January 2024

Critical Area Regulations
Monitoring Report

Snohomish County Conservation & Natural Resources | Surface Water Management

Snohomish County Planning and Development Services

Acknowledgements

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Executive Summary

Snohomish County is home to diverse natural systems that provide significant human and ecological benefits. WA State's Growth Management Act (GMA) mandates that the County creates development regulations that protect key natural resources identified as **critical areas**. The GMA also articulates a stringent 'no net loss' principle, ensuring the preservation of the **benefits of critical areas, called "functions and values."**

Functions and Values of Critical Areas

HABITAT for native birds, invertebrates, mammals, amphibians, and fish.

HYDROLOGY, including water movement and habitat formation.

WATER QUALITY processes that support healthy waters and vegetation.

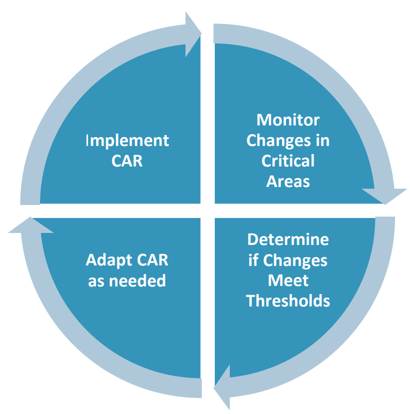
In 2006, Snohomish County revised a series of **Critical Area Regulations (CAR)** found in Snohomish County Code SCC30.62A-C & 30.65. The County's Planning and Development Services (PDS) department began implementing and enforcing CAR in 2007. In 2008, the County's Surface Water Management (SWM) division was charged with monitoring the efficacy of the new regulations as they relate to two critical areas regulated in SCC 30.62A:

- **Wetlands and their buffers** (areas surrounding the wetlands)
- **Fish and Wildlife Habitat Conservation Areas (FWHCAs) and their buffers** (streams, lakes, and marine shorelines)

SWM's monitoring program includes a baseline CAR assessment published in 2012. This 2024 report is the first update which evaluates changes in critical areas and their associated functions and values.

CAR Program Goals

The purpose of CAR monitoring is to determine if the program is meeting its intended **goals** and adapt, if necessary (see adjacent figure). The goal of this project is to respond to the Snohomish County Code 30.62A.730 requirement to report to the Council data and conclusions regarding "the effectiveness of the County in achieving no net loss of critical area functions and values". To do that, the following questions were evaluated:



- ***How have critical area buffer and shoreline conditions changed?***
- ***Have there been impacts to critical areas where CAR protections have been established by permit?***
- ***Has the County achieved a "no net loss" of critical area functions and values?***

Land cover and other changes to critical areas between 2009 and 2021 were evaluated and then compared against predetermined **Adaptive Management Thresholds**, representing levels at which functions and values might be affected. The Adaptive Management Thresholds were based on thresholds developed for the 2008 CAR Monitoring and Adaptive Management Plan, with revisions to align with current methodologies. Each threshold is accompanied by prescribed **actions** intended to prevent further impacts:

Threshold 1 Actions – Public outreach and/or enforcement and mitigation actions.

Threshold 2 Actions – Additional public outreach, enforcement, and mitigation actions; programmatic adjustments.

Threshold 3 Actions – Programmatic adjustments including code revisions.

Goal 1: How have critical area buffer and shoreline conditions changed?

Approaches to examine changes in critical area included:

1) **Countywide Land Cover Changes** – The best available scientific methods, incorporating state-of-the-art aerial imaging and AI technology, were used to examine land cover changes. Changes from 2009 and 2021 were analyzed across the entire County.
2) **Critical Area Land Cover Changes** – The same land cover methodology described above was applied, but changes were specifically evaluated in wetlands and their buffers and the buffers of FWHCAs (i.e., stream, lake, and marine shoreline buffers).
3) **River, Marine, and Lake Shoreline Condition Changes** –Changes to river, marine, and lake shorelines were evaluated using data from field surveys that primarily focused on bank armoring (bulkheads etc.). Other factors relevant to understanding the status of functions and values of shorelines were also evaluated.

Countywide Land Cover Changes

Evaluating land cover changes within and outside of critical areas, referred to as landscape or subbasin scale changes, provides insight into conditions that can impact functions and values. Changes were assessed at both the Countywide[1] and on the smaller subbasin scale (Figure 1.2). Subbasins are areas where water flows to a common stream or river. There are 58 subbasins in the study area. Changes in three key metrics were used to understand the impact of landscape changes on critical areas and functions and values:

Impervious Surface Cover – when hard surfaces such as roads or buildings increase, less water can infiltrate into the ground which can increase rapid runoff, erosion, and flooding. Critical areas such as wetlands help slow runoff and absorb and clean pollution before it reaches waterways. Landscape changes in impervious surfaces included:

- Impervious surface increased by 7,791 acres; increases were seen in all 58 subbasins.
- Highest impervious surface gains were in the southwest County, in the urban growth areas. This is expected and consistent with GMA provisions of where development should occur. North Creek and Swamp Creek subbasins accounted for 701 acres (9%) of the impervious surface increase.
- For all rural subbasins, the percent impervious increase was <3%.

Forest Cover – Snohomish County is naturally forested. Trees play an important role in slowing, capturing, and allowing rainfall to infiltrate in the ground, shading water, and providing habitat. Forest cover changes can occur from development, timber harvesting, and naturally from landslides or river channel migration. Landscape changes in forest cover included:

- Forest cover decreased by 21,415 acres at the Countywide scale.

[1]Countywide change summaries include cities and Tribal areas outside of the CAR Study Area, as changes in these areas can impact critical areas functions and values within the study area.

- Over half of forest cover decrease (63% or 13,543 acres) occurred in 11 rural subbasins in northeast and southeast areas of the County. Only 3.1% (422 acres) of this forest cover was converted to impervious area. This indicates that timber harvest, a non-permanent, rotational change in forest cover, is likely one of the main drivers.
- Two urban/suburban subbasins had higher forest cover changes: North Creek and May Creek. Changes in forest cover in North Creek are likely from development while in May Creek changes are likely due to both development and timber harvesting/natural change.
- North Creek and Swamp Creek had greater than 500 acres of forest cover change.

Positive/Negative Change – This metric accounts for all land cover changes that affected the hydrologic function of a landscape either positively or negatively. It includes impervious gain and forest cover change, but also other vegetation changes such as revegetation of bare areas (positive) or conversion of scrub/shrub areas to pasture (negative). Landscape changes for this positive/negative metric included:

- 56 of 58 subbasins had net negative changes.
- Of the ten subbasins with largest net negative changes, seven (70%) were primarily from timber harvesting/natural change.
- Three subbasins in the top ten with the highest net negative changes had more impacts from development. These include North Creek, where most of the net negative impacts were likely caused by development, and May Creek and Lower North Fork Stillaguamish, where impacts were caused by both development and timber harvesting/natural change.

What do the Countywide Land Cover Changes Mean?

As expected, Snohomish County experienced large changes in its landscape from 2009 to 2021. Most notably, total impervious surface increased and forest cover decreased. Within these changes:

- ***Forest cover change was widespread**, yet often **related to non-development activities** (such as timber harvest) where forest cover is likely to return.*
- ***Impervious surface increases** were **concentrated in urban growth areas**, which is consistent with where the GMA directs population growth.*

Critical area regulations focus on ensuring the critical area buffers remain intact, yet changes occurring outside critical area buffers at the landscape scale also impact critical area functions and values. Analyzes based on County monitoring data indicate that increases in impervious surfaces and/or forest cover loss at the subbasin scale negatively impact functions and values, even when buffers remain intact. Therefore, to effectively preserve functions and values, these cumulative impacts should be addressed using a combination of regulatory and policy tools available to the County. The study identified eight subbasins[2] where these additional options could be prioritized. These subbasins are currently rated as "excellent" or "good" for indicators of functions and values yet are experiencing high development pressure.

[2] The 8 subbasins are Little Pilchuck Creek, Lower Pilchuck Creek, Middle Pilchuck Creek, Snoqualmie Mouth, Skagit Flats South, Dubuque Creek, Allen Creek, and Lower Woods Creek – see Figure 1.2.

Critical Area Land Cover Changes

Changes in land cover were examined to determine impacts to **wetlands and their buffers and to buffers of FHWCAs which include stream, lake, and marine shorelines** [3, 4]. These existing critical areas cover approximately 114,600 acres in the CAR Study Area[5]. Key findings are:

Impervious Surface Cover Changes in Buffers: Impervious changes within critical area buffers could be due to new roads, sheds, homes, etc. Changes included:

- Impervious surface increased by 792 acres (0.7%) in buffers.
- Increases were less than 1% for streams (0.4%), marine (0.8%), and wetland (0.8%) buffers. Lake buffers experienced a 1.3% increase in impervious surface. Some of the increases in impervious area in the marine buffers could have been allowed by the Shoreline Management Program (SMP).
- Most of the impervious surface increase in stream and wetland buffers were in urban and urbanizing locations. Overestimating can occur in these areas, see Section 2.1.3 below for more information.

Forest Cover Changes in Buffers*:* Forest cover changes in buffers could be due to development, timber harvest or natural changes (tree growth/loss, stream channel migration, landslides, etc.). Changes included:

- Forest cover decreased by 2,492 acres (2.2%) in buffers. Half of the forest cover loss was in 10 subbasins with known timber harvesting.
- Wetlands and their buffers experienced the highest percentage of forest cover loss (-2.2%). Loss of wetland forest cover was found across urban, suburban, and rural areas.
- Forest cover decreases in rural areas is more likely due to natural changes and timber harvesting as compared to urban and urbanizing areas.

Positive/Negative Change (%P/N): P/N changes in buffers could be due to the factors listed above for impervious surface and forest cover changes or other less obvious impacts such as a bare area becoming vegetated with grass. Changes included:

- Stream, lake, and marine buffers had a net negative impact affecting 1,686 acres (-3.7%).
- Lake buffers had highest percent negative impact (-5.1%).
- Wetlands and their buffers had a net negative impact affecting 3,254.4 acres (-4.7%).

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[3] A buffer size of 75 ft was used for wetlands. Buffers for river, stream, lake, and marine shorelines vary depending on stream type as described in Section 2.1.1.

[4] Marine shoreline change estimates are based on Puget Sound Partnership vital sign reporting using WA Department of Fish and Wildlife (WDFW) permits, and Estuary and Salmon Recovery Program (ESRP) regional study data.

[5] The CAR Study Area excludes cities and Tribal areas where Snohomish County CAR regulations do not apply. Agricultural areas were also excluded from this analysis as they have unique CAR regulations.

Table 1: Changes to critical areas within the CAR Study Area.

Buffer Type	Total Acres	Forest Change (Acres)	Impervious Change (Acres)	Positive Change (Acres)	Negative Change (Acres)	%P/N Change	Adaptive Management Threshold
Lake	1,535	-24	20	41	120	-5%	
Marine	367	-6	3	11	28	-5%	**Threshold 2[1]**
Stream	43,348	-872	174	733	2,323	-4%	
Wetland	69,346	-1,590	595	1,170	4,425	-5%	**Threshold 2[2]**
Grand Total	114,596	-2,492	792	1,956	6,896	-5%	
% of Total Area		-2%	1%	2%	6%	-4%	

[1]The adaptive management thresholds for stream, marine, and lake buffers are: Threshold 1 = <3% change within any subbasin, Threshold 2 = 3% - 5% change within two or more subbasins, and Threshold 3 = >5% change across combined lake, marine, and stream buffers within County jurisdiction.

[2]The adaptive management thresholds for wetlands and wetlands buffers are: Threshold 1 = <5% change within any subbasin, Threshold 2 = 5% -10% change within two or more subbasins, and Threshold 3 = >10% change across combined lake, marine, and stream buffers within County jurisdiction.

Data Limitations

Table 2 describes the limitations to the buffer analysis that impact the certainty of the results.

Table 2: Data limitations that impact the accuracy of results. "County data" refers to the compilation of stream, lake and wetland data used to develop the estimates of impacts in this report.

Waterbody	Data Limitation	Impact on Results
Streams	• Stream location is not always accurate. When buffers are applied, the buffer edges are therefore not always accurate.	• Overestimate impacts to stream buffers, especially in urban areas. • Underestimate impacts to stream buffers.
	• Not all streams are mapped.	• Underestimate impacts to stream buffers.
Wetlands	• Wetland location is not always accurate. When buffers are applied, the buffer edges are therefore not always accurate.	• Overestimate impacts to wetlands and their buffers in some locations including urban areas. • Underestimate impacts to wetlands and their buffers, particularly to small wetlands and forested wetlands.
	• Not all wetlands are mapped and some mapped wetlands don't exist on the landscape.	• Overestimate impacts to wetlands and their buffers. • Underestimate impacts to wetlands and their buffers.
	• A 75-foot buffer was applied to all wetlands when County Code requires buffers ranging from 25 to 300 feet depending on wetland category and land use.	• Overestimate impacts to wetlands and their buffers. • Underestimate impacts to wetlands and their buffers, particularly to the most ecologically important wetlands.

A focused "Pilot Study" was conducted in two areas of the County (rural and urban) to assess the impact of these data limitations and provide further insight into adaptive management actions. The results of the pilot study, where two methods were used to estimate impacts to buffers, found a factor of two difference in the total impact estimates between the methods in urban area. The difference in the estimate of impacts between the two methods in the rural areas was substantially less (less than 1%). However, because the pilot study data was not representative of all urban areas within the County, as well as other data limitations, it is not appropriate to assume that Countywide estimates of urban impacts are overestimated by a factor of two.

Overall, the pilot study showed that the approach used to produce the estimates in this report provides sufficient accuracy to assess the general trends and extent of changes, even with the level of uncertainty. There is higher uncertainty for wetlands than streams due to lack of information on the location, size, and category of all County wetlands and lower uncertainty for lakes than stream as lake edges are more precise.

What do Changes to Critical Areas Mean?

Overall, wetlands and their buffers and FWHCA buffers appear to be generally intact, even though there has been some impervious surface added and forest cover lost. However, there was sufficient change to trigger Adaptive Management actions as follows:

- ***As 26 subbasins had a negative change of greater than 5% in*** *Wetlands and their buffers,* ***Adaptive Management Threshold 2*** *was triggered. Adaptive Management threshold 2 requires additional public outreach, enforcement, mitigation actions and/or programmatic adjustments.*
- ***As 33 subbasins had a negative change of greater than 3%*** *in Fish and Wildlife Conservation Areas and buffers,* ***Adaptive Management Threshold 2*** *was triggered. Adaptive Management threshold 2 requires additional public outreach, enforcement, mitigation actions and/or programmatic adjustments.*
- *The pilot study showed that the approach used to produce the estimates in this report* ***provides sufficient accuracy to assess the general trends and extent of changes****, even with the level of uncertainty.*

Recommended actions in response to these findings can be found in the Conclusion and Recommended Next Steps section (see page 12).

River, Marine, and Lake Shoreline Condition Changes

Shorelines of river, marine, and lake waters provide critical functions and values including fish and wildlife habitat, pollution removal, and resiliency of natural physical, chemical, and biological processes. Natural conditions at the land/water interface are particularly important to maintain these functions and values.

Field surveys assessed the armoring, erosion, and other factors that impact functions and values on river, marine, and lake shorelines.

Shoreline Armoring Changes: New hard, non-organic bank armoring impedes natural shoreline processes and habitat conditions. Changes included:

- River shoreline armoring decreased in the Snohomish (-0.13%) and Stillaguamish (-0.99%) watersheds while lake shoreline armoring increased 2.4%.
- Marine shoreline armoring decreased between 1,367 feet (-0.5%) and 3,210 feet (-1.2%) depending on the data source and time frame examined; net positive gains are primarily from restoration projects (Leque Island & Meadowdale); new armoring placement continues along the railroad.

Other River Shoreline Condition Indicators: Changes due to erosion, log jams, and pools can benefit or harm aquatic life, including salmonids. Changes include:

- River bank erosion and instability increased between 4-5%; some erosion is natural and positive, while other erosion is a result of development-related activities.
- Beneficial log jams within rivers increased in all areas of the Snohomish, Stillaguamish, and Pilchuck Rivers, except for the North Fork Stillaguamish River where log jam estimates are likely underestimated.
- Overall, the number of pools within rivers increased in the Snohomish, Stillaguamish, and Pilchuck Rivers.

Other Lake Condition Indicators: Changes in shoreline vegetation, which provides pollutant removal and wildlife habitat, as well as the coverage of docks on lakes, can benefit or harm lake functions and values. Changes include:

- The level of intact shoreline vegetation for lakes improved slightly (2.8%).
- Across all lakes, docks increased in density (7%) and in total surface area (from 0.88% to 0.97%).

What do Shoreline Condition Changes Mean?

Overall, armoring is pervasive along river, marine, and lake shorelines, impairing the functions and values of these critical areas. However, most this armoring was installed prior to the beginning of this study period. While there was a minor decrease in shoreline armoring for rivers and the marine area, the recent increase in shoreline armoring around lakes identifies a need for additional education and outreach to lake watershed property owners.

- ***An overall change of less than 3% in shoreline armoring*** *triggers* ***Adaptive Management Threshold 1*** *(public outreach and/or enforcement, and mitigation actions).*

Goal 2: Are there changes where CAR protections have been established by permit?

Two separate approaches were used to investigate this question. For both approaches, as subset of Critical Area Site Plans (CASPs), a product of the development permitting process, were used to identify the location of critical areas. CASPs are a site development plan recorded with the County Auditor that documents all critical areas, buffers, and restricted areas near a development activity.

For the first approach, the County conducted two studies using aerial photos to assess changes at parcels with CASPs and parcels that had active code enforcement cases. A 2019 Shoreline Management Program (SMP) report based on the analysis of 321 acres that were designated for CAR protection between June 2013 and June 2015 found that 0.3% of the acreage had been impacted. The 2020 CAR review of 1,948 acres that were designated for CAR protection between 2016 and 2018 found that 0.7% of the acreage had been impacted. The 2020 analysis classified most disturbances as minor or moderate due to clearing or grading activity, though there were a few large-scale disturbances.

For the second approach, an analysis was conducted on all available CASPs used the remote sensing land cover change methodology that used for other land cover change estimates found in this report. 3,066 acres that were designated for CAR protection were evaluated. Between 2009 and 2021, a net negative change in critical areas was estimated to be -3.5% in the urban area and -2.6% in the rural area.

Differences between the results of these two approaches are likely due to differences in methodology, scale, and time frame.

TABLE 3: SUMMARY OF IMPACTS TO CRITICAL AREAS DESIGNATED FOR PROTECTION IN THE DEVELOPMENT PERMIT PROCESS.

Study	Total Acres	Acres of CASPs impacted	Percent Impact	Timeframe
Land Cover Study	3066	116.5	-3.8%	3 to 12 years
2019 SMP Study	321.49	1.03	-0.3%	4 to 6 years
2020 CAR Study	1,948	14.9	-0.7%	2 to 4 years

As noted above, a subset of CASPs, rather than all CASPs recorded within the County, were used to determine impacts to CASP documented areas. While CASP information is available within pdf documents, it is not in the proper format for analysis. To analyze for permit compliance, CASPs must be digitized, which is a time-consuming process. Improving the availability of CASPs in an analyzable format is recommended for future studies.

What do these findings mean?

Overall, the three studies show impacts to critical areas protected by the permit process varying between 0.3% to 3.8% which is generally low, leading to the conclusion that:

- ***Most property owners appear to be complying with permit conditions by leaving protected critical areas and their buffers intact on their properties.***

Data limitations, including spatial inaccuracies, inaccurate markings of clearing/grading limits, allowed variances, etc. may explain some of the impacts found in these analyses.

Given that more comprehensive estimate of impacts to buffers were between 4% and 5% and impacts on permit-protected critical areas were estimated to be between 0.3% and 3.8%, unpermitted activities are contributing to the negative change in critical area buffers.

Goal 3: Has the County achieved a "no net loss" of critical area functions and values?

The answer to this question is not clear since there is currently no scientifically accepted method for calculating “no net loss” for this purpose and since there is a lack of long-term data for all the indicators needed to assess the condition of functions and values. Even if the amount of loss for a function and value could be more precisely calculated, linking that decline to both County CAR requirements (are the regulations adequate to protect critical areas?) and implementation (were the regulations implemented correctly to protect critical areas?), given other confounding stressors, would be extremely difficult to do.

- *There is **no exact method** to link a **change in a function or value to a CAR impact** as opposed to other stressors**.***

Given these limitations, the County used all available data to assess the status and, when possible, the change over time, in key indicators related to critical area functions and values. The most notable finding was that there is a strong connection to between changes in land cover and indicators of functions and values.

- *When **forest cover decreases** and/or **impervious surface increases,** there is a **corresponding decline** in the indicators of functions and values.*

This relationship was consistent among all land use types and applied when the land cover change occurred at the buffer or subbasin scale.

In addition to the land cover changes found in this report, countless other stressors are impacting ecosystem functions and values. These include changes in precipitation and temperature stemming from climate change, groundwater withdrawals due to permit-exempt wells, and emerging pollutants such as 6-PPDq. Based on the available evidence, the following conclusions can be reached:

- *It is likely that there has been a **loss** to **some critical area functions and values.***
- *It is likely that **negative impacts** to functions and values that can be **attributed to CAR regulations and/or implementation are minimal**, compared to **losses caused by other stressors**.*

While there has likely been a loss in functions and values, the County has engaged in actions to restore functions and value that may have offset some of those losses. Between 2009 and 2021, the County:

- Acquired 4,101 acres of land for conservation.
- Installed salmon habitat restoration improvements in 458 acres of streams, rivers, and estuaries.
- Opened access to over 68 miles of stream habitat through culvert and other fish passage improvements.
- Conducted invasive plant removal and/or native planting on 897 acres of critical areas and their buffers.

Conclusions and Recommended Next Steps

Overall, the County's CAR regulations are helping to preserve the functions and values associated with critical areas given significant growth and development. However, there have been incremental increases in impervious area and forest cover changes in critical areas over the twelve-year period that exceed Adaptive Management Thresholds. Permit protections were found largely to be effective, meaning unpermitted actions, natural events, and other stressors are likely the major causes of critical area changes.

Additional actions should be taken per the established adaptive management thresholds. These actions and specific recommendations stemming from the study findings are provided below as potential next steps for the County. Targeting actions to specific subbasins and/or waterbody types based on the findings of this study would most efficiently meet objectives.

➢ *Given development pressure and other stressors to our natural systems, it is **essential that critical area losses continue to be minimized** to ensure maximum protection of their critical area functions and values.*

Action: Education and Outreach & Enforcement

The study found that landowners are mostly following permit restrictions with limited losses of critical areas on properties with permits. Therefore, some portion of the critical area losses are likely due to unpermitted actions. A combination of increased outreach and enforcement are key solutions to preventing future loss.

Outreach to prevent critical area loss. Efforts should focus on raising awareness of critical areas, their importance, and the need for permitting when working in or near these areas. Potential target audiences for outreach and associated messages include:

- Residential property owners: increase awareness of critical areas and associated permit requirements
- Professionals (land developers, contractors, and real estate professionals): increase awareness of potential critical areas they may encounter and associated restrictions.
- Lake area homeowners: conduct lake-specific education and outreach on critical area and dock regulations as this area has had higher losses.

Educating landowners and raising awareness can also lead to increased enforcement. Once landowners are aware of what is and is not allowed, they are more likely to file a complaint with PDS's code enforcement group, hopefully reducing cumulative impacts. In addition, promoting SWM's outreach programs (LakeWise and the Streamside Landowner Program), which seek to both educate landowners and re-vegete shoreline buffers, can help offset losses.

Action: Programmatic Adjustments

Programmatic changes can help to improve protections of critical areas and buffers and monitoring and adaptive management approaches.

- **CAR Regulations Updates** (underway): review CAR regulations and update based on Best Available Science.
- **2024 Comprehensive Plan Changes** (underway):
  - A larger share of population growth is planned to be directed into Urban Growth Areas through the 2024 Comprehensive Planning update which will protect functions and values in non-urban areas.
  - Implement new codes and/or policies that will positively impact critical areas and functions and values, such as urban tree canopy preservation, the promotion of conservation projects especially on older agricultural land, and equitable access to open space.
- **Critical Areas Site Plan Tracking**: improve access to critical area site plans (CASPs) including making digitization or georeferencing a routine component of the permitting process for both residential and commercial projects.
- **Critical Area Monitoring and Adaptive Management Plan (CAR M&AM)**: Update the plan based on the methodologies used and the findings of this report to better evaluate CAR regulations in the future. Within this update, consider tools that could improve wetland and stream data accuracy. In addition, revise the Adaptive Management Thresholds for clarity and consistency with best available science.

Action: Mitigation Actions Including Conservation and Restoration

Mitigation actions set forth in this context refers to **conservation and restoration actions** that would help to offset losses in critical area functions and values and not to specific mitigation required during the development permitting process. Conservation and restoration actions are crucial for achieving "no net loss" of functions and values not only for regulatory compliance in a narrow sense, but also for supporting the wider goals of salmon recovery, clean water, and climate adaptation.

Below is a list of programs and actions that the County currently undertakes that could be supported to help offset future losses to critical area functions and values:

- Implement the County's Land Conservation Initiative.
- Restoration of habitat, with emphasis on salmon habitat, including:
  - Restoring fish passage by replacing 4-6 fish passage barriers annually.
  - Restoring salmon habitat (10 salmon habitat restoration projects are currently on SWM's six-year capital improvement plan from 2024-2030).
  - Conducting invasive plant removal & riparian buffer plantings.
  - Removing derelict vessels from marine waters that cause pollution and damage habitat.
- Protect properties for conservation through acquisitions using Conservation Future's funding, Floodplains by Design grants, and other funding sources.
- Support the Sustainable Land Strategy – a collaborative effort to promote multi-benefit fish, farm, and flood projects.
- Continue beaver management efforts that maintain their key role in supporting functions and values while still reducing flooding of public infrastructure.

TABLE 3: SUMMARY OF ADAPTIVE MANAGEMENT THRESHOLDS AND ACTIONS, TRIGGERING METRICS, AND ASSOCIATED RECOMMENDATIONS.

Threshold & Actions	Metric Triggering Threshold	Recommendations
Threshold 2 *additional public outreach, enforcement, and mitigation actions; programmatic adjustments.*	Wetlands & Wetland buffers	• Focus outreach, enforcement, mitigation, and programmatic efforts on urbanizing areas where there are greater changes. • Improve tracking of critical areas protected via permitting process to determine if future impacts are due to permitted or non-permitted activity. • Improve knowledge of wetland location and category.
Threshold 2 *additional public outreach, enforcement, and mitigation actions; programmatic adjustments.*	Stream, Marine, and Lake Shoreline Buffers	• Focus outreach, enforcement, mitigation, and programmatic efforts on lake watersheds and urban/suburban areas, particularly those where the highest negative impact was seen (>10% increase in impervious area). • Lower effort needed in areas where buffer changes are more likely related to timber harvesting and natural changes.

Threshold & Actions	Metric Triggering Threshold	Recommendations
		• Improve knowledge of stream location.
Threshold 1 *public outreach and/or enforcement*	River, Marine, and Lake Shorelines	• Focus outreach on lakefront property owners. • Continue progress towards removing river and marine shoreline armoring.

The County has a suite of regulations and policies beyond CAR to manage development while protecting functions and values including stormwater management codes and standards, Comprehensive Planning, and the Shoreline Management Program. The data in this report can help resource managers protect functions and values through this multi-pronged approach as the County continues to grow.

1.0 Introduction

As mandated by State law, Snohomish County is required to protect critical areas. Critical areas include Fish and Wildlife Habitat Conservation Areas (or FWHCAs, such as rivers and streams, lakes, marine waters, and wildlife habitat), wetlands, geologically hazardous areas, frequently flooded areas, and aquifer recharge areas. The Growth Management Act (GMA, adopted 1990) (RCW 36.70A) and the Shoreline Management Act (SMA, adopted 1971) (RCW 90.58) require protection of critical area functions and values and shoreline ecological functions, respectively (Washington State Legislature). Critical area functions and values and shoreline ecological functions are essentially the same thing and include hydrologic, chemical, geologic, and habitat processes performed or provided by elements in the natural environment – primarily water, soils, and vegetation.

Both the GMA and the SMA require local jurisdictions to adopt regulations that protect critical areas from impacts associated with land development. These regulations must be based on recommendations from scientific research that meets standards for "best available science" per requirements in Washington Administrative Code (WAC) 365-195 (Washington State Legislature). The science points to the importance of vegetation and buffers for protection of critical areas.

The standard in State law is to achieve no net loss of critical area functions and values. This standard does not mean that every square foot of critical area must be preserved. Instead, the functions performed by critical areas and buffers must be preserved or replaced through mitigation. It is recognized that development regulations alone may not achieve this no net loss standard. Snohomish County has a variety of regulatory and non-regulatory programs in place to protect critical area functions throughout the unincorporated area of the County.

Snohomish County adopted policies to protect the natural environment in early versions of the original thirteen subarea plans many years prior to adoption by the State of the GMA. Also prior to the GMA, the County adopted the Aquatic Resource Protection Plan (ARPP) which was subsequently repealed by referendum vote due to strong push back by private property rights groups. The referendum was almost immediately followed by State action to adopt the GMA in 1990, including provisions to protect critical areas and natural resource lands as an early action before any other planning could begin. The County was ultimately able to adopt its first set of GMA-based critical area regulations (CAR) in 1996.

During the ensuing years, the courts resolved many critical area related challenges and the State agencies collected scientific research and data. With the growing body of information, the State prepared guidelines and summaries of best available science to inform the next cycle of GMA-mandated reviews and updates. The County adopted a significantly revised science-based version of CAR in 2007.

Since 2007, updates to CAR have been more focused in scope with new requirements added for landslide hazard areas in the post-SR530 landslide era and an updated wetland rating system based on revisions by the Washington State Department of Ecology. Periodic updates to CAR complicate comparative analysis of code effectiveness over time.

An important component of the County's critical area protection is the periodic monitoring of the implementation and effectiveness of the critical area regulations. This requirement outlined in SCC 30.62A.710 was established by Ordinance 06-061 on October 1, 2007:

"The Executive shall develop and implement a monitoring and adaptive management program to establish a baseline and provide performance measures to determine whether the County is achieving no net loss through its policies and programs affecting wetlands and Fish and Wildlife Habitat Conservation Areas, in conformance with the Natural Environment Element of the General Policy Plan of the comprehensive plan." (Snohomish County)

SCC 30.62A.730 requires preparation of a monitoring report:

"One year prior to the GMA (RCW 36.70A.130) required review and update of the County's critical area regulations, the executive shall report to the council on the monitoring and adaptive management program, using best available science, and provide data and conclusions regarding the effectiveness of the County in achieving no net loss of critical area functions and values. If net loss is detected, using scientifically valid techniques, the executive shall report and recommend strategies for adaptive management." (Snohomish County, 2015)

A monitoring plan was developed to evaluate implementation and effectiveness of the County regulations, policies, and programs by the Department of Planning and Development Services (PDS) and the Surface Water Management (SWM) division of the Department of Conservation and Natural Resources *(Note: until January 2021, SWM was a division of the Department of Public Works).*

It should be noted that comparison of critical area mapping and monitoring results over time is complex and somewhat uncertain: regulations get updated; hydrologic features are dynamic systems; impacts on ecological functions can take many years to manifest; aerial photos may vary by geographic coverage, spatial accuracy, and pixel size; geographic information systems and mapping technologies evolve and improve; and some data sources may be incomplete, subject to varying levels of accuracy, and updated infrequently. For example, analysis of code compliance and effectiveness can be complicated by changes in code requirements associated with buffer widths. Another example relates to wetland data: the location, boundary, and spatial extent of wetlands is highly variable from one dataset to the next, each is not comprehensive in extent, and the data does not typically include wetland classification upon which regulatory buffer widths are assigned. The only certainty is that none of the available wetland datasets, even when all sources are combined, contains ALL the wetlands in the County.

In September 2008, the County Council adopted the Critical Area Monitoring and Adaptive Management Plan (SWM & PDS). The plan provides the framework for assessing the effectiveness of the County's regulations, non-regulatory environmental programs, and policies at achieving no net loss of the functions and values of wetlands and Fish and Wildlife Habitat Conservation Areas. The plan includes an adaptive management framework to increase certainty of achieving the conservation goal of preventing a net loss of critical area functions and values. The plan consists of four main components:

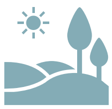
- Land cover characterization and change detection analysis,
- Shoreline conditions assessment,
- Paired catchment of functional headwater stream assessment, and
- Evaluation of code compliance and implementation for permits issued after adoption of CAR in 2007.

Because of variable economic conditions, the County has been unable to reliably assign resources to fulfill all tasks described in the 2008 Critical Area Monitoring and Adaptive Plan. Nevertheless, monitoring reports were prepared in 2012, 2014, and 2018.

In 2022, PDS and SWM began a joint project to meet SCC 30.62A.730 requirements. The goals of this project include addressing the following questions:

How have critical area buffer and shoreline conditions changed?

Are there changes where CAR protections have been established by permit?



Has the County achieved a "no net loss" of critical area functions and values?

To meet these goals, PDS and SWM collaborated to evaluate the status of critical areas as well as examine changes in critical areas since 2009 when the last critical areas assessment occurred. The changes are captured through 2021, which was the most current data when the project began. The specific monitoring objectives were guided by the original 2008 CAR Monitoring and Adaptive Management Plan but differ due to program changes over time.

To evaluate changes and impacts to critical areas and functions and values, three components were evaluated:

1. Changes to Land Cover
2. Changes to River, Lake, and Marine Shoreline Conditions
3. Assessment of Functions and Values

1.1 CAR Reporting Area and Geographic Scales

The analyses in this report were conducted using different geographies depending on what information was desired from the data. For some analyses, the data needed to be confined to the CAR regulatory area, referred to as CAR Study Area within the report. However, for other analyses, especially those related to functions and values, best available science has shown that impacts are not constrained to arbitrary human-derived lines (such as jurisdictional lines). The section below details the different geographies used in the report and where they are generally used.

CAR+Cities+Tulalip: This geography is greater than the CAR Study Area, as it includes cities and the Tulalip Reservation. It does not include the entire Snohomish County jurisdiction however, as some of the eastern forested land that is primarily under the U.S Forest Service is removed. This geography was primarily used in analyzing land cover for impervious, forest, and other changes that do not have a specific CAR Adaptive Management Threshold (see Section 1.2.4). Land cover changes at this scale can impact ecological functions and values; that is why this geography was chosen over a more limited CAR Study Area.

CAR Study Area: Some analyses were conducted using only the CAR Study Area (also referred to as CAR study boundary, Figure 1.1), which excluded data from the cities and agricultural lands. These analyses did include data from the Tulalip Reservation however, even though not all parcels on the Reservation are within County jurisdiction. This is because at the time of analysis, SWM did not have access to PDS's map of Tulalip parcels within County jurisdiction. Agricultural parcels were excluded, as agricultural activities operate under their own

CAR regulations. Data that were analyzed for Adaptive Management Thresholds (see Section 1.2.4) were confined to the CAR Study Area.

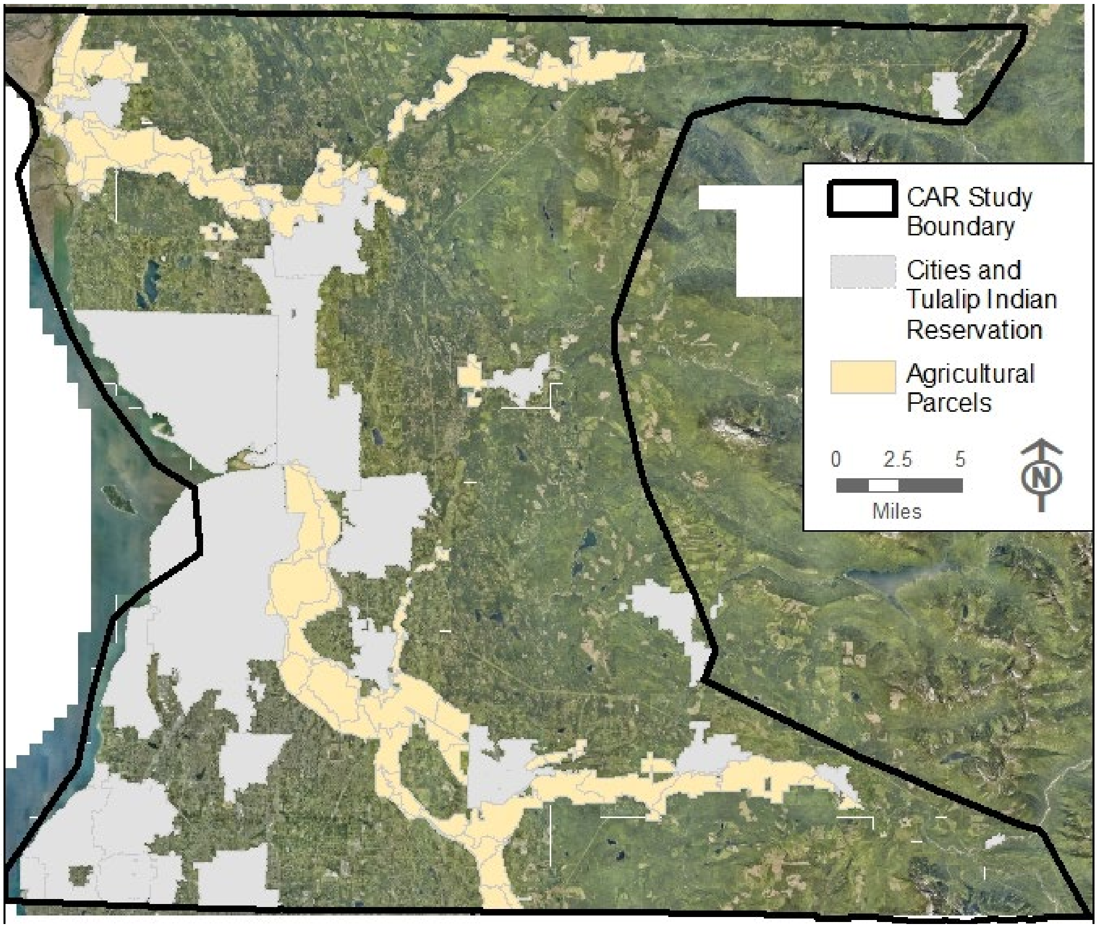


FIGURE 1.1: CAR STUDY AREA (REFERRED TO AS CAR BOUNDARY AREA IN MAP LEGEND). CITIES AND THE TULALIP TRIBAL RESERVATION ARE IN GRAY AND AGRICULTURAL PARCELS ARE IN YELLOW. CITIES AND AGRICULTURAL LANDS ARE EXCLUDED WHILE THE TULALIP TRIBAL RESERVATION AREA IS INCLUDED IN ANALYSES USING THE CAR STUDY AREA.

Watershed: River shoreline data is reported by major watershed: Stillaguamish and Snohomish. Other watersheds in the County include the Cedar-Sammamish and Puget Sound Drainages. Watershed affiliation is noted for ESA Subbasins and available in appendices.

Subbasin: Many of the analyses are reported by Endangered Species Act (ESA) defined subbasins (Figure 1.2). There are 58 subbasins in the CAR Study Area, and all subbasins can be rolled up into a watershed. Some subbasins were clipped by the CAR boundary or other jurisdictional lines and analyzed over an area smaller than their natural entirety.

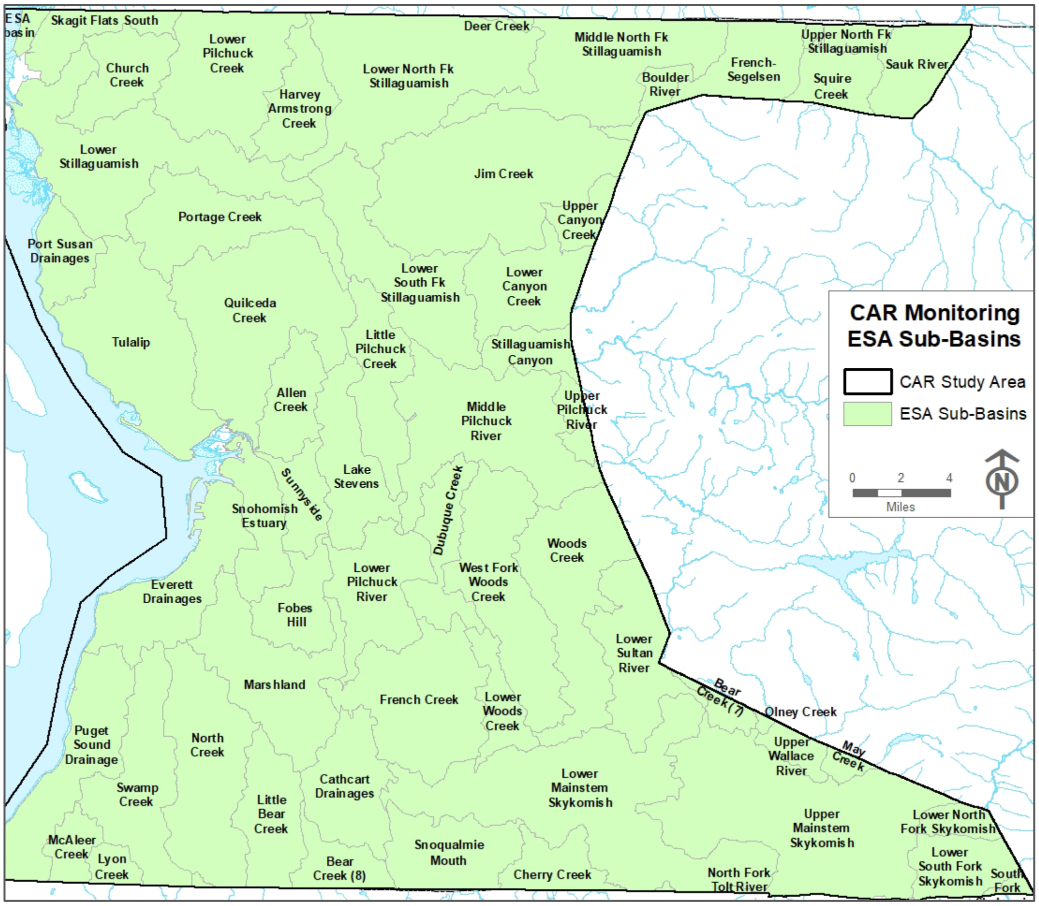


FIGURE 1.2: SUBBASIN BOUNDARIES INCLUDING THOSE CLIPPED BY CAR STUDY AREA.

Assessment Unit (AU) (Marine Shorelines): These are units derived by the Department of Ecology based on hydrology. There are 261 AUs ranging in size from 3 to 7,513 acres. AUs less than approximately 700 acres generally are those that are clipped to the CAR Study Area and or jurisdictional boundaries. All assessment units can be rolled up into a subbasin (See Appendix A.1). AUs are used to assess changes to marine shorelines, where more discrete changes by AU could be evaluated.

Rivers (Shorelines section): The Snohomish and Stillaguamish rivers were evaluated for shoreline condition and other important factors. Theses major rivers were broken into smaller segments, called reaches, for data collection and reporting. All rivers evaluated are within the CAR Study Area.

Lakes (Shorelines and Functions and Values sections): Twenty-six lakes with public access were evaluated for shoreline condition. Thirty-five lakes, including lakes with public access and some private lakes, were evaluated for current conditions and trends in functions and values. All lakes evaluated are within the CAR Study Area.

Marine (Riparian Buffers and Shorelines section): Marine shorelines make up much of the western border of the CAR Study Area; however, most of the marine shoreline south of the Snohomish River is within city jurisdictions, and some of the shoreline north of the Snohomish River is within the Tulalip Tribal Reservation. Marine shorelines were evaluated for changes in riparian buffer and bank armoring conditions. Changes in bank armoring were not re-surveyed as part of this monitoring period but are evaluated using regional assessment and summary information.

SWM State of Our Waters (SOW) Sample Frame: To evaluate stream-related functions and values, data from the SOW program, which began collecting data in 2018, was used. The sample frame, or where the SOW program operates, is slightly larger than the CAR study boundary (Figure 1.3). The SOW sample frame uses land use as a site-selection factor, as land use is known to drive impacts to stream health. Figure 1.3 displays land use within the SOW sample frame.

Agricultural Parcels: Agricultural parcels, identified using the Future Land Use Zoning Map, were excluded from many analyses as County CAR code has separate regulations for agricultural activities. A limited assessment of changes on agricultural parcels was conducted (Section 5.0). Land use zoning containing agricultural parcels is shown in Figure 1.1.

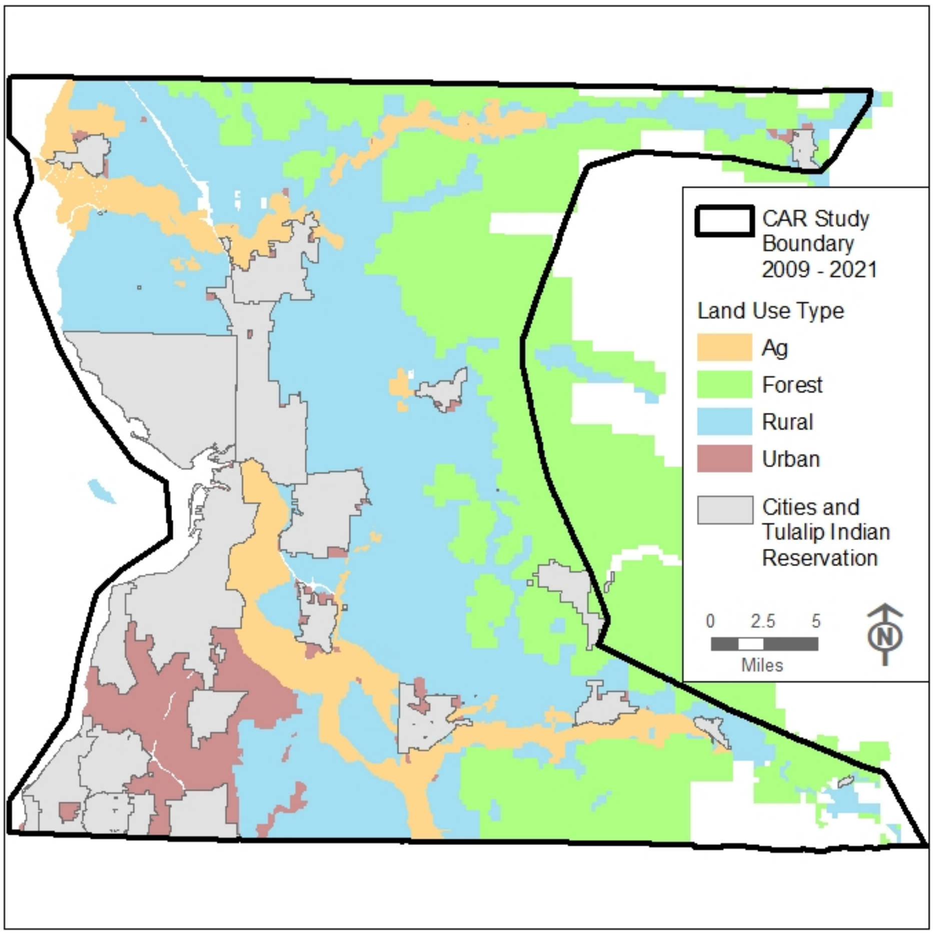


FIGURE 1.3: SOW SAMPLE FRAME (ALL AREAS IN COLOR) SHOWING LAND USE DESIGNATION BASED ON FUTURE LAND USE ZONING. CITIES AND THE TULALIP RESERVATION, WHICH ARE EXCLUDED FROM THE SOW SAMPLE FRAME, ARE IN GRAY.

1.2 Monitoring Program Elements and Adaptive Management

The monitoring program elements were selected through discussions between PDS and SWM. Some of the elements are consistent with those identified in the 2008 CAR Monitoring and Adaptive Management Plan, others are slight modifications, and some are completely different. Determining the appropriate elements to use requires balancing the data that is available, the accuracy of data, and the resources required to produce results.

Translating data about a monitoring element into a concise statement about its condition is another challenge of CAR evaluation. For some of the elements assessed in this report, the condition of the monitoring element was evaluated against an ecological condition level. The ecological condition levels were determined using best available science and are defined as:

- Ecological Condition Level 1 = Properly functioning
- Ecological Condition Level 2 = At-risk
- Ecological Condition Level 3 = Degraded

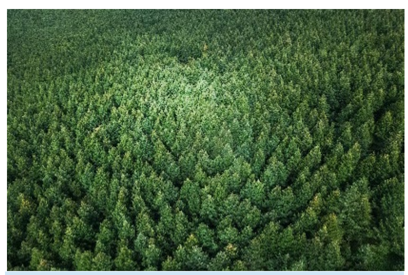
There are three categories of monitoring program elements:

- Land Cover
- Shorelines
- Functions and Values

1.2.1 Land Cover Monitoring Elements

Land cover monitoring elements estimate impacts based on how land cover changed from 2009 to 2021. Figure 1.4 shows different types of land cover changes typical in Snohomish County during the time frame. For the purposes of CAR Monitoring, we are primarily interested in changes related to development, such as new homes, businesses, roads, and other infrastructure and forest loss due to these and other activities.

New **Impervious Surfaces** such as roads, buildings, and other infrastructure.



Loss of **Forest** due to development for homes, roads, etc. and for timber harvesting.

Natural changes such as river channel migration, landslides, and vegetation growing/dying.

FIGURE 1.4: TYPICAL LAND COVER CHANGES IN SNOHOMISH COUNTY BETWEEN 2009 AND 2021.

Table 1.1 lists the monitoring elements selected for land cover, why they were selected, and ecological condition levels.

TABLE 1.1: LAND COVER MONITORING ELEMENTS, RATIONALE FOR INCLUSION, AND ECOLOGICAL CONDITION LEVEL USED FOR EVALUATING 2009, 2021 OR CHANGED CONDITIONS.

Monitoring Element	Rationale for Inclusion	Ecological Condition Levels[1]
% and/or Acre Positive Change	Positive changes are those where a land cover type changes to one that is better for hydrologic functioning. For example, land cover changing from	None

Monitoring Element	Rationale for Inclusion	Ecological Condition Levels[1]
	bare to forest would be a positive change (see Figure 2.3).	
% and/or Acre Negative Change	Negative changes are those where land cover type changes to one that is worse for hydrologic functioning. For example, land cover changing from forest to impervious would be a negative change (see Figure 2.3).	None
% and/or Acre Net Positive minus Negative change	This factor considers the net change in all land cover conversions based on their impact to hydrologic function (Figure 2.3). It is inclusive of changes due to new impervious surfaces, loss and gain of forest, as well as other more subtle changes to land cover.	None
% and/or Acre Impervious change	Impervious surfaces are detrimental to hydrologic functioning and contribute to long-term negative changes. All changes from non-impervious land cover to impervious surface are considered negative changes (see Figure 2.3).	Subbasin: Level 1 = <7% Level2 = 7-12% Level 3 = >12% Buffers: Level 1 = <3% Level2 = 3-7% Level 3 = >7%
% and/or Acre Forest Change	Evergreen and deciduous forest cover is generally considered the natural and highest functional state for hydrology. Therefore, any change from forest to another land cover is considered a negative change and any change to forest is considered positive (see Figure 2.3).	None
60% Forest/10% Impervious	This factor is considered based on older science that posited that when subbasins met or exceeded 60:10 forest-to-impervious quantities, aquatic systems should retain their functions and values. This is explored below in results evaluating functions and values. Additional evaluation is provided by an integrated land cover variable, Land Cover Index (LCI), being %Forest minus %Impervious (see Table 1.3).	Meets or does not meet 60:10 quantities in 2009 and 2021
Road Crossing Density (crossings/mile)	Locations where roads cross over streams represent impacts that fragment and potentially fill stream and wetland buffers. The locations often include stormwater outfalls where flow and pollutants can be delivered to streams.	Subbasin Level 1 = <1 crossing/mi Level 2 = 1-2 crossing/mi Level 3 = >2 crossing/mi

[1]Ecological Condition Level 1 = Properly functioning
Ecological Condition Level 2 = At-risk
Ecological Condition Level 3 = Degraded

1.2.2 Shoreline Monitoring Elements

Shoreline monitoring elements assess the change in the condition of major river, marine, and lake shorelines over time. Figure 1.5 shows common types of shoreline changes that impact functions and values in Snohomish County.

New **hard, non-organic armoring** such as large rocks along marine, lake, or river shorelines.

Removal of **natural vegetation** along shorelines in favor of lawns, views, etc.

Planting of **natural vegetation or removal of hard armoring** along shorelines.

FIGURE 1.5: TYPICAL SHORELINE CHANGES IN SNOHOMISH COUNTY BETWEEN 2009 AND 2021.

Table 1.2 lists the shoreline monitoring elements, why they were selected, and ecological conditional levels where used.

TABLE 1.2: SHORELINE MONITORING ELEMENTS, RATIONALE FOR INCLUSION, AND ECOLOGICAL CONDITION LEVELS USED FOR EVALUATING 2009, 2021 OR CHANGED CONDITIONS.

Monitoring Element	Rationale for Inclusion	Ecological Condition Level[1]
Change in length, % of length and/or Acre in Bank Armoring	While bank armoring can protect infrastructure, it negatively impacts functions and values, particularly buffer quality, river and stream channel characteristics, sediment transport, and habitat quality.	Level 1 = <10% Level 2 = 10-20% Level 3 = >20%
Change in length, % of length in Bank Erosion	There is natural erosion along bank shorelines that is critical to natural functions and values. However, human activities can increase the rate of erosion. Increased bank erosion can lead to more sediment in streams and rivers which can harm aquatic life.	Level 1 = <10% Level 2 = 10-20% Level 3 = >20%
Change in shoreline vegetation (Lakes only)	Natural, native vegetation along lake shorelines traps and filters pollution, and	Level 1 = <30% Level 2 = 30-70%

Monitoring Element	Rationale for Inclusion	Ecological Condition Level[1]
	provides great habitat for wildlife. Decreases in vegetation along shorelines can increase pollution inputs, including sediment and phosphorus, to lakes, while reducing the quality of wildlife habitat.	Level 3 = >70%
Change in density of docks (# of docks/1000 feet[2]) (Lakes only)	Docks or overwater structures shade out native plants which provide habitat and nurseries for juvenile fish. Docks also alter substrate and water quality.	Level 1 = <3 Level 2 = 3-8 Level 3 = >8

[1]Ecological Condition Level 1 = Properly functioning
Ecological Condition Level 2 = At-risk
Ecological Condition Level 3 = Degraded
[2]The metric (# of docks/1000 ft) for the density of docks in lakes was based on the Shoreline Management Program policy (PDS, 2019).

1.2.3 Functions and Values Monitoring Elements

The functions and values monitoring elements replace the paired catchment study from the 2008 Monitoring and Adaptive Management Plan. The rationale for the change is that the paired catchment study was not pursued. However, critical area regulation necessitates evaluating the condition of functions and values in some capacity. To achieve these ends, this report will use data collected by SWM's State of Our Waters (SOW) monitoring program. While the State of Our Waters program was not implemented to specifically address CAR-related questions, the data can provide insight into the status of indicators used to assess functions and values and their dependency on buffer conditions that critical area regulations are intended to protect.

The SOW program started to collect data on stream conditions in 2018. The program also incorporates the long-standing lake health program that has been in operation since the late 1990's. Therefore, this report includes information on current conditions, but not trends, for indicators related to stream functions and values. For lakes, the report includes information on both current conditions and trends given the longer data collection time frame.

Table 1.3 lists the functions and values monitoring elements, the reason why they were selected, and the ecological criteria where used. For functions and values, a variety of ecological criteria were used to evaluate condition. The evaluation was based on the element and the scientific or regulatory threshold appropriate for that element. For example, the BIBI monitoring element was evaluated using categorical bounds in the best available science condition scale, while stream temperate was evaluated as a threshold using State surface water quality standards found in WAC 173-201A (Washington State Legislature).

TABLE 1.3: FUNCTIONS AND VALUES MONITORING ELEMENTS, RATIONALE FOR INCLUSION, AND ECOLOGICAL CRITERIA, WHERE USED FOR EVALUATING 2009, 2021 OR CHANGED CONDITIONS.

Monitoring Element	Rationale for Inclusion	Ecological Criteria
Streams – land cover for stream site evaluation	Impervious area land cover (%) and/or Forest area (%) has been used regionally to evaluate stream conditions. A continuous land cover index (LCI, where LCI=%Forest	None. Used for correlation analyses.

Monitoring Element	Rationale for Inclusion	Ecological Criteria
• **Basin scale – all upstream area from sites** • **CAR scale – all stream buffers (150 ft wide) upstream from sites** • **Local Scale – buffer land cover 1 km upstream from sites**	minus %Impervious) was calculated for areas upstream of individual stream locations. The sum of land cover values used were for Subbasin LCI (SUB_LCI_SUM), CAR LCI (CAR_LCI_SUM), and Local LCI (150_1000LCI and 150_1000LCIGRS – where the pasture/grass land cover was also included).	
Streams – % of stream miles per BIBI categories	The health of benthic invertebrate (stream bug) communities provides an indicator of stream health. Benthic invertebrate health is measured using an index of biological integrity (BIBI) that considers the type, number, and functional characteristics of benthic invertebrate species.	0 – 20 = Very Poor 20 – 40 = Poor 40 – 60 = Fair 60 – 80 = Good 80 – 100 = Excellent
Streams – % of sites that meet 2008 CAR M&AM temperature performance criteria	Water temperature is an important physical factor that influences survival of aquatic life. These performance criteria are not consistent with WA State water quality standards.	Level 1 = <14°C Level 2 = 14-16°C Level 3 = >16°C[1]
Streams – % of sites that meet 7DADMax temperature water quality standards	WA State sets temperature standards to ensure survival of fish, particularly salmonids, in different life stages. Exceedances of these temperature standards can be lethal to fish and other aquatic life.	Temperature criteria varies by location per WAC 173-201A: 12°C, 16°C, 17.5°.
Streams – % of sites per Water Quality Index (WQI) categories	Water quality conditions can impact human health as well as aquatic species. Water quality is measured with an index (WQI), which incorporates eight water quality parameters into one overall score.	0 – 20 = Very Poor 20 – 40 = Poor 40 – 60 = Fair 60 – 80 = Good 80 – 100 = Excellent
Streams – % of sites per Habitat Quality Index (HQI) categories	Habitat quality directly impacts the health of aquatic life. Habitat conditions are measured with an index (HQI) that incorporates five habitat parameters into one overall score.	0 – 20 = Very Poor 20 – 40 = Poor 40 – 60 = Fair 60 – 80 = Good 80 – 100 = Excellent

Monitoring Element	Rationale for Inclusion	Ecological Criteria
Lakes – Change in water clarity pre-2009 and 2009-2021	Water clarity is measured by cloudiness in the water column. Conditions that promote excessive algae growth and fine particles suspended in the water column cause lower water clarity. Decreased water clarity impacts lake ecology, including growth of naturally occurring aquatic plants, feeding behavior in aquatic life, and predator/prey interactions.	≤ 2.0 meters = Poor 2.0 - 3.3 meters = Fair 3.3 - 5.0 meters = Good > 5.0 meters = Excellent
Lakes – Change in algae pre-2009 and 2009-2021	Algae is an important food base in lakes and naturally occurring algal communities are beneficial to other aquatic life. Some types of algae (e.g., blue-green) increase in density in response to nutrient input from their surroundings and can generate a toxic substance dangerous to pets and humans.	> 12 ug/L chlorophyll *a* = Poor > 2.8 ≤ 6.0 ug/L chlorophyll *a* and history of toxic algae or > 6.0 ≤ 12 ug/L chlorophyll *a* and no history of toxic algae = Fair ≤ 2.8 ug/L chlorophyll *a* with history of toxic algae or > 2.8 ≤ 6.0 ug/L chlorophyll *a* and no history of toxic algae = Good ≤ 2.8 ug/L chlorophyll *a* and no history of toxic algae = Excellent
Lakes – Change in nutrient levels pre-2009 and 2009-2021	Nutrients promote an increase in some types of algal density (e.g., blue-green) and have a negative impact on lake health. Changes in nutrient levels over time indicate increasing impact from surrounding land use activities.	> 30 ug/L Epilimnion Total Phosphorus and/or > 100 ug/L Hypolimnion Total Phosphorus = Poor > 20 ≤ 30 ug/L Epilimnion Total Phosphorus and/or > 60 ≤ 100 ug/L Hypolimnion Total Phosphorus = Fair > 12 ≤ 20 ug/L Epilimnion Total Phosphorus and/or > 30 ≤ 60 ug/L Hypolimnion Total Phosphorus = Good ≤ 12 ug/L Epilimnion Total Phosphorus and/or ≤ 30 ug/L Hypolimnion Total Phosphorus = Excellent
Lakes – Change in shoreline condition 2009 and 2021	Natural vegetation along shorelines promotes beneficial conditions for aquatic life. Processes like shoreline erosion and pollution transfer to lakes are minimized when shorelines are intact.	≥ 60 % shoreline armoring = Poor ≥ 30 < 60 % shoreline armoring = Fair ≥ 10 < 30 % shoreline armoring = Good

Monitoring Element	Rationale for Inclusion	Ecological Criteria
		< 10 % shoreline armoring = Excellent

[1]Ecological Condition Level 1 = Properly functioning
Ecological Condition Level 2 = At-risk
Ecological Condition Level 3 = Degraded

1.2.4 Adaptive Management

The purpose of monitoring critical areas is to determine if actions are needed to better protect these important resources. The 2008 Critical Area Monitoring and Adaptive Management Plan laid out a framework of adaptive management. Adaptive management describes actions that are enacted when a change in conditions exceed pre-determined thresholds. The types of actions taken when thresholds are exceeded is generally tied to the magnitude or significance of the change and scaled both to avoid significant impacts to ecological functions and accommodate uncertainty in the confidence that change has occurred.

Thresholds by indicator and monitoring plan component from the 2008 Critical Area Monitoring and Adaptive Management Plan are included in Table 1.4. Thresholds 1-3 in Table 1.4 highlight the level of change required to trigger actions. Actions that should be taken when the thresholds are met include:

- Threshold 1 triggers public outreach and/or enforcement and mitigation actions.
- Threshold 2 triggers additional public outreach, enforcement, and mitigation actions; programmatic adjustments.
- Threshold 3 triggers programmatic adjustments including code revisions.

Table 1.4: 2008 Critical Area Monitoring and Adaptive Management Plan adaptive management plan framework.

Plan Component	Indicator	Threshold 1[1]	Threshold 2[2]	Threshold 3[3]
Land Cover Change – Wetlands	Wetland area by type	<5% change in any indicator across County jurisdiction within any watershed relative to baseline	5-10% change in any indicator across County jurisdiction within 2 or more watersheds relative to baseline	>10% change in any indicator across County jurisdiction relative to baseline
Land Cover Change – FWHCA riparian	Riparian forest quality/ quantity index	<3% change in any indicator across County jurisdiction within any watershed relative to baseline	3-5% change in any indicator across County jurisdiction within 2 or more watersheds relative to baseline	>5% change in any indicator across County jurisdiction relative to baseline
Shorelines	% Bank Modification	<3% change in any indicator across County jurisdiction within any watershed relative to baseline	3-5% change in any indicator across County jurisdiction within 2 or more watersheds relative to baseline	>5% change in any indicator across County jurisdiction relative to baseline

[1]Threshold 1 triggers public outreach and/or enforcement and mitigation actions.

[2]Threshold 2 triggers additional public outreach, enforcement, and mitigation actions; programmatic adjustments.
[3]Threshold 3 triggers programmatic adjustments including code revisions.

Since the monitoring elements used in this effort are not consistent with those envisioned in the 2008 CAR Monitoring and Adaptive Management Plan, the framework above needed to be adjusted to align with current efforts. Table 1.5 lists the factors and thresholds used to determine the type of adaptive management needed based on this effort.

TABLE 1.5: CURRENT CRITICAL AREA MONITORING ADAPTIVE MANAGEMENT FRAMEWORK.

Plan Component	Monitoring Element	Threshold 1[1]	Threshold 2[2]	Threshold 3[3]
Land Cover Change – Wetlands	%Positive minus %Negative Change in Wetland + Wetland Buffer	<5% change across County jurisdiction within any subbasins relative to baseline	5-10% change across County jurisdiction within 2 or more subbasins relative to baseline	>10% change across County jurisdiction relative to baseline
Land Cover Change – FWHCA riparian	%Positive minus %Negative Change in Stream + Lake + Marine Buffer	<3% change across County jurisdiction within any subbasins relative to baseline	3-5% change across County jurisdiction within 2 or more subbasins relative to baseline	>5% change across County jurisdiction relative to baseline
Shorelines	% Bank Armoring	<3% change across County jurisdiction within any watershed relative to baseline	3-5% change across County jurisdiction within 2 or more watersheds relative to baseline	>5% change across County jurisdiction relative to baseline

[1]Threshold 1 triggers public outreach and/or enforcement and mitigation actions.
[2]Threshold 2 triggers additional public outreach, enforcement, and mitigation actions; programmatic adjustments.
[3]Threshold 3 triggers programmatic adjustments including code revisions.

Applying the Adaptive Management Framework requires a two-step process:

1. Data for each monitoring element was summarized at the subbasin level to determine a threshold level, based on percent change in the monitoring element. For example, percent positive minus percent negative change in wetland plus wetland buffer data was summarized for a subbasin to determine if the subbasin had <5%, 5%-10%, or <10% change. The report includes tables and figures with the Adaptive Management Thresholds by subbasins.
2. Data from above was evaluated at the subbasin (Figure 1.2) and CAR Study Area (Figure 1.1) scales to determine the threshold level for the entire CAR Study Area for the specific monitoring element. The language for evaluation is different at each threshold, as is the geographic scale of the data evaluation:
    a. Threshold 1 = "Change across County jurisdiction within any subbasin relative to baseline"
        i. Translation: If only one **subbasin or watershed** in the County met (and did not exceed) the percentage, then Adaptive Management Threshold 1 actions would be triggered.

b. Threshold 2 = "Change across County jurisdiction within 2 or more subbasins relative to baseline"
    i. Translation: If two or more **subbasins or watersheds** met the percentage, then Adaptive Management Threshold 2 actions would be triggered.
c. Threshold 3 = "Change across County jurisdiction relative to baseline"
    i. Translation: If the data summarized **at the CAR Study Area level** met the percentage, then Adaptive Management Threshold 3 actions would be triggered.

Adaptive Management Threshold determinations are included within Section 2.3 and Section 3.5.

2.0 Land Cover Methods and Results

This section discusses the methods and results from the land cover analyses.

2.1 Land Cover Methodology

Land cover was evaluated using remote sensing data and Geographic Information System (GIS) technology. The first step was to develop land cover maps for 2009 and 2021 (Figure 2.1). These maps classify the conditions of the land by category such as whether the location has water, impervious surface, forest, etc. Land cover was mapped using an Artificial Intelligence (AI) technique called the Convolutional Neural Network (CNN) in an Object-Based Image Analysis (OBIA) scheme. Identifying land cover is an iterative process, where results are evaluated by qualified personnel and, when needed, additional ground control points are collected and the CNN model is updated, and processes are rerun until the resulting land cover products meet the accuracy standard (See Appendix C).

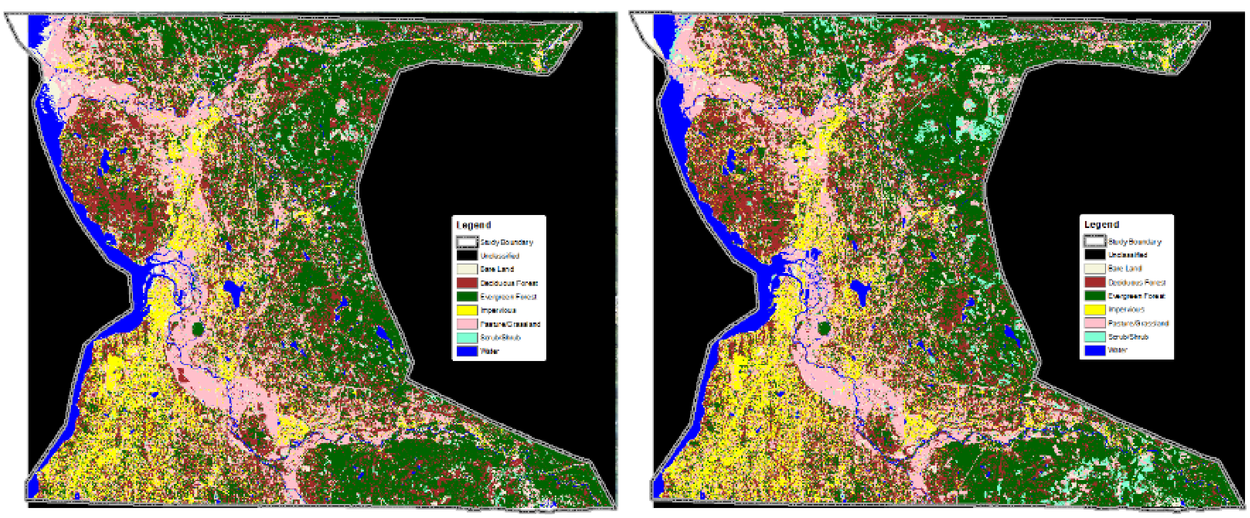


FIGURE 2.1: 2009 AND 2021 7-CLASS LAND COVER MAPS.

To ensure the 2009 and 2021 land cover maps were correct, a rigorous accuracy assessment was conducted on the 2021 7-class land cover map (Figure 2.1). The accuracy was found to be 90%. The accuracy assessment identified that the primary area of confusion was differentiating scrub/shrub land cover from pasture/grassland and forest from scrub/shrub. Because of the potential impact to results, an improvement in accuracy levels was desired. Therefore, land cover classes where accuracy levels were lower and that had similar hydrologic function were grouped together into one class. The result was grouping bare/pasture/grassland/scrub/shrub into one category. This improved the accuracy to 96%. The final output used for land cover change detection was a 4-class land cover product, with the following four classes: Forest, Impervious, Pasture/Grassland/Bare/Shrub, and Water (Figure 2.11 and Figure 2.12).

Next, the 2009 and 2021 4-class maps were compared via the AI-driven process to identify where land cover had changed. For precise change identification, change ground control points (GCPs) were gathered to train a CNN-based AI model. Subsequently, based on the change detection results, additional GCPs were acquired to refine and update the model. This was an iterative AI approach that is accurate and adaptable across different environmental conditions. The approach consists of looking for a change from one land cover category to another, such as a change from forest to water or from impervious to pasture/grassland/bare/shrub. Figure 2.2 shows where land cover changed from one land cover category to a different land cover category between 2009 and 2021.

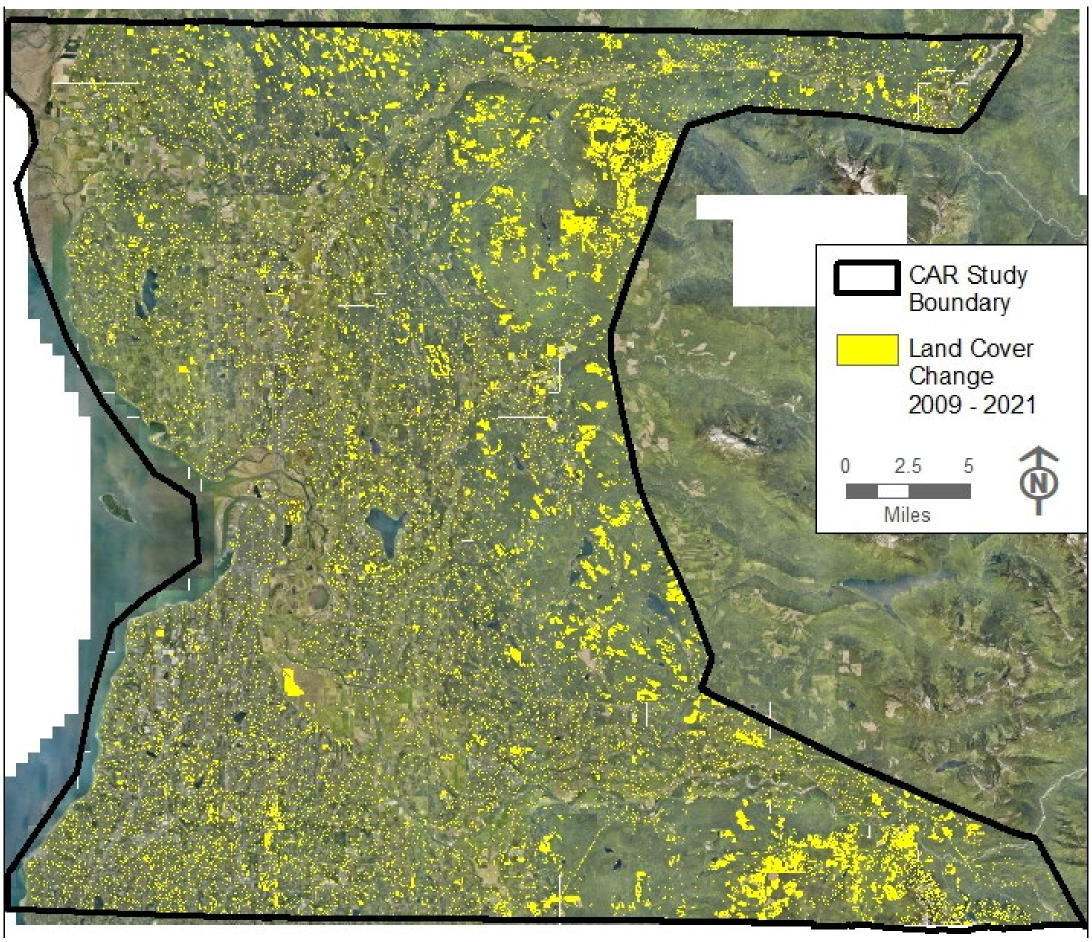


FIGURE 2.2: LAND COVER CHANGE FROM 2009 TO 2021.

Finally, to determine land cover change impact on hydrologic function, a four-class change matrix (Figure 2.3) was created. This matrix interprets land cover change as having a negative or positive hydrologic impact, depending on how land cover was converted. The composition and total areas of positive changes and negative changes were summarized for each geographic scale and combined to represent a net positive-negative change value. For, example, if a subbasin had 5% positive change types and 10% negative change types, then the net positive-negative change equals -5%.

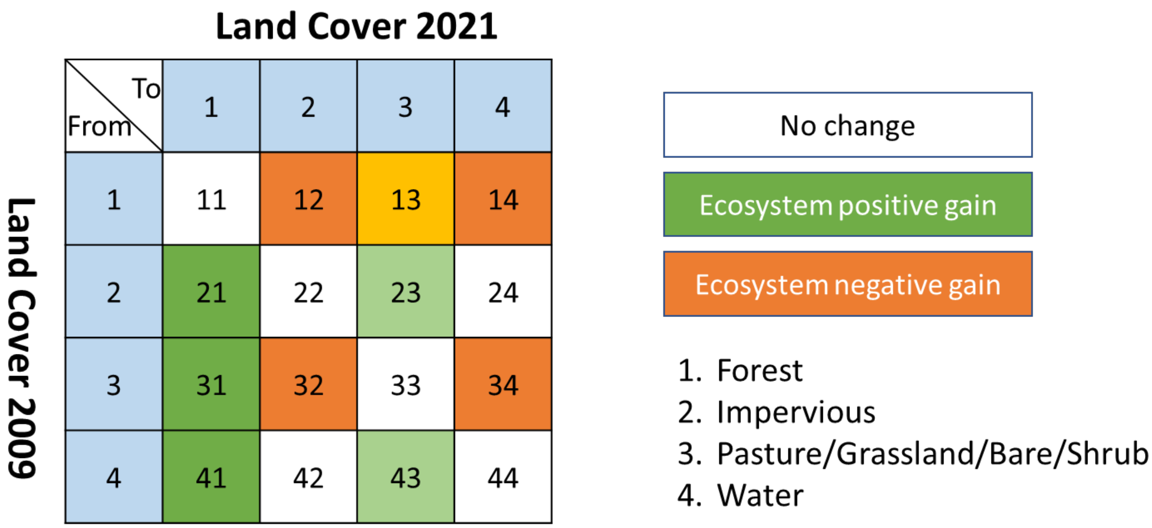


Figure 2.3: Land cover change matrix from-to change types and denotation of positive or negative effect.

The resulting dataset is technically sound and the best available science. However, as with all data, there are caveats and limitations that impact interpretation of the results. The caveats and limitations of the land cover data and how they impact the interpretations of results are discussed more fully in Section 2.1.3.

2.1.1 Stream, Lake, and Marine Riparian Buffers Methodology

Riparian buffers had to be created around stream, lake, and marine waterbodies. To create the buffers, two pieces of data are needed: 1) the location of the waterbodies and 2) the size of the buffers around the waterbodies. To identify the location of streams, lakes, and marine waterbodies, the County waterbody layer was used as a starting point. As shown in Table 2.1, SCC 30.62A.320 was used in general to determine buffer sizes (Snohomish County, 2015).

Table 2.1: Waterbody type and buffer sizes in Snohomish County Code 30.62A.320.

Critical Area Type	SCC Buffer Width
Stream/lake type “S” – typically both right and left bank shorelines are delineated and buffered landward. All river banklines were reviewed and updated in 2021. Lake shorelines are used to create the buffer.	150 feet
Stream/lake type “F” with anadromous fish species – a stream centerline is used to create the buffer or lake shorelines are used to create the buffer. Applies to all below.	150 feet
Stream/lake type “F” without anadromous fish species	100 feet
Stream/lake type “Np”	50 feet
Stream/lake type “Ns”	50 feet
Stream/lake type “U”	N/A

Marine waters – The marine shoreline at the vegetated boundary is used and the buffer extends landward.	150 feet

As with the land cover data, there are caveats and limitations to the County's waterbody layer and with the methodology used to apply buffers. These caveats and limitations and how they impact the interpretations of results are discussed more fully in Section 2.1.3.

See Appendix C for more detailed information on buffer methodology.

2.1.2 Wetlands and Wetland Buffer Methodology

Wetlands were compiled for mapping and analysis purposes from the best available sources in Snohomish County. Wetlands and their buffers require special consideration and assumptions. For wetlands, the size of buffer required is based on the wetland category and adjacent land use – a determination that may not be known until there is a proposed development and an onsite evaluation is completed. Hence, these data are not available for nearly all the wetlands in the County.

Multiple data sources were used for wetland critical area evaluation because there is no comprehensive wetlands dataset. Wetland maps were developed by merging data from the National Wetland Inventory, or NWI (USFWS; downloaded from USDA Ag Data Commons, 2022), field surveyed wetlands, County wetlands inventory, and the 2007 SWM wetland predictive model. The NWI is not inclusive of all wetlands even though it is the most comprehensive dataset available and wetland boundaries are questionable. The field surveyed wetland maps generally only include those areas where development occurred and are often not comprehensive of an entire wetland unit (only the wetland extent within a property boundary where development is occurring is mapped). The County wetlands inventory is also an outdated dataset; while wetland boundaries are better than NWI wetlands, it does not cover the extent of the CAR Study Area. For this reason, the 2007 SWM wetland model was incorporated into the dataset. The model uses a topographic wetness index, which is an indicator to estimate the ability of the land to hold water, soil type, and other characteristics to predict the location of wetlands. The Snohomish County Comprehensive Plan (2022) used the same compilation of wetland datasets. These datasets are also publicly available on the Snohomish County PDS map portal (PDS).

Figure 2.4 shows the number of wetland acres by different wetland data sources after processing the datasets for the CAR Study Area.

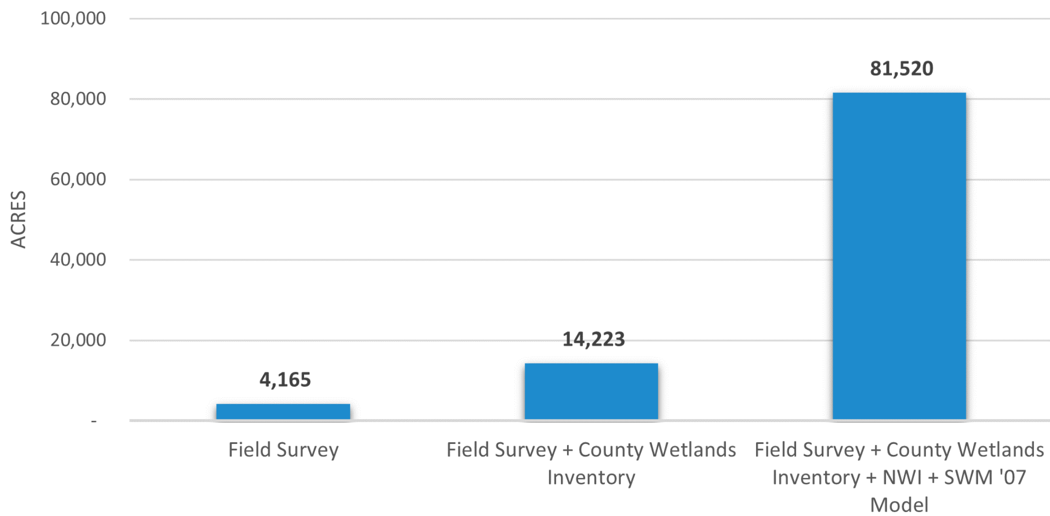


FIGURE 2.4: ACRES OF WETLANDS BY WETLAND DATA SOURCE.

To create buffers, the best option available given data limitations was to use a buffer size most implemented in the County. Through discussion with PDS, it was determined that the current wetland buffer size generally required is 60 to 75 feet (Sean Curran, pers. comm.). Therefore, a 75-foot wetland buffer was applied to all wetlands. This of course introduces error both by overestimating buffer size in some areas and underestimating it in others.

The caveats and limitations of the wetlands data and how they impact the interpretations of results are discussed more fully in Section 2.1.3.

See Appendix C for more detailed information on wetland and wetland buffer methodology.

2.1.3 Impacts of Land Cover Data Limitations and Caveats on Interpretation of Results

SWM used the best available data and tools to analyze land cover, identify waterbodies (including wetlands), and create buffers given the time and resources available for this effort. However, all data has limitations that impact the accuracy of results. Resource managers should understand these limitations as they interpret the results of this study and consider future efforts to manage critical areas and their buffers.

Table 2.2 provides a summary of the data types used in the land cover analyses and the limitations or major issues with the dataset that have implications for interpretations of the results.

TABLE 2.2: DATA SOURCE USED FOR LAND COVER ANALYSES AND ASSOCIATED LIMITATIONS FOR INTERPRETATION OF RESULTS.

Data Source/ Type	Limitations and Issues
National Agriculture Imagery Program (NAIP) Aerial imagery	• Both 2009 and 2021 imagery were captured during the leaf-on season, introducing heightened uncertainty in mapping impervious surfaces beneath tree canopies. • The image quality in 2009 was compromised by lower pixel resolution and less mature mapping technology compared to the superior image quality in 2021.

Data Source/ Type	Limitations and Issues
	• Inaccuracies in image registration between the two years resulted in elongated and imprecise change detections along roadways and within vegetation areas. • Relying solely on imagery for vegetation mapping posed limitations in distinguishing trees from scrub/shrub. The utilization of a Digital Surface Model (DSM) developed through Structure from Motion (SfM) is strongly recommended for enhanced vegetation mapping. • 2021 had a missing section along the Stillaguamish River. • Tree shading of roads, roofs, and other areas can interfere with correctly identifying change. • Tidal cycle sometimes differed between imageries (for example, if 2009 imagery was captured at low tide and 2021 imagery was captured at high tide). • Natural environmental changes, such as tree growth, tree loss, landslides, channel migration, and other vegetation changes are designated as “change”. • Waterbody delineation in narrow channels or vegetated corridors were challenging due to shadows and visibility issues. Accurate stream mapping may help improve waterbody delineation.
PDS Waterbody layer	• Not all streams are mapped. • Stream mapping cannot be assumed to be geographically precise in all cases. In other words, not all streams in Snohomish County are in the exact georeferenced location as where the map reports.
Stream buffers	• Buffers were applied to stream centerlines. Centerline location to true location accuracy is known to be problematic but is constantly improving. Therefore, the outside edge of the buffer may also extend beyond where the true buffer lies if it were to be verified by a field biologist. • Variances in buffer sizes are allowed under Snohomish County code and could not be independently accounted for in the data analysis.
Wetland buffers	• Wetland boundaries were approximated based on available data. • A 75-foot buffer was applied to all wetlands. Wetland buffer sizes range from 40-feet to 225-feet in Snohomish County code based on wetland category and land use proposal. Therefore, some wetland buffers are likely underestimated, and some are overestimated, but this 75' buffer width represents a typical and common width required by permitting.

Data Source/ Type	Limitations and Issues
	• Variances in buffer sizes are allowed under Snohomish County code and could not be independently accounted for in the data analysis.
National Wetland Inventory (United States Fish and Wildlife Service)	• This is an outdated dataset. • This dataset is missing some wetlands, especially forested and small wetlands.
Field surveyed wetland data	• Only includes wetlands where development activity occurred that triggered a wetland delineation by a County department. Also included are wetlands mapped by Tulalip Tribal staff, which is a more holistic dataset of wetlands on the Tulalip Tribal Reservation. • For those wetlands mapped for a development activity, only the portion of the wetland on the parcel(s) where the development occurred is mapped. If the boundary of the wetland expands beyond where the development occurred, this area is not included in the data.
County wetlands inventory	• This is an outdated dataset. • Dataset does not cover the entire CAR Study Area.
SWM wetland predictive model	• Based on older data, this model should have been updated based on recommendations starting with 2012 CAR Monitoring efforts. • The model predicts where wetlands would be based only on natural characteristics important for wetland formation. It does not consider how the land has been changed by development over time.
Critical Area Site Plans (CASPs)	• Only a subset of CASPs are in a GIS format that can used for analyses. New CASPs are available in PDF format and finding appropriate documents is labor intensive. • The quality of individual CASPs varies greatly. Some are handwritten with little or no precise geographic referencing while others are more accurate. • The level of detail varies between CASPs. Identifying critical areas versus buffers versus other open space was not always possible. • Analysts were unable to verify if the CASP used was the most up to date CASP.

Table 2.3 illustrates how the most impactful limitations and issues can influence the results.

TABLE 2.3: SUMMARY OF WATERBODY, DATA LIMITATIONS, AND HOW THE LIMITATIONS IMPACT RESULTS.

Data Type	Data Limitation	Impact on Results
Streams	• Stream location is not always accurate. When buffers are applied, the buffer edges are therefore not always accurate.	• Overestimate impacts to stream buffers, especially in urban areas. • Underestimate impacts to stream buffers.
	• Not all streams are mapped.	• Underestimate impacts to stream buffers.
Wetlands	• Wetland location is not always accurate. When buffers are applied, the buffer edges are therefore not always accurate.	• Overestimate impacts to wetlands and their buffers in some locations including urban areas. • Underestimate impacts to wetlands and their buffers, particularly to small wetlands and forested wetlands.
	• Not all wetlands are mapped and some mapped wetlands don't exist on the landscape.	• Overestimate impacts to wetlands and their buffers. • Underestimate impacts to wetlands and their buffers.
	• A 75-foot buffer was applied to all wetlands when County Code requires buffers ranging from 25 to 300 feet depending on wetland category and land use.	• Overestimate impacts to wetlands and their buffers. • Underestimate impacts to wetlands and their buffers, particularly to the most ecologically important wetlands.
CASPs	• CASP data is not easily accessible in the format needed for use in CAR Monitoring analysis. • The quality and quantity of information available on CASPs is highly variable.	• Large increase in standard error in estimates of impacts to critical areas in areas where development occurred. • Lack of ability to holistically evaluate effectiveness of CAR at Countywide level. Current approach is to subsample or use a pilot study area approach.

2.1.4 Pilot Study – Evaluating Data Limitations on Results and Evaluating Impacts to Sites with Permitted Development

SWM conducted a pilot case study with the goals of:

1. **Evaluating the impact of data limitations on results**: This evaluation elucidated the degree to which buffers generated from two scenarios changed results. The first scenario, referred to as "map-based", estimated impacts to buffers using the PDS waterbody, NWI, field surveyed wetlands, County wetlands inventory, and SWM wetland model data. The second scenario, referred to as "CASP-digitized", estimated impacts to buffers based only on the field-verified buffer location digitized from the CASP or other documents. There is recognized error in the presence and location of wetlands, streams, and

rivers in the "map-based" dataset (see Section 2.1.3). These errors impact buffer placement and can create outer buffer locations that are mistakenly offset (wider or narrower) than their actual extent on the ground. A quantitative analysis of error can be computed by comparing the results of the two scenarios. For this component of the pilot study, two areas were selected for analysis, one that would represent urban areas that have seen high levels of development and one that would represent rural areas with less intense development pressure (Figure 2.5).

2. **Evaluating impacts to critical areas associated with permitted development**: This evaluation looked at parcels with CASPs to determine if land cover had changed within the CASP-delineated critical area and buffer boundaries. The level of detail available allows a fine-scale evaluation to see whether critical areas are protected at sites that were developed between 2009 and 2021. All CASPs from across the County that were in a useable format were included in this analysis.

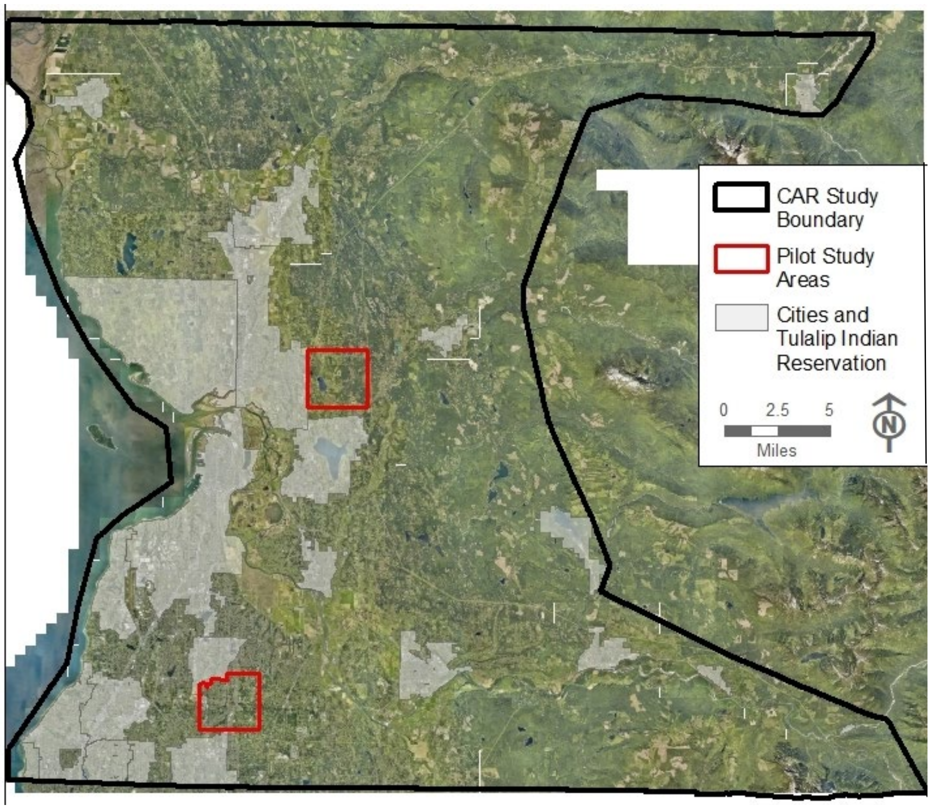


FIGURE 2.5: PILOT STUDY AREAS. THE NORTH AREA IS REFERRED TO AS THE "RURAL" PILOT AREA AND THE SOUTH AREA IS REFERRED TO AS THE "URBAN" PILOT AREA.

2.1.4.1 Evaluating Data Limitations on Results Based on Two Pilot Areas

In the two pilot areas, SWM used PDS waterbody, NWI, field surveyed wetlands, County wetlands inventory, and SWM wetland model data to create a "map-based" scenario that would estimate impacts to buffers.

A subset of field-delineated and mapped wetlands were also compiled in GIS forming the "CASP-digitized" dataset. These known locations were identified from CASPs, development applications, plat maps, and delineated and mapped drainage facility or road rights-of-way. Other known buffer boundaries were defined for streams within the pilot areas.

Land cover changes for this subset of more spatially accurate critical areas buffers and wetlands were examined. Figure 2.6 highlights the detected land cover changes within the urban pilot area, and Figure 2.7 highlights the detected land cover changes within the rural pilot area.

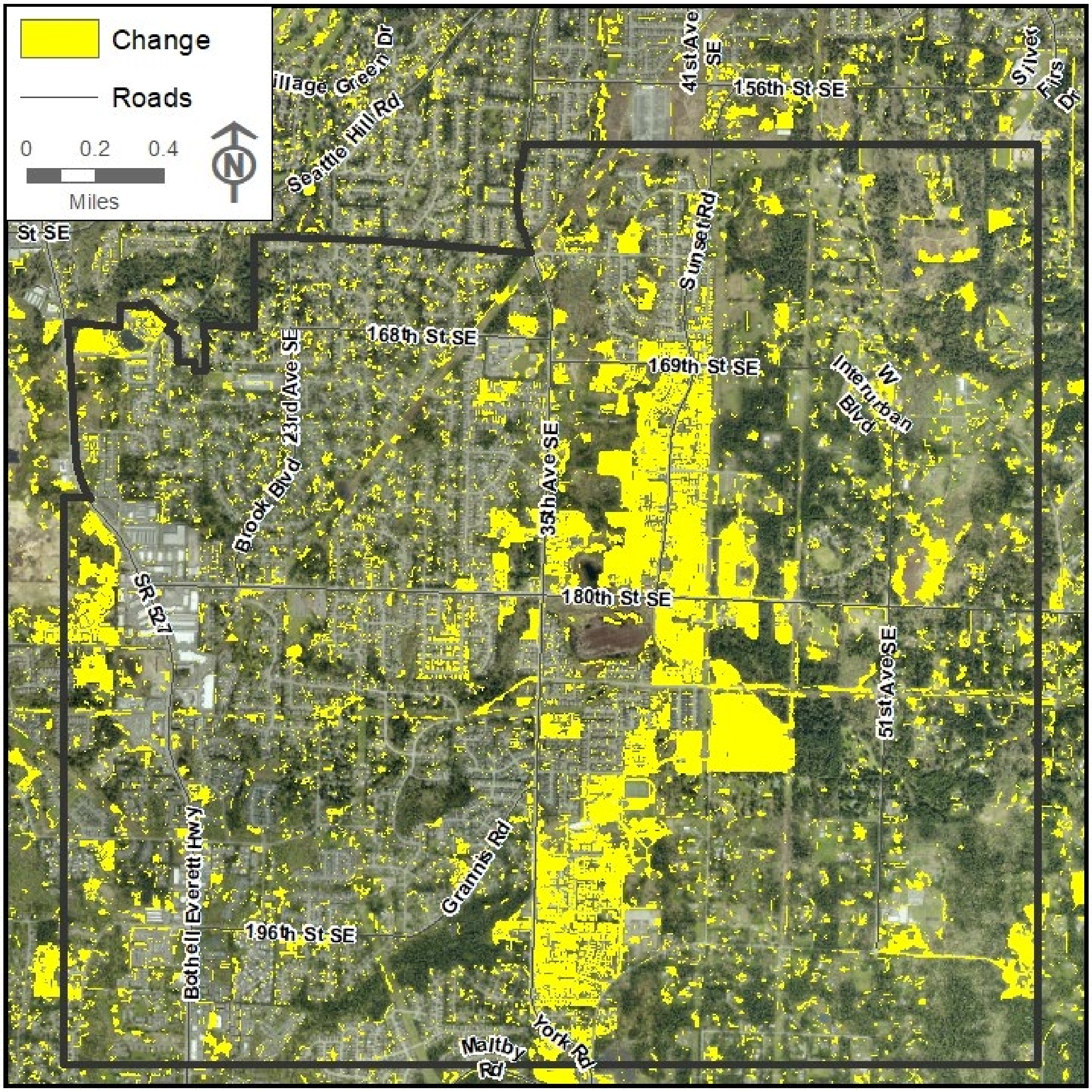


FIGURE 2.6: LAND COVER CHANGE BETWEEN 2009 AND 2021 IN THE URBAN PILOT AREA.

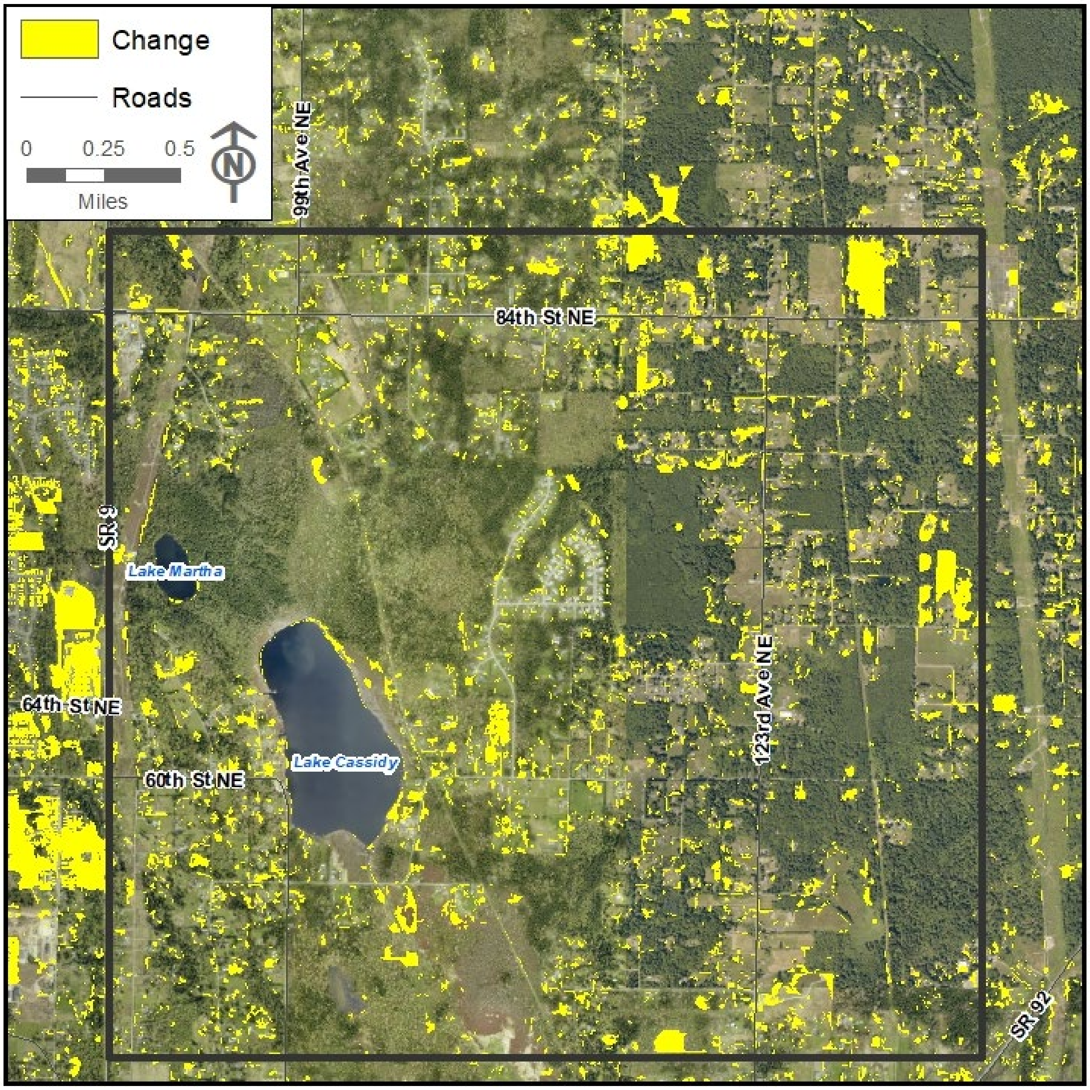


FIGURE 2.7: LAND COVER CHANGE BETWEEN 2009 AND 2021 IN THE RURAL PILOT AREA.

CASPs were then overlaid to identify field verified critical areas and buffers. This was compared to critical areas and buffers from the "map-based" data. Protected areas identified using the "CASP-digitized" scenario are shown in red and protected areas identified using the "map-based" scenario are shown in green in Figure 2.8 and Figure 2.9.

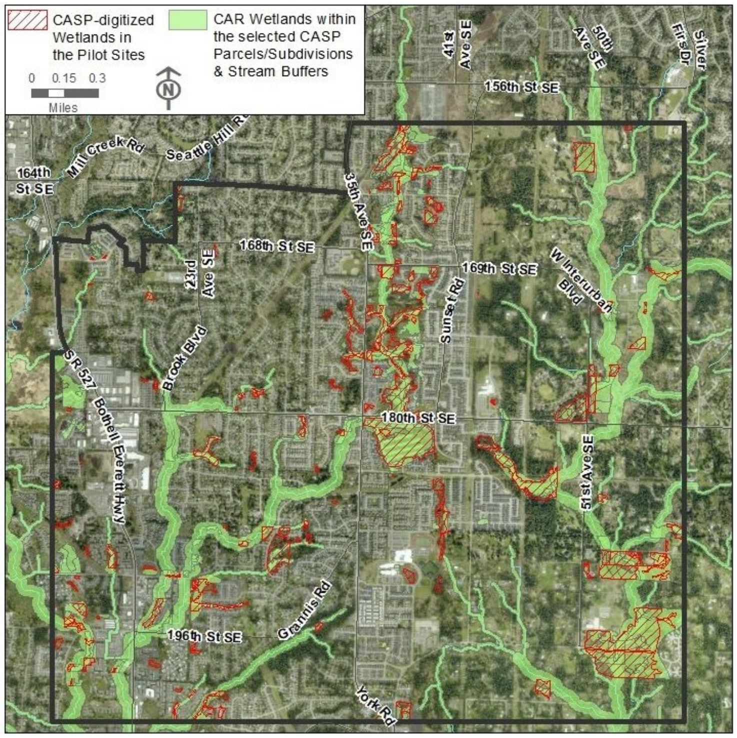


FIGURE 2.8: URBAN PILOT AREA WITH PROTECTED AREAS IDENTIFIED USING THE "CASP-DIGITIZED" SCENARIO SHOWN IN RED AND PROTECTED AREAS IDENTIFIED USING THE "MAP-BASED" SCENARIO SHOWN IN GREEN.

FIGURE 2.9: RURAL PILOT AREA WITH PROTECTED AREAS IDENTIFIED USING THE "CASP-DIGITIZED" SCENARIO SHOWN IN RED AND PROTECTED AREAS IDENTIFIED USING THE "MAP-BASED" SCENARIO SHOWN IN GREEN.

(See Appendix C for more detailed information on pilot area methodology.)

Table 2.4 shows land cover change results from the pilot areas for the “scenarios.” For each scenario, there was a loss in forest acreage and an increase in impervious area. However, the amount of change found using the “CASP-digitized” method was less than the amount of change detected using the “map-based” method. This was particularly true in the urban pilot area, where the total positive-negative change was calculated to be -9.8% of the total buffer area using the “map-based” method area. By comparison, the positive-negative change for “CASP-digitized” method was -3.5%. The difference between the two scenarios was less in the rural area (-2.6% for “CASP-digitized” vs -3.1% for “map-based”).

The “CASP-digitized” scenario is limited to locations where CASPs exist, and information was sufficient to map exact critical area boundaries and buffers. The “map-based scenario” (shaded green in Figure 2.8 and Figure 2.9) includes all mapped buffers based on the best available resources from throughout the CAR Study Area. The extent of the “map-based” method is greater and includes more stream buffers, whereas the “CASP-digitized” method includes more wetlands.

TABLE 2.4: RURAL AND URBAN PILOT AREA LAND COVER CHANGES (ACRES/%) COMPARING DELINEATED CASP BOUNDARIES AND ALL GENERAL BUFFERS.

Pilot Area		Year/ Change	Acres		Percent (%)		Percent (%) Change		
			Forest	Impervious	Forest	Impervious	Pos	Neg	P/N
RURAL	Pilot Area CASPs	2009	375.5	4.9	80.0	1.0			
		2021	370.0	7.7	78.8	1.6			
		Change	-5.5	2.8	-1.2	0.6	1.2	3.8	-2.6
	All Buffers	2009	1,696.3	66.7	73.7	2.9			
		2021	1,679.1	83.5	72.9	3.6			
		Change	-17.2	16.8	-0.7	0.7	1.4	4.5	-3.1
URBAN	Pilot Area CASPs	2009	428.1	4.0	78.8	0.7			
		2021	424.5	7.7	78.2	1.4			
		Change	-3.6	3.7	-0.7	0.7	2.7	6.2	-3.5
	All Buffers	2009	982.8	132.7	68.8	9.3			
		2021	893.2	195.3	62.5	13.7			
		Change	-89.7	62.6	-6.3	4.4	1.7	11.5	-9.8

The findings of the pilot area study highlight differences between “map-based” buffers and “CASP-digitized” protected areas and their buffers. Figure 2.10 shows one example of a field-identified and mapped CAR-digitized polygon and a “map-based” outline based on a stream watercourse centerline. New development that changed from forest to impervious area is shown (right panel). New impervious overlaps with the stream buffer in the “map-based” scenario but does not overlap with the field-identified, “CASP-digitized” scenario (brown polygon in left panel). The impact of these findings is the potential for overestimating impacts to critical area buffers, especially in urban areas where more dense development occurs and where infrastructure is often built right up to an approved buffer edge.

FIGURE 2.10: FIELD BIOLOGIST VERIFIED (CASP-DIGITIZED) CRITICAL AREAS (BROWN) DO NOT ALIGN WITH THE LOCATION OF "MAP-BASED" STREAM BUFFERS (BLUE LINES). THIS CAN LEAD TO OVERESTIMATING IMPACTS (WHERE YELLOW SHOWS BUFFERS HAVE INCREASED IMPERVIOUS AREA) COMPARED TO BENIGN OR POSITIVE CHANGES (MOSTLY GREEN AREA) ACTUALLY OVERLAPPING THE CASP-DIGITIZED POLYGON.

2.1.4.2 Evaluating Impacts to Critical Areas Associated with Permitted Development from Countywide Critical Area Site Plans (CASPs)

SWM analyzed CASPs from around the County for land cover changes within field-mapped critical areas and buffers. SWM used a combination dataset that included digitized CASPs that were used in a 2007-2009 SWM CAR Study, a 2009 to 2013 PDS CAR Study, and a 2013-2018 PDS CAR study. The total area evaluated was 3,066 acres, of which 2,268 acres were forest in 2009.

Approximately 50 acres of forest cover changed between 2009 and 2021 (Table 2.5). Impervious area increased by 31.6 acres (1%). Considering other positive and negative land cover changes, the total estimated change was -3.8 % of the total area. This -3.8% value is relatively close to the pilot area changes of -2.6% and -3.5% for rural and urban areas, respectively, found in the above analysis and likely represents the level of buffer changes affiliated with buffers protected.

SWM was unable to determine the source or type of impact for each land cover change and could not scrutinize each instance of land cover change that led to a higher calculated rate of change compared to known CASPs or other delineated buffers.

TABLE 2.5: LAND COVER CHANGE AMONG COUNTY-WIDE DIGITIZED CASPS PREVIOUSLY EVALUATED FOR CRITICAL AREA IMPACTS.

All CASPs	2009	2021	Change
Forest Acres	2,268.4	2,218.4	-50.0
Impervious Acres	25.6	57.2	31.6
Forest %	74.0	72.4	-1.6%
Impervious %	0.8	1.9	1.0%
Positive %			1.6%
Negative %			-5.4%
P/N %			-3.8%

To provide context to the SWM results, PDS has evaluated impacts to critical areas multiple times since 2008. When PDS evaluates critical area impacts to permitted development sites, a randomly selected number of digitized CASPs from a selected time frame are compared to aerial photos to determine if intrusions into critical protection areas have occurred. Critical area protection areas include both the waterbody and the buffer (i.e., wetland + wetland buffer would be evaluated for impact). The two most recent studies occurred in 2019 for the Shoreline Management Program (SMP) periodic review and a 2020 review for CAR (see Appendix B).

The 2019 SMP periodic review used 197 randomly selected CASPs recorded between June 1, 2013, and Jun 1, 2015. After 2-4 years since the CASP was recorded, the study found that 0.32% of the critical area protection area had a disturbance, or 1.03 acres out of 321.49 acres. The most common disturbance was construction of small sheds within the critical area protection area. Driveways, mowed areas, and vegetable gardens were also seen to encroach within protected areas.

The 2020 review included 644 CASPs recorded between 2016-2018, totaling 1,948 acres. Approximately one in four, or 25%, of the CASPs contained unpermitted impacts after approximately 2-4 years. The total acre impacted was 14.9 acres, or <0.8% of the total CASP acreage.

Table 2.6 summarizes the findings of the three studies.

TABLE 2.6: PERMITTED DEVELOPMENT IMPACTS TO CASP-DELINEATED CRITICAL AREAS AND BUFFERS.

Study	Total Acres	Acres of CASPs impacted	Percent Change
SWM Study	3,066	116.5	-3.8%
2019 PDS SMP Study	321.49	1.03	-0.3%
2020 PDS CAR Study	1,948	14.9	-0.7%

Based on the results, the estimated impacts are similar enough, when standardized to a 3-year period, to be confident in the likely range of impacts associated with permitted development. Differences between SWM and PDS results can partially be attributed to the vastly different time periods where PDS reviews were generally of a two-to-four-year time frame after CASP recording and SWM's review was up to 12-years after CASP recording. That longer time frame showed a greater accumulation of change could occur. The difference in approaches to change evaluation – visual inspection of air photos versus land cover raster-based classification of change detection, also contributed to the differences between the PDS and SWM studies.

2.2 Land Cover Change Results

This section covers the results of the land cover change analyses.

2.2.1 Landscape Change Results

Between 2009 and 2021, there was an overall change in impervious area (+7,791 acres) and a decrease in forest area (-21,415 acres) within the CAR+Cities+Tulalip area (no excluded areas) (Figure 2.11 and Figure 2.12). This is consistent with a County undergoing a lot of development.

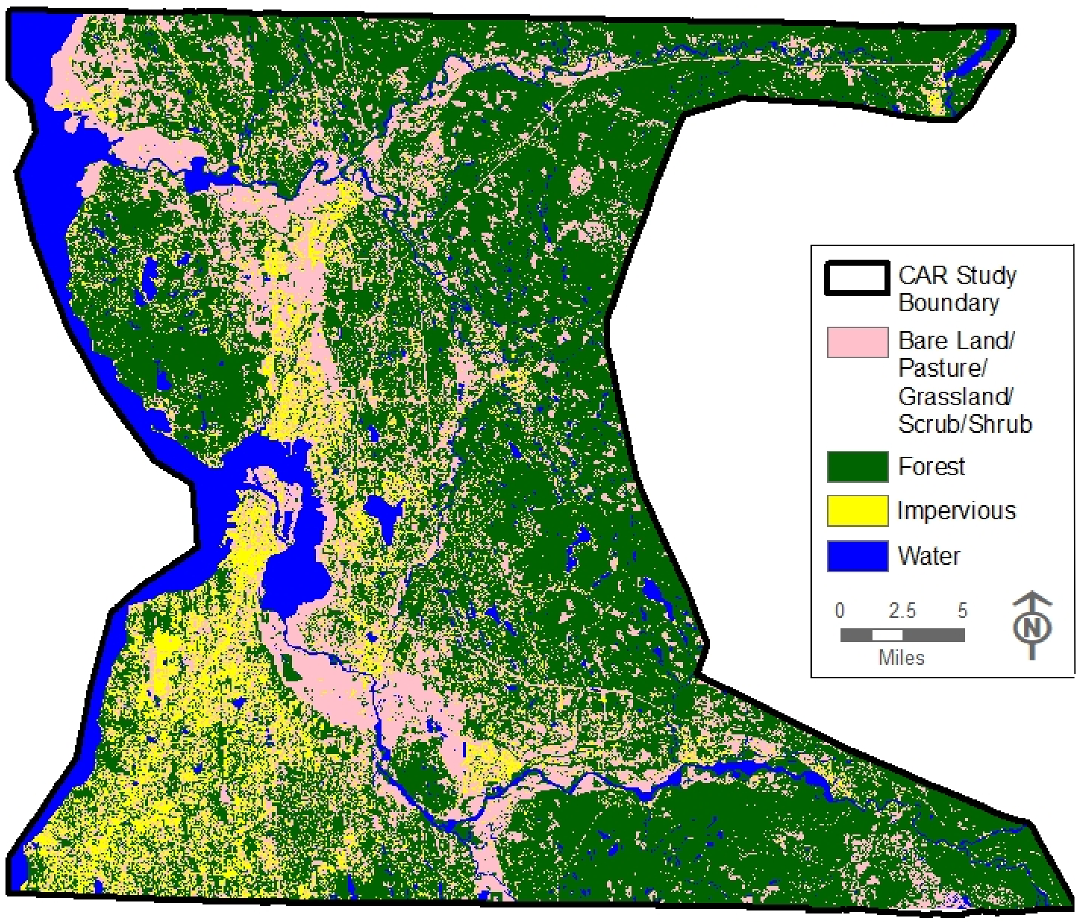


FIGURE 2.11: 2009 4-CLASS LAND COVER MAP.

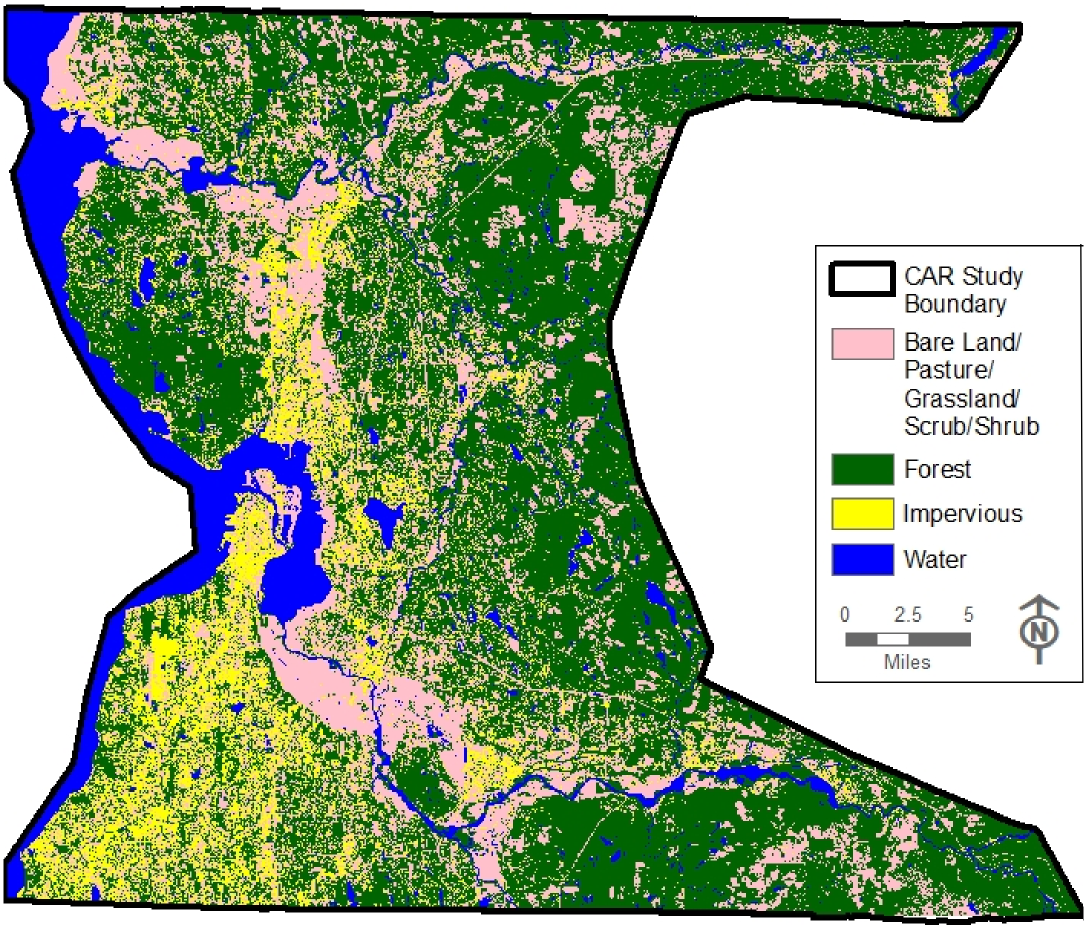


FIGURE 2.12: 2021 4-CLASS LAND COVER MAP.

The percentage of impervious surface change ranged from +8.39% in Lyon Creek, an urban subbasin in south County to +0.01% in Boulder River subbasin, a forested subbasin in northeast County near Darrington (Figure 2.13). The greatest increase in percent impervious area was associated with existing areas of higher impervious land cover in the south County, including Lyon Creek and North Creek. In consideration of the ecological thresholds for impervious area cited in

Table 1.1 (i.e., <7%, 7-12%, >12% Impervious), one subbasin (Lower Pilchuck River) increased from 7-12% (at-risk) to >12% (degraded), while 4 subbasins (Little Pilchuck Creek, Harvey Armstrong Creek, Church Creek, Port Susan Drainages) increased categories from <7% (properly functioning) to 7-12% (at-risk) during the time period.

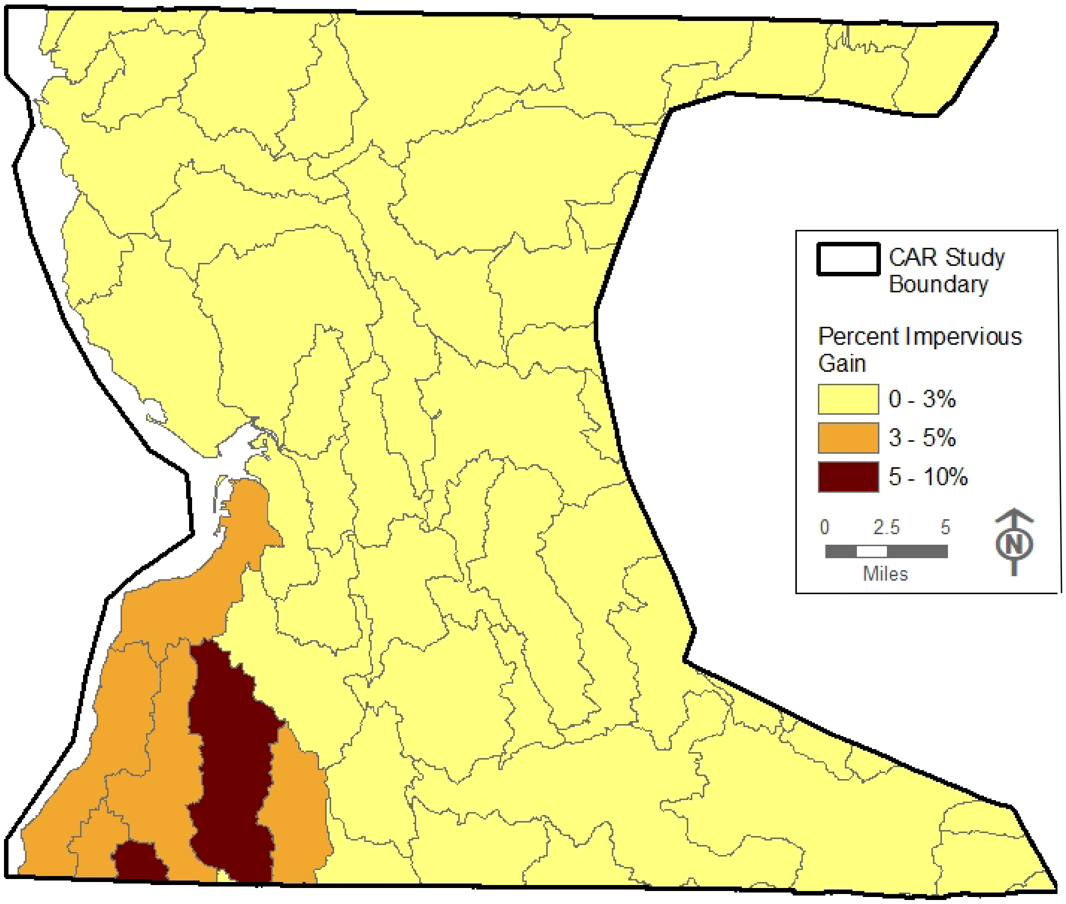


FIGURE 2.13: IMPERVIOUS CHANGE BETWEEN 2009 AND 2021 BY ECOLOGICAL CONDITION LEVELS.

There was a decline in forest cover in urban and rural areas (Figure 2.14). Among 51 of 58 (88%) subbasins, there was a decrease in forest cover over the time period. Forest change ranged from -17.02% in Upper Canyon Creek to +6.87% in Olney Creek (Table 2.7), both rural subbasins. Most of the net forest cover change, 63% or 13,543 acres, occurred in 11 rural subbasins in the northeast and southeast CAR+Cities+Tulalip area. Each of the 11 rural subbasins had >500 acres of forest cover change. Changes in forest cover have a wide range of causes and are not necessarily permanent, unlike increases in impervious surfaces. In these 11 rural subbasins combined, the amount of forest acreage that changed directly to impervious area, a sign of more impactful and permanent change, was 422 acres (or 3.1% of 13,543 acres). In both Upper Canyon Creek and Olney Creek, the net-negative and some positive changes in forest cover are likely due to both harvest and re-growth of forest as part of timber harvesting, for which County CAR do not apply. The main driver of the remaining net-negative forest change in rural subbasins similarly is timber harvesting. In urban areas, only North Creek and Swamp Creek had >500 acres of forest loss (1,463 acres total). Impervious area gains in Swamp and North Creeks combined totaled 701 acres (or 48% of 1,463 acres). This result highlights that growth and development is being focused in existing urban areas.

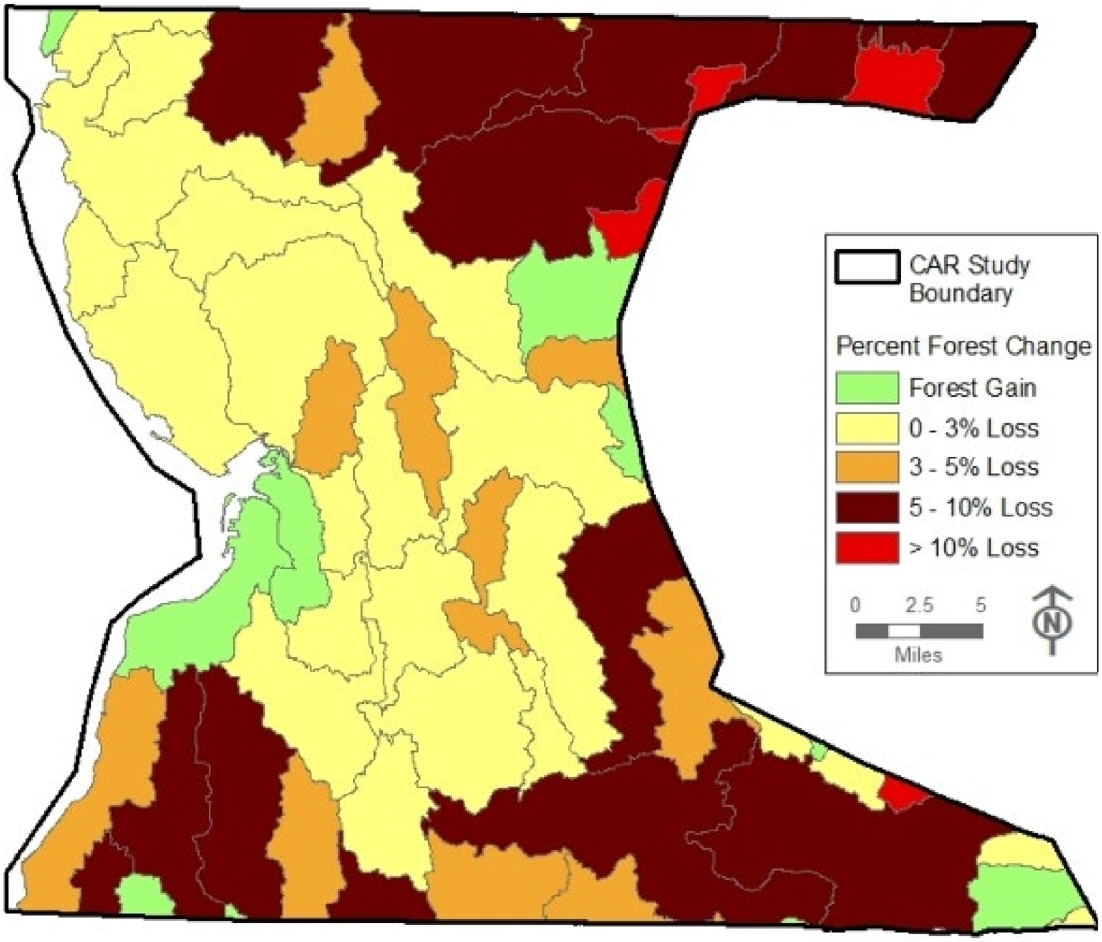


FIGURE 2.14: FOREST CHANGE BETWEEN 2009 AND 2021 BY PERCENT FOREST CHANGE BINS.

Next, subbasins were ranked based on whether they met criteria of at least 60% forest and less than 10% impervious area (referred to 60:10 criteria) (Figure 2.15). This ranking used data from the CAR+Cities+Tulalip area (no areas excluded). In 2009, 36 of 58 subbasins met the 60:10 criteria. This decreased to 34 of 58 in 2021, with Snoqualmie Mouth and Upper Canyon Creek subbasins switching from “met” to “not met”. This relatively minor change in 60:10 subbasin categorization over time belies the larger changes in total forest and impervious land cover. The relationship between the 60:10 land cover categorization and the range of functions and values and buffer condition is evaluated and discussed in Section 4.0.

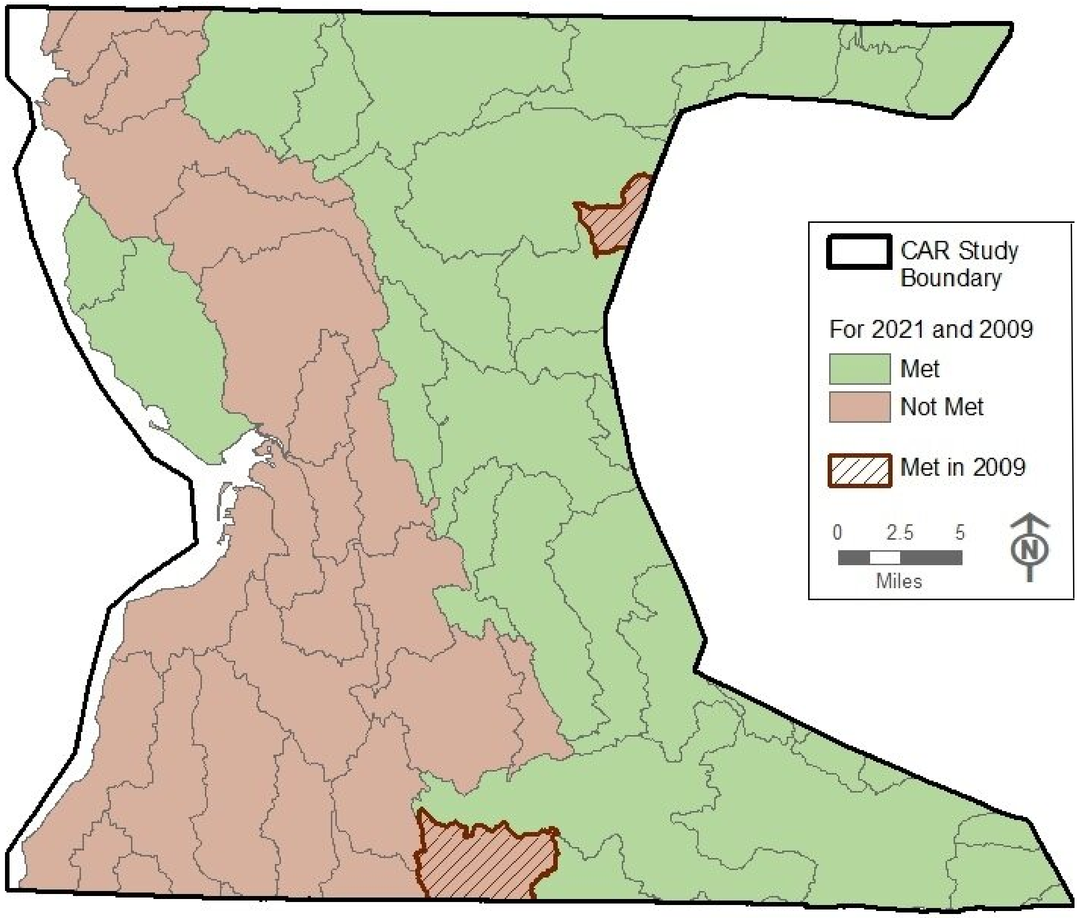


FIGURE 2.15: MAP SHOWING WHICH SUBBASINS "MET" AND "DID NOT MEET" 60:10 CRITERIA IN 2009 AND 2021, WITH THE TWO SUBBASINS THAT CHANGED STATUS HIGHLIGHTED IN RED CROSSHATCH.

The changes in forest and impervious cover were quantified along with other less prominent land cover conversion types to quantify the net change in percent positive and negative changes (referred to as %P/N). These changes reflect all land cover changes in critical area and non-critical area locations alike.

Figure 2.16 shows the %P/N change for the entre CAR+Cities+Tulalip area, no matter jurisdiction. Table 2.7 and Figure 2.17 show the %P/N change for the CAR Study Area only (excluding cities and agricultural lands). Note that subbasin results between Figure 2.16 and Figure 2.17 are the same unless a portion of a subbasin includes areas within cities or is agriculture-zoned.

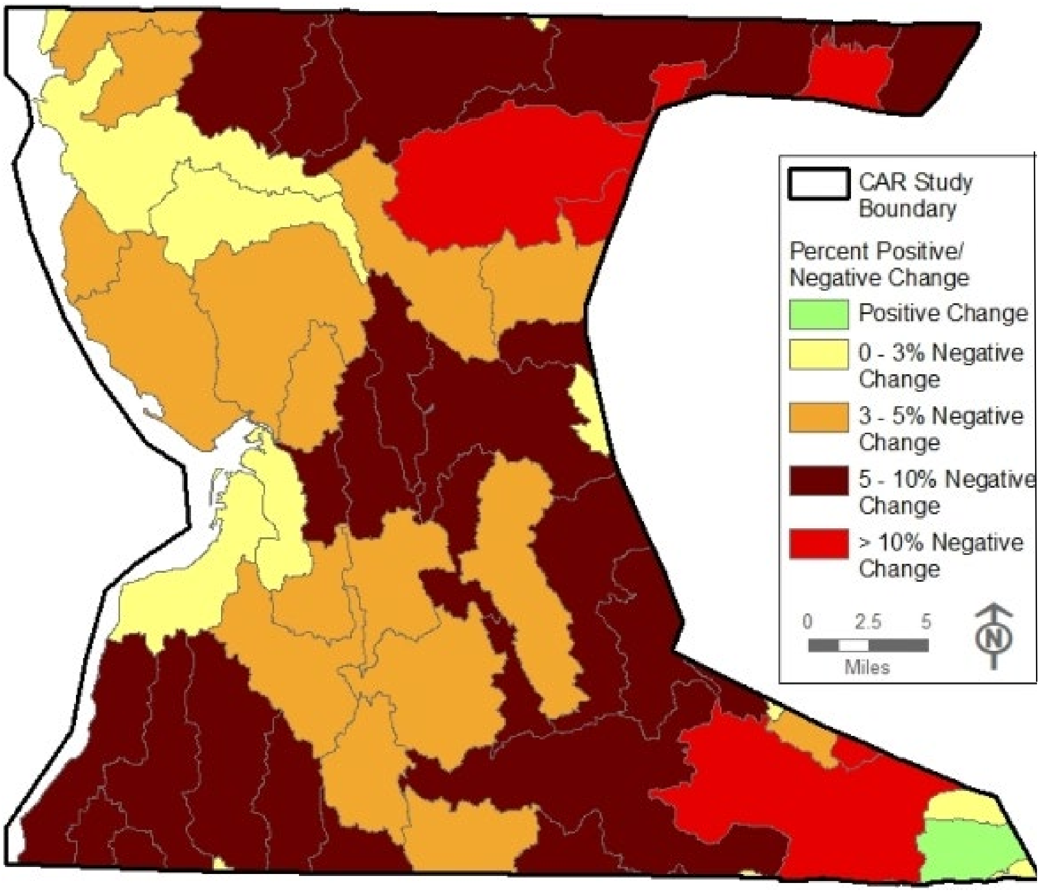


FIGURE 2.16: PERCENT POSITIVE/NEGATIVE CHANGE FOR CAR+CITIES+TULALIP AREA BETWEEN 2009 AND 2021.

TABLE 2.7: PERCENT IMPERVIOUS, FOREST, AND POSITIVE/NEGATIVE CHANGE BETWEEN 2009 AND 2021 BY SUBBASIN AT THE CAR STUDY AREA SCALE. BOLD AND UNDERLINED SUBBASINS HAVE P/N CHANGE < -5% AND BOTH HIGHER IMPERVIOUS AND FOREST CHANGE. P/N CHANGE IS INCLUSIVE OF OTHER LAND COVER CHANGE TYPES NOT SHOWN IN THIS TABLE.

Subbasin	Impervious Change	Forest Change	%P/N Change
Upper Canyon Creek	0.27	-17.02	-22.83
May Creek	1.15	-15.24	-16.36
Boulder River	0.01	-11.38	-12.36
Upper Mainstem Skykomish	0.24	-9.67	-12.16
Squire Creek	0.19	-11.49	-11.75
<u>North Creek</u>	6.87	-6.91	-11.47
Jim Creek	0.28	-8.95	-11.37
Lower North Fk Stillaguamish	0.38	-6.63	-9.40
Middle North Fk Stillaguamish	0.08	-7.00	-8.50
Stillaguamish Canyon	0.11	-4.81	-8.48
Upper North Fk Stillaguamish	0.09	-6.07	-8.48
Lower Pilchuck Creek	0.96	-5.29	-8.33
Sauk River	0.09	-7.50	-8.31
Lower Sultan River	0.62	-3.20	-7.85

Subbasin	Impervious Change	Forest Change	%P/N Change
Swamp Creek	4.84	-5.02	-7.83
Woods Creek	0.43	-5.48	-7.83
McAleer Creek	3.86	-5.91	-7.76
Harvey Armstrong Creek	0.93	-3.76	-7.54
Lower Mainstem Skykomish	0.39	-5.89	-7.50
Bear Creek (7)	0.23	-1.32	-7.41
Little Bear Creek	3.39	-4.23	-7.12
Little Pilchuck Creek	1.75	-4.59	-6.94
Puget Sound Drainage	3.26	-3.58	-6.43
Snoqualmie Mouth	1.70	-4.02	-6.36
Cherry Creek	0.24	-4.42	-6.26
Allen Creek	1.33	-4.13	-6.11
French-Segelsen	0.15	-5.22	-6.09
Bear Creek (8)	1.47	-5.49	-6.03
Dubuque Creek	1.50	-3.86	-5.92
Middle Pilchuck River	1.02	-2.91	-5.69
Lower Woods Creek	2.17	-1.81	-5.36
Skagit Flats South	0.95	-2.08	-5.00
Church Creek	1.22	-1.67	-4.82
Lower Stillaguamish	1.55	-2.17	-4.80
Lower Pilchuck River	1.75	-2.07	-4.45
Sunnyside	2.24	-0.91	-4.43
Marshland	2.69	-0.85	-4.42
Upper Wallace River	1.22	-1.73	-4.41
Lower South Fk Stillaguamish	1.03	-1.05	-4.34
Fobes Hill	2.24	-0.95	-4.31
Port Susan Drainages	1.49	-1.90	-4.26
Cathcart Drainages	1.73	-1.83	-4.10
West Fork Woods Creek	0.74	-1.05	-4.02
Tulalip	0.90	-2.07	-3.65
Portage Creek	1.16	-0.87	-3.52
Lyon Creek	8.39	5.51	-3.50
French Creek	1.53	-0.86	-3.35
Lake Stevens	1.12	-0.62	-3.23
Everett Drainages	3.90	0.77	-3.20
Lower Canyon Creek	0.25	1.06	-3.06
Quilceda Creek	0.89	-0.54	-2.73
Deer Creek	0.15	-1.29	-2.16
South Fork Skykomish	0.13	-0.34	-2.04
Olney Creek	0.21	6.87	-1.48

Subbasin	Impervious Change	Forest Change	%P/N Change
Lower North Fork Skykomish	0.15	-0.14	-1.14
Upper Pilchuck River	0.19	5.21	-0.88
Snohomish estuary	0.11	1.08	0.13
Lower South Fork Skykomish	0.12	1.24	1.00

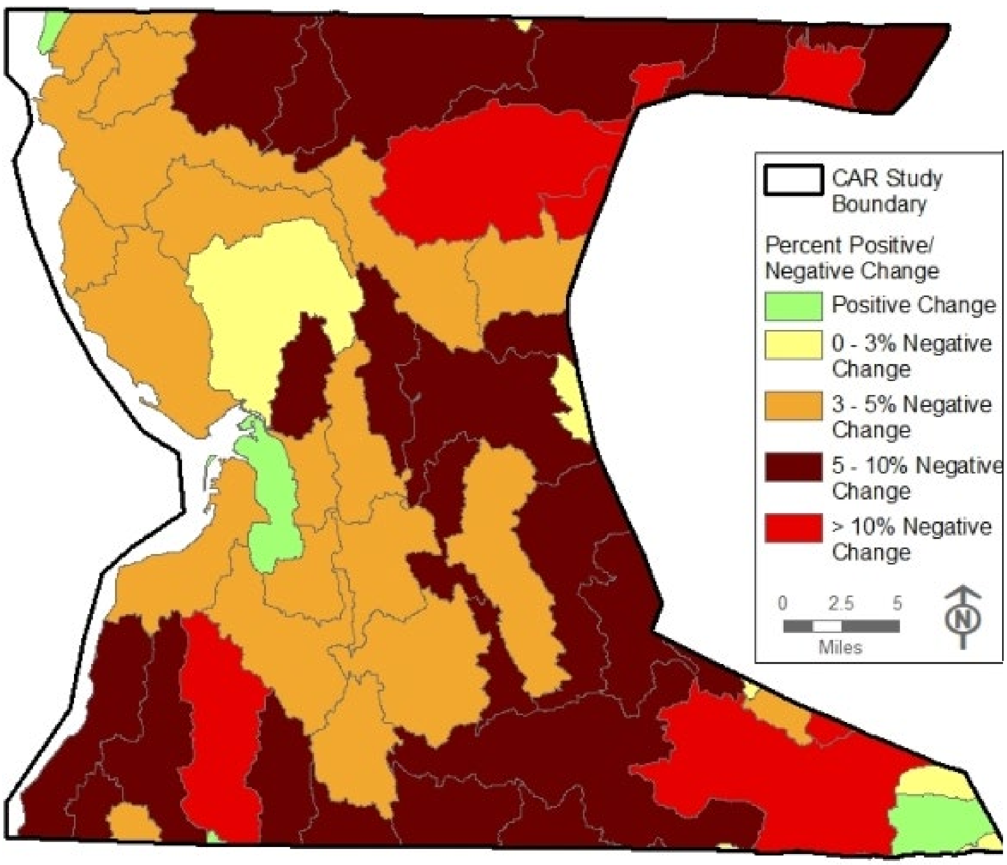


FIGURE 2.17: PERCENT POSITIVE/NEGATIVE CHANGE FOR CAR STUDY AREA (MINUS CITIES AND AG LANDS) BETWEEN 2009 AND 2021 BY ADAPTIVE MANAGEMENT THRESHOLDS.

For both extents, %P/N change ranged from -22.83% in Upper Canyon Creek to +1.00% in the Lower South Fork Skykomish, both rural subbasins. Overall, 56 of 58 (97%) subbasins had a net-negative P/N change. Among locations already urbanized, North Creek had the greatest net-negative change, and the amount of change was greater in areas outside of cities and within Snohomish County jurisdiction. Other rural areas with large net-negative change were Upper Canyon Creek, Jim Creek, May Creek, and Upper Skykomish. For the rural subbasins, some of the %P/N change can be attributed to timber harvesting. Table 2.8 shows the ten subbasins with the highest percentage of impervious gain, forest loss, and largest positive/negative within critical areas and non-critical areas loss for comparison. Red subbasins in Table 2.8 signify those most likely impacted by development (building of homes, roads, and associated infrastructure). Subbasins in green signify those most likely primarily impacted by timber harvesting and natural changes (landslides, channel migration, tree growth/loss, etc.), and subbasins in black signify those impacted by a combination of the two factors.

TABLE 2.8: TOP TEN SUBBASINS IN PERCENT CHANGE IN IMPERVIOUS GAIN, FOREST LOSS, AND POSITIVE/NEGATIVE LOSS BETWEEN 2009 AND 2021. **RED SUBBASINS** = IMPACTED BY DEVELOPMENT, **GREEN SUBBASINS** = IMPACTED BY TIMBER PRODUCTION AND NATURAL CHANGES, **BLACK SUBBASINS** = IMPACTED BY DEVELOPMENT AND TIMBER PRODUCTION/NATURAL CHANGES.

Impervious Change	Forest Change	P/N Change
Lyon Creek[1]	Upper Canyon Creek	Upper Canyon Creek
North Creek	May Creek	May Creek
Swamp Creek	Squire Creek	Boulder Creek
Everett Drainages[1]	Boulder Creek	Upper Mainstem Skykomish
McAleer Drainages[1]	Upper Mainstem Skykomish	Squire Creek
Little Bear Creek	Jim Creek	North Creek
Puget Sound Drainages	Sauk River	Jim Creek
Marshlands	Middle North Fk Stillaguamish	Lower North Fk Stillaguamish
Fobes Hill	North Creek	Middle North Fk Stillaguamish
Sunnyside[1]	Lower North Fk Stillaguamish	Stillaguamish Canyon

[1]Less than 1,000 acres in unincorporated County relative to larger total subbasin area.

Eight subbasins are nearing thresholds that could impact functions and values. These subbasins currently have lower levels of impervious area (5-10%) but have been impacted by increasing impervious area, loss of forest cover, and a %P/N <-5% over the time period. The eight subbasins are:

- Little Pilchuck Creek
- Lower Pilchuck Creek
- Middle Pilchuck River
- Snoqualmie Mouth
- Skagit Flats South
- Dubuque Creek
- Allen Creek
- Lower Woods Creek

These rural subbasins are outside of timber harvest areas so are likely primarily affected by housing and road development. While these subbasins have good to excellent functions and value levels under current conditions (see Section 4.0), they may warrant future monitoring if land cover changes continue. This would provide insight into the ability of the County's regulations, including critical area and stormwater management, to preserve ecological functions and values.

2.2.2 Fish and Wildlife Habitat Conservation Area Riparian Buffer Change Results

Riparian buffer conditions for streams, lakes, marine waters, and wetlands are included in the following tables. All the results in the section are based on the CAR Study Area (excluding cities and agricultural areas). Figure 2.18 shows the percent positive/negative change by Adaptive Management Thresholds (Table 1.5) by subbasin for the stream, lake, and marine buffer area only. This shows the highest Adaptive Management Threshold changes occurred in the highly urbanized southwest part of the County (e.g., Swamp Creek, North Creek, Little Bear Creek) and in more rural and forested subbasins farther east. Four out of 58 subbasins had positive %P/N buffer changes, but calculation for 3 of these 4 subbasins may have been affected by very low buffer acreage within the subbasin. These %P/N values may be an overestimation of buffer change due to buffer uncertainty compared to change for known CASP-digitized buffers (see Table 2.3).

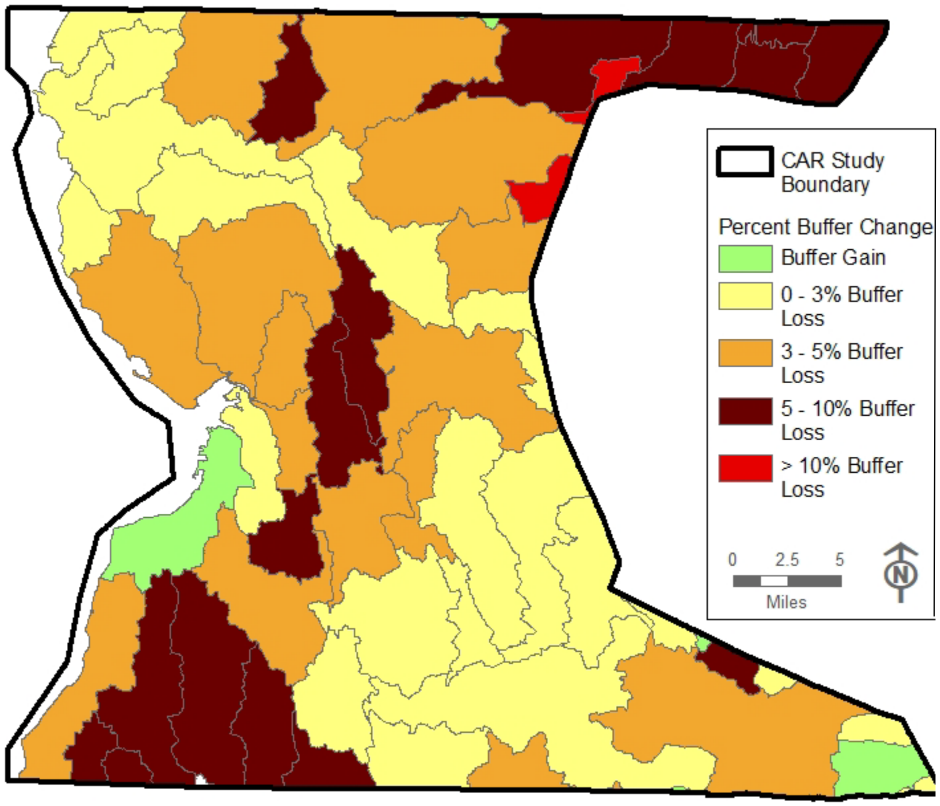


FIGURE 2.18: POSITIVE/NEGATIVE CHANGE IN STREAM, LAKE, AND MARINE BUFFERS BY ADAPTIVE MANAGEMENT THRESHOLDS BETWEEN 2009 AND 2021.

Table 2.9 shows the change in total acres of impervious and forest land cover in buffers by critical area type. Also included are the sum of land changes (acres) among four classes of land cover that are negative and positive in terms of impacts to hydrological function (Figure 2.3). This table includes changes to wetlands and their buffers as well, which are discussed in more detail in Section 2.2.3. In total, an estimated net 1,686 acres of stream, lake, and marine buffers were negatively affected, which accounts for positive changes (predominantly tree growth). Including wetlands and their buffers, a total 4,940 acres of buffer area was negatively changed, which equates to 4.31% of all buffer acres impacted.

TABLE 2.9: CHANGE IN FOREST, IMPERVIOUS, POSITIVE, NEGATIVE, AND POSITIVE/NEGATIVE PERCENT AND/OR ACRES IN LAKE, MARINE, STREAM, AND WETLAND BUFFERS.

Buffer Type	Buffer Acres	Forest Change (Acres)	Impervious Change (Acres)	Positive Change (Acres)	Negative Change (Acres)	P/N Net % Area Change
Lake	1,535.1	-23.9	20.2	41.0	119.9	-5.1%
Marine	366.8	-6.0	2.8	11.3	28.0	-4.6%
Stream	43,347.7	-871.7	174.3	732.9	2,322.8	-3.7%
Wetland	69,346.2	-1,590.0	595.1	1,170.4	4,424.8	-4.7%

Buffer Type	Buffer Acres	Forest Change (Acres)	Impervious Change (Acres)	Positive Change (Acres)	Negative Change (Acres)	P/N Net % Area Change
Grand Total	114,595.8	-2,491.6	792.3	1,955.6	6,895.6	
% of Total Area		-2.17%	0.69%	1.71%	6.01%	-4.31%

Table 2.10 shows the land cover change results for rivers, streams, lakes, and marine buffers for all subbasins. Thresholds of change (i.e., Threshold, 1, 2 and 3), based on the Adaptive Management Framework in Table 1.5, are included. Changes in all subbasins are negative except for 4 out of 58 subbasins. Some larger changes in the "Adaptive Management Threshold" column are associated with more rural and forested subbasins, while other large changes are associated with more urban/suburban subbasins (urban/suburban subbasins are highlighted rows for Threshold 3 in Table 2.10).

Table 2.10: Percent impervious, forest, positive/Negative change, Adaptive Management Thresholds, and the percent of the change due to impervious gain and forest to pasture by subbasin in stream, lake, and marine buffers. Note that the percent positive/negative (P/N) change is not solely based on the impervious and forest change columns. The last 2 columns comprise the fraction of P/N change due to impervious gain and forest loss to pasture. Thresholds are based on information provided in Table 1.5.

Subbasin	Percent Impervious Change	Percent Forest Change	Percent P/N Change	Adaptive Management Threshold	% change due to Impervious gain	% change due to Forest to Pasture
Boulder River	0.01	-14.84	-14.93	Threshold 3	0.0	98.7
Upper Canyon Creek	0.17	-5.20	-10.40	Threshold 3	1.3	97.0
Lyon Creek[1]	1.58	-8.93	-9.56	Threshold 3	14.5	85.5
Squire Creek	0.07	-8.23	-8.47	Threshold 3	0.8	98.0
Middle North Fk Stillaguamish	0.05	-7.57	-8.02	Threshold 3	0.5	98.4
French-Segelsen	0.12	-6.96	-7.72	Threshold 3	1.3	97.7
Lake Stevens	0.30	-2.28	-6.96	Threshold 3	3.4	89.1
Sauk River	0.12	-6.22	-6.73	Threshold 3	1.5	98.3
McAleer Creek[1]	6.58	-0.15	-6.58	Threshold 3	100.0	0.0
Bear Creek (8)	0.76	-5.68	-6.47	Threshold 3	10.3	87.9
North Creek	1.51	-4.84	-6.45	Threshold 3	20.5	77.2
Harvey Armstrong Creek	0.28	-4.86	-6.25	Threshold 3	4.3	94.2
Fobes Hill	0.89	-3.19	-5.86	Threshold 3	12.2	79.2
Upper North Fk Stillaguamish	0.05	-4.78	-5.75	Threshold 3	0.7	98.0
Little Pilchuck Creek	0.33	-3.36	-5.48	Threshold 3	5.1	82.2
Little Bear Creek	1.22	-3.89	-5.43	Threshold 3	18.7	80.6
Upper Wallace River	0.58	-3.23	-5.14	Threshold 3	10.0	81.9

Subbasin	Percent Impervious Change	Percent Forest Change	Percent P/N Change	Adaptive Management Threshold	% change due to Impervious gain	% change due to Forest to Pasture
Swamp Creek	1.38	-2.86	-5.03	Threshold 3	21.6	74.9
Upper Mainstem Skykomish	0.16	-3.25	-4.79	Threshold 2	2.1	96.8
Allen Creek	1.19	-2.44	-4.63	Threshold 2	20.4	76.3
Puget Sound Drainage	0.87	-3.28	-4.60	Threshold 2	17.0	73.0
Marshland	0.73	-2.86	-4.18	Threshold 2	15.5	82.8
Lower Canyon Creek	0.42	-1.28	-3.71	Threshold 2	8.8	88.2
Jim Creek	0.13	-2.39	-3.69	Threshold 2	2.3	87.2
Sunnyside	0.37	-2.50	-3.68	Threshold 2	7.6	92.4
Lower Pilchuck River	0.80	-2.12	-3.68	Threshold 2	16.0	77.3
Quilceda Creek	0.55	-1.37	-3.58	Threshold 2	11.4	81.1
Dubuque Creek	0.76	-1.83	-3.39	Threshold 2	16.4	79.7
Cherry Creek	0.06	-2.43	-3.26	Threshold 2	1.6	93.5
Tulalip	0.82	-1.14	-3.24	Threshold 2	20.0	75.7
Lower Pilchuck Creek	0.37	-1.16	-3.23	Threshold 2	8.7	86.3
Middle Pilchuck River	0.43	-1.24	-3.14	Threshold 2	9.7	83.1
Lower North Fk Stillaguamish	0.30	-1.04	-3.01	Threshold 2	6.9	88.8
Lower Woods Creek	0.73	-0.86	-2.98	Threshold 1	14.8	77.2
Portage Creek	0.40	-0.85	-2.96	Threshold 1	9.8	86.3
Bear Creek (7)	0.18	-0.70	-2.83	Threshold 1	4.6	95.0
Lower Mainstem Skykomish	0.19	-1.64	-2.72	Threshold 1	5.3	92.2
May Creek	0.77	-2.15	-2.65	Threshold 1	17.9	82.1
West Fork Woods Creek	0.24	0.01	-2.34	Threshold 1	5.8	86.3
Woods Creek	0.42	-0.28	-2.29	Threshold 1	9.8	80.7
Cathcart Drainages	0.73	-0.91	-2.14	Threshold 1	21.3	74.1
Lower South Fk Stillaguamish	0.50	-0.24	-2.13	Threshold 1	13.7	80.0
Lower North Fork Skykomish	0.94	-0.82	-1.94	Threshold 1	28.9	61.9
French Creek	0.57	-0.07	-1.75	Threshold 1	18.0	79.4
Port Susan Drainages	0.69	0.98	-1.66	Threshold 1	22.7	69.1

Subbasin	Percent Impervious Change	Percent Forest Change	Percent P/N Change	Adaptive Management Threshold	% change due to Impervious gain	% change due to Forest to Pasture
Snoqualmie Mouth	0.49	0.52	-1.59	Threshold 1	16.1	77.3
Skagit Flats South	0.46	1.22	-1.40	Threshold 1	17.9	81.3
Lower Stillaguamish	0.54	1.56	-1.18	Threshold 1	18.1	74.4
Lower Sultan River	0.34	0.50	-1.03	Threshold 1	10.2	87.9
South Fork Skykomish	0.21	0.09	-0.95	Threshold 1	13.4	83.1
Stillaguamish Canyon	0.08	1.18	-0.82	Threshold 1	1.5	63.9
Church Creek	0.48	2.68	-0.45	Threshold 1	19.0	77.9
Snohomish Estuary	0.23	0.42	-0.36	Threshold 1	29.6	14.8
Upper Pilchuck River	0.22	1.96	-0.25	Threshold 1	13.3	70.8
Deer Creek	0.00	1.25	1.25	Threshold 1	0.0	100.0
Olney Creek	0.00	5.11	1.89	Threshold 1	0.0	41.0
Lower South Fork Skykomish	0.27	3.61	2.69	Threshold 1	11.1	82.4
Everett Drainages	-0.83	8.55	6.66	Threshold 1	0.0	100.0

Figure 2.19 highlights the percent of change to impervious, from forest to pasture, and to water from another land cover type by subbasin, as well as the overall percent total negative change, organized by subbasins with the lowest percent negative change to subbasins with the highest percent negative change. This figure helps differentiate the source of land cover change in buffers between subbasins. For the urban/suburban subbasins, the negative change has greater association with a gain of >10% impervious area within the buffer compared to more rural and forested subbasins where a much higher percentage of the change is due to forest cover changes. This is presumably due to timber harvesting, river/stream channel migration, and isolated change events such as the SR530 land slide in the Middle North Fork Stillaguamish. Distinguishing between sources of change and relative permanence may influence the need for and type of adaptive management response.

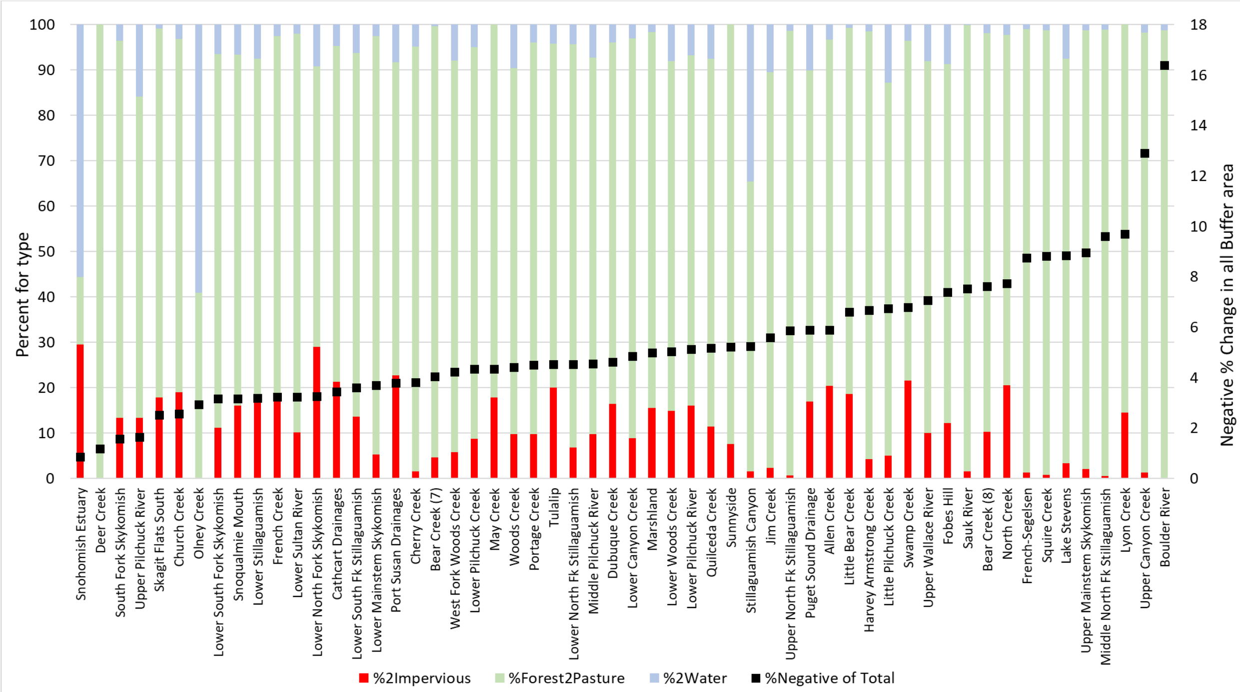


FIGURE 2.19: PERCENT CHANGE DUE TO INCREASE IN IMPERVIOUS, CHANGE FROM FOREST TO PASTURE, AND TO WATER PLUS THE PERCENT NEGATIVE CHANGE TO THE BUFFER AREA BY SUBBASIN.

Table 2.11 shows the ten subbasins with the highest percentage of impervious gain, forest loss, and largest %P/N loss in stream, lake, and marine buffers. The top ten subbasins in terms of impacts to buffers due to increases in impervious are predominantly highly developing. As discussed in Section 2.1.3, due to stream mapping issues, impacts to urban subbasin buffers are likely overestimated. In terms of forest loss and %P/N change, it is important to differentiate change that may be due to natural conditions within buffers such as channel migration, tree growth/loss, landslides, or other factors. Subbasins with larger rivers prone to channel migration or recent landslides include Middle North Fork Stillaguamish, French-Segelsen, and Sauk River.

TABLE 2.11: TOP TEN SUBBASINS IN PERCENT CHANGE IN IMPERVIOUS GAIN, FOREST LOSS, AND POSITIVE/NEGATIVE LOSS IN STREAM, LAKE, AND MARINE BUFFERS BETWEEN 2009 AND 2021.

Impervious Gain	Forest Loss	%P/N Change
McAleer Creek[1]	Boulder River	Boulder River
Lyon Creek[1]	Lyon Creek[1]	Upper Canyon Creek
North Creek	Squire Creek	Lyon Creek[1]
Swamp Creek	Middle Forth Fk Stillaguamish	Squire Creek
Little Bear Creek	French-Segelsen	Middle Forth Fk Stillaguamish
Allen Creek	Sauk River	French-Segelsen
Lower North Fk Stillaguamish	Bear Creek (8)	Lake Stevens
Fobes Hill	Upper Canyon Creek	Sauk River
Puget Sound Drainages	Harvey Armstrong Creek	McAleer Creek[1]
Tulalip	North Creek	Bear Creek (8)

[1]Less than 1,000 acres in unincorporated County relative to larger total subbasin area.

2.2.3 Wetlands and Buffers Change Results

Land cover changes to wetlands and wetland buffers were evaluated together as delineating wetland boundaries given data available was too imprecise. Evaluation of wetland buffers along with the actual wetland is consistent with our evaluation of buffers surrounding other aquatic habitats. As described above, a 75-foot buffer was applied to all wetlands to evaluate land cover changes to wetlands and their buffers. Table 2.12

Table 2.12 shows percent impervious, percent forest, percent positive minus percent net change, adaptive management thresholds of change, percent of the change due to impervious gain, and percent of the change due to forest loss for wetlands and wetland buffers by subbasin. The table is sorted based on the net percent positive minus negative change. Thresholds of change, based on the current Adaptive Management Framework (see Table 1.5) are included and graphically shown in Figure 2.20. As discussed in Section 2.1.3, due to the issues with mapping wetlands and their buffers, the results may be overestimated in terms of impervious change, particularly in highly urbanizing areas. For some wetland types, such as for forested wetlands that are hard to identify via remote sensing and may be underrepresented in mapping, loss may be underestimated.

Table 2.12: Percent impervious, forest, %P/N change, change threshold, and the percent of the change due to impervious gain and forest to pasture by subbasin in wetlands and their buffers. Note that the percent positive/negative (P/N) change is not solely based on the impervious and forest change columns. The last 2 columns comprise the fraction of P/N change due to impervious gain and forest loss to pasture.

Subbasin	Percent Impervious Change	Percent Forest Change	Percent P/N Change	Adaptive Management Threshold	% change due to Impervious gain	% change due to Forest loss
May Creek	1.70	-19.63	-20.75	Threshold 3	8.0	92.0
Upper Canyon Creek	0.27	-13.16	-17.68	Threshold 3	1.4	98.2
Squire Creek	0.18	-14.14	-14.82	Threshold 3	1.1	98.8
Middle North Fk Stillaguamish	0.15	-10.65	-14.07	Threshold 3	1.0	99.0
Boulder River	0.00	-12.38	-13.75	Threshold 3	0.0	97.7
Upper North Fk Stillaguamish	0.68	-10.06	-12.40	Threshold 3	5.4	94.6
Sauk River	0.05	-11.17	-11.27	Threshold 3	0.5	99.5
McAleer Creek	5.00	-8.69	-11.22	Threshold 3	37.9	61.6
North Creek	6.01	-6.25	-10.74	Threshold 3	46.7	50.9
Lyon Creek	4.99	-9.20	-10.72	Threshold 3	47.6	52.4
Lower North Fk Stillaguamish	0.51	-6.31	-8.86	Threshold 2	4.6	94.8
French-Segelsen	0.26	-7.62	-8.82	Threshold 2	2.7	97.3
Swamp Creek	3.53	-5.27	-8.14	Threshold 2	36.8	59.8
Lower Sultan River	0.79	-5.34	-7.86	Threshold 2	7.8	90.8
Bear Creek (7)	0.51	-1.14	-7.23	Threshold 2	5.4	94.5
Little Bear Creek	2.89	-3.73	-6.65	Threshold 2	34.1	64.9
Upper Mainstem Skykomish	0.44	-2.34	-6.21	Threshold 2	4.2	94.5

Subbasin	Percent Impervious Change	Percent Forest Change	Percent P/N Change	Adaptive Management Threshold	% change due to Impervious gain	% change due to Forest loss
Upper Wallace River	1.19	-4.06	-6.08	Threshold 2	15.5	81.2
Lower Canyon Creek	0.27	-3.94	-5.96	Threshold 2	3.7	94.5
Olney Creek	0.00	-4.43	-5.84	Threshold 2	0.0	100.0
Bear Creek (8)	1.17	-4.90	-5.78	Threshold 2	18.8	80.9
Stillaguamish Canyon	0.17	-2.12	-5.35	Threshold 2	2.4	96.3
Harvey Armstrong Creek	0.81	-2.07	-5.33	Threshold 2	12.2	82.2
Cherry Creek	0.23	-2.98	-5.29	Threshold 2	4.1	92.3
Snoqualmie Mouth	1.43	-3.37	-5.11	Threshold 2	22.8	74.3
Puget Sound Drainage	2.34	-2.09	-5.10	Threshold 2	33.6	62.5
Dubuque Creek	1.27	-2.61	-4.86	Threshold 1	19.2	80.3
Jim Creek	0.69	-2.22	-4.68	Threshold 1	10.7	88.1
Woods Creek	0.40	-1.79	-4.33	Threshold 1	6.8	92.2
Lower Woods Creek	1.39	-1.72	-4.32	Threshold 1	22.4	77.0
Marshland	1.71	-1.72	-4.24	Threshold 1	27.1	71.8
Lower South Fk Stillaguamish	0.89	-1.63	-4.24	Threshold 1	15.4	82.4
Lower Pilchuck Creek	0.68	-0.75	-4.16	Threshold 1	12.3	84.2
Cathcart Drainages	1.33	-1.48	-3.76	Threshold 1	24.1	72.8
Port Susan Drainages	0.89	-1.61	-3.75	Threshold 1	18.9	79.5
Little Pilchuck Creek	0.94	-1.21	-3.59	Threshold 1	17.5	80.0
Lower Pilchuck River	1.01	-1.10	-3.37	Threshold 1	19.8	76.6
West Fork Woods Creek	0.54	-1.35	-3.28	Threshold 1	11.4	85.8
Middle Pilchuck River	0.83	-0.91	-3.20	Threshold 1	16.9	80.4
Fobes Hill	1.14	-0.67	-3.16	Threshold 1	21.4	76.1
Lower Stillaguamish	0.86	-0.46	-3.06	Threshold 1	17.7	80.4
Church Creek	0.75	0.30	-2.96	Threshold 1	14.9	84.1
Lower Mainstem Skykomish	0.39	-1.13	-2.86	Threshold 1	8.9	88.4
Skagit Flats South	0.93	0.19	-2.83	Threshold 1	20.7	78.2
Deer Creek	0.00	-3.12	-2.74	Threshold 1	0.0	100.0
Tulalip	0.45	-0.85	-2.60	Threshold 1	13.3	85.7
French Creek	0.94	-0.20	-2.58	Threshold 1	24.2	73.7
Lake Stevens	0.56	-0.54	-2.46	Threshold 1	15.3	82.1
Allen Creek	0.87	-0.42	-2.27	Threshold 1	29.8	64.6

Subbasin	Percent Impervious Change	Percent Forest Change	Percent P/N Change	Adaptive Management Threshold	% change due to Impervious gain	% change due to Forest loss
South Fork Skykomish	0.57	-1.31	-2.11	Threshold 1	20.6	79.4
Quilceda Creek	0.67	0.02	-2.03	Threshold 1	20.0	77.9
Lower North Fork Skykomish	0.46	-1.43	-1.81	Threshold 1	19.6	80.4
Portage Creek	0.89	0.65	-1.75	Threshold 1	24.5	73.4
Upper Pilchuck River	0.02	0.84	-1.39	Threshold 1	0.9	98.8
Everett Drainages	0.02	-0.27	-0.27	Threshold 1	0.0	100.0
Sunnyside	0.53	2.76	-0.09	Threshold 1	24.7	75.3
Snohomish Estuary	0.07	0.42	0.17	Threshold 1	59.5	40.5
Lower South Fork Skykomish	0.33	2.53	0.74	Threshold 1	6.0	85.9

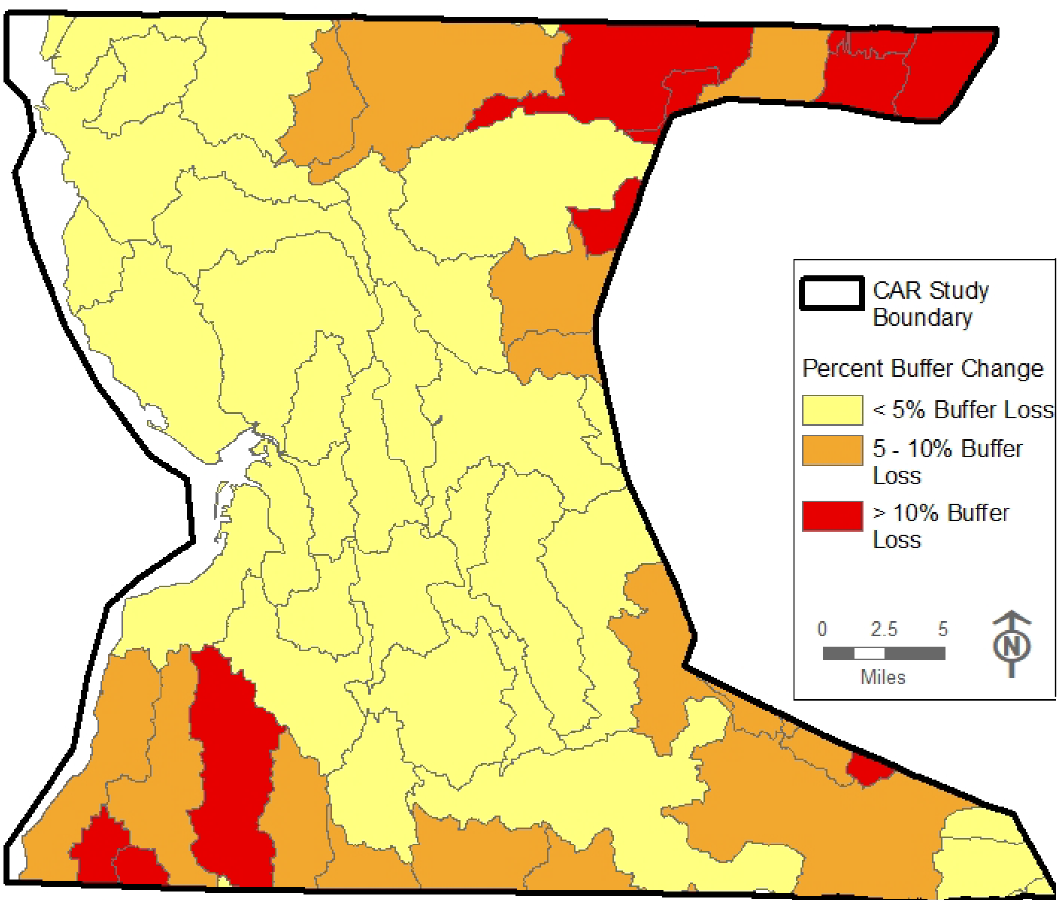


FIGURE 2.20: POSITIVE/NEGATIVE CHANGE IN WETLANDS AND WETLAND BUFFERS BY ADAPTIVE MANAGEMENT THRESHOLDS. ADAPTIVE MANAGEMENT THRESHOLDS ARE: THRESHOLD 1 = <5%, THRESHOLD 2 = 5-10%, THRESHOLD 3 = >10%.

Table 2.13 shows the ten subbasins with the highest percentage of impervious gain, forest loss, and largest positive/negative loss in wetlands and their buffers. The ten subbasins with the most impervious gain in wetlands and their buffers are predominantly urban and urbanizing locations. On average the change to impervious area is 3.1% of the total area. The largest increase in impervious area in a subbasin is 6.0% of the wetland area in North Creek.

TABLE 2.13: TOP TEN SUBBASINS IN PERCENT CHANGE IN IMPERVIOUS GAIN, FOREST LOSS, AND POSITIVE/NEGATIVE LOSS IN STREAM, LAKE, AND MARINE BUFFERS BETWEEN 2009 AND 2021.

Impervious Gain	Forest Loss	%P/N Change
North Creek	May Creek	May Creek
McAleer Creek[1]	Squire Creek	Upper Canyon Creek
Lyon Creek[1]	Upper Canyon Creek	Squire Creek
Swamp Creek	Boulder River	Middle North Fk Stillaguamish
Little Bear Creek	Sauk River	Boulder River
Puget Sound Drainages	Middle North Fk Stillaguamish	Upper North Fk Stillaguamish
Marshland	Upper North Fk Stillaguamish	Sauk River
May Creek	Lyon Creek[1]	McAleer Creek[1]
Snoqualmie Mouth	McAleer Creek[1]	North Creek
Lower Woods Creek	French-Segelsen	Lyon Creek[1]

[1]Less than 1,000 acres in unincorporated County relative to larger total subbasin area.

In urban areas, intensive development occurs up to the critical area boundary as determined through the permitting process. This involves field-based determination of critical area types, boundaries, and allowed buffer widths which ultimately may be different from a standardized 75-foot buffer width applied for this analysis. Hence, as the pilot area demonstrated, the estimate of impervious change and the net-negative %P/N is likely high.

Conversely, the loss in forest cover in wetlands and their buffers is predominantly associated with forested and rural subbasins where timber harvest or land clearing on rural lots (without adding impervious area) would be more common. Like housing development, commercial timber harvest would be intensively implemented up to managed buffer boundaries. Similar uncertainty in wetland mapping and buffer application could lead to overestimating changes in areas of timber harvest.

The subbasins that comprise the greatest P/N change include a mix of the urban and rural subbasins, where negative change in urban areas is due to increasing impervious area and in rural areas is due to greater forest cover change. As mentioned, the cumulative P/N change in the urban (North Creek) pilot area for digitized CASPs and known wetland resources was -3.5%, The change based on the standard buffers (including streams) was -9.5%. Here, the %P/N change in North Creek was -10.7%. Because of this magnitude it is likely representative of real negative change, like that found in the pilot area investigation. Eight out of 10 subbasins in Table 2.12 have net-negative %P/N values that are worse than North Creek, which likely represent real negative change in the subbasins – though much less due to impervious gain within CASPs or other regulated buffers created through permit processes. Any additional investigation of wetland impacts should focus on urban areas with greater change as a starting point.

Another notable impact to stream buffers and functions and values apart from land cover change are where roads have been built across streams. Many road crossings are older in construction and new road crossings are rare but do occur. Road crossings eliminate riparian buffer vegetation, place fill in critical areas, and add impervious area. Where roads are older, they often are accompanied by road ditch networks that channel untreated road runoff and often flow more quickly to ditch outlets connected to streams. Figure 2.21 shows the road crossing density in number per road crossing per stream mile within each subbasin. This total excludes cities and quantities are calculated for Snohomish County portions of subbasins. Road crossing frequency is highest in Swamp Creek, Church Creek, North Creek, Bear (8) Creek, Port Susan Bay Drainages, and Skagit Flats South. These subbasins exceed the highest ecological condition level (Table 1.2) indicating degraded condition. Other subbasins in more rural County subbasins have intermediate (at -risk) ecological condition (1-2 stream crossings/mi). Subbasins farther east that are mostly rural or forested have the lowest stream crossing density.

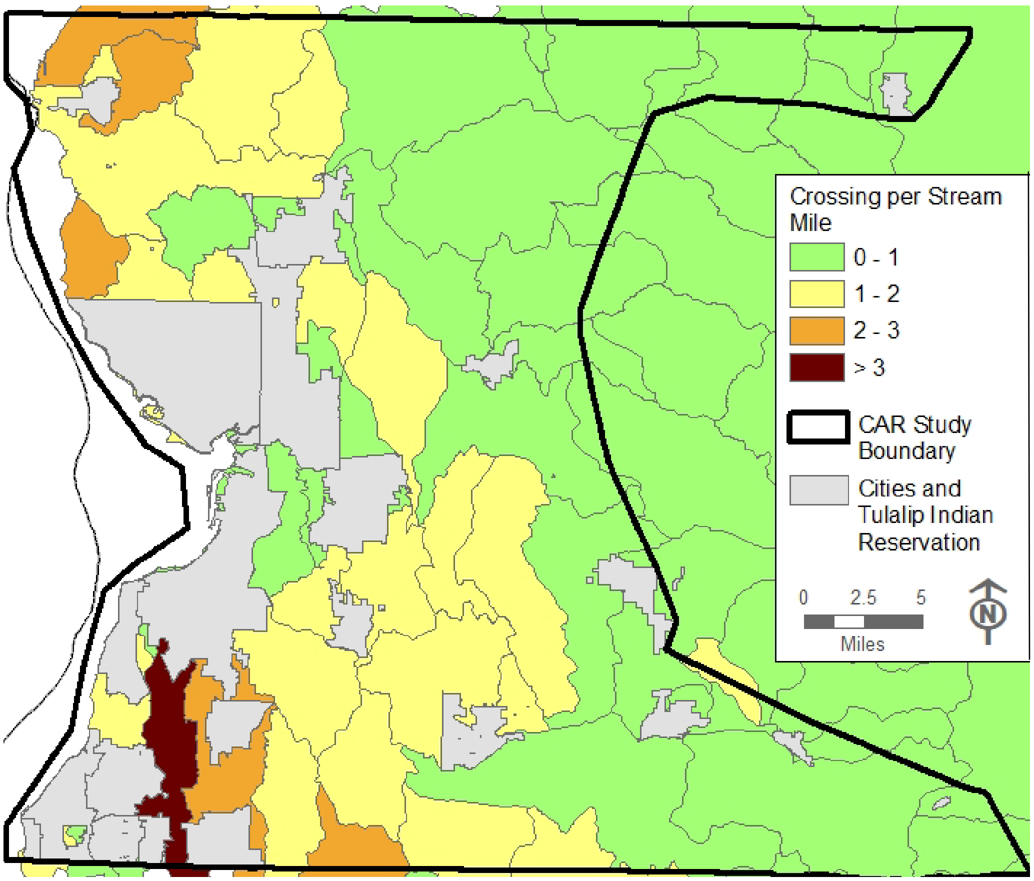


FIGURE 2.21: NUMBER OF ROADS THAT CROSS OVER STREAMS PER MILE OF STREAMS WITHIN SUBBASINS IN 2021.

Figure 2.22 shows the change in stream crossing density between 2009 and 2021. The largest increases were in North Creek, Swamp Creek, Bear Creek (8), Little Pilchuck Creek, and Port Susan Drainages. An increase in road crossings in already urbanized areas is not surprising as infill occurs and previously less accessible locations for development are utilized. Increases in more rural areas like Little Pilchuck Creek or Bear Creek (8) suggests increasing growth and development pressure, within and outside urban growth areas, which is borne out by greater land cover changes in these same subbasins. Only two subbasins had road crossing increases of one per 5-10 miles of stream, Dubuque Creek and Lower Woods Creek. Any reduction in stream crossing frequency in County jurisdiction is predominantly due to the increase crossing rate in cities and reduction in the County Road inventory.

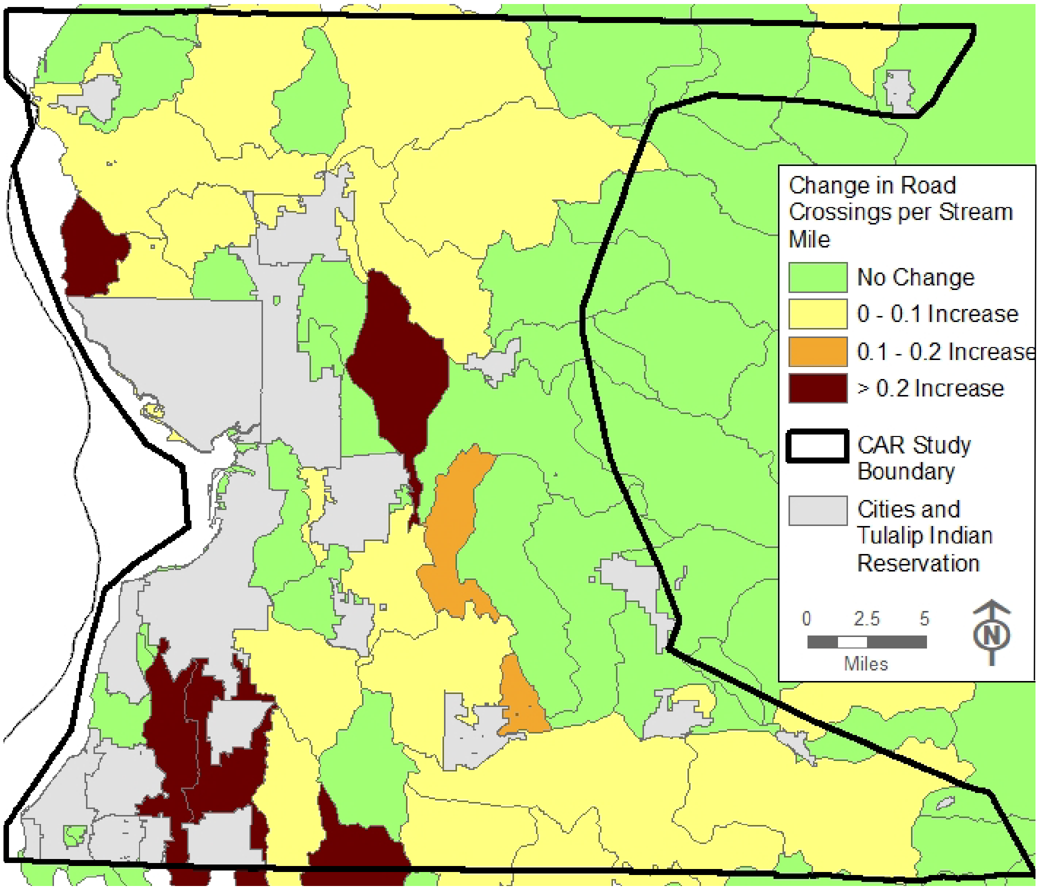


FIGURE 2.22: CHANGE IN STREAM CROSSING DENSITY FROM 2009 TO 2021.

2.3 Buffer Results and Adaptive Management Thresholds

Per Table 1.5, two Monitoring Elements were selected for evaluation against Adaptive Management Thresholds, as summarized in Table 2.14.

TABLE 2.14: STREAM, LAKE, MARINE, AND WETLAND+WETLAND BUFFERS ADAPTIVE MANAGEMENT MONITORING ELEMENTS AND THRESHOLDS.

Plan Component	Monitoring Element	Threshold 1[1]	Threshold 2[2]	Threshold 3[3]
Land Cover Change – Wetlands	% Positive - %Negative Change in Wetland + Wetland Buffer	<5% change across County jurisdiction within any subbasins relative to baseline	5-10% change across County jurisdiction within 2 or more watersheds relative to baseline	>10% change across County jurisdiction relative to baseline
Land Cover Change – FWHCA riparian	% Positive - %Negative Change in Stream + Lake + Marine Buffer	<3% change across County jurisdiction within any subbasins relative to baseline	3-5% change across County jurisdiction within 2 or more watersheds relative to baseline	>5% change across County jurisdiction relative to baseline

[1]Threshold 1 triggers public outreach and/or enforcement and mitigation actions.

[2]Threshold 2 triggers additional public outreach, enforcement, and mitigation actions; programmatic adjustments.
[3]Threshold 3 triggers programmatic adjustments including code revisions.

Table 2.15 shows results of Monitoring Element at the watershed and CAR Study Area scale. The watershed scale is included as the 2008 Monitoring and Adaptive Management plan referenced watershed areas for evaluation. The bottom row in Table 2.15 shows the highest threshold out of three that is exceeded. These threshold exceedances have implications for adaptive management, but other factors influencing net change and potential net losses are first considered in the other sections below.

For wetlands, the total change across all County jurisdiction was calculated to be -4.7%. Hence threshold three (-10% for wetlands) was not exceeded. Threshold 2 is met when two or more subbasins having 5-10% change. For wetlands and their buffers, 26 of 58 subbasins had greater than 5% change, therefore Adaptive Management Threshold 2 was met. For lake, marine, and stream buffers (FWHCAs), the total change across all County jurisdiction was calculated to be -3.7%. Hence Threshold 3 (-5% for FWHCAs) was not exceeded. Threshold 2 is met when two or more subbasins having 3-5% change. Threshold 2 was met as 33 of 58 subbasins exceeded 3% change in lake, marine, and stream buffers.

Table 2.15 also separates buffers into aquatic types including lakes, marine, and stream buffers. Lake buffers are most negatively changed, followed by marine and stream buffers. The Cedar-Sammamish watershed area, being the South County, is urbanized and has the greatest magnitude of change for each aquatic type, and wetlands, except for the North Fork Stillaguamish (-11.1% P/N change for wetlands).

TABLE 2.15: SUMMARY LAND COVER CHANGES FOR WETLANDS AND FWHCAS AMONG WATERSHEDS WITH ADAPTIVE MANAGEMENT THRESHOLD REQUIRED. **RED** SHADING EXCEEDS THRESHOLD 3. **ORANGE** SHADING EXCEEDS THRESHOLD 2.

%P/N Change						
Watershed	**FWHCAs**	**Wetlands**		**Lakes**	**Marine**	**Streams**
Snohomish/ Snoqualmie	-3.4	-2.9		-5.1	-4.0	-3.2
Cedar-Sammamish	-5.6	-7.5		-9.0	-12.1	-5.3
Mainstem Stillaguamish	-2.6	-3.4		-4.7	-1.9	-2.6
North Fork Stillaguamish	-6.2	-11.1		-2.2		-6.3
Skykomish	-2.7	-4.9		-3.1		-2.7
South Fork Stillaguamish	-3.6	-5.1		-8.0		-3.4
Grand Total	-3.70	-4.70		-5.15	-4.60	-3.64
Adaptive Management Threshold Met	**Threshold 2**	**Threshold 2**				

3.0 River, Marine, and Lake Shoreline Conditions

Natural shorelines of rivers, lakes, and marine waters provide critical functions and values including fish and wildlife habitat, pollution removal, and resiliency of natural physical, chemical, and biological processes. These functions and values are compromised when the natural conditions of shorelines are changed. Changes frequently include the removal of natural vegetation and/or the armoring of the shoreline which can include the installation of bulkheads, revetments, or fill materials.

That said, one of the primary goals of the Shoreline Management Program (SMP) is to reserve waterfront properties for future development necessary for water dependent uses, such as ports, marinas, major boat repair facilities, etc. (WDOE). When those types of developments occur and impact ecological functions and values, mitigation is required. That mitigation generally occurs offsite. Separately, the SMP specifically promulgates a shoreline restoration element, in part to meet a provision of "no net loss" of functions and values. This is the performance standard against which positive and negative changes are evaluated.

While the larger land cover analysis can provide some insight into shoreline buffers and land cover change within buffers, SWM conducted field shoreline surveys on rivers and lakes to provide a more detailed understanding of condition and changes at the land-water interface. This section discusses methods and results for river, marine, and lake shoreline survey and information from 2008 through 2021.

3.1 River Shorelines Methods and Results

Larger rivers in Snohomish County are important shoreline areas for fish and wildlife and are regulated as shorelines of the State. Larger rivers are typically inset within relatively flat floodplains which are naturally formed by way of flooding, channel migration, sediment delivery, and other processes that create important fish and wildlife habitats. However, these floodplains also host active land uses such as agriculture, transportation, industry, and residential development.

To limit hazards to this developed environment, channel migration and flooding has been altered with dikes, levees, revetments, or other erosion-limiting materials. These armored features modify streambanks and critical river edge habitats that are important for juvenile salmon rearing and survival.

River shoreline surveys quantify bank armoring and erosion and compare the results over time. Figure 3.1 shows the major river locations and year(s) when shoreline surveys were conducted. Surveys also quantify other important features for salmon, such as quantity of large woody debris jams, number of pools, and length of side channels. The identification of bank armoring (presence of modifications and geo-located start/stop points) and the estimation of percent total armoring is based on standard methodology implemented consistently since 2002 (SWM).

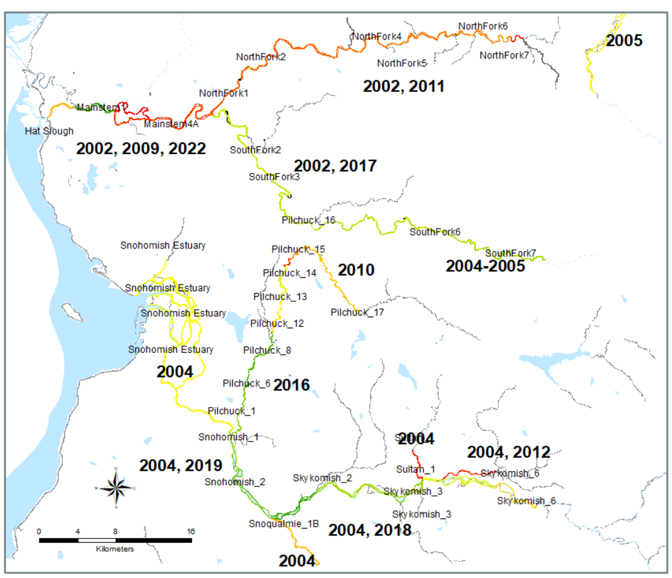


FIGURE 3.1: RIVER SURVEY REACHES AND THE YEAR(S) SURVEYED.

Table 3.1 and Table 3.2 show river survey information in the Snohomish and Stillaguamish river systems by river name and segment (upper, lower, etc.). The tables detail bank armor (%), bank erosion (%), and quantities of log jams and pools by year and the change between years. In the Stillaguamish, river segments were subsampled, so totals reflect only the count of wood jams and pools for the sampled length and not the entire river.

Overall, in the Snohomish River basin, including the Skykomish River, the bank armoring decreased by -0.43 miles/0.7 kilometers (-0.13%) and bank erosion increased by 1.68 miles/2.72 kilometers (3.95%). For the Stillaguamish River basin, the bank armoring decreased by 1.21 miles/1.96 kilometers (-0.99%) and bank erosion increased by 6.62 miles (5.1%).

In all rivers, shoreline modifications (%) exceed ecological condition limits, though little cumulative change occurred during the 2009 to 2021 time period (Table 3.1 and Table 3.2). Ecological condition limits are color coded in Table 3.1 and Table 3.2, with green indicating ecological condition level 1, orange ecological condition level 2, and red ecological condition level 3.

TABLE 3.1: SNOHOMISH BASIN RIVER BANK CONDITION COMPARING INITIAL ASSESSMENT AND SUBSEQUENT ASSESSMENTS. **GREEN** = ECOLOGICAL CONDITION LIMIT 1, **ORANGE** = ECOLOGICAL CONDITION LIMIT 2, **RED** = ECOLOGICAL CONDITION LIMIT 3.

Snohomish Basin		Assessment Years		Change
Lower Skykomish (46.6 km/29.0 miles)		2004	2018	
	%Modified	29.40%	27.50%	-1.9%
	%Eroding	14.40%	19.10%	+4.7%
	LWD Jam #	39	63 (9*)	+24
	Pool #	71	88	+17
Snohomish (24.6 km/15.3 miles)		2009	2019	
	%Modified	26.4%	27.3%	+0.9%
	%Eroding	19.7%	21.5%	+1.7%
	LWD Jam #	8	13	+5
	Pool # (side channels only)	13	15	+2
Middle Pilchuck River (54.1 km/33.6 miles)		2002	2010	
	%Modified		16.5%	
	%Eroding		31.7%	
	LWD Jam #	35	58	+23
	Pool #	ND	423	
Lower Pilchuck (27.5 km/17.1 miles)		2002	2016	
	%Modified		38.7%	
	%Eroding		12.1%	
	LWD Jam #	8	9	+1
	Pool #	ND	137	

Footnotes: *Constructed log jam count

TABLE 3.2: STILLAGUAMISH BASIN RIVER BANK CONDITION COMPARING INITIAL ASSESSMENT AND SUBSEQUENT ASSESSMENTS. **GREEN** = ECOLOGICAL CONDITION LIMIT 1, **ORANGE** = ECOLOGICAL CONDITION LIMIT 2, **RED** = ECOLOGICAL CONDITION LIMIT 3.

Stillaguamish Basin		Assessment Years		Change
Lower Stillaguamish (67.0 km/ 41.6 miles)		2009	2022	
	%Modified	31.5%	29.7%	-1.8%
	%Eroding	16.2%	22.5%	+6.3%
	LWD Jam #	11	23	+12
subsampled	Pool #	46	ND	TBD
South Fork Stillaguamish (51.7 km/32.1 miles)		2002/2009	2017	Change
	%Modified	13.7%	9.5%	-4.2%
	%Eroding	8.9%	18.0%	9.1%
	LWD Jam #	25	48 (2*)	+23
subsampled	Pool #	39	54	+15
North Fork Stillaguamish (68.5 km/42.6 miles)		2002	2011	Change
	%Modified	18.3%	16.7%	-1.6%
	%Eroding	13.9%	13.2%	-0.7%
subsampled	LWD Jam #	42	26 (1*)	-15
subsampled	Pool #	109	120	+11

*Constructed log jam count

The fraction of unstable or eroding streambanks in both river basins is high and increasing. Some streambank erosion is a natural process and should be viewed positively, as it benefits fish habitat by increasing woody material and channel sinuosity and by forming side channels. On the other hand, shoreline destabilization due to developed uses increases streambank erosion above natural levels and can cause too much sediment to enter streams, which harms fish habitat. It is important to recognize that maintaining sediment input into rivers through natural erosion is as important as limiting too much sediment. As a result, specific condition targets or Adaptive Management Thresholds are challenging to specify, especially by river. As a result, the Adaptive Management Threshold focuses on shoreline armoring.

Figure 3.2 and Figure 3.3 show changes in bank condition between two surveys. Figure 3.2 highlights an armored bank location in 2011 in the lower Stillaguamish River and Figure 3.3 shows the same location with an eroded river bank in 2022. This represents a loss in bank armor as the modified bank condition has now become natural and unstable (eroding). In this case, the reduction in bank armor was not due to actual removal of the bank armor material but rather due to channel migration.

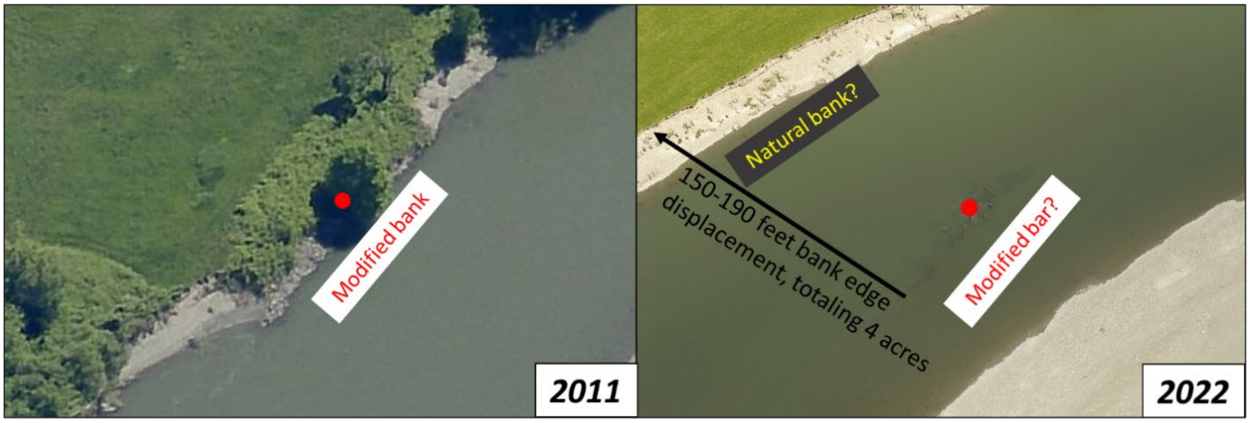


FIGURE 3.2: A CHANGE IN BANK CONDITION FROM MODIFIED AND ARMORED TO NATURAL AND UNARMORED WHERE THE RIVER ERODED, LEAVING THE OLD ARMORING MATERIAL IN THE MIDDLE OF THE CHANNEL. IMAGERY FROM PICTOMETRY COMPARING 2011 TO 2022, RED DOT PROVIDES POSITION REFERENCE.

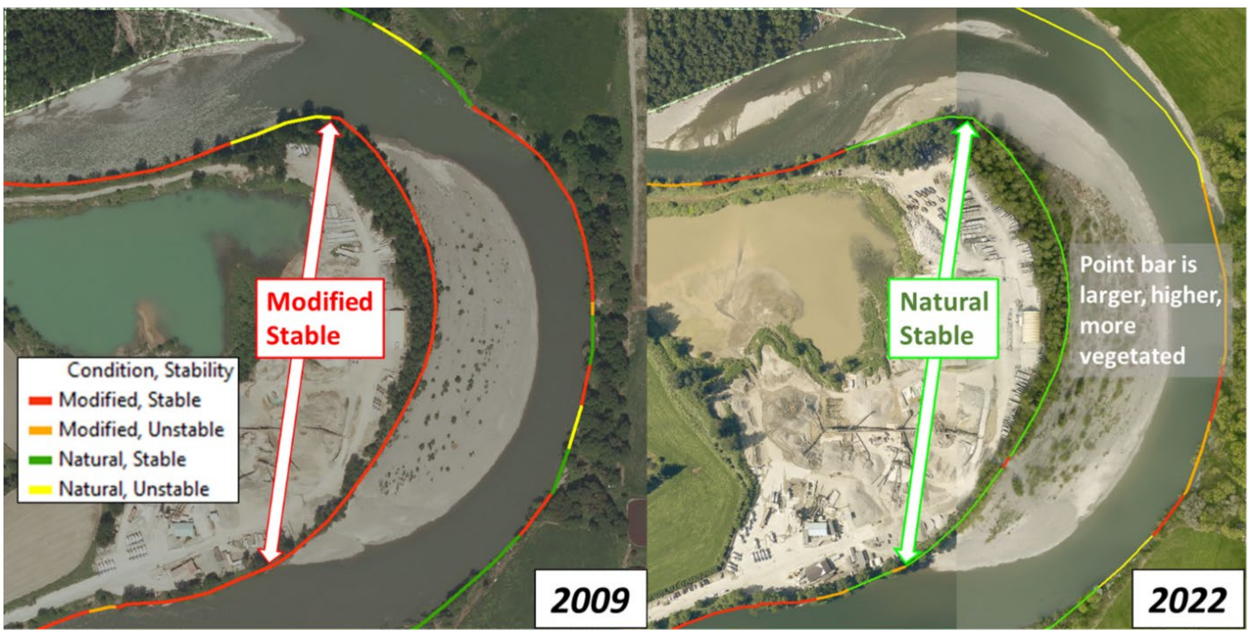


FIGURE 3.3: A CHANGE IN BANK CONDITION FROM MODIFIED AND ARMORED TO NATURAL AND STABLE WHERE THE EXISTING ARMORING HAS BEEN COVERED BY SEDIMENT DEPOSITION AND VEGETATION AS THE POINT BAR RE-VEGETATES AND MIGRATES TO THE RIGHT.

Actual instances of new bank armoring are rare relative to the existing length of bank armoring and other river modifications. Some bank armor is placed where road infrastructure is threatened by channel migration. These and other permitted new bank armoring may require mitigation.

Modifications along shorelines usually replace natural land cover conditions (i.e., forest), which in turn reduces input of large woody material that forms log jams and more frequent pool habitats. Of course, the amount of woody material, log jams, and pool habitats are also affected by other factors apart from current shoreline conditions, including historical treatment of rivers where wood was removed, and channels were dredged. Nevertheless, the current conditions of log jams and pool habitats and any differences between time periods can indicate whether there are potential positive or negative changes relevant to the evaluation of shoreline critical area functions and values.

Overall, there was a positive trend in the quantity of log jams. Table 3.1 and Table 3.2 show that the total log jam count for surveyed river segments increased in all rivers by a total of 73 log jams, though log jam count did decline in the North Fork Stillaguamish. However, the quantity of log jams in North Fork Stillaguamish is likely an underestimate as the last surveyed was in 2011, and data from other rivers surveyed since then have shown steadily increasing log jam counts. In addition, there have been 19 constructed log jams placed in the North Fork Stillaguamish. Of those 19, only one of was counted in the 2011 survey. SWM plans to resurvey the North Fork in 2024. Log jam quantity was very low in the Pilchuck River where bank armor and erosion are high. The quantity of pools is also showing a positive trend. This coincides with increases in woody material, which can be pool-forming.

3.2 Marine Shorelines

Marine shoreline modifications, namely bank armoring, were not re-surveyed by Snohomish County during this monitoring period but have been evaluated as part of regional assessment and summary. Those updated conditions were reviewed in GIS alongside 2002 shoreline armoring mapping.

For the marine shoreline south of Everett, County jurisdiction is limited. In this area, marine shoreline land use and condition is dominated by the Burlington Northern Santa Fe railroad, which runs along the shoreline. This means most of the shoreline is armored. Armored marine shorelines prevent or limit natural sediment supply and transport processes, which is harmful to the Puget Sound ecosystem. The status of shoreline conditions south of Everett at unincorporated locations, including Point Wells, Meadowdale, Picnic Point, and Norma Creek remained largely unchanged in terms of shoreline uses since the first 2002 shoreline inventory completed by Snohomish County.

North of the City of Everett to the Skagit County border, there is more unincorporated County jurisdiction along the marine shoreline. Most conditions were the same between years and datasets except for 44 unique locations. The differences observed at these locations were due to a combination of factors including:

- Under-reporting (measurement) of bank armor in 2002 – an omission error of 1,322 ft
- Over-reporting of bank armor from 2017 (new dataset) – an over-estimate of 2,089 ft
- New bank armor placement (where none was present in 2002) – a new gain of 468 ft of armor
- Armor removed since 2002 – a total reduction of 2,911 ft (predominantly at Leque Island)

Based on these measurements of estimated changed locations and lengths, shoreline armoring for the sampled marine shoreline (excludes Port of Everett, Navy base, Snohomish River delta) has been reduced by an estimated 3,210 feet compared to 2002 (or -1.2 %).

Separately, but related, a Washington Department of Fish and Wildlife project (WDFW) summarized net change in permitted shoreline armor at the regional scale (Puget Sound Partnership, 2021). Table 3.3 highlights the findings of this report in terms of the extent of new and removed shoreline armor between 2011 and 2020. It is noted in data sources that removal projects include both large scale shoreline restoration projects and smaller projects that are part of local "Shore Friendly" programs.

For Snohomish County, the extent of increase in shoreline armor was 1.3%, the lowest fraction of the total among Puget Sound Counties. The removal of shoreline armor was 6.6% of the total removed, suggesting that shoreline armor and/or the functions and values of shoreline armor that has been converted to soft-shore armoring has improved over the time frame evaluated. It is estimated that this difference between the amount of new armor and removed armor (relative to the Puget Sound-wide totals) represents a net-removal of 1,367 feet of shoreline armoring in Snohomish County between 2011 and 2020, or approximately -0.5% of the County shoreline. The reduction in length of shoreline armor between 2002 and 2017 (2,911 feet) as calculated is greater than the 2011-2020 time frame but does not specifically determine changes due to permitted versus unpermitted actions. These results together indicate that there is more armor being removed than new armor being placed along the marine shoreline.

Table 3.3: Percent of the total Puget Sound new and removed shoreline armor length within County geographic boundaries between 2011 and 2020 (PSP, 2021).

County	New Armor	Removed Armor
Clallam	6.8%	21.7%
Island	12.2%	8.1%
Jefferson	4.2%	5.6%
King	2.0%	6.9%
Kitsap	12.1%	18.4%
Mason	14.7%	5.1%
Pierce	20.1%	10.4%
San Juan	10.4%	6.4%
Skagit	10.7%	3.4%
Snohomish	***1.3%***	***6.6%***
Thurston	4.2%	7.2%
Whatcom	1.5%	0.1%

Regarding buffer conditions and land cover within County regulated shoreline areas, there were 492.16 acres of buffer in County jurisdiction. The trend of overall positive-versus-negative (%P/N) land cover conversion was -3.53%. This means that 3.53% of the 492 acres, or 17.4 acres, contained a negative change. This occurred among 26 smaller Assessment Units (AUs) evaluated along the shoreline. Sixteen of these (AUs) contained net changes that were minor (-3% to +8% net positive changes). Eleven AUs had changes < -3%, as in Threshold 2 and Threshold 3 changes, but 5 of these AUs were fronted by the unchanged railroad or Point Wells shoreline armor. Of the remaining 6 AUs, 3 AUs represented 94% of the negative buffer change acreage (13.4 acres) on the Tulalip reservation and near Warm Beach along approximately 6.5 miles of marine shoreline. This net-negative change in buffer land cover is summarized above in Section 2.3.

3.3 Lake Shorelines Methods and Results

Lake shorelines were also surveyed to determine the presence of bank armoring and the condition of shoreline vegetation. Lake shoreline vegetation provides key habitat for amphibians, waterfowl, and other aquatic life. It also captures and filters pollution from runoff before it enters lake water.

3.3.1 Lake Shoreline Methods

Lake shoreline condition surveys were conducted at all lakes with public access in unincorporated Snohomish County[6] (Figure 3.4). In total, 26 lakes were surveyed, first in 2008/2009 and again in 2021/2022. Surveys were conducted by taking visual observations of the shoreline from a boat. Data were entered into a GIS interface using aerial photos and GPS positioning for accurate locations.

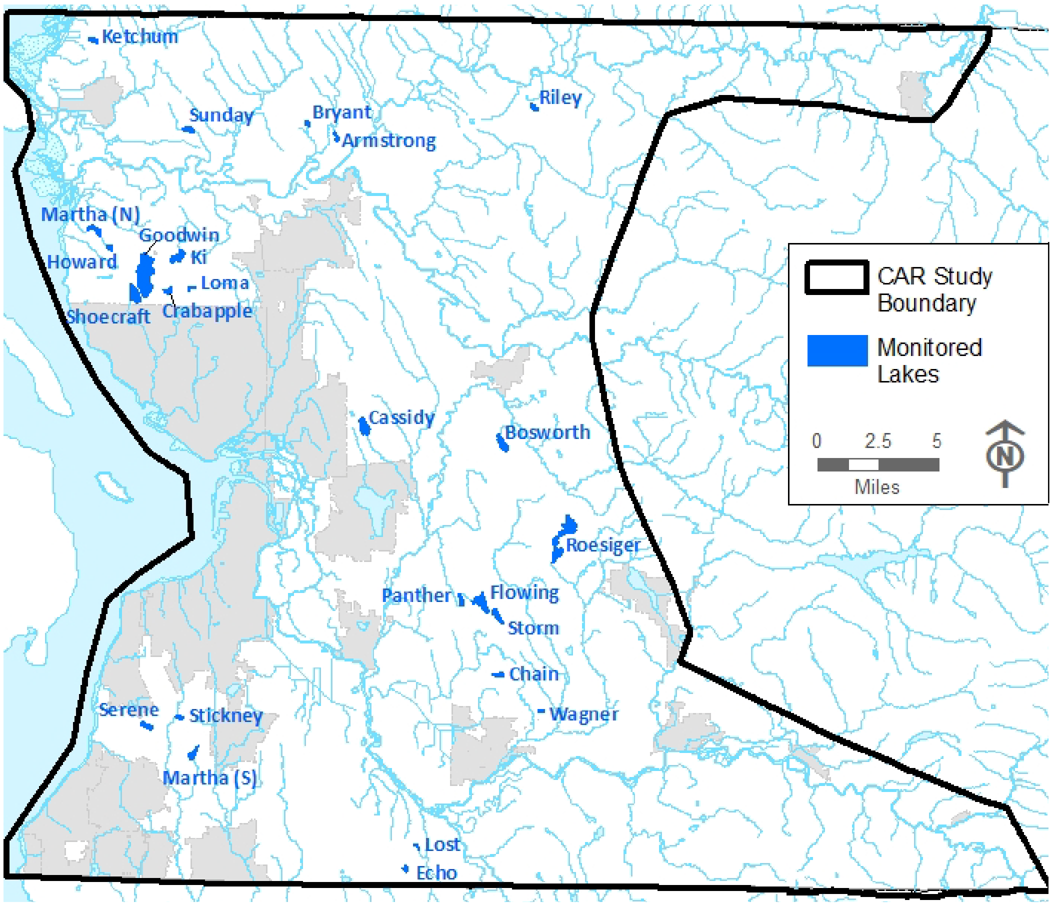


FIGURE 3.4: LAKES SURVEYED FOR SHORELINE CONDITIONS.

Shorelines were first classified as natural or modified with armoring. Armoring was classified into four types including bulkheads, revetments, fill or boat ramp as defined in Table 3.4. Shorelines vegetation was then classified as either altered (no vegetation or lawn) or intact (all other vegetation types). In the 2021/2022 survey, the complexity of vegetation was also rated on a scale of 1 to 5 as defined in Table 3.5. Full details of the shoreline survey methodology can be found in the Snohomish County Lake Management Program Quality Assurance Monitoring Plan (SWM, 2018).

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[6] Lake Stevens was also surveyed but is not included in this analysis, as the lake shoreline was mostly under the jurisdiction of the City of Lake Stevens in 2008/2009 and was fully annexed prior to the 2020/2021 surveys.

Table 3.4: Lake shoreline armoring classifications.

Natural Shorelines	Little to no human-made modifications to the shoreline structure	
Shorelines with Armoring (by type)	Bulkhead	Any constructed vertical wall built along a bank (includes bulkheads, boathouses, patios, docks etc.)
	Revetment	Materials placed along the lake shoreline edge such as rocks or natural logs that modify the shoreline edge but are not a constructed vertical wall.
	Fill	Materials such as sand or gravel put along the lake shoreline typically used to suppress vegetation to create areas for lake access or to raise the level of an area to create more shoreline or fill wet areas of yards
	Boat Ramp	An area of shoreline that has been modified to provide launching and retrieval of boats (public or private) and may consist of structural or fill materials

Table 3.5: Lake shoreline vegetation condition classifications.

Altered Vegetation	1	No vegetation present
	2	Lawns - dominant feature is lawn (turf grass) or invasive reed canary grass that is typically mowed or cut back
Intact Vegetation	3	Non-lawn - Mostly tall grasses or small shrubs; low diversity; low canopy complexity; thinner vegetation; little overhanging vegetation
	4	Vegetation has some shrubs or tree; more diversity with some overhanging vegetation but is thin or less dense. (e.g., group of hardhack but then goes to lawn; mature trees with little or no vegetation under)
	5	Dense vegetation coverage with multiple canopy layers of dense shrubs and/or mature trees; lots of overhanging vegetation

3.3.2 Lake Shoreline Armoring Results

Twenty-five lakes were surveyed over two time periods, 2008/2009 and 2021/2022. These results include both status and change over time.

The 25 lakes surveyed over the two time periods collectively have 44.35 miles of lake shoreline. In 2008, approximately 38.7% (17.15 miles) of all lake shorelines were armored (Figure 3.5; Table 3.6). This increased to 41.1% or 18.24 miles by 2021/2022, a net change of 2.4%. This included an additional 1.57 miles of shoreline armoring added and 0.48 miles removed.

When looking at individual lakes' ecological condition in 2008/2009, over half of lakes (52%) were classified as "degraded", 20% were "at risk", and 28% were considered "properly functioning". Little changed in ecological condition ratings in comparison to 2020/2021 except for two lakes: Storm which declined to "at risk" and Sunday which improved to "property functioning". However, several lakes that were already at risk did have armoring increases (Table 3.6). Lakes Bosworth and Roesiger had a 10% increase in shoreline armoring and six lakes had increases between 5 and 10% (Flowing, Howard, Serene, Shoecraft, and Storm).

There was also a surprisingly high amount of shoreline armoring removed. Some armoring loss may be an artifact of the higher resolution of data collection in 2021/2022. At lakes with high wave action or large seasonal water level changes, armoring may also have eroded away. Fill materials that were established for beaches also becomes hard to detect if vegetation begins to regrow near the shoreline. While these positive changes may not always be intentional, allowing the lake to return to natural conditions can help restore some of the benefits to the lake health, particularly if the change is accompanied by the regrowth of vegetation.

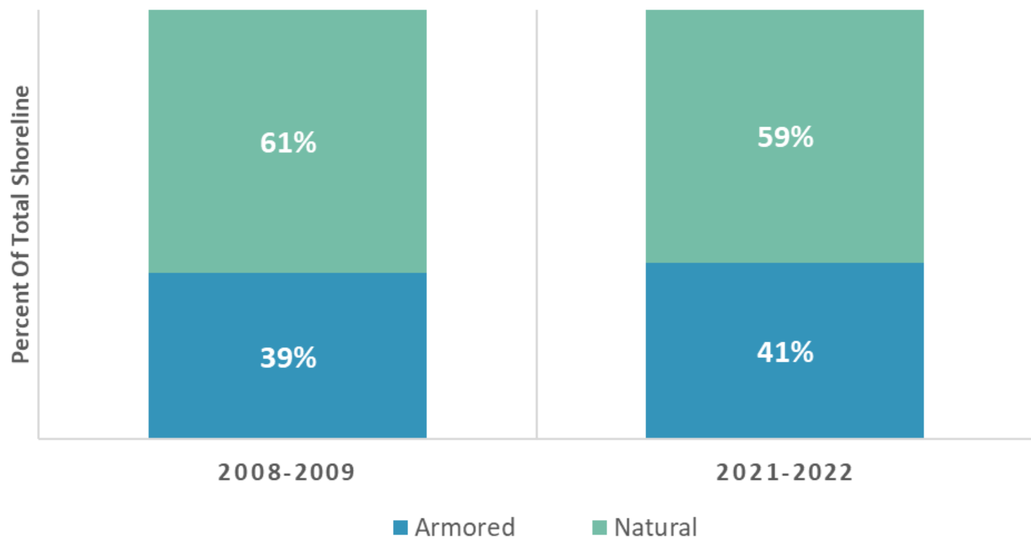

FIGURE 3.5: PERCENT OF SHORELINE ARMORING FOR ALL LAKES IN 2008-2009 AND 2021-2022.

TABLE 3.6: LAKE SHORELINE ARMORING CONDITION COMPARING 2008-2009 ASSESSMENT TO 2021-2022 ASSESSMENT. **GREEN** = ECOLOGICAL CONDITION LIMIT 1, **ORANGE** = ECOLOGICAL CONDITION LIMIT 2, **RED** = ECOLOGICAL CONDITION LIMIT 3[1].

Lakes	Total Shoreline (m)	2008-2009 Total Armored (m)	2021-2022 Total Armored (m)	2008/2009 Percent Armored	2021-2022 Percent Armored	Percent Change in Total Armored Shoreline
Armstrong	1,766	14	32	1%	2%	**1%**
Bosworth	3,498	922	1,263	26%	36%	**10%**
Bryant	1,136	0	0	0%	0%	**0%**
Cassidy	3,167	59	128	2%	4%	**2%**
Chain	1,811	14	15	1%	1%	**0%**
Crabapple	1,910	505	382	26%	20%	**-6%**
Echo	1,411	636	581	45%	41%	**-4%**
Flowing	4,261	2,194	2,438	51%	57%	**6%**

Lakes	Total Shoreline (m)	2008-2009 Total Armored (m)	2021-2022 Total Armored (m)	2008/2009 Percent Armored	2021-2022 Percent Armored	Percent Change in Total Armored Shoreline
Goodwin	9,151	6,515	6,579	71%	72%	**1%**
Howard	1,397	398	458	28%	33%	**4%**
Ketchum	2,096	647	729	31%	35%	**4%**
Ki	3,181	1,689	1,569	53%	49%	**-4%**
Loma	1,543	246	264	16%	17%	**1%**
Lost	1,219	131	163	11%	13%	**3%**
Martha North	3,007	1,133	991	38%	33%	**-5%**
Martha South	2,605	1,881	1,841	72%	71%	**-2%**
Panther	2,142	224	289	10%	13%	**3%**
Riley	1,714	18	18	1%	1%	**0%**
Roesiger	10,054	5,826	6,848	58%	68%	**10%**
Serene	2,223	1,602	1,741	72%	78%	**6%**
Shoecraft	4,045	2,168	2,367	54%	59%	**5%**
Stickney	1,805	80	61	4%	3%	**-1%**
Storm	2,718	216	380	8%	14%	**6%**
Sunday	2,210	271	41	12%	2%	**-10%**
Wagner	1,303	226	176	17%	13%	**-4%**
Total	**71,375**	**27,614**	**29,355**	39%	41%	**2%**

[1]Ecological Condition Level 1 = Properly functioning
Ecological Condition Level 2 = At-risk
Ecological Condition Level 3 = Degraded

3.3.3 Lake Shoreline Vegetation Results

In 2008/2009, approximately 58.7% (26.01 miles) of lake shoreline vegetation was altered (Table 3.7). This decreased to 55.9% (24.78 miles) in 2021/2022, meaning 2.8% of shoreline vegetation was restored to intact. The improvement in shoreline vegetation is most likely an artifact of the higher resolution data collection which allowed smaller areas of natural vegetation to be counted. There were also a few lakes with shoreline restoration that occurred because of the LakeWise outreach program, launched in 2012 (SWM). Some natural revegetation of lawns or bare areas may also have occurred.

When looking at individual lakes, the ecological condition of shoreline vegetation in 2009 was classified as "degraded" for 28% of all lakes (Table 3.7). The remaining were classified as "at risk" for (48%) or "properly functioning" for 6 lakes (24%). These classifications remained constant through 2020/2021 except for Bosworth and Echo lakes which improved from to "at risk" and Ketchum which declined to "degraded". Four lakes had 5% or greater increase in altered shoreline vegetation (Ketchum, Shoecraft, Storm, and Sunday).

The 2020/2022 the vegetation conditions were classified into five categories to better assess vegetation health (Table 3.5). Of the 26 miles surveyed, 18% had no vegetation, 38% had lawn and 56% had intact vegetation.

Within the intact vegetation, 9% had a category 3, 7% category 4 and 28% category 5. Functions and values are mostly preserved in category 4 or 5 ratings. These findings will be useful for identifying future changes.

Table 3.7: Lake shoreline altered vegetation condition comparing 2008-2009 assessment to 2021-2022 assessment. **Green** = Ecological Condition Limit 1, **Orange** = Ecological Condition Limit 2, **Red** = Ecological Condition Limit 31.

Lakes	Total Shoreline (m)	2008-2009 Total Altered Vegetation (m)	2021-2022 Total Altered Vegetation (m)	2008/2009 Percent Altered Vegetation	2021-2022 Percent Altered Vegetation	Percent Change in Total Altered Vegetation
Armstrong	1,766	57	86	3%	5%	**2%**
Bosworth	3,498	2,741	2,413	78%	69%	**-9%**
Bryant	1,136	0	25	0%	2%	**2%**
Cassidy	3,167	201	257	6%	8%	**2%**
Chain	1,811	99	122	5%	7%	**1%**
Crabapple	1,910	932	731	49%	38%	**-11%**
Echo	1,411	1,002	948	71%	67%	**-4%**
Flowing	4,261	2,733	2,666	64%	63%	**-2%**
Goodwin	9,151	8,501	8,177	93%	89%	**-4%**
Howard	1,397	714	651	51%	47%	**-5%**
Ketchum	2,096	1,413	1,650	67%	79%	**11%**
Ki	3,181	2,041	1,956	64%	62%	**-3%**
Loma	1,543	825	738	53%	48%	**-6%**
Lost	1,219	401	392	33%	32%	**-1%**
Martha North	3,007	1,807	1,468	60%	49%	**-11%**
Martha South	2,605	2,195	1,959	84%	75%	**-9%**
Panther	2,142	1,012	866	47%	40%	**-7%**
Riley	1,714	32	41	2%	2%	**0%**
Roesiger	10,054	7,992	7,227	79%	72%	**-8%**
Serene	2,223	1,947	1,833	88%	82%	**-5%**
Shoecraft	4,045	2,879	3,094	71%	76%	**5%**
Stickney	1,805	354	291	20%	16%	**-3%**
Storm	2,718	833	996	31%	37%	**6%**
Sunday	2,210	704	851	32%	39%	**7%**
Wagner	1,303	448	441	34%	34%	**-1%**
Total	**71,375**	**41,864**	**39,881**	**59%**	**56%**	**-3%**

[1]Ecological Condition Level 1 = Properly functioning
Ecological Condition Level 2 = At-risk
Ecological Condition Level 3 = Degraded

3.4 Lake Dock Methods and Results

People often install a dock for lake access as they build new homes along lake shorelines. People with existing homes also commonly add docks to improve their recreational access to lakes. While dock construction is covered by several local, State, and federal regulations beyond CAR, docks can serve as a surrogate for understanding changes to lake critical areas. In addition, overwater structures themselves negatively impact critical areas, especially shallow waters that provide fish rearing habitat as well as other benefits, as they can alter lake substrate, hydrology, and water quality. They also create shade, which alters predatory behavior and limits the growth of beneficial native plants.

The number and extent of docks and overwater structures were quantified at the same 26 public access lakes as the shoreline survey (Figure 3.4). Docks were digitized initially using 2007 aerial imagery and updated using 2020 aerial imagery. All overwater structures were counted as "docks" including permanent docks, floating docks, swim platforms, and permanent boat houses.

The number of docks at all lakes increased by 134 docks from 1,965 in 2007 to 2,099 in 2020. The density of docks can better characterize the overall impact to critical areas and was measured in docks per 1,000 linear feet of shoreline. Dock density increased 7% from 0.84 to 0.90 docks/1,000 ft (Table 3.8).

The number and density of docks was highly variable between individual lakes (Table 3.8). The ecological condition rating for dock density in 2007 was classified as "degraded" in 44% of lakes with the remaining 66% evenly split between "properly functioning" and "at risk". These classifications remained constant at all but three lakes including Echo and Howard which declined from "at risk" to "degraded" and Martha North which improved from "degraded" to "at risk". Two lakes with the highest dock density, Roesiger (14.31) and Goodwin (12.69), accounted for 41% of all inventoried docks despite only comprising 27% of the total lake shoreline.

Table 3.8: Comparison of the number and Density of docks at lakes, 2007 versus 2020 assessment. **Green** = Ecological Condition Limit 1, **Orange** = Ecological Condition Limit 2, **Red** = Ecological Condition Limit 3.

Lake	Shoreline Length (ft)	Number of Docks		Dock Density (docks/1,000 ft)		
		2007	2020	2007	2020	% Change
Armstrong	5,792	6	7	1.04	1.21	17%
Bosworth	11,473	129	135	11.24	11.77	5%
Bryant	3,726	0	0	0.00	-	0%
Cassidy	10,388	19	19	1.83	1.83	0%
Chain	5,940	0	3	0.00	0.51	>100%
Crabapple	6,265	49	48	7.82	7.66	-2%
Echo	4,628	37	43	7.99	9.29	16%
Flowing	13,976	116	131	8.30	9.37	13%
Goodwin	30,015	367	381	12.23	12.69	4%
Howard	4,582	35	41	7.64	8.95	17%
Ketchum	6,875	50	50	7.27	7.27	0%
Ki	10,434	93	107	8.91	10.26	15%
Loma	5,061	52	60	10.27	11.86	15%

Lake	Shoreline Length (ft)	Number of Docks		Dock Density (docks/1,000 ft)		
		2007	2020	2007	2020	% Change
Lost	3,998	43	49	10.75	12.26	14%
Martha North	9,863	79	77	8.01	7.81	-3%
Martha South	8,544	90	101	10.53	11.82	12%
Panther	7,026	32	37	4.55	5.27	16%
Riley	5,622	14	16	2.49	2.85	14%
Roesiger	32,977	453	472	13.74	14.31	4%
Serene	7,291	80	85	10.97	11.66	6%
Shoecraft	13,268	124	126	9.35	9.50	2%
Stickney	5,920	33	34	5.57	5.74	3%
Storm	8,915	41	49	4.60	5.50	20%
Sunday	7,249	17	17	2.35	2.35	0%
Wagner	4,274	6	11	1.40	2.57	83%
Grand Total	**234,103**	**1,965**	**2,099**	**0.84**	**0.90**	**7%**

Docks vary greatly in shape or size, so surface area is another metric that can help to assess dock impacts. The surface area of docks across the assessed lakes increased from 18.82 acres in 2007 to 20.92 acres in 2020 (Table 3.9). As a percent of surface area this is an increase from 0.88% to 0.97% dock coverage (Table 3.9). Four small lakes (25 acres or less) had more than 1.5% of the total surface area covered by docks in 2020 including Echo (2.2%), Loma (1.9%), Lost (1.9%), and Stickney (1.6%).

TABLE 3.9: TOTAL DOCK AREA AND PERCENT OF LAKE SURFACE AREA THAT DOCKS COVER, COMPARISION OF 2007 VERSUS 2020 AND PERCENT CHANGE.

Lake	Lake Area (acres)	Total Dock Area (acres)		Dock Coverage (% of Lake Surface Area)		
		2007	2020	2007	2020	% Change
Armstrong	30.8	0.06	0.05	0.2%	0.2%	-18%
Bosworth	103.0	1.14	1.15	1.1%	1.1%	1%
Bryant	21.4	0.00	0.00	0.0%	0.0%	0%
Cassidy	131.0	0.15	0.19	0.1%	0.1%	27%
Chain	38.7	0.00	0.01	0.0%	0.0%	100%
Crabapple	37.0	0.40	0.44	1.1%	1.2%	10%
Echo	21.5	0.37	0.48	1.7%	2.2%	29%
Flowing	132.5	1.02	1.34	0.8%	1.0%	31%
Goodwin	538.7	4.95	5.25	0.9%	1.0%	6%
Howard	28.1	0.26	0.31	0.9%	1.1%	17%
Ketchum	26.1	0.26	0.27	1.0%	1.0%	3%
Ki	100.6	0.85	0.99	0.8%	1.0%	16%

Lake	Lake Area (acres)	Total Dock Area (acres)		Dock Coverage (% of Lake Surface Area)		
		2007	2020	2007	2020	% Change
Loma	22.6	0.35	0.39	1.6%	1.7%	11%
Lost	13.2	0.19	0.25	1.4%	1.9%	33%
Martha North	62.9	0.65	0.64	1.0%	1.0%	-1%
Martha South	61.6	0.79	0.90	1.3%	1.5%	14%
Panther	49.0	0.25	0.30	0.5%	0.6%	17%
Riley	32.8	0.11	0.13	0.3%	0.4%	25%
Roesiger	348.1	4.28	4.82	1.2%	1.4%	13%
Serene	45.0	0.52	0.60	1.2%	1.3%	15%
Shoecraft	133.1	1.51	1.57	1.1%	1.2%	4%
Stickney	25.0	0.33	0.41	1.3%	1.6%	23%
Storm	76.0	0.24	0.27	0.3%	0.4%	14%
Sunday	48.6	0.10	0.10	0.2%	0.2%	1%
Wagner	20.6	0.04	0.07	0.2%	0.3%	67%
Grand Total	**2,148**	**18.82**	**20.92**	**0.88%**	**0.97%**	**11%**

3.5 Shoreline Results and Adaptive Management Thresholds

Per Table 1.5, the Percent Bank Armoring Shoreline Monitoring Element was selected for evaluation against Adaptive Management Thresholds 1-3, as summarized in Table 3.10.

TABLE 3.10: SHORELINE BANK ARMORING ADAPTIVE MANAGEMENT MONITORING ELEMENTS AND THRESHOLDS.

Plan Component	Monitoring Element	Threshold 1[1]	Threshold 2[2]	Threshold 3[3]
Shorelines	% Bank Armoring	<3% change across County jurisdiction within any watershed relative to baseline	3-5% change across County jurisdiction within 2 or more watersheds relative to baseline	>5% change across County jurisdiction relative to baseline

[1]Threshold 1 triggers public outreach and/or enforcement and mitigation actions.

[2]Threshold 2 triggers additional public outreach, enforcement, and mitigation actions; programmatic adjustments.

[3]Threshold 3 triggers programmatic adjustments including code revisions.

Table 3.11 shows results of the Shoreline Monitoring Element at the CAR Study Area scale. The bottom row of the table shows the highest threshold out of three that is exceeded.

TABLE 3.11: SUMMARY OF LAKE, MARINE, AND RIVER SHORELINE BANK ARMORING CHANGES WITH ADAPTIVE MANAGEMENT THRESHOLDS.

	Lakes+Marine+Rivers	Lakes	Marine[1]	Rivers[2]
Grand Total	ALL <3%	2.4%	-0.5% to –1.2%	-0.13% and -0.99%
Adaptive Management Threshold Met	**Threshold 1**			

[1]Marine shoreline change estimates based on Puget Sound Partnership vital sign reporting (PSP) using WA Department of Fish and Wildlife permits, and ESRP regional study data.
[2]Snohomish and Stillaguamish basins, respectively.

Due to data limitations, the percent of change by watershed was not possible to calculate. However, based on available evidence and a close examination of the data, there is no evidence any watershed had an increase of >3%.

4.0 Functions and Values Methods and Results

State of Our Waters (SOW) is an environmental monitoring program implemented by SWM since 2018 that collects data on the health of Snohomish County rivers, streams, and lakes. While the SOW program was not implemented to specifically test for effects of CAR regulatory actions, the data can be used to provide information on the status of conditions related to the ecological functions associated with aquatic critical areas. The primary component of SOW that began in 2018 was an annual data collection program on stream health. The lake health component, which has been operational since the mid-1990's, was incorporated into the overall program at that time.

4.1 Stream and River Methods and Results

Snohomish County has streams of varying sizes and unique stressors. To understand the health of streams in the County, the SOW program uses a randomized, probability-based sample design that is spatially balanced. All potential sample sites are stratified (or grouped) into four land use types: Urban, Rural, Agriculture (commercial and Rural) and Forest (Figure 4.1). Land use types were assigned based on geospatial overlap with Snohomish County's Future Land Use Zoning classification. This type of design allows findings from the streams sampled to be extrapolated to all streams within the broader SOW sample frame within each land use type. Additional information about the SOW sampling design can be found in the Snohomish County State of Our Waters Quality Assurance Monitoring Plan (SWM, 2020).

The SOW sample frame (Figure 4.1) is like, but not identical to, the CAR Study Area, as it includes agricultural areas as well as some forested areas in the eastern portion of the County. In total, 92 of the 96 SOW sampling locations were contained within the CAR Study Area.

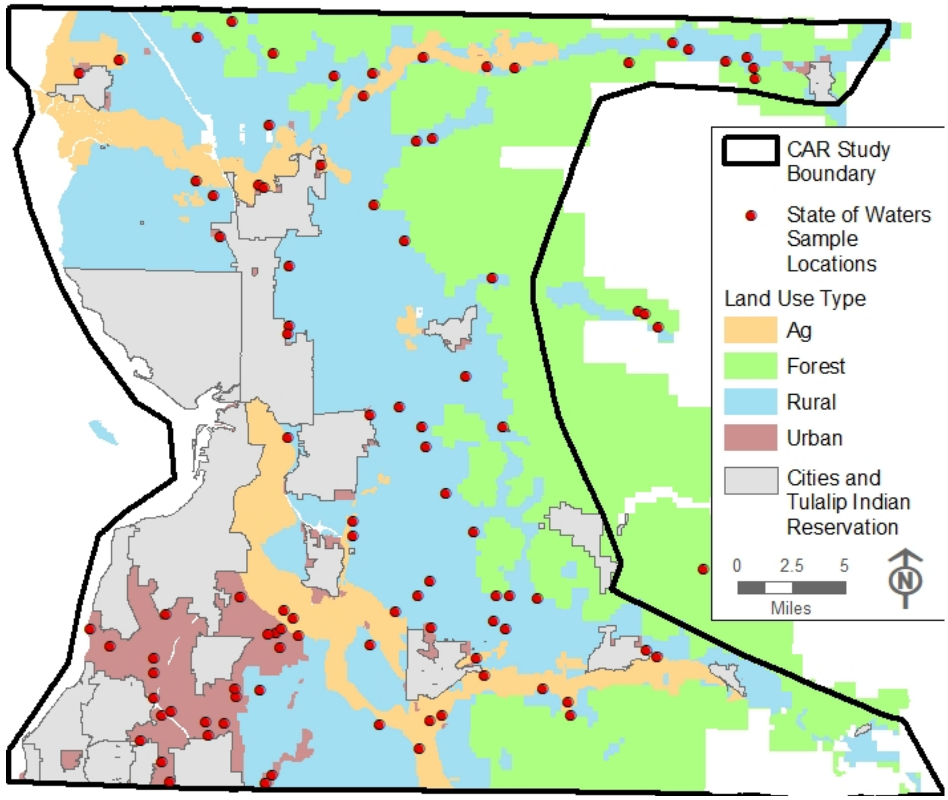

Figure 4.1: State of Our Waters 2018-2022 sampling locations and land use types.

The SOW program collects a plethora of data about the condition of aquatic life, water quality, and physical habitat in streams. This data is annually summarized into more easily digestible health ratings using indices for benthic invertebrates, water quality, and habitat. These indices are indicators of the condition of ecological functions and values. While unable to provide information on direct links between changes in land cover and direct impacts or changes to status of functions and values, the SOW program can provide the following information:

- **What is the current health status of streams?** Indices for benthic invertebrates, water quality, and habitat are used to provide insight into the current indicators related to the condition of stream functions and values. The percent of stream miles in each health rating ("excellent", "good", "fair", "poor", "very poor") for each index within the SOW sample frame is reported.
- **How does the health status of streams vary by land use?** As land use is a primary driver of stream health, information on how the health of streams vary by land use is reported. The percent of stream miles in each health rating for each index by land use is provided.
- **Is there a correlation between subbasin land cover buffer condition and index scores? And does it matter whether a site is within a subbasin that meets or does not meet the 60:10 threshold?** To provide a linkage with CAR protection of buffers, these analyses tested whether the index score was influenced by subbasin land cover condition. The Land Cover Index (LCI), which is percent forest minus percent impervious area, was tested to see if subbasin landcover impacts index scores and therefore

indicators of the health of functions and values. To determine if subbasins in better condition based on the 60:10 ratio were providing additional resiliency, the data were further categorized into sites based on this variable.

- **Is there a correlation between local riparian buffer land cover condition and index scores? And does it matter whether a site is within a subbasin that meets or does not meet the 60:10 threshold?** To provide a linkage with CAR protection of buffers, these analyses tested whether the index score was influenced by local buffer land cover condition. The LCI for local buffer land cover condition (150-foot buffer within 1-km upstream of site) was tested to see if local buffer conditions impact index scores and therefore indicators of the health of functions and values. To determine if subbasins deemed in better condition based on the 60:10 ratio were providing additional resiliency, the data were further categorized into sites based on this variable.

Stream temperature was also evaluated, including considering land cover linkages.

4.1.1 Stream Benthic Index of Biotic Integrity (BIBI)

The Benthic Index of Biotic Integrity (BIBI) is a scoring method that uses the type, number, and characteristics of benthic macroinvertebrates, stream bugs, to provide an overall indicator on the health of aquatic life in a stream. Benthic macroinvertebrate samples are collected once per year at stream sites and scores are summarized into a health rating of "excellent", "good", "fair", "poor", or "very poor". The data are reported in stream miles which allows for comparison of data across land use types.

Overall, 45% of stream miles within the SOW sample area are in "excellent" or "good" condition for benthic invertebrates, 21% are in "fair" condition and 30% in "poor" or "very poor" condition (Figure 4.2).

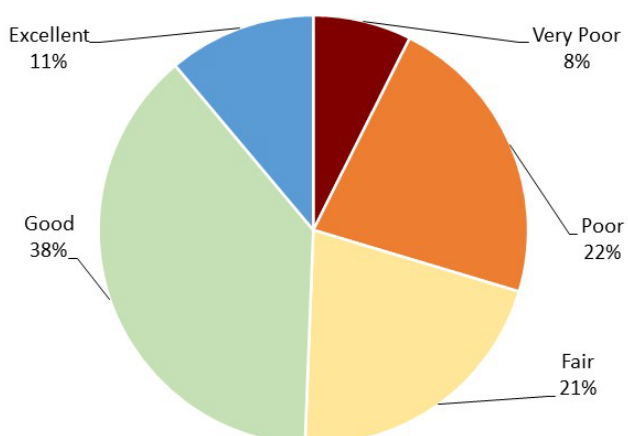

FIGURE 4.2: PERCENT OF STREAM MILES WITHIN SOW SAMPLE AREA IN EACH BIBI CONDITION CATEGORY.

A better understanding of the influences that directly impact health ratings can be seen by looking at ratings within each land use (Figure 4.3). There were a similar proportion of stream miles classified as "excellent" or "good" in both forest and rural landscapes (80% and 87%, respectively). Conversely, streams in agriculture and urban stream settings contained a much higher proportion of stream miles in "poor" and "very poor" conditions (63% and 40% respectively). In urban streams, there were no stream miles (0%) in "excellent" condition and 24% and 36% in "good" and "fair" categories, respectfully. Streams in the agriculture land use setting, which includes locations among commercial and rural areas, had the most variable conditions; from “excellent” to “very poor”.

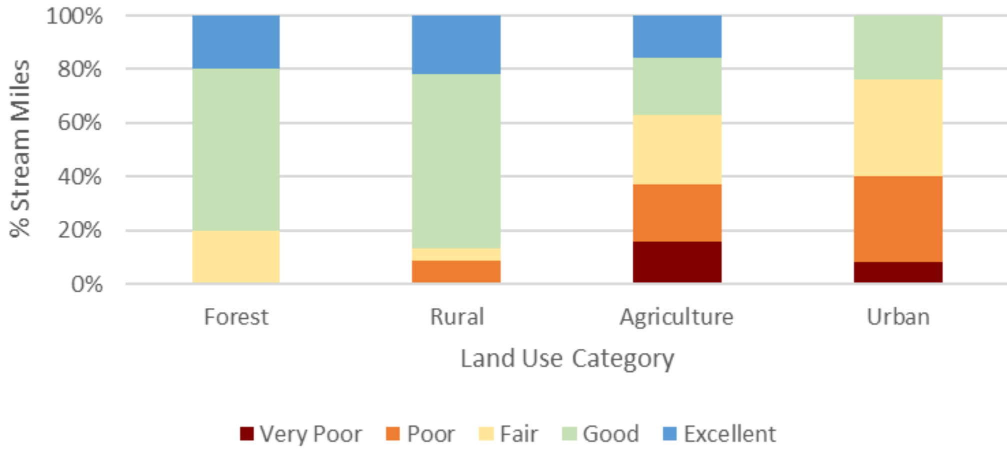

FIGURE 4.3: PERCENT OF STREAM MILES IN BIBI HEALTH CATEGORIES BY LAND USE TYPE.

BIBI conditions were next compared to land cover at the subbasin scale. Figure 4.4 shows BIBI scores versus the land cover index (LCI) at the entire subbasin scale. This graph highlights that decreasing BIBI scores are reflective of decreasing land cover (more impervious surface and/or less forest cover) at the subbasin scale. These relationships were categorized further according to the 60:10 subbasin thresholds. While subbasins that meet the 60:10 threshold (coded with 1) generally have higher LCI values and higher BIBI scores, this status does not guarantee higher scores and therefore protection of BIBI.

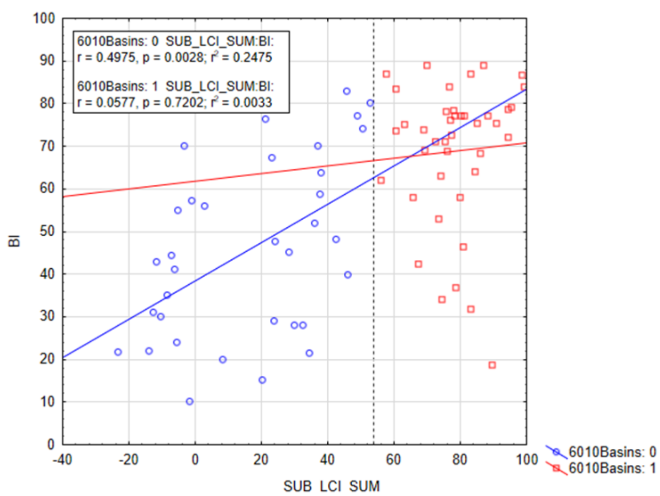

FIGURE 4.4: BIBI SCORES VERSUS SUBBASIN LAND COVER (LCI) FOR 60:10 SUBBASIN CATEGORIES.

Local buffer conditions were next tested to determine if they influence BIBI scores (Figure 4.5). A correlation between local buffer land cover and BIBI scores was found, meaning that as local buffer conditions decline due to increasing impervious or decreasing forest, BIBI scores would also be expected to decline. These relationships were categorized further according to the 60:10 subbasin thresholds. While subbasins that meet the 60:10 threshold (coded with 1) generally have higher buffer LCI values and higher BIBI scores, higher LCI and 60:10 status does not guarantee the protection of benthic invertebrates.

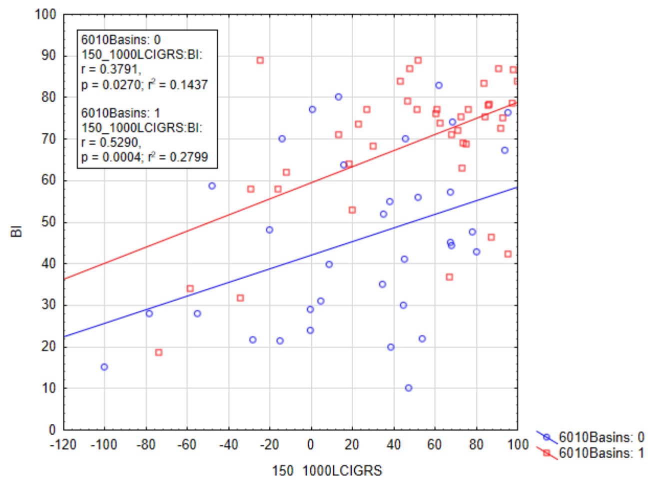

Figure 4.5: BIBI scores versus local buffer land cover for 60:10 subbasin categories.

4.1.2 Water Quality Index (WQI)

The Water Quality Index (WQI) is a tool developed by the Washington State Department of Ecology (WDOE, 2002) that combines eight water quality indicators to express results in a more easily understood manner. WQI indicators include temperature, pH, dissolved oxygen, turbidity, total suspended solids, E. coli, total persulfate nitrogen, and total phosphorus. The SOW program collects water quality samples once per month, twelve months per year. Indicator scores are aggregated over a year to produce a single annual WQI score ranging from 0-100 for each site.

Overall, 68% of stream miles within the SOW sample frame are in "excellent" or "good" condition for water quality (Figure 4.6). 13% of stream miles are in "poor" or "very poor" condition, with the remainder (19%) in "fair" condition.

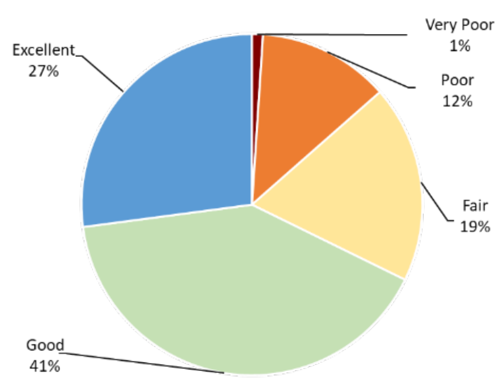

Figure 4.6: Percent of stream miles within SOW sample area in each condition category for water quality.

Figure 4.7 shows WQI health rating by land use types. Forested and rural areas have a high percentage (>80%) of "excellent" or "good" water quality; the remainder being in "fair" condition in forested land use and "fair" and "poor" in rural land uses. Urban areas have the next best water quality conditions with over 60% of the extent in "good" or "excellent" condition. The agricultural land use setting has the greatest range of WQI scores with approximately 30% of locations in each "poor", "fair", and "good" categories. The remaining 10% of locations are "excellent." Overall, water quality, summarized by the WQI, is less influenced by the gradation from more natural to altered land uses and land cover than BIBI.

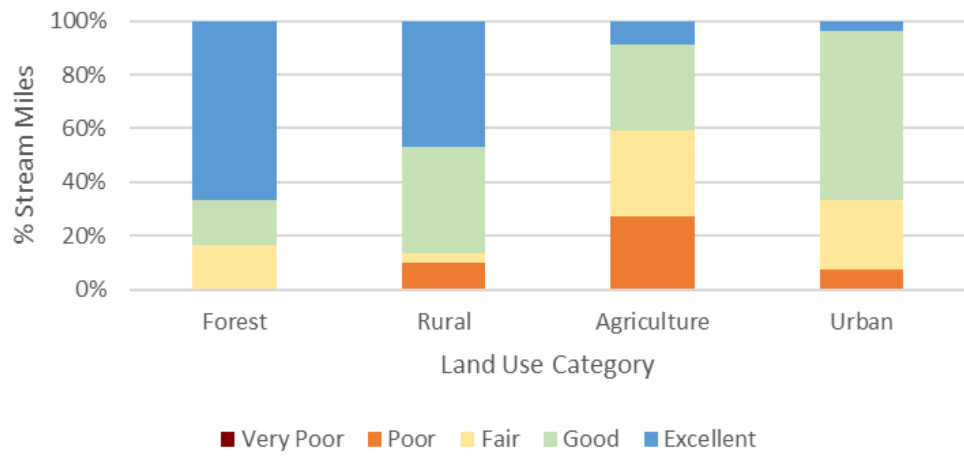

FIGURE 4.7: WATER QUALITY INDEX CATEGORIES BY LAND USE TYPES.

WQI was also statistically correlated with total subbasin land cover as represented by LCI score, but when plotted by 60:10 subbasins, WQI scores for each category were highly variable, and no land cover correlation was evident (Figure 4.8). For subbasins meeting the 60:10 conditions, there was notable variability in WQI scores, though most were "good" to "excellent". For subbasins not meeting the 60:10 criteria, WQI scores were lower, highly variable, and with no apparent relationship to upstream land cover.

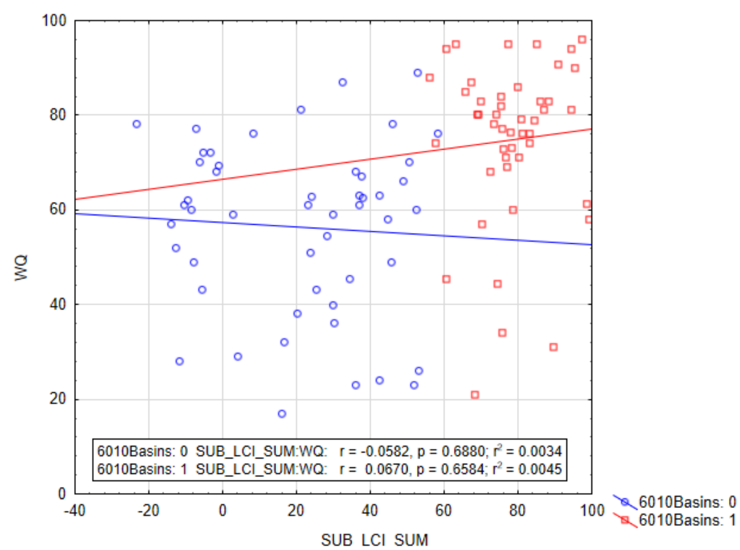

FIGURE 4.8: WQI SCORES FOR 60:10 SUBBASIN CATEGORIES PLOTTED VERSUS SUBBASIN LAND COVER CONDITION (LCI).

However, WQI scores were significantly correlated with the local buffer land cover condition just upstream from the sample location (Figure 4.9). This result also highlights a stronger correlation when the grass or pasture component of land cover in a buffer is included, which is less functional than forest land cover, and often more prevalent in buffers than built impervious surfaces. Like the correlation for BIBI scores, the results highlight that WQI scores decline according to a similar effect from declining buffer conditions for both subbasins with better land cover conditions (i.e., 60:10) and those subbasins not meeting 60:10 conditions.

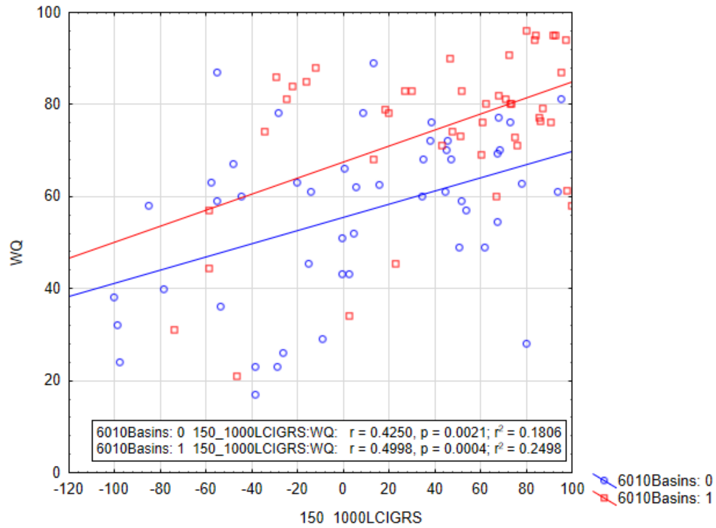

FIGURE 4.9: WQI INDEX SCORES RELATIVE TO BUFFER LAND COVER CONDITIONS FOR 60:10 SUBBASINS.

4.1.3 Habitat Quality Index (HQI) and Other Habitat Indicators

In the SOW program, stream and river habitat conditions are measured and assessed for several indicators based on suitability for salmonid habitat. Five key indicators used to construct a habitat quality index (HQI) are pool frequency, pool percent area, percent fine sediment, large wood frequency, and percent modified streambanks. These indicators are measured once per year at each stream site.

Overall, 31% of stream miles within the SOW sample frame are in "excellent" or "good" condition for habitat (Figure 4.10). The highest percentage of stream miles (45%) are in "fair" condition, while 24% are in "poor" or "very poor" condition.

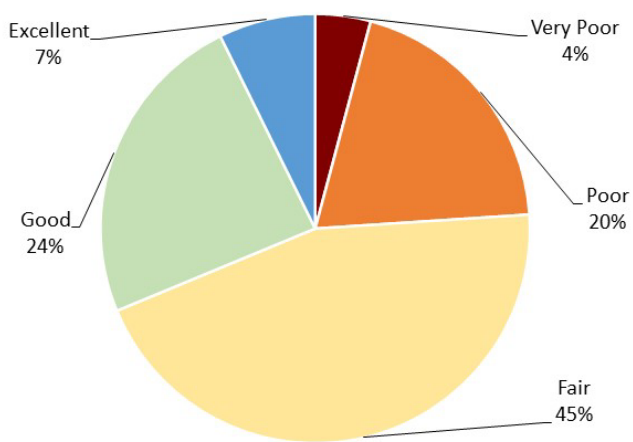

FIGURE 4.10: PERCENT OF STREAM MILES WITHIN SOW SAMPLE AREA IN EACH CONDITION CATEGORY FOR HABITAT QUALITY INDEX.

Figure 4.11 shows the results for HQI categories among land use types. Most of the stream length in forest and rural areas is in "excellent" or "good" condition. "Excellent" conditions do not exist in agricultural or urban areas, where a limited extent of "good" habitat conditions exist, while "fair" and "poor" (as well as "very poor") conditions predominate.

While HQI scores were statistically different among land use types, HQI in agricultural settings were not as depressed compared to BIBI and WQI scores. Moreover, although there were differences among land uses, the extent of differences based on analysis of variance was much less than for the other index scores. Like BIBI and WQI, scores in forest and rural areas were generally similar with a lower range in some rural areas. Lower quantities of large woody material which forms cover for fish and pool habitats drove the lower overall scores in forest and rural land use settings, where the legacy of historical logging and stream "cleaning" persists.

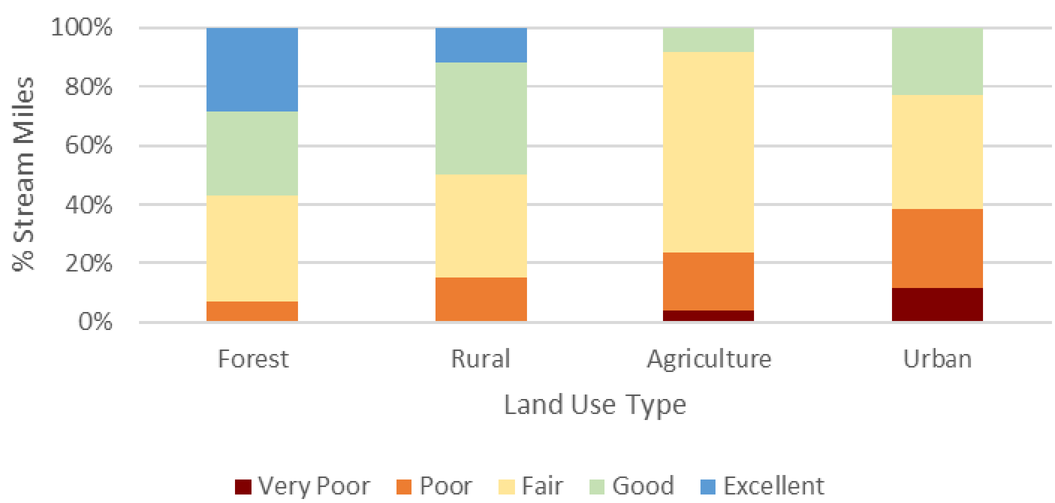

FIGURE 4.11: HQI SCORE CONDITION CATEGORIES BY LAND USE TYPES.

HQI scores were correlated with subbasin landcover represented by LCI score (the dashed line in Figure 4.12). Although 60:10 subbasins generally contained higher HQI scores, there was no correlation with subbasin LCI.

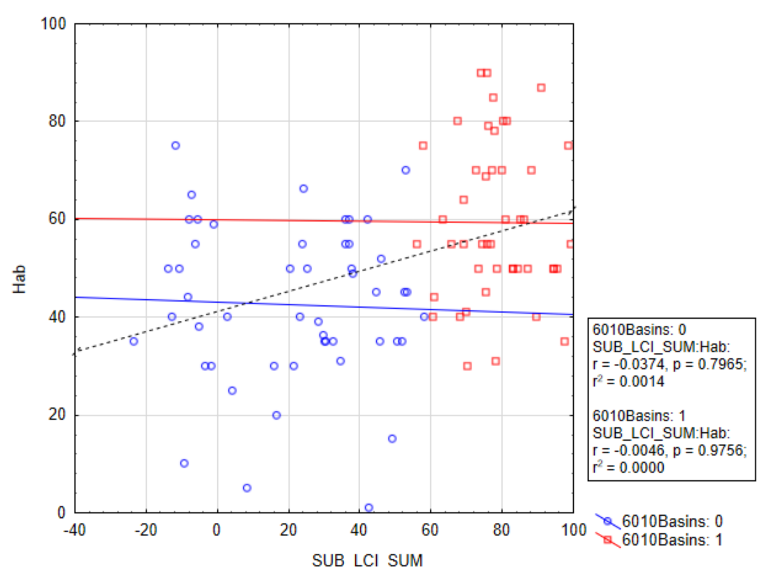

FIGURE 4.12: HQI SCORES REGRESSED AGAINST SUBBASIN LCI FOR EACH 60:10 BASIN CATEGORY.

Like other index scores, there was a significant correlation between local buffer land cover conditions and HQI scores (Figure 4.13). Like BIBI and WQI, there is a statistically significant decline in HQI scores with a decline in local buffer land cover. Stream habitat conditions, like woody material and pool habitat formed by wood, directly rely on stream buffers for the supply of natural large woody material. This result further substantiates the reliance of functions and values on buffer conditions and implies that where buffer conditions decline over time, there is potential for declining functions and values. As previously stated, the SOW monitoring program, at this time, cannot test for this change.

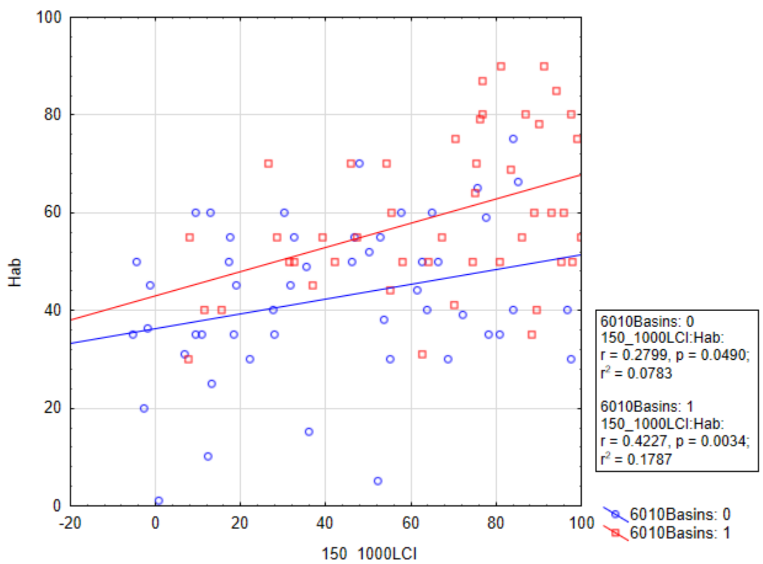

FIGURE 4.13: HQI SCORES REGRESSED AGAINST BUFFER LAND COVER LCI FOR EACH 60:10 BASIN CATEGORY.

4.1.4 Stream Temperature

The SOW monitoring program collected summer stream temperature data from 72 locations, 68 of which were from within the CAR Study Area. Stream temperature was recorded and stored continuously at 30-minute intervals using remote thermistors during the time when the Washington State core summer rearing water quality standard was applicable. The applicable temperature standards are 12°C, 16°C, and 17.5°C, depending on the specific stream locations. The calculated 7-day average of daily maximum temperatures (7DADMax) is used for evaluation. To standardize comparison among locations (where different temperature criteria applied), an 85-day period was used to evaluate the percent of time daily temperature exceeded the location criterion for each site. All sites were also evaluated for exceedances relative to 14 and 16 degrees Celsius, which was included as a criterion in the 2008 Monitoring and Adaptive Management Plan (Table 1.3).

Figure 4.14 shows the data distribution of the 7DADMax values for each site grouped by the applicable temperature criterion. Most sites sampled were located where the temperature criterion was 16°C. This category of locations has the highest observed average 7DADMax and range of temperatures observed. In all, most sites exceed and the applicable site temperature criterion (i.e., 12°C, 16°C, or 17.5°C).

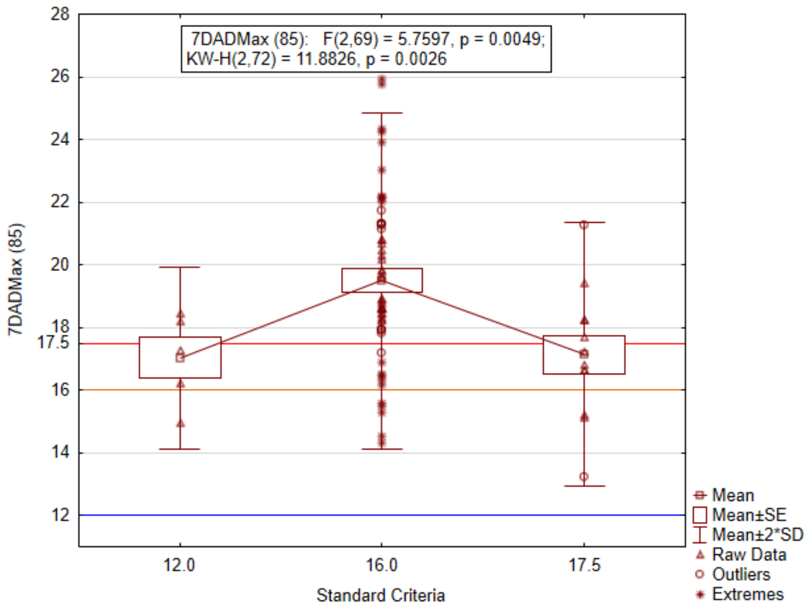

FIGURE 4.14: 7DADMAX TEMPERATURE BY SITE CATEGORIZED BY APPLICABLE TEMPERATURE CRITERIA.

Figure 4.15 shows the percentage of sites that exceed the site-based temperature criterion, and for the 85-day period, how much of the daily time, on average, the temperature criteria was exceeded. In all, 83% of locations (60 out of 72) exceed the site-specific temperature criterion and, for the 85-day summer period, the temperature criteria was exceeded 57% of the time, on average. For all sites with a 12^{o}C temperature criterion, the 7DADMax temperature was exceeded. These locations are in eastern Snohomish County, in forested river mainstem or headwater locations where the temperature criterion is stricter to protect salmonid (including bull trout) spawning and rearing habitats. Where temperature criteria are less strict, fewer sites exceed the criterion and do so for 23% of the summer-time period, on average.

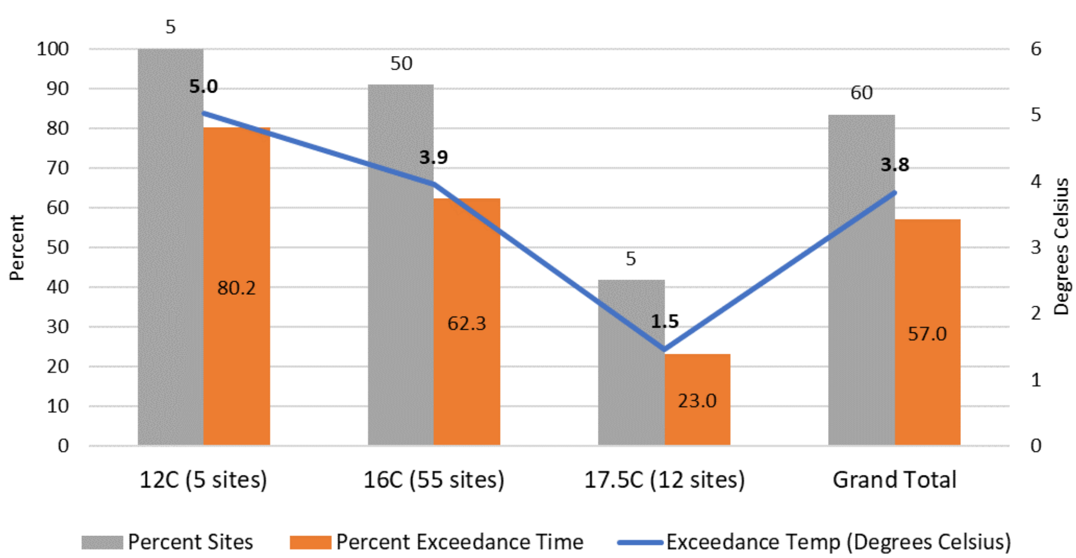

FIGURE 4.15: TEMPERATURE EXCEEDANCE BY SITE COUNT (AND %), PERCENT OF TIME IN 85-DAY SUMMER PERIOD AND AVERAGE DEGREES CELSIUS THAT THE 7DADMAX EXCEEDED TEMPERATURE STANDARDS.

To compare against the 2008 CAR Monitoring and Adaptive Management criteria, Figure 4.16 shows the percent of sites and count of sites by standard temperature criteria where the 7DADMax temperature by location was either <14^{o}C, 14-16^{o}C, or was >16^{o}C. Only 1 location out of 72 had a 7DADMax value less than 14^{o}C and this was at a location with a higher standard temperature criterion. Among all sites, 88% of locations had a 7DADmax exceeding 16^{o}C. These results indicate that stream temperature is compromised for most locations based on the criteria set forth in the 2008 CAR Monitoring and Adaptive Management Plan.

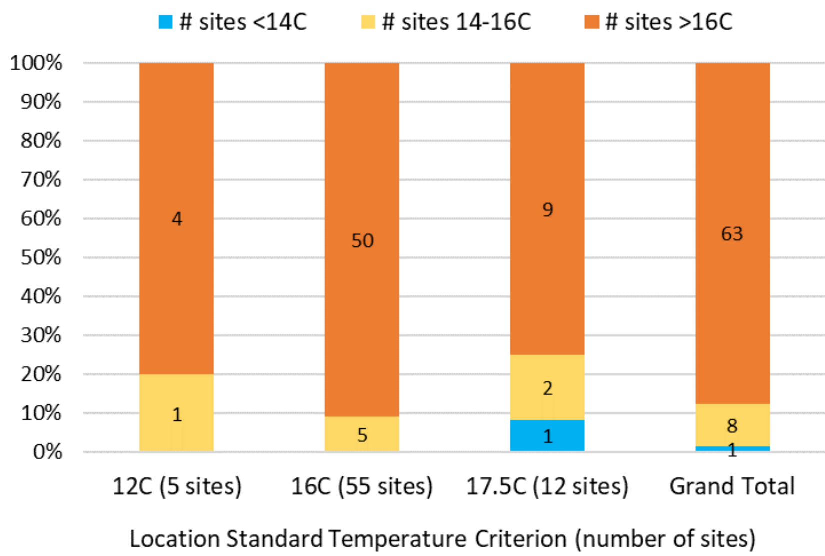

FIGURE 4.16: PERCENT AND COUNT OF SITES VS TEMPERATURE (DEGREES C) CRITERION THRESHOLDS (SEE TABLE 1.3).

Next, we evaluated the 7DADMax with land cover in buffers, channel size, canopy cover over streams, and land use type. We also evaluated the number of sites that exceeded the temperature standard and the amount of time exceeded for a standardized (85-day) summer time period. Bear in mind that comparing whether sites meet or exceed temperature standards, and for how long, when those standards differ among locations, is like comparing apples to oranges in terms of elucidating real temperature effects or direct influence from critical area buffer conditions.

First, stream bankfull channel width (BFW, in Figure 4.17) affects the amount of tree canopy cover resulting in shade over streams, such that wider streams naturally have less cover. This means that in wide streams and rivers, good buffer conditions and good canopy cover/shade may not protect stream temperature due to wider channel width that allows more solar radiation to the waterbody regardless of good buffer land cover and tree size. Because shading potential is near 100% at stream widths less than six meters, we blocked our SOW sites based on that threshold for analysis.

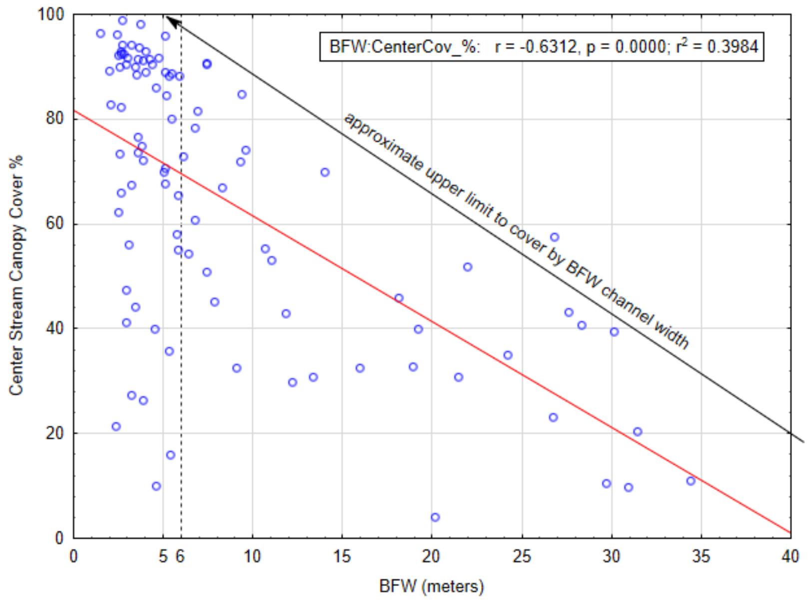

FIGURE 4.17: STREAM CANOPY COVER AS A FUNCTION OF STREAM CHANNEL WIDTH (BFW) FOR SAMPLED LOCATIONS AND UPPER LIMIT OF CANOPY COVER.

Figure 4.18 highlights that, in addition to channel width, the cover over streams is strongly correlated with local buffer land cover (LCI) for streams both greater than and less than six meters bankfull channel width, except that the canopy cover is much lower for the wider stream category, as shown above.

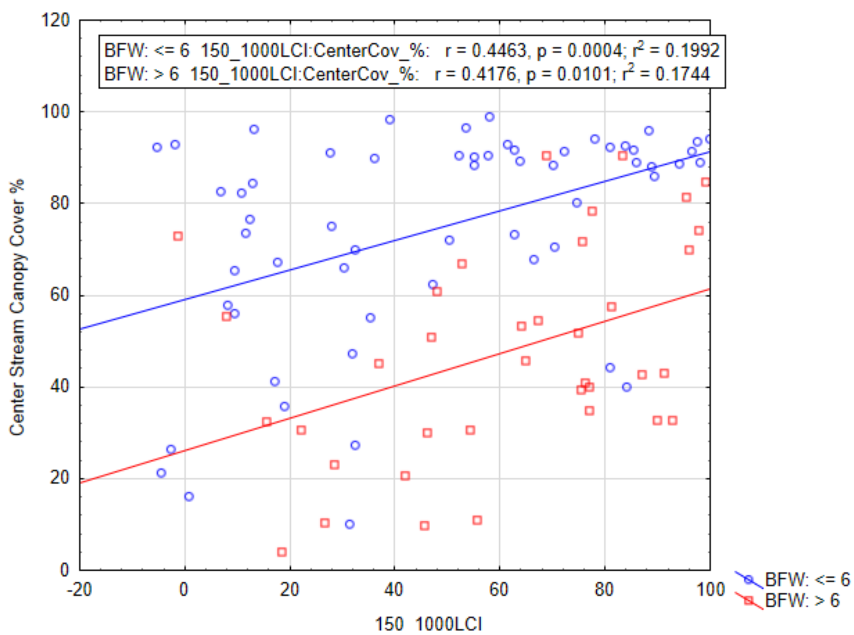

FIGURE 4.18: STREAM CANOPY COVER PLOTTED VERSUS LOCAL BUFFER LAND COVER (150 FT WIDE BUFFER FOR 1 KM UPSTREAM OF SITE LOCATION) FOR STREAMS >6 M AND <6 M BANKFULL (BFW) CHANNEL WIDTH.

Next, we tested whether the 7DADMax stream temperature was influenced by either canopy cover or buffer LCI for wider and narrower streams. Figure 4.19 shows that stream 7DADMax temperature decreases with improving canopy cover for smaller streams where canopy cover can be of greatest influence. For wider streams, temperature was higher overall where canopy cover was less (Figure 4.19), though the relationship was similar (similar slopes in the plot). This means that the amount of stream cover is influential on stream temperature, even for wider streams, but to a lesser extent, where temperature is higher.

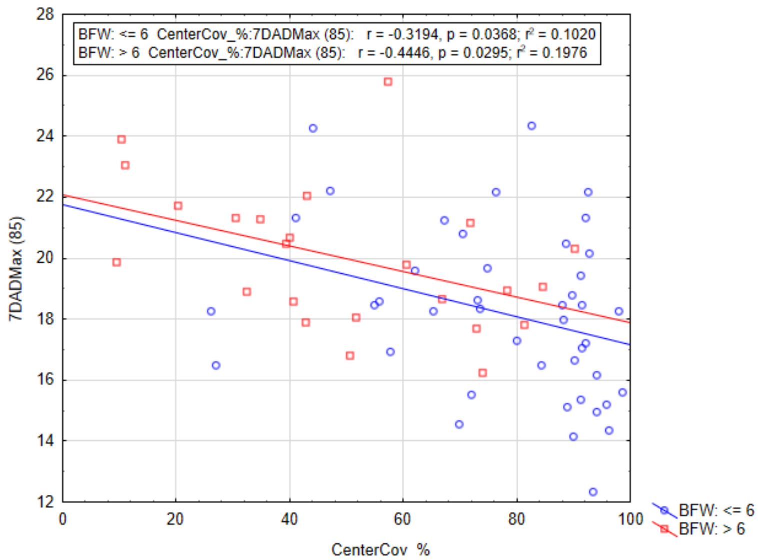

FIGURE 4.19: 7DADMAX TEMPERATURE (DEGREES CELSIUS) VS STREAM CANOPY COVER AT THE CENTER OF THE CHANNEL.

Figure 4.20 shows the influence of local stream buffer land cover (150_1000LCI in x-axis) on stream temperature for wider and narrower streams. In the case of wider streams, where good local buffer land cover can be present, temperature was higher and less sensitive to better buffer conditions, presumably because of less canopy cover due to the wider channel widths as well as an accumulation of influences on stream temperature in larger channels.

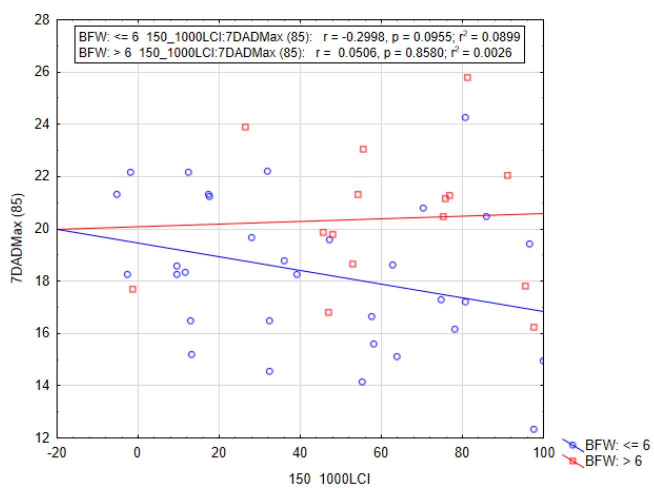

FIGURE 4.20: 7DADMAX TEMPERATURE (DEGREES CELSIUS) VERSUS LOCAL SITE-SPECIFIC BUFFER LAND COVER CONDITION.

Stream temperature is also affected by an accumulation of upstream influences and not simply by buffer conditions within 1 km upstream. Figure 4.21 shows that when the entire CAR buffer upstream from sample locations is compared to 7DADMax temperature, there is a significantly strong correlation between lower stream temperature and better buffer conditions for smaller streams – again, due to the shading potential. For larger streams, better buffers do not create lower temperatures. The larger streams in our sample are predominantly located farther east, where air temperature is higher in summer, and where wider channels are shallower, increasing exposure, all of which combine to reduce the positive impact intact buffers have on stream temperature.

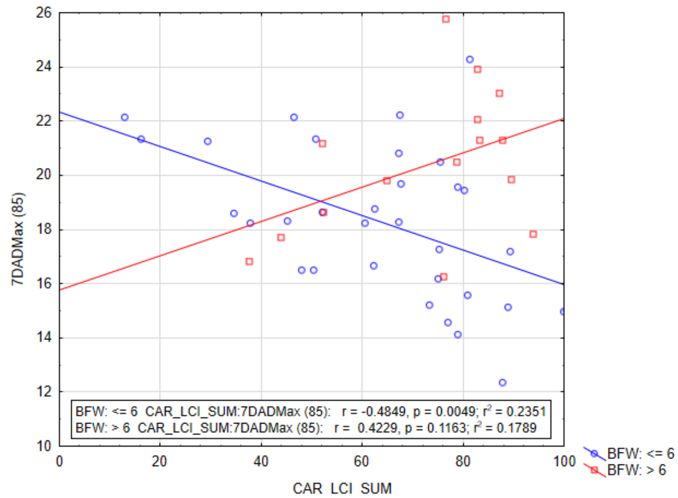

FIGURE 4.21: 7DADMAX TEMPERATURE (DEGREES CELSIUS) VERSUS TOTAL STREAM BUFFER LAND COVER CONDITION WITHIN 1 KILOMETER UPSTREAM FROM THE SOW SAMPLE LOCATION.

These results demonstrate that maximum summer temperature is lower where CAR stream buffers are in better condition, as these conditions increase the benefit from tree canopy shading, especially where that shading potential is greatest in smaller streams less than 6 meters bankfull width. Better buffers at wider streams does lead to better local cover, but a temperature response, is less detectable due to other factors. Since all streams start out with a small width, it is critical to protect stream temperature where canopy potential can be maximized which are streams with bankfull widths less than 6 meters.

4.1.5 Stream Functions and Values Summary

In summary, various indicators that provide information on the condition of critical area functions and values are highly dependent upon buffer land cover conditions. When buffer conditions decline, there is a negative change in the indicators, even when overall subbasin conditions have less development and more natural land cover.

At this time, the SOW program is not able to describe whether changes in critical area buffers over the time period evaluated in this report led to specific and quantitative changes in the indicators that support functions and values. However, given the relative differences in buffer conditions among locations evaluated and the status of indicators we summarized, it is reasonable to assume that if real buffer degradation occurs, whether due to CAR implementation or due to unpermitted actions and impacts, then indicators, and therefore functions and values, will degrade.

4.2 Lake Health Methods and Results

The SOW program includes annual monitoring of the health of between 30-35 lakes in unincorporated Snohomish County. The lake monitoring program began in 1992 and is a collaborative effort between the County and community volunteers. The focus of the monitoring is on lakes with public access but over time has also included private lakes with interested volunteers.

Volunteers collect lake health data twice a month from May through October. Data collected includes water clarity, lake temperature, and observations of recreational lake use. Water quality samples are also collected monthly from June through September. The key parameters shown in Figure 4.22 are used to assess lake health. The full monitoring methodology of the lakes program can be found in the Snohomish County Lake Management Program Quality Assurance Monitoring Plan (2018).

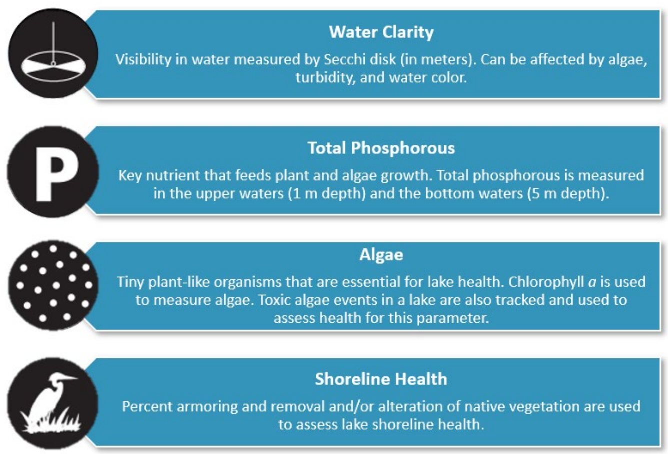

FIGURE 4.22: KEY PARAMETERS USED TO ASSESS LAKE HEALTH.

4.3 Lake Health Index

Four lake health indicators, water clarity, phosphorus, algae, and shoreline condition, are classified into one of four health categories based as shown in Figure 4.23.

Excellent	clear water, low nutrient concentrations, few aquatic plants, and low levels of algae
Good	clear water, moderate levels of nutrients, algae, and aquatic plants
Fair	limited water clarity, high nutrient concentrations, abundant plants, high levels of algae, occasional toxic blooms
Poor	very limited water clarity, very high nutrient concentrations, abundant plant growth, very high levels of algae often with toxic blooms

FIGURE 4.23: LAKE HEALTH CONDITION (INDEX) CATEGORIES.

For water quality conditions (clarity, phosphorus, and algae), lakes classified as "excellent", "good", and "fair" are all in potentially healthy states. Larger lakes are naturally expected to be in "excellent" or "good" condition, as their natural state is often deep and clear with little algae or plant production. Smaller lakes are more typically shallow with lower water clarity and higher amounts of plants and algae so may naturally be in "fair" condition for the water clarity and algae indicators. Shoreline health ratings are unique, as all lakes should naturally be in "excellent" shoreline condition. Any lake with a "poor" classification in the water clarity, phosphorous, and/or the algae health indicators is likely suffering from excessive nutrient pollution leading to unhealthy conditions.

To assess changes in functions and values, lake health categories were determined for each lake during the monitoring period (2009-2021) and compared to health categories assigned to these same lakes in the 12 years preceding CAR monitoring (1996-2008)[7] (Figure 4.24). Thirty lakes had long-term data that could be used for the assessment[8]. Maps of the lake health conditions in 2009 and 2021 can be found in Appendix A.

Overall, there were very few changes in lake health over the two time periods. There was only one change each for water clarity ("excellent" to "poor") and phosphorus ("good" to "fair"). For algae, there were no actual changes in ratings. Conversely, shoreline health showed improvement over the two time periods. Seven lakes improved their shoreline health category; specifically, four lakes went from "poor" to "fair" and three lakes from "fair" to "good". Two lakes downgraded over the from "fair" to "poor".

As it typically takes decades to see large-scale changes in lake health, this lack of change over a decade time period is expected. Lakes are large bodies of water and are generally more resilient to change than streams. development.

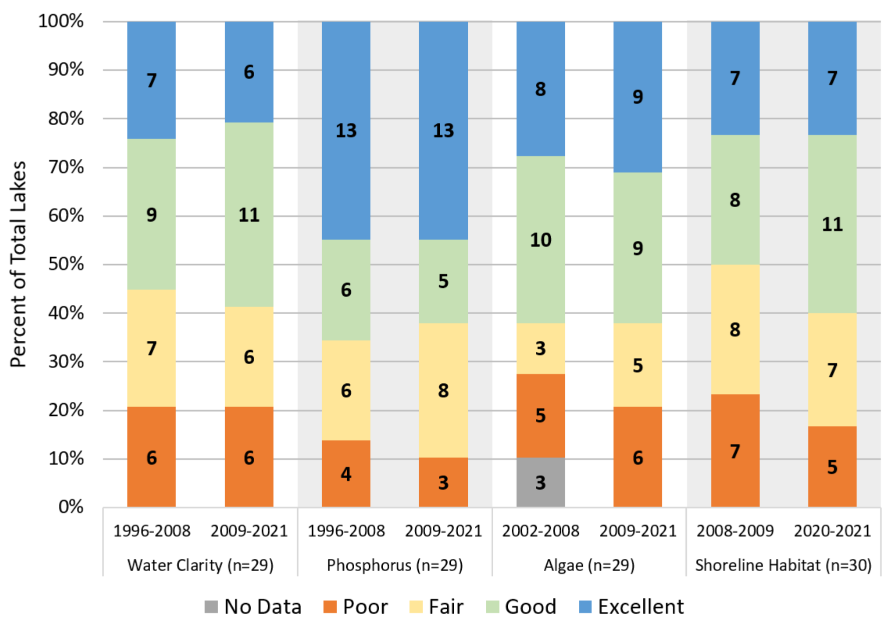

FIGURE 4.24: CHANGES IN HEALTH CONDITION CATEGORY BY PARAMETER FOR ALL LAKES BETWEEN 1996-2008 AND 2009-2021 (SHORELINE HABITAT DATA COLLECTED IN 2008/2009 AND 2020/2021).

[7] Shoreline health data were collected in 2008/2009 and 2020/2021.

[8] Lake Ketchum is one of the 30 lakes but had significant lake restoration activity, so it was excluded from the assessment of three water quality metrics (water clarity, phosphorus, and algae), as it would not represent natural change. Lake Stevens was annexed during the CAR monitoring time period and has also had restoration work, so was excluded from analysis as well.

While lake health changed very little between the time periods, an analysis was done to see if there were any statistically significant[9] trends for individual lake health indicators during the CAR monitoring period (2009-2021) as compared to the previous 12 years (1996-2008) (Figure 4.25).

While most lakes had no trend for any of the indicators assessed, meaning lake health was neither improving nor declining, the few changes that were observed indicated improvements in lake health. Most notably, two lakes showed an improving trend, and zero lakes showed a declining trend, in phosphorus levels in the upper lake waters during the CAR monitoring period. Comparatively, four lakes had a declining phosphorous trend in the upper lake waters from 1996-2008. This means that ongoing phosphorus pollution to these lakes is declining. This means that either 1) there is reduced phosphorus pollution coming into lakes or 2) the buffers around the lakes are improving, as one of their many functions is to absorb and filter out pollution before it reaches the water. CAR regulations are only able to effect change on the latter. However, both the lake critical area buffer analysis and the shoreline analysis suggest buffer habitat is declining, not improving.

Therefore, overall improvements in lake health indicators are more likely a sign of a decreasing phosphorous pollution. In 2011, the Washington State Legislature passed a ban on lawn fertilizers containing phosphorus ([RCW15.54.500](RCW15.54.500)). The ban on phosphorus fertilizers may be one explanation for the improvements in lake health despite the declining quality of lake buffers. In addition, the County's LakeWise outreach program, launched in 2012, focuses on empowering landowners to reduce phosphorus pollution from their properties from sources such as septic systems and pet waste, and through lawn and yard care.

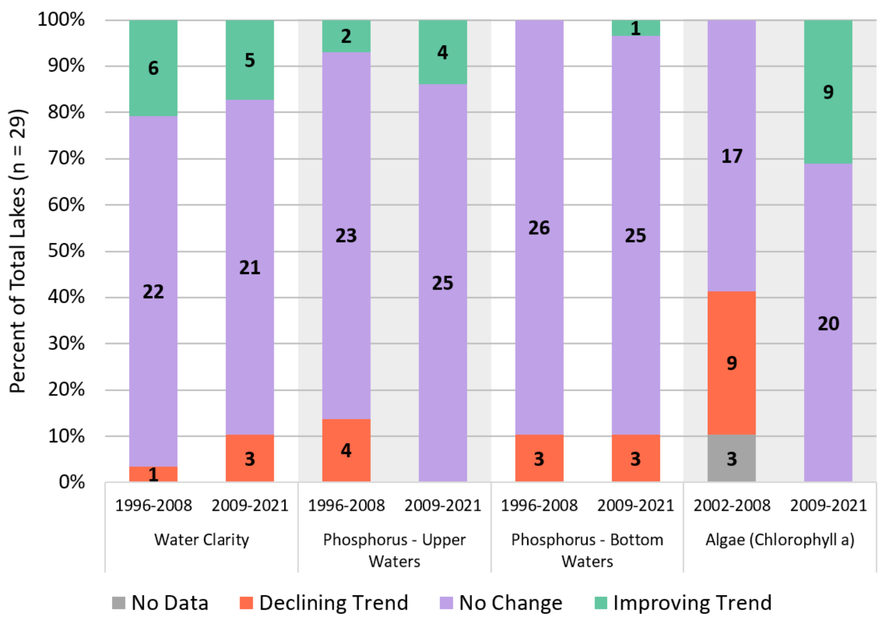

FIGURE 4.25: TRENDS IN WATER QUALITY BY PARAMETER FOR ALL LAKES BEFORE (1996-2008) AND DURING (2009-2021) CAR MONITORING PERIOD (PRE-CAR ALGAE DATA BEGINS IN 2002).

[9] Kendall tau rank correlation coefficient analysis was conducted (p value = 0.05 for water clarity and phosphorus; 0.10 for chlorophyll *a* as it has higher variability).

5.0 Impacts to Critical Areas on Agricultural Lands

Agricultural practices are regulated differently than other activities under the County's critical area code and generally rely on implementation of Best Management Practices (BMPs) and farm plans to ensure no net loss of functions and values. Because of these differences, agricultural parcels were removed from the land cover and buffer change analyses above. However, tracking changes in conditions that impact functions and values on these parcels is important to understanding the overall health of aquatic resources.

All land cover changes on agricultural parcels were evaluated (within and outside of critical areas and their buffers). Table 5.1 shows changes in impervious surface, percent positive change, percent negative change, and net percent positive minus negative change by subbasin on agricultural parcels, sorted by largest percent %P/N change. 30 of the 58 subbasins had agricultural parcels. Overall, the percent increase in impervious surface was very low, less than 2% in all subbasins. Increases in impervious surface on agricultural parcels is likely due to new infrastructure such as barns, roads, etc. Four subbasins, Snoqualmie Mouth, Lower South Fork Stillaguamish, Allen Creek, and Everett Drainages, saw a decrease in impervious surfaces within agricultural parcels. Other than the Marshlands, all subbasins had less than -5% P/N change. The larger %P/N negative change in the Marshlands is primarily due to forest cover changes, in this specific case, loss (rotation) of hybrid poplar forest crop in Marshlands.

TABLE 5.1: PERCENT IMPERVIOUS CHANGE, PERCENT POSITIVE CHANGE, PERCENT NEGATIVE CHANGE, AND PERCENT POSITIVE MINUS NEGATIVE CHANGE ON AGRICULTURAL PARCELS BY SUBBASIN.

Subbasin	% Impervious Change	% Positive Change	% Negative Change	%P/N Change
Marshland	0.64	0.58	7.92	-7.34
Lower Sultan River	1.63	2.16	6.35	-4.19
Lower North Fk Stillaguamish	0.68	1.32	4.14	-2.82
Middle North Fk Stillaguamish	0.35	1.64	4.41	-2.77
Lower Mainstem Skykomish	0.68	1.58	4.32	-2.73
Middle Pilchuck River	0.88	1.45	4.09	-2.64
Snohomish Estuary	0.45	0.08	2.70	-2.63
Cathcart Drainages	0.36	1.36	3.53	-2.17
Upper Mainstem Skykomish	0.41	1.12	3.13	-2.00
Lower Pilchuck River	1.24	2.42	4.28	-1.86
Harvey Armstrong Creek	0.82	3.59	5.42	-1.83
Quilceda Creek	0.75	1.96	3.45	-1.49
Church Creek	0.53	2.05	3.28	-1.23
Portage Creek	0.45	1.42	2.48	-1.06
Skagit Flats South	0.34	0.87	1.87	-1.00

Subbasin	% Impervious Change	% Positive Change	% Negative Change	%P/N Change
Fobes Hill	0.64	1.29	2.15	-0.86
Lower Woods Creek	1.67	4.32	4.92	-0.60
Lower Stillaguamish	0.37	0.72	1.31	-0.59
Sunnyside	0.20	0.82	1.41	-0.58
West Fork Woods Creek	1.00	2.85	3.30	-0.46
Lake Stevens	1.61	1.37	1.58	-0.21
French Creek	0.42	2.45	2.47	-0.02
Allen Creek	-0.17	0.00	0.00	0.00
Everett Drainages	-0.45	0.00	0.00	0.00
Jim Creek	0.00	0.00	0.00	0.00
Port Susan Drainages	0.00	0.00	0.00	0.00
Snoqualmie Mouth	0.41	6.11	4.96	1.15
Lower South Fk Stillaguamish	-0.03	3.40	2.16	1.24
Upper Wallace River	0.00	2.32	0.06	2.26
Woods Creek	0.32	3.49	1.04	2.45

As detailed in Section 4.0, data collected by the SOW program shows lower results in many of the indicators related to functions and values in the agricultural land use setting. Streams in agricultural lands often lack riparian cover, have higher fine sediment, lack woody material, and have altered channel geometry and streambanks, which lead to the poorer conditions.

While buffer conditions and functions and values in agricultural lands are generally in worse condition than in other land use settings, this does not mean that critical area regulations are not being implemented. The basis for regulating agricultural activities are BMPs and farm plans, which were not available for this analysis. Therefore, we do not have the ability to evaluate the implementation of these measures.

6.0 Positive Conservation and Restoration Activities

Snohomish County actively engages in habitat conservation and restoration actions that benefit functions and values. Some of the conservation and restoration actions the County engages in can be quantified including purchasing properties for conservation (acquisitions), restoring habitat for salmon recovery, replacing culverts and other fish passage barriers in streams and rivers, and improving vegetation by treating or removing invasive plants and by planting native plants. Other actions are not easily quantifiable yet may provide as much or more benefit to ecological functions and values.

6.1 Quantifiable Positive Conservation and Restoration Activities

Table 6.1 provides a summarized accounting of quantifiable County conservation and restoration actions from 2009 to 2021. None of the actions in the table are mitigation for County development activities.

TABLE 6.1: QUANTITY OF POSITIVE CONSERVATION AND PROTECTION ACTIONS BY ACTIVITY TYPE.

Activity Type	Detail 1	Detail 2
Acquisitions		
Land acquired for conservation	4,048.4 acres (non-FEMA)	17.17 acres (FEMA Hazard Mitigation)
Salmon Recovery Habitat Restoration		
Land restored	458.5 acres	
Pieces of large woody debris added	463 pieces, not inclusive of jams	
Log jams constructed	34 log jams constructed	
Fence arrays constructed	40 fence arrays (11 formed log jams)	
Fish Barrier Replacement		
Fish barriers and culverts replaced	68.51 miles of stream habitat opened	79 culverts removed
Vegetation Management		
Area treated for invasive species	679 acres	
Area planted with native species	218.4 acres	

6.2 Other, Non-Quantifiable Positive Conservation and Restoration Activities

While living with beavers can create challenges to private and public property owners, keeping them on the landscape increases hydrological storage capacity and provides many ecological benefits. When beavers build dams in streams, they in essence create natural storm attenuating ponds. These ponds naturally recharge groundwater for release to surface waters during drier summer periods and provide water quality improvement through increased residence time and bioremediation. Beaver ponds also provide diverse fish and wildlife habitat, benefitting a long list of native plant and animal species that rely on pond and wetland habitat. For more than two decades, Snohomish County has managed beavers in a way that encourages leaving them on the landscape rather than relying on lethal trapping to remove animals whose activities cause damage to public and private infrastructure. Public Works Road Maintenance, in collaboration with SWM, has developed and implemented procedures and best management practices to manage flooding created by beaver activity. These practices protect transportation infrastructure and reduce road and private property flooding while maintaining the presence of beavers and the benefits they provide. SWM also collaborates with the Snohomish Conservation District, who works directly with private property owners, to reduce private property flooding while allowing beaver activity to continue. While these actions may seem small, beavers have been and can continue to be a helpful positive contribution to the protection and restoration of ecological functions and values.

Snohomish County also has various initiatives and collaborations that support restoration and conservation. Below is a list of some of these initiatives and collaborations:

- Land Conservation Initiative
- Sustainable Lands Strategy
- Various Comprehensive Plan policies (Natural Environment, Transportation, Climate Change, etc.)
- Healthy Forest Project

- Sustainable Operations Action Plan (SOAP)
- Savvy Septic Program
- Community Floodplain Solutions

7.0 Conclusion and Recommendations

Snohomish County's population growth has resulted in increases to impervious surfaces and loss of forest cover. Much of the increase in impervious surface area is within existing urban areas, which is consistent with Growth Management Act goals of densifying urban areas. Forest cover changes are widespread throughout the County, but causes differ by location and include development, timber harvest, and natural events (channel migration, tree loss, landslides, etc.).

Overall, the amount of critical area buffers converted to impervious surfaces, the most concerning land cover change, was small. However, between increases in impervious surfaces and changes in forest cover, there was enough change that Adaptive Management Threshold 2 was met for streams+lakes+marine buffers and for wetlands and wetland buffers.

Data limitations likely caused overestimating buffer and wetland impacts in urban areas and other areas where activity, such as timber harvesting, occurs right up to critical area buffer edges. As future population growth will predominantly be allocated to urban areas, development will likely be increasingly close to buffer edges which will perpetuate the errors moving forward. Therefore, to ensure protection of buffers while enabling further development, improving the data used for this assessment is highly recommended.

Shorelines for marine and rivers were generally stable, while lake shoreline condition declined. Overall, shorelines met the bank armoring Adaptive Management Threshold 1. Because of historical armoring, shoreline functions and values are compromised but for marine and rivers, more armor is being removed than new armor is being placed. If this pattern continues, it can lead to a restoration of functions and values in rivers and the marine environment. Changes to shoreline conditions are further summarized by waterbody type below.

As understanding the conditions by waterbody type can help determine the best actions needed to adaptively management in the light of meeting threshold 2 for all buffers and wetlands, the paragraphs below provide a summary of conditions by waterbody type.

Lakes – Lakes had the highest net negative change and the highest increase in impervious acreage added to buffers, and shoreline armoring and dock density increased. It is unclear whether the increase in armoring or docks was permitted or non-permitted. The one positive finding was an increase in lake shoreline native vegetation. These finding suggest a high priority need for education and outreach to lake homeowners, with efforts made to educate homeowners on critical area regulations and dock regulation. The continuation or expansion of SWM's LakeWise program, in addition to providing more education and outreach, could help alleviate future lake buffer impacts.

Marine – Marine buffers had an increase in impervious surfaces, more bank armoring was removed than new armoring added. Because one of the purposes of the SMP is to reserve waterfront properties for development for water-dependent uses such as ports and marinas, some of the impacts may be from these types of developments. When these types of development occur, mitigation is required but it generally occurs off-site. Continuing efforts to remove bank armoring along the marine shoreline is recommended.

Stream and rivers – Stream and river buffers often have declining land cover condition. In urban/suburban subbasins, the negative changes in buffers are often associated with a gain of >10% impervious area. In rural and forested subbasins, the negative changes in buffers are more likely due to forest cover changes from timber harvesting, river/stream channel migration, and isolated change events such as the SR530 land slide in the Middle North Fork Stillaguamish subbasin. In all rivers, little cumulative change in bank armoring occurred during the 2009 to 2021 time-period. While bank armoring has slightly decreased, bank erosion and instability increased between 4-5%. Some streambank erosion is a natural process and should be viewed positively as it benefits fish but too much erosion harms aquatic life. Notably, in most river locations, log jams and pool habitat increased over time. Efforts to educate homeowners and land developers on the importance of critical areas and buffers, monitoring of subbasins with good ecological conditions and high development pressures, and continuing efforts to remove river bank armoring are recommended.

Wetlands and their buffers – Wetlands and their buffers had an increase in impervious area. The ten subbasins with the most impervious gain are predominantly urban and urbanizing locations. In rural subbasins, the negative changes to wetlands and their buffers are more often due to greater forest cover change. Focusing future efforts on better understanding impacts to wetlands and their buffers in urbanizing areas where greater changes occur is recommended.

Based on pilot study findings and the most recent PDS study, it appears that property owners are generally protecting critical areas and buffers. A PDS study for the 2019 Shoreline Master Plan of 321 acres found 0.3% of the acres had been impacted. The 2020 PDS CAR review of 1948 acres found 0.7% of the acres had been impacted. SWM conducted an analysis on 3066 acres and found a net negative change in buffers of -3.5% in the urban area and -2.6% in the rural area. SWM was unable to do a parcel-specific analysis to determine the types of changes occurring, including whether any of the changes in forest cover were due to natural changes. The differences between PDS and SWM results are likely due to methodological differences where PDS used aerial photos to look for intrusion while SWM did a land cover change analysis and due to differences in time frames where PDS's reviews where generally over two to four years while SWM's analysis was over 12 years. Overall, these results confirm the results from the land cover analyzes that buffers are being negatively impacted. While it appears that most impacts are small in size on individual parcels, cumulatively these small impacts could impact functions and values.

Determining whether the County has achieved "no net loss" to functions and values is a difficult question to answer. There is currently no scientifically accepted method for calculating "no net loss" for this purpose. In addition, there is a lack of data, especially long-term data, for all the indicators used to evaluate functions and values Even if a value of loss or gain for a function and value could be determined, linking that decline or gain to both CAR requirements (are regulations good enough to protect critical areas?) and implementation (were regulations implemented correctly to protect critical areas?) given other confounding stressors or influences would be difficult to impossible.

That being said, based on available evidence, there has likely been a loss in functions and values during the time period. It is likely that any loss (i.e., poorer conditions among a limited set of indicators) caused by **critical area regulation implementation is minimal compared to losses caused by other stressors or unpermitted actions.** Increases in impervious area and/or forest cover changes at the subbasin level, changes in precipitation and temperature due to climate change affecting flooding and drought, groundwater withdrawals due to permit-exempt wells, and emerging pollutants such as 6-PPDq, are other stressors which are cumulatively causing loss of ecosystem functions and values throughout the region.

Finally, when considering “net loss”, positive actions can help to offset any loss of functions and values due to CAR implementation. Between 2009 and 2021, the County acquired 4101 acres for conservation, restored 458 acres for salmon habitat, opened up over 68 miles of stream habitat through culvert and other fish passage improvements, and conducted vegetation management (invasive removal and/or native planting) on 897 acres. The County also has other programs that contribute positively toward restoration and conservation that are more difficult to quantify such as water quality enhancements that are intended to benefit receiving waterbodies. These positive actions could offset some net loss due to CAR implementation and development.

SWM’s State of Our Water Program, while not designed specifically for CAR-related purposes, can provide insight into the condition of the indicators used to assess functions and values. The current condition of stream functions and values vary by indicator and surrounding land use. In general, streams in rural and forested land uses are in better condition than streams in urban and agricultural land uses. Of the indicators, water quality was in the best overall condition level while habitat had the worse conditions at the Countywide level. Stream temperature was problematic Countywide, with most sites not meeting Washington State water quality standards. As the stream component of SOW is newer, there is not yet enough data to evaluate changes over time. Lake health has remained generally unchanged over time. An important takeaway that has implications for CAR is that **for the stream indicators evaluated, surrounding land use and increases in impervious surfaces and/or loss of forest cover at the subbasin and local buffer scales were shown to correlate with condition scores**. This information could help managers target education, regulatory controls, or other actions to help ensure protection of functions and values.

The County has a suite of regulations and policies beyond CAR to manage development while protecting functions and values including stormwater management codes and standards, Comprehensive Planning, and the Shoreline Management Program. Using the data in this report to target areas for future monitoring will help inform resource managers on the adequacy of this multi-pronged approach to managing development while protecting functions and values as the County continues to grow.

There were several lessons learned during this project. Many of these lessons will be integrated in the thinking of a revised CAR Monitoring and Adaptive Management Plan. As has been stated previously, an improvement in the base data, including CASPs, stream locations, and wetland locations and categories, would greatly reduce uncertainty and improve our ability to answer the questions requested by the Council and other resource managers.

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