAO study area.
- The SPTH_StudyArea column specifies if the area is in ("yes") or out ("no") of the SPTH study area
- The "Item" column denotes excluded areas with the label "Outside of Study Area"

At this point, we had two initial maps: one depicting the study area for the CAO analysis, and the other the SPTH study area.

Mapping Riparian Areas

The next step in the preparation of the initial maps was to map riparian areas – both as defined by existing CAOs and as defined by $SPTH_{200}$.

Mapping Stream Buffers as Defined by Jurisdictions' CAOs

Overview of Mapping CAO-based Stream Buffers

To map riparian areas throughout Puget Sound as described by county and city CAOs, we:

- Contacted county and city data stewards to identify the best source of riparian spatial data for their jurisdiction.
- Method 1 (Preferred): Obtained stream data attributed with fish use types (the most common criteria used in CAOs to determine appropriate riparian buffer widths) via an ArcGIS REST service endpoint (preferred) or a manual data download.
- Method 2 (Where Method 1 data were unavailable): Used the statewide DNR Hydro dataset clipped to the city or county boundaries.
- For each target city and county, created a GIS layer based upon each jurisdiction's CAO language that identifies regulatory stream buffer requirements.
- Created spatial databases to hold the data described above.
- The output of this effort was two GIS data layers, each of which covers 12 counties and 10 cities. The first output provided an approximation of minimum stream buffers for that place under the local CAO ("CAO min scenario:); the second provided an approximation of the maximum stream buffer under the local CAO ("CAO max scenario").

This process allowed us to fulfill the NTA's intent #1 (map riparian areas as defined by 22 CAOs) and #3 (create an internal intake process that allows for systematically incorporating better information sources).

Data Gathering, Organization, and Cleaning

We accessed each jurisdiction's online development regulations in the spring of 2019 to determine the criteria and corresponding default buffer distances used to designate riparian critical areas. See Appendix C, Table C9. We simplified CAO stream buffers in a master table

(Appendix C, Table C10) capturing required buffer distances for different stream types and noting other factors that determine each CAO's standard riparian buffers. After conducting a search for each county's and city's authoritative stream dataset (i.e., the one they use for depicting stream locations and attributes) from public-facing geospatial data, we spoke with staff from each jurisdiction's planning and/or GIS departments to verify we had identified the correct dataset. See Appendix C, Table C11. When speaking with local jurisdiction staff we also sought to clarify how they identified critical areas (for example, did they use both NHD and DNR Hydro to determine whether a project might impact a stream?, did they update their GIS layers of critical areas or were they static?). These discussions helped us interpret and apply their data.

Most jurisdictions assign stream buffer distances based on fish use based on DNR's forest practices water typing system. At the time of this analysis, of the 22 target jurisdictions' CAOs:

- 16 used the current DNR stream typing system (Types S, F, Np, Ns)
- 2 used the previous DNR stream typing system (Types 1-5)
- 4 used systems based on one of the two DNR systems noted above, which had been locally customized

See Appendix C, Table C12.

Of the 22 jurisdictions' authoritative stream datasets (i.e., those used to screen land use proposals):

- 11 (50%) had stream type attributions that matched the types described in their CAO (e.g., the CAO and the GIS data both referenced Type S, F, Ns, and Np streams);
- 3 (14%) had stream datasets whose stream type attributes were different than those described in their CAO (e.g., the CAO referenced Type S, F, Ns and Np streams while the GIS data showed Type 1-5 streams); and
- 8 (36%) of stream datasets were not attributed with any stream type; for these jurisdictions we used the statewide DNR hydrography layer (with some exceptions, described later).

We organized this information in two main reference tables using ArcGIS Pro. The first contained the geospatial data source URL and stream typing system used for each jurisdiction. The second table contained all possible buffer distances for each jurisdiction, including any additional criteria such as bankfull width or use by salmonids. Creating these two tables helped us organize the information in a way that aided task automation.

Before modeling riparian buffers, we needed to complete varying levels of manual (non-automated) data "cleaning" on each jurisdiction's stream dataset. When completing this task, we followed the jurisdiction's lead to the greatest extent possible. For example, jurisdiction have different practices when it comes to mapping and protecting atypical stream types -- such as X, U, and non-natural watercourses (e.g., pipelines). If the jurisdiction applied a buffer, we did as well; if the jurisdiction filtered out such stream types, we did, too.

Modeling Riparian Buffers to Reflect CAOs

We developed a series of Python scripts to process each jurisdiction's stream dataset and apply the appropriate riparian buffers based on the two reference tables described above. For six jurisdictions this was a straightforward exercise, as their CAOs did not contain additional criteria for buffer widths. For the other 16 jurisdictions, however, their CAOs contained additional criteria that depended upon project-specific or site-scale information that made determining exact buffer widths for every stream segment difficult if not impossible. For example, a CAO may require a buffer of 150 feet for a major development or 100 feet for a minor development; or it may require a 100-foot buffer for a stream that is less than 5 feet wide or a 150-foot buffer if the stream is greater than 5 feet wide. The width of the buffer in such cases depends on additional (and typically unmapped and sometimes unmappable) criteria. Appendix C, Table C10 lists variables which could result in different buffer widths for the same stream type for each jurisdiction. Since none of the datasets included attributes with these other criteria, we had no practical way of determining which criteria applied to which stream segment.

Initially, we sought to account for the potential for different buffers for a given stream segment by applying each potential buffer to each stream segment whose water type could have more than one possible buffer width. This created two problems: first, the resulting feature classes were large and complex, with potentially millions of vertices that made them nearly impossible to work with due to the amount of time they would take to load. More importantly, when it came time to perform the overlay analysis with the HRCD data, we would still be faced with the problem of having to choose a specific buffer to use for the analysis. Having no reliable way to select a buffer when the determinants of width were unknown, we decided to conduct our analysis for both the minimum buffer width and the maximum buffer width. With this "min/max" approach we could analyze HRCD change polygons using the smallest and largest buffers to get a range of change within the CAO-defined riparian area. We took this "CAO min/max" approach for 16 jurisdictions. For the other six jurisdictions (those whose stream buffers were not dependent upon unknown factors), we used an approach we called "CAO all." See Table 1.

Table 1: Jurisdictions for which the CAO min/max approach was used and for which the CAO all approached was used

CAO Min/Max Approach	CAO All Approach
Counties: Clallam, Island, Jefferson, King, Mason, Pierce, San Juan, Skagit, Snohomish, and Thurston	**Counties**: Kitsap and Whatcom
Cities: Bellevue, Bellingham, Bremerton, Everett, Seattle, Tacoma	**Cities**: Auburn, Bainbridge Island, Kent, and Renton

The following steps provide a generalized overview of how we used Python scripts to automate the application of appropriate riparian buffers to each jurisdiction's stream dataset. Full Python scripts for each jurisdiction are available from the department upon request.

1. Check the validity of the stream data source (whether ArcGIS REST service endpoint, download URL, or file path)
    a. If the URL/file path has changed or is no longer valid, send an email to department staff alerting them that the data source needs to be updated.
    b. If the URL/file path is valid, download the stream data to a "current" geodatabase.
2. Compare the newly downloaded stream data to a previous version of the data (if it

exists), housed in a "historical" geodatabase, to determine whether the data has changed since the last time it was downloaded.

   a. If this is the first time the data has been downloaded for the given jurisdiction, copy it from the temporary geodatabase into the historical geodatabase.
   b. If the data is the same as the data in the historical geodatabase, do nothing.
   c. If the data is different from the data in the historical geodatabase, replace the version in the historical geodatabase and delete the previously generated buffer feature class(es) for the given jurisdiction.

3. Clip the stream features to the city or county boundaries and dissolve on water type.
4. Buffer the stream features using the buffer distances in the water type reference table (two separate sets of buffers were produced when we used the CAO min/max approach) and save to a central geodatabase containing all jurisdictions' stream buffer datasets.
5. Create and fill in fields such as *buffer distance* and *water type*, resulting in a standard schema across all jurisdictions' stream buffer datasets.

Special Cases

There were several unconventional situations that required us to deviate from the general workflow outlined above, requiring us to perform certain steps manually. Even with just 22 jurisdictions (18% of the combined 122 counties and cities within Puget Sound), the broad variation among both CAO requirements and stream data schema, as well as other extenuating factors, made the creation of a single standardized riparian modeling process very challenging.

Perhaps the most notable exception to the standard process described above was in Skagit County, where county staff are currently making a subset of the statewide NHD their authoritative stream data source. They have been engaging with the Department of Ecology in a pilot project to attribute NHD polylines within the Skagit River basin with fish use types (see the Ecology's NHD metadata for details). Therefore, in our riparian buffer analysis of Skagit County we used NHD within the Skagit River basin, and DNR Hydro within the rest of the county.

Examples of other special cases:

- Auburn: The City is split across King and Pierce counties, so we treated each county's portion separately when conducting the riparian change analysis.
- Bainbridge Island: The City of Bainbridge Island was the only jurisdiction that already had stream buffer polygons based on water type readily available from their open data portal; we used that data instead of duplicating efforts.
- Bellevue, King County, and Thurston County: These jurisdictions identified specific buffers widths for "other" stream types (e.g., U, X), which we applied. The other 19 jurisdictions did not specify how non-standard stream types were treated, so we filtered them out.

Combining the CAO Riparian Areas with the CAO Base Layer

The next objective was to combine the CAO-min and CAO-max riparian areas with the CAO base layer. This involved:

1. For jurisdictions where we used the "CAO min/max" approach, using ArcGIS' *Merge* tool to combine all of the CAO min riparian areas into one soundwide GIS layer.
2. For jurisdictions where we used the "CAO all" approach, using ArcGIS' *Merge* tool to combine all of the CAO all riparian areas into one soundwide GIS layer.
3. Combining the results from the previous two steps into a GIS layer depicting a soundwide CAO min scenario.
4. Repeating the steps above with the CAO max riparian areas. The result was a soundwide GIS layer of CAO max scenario.
5. Using the ArcGIS *Union* tool, combining the CAO min layer with the preliminary CAO base (discussed in the previous section).
6. Simplifying the result of the previous step by dissolving riparian areas outside of the CAO study area.
7. Using the ArcGIS *Union* tool, combining the CAO min layer with the preliminary CAO initial map (discussed in the previous section).
8. Selecting appropriate records and labeling them in the Item column as "Riparian Area (CAO Minimum)" or "Non Riparian Area (CAO Minimum)".
9. Repeating steps 5-7 with the CAO max layer.

The results of steps 1-8 are seen in the GIS data provided with this report, which identifies CAO riparian areas in the "Item" column. See records marked "Riparian Area" in the files named HRCD_Analysis_CAO_Min_final and HRCD_Analysis_CAO_Max_final.

Mapping Riparian Management Zones as Defined by $SPTH_{200}$

Overview of Analytical Approach

To map riparian areas throughout Puget Sound as recommended by PHS Riparian Volume 1 we:

- Created tree productivity polygons using NRCS soils data and the NRCS Soil Data Viewer.
- Identified for each polygon the tree species with the largest $SPTH_{200}$ based on tree growth curves for those species for which site index information was provided.
- Overlaid these $SPTH_{200}$ polygons onto a prepared stream layer to tag stream segments with the $SPTH_{200}$ values.
- Buffered the tagged stream segments by the $SPTH_{200}$ values. This step included overcoming challenges caused by double-banked streams and selecting the correct (larger) $SPTH_{200}$ value in cases of overlapping buffers and multiple $SPTH_{200}$ values.

The output of this effort was a GIS layer of stream buffers that are a width of the largest $SPTH_{200}$. This allowed us to fulfill the NTA's intent #2 (map riparian areas as defined by PHS management recommendations).

Creating the Site Potential Tree Height (SPTH) Data

NRCS has mapped soil types in every county in Washington, though the extent mapped is different for each county. Most federal lands do not have NRCS soils data; likewise, there is not NRCS soil data for Seattle and Tacoma as those areas are no longer available for agriculture or forestry. In such areas, we cannot determine SPTH-based riparian buffers[9]. See Figure 8.

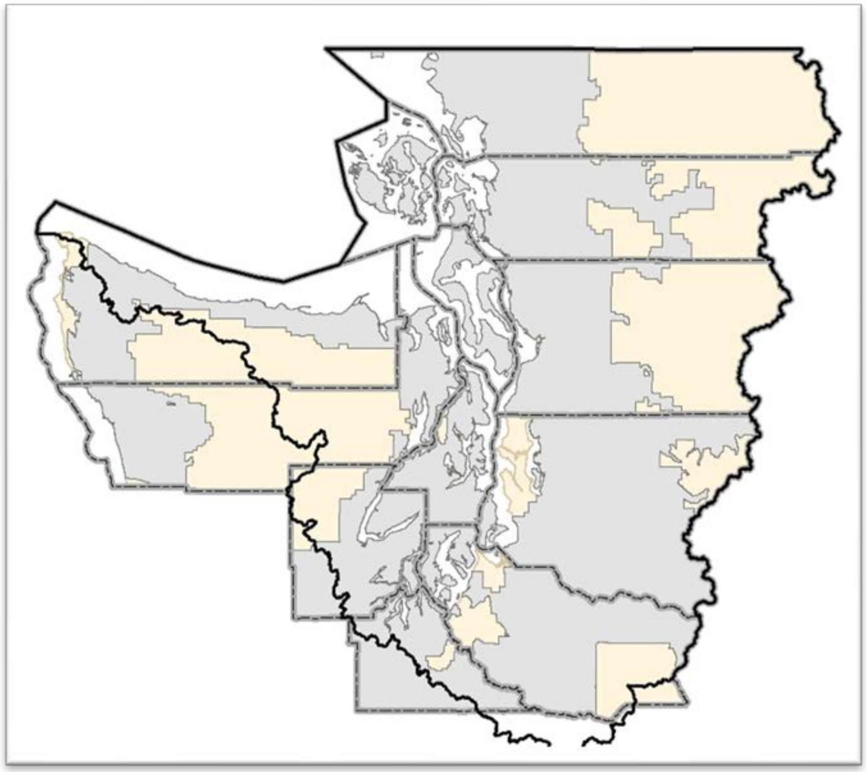


Figure 8 SPTH Study Area: Black outline shows Puget Sound basin boundary; gray depicts places where soil data was available and $SPTH_{200}$ analysis was completed; tan shows places where NRCS soil data is lacking and $SPTH_{200}$ analysis could not be conducted.

The NRCS soils data consists of polygons and have a variety of associated tabular information (attributes) from which a series of thematic maps can be created. NRCS' Soil Data Viewer tool is an extension for ArcMap that allows users to create soil-based thematic maps from the tabular attributes. One of these tabular attributes is tree productivity information used for forest management. Values for *site index* – the height a tree of a particular species will grow in a given number of years – have been estimated for each soil polygon if the soil conditions will support trees. Soil polygons with no data (e.g., because trees do not grow there) are classified as *not rated* or *not available*. The NRCS-provided site indices for tree species in the Puget Sound region are for 50 years of growth.

The NRCS Soil Survey (SSURGO 2.2) data was downloaded for each county. For each county, we used ArcMap and the Soil Data Viewer to create the tree productivity maps using the appropriate tabular attributes. These tree productivity maps had an attribute field for the 50-year site index. We exported each of these tree productivity maps to a new feature class, cleaned up the attribute fields, and copied the site index for the stream in a new attribute field named for its (e.g., RedAlderSiteIndex). We then unioned each tree feature class into a single county feature class and removed unnecessary attribute fields. Next, we added new attribute fields for tree code, site index, and the tree reference study. After selecting the largest site index

[9] Within the City of Bellingham, NRCS soil data is missing for about one-third of the city; in this area we imputed $SPTH_{200}$ values using nearby soils.

for each polygon, we input the tree name and tree reference study into the new fields.

From this table of the tree names, site indices, and reference studies, WDFW research scientist George Wilhere applied growth curves from the referenced studies to determine the 200-year site index (the 200-year site-potential tree height, $SPTH_{200}$) for each record. We then used this table to add the 200-year site index to the tree productivity soil polygons in the county feature classes. Finally, we added these finished county feature classes to a master spatial database which was used to create SPTH-based riparian buffers.

Creating the Stream Layer

We used NHD as our initial base layer when creating our $SPTH_{200}$ riparian buffer layer. We chose NHD over DNR Hydro because (a) it is becoming the nationwide, common hydrography platform, (b) it is the state standard, (c) it has more robust routing capabilities, and (d) it is the platform upon which WDFW and co-managers have built the Statewide Integrated Fish Distribution (SWIFD) layer which depicts fish use by stream segment. We started by creating a line feature called StreamRiver from the NHDFlowline feature class. For double-banked streams we used the NHDArea feature class to create a polygon feature called Stream/River (double bank streams). This process was relatively simple and straightforward; however, the resulting product left many places where the NHD lines and polygons did not intersect a NRCS soil polygon – meaning these places would not have $SPTH_{200}$ buffers. This happened frequently where the soil polygon was mapped at a different time than the NHD waterbody polygons and during the intervening time period, the rivers meandered.

To overcome this problem, we broadened the double-banked streams to include the historical Channel Migration Zone (CMZ) based on the previously mapped courses of the streams. We did this by merging and dissolving the NHD polygons and the NRCS water polygons. This had the dual benefit of (1) increasing the number of stream banks that had a $SPTH_{200}$ buffer, and (2) more closely following the recommendation of PHS Riparian Volume 2 to include the CMZ in the riparian area.

To create the final stream layer, we (1) clipped out stream lines that overlapped the double-banked stream polygons, (2) added the linework from the combined waterbody polygons to the single-line stream features, and (3) readied the attribute fields for the $SPTH_{200}$ values.

Adding the $SPTH_{200}$ Values to the Stream Layer and Buffering

To add the $SPTH_{200}$ values to the stream lines we used the ArcGIS *Identity* tool to overlay the NRCS tree productivity soil polygons. We used a series of checks to confirm that the attributes transferred successfully. In places where soil polygons had no tree productivity data, we were not able to calculate $SPTH_{200}$ values; this occurred in relatively few line segments.

To create the $SPTH_{200}$ buffers we buffered the stream lines with the $SPTH_{200}$ value. After this we used the *Union* tool to collapse the buffers onto each to avoid double counting areas with overlapping buffers (e.g., where stream lines were close together). We also eliminated any buffers of double-banked streams that fell within the stream itself. In instances of multiple $SPTH_{200}$ values for a given buffer (i.e., in buffers at the boundary of different soil types) we had to select the larger (or largest) of the possible values. To do this we created a centroid point as a unique identifier each overlapping polygons and then used the *Summary Statistics* tool to create a table of the maximum buffer distance for each centroid identifier. With this table we kept the overlapping polygon with the largest buffer distance and discarded the rest. We verified to ensure that correct overlapping buffers were being kept. This effort produced a GIS layer of $SPTH_{200}$-width buffers for each county.

Combining the SPTH Riparian Areas with the SPTH Base Layer

The next objective was to combine the SPTH-defined riparian areas identified above with the preliminary SPTH initial layer. In a process like that used for CAO-defined stream buffers, we:

1. Used ArcGIS' *Merge* tool to combine all of the county-by-county SPTH-defined riparian areas into one soundwide GIS layer.
2. Used the ArcGIS *Union* tool to combine the SPTH riparian areas layer with the preliminary SPTH initial map.
3. Simplified the result of the previous step by dissolving riparian areas outside of the SPTH study area.
4. Selecting appropriate records and labeling them in the Item column as "Riparian Area (SPTH)" or "Non Riparian Area (SPTH)".

The results of this work are seen in the GIS data provided with this report, which identifies SPTH riparian areas. (See file named HRCD_Analysis_SPTH_final, records labeled "Riparian Area" in the "Item" column.)

Discussion of the Initial Maps

At this point we had completed preparation of three initial maps: one for the CAO min scenario, one for the CAO max scenario, and one for the SPTH scenario. The CAO min and CAO max maps provided a soundwide modeled approximation of the extent riparian areas regulated by CAO. The SPTH scenario map provided a soundwide modeled approximation of the extent of riparian areas WDFW recommends be protected, as discussed in WDFW's PHS Riparian Volumes 1 and 2.

When the initial maps were completed, we evaluated what we had created. Cognizant of the limitations of our data (e.g., inherent blue line errors), here are some of our apparent key findings:

- Nearly two-thirds of the Puget Sound basin is in federal ownership, forestry, tribal ownership, or has visible surface water. That means that the GMA (and other local land use regulations) primarily regulate just slightly more than one-third of the land area in the Puget Sound basin.
    - The $SPTH_{200}$ study area includes 36.6% of the Puget Sound basin land area. Because the CAO study area excludes all but 10 cities, it covers a slightly smaller area, 34.9%.
- *How much of the study area is within riparian areas?* CAO-defined riparian areas comprise between 9.1% and 10.7% of the study area. $SPTH_{200}$-based buffers comprise roughly twice that amount: 18.3%. This pattern was fairly consistent when we broke down the region into component parts. For example:

  - Rural areas (i.e., areas outside of UGAs) have slightly more riparian areas than the soundwide average: 10% to 12% per CAOs; 21% per SPTH.
  - The density of riparian areas in UGAs is about half that of rural areas: 4% to 6% per CAOs; 9% to 10% per SPTH. The pattern is generally consistent whether the UGA is incorporated or unincorporated.
  - The portion of an individual county that is within the CAO-defined riparian area ranges from a low of 3% (Island County) to a high of 16% (Thurston County). For SPTH-defined riparian area the range is 6% (Island County) to 25% (King County).
  - Within the 10 cities analyzed, the portion of a city that is within the CAO-defined riparian area ranges from a low of 0.7% (Tacoma) to a high of 13% (Bainbridge Island). For SPTH-defined riparian areas the range for the same set of cities[10] is 8% (Auburn) to 11% (Bainbridge Island) or 17% (if Bremerton, with its protected drinking water watershed, is included).
  - For more details of portion of a geography within riparian buffers, see Table D13 in Appendix E.

- No two CAOs from our 22 target jurisdictions were the same. Major differences:
  - Some use the current DNR water typing system; others use the older DNR system; others used a locally modified version.
  - Jurisdictions use a wide variety of buffer criteria other than water type (e.g., bankfull width, anadromous use)
- The width of stream buffers for similar water types varied significantly by jurisdiction. Range of widths for stream types (grouping based on DNR's current water typing system):
  - Type S: 100′ to 250′
  - Type F: 75′ to 250′
  - Type Np: 25′ to 225′
  - Type Ns: 5′ to 225′
- The $SPTH_{200}$ buffers varied from 100′ to 260′; see Table 2.

With the three initial maps completed, the next step was to overlay HRCD datasets on the initial maps and calculate the performance indicators.

Calculating CAO Performance Indicators

Once we had completed the initial maps for the three critical area scenarios (CAO min, CAO max, and $SPTH_{200}$), the next task was to overlay two WDFW datasets (HRCD polygons and tree canopy polygons) used to calculate the five performance indicators. After trying a variety of approaches, we finally settled on the method described below. This description fulfills the first half of NTA's intent #4 (describe a methodology for using HRCD to evaluate riparian change).

[10] Excluding Seattle (because we had no NRCS soil data) and Tacoma (for which we had NRCS soil data for only 1.5% of the city's land area).

Table 2 Simplified overview of jurisdictions' CAO riparian buffer widths (as of spring 2019). For this table, each jurisdiction's stream categorization was approximated using a best fit to DNR's current stream classification system.

	Type S*	Type F*	Type Np*	Type Ns*	Range depends on (footnote)
Counties					
Clallam	150	65, 150[1]	60, 100[1]	50	[1]Minor/major new development
Island	150	100	75	50	
Jefferson	150	150	75	50, 75[1]	[1]Grade >/< 20%
King	115, 165[1]	115, 165[1]	25, 65	25, 65	[1]In/out UGA & condition
Kitsap	200	150	50	50	
Mason	150	150	100	75	
Pierce	100	150	35, 65, 115[1]	35, 65, 115[1]	[1] >/< ¼ mile of Type F, Support critical fish spp
San Juan	110	110	50	5, 30[1]	[1]If flow < 6 mo/yr banks must be vegetated
Skagit	200	100, 150[1]	50	50	[1]BFW
Snohomish	150	100, 150[1]	50	50	[1]Anadromous/Non-anadromous
Thurston	250	150, 250[1]	100, 150[2], 225[3]	100, 150[2], 225[3]	[1]BFW; [2]Drains to F, [3]Mass wasting potential
Cities					
Whatcom	150	100	50	50	
Auburn	100	75	25	25	
Bainbridge Island	NA	200	100	50, 75[1]	[1]Connected to F or Np
Bellevue	50, 100[1]	50, 100[1]	25, 50[1]	25, 50[1]	[1]Developed/undeveloped site
Bellingham	250	75-200[1]	50-150[1],200-225[2]	50-100[1],200-225[2]	[1]Varies by stream, [2] Mass wasting potential
Bremerton	175	150	50	35	
Everett	100	100, 150[1]	50, 75[1]	50, 75[1]	[1]Vegetation quality
Kent	200	100	40	40	
Renton	100	115	75	50	
Seattle	NA	50,75,100[1,2]	50 ,100[2]	50 ,100[2]	[1]Anadromy; [2]Lot existence before/after 2006
Tacoma	150	100, 150[1]	100	25, 75	[1]Salmonid presence; [2] Drains to S, F, or Np

* Best approximation of this classification.

BFW = Bankfull width, UGA = Urban Growth Area, NA = Not applicable (not in study area)

Combining Initial Maps with HRCD Change Data

The intent of this analysis was to develop indicators regarding the effectiveness of CAOs in shifting development away from riparian areas. In keeping with this intent, we did not consider all types of changes identified by HRCD polygons. Specifically, we did *not* consider changes due to forestry, stream channel migration that took out trees, or trees removed by other natural causes such as landslides or wildfires. This analysis considered (1) tree canopy loss and (2) total change (which includes additions of both impervious and semi-pervious surfaces, plus tree canopy loss). Although HRCD data allows us to independently evaluate impervious and semi-pervious additions, we chose not to do so because it would have added to the complexity of the results with little or no additional insights.

HRCD polygons reflect the proportion of the polygon that experienced change in quartiles (0%, 25%, 50%, 75%, or 100%). When HRCD polygons are overlaid on top of riparian polygons, it is a common occurrence for the HRCD polygon to be partially within and partially outside of the riparian polygon. When this occurs, we assumed the amount of change within the riparian area was proportional to the amount of change within the HRCD polygon as a whole. For example, if a 2.0-acre HRCD polygon reports a total change of 75%, we know there was 1.5 acres of change within the polygon. If the HRCD polygon was one-third in the riparian area, this analysis assumes that 0.5 acres of change occurred in the riparian area and 1.0 acres of change outside the riparian area. The error introduced by this assumption is unquantified, but likely to be small (especially over larger areas, where errors will likely cancel each other out).

The steps we took to overlay the HRCD data with the CAO min base layer:

1. Opened HRCD file and entered a definition query that excluded all records whose Change Agent Name equaled "Forestry" or "Stream" or "other, natural."
2. In the HRCD file's Layer Properties, we turned off all fields except Start Year, Total Change (percent), Tree Decrease (percent) and Area (acres).
3. We opened the CAO min base layer and selected all records whose Item field equaled "Riparian Area" or "Non Riparian Area" (but *not* those marked "Out of Study Area").
4. We used the *Select by Location* tool to select the HRCD polygons that intersected the selected polygons in the CAO min base layer. We saved this as HRCD_Subset_CAO_Min.
5. We use the ArcGIS *Union* tool to combine the CAO min base layer with the HRCD Subset layer. We saved results as "HRCD_Analysis_CAO_Min".
6. We opened the new HRCD_Analysis_CAO_Min file and added four new fields:
    a. Acres
    b. Percent In Item
    c. Tree Loss Acres
    d. Total Loss Acres
7. We used the *Calculate Geometry* feature to fill in the Acres field.
8. To calculate the Percent In Item field we divided the Acres field by the Area (acres) field.
9. To calculate the Tree Loss Acres field, we multiplied the Tree Decrease (percent) field by the Area (acres) field by the Percent In Item field.
10. To calculate the Total Loss Acres field, we multiplied the Total Change (percent) field by the Area (acres) field by the Percent In Item field.

We then replicated these steps to complete the HRCD analysis for the CAO max and SPTH scenarios. The result of this effort was three geofiles provided as part of this NTA's deliverables: HRCD_Analysis_CAO_Min_final, HRCD_Analysis_CAO_Max_final, and HRCD_Analysis_SPTH_final.

The data table associated with each of these files was converted to an Excel spreadsheet to facilitate use of pivot table functionality to calculate performance indicators for each of the three scenarios.

Intersecting Tree Canopy Data with Riparian Areas

The final GIS work required to calculate performance indicators was to determine the quantity of tree canopy within the riparian areas under the three scenarios.

To calculate the percentage of riparian area with tree canopy we used a high resolution tree canopy dataset produced by WDFW's Habitat Science Landscape Spatial Analytics Section using 1m aerial imagery and LIDAR elevation maps. This data is distinct from (but associated with) HRCD data. It is available on the WDFW HRCD Hub. We carried out the following steps to get this information into a format where we could use it to calculate performance indicators:

1. From the HRCD_Analysis_CAO_Min_final dataset we selected all records with an Item equal to "Riparian Area"; we saved these records as PS_Trees_CAO_Min.
2. We added a field "Tree Canopy". We selected all polygons that were HRCD change polygons (Start Year >0) and entered "Change" in this field.
3. We used the *Union* tool to combine the PS_Trees_CAO_Min layer with the soundwide tree canopy dataset.
4. We selected the records that had canopy cover and deselected those already labeled as "Change" in the Tree Canopy field. In these records we set the Tree Canopy field to "Yes".
5. The remaining Tree Canopy records were set to "No".

These same steps were then applied to the CAO max and SPTH scenarios. The result of this effort was three geofiles provided as part of this NTA's deliverables: PS_Trees_CAO_Min, PS_Trees_CAO_Max, and PS_Trees_SPTH.

The data table associated with each of these files was converted to an Excel spreadsheet to facilitate use of pivot table functionality to calculate performance indicators for each scenario.

Calculating Performance Indicator #1: Portion of Riparian Area that has Trees

For each scenario, the Item field contains three values: "Riparian Area", "Non Riparian Area", and "Outside of Study Area." Calculating the percentage of riparian area with tree cover is simply a matter of summing acres with canopy cover and dividing by the total acreage of riparian area within the study area.

Calculating Performance Indicator #2: Acres of Riparian Trees that will be Lost in a Decade

Calculating this indicator requires first calculating indicators #1 and #3. From indicator #1 we get the number of acres of riparian areas that currently have tree canopy. From indicator #3, we get the number of acres of tree loss for the most recent decade. Indicator #2 reports both the total number of acres of riparian trees that are expected to be lost at the next decade if the rate of loss from the previous decade holds steady; as well as the proportion (percentage) of treed riparian area that number represents.

Calculating Performance Indicator #3: Acres of Change (Tree Cover and Total) per Year in Riparian Areas

For each scenario the TreeLossAc and TotalLossAc fields contain the acreages of tree canopy cover loss and total loss for that record. To calculate this indicator, we used a pivot table with the following settings:

- Filter: Item (select only Riparian Areas)
- Column: StartYr
- Row: Sum Values
- Sum Values: Sum of TreeLossAc; Sum of TotalLossAc

The same result could be obtained in ArcGIS (with the added benefit of being able to see the selected polygons) by selecting the riparian parcels (in Item) and summarizing the StartYr with summary statistic selected for TreeLossAc (Sum) and TotalLossAc (Sum).

To get the annual rates of change, we divided the results by the number of years in the period (three for the 2006-2009 period, two for all the others). These numbers are plotted on a line graph to show change over time and the relationship between change due to tree loss and overall change.

Calculating Performance Indicator #4: Change within Riparian Area vs. Change outside of Riparian Areas

As with the calculation for indicator #3, calculation of this indicator involves summing total change within riparian areas. This indicator also requires the summation of total change in non-riparian areas. To calculate change for the full period of record, we used the following pivot table settings:

- Filter: none
- Column: none
- Row: Item
- Sum Values: Sum of TotalLossAc

This provided numbers for change acres by riparian and non-riparian areas. To get the final number for this indicator, we multiplied the acres of riparian loss by 10 then divided by the acres of total change in non-riparian areas. The raw numbers for this calculation could also be obtained in ArcGIS by summarizing the Item with Summary Statistic selected for TotalLossAc (Sum).

Calculating Performance Indicator #5: CAO Power Score: Ratio of Change outside of Riparian Areas to Change within Riparian Areas

As with the calculation for indicator #4, calculation of this indicator involves summing total change within riparian areas and non-riparian areas. However, for this indicator we sum total change by time period. Again, with the pivot table this a simple indicator to calculate. We used the following pivot table settings:

- Filter: none
- Column: StartYr
- Row: Item
- Sum Values: Sum of TotalLossAc

The same result could be obtained in ArcGIS by selecting riparian areas (Item = Riparian area), summarizing the Start Year with Summary Statistic selected for TotalLossAc (Sum), then repeating the summarization with non-riparian areas selected.

In the accompanying Excel spreadsheet for calculating and reporting standard indicators, the graph for indicator #5 shows the Power Score by time period. This is obtained by dividing the acres of non-riparian change by the acres of riparian change for each time period.

Discussion of the Performance Indicators

In this section we discuss the findings of our performance indicators. We report findings by soundwide averages[11]; temporal trends; trends by buffer width as represented by the three scenarios analyzed (CAO min, CAO max, and SPTH); trends by land use category (urban or rural); and geographic trends.

We provide this information because oftentimes performance indicators in isolation are not informative. Context enables the user to determine the "so what" from the indicator. This context can be provided by reporting the performance indicator in relation to a regional average, in comparison with similar jurisdictions, or the same jurisdiction within a different time period.

This NTA originally intended to provide results of this analysis geographically by jurisdiction. As stated earlier, we decided not to report this specific information since the unquantified error of "blue lines" prevents us from specifying a level of confidence in our results. However, we felt that it was still important to demonstrate how these indicators can provide insights when considered geographically. To demonstrate such trends, we conducted analysis of our indicators for most of the Water Resource Inventory Areas (WRIAs) within the study area. We consider WRIAs are an

[11] The averages we provide are for illustrative purposes only, as a way to make comparisons which we think are helpful. For example, when we report numeric rates of change at the WRIA level as being "below average", "average", or "above average", these are simply in relation to one another. We do not have sufficient information to know "how much" change in a riparian area is too much. In other words, it is possible that the rates of change we see in every WRIA is problematic biologically, or that none of them is.

appropriate scale because:

- they are closely related to the freshwater range of salmon stocks and, hence, our agency's mandate of protecting fish species and maintaining fisheries;
- they are large enough to not be overly influenced by rare events yet small enough to reflect regional differences;
- they are established and well known by local governments, state agencies, and tribes; and
- they cross city and county jurisdictional boundaries so that no particular jurisdiction is directly implicated by a trend within a WRIA (we do not provide results of WRIA 2 [San Juan] or WRIA 6 [Island County] as these WRIAs coincide with county boundaries).

Indicator #1: Percent of Tree Canopy in Riparian Area

Unlike other indicators -- which report change through time -- this indicator reports the amount of riparian tree canopy present as of the summer of 2017.

The portion of riparian areas within our study area that have tree canopy was 73% for both CAO min and CAO max scenarios and 77% for the SPTH scenario.

Trends by width of riparian buffer: We hypothesized that areas closer to streams – because they are protected by CAOs – would have more canopy cover than areas farther from the stream. Because virtually all SPTH buffers are substantially wider than the regulatory stream buffers in the 22 CAOs we examined, we expected to see lower tree canopy percentages overall in the SPTH buffers compared to the CAO buffers. Unexpectedly, this was not borne out by the soundwide data.

When we looked at canopy coverage only in urban areas, we did see the pattern we expected: more trees (i.e., higher tree canopy percentage) in the CAO buffers and fewer trees (lower tree canopy percentage) in the SPTH buffers. See Figure 9. This aligned with our hypothesis that CAOs shift development away from streams. However, it was the rural areas (unincorporated, non-UGAs) that drove the soundwide pattern of fewer trees in narrow buffers and more trees in wider buffers. These

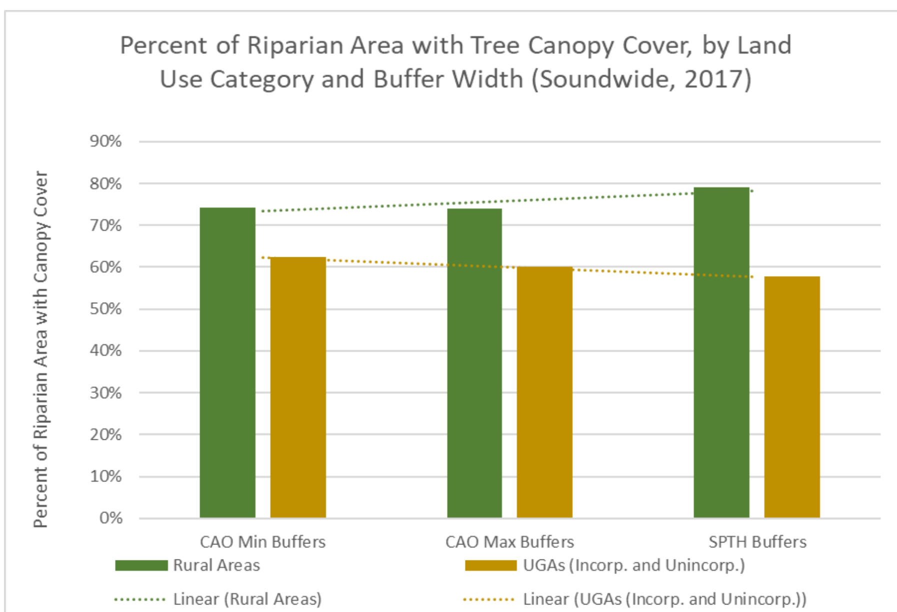


Figure 9: Riparian Tree Cover by Width of Buffer

patterns were found throughout the Sound: all WRIAs' urban areas exhibited this trend, as did the rural portions of nearly all (17 of 19) WRIAs.

Further analysis would be needed to investigate why rural areas have a lower percentage of trees in narrower buffers compared to wider ones. Is it due to the prevalence of wetlands within CAO buffers that preclude tree growth? The continuing effects of historical development near rural streams? Additional analysis looking at rates of change within buffer widths of equal intervals (e.g., 50', 100', 150', 200') and within wetlands may be able to explain this phenomenon in greater detail.

Trends by land use category: As expected, we noted a considerably lower percentage of trees in urban riparian areas compared to rural riparian areas. Soundwide, 79% of the study area's rural SPTH stream buffers had tree canopy; within UGAs this amount was 58%. Curiously, we noted that on average, riparian areas in incorporated cities had about 8% *more* tree cover than riparian areas in unincorporated UGAs. This finding was consistent across the three scenarios; we have no explanation about why this is the case. See Table 3.

Table 3: Indicator #1: Portion of Critical Areas that had Tree Canopy Cover (2017)

Geography	CAO Min	CAO Max	SPTH
Puget Sound	73%	73%	77%
Rural areas	74%	74%	79%
Cities (only those in both the CAO and SPTH analyses)	67%	64%	64%
Unincorporated UGAs	58%	56%	57%

Geographic Trends: Our WRIA-by-WRIA assessment showed that the percentage of tree canopy cover within riparian areas (based on the CAO min) ranged from 44% to 93%. See Figure 10. These geographic trends were similar among the three scenarios. Our best explanation for these trends is that they reflect a combination of historic land uses, current land use intensity, and forest growth potential, among other factors.

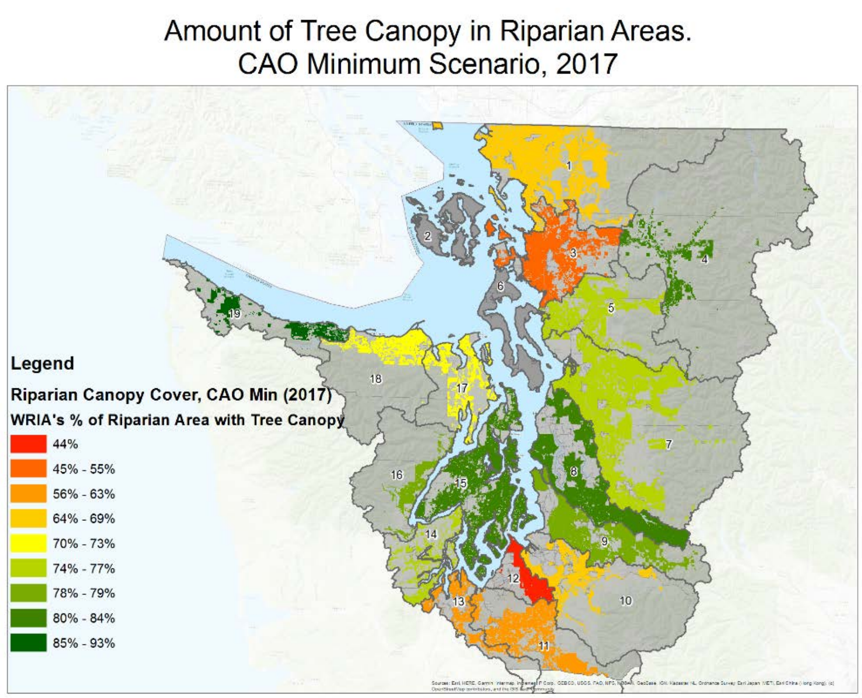


Figure 10: Tree Cover in Riparian Areas (2017)

Notes:

1. The portion of WRIAs shown in grey are outside of the study

area; events in those areas did not figure into this study's calculations.

2. When considering where to carry out stream restoration projects, riparian areas that lack trees should receive priority consideration. From this perspective the ubiquity of riparian areas that lack canopy cover means that restoration planners would likely not need to look far for a stream that would benefit from a tree planting project. The geofiles showing riparian areas lacking tree cover could serve as a resource for restoration planners or developers seeking a place to carry out compensatory mitigation for unavoidable riparian tree disturbances.

Indicator #2: Decadal Loss of Tree Canopy

Soundwide, we found the decadal rates of riparian tree loss to be 0.25% (CAO min), 0.59% (CAO max), and 0.96% (SPTH) based on the 2006-2017 rates of riparian change.

These rates are lower than we anticipated: clearly, our expectations were based on a perception that widespread riparian change is extensive. Fully recognizing the caveats identified previously, at the actual rates detected in this analysis, it appears that the tree loss due to development within CAO minimum buffers *at the soundwide scale* would amount to less than 10% in the next century. However, once we looked at rates of change within subsets of the basin, we started to see important distinctions.

Trends by width of riparian buffer: As noted for the previous indicator, we observed an apparent and unexpected decrease in canopy cover soundwide within narrower riparian buffers. In contrast, when it comes to *change* within riparian areas, we saw strong and consistent soundwide trends towards more change within wider (SPTH) buffers. This apparent lower rate of change within CAO buffers lends support to our hypothesis that, generally speaking, CAOs are effective at shifting development out of riparian areas. It also supports the idea that legacy land use practices are primarily responsible for the lack of trees in riparian areas rather than current practices.

Trends by land use category: When we explored this indicator for urban areas specifically, the rate of riparian tree loss appeared to be higher than the soundwide average, both in cities and in unincorporated UGAs. See Table 4. For example, the portion of riparian trees expected to be lost in the next decade (based on the previous decade's rate) in all CAO buffers in unincorporated UGAs is 0.65% to 1.7% - while these rates are low, they indicate that losses continue to occur. The degree to which offsetting restoration is occurring is unknown. Lowering the rate of loss will likely require cities and counties to make a concerted effort to conserve existing riparian trees within UGAs. This loss rate may also be useful when determining the scale of tree replanting projects that may be appropriate for a jurisdiction. Given the relatively low rate of riparian tree loss, it seems possible that, in time, riparian revegetation efforts could overcome the rate of riparian tree loss.

Table 4: Indicator #2: Portion of Riparian Trees predicted to be lost in the next decade, based on the previous decade.

Geography	CAO Min	CAO Max	SPTH
Puget Sound	0.25%	0.59%	0.96%
Rural areas	0.23%	0.54%	0.63%
Urban areas	0.58%	1.42%	2.06%
Cities*	0.50%	1.17%	1.94%
Unincorporated UGAs	0.65%	1.70%	2.41%
*A different set (smaller number) of cities was assessed under the CAO scenarios than under the SPTH scenario			

Geographic trends: A WRIA-by-WRIA analysis shows decadal riparian tree loss rates ranging from 0.2% to 4.9% for the CAO minimum buffers; 0.2% to 6.8% for the CAO maximum buffers; and 0.3% to 11.2% for SPTH-width buffers. See Figure 11.

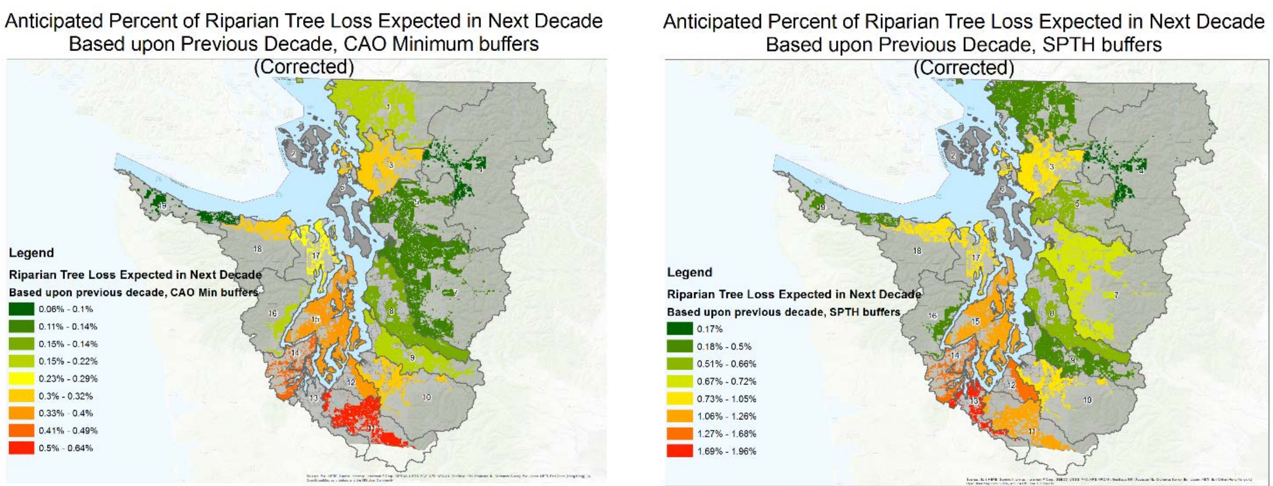


Figure 11: Anticipated Loss of Riparian Trees in the Next Decade, CAO Min buffers (left) and SPTH buffers (right)

Note that although the overall rates of loss are much higher when considering the wider $SPTH_{200}$ buffers, the pattern among the WRIAs in the two scenarios is relatively stable. For regional riparian conservation entities, this means that whether the intent is to conserve trees close to a stream or within the full $SPTH_{200}$ riparian area, the WRIAs to focus on are probably the same. For local entities, this could be useful for deciding how urgently riparian tree conservation efforts are needed and whether such efforts should focus on CAO-defined buffers, or $SPTH_{200}$-width buffers (e.g., through incentives).

Indicator #3: Acres of Change Per Year in Riparian Areas

As with the previous two indicators, the soundwide average for Indicator #3 is largely driven by the rural trend.

Soundwide, riparian areas (CAO min) in the study area experienced 564 acres of tree loss and

689 acres of total change between 2006 and 2017. This equates to 2.0 acres of tree loss and 2.5 acres of total change per 1,000 acres of riparian area. On an annual basis this equates to 0.22 acres of total change per 1,000 acres of riparian area.

These rates of change varied by time period, buffer width (scenario), land use category, and type of change within the buffer.

Trends by time period: For this project, HRCD data provided five data points through time to compare rates of change. A downward trend in change through time would indicate that CAOs are gaining in their ability to minimize/avoid change within riparian areas. As shown in Figure 12, total riparian change (CAO min) varied between about 55 and 75 acres per year; in the SPTH riparian buffer the total change varied between about 360 and 470 acres per year. The weak but upward trend of the lines seems to indicate that CAOs are becoming less effective at avoiding/minimizing change within riparian areas.

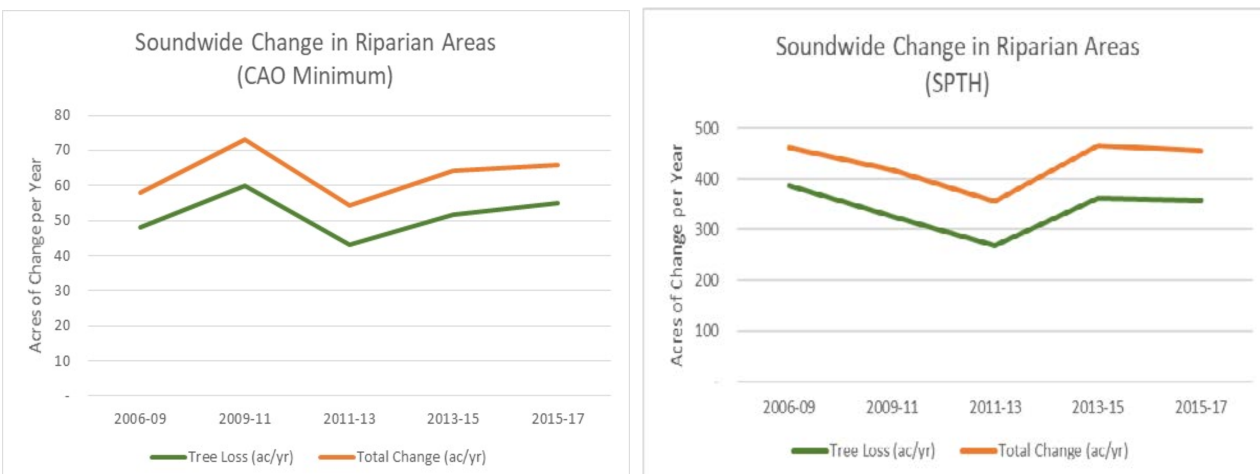


Figure 12: Annual Rates of Change (Canopy Loss and Total Change) in Riparian Area by Time Period (2006-2017).

The relatively sharp upward trend in the 2009-11 time period in the CAO min and CAO max scenarios is anomalous, as the trend seen in the SPTH data of a falling line between 2006 and 2013 is more representative of soundwide trends (uplands and riparian) which likely reflects overall slower development rates due to the 2008-2009 Great Recession. Further analysis into the CAO min data revealed a 26-acre restoration project on the Skagit delta involving the removal of dike-associated trees was responsible for much of the 2009-11 spike.

Trends by width of riparian buffer: We expected to see that as buffers got wider, the rates of change within the buffers would increase – especially when expanding the buffer to the SPTH width (which is usually well beyond even the CAO max buffer). This is what we found. See Figure 13. For example, 4.4% of the land area within UGAs is located within the CAO min riparian buffer. Within these CAO min riparian buffers, the rate of change is a relatively low 5.8 acres of change for every 1,000 acres of riparian area. When the buffer is expanded slightly to the CAO max width (covering 5.5% of the UGA's land area), the rate of change more than doubles, to 14.9

acres of change for every 1,000 acres of riparian area[12]. When expanding the buffer to the full SPTH width (which covers 9.8% of UGAs), the rate of change increased to 22.8 acres of change for every 1,000 acres of riparian area. This approaches UGAs' overall rate of change (not just within critical areas) of 36 acres of change per 1,000 acres of UGA – indicating a change-rich, rapidly developing environment. Thus, CAOs do seem to be shifting urban development away from urban riparian areas.

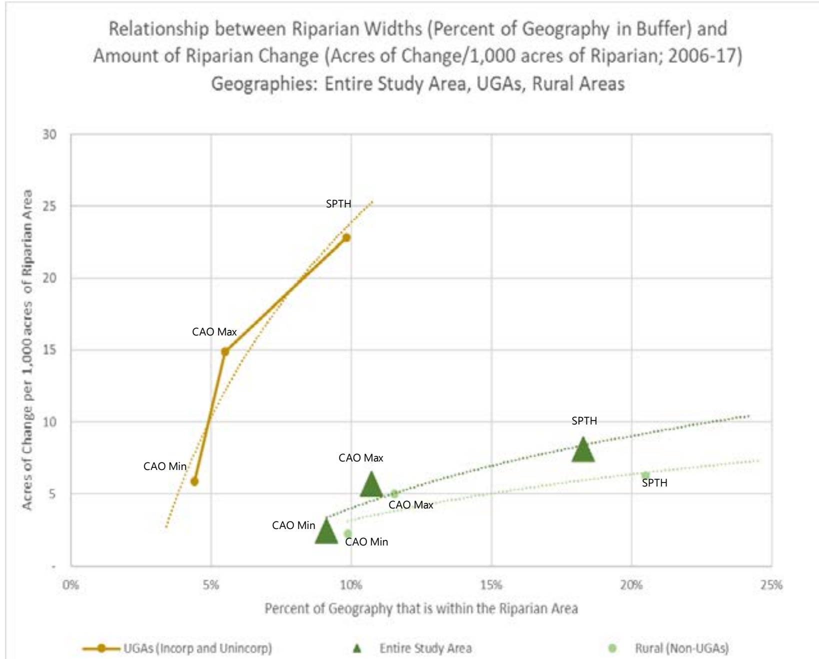


Figure 13: Relationship between Rates of Riparian Change and Buffer Width.

In rural areas the trends are similar – but the overall rate of change is about one-third that of urban areas. As the buffer width increased from the CAO min width (9.9% of the rural area) to the CAO max width (11.6% of the rural area), the rate of change within riparian areas increased from 2.2 to 5.0 acres of change for every 1,000 acres of riparian area. When the SPTH buffers were analyzed, the amount of area nearly doubled 20.5% of the rural area) yet the rate of change increased only slightly, to 6.2 acres of change per 1,000 acres of riparian area. However, this is considerably less than the overall rural change rate (not just within critical areas) of 12 acres of change per 1,000 acres of rural land area. It would thus seem that rural CAOs are steering development away from their riparian areas.

Trends by land use category. Unsurprisingly, urban and urbanizing areas appear to be experiencing significantly more change than rural areas. Within our study area we found that change within urban riparian areas occurred at rates of 2.6 to 3.7 times that of rural areas. See Figure 14.

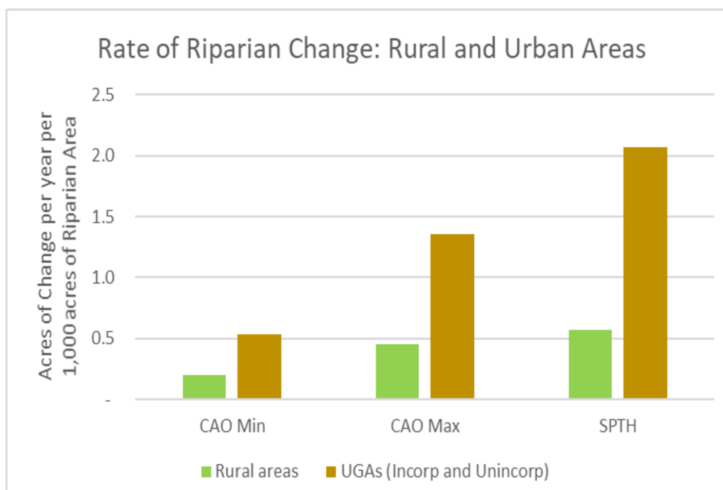


Figure 14: Riparian Change Rates in Rural and Urban Areas.

[12] This sharp rise in the rate of change is consistent with our expectation that the rate of change would be high immediately outside of the CAO buffer because that is where development that may not occur within the buffer is shifted to.

Geographic Trends. The normalized rate of change (acres of riparian change per 1,000 acres of riparian area) allows for direct comparison across geographic areas. For example, Figure 15 shows the average annual rate of riparian change by WRIAs for the CAO min scenario. WRIAs shown in red are experiencing relatively high rates of riparian change. Those in yellow area experiencing slightly higher than average rates of change, and those in green are seeing less than average rates of change in riparian areas. By this indicator, WRIAs shown in green are served by CAOs that appear to be delivering better-than-average on-the-ground results. This map initially surprised us as we expected to see higher rates of change in places with the highest population (i.e., I-5 corridor from Tacoma to Everett) but this does not appear to be the case.

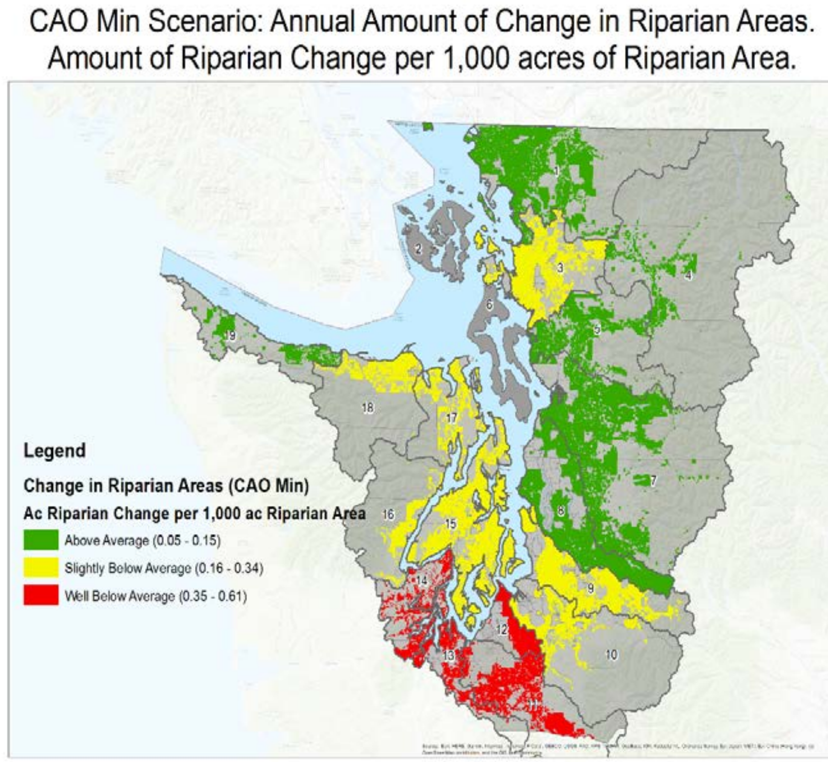


Figure 15: Average Annual Amount of Riparian Change by WRIA.

When interpreting this map, it is important to keep in mind two caveats. First, it's important to acknowledge the possibility, if not likelihood, that there is a high degree of variability of change within each WRIA itself: After all, there will be multiple governance structures and potentially wide variabilities in land use patterns. Second, although we report the rates of change here using a relative scale, this is not a qualitative assessment about what rates of change are or are not considered acceptable.

Trends by type of change within riparian buffer: This analysis looks at two types of change: Change in tree canopy cover and total change (tree loss plus addition of impervious/semi-pervious surfaces). Soundwide, the proportion of total change due tree canopy loss is 82% to 83% for the CAO scenarios. In rural areas it was slightly higher (85% to 87%), whereas in UGAs it was only 63% to 67% [meaning in UGAs, new impervious/semi-pervious surfaces comprised a larger percentage (about one-third) of the total change]. We had hypothesized that in UGAs the proportion of change due to an increase in impervious/semi-pervious surfaces would be higher than in rural areas. This trend was borne out by the data. See Figure 16.

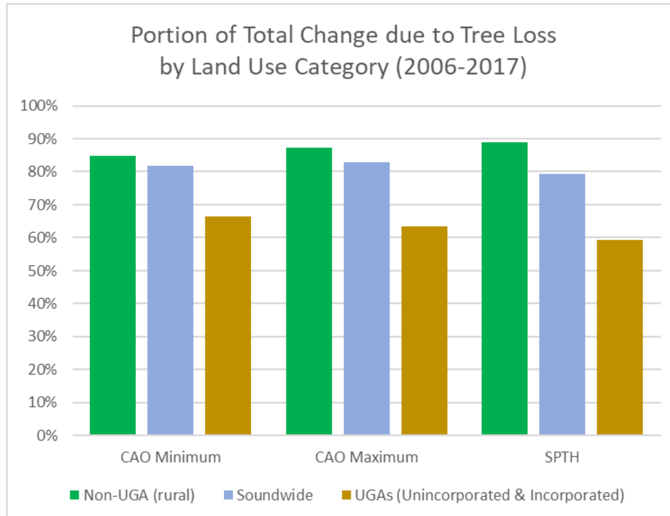


Figure 16: Portion of Total Change Due to Tree Loss.

As seen in Figure 16, the general pattern (especially at broader scales, e.g., soundwide urban or soundwide rural vs. a small individual jurisdiction) is for the proportion of change due to tree canopy loss to be fairly stable – in the vicinity of 85% for rural areas and 65% for urban areas. If one sees a pattern of higher-than-average amounts of change due to impervious surfaces within riparian areas, that may be an indication that the CAO is not being effective at shifting development away from riparian areas. This may warrant further investigation. In general, when searching for such anomalies, it is important to expect wider variation when looking at a relatively small area and/or a relatively short timeframe because the anomaly may be the result of a single event.

Some local governments may find this indicator is most useful when used to compare their normalized change rates to soundwide averages or change rates of similar jurisdictions; others may find this indicator most useful when used to look within their jurisdiction to identify periods when the their CAO provided (or did not provide) on-the-ground results as hoped. We believe regional entities trying to decide how to allocate resources will find the normalized change rates most useful.

Indicator #4: Change within Riparian Area vs. Change outside of Riparian Areas

For every ten acres of change in non-riparian areas, how many acres of change occur within riparian areas? The soundwide answer is 0.15 acres for the CAO min scenario, 0.41 acres for the CAO max scenario, and 0.84 ac for the SPTH scenario. Consistent with the other indicators, we see strong trends in how this indicator varies by type of land use, riparian width, and geography.

Trends by type of land use: Although the *overall* rates of change within rural areas is much lower than in urban areas, the *relative* rate of riparian vs. upland change in rural areas is more than double that of urban areas. See Table 5.

Table 5: For every 10 acres of upland change, how many acres of change occur within riparian areas?

Geography	CAO Min	CAO Max	SPTH
Puget Sound	0.15	0.41	0.84
Rural areas	0.19	0.49	1.12
UGAs (Incorporated* and Unincorporated)	0.07	0.23	0.55
*A different set (smaller number) of cities was assessed under the CAO scenarios than under the SPTH scenario			

The intent of CAOs is not to preclude all changes in riparian areas, but rather to shift more development out of riparian areas and into the uplands. This indicator suggests that this shift is happening to a greater extent in urban areas than in rural areas. Said another way, while change in rural areas happens to a lesser extent (both inside and outside of stream buffers), it appears that efforts within the Puget Sound urban communities we examined are relatively more successful at conserving riparian areas than in Puget Sound rural communities. This is not to denigrate rural conservation efforts: the challenge is greater in rural areas because stream buffers comprise a much larger portion of the landscape than in urban areas. (In other words, it's easier to avoid development in urban riparian areas because stream buffers comprise a smaller portion of the total urban landscape.)

Trends by width of riparian buffer: As stream buffers cover more of a geographic region (i.e., the buffers themselves are wider, and/or are more dense) we see more relative acres of riparian change. Figure 17 shows this: when we compare riparian buffers that cover a larger percentage of the watershed, (farther to the right on the graph), we see that the relative amount of riparian change within those areas also increases (higher up on the graph). As explained earlier, riparian density is typically lower in urban areas compared to rural areas (in Figure 17, the points for urban areas are the farthest left). Note that when buffers comprise ~10% of the landscape (rural = CAO min; UGAs = SPTH), the urban rate is nearly three times that of the rural rate (0.6 vs 0.2).

This graph can provide helpful context for communities that are trying to understand how effective their CAO currently is performing relative to the "average" community. For example, say an urban community knows that their stream buffers comprise 7.5% of the jurisdiction. With that percentage of riparian area, the average amount of riparian change for every 10 acres of upland change in an urban setting is 0.4 (Point "A" in Figure 17). If their relative rate of change was 0.6 acres of riparian change for every 10 acres up upland change (Point "B"), they may decide it is reasonable for them to set an initial benchmark for improvement of 0.4 and then determine what steps they need to take to achieve that target.

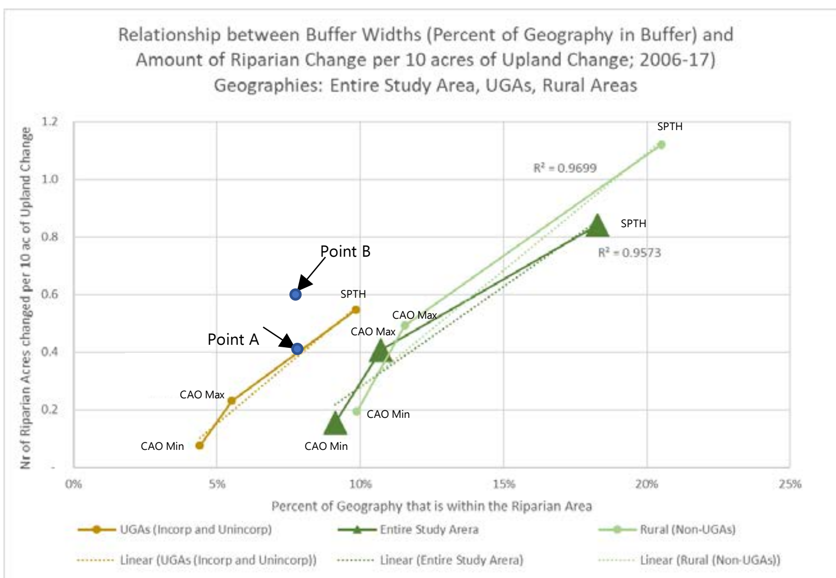


Figure 17: Rates of Relative Change by Buffer Width and Land Use Type. In each series the first (lowest) marker is the CAO Min, then CAO Max, and last is the SPTH scenario.

Geographic trends. Figure 18 provides a spatial representation of this indicator for the CAO min scenario. Again, this map initially surprised us as we expected to see higher rates of change in places with the highest population areas (i.e., I-5 corridor from Tacoma to Everett).

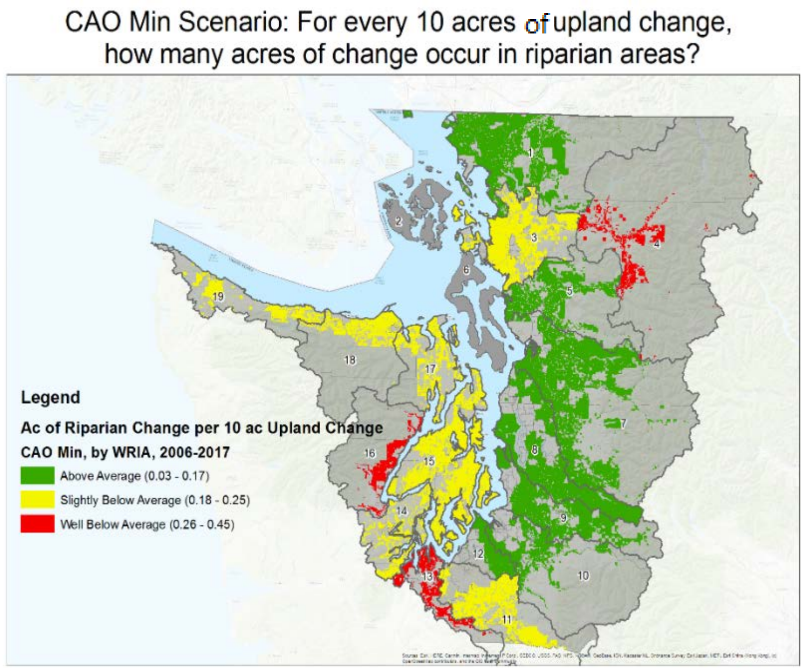


Figure 18: Riparian and Upland Relative Change Rates

Again, we will reiterate that it is important to understand that any single indicator by itself does not paint a full picture of CAO performance. We often need to explore two or more indicators (and/or two or more scenarios) at a time to get a clearer sense of what we are seeing. For example, four WRIAs are green in both Figure 15 and Figure 18 (WRIAs 1, 5, 7, and 8), meaning they have both above-average rates of change within riparian areas ("absolute change") and when comparing riparian to upland change ("relative change"). Priority actions to improve indicators may be different in a place with a low relative rate vs a high relative rate; but such analysis is beyond the scope of this project.

Indicator #5: Power Score: Ratio of Change Outside of Riparian Area to Change Within Riparian Areas

The "power score" is the result of dividing the acres of change outside of riparian area by the acres of change inside of riparian areas. Bigger is better (i.e., a larger number means relatively less development is occurring within riparian areas). Soundwide, the power score is 65 for the CAO min scenario, 25 for the CAO max scenario, and 12 for the SPTH scenario.

This performance indicator is the inverse ratio of performance indicator #4 (without the scaling factor), so the trends identified in the preceding section will also be seen for this indicator. This indicator provides a simple indication of CAO effectiveness. Of course, it is just one number and cannot by itself convey a full understanding of a matter as complex as a CAO. To its credit, this indicator is relatively simple to interpret because it typically ranges from about 5 to the low 100's (sometimes more) and people can easily understand and remember that "bigger is better."

Trends by types of land use. Table 6 shows the power scores for rural and urban areas. As with indicator #4 urban areas fare much better by this measure than rural areas.

Table 6: Power score: Ratio of change outside of riparian areas to change within riparian areas.

Geography	CAO Min	CAO Max	SPTH
Puget Sound	65	25	12
Rural areas	52	20	9
UGAs (Incorporated* and Unincorporated)	135	43	18
*Cities assessed under the CAO scenarios are different than the cities assessed under the SPTH scenario			

Trends by width of riparian buffer: There is a strong trend that as riparian buffers get wider, the CAO power score decreases. This is true at the soundwide scale as well as at finer scales, such as the WRIA scale, as shown in Figure 19. As with previous indicators, we compared riparian width (using the percent of geography within a riparian buffer) with CAO power score. As seen in Figure 19 we see a strong trend for decreasing power scores with increasing buffer widths. This again shows that, as riparian buffers get larger, it appears to be increasingly difficult (uncommon) for a development to be effectively shifted out. Figure 20 shows this relationship another way, using the ratio of the axes in Figure 19. In both graphs we excluded WRIA 12 (Chambers-Clover) as it is anomalous due to the small amount of riparian area and nearly half of the WRIA being outside the study area. WRIAs 2 and 6 are also excluded as they align exactly with county boundaries.

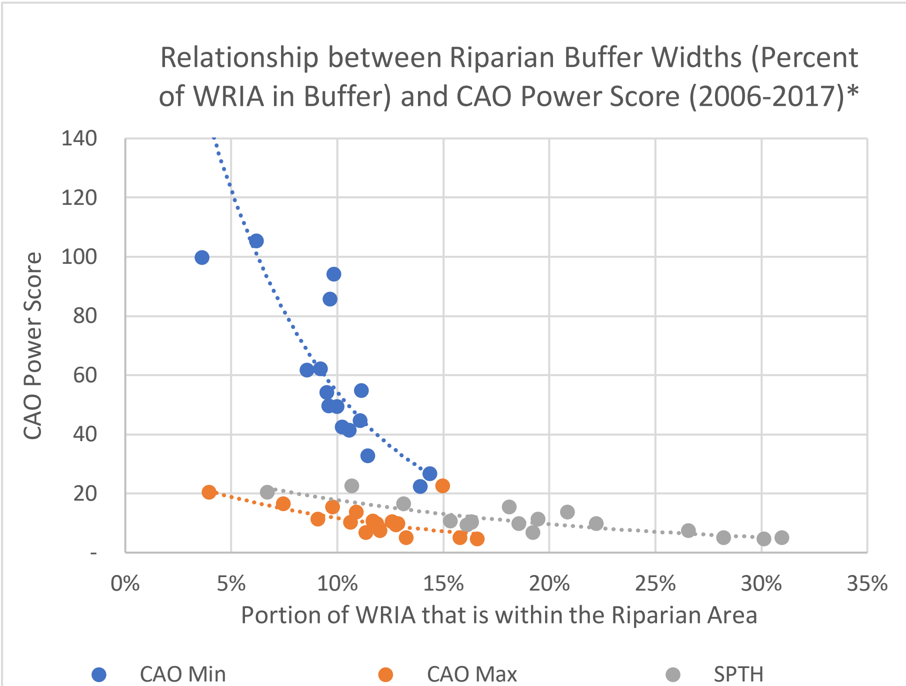


Figure 19: CAO Power Score vs Portion of WRIA that is within a Riparian Buffer. Each dot represents a WRIA; WRIA 12 is excluded from the CAO Min scenario.

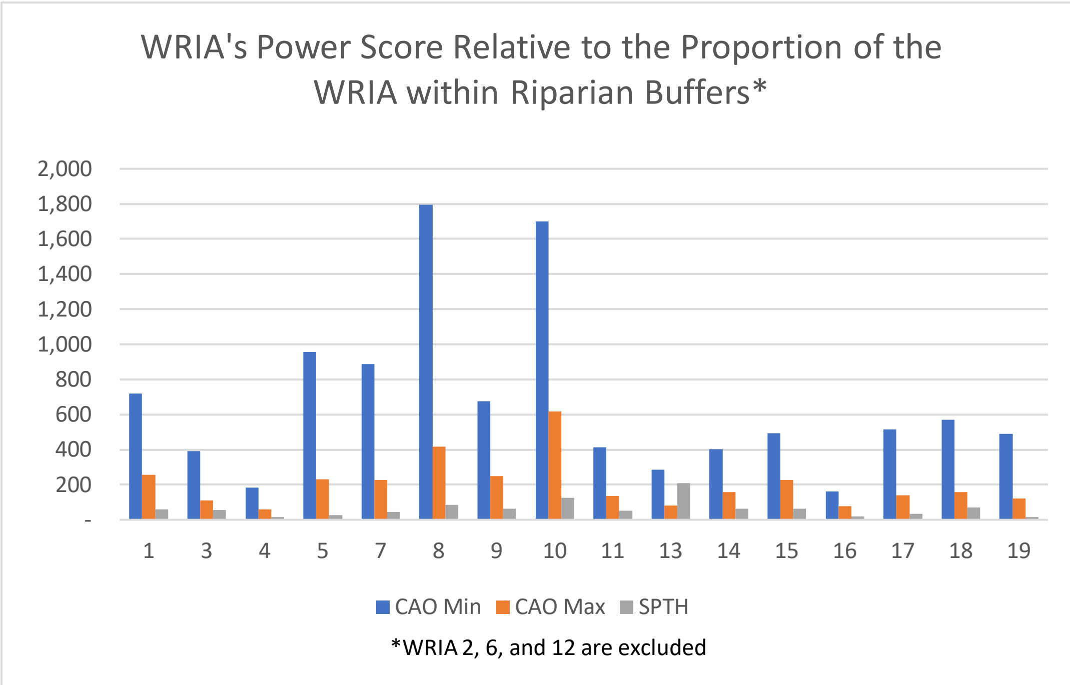


Figure 20: Ratio of CAO Power Score to Portion of WRIA that is within a Riparian Buffer (these are the two axes in the previous graph. WRIAs 2, 6, and 12 are excluded. This shows that the CAO Power Score is larger when considering a narrower buffer (blue bars are larger than orange, which are larger than grey bars).

Geographic trends.

The WRIA-by-WRIA trends for this indicator mirror those of the previous indicator Figure 21 shows a map of WRIAs compared to soundwide averages. As with Figure 18, above average scores are found in the eastern part of the Sound. This indicator, when used in conjunction with a scatter plot of its constituent parts, provides helpful insights about CAO effectiveness. By placing the component part of this indicator on a scatter plot we can show important context that is lost with the singular CAO Power Score. For example, both WRIAs 15 and

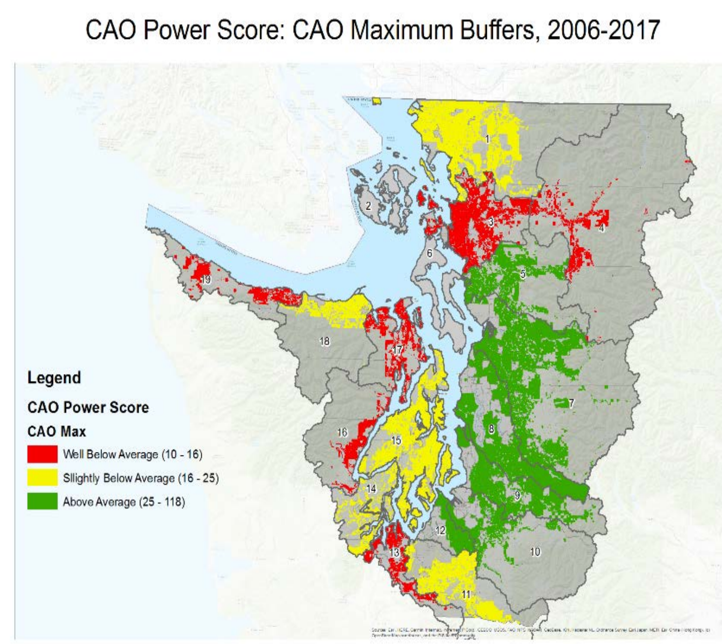


Figure 21: CAO Power Score, CAO Min buffers

17 have a score of 49 in the CAO min scenario, yet a quick glance at Figure 22 (top graph), shows that while the ratio may be the same, the WRIAs are experiencing very different rates of change, and that different approaches may be appropriate when contemplating ways to address CAO performance. For starters, the high rate of change in WRIA 15 riparian areas would likely lead regional entities and state agencies (e.g., WDFW, Commerce) to seek ways to bring state or regional resources to bear to assist in decreasing the rate of change within its riparian areas.

These scatter plots are potentially useful in many ways. The trend line separates those WRIAs on the left that are doing relatively well (above average) from those that are doing relatively less well (below average).

How could this graph be applied? Say a county council decided they wanted to adaptively manage their CAO, they could plot themselves on this graph and see if they

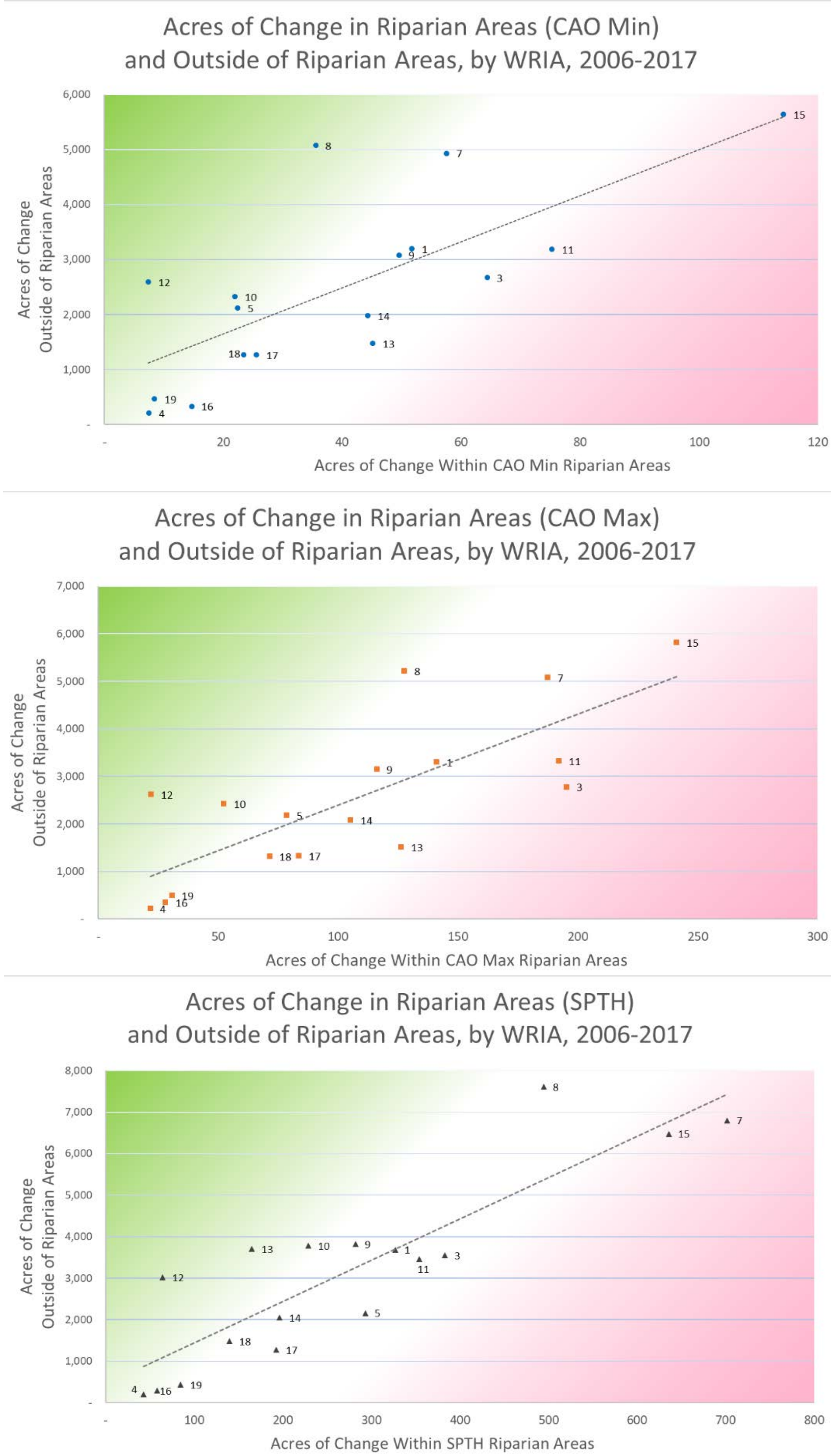


Figure 22: Acres of Riparian Change vs. Upland Change, three scenarios, by WRIA.

are to the left or right of the trend line. If they are to the right, they may decide to establish a benchmark of that puts them at or above the soundwide average by 2025. They assume (reasonably) that their rate of upland change will not appreciably change; therefore, to figure out what specific number they need to achieve to meet their benchmark, they will need to move horizontally to the left on the chart until they hit the trend line. The number on the *x* axis is their target of riparian acres of change.

Potential Sources of Error

To foster transparency and to facilitate future efforts to improve upon our methods, we provide an overview of what we consider to be key potential sources of error. These should be considered when interpreting our own results, as well as the results of any subsequent efforts that use the methodology we have outlined.

We have not established specific error rates for the maps, or the performance indicators discussed in this project. We cannot quantify a confidence level for the results presented in this report. While error rates (omission and commission) have been established for HRCD, we have not assessed error rates for this project's practice of overlaying HRCD with riparian buffers. As a result, we are unable to establish confidence intervals for any of the performance indicators.

Initial Maps

Field-verification of initial maps was not undertaken as part of this project. The key sources of potential error in initial maps:

- Removal of lands based on a forestry jurisdiction assumption where land uses are in fact subject to the GMA (i.e., conversions).
- Removal from the initial map of mis-identified forestry lands and the non-removal of lands that are forestry lands where land use activities were not subject to the GMA during the period of record.
- Removal from the initial map of federal and tribal lands where land uses are in fact subject to the GMA.
- Incorrect locations of UGA and city boundaries.
- Omitting UGA and city boundary changes that occurred during the period of record.

Mapping Stream Buffers

As we stated early on, we know that existing stream maps have numerous errors, and that these errors are currently unquantified. Field-verification of stream buffer maps was not undertaken as part of this project.

The key sources of potential error in CAO-defined stream buffer maps:

- Buffer polygons are based on stream layers for which accuracy assessments have not been completed. The stream layers contain unquantified errors of omission where the mapped stream network fails to map actual streams or streams are mapped in the wrong location. The layers also contain errors of commission where streams are mapped where they do not exist.

- Blue line inaccuracies are a significant issue that WDFW is exploring ways to identify, quantify, and rectify. See NTA 2018-0436.

- This analysis represents an oversimplification of riparian areas as defined by CAOs
  - CAOs frequently include criteria other than stream type that must be considered when determining stream buffer distances. Our min/max approach (which only reflects changes by water type) reduces, but does not eliminate, this error.
  - We did not consider nor map CAO-allowed buffer reductions (e.g., buffer averaging, Reasonable Use Exceptions, and variances).
- This analysis used riparian buffers in a way that is different they how they are applied by local governments.
  - We used jurisdiction-wide maps from a "top-down" perspective to map stream buffers across the jurisdiction; this is contrary to how jurisdictions implement CAOs, which is from the "bottom up"; i.e., determining and applying buffers based on site visits and site-scale information.
- Buffer polygons may be too narrow. Stream buffer polygons are typically based on stream center lines, whereas the regulatory buffer typically starts at bankfull width. This will result in erroneously narrow buffers and errors of omission. See Figure 23.

The key sources of potential error in SPTH-defined stream buffer maps:

- The previous two errors discussed above (hydrography errors and measuring from the stream's centerline) apply to SPTH-buffers as well. However, the error caused by measuring the buffer from the centerline is partially reduced because SPTH buffers were more often based on stream polygons (rather than stream centerlines) than were the CAO-defined stream buffers.
- Errors related to the NRCS soil polygons could cause us to show $SPTH_{200}$ buffers that are wider or narrower than the actual width of the riparian ecosystem. Potential sources of errors include misidentification of the soil type present, the boundaries of those soil types, the productivity of those soils, and the studies from which the 200-year SPTH is determined.

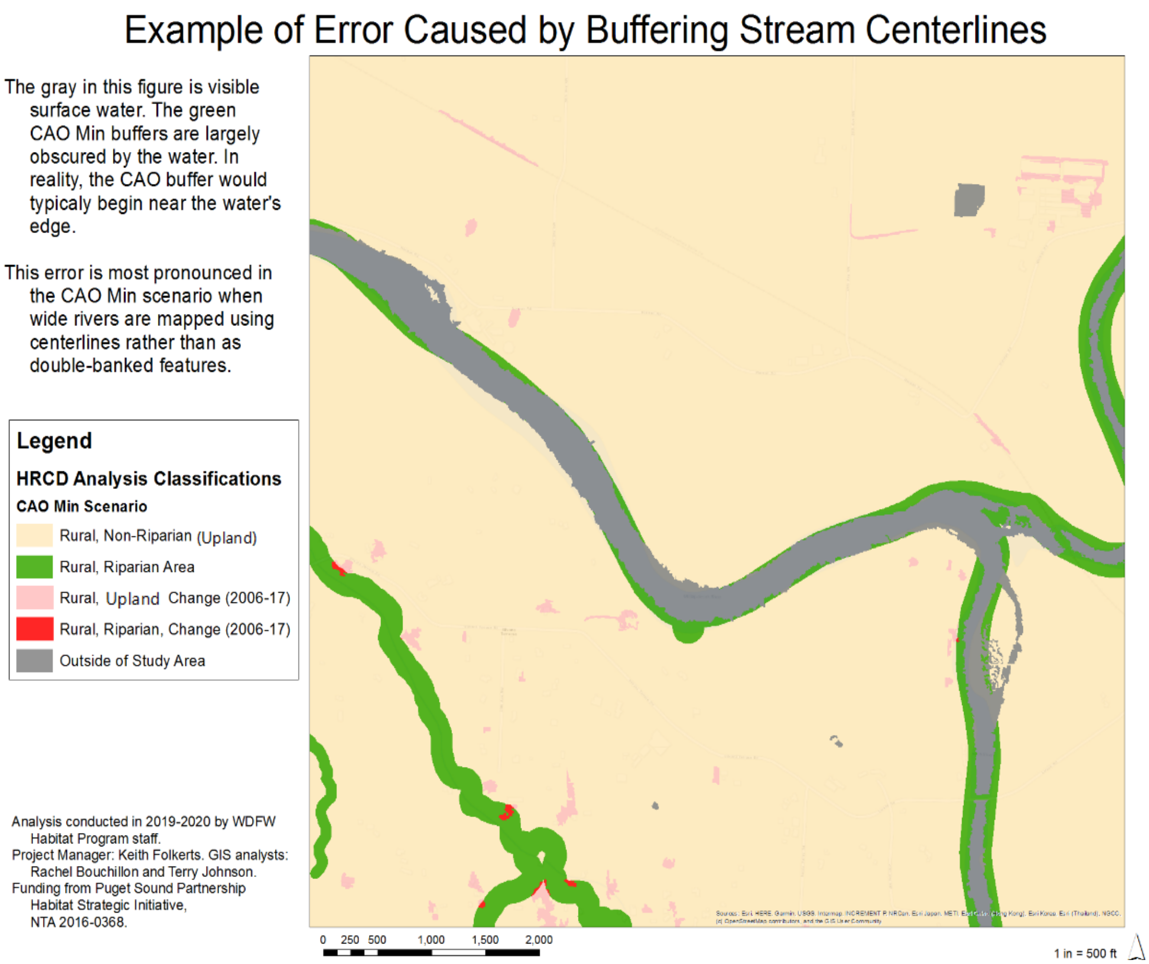


Figure 23: Example of error caused by buffers centerlines rather than width of river.

Performance Indicators

Despite steps to validate the accuracy of calculations, errors may have occurred in the process of calculating the performance indicators. Key potential sources of error include:

- It is possible that the change acreages identified by HRCD were inaccurately associated with study area polygons and tabulated. Errors could have been made when overlaying HRCD with the study area, eliminating polygons outside of the study area, subdividing the study area (by riparian/non-riparian areas, UGAs/city boundaries, and WRIAs), or summing acreages by various attributes (e.g., total change within CAO Min buffers in rural areas).
- Errors could have been made when overlaying the study area's stream buffers with the high resolution tree canopy datasets.

Lessons Learned: Riparian Mapping and CAO Performance Indicators

A hallmark of learning institutions is that they identify and communicate lessons learned from undertakings. In this section we summarize our lessons learned.

Lesson #1: Current hydrology datasets are inadequate.

The hydrology datasets at the federal, state, and local levels lack accuracy and alignment. As discussed, errors are unquantified and all too common in the federal NHD and state DNR Hydro. Most local governments rely on DNR Hydro for their authoritative GMA hydrology layer even though that layer was designed (and is maintained) primarily to inform forestry decisions and is not consistent with best available science for riparian management under GMA. We found instances of local governments relying on "snapshots" of DNR Hydro (likely from when their CAO was last updated) – meaning these local governments are not benefitting from regular updates to DNR Hydro. We lack standardization across jurisdictions; this is true for blue lines, the criteria for determining buffer widths, and the widths themselves These challenges have many sources:

- DNR Hydro was the only hydrology layer available when CAOs were initially crafted, so it became the default option.
- Local governments have not been provided funding to incorporate the latest technologies such as online maps; nor have they been provided funding or technical support to switch from DNR Hydro to NHD.
- DNR has not been funded to migrate DNR Hydro to be NHD-based.
- WDFW has not been funded to develop and disseminate a regionwide stream typing system for GMA purposes that aligns with the latest science.

We point out these challenges not to criticize federal, state, or local government agencies, but simply to point out that currently, hydrology layers are problematic.

This situation can result in development occurring with undersized buffers if streams are missing or fish-bearing waters are misidentified. It also results in challenges to efforts to look regionwide at stream or riparian issues and prioritize restoration or conservation efforts.

Lesson #2: Initial mapping of riparian areas soundwide *using standard data* was straightforward and should also be easy to update in the future.

Our efforts to create a soundwide map of SPTH-derived riparian areas used soundwide data (NHD hydro and NRCS soil polygons) to produce soundwide results. This was a relatively simple process. As better data becomes available (through periodic updates or new sources), it would be relatively simple to update our map of SPTH-derived riparian areas.

Lesson #3: Mapping CAO riparian areas soundwide *using local data and local standards* is prohibitively difficult and expensive

In this NTA, WDFW attempted to develop and maintain a data system for incorporating spatial and tabular data from local governments. This effort was unsuccessful, in large part due to the heterogeneity of data and the absence of data standards.

More specifically, our efforts to create a soundwide map of CAO-derived riparian areas using local data (as much as possible) and local standards (e.g., buffers for Type F streams in X County are 150') was a very challenging part of our project. We only attempted this for the 12 Puget Sound counties and just 10 (of more than 100) cities but we quickly realized that this effort is too complex to be sustainable, due to the varying quality and availability of local stream data and the wide variation among individual jurisdictions' CAOs. In addition, these maps fail to reflect site-scale conditions (e.g., bankfull width) or project-specific factors (e.g., major vs minor development) which are often used to determine buffer width. Because even attempts by a single local government to map their own CAO would not be able to overcome some of such challenges, when decisions are based on modeled CAO buffers, users must understand that buffers cannot always be modeled with complete accuracy.

With some standardization of data (e.g., using NHD and SWIFD and to model CAO stream buffers) and simplification of CAO requirements (e.g., using the CAO min buffer where a range of buffers is possible), it would be possible to use GIS modeling techniques to approximate CAO riparian buffers soundwide. However, land use decision makers would need to understand the limitations of such maps.

Lesson #4: HRCD and associated datasets are very useful for developing CAO performance indicators that describe on-the-ground results

The HRCD dataset, high resolution tree canopy dataset, and visible surface water dataset were reliable and indispensable when calculating these performance indicators. They performed extremely well. The HRCD dataset's utility increases with each additional time period because longer-term trends appear (e.g., effects of recently updated CAOs). These datasets allow for a parcel-scale analysis to be applied throughout the entire region, enabling a basin-wide assessment of trends and prioritization.

HRCD can be used to identify trends and anomalies, and to conduct some preliminary investigation into such trends and anomalies. It is also quite capable of identifying places that warrant further investigation through other means (e.g., site visits or looking at project-level details).

Currently, some HRCD data (including associated datasets of visible surface water and high resolution tree canopy) is available only at the WRIA scale, but would be more useful to local governments if we made them available on a county-by-county and soundwide basis. We are currently working to do this, with the intent of having it available by the time we present our HRCD/CAO performance indicators webinar in March 2021.

Lesson #5: CAO performance indicators can be useful at local and regional scales.

The CAO performance indicators we identified appear to be useful for rolling up site-scale occurrences to identify jurisdiction-scale and soundwide trends. We think that local governments will find these indicators helpful for understanding how well their CAOs are performing and in exploring ways to improve them. We think these indicators provide accurate, timely information about salient aspects of CAOs. We also see utility in the performance indicators for state agencies as they prioritize restoration and conservation efforts.

We encourage others to scrutinize our performance indicators to identify ways they could be improved.

Lesson #6: It is possible to apply these indicators to any mapped, CAO-defined critical area in which HRCD-identifiable changes occur.

The only type of critical area we analyzed was riparian areas, which proved to be complex. Given this, we were unable to analyze as part of this project other types of FWHCAs; or wetlands (and wetland buffers), geohazards, or frequently flooded areas. However, we believe the methodology we developed could be applied to any critical area. As long as the initial map subdivides the jurisdiction into “critical areas” and “non-critical areas”, the methods described will provide information about how effectively jurisdictions are avoiding and minimizing change within those other types of critical areas.

That said, the accuracy of the performance indicators depends upon the accuracy of mapped critical areas. We acknowledge it can be difficult to map critical areas. For example. efforts to map wetland buffers are challenging because the factors that determine buffer width are not typically provided in regional databases – instead, they are determined through site-scale field analysis. We also acknowledge that within some critical areas, changes in tree cover or imperviousness are allowed if certain measures (which HRCD cannot see) are taken. For example, within frequently flooded areas, CAOs often only prohibit developments that decrease the flood storage capacity. Nevertheless, even if the mapped critical areas are modeled “best approximations,” we believe these indicators can provide valuable information for local planners.

Part II: Sharing Information Developed via this NTA

Sharing Results with PSP

Throughout the course of this NTA, we have presented ideas to PSP committees and received their feedback. Specifically, we presented:

- To PSP staff and the Implementation Strategy Work Group on August 8, 2018;
- At an ad hoc land use subcommittee of the Ecosystem Coordination Board (ECB) on September 25, 2018;
- At PSP's "Above and Beyond" workshop on October 31, 2018;
- To PSP staff (status update) on April 11, 2019; and
- To the full ECB on May 29, 2019.

We had initially planned to provide PSP with a technical report outlining jurisdiction-by-jurisdiction results. When this approach was changed due to the previously discussed issues related to blue line errors, we shifted many of the elements originally slated for that technical report to this final report. However, we consider this final report to be an administrative report instead of the technical report initially intended, which would have included a higher degree of scientific review.

A presentation regarding this NTA would have been made at the 2020 Salish Sea Ecosystems Conference had it not been cancelled due to the coronavirus pandemic.

WDFW staff are prepared to present the indicators, findings, and lessons learned described in this Final Report to PSP staff and committees.

Sharing Results with Local Governments

1. HRCD/Performance Indicators Webinar

A major thrust of this NTA was to develop a webinar regarding these performance indicators to be held for local government planners as part of a webinar series hosted by the Department of Commerce regarding CAO monitoring and adaptive management. This 11-webinar series is funded largely via a separate PSP NTA (2018-0327) and will be presented to local government planners weekly, on Wednesday mornings, between January 13, 2021 and March 24, 2021. The HRCD/performance indicators webinar will be held 9-11 am, March 17. This webinar will be presented primarily by NTA project manager Keith Folkerts, with assistance from Robin Hale of our Habitat Program Science Division's Landscape Spatial Analytics Section.

Folkerts participated in the planning of the webinar series, taking an active role in the roughly bi-weekly planning meetings that took place through much of 2020.

The draft slide deck for this webinar is provided as part of this Final Report's supporting documents.

2. Tool for Generating Standardized Report of Performance Indicators

As part of this NTA, we have developed an Excel file which local governments can use to prepare a report of CAO performance indicators for their jurisdiction. Local governments need only enter a prescribed set of inputs and the file auto-generates a four-page report providing graphs and tables of the performance indicators described in this document.

The instructions for how to use this file are found in Appendix F and will be discussed during the March 17 webinar.

Part III: Technical Support for LIO Outreach

In the course of this NTA, we also provided GIS technical support for a separate Puget Sound Partnership initiative (NTA 2018-0652) focused on better defining "ecologically important lands" as described in the Land Development and Cover Implementation Strategy (LDC IS). This was largely a standalone project that leveraged WDFW GIS staff skillsets to assist WA DNR Habitat Strategic Initiative (HSI) staff in a high priority outreach project.

What we set out to do

The LDC IS currently has a region-wide map of ecologically valuable lands under high pressure from development; this map is called the "Indicator Land Base." This map was developed from the top down based on regional data, rather than from the bottom up using local data. This outreach element was designed to help regional groups identify and convey their ecologically important areas to the LDC IS.

The primary objective of this outreach project was to improve our understanding of which ecological attributes and functions different Local Integrating Organizations (LIOs) use to identify lands of "high habitat or biodiversity value." We sought to engage the participating LIOs in a collaborative process for refining how these criteria are established, as well as synthesize their ideas and local knowledge to inform the creation of geospatial resources unique to their region.

What we did

Three of the ten existing LIOs initially opted into this study: the Snohomish-Stillaguamish LIO, the Strait Ecosystem Recovery Network (ERN), and the Island LIO. HSI staff sent an online survey to gauge LIO members' views regarding the relative value of different critical areas, perceived development pressures on these areas, and the quantity and quality of available data regarding these areas. One survey question asked participants to mark, on an online map, up to five ecologically important areas in their LIO. HSI staff analyzed the results of these surveys and WDFW GIS staff produced printed and online map products in order to facilitate subsequent discussions regarding critical area data at meetings for each of the three LIOs. Next, HSI staff presented these results to LIO members and led a discussion of their reactions to the survey findings. From these meetings we identified priority spatial data sources for each LIO and what we needed to do next to produce geospatial deliverables tailored to each LIO's needs.

Due in large part to the COVID-19 pandemic, we had to alter our scope of work and deliverables for this effort. Rather than reconvening with LIOs in a series of meetings to create and refine maps of each LIO's lands of high ecological value, we (a) mapped LIO-identified ecologically import "hotspots", (b) determined which readily available regional GIS layers might lend useful insights into each hotspot (e.g., HRCD, PHS, Natural Heritage Program wetlands), and (3) reported relevant attributes from various GIS layers associated with each hotspot. This yielded a list of key, ecologically related attributes (e.g., HRCD-identified changes, presence of Priority Habitats) for each hotspot, and the list provided a basis for understanding why LIOs selected these places as ecological hotspots.

Discussion: Findings, Results, and Lessons Learned

We learned a lot from our survey and the LIO meetings.

First, we heard widespread support for the idea of mapping ecologically important areas. LIOs said it was critically important to both accurately identify ecologically important areas during land use planning and to prioritize their protection. We heard that entire classes of ecologically important areas (e.g., wetlands) often are not mapped accurately, leading to their degradation. Of interest to this broader NTA, we heard that high quality data is also crucial when identifying and applying performance indicators for ecologically important areas. We also heard that the relative importance of critical area types varied between LIOs (e.g., aquifer rechange areas are more important to some LIOs than others). When asked to identify ecologically important areas on a map, we found it interesting that participants overwhelmingly identified river valleys, deltas, and shorelines; often these were within UGAs.

From a substance perspective, we learned that when identifying ecologically important lands it is important to distinguish between *restoration* and *conservation*. Each LIO said that their highest priority areas were different if they were considering restoration or conservation priorities. We learned that it's important to identify and withdraw from consideration currently protected areas (e.g., state wildlife areas) so LIOs can consider where to focus future restoration and conservation efforts. We also heard that maps of ecologically important lands should be as fine-scale as possible (e.g., parcel-based) if they are to inform local land use decisions. Because information is evolving, LIOs said that local maps of ecologically important lands should be dynamic rather than static (i.e., consisting of just a snapshot-in-time.) Ideally, such a map would also integrate data from different levels of government and be easy to update.

Finally, from a process perspective, we learned that it is important to have both executive and technical staff present when having discussions. Executive staff often needed to consult with their technical staff before being able to provide us with certain information; technical staff generally needed to confer with executive staff for project buy-in and approval for any decisions made as a result of these meetings. We noted that discussion topics among executive committee members focused on broader, big-picture land use ideas, while dialogue among technical staff centered on data and the specifics of current efforts to protect high-value lands. Being able to talk to both groups in the same meeting sped up information gathering and resulted in more dynamic discussions.

As a result of our surveys and meetings, we digitized the LIO-identified ecologically important "hotspots" to the best of our ability. See Appendix F.

Based on our discussion – and being limited to readily available regional GIS layers – we determined we could provide useful information about each hotspot from the following data sources including HRCD, PHS, and DNR's Natural Heritage Program. See Table F15. The details of the characteristics of these hotspots are provided in Tables F16-18.

That concluded the work we were asked to do for this LIO outreach technical support task, but the broader LIO outreach effort is continuing beyond the time of this NTA (0368). Readers are referred to that effort for additional details.

Part IV: Recommendations for Future Work

Table 7 identifies ten potential follow-on projects worthy of consideration: Nine of these efforts would be conducted by one or more state agencies; the other would be the responsibility of local governments but with the support and assistance of the state.

In general, these fall into three categories:

1. **Continue producing the data** upon which performance indicators rely (item 1).
2. Take next steps to **advance the use of performance indicators** among local governments (items 2-4 and 9) and by the state (item 10).
3. Take next steps for the state to **improve the mapping of riparian areas** (items 5-7) and **other critical areas** (item 8).

Table 7: Potential follow-on projects

Item	Overview	Priority/ Sequence	Difficulty/ Duration
1. WDFW keeps producing HRCD and associated datasets	WDFW secures reliable funding to continue producing HRCD, visible surface water, and high resolution tree canopy datasets.	Highest/ Continue	Medium On-going
2. WDFW helps local governments calculate performance indicators	WDFW helps local governments calculate this NTA's performance indicators for their jurisdiction.	High/Start now	Low (6 months-1 year)
3. State identifies additional performance metrics	State facilitates process to identify other CAO performance indicators based on #1 and the 2021 Commerce-led CAO adaptive management webinars.	Medium/Do after success with #1	Low (~1-2 years)
4. Local governments adopt benchmarks for performance indicators with state assistance	Locals adopt benchmarks in countywide planning policies and/or comprehensive plans. State provides technical assistance and funding.	Med-High/ Do after success with #1, 2	Medium (~4 years)
5. State develops standardized GMA hydrography layer	State leads effort to create and maintain a statewide, polygon-based GIS layer based on NHD for GMA use.	High/Can start now	High (~2 years to create)
6. WDFW develops standardized GMA stream typing system	WDFW creates and maintains a recommended statewide stream typing system for GMA based on #5.	High/Can start now; Best to do with #4	High (~2 years to create)
7. WDFW develops standardized GMA Riparian Management Zone (RMZ) layer	WDFW creates and maintains GIS layer of recommended RMZs based on standardized GMA hydrography layer and stream typing.	High/Do after #4, 5	High (~2 years to create)
8. State develops standardized GMA layers for other critical areas	State agencies create and maintain GIS layers of recommended GMA critical areas (Ecology: Wetlands, frequently flooded areas, aquifer recharge areas; DNR: Geohazards; WDFW: FWHCAs)	Medium/ Varies; some can start now	High (2-4+ years to create each)
9. Commerce creates land use simulation platform for modeling scenarios	Commerce continues efforts to create a platform that uses standardized, agency-recommended critical areas to model and evaluate land use scenarios.	Med-High/ Iterative process	High (4+ years to create)
10. Commerce assesses efficiency of accommodating growth	Commerce uses data from HRCD, the 2020 Census, and Puget Sound Mapping project to evaluate how much change occurs on a "per new person" basis for different development patterns.	Med/Can do when Census data available	Easy: 2 months

Evaluation of Measures of Success

The NTA contract calls upon WDFW to evaluate the successfulness of this NTA. To do so, below we state each of the original performance standards identified in the contract and provide a brief response (with references to other sections of this final report for amplification).

Performance Standard: **The final report will include analyses of the system created to create maps of riparian areas and other critical areas.**

Response: Our system to create maps of riparian areas as defined by local government CAOs was **partially successful**. We ultimately **succeeded in creating soundwide maps** of stream buffers as described in CAOs of 12 counties and ten cities. We were able to find relevant spatial data (often available online) from several local governments. We were able to retrieve that data from most (but not all) local governments and put it into a local database from which we could map stream buffers. However, this system **ultimately did not achieve its intended purpose** of creating an automated (and easily updatable) system of gathering, synthesizing and displaying local government data and riparian buffers. This was due to a lack of standards and conventions around, and disparate nature of, local government spatial data and CAO requirements. CAOs' complexity and reliance on information not available to us degraded the accuracy of the modeled stream buffers. Also, this process involved many manual steps.

Due to these data and regulatory consistency challenges, we revised the NTA's scope to exclude attempts to incorporate other types of critical areas into this system and map them.

For more information, see "Mapping Stream Buffers as Defined by Jurisdictions' CAOs" on page 16.

Performance Standard: **Included with the final project report will be an updated Project Factsheet**

Response: Completed. See Appendix B.

Performance Standard: **The final report shall include a brief comparison of actual accomplishments to the outputs/outcomes established in the assistance agreement work plan for the term of the contract.**

Response: See Table 8 and the bullets below it.

Table 8 Comparison of Work Plan Items to Actual Accomplishments

Work Plan Item	Actual Accomplishment
GIS map of riparian areas throughout the Puget Sound basin of riparian areas ~~(and other critical areas)~~ compiled from each county and at least the 10 largest cities	**Achieved**. See GIS files. Due to CAO complexities for 16 CAOs we modeled minimum and maximum likely buffers.
A database depicting each jurisdiction's standard stream buffers.	**Partially achieved**. We created a database of each jurisdiction's standard stream buffers, but due to CAOs' complexity and lack of standardization, we were unable to make this a highly-automated process.
GIS map of $SPTH_{200}$ riparian areas throughout the Puget Sound basin	**Achieved**. See GIS files.
A report that estimates the rate of change in critical areas for four time periods between 2006 and 2015.	**Achieved** (for riparian areas but not other critical areas; we included a fifth period, 2015-2017). See Discussion of the Performance Indicators, starting on page 29.

Items dropped from the original work plan:

- Map other critical areas throughout the Puget Sound basin (as funding allows), based on data obtained from local jurisdictions. (As stated above, we did not map other critical areas.)
- Presentation of findings at the 2020 Salish Sea Research Conference (the 2020 conference was scaled down due to the Covid-19 pandemic, and the planned presentation was cancelled.)
- Evaluate and report rates of change within critical areas by jurisdiction (instead, we have done this by land use category [e.g., rural/urban]; by buffer width scenario (CAO min, CAO max, SPTH); by type of change [e.g., impervious addition, tree canopy loss]; and by WRIA).

Performance Standard: **The final report shall include the reasons for slippages if established outputs/outcomes were not met.**

Response:

This contract performance period was extended by one year, primarily to accommodate a delay in finalizing PHS Riparian Volumes 1 and 2. The contract was amended to reflect the changed delivery due dates.

The contract deliverables were amended to eliminate the optional elements of mapping of wetlands, geohazards, and floodplains. These were removed due to what we learned about the complexity of mapping riparian areas using local data, and the additional complexity and uncertainty that would have been the result of adding even more types critical areas (and critical areas for which other state agencies are the primary authorities). However, we believe the methodology we prepared will work for any place where clearing and development is restricted (e.g., wetlands, other critical areas, greenbelts). Future applications of this method (e.g., by local governments) could include such places.

The contract was amended to eliminate a presentation at the Salish Sea Research Conference as the conference was cancelled due to the pandemic. (In its place we created a webinar for a CAO Monitoring and Adaptive Management series to be hosted by Commerce in early 2021.)

Performance Standard: **The final report shall include analysis and information of cost overruns or high unit costs.**

Response: The project stayed within its contractual amount. When the deliverable required more staff time than the contract allowed, WDFW covered expenses with non-NTA funds.

The cost of the HRCD webinar for the Commerce CAO Monitoring and Adaptive Management series had a higher unit cost than PSP originally expected. The high cost was to allow for a year of WDFW participation on the planning committee for the series.

Appendix A

Primary Statewide GIS Data Layers Utilized

Dataset	Description	Author	Source	Metadata
National Hydrology Dataset	Locations of waterbodies	USGS (Ecology is state's Data Steward)	Geospatial Open Data Portal here	here
DNR Stream Types	Forest practices water body types	DNR	Geospatial Open Data Portal	here
NRCS, Soil Survey (SSURGO 2.2)	Site Index: Spatial and Tabular Data for determining site-potential tree heights	NRCS	NRCS' Web Soil Survey here	here
High Resolution Change Detection	Change polygons, 2- or 3-year increments, 2006-2017	WDFW	Geospatial Open Data Portal	here
Municipal/UGA Boundaries	City and Urban Growth Area Boundaries	Ecology	Geospatial Open Data Portal	here
Major Public Lands	Federal and tribal land (areas not subject to GMA)	DNR	Geospatial Open Data Portal	here
Forestry lands	Parcels taxed as Forestland	Ecology/County Assessors	Geospatial Open Data Portal	here
Shoreline Management Act Boundaries	City and County SMP Boundaries for lakes, rivers, and marine waters	Ecology	Geospatial Open Data Portal	lakes, streams, marine waters

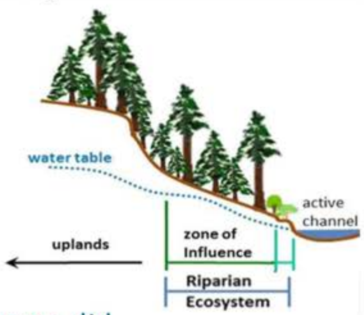
Appendix B

Updated Project Factsheet

PUGET SOUND
National Estuary Program

EVALUATING CAOs: MAPPING RIPARIAN AREAS

In this project, the Washington Department of Fish and Wildlife proposed performance indicators regarding the effectiveness of Critical Area Ordinances (CAOs) in steering habitat disturbances away from riparian (streamside) areas. We did this by mapping riparian areas and identifying ways to track how much clearing and development occurred in these areas since 2006.



What we did

We created maps showing

- Riparian ecosystems (as defined by WDFW)
- Riparian buffers (as defined by 22 local CAOs)
- Land cover changes within those areas

We described five performance indicators and described Soundwide averages and trends for each.

How we're doing it

We used GIS to create two map layers of riparian areas—one based on how tall trees grow and one based on CAOs buffers. We then used our High Resolution Change Detection dataset to determine how much change occurred in each riparian area.

WHY IS THIS ISSUE IMPORTANT

Sustaining and recovering Puget Sound and salmon relies on conserving riparian areas as the region grows. County and city CAOs are a primary tool for this.

WHAT YOU CAN DO

When your local CAO is updated, work with elected officials and planners to create strong protections for riparian areas, including ongoing evaluations of how well the CAO works and ways it could work better. Volunteer with your local Stream Team. Remove invasive species and plant native trees in riparian areas.

ABOUT WA DEPT OF FISH & WILDLIFE

Fish and wildlife are property of the state; WDFW is charged by the Legislature with perpetuating fish and wildlife on behalf of the people of Washington.

WDFW advises local governments on land use matters through the Priority Habitats and Species (PHS) program and 25 Habitat Biologists in the Puget Sound region. PHS recently released a summary of science and management recommendations regarding riparian areas. WDFW scientists created the High Resolution Change Detection dataset to help local planners evaluate habitat changes caused by development.

FOR MORE INFORMATION

https://wdfw.wa.gov/conservation/phs/

Keith Folkerts, WA Dept of Fish & Wildlife
keith.folkerts@dfw.wa.gov, 360-902-2390

Appendix C

Table C9: Jurisdictions' CAO provisions specifying stream protections.

Jurisdiction	Links to code provisions used to identify CAO protections for streams
Counties	
Clallam	CCC 27.12.315(1)(a), Table 6
Island	ICC 17.02B.420(C)
Jefferson	JCC 18.22.630, Table 18.22.630(1)
King	KCC 21A.24.358(B-D)
Kitsap	KCC 19.300.315(A)(1), Table 19.300.315
Mason	MCC 8.52.170, Table 8.52.170(C)
Pierce	PCC 18E.40.060(B), Table 18E.40.060-1
San Juan	SJCC 18.35.130 Table 18.35.130-2
Skagit	SCC 14.24.530(1)(c)
Snohomish	SCC 30.62A.320(1)(a), Table 2a
Thurston	TCC 24.25.020, Table 24.25-1
Whatcom	WCC 16.16.740(B)(3)
Cities	
Auburn	AMC 16.10.090(E)(2)
Bainbridge Island	BIMC 16.20.110(E)(2), Table 1
Bellevue	BMC 20.25H.075(C)(1)(a)
Bellingham	BMC 16.55.500(D)(1), Table 16.55.500(A)
Bremerton	BMC 20.14.730(d), Table 1
Everett	EMC 19.37.170(A)(3), Table 37.5
Kent	KMC 11.06.680(B)
Renton	RMC 4-3-050.G.2.
Seattle	SMC 25.09.012(D)(5); SMC 25.09.200(A)(3)
Tacoma	TMC 13.11.420(B)(1), Table 6

Note: Some buffer distance guidelines for Type S streams are found in the jurisdictions' Shoreline Master Program regulations rather than their CAOs.

Table C10: Summary of stream buffers from jurisdictions' Critical Area Ordinances.

Jurisdiction	Water Type	Buffer Width (ft)	Additional Criteria (if applicable)
Counties			
Clallam	1	150	
Clallam	2	150	Buffer for major new developments
Clallam	2	65	Buffer for minor new developments
Clallam	3	100	Buffer for major new developments
Clallam	3	60	Buffer for minor new developments
Clallam	4	50	
Clallam	5	50	
Island	S	150	
Island	F	100	
Island	Np	75	
Island	Ns	50	
Jefferson	S	150	
Jefferson	F	150	
Jefferson	Np	75	
Jefferson	Ns	75	Grade >= 20%
Jefferson	Ns	50	Grade < 20%
King	S	165	Outside of UGA, or within UGA and designated High on *Basin and Shoreline Conditions Map*
King	S	115	Within UGA, but not designated High on *Basin and Shoreline Conditions Map*
King	F	165	Outside of UGA, or within UGA and designated High on *Basin and Shoreline Conditions Map*
King	F	115	Within UGA, not designated High on *Basin and Shoreline Conditions Map*
King	N	65	
King	O	25	
Kitsap	S	200	
Kitsap	F	150	
Kitsap	Np	50	
Kitsap	Ns	50	
Mason	S	150	
Mason	F	150	
Mason	Np	100	
Mason	Ns	75	
Pierce	S1	100	
Pierce	F	150	Types F1 and F2
Pierce	N1	115	Type Np or Ns stream located within 1/4 mile of confluence with Type F water
Pierce	N2	65	Type Np or Ns stream located more than 1/4 mile upstream from confluence with Type F water, or not connected to Type F water
Pierce	N3	35	Waters that do not support any critical fish species
San Juan	S	110	
San Juan	F	110	

Jurisdiction	Water Type	Buffer Width (ft)	Additional Criteria (if applicable)
San Juan	Np	50	
San Juan	Ns	30	If stream flows < 6 months/year, banks just need to be vegetated
Skagit	S	200	
Skagit	F	150	BFW > 5ft
Skagit	F	100	BFW <= 5ft
Skagit	Np	50	
Skagit	Ns	50	
Snohomish	S	150	
Snohomish	F	150	Anadromous
Snohomish	F	100	Non-anadromous
Snohomish	Np	50	
Snohomish	Ns	50	
Thurston	S	250	
Thurston	F	250	BFW > 20ft
Thurston	F	200	BFW 5ft to 20ft
Thurston	F	150	BFW < 5ft
Thurston	Np	150	Drains to Type S or F stream, or to Puget Sound
Thurston	Np	225	High mass wasting potential
Thurston	Ns	150	Drains to Type S or F stream, or to Puget Sound
Thurston	Ns	225	High mass wasting potential
Thurston	Other	100	
Whatcom	S	150	
Whatcom	F	100	
Whatcom	Np	50	
Whatcom	Ns	50	
Cities			
Auburn	I	100	
Auburn	II	75	
Auburn	III	25	
Auburn	IV	25	
Bainbridge Island	F	200	
Bainbridge Island	Np	100	
Bainbridge Island	Ns	75	Connected to F or Np
Bainbridge Island	Ns	50	Not connected to F or Np
Bellevue	S	100	Undeveloped site
Bellevue	S	50	Developed site
Bellevue	F	100	Undeveloped site
Bellevue	F	50	Developed site
Bellevue	N	50	Undeveloped site
Bellevue	N	25	Developed site
Bellevue	O	25	
Bellingham	F	75	Minimum; some vary by specific stream and stream segment
Bellingham	F	200	Maximum; some vary by specific stream and stream segment
Bellingham	Np	50	Minimum

Jurisdiction	Water Type	Buffer Width (ft)	Additional Criteria (if applicable)
Bellingham	Np	150	Maximum
Bellingham	Ns	50	Minimum
Bellingham	Ns	100	Maximum
Bellingham	Np	200	Minimum - high mass wasting risk
Bellingham	Np	225	Maximum - high mass wasting risk
Bellingham	Ns	200	Minimum - high mass wasting risk
Bellingham	Ns	225	Maximum - high mass wasting risk
Bremerton	S	175	
Bremerton	F	150	
Bremerton	Np	50	
Bremerton	Ns	35	
Everett	S	100	
Everett	F	100	Intact native vegetation
Everett	F	150	Unvegetated, sparsely vegetated, vegetated with invasive species
Everett	Np	50	Intact native vegetation
Everett	Np	75	Unvegetated, sparsely vegetated, vegetated with invasive species
Everett	Ns	50	Intact native vegetation
Everett	Ns	75	Unvegetated, sparsely vegetated, vegetated with invasive species
Kent	1	200	
Kent	2	100	
Kent	3	40	
Renton	S	100	
Renton	F	115	
Renton	Np	75	
Renton	Ns	50	
Seattle	F	100	Riparian management area; development generally prohibited, with some exceptions
Seattle	F	75	Anadromous; lots existing prior to May 2006
Seattle	F	50	Non-anadromous; lots existing prior to May 2006
Seattle	Np	100	Riparian management area; development generally prohibited, with some exceptions
Seattle	Np	50	Lots existing prior to May 2006
Seattle	Ns	100	Riparian management area; development generally prohibited, with some exceptions
Seattle	Ns	50	Lots existing prior to May 2006
Tacoma	S	150	Includes streams of local significance (Puyallup River, Hylebos Creek, Puget Creek, Wapato Creek, and Swan Creek)
Tacoma	F	150	Salmonids
Tacoma	F	100	Non-salmonids
Tacoma	Np	100	
Tacoma	Ns	75	Connected to S, F, or Np
Tacoma	Ns	25	Not connected to S, F, or Np

Table C11: Jurisdictions' authoritative stream dataset and datasets used for this analysis (if different). For a discussion of why different sources were sometimes used, see "Special Cases" on page 19

Jurisdiction	**Authoritative Stream Dataset URL** (at the time of analysis)	**Dataset Used for Analysis** (if different)
Counties		
Clallam	Streams	
Island	Streams – Regulatory	
Jefferson	DNR Streams (Fish Habitat)	
King	Streams	DNR Hydrography
Kitsap	DNR / WFC Hydro	
Mason	DNR Water Courses	
Pierce	Hydro – Centerlines	DNR Hydrography
San Juan	Fish Distribution (Wild Fish Conservancy)	
Skagit*	Hydro-Arcs	DNR Hydrography, NHD
Snohomish	Snohomish County Streams	
Thurston	Thurston Streams	DNR Hydrography
Whatcom	N/A	DNR Hydrography
Cities		
Auburn	Streams	
Bainbridge Island	All_Streams	Streams_Current_Buffer1
Bellevue	Formerly Streams Inside Bellevue, now Stream	DNR Hydrography
Bellingham	Streams	DNR Hydrography
Bremerton	Gisdb_common.DBO.hydrology	DNR Hydrography
Everett	Stream Flowlines	DNR Hydrography
Kent	Hydro_sys3 *(shapefile)*	
Renton	Streams (Classified)	
Seattle	Urban Watercourses	DNR Hydrography
Tacoma	Streams	DNR Hydrography

*Skagit County was in the process of transitioning to using the National Hydrography Dataset (NHD) as their authoritative stream data source at the time of this analysis.

Table C12: Basis for jurisdictions' stream typing system.

Jurisdiction	**Stream Typing System** (at the time of analysis)	Does Authoritative Dataset Contain Stream Type Attributes?
Counties		
Clallam	Old DNR	Yes
Island	Current DNR	Yes
Jefferson	Current DNR	Yes
King	Modified Current DNR (S, F, N, O)	No
Kitsap	Current DNR	Yes
Mason	Current DNR	Yes
Pierce	Modified Current DNR (S1; F1, 2; N1, 2; N3)	No
San Juan	Current DNR	Yes
Skagit	Current DNR	No*
Snohomish	Current DNR	Yes
Thurston	Current DNR	Yes (but Old DNR)
Whatcom	Current DNR	No
Cities		
Auburn	Old DNR	Yes (but Current DNR)
Bainbridge Island	Current DNR	Yes
Bellevue	Modified Current DNR (S, F, N, O)	Yes
Bellingham	Current DNR	No
Bremerton	Current DNR	No
Everett	Current DNR	No
Kent	Modified Old DNR (1, 2, 3)	Yes
Renton	Current DNR	Yes
Seattle	Current DNR	Yes (but Old DNR)
Tacoma	Current DNR	No

"Current DNR" = current WA DNR forest practices water typing system (S, F, Np, Ns)
"Old DNR" = former WA DNR forest practices water typing system (1, 2, 3, 4, 5)

*Skagit County was in the process of transitioning to NHD as their authoritative stream data source.

Appendix D

Table D13: Portion of select areas within riparian geographies as determined by three methods of modeling riparian areas.

Geography	CAO Minimum	CAO Maximum	$SPTH_{200}$
Puget Sound	9.1%	10.7%	18.3%
Unincorporated, Non-UGA (Rural areas)	9.9%	11.6%	20.5%
Unincorporated UGAs	5.0%	6.1%	8.9%
Cities (incorporated)	3.9%	5.0%	10.2%
Counties (unincorporated):			
Clallam	9.9%	12.0%	22.2%
Island	2.9%	3.3%	6.1%
Jefferson	10.5%	12.2%	20.9%
King	11.2%	13.7%	25.4%
Kitsap	10.0%	10.0%	16.5%
Mason	12.4%	13.6%	21.4%
Pierce	7.4%	9.0%	14.9%
San Juan	3.6%	3.9%	6.8%
Skagit	12.2%	14.4%	22.8%
Snohomish	8.3%	10.3%	21.1%
Thurston	12.1%	15.5%	14.7%
Whatcom	8.5%	8.5%	19.8%
Average	**9.5%**	**11.2%**	**19.7%**
Minimum	***2.9%***	***3.3%***	***6.1%***
Maximum	***12.4%***	***15.5%***	***25.4%***
Cities within CAO Study Area			
Auburn	2.7%	2.7%	8.10%
Bainbridge Island	13.3%	13.3%	10.9%
Bellevue	2.5%	4.9%	10.2%
Bellingham	4.2%	11.2%	12.2%
Bremerton	7.6%	8.0%	17.0%
Everett	4.3%	6.3%	11.2%
Kent	5.8%	5.8%	8.89%
Renton	5.2%	5.2%	10.0%
Seattle	0.99%	1.2%	*
Tacoma	0.74%	1.4%	*
Average	**3.9%**	**5.0%**	**10.9%***
Minimum	**0.74%**	**1.2%**	**8.1%***
Maximum	**13.3%**	**13.3%**	**17.0%**

* Results from Seattle and Tacoma are excluded because 98.5% of Tacoma is *outside* of the SPTH Study Area and 100% of Seattle is *outside* of the SPTH Study Area. All others listed cities are have between 85% and 99% of their area *within* the SPTH Study Area.

Geography	CAO Minimum	CAO Maximum	$SPTH_{200}$
WRIAs			
1. Nooksack	8.6%	9.1%	19.5%
2. San Juan	3.6%	3.9%	6.7%
3. Lower Skagit / Samish	10.6%	12.8%	16.1%
4. Upper Skagit	14.4%	16.6%	30.1%
5. Stillaguamish	9.8%	12.0%	26.6%
6. Island	2.9%	3.3%	5.9%
7. Snohomish	9.7%	11.9%	22.2%
8. Cedar-Sammamish	7.9%	9.8%	18.1%
9. Duwamish-Green	9.2%	10.9%	20.9%
10. Puyallup-White	6.2%	7.5%	13.1%
11. Nisqually	10.2%	12.8%	18.6%
12. Chambers-Clover	2.0%	2.4%	3.9%
13. Deschutes	11.4%	15.0%	10.7%
14. Kennedy-Goldsborough	11.1%	12.6%	16.3%
15. Kitsap	10.0%	10.6%	16.3%
16. Skokomish-Dosewallips	13.9%	15.8%	28.2%
17. Quilcene-Snow	9.6%	11.3%	19.2%
18. Elwah-Dungeness	9.5%	11.7%	15.3%
19. Lyre-Hoko	11.1%	13.2%	31.0%
Average	9.1%	10.7%	18.3%
Minimum	**2.0%**	**2.4%**	**3.9%**
Maximum	**14.4%**	**16.6%**	**31.0%**

Appendix E

Instructions for use of Excel file

This document provides instructions for how to use datasets from WDFW (High Resolution Change Detection [HRCD] and tree canopy cover) to report on a standard set of performance indicators regarding the effectiveness of local Critical Area Ordinances (CAOs) for jurisdictions in the Puget Sound basin.

The proposed indicators provide quantitative details regarding:

- the proportion of tree cover within critical areas as of 2017 and the anticipated amount of critical area tree loss in the next decade based on prior trends,
- the quantity and rate of critical area change (total change and canopy cover change), and
- the relative rates of change in critical areas compared to non-critical areas.

Together, these indicators can provide a comparison through time (back to 2006) and across jurisdictions of the relative effectiveness of jurisdictions' critical area protections. We term CAOs that appear to shift development out of critical areas – even when the community is experiencing a high growth rate – as being a highly effective (strong.). Conversely, we term CAOs that allow changes in critical areas during times of low or high community growth as being less effective (permissive.). By considering the community growth rate and the overall amount of tree cover in critical areas, the indicator is placed within context, which can be useful when deciding what actions to take to improve CAOs.

By following the instructions below, users can input data into the accompanying Excel spreadsheet and see how they are used to generate the indicators.

These instructions are written for users of ArcGIS 10.6; users of different versions of ArcGIS may experience slight differences. For questions, contact Keith Folkerts at keith.folkerts@dfw.wa.gov.

Part 1: Prepare Initial Map

In this phase we create a GIS map that shows a best approximation of terrestrial lands where the county or city regulates land use and is responsible for protecting critical areas. See Table 13 for a list of recommended data sources (if better local data is not available).

1. Starting with a polygon of the jurisdiction, *remove* surface water (lakes and large rivers but *not* wetlands—just places that trees can't grow and/or development cannot occur). Also *remove* areas where local land use regulations (GMA/SMA) are not the primary land use laws. These may include areas under the jurisdiction of the federal or tribal governments and designated forestry areas (Assessor code = 88 or 95) where the Forest Practices Act is primary. Counties should remove incorporated areas (and Urban Growth Areas [UGAs] if the Critical Areas within that UGA are regulated by a city).
2. Create a best estimate map layer of wetlands and their buffers. Wetland buffers may need to be estimated as regional data sources do not include buffer widths.
3. Create a best estimate map layer of streams and lakes and their CAO-defined buffers.

4. Create a best estimate map layer of CAO-defined Frequently Flooded Areas.
5. Create a best estimate map layer of CAO-defined Geological Hazard Areas and their setbacks (only include areas where development is essentially precluded without extraordinary measures).
6. Create a best estimate map layer of other CAO-defined Critical Areas (only include areas where development is essentially precluded without extraordinary measures).
7. Merge all the critical areas identified in steps 2-6 into a single layer. Dissolve into a single polygon.
8. Union the polygons from step 1 and step 7.
9. In this unioned polygon's attribute table create a field called "Category"; select and label the critical areas "Critical Areas" and the remainder "Non-Critical Areas".
10. Add a field "BaseMapAcres" and have the GIS populate both the Critical Areas and Non-Critical Areas records with the acreage. Save this file as "City_basemap" (insert the name of your city or county in place of “City”).
11. Open the “HRCD Indicators Spreadsheet”, click on the Input Summary Statistics tab. Fill out Boxes 1 and 2 (HRCD start and end years). Cut and paste the acreages calculated in Step 10 into Boxes 3 and 4.

Table 14: Recommended Sources of GIS data

Data Layer	Step	Recommended Data Sources
UGAs, city boundaries	1	Geo.wa.gov: Ecology UGAs, L&I City Limits.
Non-terrestrial areas	1	WDFW HRCD Hub: WDFW's Visible Surface Water Geo.wa.gov: NHD Waterbody, NHDArea, DNR Hydrography – Water Bodies
Non-GMA areas	1	Geo.wa.gov: Ecology's tribal lands, DNR's Major Public Lands, WSDOT's Tribal Reservation and Trust Lands
Forestry Lands	1	Geo.wa.gov: Commerce's Puget Sound Mapping Project Local Assessor data (standard land use codes 88 and 95)
Wetlands	2	Ecology: Modeled Wetlands Inventory USFS: National Wetlands Inventory Geo.wa.gov: DNR Forest Practices Wetlands, DNR.wa.gov: Wetlands of High Conservation Value
Streams and lakes	3	Geo.wa.gov: NHD Flowline, NHD Waterbody, NHDArea (double-banked rivers, marine water), WDFW's Statewide Washington Integrated Fish Distribution (SWIFD), DNR Hydrography-Watercourses, DNR Hydrography – Water Bodies, WDFW's Visible Surface Water
Frequently Flooded Areas	4	Geo.wa.gov: Ecology Flood Hazard Map
Geological Hazard Areas	5	DNR Portal: DNR Landslide Compilation, DNR NEHRP Site Class and Liquefaction Susceptibility
Other Critical Areas	6	Fish and Wildlife Habitat Conservation Areas: Consult WDFW's PHS on the Web Critical Aquifer Recharge Areas: Consult Ecology information
High Resolution Change Detection	11	Geo.wa.gov: High Resolution Change Detection
Canopy Cover	27	Geo.wa.gov: Search for "Canopy Cover" in search box *(anticipated to be available in late January 2021)*
HRCD Indicators Spreadsheet	16, 22-26, 32	Contact WDFW's Keith Folkerts at keith.folkerts@dfw.wa.gov

Part 2: Intersect Initial Map Polygon with WDFW's High Resolution Tree Canopy Cover Polygons

In this phase we obtain the latest version of WDFW's tree canopy dataset and intersect it with your jurisdiction's initial map.

12. Download and extract the latest (2017) canopy cover file for your city or county.
13. Add the unzipped 2017 tree canopy file (e.g., x_County_2017_TreeCanopy).
14. Use the Clip tool under the Geoprocessing tab to clip the tree polygons to the city. Input Feature = "City_basemap"; Clip Features = x_County_2017_TreeCanopy". Save the output file as "Trees2017_City".
15. Open the Attribute Table for Trees2017_City. Click Add Field, enter "Tree_acres" and Type = Float.
16. Right click on the Tree_acres column and select Calculate Geometry and select Units = Acres (US) [ac].
17. Cut and paste the numbers in the Tree_acres column into the *HRCD Indicators Spreadsheet* Boxes 5 and 6 (Critical Areas and Non-Critical Areas, respectively).

Part 3: Intersect initial map polygon with HRCD

In this phase we obtain the latest version of the HRCD dataset and intersect it with your jurisdiction's initial map.

18. Download and extract the latest HRCD data.
19. Add the HRCD polygons. Use the Select by Feature tool to select the HRCD polygons that intersect the City_basemap.
20. Use the Export Data feature to save the selected HRCD polygons as "HRCD_06_17_City".
21. Open "HRCD_06_17_City" and add five new fields (type = float):
    a. "PortionCriticalArea"
    b. "ChangeAcresCriticalArea"
    c. "CanopyLossAcresCriticalArea"
    d. "PortionNonCriticalArea"
    e. "ChangeAcresNonCriticalArea"
22. Union "City_basemap" with "HRCD_06_17_City"; save the output feature class as "HRCD_Analysis_City"

Part 4: Generate Change Statistics and Indicators

In this phase calculate the amount of change that happened in Critical Areas and non-Critical Areas, enter results into a spreadsheet to generate key performance indicators.

23. Open the "HRCD_Analysis_City" table
24. Calculate the "PortionCriticalArea" field by

   a. Selecting HRCD polygons within Critical Areas (except for those HRCD polygons that are outside the city boundary or that report changes due to stream movement or other natural causes). To do this in the Select by Attribute tool enter "FID_City_basemap = 2 and FID_HRCD_06-17_City <> -1" and CngAgnNm <> 'Stream' and CngAgnNm <> 'Other, Natural'. Click Apply.
   b. In the table select the "PortionCriticalArea" field and open the Field Calculator.
   c. Divide the selected polygons' acreage by the "Acres" by entering "[SHAPE_Area] / 43560 / [Acres]"

25. Calculate the "ChangeAcresCriticalArea" field by
    a. With the same records selected as in the previous step, selecting "ChangeAcresCriticalArea" field and opening the Field Calculator.
    b. Multiply each polygon's percent of change times its original size times the portion that is within Critical Areas. Enter "[PercentC] * [Acres] * [PortionCriticalArea]".
26. Calculate the "CanopyLossAcresCriticalArea" field by
    a. With the same records selected as in the previous two steps, selecting "CanopyLossAcresCriticalArea" field and opening the Field Calculator.
    b. Multiply each polygon's percent of canopy loss times its original size times the portion that is within Critical Areas. Enter "[TreeDec] * [Acres] * [PortionCriticalArea]".
27. Calculate the "PortionNonCriticalArea" field by
    a. Selecting HRCD polygons within NonCritical Areas except for those HRCD polygons that are outside the city boundary or that report changes due to stream movement or other natural causes). To do this in the Select by Attribute tool enter "FID_City_basemap = 1 and FID_HRCD_06-17_City <> -1" and CngAgnNm <> 'Stream' and CngAgnNm <> 'Other, Natural'. Click Apply.
    b. In the table select the "PortionNonCriticalArea" field and open the Field Calculator.
    c. Divide the selected polygons' acreage by the "Acres" by entering "[SHAPE_Area] / 43560 / [Acres] "
28. Calculate the "ChangeAcresNonCriticalArea" field by
    a. With the same records selected as in the previous step, selecting "ChangeAcresNonCriticalArea" field and opening the Field Calculator.
    b. Multiply each polygon's percent of change times its original size times the portion that is within Non-Critical Areas. Enter "[PercentC] * [Acres] * [PortionNonCriticalArea]".

29. Open the WDFW-provided spreadsheet called "HRCD Benchmark Spreadsheet" and click on the Input Summary Statistics tab. Yellow-highlighted boxes will be filled in with info from the HRCD_Analysis_City table.
30. Get info for Boxes 1 and 2: (HRCD start and end years) from StartYr (smallest) and EndYr (largest). Get info for Boxes 3 and 4 (Acres of Critical Areas and Non-Critical Areas) from. BaseMapAcres column.
31. To get info for Box 5 (Acres of Change within Critical Areas by each time period):
    a. From StartYr column select 2006 (in Select by Attributes enter “StartYr = 2006”)
    b. Right click on the Column "ChangeAcresCriticalArea" chose Statistics, copy the Sum and paste it in the spreadsheet.
    c. In the Select by Attributes box, change the start year to 2010, get the Sum statistic for the selected records. Repeat with the Start Yr = 2012, 2014, and 2016.
32. To get info for Box 6 (Acres of Canopy Loss within Critical Areas by each time period) we follow the same process:
    a. From StartYr column select 2006 (in Select by Attributes enter “StartYr = 2006”)
    b. Right click on the Column "CanopyLossAcresCriticalArea" chose Statistics, copy the Sum and paste it in the spreadsheet.
    c. In the Select by Attributes box, change the start year to 2010, get the Sum statistic for the selected records. Repeat with the Start Yr = 2012, 2014, and 2016.
33. To get info for Box 7 (Acres of Change within Non Critical Areas by each time period) we follow the same process:
    a. From StartYr column select 2006 (in Select by Attributes enter “StartYr = 2006”)
    b. Right click on the Column "ChangeAcresNonCriticalArea" chose Statistics, copy the Sum and paste it in the spreadsheet.
    c. In the Select by Attributes box, change the start year to 2010, get the Sum statistic for the selected records. Repeat with the Start Yr = 2012, 2014, and 2016.

Appendix F

Products from LIO Outreach Effort

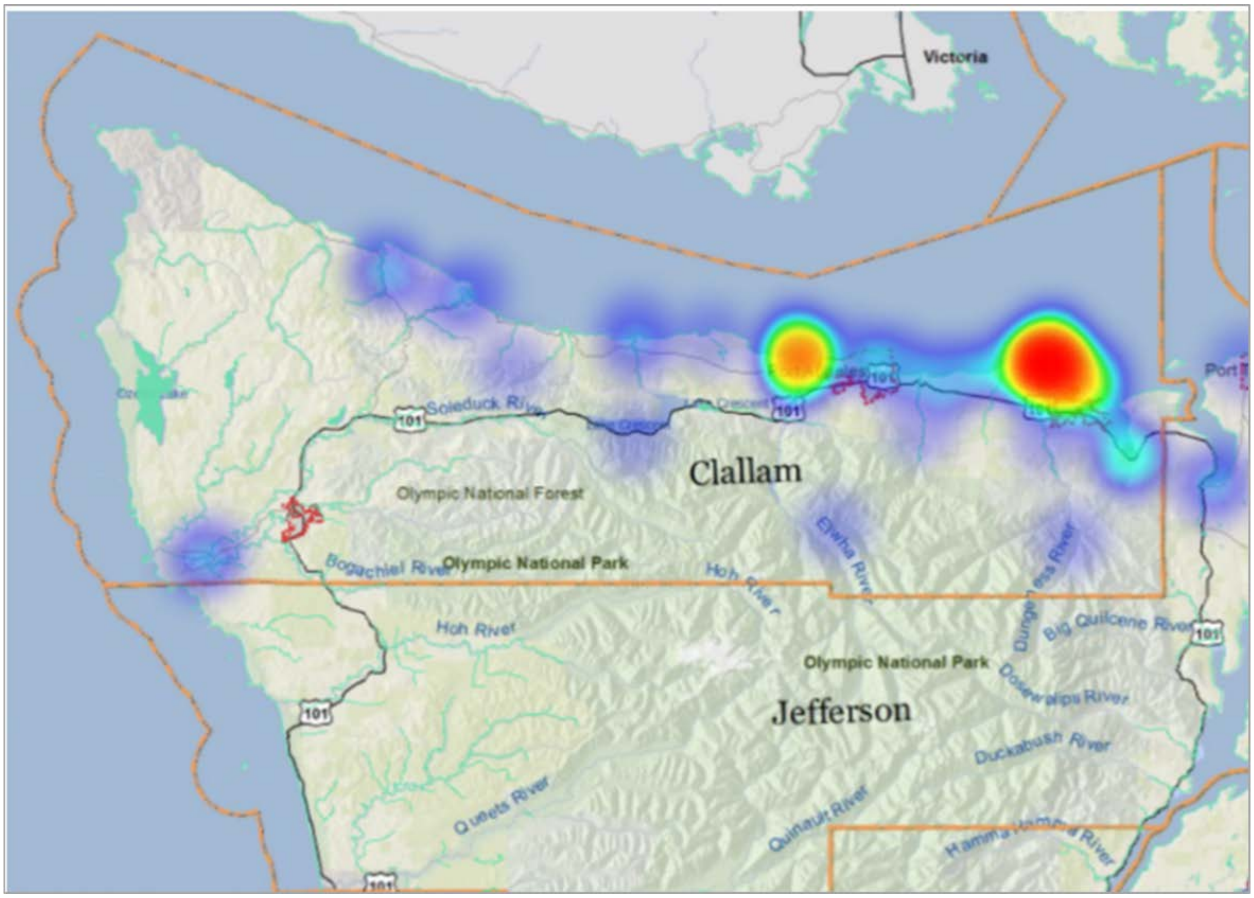


Figure F24: Approximation of areas identified by respondents in the Strait Ecosystem Recovery Network as having high ecological value for protection and/or restoration purposes. The maps identify potential hotspots; the "hotter" the color, the more likely it is to be considered a hotspot.

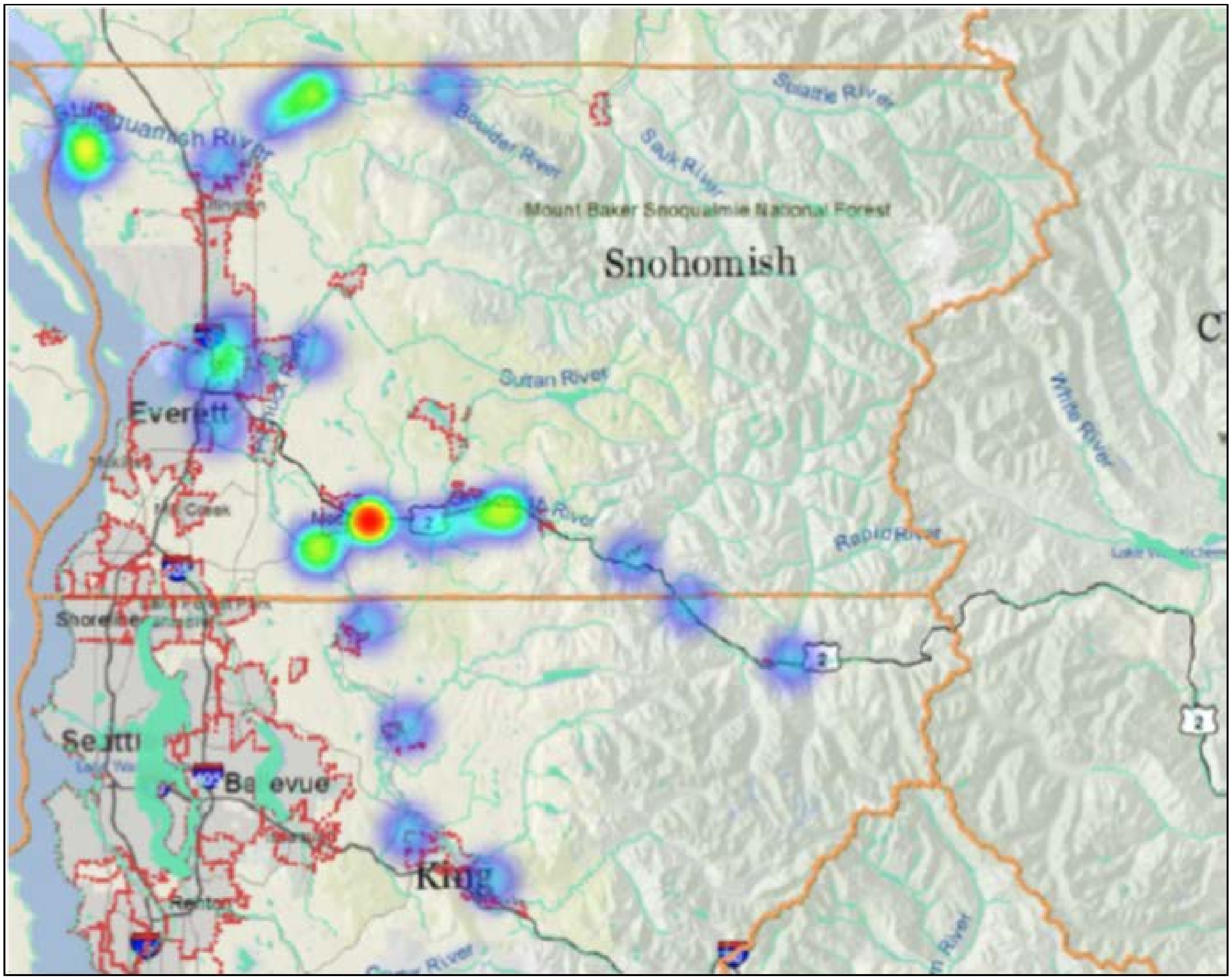


Figure F25: Approximation of areas identified by respondents in the Snohomish/Stillaguamish LIO as having high ecological value for protection and/or restoration purposes.Figure F26: Approximation of areas identified by respondents in the Snohomish/Stillaguamish LIO as having high ecological value for protection and/or restoration purposes. The maps identify potential hotspots; the "hotter" the color, the more likely it is to be considered a hotspot.

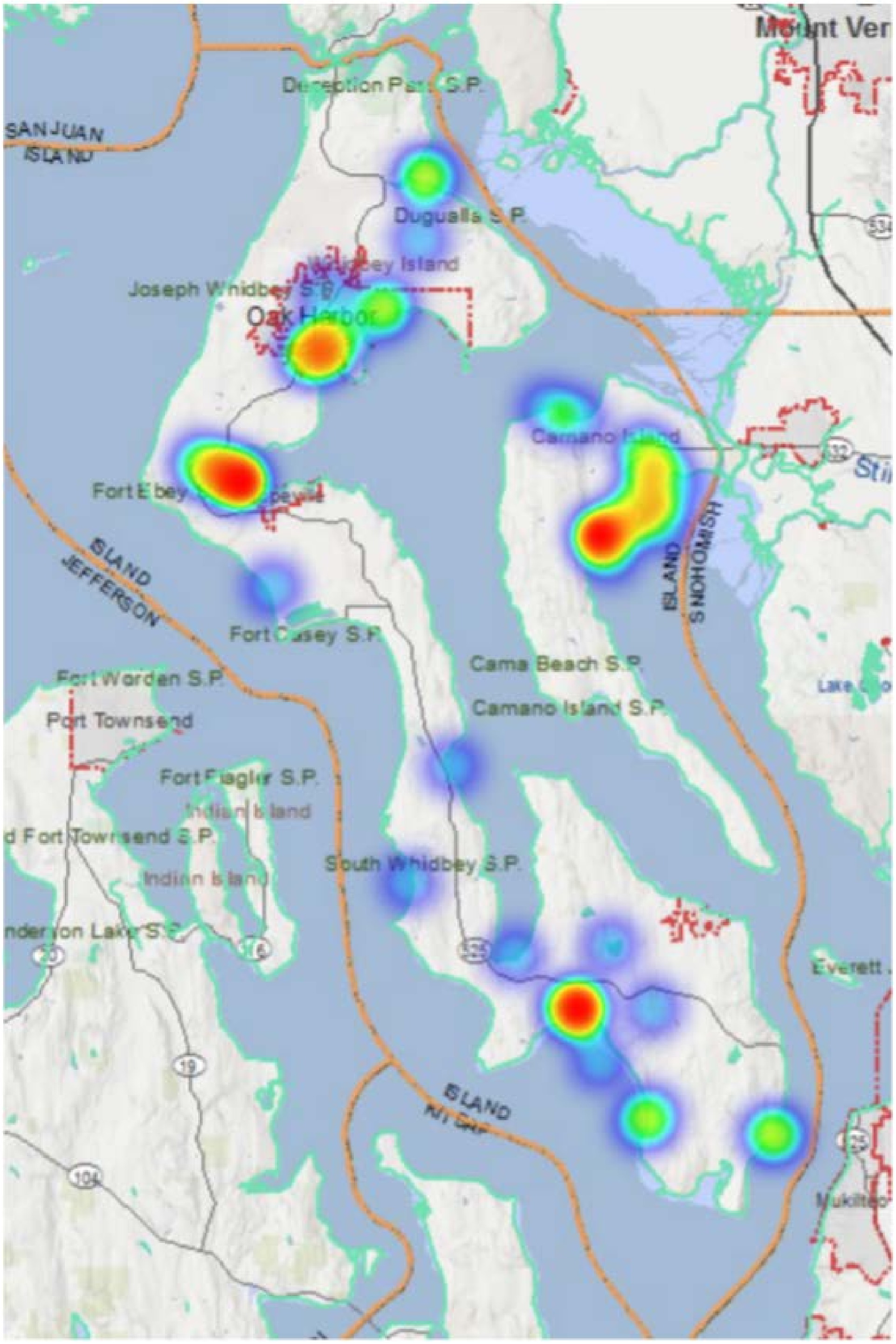


Figure F27: Approximation of areas identified by respondents in the Island LIO as having high ecological value for protection and/or restoration purposes.Figure F28: Approximation of areas identified by respondents in the Island LIO as having high ecological value for protection and/or restoration purposes. The maps identify potential hotspots; the "hotter" the color, the more likely it is to be considered a hotspot.

Table F15: Datasets Used in Characterizing Ecologically Important Hotspots

Source Agency	Dataset Name	Attribute(s) Reported, per Hotspot	Special Considerations/Filters; Comments
Commerce	Generalized Land Use 2012	Total acres by master category	
WDFW	Priority Habitat and Species - Points	List of species observed	Only included observations after 1/1/2015
WDFW	Priority Habitat and Species - Lines	List of fish species/runs	
WDFW	Priority Habitat and Species - Polygons	List of species	Excluded wetlands (Class_Name <> "N/A")
WDFW	High Resolution Change Detection	Total change acres by change agent type	Only included 2015-2017 time period
WDFW	Fish Passage Barriers	Count of total barriers, partial barriers, non-barriers, and barriers with unknown passability	
WDFW	Forage fish survey points	List of forage fish species observed	Only included observations after 1/1/2015
WDFW	State Wildlife Action Plan (SWAP) habitat suitability	List of SWAP species with suitable habitat present	Included any overlap with areas marked "Generally Associated" or "Closely Associated"
WADNR	National Heritage Program rare plant current occurrence	List of rare vascular and non-vascular plant species	
WADNR	Natural Heritage Program Wetlands of High Conservation Value current occurrence	Total acres by wetland type	
WADNR	Oak Grasses 2005	Total acres by grassland type	
Ecology	Puget Sound Watershed Characterization: Water Flow Overall Importance	Count of highest importance level achieved and associated value	Comment: All high and medium Snohomish-Stillaguamish and Strait hotspots had at least one "H - Highest Restoration" analysis unit present, so only count of analysis units reported
Ecology	Biological Condition Based on Biologic Index of Biological Integrity Sampling Results	Count of points by biological condition	Only included event dates after 1/1/2015
NOAA	Endangered Species Critical Habitat: Chinook, Puget Sound	Yes/no presence/absence of critical habitat	Comment: Polygons (marine and nearshore) and lines (riverine)
NOAA	Endangered Species Critical Habitat: Chum, Hood Canal Summer run	Yes/no presence/absence of critical habitat	Comment: Polygons (marine and nearshore) and lines (riverine)
NOAA	Endangered Species Critical Habitat: Steelhead, Puget Sound	Yes/no presence/absence of critical habitat	Comment: Lines only
NOAA	Endangered Species Critical Habitat: Rockfish, Puget Sound	Yes/no presence/absence of critical habitat	Comment: Polygons only

Table F16: Snohomish/Stillaguamish LIO Attributes of Biological Hotspots

Hotspot ID	A	C	F	H	I	J	K
Hotspot response level	Medium	Medium	Medium	Medium	High	Medium	Medium
Hotspot size, acres	5595	7024	16168	4531	5242	2290	11773
Breakdown of land use types by master category, acres	Agricultural Area: 3602.77, Industrial: 142.21, Intensive Urban: 154.28, PROW: 9.72, ROW: 204.78, Rural Character Residential: 95.98, Undesignated: 12.78, Urban Character Residential: 253.66, Water: 1395.08	Agricultural Area: 1372.39, Forest Lands: 2547.28, PROW: 1.82, ROW: 300.02, Rural Character Residential: 3895.80, Undesignated: 0.36, Water: 111.74	Active Open Space and Recreation: 802.52, Agricultural Area: 4641.66, Industrial: 1326.31, Intensive Urban: 1030.79, PROW: 56.19, Public: 25.08, ROW: 1479.51, Rural Character Residential: 529.55, Tribal: 346.88, Undesignated: 107.23, Urban Character Residential: 4064.20, Water: 1757.77	Active Open Space and Recreation, Agricultural Area, Forest Lands, Intensive Urban, PROW, ROW, Rural Character Residential, Undesignated, Water	Active Open Space and Recreation, Agricultural Area, Forest Lands, Industrial, Intensive Urban, PROW, ROW, Rural Character Residential, Undesignated, Urban Character Residential, Water	Agricultural Area, Forest Lands, PROW, ROW, Rural Character Residential, Water	Agricultural Area, Forest Lands, Industrial, Intensive Urban, PROW, Public, ROW, Rural Character Residential, Undesignated, Urban Character Residential, Water
PHS species observations (points)	N/A	Myotis spp	N/A	N/A	N/A	N/A	N/A
PHS listed occurrence fish species/runs (lines)	Bull Trout, Chinook, Chum, Coho, Cutthroat, Dolly Varden/Bull Trout, Fall Chinook, Fall Chum, Pink, Pink Salmon Odd Year, Rainbow Trout, Resident Coastal Cutthroat, Sockeye, Steelhead, Summer Chinook, Summer Steelhead, Winter Steelhead	Bull Trout, Chinook, Chum, Coho, Cutthroat, Dolly Varden/Bull Trout, Fall Chinook, Fall Chum, Pink, Pink Salmon Odd Year, Rainbow Trout, Resident Coastal Cutthroat, Sockeye, Steelhead, Summer Chinook, Summer Steelhead, Winter Steelhead	Bull Trout, Chinook, Chum, Coho, Cutthroat, Dolly Varden/Bull Trout, Fall Chinook, Fall Chum, Pink, Pink Salmon Even Year, Pink Salmon Odd Year, Resident Coastal Cutthroat, Sockeye, Steelhead, Summer Chinook, Summer Steelhead, Winter Steelhead	Bull Trout, Chinook, Chum, Coho, Cutthroat, Dolly Varden/Bull Trout, Fall Chinook, Fall Chum, Pink, Pink Salmon Even Year, Pink Salmon Odd Year, Rainbow Trout, Resident Coastal Cutthroat, Steelhead, Summer Chinook, Summer Steelhead, Winter Steelhead	Bull Trout, Chinook, Chum, Coho, Cutthroat, Dolly Varden/Bull Trout, Fall Chinook, Fall Chum, Pink, Pink Salmon Even Year, Pink Salmon Odd Year, Rainbow Trout, Resident Coastal Cutthroat, Steelhead, Summer Chinook, Summer Steelhead, Winter Steelhead	Bull Trout, Chinook, Chum, Coho, Cutthroat, Dolly Varden/Bull Trout, Fall Chinook, Fall Chum, Pink, Pink Salmon Even Year, Pink Salmon Odd Year, Rainbow Trout, Resident Coastal Cutthroat, Steelhead, Summer Chinook, Summer Steelhead, Winter Steelhead	Bull Trout, Chinook, Chum, Coho, Cutthroat, Dolly Varden/Bull Trout, Fall Chinook, Fall Chum, Pink, Pink Salmon Even Year, Pink Salmon Odd Year, Rainbow Trout, Resident Coastal Cutthroat, Steelhead, Summer Chinook, Summer Steelhead, Winter Steelhead
PHS listed occurrence species (polygons)	Dungeness crab, Great blue heron	N/A	Dungeness crab	Trumpeter swan	N/A	N/A	N/A
HRCD change acres by change agent type for 2015-2017 time period	Development: 3.40, Other/Non-Natural: 1.19, Stream: 0.09, Tree Removal: 0.41	Forestry: 78.98, Stream: 1.87, Tree Removal: 11.65	Development: 64.20, Other/Natural: 1.99, Other/Non-Natural: 58.13, Redevelopment: 3.65, Retention Pond: 2.57, Tree Removal: 28.58	Development: 2.21, Other/Natural: 0.09, Other/Non-Natural: 1.82, Stream: 7.35, Tree Removal: 9.11	Development: 9.70, Other/Natural: 0.13, Other/Non-Natural: 0.60, Redevelopment: 1.49, Stream: 3.16, Tree Removal: 7.74	Development: 0.95, Other/Non-Natural: 0.05, Stream: 1.38, Tree Removal: 4.00	Development: 3.36, Other/Non-Natural: 1.09, Stream: 29.56, Tree Removal: 29.45
Count of fish passage barriers by severity	Non-barrier: 12, partial barrier: 3, total barrier: 2	Non-barrier: 8, partial barrier: 21, total barrier: 7	Non-barrier: 26, partial barrier: 22, total barrier: 28, barrier with unknown passability: 3	Non-barrier: 5, partial barrier: 1, total barrier: 1, barrier with unknown passability: 2	Non-barrier: 6, partial barrier: 3, total barrier: 2	Non-barrier: 6, partial barrier: 5, total barrier: 2, barrier with unknown passability: 1	Non-barrier: 34, partial barrier: 47, total barrier: 22, barrier with unknown passability: 3
Forage fish species observed	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Hotspot ID	A	C	F	H	I	J	K
SWAP species with suitable habitat	Western pond turtle, Marbled murrelet, Townsend's western big-eared bat, Peregrine falcon, Bald eagle, Hoary bat, Silver-haired bat, Western screech owl, Purple martin, Oregon spotted frog, Western bluebird	Western pond turtle, Western toad, Marbled murrelet, Townsend's western big-eared bat, Peregrine falcon, Bald eagle, Hoary bat, Silver-haired bat, American pika, Western screech owl, Oregon spotted frog, Western bluebird	Western pond turtle, Western toad, Marbled murrelet, Yellow-billed cuckoo, Townsend's western big-eared bat, Peregrine falcon, Bald eagle, Hoary bat, Silver-haired bat, American pika, Western screech owl, Purple martin, Oregon spotted frog, Western bluebird	Western pond turtle, Marbled murrelet, Yellow-billed cuckoo, Townsend's western big-eared bat, Peregrine falcon, Bald eagle, Hoary bat, Silver-haired bat, Western screech owl, Purple martin, Oregon spotted frog, Western bluebird	Western pond turtle, Marbled murrelet, Yellow-billed cuckoo, Townsend's western big-eared bat, Peregrine falcon, Bald eagle, Hoary bat, Silver-haired bat, Western screech owl, Purple martin, Oregon spotted frog, Western bluebird	Western pond turtle, Marbled murrelet, Yellow-billed cuckoo, Townsend's western big-eared bat, Peregrine falcon, Bald eagle, Hoary bat, Silver-haired bat, Western screech owl, Oregon spotted frog, Western bluebird	Western pond turtle, Western toad, Marbled murrelet, Yellow-billed cuckoo, Townsend's western big-eared bat, Peregrine falcon, Bald eagle, Hoary bat, Silver-haired bat, American pika, Western screech owl, Oregon spotted frog, Western bluebird
NHP rare plants present	N/A	N/A	Black lily	N/A	N/A	N/A	N/A
NHP wetlands of high conservation value, acres by type	(Chairmaker's Bulrush, Common Threesquare) Tidal Salt Marsh: 1809.31	N/A	Lyngby's Sedge Salt Marsh: 268.93, Tufted Hairgrass - Pacific Silverweed Salt Marsh: 491.65, Sitka Spruce / Red-osier Dogwood / Yellow Skunk-cabbage Swamp Forest: 193.93, (Hardstem Bulrush, Softstem Bulrush) Tidal Marsh: 344.80, Pacific Silverweed - Douglas Aster Salt Marsh: 491.65	N/A	N/A	N/A	N/A
Oak woodlands, acres by type	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PSWC # of AU with High Water Flow Overall Importance Rank, Highest Restoration Value	4	1	2	2	3	2	6
PS BIBI sites, count by biological condition	N/A	Fair: 1	Poor: 1	N/A	N/A	N/A	Excellent: 1
NOAA marine endangered species critical habitat (polygons)	Puget Sound Chinook	N/A	Puget Sound Chinook	N/A	N/A	N/A	N/A
NOAA riverine endangered species critical habitat - (lines)	Puget Sound Chinook, Puget Sound Steelhead	Puget Sound Chinook, Puget Sound Steelhead	Puget Sound Chinook, Puget Sound Steelhead	Puget Sound Chinook, Puget Sound Steelhead	Puget Sound Chinook, Puget Sound Steelhead	Puget Sound Chinook, Puget Sound Steelhead	Puget Sound Chinook, Puget Sound Steelhead

Table F17: Island LIO Attributes of Biological Hotspots

Hotspot ID	A	C	D	E	L	N	O	P	Q	R
Hotspot response level	Medium	Medium	Medium	High	High	Medium	Medium	Medium	Medium	High
Hotspot size, acres	954.9	966.6	2109	2638	1420	1012	1166	1161	2761	1699
PHS species observation pts	Western toad	N/A	N/A	N/A	N/A	Big brown bat, Little brown bat	N/A	N/A	N/A	N/A
PHS listed occurrence fish species/runs (lines)	Coho, Pacific Sand Lance, Resident Coastal Cutthroat	Pacific Sand Lance, Surf Smelt	Pacific Sand Lance, Surf Smelt	Pacific Sand Lance, Surf Smelt	Surf Smelt	Coho, Fall Chum, Resident Coastal Cutthroat	Coho, Fall Chum, Resident Coastal Cutthroat, Surf Smelt	Pacific Sand Lance, Surf Smelt	N/A	Coho, Pacific Sand Lance, Surf Smelt
PHS species occurrence (polygons)	Dungeness crab, Pacific herring	Harlequin duck	Harlequin duck	N/A	Dungeness crab	Dungeness crab, Pacific geoduck	Dungeness crab, Pacific geoduck	Dungeness crab	Gray whale	Dungeness crab, Gray whale, Pacific herring
HRCD change ac by change agent type 2015-2017 time period	Development: 0.60, Other/Natural: 0.03, Retention Pond: 2.98, Tree Removal: 0.47	Development: 0.32, Tree Removal: 0.35	Development: 3.49, Other/Natural: 0.08, Tree Removal: 0.76	Tree Removal: 0.45, Redevelopment: 0.10	Development: 0.23, Tree Removal: 0.36	Development: 0.67, Tree Removal: 1.58	Tree Removal: 5.11	Development: 0.59, Tree Removal: 0.47, Redevelopment: 0.24	Null: 0.28, Development: 0.85, Other/Natural: 0.07, Tree Removal: 3.52	Development: 2.23, Tree Removal: 10.80
Count of fish passage barriers by severity	N/A	N/A	N/A	Non-barrier: 1	Partial barrier: 1	Partial barrier: 5, total barrier: 1	N/A	Non-barrier: 1, partial barrier: 1, total barrier: 6	Partial barrier: 1	Non-barrier: 5, partial barrier: 7, total barrier: 4
Forage fish spp observed	N/A	Surf smelt	Surf smelt	Surf smelt	N/A	N/A	Surf smelt	Surf smelt	N/A	Surf smelt
SWAP species with suitable habitat	Western pond turtle, Western toad, Marbled murrelet, Townsend's western big-eared bat, Peregrine falcon, Bald eagle, Hoary bat, Silver-haired bat, Purple martin, Oregon spotted frog, Western bluebird	Western pond turtle, Western toad, Marbled murrelet, Townsend's western big-eared bat, Peregrine falcon, Bald eagle, Hoary bat, Silver-haired bat, Purple martin, Oregon spotted frog, Western bluebird	Western pond turtle, Western toad, Marbled murrelet, Townsend's western big-eared bat, Peregrine falcon, Bald eagle, Hoary bat, Silver-haired bat, Purple martin, Oregon spotted frog, Western bluebird	Western pond turtle, Western toad, Marbled murrelet, Townsend's western big-eared bat, Peregrine falcon, Bald eagle, Hoary bat, Silver-haired bat, Purple martin, Oregon spotted frog, Western bluebird	Western pond turtle, Western toad, Marbled murrelet, Townsend's western big-eared bat, Peregrine falcon, Bald eagle, Hoary bat, Silver-haired bat, Purple martin, Oregon spotted frog, Western bluebird	Western pond turtle, Western toad, Marbled murrelet, Townsend's western big-eared bat, Peregrine falcon, Bald eagle, Hoary bat, Silver-haired bat, Purple martin, Oregon spotted frog, Western bluebird	Western pond turtle, Western toad, Marbled murrelet, Townsend's western big-eared bat, Peregrine falcon, Bald eagle, Hoary bat, Silver-haired bat, Purple martin, Oregon spotted frog, Western bluebird	Western pond turtle, Western toad, Marbled murrelet, Townsend's western big-eared bat, Peregrine falcon, Bald eagle, Hoary bat, Silver-haired bat, Purple martin, Oregon spotted frog, Western bluebird	Western pond turtle, Western toad, Marbled murrelet, Townsend's western big-eared bat, Peregrine falcon, Bald eagle, Hoary bat, Silver-haired bat, Purple martin, Oregon spotted frog, Western bluebird	Western pond turtle, Western toad, Marbled murrelet, Townsend's western big-eared bat, Peregrine falcon, Bald eagle, Hoary bat, Silver-haired bat, Purple martin, Oregon spotted frog, Western bluebird
NHP rare plants present	N/A	N/A	N/A	White-top aster	N/A	N/A	N/A	N/A	N/A	Black lily

Hotspot ID	A	C	D	E	L	N	O	P	Q	R
NHP wetlands of high conservation value, acres by type	N/A	N/A	Oregon White Oak / Common Snowberry / Long-stolon Sedge: 74.47	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Oak woodlands, acres by type	N/A	N/A	Urban Oak Canopy: 17.87, Oak-Dominant Forest or Woodland Canopy: 8.81	Shrubland Potentially Restorable to Grassland: 29.15, Unsurveyed Grassland: 12.31	N/A	N/A	N/A	N/A	N/A	N/A
PSWC highest Water Flow Overall Importance Rank achieved & associated value, count of relevant analysis units	H - Highest Restoration: 1	MH - Restoration: 1	MH - Restoration: 2	MH - Restoration: 2	H - Highest Restoration: 2	H - Highest Restoration: 1	H - Highest Restoration: 1	H - Highest Restoration: 2	H - Highest Restoration: 3	H - Highest Restoration: 2
PS BIBI sites, count by biological condition	N/A	N/A	N/A	N/A	N/A	N/A	Poor: 1	N/A	N/A	N/A
NOAA marine endangered species critical habitat (polygons)	Puget Sound Chinook	Puget Sound Chinook	Puget Sound Chinook	Puget Sound Chinook	Puget Sound Chinook, Puget Sound Rockfish	Puget Sound Chinook	Puget Sound Chinook, Puget Sound Rockfish	Puget Sound Chinook	Puget Sound Chinook	Puget Sound Chinook
NOAA riverine endangered species critical habitat - (lines)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table F18: Strait Ecosystem Recovery Network Attributes of Biological Hotspots

Hotspot ID	G	H	M
Hotspot response level	High	High	Medium
Hotspot size, acres	16892	43201	6000
PHS species observations (points)	Yuma myotis	N/A	N/A
PHS listed occurrence fish species/runs (lines)	Bull Trout, Chinook, Chum, Coho, Cutthroat, Dolly Varden/Bull Trout, Fall Chinook, Fall Chum, Kokanee, Pink, Pink Salmon Odd Year, Rainbow Trout, Resident Coastal Cutthroat, Sockeye, Spring Chinook, Steelhead, Summer Steelhead, Surf Smelt, Winter Steelhead	Bull Trout, Chinook, Chum, Coho, Cutthroat, Dolly Varden/Bull Trout, Fall Chinook, Fall Chum, Pacific Sand Lance, Pink, Pink Salmon Odd Year, Resident Coastal Cutthroat, Sockeye, Spring Chinook, Steelhead, Summer Chum, Summer Steelhead, Surf Smelt, Winter Steelhead	Chum, Coho, Cutthroat, Fall Chum, Pacific Sand Lance, Resident Coastal Cutthroat, Steelhead, Summer Chum, Winter Steelhead
PHS listed occurrence species (polygons)	Dungeness crab, Great blue heron, Harlequin duck, Marbled murrelet, Northern spotted owl, Pacific geoduck, Pinto abalone, Red sea urchin, Taylor's checkerspot	Dungeness crab, Great blue heron, Harlequin duck, Marbled murrelet, Northern spotted owl, Pacific geoduck, Pacific herring, Red sea urchin, Roosevelt elk, Taylor's checkerspot, Trumpeter swan, Wood duck	Marbled murrelet, Northern spotted owl, Pacific geoduck, Pacific herring
HRCD change acres by change agent type for 2015-2017 time period	Development: 14.80, Forestry: 0.05, Other/Natural: 4.09, Other/Non-Natural: 4.66, Redevelopment: 1.66, Retention Pond: 0.77, Stream: 5.12, Tree Removal: 61.83	Development: 124.85, Forestry: 78.76, Other/Natural: 1.17, Other/Non-Natural: 0.91, Redevelopment: 0.21, Stream: 24.29, Tree Removal: 76.50	Development: 0.71, Forestry: 21.30, Tree Removal: 43.22
Count of fish passage barriers by severity	Non-barrier: 21, partial barrier: 17, total barrier: 26	Non-barrier: 78, partial barrier: 230, total barrier: 72, barrier with unknown passability: 5	Non-barrier: 6, partial barrier: 26, total barrier: 43
Forage fish species observed	N/A	Surf smelt	N/A
SWAP species with suitable habitat	Western pond turtle, Western toad, Marbled murrelet, Townsend's western big-eared bat, Copes giant salamander, Peregrine falcon, Bald eagle, Hoary bat, Silver-haired bat, Olympic marmot, Western screech owl, Purple martin, Oregon spotted frog, Olympic torrent salamander, Western bluebird	Western pond turtle, Western toad, Marbled murrelet, Townsend's western big-eared bat, Peregrine falcon, Bald eagle, Hoary bat, Silver-haired bat, Olympic marmot, Western screech owl, Oregon vesper sparrow, Purple martin, Oregon spotted frog, Olympic torrent salamander, Western bluebird	Western pond turtle, Western toad, Marbled murrelet, Townsend's western big-eared bat, Peregrine falcon, Bald eagle, Hoary bat, Silver-haired bat, Western screech owl, Purple martin, Oregon spotted frog, Western bluebird
NHP rare plants present	Branching montia, Yerba de selva	Powdery twig lichen	Niebla lichen
NHP wetlands of high conservation value, acres by type	Douglas-fir / Common Snowberry - Ocean Spray: 64.99, North Pacific Herbaceous Bald and Bluff: 154.61, Roemer's Fescue - Field Chickweed - Prairie Junegrass Grassland: 91.27	Saltgrass - (Pickleweed) Salt Marsh: 263.72, American Dunegrass - Japanese Beachpea: 357.67, (Dwarf Saltwort, Virginia Glasswort) Tidal Salt Marsh: 394.99, Bighead Sedge: 357.67, Oregon White Oak - Douglas-fir Forest: 38.13, Douglas-fir / Common Snowberry - Ocean Spray: 141.84, Cusick's Sedge - (Marsh Cinquefoil) Fen: 81.60, Red Fescue - Silver Burweed: 357.67, Douglas-fir - Grand Fir / Common Snowberry / Alaska Oniongrass: 372.00	Douglas-fir - Western Hemlock / Cascade Barberry - Western Swordfern Forest: 280.66
Oak woodlands, acres by type	N/A	Exotic (Non-Native) Grassland: 16.57, Scattered Oak Canopy: 13.35, Oak-Dominant Forest or Woodland Canopy: 12.83, Oak-Conifer Forest or Woodland Canopy: 4.55, Urban Oak Canopy: 1.94	N/A
PS watershed characterization, # of analysis units with High Water Flow Overall Importance Rank and Highest Restoration Value	5	5	3
PS BIBI sites, count by biological condition	N/A	Poor: 1, Very poor: 1	N/A
NOAA endangered marine spp critical habitat (polygons)	Puget Sound Chinook	Hood Canal Summer Chum, Puget Sound Chinook, Puget Sound Rockfish	Hood Canal Summer Chum, Puget Sound Chinook, Puget Sound Rockfish
NOAA riverine endangered spp critical habitat - (lines)	Puget Sound Chinook, Puget Sound Steelhead	Hood Canal Summer Chum, Puget Sound Chinook, Puget Sound Steelhead	Hood Canal Summer Chum, Puget Sound Steelhead