Best Available Science Review

Clallam County Critical Areas Ordinance Update (DRAFT)

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Prepared for:

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Table of Contents

List of Figures

List of Tables

1. Introduction

1.1 Report Purpose

This review of the best available science (BAS) was compiled to support Clallam County's Critical Areas Ordinance (CAO) update. As a requirement of the Washington State Growth Management Act (GMA) cities and counties must "include the 'best available science' when developing policies and development regulations to protect the functions and values of critical areas and must give 'special consideration' to conservation or protection measures necessary to preserve or enhance anadromous fisheries"[1] (WAC 365-195-900). Regulated critical areas include wetlands, critical aquifer recharge areas, fish and wildlife habitat conservation areas, frequently flooded areas, and geologically hazardous areas (RCW 36.70A.030 and CCC 27.12).

BAS means the current and best available information that follows a valid scientific process as specified in WAC 365-195-900 through WAC 365-195-900. According to WAC 365-195-905, characteristics of a valid scientific process include peer review, standardized methods, logical conclusions and reasonable inferences, quantitative analysis, proper context, and references. Common sources of scientific information include research, monitoring, inventory, modeling, assessment, and synthesis (WAC 365-195-905). BAS literature reviews are a synthesis of the current scientific body of knowledge, and only resources that meet these requirements are included as reference materials for this BAS.

The BAS review is a resource for critical area management but is not intended to provide definitive answers for all policy and regulatory decisions. Policy and regulations should incorporate BAS but also necessitate decision-making processes based on societal values. Additionally, ecological systems are highly complex, and the scientific body of knowledge is constantly evolving with the advancement of new research and technology. Despite these advancements, there are limits to the current state of science and certain topics may not be fully understood. Where there is scientific disagreement in the literature about a particular subject, this review presents a range of potential ideas, theories, or findings. In accordance with WAC 365-195-920, decision-makers may opt for a precautionary, or no-risk approach, when scientific information is incomplete.

The GMA now requires CAOs to incorporate and evaluate the effects of climate change on each type of critical area. Climate change is anticipated to have a profound influence on natural systems and inclusion of these topics allows decision-makers to respond by incorporating climate resilience into policy and regulations.

This BAS review serves as a reference for Clallam County for planned CAO updates, a component of comprehensive updates to the unified development code. Following the establishment of this BAS

[1] Anadromous refers to fish or fish species that spend portions of their life cycle in both fresh and salt waters, entering fresh water from the ocean to spawn.

review, a gap analysis will be developed to identify current shortcomings and provide recommendations on critical area regulation updates.

2. Critical Aquifer Recharge Areas (CARAs)

2.1 Definition

Critical aquifer recharge areas (CARAs) are defined in the Washington Administrative Code (WAC) 365-190-030 as follows:

> *Critical aquifer recharge areas "are areas with a critical recharging effect on aquifers used for potable water, including areas where an aquifer that is a source of drinking water is vulnerable to contamination that would affect the potability of the water, or is susceptible to reduced recharge."*

The Clallam County Code (CCC) 27.12.610 classifies CARAs as follows:

> *All Clallam County lands and shorelands shall be classified as having either a high, moderate or low aquifer recharge potential. At a minimum, classification shall be based on soil permeability and recharge potential as described within the soil survey of Clallam County. Where adequate information is available, aquifer recharge potential shall be further classified based on the recharge potential of surficial geologic materials, presence or absence of restrictive layers, surface and ground water monitoring data, well head protection areas, depth to ground water, topography (i.e., slopes), and locally adopted ground water protection plans and studies.*

The Clallam County designation specifies that lands and shorelands classified as high aquifer recharge potential and aquifer susceptibility possess a critical recharging effect on aquifers used for potable water. These areas are delineated on maps available from the Clallam County Department of Community Development. CARA areas may also be designated due to special circumstances, including areas with a high level of susceptibility or vulnerability to contamination, or known well head protection areas for Class A water systems. A well head protection area is the surface and subsurface area surrounding a well or well field that supplies a public water system through which contaminants are likely to pass and eventually reach the water well(s) as designated under the Federal Safe Drinking Water Act.

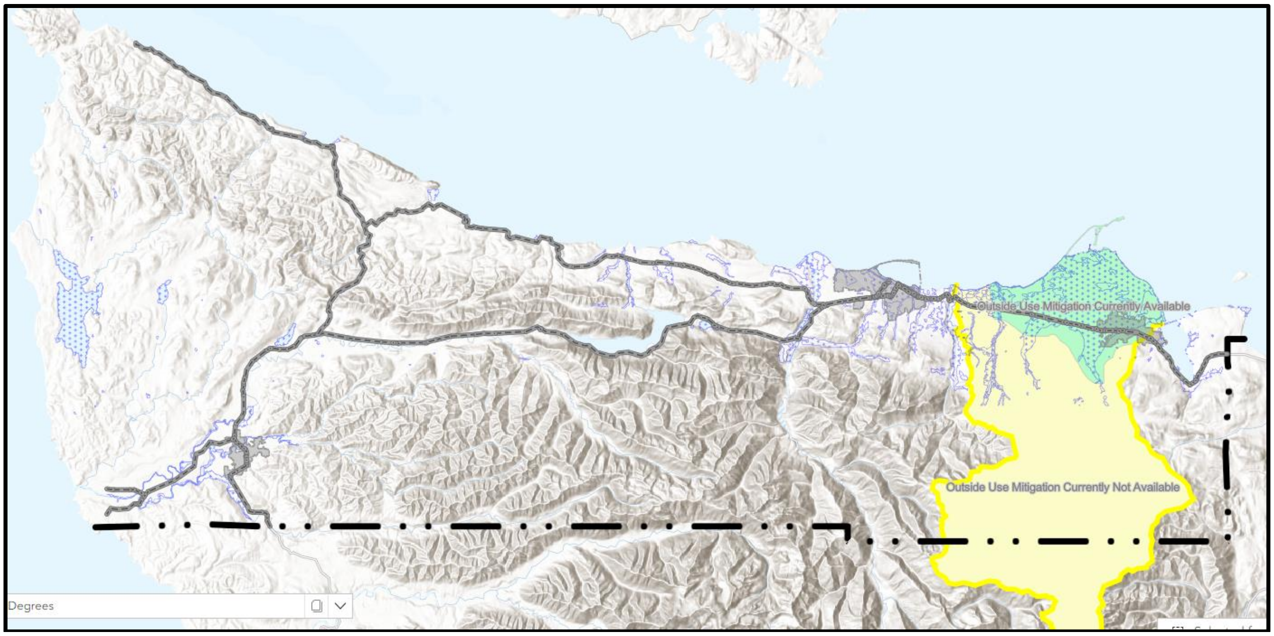

Figure 1. Clallam County CARA map.[2]

Groundwater is water that exists underground in saturated pore spaces of soil and rock. The upper surface of the saturated zone is called the water table. An aquifer is a geologic formation that readily transmits groundwater to wells or springs above ground. According to WAC 173-150-030, an aquifer is defined as *"any geologic formation that will yield water to a well or other withdrawal works in sufficient quantity for beneficial use."* Aquifer recharge occurs when water infiltrates the ground and flows to an aquifer. An aquifer can be confined or unconfined. An unconfined aquifer is one with no aquitard (a geologic formation that does not readily transmit water) or aquiclude (a geologic formation that does not allow for the transmission of water) between the water and the ground surface. A confined aquifer is a deeper aquifer that is separated from the surface by an aquitard or aquiclude and is often under pressure. Groundwater recharge areas are characterized by decreasing hydraulic head with depth (the direction of groundwater movement is downward). Groundwater discharge areas are characterized by increasing hydraulic head with depth (the direction of groundwater movement is upward, towards the surface) (Driscoll, 1986; Winter, 1998).

The Department of Ecology considers *aquifers used for potable water* as those with existing wells or and their protection area, a sole-source aquifer, planned to be used for potable water in the future, and aquifers otherwise identified as an important supply (Ecology, 2021a). Maintenance of potable water uses, and potential uses of aquifers require the management of water quality and quantity, which is covered in the following section.

[2] https://clallam-county-portal-clallam.hub.arcgis.com/apps/23bbb33c10b24b4c8706e89ae98f7add/explore (blue dotted areas are delineated CARAs and yellow/green areas represent zones under the Dungeness rule)

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2.2 Functions and Values

The goal of establishing CARAs is to protect the functions and values of a community's drinking water by preventing pollution and maintaining supply. RCW 36.70A.172 requires counties and cities to include the best available science in developing policies and development regulations to protect the functions and values of critical areas. In addition, counties and cities are also required to give special consideration to conservation or protection measures necessary to preserve or enhance anadromous fisheries (Ecology, 2021a). Since groundwater is a vital component of stream flow, it is necessary to maintain the groundwater supply to streams where needed to protect salmon and other anadromous species. Groundwater conditions can also influence geologic hazards, including landslide hazards and erosion hazards.

2.2.1 Water Quality

While CARAs serve to replenish groundwater supplies, they can also serve as a conduit for the introduction of contaminants to groundwater. Vulnerability to public water supply is primarily influenced by two main factors, the history of contamination loading and hydrogeologic susceptibility of the aquifer (WDOH, 2017).

Contamination loading refers to the quantity and types of pollutants present in an area, including exposure concentration, frequency, and chemical composition. Together, susceptibility and loading potential determine the vulnerability of an aquifer. To be considered vulnerable, an aquifer would need to be both susceptible and have significant contamination loading. For example, a highly susceptible aquifer may have a low vulnerability if the land use within the area is primarily open space, since there is minimal contamination loading. Likewise, an industrial site with multiple leaking storage containers may not create significant vulnerability if it is separated from the nearest aquifer by several hundred feet of dense glacially compressed clay.

Aquifer susceptibility refers to how easily water and pollutants can move from the surface through the ground to reach the underlying aquifer. There are many factors which influence susceptibility including the following (Eberts et al., 2013; Ecology, 2021a):

1. Characteristics of the vadose zone including depth to watertable and travel time. Travel time is influenced by hydrogeological factors including material composition and preferential flow paths.
2. Permeability
3. Infiltration rate
4. Chemical retardation
5. Adsorption
6. Hydraulic conductivity
7. Hydrologic and pressure gradients
8. Groundwater flow direction

9. Groundwater flow rate

Permeability of the vadose zone can be estimated from soil and geologic mapping. The Washington Department of Natural Resources (DNR) has an interactive web-based geologic map of the state which provides some insight into the permeability of the vadose zone[3]. Depth to an aquifer of a site can also be estimated by examining existing public data such as well logs in the vicinity. As mentioned above, well logs are available on the Ecology website[4]. Using nearby well data alone may be insufficient. Aquifers are managed and monitored by local water purveyors, in this case, Clallam County Public Utility District (PUD).

2.2.2 Water Quantity

Potable water and groundwater-dependent, landscape-scale ecological processes are both supported by groundwater quantity and can be influenced by land use and human activities. This section provides a description of hydrologic processes in aquifers related to water quantity and the effects of human activities on these resources.

The quantity of water available in an aquifer is a balance between recharge, storage, and discharge. Aquifers have discrete recharge and discharge areas. Since groundwater movement is the result of downward gravitational forces, the location of recharge areas in aquifers is typically at a higher elevation than its discharge areas. This pattern is not universal, as subsurface conditions may affect groundwater flow and hydrologic gradients may differ from surficial topography. Aquifer recharge can originate from rainfall, snowmelt, lakes, rivers, streams, or wetlands. Aquifer discharge occurs when water leaves the aquifer and is discharged to surface water. These areas can include seeps, springs, wetlands, streams, lakes, estuaries, and shorelines. Extraction from wells or by other means is also considered an aquifer discharge.

Land use and development typically alter the dynamics of aquifer recharge within a basin. For example, replacing forests with buildings, roads, driveways, lawns, and even pastures typically reduces the recharge to underlying aquifers, while simultaneously increasing the peak runoff rates to streams. In rare instances, however, some land uses can increase recharge rates. For example, if homes in an area receive water from a river or lake and discharge that water into septic systems, the result can be an increase in recharge to the underlying aquifer, and one that has potential for introducing contaminants (Dunne & Leopold, 1978; Winter, 1998).

Agricultural, residential, commercial, and/or industrial development may result in alterations to the natural hydrologic cycle by stripping vegetative cover, removing, and destroying native soil structure, modifying surface drainage patterns, and adding impervious and nearly impervious surfaces, such as roads and other compacted soils Loss of water in stream channels and riparian areas due to water

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[3] https://fortress.wa.gov/dnr/geology/?Site=wigm
[4] http://apps.ecy.wa.gov/welllog/mapsearch.asp

withdrawal and consumptive use of water from streams, rivers and aquifers further reduces groundwater recharge (Ecology, 2021a).

Recharge to an aquifer is dependent on precipitation and infiltration into the soil below the root zone. Infiltration below the root zone is controlled by several factors, including temperature, wind, soil type, geology, vegetation type, and land surface slope. The root zone is an important factor to consider, since evaporation and transpiration of water by plants reduces the water available for groundwater recharge and can account for much or most of the rainfall during some months (Shao, Bingcheng, & Jiming, 2019).

Changes in groundwater recharge and withdrawal of water by wells are the primary drivers of reductions in groundwater quantity. The Hirst Decision (*Whatcom County vs. Hirst 2016*) is a landmark case where the Washington State Supreme Court ruled that water is not legally available if a new well would impact a protected river or stream, or an existing senior water right. In response, Ecology collaborated with local partners to develop watershed plans under the Streamflow Restoration Act (Engrossed Substitute Senate Bill 6091) in Water Resource Inventory Areas (WRIA) 7, 8, 13, 14, and 15.

Clallam County is primarily in WRIAs 20 (Soleduc) and 18 (Elwha-Dungeness) with small portions in 17 (Quilcene-Snow) and 19 (Lyre-Hoko). The Dungeness watershed is covered under the Dungeness rule (ESSB 6091) which protects instream flows that are needed to support salmon populations. The rule is based on the Elwha-Dungeness Watershed Plan adopted under RCW 90.82.

The Watershed Planning Act (ESHB 2514) is also applicable to CARAs in Washington State. This legislation, created in 1998, encourages voluntary planning by local governments, citizens, and tribes for water supply and use, water quality, and habitat at the WRIA or multi-WRIA level. Grants are available to conduct assessments of water resources and develop goals and objectives for future water resource management.

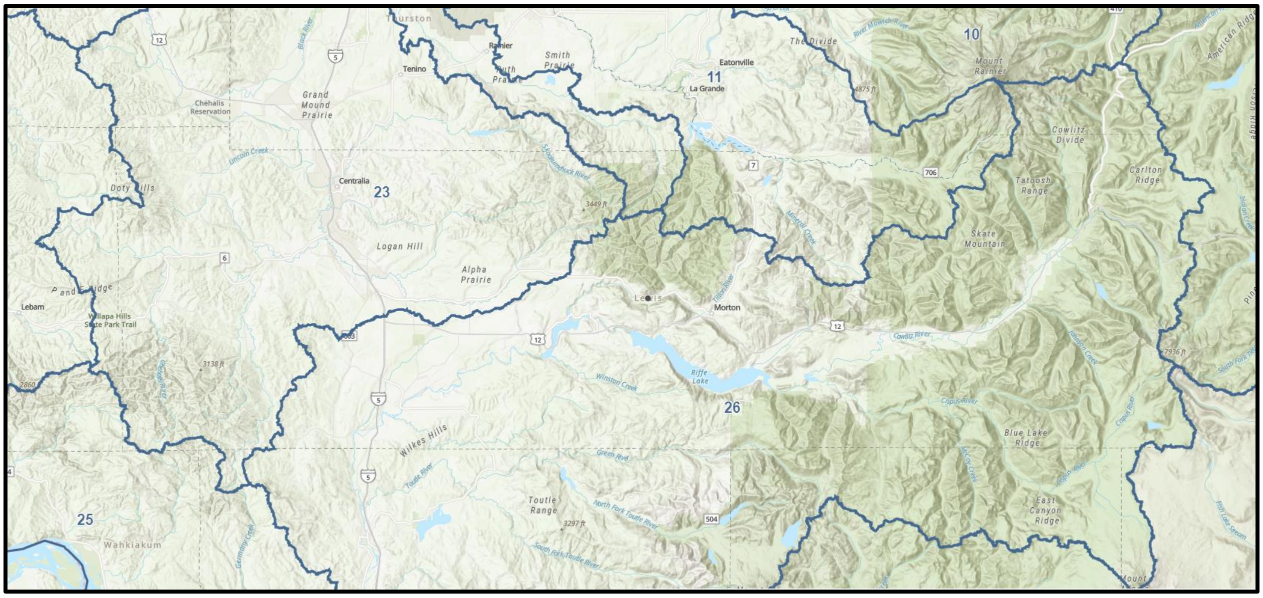

Figure 2. Clallam County WRIA Map.[5]

2.3 Key Protection Strategies

Key protection strategies for CARAs are still based on identifying and protecting CARAs through regulations and educational community outreach. Current 2021 Ecology CARA Guidance recommends the following eight steps to characterize and protect CARAs in a local community:

1. Identify where groundwater resources are located.
2. Analyze the susceptibility of the natural setting where groundwater occurs.
3. Inventory existing potential sources of groundwater contamination.
4. Classify the relative vulnerability of groundwater to contamination events.
5. Designate areas that are most at risk to contamination events.
6. Protect by minimizing activities and conditions that pose contamination risks.
7. Ensure that contamination prevention plans and best management practices (BMPs) implemented and followed. Review BMPs for infiltration designs with water quality treatment. Stormwater control usually affects the vadose zone and seasonal water tables with low risk to deeper water supply aquifers. Some exceptions are those glacial outwash plains with extensive deposits of coarse gravels near the surface.
8. Manage groundwater withdrawals and recharge impacts to:
    i. Maintain availability for drinking water sources.
    ii. Maintain stream base flow from groundwater to support in-stream flows, especially for salmon-bearing streams.

[5] https://gis.ecology.wa.gov/portal/apps/webappviewer/

Watershed planning is recommended to maintain in-stream flow as required by the 2018 Streamflow Restoration Act and for water supply planning under the 1998 Watershed Planning Act (Ecology 2021a).

Clallam County details performance standards for development activities in CCC 27.12.615. The Clallam County Land Division Code is also evaluated for development activity impacts to ground water and CARAs. CCC 27.12.865 lists requirements for mitigation plans when impacts on CARAs are unavoidable.

A hydrologic assessment is required for mitigation and must include:

1. Geologic setting and soils information of site and surrounding area;
2. Water quality data, including pH, temperature, conductivity, nitrates, and bacteria;
3. Location and depth of perched water tables;
4. Recharge potential of facility site (permeability/transmissivity);
5. Hydrologic budget;
6. Local ground water flow, direction and gradient;
7. Location, depth and other water quality data on the three shallowest wells or springs located within 1,000 feet of site;
8. Impacts on well head protection areas located within the development proposal;
9. Surface water locations within 1,000 feet of the site;
10. Discussion of the effects of the proposed project on ground water quality and quantity;
11. Recommendations on appropriate mitigation, if any, to assure that there shall be no measurable exceedence of minimum state ground water quality standards or measurable reduction in available quantity of ground water;
12. Emergency management plan; and
13. Provide for contaminant release detection.

Clallam County maintains CARA mapping and GIS layers which are available to the public via the Clallam County GIS Web Map[6]. GIS data is also available for download from the Clallam County GIS library.[7] Sole Source Aquifers (SSAs) are not present in Clallam County.[8]

2.4 Climate Change Impacts & Mitigation

Climate change impacts to groundwater quality and quantity are influenced by regional trends as summarized below. Changes to surface water inputs can alter the timing, frequency, and duration of surface water presence and are projected to alter hydrologic patterns that can affect interactions with groundwater.

Clallam County prepared a Climate Action Plan in 2023 to mitigate greenhouse gas emissions from County government operations (Cascadia, 2023). The impacts of climate change are already being observed in Clallam County, including warmer maximum temperatures, rising sea levels along

[6] https://clallam-county-portal-clallam.hub.arcgis.com/apps/23bbb33c10b24b4c8706e89ae98f7add/explore
[7] https://www.clallamcountywa.gov/879/Maps-GIS-Information
[8] https://epa.maps.arcgis.com/apps/webappviewer/index.html?id=9ebb047ba3ec41ada1877155fe31356b

coastlines, and increased extreme weather events including drought and flooding. Aspects of climate change affecting CARAs include:

- Changes in precipitation levels in summers may reduce ground surface saturation during the growing season (Mauger et al. 2019). Higher temperatures will also increase the rate of evaporation in surface waters. This will likely reduce wetland areas and the groundwater recharge they provide during the dry season. This can influence streams, wetlands, and other surface waters impacted by groundwater in addition to anthropogenic consumption.

- Wildfires will introduce more particulates and contaminants into the environment, which settle on surface water and infiltrate into groundwater (Burton et al. 2016; Mansilha et al. 2020).

- Increased winter flooding increases the likelihood of overwhelming stormwater treatment facilities and flooding roads. Thereby transporting contaminants into surface water, including local streams and wetlands that can infiltrate and contaminate aquifers (Mauger et al 2019).

- Rising sea levels increases the potential for saltwater intrusion into coastal aquifers (Mauger et al. 2015).

- Demand for aquifers may increase as crops require greater levels of groundwater consumption to compensate for changes in precipitation.

Altered patterns of precipitation resulting from climate change are projected to include earlier peak stream flows, increased frequency, and extent of flooding, and reduced summer flows (Mauger, et al., 2015). Groundwater is believed to be more resilient to the effects of climate change relative to surface water resources (HDR 2019). The primary stressors to aquifers are changes in the timing and amount of groundwater recharge, and increased pressure to use groundwater as surface water conditions change. Ecology recommends focusing on water conservation as a strategy to plan for climate change impacts (Ecology, 2021a).

Other stressors on CARAs that may require further study include reclaimed water use and temporary construction dewatering. Ecology recommends that jurisdictions conduct a multi-year infiltration study (Ecology, 2021a). Population growth also presents challenges for protecting CARAs as land use intensity increases (Ecology, 2021a). For example, multi-year droughts can increase reliance on groundwater source, lead to reductions in groundwater tables, aquifer depletion, and potentially result in saltwater intrusion (Asinas et. al., 2022).

2.4.1 Strategies to Manage Climate Change Impacts on CARAs

- Manage stormwater to maintain groundwater recharge in CARAs. Utilize a 20-year planning horizon to manage supply and demand given climate trends and projections (Asinas et. al., 2022).

- Design stormwater systems to better mimic natural systems and mitigate some of the functions lost elsewhere in the landscape due to changes in surface and groundwater inputs. For example, the use of roadside bioswales may be expanded. Stormwater treatment capacity may be increased as needed to protect water quality and manage water quantity.

- Planning for increased flooding can reduce the likelihood of contaminated runoff events.

- Preserve open space and concentrate urban development away from CARAs.

- If necessary, strengthen regulatory protection of CARAs. For example, the County may review the CARA mapping, determine the areas of highest risk to drinking water, and prioritize protection of those areas. The County can reduce the risk of groundwater contamination by prohibiting land uses that are high risk within high priority areas. Public outreach education on best management practices (BMPs) for spills and leaks can also be improved.

- Continue to protect CARAs by maintaining updated CARA maps and classifications.

- Review regulatory requirements for reclaimed water use and temporary dewatering during construction to ensure adequate protections are in place. This may involve additional County-specific studies.

- Continue to modify public outreach efforts to educate residents about best practices in CARAs and promote water conservation and water use efficiency programs.

- Promote and incentivize low impact development, specifically infiltration of clean runoff to support aquifer recharge.

- Balance growth and development with preservation and restoration of open spaces and native vegetation tracts.

3. Frequently Flooded Areas (FFA)

3.1 Definitions

Frequently flooded areas (FFAs) are floodplains and flood prone areas that pose a risk to public safety. FFAs also serve important habitat functions for fish and wildlife. FFAs are defined in WAC 365-190-030(8) as follows:

> *Frequently flooded areas "are lands in the flood plain subject to at least a one percent or greater chance of flooding in any given year, or within areas subject to flooding due to high*

groundwater. These areas include, but are not limited to, streams, rivers, lakes, coastal areas, wetlands, and areas where high groundwater forms ponds on the ground surface."

The Clallam County definition of a frequently flooded area is in CCC 27.12.510:

Frequently flooded areas shall be classified as floodways, floodplains, and special flood hazard areas. "Floodway" refers to the channel of a stream, plus any adjacent areas, that must be kept free of encroachment in order to discharge the base flood without cumulatively increasing water surface elevation more than one foot. "Floodplain" refers to the area of land that would be covered with water during a flood, and includes the floodway and the special flood hazard area. "Special flood hazard area" means the floodway and adjoining land which is subject to a one percent or greater chance of flooding in any given year, as determined by engineering studies accepted by Clallam County. Coastal high hazard areas are located within special flood hazard areas.

3.2 Functions and Values

Floods are regularly occurring weather events that can result in destruction of property and loss of life but are also responsible for ecological processes that sustain river systems. Floods typically occur following large storm events but may also result from a collapse of impounded water, such as from a dam or levee failure, or beaver activity. FFAs are dynamic and ecologically productive environments that provide important habitats for fish and wildlife and floodplain storage that alleviate downstream flood zone impacts. These processes overlap with many of the functions of Fish and Wildlife Conservation Areas (FWHCAs) as discussed in Section 6.2.1, so this section briefly summarizes processes and functions as they relate to floodplain dynamics.

Dynamic hydrologic processes, including the mobilization of large woody debris and other allochthonous inputs, can be critical to the maintenance of fish and wildlife habitat (Naiman & Decamps 1997; Petts et al. 2005). High-flow channels carved into floodplains provide important habitat for a variety of fish species and create areas of refuge from the high-velocity flows. Streams overtop their banks during periods of high flow and deposit sediment, cumulatively forming a flood plain (Dunne & Leopold 1978; Knighton 1998). Floodplains also provide storage of floodwaters that can reduce the severity of other areas in the watershed and contribute to infiltration and aquifer recharge.

Streams are often modified to protect development from destructive floods, typically in the form of channel straightening and armoring. These modifications can cause rivers to become disconnected from their natural floodplains and associated wetlands (Booth 1990). Other land use changes associated with urbanization such as impervious surfaces and deforestation also influence floodplains by increasing the magnitude and frequency of floods (Booth et al. 2002). In landscape-level assessments, patterns of urban development, particularly impervious surface area and distribution, have been demonstrated to influence watershed functions (Alberti et al. 2006). Among these are stream channel downcutting, a process associated with watersheds that have frequent and short duration high peak flows, that further disconnects floodplains, increases in-stream erosion, and deposits sediment in downstream environments leading to blocked culverts (Booth 1990).

Flooding can result in significant economic costs from damaged homes and infrastructure, business disruption, and loss of life. Floodplains have been used for agriculture, residential development, and urbanization for centuries because the geographic locations tend to be well-suited for development during periods between floods. The proximity of development to rivers and large water bodies, and advantages in travel, transport, and discharge of waste, otherwise provide ideal settlement locations. Dikes, levees, and associated floodplain fill have been a historically common approach to protecting development, which has consequentially worsened flood impacts to some downstream areas and sometimes failed to protect the areas that were intended. Altered river dynamics, including sediment and large woody debris accumulation as well as increased flows associated with upstream land use changes, have overwhelmed some aging flood control works that have not been maintained or improved. The human and societal costs of flooding have increased over time as the population and amount of infrastructure in floodplains has increased and from climate change.

The primary river flood hazards are associated with the Quillayute River, Bogachiel River, Calawah River, Sol Duc River, East Dickey Creek, Sekiu River, Hoko River, Clallam River, Reed Creek, Elwha River, Morse Creek, and Dungeness River. River flooding hazards are primarily located near the mouths of the rivers in the northern, central, and western portions of the County, along the extent of Highways 101, 110, and 110 Spur. Ediz Hook, Port Angeles, Gibbon, and Travis spits in the mouth of Sequim Bay may become inundated with high tides and storm surges. The Clallam, Elwha and Dungeness tidal areas are also impacted by high tides and river flooding. Kinkade Island is highly vulnerable to flooding and erosion as it is in the floodplain and meander hazard zone. Several flow paths throughout Kinkade Island receive flow from groundwater and surface water. Jimmycomelateley Creek and the lower Sequim delta were also areas of historic flooding. The Jamestown S'Klallam Tribe, the Clallam Conservation District, Clallam County, and other stakeholders completed a restoration project to return the functionality of the creek's floodplain and to improve fish passage. (Clallam County, 2019)

3.3 Key Protection Strategies

Floodplain protection strategies serve the dual purpose of protecting property and infrastructure, and the ecological integrity of streams and watersheds. Clallam County developed a natural hazard mitigation plan in conjunction with ports of Port Angeles, Clallam County Public Utilities District (PUD), Peninsula College, the cities of Forks, Sequim, Port Angeles and the Elwha Klallam and Jamestown S'Klallam tribes. The purpose of the plan is to review and manage natural hazards and was most recently updated in 2019 (Clallam County, 2019). A separate Dungeness River Comprehensive Flood Hazard Management Plan was also developed in 2009 (Dungeness Flood Hazard Advisory Committee, 2009)

All development within designated FFAs is regulated by Clallam County Construction Code, Chapter 21.01 CCC. Building within the floodplain requires a flood elevation certificate completed by a civil engineer licensed in the State of Washington, demonstrating that the proposed development will not result in more than a one-foot increase in flood levels during the occurrence of the base flood discharge. In addition to the critical area buffer requirements and other applicable protection standards of Clallam County Construction Code, CCC 27.12.515 lists conditions that apply to structures constructed within designated FFAs.

Floodplain management is generally based on a no adverse impact strategy (ASFPM, 2003). This approach requires floodplain property owners to ensure that their land use does not adversely affect flood storage or flood risk for others, including risks of flow velocities and erosion. This is commonly achieved by requiring no net increase in flood elevations. This approach protects natural floodplain processes and encourages restoration, such as reconnecting side channels and reducing armoring.

The Federal Emergency Management Agency (FEMA), in cooperation with the state, county, tribes, and local communities within Clallam County are using updated data and GIS technology to create updated Flood Insurance Rate Maps (FIRMs) to represent the risk of flooding more accurately in the area. New maps will help the community better understand flood risks, which allows for more informed decisions about how to protect against damage and loss. Currently, the flood maps are considered preliminary and open for public review and input.

Figure 3. Image obtained from Clallam County floodplain mapping application.[9]

3.4 Climate Change Impacts & Mitigation

Climate change in the Pacific Northwest is anticipated to result in wetter autumns and winters and drier summers (Mote & Salathe Jr., 2010). Climate change models predict that the frequency of atmospheric rivers, which contribute to severe deluges in rainwater and other extreme weather events, will become more frequent and severe (Mauger & Kennard, 2017; Salathe, et al., 2014). Greater flood risks are

[9] https://storymaps.arcgis.com/stories/4f2741a3af714c16b75775a1a9a8b5ed

predicted because of the increased precipitation paired with the increased frequency and intensity of extreme weather events (Ecology, 2021b). The resulting increase in floodwater elevation and expansion of floods to new areas is a risk to property and public safety. Climate change can also influence flooding in coastal areas due to sea level rise, high tides, storm surges and waves (Mauger and Kennard 2017). Extreme floods impose both positive and negative effects on stream health. Impacts include physical trauma and stress to aquatic organisms, displacement or stranding, erosion and sedimentation, loss of vegetation, pollution, disruptions to food webs and spawning, and disrupted migration. As a result, extreme floods have been documented to reduce fish densities (Milner et al. 2013). However, some studies show that fish assemblages are resilient to the effects of floods at a basin scale and recover quickly (George et al. 2015). Potential positive effects include the creation of new habitats and nutrient redistribution (Peters et al. 2015).

3.4.1 Strategies to Manage Climate Change Impacts to FFAs

The Washington Silver Jackets is an interagency group that was formed in 2010 to plan and manage flood risks. This group works to develop improved estimates of future flooding, develop resources for local planners, build capacity and coordinate on resiliency, improve public engagement, and coordinate floodplain management goals (Mauger & Kennard, 2017). The University of Washington Climate Impacts Group has collaborated with the Washington Silver Jackets to integrate climate change predictions and impacts into flood management planning efforts. This resulted in the development of the report: *Integrating Climate Resilience in Flood Risk Management: a Work Plan for the Washington Silver Jackets Team* which provides a framework for strategic management (Mauger & Kennard 2017). The work plan recommendations include:

- Develop improved estimates of future flood impacts (Mauger & Kennard 2017).
- Develop resources for local planners (Mauger & Kennard 2017).
- Build capacity and coordination on resiliant floodplain management (Mauger & Kennard 2017).
- Improve public engagement (Mauger & Kennard 2017).
- Coordinate floodplain goals and mangement (Mauger & Kennard 2017).
- Maintain and update CFHMP and SMP to support stormwater management, salmonid habitat, and streamflow planning (Ecology 2021a).
- Implement and enforece Clallam County and Washington State laws and policies regarding flood prevention during permitting and development.
- Encourage and incentivize floodplain restoration actions to restore floodplain connectivity to streams and wetlands and protect or restore riparian corridors to maintain microclimate.
- Utilize the FEMA Climate Resiliency approach to support flood hazard management planning and follow grant funding opportunities.
- Refine topographic floodplain analysis to identify potential changes in floodplain extents.

4. Geologically Hazardous Areas

Consistent with WAC 365-190-030, geologically Hazardous Area are:

> *Areas that because of their susceptibility to erosion, sliding, earthquake, or other geological events, are not suited to the siting of commercial, residential, or industrial development consistent with public health or safety concerns.*

Per hazards (RCW 36.70A.030(9) and WAC 365-190-120), The four main types of geologically hazardous areas recognized in the GMA are erosion hazard areas; landslide hazard areas; seismic hazard areas, and areas subject to other geologic events such as coal mine hazards and volcanic hazards. Clallam County regulates volcanic, landslide, seismic, mine, and erosion hazard areas in CCC Chapter 27 Part 4 (CCC 27.12.400).

The purpose of regulating activities in geologically hazardous areas is to protect the public from potential risks. Geologic events may occur in hazard areas that can result in property damage, injury, and the loss of life. The type of land use in these areas influences the level of risk by increasing consequences to life and property and may increase the potential for a hazardous event in some cases. There is public interest in regulating these areas because a geologic event occurring on one property can impact surrounding areas. It is important to identify where such hazard areas are, and to ensure that activities and development in those areas are managed for safety and stability.

Although the general protective approach is to avoid disturbing geologic hazard areas, WAC 365-190-080(4) states "Some geological hazards can be mitigated by engineering, design, or modified construction or mining practices so that risks to health and safety are acceptable".

4.1 Definitions

4.1.1 Landslide Hazard Area

Landslide hazard areas are areas identified as having the potential for mass wasting due to a combination of geologic, seismic, topographic, hydrologic, or human-created factors. Regulated landslide hazard areas are classified for regulation within Clallam County by the presence of any of the following indicators in CCC 27.12.410:

Landslide Hazard Areas: *Lands potentially subject to mass movement due to a combination of geologic, topographic, and hydrologic factors. The following classifications shall be designated as landslide hazards and are subject to the requirements of this chapter:*

> *(i) Areas of historic, existing, or ongoing landslide activity as evidenced by downslope movement of a mass of materials including rock, soils, fills, and vegetation.*
>
> *(ii) Glaciolacustrine silt and clays on terraces.*

(iii) Slopes fifteen (15) percent or steeper with a combination of: slowly permeable silt and clay interbedded sand and gravel, and sidehill springs or seeps from perched water tables.

(iv) Soils mapped and described by the Soil Survey of Clallam County, Washington, issued February 1987, as amended, classified as having a severe or very severe erosion hazard potential.

(v) Planar slope forms sixty-five (65) percent or steeper with vertical relief of ten (10) or more feet, except areas composed of consolidated rock.

(vi) Concave slope forms twenty-five (25) percent or steeper with vertical relief of ten (10) or more feet, except areas composed of consolidated rock.

(vii) Any slopes greater than eighty (80) percent subject to rockfall during seismic shaking.

(viii) Marine coastlines including marine bluffs potentially unstable due to wave action or mass wasting and littoral dune systems which border the ordinary high water mark.

(ix) Ravines with a vertical relief of ten (10) or more feet in depth except areas composed of consolidated rock.

(x) Channel meander hazard. Areas subject to the natural movement of stream channel meanders associated with alluvial plains where long-term processes of erosion and accretion of the channel can be expected to occur. Such meander hazards are characterized by abandoned channels, ongoing sediment deposition and erosion, topographic position, and changes in the plant community, age, structure, and composition. These areas do not include areas protected from channel movement due to the existence of permanent levees or infrastructure improvements such as roads and bridges constructed and maintained by public agencies. These areas also do not include areas outside the meander hazard which may be subject to rapid movement of the entire stream channel or avulsion.

(xi) Any area located on or adjacent to an active alluvial fan or debris flow, presently or potentially subject to inundation by debris or deposition of stream-transported sediments.

(xii) Slopes that are parallel or sub-parallel to planes of weakness, such as bedding planes, joint systems, and fault planes in subsurface materials.

4.1.2 Seismic Hazard Area

Seismic hazard areas are areas subject to damage resulting from earthquake-induced landsliding, seismic ground shaking, dynamic settlement, fault rupture, soil liquefaction, or flooding caused by tsunamis and seiches. Seismic hazards are identified in the Washington State DNR Geologic Information Portal[10]. The DNR Geologic Information Portal contains information projecting the Cascadia, Seattle and Tacoma Seismic Scenarios which extend throughout Clallam County.

Regulated seismic hazard areas are identified for regulation within Clallam County by the presence of any of the following indicators:

[10] https://geologyportal.dnr.wa.gov/

Seismic Hazard Areas. Lands meeting the following classifications shall be designated as seismic hazard and are subject to the requirements of this chapter.

(i) Landslide hazard areas and materials.

(ii) Artificial fills especially on soils listed in subsection (1)(c)(iii)of this section and areas with perched water tables.

(iii) The following soil types described within the Clallam County soil survey as beaches, Mukilteo muck, Lummi silt loam, Sequim-McKenna-Mukilteo complex, and Tealwhit silt loam.

(iv) Other areas as determined by the Clallam County Building Official pursuant to 1997 Washington State Uniform Building Code, Chapter 18, as amended.

4.1.3 Mine Hazard Area

Mine hazard areas are directly underlain by, adjacent to or abutting, or affected by old mine workings such as adits (horizontal passage), tunnels, drifts, or airshafts that have the potential for subsidence.

The County does not list or describe mine hazards, however the DNR Washington Geologic Information Portal[11] shows numerous active surface mines. The portal also shows hazardous material locations such as mercury and radon, uranium bearing rocks, oil, and gas wells Erosion Hazard Areas.

4.1.4 Erosion Hazard Area

Erosion Hazard Areas regulated by Clallam County include shoreline, riverine, and soil erosion hazard areas. Shoreline erosion hazard areas include areas landward of the ordinary high water mark (OHWM) of a freshwater (lake or pond). Riverine erosion hazard areas include the channel migration zones (CMZ) of rivers listed above in CMZ section. Soil erosion hazard areas contain slopes of twenty (20) percent or greater and are classified as having severe, or very severe erosion potential by the Soil Conservation Service, US Department of Agriculture (USDA).

Clallam County defines erosion hazards areas as follows:

Erosion Hazard Areas. Lands meeting the following classifications shall be designated as erosion hazard and are subject to the requirements of this chapter:

(i) Landslide hazard areas.

(ii) Areas of existing erosion activity which causes accelerated erosion, sedimentation of critical areas, and/or threatens public health, safety, and welfare.

(iii) Any slope forty (40) percent or steeper with a vertical relief of ten (10) or more feet, except areas composed of consolidated rock.

[1111] The portal shows the County having very strong to severe shaking during a Cascadia seismic scenario, moderate to strong shaking during a Seattle seismic scenario, and light to strong shaking during a Tacoma Seismic scenario.

(iv) Concave slope forms equal to or greater than fifteen (15) percent with a vertical relief of ten (10) or more feet, except areas composed of consolidated rock.

(v) Soils classified by the soil survey of Clallam County as having a moderate, severe, or very severe erosion hazard potential.

4.2 Hazard Characterization

Clallam County defines geologically hazardous areas as areas within 200 feet of a landslide, erosion, or seismic hazard area. The County does not list or describe mine hazards, volcanic hazards, or tsunamis, however the DNR Washington Geologic Information Portal[12] shows numerous active surface mines. The portal also shows hazardous material locations such as mercury and radon, uranium bearing rocks, oil, and gas wells. The portal does not indicate any volcanic hazards; however, tsunami hazard areas are delineated along the entire coastline. The portal shows the County having very strong to severe shaking during a Cascadia seismic scenario, moderate to strong shaking during a Seattle seismic scenario, and light to strong shaking during a Tacoma Seismic scenario.

4.2.1 Landslide Hazard Area

Landslides are difficult to predict because bluff geology, sediment composition, topography, and hydrology all influence risk of failure. Steeper slopes are more prone to failure due to increased gravitational stresses (Shipman 2004). Certain land use modification and development activities have the potential to increase the likelihood of landslides, such as vegetation removal and creation of new impervious surfaces. In addition to anchoring sediments, the process of evapotranspiration by plants transforms groundwater into atmospheric vapor and intercepts rainwater (Schmidt et al. 2001; Watson and Burnett 1995). There are between 1,000-2,000 earthquakes which occur annually between Washington and Oregon, although most are small and fewer than 25% are perceptible (Cooper 2006; McCrumb et al. 1989). The probability of occurrence and risk of earthquakes depends on location, and seismic hazard areas have been mapped to identify areas with the greatest risk.

Alluvial fans are triangle shaped deposits of sediment which occur when mountainous areas approach topographically flatter areas. They are included in the concept of landslide hazard areas although they also share characteristics of flood hazard areas due to the associated risks including debris flows, flash floods, mudflows, and outburst floods. These types of flows are extremely dangerous even at small levels because of the destructive nature of swiftly moving large debris and floodwaters. The risk of flash floods and debris flows increases following wildfires due to changing hydrologic characteristics in landscapes with bare soils and lacking vegetation [Washington Geological Survey's Wildfire-Associated Landslide Emergency Response Team (WALERT), 2023].

[1212] The portal shows the County having very strong to severe shaking during a Cascadia seismic scenario, moderate to strong shaking during a Seattle seismic scenario, and light to strong shaking during a Tacoma Seismic scenario.

The DNR Geologic Information Portal provides mapping for known landslide areas within Clallam County.

4.2.2 Seismic Hazard Area

Secondary hazards associated with seismic events include liquefaction of the soil, rockfall, landsliding, dam failure, levee failure, and tsunamis or seiches. Liquefaction hazard areas within Clallam County are mapped by the Washington Department of Natural Resources, in addition to seismic site class and seismic design categories. Nearly all areas of Clallam County have some level of seismic risk, even outside of designated critical areas. The anchoring and hydrologic functions of vegetation lower the risk of slope failure and shallow-rapid landslides (Schmidt, et al., 2001).

The DNR Geologic Information Portal[12] provides mapping for known seismic hazard areas within Clallam County.

4.2.3 Mine Hazard Area

Clallam County, Washington has 246 records of mining claims on public land managed by the Bureau of Land Management (BLM).

Active and closed mines pose potential hazards because they can lead to increased risks of erosion, mass wasting, and landslides near surface mines, and subsidence over collapsed tunnels and shafts in subsurface mines. Since the potential risks of subsurface mines are not obvious, evaluation and disclosure to landowners is essential to protecting infrastructure and public safety.

4.2.4 Erosion Hazard Area

Erosion hazard areas present risks to infrastructure, the environment, and public safety. For example, erosion may undermine the foundation of buildings or other structures and increase the risk of landslides which threaten property and human life. There is also a direct link between erosion and impacts to other aquatic critical areas including streams, ponds, and wetlands (Dubois et al. 2018).

Erosion and landslides are natural processes that contribute sediment, rocks, and large woody debris to streams and other waterbodies. The introduction of periodic pulses or chronic turbidity and suspended solids associated with erosion has been demonstrated to harm certain types of aquatic life, particularly salmonids (Bash et al. 2001). This can occur from activities such as clearing vegetation and the creation of new impervious surfaces, which can introduce sediments and pollutants to natural waterways (Booth 1991). Further discussion of the effects of erosion and sediment on streams is provided in Section 6.2.1.

The stability of erosion hazard areas is influenced by the vegetation composition, structure, and cover. Vegetation reduces erosion through rainwater interception and by anchoring soils within root networks (Booth et al. 2002; Naiman and Decamps 1997). In cleared areas, rainfall tends to concentrate in small channels, and sediment can be mobilized as the water gains depth, volume, and increased flow. Small channels or rills can eventually develop into gullies in these types of exposed soils.

Alluvial fans are triangle shaped deposits of sediment which occur when mountainous areas approach topographically flatter areas. They are included in the concept of landslide hazard areas although they also share characteristics of flood hazard areas due to the associated risks including debris flows, flash floods, mudflows, and outburst floods. These types of flows are extremely dangerous even at small levels because of the destructive nature of swiftly moving large debris and floodwaters. The risk of flash floods and debris flows increases following wildfires due to changing hydrologic characteristics in landscapes with bare soils and lacking vegetation (WALERT 2023).

4.3 Key Protection Strategies

The primary goal of protection measures for geologic hazards is to protect people and property. The primary mechanism for protecting people is limiting the risk to people by limiting the occupancy and limiting the development of essential or hazardous facilities in geologically hazardous areas.

Erosion hazards, landslide hazards, and seismic hazards can be mapped and classified. The classification systems can be used to determine site limitations and development requirements. If development is proposed within the buffer or erosion hazard or landslide hazard area, rigorous design and construction standards should be adhered to in order to prevent the development from causing instability, either at the site or elsewhere on the slope. Any such development in the hazard area or its buffer should be evaluated on a site-specific basis by a licensed geotechnical engineer or engineering geologist. Data used in such analyses should be site-specific and include subsurface exploration and testing of soils at an appropriate frequency across the site.

Additional protection strategies were identified by the SR-530 Landslide Commission following the Oso mudslide that occurred in March 2014. Recommendations from the commission include integrating and funding Washington's emergency management system, supporting a statewide landslide hazard and risk mapping program, establishing a geologic hazards resilience institute, conducting landslide investigations, and advancing public awareness of geologic hazards. Integrating Washington's emergency management system would bring together, "the Governor's office, the [state] Legislature, tribes, county and municipal government, first responders, transportation agencies, non-government support agencies, the private sector, and members of the public" (SR 530 Landslide Commission, 2014). To improve landslide hazard and risk mapping, collaboration among agencies and landowners is recommended along with risk prioritization, utilization of lidar mapping and GIS database tools. The commission recommends the governor establish a geologic hazards institute focused on education, outreach, research needed, and best professional practice guidelines (SR 530 Landslide Commission, 2014).

Per the SR-530 Landslide Commission's findings, updates to critical area regulations are recommended to better identify and regulate land uses in geologic hazard areas. This may include requiring geologic risk assessments as part of subdivision permit application reviews, slope-density regulations, conservation easements, and grading ordinances (SR 530 Landslide Commission, 2014). Slope-density calculation is a method for determining the number of allowable development units in subdivisions with geological hazards. Usually the steeper the slope, the fewer the number of units permitted.

Seismic hazards can be managed by applying earthquake resistant building standards to "at risk" areas. The Washington State Building Code (WAC 51-50) offers guidance from the 2018 International Existing Building Code with amendments specific to the State, including several directly related to seismic standards. Adherence to this guidance can mitigate seismic hazards.

4.4 Climate Change Impacts and Mitigation

Geologically hazardous areas, particularly erosion hazard areas, and landslide hazard areas, are anticipated to be influenced by climate change. Climate change models project warmer, drier summers, and increased precipitation in other seasons while maintaining roughly the same amount of annual precipitation (Dalton et al. 2013). Extreme precipitation events modeled by the UW Climate Impacts Group are expected to increase in intensity and frequency (Mauger et al. 2021). Increased magnitude and frequency of rain events can lead to over-saturated soils and contribute to slope instability in hazard areas. Consequentially, geologic hazard risks are anticipated to increase because rainfall intensity and duration are known indicators of landslide events (Chleborad 2006; DNR 2020). Additionally, the severity and frequency of wildfire is expected to increase, heightening susceptibility to erosion and landslide hazards (Mauger et al. 2015).

Changing climate is also anticipated to affect vegetation community composition and native plant mortality due to shifts in plant hardiness zones and species ranges (Lenoir & Svenning 2015). Existing species assemblages, canopy types, and root systems may be disrupted and displaced by invasive species. Although plant provenance is not the only indicator of a plant's capability to stabilize slopes, opportunistic invasive plants often have shallow root systems and short lifespans that are less effective at anchoring soils than native counterparts. Himalayan blackberry, for example, is a widespread invasive plant likely to displace lost plants and has shallow root system and can cause soil erosion by preventing the establishment of native counterparts (Gaire 2015). High levels of plant diversity also generally improve soil stability by combining multiple forms of root architecture (Ghestem et al. 2014).

4.4.1 Management Recommendations for Climate Change Impacts

- Encourage or require climate-informed design for development and infrastructure in or near geologic hazard areas (DNR, 2020).
- Require appropriate surface and ground water management practices for development near coastal bluffs.
- Encourage utilization of soft shore protection strategies.

- Identify and prioritize geologic hazards within the County, then update mapping as needed using current practices such as LiDAR and GIS database tools.
- Keep in communication with the Governor's office to ensure the County is included in statewide collaborative efforts to manage geologic hazard areas.
- Manage vegetation for climate resilience and slope stability.

5. Wetlands

5.1 Definition

Scientists have worked to develop a wetland definition based on scientifically defensible criteria since interest in managing and protecting wetland resources scaled up in the 1950's. At the time the Clean Water Act of 1977 (CWA) was signed into law, a definition was agreed upon and applied consistently at a national scale. It is defined as follows (33 CFR 328.3):

> *"Wetlands are areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas."*

Washington State also has a wetlands definition that is similar to the CWA but includes certain exceptions for artificial wetlands. It is defined in WAC 365-190-030(22) as follows:

> *'Wetland' or 'wetlands' means areas that are inundated or saturated by surface water or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas. Wetlands do not include those artificial wetlands intentionally created from nonwetland sites, grass-lined swales, canals, detention facilities, wastewater treatment facilities, farm ponds, and landscape amenities, or those wetlands created after July 1, 1990, that were unintentionally created as a result of the construction of a road, street, or highway. However, wetlands may include those artificial wetlands intentionally created from nonwetland areas to mitigate conversion of wetlands, if permitted by the county or city.*

Clallam County Code defines wetlands in CCC 27.10.210 as:

> *Regulated wetlands are those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Regulated wetlands generally include, but are not limited to: swamps, marshes, bogs, ponds, including their submerged aquatic beds and similar areas. Wetlands*

do not include those artificial wetlands intentionally created from nonwetland sites, including, but not limited to: irrigation and drainage ditches, grass-lined swales, canals, detention facilities, wastewater treatment facilities, farm ponds, and landscape amenities, or those wetlands created after July 1, 1990 (adoption date of Chapter 36.70A RCW, Growth Management Act), that were unintentionally created as a result of the construction of a road, street, or highway. Wetlands created as mitigation and wetland modified for approved land use activities shall be considered as regulated wetlands.

5.2 Functions and Values

Wetland processes provide many functions that are recognized for their social, ecological, and economic benefits. Three functional categories, which include water quality, hydrology (water quantity), and habitat, are typically considered to be most crucial in terms of their influence on that natural and built environment and are the focus of this analysis. Wetland values refer to the resources a wetland provides that are valued by society, for their ecological, economic, recreational, or aesthetic benefits.

Wetland functions are influenced by the hydrogeomorphic characteristics of a site which affect how water moves through a wetland system (Brinson 1993; Hruby 2014). For example, wetlands situated in depressions (depressional wetlands), have greater floodwater retention capacity than slope or flat wetlands. Wetland functions are also influenced by landscape scale and site scale characteristics including vegetation structure, hydroperiods, proximity to potential sources of pollution, and priority habitat corridors and connectivity. Many of the functions and services wetlands provide are valuable to society, such as water storage, flood protection, pollutant and nutrient attenuation, and habitat supporting fisheries (Hattermann et al. 2008). Since these functions are provided naturally, or through restoration projects they are often less costly than engineered solutions (Hattermann et al. 2008).

For regulatory purposes in Washington, wetland functions and values are typically categorized in a rating system. The most widely accepted rating system, the *Washington State Wetland Rating System for Western Washington: 2014 Update, version 2*, was developed by the Department of Ecology and is considered to be the regional standard by all regulating agencies (Hruby and Yahnke 2023). This rating system is a rapid assessment tool that evaluates wetland functions in the categories of water quality, hydrology, and habitat, among a framework of three dimensions of site potential, landscape potential, and societal value (Hruby and Yahnke 2023).

5.2.1 Water Quality Functions

Wetlands can improve water quality in waterways through several physical, chemical, and biological processes including settling, filtration, diffusion, volatilization, oxidation, precipitation, adsorption, ion exchange, UV radiation, biodegradation, evapotranspiration, and biotransformation. (Shao, Bingcheng, & Jiming, 2019). Wetlands perform these functions to varying degrees depending on several factors including residence time of polluted waters, vegetation structure and density, and soil composition (Hruby & Yahnke, 2023). Wetlands uptake nutrients, particularly nitrogen and phosphorus, and mediate the effect of nutrient spikes to downstream areas (Sheldon, et al., 2005). Wetland plants and associated microorganisms can take up and remove nitrogen through the biochemical processes of nitrification and denitrification, which occur in respective aerobic and anaerobic conditions (Sheldon, et al., 2005). Low oxygen concentrations that are common in wetland environments allow them to be sinks for copper, a heavy metal (Kerr et.al., 2009). Studies of constructed wetlands have shown wetland plants remediate pharmaceuticals and personal care products (PPCPs) to various extents (Zhang et.al, 2014).

5.2.2 Hydrologic Functions

Hydrologic wetland functions include groundwater recharge, reduction in peak surface water flows, reduced stream erosion, and flood-flow desynchronization (Sheldon, et al., 2005). Flood-flow desynchronization is a landscape-scale process where peak flows of sub-basins vary temporally in a watershed and lower the magnitude of downstream flooding (Adamus et.al, 1991). This has a cumulative effect on magnitude and intensity of individual peak flow events (Sheldon, et al., 2005).

Impervious surface area within a drainage basin has been demonstrated to alter wetland hydrology by increasing or decreasing flows from the surrounding landscape, affecting hydroperiods and flood severity (Sheldon, et al., 2005). These modified hydroperiod regimes are often accompanied by other impacts, such as stream channel erosion and downcutting, and sediment deposition (Sheldon, et al., 2005). Changes in wetland ponding depths, hydroperiods, or water level fluctuation dynamics can also impact wetland plant communities (Schueler, 2000).

5.2.3 Habitat Functions

A diverse group of fauna depend on wetlands for at least a portion of their life cycle, including wetland-associated mammals, waterfowl, fish, invertebrates, reptiles, and amphibians (Kaufmann & Faustini, 2012) (Sheldon, et al., 2005). There are a diverse range of ecological variables and factures which influence habitat functions and quality, such as buffer width and condition, vegetative structure, habitat interspersion, wetland hydroperiods, and landscape setting (Hruby & Yahnke, 2023). A meta-analysis of the relative effects of landscape-scale wetland area and landscape matrix quality on wetland vertebrates found that while species abundance generally increases in landscapes with more wetland areas, the abundance of some taxa such as amphibians are more sensitive to the larger landscape condition (Quesnelle, Lindsay, & Fahrig, 2015). Native species diversity for most taxa is also negatively correlated with the degree of urbanization, though overall species richness is often greatest in areas of intermediate disturbance (Guderyahn et al. 2016; Müller et al. 2016).

Wildlife are also sensitive to water quality impairments which affect wetlands. Additionally, habitat fragmentation tends to reduce the habitat functions and values a wetland provides (Azous and Horner 2010; Sheldon et al. 2005). Land disturbance associated with urban and rural development results in habitat loss and reduces the area of buffers between wetlands and human land use impacts.

5.3 Key Protection Strategies

Wetlands are protected through government regulations at the local, state, and federal levels, with each requiring impact avoidance, minimization, and mitigation. Effective wetland protection strategies include regulatory protocols to identify and classify wetlands, assign buffer widths, and require impact avoidance and compensatory mitigation for any wetland or buffer impacts. Additionally, preservation of local and landscape-scale corridors can be protected by establishing corridor protection regulations for developments near wetlands.

5.3.1 Wetland Identification and Classification

To protect wetlands, a qualified professional must first identify them. The nationwide standard for wetland delineations is the 1987 Army Corps of Engineers (Corps) *Wetlands Delineation Manual* with the *Regional Supplement to the Corps of Engineers Wetland Delineation Manual: Western Mountains, Valleys, and Coast Region Version 2.0* (Regional Supplement). The Regional Supplement provides greater detail on determining the presence or absence of wetlands specific to the region.

The *Ecology Wetland Rating System for Western Washington* was first issued in 2004, annotated in 2006, revised in 2014, and annotated in 2023. One major change made during 2014 update provides intermediate categories for each assessed function, scoring to a high, medium, or low ranking. These were thought to better reflect the coarseness of the tool. Additional clarifications were added to the rating system guidance in Version 2 to incorporate annotations from the prior version (Hruby & Yahnke, 2023)

Jurisdictional status of a wetland can vary depending on the government agency and the statute regulations under consideration. For example, the CWA only applies to wetlands that meet specific criteria regarding connectivity to Waters of the U.S., and do not apply to isolated wetlands. Local and state wetland regulations are more broadly encompassing, but generally exclude artificially created stormwater features, for example.

5.3.2 Wetland Buffers

Wetlands in Washington are protected from surrounding land uses through buffer requirements based on recommendations from the Department of Ecology. Similar to wetlands, buffers also provide functions that have ecological, sociological, and economic benefits. Wetland buffer functions include moderation of stormwater inputs, sediment removal, pollutant abatement, microclimate, habitat for wetland-dependent fauna, habitat connectivity, and disturbance screening (Sheldon, et al., 2005). Buffer functions vary depending on a wide variety of factors, including the vegetation community, gradient, soil conditions, and adjacent land use intensity to name a few (Sheldon, et al., 2005).

In 2005, Sheldon et al. developed a synthesis of the science for wetlands in Washington which included the topic of buffer widths efficacy. In this, the topics of buffer widths relative to water quality functions, hydrologic maintenance, wildlife habitat, and disturbance barrier effectiveness are reviewed. Due to a similarity of processes and function, studies on stream buffer widths were compiled into the synthesis (Sheldon, et al., 2005).

BUFFER APPROACHES

Ecology provides guidance for wetland buffers framed around several alternatives in Wetlands in Washington State - Volume 2: Guidance for Protecting and Managing Wetlands– Protecting and Managing Wetlands, Appendix 8-C (Granger 2005) and 2022 Ecology Guidance for Critical Area Ordinance Updates. Both guidance documents provide similar but slightly differing approaches, and both are consistent with BAS currently.

Current Ecology wetland guidance documents outline the following primary factors to consider when determining buffer widths (Ecology 2022):

- The wetland type and the functions needing protection (buffers filter sediment, excess nutrients, and toxics; screen noise and light; provide forage, nesting, or resting habitat for wetland-dependent species; etc.),
- The types of adjacent land use and their expected impacts, and
- The characteristics of the buffer area (slope, soils, vegetation).

Three wetland buffer alternatives are presented in the current Ecology guidance for CAO updates.

As buffer determination options are reviewed, it is important to note that, "Ecology's buffer width recommendations are based on the assumption that the buffer area is well vegetated with native species appropriate to the ecoregion" (Ecology 2022). Those buffer options are:

- **Option 1.** Width based on wetland category and habitat score, if minimization measures are applied, and a habitat corridor is provided. If a habitat corridor is not provided or minimization measures are not implemented, then buffer width requirements increase. Modified buffers should be not less than 75 percent of the otherwise required buffer. Option 1 provides the most flexiblity.
- **Option 2.** Width based on wetland category and modified by the intensity of the impacts from proposed land use. Option 2 decreases regulatory flexibility and eliminates buffer averaging and reduction provisions through the application of corridors and minimization measures.
- **Option 3.** Width based on wetland category only. Option 3 is the least flexible and simplest to administer.

FUNCTIONALLY DISCONNECTED BUFFER AREAS

In urban areas, standard buffer widths are sometimes interrupted by development. When a buffer area is functionally disconnected from a wetland, Ecology recommends providing clear direction on how buffer regulations address this condition by providing specific criteria. A distinction between minor and major developments is central to determining if a functional barrier is present (Ecology 2022). Minor developments, such as trails, accessory structures, and driveways for a single residence would not completely block wetland buffer functions (Ecology 2022). Significant developments associated with the complete loss of buffer functions include public infrastructure (paved roads, railroads), housing developments, or commercial structures. An interruption may impact all or just a portion of a buffer area (Ecology 2022).

INFLUENCE OF BUFFERS ON HYDROLOGY

Wetland buffers can mediate the effects of surrounding land use impacts, with variable interactions depending on site conditions and landscape position. Development and impervious surfaces often result in runoff to surface waterbodies which negatively alters hydrologic regimes and introduces pollutants to waterways, these impacts are reduced by the presence of wetland buffers. Infiltration of rainwater to soils in wetland buffers reduces surface flows and improves groundwater recharge. Vegetation slows the movement of surface runoff, allowing for greater time for infiltration to occur, which slows or desynchronizes hydrologic inputs into the wetland and potentially diverts them to other groundwater systems. Leaf and other vegetative litter on and in the soil also capture water and improve the soil's infiltration capacity (Castelle, et al., 1992a). Vegetation also intercepts rainwater and converts liquid water back to atmospheric vapor through evapotranspiration. Buffer characteristics that influence performance of hydrologic maintenance are vegetation cover, soil infiltration capacity, rainfall intensity, and antecedent soil moisture conditions (Wong and McCuen 1982).

Buffers also function to control erosion by slowing water flow and improving infiltration. Buffer vegetation can reduce erosion by capturing sediment before it enters the wetland, through soil stabilization by roots, and reduction in rain energy by both the vegetation canopy and organic material on the soil (Castelle, et al. 1992a). Vegetation composition and structure in buffers are important factors in the capability of a buffer to perform this function. Plants with fine roots are most effective at preventing erosion by binding the soil (McMillan 2000).

INFLUENCE OF BUFFERS ON WATER QUALITY

Buffers protect water quality in wetlands through the removal of sediment and suspended solids, nutrients, pathogens and toxic substances, and other pollutants (Castelle et al. 1992a; McMillan 2000; Sheldon et al. 2005). The ability of a buffer to improve water quality depends on several variables such as slope, vegetation composition, leaf and wood litter, soil type, the type of pollutant, size of the basin, and the fate of stormwater conveyance from adjacent land use (Desbonnet et al. 1994; McMillan 2000). Buffers are typically higher functioning when they have a structurally complex mix of trees, shrubs, and groundcovers, an abundance of downed wood and leaf litter, and low slopes (Hruby 2013). This is in-part facilitated by physical and biological processes, such as the retention, binding, and filtering of sediments and pollutants through wood or leaf litter, and the breakdown and uptake of pollutants by plants and microorganisms in the soil (Castelle et al. 1992a; Desbonnet et al. 1994; McMillan 2000). Buffer vegetation can reduce sediment input to the wetland through the stabilization of soils by roots, and reduction in runoff via rainwater interception and buildup of organic material on the soil (Castelle, et al. 1992a). Shading and wind reduction by buffer vegetation also influence water quality by maintaining cooler temperatures. Water temperature in wetlands can be critical to the survival of aquatic wildlife species, but more importantly from a water quality perspective, it helps maintain sediment-pollutant bonds, increases the water's dissolved oxygen capacity, and limits excessive algal growth (Castelle et al. 1992a; McMillan 2000; Sheldon et al. 2005).

Approximately 50% of overall pollution removal, except nitrogen, occurs in the first 16 ft (5 m) of buffer and 70% occurs at 115 ft (35 m) (Desbonnet, et al. 1994). For sediments and suspended solids, 60% removal is achieved with a 7 ft buffer (2 m), and 80% removal is achieved at 82 ft (25 m) (Desbonnet, et al. 1994). Phosphorus removal of 60% is achieved with buffer of 39 ft (12 m), and 80% is achieved at 279 ft (85 m) (Desbonnet, et al. 1994). An analysis of a range of buffer widths by specific water quality function identified the following effective buffers: 5 to 100 meters (16 to 330 feet) for sediment removal; 10 to 100 meters (33 to 330 feet) for nitrogen removal; 10 to 200 meters (33 to 656 feet) for phosphorus removal; and 5 to 35 meters (16 to 100 feet) for bacteria and pesticide removal (McMillan, 2000; Sheldon, et al., 2005).

INFLUENCE OF BUFFERS ON WILDLIFE HABITAT

Wetland buffers provide habitat for a wide variety of wildlife species and are particularly essential for wetland-dependent and wetland-associated species that require adjacent terrestrial habitat during their life cycle. They also provide habitat well suited for non-wetland-dependent species that prefer habitat edges, use the wetland as a source of drinking water, or use the protected buffer corridors for migrations and movements.

The current body of research includes a range of studies which assess how certain focal species utilize buffers at varying widths, following disturbance events or land use changes. One study in urban King County found that bird diversity was positively correlated with the percentage of a wetland perimeter with vegetated buffers, though only a minor increase in diversity was found with the tested buffer widths of 50, 100, and 200 feet (Milligan, 1985). One literature summary reports an effective buffer range of 50 feet (15 m) for many bird species up to 3,280 feet (1,000 m) for native amphibians (Milligan 1985) (Azous and Horner 2010). Many studies recommend buffers between 150 and 300 feet with minimum buffer widths of 50 to 75 feet to provide general avian habitat (Desbonnet et.al, 1994; Ecology, 1992) . Wildlife corridor to connect wetlands is recommended by McMillan (2000) to be at least 98 feet, and Reichter (1997) recommends 490 feet as a minimum travel corridor. A synthesis by Sheldon et al. (2005) found that scientific literature suggests buffer widths for habitat protection range between 50 and 300 feet depending on factors including wetland habitat conditions, target species, buffer condition, and surrounding land uses.

In addition to providing habitat for wetland-dependent and wetland-associated species, buffers provide a barrier between a wetland and the various vectors for human encroachment, including noise, light, trampling of vegetation, and the introduction of garbage and other pollutants. Buffer widths necessary to effectively reduce impacts vary by intensity of the adjacent land use. Buffer widths of 49 feet to 98 feet can effectively screen low-intensity land uses, such as agriculture and low-density residential. High intensity land use, such as high density residential (more than 1 unit/acre), commercial and industrial, require buffer widths of 98 feet to 164 feet (Sheldon, et al. 2005). The buffer itself, and the functions that it provides, is influenced by the degree of human-related disturbance. Buffers less than 50 feet wide experienced the most loss of buffer function related to human disturbance, and this loss is related to gradual reduction in buffer width as adjacent land uses encroach (Castille, et al., 1992b).

MITIGATION SEQUENCING

Mitigation sequencing is the structured process of avoiding, minimizing, and mitigating all impacts to a particular resource. Clallam County has incorporated mitigation sequencing into existing wetland regulations, according to CCC 27.12.840. This is consistent with federal directives to achieve no net loss of wetland functions and values. Mitigation sequencing is also required by the 2008 Wetlands Compensatory Mitigation Rule issued by the U.S. Environmental Protection Agency (2008) and WAC 197.11.768. Per current Ecology guidance for CAO updates, mitigation sequencing must be applied in the following order (Ecology 2022):

- Avoiding the impact altogether by not taking a certain action or parts of an action;
- Minimizing impacts by limiting the degree or magnitude of the action and its implementation, by using appropriate technology, or by taking affirmative steps to avoid or reduce impacts;
- Rectifying the impact by repairing, rehabilitating, or restoring the affected environment;
- Reducing or eliminating the impact over time by preservation and maintenance operations during the life of the action;
- Compensating for the impact by replacing, enhancing, or providing substitute resources or environments; and/or ,
- Monitoring the impact and taking appropriate corrective measures.

COMPENSATORY MITIGATION

Compensatory mitigation may be achieved through a programmatic approach or an approved permittee-responsible mitigation (PRM) plan. Programmatic approaches utilize third-party sponsors to obtain mitigation credits, such as a mitigation bank or in-lieu fee (ILF) program. PRM is an applicant managed mitigation project. PRM is typically concurrent with wetland impacts, but it may be done in advance. Mitigation banks are state certified to ensure ecological replacement is achieved. ILF programs collect fees and apply the funds to restoration projects within the service area. ILF programs are reviewed and approved by the Corps and Ecology. Whereas, PRM applicants must complete installation, site maintenance and monitoring, and adaptive management as needed to achieve approved mitigation plan goals and performance standards (Ecology, 2021b)

Ecology's recommendations for mitigation ratios for projects in Western Washington depend on the wetland category and type of mitigation action (Granger, et al., 2005). Mitigation ratios for direct wetland impacts are increased to account for temporal losses (Ecology, 2022). When applying advanced mitigation, the Ecology recommended ratios account for the wetland category and proposed mitigation actions (Ecology, 2021b).

To address ecologic priorities in Washington State's watersheds, Ecology has developed additional guidance and tools for applicants, including details on using a watershed approach for mitigation site selection and the Credit-Debit Method (Hruby T. , 2012; Hruby, Harper, & Stanley, 2009). The credit-debit method is a system to calculate mitigation credits needed for a given project. The credit calculations can be used to determine compensation when utilizing in-situ mitigation, or a mitigation bank or in-lieu fee program. Depending on specific site conditions, this may result in less or more mitigation than would be required under a set the traditional mitigation ratio guidance (Hruby T., 2012).

Compensatory wetland mitigation methods in order of preference are:

1) Restoration: Re-establishment,
2) Restoration: Rehabilitation-hydrologic processes restored,
3) Creation (establishment),
4) Preservation, and
5) Enhancement.

Ecology recommends applying at least a one-to-one ratio to buffer impacts (Ecology 2022). However, if buffer modifications exceed standard allowances, such as retaining at least 75 percent of the standard buffer width, then Ecology recommends evaluating indirect wetland impacts to determine appropriate compensatory mitigation (Ecology 2021b).

MONITORING

Evaluations of wetland mitigation outcomes found that most wetland mitigation does not fully replace impacted functions and falls short of the goal of no net loss (Ecology, 2008). The goal of no net loss of wetland function cannot be achieved through mitigation alone, but may be met through several factors, including adequate monitoring and maintenance and appropriate performance standards. Factors that reduce the risk of mitigation failure include; detailed functional assessment, high success standards, detailed mitigation plans, larger bonds with up-to-date market values, high replacement ratios, and greater expertise.

5.4 Climate Change Impacts & Mitigation

Climate change is predicted to significantly impact wetland ecosystems by altering hydrology, reducing biodiversity, disrupting carbon storage, modifying community composition, and increasing rates of disease (Aukema et al. 2017; Burkett and Kusler 2000; Lee et al. 2015). Altered hydrology and precipitation patterns from climate change may alter community composition and result in earlier drawdowns of wetlands during droughts, a process that will likely result in wetland loss (Lee et al. 2015). Wetlands may also experience greater polarity in seasonal water levels with increased ponding during wet seasons and decreased water levels during dry seasons (Halabisky 2017). Sea level rise is also expected to change the landscape of coastal wetlands, resulting in wetland loss, spatiotemporal changes to coastal wetland distribution, and shifts in community composition resulting from disturbance, climate change effects, and elevated salinity (Burkett and Kusler 2000). Climate change impacts on biodiversity are discussed in Section 6.4. and are caused by a wide range of effects that modify habitats from historic baselines and reduce biodiversity (Aukema et al. 2017). Furthermore, warming effects may result in a disruption of carbon storage, by reducing storage rates or even reverting some wetlands from carbon sinks to carbon sources, particularly in boreal peatlands (Burkett and Kusler 2000).

Wetlands also provide functions that assist in the mediation of climate change impacts. Wetlands and wetland buffers, like riparian corridors, support a shaded and cool microclimate that provides refuge for wildlife from higher temperatures as well as wildlife corridors at a local or landscape scale (ASWM 2015). Additionally, wetlands help offset climate change through carbon storage by protecting the remineralization of organic stocks and sequestering greenhouse gas emissions (Gallagher et al. 2022). Carbon stocks in undisturbed wetlands are approximately twice as high as carbon storage in wetlands disturbed by human-driven land use changes (Nahlik and Fennessy 2016). However, it is uncertain whether this is a causal relationship or influenced by patterns of human settlement in avoiding the wettest sites which are challenging to develop. Bogs and peatlands are important carbon sinks that could release hundreds of years of stored carbon if disturbed (Nahlik and Fennessy 2016).

Although wetlands are dynamic by nature, the ability to adapt to change has limits. For instance, alterations in stormwater runoff conditions and changes to seasonal wetland hydrologic cycles can reduce the ability of wetland soil bacteria and plants to retain, process, and sequester pollutants (EPA 2015). Climate change is also impacting native plant species distribution, and the adaptative potential and climate tolerance for native plant species is the subject of current research(Vose et al. 2012).

5.4.1 Strategies to Manage Climate Change Impacts to Wetlands

- Continue to encourage and incentivize direct wetland impact avoidance to maintain existing carbon storage.
- Continue to regulate wetland buffers to encourage and require width retention/limitations and enhancement with native vegetation. Both voluntary and required restoration planting should be paired with monitoring and maintenance that allows for dry season irrigation and adaptive management.
- Continue to manage and regulate stormwater infrastructure to avoid and minimize discharges of untreated runoff to wetlands.
- Apply increased protections to bog wetlands and associated buffers to prevent stormwater impacts that could change pH and alter sensitive plant communities.
- Consider assisted migration for seed selection of native plants from locations that are better adapted to future climate conditions.

6. Fish and Wildlife Habitat Conservation Areas (FWHCAs)

6.1 Definitions

Washington State defines fish and wildlife conservation as "land management for maintaining populations of species in suitable habitats within their natural geographic distribution so that the habitat available is sufficient to support viable populations over the long term and isolated subpopulations are not created" (WAC 365-190-130). Fish and Wildlife Habitat Conservation Areas (FWHCAs) are lands designated for this conservation action and are defined under WAC 365-190.130.

Clallam county defines these areas as aquatic and wildlife areas in the following manner (CCC 27.12.310).

> **Aquatic Habitat Conservation Areas**
>
> *Includes those streams, lakes, marine waters and their associated wetlands and floodplains defined as shorelines of the State in the Shoreline Management Act of 1971 and the Clallam County Shoreline Master Program, which are also categorized as "shorelands" under Chapter 90.58 RCW, Shoreline Management Act, as now or hereafter amended, and those streams, lakes and wetlands which meet the criteria for Type 1 – 5 waters as defined herein.*
>
> *Streams include those areas where the surface water flow is sufficient to produce a defined channel or bed. A defined channel or bed is an area which demonstrates clear evidence of the passage of water and includes but is not limited to bedrock channels, gravel beds, sand and silt beds and defined-channel swales. The channel or bed need not contain water year-round. This does not include irrigation ditches, canals, storm or surface water runoff devices or other artificial watercourses unless they are used by salmon or used to convey streams naturally occurring prior to construction.*
>
> **Wildlife Habitat Conservation Area**
>
> *Class I Wildlife Habitat Conservation Area. Those lands including the following:*
>
> *(i) Habitats recognized by federal or State agencies for federal and/or State listed endangered, threatened, and sensitive species documented in maps or data bases available to Clallam County and its citizens and which, if altered, may reduce the likelihood that the species will maintain and reproduce over the long term. This includes known locations of nests, rookeries, or other breeding areas for species of concern recognized by local, state, and federal public agencies having jurisdiction over such species.*
>
> *(ii) Habitats targeted for preservation by federal, State and/or local government which provide fish and wildlife habitat benefits, such as important waterfowl areas identified by the U.S. Fish and Wildlife Service.*
>
> *(c) Class II Wildlife Habitat Conservation Area. Those lands including the following:*

(i) Priority habitats not classified as Class I for State listed candidate and monitor species documented in maps or data bases available to Clallam County and its citizens, and which, if altered, may reduce the likelihood that the species will maintain and reproduce over the long term.

(ii) Priority habitats not classified as Class I. These habitats may include wetlands, aquatic conservation areas, marine bluffs, stream ravines, caves, cliffs, islands, meadows, old-growth/mature forest, snag-rich areas, talus slopes, urban natural open space, and those land and water areas identified as significant habitat corridors under the Clallam County Comprehensive Plan, CCC Title 31.

6.2 Functions and Values

FWHCA functions include the biological, chemical, and physical processes occurring on lands and ecosystems that influence wildlife. Since wildlife may include all species from the largest megafauna to microorganisms, these functions encompass a complex web of interacting ecological processes. At the highest level, FWHCAs provide wildlife with the habitat requirements necessary to survive and persist. This section discusses functions of FWHCAs most relevant to wildlife and habitat management, with a focus on streams and riparian areas. Functions of certain habitat areas are also considered if relevant to a particular societal value other than wildlife.

FWHCA values the range of societal, economic, and ecological benefits provided by these lands and the wildlife which may inhabit them. These include *indirect values* that include non-consumptive uses such as recreation, tourism, scientific research, option values (valuing future opportunities), and intrinsic existence values (Chardonnet et al., 2002). They also include *direct values*, the consumptive and productive uses such as commercial harvest, hunting, timber, and firewood (Chardonnet et al., 2002). These values represent diverse public interests and attitudes toward wildlife issues which change over time (Teel & Manfredo, 2010).

6.2.1 Streams, Lakes and Ponds, and Riparian Areas

Streams, lakes, ponds, and their associated riparian areas provide critical habitat for a diversity of wildlife species and directly contribute to surface and subsurface hydrology as well as nutrient and energy exchange across the landscape. The following section describes the functions and values most prominent to stream, lakes, ponds, and riparian area ecosystems as well as land use activities including (1) land cover and impervious surfaces; (2) recruitment of large woody debris to aquatic areas; (3) shade, temperature, and microclimates; (4) stream migration and bank stability.

Human development is well documented to negatively impact aquatic ecosystems and is often evaluated using landscape scale metrics such as impervious surface, and other land cover measures. Impervious surface is positively correlated with high flow volumes, daily streamflow variability and negatively correlated with groundwater recharge rates and summer low flow volumes (Burges et al. 1998, Jones 2000, Konrad & Booth 2005, Cuo et al. 2009). Other types of development also result in hydrological changes including soil compaction, draining, and ditching across the landscape, and logging (Booth & Jackson 2002; Moore & Wondzell 2005). Together, these landscape modifications have been documented to reduce rates of infiltration, evapotranspiration, and groundwater storage (Sheldon et al. 2005). As a result, flows are less desynchronized and become more variable and volatile (Sheldon et al. 2005).

A study assessing changes in forest canopy, stream flows, and stream bank erosion, found that if forest retention is less than 40 percent within a watershed, unstable channels are expected to occur (Booth, Hartley, & Jackson, 2002). Increased erosion and bank instability coupled with a reduction of forest cover has been found to simplify stream morphology, leading to incised, wider, straighter stream channels (Konrad & Booth, 2005). This less dynamic stream morphology is linked to accelerated water transport and reduced temporary instream flood storage capacity (Kaufmann & Faustini, 2012). Positive correlations have been found between spawner abundance and forested areas; negative correlations were found between spawner abundance and areas converted to agriculture or urban development (Pess, et al., 2002).

RECRUITMENT OF LARGE WOODY DEBRIS TO AQUATIC AREAS

Large woody debris (LWD) plays a significant role in the geomorphic formation of streams channels by deflecting and redirecting stream flows, and influencing sediment storage, transport, and deposition rates (Quinn, T., Wilhere, & Krueger, 2020). These processes result in complex and diverse channel morphologies that include dam pools, plunge pools, riffles, glides, undercut banks, and side channels (Quinn, T., Wilhere, & Krueger, 2020). The creation of these features is also facilitated by variability in stream flow velocity which factors into scour, sediment deposition, and pool formation. Large wood actuates the downward scour necessary for streams to create pools, which provides protective cover for fish in those pools (Quinn, T., Wilhere, & Krueger, 2020).

These processes result in complex and spatially heterogeneous stream habitats which support diverse communities of aquatic species. LWD and associated habitat complexities provide conditions suitable for rearing, and refugia from predators. In one study, the density of juvenile salmonids was found to be substantially higher in streams in which LWD was experimentally introduced (Roni & Quinn, 2001). Similarly, Fausch and Northcote (1992) found that streams containing large amounts of LWD supported populations of juvenile cutthroat trout and coho salmon five times greater than streams within the same river system that had been cleared of LWD.

The aggregation of LWD and associated entrapment of smaller branches, limbs, leaves, and other material reduce flow conveyance in small streams and increase temporary flood storage (Dudley, S.J., Fischenich, & Abt, 1998). By retaining smaller organic debris, LWD provides substrate for microbes and algae, and prey resources for macroinvertebrates (Bolton, A. & Shellberg, 2001). The overall influence of LWD on biological processes is greater in smaller streams than larger ones (Harmon, M.E., et al., 1986). This is similar to the relationship with riparian areas, in which allochthonous inputs compose a greater proportion of small stream volume than large streams and are more influential on biological processes (Vannote et.al., 1980). In small channels, LWD provides a structural component in the stream that controls rather than responds to hydrologic and sediment transport processes (Gurnell, A.M., Piegay, Swanson, & Gregory, 2002). It follows that large wood is responsible for significant sediment storage in small channels, thereby increasing channel stability (May & Gresswell, 2003; Nakamura & Swanson, 1993; Quinn, T., Wilhere, & Krueger, 2020). In a study where wood was experimentally removed from streams, Bilby (1981) found increased sediment mobilization and reduced storage. LWD that partially blocks flow may also encourage hyporheic flow through the streambed substrate (Poole & Berman, 2001; Wondzell, S.M. & Lanier, 2009).

Large wood recruitment are typically introduced to streams as a result of bank erosion, windthrow, landslides, debris flows, snow avalanches, and tree mortality due to fire, ice storms, insects, and disease (Swanson, F.J., Lienkaemper, & Sedell, 1976; Maser, Cline, Cromack Jr., Trappe, & Hansen, 1988). Large woody debris can enter channels through individual trees falling into the stream, as well as through larger disturbances (Bragg, 2000). In a comparison of 51 streams with varying channel characteristics in mature forests of British Columbia, a study found that tree mortality was the most common entry mechanism of LWD where the source could be identified (Johnston et.al, 2011). Streambank erosion and associated channel migration is also a common method of wood recruitment in large alluvial channels (Murphy & Koski, 1989), whereas in LWD recruitment in smaller, steeper channels occurs primarily through slope instability and windthrow (May and Gresswell 2003).

The probability of a tree entering the channel decreases with distance from the streambank (McDade, Swanson, McKee, Franklin, & Van Sickle, 1990; Grizzel, McGowan, Smith, & Beechie, 2000). Past research has found that most LWD originates within approximately 30 m (98 ft) of a watercourse (Murphy & Koski, 1989; McDade et.al., 1990; Van Sickle & Gregory, 1990). In 90 percent of the 51 streams surveyed in British Columbia, 90 percent of the LWD at a site originated within 18 m (59 ft) of the channel (Johnston et.al., 2011). May and Gresswell (2003) found that wood was recruited from distances farther from the stream channel in small, steep channels (80% from 50 m (164 ft) from the channel), compared to broad alluvial channels (80 percent from 30 m (98 ft) from the channel) because of the significance of hillslope recruitment in narrow valleys.

The likelihood of downstream transport of LWD is dependent on the length of wood relative to bankfull width of the stream (Lienkaemper & Swanson, 1986). Wood that is shorter than the average bankfull width is transported more readily downstream compared to wood that is longer than the bankfull width (Lienkaemper & Swanson, 1986). Therefore, large wood is rarely transported downstream from small channels less than 5 m (16 ft) in width (May & Gresswell, 2003).

Beaver dams incorporate both small and large wood, and serve to slow water, retain sediment, and create pools and off-channel ponds used by rearing coho salmon and cutthroat trout (Naiman et al. 1988, Pollock et al. 2004). The removal of these structures throughout history has been linked to a significant reduction in coho salmon summer and winter rearing habitat in the nearby Stillaguamish River (Pollock et al. 2004). In Washington House Bill 2349, the Washington legislature states that "*beavers have historically played a significant role in maintaining the health of watersheds in the Pacific Northwest and act as key agents in riparian ecology.*" They continue with "*The benefits of active beaver populations include reduced stream sedimentation, stream temperature moderation, higher dissolved* *oxygen levels, overall improved water quality, increased natural water storage capabilities within watersheds, and reduced stream velocities. These benefits improve and create habitat for many other species, including endangered salmon, river otters, sandhill cranes, trumpeter swans, and other riparian and aquatic species."* These statements indicate the policy support of beaver conservation, are consistent with scientific evidence, and recognize that beavers play an important role in stream ecosystems. Relocations and introductions to stream ecosystems can be beneficial wildlife management practices. Conditions for wild beaver release are provided in RCW 77.32.585. Related to this legislation, WDFW has instigated a beaver relocation program.

SHADE, TEMPERATURE, AND MICROCLIMATE

Riparian vegetation influences stream temperatures and microclimate conditions such as air temperature, wind, light, and moisture. Factors affecting water temperature and microclimate include shade, orientation, relative humidity, ambient air temperature, wind, channel dimensions, groundwater, hyporheic exchange rates, and overhead cover (Quinn et al. 2020).

Salmon and other native freshwater fish require cool waters for migrating, rearing, spawning, incubation, and emergence, with summer maximum temperature recommendations ranging from 55-68°F (EPA 2003). Thermal tolerances differ by species; salmonids have been studied frequently due to their cultural and economic importances, relative sensitivity to high temperatures, and narrow thermal tolerance (Quinn et al. 2020). Amphibians also have narrow thermal tolerances, and they are particularly sensitive to changes in microclimate conditions (Bury 2008). Several studies have documented significant increases in maximum stream temperatures associated with the removal of riparian vegetation (Beschta et al. 1987; Murray et al. 2000, Moore et al. 2005, Gomi et al. 2006). Considering the correlation between riparian vegetation and stream temperature, loss of vegetation presents a risk to the affected fish species. The importance of riparian vegetation in maintaining viable stream temperatures is clear in the literature (Quinn et al. 2020).

A number of studies have considered the extent to which various riparian zone widths modulate stream temperature. In headwater streams in British Columbia, 10 m (33 ft) riparian zones generally minimized effects to stream temperature from timber harvest, although maximum daily temperatures reached 3.6°F higher than control streams (Gomi, Moore, & Dhakal, 2006). A comparative study of 40 small streams in the Olympic Peninsula found that mean daily maximum temperatures were 2.4°C higher in logged compared to unlogged watersheds, and that logged watersheds had greater diurnal fluctuations in water temperatures (Pollock et.al., 2004). Another study of streams in Washington found that stream temperatures were most closely correlated with vegetation parameters associated with the riparian area, such as total leaf area and tree height, and that the effect of buffer width was less significant, particularly for buffers larger than 30 m (98 ft) (Sridhar et.al., 2007). These findings are consistent with an earlier study relating angular canopy density, a proxy for shading, to riparian buffer width; which found that the correlation between shade and riparian buffer width increases up to around 30 m (98 ft) (Beschta, 1987). Therefore, for buffers less than 30 m (98 ft), buffer width is expected to be more closely related to shading and stream temperatures than buffers over 30 m (98 ft).

Riparian microclimate affects many ecological processes and functions, including plant growth, decomposition, nutrient cycling, succession, productivity, migration and dispersal of flying insects, soil microbe activity, and fish and amphibian habitat (Brosofske et.al., 1997). Riparian buffers necessary to maintain forest microclimate are controlled by edge effects, which tend to extend well into forested areas adjacent to clearings. However, riparian buffers ranging from 10-45 meters in width may minimize microclimate effects related to light, soil, and air temperatures. A study of small streams in Western Washington indicated that buffers greater than 45 m (147 ft) wide are generally sufficient to protect riparian microclimate in streams (Brosofske et.al, 1997).

STREAM MIGRATION AND BANK STABILITY

Streams migrate naturally which often results in complex natural geomorphology, floodplains, and heterogeneous ecosystems. One consequence is the erosive power of streams which threaten human infrastructure. Bank stability is influenced by factors such as bank material, hydraulic forces, and vegetation (Ott, 2000). Riparian vegetation improves bank stabilization through root networks which encapsulate and anchor soil particles and rocks, thereby reducing soil movement. Vegetation also reduces the quantity of surface water runoff through rainwater capture and evapotranspiration. The effectiveness of bank stabilization is also dependent on the type of vegetation present. For example, woody vegetation tends to provide greater bank stability than herbaceous vegetation because woody vegetation has larger and firmer roots that extend deeper into the streambank (Wynn & Mostaghimi, 2007).

Bank stability is lower in urban watersheds because factors such as vegetation composition and hydraulic forces are degraded. The width of vegetated riparian buffers improves bank stability up to approximately 80 to 100 feet, after which diminishing returns limit marginal benefits (Castelle, Johnson, & Conolly, 1994)

Riparian Influence on Water Quality

Water quality is characterized by several physical, chemical, and biological factors, including temperature, suspended sediment, nutrients, metals, pathogens, and other pollutants. These water quality parameters are influenced by riparian areas, and other terrestrial environments which control shade and runoff.

Conversion of natural environments to developed sites often results in a reduction of infiltration and an increase in surface flows, resulting in sediment and contaminants to be transported more directly to receiving bodies, bypassing natural soil filtration and flow attenuation processes. Consequentially, urban areas tend to contribute a disproportionate amount of sediment and contaminants to receiving waters (Sorrano et al. 1996). Heavy metals, bacterial pathogens, as well as PCBs, hydrocarbons, and endocrine-disrupting chemicals are aquatic contaminants that are commonly associated with urban and agricultural land uses.

The full suite of sublethal and indirect effects of urban contaminants and combinations of contaminants on aquatic organisms is under study. Likely some contaminants with potentially severe repercussions for fish and wildlife have yet to be identified. For example, research in the Puget Sound region had identified mature coho salmon that return to urban creeks and die before spawning, a condition called pre-spawn mortality (Feist et al. 2011, Sholz et al. 2011). After a prolonged investigation, the specific cause of the condition has been recently attributed to 6PPD-quinone, a breakdown product of tire wear (Tian et al., 2020). Coho pre-spawn mortality is also positively correlated with the relative proportion of roads, impervious surfaces, and commercial land cover within a basin (Feist et al. 2011

Sediment

Sediment input to streams is supplied by bed and bank erosion, landslides, and upland erosion processes. These processes occur naturally but are acutely associated with and accelerated by forest practices and development activities. Other contaminants, including heavy metals and phosphorus, readily bond to suspended clay particles, and these contaminants are often transported with fine sediment in stormwater.

Excess inputs of fine sediments (e.g., silt and clay particles) into stream channels reduce habitat quality for certain species of fish, amphibians, and macroinvertebrates. Fine sediment adversely affects stream habitat by filling pools, embedding gravels, reducing gravel permeability, and increasing turbidity. In salmon-bearing streams, fine sediment fills interstitial spaces in redds, reducing the flow of oxygenated water to developing embryos and reducing egg-to-fry survival (Jensen et al. 2009). For example, highly turbid water can impair fertilization success in spawning salmonids and interfere with the respiration and reproduction of amphibians (Galbraith et al. 2006; Knutson et al. 2004). Fine sediments that settle out of the water column can smother gravel and cobble streambeds that are essential habitat for salmonid spawning and for benthic macroinvertebrates.

Excessive sediment loads can significantly degrade water quality. Additionally, sediments tend to serve as a transport mechanism for other pollutants, carrying attached contaminants from upland sources to the stream channel. Suspended sediment can also cause gill abrasion in fish and interfere with foraging and predator avoidance (Quinn et al. 2020).

Vegetated riparian zones help stabilize stream banks by slowing and filtering overland flow and temporarily storing sediment that is gradually released to both seasonal and perennial streams. Sediment filtration is also high within intermittent and ephemeral streams, presumably because of the high interface with vegetative structures and the flux in water surface elevation, which allows for sediment storage along the streambanks (Dietrich and Anderson 1998).

Upland clearing and grading can result in long-term increases in fine sediment inputs to streams (Gomi et al. 2005, Jackson et al. 2007). Numerous studies have investigated the effectiveness of varying widths of buffers at filtering sediment. These studies have typically found high sediment filtration rates in relatively narrow buffer areas without a significant improvement in sediment retention beyond 15 meters (Abu-Zreigh et al. 2004; Parkyn 2004; Sheridan et al. 1999; Wenger 1999; Yuan et al. 2009).

However, field plot experiments tend to have much shorter field lengths (e.g., hillslope length contributing to drainage) than would be encountered in real-world scenarios (i.e., ~5:1 ratio of field length to riparian width for a field plot compared to 70:1 ratio in NRCS guidelines). Since water velocities tend to increase with field length, field plot experiments may suggest better filtration than would be encountered under real-world conditions. Additionally, field-scale experiments generally do not account for flow convergence, which reduces sediment retention or for stormwater components that bypass filter strips through ditches, stormwater infrastructure, and roads (Helmers et al. 2005; Verstraeten et al. 2006). Therefore, the effectiveness of filter strips at filtering sediment under real world conditions and at the catchment scale is likely to be lower than what is reported in field plot experiments.

Additionally, studies on sediment retention in riparian zones are often based on a single storm event, rather than accounting for sediment accumulation over time. Two of the reviewed studies used Cesium-137 to track the location of sediment deposition over many years (Wenger 1999). The findings of these studies suggest that riparian zones from 30-100 m (98-328 ft) or more may be necessary to provide long-term sediment retention and that studies of short-term sediment retention underestimate the riparian zone width needed for ongoing sediment filtration (Wenger 1999).

In addition to riparian zone width, the slope, vegetation density, and sediment composition of a riparian area have a significant bearing on sediment filtration potential (Jin and Romkens 2001). A recent model of sediment retention in riparian zones found that a grass riparian zone as small as 4 m (13 ft) could trap up to 100% of sediment under specific conditions (i.e., 2% hillslope over fine sandy loam soil), whereas a 30 m (98 ft) grass riparian zone would retain less than 30% of sediment over silty clay loam soil on a 10% hillslope (Dosskey et al. 2008) (Figure 4). This study demonstrates the effects that soil type and hillslope have on sediment retention.

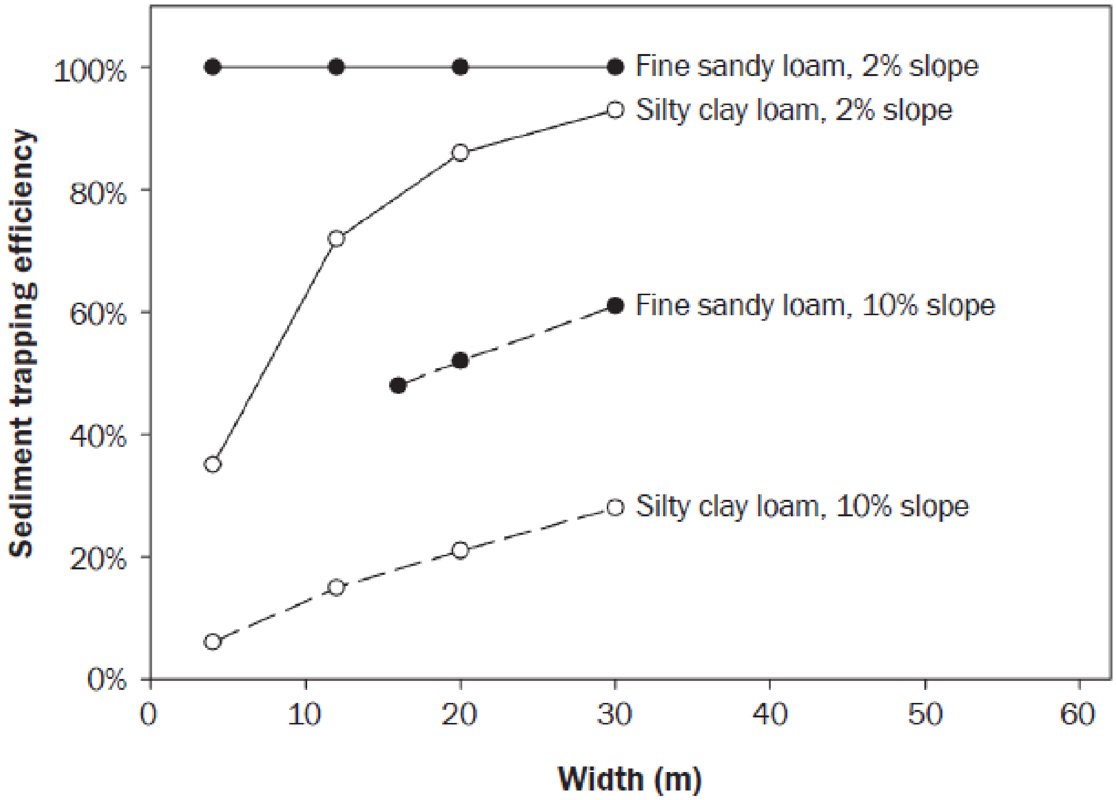

Figure 4. Sediment trapping efficiency related to soil type, slope, and buffer width. From Dosskey et al. (2008).

Multiple studies have found that larger particles tend to settle out within the first 3-6 m (10-20 ft) of the riparian zone, but finer particles that tend to degrade instream habitat, such as silt and clay, need a larger riparian zone, ranging from 15-120 m (49-394 ft), for significant retention (Parkyn, 2004).

Vegetative composition within the buffer also affects sediment retention. Vegetation tends to become more effective at sediment and nutrient filtration several years after establishment for both grass and forested buffers (Dosskey et al. 2007). Thin-stemmed grasses may become overwhelmed by overland flow while dense, rigid-stemmed vegetation provides improved sediment filtration that is expected to continue to function better over successive storm events (Yuan et al., 2009).

Nutrients

Established vegetation in a dense composition can provide effective sediment and nutrient filtration (Dosskey et al. 2007). Riparian zones can also reduce nitrogen pollution through nutrient uptake, assimilation by vegetation, and denitrification (Sobota et al. 2012). In excess concentrations, nitrogen and phosphorus can lead to poor water quality conditions, including reduced dissolved oxygen rates, increased pH, and eutrophication (Mayer et al. 2005, Mayer et al. 2007). Excessive amounts of nitrogen and phosphorus speed up eutrophication and algal blooms in receiving waters, which can deplete the dissolved oxygen in the water and result in poor water quality and fish kills (Mayer et al. 2005).

Riparian zones can reduce nitrogen pollution through nutrient uptake, assimilation by vegetation, and through denitrification (Sobota et al. 2012). The rate of nitrogen removal from runoff varies considerably depending on local conditions, including soil composition, surface versus subsurface flow, riparian zone width, riparian composition, and climate factors (Mayer et al. 2005, Bernal et al. 2007, Mayer et al. 2007). Nutrient assimilation is also dependent on the location of vegetation relative to the nitrogen source, the flowpath of surface runoff, and position in the landscape (Baker et al. 2006).

Nutrients enter waterways through channelized runoff, groundwater flow, and overland flow. Nitrogen loading is often associated with agricultural activities, whereas low density residential development has been found to result in nitrate levels comparable to a forested basin (Poor and McDonnell 2007).

Mayer et al. (2005, 2007) found that there was little relationship between riparian zone width and removal of *subsurface* nitrates. Subsurface nitrates were removed effectively regardless of riparian zone width. Conversely, nitrate removal from *surface* runoff *is* related to riparian zone width, and 50%, 75%, and 90% of surface nitrate removal was measured at widths of 27 m (88 ft), 81 m (266 ft), and 131 m (430 ft) respectively (Mayer et al. 2007). This suggests that surface water infiltration in the riparian zone should be a priority to promote effective nutrient filtration. Where soils are poorly drained and infiltration capacity is limited, the effectiveness of nutrient removal in riparian buffers may also be limited (Wigington et al 2003).

The size and species composition of the riparian zone buffer also affects the efficiency of nutrient removal, but studies are conflicting as to whether grass, wetland, herbaceous, or forested buffers are most effective at removing nutrients (Polykov 2005). Where nitrogen-fixing species predominate, such as red alder, these buffers tend to have higher soil nitrate concentrations (Monohan 2004).

Removal of phosphorus in surface runoff by riparian buffers is dependent on the form of phosphorus entering the buffer. Whereas phosphorus that is adsorbed by soil particles is effectively removed through sediment retention within a buffer, the retention of soluble phosphorus relies on infiltration and uptake by plants (Polyakov et al. 2005). One long-term study found that phosphorus uptake was directly proportional to the plant biomass production and root area over the four-year study period (Kelly et al. 2007). If a riparian buffer becomes saturated with phosphorus, its capacity for soluble phosphorus removal will be more limited (Polyakov et al. 2005). Another long-term study found that following a 15-year establishment period, a 40-meter (131 ft) wide, three-zoned buffer reduced particulate phosphorus by 22 percent, but dissolved phosphorus exiting the buffer was 26 percent higher than the water entering the buffer, so the buffer resulted in no net effect on phosphorus (Newbold et al. 2010).

In summary, most riparian zones reduce subsurface nutrient loading, but extensive distances are needed to reduce nutrients in surface runoff. Filtration capacity decreases with increasing loads (Mayer et al. 2005), so best management practices across the landscape that reduce nutrient loading will reduce the amount of nutrients which enter streams and other surface waters.

Metals

Although most metals can be toxic at high concentrations, cadmium, mercury, copper, zinc, and lead are particularly toxic even at low concentrations. Chronic and acute exposure to heavy metals have been found to impair, injure, and kill aquatic plants, invertebrates, fish, and particularly salmonids (Grant and Ross 2002, Dethier 2006, Hecht et al. 2007, McIntyre et al. 2008, McIntyre et al. 2012). The toxicity of metals is influenced by a variety of factors including (Duffus et al 2002; Nagajyoti et al. 2010; Tchounwou et al. 2012; Wang & Rainbow 2008):

- Properties of the metal
- Duration, frequency, and concentration of exposure
- The form and bioavilability of the metal at the time of exposure
- Environmental conditions including water chemistry and physical properties such as pH, temparature, and salinity
- Synergistic, additive, or antagonistic interactions of co-occurring contaminants
- Species sensitivity
- Life stage
- Physiological ability to detoxify and/or excrete the metal and,
- The condition of the exposed organism.

Metals are typically transported to the aquatic environment through fossil fuel combustion, industrial emissions, municipal wastewater discharge, and surface runoff (ESV Environment Consultants 2003). In general, heavy metals and hydrocarbons (e.g., leaked motor oil, polycyclic aromatic hydrocarbons) are found in road runoff, and these contaminants can reach the County's streams directly through existing stormwater systems. Stormwater systems that circumvent buffers limit the opportunity to filter runoff through adjoining soils and vegetation. Accordingly, stream buffers are typically underutilized for treatment of metals, hydrocarbons, and other pollutants found in typical stormwater runoff.

Copper brake pad dust has also been linked to chronically depressed Chinook salmon populations (U.S. EPA 2007). The U.S. EPA is working to reduce the use of copper and other heavy metals in motor vehicle brake pads through the *Copper-Free Brake Initiative* (U.S. EPA 2015a).

Pathogens

Waterborne pathogens associated with human and animal wastes are a concern for direct and indirect human exposure. Fecal coliform bacteria, specifically E. coli, is typically used as an indicator of the possible or presumed presence of a suite of bacterial and viral pathogens. Fecal pollution tends to be positively correlated with human population densities and impervious surface coverage (Glasoe and Christy 2004). The main sources of fecal pollutants include municipal sewage systems, on-site sewage systems, stormwater runoff, marinas and boaters, farm animals, pets, and wildlife (Glasoe and Christy 2004). As municipal wastewater systems have improved treatment quality and capacity in recent years, increasingly, non-point source pollution, including septic systems, stormwater, wildlife, and pets, is responsible for fecal contaminants in surface water (Glasoe and Christy 2004).

Herbicides and Pesticides

Commonly used herbicides, pesticides, and other pollutants may also affect aquatic communities, and the acute and chronic effects of these chemicals or combinations of chemicals are not always well understood. Additionally, effects documented in the laboratory may differ significantly from effects identified in a field setting (Relyea 2005, Thompson et al. 2004). The effects of these chemicals may be long-lasting, as has been observed for legacy pollutants such as polychlorinated biphenyls (PCBs) and polycyclic aromatic hydrocarbons (PAHs) in salmon, seabirds, and marine mammals in Puget Sound (Calambokidis et al. 1984, Ross et al. 2000, Wahl and Tweit 2000, Grant and Ross 2002, O'Neill et al. 2009).

Herbicides and pesticides may reach aquatic systems through a number of pathways, including surface runoff, erosion, subsurface drains, groundwater leaching, and spray drift. Narrow hedgerows have been found to limit 82-97 percent of the aerial drift of pesticides adjacent to a stream (Lazzaro et al. 2008). In runoff, herbicide retention in a buffer is dependent on the percentage of runoff that infiltrates the soil (Misra et al. 1996). A study of herbicides in simulated runoff found that 6-meter-wide vegetated buffers were sufficient to remove 100% of the tested herbicides (Otto et al. 2008). A meta-analysis found that filtration effectiveness increased logarithmically from 0.5 m to an asymptote at approximately 18 m (Zhang et al. 2010). In summary, relatively narrow vegetated buffers may be effective in limiting herbicides and pesticides from reaching aquatic habitats in surface runoff, erosion, and spray drift; however, these processes are best managed using best management practices in herbicide and pesticide applications to avoid contaminating groundwater (Reichenberger et al. 2007).

Pharmaceuticals

Pharmaceuticals are another class of contaminants which have been demonstrated to have negative impacts on the health of humans and aquatic organisms. There are a wide range of pharmaceutical compounds and toxicological research is variable, with many that are poorly understood. Many commonly used pharmaceuticals are found in wastewater, particularly around more urban areas (Long et al. 2013). Many common pharmaceuticals have endocrine-disrupting properties, which can affect fertility and development in non-target aquatic species (Caliman and Gavrilescu 2009). The existing and potential population-scale effects of these chemicals in the environment are not yet well-understood (Mills and Chichester 2005, Caliman and Gavrilescu 2009).

FISH AND WILDLIFE HABITAT

The primary function of FWHCAs is the role they provide as habitat for fish and wildlife. All the functions and processes listed above relate to habitat, and this section provides additional information on ecosystems, communities, and wildlife species. Habitat is the physical place an organism occupies at any stage of its life history for a particular species. Since species have evolved and adapted to the environmental conditions within their historic range, such baseline conditions can be used to determine types of suitable habitat. Associated habitat selection research is also conducted to refine the types of habitat preferred by a species at multiple spatial scales. The historic range of variability (HRV) is a useful metric of baseline conditions because environments change over time, particularly in response to disturbances processes and temporal shifts (Morgan et al. 1994).

The emergence of urbanization and other human development has had a profound effect on wildlife and their ecosystems, altering behavior, population dynamics and demographics, community composition, and may result in extirpations or extinctions of entire species (Gaston 2010). These impacts are largely driven by habitat loss, degradation, and fragmentation; processes that constrict habitats into smaller and smaller patches until a species can no longer persist (Wiegand et al. 2005; Young et al. 2016). The effects of urbanization on wildlife are also exacerbated by direct harvest, invasive species, pollution, and climate change which contribute to defaunation on a global scale (Young et al. 2016). Habitat loss and fragmentation are significant drivers in biodiversity loss. As described by MacArthur and Wilson (1967), the species area relationship posits that biodiversity is lower in smaller habitat patches. As land is developed, continuous tracts of native habitat are reduced to patches, which become progressively smaller and more isolated. This is compounded by fragmentation by roads, fences, buildings, and other infrastructures which restricts interpatch movements and migrations (Wiegand et al. 2005). Ecological impacts of development are often overlooked and landscape-scale changes, particularly habitat fragmentation, alter the structure and function of those ecosystems (Dale et al. 2000).

Clallam County contains ecosystems which range from alpine mountain peaks to marine waters of the Pacific Ocean and Strait of Juan de Fuca. Most of the land in Clallam County was historically forestlands at low to middle elevations, and alpine shrublands, grasslands, and parklands in the higher peaks of the Olympic Mountains (Johnson & O'Neil 2001). Marine environments, aquatic areas, and wetlands are also abundant within Clallam County (Johnson & O'Neil 2001). Each ecosystem is host to a variety of wildlife species, and the range and ecological niche of individual species may overlap several ecosystem types.

Habitat features at a local scale or micro scale are also important to patterns of habitat use by wildlife. For example, woodpeckers rely on decadent wood for foraging and nesting, and marbled murrelets require specific types of nesting platforms. Since there are innumerable wildlife species, each with specific habitat requirements, protection of habitat elements common to a wide range of taxa is critical for ecosystem function.

Habitat composition at the local level is influential at predicting species richness and abundance. The diversity of physical and biological habitat elements in a particular area, also known as heterogeneity, is associated with species richness due to offering greater overlap in niche requirements (Callaghan et al. 2019; Parker et al. 2014). Heterogeneity can be evaluated through multiple spatial scales, and through a range of potential environmental metrics such as species richness, plant community composition, community interspersion, physical and vegetation structure, amount of edge, etc. Other local scale factors associated with species richness include patch area, habitat richness, level of management, herb, shrub, and tree density, cover, and structure, vegetation species richness, microclimate, bare soils, and edge effects (Beninde et al. 2015).

Certain habitat types, or microhabitats have been identified by WDFW as priority habitats which are present in Clallam County. In addition to aquatic and riparian habitats discussed previously, these include biodiversity areas and corridors, herbaceous balds, old-growth/mature forests, Oregon white oak woodlands, westside prairie, caves, cliffs, talus, and snags and logs. These specific habitats are recognized for either their role as biodiversity hotspots, or because they are habitat elements critical for individual species, or groups of species.

Aquatic ecosystems, including streams, lakes, and wetlands provide habitat for a broad range of fauna including invertebrates, reptiles and amphibians, anadromous and resident fish, birds, and mammals. For example, wetlands with surface connections to salmon-bearing streams provide backwater refuge for anadromous fish when ponded water at least 18 inches deep, low flow conditions are present, and overhanging or submerged plants provide adequate cover (Sheldon et al. 2005). Aquatic invertebrates that depend on stream and wetland ecosystems are important to aquatic trophic systems or food webs (Rosenberg & Danks 1987; Sheldon et al. 2005; Wissinger 1999). Native frogs and salamanders require wetlands for breeding. Buffer conditions, habitat interspersion, wetland hydroperiod, and emergent plants are all important factors that impact amphibian richness and abundance (Sheldon et al. 2005). Waterfowl rely upon riparian ecosystems for all or part of their life cycle (Kauffman et al. 2001; Sheldon 2005). The suitability of habitat for birds is dependent on buffer condition and width, the presence of snags or other perches, corridor connections, open water, and forest canopy cover (Sheldon et al. 2005). Water-associated mammals such as beaver and muskrat also seek out well-buffered vegetated corridors, interspersed habitats with open water, and a seasonally stable water level (Sheldon et al. 2005). According to a Washington Department of Fish and Wildlife (WDFW) management recommendation plan conducted by Knutson and Naef (1997) a predominance of terrestrial vertebrate species in Washington are dependent on streams and riparian areas, including wetlands. Semlitsch and Bodie (2003) found that upland areas surrounding wetlands are core habitats for many semi-aquatic species, such as amphibians and reptiles.

Ecological resources of these aquatic areas support high levels of species diversity and abundance since they are generally structurally complex, maintain connectivity to other ecosystems, have plentiful sources of food and water, and a moist moderate microclimate (Knutson and Naef 1997). Riparian and wetland ecosystems also support a diverse range of native plant species. Wetland characteristics that are correlated with plant richness are the hydroperiod, duration of flooding, and variation in water depths (Schueler 2000; Sheldon et al. 2005).

The performance of stream and wetland habitat functions is affected to varying degrees by the width and composition of the surrounding buffers. Disturbance vectors include but are not limited to habitat loss, habitat modification, noise, light, physical intrusion by equipment, people, pets, air and water pollution, and garbage. Each of these can result in one or more of the following: disruption of essential wildlife activities, damage to native vegetation and invasion of non-native species, erosion, or fill, among others.

Cumulative impacts of direct and indirect riparian ecosystem alterations, including hydrologic changes, compromised water quality, and habitat fragmentation tend to reduce the habitat functions and values of wetlands and riparian areas (Azous & Horner 2010; Sheldon et al. 2005).

6.2.2 State & Federal designated Endangered, Threatened, or Sensitive Species

WDFW lists priority habitats and species (PHS) by county. Table 1 includes a summary of the Clallam County PHS list. As WDFW notes, habitats and species can change over time as distributions expand or contract. Clallam County includes habitat types that are known to be used or could potentially be used by bird and mammal species of interest, including those species with state or federal status and WDFW priority species.

Table 1. Clallam County priority species list (source: WDFW).

	Species/ Habitats	State Status	Federal Status
Habitats	Biodiversity Areas & Corridors		
	Herbaceous Balds		
	Old-Growth/Mature Forest		
	Oregon White Oak Woodlands		
	West Side Prairie		
	Riparian		
	Freshwater Wetlands & Fresh Deepwater		
	Instream		
	Open Coast Nearshore		
	Coastal Nearshore		
	Puget Sound Nearshore		
	Caves		
	Cliffs		
	Snags and Logs		
	Talus		
Fishes	Pacific Lamprey		
	River Lamprey	Candidate	
	Green Sturgeon		Threatened
	White Sturgeon		
	Olympic Mudminnow	Sensitive	
	Pacific Herring		
	Eulachon		Threatened
	Longfin Smelt		
	Surfsmelt		
	Bull Trout/ Dolly Varden	Candidate	Threatened
	Chinook Salmon		Threatened (Upper Columbia Spring run

	Species/ Habitats	State Status	Federal Status
	is Endangered)"		
	Chum Salmon		Threatened
	Coastal Res./ Searun Cutthroat		
	Coho Salmon		Threatened – Lower Columbia
	Kokanee		
	Pink Salmon		
	Pygmy Whitefish	Sensitive	
	Rainbow Trout/ Steelhead/ Inland Redband Trout	Candidate	Threatened
	Sockeye Salmon		Threatened – Ozette Lake
	Endangered – Snake River"		
	Pacific Cod		
	Pacific Hake		
	Walleye Pollock		
	Black Rockfish		
	Bocaccio Rockfish		Endangered
	Brown Rockfish		
	Canary Rockfish		Threatened
	China Rockfish		
	Copper Rockfish		
	Greenstriped Rockfish		
	Quillback Rockfish		
	Redstripe Rockfish		
	Tiger Rockfish		
	Widow Rockfish		
	Yelloweye Rockfish		Threatened
	Yellowtail Rockfish		
	Lingcod		
	Pacific Sand Lance		
	English Sole		
	Rock Sole		
Reptiles	Northwestern Pond Turtle	Endangered	
Amphibians	Van Dyke's Salamander	Candidate	
	Western Toad	Candidate	
Birds	Brown Pelican		
	Cassin's Auklet	Candidate	
	Common Loon	Sensitive	
	Marbled Murrelet	Endangered	Threatened
	Short-tailed Albatross	Candidate	Endangered
	Tufted Puffin	Endangered	
	Western grebe	Candidate	

	Species/ Habitats	State Status	Federal Status
	W WA nonbreeding concentrations of: Loons, Grebes, Cormorants, Fulmar, Shearwaters, Storm-petrels, Alcids		
	W WA breeding concentrations of: Cormorants, Storm-petrels, Terns, Alcids		
	Great Blue Heron		
	Western High Arctic Brant		
	Cavity-nesting ducks: Wood Duck, Barrow's Goldeneye, Common Goldeneye, Bufflehead, Hooded Merganser		
	Harlequin Duck		
	Waterfowl Concentrations		
	Golden Eagle	Candidate	
	Northern Goshawk	Candidate	
	Sooty Grouse		
	W WA nonbreeding concentrations of: Charadriidae, Scolopacidae, Phalaropodidae		
	Band-tailed Pigeon		
	Northern Spotted Owl	Endangered	Threatened
	Vaux's Swift		
	Oregon Vesper Sparrow	Endangered	
Mammals	Dall's Porpoise		
	Blue Whale	Endangered	Endangered
	Humpback Whale	Endangered	Endangered
	Gray Whale	Sensitive	Endangered
	Sperm Whale	Endangered	Endangered
	Harbor Seal		
	Orca (Killer Whale)	Endangered	Endangered
	Harbor Porpoise	Candidate	
	Northern Sea Otter	Threatened	
	California Sea Lion		
	Steller Sea Lion		
	Roosting Concentrations of: Big-brown Bat, Myotis bats, Pallid Bat		
	Townsend's Big-eared Bat	Candidate	
	Keen's Myotis	Candidate	
	Olympic Marmot	Candidate	
	Fisher	Endangered	
	Marten		
	Columbian Black-tailed Deer		
	Mountain Goat		
	Elk		
Invertebrates	Pinto (Northern) Abalone	Endangered	
	Pacific Geoduck		

	Species/ Habitats	State Status	Federal Status
	Butter Clam		
	Native Littleneck Clam		
	Manila (Japanese) Littleneck Clam		
	Olympia Oyster	Candidate	
	Pacific Oyster		
	Pacific Razor Clam		
	Dungeness Crab		
	Pandalid shrimp (Pandalidae)		
	Beller's Ground Beetle	Candidate	
	Hatch's Click Beetle	Candidate	
	Western Bumble Bee	Candidate	Candidate
	Johnson's Hairstreak	Candidate	
	Makah Copper	Candidate	
	Puget Blue	Candidate	
	Sand-verbena Moth	Candidate	
	Valley Silverspot	Candidate	
	Taylor's Checkerspot	Endangered	Endangered
	Red Sea Urchin		

6.3 Key Protection Strategies

6.3.1 Streams, Lakes[13] and Ponds, and Riparian Areas

STREAM CLASSIFICATION

Aquatic areas are classified so that they can be managed and regulated based on their characteristics, fish use, and functions. Characteristics common to water typing systems are flow volume, fish use and accessibility, seasonality, and presence of salmonids. The DNR is encouraging all jurisdictions within the State to adopt the permanent water typing system upon completion of fish habitat water type mapping. The permanent system provides four stream classes, Type S (Waters of the State), Type F (fish habitat present), Type Np (non-fish habitat stream with perennial flow), and Ns (non-fish habitat stream with seasonal flow). The water typing system is detailed in WAC 222-16-030.

[13] Lakes that exceed 20-acres are regulated separately under the Shoreline Master Program, therefore discussed BAS is focused on lakes smaller than this threshold.

RIPARIAN MANAGEMENT ZONES

In 2020, the Washington Department of Fish and Wildlife developed BAS guidance for the protection of riparian areas (Rentz et al. 2020). The guidance emphasizes a shift in terminology and framework from the concept of "*stream buffers*" to "*riparian management zones*" (RMZs). A RMZ is defined as "…*a scientifically based description of the area adjacent to rivers and streams that has the potential to provide full function based on the SPTH [site potential tree height] conceptual framework*." Further, a RMZ is recommended to be regulated as a fish and wildlife habitat conservation area itself to protect its fundamental value, rather than as a buffer for rivers and streams (Rentz et al. 2020). Stream buffers are established in local critical areas ordinances based on best available science and are intended to protect streams but may or may not provide full riparian function or a close approximation of it. To achieve full riparian function, the guidance recommends that RMZs be considered a delineable, regulatory critical area and that the guidance be applied to all streams and rivers, regardless of size and type.

Washington Department of Fish and Wildlife's current recommendations for establishing RMZ widths are based primarily on a site potential tree height (SPTH) framework. The SPTH is defined as "…*the average maximum height of the tallest dominant*[14] *trees (200 years or more) for a given site class*." Exceptions may occur where SPTH is less than 100 feet, in which case the agency recommends assigning a RMZ width of 100 feet at a minimum to provide adequate biofiltration and infiltration of runoff for water quality protection from most pollutants, but also in consideration of other habitat-related factors including shade and wood recruitment. A 100-foot-wide buffer is estimated to achieve 95% pollution removal and approximately 85% surface nitrogen (Rentz et al. 2020). Washington Department of Fish and Wildlife recommends measuring RMZ widths from the outer edge of the channel migration zone (CMZ), where present, or from the ordinary high water mark where a CMZ is not present.

To apply their methodology, Washington Department of Fish and Wildlife has developed a web-based mapping tool for use in determining SPTH based on the 200-year site index. Modeled SPTH range from 75-231 feet. Where SPTH is 100 feet or more, the agency recommends RMZ establishment within one SPTH, driven by the largest dominant tree species at any location. Acknowledging that establishing functional RMZs using the recommended methods may not be practical in many developed areas, Washington Department of Fish and Wildlife recommends effective watershed management, preservation, and protection, resulting in nearly full restoration of riparian ecosystem habitat functions as is feasible within existing constraints. Washington Department of Fish and Wildlife RMZ establishment and management recommendations are detailed in their *Riparian Ecosystems, Volume 2: Management Recommendations* document (Rentz et al. 2020). Examples of watershed-scale approaches include considering stormwater management adjacent to pollution generating impervious surface areas and prioritizing impassable culverts on fish-bearing streams.

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[14] Dominant trees are those which extend above the normal level of the forest canopy.

A graphical representation of the Forest Ecosystem Management Assessment Team (FEMAT) Curves are shown in Figure 5, which are considered in WDFW's recommendations for establishing the dimensions of RMZs (Rentz et al. 2020). The figure depicts the effectiveness of several functions based on buffer width from the edge of a stream. SPTH is a practical buffer dimension because it is large enough to protect nearly all riparian functions and further increases yield diminishing returns.

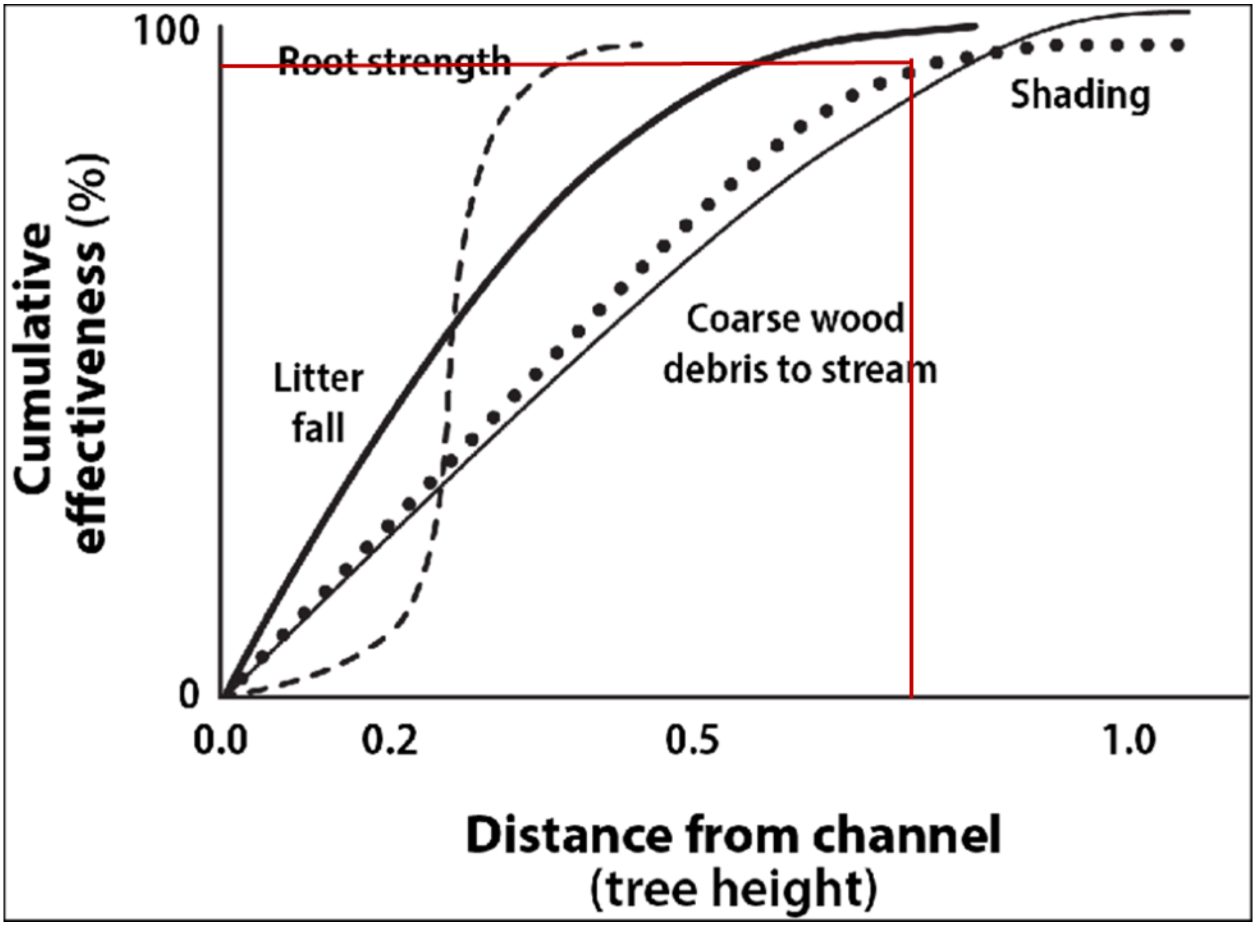

Figure 5. The "FEMAT Curves": a conceptual model of the contributions of key riparian ecosystem functions which influence aquatic ecosystems by distance and cumulative effectiveness. Tree height refers to the average relative height of the site potential tree height (reproduced from FEMAT 1993).

Many scientific studies that examine the functions and values associated with riparian areas have been conducted in forested environments. However, there are fundamental differences between forested, agricultural, and urban areas, including land use and hydrology. Riparian studies often do not account for the contribution of engineering and public works projects, such as surface-water detention facilities, which can supplement natural riparian function in urban settings.

BAS-based literature points to a range of recommended management measures and buffer considerations to help maintain habitat functions for fish and wildlife. Effective methods to reduce impacts from urbanization and manage associated runoff can include the following:

- Limiting development densities and impervious surface coverage;
- Limiting vegetation clearing and retaining forest cover;
- Concentrating impact activities, particularly roads and pollutant sources, away from watercourses;
- Limiting the total area of roads and requiring joint use of new access roads;
- Protecting vegetation and limiting development on or near hydrologic source areas;
- Maintaining densely vegetated riparian buffers with native trees, shrubs, and groundcover species;
- Low impact development (LID);
- Municipal stormwater treatment;
- Public education.

In an analysis of riparian zone ordinances, Wenger and Fowler (2000) support using approaches that allow some flexibility in how policies are implemented on a parcel scale. Whereas variable-width policies provide greater flexibility and adaptability to address site-specific conditions, it is noted that fixed buffer widths are more easily established, require a lesser degree of scientific knowledge to implement, and generally require less time and money to administer (Castelle, Johnson, & Conolly, 1994). Thus, although stream and riparian conservation measures should be based on the best available science, some level of policy interpretation must be made by a local jurisdiction.

If fixed-width buffers are implemented, buffers should be sufficiently wide to ensure that riparian buffers are effective under a range of variable conditions. The ranges of effective buffer widths (as outlined in each subsection) based on each function that were previously discussed are summarized below in Table 2.

Table 2. Range of Effective Buffer Widths for Each Applicable Riparian Function.

Function	Range of Effective Buffer Widths	Notes on Function
Water Quality		
Sediment	4-30 m (13-98 feet), up to 120 m (394 feet) for fine sediment	Filtration is widely variable depending on slope and soils.
Nutrients	Subsurface flow: not dependent on buffer width	In addition to buffer width, the rate of nutrient removal is dependent on infiltration, soil composition, and climate. Filtration capacity decreases with increasing loads, so best

Function	Range of Effective Buffer Widths	Notes on Function
	Surface flow: 15-131 m (49-430 feet)	management practices that reduce nutrient loading will improve riparian function.
Metals	NA- Appropriate buffer width not established	Stormwater system improvements to slow and infiltrate runoff could help reduce metals entering aquatic systems.
Pathogens	NA- Appropriate buffer width not established	Minimizing the density of septic systems, maximizing the distance of septic systems from aquatic resource areas, and promoting pet waste management will help limit the transport of pathogens to aquatic systems.
Herbicides	6-18 m (20-59 feet)	Best management practices during application of herbicides and pesticides can help limit leeching to groundwater.
Pharmaceuticals	NA- Appropriate buffer width not established	Best management practices for disposal of pharmaceuticals may limit potential impacts.
Bank Stabilization	10-30 m (33-98 feet)	Beyond 98 feet from the stream, buffers have little effect on bank stability.
Stream Temperature	10-30 m (33-98 feet)	Leaf cover is more closely related to stream temperature than buffer width.
Microclimate	(10-45 m) 33-150 feet	Most microclimate changes occur within 10-45 m (33 to 150 feet) from the edge, but microclimate effects extend over 240 m (790 feet) from the forest edge.
Invertebrates and Detritus	30 m (98 feet)	Areas with 10 m (33 ft) buffers exhibit changes in invertebrate community composition.
Wildlife Habitat	100 to 600 feet	Minimum width for supporting habitat varies among taxa, guides, and species. Functions include both corridor (travel and migration) and support of lifecycle stages, including breeding.
In-stream Habitat (large woody debris – LWD)	18-50 m (59 to 164 feet)	Although most LWD is recruited from the area adjacent to the stream, treefall from beyond 1 SPTH may affect LWD loading.

To achieve improved water quality in the County's streams, small lakes, and ponds, riparian buffer areas should be utilized effectively to provide both biofiltration of stormwater runoff and protection from adjacent land uses. Both goals can be achieved by providing dense, well-rooted vegetated buffer areas.

Biofiltration swales, created wetlands, and infiltration opportunities for specific stormwater runoff discharges can be utilized to intercept runoff before it reaches stream channels. Stormwater runoff that is conveyed through stream buffers in pipes or ditch-like channels and discharged directly to stream channels "short circuits" or bypasses buffer areas and receives little water quality treatment via biofiltration. In areas where stormwater flows untreated through riparian buffer areas, the buffer is underutilized and is prevented from providing the intended or potential biofiltration function.

FEMA FLOODPLAIN HABITAT ASSESSMENTS

In 2008, the National Marine Fisheries Service (NMFS) issued a Biological Opinion under Section 7 of the Endangered Species Act (ESA), which found that the implementation of the National Flood Insurance Program (NFIP) in the Puget Sound region jeopardized the continued existence of federally threatened salmonids and resident killer whales. As a result, NMFS established Reasonable and Prudent Alternatives to ensure that development within the Special Flood Hazard Area (100-year floodplain), floodway, CMZ, and riparian buffer zone do not adversely affect water quality, flood volumes, flood velocities, spawning substrate, or floodplain refugia for listed salmonids. Because the NFIP is implemented by the Federal Emergency Management Agency (FEMA) through participation by local jurisdictions that adopt and enforce floodplain management ordinances, FEMA has delegated responsibility to the local jurisdictions to ensure that development does not adversely affect listed species. Projects within FEMA-designated floodplains are required to prepare habitat assessments to ascertain their potential effects on federally listed endangered species. Floodplain storage volumes may not be decreased, nor base flood level elevations increased.

6.3.2 Endangered, Threatened, or Sensitive Species and Species of Local Importance

Effective BAS-based strategies can be applied to protect all Federal and State endangered or threatened species and WDFW-identified Priority Species and Habitats (PHS). Not all FWHCAs are water bodies or riparian areas associated with those water bodies. WDFW, USFWS, and NMFS provide information on species-specific management recommendations for certain species that can be used to guide management at the county level or site level. There is widely available information for high profile species, though many regulated species are poorly researched and lack specific management recommendations from state agencies. Where species-specific management recommendations are available from WDFW guidance documents, those should be followed or adapted to local regulations. Examples are Management Recommendations for Washington's Priority Species; Invertebrates (Larsen 2018); amphibians and reptiles (Larsen 1997); Birds (Larsen 2018); and mammals (WDFW 2010). General recommendations for management strategies to protect terrestrial habitat are listed below.

GENERAL TERRESTRIAL HABITAT MANAGEMENT RECOMMENDATIONS

- Existing high quality habitats should be retained because habitat loss is one of the most important factors influening biodiversity and loss of species (Beninde et al. 2015).

- Generally, plan development to minimize fragmentation of native habitat, particularly large, intact habitat areas. Where large forest stands exist, manage for forest-interior species and avoid fragmentation (Donnelly and Marzluff 2004, Diffendorfer et al. 1995, Mason et al. 2007, Orrock and Danielson 2005, Pardini et al. 2005 and others).
- Manage agricultural development to limit fragmentation and edge; preserve vegetative structural diversity whenever possible in agricultural areas by retaining hedge rows and areas of native vegetation (Southerland 1993).
- Protect priority habitats that have a primary association with an ESA-list species or species of local importance by continuing to regulate for adherence to WDFW management recommendations and other applicable regulatory requirements.
- Control invasive species where needed on a site- and species-specific basis. Address invasive species specifically addressed in areas where environmental conditions tend to promote infestation, including created edges, roadways, and riparian zones where they are contiguous with developed areas that may act as a seed source (Olden et al. 2004, Pimentel et al. 2005, McKinney 2002 and others).
- Maintain or provide habitat connectivity with vegetated corridors between habitat patches (Schaefer 2003, Clair 2008, Gilbert-Norton et al. 2010 and others).
- Protect, maintain, and promote habitat features such as snags and downed wood (Blewett and Marzluff 2005).
- Manage for an increase in native vegetative cover in landscaping and discourage lawns (Nelson and Nelson 2001).
- Plan habitat areas away from roads (Fahrig et al. 1995, Lehtinen et al. 1999).
- Promote buffers of adequate width to support wildlife guilds in adjacent habitat (Ficetola et al. 2008, Semlitsch and Bodie 2003, Crawford and Semlitsch 2007).
- Identify existing habitat patches and corridors and maintain connectivity with vegetated corridors to limit fragmentation and edge habitat (Gillies et al. 2008, Gilbert-Norton et al. 2010). Preserve habitat patches of at least moderate size 35 ha (86 ac) within developed areas (Kissling and Garton 2008).
- Promote restoration of FWHCAs, buffers, and other management zones through critical area regulations and public outreach. Encourage stewardship on a parcel by parcel and county-wide scale.

6.4 Climate Change Impacts & Mitigation

Climate change is predicted to result in significant and irreversible impacts on fish and wildlife, and their habitats. Global change is anticipated to result in habitat loss and modification through temperature changes, sea level rise, ocean acidification, extreme weather events, changes in precipitation, biological invasions, food web disruptions, and disease (Lyons et al. 2022; Nagelkerken 2023). The range of effects on fish and wildlife depend on species specific interactions and may include range shifts, phenological shifts, changes to morphology and behavior, biodiversity loss, and extinction (Sattar 2021). The cumulative impacts of these factors to wildlife are anticipated to result in loss of biodiversity and increases to extinction rates (Sattar 2021).

Changes in temperatures and seasonal precipitation patterns are projected to place additional stressors on FWHCAs. Some loss of riparian vegetation is anticipated due to the stresses of climate change, primarily warmer and drier summers. A reduction in riparian vegetation potentially triggers a cascading effect. A decrease in riparian vegetation would decrease shading, increase stream temperature, decrease detrital inputs, reduce available habitat structure, and reduce stream bank stability. Changes in seasonal hydrologic cycles may increase frequency and magnitude of flashy runoff events, mobilize greater volumes of sediments and pollutants into streams, and reduce groundwater recharge that supports base stream flows in summer. FWHCA functions and values, and instream habitats are particularly negatively impacted by excess sediment discharge and deposition.

Hot dry summers are projected to reduce stream flow volumes and increase instream temperatures. This stressor is compounded by extreme precipitation events, flooding, and erosion. All these stressors reduce instream habitat quality and stress salmonid populations, including Chinook salmon, the preferred food source for Orca whales. Global warming poses a threat to freshwater fish habitat (Crozier et al. 2008).

6.4.1 Strategies to manage climate change impacts to FWHCAs

The following actions or policies have been developed by the City of Redmond (2022) in collaboration with the University of Washington Climate Impacts Group and have the potential to reduce negative climate change impacts on FWHCAs within Clallam County.

- Promote retention of significant trees and maintain tree replacement requirements.
- Encourage and incentivize enhancement and restoration of native forest patches throughout the County, particularly where connectivity to one or more FWHCAs is identified. Both voluntary and required restoration planting should be paired with monitoring and maintenance that allows for dry season irrigation and adaptive management.
- Encourage the use of local nursery plant stock grown under current conditions to increase resilience of plant communities considering climate stressors.
- Manage stormwater infrastructure to avoid and minimize discharges of increased and/or untreated runoff to streams and thereby offset the anticipated increase in intensive rainfall events. Promote the use of LIDs as a tool to effectively manage stormwater for minimal downstream impacts.
- Update and maintain regulations for habitats and species of local importance. This may include adding mapping resources to help identify the locations of potential habitats and species requiring protection and management.
- Prioritize protection of streams and riparian corridors to reduce the stresses of climate change on native fish species and anadromous fish, such as chinook salmon.

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