Chehalis Basin Strategy

Aquatic Species Restoration Plan

Aquatic Species Restoration Plan Steering Committee

Phase I: November 2019

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ACRONYMS AND ABBREVIATIONS

ASRP	*Aquatic Species Restoration Plan*
BMP	best management practice
CFAR	Community Flood Assistance & Resilience
cfs	cubic feet per second
Chehalis Tribe	Confederated Tribes of the Chehalis Reservation
Ecology	Washington State Department of Ecology
EDT	Ecosystem Diagnosis and Treatment
ESA	Endangered Species Act
GLO	General Land Office
GSU	geospatial unit
HSRG	Hatchery Scientific Review Group
I-5	Interstate 5
LiDAR	Light Detection and Ranging
M&AM	monitoring and adaptive management
NOAA	National Oceanic and Atmospheric Administration
NOAA model	NOAA Northwest Fisheries Science Center salmonid life-cycle model
RCO	Washington State Recreation and Conservation Office
RCW	Revised Code of Washington
RFP	Request for Proposal
RM	river mile
SMP	Shoreline Master Program
SR	State Route
SRT	Science and Technical Review Team
TMDL	Total Maximum Daily Load
UGA	Urban Growth Area
USFWS	U.S. Fish and Wildlife Service
WAC	Washington Administrative Code
WDFW	Washington Department of Fish and Wildlife
WDNR	Washington Department of Natural Resources
WRIA	Water Resource Inventory Area

EXECUTIVE SUMMARY

The Chehalis Basin is a region rich in native wildlife, working lands, and cultural significance that is economically and ecologically vital to the state and region. The basin is one of the only remaining river basins in Washington where no salmon species are listed as threatened or endangered. It is also home to the most diverse assemblage of amphibian species in the state, including Oregon spotted frog (an Endangered Species Act [ESA] threatened species) and numerous other native fish and wildlife species. The 2,700-square-mile Chehalis Basin (Water Resource Inventory Areas 22 and 23) has more than 3,400 miles of identified perennial streams and is the second largest watershed in Washington State. The basin encompasses the Chehalis River and its tributaries, all other tributaries to Grays Harbor (see Figure S-1 at the end of this section), and a large expanse of floodplain habitats with lower levels of development than many other basins in the Pacific Northwest. The fish and aquatic resources of the Chehalis Basin are of regional, national, and international significance to tribal, commercial, and sport fishing interests.

However, the ecosystem has been substantially changed from historical conditions through activities such as removal of wood from rivers, use of splash dams, channel straightening, and removal of riparian forest. These actions contributed to channel incision that disconnected the river from side channels and floodplain wetlands and reduced cover, shading, and aquatic habitat area. After decades of significant degradation of habitat and natural processes from development and land uses, aquatic species face a grave future under the status quo.

The *Aquatic Species Restoration Plan* (ASRP) is a major element of the Chehalis Basin Strategy, an initiative led by the State Office of the Chehalis Basin and overseen by the Chehalis Basin Board. The Quinault Indian Nation, the Confederated Tribes of the Chehalis Reservation, and the Washington Department of Fish and Wildlife have been key co-authors in the ASRP's creation.

Estimates indicate that existing salmon populations are less than half of their historic run sizes, with spring-run Chinook salmon currently just 23% of historic run sizes in the Chehalis Basin (PFMC 2019; Hiss and Knudsen 1993). Sustaining the productivity of native aquatic species will require rebuilding ecosystem resiliency through a network of interconnected habitats. Without aggressive protection and restoration actions, climate change and future human development will increasingly threaten the viability of aquatic species in the Chehalis Basin. If meaningful actions are not taken, the best available science projects devastating effects—for example, the basin's spring-run Chinook salmon, an important food source for tribal communities as well as for orca whales, could be extinct by the end of the century. This bleak outlook demands urgent attention, but it also presents historic opportunity. By following the roadmap laid out in this *Aquatic Species Restoration Plan* (ASRP), the basin's aquatic species and habitats can be restored and protected now to help ensure a resilient, flourishing basin into the future. The Chehalis Basin holds great promise when compared to other regions in the state where more significant degradation and ESA listings have already occurred and population and development pressures are greater. Opportunity still exists to avoid more intensive regulatory-driven recovery measures and act on our stewardship responsibilities in the Chehalis Basin to ensure a brighter future for native salmon and aquatic species, along with the communities who depend on and benefit from them.

An aggressive, sustained level of commitment and action will be required to restore the basin's habitats. The ASRP portrays a comprehensive analysis of necessary actions, which is based on a quantity and quality of coordinated scientific

> "Our Chehalis culture is inseparably linked to the Chehalis River, which we call nsúlapš, which translates literally to 'my river of wealth.' The abundance provided by this watershed has fed our people and shaped our lifeways since a time beyond the reach of memory. Protecting and enhancing the aquatic resources of the Chehalis Basin must be vigorously pursued to preserve the river for the benefit of all citizens and future generations. The Confederated Tribes of the Chehalis Reservation support the immediate and comprehensive restoration efforts described in the *Aquatic Species Restoration Plan* and look forward to a future of a healthy, sustainable watershed."
>
> —Harry Pickernell, Chairman, Confederated Tribes of the Chehalis Reservation

> "The lower Chehalis River and its estuary make up the most important economic waterway for Quinault fishermen. The ambitious scale and generational perspective of the ASRP truly matches the uphill battle we face in rebuilding our sacred salmon runs. We appreciate the commitment and look forward to working with the state and other leaders across the Basin to see it come to fruition."
>
> —Tyson Johnston, Vice-President, Quinault Indian Nation

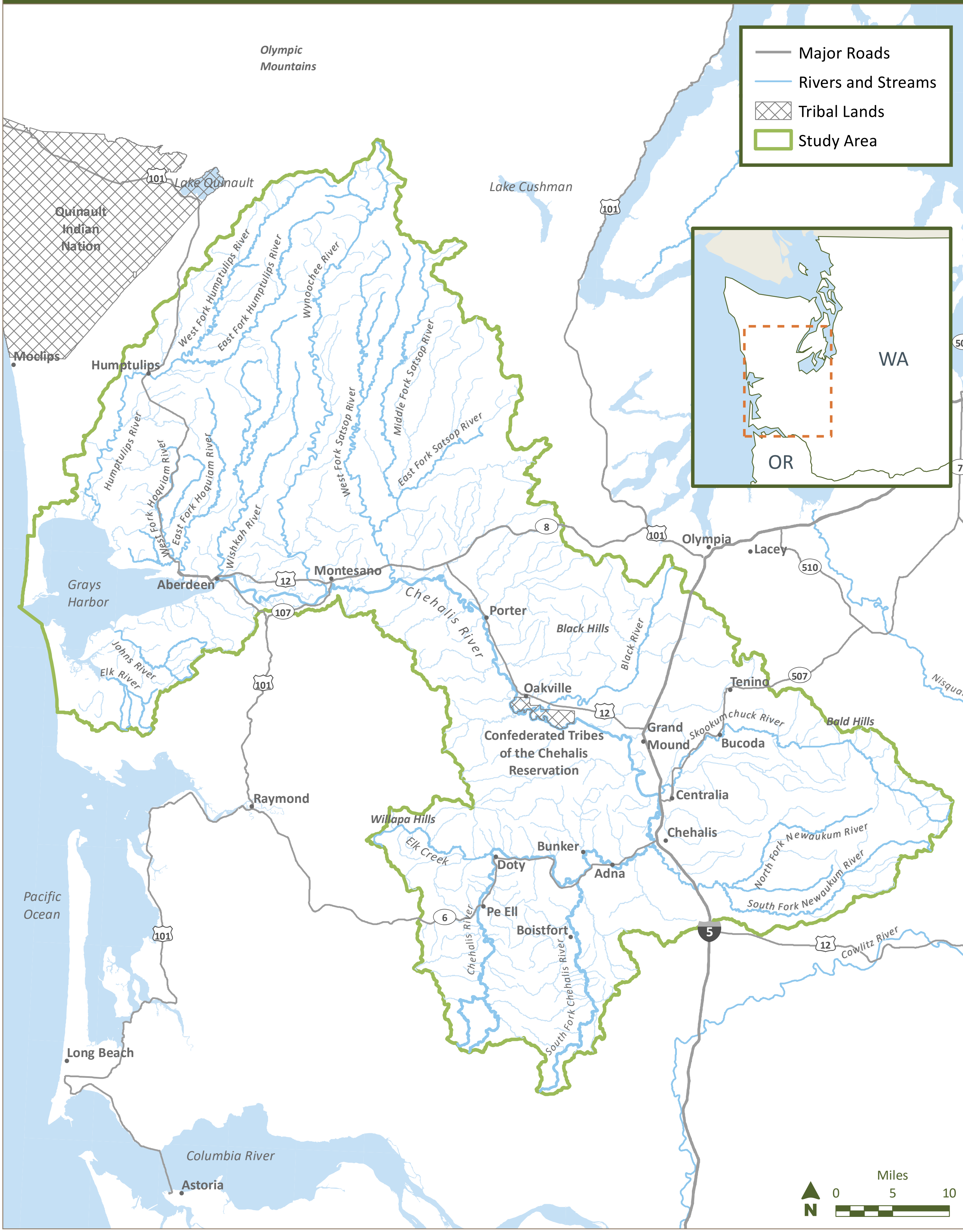
analysis unprecedented anywhere in Washington. It provides a detailed, science-based roadmap for restoring habitat and protecting intact ecosystems of aquatic species along the rivers and streams in the Chehalis Basin. The actions identified through the ASRP chart a course toward the best chance to support healthy and harvestable salmon populations, robust and diverse populations of native aquatic and semi-aquatic species, and productive ecosystems that are more resilient to climate change and human-caused stressors.

> "The Chehalis River and its tributaries provides for culturally and economically important commercial, sport and tribal fisheries. The technical work over the last seven years has moved the basin from data poor to a much richer understanding of the ecological processes, aquatic species, and means to reduce flood damage."
>
> —Kelly Susewind, Director, Washington Department of Fish and Wildlife

Collectively, the ASRP strives to honor the social, economic, and cultural values of the region and maintain working lands. The importance of community involvement in the ASRP cannot be overstated—most of the actions proposed in the ASRP would occur on private land, and the program relies on landowners willing to collaborate in this important undertaking to be successful. The prospect for recovery is highly achievable in the Chehalis Basin, largely because much of the land use is still rural agriculture and working forest lands and the basin does not yet have highly developed, sprawling urban centers (as is the case in other regions of the state).

The scope of the ASRP focuses on taking action where the greatest potential exists to provide substantial gains for aquatic species, while recognizing the dynamic uncertainties of external factors such as estuary, ocean, hatchery, harvest, invasive species, and climate change conditions. The ASRP honors existing community values, builds on previous actions to protect and restore basin habitat and ecological processes, and complements investments the state has already made in aquatic species habitat restoration and protection.

Figure S-1
Chehalis Basin



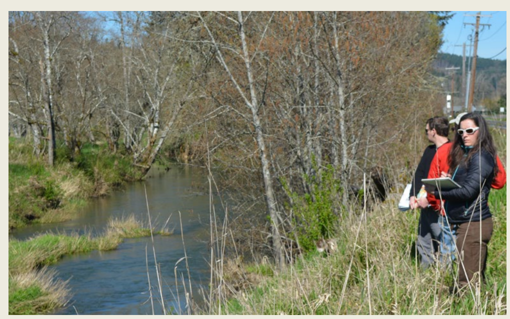
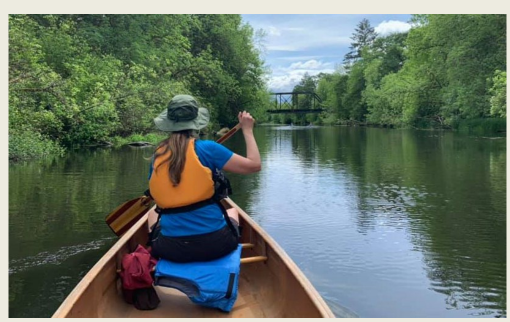
Aquatic Species Restoration Plan Development

The Quinault Indian Nation, the Confederated Tribes of the Chehalis Reservation, and the Washington Department of Fish and Wildlife have worked together with farmers, foresters, conservationists, other state agencies, local governments, and local landowners to understand opportunities and challenges and to inform the development of this plan.

The ASRP is being developed as a major component of the Chehalis Basin Strategy through a collaborative, sustained effort in three phases. This ASRP Phase 1 document illustrates what is known about the basin, explores what the program could achieve under different scenarios (or levels of effort), and presents estimated costs for each scenario. The document analyzes each of the basin's ecological regions (see Section 5), identifies geographic priorities for action, conducts modeling of expected outcomes, and refines prior outcome and investment estimates. The ASRP co-authors and the Chehalis Basin Board will use feedback received from stakeholders and the public on this ASRP Phase 1 document to inform the next phases of plan development.

Phase 2 of the ASRP includes detailed science and policy work to refine the priorities for sequencing specific projects and actions, refine cost estimates, develop a full Monitoring and Adaptive Management (M&AM) Plan, and coordinate the ASRP with other elements of the Chehalis Basin Strategy. Continued involvement by local groups and implementing parties will be needed as the ASRP continues to build strategies for successful implementation—including landowner participation, project planning, and project evaluation processes. The Chehalis Basin Board will then engage in a public process with tribes, local and state government agencies, the broader basin



Bottom photo credit: Kasia Pierzga

community, and other interested stakeholders to ultimately recommend a long-term Chehalis Basin Strategy to the Washington State Legislature. This long-term strategy will include a refined Phase 3 ASRP, which will outline desired outcomes and the associated level of investment needed to achieve those outcomes, along with the Board's recommended flood damage reduction actions. The Board's recommended long-term strategy is anticipated in late 2020.

Development of Strategies and Actions

A key element necessary for developing a restoration plan is to strategically prioritize essential actions, including where and when those actions should occur to provide the greatest short-term and long-term habitat benefits. To support the prioritization process, the basin was examined as 10 ecological regions based on underlying geology, topography, climate and hydrologic regime, and channel characteristics. The strategic prioritization was informed by the following:

- Recent scientific studies, mapping, and fish passage barrier assessments
- Current and historical knowledge and expertise from Chehalis Basin scientists and practitioners
- Pertinent historical data and mapping for the Chehalis Basin
- The Ecosystem Diagnosis and Treatment (EDT) salmon habitat model
- Baseline information from the National Oceanic and Atmospheric Administration (NOAA) salmonid life-cycle model
- On-the-ground observations and analyses by the ASRP Science and Technical Review Team
- Chehalis Basin-specific climate change modeling projections

The prioritization process identified areas within each of the basin's ecological regions with the best opportunities to protect and improve species performance and increase spatial distribution and diversity of species. This Phase 1 document provides projections of conditions the ASRP could achieve under three additive restoration scenarios (see Figure S-2), which were built from the prioritization process, along with estimated costs for each scenario. The scenarios were built on the following key themes toward sustained, long-term restoration of vital ecosystem functions:

- Scenario 1 protects and enhances existing core habitats for all aquatic species. It protects and restores more than 200 miles of river/stream habitat; corrects 200 fish passage barriers, improving access to approximately 200 miles of river/tributary habitat; and restores more than 9,000 acres of riparian and floodplain habitats.
- Scenario 2 builds on Scenario 1 to protect and enhance existing core habitat areas, with the additional focus of restoring the best opportunities to benefit multiple species and increase spatial distribution. Adding more enhancement opportunities, this scenario protects and restores more than 300 miles of river/stream habitat; corrects 300 fish passage barriers, improving access to more than 300 miles of river/tributary habitat; and restores more than 10,200 acres of riparian and floodplain habitats.

- Scenario 3 builds on Scenario 2, with an added focus of increasing spatial and life history diversity and distribution of species throughout more of the basin. It protects and restores 450 miles of river/stream habitats; corrects 450 fish passage barriers, improving access to more than 400 miles of river/tributary habitat; and restores more than 15,300 acres of riparian and floodplain habitats.

Each scenario will restore impaired ecosystem processes and protect high functioning areas by targeting the following:

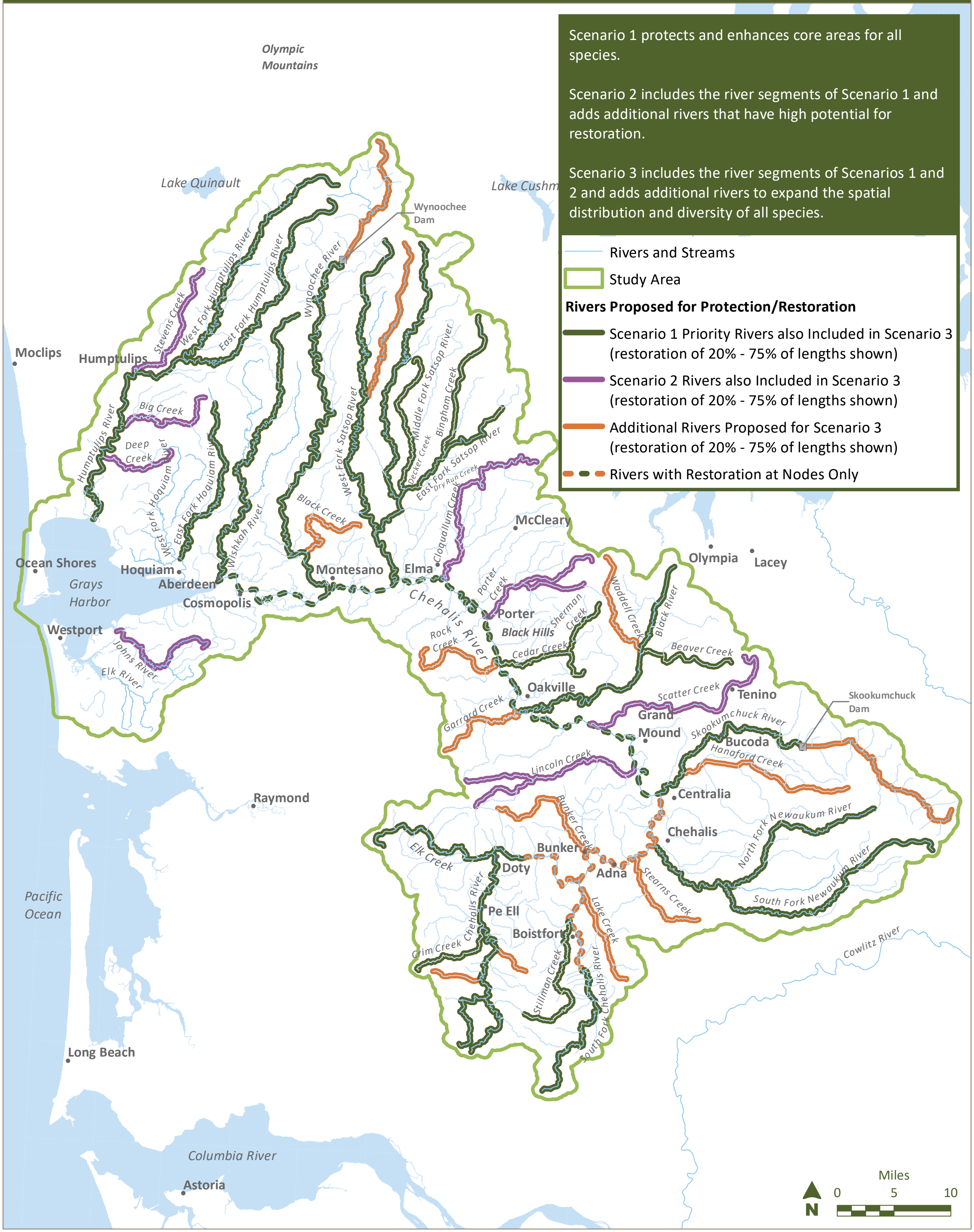
- Riparian forested areas that can provide the large wood, nutrients, shading and cooling, stream bank protection, and fish and wildlife migration corridors needed by aquatic species
- Floodplain and off-channel habitats and wetlands that will improve watershed connectivity, water storage and exchange to augment low flows and reduce water temperatures, and highly diverse fish and wildlife habitat
- In-channel large wood restoration to increase cover and roughness, decrease channel incision, retain and sort sediments, create deep pools, and improve channel complexity and floodplain connectivity in strategic locations
- Correction of selected fish passage barriers to improve access to upstream habitats

To understand the potential benefits of conducting restoration, the three scenarios were compared to two baseline conditions: 1) a Base scenario, which reflects current conditions throughout the basin; and 2) a No Action scenario, which represents projected future conditions without the ASRP, based on modeling. The modeled No Action scenario accounts for potential negative effects from climate change and development pressures, as well as anticipated positive effects from the maturation of riparian forests within managed forest lands[1] as presently required under the Washington Forest Practices Act. The three restoration scenarios also incorporate the assumptions listed in this section and apply differing levels of restoration and protection actions. To evaluate potential future conditions, mid-century (approximately 2040) and late century (approximately 2080) conditions were selected for comparison based on available climate projections.

In addition to outlining and evaluating the three restoration scenarios, this ASRP Phase 1 document identifies strategies and the types of actions needed to protect unique habitats and strategic areas that support critical ecosystem functions and native species. It also outlines approaches for basin communities to more effectively plan for current and future conditions, and it discusses strategies needed to engage landowners and local governments to ensure support and implementation of the ASRP actions. The magnitude of proposed actions relies on community support through effective land use planning protections and landowner participation to be successful. Finally, this ASRP Phase 1 document identifies potential ways to build the institutional capacity of existing organizations to ensure the ASRP is truly a community-based restoration, protection, and planning program.

[1] "Managed forest lands" are defined as lands outside of federal management that are more than 80 contiguous forested acres. Managed forest lands include publicly and privately managed forest lands, most of which fall under the Washington Forest Practices Act and Habitat Conservation Plans. Most of the areas outside of managed forest lands are downstream of the publicly and privately managed forest lands.

Figure S-2
Summary of Rivers Included in ASRP Protection and Restoration Scenarios



Expected Outcomes and Associated Costs

The ASRP development process has included a detailed analysis and modeling of potential climate impacts at the watershed level. If no action is taken, model results project that anticipated future climate change and habitat degradation will lead to substantial declines for all salmon and steelhead species. The effects of climate change and habitat degradation will also have similar negative effects on the suite of amphibian species. The effects are especially sobering for spring-run Chinook salmon, which are anticipated to decline to the point of becoming functionally extinct by 2080. The projected declines in salmon species are so extensive that even substantial restoration scenarios are projected to result in only modest gains (see summary in Figure S-3). These declining baseline model results point to a dire future for species in the basin unless unprecedented, aggressive action is taken immediately to reverse the trajectory for salmon and other aquatic species. The longer we wait, the harder it will be.

Understanding Expected Outcomes

It is important to note that the modeled outcomes assume all ASRP actions are implemented immediately. Implementation will take two or more decades, so additional actions may be necessary to achieve desired outcomes. If habitat conditions degrade from present-day conditions due to human activities and/or climate change impacts before ASRP implementation, the expected outcomes of ASRP actions will be reduced.

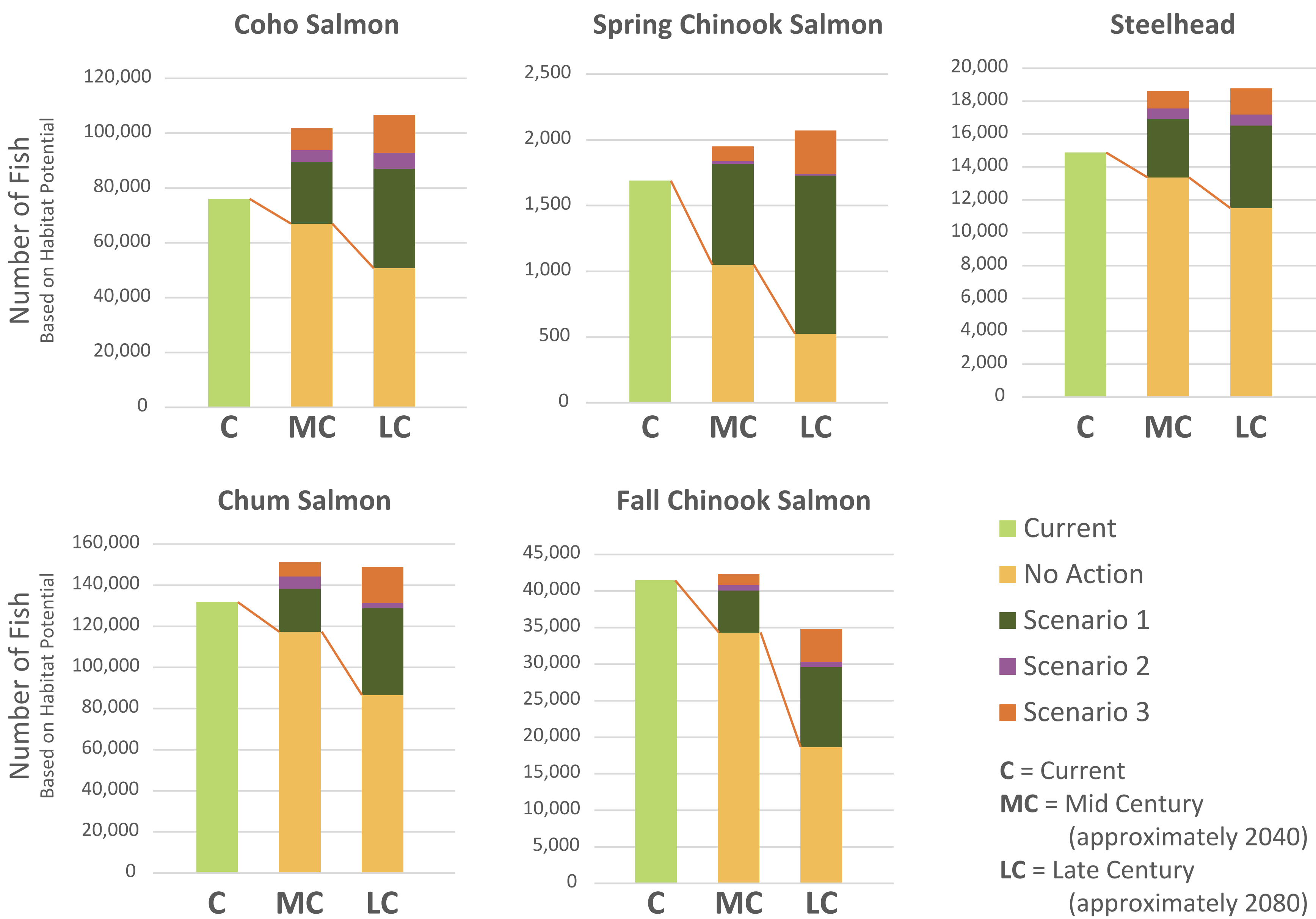
Uncertainties and variability of fish population modeling results are discussed further in Section 7.3. Population estimates are based on habitat potential—the amount of fish the improved habitat could support—and not actual run sizes. They should not be interpreted as a guarantee of the number of fish that will be produced in, or return to, the basin.

Implementing Scenario 1 would generally halt the species declines that are projected to occur from climate change in the mid-century time frame. Compared to the No Action scenario, Scenario 1 would provide substantial gains to salmon and steelhead by both mid-century and late century.

Scenario 2 would provide modest additional benefits beyond the Scenario 1 projections and focuses on important smaller sub-basins that historically produced healthy runs of coho salmon, chum salmon, and steelhead. In addition, Scenario 2 targets geographic areas that could provide significant available quality habitat for amphibian species, which is not illustrated in these modeling results.

Scenario 3 would provide more substantial habitat gains above both Scenarios 1 and 2 and also expands spatial diversity (or distribution of local populations) for coho salmon, spring- and fall-run Chinook salmon, and steelhead into more geographic areas of the basin. Scenario 3 is the only scenario that would significantly increase ecosystem resiliency, therefore reducing the risk of functional extinction for any localized population. Similar to reducing the risk of loss by diversifying a stock portfolio, enabling species to be distributed more broadly throughout the basin through Scenario 3 would reduce the extinction risk to any one localized population.

Figure S-3
Expected Outcomes for Salmon



Species Population Response

Strategies and actions proposed in this phase of the ASRP would restore and protect vital habitat and impaired processes throughout the basin. Analysis of the impact of restoration scenarios on salmon and steelhead indicates that restoration could have a substantial and tangible benefit over no action (see Figure S-3). The ability to positively affect salmon and steelhead depends, in part, on the investment in restoration and protection of their habitats.

The outcomes for aquatic species other than salmonids have not been quantified to the same extent at this time because much less information exists about these species. The restoration and protection actions in this ASRP Phase 1 document are likely to result in substantial positive outcomes for the range of potential aquatic indicator species within the ASRP. Further recommendations for other native aquatic species will be developed in the next phases of the ASRP.

Cost Estimates

Cost estimates have been developed for the three scenarios and additional investments needed to ensure a resilient future for the Chehalis Basin. The combination of sustained aggressive funding, basin-wide landowner willingness, large-scale political support, and committed implementation are vital to the success of this plan. The cost estimates for the restoration scenarios range from a low of $300 million to $600 million for Scenario 1 to a high of $550 million to $1.1 billion for Scenario 3. These estimates include costs associated with protection of existing habitat conditions from human activities, removal of fish passage barriers, placement of large wood and logjams in stream channels, planting native trees and shrubs in riparian zones, reconnecting side channels and wetlands, and restoring floodplain habitats for aquatic species.

The biggest contributor to the cost estimates is the construction of riparian and floodplain habitats as outlined in Section 8. Funding the restoration and protection actions at the scales proposed would directly address the most significant limiting factors for aquatic species in sub-basins throughout the Chehalis Basin. In addition to costs associated with riparian and instream restoration and protection, estimates include costs for land use planning and process protection strategies, community involvement actions, and ongoing operations and maintenance. The sustained and holistic funding and implementation of the ASRP is a long-term investment in the communities of the Chehalis Basin.

A real potential exists for significantly improving wild salmon runs and other aquatic species in the Chehalis Basin—improvements that will be resilient to the threats of climate change and deliver sustainable ecological services and other cultural and economic benefits to the basin and its residents.

Following review of this document, additional analysis will occur to develop a refined ASRP scenario that can be selected by the Chehalis Basin Board to be carried forward as a final plan. In addition, further refinements to actions, outcomes, and costs will be provided; a detailed implementation and sequencing plan will be developed; and efficiencies between projects will be identified.

Through the strategies documented in this plan, the ASRP provides a detailed, science-based roadmap for restoring habitat and protecting unique ecosystem features for aquatic species along the rivers and streams in the Chehalis Basin—areas where climate change and habitat degradation pose grave risks to the native species that depend on the freshwater environment. The ASRP is a historic opportunity to reverse the alarming trends of decline by using a collaborative, community-driven, science-based approach. When implemented, the ASRP will protect and restore ecosystem resiliency throughout the Chehalis Basin, now and into the future. Through aggressive investment, landowner participation, sustained political commitment, and community planning, the ASRP can not only halt the decline of native species—it can also build a resilient ecosystem that sustains aquatic species for future generations.

1 INTRODUCTION

1.1 Background

The natural resources of the Chehalis Basin have supported native people for thousands of years and continue to provide value to both tribal and non-tribal people of the basin. The basin's historically plentiful salmon, lamprey, shellfish, and wildlife have major cultural, recreational, and economic roles. The rich floodplain soils and old-growth forests also made the region attractive to settlers for farming and forestry. Today, although most of the old-growth forests are gone and there has been significant development, the watershed remains an important ecosystem. The basin's resources support the cultures of two federally recognized tribes, and the basin's position along key transportation and shipping routes near major population centers provides economic benefits to the community and Washington State.

Many species of fish are found in the Chehalis Basin, including salmonids such as steelhead and Chinook, coho, and chum salmon. Extensive and varied habitats within and adjacent to rivers and streams in the Chehalis Basin also support Olympic mudminnow (endemic to Western Washington), the most diverse amphibian species assemblage in Washington including Oregon spotted frog (an Endangered Species Act [ESA] threatened species), and numerous other native fish and wildlife species. See Section 3 for additional information on species in the basin.

These aquatic resources are not boundless, however, and the basin faces increasing threats to its ecosystems and its natural resource heritage. For more than 100 years, the health of the Chehalis Basin's rivers, streams, and aquatic species has declined without a comprehensive response. Therefore, the protection and restoration of habitat for aquatic species has become more important than ever for many people in the Chehalis Basin. Sustaining the productivity of native aquatic species will require restoring ecosystem resiliency through a network of interconnected habitats.

> **If action is not taken, communities and natural resources will experience greater hardships and loss.**
>
> Beginning in the 1850s and continuing today, humans have caused extensive impacts to aquatic species habitat. Although salmon runs have had many good returns during the last 30 years, average runs display a long-term decline, and poor returns of one or more species of salmon in most years have significantly limited tribal and non-tribal harvest to protect the most vulnerable species. In recent years, summers have become drier with warmer stream temperatures and lower streamflows, and these conditions are predicted to get worse in the future.
>
> With no action, the future for aquatic species in the basin is predicted to be significantly worse. People, communities, and natural resources could suffer at unprecedented levels. In other places (outside the basin), declines in habitat have resulted in ESA listings, causing federal government intervention into local actions and limitations on private landowners and the harvesting of salmon.

Without aggressive protection and restoration actions, climate change and future human population growth will increasingly threaten the viability of aquatic species in the Chehalis Basin.

This bleak outlook demands urgent attention, and also presents historic opportunity. By following the roadmap laid out in this *Aquatic Species Restoration Plan* (ASRP), the basin's aquatic species and habitats can be restored now to help ensure a resilient, flourishing basin into the future. The Chehalis Basin holds great promise when compared to other regions in the state where more significant degradation and ESA listings have already occurred and population and development pressures are greater. There is still time to avoid more intensive recovery measures and act on our stewardship responsibilities in the Chehalis Basin to ensure a brighter future for ecosystem resiliency, native salmon and aquatic species, and the communities who depend on and benefit from them.

An aggressive and sustained level of commitment and action will be required to restore the basin's habitats. The necessary actions are being comprehensively analyzed through the ASRP, which is based on a quantity and quality of coordinated scientific analysis unprecedented anywhere in Washington. The ASRP provides a detailed, science-based roadmap for restoring aquatic species habitat and protecting ecosystems along the rivers and streams in the Chehalis Basin.

A vision was developed to describe the desired outcome of actions to be undertaken as part of the ASRP.

ASRP Vision Statement

The vision of the ASRP is to utilize the best available scientific information to protect and restore habitat in the Chehalis Basin in order to support healthy and harvestable salmon populations, robust and diverse populations of native aquatic and semi-aquatic species, and productive ecosystems that are resilient to climate change and human-caused stressors while honoring the social, economic, and cultural values of the region and maintaining working lands.

The ASRP is one component of the Chehalis Basin Strategy, which is intended to be a program of integrated actions focused on aquatic species habitat restoration and flood damage reduction over both the short and long term, while avoiding or minimizing adverse environmental, social, cultural, agricultural, and economic impacts. Since 2011, the Washington State Governor and Legislature have made significant investments in identifying potential solutions. Through mid-2017, the Governor's Chehalis Basin Work Group worked with a team of natural and water resource experts from federal and state agencies, tribes, and restoration practitioners to oversee a series of technical analyses to support decision-making on long-term, large-scale actions. In the short term, strategy recommendations have enabled the implementation of high-priority aquatic species habitat restoration projects and local small-scale flood damage reduction projects in the basin. These projects have occurred in coordination with the Chehalis Basin Lead Entity and Chehalis River Basin Flood Authority. The Chehalis Basin Board, established in July 2017 consistent with Revised Code of Washington (RCW) 43.21A.731, is currently developing a long-term strategy for the Chehalis Basin. Recommendations on a long-term Chehalis Basin Strategy are anticipated in 2020. The strategy will include the following two overarching types of actions: 1) aquatic species habitat restoration and protection; and 2) flood damage reduction.

The ASRP is the component of the Chehalis Basin Strategy that focuses on habitat restoration and protection. Over the past 8 years, there has been a significant increase in data collection and research, and analyses have focused on developing a more robust understanding of the aquatic species in the basin, their habitats, the processes that maintain them, and the ecosystem interactions. The ASRP is being developed by the ASRP Steering Committee and the ASRP Science and Technical Review Team (SRT). Committee members of both groups are listed in Appendix E; roles are discussed in Section 1.4. The data, research, and analyses by numerous parties have been used to develop a robust, collaborative, science-based understanding of the habitats and aquatic species in the Chehalis Basin. The basin-wide ASRP seeks to design and encourage implementation of actions intended to do the following:

- Protect and preserve ecosystems and aquatic species and habitats.
- Restore degraded ecosystems, reconnect habitat, and restore habitat-forming processes.
- Re-establish natural ecosystem processes resilient to climate change and other human actions.
- Foster the community and institutional capacity needed to implement and maintain the ASRP over the long term.

ASRP Goals

Goals were developed to guide the ASRP strategies, actions, and restoration scenarios (see Section 4 for additional details and sub-goals):

- Protect and restore natural habitat-forming processes within the Chehalis Basin watershed context.
- Increase the quality and quantity of habitats for aquatic species in priority areas within the Chehalis Basin.
- Protect and restore aquatic species viability within and across the Chehalis Basin considering viable species population parameters.
- Increase watershed resiliency to climate change by protecting and improving natural water quantity and timing characteristics and water quality characteristics.
- Build recognition of and support for ASRP actions and the ways the ASRP supports resilient human communities.

Besides the ASRP, a number of flood damage reduction actions are being evaluated through separate processes. These include changes to local floodplain management regulations and floodproofing of structures, the Community Flood Assistance & Resilience (CFAR) Program, the Aberdeen/Hoquiam North Shore Levee, and a flood retention facility being considered on the mainstem Chehalis River. Actions undertaken as part of the ASRP are not mitigation for the effects of flood damage reduction actions such as construction of a flood retention facility, new or improved levee systems, or local-scale flood damage reduction. If flood damage reduction actions are implemented, mitigation for these actions should be consistent with the ASRP actions and strategies.

1.2 Purpose

The ASRP is based upon robust scientific research and analysis and demonstrates the urgent need for action. Scientists predict that unless there is dedicated investment and intervention, aquatic species will see further dramatic declines in the future due to climate change and other stressors. The basin's spring-run Chinook salmon—important to those interested in the Chehalis system and an important food source for tribal communities, orca whales, and a suite of other species in the freshwater and marine food webs—could be extinct by the end of the century (or earlier, in some sub-basins).

Through community involvement, planning efforts, and increased institutional capacity, the ASRP provides a detailed, science-based roadmap for restoring aquatic species habitat and protecting ecosystems along the rivers and streams in the Chehalis Basin—where climate change and habitat degradation pose grave risks to the freshwater environment. The ASRP is a strategic plan based on the most effective approaches to be taken for the most significant benefits.

This ASRP Phase 1 document builds on the prior November 2017 *Initial Outcomes and Needed Investments for Policy Consideration* document (ASRP SC 2017) and presents new options to the Chehalis Basin Board, tribes, state agencies, and local communities for what the ASRP could achieve under different scenarios, along with associated estimated costs for each scenario. Whereas the Initial Document summarized initial expected outcomes and associated investments at a basin scale, this ASRP Phase 1 document includes analysis of details relative to the basin's ecological regions (see Section 5), additional modeling of expected outcomes, and refinements to prior outcome and investment estimates. A refined *Scientific Foundation* is provided (Appendix A), as well as a *Monitoring and Adaptive Management (M&AM) Framework* (Appendix B), which will be developed into a plan as the ASRP moves forward. The science and policy work for the scenarios and actions in this ASRP Phase 1 document has also been further developed from the Initial Document.

The ASRP takes care to honor the social, economic, and cultural values of the Chehalis Basin's residents and provides an ambitious but realistic timeline for implementation.

The ASRP is being developed through a collaborative, sustained effort. Regional tribes have been key leaders in the ASRP's creation, and farmers, foresters, conservationists, Washington State, and local landowners have been important stakeholders in the plan's creation. They are all critical to the success of ASRP efforts.

The importance of community involvement in the ASRP cannot be overstated—most of the actions proposed in the ASRP would occur on private land, and the program relies on landowners willing to collaborate in this important undertaking to be successful. The prospect for recovery is highly achievable in the Chehalis Basin, largely because much of the land use is still rural agriculture and working forest lands and the basin does not yet have highly developed, sprawling urban centers (as is the case in other regions of the state).

The Chehalis Basin Board, tribes, and state agencies will use the public feedback on this ASRP Phase 1 document to develop recommendations to the Washington State Legislature related to the desired outcomes and necessary level of investment. Further discussion among the governments and organizations will be required to determine next steps in development and implementation of the final ASRP. It is anticipated that Phases 2 and 3 of ASRP development will include additional data gathering and modeling to further reduce uncertainties for the selected scenario, as well as development of the M&AM Plan and a complete Implementation Plan with design and funding guidance for projects under the selected restoration and protection scenario. The ASRP will be updated and refined based on comments received during the public comment period for the ASRP Phase 1 document. Guidance to practitioners regarding the sequencing and design of the projects will also be developed.

The final ASRP document will present refined models and analysis of the ASRP scenario that is chosen to be carried forward, and it will provide the roadmap for implementation of the ASRP. The ASRP will be fully developed and integrated with the other elements of the Chehalis Basin Strategy in 2020. The ASRP is a "living" plan, meaning it is intended to be updated, refined, and adaptively managed through time. More information on this process is provided in Section 1.4.

1.3 Approach and Scope

Geographically, the ASRP encompasses the entire Chehalis Basin (Water Resource Inventory Areas [WRIAs] 22 and 23[1]), which drains an area of approximately 2,700 square miles and contains 1,391 streams with more than 3,400 stream miles. Sustaining the productivity of native aquatic species will require restoring ecosystem resiliency through a network of interconnected aquatic and terrestrial habitats along these rivers and streams. The scope of the ASRP is focused on freshwater conditions within the basin that affect the survival of aquatic species and those freshwater habitats that support wild, native aquatic species. This plan does not address conditions in the estuary at this time, although the estuary is recognized as very important to aquatic species survival and will be further addressed in a future phase.

> The ASRP is focused on protecting and restoring habitat and ecological processes in the freshwater environment in locations where there is a potential to provide substantial gains for aquatic species.

The ASRP is focused on restoration and protection of aquatic habitat and does not address harvest, changes in ocean conditions, or other external issues. Recommendations for hatchery operations and harvest are under the authority of the fisheries co-managers (Washington State and tribes). Additionally, the ASRP aims to restore and protect aquatic species habitat and ecosystem resiliency; increasing hatchery production in the Chehalis Basin is not a mechanism to achieve those goals, and therefore the

[1] For the purposes of water resource planning under the Washington State Watershed Planning Act of 1998 (90.82 RCW), the Chehalis Basin is divided into WRIAs 22 and 23 (CBP 2004). WRIAs are delineated based on major watersheds, or areas draining into a waterbody. WRIAs 22 and 23 represent the lower and upper Chehalis River watersheds.

ASRP is focused on actions that will result in restoration and protection of habitat. Hatcheries are a point-source solution to production of a specific species, and habitat restoration is a much larger, integrated solution to a wider set of issues. The ASRP recommendations may also benefit hatchery fish by improving habitat and food web conditions in the basin. No feasible methods currently exist to address changes in ocean conditions that also influence anadromous species survival. The modeled future conditions in this ASRP Phase 1 document do include estimates for additional ongoing degradation of aquatic habitats from human development and other factors including climate change. While the primary focus is aquatic species habitat in the freshwater environment, the ASRP recognizes that people are an integral part of the landscape. As such, the community will be engaged in developing the ASRP, and landowners will continue to be engaged on a voluntary basis in habitat actions.

A strategic approach is used in the ASRP, one that considers the basin as a whole, as well as the spatial and temporal relationships that influence watershed processes, habitat conditions, and biological responses of native species. The ASRP focuses on protecting and restoring the natural watershed processes that are important in the formation, condition, and function of aquatic habitats. This process-based strategic approach addresses both the underlying causes of habitat impairment and the protection and restoration potential of a given reach, and it supports the development of strategies and actions that are resilient to future changes in watershed conditions. Figure 1-1 illustrates how cause and effect process linkages were used to identify the causes of impairment and where the potential gains for aquatic species can be provided. This same approach will be used to adaptively manage the ASRP, as it assumes some level of human influence on habitat conditions will continue into the future.

Figure 1-1
Conceptual Process Diagram

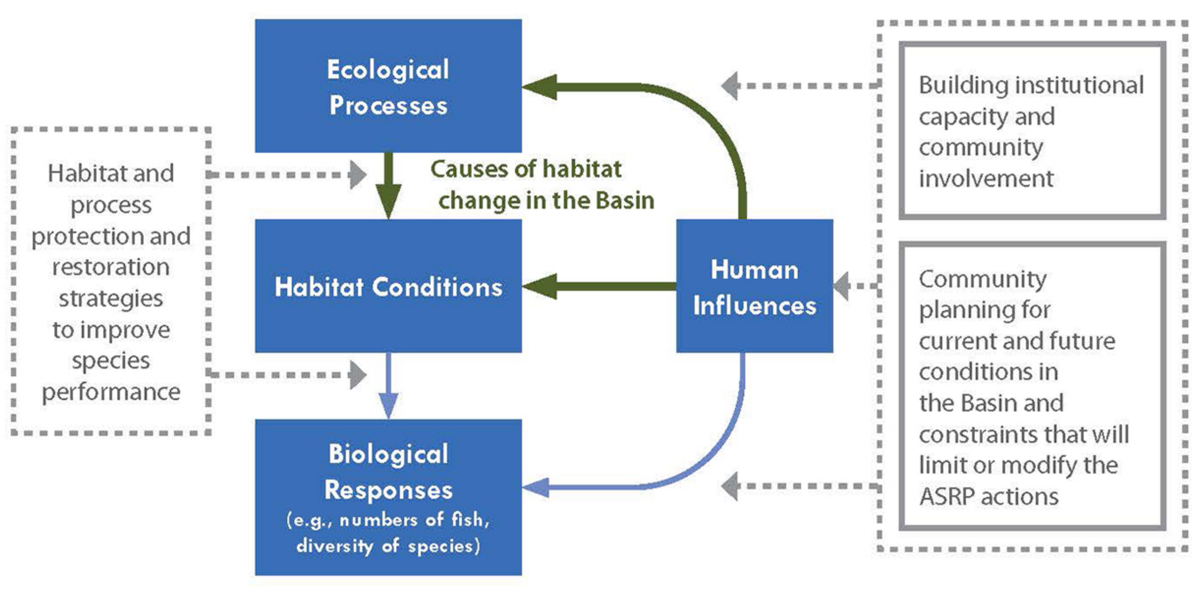
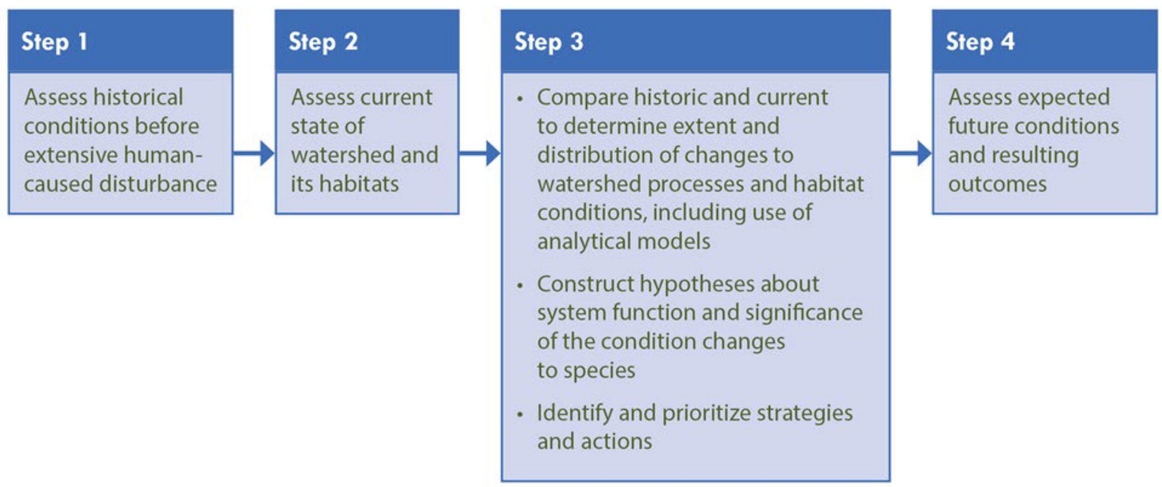


Figure 1-2 illustrates the diagnostic procedure used in the ASRP to assess changes to aquatic habitats from their historical state, how these changes have impacted aquatic species performance, and how future changes may affect habitats and species (refer to the *Scientific Foundation* in Appendix A for additional details).

Figure 1-2
ASRP Diagnostic Procedure



The ASRP utilizes a two-model approach to better understand future projections under the range of scenarios presented. The models are the Ecosystem Diagnosis and Treatment (EDT) model and the National Oceanic and Atmospheric Administration (NOAA) Northwest Fisheries Science Center salmonid life-cycle model (NOAA model). These two models are different in their structure and analysis but utilize many of the same datasets as inputs. Using two models and verifying the results with the other helps ensure that they are useful tools that can be employed as one of the methods to strategically prioritize areas and actions that can have the most uplift to native aquatic species. Strategic prioritization uses model results but is also informed by many other data sources (described further in Section 4). While the model results portray population-level estimates of specific salmon species, the ASRP is focused more broadly on protecting and enhancing the quality and quantity of aquatic species habitats in the Chehalis Basin. The modeling efforts are further described in Appendix C.

This ASRP Phase 1 document provides projections for the conditions the ASRP could achieve under different scenarios, along with associated costs for each scenario. The diagnostic procedure shown in Figure 1-2 was used to develop the scenarios. The three resulting ASRP scenarios presented in this document are compared to a Base scenario and a No Action scenario. The three ASRP scenarios and the No Action scenario were evaluated relative to mid-century (approximately 2040) and late-century (approximately 2080) conditions. See Sections 4, 5, and 7 for more details of the scenarios, actions, and expected outcomes presented in this document.

The Phase 3 ASRP document will refine analysis of the ASRP scenario that is chosen to be carried forward. This could be at the level presented in one of the scenarios in this document or at a different level than these scenarios. In the Phase 3 ASRP, refinements to actions, outcomes, and costs will be provided; implementation sequencing will be detailed; and efficiencies between projects will be identified.

Baseline Scenarios Used for Comparison and Evaluations

Baseline scenario/current conditions include the following:

- Current habitat conditions, including instream, riparian, and floodplain conditions
- Known fish passage barriers

No Action scenario conditions include the following:

- No additional restoration
- Only fish passage barrier corrections that fulfill requirements of existing forest practice regulations and/or federal court injunction mandates
- Potential future degradation from land use and climate change predictions
- Maturing of streamside buffers in managed forests

Phases 2 and 3 of ASRP development will build on Phase 1 work, while integrating public feedback provided on this document to help refine each of the strategies detailed. Work items for those phases are anticipated to include the following:

- Information at a more detailed geography and more detailed limiting factors, including information on estuary conditions
- Modifications and selection of a preferred scenario for the restoration and protection strategies, as well as fully developed community planning, community involvement, and institutional capacity strategies (further strategy development would include needs for the estuary, refined modeling that can better guide ASRP actions, more developed land use elements, additional measures that could improve fall-run Chinook salmon projections, invasive species management planning, and other refinements)
- Identification of remaining critical data gaps
- A fully developed M&AM Plan
- A detailed Implementation Plan, including sequencing, a plan for coordination with local groups and implementing parties, design guidance and standards for project actions, and guidance for practitioners

- A funding strategy, including updated cost estimates
- Details of the relationship to other Chehalis Basin Strategy actions, such as a potential flood retention structure or other actions

1.4 Aquatic Species Restoration Plan Development

The ASRP is being developed by the Steering Committee and the SRT (committee members of both groups are listed in Appendix E). The Steering Committee directs the staff and technical work to develop the ASRP. Steering Committee voting members are representatives from the Washington Department of Fish and Wildlife [WDFW], Quinault Indian Nation, and Confederated Tribes of the Chehalis Reservation (Chehalis Tribe); non-voting ex-officio members are representatives from the Washington Department of Ecology (Ecology), Washington Department of Natural Resources (WDNR), and Chehalis Basin Lead Entity. The Steering Committee created the SRT to provide advice and assistance as it develops recommendations for the Chehalis Basin Board. Regular Steering Committee meetings are held to discuss ASRP development, and the voting members use a consensus model for decision-making. The participation and input of the Steering Committee ensures that the ASRP is based on a shared roadmap and established science.

The SRT was formed in 2017 to advise the Steering Committee. Considerations for the SRT typically include responding to questions from the Steering Committee, providing technical review of ASRP elements, identifying important scientific issues that need to be addressed, developing ASRP elements, and providing technical peer review of the ASRP products. Regular SRT meetings are held to discuss issues and develop guidance. SRT members were also part of groups that developed the *Scientific Foundation* and the *M&AM Framework* for the ASRP (Appendices A and B). The M&AM Team was developed as a subgroup of the SRT, with monitoring specialists from the region included. The Steering Committee also utilizes logistical, scheduling, and process development capacity from the Coordination Team. This group is composed of key staff and consultant capacity to ensure Steering Committee ideas and concepts are developed in a timely fashion and that coordination with the Office of Chehalis Basin within Ecology occurs on intersecting work elements.

There is an existing culture of improving ecosystems in the Chehalis Basin, and concerted efforts have been underway for the past 20 years to improve and protect habitat for aquatic species. With support from state and federal funding allocated to the basin through the Washington State Salmon Recovery Funding Board, $19 million has been put toward on-the-ground projects since 1999. These projects—involving extensive efforts by many people across a large geographic area—have been spearheaded by land trusts, the basin's fisheries' task force, counties, cities, tribes, conservation districts, non-governmental organizations, and state agencies. Project work has been completed by local contracting companies and often involves volunteer groups in planting trees, erecting signage, and educational activities. Local citizens and elected officials have frequently served on project review committees, ensuring that these projects align with local values and interests. Other funding sources have also been used to protect natural areas, address fish passage barriers on industrial forest lands and small forest ownership lands, improve stormwater quality, and educate basin-area youth about ways they can help salmon.

The ASRP builds on this existing culture and previous years of work; studies conducted by WDFW, Ecology, and others; peer-reviewed scientific literature and research; and findings from the *Aquatic Species Enhancement Plan*, its associated *Data Gaps Report*, and the *Effects of Flood Retention Alternatives and Climate Change on Aquatic Species* (ASEPTC 2014a, 2014b, 2014c), as well as the *Initial Outcomes and Needed Investments for Policy Consideration* document (ASRP SC 2017), into the framework and modeling efforts for the ASRP. Extensive research, mapping, assessments, and modeling specific to the Chehalis Basin were conducted and incorporated into the development of the ASRP. In 2018, the SRT conducted site visits to further assess conditions, and a Science Symposium was held to review research from Chehalis Basin scientists and receive input from local experts and practitioners. The *Scientific Foundation* in Appendix A further describes the scientific principles, assumptions, concepts, and primary approaches upon which the ASRP is based.

The ASRP is being developed with an eye to other ongoing governmental and non-governmental projects and programs (alignment with other programs will be detailed in the final ASRP document). Researchers and other technical experts are called upon to provide input and modeling that contributes to SRT discussions and Steering Committee direction. Implementing partners in ecosystem restoration and salmon recovery efforts in the Chehalis Basin have been important to this process and are vital to the success of the ASRP (these partners are listed in Appendix E). Additional information relative to implementation of the final ASRP will be developed during future phases. Other local groups and implementing parties will need to continue to be involved as the ASRP planning and evaluation process moves forward to ensure implementation success. The Chehalis Basin Board will then engage in a public process with tribes, local and state government agencies, and the broader Chehalis Basin community to develop recommendations for a long-term Chehalis Basin Strategy incorporating the ASRP recommendations. Recommendations are anticipated in 2020.

2 HISTORY, CURRENT CONDITIONS, AND FUTURE FOR THE CHEHALIS BASIN

This section summarizes important Chehalis Basin conditions—past, present, and likely future—that most affect aquatic species and are important to an understanding of the ASRP scenarios.

Ecosystem resiliency and sustained productivity of many wild, native aquatic species requires a network of complex interconnected habitats, which are created, altered, and maintained by natural ecosystem processes in freshwater, the estuary, and the ocean. Disturbance in watersheds due to fire, floods, and erosion were historically a part of these watershed processes. Over long periods, natural processes formed and reformed patterns of habitats for the different aquatic species.

Fundamental to understanding what conditions may be limiting ecosystem resiliency and aquatic species health and survival (presented in Section 1.3 and further discussed in Section 3 and Appendix A) is an assessment of how the watershed and its aquatic habitats have been changed over the past 200 years (Lichatowich et al. 1995) and an accurate evaluation of current conditions. The historical condition is used as a reference against which to compare current conditions and to understand the capability of the watershed to support multiple species. Even before extensive human-caused changes, inherent limitations existed on the aquatic species that the Chehalis Basin could support with the geologic, climatic, and environmental conditions, as well as the watershed process interactions that shape and maintain landforms and habitat.

Understanding how the watershed has changed from the historical condition and the current factors that limit the performance of aquatic species within the natural context of the watershed allows for an identification of where conditions have been most changed, what specific physical and chemical conditions now exist, what the limiting factors are for the performance of the species, and which restoration strategies and actions could be taken to address the limiting factors—and which are likely to have the most success. More details on historic and current conditions and limiting factors are included in Section 5.

Past, Present, and Future

The Chehalis Basin holds great promise when compared to other regions in the state where more significant degradation and ESA listings have already occurred and population and development pressures are greater. Opportunity still exists to avoid more intensive regulatory-driven recovery measures and act on our stewardship responsibilities in the Chehalis Basin to ensure a brighter future for native salmon and aquatic species, along with the communities who depend on and benefit from them.

The ASRP seeks to restore ecosystem processes and habitats in key parts of the Chehalis Basin. The ASRP does not attempt to restore the Chehalis Basin to historical conditions.

Re-establishing the historical condition is not the goal for the ASRP, but it is a valuable reference. The ASRP is expected to move the watershed toward the direction of the historical reference condition and restore habitat functions within the context of current and future land use, development, and climate change. An assessment of expected future conditions and resulting changes to aquatic habitats and species performance are also key to understanding the scale of protection and restoration that may be necessary to ensure the long-term health and resilience of the watershed. Without aggressive action taken immediately to reverse the current and future trajectory, model results project that anticipated climate change and habitat degradation will lead to a dire future for the ecosystems and species in the basin. The longer we wait, the harder it will be to change direction.

2.1 Historical Conditions

The most significant findings from assessing historical conditions are the following:

- Extensive floodplain wetlands and sloughs existed.
- Floodplains were dominated by a wide variety of plant communities, including mature forests consisting primarily of maple, Western red cedar, Sitka spruce, Douglas-fir, willow, cottonwood, alder, or Oregon ash; shrub communities consisting of willows, dogwood, vine maple, or spirea; beaver ponds and marshes with grasses, sedges, rushes, and aquatic plants; and both wet and dry prairies with oak woodland.
- River and stream channels were more winding, with multiple channels, compared to current conditions.
- River and stream channels were generally narrower and had lower banks than current conditions.
- Flooding occurred more frequently in most floodplain areas, and groundwater levels were higher.
- River and stream channels had large volumes of wood material and logjams, which split channels into smaller, narrower channels separated by forested islands.

These historical conditions differ from current conditions, described in Section 2.2, and relate directly to the quantity and quality of available aquatic habitat.

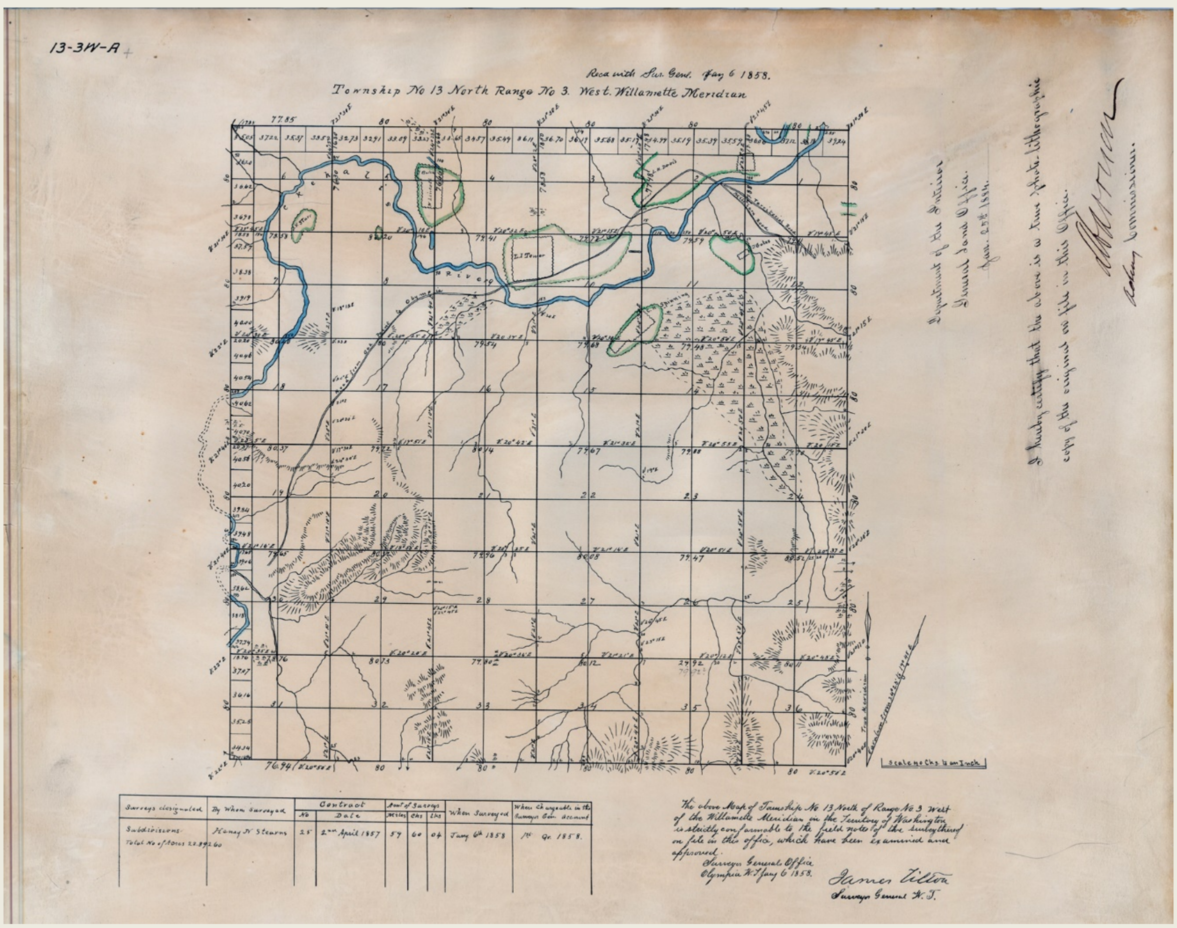
Methods Used to Assess Historical Conditions

General Land Office (GLO) maps and notes from the mid- to late 1800s provide a key source of information about the historical conditions of the Chehalis Basin. Light Detection and Ranging (LiDAR) imagery is another powerful tool for identifying historical geomorphic landforms, such as former river meander bends. Taken together, these data characterize the topography, hydrology, and ecology of the Chehalis Basin prior to widespread forest clearing, conversion to agriculture, and other impacts from settlement.

As part of the Chehalis Basin Strategy effort, Natural Systems Design (Abbe et al. 2016) and NOAA Northwest Fisheries Science Center digitized the GLO mapping to help quantify the types and quantities of historical aquatic habitats. These efforts have been used in the modeling used in the ASRP (EDT and NOAA modeling).

Watershed processes began to change with the rapid alteration of watersheds in the Pacific Northwest beginning about 200 years ago due to land use and development. Habitat-forming processes were typically changed in ways that adversely affected the abundance and survival of native aquatic species, such as salmon (Beechie et al. 2003). For example, removal of riparian forests has substantially reduced the input of large wood, other organic matter, and insects into streams. This reduces the complexity of instream habitats as large wood forms pools and traps sediments that provide spawning habitat. The reduction of organic matter and insects reduces the overall production of aquatic plants and invertebrates and reduces food available for fish and other species.

The SRT interpreted historical data to document assumptions of the channel lengths and areas of floodplain habitat that were assumed to be present in historical conditions. ASRP modeling efforts were directly informed by General Land Office (GLO) mapping from the late 1800s and interpretation of current Light Detection and Ranging (LiDAR) data that show remnant channels and other floodplain features. It is important to recognize that historical habitat conditions are not well documented—the GLO mapping was done for the purposes of documenting land claims and potentially suitable areas for agriculture and timber harvest. Thus, channel configurations, wetlands, and floodplain features are only partially described.



An example GLO map, which shows abundant wetlands along Stearns Creek.

Starting in the mid-1800s, emigrants moving westward began settling the Chehalis Basin. Key activities included converting prairie and other habitats to farms, harvesting timber, and constructing roads and buildings. Large wood was removed to facilitate navigation and transport of wood and other materials along the rivers. Splash dams were used to block channels and pond water for the temporary storage of logs; splash gates were then opened to release water and rapidly carry the logs downstream. The sudden release of water, combined with active practices to clear the channel of any logjams that could trap the logs en route to the mill, resulted in bed scour and channel incision. Research on the geomorphic legacy of splash dams in the Oregon Coast Range (where similar logging practices to those used in the Chehalis River watershed could be assumed) showed that splash dam releases were comparable to a 100-year flood in mainstem channels and exceeded the 100-year flood magnitude in headwater regions (Phelps 2011). Further details on historical conditions and changes are provided in Section 5.

2.2 Current Conditions

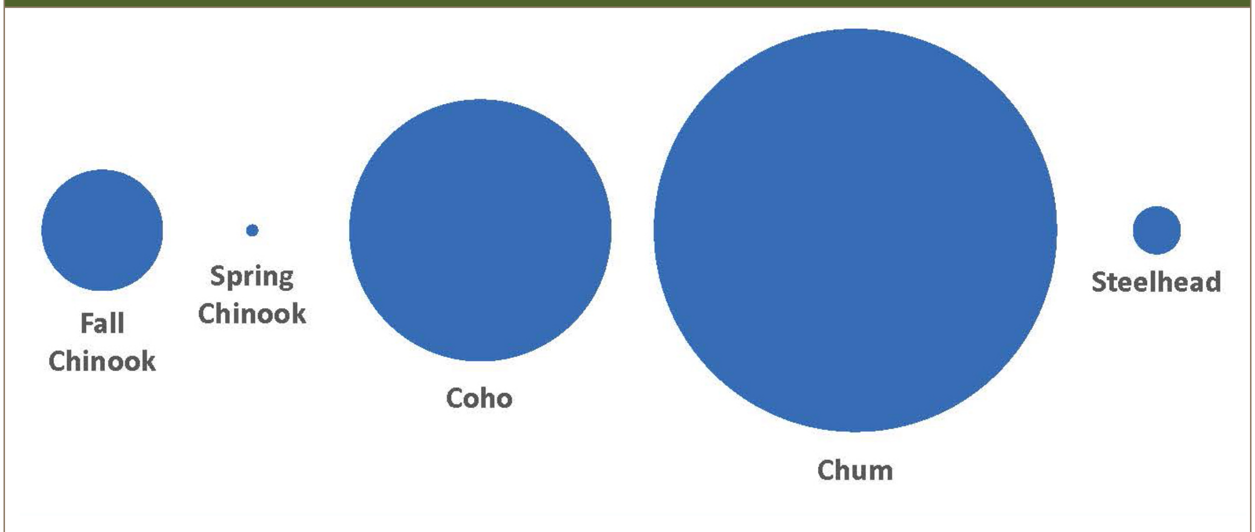
Over the past 200 years, numerous changes have occurred to watershed processes and functions. The Chehalis Basin still provides habitat for a large variety of fish and wildlife along the more than 3,400 miles of perennial streams and rivers, within the floodplain, and throughout the forestlands of the basin. Some of these fish and wildlife species are abundant, while others are ESA-listed as threatened or endangered (Oregon spotted frog, bull trout, green sturgeon, and Pacific eulachon), are federal species of concern (Pacific lamprey, Western toad, and Western pond turtle), or have state status (see Section 3 for more details). The basin is one of the few watersheds in Washington that does not have salmonid species (except for bull trout) listed under the ESA. While floodplain connectivity has been reduced throughout the basin, areas that retain some connectivity provide important habitats for the life cycles of many aquatic species. The basin supports seven species of salmonids, numerous other native fish species (including the endemic Olympic mudminnow), and the highest amphibian species richness in Washington (Cassidy et al. 1997). Existing anadromous and shellfish resources of the Chehalis Basin and Grays Harbor are of regional and national significance to tribal, commercial, and sport fishing.

Assessing the Current State of the Watershed and Its Habitats

A substantial amount of information has been assembled over the past several decades to characterize the current condition of aquatic habitats across the Chehalis Basin. Most notably, more recent assessments of habitat conditions have been done in large parts of the upper basin, including the mainstem Chehalis River, by WDFW, Anchor QEA, LLC, and Natural Systems Design, as described in the *Analysis of Salmonid Habitat Potential to Support the Chehalis Basin Programmatic Environmental Impact Statement* (McConnaha et al. 2017). Pierce et al. (2017) used aerial image analyses to determine changes in land cover in portions of the mainstem Chehalis River floodplain between 1938 and 2013. Additional assessment work on current conditions has been performed by NOAA Northwest Fisheries Science Center.

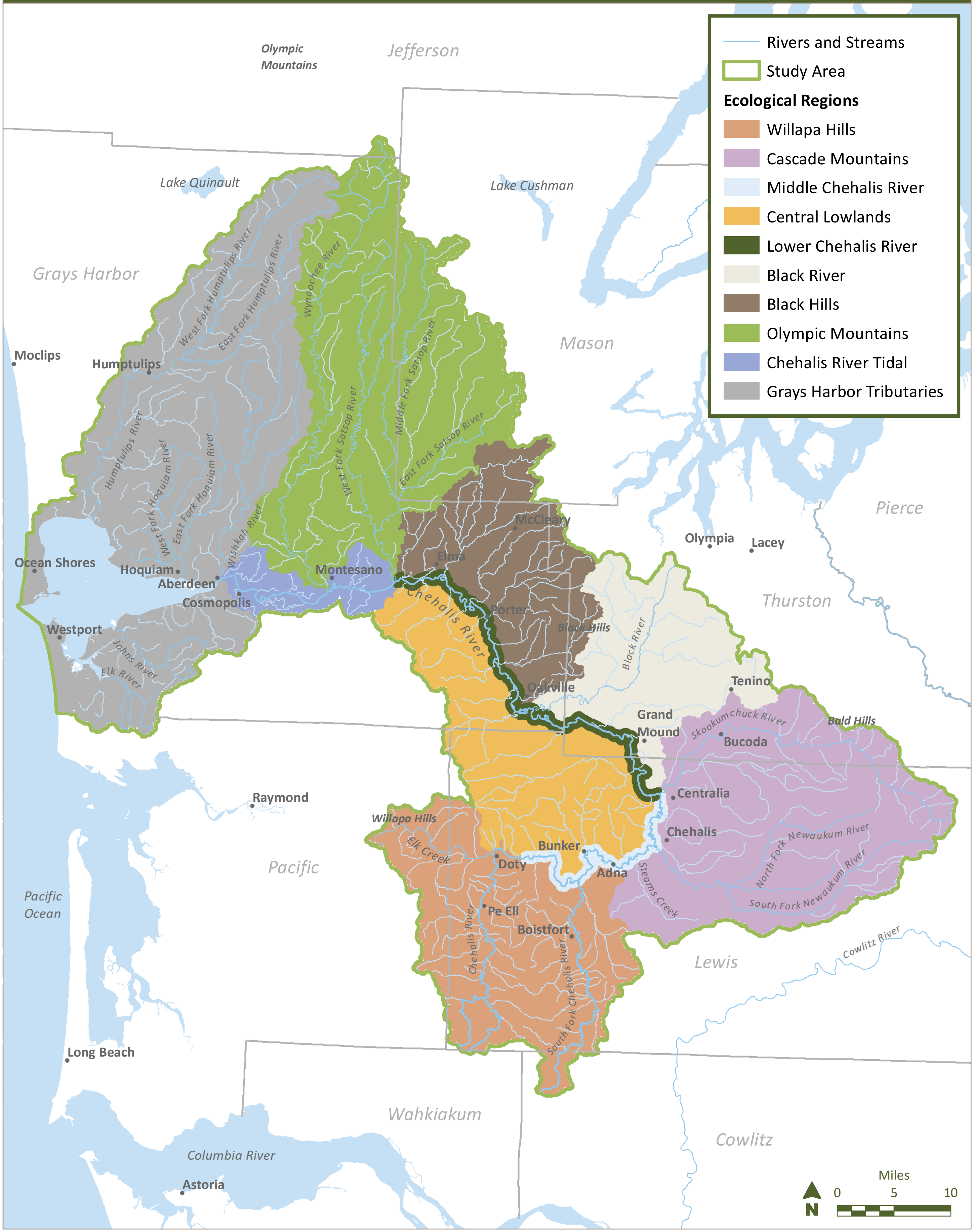
Although salmon run sizes are highly variable from year to year (both high and low returns), average runs display a significant long-term decline (Hiss and Knudsen 1993; PFMC 2019). Low returns of one or more species of salmon in several recent years have significantly limited tribal and non-tribal harvest to protect the most vulnerable species. The salmonid species rely on different key habitats throughout their life histories (see Section 3); thus, changes in the basin's habitats have affected the species in different ways. Figure 2-1 illustrates the relative potential of current habitat in the basin to produce salmon and steelhead. Some estimates indicate that the potential of existing habitat to produce salmon has been reduced by as much as 80% (ASEPTC 2014a) due to the loss or degradation of aquatic habitats.

Figure 2-1
Estimated Relative Potential Salmonid Abundance Based on Current Chehalis Basin Habitat



Because of the size and diversity of the basin, the ASRP uses the concept of ecological regions. Ecological regions are areas that have distinct geologic and hydrologic characteristics and processes; the boundaries around the ecological regions were drawn to group similar systems and habitat types together. Figure 2-2 shows the 10 ecological regions identified based on current ecological characteristics and processes—such as geologic, climatic, and topographic conditions. Characteristics of these 10 ecological regions are detailed in Section 5.

Figure 2-2
Chehalis Basin Ecological Regions



Human actions have had considerable impact on watershed processes in the Chehalis Basin. Like much of Southwestern Washington, the predominant land cover in the Chehalis Basin is still forestlands/grasslands/wetlands (80%), followed by developed lands and agriculture; however, most natural plant communities have been highly modified for timber production and other uses. The predominant land cover[2] in the floodplain of the mainstem Chehalis River in 2013 was agriculture (47%), forest canopy (33%), and development (4%). In the upstream (southern) portion of the Chehalis Basin above Pe Ell, the Chehalis River valley is relatively narrow with less natural floodplain area, and land use is predominantly managed timber lands. Major transportation infrastructure of statewide importance, including Interstate 5 (I-5) and the BNSF Railway Company and Union Pacific Railroad lines, cut through the middle of the basin within the floodplain. In much of the Chehalis Basin (except in the urbanized areas of Centralia/Chehalis), the mainstem Chehalis River valley is wide and predominantly agricultural. Many of the major tributaries to the Chehalis River also have extensive floodplains in their lower reaches with agricultural development. Aberdeen, Hoquiam, and Cosmopolis are located at the Grays Harbor estuary, where extensive alterations have been made to the estuarine habitats in those areas.

Current conditions related to quantity and quality of aquatic habitat in the Chehalis Basin and how it has changed from historical conditions are summarized as follows (additional details are provided at the ecological region scale in Sections 5.1 through 5.10):

- The construction of railroads, roads, and other development in floodplains and across rivers and streams has created fish passage barriers and disconnected many floodplain areas from the rivers.
- In the last few decades, the Chehalis Basin has experienced extreme flooding, which is damaging to human land uses and habitat stability, and extreme drought conditions (low streamflows during summer months), which has affected both water quality and flow.
- In areas dominated by agricultural lands that lack riparian forest cover, in cities, and in towns, water quality is impaired in many areas from runoff of various pollutants or from a lack of shading, and water quality is generally moderate to poor (Ecology 2018, 2015a; Anchor QEA 2014). The primary water quality parameters that are typically of concern in the Chehalis River are temperature, dissolved oxygen, pH, turbidity, nutrients, chlorophyll-a, and fecal coliform bacteria.
- Many miles of the mainstem Chehalis River have eroded below the channel's former riverbed elevation. As a result, the river is less frequently connected to its floodplain in many areas. "Incision" refers to the down-cutting of the river from high water velocities eroding bed sediments. It can be exacerbated by land use actions that constrain the river's natural meandering process, such as bank protection and levees, concentration of flow into a single channel with higher velocities, and the removal of fallen trees and wood from the channel that tend to slow velocities and erosion.
- In a natural context, instream large wood that helps reduce channel incision, trap sediments, and maintain side channels, pools, forested islands, and floodplains would be supplied from

[2] The land cover assessment by Pierce et al. (2017) assumed that all vegetation in the floodplain is either agriculture or canopy. The mapping quantified agriculture to include all herbaceous areas and half of the shrub/small tree areas. Canopy included all forested areas and half of the shrub/small tree areas. Development included built areas.

local bank erosion and channel migration into the riparian zone. However, with fewer and smaller trees in the riparian zone and floodplain, much less wood is currently supplied from these sources, and the wood is not large enough to remain in the channel during high flows (Abbe and Montgomery 1996; Collins et al. 2002; Beechie 2018). Recent flood events recruited wood from landslides and debris torrents in the upper Chehalis Basin and tributaries, but much of this was deposited in farm fields and other areas of the floodplain or was removed from the channel to minimize hazards to bridges and other infrastructure.

- Dams, such as those on the Wynoochee and Skookumchuck rivers, have reduced the natural sediment and wood supply to downstream reaches, promoting channel incision, which reduces the natural processes that form and sustain aquatic habitat; inundated many miles of salmon spawning and rearing habitat upstream of the dams, eliminating production from these habitats; and created barriers to fish passage and upstream and downstream movements.
- Land drainage (ditching, diking, and tiling), beaver trapping, and logjam removal vastly diminished groundwater recharge and the extent and quality of floodplain wetlands that once provided important rearing habitat for juvenile salmon and other native fish, amphibians, and reptiles.
- Degradation of spawning and rearing habitat has been caused by factors such as increased streambed scour and erosion and deposition of fine sediments, loss of channel complexity and floodplain and habitat connectivity, loss of riparian forests, land conversion, loss of in-channel large wood and logjams, wetland and swamp drainage, stream channelization, and water quality degradation due to increased summer temperatures.
- The spread of invasive plants and animals has impacted habitat structure, competition, predation, and species composition, impacting both aquatic and terrestrial ecosystems of the Chehalis Basin.

Scientific studies were conducted through the Chehalis Basin Strategy to better understand the presence and distribution of aquatic species and how the basin has changed over time. These included in-depth analyses of temperature, gradient, and presence of native and invasive fish, amphibian, and other aquatic species. During summer months, water temperatures were generally cooler in high-elevation upstream locations and warmed in a downstream direction. Fish assemblage patterns were directly tied to temperature; native salmonid species occupied upstream cooler locations, and the fish assemblage transitioned in a downstream direction to native minnow (cyprinid) species and finally non-native centrarchid species (Winkowski et al. 2018). This study suggests that in lower-elevation areas that are generally flatter, habitat is already degraded and hospitable to invasive species of fish. In addition, these areas have been modified for human development and intensive land uses due to their accessibility, which places more strain on the local aquatic species habitat. A study in progress includes an analysis of historic and current beaver distribution, which provides a vital lens into historic habitat conditions as well as landowner receptivity to beaver presence today.

Aquatic habitat throughout the Chehalis Basin has been extensively altered by humans since the 1850s through a variety of activities including agriculture, logging, gravel mining, dredging, dams, water diversions, transportation infrastructure, and point and non-point source pollution. Many of the earliest alterations were within the floodplain of the Chehalis River and certainly affected some of the more productive aquatic habitats. While settlers often received an initial benefit from the changes to the Chehalis Basin, construction of infrastructure within the floodplain exposed this infrastructure to damage and loss from flooding, and the resident tribes, fish, and wildlife were significantly impacted by these actions. Degradation of aquatic habitats is of particular concern because the salmonid species that are negatively impacted by this degradation have particular significance to the basin's cultures, communities, and economies.

2.3 Future Conditions

Future conditions in the Chehalis Basin will likely be affected by a range of factors, including climate change, human population growth, land use, and resource needs—all of which will exacerbate current problems and continue to contribute to an uncertain future for aquatic species. The following projections for several of these significant drivers of future conditions in the basin were incorporated into the modeling outcomes in this ASRP Phase 1 document:

- Future climate change (see Section 2.3.1) is projected to affect temperature, precipitation, and other factors that will further degrade habitat conditions and reduce the abundance of native aquatic species in the Chehalis Basin, which may jeopardize the continued existence of some species (Winkowski and Zimmerman 2019).
- Future development (see Section 2.3.2)—driven by human population growth and future land use changes—is projected to reduce forested land cover, increase fine sediment, increase streambed scour, and

Determining Expected Future Conditions and Resulting Impacts

In 2018, the University of Washington Climate Impacts Group used outputs from two global climate models and dynamically downscaled them to smaller geographic areas such as the Pacific Northwest, Washington, and specific watersheds. Climate change has been modeled for several categories (e.g., temperature, precipitation, and sea level) across three time periods for comparison: 1970 to 2015, 2016 to 2060, and 2055 to 2099.

WDFW developed a Thermalscape model as part of the assessment of water temperatures and native fish distribution to incorporate recent empirical data collected in the basin with the NorWeST predictions of future climate change (Winkowski and Zimmerman 2019). This model was extrapolated to account for water temperature increases with climate change in the basin tributaries to support ASRP modeling.

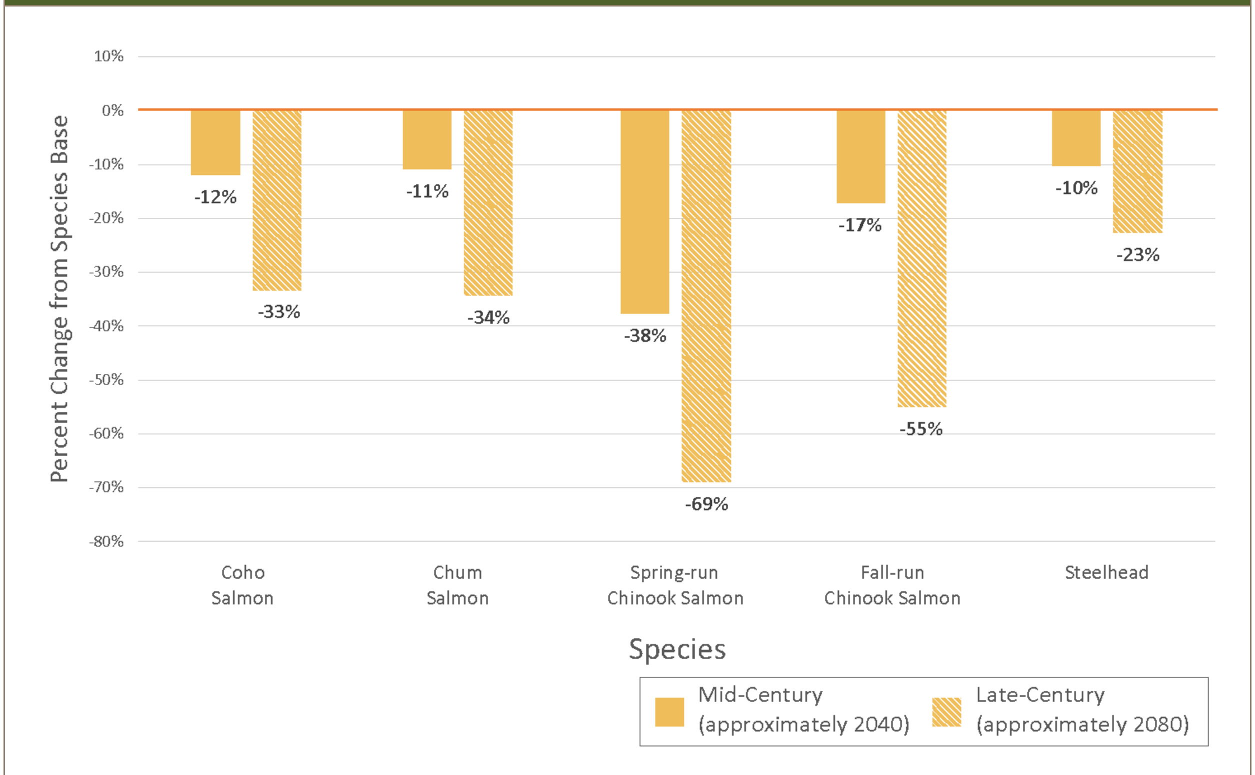
An exercise was also conducted to estimate locations and types of potential land cover changes resulting from future development that might occur by mid-century (2040). The locations and types of assumed potential development were based on planning by local governments under the Growth Management Act. Based on local comprehensive and future land use plans and maps, the percent of each Urban Growth Area (UGA) in the basin that would convert to another use/land cover type by 2040 was estimated. Outside of UGAs and managed forest areas, current habitat conditions were assumed to degrade by 5% by 2040 and by 10% by 2080.

Projected increases in water temperature and changes in both peak winter flows and low flows—as well as changes from development—have been translated into impacts on habitat conditions in the Chehalis Basin. These future changes, which are hypotheses, provide the basis for projecting effects on aquatic species performance using quantitative modeling. The future climate and development projections chosen for use in the models for the purpose of this analysis were agreed to by the SRT.

reduce riparian cover, thereby affecting stream temperature and other relevant habitat attributes.

These projected changes as a result of future climate conditions and future land use were incorporated into the No Action scenario in the EDT model to project future changes to salmonid populations. Modeling outcomes for the No Action scenario (Section 4) take into account the effects of these expected changes. Expected population declines for salmon species, as modeled in EDT, are shown in Figure 2-3.

Figure 2-3
No Action Scenario – Expected Change from Current Species Base



2.3.1 Climate Change

Because watershed processes are directly affected by climate, a change in climate can affect where and how people, plants, and animals live (e.g., based on food production, availability and use of water, and health risks). For example, a change in the usual timing and severity of rains or temperatures can affect when insects hatch or the frequency, magnitude, and timing of when streamflows are highest and when floods occur. This can affect the historically synchronized pollination of crops, food for migrating birds, spawning of fish, water supplies for drinking and irrigation, forest health, and more (Ecology 2015b). Temperature and precipitation changes can shift the composition of plant communities and change insect or disease occurrences within forests and farms, which could cause changes in animal communities (WDNR 2009).

Climate change has the potential to affect important variables throughout the Chehalis Basin, and climate change parameters were integrated into the models used for the ASRP to project well-informed future baseline conditions. Some important projections include the following:

- Increases in annual air temperature of 3.3°F to 9.7°F by 2070 to 2099 (compared to the period from 1970 to 1999) are projected. These increases are projected to be largest in the summer (Mote et al. 2014).
- Changes in quantity and timing of precipitation could translate into changes in streamflow magnitude and changes in the frequency of floods. Annual precipitation is projected to increase in both frequency and intensity in the winter, and peak flows are expected to increase on average by 12% by 2040 (mid-century) and by 26% by 2080 (late century) (Karpack and Butler 2019). Increased frequency and intensity of streamflow is likely to increase channel scour, which has a number of secondary effects (e.g., patterns of wood recruitment and stream substrate material distribution and channel incision). These flow changes can also destroy salmon and steelhead redds and reduce survival of rearing species such as coho salmon and steelhead. Summer precipitation is projected to decrease in magnitude by as much as 30% (Mote et al. 2014), decreasing base flows. Extreme daily precipitation events may increase up to 20%.
- Summer stream water temperatures are expected to increase because of increases in air temperatures and lower summer streamflows (Van Glubt et al. 2017). The increase in stream water temperatures would reduce the quality and quantity of freshwater habitat, especially for salmonid species that become stressed from high water temperatures (Mantua et al. 2010). Warmer stream temperatures in the future may positively impact invasive species currently present in the basin; this would cause additional stresses for native species (Winkowski and Zimmerman 2019).
- Changes in sea level would affect the extent of tidal influence and associated low-elevation areas. Sea level rise could result in the decline (in quality and extent) of coastal wetlands, tidal flats, and beaches (Mote et al. 2014). By 2025, sea level rise is projected to result in habitat transitions from forested freshwater tidal swamp to brackish and freshwater marsh in lower river surge plain areas, where rising water levels and increased saltwater intrusion would cause trees to die. In the inner estuary and greater Grays Harbor areas, there would be a loss of low-elevation tidal mud and sand flats (ASEPTC 2014a). Sea level rise would also inundate areas that are currently uplands, transitioning those areas to wetlands. Changes in habitat types and areas could reduce habitat for some native species and life history stages and favor other native or invasive species.
- Climate change would alter forests by increasing wildfire risk, increasing insect and tree disease outbreaks, and forcing longer-term shifts in forest types and species, such as to other species of conifers (e.g., pines) or deciduous tree species. Larger-scale shifts in plant communities could affect processes such as wood recruitment and transport and the formation of aquatic habitats. Climate change could also change what farm crops are suitable in the basin.

2.3.2 Potential Future Development

To anticipate habitat degradation resulting from changes in land cover as a result of future development, an evaluation was conducted to estimate where and what types of potential development might occur within the basin by the mid-century time frame (approximately 2040). Development that might occur was based on the planning that has been done by local governments, specifically comprehensive plans and future land use plan elements and maps. The resulting land cover changes were then used in the EDT model to represent the degree to which the change in land use could degrade habitat potential for salmon and steelhead. Key elements of the analysis include the following:

- The evaluation focused on geographic areas outside of managed forest areas.
- It is more difficult to predict rates or locations of development beyond the next 20 years with currently available information. Based on local Comprehensive and Future Land Use Plans and maps, the percent of each Urban Growth Area (UGA) that would convert to another use/land cover type by the mid-century time frame (approximately 2040) was estimated. No similar exercise was done within UGAs for the late-century time frame (approximately 2080).
- "Intensity scalers" were established by the SRT, which were used to represent the degree to which the change in land use would degrade various physical, chemical, and habitat parameters within the EDT model.
- Outside of UGAs, currently available information does not suggest how intense development will be or how it is likely to be distributed across the landscape. Although at this time the potential nature of future development cannot be quantitatively predicted or estimated, human population density is likely to increase and be detrimental to aquatic resources. For the ASRP analysis, the SRT recommended an assumption of habitat degradation of 5% in the mid-century time frame outside of UGAs and managed forests and of 10% in the late-century time frame in reaches outside managed forests. These degradation factors are in addition to the degradation estimated within UGAs as described previously.

2.3.3 Desired Future Conditions

The desired future conditions envisioned by the ASRP are based on the vision of providing healthy and harvestable salmon populations, robust and diverse populations of native aquatic species, and productive ecosystems that are resilient to climate change and human-caused stressors, while also honoring the social, economic, and cultural values of the region. To achieve the vision, the ASRP and the Chehalis Basin Strategy seek to provide the following:

- A substantial increase in the quantity and quality of aquatic habitats distributed throughout the Chehalis Basin and improvements in the natural processes that sustain these habitats, including the following:
  - Diverse and complex river and stream channel habitats such as clean spawning gravels, deep cold pools, and complex cover and in-channel structure from wood and riparian vegetation

- More frequent exchange and connectivity between the rivers and low-lying floodplains to increase off-channel habitats and wetlands and store and infiltrate floodwaters
- Restored riparian habitats including coniferous and deciduous forested areas and shrub and marsh habitats
- Restored wetlands and wet prairies to provide diverse habitat for many native aquatic species and improve water quality and water storage
- Accessible and connected habitats through removing fish passage barriers and improving floodplain habitat connectivity, as well as connections between aquatic and upland habitats
- Reduced water temperatures and increased water availability (increased flows during low flow periods) through increased groundwater and surface water connections, shading, and water conservation to benefit aquatic species and human uses and to reduce the effects of climate change
- A mosaic of high-quality habitats that are protected for future generations

Because there are ongoing stressors such as climate change, continued population growth and development, and the spread of non-native species that are continuing to degrade habitats and processes, the ASRP seeks to move quickly to address these and other factors that could prevent the realization of the desired future conditions.

3 AQUATIC SPECIES AND THEIR HABITATS

3.1 Potential Indicator Species

Species that serve as useful indicator species are ones that, because of their habitat utilization patterns or life histories, represent larger species assemblages and demonstrate habitat conditions important to those species (McGeoch 1998; Carignan and Villard 2002; Niemi and McDonald 2004). Because the ASRP is an ecosystem-based plan, indicator species serve to represent the broad range of aquatic habitats present in the Chehalis Basin and the natural processes that form and maintain these habitats. Table 3-1 lists the potential indicator species of fish and wildlife used to inform the restoration and protection strategy and action development for the ASRP. It is not generally intended that restoration actions be directed at an individual species but rather that restoration actions will promote physical, chemical, and biological conditions that support multiple indicator species. In addition to fish and wildlife species, the variety of plants that occur in the aquatic, riparian, and floodplain habitats of the basin play a major role in providing the structure and function of the habitats. While not described in this section as potential indicator species, plant species are noted as key components of the habitats used by the fish and wildlife species. The widespread distribution of invasive plant, fish, and wildlife species also affects the structure and function of the ecosystem and the productivity and survival of fish and wildlife species. Indicator species for the purposes of monitoring and adaptively managing the ASRP will be selected as part of the development of a comprehensive M&AM Plan in a future phase of the ASRP. Inclusion of key plant species as selected indicator species could be built into the M&AM Plan.

More detail on the scientific basis for using indicator species and their applicability to monitoring the success of the ASRP is provided in Appendices A and B.

Table 3-1
Aquatic Species Restoration Plan Potential Indicator Species

STANDARD ENGLISH NAME (COMMON NAME)	SCIENTIFIC NAME	STATUS[1]	HABITAT INTEGRATOR[2]
Winter-run steelhead	*Oncorhynchus mykiss*	None	AOT
Coho salmon	*Oncorhynchus kisutch*	None	AOT
Fall-run Chinook salmon	*Oncorhynchus tshawytscha*	None	AOT
Spring-run Chinook salmon	*Oncorhynchus tshawytscha*	None	AOT
Chum salmon	*Oncorhynchus keta*	None	AOT
Mountain whitefish	*Prosopium williamsoni*	None	AT
Eulachon	*Thaleichthys pacificus*	SGCN, FT, SC	AOT
Pacific lamprey	*Entosphenus tridentatus*	SGCN, FCO	AOT

STANDARD ENGLISH NAME (COMMON NAME)	SCIENTIFIC NAME	STATUS[1]	HABITAT INTEGRATOR[2]
Olympic mudminnow	*Novumbra hubbsi*	SS	AT
Speckled dace	*Rhinichthys osculus*	None	AT
Largescale sucker	*Catostomus macrocheilus*	None	AT
Riffle sculpin	*Cottus gulosus*	None	AT
Reticulate sculpin	*Cottus perplexus*	None	AT
Coastal tailed frog	*Ascaphus truei*	FFR	AT
Western toad	*Anaxyrus boreas*	SC, FCO	AT
Northern red-legged frog	*Rana aurora*	None	AT
Oregon spotted frog	*Rana pretiosa*	SE, FE	AT
Van Dyke’s salamander	*Plethodon vandykei*	FFR	
Great blue heron	*Ardea herodias*	SGCN	AOT
Barrow’s goldeneye	*Bucephala islandica*	SGCN	AOT
Wood duck	*Aix sponsa*	SGCN	AT
North American beaver[3]	*Castor canadensis*	None	AT
Western pond turtle	*Actinemys marmorata*	SE, FCO	AT
Western ridged mussel	*Gonidea angulata*	None	AT

Notes:

1. Species Status Key:
   SS: State Sensitive
   SC: State Candidate
   SE: State Endangered
   SGCN: Species of Greatest Conservation Need (WDFW 2015)
   FCO: Federal Species of Concern
   FT: Federal Threatened
   FE: Federal Endangered
   FFR: Forest and Fish Target Species
2. Habitat Integrator Key:
   AOT: Aquatic-Ocean-Terrestrial
   AT: Aquatic-Terrestrial
3. North American beaver is also a habitat engineer.

3.1.1 Salmonids

> **Salmonid Life Histories**
>
> **Anadromous:** Spawning in freshwater, juvenile rearing in freshwater and saltwater, migrating to saltwater for adult rearing
>
> **Resident:** Entire life history occurs in rivers and/or streams

Unlike other regions of Washington, none of the primary Chehalis Basin salmon and trout runs are listed under the ESA. Of the six runs present (fall-run Chinook salmon[*Oncorhynchus tshawytscha*], spring-run Chinook salmon, chum salmon [*O. keta*], coho salmon [*O. kisutch*], winter-run steelhead [*O. mykiss;* including freshwater resident rainbow trout], and coastal cutthroat trout [*O. clarkii clarkii*]), only spring-run Chinook salmon and coastal cutthroat trout appear to have not been augmented by hatchery releases. The other four runs either are currently or were historically augmented by hatchery releases. Life histories, habitat usage, and residency time of the Chehalis Basin's salmonids can differ greatly between and within species.

The Coastal/Puget Sound distinct population segment of bull trout (*Salvelinus confluentus*) is listed under the ESA as a threatened species, and critical habitat has been designated to include Grays Harbor and the lower Humptulips, lower Wishkah, lower Chehalis, Wynoochee, and Satsop rivers (USFWS 2010). Bull trout or native char have been documented within Grays Harbor (Sandell et al. 2014) and have been observed in the West Fork Humptulips River (Winkowski et al. 2018). WDFW has mapped bull trout on its SalmonScape website as present within the lower Humptulips, upper Wishkah, Wynoochee, and Satsop rivers (WDFW 2019). However, very little information exists for bull trout, and it is not known if they spawn within the Chehalis Basin. Bull trout have not been included as a potential indicator species for the ASRP.

The diversity of salmonid habitat use makes connectivity a critical issue for salmonid survival. Connectivity provides access to natal spawning grounds, the ability to move between different rearing habitats, and the opportunity to escape from adverse conditions such as high water temperatures, and it allows populations to recolonize areas after catastrophic events. The potential salmonid indicator species rely on different key habitats throughout their life histories, as summarized in the following paragraphs.

Chinook Salmon

The Chehalis Basin has both a spring-run and a fall-run of Chinook salmon, detailed as follows:

- Spring-run Chinook salmon enter freshwater as adults during spring and early summer. During the summer months, the adults hold in cool refugia, including tributaries and mainstem confluences (Liedtke et al. 2016), with spawning occurring in the upper basin (upper Chehalis, lower South Fork Chehalis, Newaukum, and Skookumchuck rivers).
- Fall-run Chinook salmon enter freshwater as adults from August through early November and spawn in fall shortly after the spring-run Chinook salmon, with a wider spawning distribution (lower Chehalis [Satsop to Skookumchuck rivers], upper Chehalis, lower South Fork Chehalis,

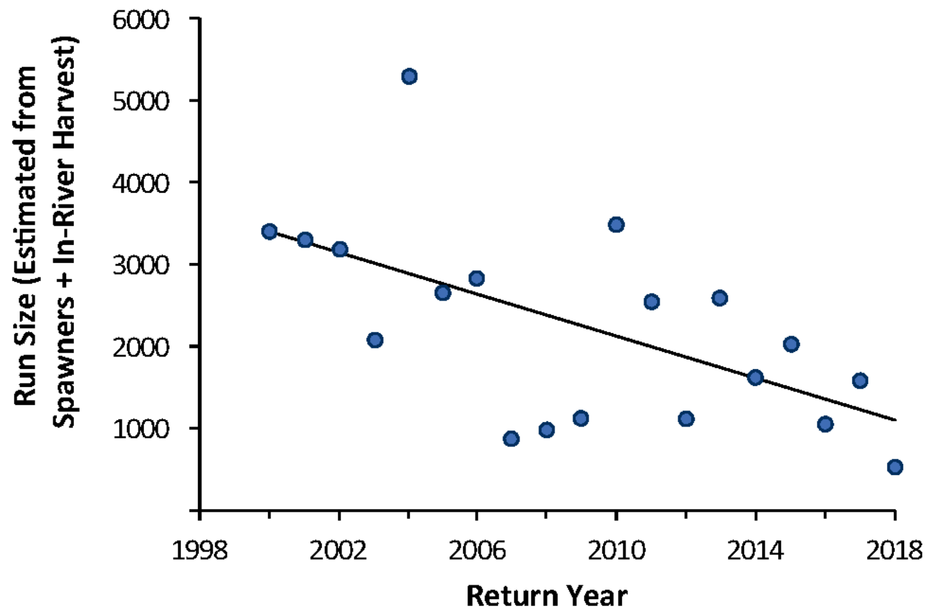
Newaukum, Skookumchuck, Satsop, Wynoochee, Wishkah, Hoquiam, and Humptulips rivers and some smaller tributaries).

Almost all Chinook salmon in the basin exhibit ocean-type life histories, and juveniles emigrate seaward within their first year; thus, Chinook salmon spend a moderate amount of time in freshwater compared to other salmonid species in the basin (several months). Both fall-run and spring-run Chinook salmon rely on estuarine habitats as they spend extended time feeding and growing in the estuary as juveniles prior to migrating to the ocean (Sandell et al. 2014; Bottom et al. 2011). Recent research in Grays Harbor indicates that Chinook salmon subyearlings are widespread throughout the estuary habitat, with continued growth prior to ocean entry (Sandell et al. 2014).

Spring-run Chinook salmon are particularly vulnerable to high water temperatures due to their migration timing and extensive holding (3 to 6 months) prior to spawning. Adults must hold during the summer months and find deep cold-water pools or other suitable cold-water areas. Shallow-water margin habitats along the mainstem Chehalis River are likely very important for juveniles for feeding during their downstream migration, as has been observed in other rivers (Beechie et al. 2005).

Differences between spring-run and fall-run Chinook salmon are actively being researched. Results of recent genetic studies on spring-run and fall-run Chinook salmon (Prince et al. 2017) have identified a genetic difference between the two runs. This new information illuminates a much higher risk for spring-run Chinook throughout the Pacific Northwest and the Chehalis Basin (Thompson et al. 2019). This genetic study work is continuing, and future results could have significant implications for the survival of the spring run and options for protecting and enhancing the spring run. Figure 3-1 shows the recent trends of spring-run Chinook salmon populations in the Chehalis River and highlights the downward trend, even though year-to-year abundance is highly variable. The lowest year on record was in 2018, and data from 2019 may show even lower numbers.

Figure 3-1
Trend in Chehalis In-River Wild Spring-Run Chinook Salmon Run Size Estimates



Note:
Figure adapted from Lestelle et al. 2019

Coho Salmon

Coho salmon spawn throughout the Chehalis Basin in both large and small sub-basins. They typically enter freshwater in mid- to late fall and spawn from late October through January. Coho salmon juveniles overwinter and migrate downstream as yearlings. Thus, high water temperatures affect rearing juveniles more than other life stages. Juveniles use side channels, beaver ponds, floodplain wetlands, and backwaters for overwintering and summer rearing when available. Fish that use off-channel and beaver pond habitats can have higher survival and overall production (Beechie et al. 1994; Reeves et al. 1989).

Juvenile summer habitat appears to be limited in the Chehalis Basin due to warm stream temperatures (Winkowski et al. 2018; Winkowski and Zimmerman 2019). The more complex the habitat, the greater the numbers of coho salmon juveniles that can be supported (Sandercock 1998). Streams with more structure (e.g., logs, rootwads, or undercut banks) support more fish not only because they provide more usable habitat but also because they provide more food and cover from predators (Scrivener and Andersen 1982). Large wood also traps coarser sediment for spawning grounds and supports nutrient cycling by trapping fish carcasses and leaf litter (Salo and Cundy 1987; Myers et al. 1998; Spence 1995). As coho salmon migrate downstream as smolts, they may feed in a variety of habitats, if accessible, such as off-channel wetlands, side channels, and tidal habitats.

Chum Salmon

Chum salmon spend less time in freshwater than other salmon species. Adults enter the river in the fall and spawn soon after, largely in Grays Harbor tributaries, lower Chehalis River tributaries, and the mainstem Chehalis River. Upon emergence from the gravel, fry immediately migrate downstream to the estuary (Salo 1998). Chum salmon are most dependent on high-quality spawning habitat, such as spring-fed channels, and estuarine habitats due to their short residence in freshwater.

Winter-Run Steelhead

Adult winter-run steelhead in the Chehalis Basin enter freshwater from late November through April and spawn in the spring months (March to June) primarily at 4 or 5 years of age as first-time spawners (Quinault Department of Fisheries [unpublished]). Steelhead are iteroparous (i.e., adults can spawn more than once). Fry emerge from the gravel in early summer and, in the Chehalis Basin, generally rear for 2 to 3 years in freshwater. Fry use low-velocity margin habitats after emergence and juveniles move into areas of fast water and large substrate as they grow. Similar to coho salmon, more structurally complex habitats (e.g., with more wood) can support more juvenile steelhead.

3.1.2 Other Native Fish

Mountain Whitefish[3]

Mountain whitefish (*Prosopium williamsoni*) spawning occurs in September through January (Wydoski and Whitney 2003). For rearing, mountain whitefish have been found to prefer deep (greater than 5 feet) medium or large rivers with minimal flow (Winkowski and Kendall 2018). In summer, adult mountain whitefish tend to occur in small groups in pools. Their densities are low in the Chehalis River compared to other resident trout species, and juvenile mountain whitefish are rarely sighted (Winkowski et al. 2018).

Pacific Eulachon

Pacific eulachon (*Thaleichthys pacificus*) is an important prey species for a variety of Pacific Northwest fish, marine mammals, and birds (Wydoski and Whitney 2003; Sigler et al. 2004). The species is anadromous, returning to spawn in freshwater from December to March (Wydoski and Whitney 2003). Spawning generally occurs in lower-gradient river reaches (Gustafson et al. 2010) in areas with coarse sand and gravel sediments (McLean et al. 1999; Wydoski and Whitney 2003; DFO 2004). The Chehalis, Humptulips, and Wynoochee rivers have been identified as supporting spawning runs of eulachon (Wilson et al. 2006). Persistent low spawning returns beginning in the mid-1990s prompted the 2010 listing of the eulachon southern distinct population segment (populations that spawn south of the Nass River, British Columbia) as threatened under the ESA.

Pacific Lamprey

Pacific lamprey (*Entosphenus tridentatus*) spawn and rear throughout the Chehalis Basin (Wydoski and Whitney 2003; Henning et al 2007; Jolley et al. 2016). Migration begins up to 1 year before spawning

[3] Mountain whitefish are salmonids, but they are discussed separately from the salmon and trout species in this document.

occurs (Wydoski and Whitney 2003). Pacific lamprey use deep pools for pre-spawning holding; however, they also use shallow water depths of 0.1 to 1.5 meter, bedrock crevices, and large boulders (Starcevich et al. 2014). Similar to anadromous salmonids, Pacific lamprey stop feeding upon entry into freshwater, and nests are generally located in riffles or pool edges of moderate- to high-flow streams (Moser and Close 2003), relying exclusively on stored nutrients until they spawn. Lamprey larvae drift and settle into slow-velocity habitats with fine substrates, where they reside as ammocoetes for 4 to 7 years before outmigrating to the ocean.

Olympic Mudminnow

Olympic mudminnow (*Novumbra hubbsi*) only occur in (i.e., are endemic to) Western Washington. The majority of their distribution is in low-elevation off-channel habitats of the mainstem Chehalis River and its larger tributaries (Mongillo and Hallock 1999; Wydoski and Whitney 2003). Olympic mudminnow is a state sensitive species. They prefer slow-moving streams, wetlands, and ponds with aquatic vegetation, muddy substrate, and cool water (Mongillo and Hallock 1999; Kuehne and Olden 2016). Population abundance decreases with an increase in predatory fish species (Beecher and Fernau 1982; Mongillo and Hallock 1999); the Olympic mudminnow detections in the Chehalis Basin appear to be aggregated in areas with cold springs (13°C to 15°C [55°F to 59°F]; Kuehne and Olden 2016) but were also widespread in off-channel habitats surveyed as part of the stillwater-breeding amphibian studies (Hayes et al. 2016). The loss of wetland and off-channel habitat for spawning and rearing and the presence of non-native predator species have likely had a significant impact on Olympic mudminnow abundance in the Chehalis Basin.

Speckled Dace

Although speckled dace (*Rhinichthys osculus*) are common throughout Washington, little is known about the current population in the Chehalis Basin. The species prefers colder water streams. Adults prefer larger substrate (cobble and boulder) in swifter currents, and juveniles prefer smaller substrate in low-velocity habitat (Winkowski et al. 2018; Andrusak and Andrusak 2011). Speckled dace are most frequently found in areas where they can find protection under overhanging vegetation or woody material (University of California 2019).

Largescale Sucker

Largescale sucker (*Catostomus macrocheilus*) is an endemic species to the Pacific Northwest and has been found in the mainstem and upper Chehalis, North Fork Newaukum, and West Fork and East Fork Satsop rivers as well as in several off-channel sites in the floodplain of the mainstem Chehalis River and its larger tributaries (Hughes and Herlihy 2012; Winkowski et al. 2016; Zimmerman and Winkowski 2016). The species is a bottom-dweller that prefers cooler, deeper water (greater than 5 feet deep; Winkowski and Kendall 2018).

Sculpin

Several species of sculpin occur in the Chehalis Basin, including the Coast Range (*Cottus aleuticus*), prickly (*C. asper*), shorthead (*C. confusus*), riffle (*C. gulosus*), reticulate (*C. perplexus*), and torrent (*C. rhotheus*) sculpin (Wydoski and Whitney 2003; Hughes and Herlihy 2012). Members of this genus are frequently difficult to identify to species and, as a result, two similar and co-occurring species—reticulate and riffle sculpin—were used to represent the grouping as potential indicator species. Both reticulate and riffle sculpin are generalists, using slow-water pools and riffles. The species breeds in the spring, with riffle sculpins building nests in rotting logs and reticulate sculpins spawning under rocks. Males from both species guard their nests until the fry emerge (Wydoski and Whitney 2003). Sculpins have been observed in the upper Chehalis River (Winkowski et al. 2016), the mainstem Chehalis River (Hughes and Herlihy 2012), and in off-channel floodplain and emergent floodplain wetland habitats of the middle and lower Chehalis River, including torrent, riffle, reticulate, and prickly sculpin (Hayes et al. 2016, 2019; Henning et al. 2007).

3.1.3 Amphibians

Coastal Tailed Frog

Coastal tailed frog (*Ascaphus truei*) is thought to be the most sensitive stream-breeding species primarily occurring in headwater streams (Adams and Bury 2002). Surveys conducted by WDFW in 2015 and 2016 indicate that the species may have a wider distribution at higher elevations and in forested sections of the Chehalis Basin system, primarily in headwater streams (Hayes et al. 2016). Coastal tailed frogs are nocturnal and rest under rocks in cold streams during the day, emerging at night to forage in streams and along streambanks for invertebrate prey (Nussbaum et al. 1983; Stebbins 1985). Coastal tailed frogs deposit their eggs on the underside of rocks in streams. Metamorphosis occurs 2 to 5 years later (Hallock and McAllister 2005); tadpoles graze on biofilms that include algae and seasonally pollen, whereas post-metamorphic stages (juveniles and adults) consume primarily insects (Nussbaum et al. 1983).

Western Toad

Western toad (*Anaxyrus boreas*) is a stillwater-breeding species that, in the Chehalis Basin system, breeds instream. It delays breeding until water levels are near base flow in early summer and then breeds either in stillwater pockets adjacent to mainstem channels or in the mainstem where shallow shelves exist and flow is extremely slow. Western toads are known to be present in the upper Chehalis, South Fork Chehalis, lower Newaukum, Wynoochee, and lower Satsop rivers (Hayes et al. 2016). Surveys in the Chehalis Basin have only found breeding to occur in unvegetated stillwater margins of larger rivers without canopy cover. Breeding was not observed in floodplain off-channel habitats that are known to provide breeding habitat in other basins. Natural hydrologic and channel migration processes maintain these open, shallow-water habitats. When not breeding, Western toads are found primarily in terrestrial habitats including grasslands, scrublands, woodlands, forests, and mountain meadows (Nussbaum et al. 1983; Stebbins 1985; Vander Haegen et al. 2001).

Northern Red-Legged Frog

Northern red-legged frogs (*Rana aurora*) occupy low-gradient riverine, floodplain, and lacustrine habitats, including freshwater marshes and wet meadows (Nussbaum et al. 1983; Stebbins 1985; Burke Museum 2019). Adult northern red-legged frogs move seasonally away from water when not breeding, a move that can frequently extend several kilometers (Hayes et al. 2008; Grand et al. 2017). They breed in late winter in permanent or long-hydroperiod stillwater habitats with some kind of aquatic vegetation, where the frogs consistently attach their eggs to a vegetation brace (Hayes et al. 2008). Within the Chehalis Basin, floodplain off-channel pond and marsh habitats provide very important habitat for northern red-legged frogs, but the presence of invasive fish species poses a significant threat to their occupancy (Holgerson et al. 2019) and, as a consequence, potentially to their survival.

Oregon Spotted Frog

Oregon spotted frog (*Rana pretiosa*) is listed as a federally and state threatened species with critical habitat designated in the Black River Ecological Region (USFWS 2016). Oregon spotted frogs have an entirely aquatic life history, are warm water adapted (requiring summer water temperatures that exceed 20°C [68°F]), and are found exclusively in perennial waterbodies including marshy edges of ponds and lakes or floodplain ponds connected to streams (USFWS 2016). Oregon spotted frogs are only known to be present in the Black River Ecological Region, occupying ponds and emergent wetlands. They breed in early spring in shallow water. Tadpoles use warm, shallow water with dense emergent and submerged vegetation (Lannoo 2005). Emergent wetlands without canopy cover, aquatic movement corridors, and limited non-native predator presence are primary elements of critical habitat for this species (USFWS 2016). The entirely aquatic lifestyle and warmer water requirements of Oregon spotted frogs likely explain their absence in mainstem Chehalis River floodplain off-channel habitats, where warm-water-adapted invasive species are abundant.

Van Dyke's Salamander

Van Dyke's salamander (*Plethodon vandykei*) is a cool-weather-adapted species, which in the Chehalis Basin headwaters is more frequent at higher elevations. Though the life history of this species is poorly understood, a recent literature review revealed that Van Dyke's salamander, the coolest-weather adapted of amphibians in Washington State, may be the species that is most vulnerable to climate change (Hayes et al. 2018). Van Dyke's salamanders in the Willapa Hills are typically not surface active when temperatures exceed 14°C (57°F), and individuals are almost always found in the moist riparian bands close to the wetted edge of a permanent stream.

3.1.4 Birds

Great Blue Heron

Great blue herons (*Ardea herodias*) are moderately abundant and widely distributed in the aquatic off-channel habitats in the Chehalis River floodplain and within the Grays Harbor estuary system (Hamer et al. 2017; Nisqually and USFWS 2016). The birds typically nest in large groups, with colonies containing up to 500 nests; because of this, great blue herons are highly vulnerable to disturbance, predation, and competition for nesting habitat (Azerrad 2012). For foraging habitat, herons are territorial and can use terrestrial, freshwater, and saltwater sites. Coastal herons prefer eelgrass meadows and estuarine systems for foraging on small fish and marine invertebrates, whereas interior herons usually feed in wetland complexes, large rivers, creeks, and lakes. Outside of the breeding season, foraging habitat is more diverse and herons can be found preying on small mammals in more terrestrial habitats.

Cavity-Nesting Ducks

Cavity-nesting ducks in Washington primarily nest in tree cavities previously created by other species or by natural decay or damage (Lewis and Kraege 2000). Cavities must include an entrance that is at least 3.5 inches in diameter, and most cavity-nesting ducks prefer larger trees (greater than 24 inches in diameter at breast height) near water habitats. Availability of wetland habitat for foraging and availability of suitable nesting sites are limiting factors for cavity-nesting ducks. The following two potential indicator species rely on different key habitats throughout their life histories:

- Barrow's goldeneye (*Bucephala islandica*) is a species that is generally representative of Chehalis Basin sea ducks. They prefer open-water habitat, with less reliance on vegetated brood escape cover than other cavity-nesting ducks (Lewis and Kraege 2000). Generally, sea ducks were the least abundant ducks found during waterfowl surveys conducted from 2015 to 2016 in the Chehalis Basin floodplain (Hamer et al. 2017).
- Wood duck (*Aix sponsa*) is a species that is generally representative of surface-feeding ducks. Forested and scrub-shrub wetlands are commonly used by wood ducks. Wood ducks use forested areas for nesting and roosting in trees and foraging for fruits and seeds (Fielder 2000). Wood ducks more commonly use deciduous trees with small cavity entrances, and these features are the main limiting factor for wood ducks when selecting suitable habitat. Nests also must be near slow-moving shallow water with many invertebrates, a main prey item for wood ducks. Wood ducks in the Chehalis Basin floodplain exhibit a positive relationship with open-water habitat with less wood and emergent vegetation, likely due to the proximity of available wooded nesting areas (Hamer et al. 2017).

3.1.5 Mammals

North American Beaver

North American beavers (*Castor canadensis*) have an important engineering influence on local hydrology (Naiman et al. 1988; Burns and McDonnell 1998) and the associated cascade of effects on instream, side channel, and adjacent riparian forest habitats (Pollock et al. 1995; Rosell et al. 2005). North American beavers are found along rivers and in small streams, lakes, and marshes. They prefer calm, deep water, but in areas where their preferred habitat is not available, they will create it by building dams across waterbodies and impounding water. Beaver dams create slow-water ponds and adjacent floodplain wetlands that retain sediment, increase groundwater recharge, and increase food web productivity (Pollock et al. 2003). Beaver ponds are important habitats for numerous fish and amphibian species. Surveys by WDFW during 2015 to 2016 suggest that beavers are widespread in the Chehalis Basin, but their distribution is not well documented.

3.1.6 Reptiles

Western Pond Turtle

Western pond turtles (*Actinemys marmorata*) inhabit marshes, sloughs, moderately deep ponds, and slow-moving sections of creeks and rivers (Holland 1994). The turtles require abundant aquatic vegetation and protected shallow areas where juveniles may rest and feed under cover. In Washington, they overwinter in upland habitats adjacent to waterbodies or in mud bottoms of lakes or ponds. Basking sites—such as partially submerged logs, vegetation mats, rocks, or mud banks—are a critical habitat requirement for Western pond turtles.

The species is believed to be functionally extirpated from the Chehalis Basin. WDFW surveys in the Chehalis River floodplain in areas with off-channel habitat features did not record any turtle observations (Hayes et al. 2016, 2019). However, not all potential habitat has been surveyed (e.g., only about 60% of the extensive off-channel habitats in the Chehalis River floodplain have been surveyed), so the possibility of occurrence cannot be excluded.

3.1.7 Invertebrates

Western Ridged Mussel

Freshwater mussel species have a parasitic larval stage that requires a host that is most often a specific fish species; their distributions reflect movement and colonization of their host species (Jepsen 2009; Nedeau et al. 2009). Western ridged mussels (*Gonidea angulata*) are found along bank edges in areas with stabilizing boulders and clay substrate and areas with fine sediments as well as gravels (Blevins 2018). Adult freshwater mussels live within or on the bottom of river or stream habitats, and they tend to concentrate in areas with consistent flows and substrate conditions. Freshwater mussel species are vulnerable to declines because they typically require good water quality, cannot rapidly evade changing environmental conditions, and have specific parasite-host relationships for their larvae that can be disrupted if the host fish is no longer present (Nedeau et al. 2009). Mussel beds can be occupied and persist for hundreds of years, providing an ongoing source of larvae into the larger watershed population. Mussels also filter substantial quantities of water and may reduce turbidity and nutrients in water. Their movements help stir the sediment and increase the exchange of oxygen that can benefit other macroinvertebrates (Nedeau et al. 2009).

4 AQUATIC SPECIES RESTORATION PLAN APPROACH

The ASRP vision (see Section 1.2) describes the desired outcome of actions to be undertaken as part of the ASRP. Guiding goals are introduced in Section 4.1, and the strategies and actions to achieve the ASRP vision are presented in Section 4.2.

A *Scientific Foundation* was developed early in the planning process to establish the scientific rationale and guiding principles for the plan and to instill confidence for the partners developing, implementing, monitoring, and adaptively managing the ASRP. The *Scientific Foundation* (Appendix A) describes the scientific principles, assumptions, concepts, and primary approaches upon which the ASRP is based. In summary, its sections describe the following:

- **Foundational Principles** includes general principles for scientific practice and conservation-related principles such as how aquatic species life histories and productivity are tied to the ecosystem.
- **Foundational Assumptions** includes how species success is linked to the quality and quantity of habitat and how their success has been affected by historical land alterations and will be affected by future climate and continued land development.
- **Foundational Concepts** describes the use of potential indicator species, viable salmonid population metrics, and the role of habitats in supporting the wide variety of life history needs for the species.
- **Basis for Developing Strategies and Actions** describes the rationale and scientific basis for the recommendations in the ASRP.
- **Adaptive Management, Monitoring, and Evaluation** speaks to the importance of systematic disclosure and transparency regarding uncertainties, data management, and decision-making. A separate *M&AM Framework* (Appendix B) was developed in Phase 1, and a full M&AM Plan will be completed in Phase 2.

4.1 Aquatic Species Restoration Plan Goals

Goals have been developed for the ASRP to guide the development of the strategies and actions and the development of restoration scenarios. Following this draft ASRP document, measurable criteria or objectives will be developed in coordination with the development of a preferred restoration scenario and the full development of the M&AM Plan. The M&AM Plan will focus on the collection of data that directly address the measurable objectives. The guiding goals for future development of the objectives are as follows:

- Protect and restore natural habitat-forming processes within the Chehalis Basin watershed context.
  - Protect and restore natural riverine processes including channel migration, sediment and wood transport, and floodplain connectivity.
  - Protect and restore riparian processes and functions including cover, shade, inputs of large wood, leaf litter and insect inputs to the aquatic food web, sediment and erosion functions, nutrient and pollutant trapping and filtering, and floodplain processes.
- Increase the quality and quantity of habitats for aquatic species in priority areas within the Chehalis Basin.
  - Significantly increase quality of and access to instream habitat for aquatic species (including habitat needs for migration, reproduction, rearing/feeding, and overwintering habitats).
  - Protect and enhance existing functioning core habitats for species across their life history trajectories.
  - Increase habitat complexity and diversity.
  - Protect and restore native riparian, floodplain, off-channel, and wetland habitats.
  - Minimize suitability for invasive species within instream and riparian habitats.
- Protect and restore aquatic species viability within and across the Chehalis Basin considering viable species population parameters.
- Increase watershed resiliency to climate change by protecting and improving natural water quantity and timing characteristics and water quality characteristics.
- Build recognition of and support for ASRP actions and the ways the ASRP supports resilient human communities (via elements such as water conservation, floodplain preservation, citizen science participation, centralized data, and other features).

4.2 Strategies and Actions

The ASRP is structured around the following five strategy categories—described in in Sections 4.2.1 through 4.2.5—determined important to the recovery of aquatic species and achieving the ASRP vision:

- Habitat and Process Protection
- Restoration
- Community Planning
- Community Involvement
- Institutional Capacity

> **Actions will only be conducted where there is voluntary agreement by the landowners—success of the ASRP is dependent on creating a successful collaboration with private landowners.**
>
> Farmers and other landowners play an important stewardship role in the basin. Their leadership is urgently needed to support healthy fish populations and the long-term prosperity of working lands.
>
> Landowners serve as stewards of the basin's resources. The plan recognizes private property rights, and restoration will only occur where there is voluntary participation. While participation is voluntary, incentives for participating landowners are available to encourage the larger-scale participation needed across the basin.

It is important to note that the strategies are interconnected, and for the ASRP to be successful, all of the strategies need to be implemented in ways that are mutually supportive. For example, the ability to protect or restore habitat is critically dependent on community planning, and only community-supported efforts can ensure success. Successful protection of existing habitat will require directed community planning efforts, and successful implementation of restoration will require voluntary actions of landowners in a much more significant way than in other existing programs. This integration of strategy implementation through the ASRP would involve changes to "business as usual," and the only way for this to succeed is through community-supported efforts.

Given this complexity, not all strategies have been assessed to the same extent for this ASRP Phase 1 document. Phase 1 focuses on identifying the restoration and protection actions and the level of restoration necessary to achieve desired outcomes, including identifying and assessing three restoration scenarios that represent different approaches and investment levels. Future phases will provide more in-depth descriptions of the mechanisms needed to fully implement the other three strategies—community planning, community involvement, and institutional capacity. The Steering Committee has identified and is assessing various potential actions for these strategies. Future phases of ASRP development will assess and refine the actions for the ASRP scenario chosen to be carried forward.

Each strategy in Sections 4.2.1 through 4.2.5 is first described with an overview statement (highlighted in a callout box) of what is included in the strategy category and the rationale behind the strategy. Major actions are identified in general bullet lists to represent the significant actions that could be included under the strategy category. The implementation of each of these actions would include a wide range of detailed considerations that will be developed further during future phases of the ASRP for the chosen scenario. A description of what the implementation of each strategy would likely entail is also included with each of the strategy categories. Where available, specific actions from these sections are further recommended at the scale of each ecological region in Section 5.

4.2.1 Habitat and Process Protection

> Protect ecosystems, unique habitats, and strategic areas that currently support critical ecosystem functions and native aquatic species.

While the ASRP is called a restoration plan, actions to protect existing ecosystem processes and aquatic habitats are a vital part of restoration and thus are key to the plan. To see improvement for key aquatic species and potentially avoid future declines, focused protection will be needed to prevent the loss of existing habitats important to aquatic species and ecosystem processes. This effort will require close partnerships with landowners, and multiple approaches could be used to ensure that the existing benefits are maintained. These actions could include voluntary stewardship planning, incentives to landowners, and revised best management practices (BMPs), as well as other creative programs devised by local governments and community/private/government partnerships.

Habitat protection could also occur by working with land trusts and other entities using a combination of easements, land acquisitions, water rights purchases and leasing, water conservation promotion, and other developed tools. Programs that potentially could be developed specifically for ASRP implementation include long-term lease incentives, community forests or cooperative forests, transfer of development rights, public benefit reduced taxation, conservation futures, and other types of incentives.

Protection actions will be implemented concurrently with restoration actions (see Section 4.2.2); however, additional protection actions will also be required to protect the habitat of salmon and other aquatic species. Protecting existing high-quality habitats can be more effective than restoring degraded habitats in most cases, and it can be a successful strategy in implementing the ASRP.

The following habitat and process protection actions have been identified:

- Develop and promote voluntary stewardship participation in habitat protection.
- Support existing tax incentives and develop additional incentives to landowners to maintain forests on their lands.
- Develop incentives for channel migration and floodway protection.
- Develop cooperative relationships with working lands (such as farming and commercial forestry) to enable protection of ecosystems, unique habitats, and critical ecosystem functions.
- Develop opportunities with commercial timber landowners to promote financially beneficial options for longer forest rotations (e.g., larger size timber for restoration).

- Protect against degradation from development in areas identified as sensitive or unique habitats.
- Ensure that BMPs for activities like road maintenance, utility construction, and streamside activities effectively protect species and habitats.
- Provide resources and support for the enforcement of current regulations intended to provide protection for aquatic species and habitats.
- Acquire property or development rights through easements for areas that have unique or extremely high value for species or ecosystem processes.
- Implement programs that protect and enhance flows in rivers and streams.

Priority Protection Areas

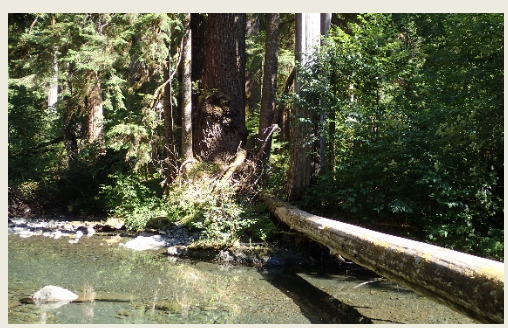
Many lands throughout the Chehalis Basin provide important ecosystem processes and high-quality habitat for aquatic species but could be subject to future degradation. Any future loss of resources diminishes the ability of ASRP actions to achieve the projected outcomes for aquatic species—thus driving the importance of protection actions. A number of these areas were identified through a compilation of available scientific and geographic information, SRT discussion of areas and habitats important for protection, and input from local biologists. Threats to ecological function at those locations were then identified through a review of existing local comprehensive plans and critical areas regulations. The anticipated loss of habitat and ecosystem processes from climate change, population growth, and human activities was estimated, and these expected changes were also incorporated into modeling to analyze potential future conditions and outcomes of the restoration and protection scenarios (see Section 7 for expected outcomes).

General priority protection areas and features were identified based on the current level of knowledge of high-quality habitats and potential threats (Table 4-1). It is likely that core habitats identified for salmon and steelhead overlap with other native

Critical ***ecosystem functions*** are the physical, chemical, and biological cycles that create and maintain suitable conditions for plant and animal life and are supported by the ***natural processes*** through which water, sediment, and organic matter flow to form and sustain habitats for plants and animals. As examples, the processes of erosion and sediment transport can form and reform habitats for aquatic species, and plants along the water's edge provide nutrients and insects that support the aquatic food web.

Core habitats are the areas that currently have characteristics and natural processes that are highly productive and currently stable for the species of interest and are used year after year by these species.

Unique habitats and features are areas with natural processes and habitat characteristics that are not widely available or are more easily damaged. The unique habitats and features of interest may support rare species with specific core habitat requirements, or they may provide a natural process with a function that is particularly threatened by climate change, human population growth, land use, or resource needs.



Intact mature native riparian areas are one of the unique habitats and features that are a priority for protection.

fishes such as mountain whitefish and Pacific lamprey; however, other native fishes were not included because there is currently a lack of a clear understanding of their core habitats. As research continues, these areas will likely be identified. Further investigations are recommended in this strategy to locate additional areas and specific parcels and features for protection priority in the future. The ASRP, as it is further developed, will continue to identify and recommend actions to effectively protect and reduce threats to priority land types and habitats.

Table 4-1
Protection Priority Areas

UNIQUE HABITATS AND FEATURES
Glacial outwash and deposits with unique porous soils for groundwater infiltration and discharge of cold water to streams
Rare wet and dry prairie habitats
Cold-water inputs into the Chehalis River from key tributaries and groundwater flows and existing cold-water refugia
Intact mature native riparian areas
Headwater lakes and ponds in the Cascade and Olympic mountains that have a unique amphibian assemblage
Tidal surge plain habitats in the Chehalis, Hoquiam, Wishkah, and Humptulips rivers

CORE HABITATS FOR AQUATIC SPECIES[1]	
Upper Chehalis River (above Pe Ell), including the East Fork and West Fork Chehalis rivers and other major tributaries	• Core habitat[2] for fall-run Chinook salmon, coho salmon, steelhead (spawning and summer rearing) • Highest density of Western toad in the basin • Northern red-legged frog • Former stronghold for spring-run Chinook salmon
Upper Chehalis River headwater streams	• Important for stream-breeding (e.g., coastal tailed frog) and riparian-breeding (e.g., Van Dyke's salamander) amphibians • Most diverse assemblage of amphibians in the basin
Elk Creek	• Relatively intact floodplain with mature trees and beaver ponds within a managed forest context • Supports relatively high populations of coho salmon and steelhead for the size of the stream
Skookumchuck and Newaukum rivers	• Core habitat for spring-run Chinook salmon and coho salmon (Newaukum and Skookumchuck rivers) • Cold water and overwintering habitats in all forks of the Newaukum River (and key tributaries)
Black River and key tributaries (including Beaver, Allen, and Dempsey creeks)	• Core habitat for Oregon spotted frog (emergent wetlands) and Olympic mudminnow • Unique glacial outwash and wetland system • Area still supports a relatively high population of coho salmon • Historically healthy population of chum salmon
East Fork Satsop River and its tributaries (including Dry Run, Dry Bed, Decker, and Bingham creeks)	• Core habitat for Western toad, coho salmon, chum salmon, fall-run Chinook salmon, and resident trout • Unique glacial deposits and large wetland systems with extensive groundwater, providing key cold water inputs

CORE HABITATS FOR AQUATIC SPECIES[1]	
	• Could experience future development that would exacerbate climate change effects such as reduced flows and increased water temperatures
Mainstem lower Satsop River and lower East Fork Satsop River	• Core habitat for coho salmon, chum salmon, steelhead, and fall-run Chinook salmon (spawning, holding), as well as Western toad
Middle Wynoochee River (particularly RMs 28 to 48)	• Core habitat for coho salmon, chum salmon, steelhead, and fall-run Chinook salmon
Lower Wynoochee River	• Core habitat for Western toad
Headwater lakes in Wynoochee, West Fork Satsop, and Skookumchuck river sub-basins	• Unique amphibian assemblages and species diversity
Mainstem lower Chehalis River off-channel wetlands and wet prairies	• Core habitat for North American beaver, northern red-legged frog, Olympic mudminnow, Barrow's goldeneye, and common goldeneye
Chehalis Tidal Zone	• Large areas are protected but should be expanded where feasible because it is an important migration corridor for all salmon species with important tidal rearing habitats and waterfowl habitats • Important climate change and sea level rise adaptation area
East Fork and West Fork Humptulips rivers	• Core habitat for coho salmon, chum salmon, steelhead, and fall-run Chinook salmon • West Fork Humptulips River has some of the most intact habitat in the basin, with mature riparian forest within the Olympic National Forest and substantially cooler summer temperatures compared to other sub-basins

Notes:
1. See Sections 5.1 through 5.10 for more details on these unique habitats and features.
2. Core habitats are those areas that are highly productive and currently stable for the aquatic species and are used year after year.

Recommended Actions to Protect Unique and High-Quality Habitats

Methods for advancing protection of these important ecological areas and reducing the threat of degradation are identified at a programmatic scale in the following bullets (specific protection priority areas are discussed in more detail at the ecological region scale in Sections 5.1 through 5.10):

- **Cold-Water Inputs (Groundwater, Springs, Cold Tributaries, Seeps)**
  - Maintain forest cover for aquifer recharge and stream shading.
  - Limit impervious surfaces and groundwater withdrawals in critical recharge areas.
  - Protect key groundwater watershed areas surrounding the West Rocky Prairie and other key glacial wetland locations.
- **Seasonally Dry Glacial Deposit Streams**
  - Protect aquifers through limiting impervious surfaces and groundwater withdrawals.
  - Protect forest canopy cover in watersheds.

- **Floodplain Wetlands and Prairies**
  - Focus regulations and incentives to maintain connectivity between rivers and floodplains and maintain frequent flooding.
  - Provide incentives to maintain and expand riparian buffers.
  - Provide education to landowners on the benefits of beavers and incentives to encourage them to allow beavers.
  - Limit impervious surfaces and groundwater withdrawals.
  - Provide invasive species management and additional research to promote best practices.
- **Headwater Streams**
  - Protect key areas and experiment to promote sediment retention, water temperature reductions, and water storage.
  - Work with timber landowners to promote longer forest harvest rotations to protect headwater streams in key areas.
  - Provide incentives to forest landowners to maintain large wood within stream channels.
- **Areas of Intact (or Less Modified) Hydrologic Processes**
  - Purchase or lease water rights to protect instream flows.
  - Use acquisitions or easements to protect channel migration.
  - Promote retaining forest cover and using longer harvest rotations.
  - Provide incentives to forest landowners to maintain large wood within stream channels.
  - Enhance fish passage into existing protected municipal watersheds (e.g., Hoquiam and Wishkah rivers).
- **Key Spawning Areas and Gravel Sources**
  - Protect natural channel migration processes and existing instream wood.
  - Provide incentives to maintain and expand riparian buffers.

4.2.2 Restoration

Restore ecosystem functions to support native aquatic and semi-aquatic species.

ASRP Phase 1 efforts have focused on identifying the restoration actions necessary to achieve desired outcomes. These actions were devised to address both short- and long-term habitat needs. Short-term actions focus on instream and floodplain actions to enhance the complexity and connectivity of the river channel as well as riparian actions to enhance riparian function in the future. Long-term actions assume that functioning riparian zones would continue to enhance the complexity and connectivity of the river to its floodplain over time through natural processes. Specific actions include the following:

- Remove human-caused barriers to fish passage.
- Reconnect off-channel and floodplain habitats.

- Restore habitat-forming processes through measures such as large wood installation to scour pools, trap sediments, and promote side channels.
- Restore self-sustaining forested riparian zones and processes.
- Re-create key habitat features such as beaver ponds and side channels.
- Remove and/or relocate infrastructure and buildings at a high risk of flooding from restoration actions.
- Integrate experimental features and monitoring into restoration actions to learn the most effective elements for restoring habitats and processes.

A key element necessary for developing a restoration plan is to strategically prioritize where restoration actions should occur to provide the greatest potential for success in improving natural processes and ecosystem resilience and increasing habitats for aquatic species. This ASRP Phase 1 document includes a strategic prioritization and has identified three restoration scenarios and actions aimed at achieving the ASRP vision. These scenarios represent different approaches and investment levels. A final restoration scenario will be developed as the proposed restoration plan for the final ASRP following stakeholder and public review of this ASRP Phase 1 document.

To support the prioritization process, the SRT organized the basin into 10 ecological regions based on the underlying geology, topography, climate and hydrologic regime, and channel morphology (see Section 5). The ecological regions are further subdivided into 93 sub-basins containing 180 geospatial units (GSUs) to facilitate identifying and prioritizing areas for restoration. A GSU is typically a major segment of a river or may be an entire small tributary sub-basin. Refer to Appendix C for additional information and a map of Chehalis Basin GSUs.

The SRT provided recommendations for the strategic prioritization informed by the following:

- Technical research conducted for the Chehalis Basin Strategy to date, including studies, mapping, and fish passage barrier assessments conducted by WDFW, Ecology, and others
- Current and historical knowledge and expertise through presentations and input from Chehalis Basin scientists and practitioners
- Pertinent historical data and mapping for the Chehalis Basin
- The EDT salmon habitat model
- Baseline information from the NOAA model
- On-the-ground observations and analyses by the SRT
- Chehalis Basin-specific climate change modeling projections

Table 4-2 summarizes the core areas and habitats for the potential indicator species and key areas that provide the best opportunity to improve species' performance and increase spatial distribution and diversity. This information was used to develop the restoration scenarios that are evaluated in this ASRP Phase 1 document.

Table 4-2
Potential Indicator Species' Habitat Areas (Not All Species Are Included)

SPECIES OR ASSEMBLAGE	CORE HABITAT AREAS TO PROTECT AND ENHANCE	SECONDARY HABITAT AREAS WITH HIGH POTENTIAL FOR RESTORATION	HABITAT AREAS TO EXPAND DISTRIBUTION WITH RESTORATION	KEY ISSUES
Spring-run Chinook salmon	Cascade Mountains, predominantly the Skookumchuck and Newaukum river sub-basins	Willapa Hills, upper Chehalis River, South Fork Chehalis River	Middle Chehalis and upper Skookumchuck rivers (above Skookumchuck Dam)	Water temperatures, cold-water holding pools, spawning separation from fall-run Chinook salmon, poaching, estuary habitat, non-native predators, restricted distribution
Fall-run Chinook salmon	Willapa Hills (upper Chehalis River), Cascade Mountains, Lower Chehalis River, Olympic Mountains, Grays Harbor Tributaries (East Fork and West Fork Humptulips rivers)	Middle Chehalis River, South Fork Chehalis River, Black Hills, lower Humptulips River	Middle Chehalis, Black, upper Wynoochee, and Skookumchuck rivers	Spawning habitat, shallow margin and off-channel rearing, tidal and estuary habitat, non-native predators
Coho salmon	Willapa Hills, Cascade Mountains, Lower Chehalis River, Olympic Mountains, Grays Harbor Tributaries	Lowland streams including Black Hills, Stearns Creek, Hanaford Creek, Elk Creek, South Bay tributaries	Central Lowlands, Black Hills, wetland prairie systems	Floodplain wetlands, off-channel habitats, beaver ponds, non-native predators
Chum salmon	Olympic Mountains, Grays Harbor Tributaries	Black River, Lower Chehalis River	Black Hills, Central Lowlands	Spawning habitat, habitat diversity, estuary habitat
Steelhead	Willapa Hills, Olympic Mountains, Grays Harbor Tributaries	South Fork Chehalis River, Newaukum River, Black Hills, Wynoochee River	Black Hills, South Bay tributaries	Hatchery influences, instream habitats, habitat diversity, water temperature
Olympic mudminnow	Lower Chehalis River and low-gradient areas of the Cascade Mountains, Black River, Black Hills, Olympic Mountains, Grays Harbor Tributaries	Middle Chehalis River	Central Lowlands	Low-velocity and off-channel habitats, non-native predators

SPECIES OR ASSEMBLAGE	CORE HABITAT AREAS TO PROTECT AND ENHANCE	SECONDARY HABITAT AREAS WITH HIGH POTENTIAL FOR RESTORATION	HABITAT AREAS TO EXPAND DISTRIBUTION WITH RESTORATION	KEY ISSUES
Mountain whitefish	Widespread in Chehalis Basin	Not known	Not known	Fish passage barriers, spawning habitat
Pacific lamprey	Widespread in Chehalis Basin	Not known	Not known	Fish passage barriers, water quality, spawning habitat, low-velocity rearing habitat
Eulachon	Chehalis River Tidal, Olympic Mountains, Grays Harbor Tributaries	N/A	N/A	Water temperatures, industrial discharges
Stream-breeding amphibians (particularly coastal tailed frog)	Willapa Hills, Olympic Mountains	Cascade Mountains	Black Hills	Riparian condition, groundwater, coarse substrate
Western toad	Willapa Hills, Olympic Mountains, Grays Harbor Tributaries	Middle Chehalis River, Cascade Mountains	Further extent in all occupied sub-basins	Hydroperiod, channel migration and scour, shallow water margins
Stillwater-breeding amphibians (particularly northern red-legged frog)	Lower Chehalis River, headwaters	Chehalis River Tidal (freshwater areas)	Middle Chehalis River, lower-gradient areas of Olympic Mountains, Black River, Central Lowlands	Off-channel habitats, predators, invasive species, natural hydroperiod
Riparian-breeding amphibians (particularly Van Dyke's salamander)	Willapa Hills, Olympic Mountains	Cascade Mountains	Cascade Mountains	Riparian condition, groundwater, local water table
Oregon spotted frog	Black River tributaries	Expanded areas of Black River	Expanded areas of Black River	Emergent wetlands, invasive species, stable hydroperiod
North American beaver	Throughout basin	South Fork Chehalis, Newaukum, Skookumchuck, and Lower Chehalis rivers	Lowland areas of Central Lowlands, Black River, and Black Hills	Lack of riparian zones, human/beaver conflicts (tolerance for localized ponding/flooding)

SPECIES OR ASSEMBLAGE	CORE HABITAT AREAS TO PROTECT AND ENHANCE	SECONDARY HABITAT AREAS WITH HIGH POTENTIAL FOR RESTORATION	HABITAT AREAS TO EXPAND DISTRIBUTION WITH RESTORATION	KEY ISSUES
Waterfowl potential indicator species	Lower Chehalis River, Chehalis River Tidal	Middle Chehalis River	Floodplain areas of Cascade Mountains, Black River, Olympic Mountains, and Grays Harbor Tributaries	Floodplain wetlands, native emergent species
Freshwater mussels (particularly Western ridged mussel)	Middle Chehalis River, Cascade Mountains	Olympic Mountains	Expand within existing core areas	Water temperature

4.2.2.1 Development of Restoration Scenarios

The *Initial Outcomes and Needed Investments for Policy Consideration* document (ASRP SC 2017) identified two potential scales of restoration (medium and high) that could achieve significant improvements to aquatic species habitats in the face of climate change. During that phase of ASRP development, there was interest in considering a broader range of scales of restoration and developing a restoration plan more targeted to high-priority areas where restoration was most needed and likely to be effective. Thus, three scenarios were developed in consideration of the following primary questions:

1. Where do the potential indicator species occur in the basin?
2. Which ecological regions currently support the highest abundances and/or distribution of the potential indicator species, and how do the ecological regions compare for each species (or group of species)?
3. What is the relative importance of protection and restoration measures by species within each ecological region?
4. What are the most critical issues (or limiting factors) to be addressed within each ecological region (or GSU), both now and projected into the future?
5. What are the priority actions to be considered in addressing the limiting factors in each region for each species?
6. What is the relative importance of the different segments of the mainstem Chehalis River to each species?

While considering these questions, the importance of protecting and improving (as needed) the core habitat areas for each species was highlighted. Secondary to protecting the existing highly productive habitats is the need and potential to restore habitats in areas where a species may still occur but is declining or otherwise negatively affected by reduced habitat conditions. Lastly, some species have been locally extirpated from areas in which they formerly occurred, so restoring habitat in these areas is also important to expand the distribution and provide resiliency to climate change and other future risks.

In this Phase 1 of the ASRP, new scales of scenarios were built out, generally encompassing known information about the distribution and habitat needs for all of the potential indicator species. It is important to note that these scenarios build upon each other (e.g., Scenario 2 incorporates all the elements of Scenario 1 and then includes restoration of secondary habitats; Scenario 3 incorporates all the elements of Scenario 2 and includes restoration to expand the distribution of the species.) The Phase 1 scenarios follow these key themes:

- **Scenario 1:** Protect and enhance core habitats for all aquatic species. Restoration is proposed to occur on approximately 222 miles of rivers.
- **Scenario 2:** Protect and enhance core habitats and restore key opportunities. Restoration is proposed to occur on approximately 316 miles of rivers.
- **Scenario 3:** Protect and enhance core habitats, restore key opportunities, and expand spatial distribution. Restoration is proposed on approximately 450 miles of rivers.

These scenarios were then modeled using both EDT and NOAA models, both of which were tailored to the ASRP and incorporate a substantial amount of new information (Appendix C) to help inform consideration of whether the scale of restoration proposed by these scenarios is sufficient to achieve the ASRP vision. While the restoration scenarios considered in this document are of unprecedented scale in Washington State, it is important to note that 222 to 450 miles of restoration is only about 10% of the basin's perennial stream miles.

4.2.2.2 Restoration Scenarios

The scenarios identify the appropriate geographic locations to conduct restoration activities, and an evaluation of the limiting factors for the aquatic species in the basin informed the type of restoration actions that should occur. These actions were devised to address both short- and long-term habitat needs. Short-term actions focus on instream and floodplain restoration actions to enhance the complexity and connectivity of the river channel as well as riparian restoration actions to enhance riparian function in the future. Over the long-term, it is assumed that if protected to maturity, the riparian areas would continue to enhance the complexity and connectivity of the river channel through natural processes. It is important to stress that the restoration would occur with participation of both public and private landowners to achieve the substantial outcomes needed. Specific restoration actions under this approach include the elements described in the following subsections and summarized in Table 4-3. More details on specific recommended actions and locations are provided in Section 5.

Removal of Fish Passage Barriers

An ongoing collaborative effort is identifying numerous human-built barriers that are blocking fish access to substantial areas of quality upstream habitats throughout the basin. Under the scenarios evaluated, between 200 and 450 of these barriers would either be removed or replaced with appropriately sized culverts or bridges, or improvements to some existing fish ladders, to provide long-term fish passage for native fish at all life history stages, accommodate flood flows and sediment and wood transport, and prevent barriers from reforming in the future (Table 4-3).

An example of a fish passage barrier.

Restoration of Floodplain Habitats

Due to historical land use changes, many floodplain habitats important to a range of aquatic species have become degraded and disconnected from rivers within the Chehalis Basin. In many areas, impediments to channel migration and floodplain connectivity could be removed (such as riprap bank protection). In other areas, the river channels are incised, and placement of stable large wood structures could promote floodplain connectivity by maintaining and increasing flows into off-channel habitats and retaining gravel and smaller wood, halting and reducing channel incision over time. In some parts of the basin, floodplain connectivity is constrained by land uses, and more active reconnection (excavation) of floodplain habitats—such as side channels, oxbows, and wetlands—may be necessary. These actions are intended to substantially increase the quantity and quality of these important habitats. Under the evaluated scenarios, restoration of the 222 to 450 miles of river channels would include features to actively or passively reconnect floodplain habitats (primarily in areas outside of managed forests, 125 to 250 miles of the restored channel areas).

Restoration of Riparian Corridors and Processes

Riparian corridors provide multiple functions and processes for aquatic species, including shading to maintain cool water temperatures, recruitment of large wood to form a variety of in-channel and off-channel habitats, inputs of nutrients and insects to the aquatic food web, normalization of erosion and sediment deposition, reduction of pollutant runoff from adjacent areas, and provision of wildlife habitat. Riparian corridors would be restored by invasive species control and riparian plantings in priority areas outside of managed forests; widths and species composition would vary depending on the size of the river, the geomorphology of the restoration site, and infrastructure and landowner constraints, but they could range from an average of 500 feet (per side) on large rivers to 100 feet (per side) on small rivers (Table 4-3). Corridor widths are intended to encompass space for ongoing channel migration and riparian growth and were conservatively developed for cost estimates. The restoration of riparian corridors would occur over a range from 125 to 250 miles of rivers, depending on the scenario ultimately selected. Since most of the land is privately owned, voluntary landowner agreements and potential incentive options for land use conversions will be necessary for the restoration actions at the scale proposed.

Within managed forests, stream channel migration zones and riparian areas are protected through the Forest Practices Act (76.09 RCW). However, many of the riparian zones currently protected are relatively young (20 to 30 years old) and are dominated by deciduous species. Over time, these riparian areas will mature and provide increasing function. Supplemental riparian restoration within managed forests could be a need and an effective restoration action in some areas.

Restoration of Large Wood in Rivers

Because the natural recruitment of wood from restored riparian corridors will take many decades to be fully achieved as trees mature, the strategy includes installing stable large wood (both as individual pieces and logjams) in priority river reaches to jump-start natural processes throughout the basin. These actions would occur in conjunction with the restoration of riparian corridors outside of managed forests. Within managed forests where Forest Practices Rules (Washington Administrative Code [WAC] 222-08) already require the protection of riparian buffers and

An example of a stable engineered large wood structure.

channel migration zones, large wood would be installed with minimal other actions, although some supplemental riparian restoration could also be included. Large wood promotes key processes and habitats, such as reducing water velocities, reducing channel incision, promoting floodplain and groundwater connectivity, and forming deep pools and side channels; trapping and sorting sediments and smaller wood; and providing cover for aquatic species, nutrients to the food web, and habitat for invertebrates. Large and stable key pieces would be installed as engineered logjams, multipiece structures, or single logs along approximately 220 to 450 miles of rivers, depending on the scenario selected (Table 4-3). Large wood installation would be designed to minimize risk to public safety and infrastructure.

Restoration of Wetlands and Lakes

To specifically restore habitats for key life history stages of native amphibians and other aquatic plant and animal species in the short term, creation and reconnection of depressional wetlands in floodplain areas are included in this strategy. These wetlands provide seasonal habitat for amphibian egg-laying and juvenile development. Removal of invasive aquatic animal species from some glacial outwash lakes is also included to reduce predation and competition with native amphibians and non-salmonid fishes and bolster their populations and distribution in the short term. Since removal of invasive aquatic species is expensive and labor intensive, this element will only be targeted for specific locations where it is likely to be effective.

All of these restoration actions are proposed within each scenario. Table 4-3 summarizes the proposed restoration actions and scale of treatment within the scenarios.

Table 4-3
Restoration Actions and Level of Treatment for the Scenarios

ACTION	APPROXIMATE TREATMENT LEVEL[1]	APPROXIMATE MILES	APPROXIMATE ACRES
Remove Fish Passage Barriers	• 200 to 450 fish passage barriers	200 to 440 with improved accessibility	N/A
Actively Restore Floodplain Habitats	Per 2 miles of other restoration elements: • One side channel/oxbow • One floodplain wetland	125 to 250	2,500 to 5,000
Restore Riparian Corridors and Processes	Riparian width goals[2,3] (each bank) in feet: • Large rivers: 500 • Medium rivers: 300 • Small streams: 100	125 to 250	9,600 to 15,000
Install Large Wood	Key pieces per mile: • Large/medium rivers: 65 • Small streams: 175	220 to 450	N/A
Restore Other Aquatic Habitats	• Create depressional wetlands in the floodplain • Remove invasive species from glacial outwash lakes	N/A	N/A

Notes:
1. Treatment levels identified were developed to inform costing assumptions and for use in modeling.

2. Corridor widths are intended to encompass space for channel migration and still maintain a riparian zone; widths will be scaled as appropriate to specific locations based on geomorphic conditions, infrastructure, and landowner constraints.
3. Large rivers: greater than 30 meters (97 feet) bankfull width; medium rivers: 10 to 30 meters (33 to 97 feet) bankfull width; small streams: 0 to 10 meters (0 to 33 feet) bankfull width.

Ponds—such as those associated with beaver dams—benefit hydrology by storing runoff and allowing water to slowly enter groundwater or other waterbodies and by creating wetland and pond habitats that provide high-quality juvenile salmonid rearing habitat.

A ***beaver dam analog*** is a restoration tool to create a low and semi-porous wood structure to mimic a beaver dam.

Figures 4-1, 4-2, and 4-3 illustrate the three scenarios. The restoration actions listed previously in this section are proposed for all of the scenarios. For this document, fish passage barriers have not been ranked, but for costing purposes, fish passage barrier removal is included within the priority areas for each scenario and a few additional sub-basins with substantial barriers. In-channel large wood placement would occur both as engineered logjams and individual pieces (depending on stream size); riparian restoration, floodplain reconnections and restoration, and wetland restoration would occur in all priority areas for each scenario. Placement of beaver dam analogs in small- to medium-sized streams may be an appropriate action to encourage beaver use and mimic natural beaver ponds that were historically widespread in small streams throughout the basin. Beaver dam analogs and large wood can also work in conjunction with one another in larger streams to provide more diverse habitat and encourage beaver colonization. In the mainstem Chehalis River and in the lower South Fork Chehalis River, more intensive land uses make restoration along longer reaches much more difficult. Instead, restoration is proposed to focus on “nodes” of habitat that would include a large floodplain site (approximately 150 acres) on one bank of the river and could include restoration of large remnant oxbows with up to 1 mile of instream habitat. The node concept could also apply to other rivers and reaches in the basin where longer restoration reaches are not feasible.

Table 4-4 summarizes the proposed GSUs within each scenario and the proposed miles of restoration on the primary streams and rivers within each GSU. The GSUs were created as manageable units for modeling and evaluating restoration opportunities (generally 5- to 30-mile reaches, representing the major forks of larger rivers or representing entire small sub-basins). Thus, the GSUs do not all include their tributaries (some GSUs were created specifically to include all tributaries to a larger river reach—for example, “Lower Wynoochee River Tributaries”).

Figure 4-1
ASRP Scenario 1, Protect and Enhance Core Habitats

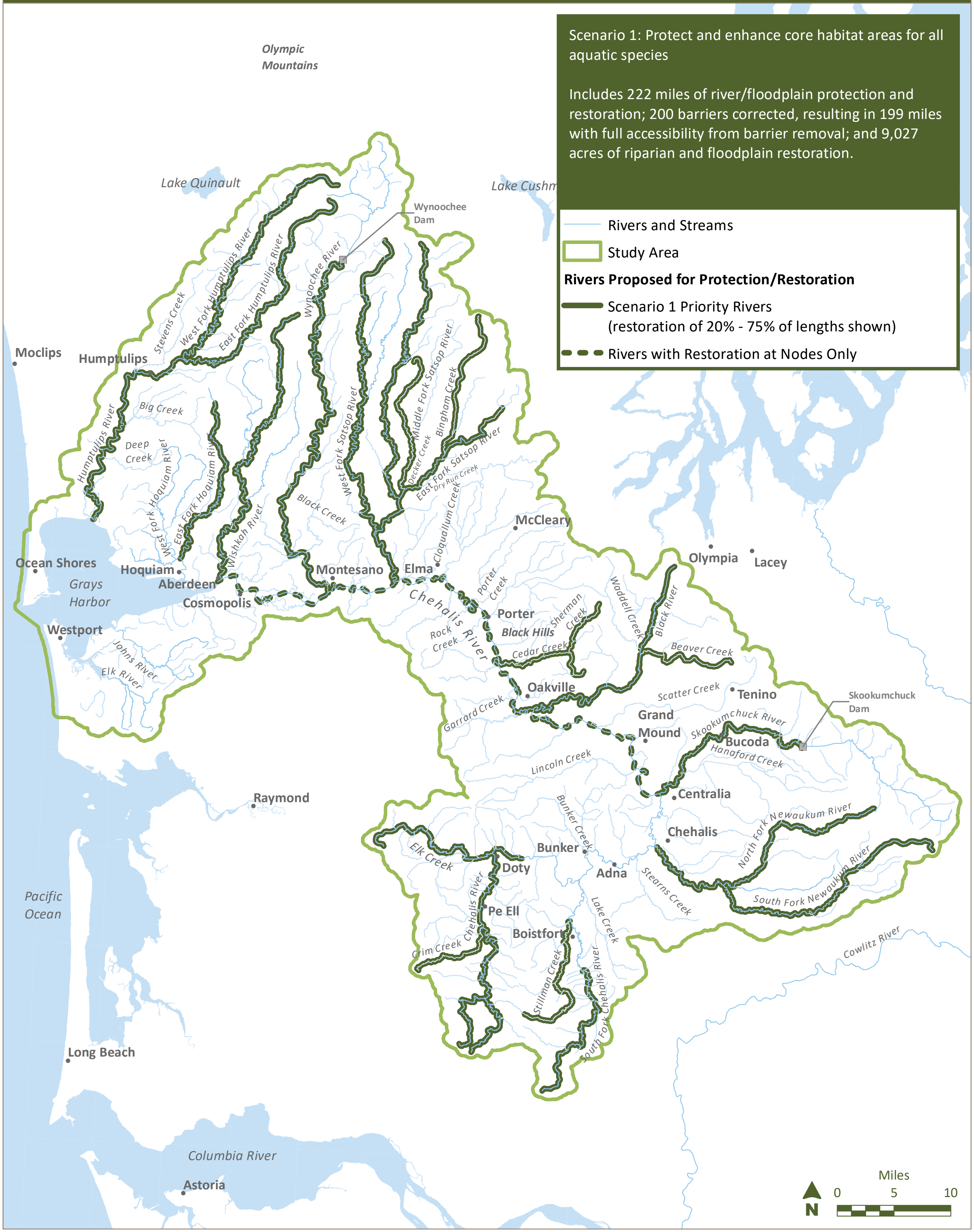


Figure 4-2
ASRP Scenario 2, Protect Core Habitats and Restore Key Opportunities

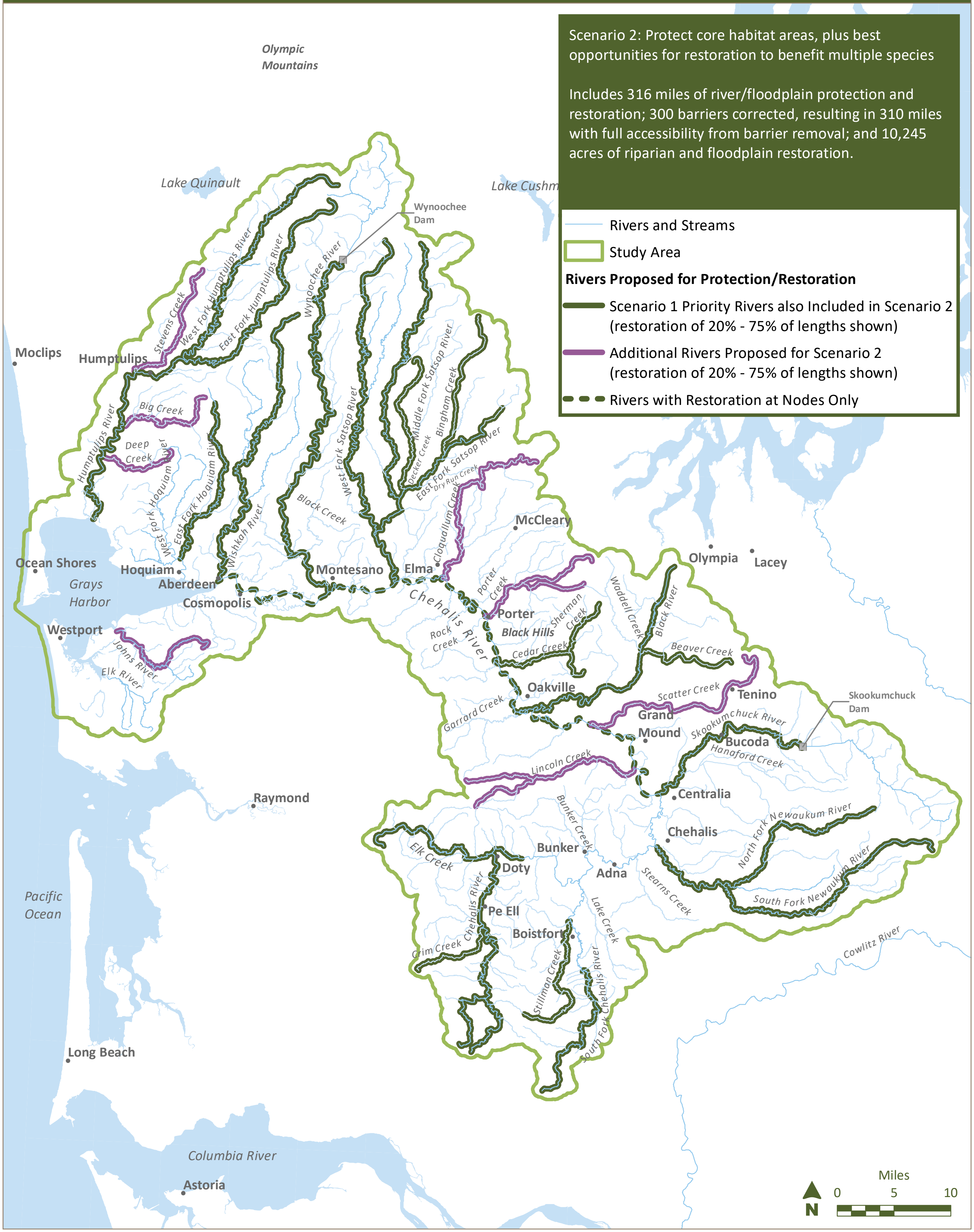


Figure 4-3
ASRP Scenario 3, Protect Core Habitats and Expand Distribution

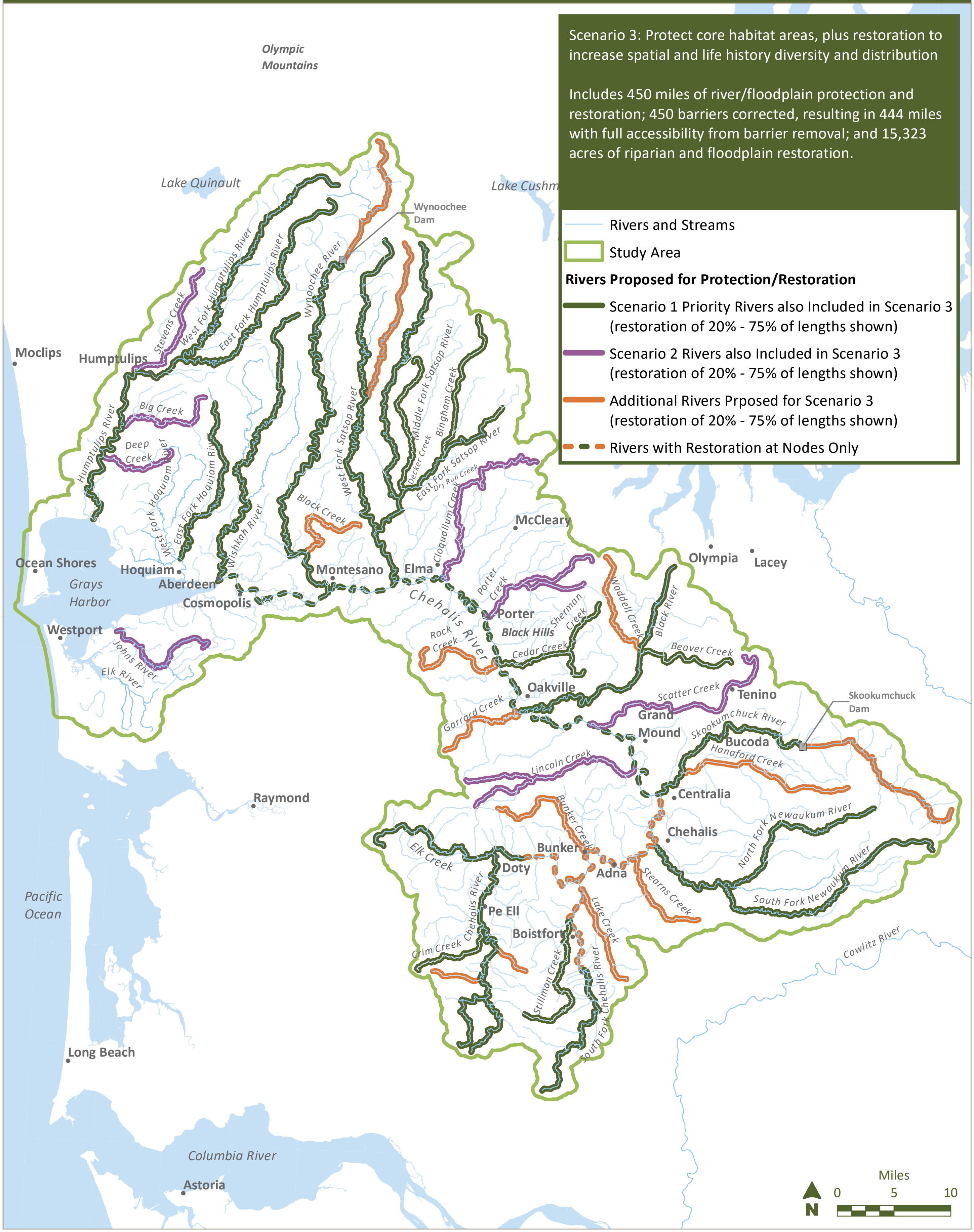


Table 4-4
Restoration Scenarios

GSU[1]	RIVER MILES OF STREAM WITHIN GSU	GSU INCLUDES TRIBUTARIES	GSU PRIMARILY MANAGED FOREST	PROPOSED RESTORATION (MILES) SCENARIO 1	SCENARIO 2	SCENARIO 3	COUNTY	SIZE CLASS	BARRIERS PROPOSED FOR REMOVAL IN GSU[2]
GRAYS HARBOR TRIBUTARIES ECOLOGICAL REGION									
Lower Humptulips River	RMs 0–9			3	3	5	Grays Harbor	L	0
Middle Humptulips River	RMs 9–28.1			6	8	11	Grays Harbor	L	0
East Fork Humptulips River	RMs 0–29		Y	10	14	14	Grays Harbor	M	16
West Fork Humptulips River	RMs 28.1–46		Y	6	12	12	Grays Harbor	M	1
Big Creek (Humptulips)	RMs 0–10	Y		0	4	6	Grays Harbor	S	16
Stevens Creek	RMs 0–10	Y		0	5	7	Grays Harbor	M	1
Deep Creek	RMs 0–4.5	Y	Y	0	3	3	Grays Harbor	S	7
Johns River	RMs 1–10	Y	Y	0	4	7	Grays Harbor	S	5
East Fork Hoquiam River	RMs 0–22			7	7	7	Grays Harbor	M	16
Lower Wishkah River	RMs 0–18			6	6	6	Grays Harbor	M	6
Upper Wishkah River	RMs 18–33			5	5	8	Grays Harbor	M	2
OLYMPIC MOUNTAINS ECOLOGICAL REGION									
Mainstem Lower Satsop River	RMs 0–6.6			3	3	3	Grays Harbor	L	16
Lower East Fork Satsop River	RMs 6.6–18			6	6	6	Mason	M	0
Lower Middle Fork Satsop River	RMs 0–21			7	11	11	Grays Harbor	M	3
Lower West Fork Satsop River	RMs 0–18.6			6	9	9	Grays Harbor	M	0
Decker Creek	RMs 0–15.8	Y	Y	5	8	8	Mason	M	16
Bingham Creek	RMs 0–13.8	Y	Y	5	7	7	Mason	M	13

GSU[1]	RIVER MILES OF STREAM WITHIN GSU	GSU INCLUDES TRIBUTARIES	GSU PRIMARILY MANAGED FOREST	PROPOSED RESTORATION (MILES) SCENARIO 1	SCENARIO 2	SCENARIO 3	COUNTY	SIZE CLASS	BARRIERS PROPOSED FOR REMOVAL IN GSU[2]
Upper West Fork Satsop River	RMs 18.6–35		Y	7	7	11	Grays Harbor	M	1
Upper Middle Fork Satsop River	RMs 21–30		Y	4	4	6	Mason	M	12
Upper East Fork Satsop River	RMs 18–28		Y	3	4	6	Mason	M	1
Lower West Fork Satsop River Tributaries	RMs 0–5	Y	Y	0	4	6	Grays Harbor	S	6
Canyon River	RMs 0–15	Y	Y	0	0	7	Grays Harbor	M	1
Dry Run Creek	RMs 0–6.6	Y	Y	0	0	3	Mason	S	16
Lower Wynoochee River	RMs 0–20.4			7	7	10	Grays Harbor	L	0
Middle Wynoochee River	RMs 20.4–50		Y	10	14	15	Grays Harbor	L	2
Black Creek (Wynoochee)	RMs 0–7	Y		0	0	5	Grays Harbor	M	13
Wynoochee Reservoir	RMs 50–55	Y	Y	0	0	2	Grays Harbor	L	2
Upper Wynoochee River	RMs 55–58	Y	Y	0	0	2	Grays Harbor	M	1
BLACK HILLS ECOLOGICAL REGION									
Cloquallum Creek	RMs 0–20	Y		0	10	10	Grays Harbor	S	40
Porter Creek	RMs 0–11	Y	Y	0	4	6	Grays Harbor	S	5
Cedar and Sherman Creeks	RMs 0–10, RMs 0–5	Y	Y	6	6	9	Grays Harbor	S	4
BLACK RIVER ECOLOGICAL REGION									
Lower Black River	RMs 0–18.6			6	9	9	Thurston	M	0
Upper Black River	RMs 18.6–28			3	3	3	Thurston	M	0
Dempsey Creek	RMs 0–20	Y		1	1	1	Thurston	M	0
Scatter Creek	RMs 0–20	Y		0	7	7	Thurston	S	7
Beaver and Allen Creeks	RMs 0–7, RMs 0–5	Y		6	6	6	Thurston	S	11

GSU[1]	RIVER MILES OF STREAM WITHIN GSU	GSU INCLUDES TRIBUTARIES	GSU PRIMARILY MANAGED FOREST	PROPOSED RESTORATION (MILES) SCENARIO 1	SCENARIO 2	SCENARIO 3	COUNTY	SIZE CLASS	BARRIERS PROPOSED FOR REMOVAL IN GSU[2]
Waddell Creek	RMs 0–9	Y	Y	0	0	5	Thurston	S	2
CENTRAL LOWLANDS ECOLOGICAL REGION									
Lincoln Creek	RMs 0–15	Y		0	9	9	Lewis	S	14
Garrard Creek	RMs 0–7	Y		0	0	5	Grays Harbor	S	6
Rock Creek	RMs 0–5	Y		0	0	5	Grays Harbor	S	0
Bunker Creek	RMs 0–12	Y		0	0	6	Lewis	S	6
CASCADE MOUNTAINS ECOLOGICAL REGION									
Lower Skookumchuck River	RMs 0–22			11	11	11	Thurston	M	0
Upper Skookumchuck River	RMs 22–29, RMs 0–2	Y		0	0	9	Lewis	M	1
Hanaford Creek	RMs 1–15	Y		0	0	8	Lewis	S	15
Lower Newaukum River	RMs 0–11.4			6	6	6	Lewis	M	0
South Fork Newaukum River	RMs 11.4–32			14	14	14	Lewis	M	0
North Fork Newaukum River	RMs 0–18			10	10	10	Lewis	M	1
Stearns Creek	RMs 0–9	Y		0	0	5	Lewis	S	24
WILLAPA HILLS ECOLOGICAL REGION									
Elk Creek	RMs 3–13	Y	Y	5	8	8	Lewis	M	2
Chehalis River Above Crim Creek	RMs 108.5–118.8		Y	5	5	8	Lewis	M	4
Chehalis Rainbow Falls to Crim Creek	RMs 97–108.5			6	6	6	Lewis	M	1
East Fork Chehalis River	RMs 119–126	Y	Y	6	9	14	Lewis	M	16
West Fork Chehalis River	RMs 0–7	Y	Y	3	5	7	Lewis	M	2
Crim Creek	RMs 0–6	Y	Y	3	4	4	Lewis	S	1

GSU[1]	RIVER MILES OF STREAM WITHIN GSU	GSU INCLUDES TRIBUTARIES	GSU PRIMARILY MANAGED FOREST	PROPOSED RESTORATION (MILES) SCENARIO 1	SCENARIO 2	SCENARIO 3	COUNTY	SIZE CLASS	BARRIERS PROPOSED FOR REMOVAL IN GSU[2]
Thrash Creek	RMs 0–4.5	Y	Y	0	0	2	Lewis	S	1
Big Creek (UC)	RMs 0–3	Y	Y	0	0	2	Lewis	S	16
Stillman Creek	RMs 0–8	Y		5	5	5	Lewis	M	4
Lake Creek	RMs 0–9	Y		0	0	5	Lewis	S	6
Lower South Fork Chehalis River	RMs 0–14			0	0	3	Lewis	M	0
Upper South Fork Chehalis River	RMs 14–27		Y	6	9	9	Cowlitz	M	0
CHEHALIS RIVER ECOLOGICAL REGIONS									
Middle Chehalis River, South Fork to Rainbow Falls	RMs 88.5–97			0	0	3	Lewis	L	0
Middle Chehalis River, Newaukum to South Fork	RMs 75.5–88.5			0	0	4	Lewis	L	5
Middle Chehalis River, Skookumchuck to Newaukum	RMs 67–75.5			0	0	3	Lewis	L	0
Lower Chehalis River, Satsop to Porter	RMs 21–33			3	3	4	Grays Harbor	L	0
Lower Chehalis River, Porter to Black	RMs 33–47			3	3	4	Grays Harbor	L	0
Lower Chehalis River, Black to Skookumchuck	RMs 47–67			4	4	4	Thurston	L	0
Tidal Zone	RMs 10–21	Y		4	4	7	Grays Harbor	L	23
Scenario Totals (Rounded)				**222**	**316**	**450**			

Notes:

1. See Figures 4-1, 4-2, and 4-3 for scenarios and depiction of associated GSU locations.
2. The number of barriers estimated for removal in each GSU are those identified as full or partial fish passage barriers from the WDFW culvert database (2018) and included within the EDT-modeled salmon spawning distribution. They are not meant to represent the total number of culverts or barriers in the entire GSU.

4.2.3 Community Planning

> Align ASRP goals and community plans to improve current and future ecosystem resiliency in the Chehalis Basin.

Within the Chehalis Basin, effective community planning will be critical to the long-term success of the ASRP. Without alignment of community planning and the ASRP, restoration and protection actions will not be supported through long-term local policies. In order to protect the investment Washington State is making through the ASRP, coordinated planning is necessary. The planning actions proposed under the ASRP involve a wide range of activities, including but not limited to community planning, land management, permitting, and urban growth planning. Many of these activities currently occur in relative isolation from each other. The extent and scale of ASRP restoration actions would affect the local landscape through land use management changes for communities throughout the basin. As a result, for communities to plan for and implement actions associated with the ASRP, planning activities would likely need to be coordinated and integrated across state, county, and local jurisdictions.

A first step to implementing cohesive and comprehensive community planning through the ASRP is an assessment of existing comprehensive plans, zoning, critical areas regulations, and other land use regulations completed alongside local governments to see if adjustments would be needed to make them consistent with the approaches included in the ASRP. Community plans, policies, and regulations would likely need to be revised to align the needs of landowners and the goals of the ASRP. In order for this to occur, local governments would likely need to develop creative programs and policies that balance the needs of the community, requirements of the Growth Management Act (36.70A RCW), and the needs of aquatic species in the basin. See Section 4.2.5 for the institutional capacity funding assistance that is planned as part of the strategies.

The following community planning actions have been identified:

- Work to ensure land use and community plans for the basin are consistent with the ASRP goals and vision.
- Support the implementation of comprehensive planning efforts that further the goals identified in the ASRP and the other interests of the local community.
- Develop partnerships work with local governments to develop creative programs and policies that protect habitat and ecosystem processes.

ASRP Phase 1 development included the identification of impacts that the proposed actions would have on major land use types and relevant habitats in the basin. Community plans and local and state regulations were also reviewed to determine if they were in alignment with the goals and vision of the ASRP. This review included the following: 1) county and city codes, comprehensive plans, shoreline management plans, and tribal plans; 2) hatchery management plans; and 3) the Streamflow Restoration

Act (90.94 RCW). An overview of the plans, policies, and regulations that are already in alignment with the ASRP—as well as suggestions for further alignment—are included in the following subsections.

The Chehalis Basin Strategy team, including the developers of the ASRP, will work with governments, agencies, and other community groups to resolve inconsistencies between ASRP restoration and protection actions and existing plans and policies to achieve a shared vision for the basin.

City, County, and Tribal Codes and Plans

- **Lewis County:** The *Lewis County Comprehensive Plan* establishes long-term goals, policies, and land use patterns for growth over a 20-year period in the County (Lewis County 2018). It includes a Land Use element with policies to protect critical areas. The *Lewis County Shoreline Master Program* (SMP) is a comprehensive land use plan that protects shoreline processes, promotes public access, accommodates appropriate shoreline uses, and balances public and private interests (Lewis County 2017). The SMP includes identification of priority habitat as those habitat types with unique or significant value to one or more species, including fish spawning habitat. The County has regulations and policies in place to achieve the following:
  - Maintain forest cover (SMP Regulation 5.09.02).
  - Increase riparian canopy through encouraging voluntary stewardship, restoration activities, and invasive species management (Lewis County Code 17.38.130(2); Comprehensive Plan Policy NE 4F.3).
  - Protect streams from development (Comprehensive Plan Policies NE 4D.3–4; SMP Management Policy 3.01.03(C) and Regulation 5.02.02).
  - Protect surface and groundwater and reduce withdrawals (Lewis County Code 17.38.830; Comprehensive Plan Policies NE 4C.1–3).
  - Prevent new development from interfering with the process of channel migration or causing a net loss of ecological functions (SMP Regulation 4.05.02).
  - Preserve and enhance resources for anadromous fish and other species; preserve the functions and values of critical resources; promote the restoration of anadromous fish habitat; and support projects from the County's Shoreline Restoration Plan (Lewis County 2016), the ASRP, and studies from the lead entities for salmon recovery (Comprehensive Plan Policies NE 4F.1–4F.4).

  Opportunities to strengthen alignment between the ASRP and Lewis County Planning will be further identified in partnership between the programs and discussed in a future phase of the ASRP.
- **Thurston County:** The *Thurston County Comprehensive Plan* guides the growth of unincorporated areas and subareas in the County through policies and goals related to zoning and Thurston County Code implements these polices through development regulations (Thurston County 2015). The plan includes chapters on the natural environment and natural resource lands. The Thurston County SMP presents policies for allowable land uses and zoning within shoreline jurisdiction, including policies and goals protecting critical areas and natural

resources (Thurston County 1990). The County has regulations and policies in place to achieve the following:

- Protect water quantity and quality for fish and protect cold water inputs (Comprehensive Plan Policies Chapter 9 B4, E9).
- Maintain or increase forest cover (Comprehensive Plan Policies Chapter 3III).
- Establish and protect riparian habitat and identify priorities to maintain or restore riparian habitat (Comprehensive Plan Policies Chapter 3III; Chapter 9 E4, E7).
- Protect streams, wetlands, floodplains, and prairies from development in order to avoid degradation of water quality or habitat functions (Comprehensive Plan Policies Chapter 9 C3, C6; Thurston County Code 24.25.080).
- Limit impervious surfaces and development in sensitive areas (Comprehensive Plan Policies Chapter 9 E6, E7, E14; Thurston County Code 24.25.080).
- Allow room for natural channel migration (Comprehensive Plan Policies Chapter 9 D1, D4; Thurston County Code 24.20.005).
- Reduce surface and groundwater withdrawals to protect streamflow volume and temperature (Comprehensive Plan Chapter 9 Goals B and C).

The County is currently working to update its Comprehensive Plan to comply with new state laws and account for population growth through the year 2040. The County is also currently working to update its SMP. Key proposed changes to the SMP include simplifying regulations so that they are easier to understand and removing unclear requirements. Additions to Thurston County Code to strengthen alignment with ASRP priorities include protecting floodplain connectivity and maintaining spawning gravels and sources by increasing wood recruitment.

- **Grays Harbor County:** The *Grays Harbor Comprehensive Plan* provides community goals and policies for long-range planning, development, and zoning (Grays Harbor County 2007). The plan includes a Resource Lands and Critical Areas element. The Grays Harbor County SMP presents policies for allowable land uses and zoning within shoreline jurisdiction (Grays Harbor County 1974). The County has regulations and policies in place to achieve the following:
  - Protect wetlands, floodplains, riparian areas, and fish and wildlife habitat conservation areas from degradation and development (Grays Harbor County Code 18.06.140; SMP Chapter 2).
  - Manage invasive species and prevent their introduction into wetlands or fish and wildlife habitat conservation areas (Grays Harbor County Code 18.06.140).

  Updates to the Grays Harbor County SMP and critical area protection ordinance are underway. The draft SMP that is currently in final review with Ecology contains regulations to protect channel migration zones and riparian vegetation, along with general development regulations related to shoreline areas in the County (Grays Harbor County 2018). Additions to Grays Harbor County Code to strengthen alignment with ASRP priorities include protecting and reducing surface and groundwater withdrawals, protecting and increasing forest and riparian cover, minimizing impervious surfaces, protecting and retaining spawning gravels and sources by improving wood recruitment, and increasing channel migration.

- **Mason County:** Mason County's Comprehensive Plan update, *Mason County Plan 2036,* guides the development and public policy decisions that will shape the County in the coming decades (Mason County 2017a). The Mason County SMP regulates land use and development within 200 feet from rivers, lakes, and marine shorelines (Mason County 2017b). Both the comprehensive plan and SMP include objectives and policies for restoration and protection of natural resources, including riparian areas and shorelines. The plans also have objectives to coordinate with nearby counties on conservation plans and programs to ensure that protection measures occur at the watershed scale. The County has regulations and policies in place to achieve the following:
  - Restore shoreline ecological functions and floodplain connectivity (SMP 17.50.260(A)).
  - Improve habitat for salmon populations by implementing habitat restoration actions that improve water quality, restore native vegetation, and reduce sediment input to streams and rivers (SMP 17.50.260(A); Mason County Code 8.52.170).
  - Protect wetlands and groundwater by minimizing development impacts and protecting water quality from degradation (Mason County Code 8.52.110 and 8.52.120).

  ASRP protection policies that could potentially be added to Mason County Code include maintaining and increasing riparian and forest cover, protecting surface waters and water temperatures, and improving floodplain connectivity.
- **The Confederated Tribes of the Chehalis Reservation:** The Chehalis Tribe has regulations in the Chehalis Tribal Code to achieve the following:
  - Protect the quantity and quality of groundwater (Chehalis Tribal Code 11.45.050).
  - Protect natural resources from degradation (Chehalis Tribal Code 11.05.160).
  - Protect and minimize adverse effects on fish, wildlife, water quality, and existing shoreline and stream processes (Chehalis Tribal Code 11.05.320).
  - Avoid adverse effects to ecologically or culturally sensitive lands including all waterbodies, channel migration zones, tribal ceremonial sites, and cemeteries (Chehalis Tribal Code 11.15.050.E).

  Tribal zoning policies also address development in the floodplain and encourage planting and maintaining riparian buffers on mainstem and tributary streams.
- **The City of Chehalis:** The *Chehalis Comprehensive Plan 2017* outlines goals for the city over the next 20 years and includes a chapter on the natural environment (City of Chehalis 2017). It contains goals and policies for sensitive areas such wetlands, open spaces, and fish and wildlife habitat. The City of Chehalis adopted the Lewis County SMP (City of Chehalis 2002). The SMP sets forth policies, rules and regulations for the development of the shorelines within the city limits. The City of Chehalis has regulations and policies in place to achieve the following:
  - Prevent degradation of the natural environment and protect unique, fragile, and valuable elements of the environment (Chehalis Municipal Code 17.21.010).
  - Protect groundwater quality and quantity (Comprehensive Plan Chapter 2 Goal NE.06.00).
  - Protect, conserve, and enhance the ecological functions of important fish and wildlife in riparian areas (Comprehensive Plan Chapter 2 Goal NE.13.00).

  - Consider conservation and protection measures to preserve or enhance anadromous fisheries (Chehalis Municipal Code 17.21.010; Comprehensive Plan Chapter 2 Policy NE.13.08).
  - Preserve and enhance native vegetation in riparian and wetland habitats (Chehalis Municipal Code 17.21.071; Comprehensive Plan Chapter 2 Policy NE.13.03).

  The City of Chehalis is currently updating its SMP (City of Chehalis 2019). The draft SMP contains detailed policies and regulations to protect critical areas including wetlands and fish and wildlife habitat areas. In order to align the Comprehensive Plan with the ASRP, the City of Chehalis could cite the ASRP as one of the relevant scientific reports cited in its Comprehensive Plan Policy NE.13.01.
- **The City of Centralia:** The *Centralia Comprehensive Plan 2018–2040* establishes the goals and policies to guide future decision-making concerning the physical, economic, and social development of the city for the next 20 years (City of Centralia 2018). The City of Centralia SMP guides future use and development of the city's shorelines and ensures there is no net loss of shoreline ecological functions and processes (City of Centralia 2019). The City of Centralia has regulations and policies in place to achieve the following:
  - Protect surface and groundwater quality and quantity (Centralia Municipal Code 16.16.030; Comprehensive Plan Goal EN 6).
  - Consider conservation and protection measures to preserve or enhance anadromous fisheries (Centralia Municipal Code 16.16.030; Comprehensive Plan Policy EN 9.8).
  - Conserve native vegetation and encourage the removal of non-native vegetation and invasive species (SMP Section 5.7; Centralia Municipal Code 16.20.100).
- **The City of Aberdeen**: The *Aberdeen 2001 Comprehensive Plan* provides direction for all future governmental land use actions within the city (City of Aberdeen 2001). It contains policies and goals for natural resources and critical areas. The City of Aberdeen SMP contains policies and regulations for activities taking place within the shoreline jurisdiction (City of Aberdeen 2017). The City of Aberdeen has regulations in place to achieve the following:
  - Protect fish and wildlife habitat (Aberdeen Municipal Code 14.100.540; Comprehensive Plan Chapter 9.3).
  - Prevent impacts to water quality in order to avoid a loss of ecological functions (Aberdeen Municipal Code 14.50.460; SMP 4.07).
  - Protect groundwater recharge areas from potential pollution (Comprehensive Plan Chapter 9.3). In order to strengthen this policy, the city could add a policy to protect the quantity of groundwater within the city.
- **The City of Montesano:** The *City of Montesano Comprehensive Plan* was produced to shape future development in order to advance community goals (City of Montesano 2008). The natural environment section of the Comprehensive Plan contains planning objectives for critical areas including wetlands and floodplains. The Montesano SMP contains goals that express the long-

term vision of the city's citizens for their shorelines (City of Montesano 1992). The City of Montesano has regulations and policies in place to achieve the following:

  - Avoid and minimize shoreline uses and activities that could have adverse impacts on fish and wildlife resources, including spawning, nesting, rearing, and habitat areas and migratory routes (SMP 7.03B; Montesano Municipal Code 14.30.070).
  - Minimize adverse impacts of shoreline use and activities on the environment in areas such as floodways and estuaries (SMP 7.03B, 7.04B).

  The City of Montesano is currently updating its SMP (City of Montesano 2016). The new SMP contains policies and regulations to ensure that development will not cause a net loss of ecological functions by requiring mitigation for shoreline impacts.

- **The City of Hoquiam:** The *City of Hoquiam Comprehensive Land Use Plan* was prepared to guide the future physical development of the community over the next 20 years (City of Hoquiam 2009). It contains specific goals and objectives for environmental management. The City of Hoquiam SMP was prepared with the intent of balancing development and protection in the shoreline environment (Hoquiam Municipal Code Chapter 11.05; City of Hoquiam 2017). The city has regulations and policies in place to achieve the following:
  - Protect and restore fish and wildlife conservation areas (Comprehensive Plan Land Use Action Steps 6.3.A through 6.3.F; Hoquiam Municipal Code 11.06.240 and 11.05.850).
  - Participate in regional watershed planning through the Chehalis Basin Partnership to promote Hoquiam's interests and obtain the resources to implement action steps (Comprehensive Plan Land Use Action Step 6.5.F).
  - Work to eliminate invasive species and encourage the planning and enhancement of native vegetation in shoreline areas (Hoquiam Municipal Code 11.05.330(1)).
  - Provide development strategies for managing environmental assets and constraints, including fish and wildlife habitat conservation areas and other critical areas (Comprehensive Plan Part 6.0).

Hatchery Management Plans

Hatchery management and policies are a co-management effort between WDFW and the tribes in the Chehalis Basin. While the ASRP recognizes hatcheries and hatchery management are not under the purview of the ASRP, there is interaction between the ASRP and the fisheries co-managers to understand the impacts of hatcheries on the salmonid species in the basin. Hatchery practices have been summarized as part of this effort to identify potential interactions between hatchery operations and restoration planning. While these interactions are still not well understood, identifying the level of hatchery production and current practices is important to understand potentially relevant interactions. It is intended that this topic would be more fully developed in future phases and integrated into the final ASRP. Hatchery management plans exist for each operating hatchery, and they have been evaluated to understand any practices that may affect restoration and/or protection recommendations through the ASRP. Operationally, each hatchery follows its own management plan practices when producing, rearing, and releasing fish.

There are several hatchery programs operating in the basin. The following is a summary of their programs and relevant practices:

- All hatchery programs that produce adult returns are marked by a clipped adipose fin, except for one double index tag group. The double index tag program is from Bingham Creek Hatchery and includes coho salmon that are tagged with coded wire tags but are not adipose clipped. The double index tag program includes approximately 20% of the total coho salmon release annually, or about 70,000 fish. Double index tag programs are used to evaluate differences in encounters between clipped and unclipped fish.
- The Satsop Springs Chinook and chum salmon programs are designed for supplementation purposes to increase populations of these species.
- The basin contains two segregated hatchery programs where the broodstock is only of out-of-basin hatchery origin. They include the following:
  - Humptulips River summer- and winter-run steelhead
  - Wynoochee River summer-run steelhead
- All other hatchery releases (operated by WDFW and fisheries cooperative groups) are integrated programs, which means that genetics from wild salmon populations are integrated into the hatchery production. The goal of these programs is for approximately 30% of the broodstock to be from wild-origin salmon.

The congressionally established Hatchery Scientific Review Group (HSRG) identified locally adaptive genetic traits that are essential for relative fitness of natural salmon and steelhead populations. They have developed and provided guidelines for hatchery production to minimize the loss of relative fitness of natural populations through managing genetic flow between hatchery and natural productions. WDFW's Hatchery Reform Policy uses principles, standards, and recommendations of the HSRG to guide the management of its hatcheries. The HSRG is currently updating its statewide recommendations for hatchery management plans, which are non-regulatory; however, HSRG recommendations can provide information about how each hatchery is performing related to their production and operational goals. These recommendations could also be used by WDFW to develop compliance measures or provide recommendations or revisions as part of the ASRP. These recommendations could also inform understanding of the interaction between hatchery operations and restoration planning.

Streamflow Restoration Act Planning

The Chehalis Basin Partnership is currently developing an addendum to its 2004 *Chehalis Basin Watershed Management Plan* (CBP 2004) to address Streamflow Restoration Act requirements. The addendum will recommend projects to offset streamflow impacts from new small domestic groundwater wells—called "permit-exempt wells"—over a 20-year time frame. The requirements and objectives of this effort are symbiotic with the ASRP in that many aquatic species needs are connected to adequate streamflows. When complete and adopted by Ecology (required by February 2021), the Watershed Plan Addendum will recommend "offset projects" that return flow to streams and rivers that have instream flow-limiting factors and where future development is projected to worsen conditions.

The addendum will also recommend aquatic habitat restoration projects that do not directly return flow to streams and rivers but support aquatic species through the restoration strategies and actions proposed by the ASRP.

4.2.4 Community Involvement

> Engage landowners and Chehalis Basin communities to ensure a successful plan through landowner input and support of implementation.

The success of the ASRP is critically dependent on the voluntary actions of landowners. Therefore, the needs and concerns of landowners need to be taken into consideration at every step of the ASRP development and implementation. The importance of community involvement cannot be overstated—most of the actions in the ASRP will occur on private land and would only occur if landowners are willing. Achieving the restoration outcomes will require strong relationships between those entities implementing projects and landowners and the wider community. These relationships take time to develop, so outreach and involvement actions began early and will continue to occur often throughout the ASRP development and implementation process. Initial discussions have identified the following potential community involvement actions:

- Develop an ongoing process of landowner engagement, including communication pathways, to incorporate the initiative and expertise of landowners into ASRP planning and implementation efforts.
- Collaborate with and develop incentives for habitat protection and restoration participation with private and commercial landowners (including timber landowners).
- Develop a shared community vision across the Chehalis Basin for implementation of the ASRP.
- Continue to develop and implement an outreach and involvement plan for residents of the Chehalis Basin.
- Support the efforts of existing organizations working on restoration outreach efforts in the Chehalis Basin (see Appendix E for a list of organizations).
- Ensure that restoration and protection actions are developed in concert with landowners and meet their needs as well as aquatic species habitat needs.
- Provide a timely and transparent process to develop and implement projects.

During development of the ASRP Phase 1 document, approximately 25 landowner outreach meetings throughout the basin were led by the conservation districts to discuss potential priorities for specific areas and get landowner perspectives on proposed restoration activities. A concerted effort in the basin created open forums for creative thinking and targeted feedback on what has been developed thus far. Landowners discussed the implementation of proposed actions by the ASRP in their community as well as conceptual incentive options and project-level capacity funding. To foster growth in community relationships, the conservation districts have been keeping up with landowners, including those involved in early implementation projects, by bringing development information to each event.

To further develop the community involvement strategy, outreach meetings with landowners—in coordination with the conservation districts—will continue to occur across the basin. These meetings provide great value in vetting project ideas in the local community, discussing incentive options, and understanding what is being planned through the larger basin-wide ASRP implementation. In addition, outreach and collaboration will occur with other groups who are already working with landowners on natural resource issues or providing public education (Appendix E). Also, participating in community events such as the Onalaska Apple Harvest Festival and Chehalis Watershed Festival could allow the program to connect with larger community audiences. The agricultural community will also have opportunities to interact with strategies that are developed as part of the ASRP through local meet-ups and educational forums organized by regional agricultural initiatives. Improvements to agricultural viability are being coordinated across the Chehalis Basin Strategy to provide additional incentives.

Additional work will continue in Phases 2 and 3 to determine appropriate community involvement actions. Throughout the process, input will continue to be sought to identify landowner needs in the basin, develop innovative approaches to implement the ASRP actions, and plan for a future that provides benefits to both humans and aquatic species. Depending on the scenario selected, restoration would include approximately 225 to 450 river miles (RMs; about 10% of the basin's perennial streams) and 9,600 to 15,000 acres of riparian and floodplain habitat, which will need to involve voluntary collaboration with landowners. In addition, protection measures will encompass up to 3,000 acres of existing high-quality or unique habitats. State agencies and other basin organizations implementing and adaptively managing the ASRP will need to work closely with landowners and others in the community to provide options and approaches that work for all parties.

4.2.5 Institutional Capacity

> Build institutional capacity of existing organizations and individuals for restoration, protection, and planning processes to ensure the ASRP is a community-based restoration program.

The ASRP scenarios would involve a concerted level of protection and restoration actions never before seen in the Chehalis Basin or the state as a whole. Currently, limited in-basin capacity exists to design and implement these actions at the proposed scale. Significant investment will be needed to expand capacity within the basin, because expedited implementation of ASRP actions presents the greatest likelihood of positive outcomes for habitats and species (see Section 7). To successfully implement actions at the required scale, this strategy would build on and support the work of existing organizations, as well as support creativity in how local organizations approach working toward the goals of the ASRP. Expanded investment could provide increased staff, equipment, restoration design and contractor skill sets, and other opportunities, which will be developed with basin organizations. Another key component of successful ASRP implementation would likely be enhanced and focused coordination between regional, tribal, state, and federal agencies. The ASRP relies on the capacity of local organizations to sponsor and implement the plan with funding and management support. This can include the role of sponsorship on small and large restoration and protection projects.

Additional work will be done in Phases 2 and 3 of the ASRP development to determine appropriate institutional capacity actions. Initial discussions have identified the following potential actions:

- Provide technical training on process-based restoration practices and principles.
- Provide funding for groups and individuals interested in restoration and protection projects.
- Build on and support the work of existing organizations with missions that overlap with the ASRP vision.
- Create a centralized and transparent system for project development and monitoring.
- Work to align the project development process with existing restoration efforts in the basin.
- Provide incentives for the adoption of ASRP recommendations.
- Support existing technical assistance programs for landowners.
- Streamline permitting processes for restoration and protection projects.

Work to increase the capacity of local restoration partners has already begun through Phase 1. The potential for capacity-building and project development grants is under development through the 2019 ASRP Request for Proposals (RFP). These grants are intended to allow organizations to increase their capacity in order to develop and manage additional projects for the implementation of the ASRP. In addition, capacity grants will allow organizations to develop more partnerships with landowners than would be feasible under current staffing capacity. Additional partnerships as well as conceptual projects will lay the foundation for increased implementation in the biennia to come.

To build on and support the efforts of existing organizations with missions that overlap with the ASRP vision, numerous volunteer forums and educational institutions were identified in the basin for potential partnerships in future phases of development of the institutional capacity strategy (see the list of implementation and education partners in Appendix E).

5 ECOLOGICAL REGIONS

The Chehalis Basin is very large—approximately 2,700 square miles, with more than 3,400 perennial stream miles in the basin including the Chehalis River, its tributaries, and all other tributaries to Grays Harbor. Various aquatic species use the extensive and varied habitats within and adjacent to these rivers and streams. The species use different parts of the basin for their entire life history or use specific types of habitats during different life stages.

The physical diversity of the basin has given rise to a high diversity of species and a unique spatial structure. The value of a range of productive habitat across the basin and high diversity of biological characteristics can be compared to the value of a diversified financial investment portfolio that spreads financial risk. In both cases, diversity provides a range of options to respond to uncertain future events and promotes resiliency to variation and change. Biological resiliency will become increasingly important in the face of climate change and future human development of the basin.

> Biological ***spatial structure*** refers to the pattern of aquatic species production across the landscape that results from the spatial variation in habitat quality and quantity across the watershed.
>
> This pattern contributes to the biological ***diversity*** of aquatic species populations and is believed to contribute to the resiliency of species to environmental variability and change. Biological diversity can include biological spatial structure but also includes variation in morphology, behavior, and life history that may have a genetic basis.

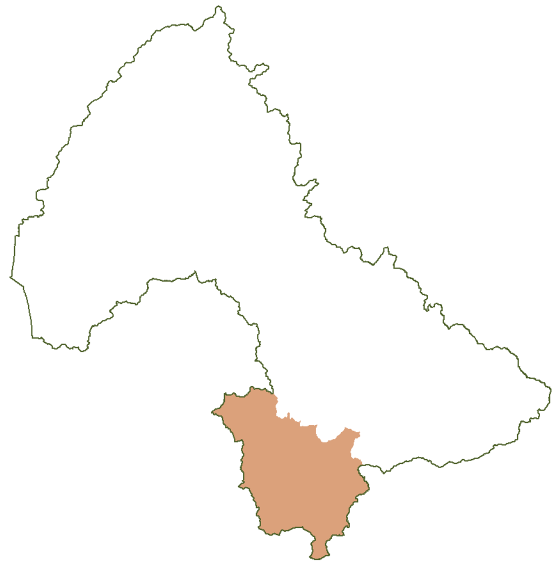
To evaluate the unique characteristics across the basin and recommend actions appropriate to the range of conditions, the ASRP uses the concept of ecological regions to subdivide the basin. Ten ecological regions (see Figure 2-1 in Section 2) were identified based on distinct ecological characteristics and processes—such as geologic, climatic, and topographic conditions—that could warrant specific strategies and actions. Characteristics of these 10 ecological regions are summarized in Table 5-1; Sections 5.1 through 5.10 further detail the conditions and limiting factors of each ecological region, along with an outline for potential application of the strategies and actions detailed in Section 4.

Table 5-1
Summary of Ecological Regions

ECOLOGICAL REGION	SUB-BASINS	KEY CHARACTERISTICS			
		GEOLOGIC	CLIMACTIC	GEOMORPHIC	LAND USE
Willapa Hills	• Upper Chehalis River (above Rainbow Falls) and East Fork and West Fork Chehalis rivers • South Fork Chehalis River • Elk Creek • Upper Chehalis River tributaries	Seafloor sedimentary and volcanic geology	High rainfall	Upper Chehalis River and tributaries are confined or partly confined; South Fork Chehalis River and tributaries are unconfined but incised; moderate and low gradient	Primarily managed timber land use in upper areas, lowlands predominantly agriculture
Cascade Mountains	• Newaukum River • Skookumchuck River • Stearns Creek • Salzer Creek • Dillenbaugh and urban creeks	Lower-elevation region of volcanic Cascade Range	Moderate rainfall	Unconfined but incised streams; low to moderate gradient	Mix of managed timber land, agriculture, and residential and urban land uses
Middle Chehalis River	• Chehalis River from the confluence with the Skookumchuck River to Rainbow Falls	Large river and alluvial floodplain	Moderate rainfall, highly prone to flooding	Unconfined but incised, wide alluvial valley; low gradient	Mix of agricultural and residential and urban land uses
Central Lowlands	• Bunker Creek • Lincoln Creek • Independence Creek • Rock Creek • Garrard creek • Other western tributaries to the Chehalis River	Low-elevation seafloor sedimentary and volcanic Coast Range hills	High rainfall	Low-gradient small streams that include unconfined wetland valleys and partly confined reaches; incised in many reaches	Primarily managed timber land and agricultural land uses
Lower Chehalis River	• Chehalis River from the confluence with the Satsop River to the confluence with the Skookumchuck River	Large river and alluvial floodplain	Moderate to high rainfall, highly prone to flooding	Unconfined, wide alluvial valley; low gradient; incised in some reaches	Mix of agricultural and residential land uses

ECOLOGICAL REGION	SUB-BASINS	KEY CHARACTERISTICS			
		GEOLOGIC	CLIMACTIC	GEOMORPHIC	LAND USE
Black River	• Black River and its tributaries • Scatter Creek • Prairie Creek	Low-elevation coarse glacial deposits	Moderate rainfall	Unconfined valleys; very low gradient; partly confined tributaries from the west	Mix of agriculture, residential, and urban land uses
Black Hills	• Cedar Creek • Porter Creek • Mox Chehalis Creek • Other northeastern tributaries to the Chehalis River	Low-elevation glacial till and moraine deposits	High rainfall	Low- to moderate-gradient small streams that include unconfined and partly confined reaches; incised to bedrock in some reaches	Primarily managed timber and residential land uses
Olympic Mountains	• Satsop River • Wynoochee River • Other northwestern tributaries to the Chehalis River	Higher-elevation seafloor sedimentary and volcanic Olympic Mountains	High rainfall	Low- to moderate-gradient rivers that include partly confined upper reaches and unconfined wide alluvial valleys; incised to bedrock in some reaches; substantial gravel instability and transport	Primarily managed timber lands with some agricultural and residential land uses
Chehalis River Tidal	• Tidally influenced reach of the Chehalis River from Grays Harbor to the confluence with the Satsop River	Large freshwater tidal floodplain, highly prone to flooding	High rainfall	Very low-gradient wide alluvial tidal valley	Mix of agricultural and residential and industrial land uses
Grays Harbor Tributaries	• Wishkah River • Hoquiam River • Humptulips River • Other tributaries that directly enter Grays Harbor, including the South Bay tributaries	Lower-elevation seafloor sedimentary and volcanic Coast Range	High rainfall	Low- to moderate-gradient rivers that include confined and partly confined upper reaches and unconfined wide alluvial and tidal valleys	Primarily managed timber lands with some residential land uses

5.1 Willapa Hills Ecological Region



5.1.1 Overview

The Willapa Hills Ecological Region encompasses the upper Chehalis River (above Rainbow Falls) and tributaries, including East Fork and West Fork Chehalis rivers, Elk Creek, and the South Fork Chehalis River and its tributaries (Figure 5-1). This ecological region encompasses 316 square miles (greater than 200,000 acres) and represents approximately 12% of the overall Chehalis Basin. The maximum elevation in the watershed is 3,113 feet at Boistfort Peak (also called Bawfaw). The Chehalis River arises in the East Fork and West Fork, and primary tributaries to the upper Chehalis River include Thrash, Crim, Rock, and Elk creeks and the South Fork Chehalis River. Primary tributaries to the South Fork Chehalis River include Stillman and Lake creeks.

Important Features and Functions

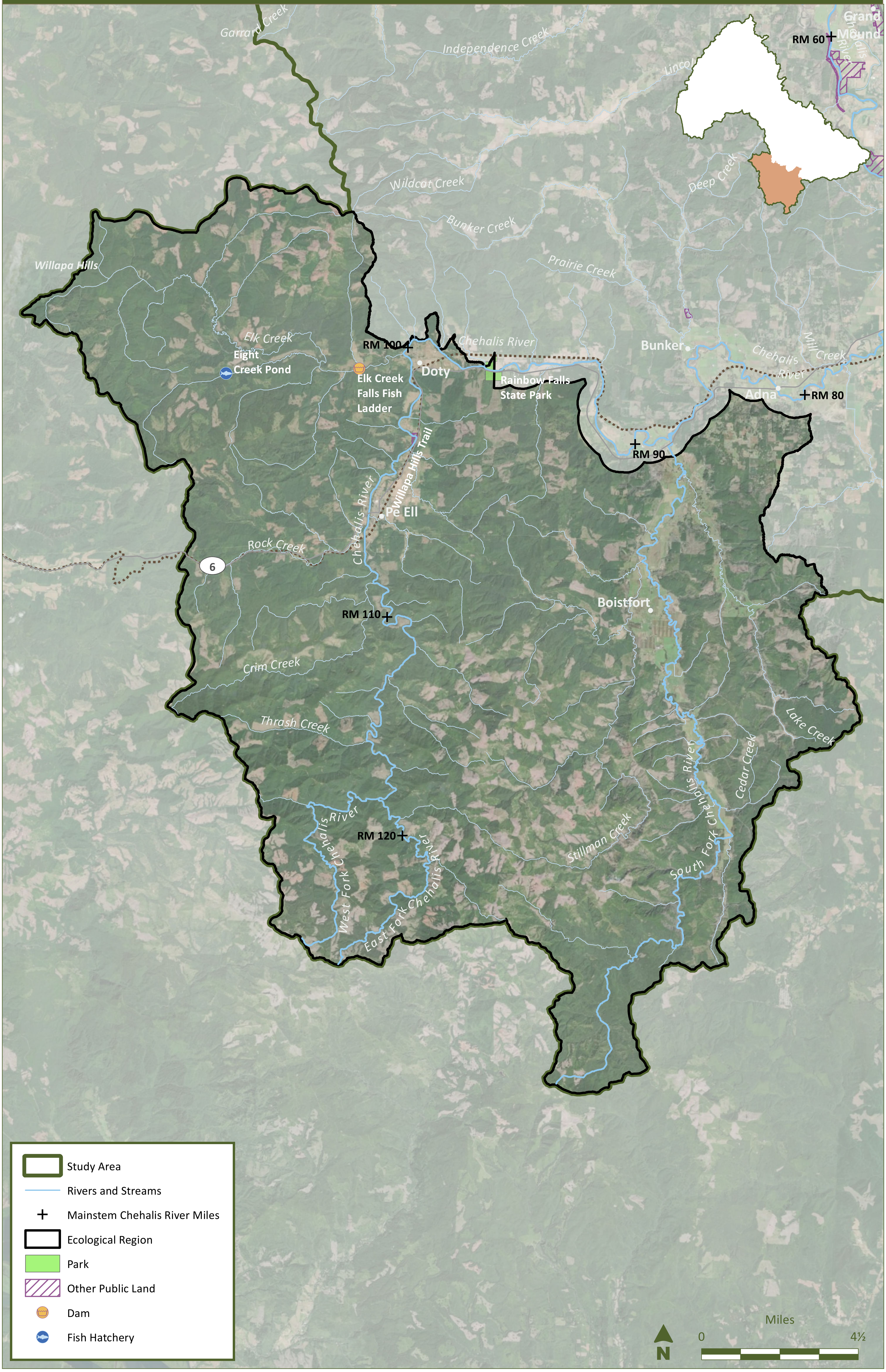
- Willapa Hills was a former stronghold of spring-run Chinook salmon, but species occurrence has been highly variable and notably decreasing in recent years, leading to concerns about local extirpation.
- The upper Chehalis River supports a relatively large number of wild winter-run steelhead (Ashcraft et al. 2017).
- This ecological region anchors the location in the watershed where anadromous fish life histories have the longest distance in their migrations upstream of the estuary (promoting substantial life history diversity).
- The greatest diversity of amphibians is in this ecological region. It is the only region with Dunn's salamander, has the highest densities of Western toad in the basin, and is an important area for both coastal tailed frog and Van Dyke's salamander.

The Willapa Hills geology is predominantly Tertiary volcanic and marine-derived sedimentary rocks. The sedimentary McIntosh Formation is composed of siltstone, shale, and sandstone with interbeds of basalt flows and basaltic sandstone. Coal seams are found within these units. Columbia River basalts overlie these rocks in some areas. Uplift of the volcanic and sedimentary rocks resulted in the higher elevation of the Willapa Hills. The Doty Fault Zone is an east-west trending fault zone that initiates along the northern boundary of the Willapa Hills Ecological Region, about 3 miles northwest of Doty, and extends east. It is the only fault zone suspected of being active in the Chehalis Basin (HDR and Shannon & Wilson 2015). Upland slopes can be quite steep and susceptible to landslides in many areas.

Precipitation in the Willapa Hills Ecological Region is dominated by rainfall, with higher elevations occasionally receiving snow. Average annual precipitation is 120 inches or higher in the upper watershed (WSE 2014) and 58 inches near Doty.

The Willapa Hills Ecological Region is primarily within Lewis County (159,622 acres, or 79%), with a small portion in Pacific County (36,873 acres, or 18%) and an even smaller portion in Cowlitz County (5,427 acres, or 3%), and it is just touching the edge of Wahkiakum County (5,427 acres, or <1%). Towns within this ecological region include Doty, Pe Ell, and Boistfort.

Figure 5-1
Willapa Hills Ecological Region Map



Aerial Photo Source: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

5.1.2 Historical Conditions and Changes

Historical records for the pre-Euro-American settlement condition are not available, but available historical records and maps indicate that the Willapa Hills Ecological Region was dominated by old-growth Western hemlock and Western red cedar forest, including other important species such as Douglas-fir. Smith and Wenger (2001) indicated that a large fire burned the Stillman Creek watershed around 1800, resulting in a nearly uniform stand of Douglas-fir. Prairies were noted by early settlers, including Pe Ell and Boistfort prairies, many of which were typically inundated each spring (WNPS 1994), implying historical connectivity to rivers and streams. GLO maps noted that beaver swamps, hardhack (*Spirea douglasii*) swamps, and other wetlands were present in substantial areas along the South Fork Chehalis River and Lake Creek.

Key changes that occurred in the Willapa Hills Ecological Region following Euro-American settlement were extensive timber harvest and agricultural development in some areas, notably along the South Fork Chehalis River. Similar to other regions of the basin, splash dams were used to transport timber downstream (see the description in Section 2.1). At least nine splash dams were documented in the Willapa Hills Ecological Region, including some of the largest splash dams used in the basin; four were used on Elk Creek and its tributary, Nine Creek; three were on Rock Creek and other tributaries to the upper Chehalis River; and two were on the South Fork Chehalis River and its tributary Stillman Creek (Wendler and Deschamps 1955). Gravel mining also occurred in Stillman Creek. Agricultural development as well as road, bridge, and residential construction likely also incrementally moved and straightened many of the rivers and creeks and drained wetlands in the Willapa Hills Ecological Region over time. All of these actions contributed to wood removal, channel incision, and floodplain disconnection. Other historical changes to rivers include the disconnection of a meander on the West Fork Chehalis River for road construction that created the West Fork Falls fish barrier, provision of a fish ladder on Elk Creek Falls (RM 1.5 on Elk Creek) in 1972 to pass coho salmon and steelhead, and reduction of the Fisk Falls barrier on the upper Chehalis River in 1970 to improve fish passage (WDF 1975). Chum salmon were noted to have been present in the South Fork Chehalis River in the 1930s (Royal 1931).

To support the ASRP analysis and EDT modeling efforts, the SRT developed assumptions of the channel lengths and areas of floodplain habitat that were likely to be present in historical conditions. These assumptions were based on the GLO mapping from the late 1800s, more recent historical aerial photographs, and interpretation of current LiDAR data that show many remnant channels and other floodplain features across the basin. For the Willapa Hills, the upper Chehalis River is generally confined within a narrow valley, so historical conditions would not likely have included any significant differences in main channel and side channel length or floodplain area. However, large wood has been removed from the channel, and the historical use of splash dams caused channel incision to bedrock in many locations. The East Fork and West Fork Chehalis rivers and major tributaries such as Crim Creek are partly confined in slightly wider valleys and may historically have had more sinuous channels, with side channels in some locations, and 2 to 3 times the area of connected floodplain. Elk Creek, the South Fork

Chehalis River, lower Stillman Creek, and Lake Creek have wide valleys that do not confine the streams, with many remnant floodplain features visible in LiDAR data. Channels and side channels were interpreted to have been nearly double the length that currently exists, with 3 or more times the connected floodplain area. In all of the streams and rivers of the Willapa Hills Ecological Region, large wood has been removed from channels and channel incision has occurred to some extent.

5.1.3 Current Conditions

Current conditions reflect ongoing forest management, agricultural land uses, and residential and commercial development. Land cover is 48% coniferous forest, 23% shrub, 8% grassland, 4% agriculture, 5% developed, and small percentages of other cover[4] (Figure 5-2). Much of the upper areas of the Willapa Hills Ecological Region are commercially managed timber forest.

An assessment of riparian conditions and functions by NOAA (Beechie 2018) indicates that the majority of the riparian areas in the Willapa Hills Ecological Region are impaired or moderately impaired[5] for wood recruitment due to the young age of trees present within riparian areas and/or the width of riparian buffers. The major flood event in 2007 caused numerous landslides that recruited and then transported substantial quantities of wood downstream that was generally removed from the ecological region after the flooding; this led to even lower current potential rates of wood recruitment. In areas of agricultural and residential development (e.g., South Fork Chehalis River and Chehalis River between Rainbow Falls and Crim Creek), fewer than 5% of the reaches have larger trees in the riparian zone. The lack of trees also affects cover and provides low levels of shading.

Willapa Hills Current Snapshot

Condition of Watershed Processes:
Hydrology – moderately impaired
Floodplain connectivity – impaired
Riparian condition – impaired
Water quality – impaired

Restoration Potential: High

Protection Potential: Moderate

Geographic Spatial Units: Upper Chehalis River, East Fork Chehalis River, West Fork Chehalis River, Crim Creek, Elk Creek, South Fork Chehalis River, Stillman Creek, and Lake Creek

Salmon Use and Potential: High for spring-run Chinook salmon, fall-run Chinook salmon, coho salmon, and steelhead

Non-Salmon Use and Potential: Western toad, coastal tailed frog, Van Dyke's salamander, northern red-legged frog, North American beaver, Olympic mudminnow, largescale sucker, mountain whitefish, Pacific lamprey, riffle and reticulate sculpin, and speckled dace

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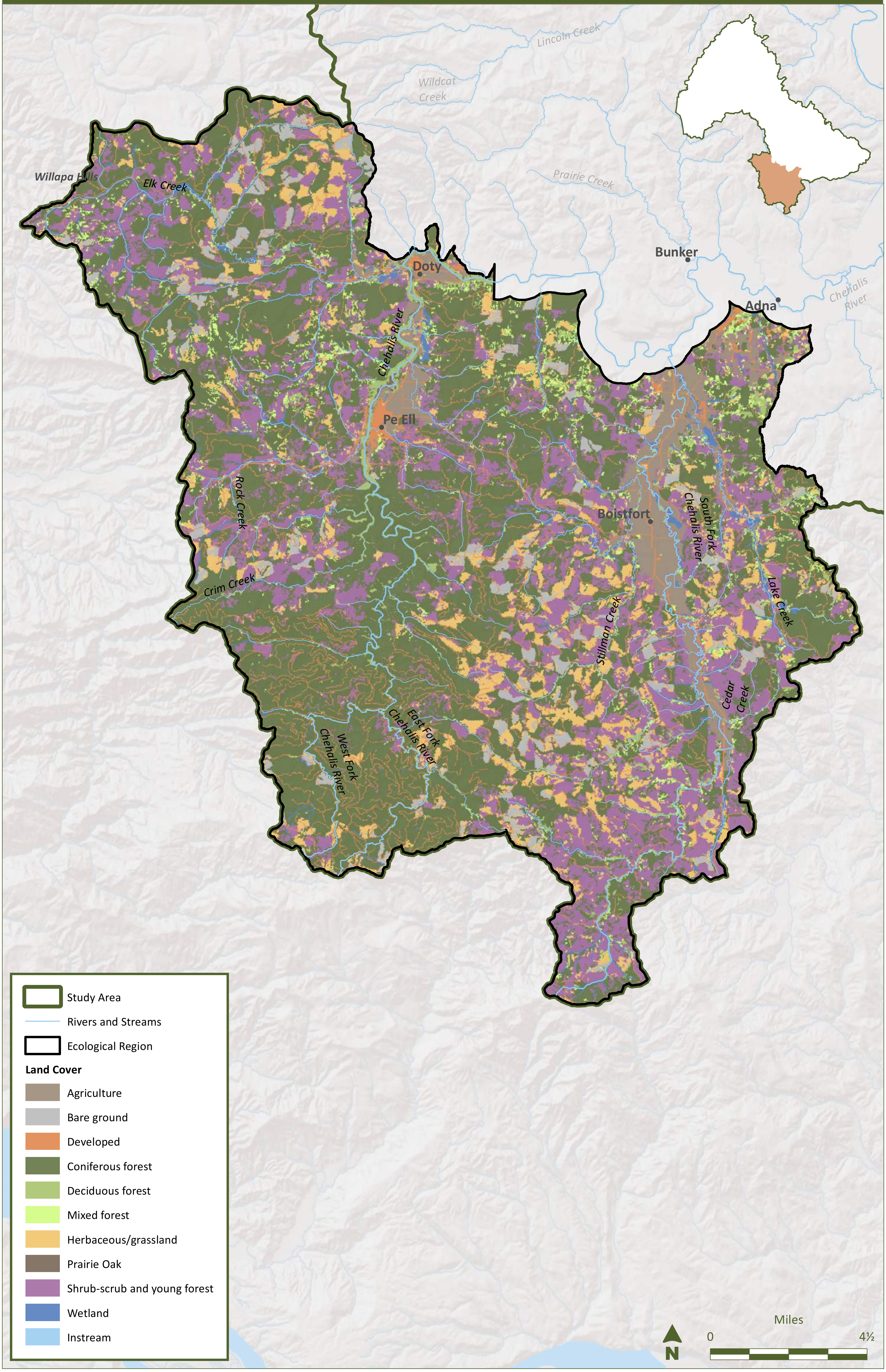
[4] Land cover data from Multi-Resolution Land Characteristics Consortium, National Land Cover Database 2011, augmented by WDFW Habitat Guild 2015 floodplain data where available.
[5] Condition of watershed processes categorized based on procedures in Beechie et al. 2003.

Figure 5-2
Willapa Hills Ecological Region Land Cover



Water quality is impaired in many areas of the Willapa Hills Ecological Region, primarily for temperature, low dissolved oxygen, and bacteria (Ecology 2018). Recent temperature monitoring in the upper Chehalis (RMs 98 and 117.7) and South Fork Chehalis (RMs 1.7 and 16.8) rivers by WDFW (2014 to 2015 data) indicates that water temperatures regularly exceed the 16°C (61°F) core summer salmonid habitat criterion from May through September,[6] and they typically exceed the 13°C (55°F) supplemental spawning incubation criterion (September 15 to July 1) in September and May to July (Ecology 2016, 2011a). The *Upper Chehalis River Basin Temperature Total Maximum Daily Load* (TMDL; Ecology 2001)[7] has designated a goal of 18°C (64°F) for the upper Chehalis River, with the primary goals of increasing shading along the Chehalis and South Fork Chehalis rivers and decreasing the width of the South Fork Chehalis River. It is also critical to prevent further reductions in flows and improve low flows if feasible.

WDFW's Thermalscape model indicates that from 2013 to 2018, the majority of stream reaches within the Willapa Hills Ecological Region (ranging from 46% [2018] to 76% [2015] of the reaches) equal or exceed a mean August temperature of 16°C (61°F) and are projected to increase to 91% and 100% of reaches in 2040 and 2080, respectively, without restoration actions (Winkowski and Zimmerman 2019).

The NOAA model that incorporates mature riparian conditions and anticipated climate change shows a likely future increase in summer water temperatures ranging from 1.5°C (2.7°F) to more than 2.5°C (4.5°F) in this region by 2080 (Beechie 2018). The South Fork Chehalis River was the only area where the model showed a lesser future temperature increase (because the current riparian condition is very poor on the South Fork Chehalis River).

The river channels are predominantly one primary channel with varying levels of incision. Abbe et al. (2016) estimated potential levels of channel incision in several locations, ranging from 15 to 30 feet on the Chehalis River, 17 feet on Crim Creek, 2 to 4 feet on Elk Creek, 2 to 11 feet on the South Fork Chehalis River, 0 to 4 feet on Lake Creek, and 0 to 8 feet on Stillman Creek.

Existing mapping of wetlands (Ecology 2011b) shows large wetland areas adjacent to Jones Creek, Elk Creek, the South Fork Chehalis River, Lake Creek, Lost Creek, and in some areas along the upper Chehalis River below Pe Ell. Historical and current areas of floodplain marsh and pond habitats were documented by NOAA using GLO mapping (Beechie 2018). They found the South Fork Chehalis River floodplain has lost about half of the historical marsh habitat (remaining marsh is heavily modified) and nearly all of the historical beaver pond habitat. Elk Creek still retains much of its historical beaver pond habitat. Fish passage barriers do not generally block mainstem reaches in the Willapa Hills Ecological Region—although the human-caused West Fork Falls fish barrier blocks all upstream fish passage. Barriers impede passage into many small tributaries, including Rock and Lake creeks. Approximately 50 fish passage barriers were incorporated into the EDT model[8] for the Willapa Hills Ecological Region.

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[6] 7-day average daily maximum temperatures reached more than 25°C (77°F) in the South Fork Chehalis River and more than 23°C (73°F) in the upper Chehalis River.
[7] The *Upper Chehalis River Basin Temperature TMDL* (Ecology 2001) covers the basin upstream of Porter.
[8] Fish passage barrier data from WDFW processed through EDT model.

Landslides following heavy precipitation are a common occurrence in this region due to the unstable soils and steep slopes. Multiple authors (Turner et al. 2010; Whittaker and McShane 2012) documented more than 2,500 landslides in the Upper Chehalis Basin associated with the 2007 storm event, where 12 to 26 inches of rain fell in a 4-day period in parts of the Chehalis Basin (WSE 2014). These landslides occurred most frequently in young stands of trees (less than 10 years), on steep slopes, and where rainfall intensities far exceeded the threshold for precipitation that would be considered a 100-year event.

The percentage of fine sediment in streams was modeled by NOAA based on the density of roads and channel gradient; this modeling indicated that 15% to 20% fines are likely to be present throughout the ecological region, compared to 9% to 14% fines as modeled for historical conditions (Beechie 2018). The upper Chehalis River (above Crim Creek) naturally has lower levels of fine sediment than the South Fork Chehalis River sub-basin.

The Willapa Hills Ecological Region is one of the few spawning areas for spring-run Chinook salmon, and it also has runs of fall-run Chinook salmon, coho salmon, and steelhead. The upper Chehalis River supports a relatively large number of wild winter-run steelhead (Ashcraft et al. 2017). The Willapa Hills Ecological Region is one of only two key strongholds for Van Dyke's salamander, a riparian-dwelling amphibian that is a state candidate species. Populations of this species in the Willapa Hills, potentially the amphibian most vulnerable to climate change, are typically surface active at temperatures ≤13.8 C (≤57 F). Poor riparian habitat conditions are a key limiting factor for this species. Other non-salmon indicator species present in this region include Western toad, coastal tailed frog, northern red-legged frog, North American beaver, Olympic mudminnow, largescale sucker, mountain whitefish, Pacific lamprey, riffle and reticulate sculpin, and speckled dace. Each year, hatchery-raised juvenile coho salmon (approximately 100,000 fish) and steelhead (approximately 32,000 fish) from Skookumchuck Hatchery are released into Eight Creek Pond (a tributary to Elk Creek) as part of the mitigation for Skookumchuck Dam (Cascade Mountains Ecological Region). It is not known to what extent these hatchery-origin fish affect wild fish production in Elk Creek and in the mainstem Chehalis River in the vicinity and downstream of Elk Creek.

5.1.4 Limiting Factors

Limiting factors for salmonids have been identified in several assessments of the Chehalis Basin, including the EDT (ICF 2019) and NOAA modeling (Beechie 2018) conducted for the ASRP and earlier studies (GHLE 2011; Smith and Wenger 2001). Additional limiting factors and a diagnosis of what is working and what is broken in the ecological region were determined by the SRT, drawing on local basin knowledge and reconnaissance conducted within the region.

The combined results of these assessments indicate that the major issues for salmonids in the region are as follows (in relative order of importance):

- High water temperatures
- Reduced quantity and quality of instream habitats
- Low habitat diversity (lack of side channels, large wood, floodplain habitats, and beaver ponds)
- Flows (both low and high flows)
- Channel instability and bed scour
- Sediment conditions (fine sediment and bedrock)
- Poor riparian conditions
- Fish passage barriers

> **Diagnostic Snapshot**
>
> - Substantial parts of all rivers and streams in the Willapa Hills have been historically severely scoured, and they lack wood.
> - Severe disturbance via past storm events in the Willapa Hills had a large impact on stream conditions. Recolonization after flood events of salmonids and Western toad appears to be rapid on the upper Chehalis River and Stillman Creek (less than 10 years). Despite this rebound, habitat conditions continue to be in a degraded condition.
> - The relatively intact wetland and beaver pond complex in the Elk Creek watershed is an example of what many of the valleys now dominated by agriculture may have historically looked like.
> - Severe incision and poor riparian and floodplain habitat conditions are found in the South Fork Chehalis River.
> - A key issue in this region is the overall warmer temperatures in the upper Chehalis and South Fork Chehalis rivers compared to other regions with similar-elevation headwaters that may be related to numerous areas of exposed bedrock.

The identified issues for salmonids are generally consistent with earlier findings from Smith and Wenger (2001) and the Chehalis Basin Lead Entity (GHLE 2011), which indicated that the key limiting factors in this ecological region include fish passage barriers, riparian conditions, sediment conditions, channel incision and loss of floodplain connectivity, and high water temperatures. ASRP results indicate different priorities; water temperature and lack of large wood are the most substantial limiting factors, along with a lack of beaver ponds and floodplain connectivity, particularly in the South Fork Chehalis River sub-basin. Fish passage barriers are relatively lower priority because they primarily occur on smaller streams in this ecological region and timber landowners are actively addressing many barriers on forest roads. Addressing two key fish passage barriers (West Fork Falls and the waterfall and fish ladder on lower Elk Creek) and some of the numerous fish passage barriers in the South Fork Chehalis River sub-basin could also provide substantial benefits to salmon and steelhead. Non-native predator species such as smallmouth bass also have the potential to limit native aquatic species, particularly with continued warming temperatures with climate change. This issue is continuing to be studied.

Limiting factors and threats to non-salmon indicator species are not well understood, but they potentially include high water temperatures, migration barriers, changes in flow conditions and water level variations, fine sediments, riparian conditions, and non-native predator species (as identified for Pacific lamprey by Clemens et al. [2017]). Limited riparian shading and warmer water temperatures benefit Western toad, in contrast to most other native aquatic species; however, improvements in natural processes of channel migration and riparian turnover would help maintain a variety of habitats, including the kinds of recently disturbed habitats that support Western toad.

5.1.5 Strategies and Actions in the Ecological Region

5.1.5.1 Habitat and Process Protection

The protection actions described in Section 4.2.1 are all appropriate in the Willapa Hills Ecological Region, including acquisitions or easements in areas of high-quality habitat. Based on existing conditions, the following areas and actions are recommended for a protection focus:

Upper reaches of Elk Creek should be protected and enhanced within the managed forest context for salmonid refuge.

- Protect existing high-quality habitats such as the wetland and beaver pond complex in the upper valley portion of Elk Creek to provide coho salmon and steelhead overwintering habitat and support diverse life histories for multiple salmon species.
- Protect several headwater stream areas (small tributaries to the upper Chehalis River and Stillman Creek) to maintain a high diversity of amphibian species and promote shading and water temperature moderation along with protecting and enhancing summer low flows.
- Protect the upper Chehalis River (above Pe Ell), including the East Fork and West Fork Chehalis rivers, which are core spawning and rearing habitat for several salmonid species.
- Investigate the potential for water conservation in the South Fork Chehalis River sub-basin to reduce surface and/or groundwater withdrawals to address low-flow conditions.
- Protect and enhance cool-water tributary confluences with the Chehalis River for spring-run Chinook salmon holding.

The majority of the Willapa Hills Ecological Region is within Lewis County, which has regulations and policies in place to maintain forest cover, increase riparian canopy, protect streams from development, and protect surface and groundwater and reduce withdrawals. The Lewis County SMP identifies priority habitat as those habitat types with unique or significant value to one or more species, including fish spawning habitat, and contains regulations that new development should not interfere with the process of channel migration (Lewis County 2017). The County has a policy to support projects from the Lewis County Shoreline Restoration Plan (Lewis County 2016), the ASRP, and the lead entities for salmon recovery. As part of community planning strategies (Section 5.1.5.3), funding support to align regulations with the ASRP and conduct enforcement will be considered.

The upper watershed was historically a stronghold for spring-run Chinook salmon. These areas also provide habitat for North American beaver, amphibians, and other indicator species. First-order headwater streams within forested lands could be further protected to reduce downstream degradation of aquatic habitats.

Streams show channel incision to bedrock in many locations.

General protection priorities for Lewis County in the Willapa Hills Ecological Region are as follows:

- Protect spawning gravel sources and retain spawning gravels (protect channel migration and improve wood recruitment).
- Protect and reduce water temperatures by maintaining or increasing forest cover, riparian canopy, and floodplain connectivity.
- Protect from development.
- Protect headwater streams by maintaining and increasing forest cover.
- Protect the floodplain, channel migration zone, riparian zone, and beaver ponds.

5.1.5.2 Restoration

The restoration actions described in Section 4.2.2 are all appropriate in the Willapa Hills Ecological Region. Based on existing conditions, the following areas and actions are recommended for a restoration focus:

- Install functional stable wood structures and beaver dam analogs throughout the upper Chehalis and upper South Fork Chehalis rivers to trap sediment and smaller wood, creating stable spawning and incubation habitat and cool-water pools. This action could be implemented rapidly in areas managed by one landowner (e.g., timber landowners).
- Address water temperature problems through combinations of beaver dam analogs, beaver dams, floodplain reconnection, and riparian restoration and experimental approaches such as pre-filled sediment wedges.
- Test restoration of wetland prairie habitat at Lake Creek, including encouraging beavers or using beaver dam analogs. Coho salmon and stillwater-breeding amphibians could particularly benefit

from beaver dams (and close proximity to forested habitat for amphibian movement). Wetland prairie areas were historically a significant component of the Chehalis Basin.

- Implement and monitor early action restoration work on lower Stillman Creek to learn about the effectiveness of restoration techniques, particularly for coho and spring-run Chinook salmon.
- Continue monitoring upper Stillman Creek relative to recovery from the 2007 storm event and identify where engineered logjams or anchoring of existing wood would best promote longer-term habitat stability and function.
- Reconnect floodplains in targeted areas of the South Fork Chehalis River using a "node" concept, wherein refuge areas would be spaced along the channel length and available to fish as they travel throughout the system. Associated with nodes, locally raise the stream bed and increase floodplain connectivity through instream stable wood placement. This could have symbiotic groundwater storage benefits that will also benefit instream flows.
- Test enhancement of first- and second-order headwater streams in upper Stillman Creek and/or upper Chehalis River tributaries with wood installation and improvement of long-term canopy cover to test increased groundwater recharge and low-flow support. These small headwater streams are likely to be particularly vulnerable to climate change flow changes.
- Prioritize buffer length over width on the South Fork Chehalis River to promote shading and cover along its length.
- Remove or address key fish passage barriers including West Fork Falls, Elk Creek Falls and fish ladder, and multiple barriers on tributaries to the upper Chehalis and South Fork Chehalis rivers. Individual fish passage barrier replacements have not been prioritized or ranked in this phase of the ASRP.

Fish passage barriers block access to many miles of upstream habitat.

Lower Stillman Creek has opportunities for floodplain reconnection in the Willapa Hills Ecological Region.

Priority restoration areas in the Willapa Hills Ecological Region include the mainstem Chehalis River above Rainbow Falls; East Fork and West Fork Chehalis rivers; upper South Fork Chehalis River; and Stillman, Lake, Big, Crim, Thrash, and Elk creeks.

Weyerhaeuser has been monitoring post-flood conditions on Stillman Creek for more than 10 years (Weyerhaeuser 2018); these data may support further research and controlled studies on passive recovery or supplemental restoration.

5.1.5.3 Community Planning

As noted in Section 4.2.3, community planning actions would be coordinated with state and local governments, landowners, and other stakeholders to ensure the long-term success of the ASRP. Focus programs and policies that could be developed or investigated in the Willapa Hills Ecological Region include the following:

- WDFW could investigate potential hatchery fish effects on wild fish production in Elk Creek.
- Discuss with Lewis County additional planning measures that could effectively promote and protect the following:
  - Riparian maturation and wood recruitment for retention of spawning gravel and sources
  - Water temperatures and floodplain connectivity
  - Beaver ponds
- As the Chehalis Basin Strategy becomes more integrated, coordinate the ASRP with the CFAR Program to build habitat restoration and protection actions into community flood risk reduction efforts (such as restoring areas where structures and people have been relocated from floodplains).

5.1.5.4 Community Involvement

As noted in Section 4.2.4, community involvement and voluntary landowner participation are essential to the success of the ASRP, and the actions described in that section will be further evaluated for the Willapa Hills Ecological Region in Phases 2 and 3 based on the restoration and protection scenario selected. Based on the specific issues in this area, the following actions are recommended for focused community involvement:

- Continue outreach, engagement, and involvement processes to incorporate landowner expertise into ASRP planning and local implementation efforts.
- Continue to share with the community about early action restoration work on Stillman Creek and discuss results of the experimental actions.
- Partner with and support the efforts of existing local organizations (see Appendix E for a list of potential partner organizations).

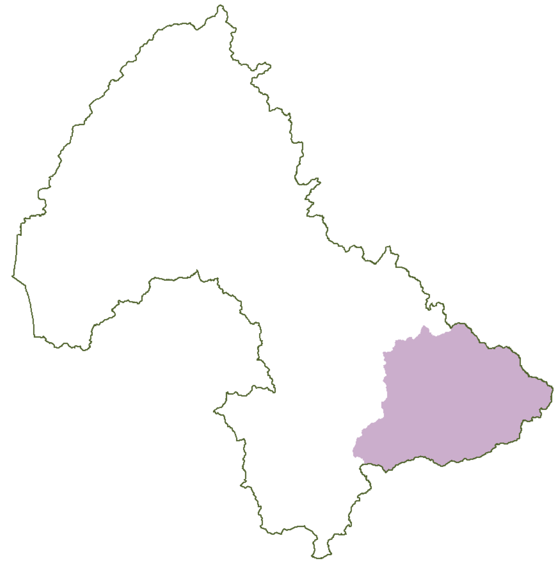
5.1.5.5 Institutional Capacity

The institutional capacity strategy is intended to build on and support the work of existing organizations, as well as support creativity in how local organizations approach working toward the goals of the ASRP. The actions described in Section 4.2.5 will be further evaluated for the Willapa Hills Ecological Region in Phases 2 and 3 based on the restoration and protection scenario selected. Based on the specific issues in this area, the following focused institutional capacity actions are recommended:

- Provide technical training on process-based restoration practices and principles.
- Provide funding for groups and individuals interested in restoration projects.
- Build on and support the work of existing organizations with missions that overlap with the ASRP vision (see Appendix E for a list of potential groups).

5.2 Cascade Mountains Ecological Region

5.2.1 Overview



The Cascade Mountains Ecological Region encompasses the southeastern part of the Chehalis Basin, including the Newaukum and Skookumchuck rivers and their tributaries, Stearns and Salzer creeks, and other tributaries to the east bank of the Chehalis River near Chehalis and Centralia (Figure 5-3). This region encompasses 424 square miles (greater than 270,000 acres) and represents approximately 16% of the overall Chehalis Basin. The Skookumchuck and Newaukum rivers arise in the Bald Hills, a lower-elevation spur of the Cascade Mountains. The highest elevation in the ecological region is Huckleberry Mountain at 3,800 feet. The Skookumchuck River arises around 3,000 feet in elevation near Huckleberry Mountain, the South Fork Newaukum River originates at Newaukum Lake at about 3,000 feet in elevation, and the North Fork Newaukum River originates near Windy Knob at about 2,600 feet in elevation.

The Cascades Mountains Ecological Region geology is predominantly volcanic and continental sedimentary rocks, including sandstone and conglomerate. Notably, the sedimentary Skookumchuck formation contains coal-bearing deposits. Some lobes of glacial deposits extend into the north side of the Skookumchuck River valley, providing coarse gravels to the river system. The Doty Fault Zone extends east of Centralia and Chehalis into the Cascades Mountains Ecological Region.

Precipitation in the Cascade Mountains Ecological Region is dominated by rainfall, with higher elevations occasionally receiving snow. Average annual precipitation is 45 to 75 inches and can be higher in the upper mountain areas. Generally, this

Important Features and Functions

- The Newaukum and Skookumchuck rivers support the majority of the spring-run Chinook salmon population in the Chehalis Basin. Improving conditions for this population, especially enhancing summer holding habitat, is a key consideration for restoration in these watersheds.
- Diverse channel gradient, confinement, and size is a natural condition of the landscape that affects channel and floodplain complexity in this region, but many reaches have become incised due to historical use of splash dams and other activities.
- Deep-seated landslides in the upper Newaukum River watershed produce episodic sediment flows to downstream reaches.
- Hanaford Creek has extensive floodplain wetlands, though channelization and industrial land use impacts are also prominent.
- Non-native species (basses, sunfishes, catfishes, perches, and bullfrogs) are observed in the lower reaches of the Newaukum and Skookumchuck rivers.

(continues on next page)

part of the Chehalis Basin receives less precipitation than other parts of the basin and includes the low-elevation areas around Centralia and Chehalis.

The Cascade Mountains Ecological Region is primarily within Lewis County (215,712 acres, or 79%), with the northern portion within Thurston County (56,017 acres, or 21%). Cities and towns in this region include Bucoda, Centralia, and Chehalis.

Important Features and Functions (Continued)

- There is a significant presence of hatchery fish.
- This ecological region supports multiple salmon and lamprey species.

Figure 5-3
Cascade Mountains Ecological Region Map

Aerial Photo Source: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

5.2.2 Historical Conditions and Changes

Historical records for the pre-Euro-American settlement condition are not available, but available historical records and maps indicate that the Cascade Mountains Ecological Region was dominated by old-growth Western hemlock forest, including other important species such as Douglas-fir and Western red cedar. Numerous prairies were present in the alluvial valleys, including both wet prairies that were typically inundated each spring and dry prairies that were not inundated (WNPS 1994). GLO maps show a large prairie adjacent to the lower Newaukum River and Dillenbaugh Creek, a large wet prairie adjacent to the lower South Fork Newaukum River, numerous smaller wetlands and prairies along the South Fork Newaukum River and its tributaries and the large Alpha Prairie in the upper Middle Fork Newaukum River, a large prairie around the confluence of the North Fork Newaukum River and Lucas Creek, and a large swamp with deep water and willow and ash along lower Stearns Creek. The numerous tributaries to the Chehalis River from the Cascade Mountains Ecological Region historically flooded frequently in their lower reaches and into the Chehalis River floodplain, as illustrated by the following quote from early settlers (Smith 1941):

> *"One immigrant party, it is said, camped one night at McElroy's, now the site of the Southwest Washington Fair Grounds just south of Centralia. In the morning, when they awoke, they found themselves on a tiny island in the center of a sea of water—a mile to dry land in all directions. McElroy (Salzer) Creek had flooded the area during the night."*

Key changes that occurred in the Cascade Mountains Ecological Region following Euro-American settlement were extensive timber harvest and agricultural development in some areas, notably in the Newaukum and Skookumchuck river valleys, and urban development on the lower Newaukum and Skookumchuck rivers associated with Chehalis and Centralia and the major transportation corridors. Similar to other regions of the basin, splash dams were used (see the description in Section 2.1). At least three splash dams were known to have been used on the Skookumchuck River and one on the lower Newaukum River (Wendler and Deschamps 1955), contributing to wood removal and channel incision. Agricultural development as well as road, bridge, railroad, residential, and urban construction likely also incrementally moved and straightened many of the rivers and creeks in the Cascade Mountains Ecological Region over time. Other historical changes to rivers include the construction of Skookumchuck Dam in 1970 that entirely blocked fish access to the upper 20 miles of the mainstem Skookumchuck River and several tributaries, gravel mining in the Newaukum and South Fork Newaukum rivers until at least the 1970s, and construction of a water supply diversion at a small falls on the North Fork Newaukum River (RM 12.5) that blocked fish access

Infrastructure in the floodplain has disrupted natural processes, as illustrated by this riprap embankment protecting a bridge crossing.

until a ladder was constructed in 1970 (WDF 1975). Significant changes have occurred in the Hanaford Creek drainage associated with coal mining, channel straightening, and land drainage and filling. The Skookumchuck Dam augments flows in the Skookumchuck River to ensure a reliable water supply for the Centralia Steam Plant, but water withdrawals also reduce flow volumes.

To support the ASRP analysis and EDT modeling, the SRT developed assumptions of the channel lengths and areas of floodplain habitat that were likely to be present in historical conditions. These assumptions were based on the GLO mapping from the late 1800s, more recent historical aerial photographs, and interpretation of current LiDAR data that show remnant channels and other floodplain features across the basin. All of the primary rivers within the Cascade Mountains Ecological Region are generally unconfined with wide valleys. The upper reaches of the Skookumchuck and North Fork and South Fork Newaukum rivers are partially confined in narrower valleys. It is likely that channels and side channels would have historically been nearly double the current length, with 3 or more times the area of connected floodplain. In all of the streams and rivers of the Cascade Mountains Ecological Region, large wood has been removed from channels and channel incision has occurred to some extent.

5.2.3 Current Conditions

Current conditions reflect ongoing forest management; agricultural land uses; and residential, commercial, and industrial development. Land cover is 29% coniferous forest, 8% mixed forest, 6% deciduous forest, 23% shrub, 9% grassland, 9% agriculture, 8% developed, 5% wetland, and small percentages of other cover[9] (Figure 5-4).

An assessment of riparian conditions and functions by NOAA (Beechie 2018) indicates that the vast majority of the riparian areas in the Cascade Mountains Ecological Region are impaired for wood recruitment due to the young age of trees present within riparian areas. Fewer than 5% of the reaches in the Skookumchuck and Newaukum rivers have larger trees in the riparian zone. The lack of trees in the riparian zone also reduces cover and provides very low levels of shading.

Cascade Mountains Current Snapshot

Condition of Watershed Processes:
Hydrology – moderately impaired
Floodplain connectivity – impaired
Riparian condition – impaired
Water quality – impaired

Restoration Potential: High

Protection Potential: Moderate

Geographic Spatial Units: Newaukum River, North Fork Newaukum River, South Fork Newaukum River, Middle Fork Newaukum River, Skookumchuck River, Hanaford Creek, Salzer Creek, and Stearns Creek

Salmon Use and Potential: High for spring-run Chinook salmon, fall-run Chinook salmon, coho salmon, and steelhead

Non-Salmon Use and Potential: Coastal tailed frog, Van Dyke's salamander, northern red-legged frog, North American beaver, Olympic mudminnow, largescale sucker, mountain whitefish, Pacific lamprey, riffle and reticulate sculpin, speckled dace, Western ridged mussel, great blue heron, and wood duck

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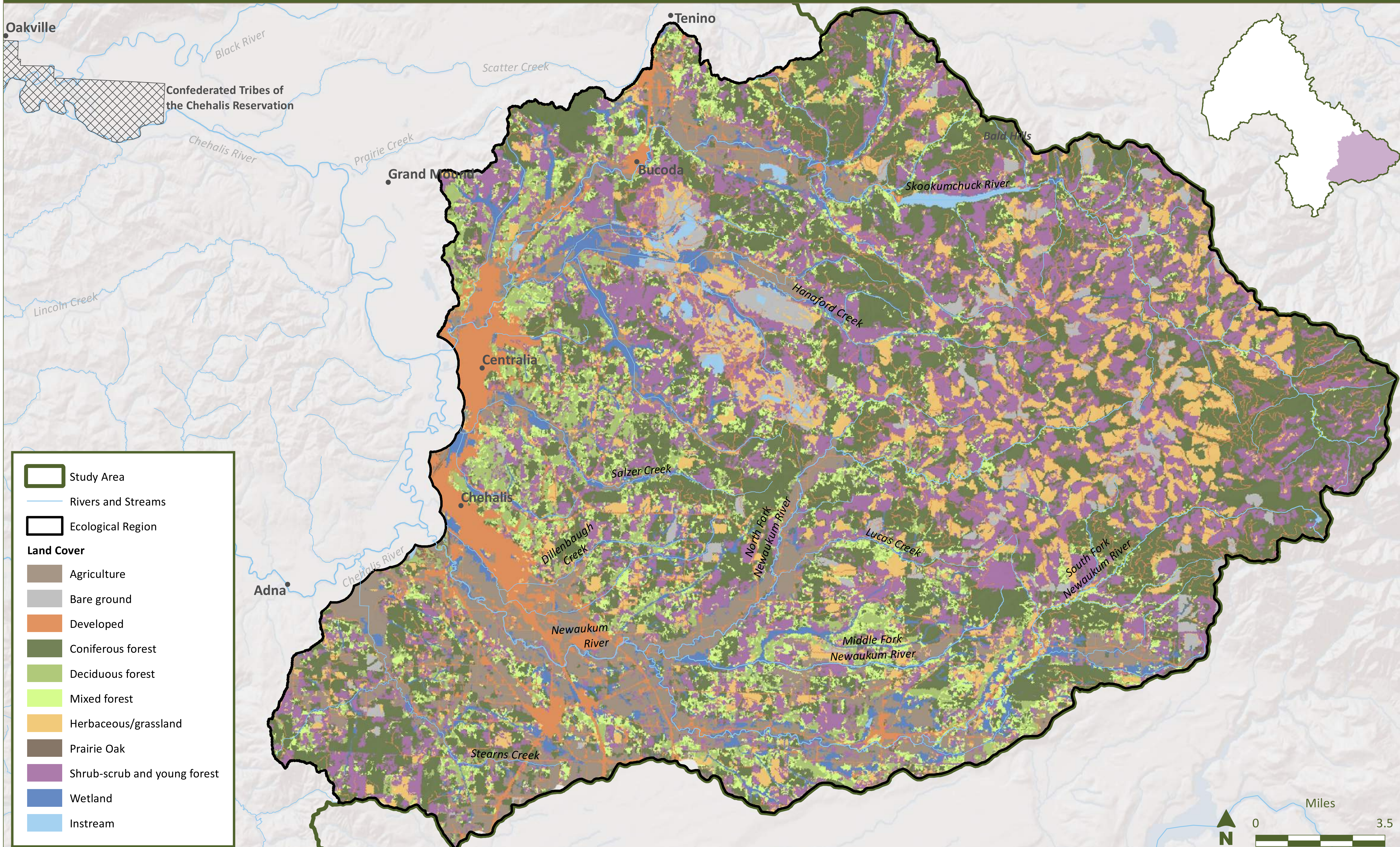
[9] Land cover data from Multi-Resolution Land Characteristics Consortium, National Land Cover Database 2011, augmented by WDFW Habitat Guild 2015 floodplain data where available.

Figure 5-4
Cascade Mountains Ecological Region Land Cover



Skookumchuck Dam and its reservoir cause disconnection of the upper and lower watershed and of physical and biotic processes, though the dam releases also augment low flows with cool reservoir water.

Water quality is impaired in multiple reaches in the Cascade Mountains Ecological Region, primarily for temperature, low dissolved oxygen, and bacteria (Ecology 2018). Non-native invasive species are present in the mainstem Newaukum and Skookumchuck rivers. Recent temperature monitoring in the Newaukum (RM 4; RM 27.3 South Fork; RM 6.3 North Fork) and Skookumchuck (RMs 4.5 and 18.5) rivers by WDFW (2014 to 2015 data) indicates that downstream of Skookumchuck Dam, water temperatures increase[10] and regularly exceed the 16°C (61°F) core summer salmonid habitat criterion from May through September,[11] and they typically exceed the 13°C (55°F) supplemental spawning incubation criterion (September 15 to July 1) in September and May to July (Ecology 2016, 2011a). The *Upper Chehalis River Basin Temperature TMDL* (Ecology 2001) has designated a goal of 18°C (64°F) for the upper Chehalis River, with the primary goals of increasing shading along the Skookumchuck and Newaukum rivers and decreasing the width of the Newaukum River. It is also critical to prevent further reductions in flows and improve low flows if feasible.

WDFW's Thermalscape model indicates that from 2013 to 2018, the majority of stream reaches of the Cascade Mountains Ecological Region (ranging from 48% [2018] to 64% [2015] of the reaches) had mean August temperatures equal to or exceeding 16°C (61°F) and are projected to increase to 75% and 96% of the reaches in 2040 and 2080, respectively, without restoration actions (Winkowski and Zimmerman 2019).

The NOAA model that incorporates mature riparian conditions and anticipated climate change shows a likely future increase in summer water temperatures ranging from 1.5°C (2.7°F) to more than 2.5°C (4.5°F) in this region by 2080 (Beechie 2018). Salzer and Hanaford creeks were the only areas in the Cascade Mountains Ecological Region where a lesser future water temperature increase was projected because current conditions are so poor that a mature riparian corridor could provide reduced water temperatures even with climate change. If riparian forests are not allowed to mature, temperature increases would be even higher.

The current river channels are predominantly one primary channel, although short side channels are present on the Skookumchuck and South Fork Newaukum rivers, with varying levels of incision throughout the region. Abbe et al. (2016, 2018) estimated levels of channel incision in several locations in the Cascade Mountains Ecological Region, including 0.4 to 2.5 feet on the Middle Fork Newaukum

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[10] The temperature of the water released from Skookumchuck Dam typically ranges from 10 to 14°C (50 to 57°F), and the dam provides water supply to Skookumchuck Hatchery (Emrich 2018)

[11] The 7-day average daily maximum temperatures reached more than 25°C (77°F) in the lower Skookumchuck and lower Newaukum rivers, even though cool water is typically released from Skookumchuck Dam, and exceeded 20°C (68°F) in the North Fork Newaukum River.

River, nearly 10 feet on the lower Newaukum River, 1.3 to 6 feet on the North Fork Newaukum River, 2 to more than 11 feet on the South Fork Newaukum River, 0 to 6 feet on Stearns Creek, and 4 to 5 feet on the Skookumchuck River. Existing mapping of wetlands (Ecology 2011b) shows relatively large wetland areas adjacent to Stearns Creek; the Newaukum River; Dillenbaugh Creek; the Middle Fork, North Fork, and South Fork Newaukum rivers; and Salzer and Hanaford creeks.

Historical and current areas of floodplain marsh and beaver pond habitats were documented by NOAA using GLO mapping (Beechie 2018). They found the Skookumchuck River sub-basin (including Hanaford Creek) has lost 90% of its historical marsh habitat and the Newaukum River sub-basin has lost about 75%; the Skookumchuck River sub-basin has lost about 75% of its historical beaver pond habitat and the Newaukum River sub-basin has lost about 90%. Fish passage barriers include Skookumchuck Dam and numerous barriers on tributaries to all of the rivers. Approximately 200 fish passage barriers were incorporated into the EDT model[12] for the Cascade Mountains Ecological Region, with the largest number present on tributaries to the South Fork Newaukum River.

The percentage of fine sediment in streams was modeled by NOAA based on the density of roads and channel slope; this modeling indicated 14% to 15% fines are likely to be present in the Newaukum River and 19% to 21% fines in the lower Skookumchuck River, which is a substantial increase from modeled historical conditions that indicated 8% to 11% fines in the Newaukum River and 15% to 19% fines in the Skookumchuck River (Beechie 2018). Skookumchuck Dam prevents the transport of coarse sediment (gravels) and wood from the upper basin and WDFW Fish Program staff have observed a general trend of substrate below the dam becoming coarser over time (indication of gravel starvation).

The Cascade Mountains Ecological Region is currently the stronghold for spring-run Chinook salmon, with approximately 74% of spring-run Chinook salmon spawning occurring in the Skookumchuck and Newaukum rivers (Holt 2018a; 1991 to 2017 average), and fall-run Chinook salmon, coho salmon, and steelhead are also present. Non-salmon indicator species include coastal tailed frog, Van Dyke’s salamander, northern red-legged frog, North American beaver, Olympic mudminnow, largescale sucker, mountain whitefish, Pacific lamprey, riffle and reticulate sculpin, speckled dace, and Western ridged mussel. The bird indicator species present include great blue heron and wood duck.

All hatchery releases in this ecological region originate from Skookumchuck Hatchery and are integrated programs. These consist of coho salmon and steelhead releases for mitigation and harvest opportunity purposes and are detailed as follows:

- There are four coho salmon fry releases by schools or conservation districts totaling about 50,000 fish (sized less than 1 gram per fish). The scales of these programs are not large enough to significantly contribute to population sizes.
- One remote incubation box is intended to rear 40,000 coho salmon eyed eggs to fry. These fish are too small to mark and are also not believed to contribute to adult returns.

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[12] Fish passage barrier data from WDFW processed through EDT model.

- One cooperative project in Stearns Creek releases 46,000 coho salmon smolts each year.
- Skookumchuck Hatchery releases 100,000 coho salmon and 75,000 steelhead into the Skookumchuck River to mitigate for lost harvest opportunity caused by Skookumchuck Dam. Skookumchuck Hatchery also provides fish released into the Newaukum River (Lake Carlisle, Gheer Creek). Releases in the Willapa Hills Ecological Region are described in Section 5.1.3 and further detailed as follows:
  - Net pens in Lake Carlisle are operated by Onalaska High School. Skookumchuck Hatchery provided fry-sized fish for these programs. Fish reared in these net pens are released into Gheer Creek. There is also on-site rearing at the high school for steelhead. The goal is to release 50,000 normal-timed and 50,000 late-timed coho salmon and 25,000 steelhead smolts into Gheer Creek. Another 5,000 pre-smolt steelhead are released into the Newaukum River.
  - The Skookumchuck Hatchery releases of steelhead in the Skookumchuck River appear to be reducing the genetic diversity of the wild steelhead population in the Skookumchuck River based on recent genetic work (Seamons et al. 2017).

5.2.4 Limiting Factors

Limiting factors for salmonids have been identified in several assessments of the Chehalis Basin, including the EDT (ICF 2019) and NOAA modeling (Beechie 2018) conducted for the ASRP and earlier studies (GHLE 2011; Smith and Wenger 2001). Additional limiting factors and a diagnosis of what is working and what is broken in the ecological region were determined by the SRT, drawing on local basin knowledge and reconnaissance conducted within the region.

The combined results of these assessments indicate that the major issues for salmonids in the region are as follows (in relative order of importance):

- High water temperatures (significant issue for spring-run Chinook salmon, including lack of cold-water holding pools)
- Low habitat diversity (lack of side channels, large wood, floodplain habitats, and beaver ponds)
- Reduced quantity and quality of instream habitats
- Poor riparian conditions
- Flow conditions (both low and high flows)
- Fish passage barriers
- Predation
- Fine sediment
- Channel instability

These identified issues for salmonids are consistent with earlier findings from Smith and Wenger (2001) and the Chehalis Basin Lead Entity (GHLE 2011), which indicated that the key limiting factors in this ecological region include riparian conditions, loss of floodplain connectivity, sediment conditions, fish passage barriers, lack of large wood, water quantity, and high water temperatures. Model results are in agreement in relative priorities of limiting factors.

Diagnostic Snapshot

- There is a lack of wood, channel incision, poor riparian conditions, and disconnected floodplains throughout this region.
- Lower reaches of the Newaukum and Skookumchuck rivers have high water temperatures.
- Many landowners farm or mow grasses to the channel edge, which reduces shading (temperature), food inputs (terrestrial insects), and other stream characteristics.
- WDFW snorkel and passive integrated transponder (PIT)-tag studies showed that juvenile coho salmon and steelhead are present in the lower South Fork Newaukum River in May and June, but some combination of mortality and upstream migration in July results in limited use for summer rearing habitat.
- Invasive plant species, including reed canarygrass, knotweeds, and blackberries, are present.
- Many areas lack stable gravel due to a lack of wood. The lower extents of the Newaukum and Skookumchuck river sub-basins are heavily silted from upstream land uses and runoff. Siltation reduces survival of incubating eggs and affects the availability of benthic food resources.
- Spring-run Chinook salmon reach summer holding areas by late June and remain there throughout the summer until spawning begins in September. During this holding period, they are highly vulnerable to illegal harvest, which is known to occur within this ecological region.
- Skookumchuck Dam disconnected the upper and lower watershed and disrupted wood and sediment transport processes.
- Salzer, China, Coal, and Dillenbaugh creeks all have visible urban creek impacts.

Limiting factors and threats to non-salmon indicator species are not well understood, but they potentially include high water temperatures, migration barriers, changes in flow conditions and water level variations, fine sediments, riparian conditions, and non-native predator species (as identified for Pacific lamprey by Clemens et al. [2017]). Invasive fish species may also present a special problem to the non-salmon fauna in the few higher-elevation lakes and ponds in this ecological region.

5.2.5 Strategies and Actions in the Ecological Region

5.2.5.1 Habitat and Process Protection

Many of the protection actions described in Section 4.2.1 are appropriate in the Cascade Mountains Ecological Region, particularly acquisitions or easements to protect high-functioning habitats. Based on existing conditions, the following areas and actions are recommended for a protection focus:

- Protect this ecological region at a high intensity because of its critical function as a spring-run Chinook salmon core area and its high vulnerability to increasing development.
- Protect headwater lakes in the Skookumchuck River sub-basin for unique amphibian assemblages and species diversity.

The majority of the Cascade Mountains Ecological Region is within Lewis County, which has regulations and policies in place to maintain forest cover, increase riparian canopy, protect streams from development, and protect surface and groundwater and reduce withdrawals. The Lewis County SMP identifies priority habitat as those habitat types with unique or significant value to one or more species, including fish spawning habitat, and contains regulations that new development should not interfere with the process of channel migration (Lewis County 2017). The County has a policy to support projects from the Lewis County Shoreline Restoration Plan (Lewis County 2016), the ASRP, and the lead entities for salmon recovery.

The northern portion of the ecological region is within Thurston County, which has regulations in place to protect water quantity and quality; maintain or increase forest cover; establish and protect riparian habitat; protect streams, wetlands, floodplains, and prairies from development; limit impervious surfaces; and allow channel migration.

Stream conditions lacking wood and mature riparian areas are common throughout the Cascade Mountains Ecological Region.

The upper South Fork Newaukum River, including the Pigeon Springs area, is a key cold-water refuge for spring-run Chinook salmon and other indicator species that should be protected.

As part of the community planning strategy (see Section 5.2.5.3), funding support to align both counties' regulations with the ASRP and conduct enforcement will be considered.

Additionally, general protection priorities for Lewis County in the Cascade Mountains Ecological Region are as follows:

- Protect cold water habitats in all forks of the Newaukum River (and key tributaries).
- Protect overwintering habitats in the lower North Fork and South Fork Newaukum rivers.

General protection priorities for Thurston County in the Cascade Mountains Ecological Region are as follows:

- Protect cold water inputs.

5.2.5.2 Restoration

The restoration actions described in Section 4.2.2 are all appropriate in the Cascade Mountains Ecological Region. Based on existing conditions, the following areas and actions are recommended for a restoration focus:

- Conduct restoration at a high intensity because of the region's critical function as a spring-run Chinook salmon core area.
- Install stable functional wood structures and beaver dam analogs throughout the Skookumchuck and Newaukum rivers to trap sediment and smaller wood, creating stable spawning and incubation habitat and cool-water pools.
- Strategically select wet prairie habitats, such as those in Stearns and Hanaford creeks, where larger, contiguous areas of the habitat could be restored.

Stearns Creek is a priority for lowland marsh and prairie restoration. Like other creeks in the Cascade Mountains Ecological Region, much of Stearns Creek is restricted by fish passage barriers, channelization, poor riparian conditions, loss of floodplain habitats, and high water temperatures.

- Restore riparian buffers and instream wood for shading, channel complexity, and floodplain connectivity to improve summer rearing and holding habitat for salmonids, starting in the upper reaches of the Skookumchuck and Newaukum river forks and moving downstream. Restore riparian areas to maintain cool water temperatures moving downstream on the Skookumchuck and Newaukum rivers.
- Reconnect floodplains where feasible, as there are many low-gradient reaches and channel incision levels that still allow for floodplain connectivity. This would also promote groundwater aquifer recharge and low flow maintenance. Large wood structures can promote this connectivity.

- Remove fish passage barriers where good quality habitat exists upstream; fish passage barriers are most significant in Hanaford Creek and the South Fork Newaukum River tributaries.
- Evaluate the potential benefits and costs of Skookumchuck Dam removal or operational changes to benefit aquatic species.
- Implement and monitor the early action restoration projects in the Skookumchuck and South Fork Newaukum rivers to evaluate the effectiveness of restoration techniques and identify additional opportunities for restoration projects.

Priority areas for restoration in the Cascades Mountains Ecological Region include the lower Skookumchuck River, the mainstem Newaukum River and all forks, Hanaford Creek, and Stearns Creek. Actions in the Skookumchuck and Newaukum rivers will most directly address spring-run Chinook salmon habitat.

5.2.5.3 Community Planning

As noted in Section 4.2.3, community planning actions would be coordinated with state and local governments, landowners, and other stakeholders to ensure the long-term success of the ASRP. Focus programs and policies that could be developed or investigated in the Cascade Mountains Ecological Region include the following:

- WDFW could evaluate Skookumchuck Hatchery releases of hatchery fish on wild populations, consider options to reduce and minimize genetic and competitive effects, and evaluate the effectiveness of hatchery outplants at providing adult returns.
- Discuss with Lewis County additional planning measures that could effectively promote and protect the following:
  - Maturation of riparian forest and wood recruitment for retention of spawning gravel and sources
  - Cold water temperatures and floodplain connectivity
  - Beaver ponds
- Discuss with Thurston County additional planning measures that could effectively promote and protect the following:
  - Floodplain connectivity
  - Surface and groundwater volumes through reduction of withdrawals
  - Improved wood recruitment for retention of spawning gravel and sources
- As the Chehalis Basin Strategy becomes more integrated, coordinate the ASRP with the CFAR Program to build habitat restoration and protection actions into community flood risk reduction efforts (such as restoring areas where structures and people have been relocated from floodplains).

5.2.5.4 Community Involvement

As noted in Section 4.2.4, community involvement and voluntary landowner participation are essential to the success of the ASRP, and the actions described in that section will be further evaluated for the Cascade Mountains Ecological Region in Phases 2 and 3 based on the restoration and protection scenario selected. Based on the specific issues in this area, the following actions are recommended for focused community involvement:

- Increase community involvement in protecting spring-run Chinook salmon in summer holding areas.
- Provide education and public awareness to reduce poaching.
- Continue outreach, engagement, and involvement processes to incorporate landowner expertise into ASRP planning and local implementation efforts.
- Partner with and support the efforts of existing local organizations (see Appendix E for a list of potential partner organizations).

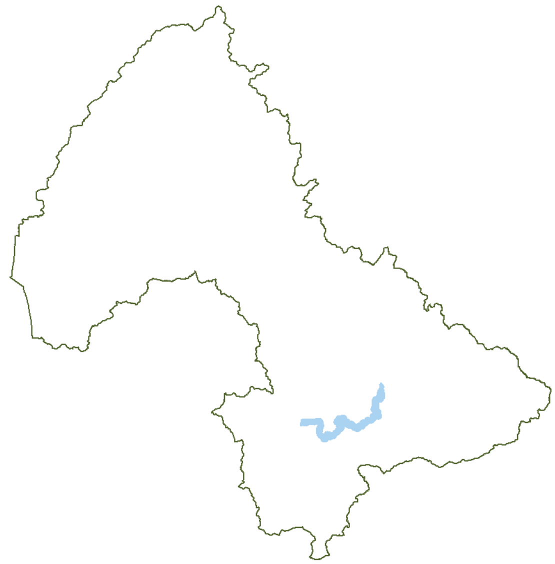
5.2.5.5 Institutional Capacity

The institutional capacity strategy is intended to build on and support the work of existing organizations, as well as support creativity in how local organizations approach working toward the goals of the ASRP. The actions described in Section 4.2.5 will be further evaluated for the Cascade Mountains Ecological Region in Phases 2 and 3 based on the restoration and protection scenario selected. Based on the specific issues in this area, the following focused institutional capacity actions are recommended:

- Increase enforcement against poaching.
- Provide incentives to willing landowners for riparian planting in agricultural areas.
- Provide technical training on process-based restoration practices and principles.
- Provide funding for groups and individuals interested in restoration projects.
- Build on and support the work of existing organizations with missions that overlap with the ASRP vision (see Appendix E for a list of potential groups).

5.3 Middle Chehalis River Ecological Region

5.3.1 Overview



The Middle Chehalis River Ecological Region encompasses the mainstem Chehalis River and its floodplain from approximately RM 97 (Rainbow Falls) to RM 67 (Skookumchuck River confluence; Figure 5-5). This ecological region encompasses 26 square miles (nearly 17,000 acres) and represents approximately 1% of the overall Chehalis Basin. The entire ecological region is low-elevation alluvial valley ranging from about 300 feet in elevation near Rainbow Falls to about 180 feet in elevation in Centralia.

The mainstem middle Chehalis River floodplain geology is predominantly recent alluvium; however, continental glacial ice sheets extended more than once into the Chehalis Basin. The Middle Chehalis River Ecological Region was affected by glacial outwash and the deposition of coarse glacial outwash sediments as far south as Centralia, as well as the formation of a glacial lake that extended from the Skookumchuck River to the Newaukum River confluence and deposited fine-grained lacustrine sediments (Bretz 1913, cited in Gendaszek 2011). The Doty Fault Zone extends east of Centralia and Chehalis, through the Middle Chehalis River Ecological Region.

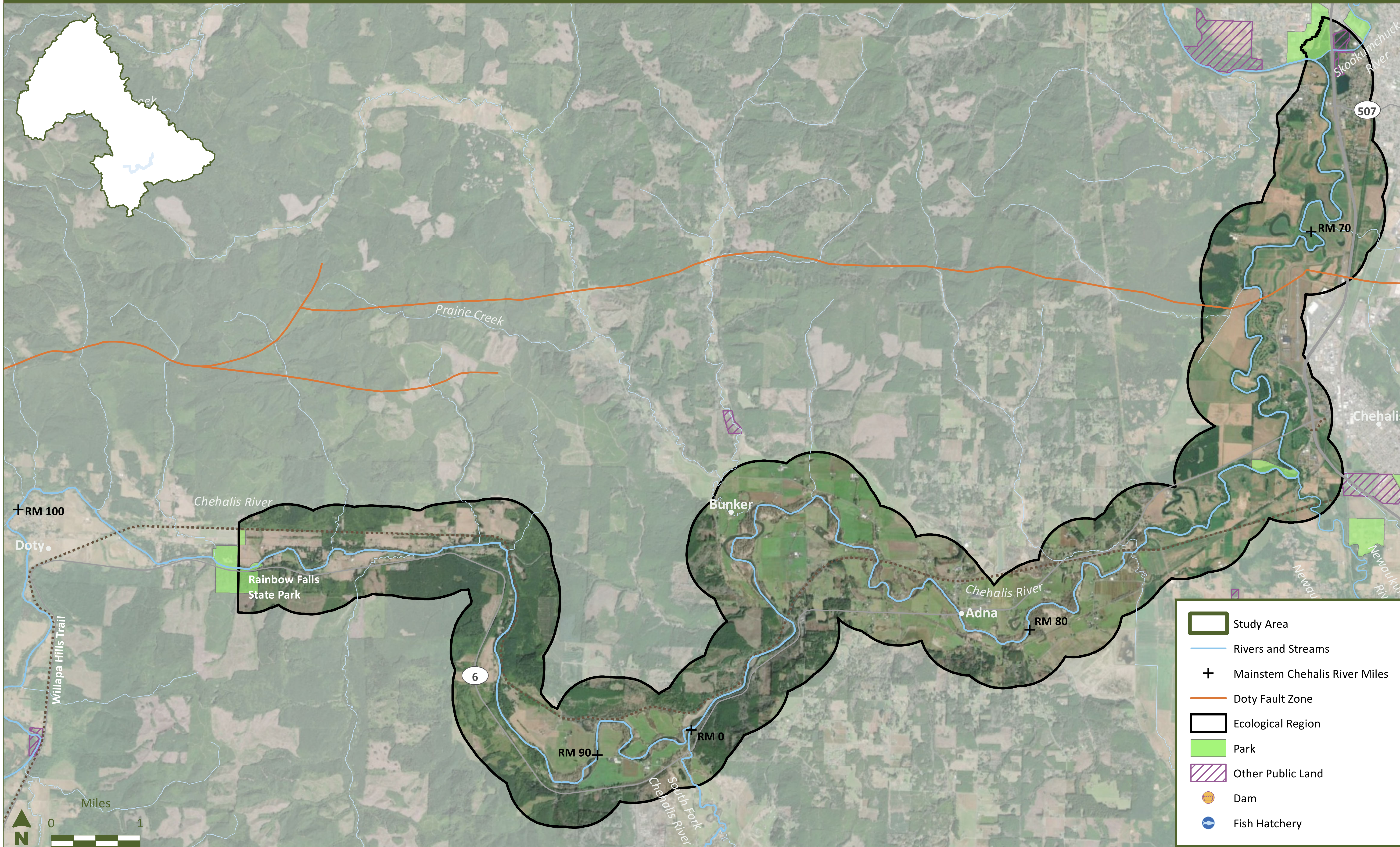
Important Features and Functions

- Migratory fish from all sub-basins in the upper Chehalis Basin pass through this region, making its ecological function more impactful to large areas.
- The ecological region is characterized by a large and deep incised river channel and a large series of off-channel aquatic habitats, including oxbows.
- Many invasive fish species, especially centrarchid fishes (basses, crappies, and sunfishes), are found in off-channel habitats and in the mainstem Chehalis River.

Precipitation in this ecological region is dominated by rainfall; however, average annual precipitation varies from 43 to 50 inches in the Middle Chehalis River Ecological Region lowlands—a relatively lower precipitation range than many other regions in the basin (Gendaszek 2011).

The Middle Chehalis River Ecological Region is entirely within Lewis County. The town of Adna is within this ecological region, and the cities of Chehalis and Centralia are adjacent to the ecological region.

Figure 5-5
Middle Chehalis River Ecological Region Map



Aerial Photo Source: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

5.3.2 Historical Conditions and Changes

Stearns Creek, an important small tributary, historically included wetland and prairie habitat at the confluence with the Chehalis River. Current conditions at the creek mouth, viewed from the Willapa Hills Trail, illustrate sediment deposition.

Historical records for pre-Euro-American settlement conditions are not available, but available historical records and maps indicate that the Middle Chehalis River Ecological Region below the South Fork Chehalis River was dominated by sloughs, oxbows, prairies, brush, and timber. Survey notes from GLO mapping indicate a wide cottonwood riparian zone fringing on the river channel. Upstream of the confluence with the South Fork Chehalis River, as the floodplain narrows, mapping indicates more coniferous timber (fir). Numerous prairies were present in the alluvial valleys, including both wet prairies that were typically inundated each spring and dry prairies that were not inundated (WNPS 1994). GLO maps show a large prairie north of the river extending along RMs 78 to 81. This implies frequent connectivity between the river and its floodplain wetlands. Historically, this portion of the Chehalis River was far more connected to its floodplain as compared to its currently incised condition, as illustrated by the following quote from early settlers (Smith 1941):

> *"The flooded land (Chehalis valley) about a mile south of the Skookumchuck mentioned by Patterson Laurk was the section from the outlet of what is now Salzer Valley on towards the outskirts of the present city of Chehalis. Frequently, in winter, this whole area was like one large lake about four miles across. It is within the memory of many older residents that canoes often plied over this flooded section."*

Key changes that occurred in the Middle Chehalis River Ecological Region following Euro-American settlement were timber harvest and agricultural development throughout the floodplain and urban development associated with Chehalis and Centralia and the major transportation corridors (including I-5, railroad lines, State Route [SR] 6, and the Chehalis-Centralia Airport). Similar to other ecological regions, splash dams were used (see the description in Section 2.1). Two splash dams were known to have been used on the Chehalis River at or just above the Middle Chehalis River Ecological Region boundary (near Doty and Rainbow Falls; Wendler and Deschamps 1955), contributing to wood removal and channel incision. Agricultural development as well as road, bridge, and residential construction likely also moved and straightened some areas of the Chehalis River. An analysis of channel migration from 1945 to 2013 indicates that migration rates ranged from 1.8 to over 67 feet per year but occurred from typically slow bank erosion on the outside of meander bends (Watershed GeoDynamics and Anchor QEA 2014). Only a few reaches showed significant migration, located in the upper part of the ecological region (i.e., RMs 90 to 91, 86 to 88, and 83 to 86). Much of the mainstem channel downstream of the confluence with the South Fork Chehalis River has essentially stayed in place since the 1940s, as large-scale conversions to agriculture had already occurred by that time. A recent study of floodplain land cover changes (Pierce et al. 2017) indicates that agricultural development continued at a slower rate from 1938 through the mid-1970s (approximately 16 acres per year converted to agriculture), but since the 1970s, there has been a slow decline in agricultural acreage (a loss of 7 acres per year) and a modest increase in conversion to development (a gain of 8 acres per year). Pierce et al. (2017) found there was an increase in forest canopy during both time periods. Modeling conducted by NOAA (Beechie 2018) for the ASRP indicated significant losses in marsh and beaver pond habitats in the middle Chehalis River floodplain—about 80% and 50%, respectively (primarily in the area between the South Fork Chehalis River and the Skookumchuck River).

To support the ASRP analysis and EDT modeling efforts, the SRT developed assumptions of the channel lengths and areas of floodplain habitat that were likely to be present in historical conditions relative to current conditions. These assumptions were based on the limited data available from GLO mapping from the late 1800s and interpretation of current LiDAR data that show remnant channels and other floodplain features.

This portion of the Chehalis River is unconfined and low gradient within a wide alluvial valley. Compared to historical conditions, the river channel length is not significantly reduced, but side channels would have historically been far more prevalent, and the river would have had 5 or more times the area of frequently connected floodplain. The middle Chehalis River appears more incised than most other parts of the basin. Large wood has been removed, and the riparian zone is very narrow. Abbe et al. (2016, 2018) estimated levels of channel incision in several locations in the Middle Chehalis River Ecological Region, from 6 to 24 feet and typically about 10 feet.

5.3.3 Current Conditions

Current conditions in the Middle Chehalis River Ecological Region reflect ongoing agricultural land uses and residential and commercial development. Land cover is 36% agriculture, 13% deciduous forest, 11% prairie oak, 10% coniferous forest, 10% developed, 7% shrub, 3% wetland, 3% mixed forest, and small percentages of other cover[13] (Figure 5-6).

An assessment of riparian conditions and functions by NOAA (Beechie 2018) indicates that the vast majority of the riparian areas in the Middle Chehalis River Ecological Region are impaired for wood recruitment, with only about 11% of the region containing larger trees that could provide cover. Overall, the Middle Chehalis River Ecological Region has very low levels of shading.

Middle Chehalis River Current Snapshot

Condition of Watershed Processes:
Hydrology – impaired
Floodplain connectivity – impaired
Riparian condition – impaired
Water quality – impaired

Restoration Potential: Moderate

Protection Potential: Low

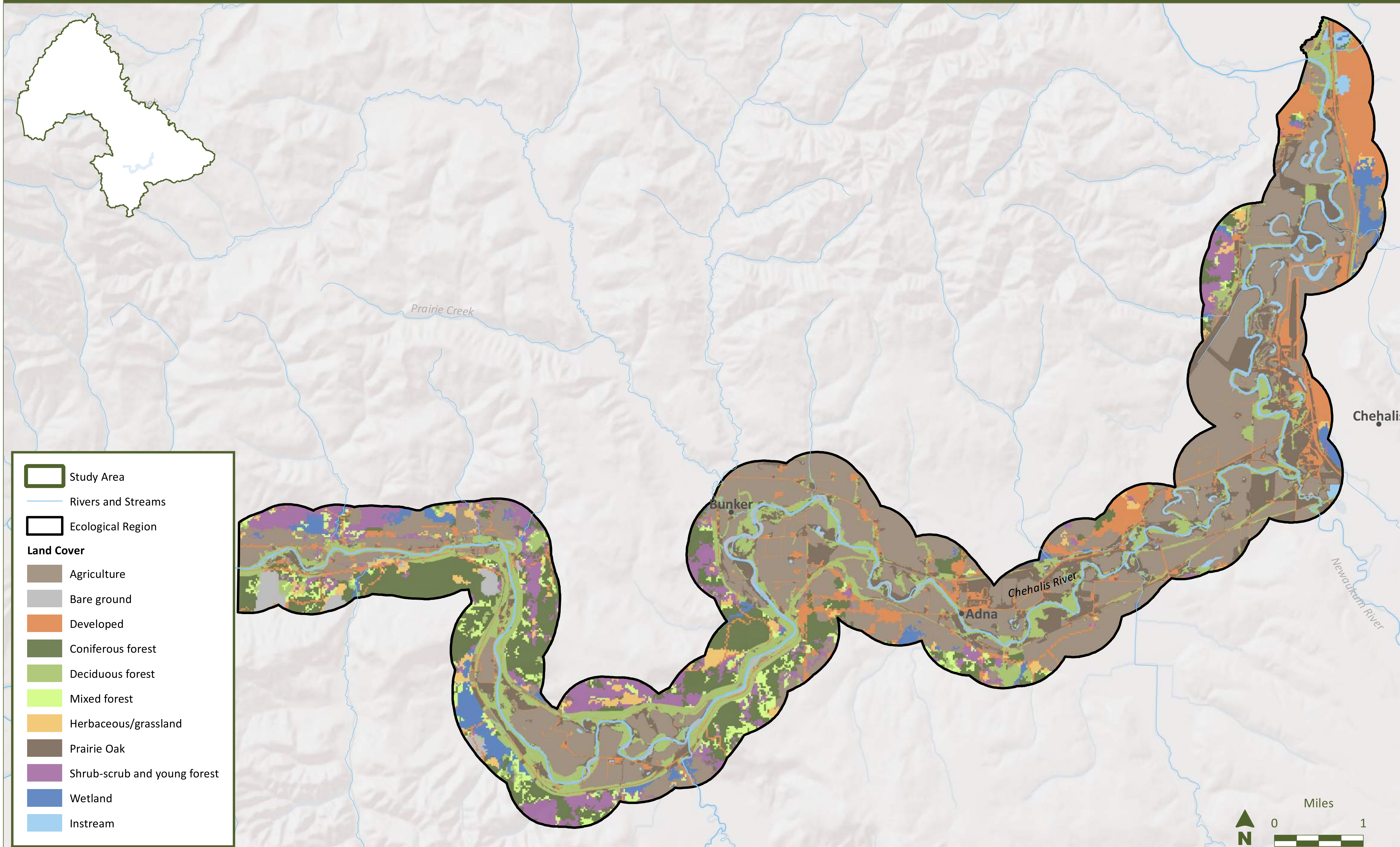
Geographic Spatial Units: Chehalis River Mainstem Reaches: Elk Creek to South Fork Chehalis River, South Fork Chehalis River to Newaukum River, and Newaukum River to Skookumchuck River

Salmon Use and Potential: Fall-run Chinook salmon, spring-run Chinook salmon, coho salmon, and steelhead

Non-Salmon Use and Potential: Western toad, northern red-legged frog, North American beaver, Olympic mudminnow, largescale sucker, mountain whitefish, Pacific lamprey, riffle and reticulate sculpin, speckled dace, Western ridged mussel, great blue heron, common goldeneye, and wood duck

[13] Land cover data from Multi-Resolution Land Characteristics Consortium, National Land Cover Database 2011, augmented by WDFW Habitat Guild 2015 floodplain data where available.

Figure 5-6
Middle Chehalis River Ecological Region Land Cover



Base flows have been established upstream of the Newaukum River (75 cubic feet per second [cfs] from August 15 to September 15; WAC 173-522-020). If base flows drop below the required minimums, junior water rights holders can be required to curtail water withdrawals. In 2007, the first curtailment requests were made by Ecology. Similar requests were made in 2015 (Gallagher 2015) and 2016.

Water quality is impaired in multiple reaches in the Middle Chehalis River Ecological Region, primarily for temperature, low dissolved oxygen, and bacteria, although dioxins, polychlorinated biphenyls (PCBs), and non-native invasive species are found from the confluence with the South Fork Chehalis River downstream to near Centralia (Ecology 2018).

The Middle Chehalis River Ecological Region is limited by infrequent instream pools and inadequate riparian conditions. In this area upstream of the confluence with the Newaukum River, the Chehalis River shows channel incision, an eroding bank, and a lack of functioning riparian vegetation and wood.

Recent temperature monitoring by Ecology indicates that temperatures at RMs 62 and 72.5 regularly exceed water quality standards (16°C [61°F] core summer salmonid habitat) from May through September, and they typically exceed the 13°C (55°F) supplemental spawning incubation criterion (September 15 to July 1) in September and May to July (Ecology 2016, 2011a).[14] The *Upper Chehalis River Basin TMDL* (Ecology 2001) has designated a goal of 18°C (64°F) for the Chehalis River (down to RM 30), with the primary goals of increasing shading along the tributaries and mainstem as well as improving low flows.

WDFW's Thermalscape model indicates that from 2013 to 2018, all stream reaches (100%) of the Middle Chehalis River Ecological Region were characterized by mean August temperatures equal to or exceeding 16°C (61°F) (Winkowski and Zimmerman 2019). This condition is projected to continue with climate change.

The NOAA model that incorporates mature riparian conditions and anticipated climate change shows a likely future increase in summer water temperatures ranging from 0.5°C (0.9°F) to 1.5°C (2.7°F) by 2080 (Beechie 2018), which is lower than other ecological regions because this portion of the Chehalis River already has such high temperatures.

Existing mapping of wetlands (Ecology 2011b) shows relatively large wetland areas in the following locations:

- North and south of the Chehalis River west of the Newaukum River confluence
- Around lower Salzer Creek within the floodplain

[14] The middle Chehalis River regularly exceeds 25°C (77°F) during July and August near RM 75 (below the Newaukum River confluence; [Ecology gage data]).

- West of the Chehalis River near RMs 68 to 69 and in the lower Scheuber Ditch area
- At the confluence with the Skookumchuck River

Only five fish passage barriers were incorporated into the EDT model[15] for the Middle Chehalis River Ecological Region, with none on the mainstem river.

The percentage of fine sediment in streams was modeled by NOAA based on the density of roads and land uses; this modeling indicated 15% to more than 18% fines in the Chehalis River between Elk Creek and the South Fork Chehalis River and 17% to 21% fines in the Chehalis River from the South Fork Chehalis River to the Skookumchuck River. This is a substantial increase from modeled historical conditions (Beechie 2018) that ranged from 10% to 15% fines in the Chehalis River between Elk Creek and the South Fork Chehalis River and 14% to 18% fines in the Chehalis River from the South Fork Chehalis River to the Skookumchuck River.

There are recent invasive aquatic plant issues, particularly the presence of Brazilian elodea, in the Centralia reach of the mainstem Chehalis River. In 1998, Brazilian elodea was observed in the river, and multiple agencies and the Chehalis Tribe have conducted removal efforts since the early 2000s. The area of infestation has been substantially reduced (Thurston County 2019). However, the river is at risk for further invasions by a variety of invasive aquatic plants that tend to reduce dissolved oxygen and trap fine sediments.

The Middle Chehalis River Ecological Region is an important transportation corridor for spring-run Chinook salmon, fall-run Chinook salmon, coho salmon, and steelhead. Chinook salmon spawning (both runs) also occurs in the ecological region. Non-salmon indicator species present include Western toad, northern red-legged frog, Western ridged mussel, North American beaver, Olympic mudminnow, largescale sucker, mountain whitefish, Pacific lamprey, riffle and reticulate sculpin, and speckled dace. The bird indicator species present include great blue heron, common goldeneye, and wood duck. Floodplain habitats along the Chehalis River are of particular importance to northern red-legged frog and other stillwater-breeding amphibians, as well as both native and non-native fish species, such as smallmouth bass.

[15] Fish passage barrier data from WDFW processed through EDT model.

5.3.4 Limiting Factors

Limiting factors for salmonids have been identified in several assessments of the Chehalis Basin, including the EDT (ICF 2019) and NOAA modeling (Beechie 2018) conducted for the ASRP and earlier studies (GHLE 2011; Smith and Wenger 2001). Additional limiting factors and a diagnosis of what is working and what is broken in the ecological region were determined by the SRT, drawing on local basin knowledge and reconnaissance conducted within the region.

The combined results of these assessments indicate that the major issues for salmonids in the region are as follows (in relative order of importance):

- High water temperatures
- Low habitat diversity (lack of side channels, floodplain wetlands, and large wood)
- Reduced quantity and quality of instream habitats
- Predation (non-native fish species)
- Sediment conditions (fine sediment accumulations)
- Poor riparian conditions
- Loss of floodplain habitat and beaver ponds
- Reduced channel length and increased channel width
- Flow conditions (both low and high flows)
- Channel instability (bed scour and gravel transport)

> **Diagnostic Snapshot**
>
> - There is a lack of wood throughout this region.
> - Channel migration and channel-forming processes have degraded over time. Over multiple decades, the banks of the mainstem have been artificially stabilized (e.g., riprap) by landowners desiring to protect property from the river. Artificial stabilization has resulted in less migration of the mainstem and creation of few off-channel areas, and now many of the existing off-channel areas are disconnected from the river and newer off-channel areas are not being created.
> - Invasive fish species (especially centrarchid fishes such as basses, crappies, and sunfishes) and bullfrogs are widespread in this ecological region.
> - The main channel is largely disconnected from its floodplain. Riparian zones are narrow to nonexistent in much of the reach.
> - High water temperatures are a significant issue. Plumes of cooler water near the Chehalis River confluences with the Skookumchuck and Newaukum rivers may be critical to providing refuges during the summer months, especially for adult spring-run Chinook salmon.

These identified issues for salmonids are consistent with earlier findings from Smith and Wenger (2001) and the Chehalis Basin Lead Entity (GHLE 2011), which indicated that the key limiting factors in this ecological region include riparian conditions, channel incision, water quality, floodplain conditions, lack of large wood, water quantity, and sediment conditions. Model results indicate similar priorities for the limiting factors. NOAA model results indicate that the lack of large wood and floodplain habitats have significant effects on fall-run Chinook salmon and fine sediment has a moderate effect on fall-run Chinook salmon.

Limiting factors and threats to non-salmon indicator species are not well understood but may include non-native predator species, high water temperatures, migration barriers, changes in flow conditions and water level variations, fine sediments, and poor riparian conditions (as identified for Pacific lamprey by Clemens et al. [2017]).

5.3.5 Strategies and Actions in the Ecological Region

5.3.5.1 Habitat and Process Protection

Some of the protection actions described in Section 4.2.1 are not feasible in the Middle Chehalis River Ecological Region due to the existing level of development; however, particularly in areas less constrained by existing land uses, the following areas and actions are recommended for a protection focus:

- Protect existing wet prairie.
- Protect existing riparian forest.
- Protect and enhance cool-water inputs at tributary confluences.

Tributaries influence conditions in the mainstem Chehalis River, and the effectiveness of actions in other ecological regions will be influenced by conditions in the mainstem. This image shows an important confluence with the Newaukum River, which can deliver inputs of wood and gravel and can provide a cooling influence on water temperatures.

The Middle Chehalis River Ecological Region is entirely within Lewis County, which has regulations and policies in place to maintain forest cover, increase riparian canopy, protect streams from development, and protect surface and groundwater and reduce withdrawals. The Lewis County SMP identifies priority habitat as those habitat types with unique or significant value to one or more species, including fish spawning habitat, and contains regulations that new development should not interfere with the process of channel migration (Lewis County 2017). The County has a policy to support projects from the Lewis County Shoreline Restoration Plan (Lewis County 2016), the ASRP, and the lead entities for salmon recovery.

As part of the community planning strategy (see Section 5.3.5.3), funding support to align County, Chehalis, and Centralia regulations with the ASRP and conduct enforcement will be considered.

5.3.5.2 Restoration

The restoration actions described in Section 4.2.2 are not all appropriate in the Middle Chehalis River Ecological Region due to the high level of incision and difficulty of reconnecting floodplains where there is significant development. Based on existing conditions, the following areas and actions are recommended for a restoration focus:

This glide habitat near Chehalis River RM 78 shows the need for wood and structural habitat elements and the potential for floodplain reconnection.

- Focus on restoration of habitat, such as reconnection of oxbows, using a "node" concept, wherein refuge areas would be spaced along the channel length and available to fish as they travel throughout the system. This may require more costly excavation due to the level of incision.
- Protect existing riparian forest and restore additional areas of riparian forest, particularly where this can be combined with habitat benches and nodes.
- Develop and test restoration of floodplain wetlands that dry out in the summer to minimize habitat opportunities for invasive species.
- Install stable large wood structures to promote trapping and stability of coarse gravel and to form deep pools, primarily upstream of the Newaukum River confluence.

Priority restoration areas in the Middle Chehalis River Ecological Region are remnant oxbows and other off-channel wetlands.

5.3.5.3 Community Planning

As noted in Section 4.2.3, community planning actions would be coordinated with state and local governments, landowners, and other stakeholders to ensure the long-term success of the ASRP. Focus programs and policies that could be developed or investigated in the Middle Chehalis River Ecological Region include the following:

- Discuss with Lewis County whether identified additional planning measures could effectively promote and protect the following:
  - Maturation of riparian zones and wood recruitment for retention of spawning gravel and sources
  - Cool water inputs and floodplain connectivity

- As the Chehalis Basin Strategy becomes more integrated, coordinate the ASRP with the CFAR Program to build habitat restoration and protection actions into community flood risk reduction efforts (such as restoring areas where structures and people have been relocated from floodplains).

5.3.5.4 Community Involvement

As noted in Section 4.2.4, community involvement and voluntary landowner participation are essential to the success of the ASRP, and the actions described in that section will be further evaluated for the Middle Chehalis River Ecological Region in Phases 2 and 3 based on the restoration and protection scenario selected. Based on the specific issues in this area, the following actions are recommended for focused community involvement:

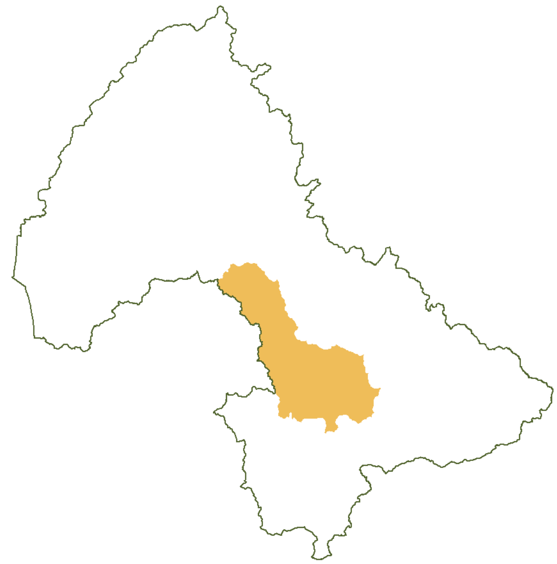
- Continue outreach, engagement, and involvement processes to incorporate landowner expertise into ASRP planning and local implementation efforts.
- Partner with and support the efforts of existing local organizations (see Appendix E for a list of potential partner organizations).

5.3.5.5 Institutional Capacity

The institutional capacity strategy is intended to build on and support the work of existing organizations, as well as support creativity in how local organizations approach working toward the goals of the ASRP. The actions described in Section 4.2.5 will be further evaluated for the Middle Chehalis River Ecological Region in Phases 2 and 3 based on the restoration and protection scenario selected. Based on the specific issues in this area, the following focused institutional capacity actions are recommended:

- Provide technical training on process-based restoration practices and principles.
- Provide funding for groups and individuals interested in restoration projects.
- Build on and support the work of existing organizations with missions that overlap with the ASRP vision (see Appendix E for a list of potential groups).

5.4 Central Lowlands Ecological Region



5.4.1 Overview

The Central Lowlands Ecological Region encompasses the multiple small tributaries that arise in the low Doty Hills and low foothills toward Grays Harbor and enter the Chehalis River from its left bank (Figure 5-7). This ecological region encompasses 250 square miles (greater than 160,000 acres) and represents approximately 9% of the overall Chehalis Basin. The highest point in this ecological region is 2,487 feet in the Doty Hills. Bunker Creek arises in the northern part of the Willapa Hills at approximately 1,100 feet in elevation; Lincoln and Garrard creeks arise as forks in the Doty Hills at approximately 2,000 feet in elevation; Independence Creek arises in the low foothills at approximately 500 feet in elevation; and Rock Creek arises in the low foothills at approximately 800 feet in elevation.

Important Features and Functions

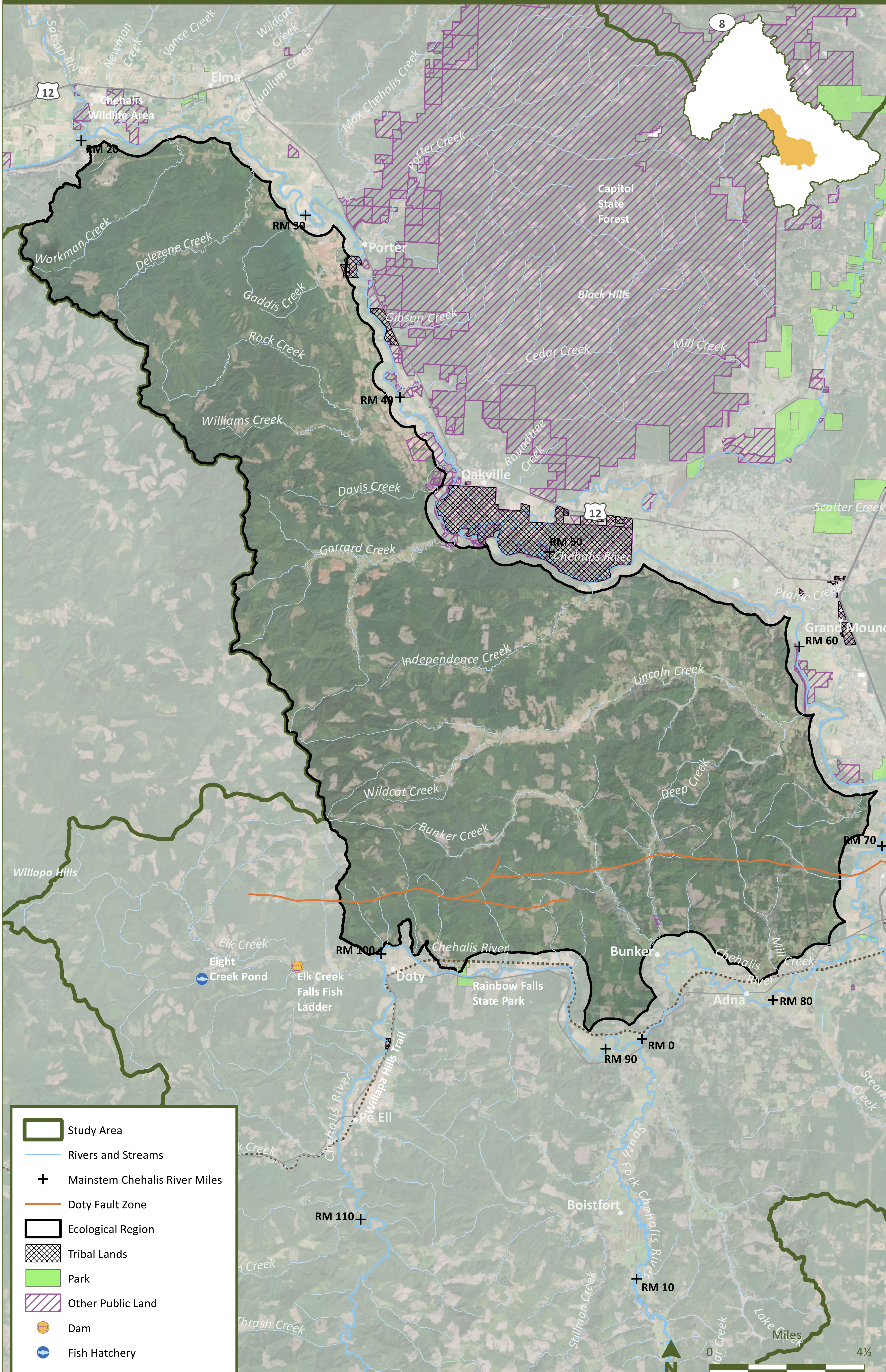
- Abundant wetlands and beavers were likely key components of historical conditions on the small, low-gradient streams.
- This ecological region has important spatial diversity areas for many species.
- There is a significant wood duck population along Lincoln Creek.
- Climate change will increase the frequency of high flows and low flows with associated bed/bank scour and stream drying.
- Restoring slough habitat with groundwater inputs may provide chum salmon spawning habitat, increasing the overall spatial footprint used by the Grays Harbor chum salmon population.

The geologic landscape of the Central Lowlands Ecological Region is generally similar to the Willapa Hills Ecological Region and comprises marine-derived volcanic and sedimentary rocks, including the volcanic-derived Crescent Formation and the seafloor sedimentary McIntosh Formation rock. The McIntosh Formation is composed of siltstone, shale, and sandstone with interbeds of basalt flows and basaltic sandstone. Columbia River basalts overlie these rocks in some areas. The Central Lowlands are generally lower in elevation than the Willapa Hills.

Precipitation in the Central Lowlands Ecological Region is dominated by rainfall. Average annual precipitation is 50 to 100 inches.

The Central Lowlands Ecological Region is primarily within Lewis County (95,307 acres, or 59%) and Grays Harbor County (56,832 acres, or 35%), with a smaller potion in Thurston County (7,526 acres, or 5%), and it is just touching the edge of Pacific County (530 acres, or <1%).

Figure 5-7
Central Lowlands Ecological Region Map



Aerial Photo Source: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

5.4.2 Historical Conditions and Changes

Historical records for the pre-Euro-American settlement condition are not available, but GLO maps from the 1860s to 1880s indicate that the Central Lowlands Ecological Region was dominated by old-growth Douglas-fir forest on the hillslopes and marshy wetlands in the lower floodplains of several creeks, particularly Bunker and Lincoln creeks. Similar to other regions of the basin, splash dams were used (see the description in Section 2.1). Wendler and Deschamps (1955) documented one splash dam on each of Deep, Independence, and Williams creeks and two splash dams on Rock Creek. Van Syckle (1980) noted the extensive use of splash dams on Delezene Creek for many decades up through 1909, when the streambed became unfit for sluicing logs. Key changes that occurred in the Central Lowlands Ecological Region following Euro-American settlement were extensive timber harvest and agricultural development in the lower ends of the streams. Agricultural development as well as road, bridge, and residential construction likely also incrementally moved and straightened some of the rivers and creeks in the Central Lowlands Ecological Region over time. Historically, streams such as Lincoln Creek were frequently connected to their floodplain, both from runoff within their sub-basins and influences from the Chehalis River, as illustrated by the following quote from early settlers (Smith 1941):

> *"This long, winding creek (Lincoln or 'Natcheles' Creek) cuts through the valley for many miles until it reaches what is now Galvin. Here it joins the Chehalis River. Early settlers remember that in the summer time it was just an ordinary stream, but in the winter its valley presented a different view. Log jams in the Chehalis River backed the water up the creek, making the valley a sea from hill to hill."*

Several of the creeks in the Central Lowlands Ecological Region supported chum salmon perhaps as late as the 1950s (including Bunker and Deep creeks), and some actions, such as logjam removal, were undertaken at that time to address perceived fish passage problems (WDF 1975; Preston and Kiemle 1952).

To support the ASRP analysis and EDT modeling efforts, the SRT developed assumptions of the channel lengths and areas of floodplain habitat that were likely present in historical conditions. These assumptions were based on the GLO mapping from the late 1800s, more recent historical aerial photographs, and interpretation of current LiDAR data that show remnant channels and other floodplain features across the basin. The streams within the Central Lowlands Ecological Region are unconfined to partly confined and low gradient within moderately sized valleys. Compared to historical conditions, the stream channel lengths do not appear to be significantly reduced, but side channels would have historically been far more prevalent on Bunker and Lincoln creeks, and the streams could have had up to 3 times the area of frequently connected floodplain with diverse riparian forest and large wood. Large wood has been removed from the channels throughout this region.

5.4.3 Current Conditions

Current conditions reflect ongoing forest management, agricultural land uses, and residential development. Land cover is approximately 44% coniferous forest, 19% scrub-shrub, 7% mixed forest, 7% deciduous forest, 7% grassland, 6% agriculture, 5% developed, 3% wetlands, and small percentages of other cover[16] (Figure 5-8). The Central Lowlands Ecological Region is primarily forested uplands with rural residential or small agricultural properties in the lowland valleys. There are almost no parks or protected areas in this ecological region. Substantial areas of disturbed wetlands are mapped as present along Bunker, Lincoln, and Independence creeks (Ecology 2011b).

An assessment of riparian conditions and functions by NOAA (Beechie 2018) found that most of these creeks are impaired for wood recruitment, but levels of shading are moderately reduced from the reconstructed historical conditions, except in the agricultural areas of Lincoln Creek and portions of Bunker Creek.

Central Lowlands Current Snapshot

Condition of Watershed Processes:
Hydrology – impaired
Floodplain connectivity – moderately impaired
Riparian condition – impaired
Water quality – impaired

Restoration Potential: Moderate

Protection Potential: Moderate

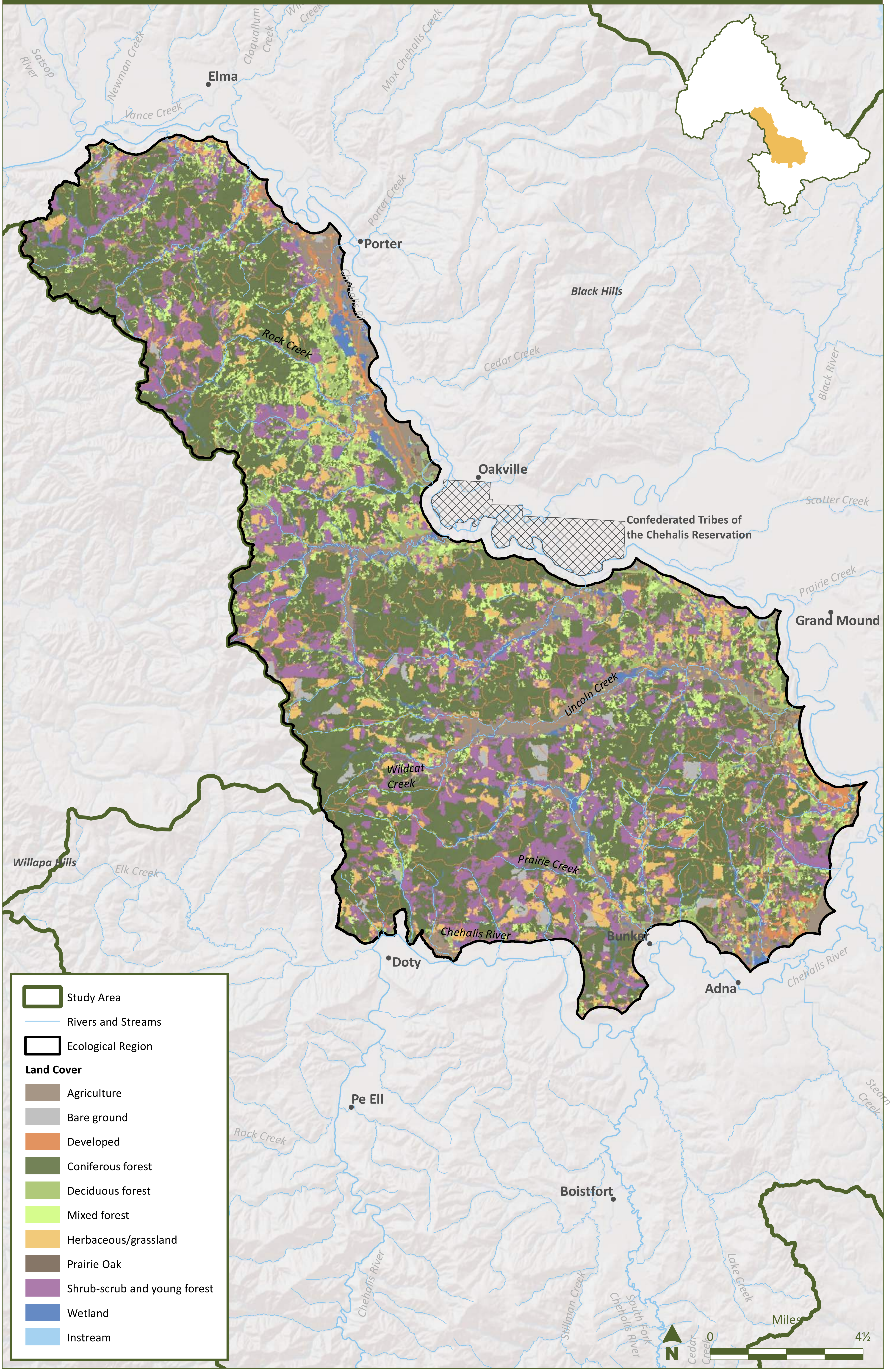
Geographic Spatial Units: Bunker Creek, Lincoln Creek, Independence Creek, Mill Creek, Coal Creek, Garrard Creek, Rock Creek, Delezene Creek, and Workman Creek

Salmon Use and Potential: Coho and chum salmon, winter-run steelhead

Non-Salmon Use and Potential: Western toad, northern red-legged frog, North American beaver, Olympic mudminnow, largescale sucker, mountain whitefish, Pacific lamprey, riffle and reticulate sculpin, speckled dace, great blue heron, and common goldeneye

[16] Land cover data from Multi-Resolution Land Characteristics Consortium, National Land Cover Database 2011, augmented by WDFW Habitat Guild 2015 floodplain data where available.

Figure 5-8
Central Lowlands Ecological Region Land Cover



There is a significant contrast between stream reaches with only limited riparian zone and areas with riparian forested habitat. Riparian cover also tends to support more spawning than areas with less cover.

Water quality is impaired in multiple reaches in the Central Lowlands Ecological Region, primarily for temperature, low dissolved oxygen, bacteria, and pH (Ecology 2018). Recent temperature monitoring in the Central Lowlands Ecological Region (lower Rock and Garrard creeks) by Ecology (2015 data) indicates that temperatures regularly exceed water quality standards (16°C [61°F] core summer salmonid habitat) from June through September and typically exceed the 13°C (55°F) supplemental spawning incubation criterion (September 15 to July 1) in June and July (Ecology 2016, 2011a).[17] The *Upper Chehalis River Basin Temperature TMDL* (Ecology 2001) has designated a goal of 18°C (64°F) for the upper Chehalis River, with the primary goals of increasing shading on Lincoln Creek by 19%, although the increased shading was not projected to achieve the 18°C (64°F) requirement.

WDFW's Thermalscape model indicates that from 2013 to 2018, the vast majority of stream reaches of the Central Lowlands Ecological Region (ranging from 93% [2018] to 100% [2014, 2015, and 2017] of reaches) have mean August temperatures equal to or exceeding 16°C (61°F) and are projected to increase to all reaches (100%) in 2040 and 2080, respectively, without restoration actions (Winkowski and Zimmerman 2019).

The NOAA model that incorporates mature riparian conditions and anticipated climate change shows a likely future increase in summer water temperatures ranging from 0.5°C (0.9°F) to more than 2.5°C (4.5°F) by 2080 in the Central Lowlands Ecological Region, although some cooling potential exists for Lincoln Creek and portions of Bunker Creek (Beechie 2018) where riparian shading is currently very low.

Existing wetland mapping (Ecology 2011b) shows extensive areas of wetlands along Bunker, Lincoln, and Independence creeks, although many areas are disturbed. Channel incision was estimated in Bunker and Deep creeks by Abbe et al. (2016) as ranging from less than 1 foot to more than 6 feet (deeper incision closer to the Chehalis River confluence that may be associated with mainstem Chehalis River incision), likely as a result of historical splash dams, removal of wood from the channels, and straightening and ditching. Approximately 80 fish passage barriers were incorporated into the EDT model,[18] present across all streams in the Central Lowlands Ecological Region.

[17] Rock and Garrard creeks occasionally exceed 20°C (68°F) based on limited Ecology sampling (Ecology gage data).
[18] Fish passage barrier data from WDFW processed through EDT model.

Little information is available on sediment conditions for the Central Lowlands Ecological Region; however, these streams were noted as having predominantly sand and small gravels present in the 1960s (WDF 1975).

The salmonid species present in the Central Lowlands Ecological Region include coho and chum salmon and winter-run steelhead. Non-salmon indicator species include Western toad, northern red-legged frog, North American beaver, Olympic mudminnow, largescale sucker, mountain whitefish, Pacific lamprey, riffle and reticulate sculpin, and speckled dace. The bird indicator species present include great blue heron and common goldeneye.

There are two remote incubation boxes in the Central Lowlands Ecological Region that are intended to rear 45,000 and 46,500 coho salmon eyed eggs to fry in Gabel Creek and Tapp Creek, respectively, which are tributaries to Deep Creek. These programs are too small to significantly contribute to population sizes.

5.4.4 Limiting Factors

Limiting factors for salmonids have been identified in several assessments of the Chehalis Basin, including the EDT (ICF 2019) and NOAA modeling (Beechie 2018) conducted for the ASRP and earlier studies (GHLE 2011; Smith and Wenger 2001). Additional limiting factors and a diagnosis of what is working and what is broken in the ecological region were determined by the SRT, drawing on local basin knowledge and reconnaissance conducted within the region.

The combined results of these assessments indicate that the major issues for salmonids in the region are as follows (in relative order of importance):

- Reduced quantity and quality of instream habitats
- Low habitat diversity (lack of side channels, large wood, floodplain connectivity, and beaver ponds)
- Fish passage barriers
- High water temperatures
- Predation (non-native fish species)
- Sediment conditions (fine sediments)
- Channel instability (bed scour and sediment transport)
- Channel width
- Flow (low and high flows)

Diagnostic Snapshot

- Bunker, Lincoln, Independence, and Garrard creeks have extensive floodplains and wetlands (proportionately large for the streams). Floodplain functions are frequently compromised by agricultural development and roads.
- The ecological region is lacking wood.
- The ecological region is lacking beavers.
- Poor riparian conditions or young trees exist in many locations.
- Floodplain development is relatively low compared to other ecological regions.
- Substantial channel length lacks stable gravel.
- Invasive plant species, including reed canarygrass, are present.

These identified issues for salmonids are generally consistent with earlier findings from Smith and Wenger (2001) and the Chehalis Basin Lead Entity (GHLE 2011), which indicated that the key limiting factors in this ecological region include sediment conditions, riparian conditions, floodplain conditions, fish passage barriers, lack of large wood, water quality, and water quantity. However, the ASRP assessment has identified a higher priority for floodplain connectivity, beaver ponds, and large wood than the earlier findings.

Limiting factors and threats to non-salmon indicator species are not well understood but may include high water temperatures, changes in flow conditions and water level variations, fine sediments, riparian conditions, and non-native predator species (as identified for Pacific lamprey by Clemens et al. [2017]).

5.4.5 Strategies and Actions in the Ecological Region

5.4.5.1 Habitat and Process Protection

Many of the protection actions described in Section 4.2.1 are appropriate in the Central Lowlands Ecological Region. Based on existing conditions, the following areas and actions are recommended for a protection focus:

- Protect existing riparian forested areas.
- Protect existing wetlands.
- Test protection and enhancement of headwater streams (mostly first-order streams) to improve canopy cover and connectivity to groundwater because of their sensitivity to climate change.

The majority of the Central Lowlands Ecological Region is within Lewis County, which has regulations and policies in place to maintain forest cover, increase riparian canopy, protect streams from development, and protect surface and groundwater and reduce withdrawals. The Lewis County SMP identifies priority habitat as those habitat types with unique or significant value to one or more species, including fish spawning habitat, and contains regulations that new development should not interfere with the process of channel migration (Lewis County 2017). The County has a policy to support projects from the Lewis County Shoreline Restoration Plan (Lewis County 2016), the ASRP, and the lead entities for salmon recovery.

More intensive residential or small farm development could harm instream flows as well as limiting options for restoration. There is a potential for riparian easements along the tributary streams; this could retain farming and provide an opportunity for greatly improved habitats.

Larger streams in the Central Lowlands Ecological Region—such as Bunker, Lincoln, Independence, and Garrard creeks—have relatively extensive floodplains and wetlands that should be protected and enhanced.

The northern portion of the ecological region is in Grays Harbor County, which has regulations and policies in place to protect wetlands, floodplains, riparian areas, and fish and wildlife habitat conservation areas from degradation and development; and manage invasive species. Grays Harbor County's draft SMP that is currently in final review with Ecology contains regulations to protect channel migration zones and riparian vegetation, along with general development regulations related to shoreline areas in the County (Grays Harbor County 2018).

As part of the community planning strategy (see Section 5.4.5.3), funding support to align both counties' regulations with the ASRP and conduct enforcement will be considered.

5.4.5.2 Restoration

The restoration actions described in Section 4.2.2 are all appropriate in the Central Lowlands Ecological Region. Based on existing conditions, the following areas and actions are recommended for a restoration focus:

- Restore riparian areas wherever feasible to maintain cooler water temperatures.
- Place extensive stable instream wood to capture alluvium (finer gravel); increase variations in bed textures; increase the number of pools and cover; raise streambeds; and increase floodplain, wetland, and groundwater connectivity.
- Construct beaver dam analogs and promote beaver use and creation of beaver ponds.
- Address fish passage barriers.
- Protect and enhance areas around confluences with the mainstem Chehalis River to provide deep cold-water pools for spring-run Chinook salmon holding, particularly Bunker and Deep creeks.
- Restore riparian and floodplain habitats along the lower ends of streams where they enter the Chehalis River valley.
- Prioritize Bunker, Lincoln, and Garrard creeks for channel, floodplain, and riparian restoration (large wood, floodplain reconnection, invasive control, and riparian management).

Bunker, Lincoln, and Garrard creeks are priorities for channel, floodplain, and riparian restoration. Existing riparian forested areas should be protected, and beavers (or the use of beaver dam analogs) should be encouraged. Large wood should be installed.

Climate change will increase the frequency of high flows and low flows with associated bed/bank scour and stream drying. Wood, wetlands, and riparian forest could moderate this effect.

Priority areas for restoration in the Central Lowlands Ecological Region include Bunker, Lincoln, Independence, Garrard, and Rock creeks. Consideration may need to be given to identifying a subset of streams for more expansive restoration combined with protection. Such a strategy should be weighed against doing less-intensive work over a larger number of streams.

5.4.5.3 Community Planning

As noted in Section 4.2.3, community planning actions would be coordinated with state and local governments, landowners, and other stakeholders to ensure the long-term success of the ASRP. Focus programs and policies that could be developed or investigated in the Central Lowlands Ecological Region include the following:

- Discuss with Lewis County additional planning measures that could effectively promote and protect the following:
  - Cool water temperatures and floodplain connectivity
  - Beaver ponds
- Discuss with Lewis County additional planning measures that could effectively promote and protect the following:
  - Surface and groundwater supplies through reduction of withdrawals
  - Minimization of impervious surfaces
- Discuss with both Lewis and Grays Harbor counties additional planning measures that could effectively promote the following:
  - Maturation of riparian forest and improved wood recruitment for retention of spawning gravel and sources
  - Increasing channel migration
- As the Chehalis Basin Strategy becomes more integrated, coordinate the ASRP with the CFAR Program to build habitat restoration and protection actions into community flood risk reduction efforts (such as restoring areas where structures and people have been relocated from floodplains).

5.4.5.4 Community Involvement

As noted in Section 4.2.4, community involvement and voluntary landowner participation are essential to the success of the ASRP, and the actions described in that section will be further evaluated for the Central Lowlands Ecological Region in Phases 2 and 3 based on the restoration and protection scenario selected. Based on the specific issues in this area, the following actions are recommended for focused community involvement:

- Continue outreach, engagement, and involvement processes to incorporate landowner expertise into ASRP planning and local implementation efforts.
- Partner with and support the efforts of existing local organizations (see Appendix E for a list of potential partner organizations).

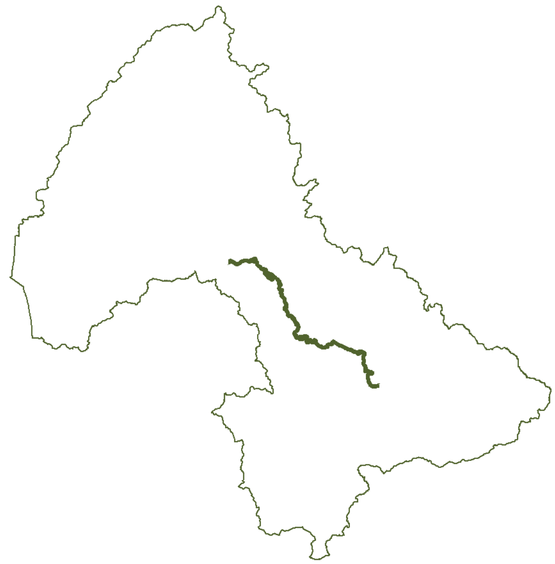
5.4.5.5 Institutional Capacity

The institutional capacity strategy is intended to build on and support the work of existing organizations, as well as support creativity in how local organizations approach working toward the goals of the ASRP. The actions described in Section 4.2.5 will be further evaluated for the Central Lowlands Ecological Region in Phases 2 and 3 based on the restoration and protection scenario selected. Based on the specific issues in this area, the following focused institutional capacity actions are recommended:

- Provide technical training on process-based restoration practices and principles.
- Provide funding for groups and individuals interested in restoration projects.
- Build on and support the work of existing organizations with missions that overlap with the ASRP vision (see Appendix E for a list of potential groups).

5.5 Lower Chehalis River Ecological Region

5.5.1 Overview



The Lower Chehalis River Ecological Region encompasses the mainstem Chehalis River and its floodplain from approximately RM 67 (Skookumchuck River confluence) to RM 20 (Satsop River confluence; Figure 5-9). This ecological region encompasses 28 square miles (nearly 18,000 acres) and represents slightly over 1% of the overall Chehalis Basin. The entire ecological region is low-elevation alluvial valley ranging from about 180 feet in elevation in Centralia to about 80 feet in elevation near the Satsop River confluence.

The lower Chehalis River floodplain geology is predominantly recent alluvium; however, there is more influence from the glacial outwash deposits, with coarse-grained deposits from the Skookumchuck River confluence to the Black River confluence (Gendaszek 2011).

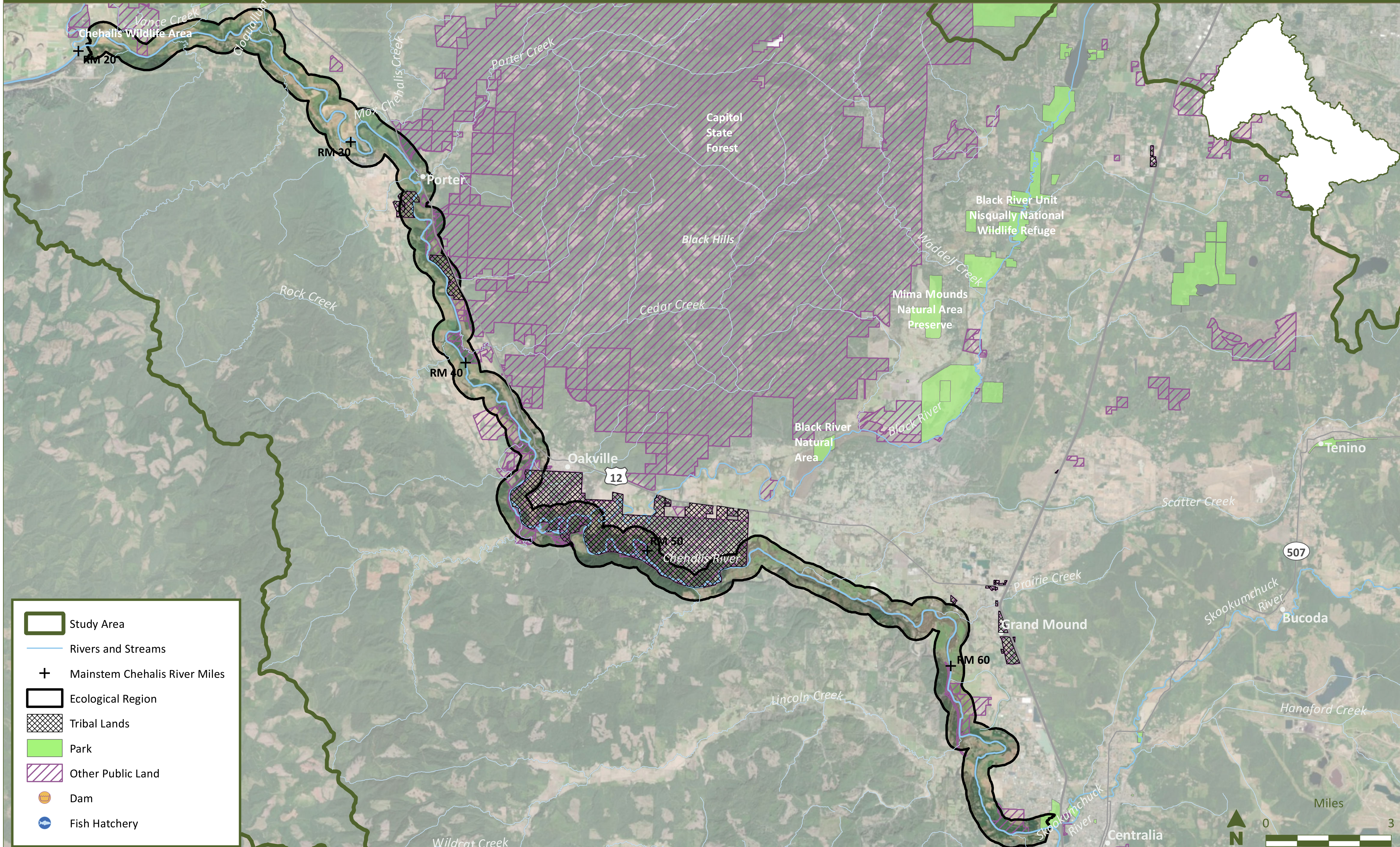
Precipitation in this ecological region is dominated by rainfall; average annual precipitation varies from 50 to 75 inches in the Lower Chehalis River Ecological Region down to the town of Elma and up to 100 inches below Elma (Gendaszek 2011).

The Lower Chehalis River Ecological Region is primarily within Grays Harbor County (11,906 acres, or 66%), with smaller portions in Thurston County (3,656 acres, or 20%) and Lewis County (2,360 acres, or 13%). This ecological region includes the portion of the Chehalis River between Centralia and just past Elma. The Chehalis Reservation is located along approximately 10 miles of the Lower Chehalis River, and the Chehalis Tribe also owns additional key floodplain and river habitats downstream of the reservation. Cities and towns in this ecological region include Grand Mound, Oakville, Rochester, Porter, and Elma.

Important Features and Functions

- The Chehalis River has the highest densities of coho salmon per area of watershed, which is related to the abundance of overwintering habitat naturally provided in the wide and meandering floodplain. It also has the highest densities of native stillwater-breeding amphibians and native non-salmonid fish.
- Migratory fish from all sub-basins above the tidal areas pass through this region, making its ecological function more impactful to large areas.
- The floodplain is extensive along the river's mainstem through the Lower Chehalis River Ecological Region, which could present numerous opportunities for floodplain reconnection.
- This area has the largest number of diverse off-channel habitats of all the ecological regions.

Figure 5-9
Lower Chehalis River Ecological Region Map



Aerial Photo Source: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

5.5.2 Historical Conditions and Changes

Historical records for pre-Euro-American settlement conditions are not available, but available historical records and maps indicate that the Lower Chehalis River Ecological Region below the Skookumchuck River was dominated by wetlands, prairies, brush, and timber. GLO maps show a major channel change of the river downstream of Ford's Prairie and extensive wetlands alongside both the old and new channels. A large sand island was noted adjacent to the Chehalis Reservation, along with numerous sand and gravel bars along the river. A very lengthy disconnected slough was shown in the floodplain in the vicinity of Mox Chehalis Creek, and two large wetland complexes were shown associated with Vance and Newman creeks in the Chehalis River floodplain. This implies frequent connectivity between the river and its floodplain wetlands.

Key changes that occurred in the Lower Chehalis River Ecological Region following Euro-American settlement were timber removal and agricultural development throughout the floodplain and gravel removal in both the channel and floodplain. Most of the agricultural development occurred prior to 1938. The Pierce et al. (2017) study of floodplain land cover changes indicates that agricultural development continued at a slower rate from 1938 through the mid-1970s at a rate of approximately 33 acres per year converted to agriculture and a loss of 67 acres per year of forest canopy. Since the 1970s, there has been a slow decline in agricultural acreage (a loss of 14 acres per year) but an increase in forest canopy (a gain of 19 acres per year). There was limited development in the floodplain during both periods. The modeling conducted by NOAA (Beechie 2018) for the ASRP indicated significant losses in marsh and beaver pond habitats in the lower Chehalis River floodplain from historical conditions to current (losses of about 50% and 60%, respectively).

To support the ASRP analysis and EDT modeling efforts, the SRT developed assumptions of the channel lengths and areas of floodplain habitat that were likely to be present in historical conditions. These assumptions were based on the GLO mapping from the late 1800s, more recent historical aerial photographs, and interpretation of current LiDAR data that show numerous remnant channels and other floodplain features. The lower Chehalis River is unconfined and low gradient within a wide alluvial valley. Compared to historical conditions, the river channel length does not appear to be significantly reduced, but side channels would have historically been far more prevalent, and the river would have had 5 or more times the area of frequently connected floodplain. Large wood has been removed, and the forested riparian zone is very narrow.

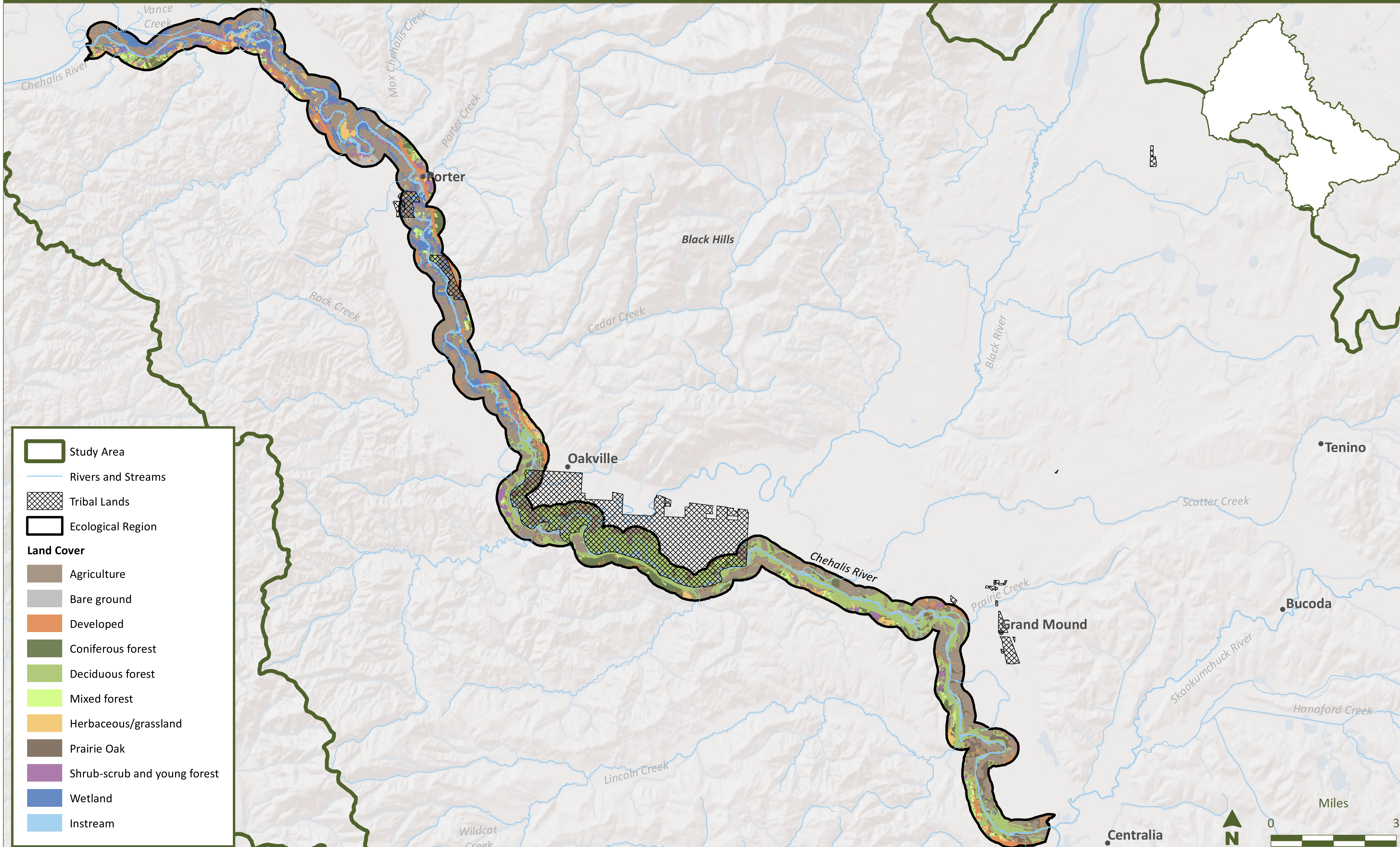
5.5.3 Current Conditions

In the Lower Chehalis River Ecological Region, land cover is 34% agriculture, 24% deciduous forest, 8% wetland, 7% developed, 5% prairie oak, 5% shrub, 4% coniferous forest, 3% grassland, and small percentages of other cover[19] (Figure 5-10). Significant areas of forested floodplain are present on the Chehalis Reservation.

> **Lower Chehalis River Current Snapshot**
>
> **Condition of Watershed Processes**:
> Hydrology – impaired
> Floodplain connectivity – impaired
> Riparian condition – impaired
> Water quality – impaired
>
> **Restoration Potential**: High
>
> **Protection Potential**: Moderate
>
> **Geographic Spatial Units**: Chehalis River Mainstem Reaches: Skookumchuck River, Skookumchuck River to Black River, Black River to Porter, and Porter to Satsop
>
> **Salmon Use and Potential**: Fall- and spring-run Chinook salmon, coho salmon, chum salmon, and steelhead
>
> **Non-Salmon Use and Potential**: Western toad, northern red-legged frog, North American beaver, Olympic mudminnow, largescale sucker, mountain whitefish, Pacific lamprey, riffle and reticulate sculpin, speckled dace, Western ridged mussel, great blue heron, Barrow’s goldeneye, common goldeneye, and wood duck

[19] Land cover data from Multi-Resolution Land Characteristics Consortium, National Land Cover Database 2011, augmented by WDFW Habitat Guild 2015 floodplain data where available.

Figure 5-10
Lower Chehalis River Ecological Region Land Cover



Base flows have been established for the lower Chehalis River (165 cfs at Grand Mound and 260 cfs at Porter from August 15 to September 15; WAC 173-522-020). If base flows drop below the required minimums, junior water rights holders can be required to curtail water withdrawals. In 2007, the first curtailment requests were made by Ecology. Similar requests were made in 2013 and each year between 2015 (Gallagher 2015) and 2019.

Lower mainstem habitats have degraded riparian conditions, as shown here across from a boat launch near Porter. Substantial recreational river use and sport fishing occur throughout the Lower Chehalis River Ecological Region.

Lower mainstem habitats are limited in diversity and could be enhanced by installing stable wood, riparian restoration, and off-channel reconnection actions.

Water quality is impaired in in the Lower Chehalis River Ecological Region for temperature, low dissolved oxygen, and bacteria, although dioxins and invasive species are also listed as impairments (Ecology 2018). Recent temperature monitoring at RMs 28.6 and 42.2 by Ecology indicates that temperatures regularly exceed water quality standards (16°C [61°F] core summer salmonid habitat) from May through September and typically exceed the 13°C (55°F) supplemental spawning incubation criterion (September 15 to July 1) in September and May to July (Ecology 2016, 2011a).[20] The *Upper Chehalis River Basin Temperature TMDL* (Ecology 2001) has designated a goal of 18°C (64°F) for the Chehalis River (down to RM 30), with the primary goals of increasing shading along the tributaries and mainstem as well as improving low flows.

WDFW's Thermalscape model indicates that from 2013 to 2018, the vast majority of stream reaches within the Lower Chehalis River Ecological Region (ranging from 95% [2018] to 97% [2014 to 2017] of reaches) had mean August temperatures equal to or exceeding 16°C (61°F) and are projected to increase to 99% and 100% of reaches in 2040 and 2080, respectively, without restoration actions (Winkowski and Zimmerman 2019).

The NOAA model that incorporates mature riparian conditions and anticipated climate change shows a likely future increase in summer water temperatures ranging from 0.5°C (0.9°F) to 1.5°C (2.7°F) by 2080, with water temperatures in some reaches increasing up to 2.5°C (4.5°F) (Beechie 2018).

[20] The lower Chehalis River frequently reaches 25°C (77°F) in July and/or August (Ecology gage data).

The lower mainstem Chehalis River is less incised than other areas of the basin and has a large number of remnant oxbows that are frequently connected. Existing mapping of wetlands (Ecology 2011b) shows relatively large wetland areas in the following locations:

- Around the Black River confluence
- In the floodplain around lower Roundtree and Davis creeks
- In much of the floodplain south of the Porter Creek confluence
- In substantial areas of the floodplain south of the Cloquallum Creek confluence
- Around Vance Creek

The Ecology mapping also shows remnants of several meanders near the Prairie Creek confluence and numerous former meanders throughout the floodplain near the lower Black River. Only nine fish passage barriers were incorporated within the EDT model for the Lower Chehalis River Ecological Region, with none on the mainstem river.

The percentage of fine sediment in streams was modeled by NOAA based on the density of roads and land uses; this modeling indicated 17% to 18% fines in the Chehalis River below the Skookumchuck River, which is a substantial increase from modeled historical conditions (Beechie 2018).

There are recent invasive aquatic plant issues, particularly the presence of Brazilian elodea, in the mainstem Chehalis River downstream of the Skookumchuck River. In 1998, Brazilian elodea was observed in the river, and multiple agencies and the Chehalis Tribe have conducted removal efforts since the early 2000s. The area of infestation has been substantially reduced (Thurston County 2019). However, the river is at risk for further invasions by a variety of invasive aquatic plants that tend to reduce dissolved oxygen and trap fine sediments.

All upstream stocks of anadromous salmonids pass through the Lower Chehalis River Ecological Region. All but one of the non-salmon indicator species are present (there is a lack of Western toad). Barrow’s goldeneye are also present. Floodplain habitats along the Chehalis River are of particular importance to northern red-legged frog and four other stillwater-breeding amphibian species, as well as at least 27 species of native and non-native fishes.

5.5.4 Limiting Factors

Limiting factors for salmonids have been identified in several assessments of the Chehalis Basin, including EDT (ICF 2019) and NOAA modeling (Beechie 2018) conducted for the ASRP and earlier studies (GHLE 2011; Smith and Wenger 2001). Additional limiting factors and a diagnosis of what is working and what is broken in the ecological region were determined by the SRT, drawing on local basin knowledge and reconnaissance conducted within the region.

The combined results of these assessments indicate that the major issues for salmonids in the region are as follows (in relative order of importance):

- Low habitat diversity (lack of side channels, large wood, floodplain connectivity, and marshes)
- Reduced quantity and quality of instream habitats
- Predation (non-native fish species)
- Sediment conditions (fine sediments)
- High water temperatures (from local conditions and cumulative upstream influences)
- Channel width and length

These identified issues for salmonids are generally consistent with earlier findings from Smith and Wenger (2001) and the Chehalis Basin Lead Entity (GHLE 2011), which indicated that the key limiting factors in this ecological region include riparian conditions, water quality, floodplain conditions, lack of large wood, water quantity, and sediment conditions.

Limiting factors and threats to non-salmon indicator species are not well understood but may include high water temperatures, changes in flow conditions and water level variations, fine sediments, riparian conditions, and non-native predator species (as identified for Pacific lamprey by Clemens et al. [2017]).

Diagnostic Snapshot

- This ecological region is lacking wood nearly everywhere.
- There is limited spawning habitat (identified between Oakville and Porter), and summer temperatures are too high to support juvenile salmonid rearing.
- Non-native species such as bullfrogs and bass (smallmouth and largemouth) are prevalent throughout this ecological region. The timing of introduction of these species is unknown, but most are major piscivores that are known to have or likely to have negative interactions with native fishes and the larval stages of native amphibians.
- Invasive plant species, including reed canarygrass, Himalayan blackberry, Japanese knotweed, tansy ragwort, Scotch broom, and Eurasian milfoil, are present.
- This ecological region has experienced the greatest loss of floodplain wetland habitats.
- The main channel is more connected to its floodplain in this ecological region than in the Middle Chehalis River Ecological Region. Forested riparian zones are narrow to non-existent, there is very little stable large wood (although more present on the Chehalis Reservation), and there are there are moderate lengths of riprap and channel control.

5.5.5 Strategies and Actions in the Ecological Region

5.5.5.1 Habitat and Process Protection

Some of the protection actions described in Section 4.2.1 are not feasible in the Lower Chehalis River Ecological Region due to the existing level of development; however, particularly in areas less constrained by existing land uses, the following areas and actions are recommended for a protection focus:

- Protect existing off-channel wetlands and wet prairies.
- Protect existing riparian forest.
- Protect cool-water inputs at tributary confluences.

Hoxit Pond, which is already protected, is an example of off-channel conditions that could be enhanced or restored in other locations to provide important habitat for amphibians.

Several floodplain areas in the Lower Chehalis River Ecological Region are owned by Washington State or the Chehalis Tribe. This site is seasonal floodplain habitat protected by the Chehalis Tribe, which could be an important location to experiment and learn from restoration techniques to achieve floodplain connectivity (by excavation and/or locally raising water levels).

The majority of the Lower Chehalis River Ecological Region is within Grays Harbor County, which has regulations and policies in place to protect wetlands, floodplains, riparian areas, and fish and wildlife habitat conservation areas from degradation and development and manage invasive species. Grays Harbor County's draft SMP that is currently in final review with Ecology contains regulations to protect channel migration zones and riparian vegetation, along with general development regulations related to shoreline areas in the County (Grays Harbor County 2018).

The middle portion of the Lower Chehalis River Ecological Region is in Thurston County, which has regulations in place to protect water quantity and quality; maintain or increase forest cover; establish and protect riparian habitat; protect streams, wetlands, floodplains, and prairies from development; limit impervious surfaces; and allow channel migration.

A smaller upriver portion of this region is in Lewis County, which has regulations and policies in place to maintain forest cover, increase riparian canopy, protect streams from development, and protect surface and groundwater and reduce withdrawals. The Lewis County SMP identifies priority habitat as those habitat types with unique or significant value to one or more species, including fish spawning habitat, and contains regulations that new development should not interfere with the process of channel migration (Lewis County 2017). The County has a policy to support projects from the Lewis County Shoreline Restoration Plan (Lewis County 2016), the ASRP, and the lead entities for salmon recovery.

The Chehalis Tribe has zoned much of the shoreline within its jurisdiction for protection as riparian management zones or floodplain that provides protection for these areas. The Chehalis Tribe has regulations to protect the quantity and quality of groundwater; protect natural resources from degradation; protect and minimize adverse effects on fish, wildlife, water quality, and existing shoreline and stream processes; and avoid adverse effects to ecologically or culturally sensitive lands including all waterbodies, channel migration zones, tribal ceremonial sites, and cemeteries. Tribal zoning policies also address development in the floodplain and encourage planting and maintaining riparian buffers on mainstem and tributary streams.

As part of the community planning strategy (see Section 5.5.5.3), funding support to align the counties' and tribal regulations with the ASRP and conduct enforcement will be considered.

5.5.5.2 Restoration

The restoration actions described in Section 4.2.2 are not all appropriate in the Lower Chehalis River Ecological Region due to the difficulty of reconnecting floodplains in more agriculture-intensive areas and where structures and infrastructure could be threatened by flooding. Based on existing conditions, the following areas and actions are recommended for a restoration focus:

- Focus on restoration of habitat, such as improving connectivity of oxbows and side channels, using a "node" concept, wherein refuge areas would be spaced along the channel length and available to fish as they travel throughout the system.
- Protect existing riparian forest and restore additional areas of riparian forest, particularly where this can be combined with habitat benches and nodes.
- Test restoration of floodplain wetlands that dry out in the summer to minimize habitat for non-native invasive fish species and bullfrog.
- Install large wood to promote pool formation and stability of coarse gravel.


Backwaters and remaining side channels along the mainstem Chehalis River provide opportunities for restoration.


Gravel bars are prevalent in the lower Chehalis River near RM 35. Both in-channel and floodplain habitats could be enhanced with installation of stable wood and riparian restoration.

Priority areas for restoration in the Lower Chehalis River Ecological Region include large oxbows and side channels, floodplain wetlands, and cold-water tributary confluences. Opportunities for restoring nodes of habitat, including oxbows and tributary confluences, by partnering with the Chehalis Tribe are high priority.

5.5.5.3 Community Planning

As noted in Section 4.2.3, community planning actions would be coordinated with state and local governments, landowners, and other stakeholders to ensure the long-term success of the ASRP. Focus programs and policies that could be developed or investigated in the Lower Chehalis River Ecological Region include the following:

- Discuss with Grays Harbor County additional planning measures that could effectively promote and protect the following:
  - Surface and groundwater supplies through reduction of withdrawals
  - Minimization of impervious surfaces
  - Maturation of riparian forest and wood recruitment for retention of spawning gravel and sources
  - Increasing channel migration in some locations
- Discuss with Thurston County additional planning measures that could effectively promote and protect the following:
  - Floodplain connectivity
  - Surface and groundwater supplies through reduction of withdrawals
  - Maturation of riparian forest and wood recruitment for retention of spawning gravel and sources
- As the Chehalis Basin Strategy becomes more integrated, coordinate the ASRP with the CFAR Program to build habitat restoration and protection actions into community flood risk reduction efforts (such as restoring areas where structures and people have been relocated from floodplains).

5.5.5.4 Community Involvement

As noted in Section 4.2.4, community involvement and voluntary landowner participation are essential to the success of the ASRP, and the actions described in that section will be further evaluated for the Lower Chehalis River Ecological Region in Phases 2 and 3 based on the restoration and protection scenario selected. Based on the specific issues in this area, the following actions are recommended for focused community involvement:

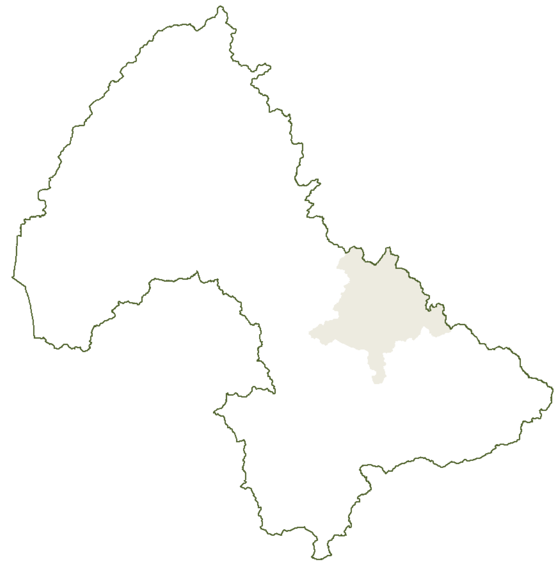
- Continue outreach, engagement, and involvement processes to incorporate landowner expertise into ASRP planning and local implementation efforts.
- Partner with and support the efforts of existing local organizations (see Appendix E for a list of potential partner organizations).

5.5.5.5 Institutional Capacity

The institutional capacity strategy is intended to build on and support the work of existing organizations, as well as support creativity in how local organizations approach working toward the goals of the ASRP. The actions described in Section 4.2.5 will be further evaluated for the Lower Chehalis River Ecological Region in Phases 2 and 3 based on the restoration and protection scenario selected. Based on the specific issues in this area, the following focused institutional capacity actions are recommended:

- Provide technical training on process-based restoration practices and principles.
- Provide funding for groups and individuals interested in restoration projects.
- Build on and support the work of existing organizations with missions that overlap with the ASRP vision (see Appendix E for a list of potential groups).

5.6 Black River Ecological Region



5.6.1 Overview

The Black River Ecological Region encompasses the Black River and its tributaries, such as Waddell and Beaver creeks and the Scatter Creek and Prairie Creek independent drainages (Figure 5-11). This ecological region encompasses 200 square miles (greater than 127,000 acres) and represents approximately 7% of the overall Chehalis Basin. The highest point in this ecological region is Capitol Peak at 2,659 feet in the Capitol State Forest. The Black River arises in the low-elevation divide between the Chehalis Basin and Puget Sound at Black Lake, at 131 feet in elevation, and the low adjacent hills, at approximately 180 feet in elevation. Waddell Creek arises in the Capitol State Forest at approximately 450 feet in elevation.

The geologic landscape of the Black River Ecological Region was largely formed from the deposition of materials from continental glaciation. The Puget Lobe of the Cordilleran Ice Sheet extended into the Chehalis Basin at least twice, with the deposition of a terminal moraine north of Rochester (Gendaszek 2011). As the Puget Lobe retreated, meltwater channels drained south, creating a series of channels and valleys and depositing recessional glacial outwash in the Chehalis River and its tributaries (Skookumchuck River, Black River, Satsop River, and Scatter Creek; Gendaszek 2011). The Black River Ecological Region has glacial lakes and relatively large areas of wetlands that make this ecological region unique.

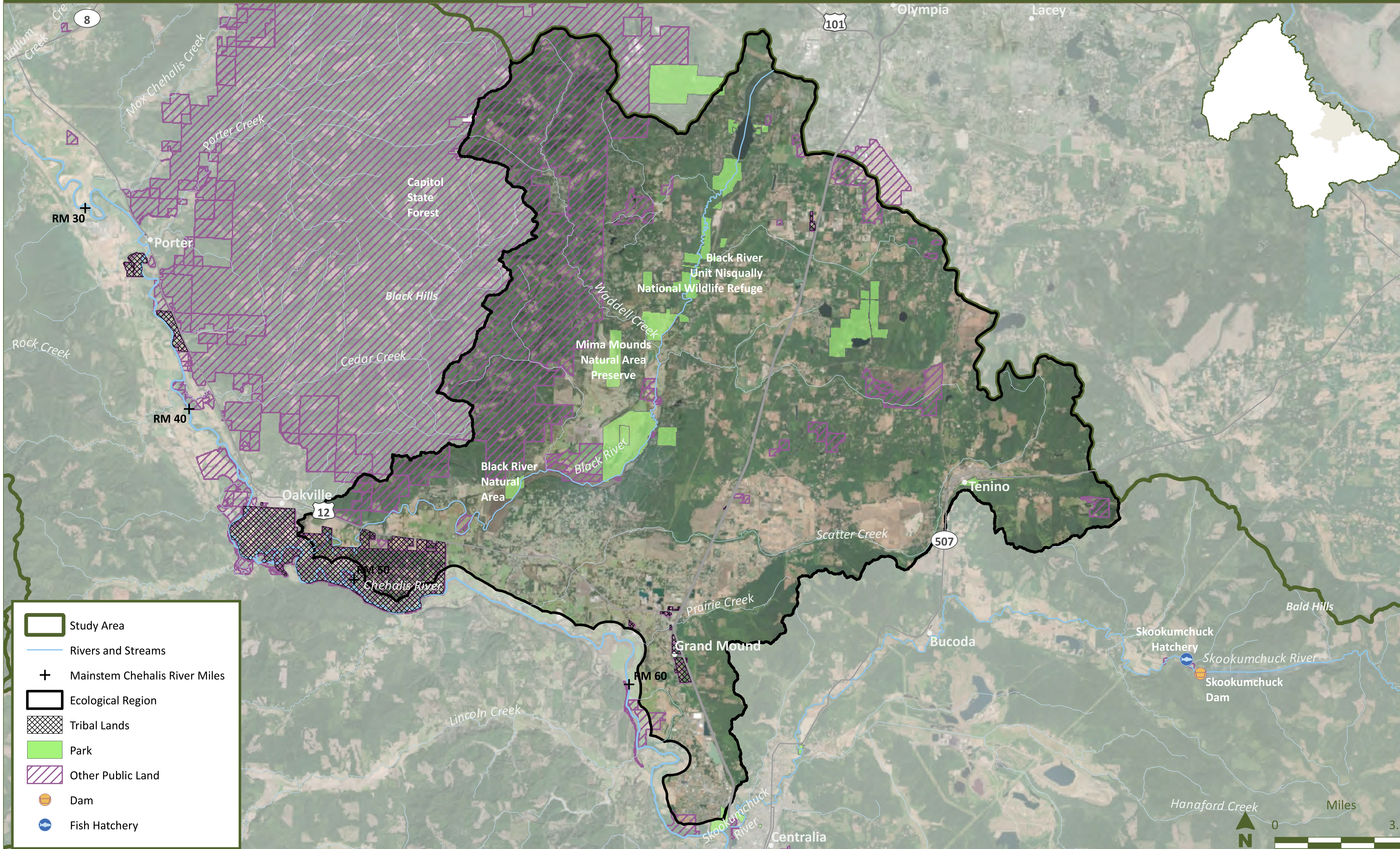
Precipitation in the Black River Ecological Region is dominated by rainfall. Average annual precipitation is 45 to 75 inches. Generally, this part of the Chehalis Basin receives less precipitation and includes low-elevation areas along the I-5 corridor.

Important Features and Functions

- Extensive low-gradient wetland complexes found in the Black River Ecological Region are currently unique in the Chehalis Basin. There may be springs and groundwater inputs.
- State wildlife lands and extensive marsh systems limit land development in much of this ecological region, which offers important protections to aquatic species.
- The presence of Oregon spotted frog is unique to this ecological region. Olympic mudminnow is also widespread and has frequent co-occurrence with Oregon spotted frog.
- West Rocky Prairie is a unique area with several types of headwater prairie habitats that support multiple sensitive species.
- Stream temperature is particularly important to summer habitat for juvenile coho salmon and summer holding habitat for adult spring-run Chinook salmon.
- This ecological region has the highest development pressure within the basin.

The Black River Ecological Region is primarily within Thurston County (119,953 acres, or 94%), with smaller portions in Grays Harbor County (3,988 acres, or 3%) and Lewis County (3,280 acres, or 3%). Cities and towns within this ecological region include Rochester, Tenino, Grand Mound, Littlerock, Maytown, and parts of Olympia.

Figure 5-11
Black River Ecological Region Map



Aerial Photo Source: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

5.6.2 Historical Conditions and Changes

Historical records of the pre-Euro-American settlement conditions are not available, but available historical records and GLO maps from 1856 indicate that the Black River Ecological Region was dominated by gravelly prairies with a large area of swamp (alder, willow, and spruce) around the upper Black River (WNPS 1994). It is likely there were an abundance of beaver and beaver ponds. Key changes that occurred in the Black River Ecological Region following Euro-American settlement were agricultural, residential/commercial, and major transportation corridor (including I-5, SR 12, and railroad lines) development. Agricultural development as well as road, bridge, and residential construction likely also incrementally moved and straightened some of the rivers and creeks in the Black River Ecological Region over time.

Scatter Creek was an important historical habitat for salmon and other indicator species. This area is currently threatened by impaired riparian function, loss of floodplain habitats, and low flows. Scatter Creek could be enhanced by protection of flows and restoration of beaver habitat and wood.

The low-gradient and meandering Black River, along with Scatter and Prairie creeks, formerly supported significant runs of chum and coho salmon, but these populations are now reduced.

To support the ASRP analysis and EDT modeling, the SRT developed assumptions of the channel lengths and areas of floodplain habitat that were likely to be present in historical conditions. These assumptions were based on the GLO mapping from the late 1800s, more recent historical aerial photographs, and interpretation of current LiDAR data that show remnant channels and other floodplain features. The Black River and its east-side tributaries are unconfined and very low gradient within a wide glacial plain. Compared to historical conditions, the river channel length does not appear to be significantly reduced, but side channels would have historically been far more prevalent, and the river would have had up to 3 times the area of frequently connected floodplain. Large wood has been removed, and the riparian zone is patchy. However, the Black River retains much of its wetland characteristics in multiple reaches, maintaining high-quality habitat.

5.6.3 Current Conditions

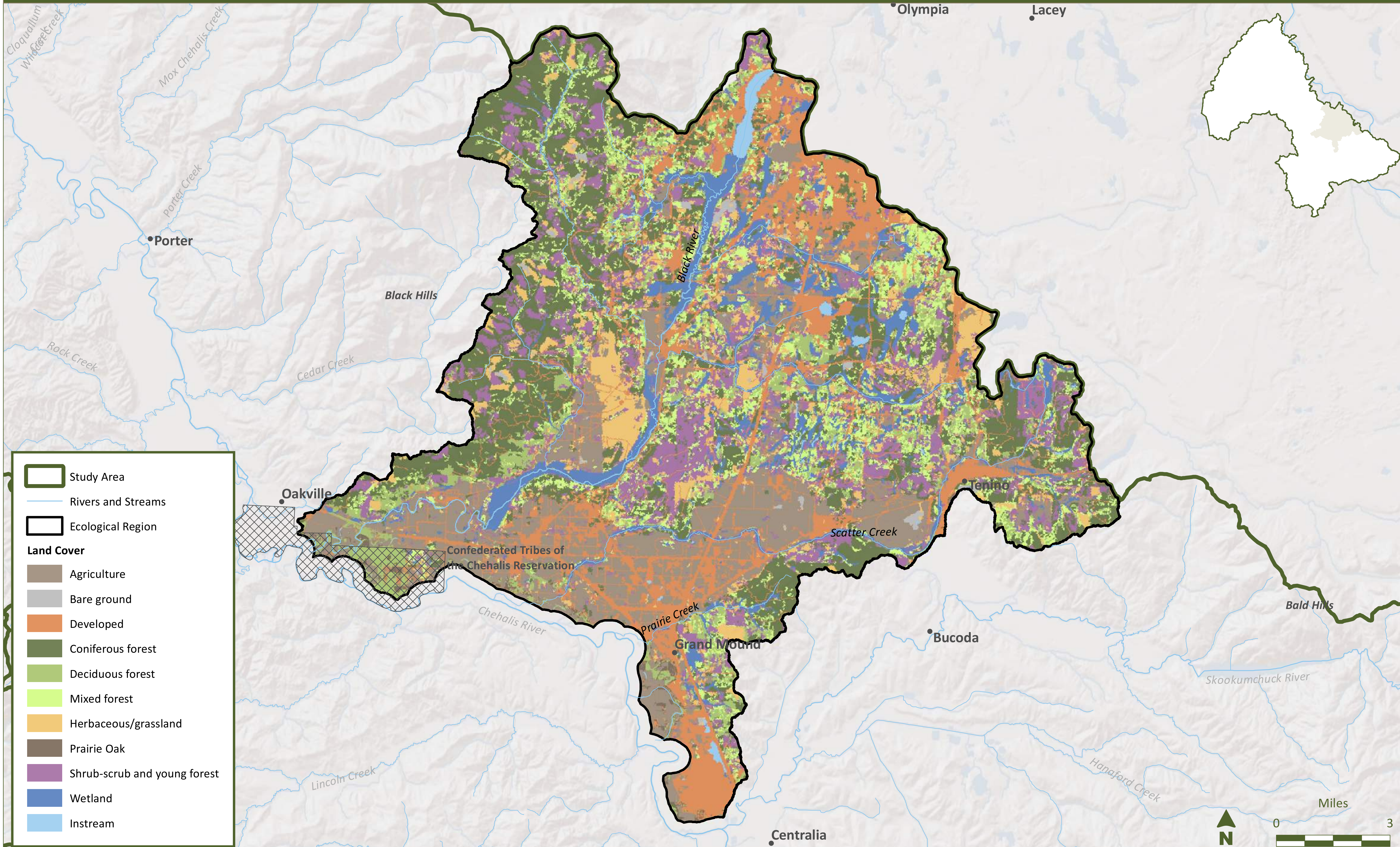
Current conditions reflect ongoing forest management, agricultural land uses, and residential and commercial development. Land cover in the Black River Ecological Region is approximately 22% coniferous forest, 16% developed, 15% agriculture, 14% scrub-shrub, 10% mixed forest, 8% wetland, 7% deciduous forest, 7% grassland, and small percentages of other cover[21] (Figure 5-12).

> **Black River Current Snapshot**
>
> **Condition of Watershed Processes:**
> Hydrology –impaired
> Floodplain connectivity – moderately impaired
> Riparian condition – moderately impaired
> Water quality – impaired
>
> **Restoration Potential**: High
>
> **Protection Potential:** Moderate
>
> **Geographic Spatial Units**: Upper Black River, Lower Black River, Prairie Creek, and Scatter Creek
>
> **Salmon Use and Potential**: Fall-run Chinook salmon, coho salmon, chum salmon, and steelhead
>
> **Non-Salmon Use and Potential:** Coastal tailed frog, Oregon spotted frog, northern red-legged frog, Western toad, North American beaver, Olympic mudminnow, largescale sucker, mountain whitefish, Pacific lamprey, riffle and reticulate sculpin, speckled dace, great blue heron, Barrow's goldeneye, common goldeneye, and wood duck

The Black River still retains a mosaic of riparian areas and palustrine forested, scrub-shrub, and emergent wetlands that represent one of the largest remaining relatively undisturbed freshwater wetland systems in the Puget Sound region (USFWS 2018). A wide corridor of wetlands is present along the Black River, downstream from Black Lake, for approximately 7 miles; much of this wetland area is protected in the Black River Unit of the Nisqually National Wildlife Refuge. Another significant area of wetlands is present along the Black River from RM 10 to RM 16 within the Glacial Heritage Preserve and Black River Natural Area. Tributaries such as Salmon and Beaver creeks retain large wetland areas (Ecology 2011b). Scatter Creek also retains a large component of floodplain remnant wet prairies. An assessment of riparian conditions and functions by NOAA (Beechie 2018) indicates that the majority of the riparian areas in the Black River Ecological Region are impaired for wood recruitment, with less than 5% functioning due to the young age of trees. In the U.S. Fish and Wildlife Service (USFWS 1993) assessment of the Chehalis Basin, a large quantity of wood was noted in Waddell and Mima creeks. A moderate number of beaver dams were noted in those creeks as well. Levels of shading are moderately impaired on the Black River (Beechie 2018).

[21] Land cover data from Multi-Resolution Land Characteristics Consortium, National Land Cover Database 2011, augmented by WDFW Habitat Guild 2015 floodplain data where available.

Figure 5-12
Black River Ecological Region Land Cover



Water quality is impaired in multiple reaches in the Black River Ecological Region, primarily for temperature, low dissolved oxygen, pH, and bacteria (Ecology 2018). Recent temperature monitoring in the Black River (RM 2.5 and 7.2) by WDFW indicates that temperatures regularly exceed water quality standards (16°C [61°F] core summer salmonid habitat) from May through September,[22] and they typically exceed the 13°C (55°F) supplemental spawning incubation criterion (September 15 to July 1) from May to July (Ecology 2016, 2011a). The *Upper Chehalis River Basin Temperature TMDL* (Ecology 2001) has designated a goal of 18°C (64°F) for the Chehalis River, with the primary goals of increasing shading on the Black River by 30% and reducing the width of the Black River by 60%.

WDFW's Thermalscape model indicates that from 2013 to 2018, the majority of stream reaches of the Black River Ecological Region (ranging from 72% [2018] to 95% [2014, 2015, and 2017] of the reaches) had mean August temperatures equal to or exceeding 16°C (61°F) and are projected to increase to 96% and 98% of the reaches in 2040 and 2080, respectively, without restoration actions (Winkowski and Zimmerman 2019).

The NOAA model that incorporates mature riparian conditions and anticipated climate change shows a likely future increase in summer water temperatures ranging from 1.5°C (2.7°F) to more than 2.5°C (4.5°F) by 2080 in the Black River Ecological Region (Beechie 2018).

A high concentration of groundwater wells are present in the Black River Ecological Region, and the Black River and Scatter Creek have been closed to further consumptive water uses during the summer (QIN 2016).

Historical and current areas of floodplain marsh and pond habitats were documented by NOAA using GLO mapping (Beechie 2018). They found the Black River sub-basin has lost or had significant modifications to approximately 65% of its marsh habitats, but it has much of the historical pond habitat (although it has been changed from natural ponds to modified ponds). In Scatter Creek, approximately 50% of the historical marsh habitat and 70% of the historical beaver pond habitat have been lost.

More than 50 fish passage barriers were incorporated into the EDT model[23] for the Black River Ecological Region, primarily located on tributaries.

The percentage of fine sediment in streams was modeled by NOAA based on the density of roads and land uses; this modeling indicated 19% to 22% fines are likely to be present in the Black River and Scatter Creek, which is only a slight increase from modeled historical conditions of 17% to 21% fines (Beechie 2018).

Salmon species present in the Black River Ecological Region include fall-run Chinook salmon, coho salmon, chum salmon, and steelhead. The Washington Department of Fisheries (1975) noted that the Black River and Scatter and Prairie creeks formerly supported significant runs of chum salmon, but these

[22] Temperatures regularly exceed 23°C (73°F) in the Black River in July and August (WDFW gage data).
[23] Fish passage barrier data from WDFW processed through EDT model.

populations are much reduced now. They also noted that the lower Black River had high numbers of predatory fish. Non-salmon indicator species present include Western toad, coastal tailed frog, Oregon spotted frog, northern red-legged frog, North American beaver, Olympic mudminnow, largescale sucker, mountain whitefish, Pacific lamprey, riffle and reticulate sculpin, and speckled dace. The Black River Ecological Region is the only known area in which the Oregon spotted frog occurs in the Chehalis Basin and one of only six known locations in Washington (WDFW 2012). The bird indicator species present include great blue heron, Barrow's goldeneye, common goldeneye, and wood duck.

Each year, Littlerock Elementary School releases coho salmon fry (about 500 fish) into Beaver Creek. The fish are less than 1 gram per fish at the time of their release. The fish are too small to mark but are not believed to contribute to adult returns.

5.6.4 Limiting Factors

Limiting factors for salmonids have been identified in several assessments of the Chehalis Basin, including the EDT (ICF 2019) and NOAA modeling (Beechie 2018) conducted for the ASRP and earlier studies (GHLE 2011; Smith and Wenger 2001). Additional limiting factors and a diagnosis of what is working and what is broken in the ecological region were determined by the SRT, drawing on local basin knowledge and reconnaissance conducted within the region.

The combined results of these assessments indicate that the major issues for salmonids in the region are as follows (in relative order of importance):

- High water temperature
- Reduced quantity and quality of instream habitats
- Low habitat diversity (lack of side channels, large wood, floodplain connectivity, and beaver ponds)
- Fish passage barriers
- Sediment conditions (fine sediments)
- Predation (non-native fish species and bullfrogs)
- Low flows
- Channel instability

> **Diagnostic Snapshot**
>
> - The ecological region is lacking wood nearly everywhere.
> - Substantial channel length lacks stable gravel.
> - Invasive plant species, including reed canarygrass, are present.
> - The extensive, relatively intact marsh habitat and lakes are high protection priorities.
> - The entire ecological region is vulnerable to development impacts from the greater Olympia-Tumwater area.
> - The Black River has been channelized and widened, and possible impacts of those modifications have not been evaluated.
> - Scatter Creek instream flows may be impacted by groundwater pumping and the historical diversion of one of its headwater tributaries outside of the basin. Some reaches go dry in summer and fall months.

These identified issues for salmonids are consistent with earlier findings from Smith and Wenger (2001) and the Chehalis Basin Lead Entity (GHLE 2011), which indicated that the key limiting factors in this ecological region include riparian conditions, water quality, water quantity, floodplain conditions, lack of large wood, gravel (sediment) conditions, and fish passage barriers.

Limiting factors and threats to non-salmon indicator species are not well understood but may include high water temperatures, migration barriers, changes in flow conditions and water level variations, fine sediments, riparian conditions, and non-native predator species (as identified for Pacific lamprey by Clemens et al. [2017]).

5.6.5 Strategies and Actions in the Ecological Region

5.6.5.1 Habitat and Process Protection

Many of the protection actions described in Section 4.2.1 are appropriate in the Black River Ecological Region, particularly acquisitions and easements to protect high-quality habitats and unique features. Based on existing conditions, the following areas and actions are recommended for a protection focus:

- Ensure continued protection of Oregon spotted frog habitat (ponds and marshes). Protect headwaters of already protected prairie marshes.
- Identify and protect areas with cool-water and groundwater inputs.
- Protect instream flows and groundwater tables by reducing or preventing surface or groundwater withdrawals.
- Protect functioning wet prairie, floodplain, and marsh habitats, especially in the Allen Creek area.

The majority of the Black River Ecological Region is within Thurston County, which has regulations in place to protect water quantity and quality; maintain or increase forest cover; establish and protect riparian habitat; protect streams, wetlands, floodplains, and prairies from development; limit impervious surfaces; and allow channel migration.

A mosaic of riparian areas and palustrine forested, scrub-shrub, and emergent wetlands in the ecological region represent one of the largest remaining relatively undisturbed freshwater wetland systems in the Puget Sound region. The extensive associated wetland system should be further protected and enhanced.

The Black River Ecological Region is the location of the only known area in which Oregon spotted frog occur in the Chehalis Basin, and it is one of only six such areas in Washington. West Rocky Prairie, one of several known Oregon spotted frog-occupied sites in this ecological region, is an example of marsh and pond habitats that should be targeted for protection and restoration.

As part of the community planning strategy (see Section 5.6.5.3), funding support to align the County regulations with the ASRP and conduct enforcement will be considered.

General protection priorities for Thurston County in the Black River Ecological Region are as follows:

- Protect rocky glacial outwash wetlands/prairies from development and groundwater withdrawals and limit impervious surfaces.
- Protect wetlands/floodplains associated with the Black River and tributaries from development and surface and groundwater withdrawals.
- Maintain spawning gravels and sources by increasing wood recruitment and allowing channel migration.

5.6.5.2 Restoration

The restoration actions described in Section 4.2.2 are all appropriate in the Black River Ecological Region. Based on existing conditions, the following areas and actions are recommended for a restoration focus:

- Ensure continued restoration/management of Oregon spotted frog habitat (ponds and marshes).
- Reduce or prevent surface or groundwater withdrawals that could decrease instream flows, including reconnecting diverted tributaries, particularly in systems like Scatter Creek.
- Restore riparian areas along the Black River, lowland tributaries, and Scatter and Prairie creeks.
- Install large wood structures with the objective of restoring anabranching channel patterns where appropriate and promoting beaver ponds.

Priority restoration areas in the Black River Ecological Region include both the lower and upper Black River and Dempsey, Beaver, Allen, Waddell, and Scatter creeks.

5.6.5.3 Community Planning

As noted in Section 4.2.3, community planning actions would be coordinated with state and local governments, landowners, and other stakeholders to ensure the long-term success of the ASRP. Focus programs and policies that could be developed or investigated in the Black River Ecological Region include the following:

- Discuss with Thurston County additional planning measures that could effectively promote and protect the following:
  - Floodplain connectivity
  - Surface and groundwater through reduction of withdrawals
  - Improved wood recruitment for retention of spawning gravel and sources

- As the Chehalis Basin Strategy becomes more integrated, coordinate the ASRP with the CFAR Program to build habitat restoration and protection actions into community flood risk reduction efforts (such as restoring areas where structures and people have been relocated from floodplains).

5.6.5.4 Community Involvement

As noted in Section 4.2.4, community involvement and voluntary landowner participation are essential to the success of the ASRP, and the actions described in that section will be further evaluated for the Black River Ecological Region in Phases 2 and 3 based on the restoration and protection scenario selected. Based on the specific issues in this area, the following actions are recommended for focused community involvement:

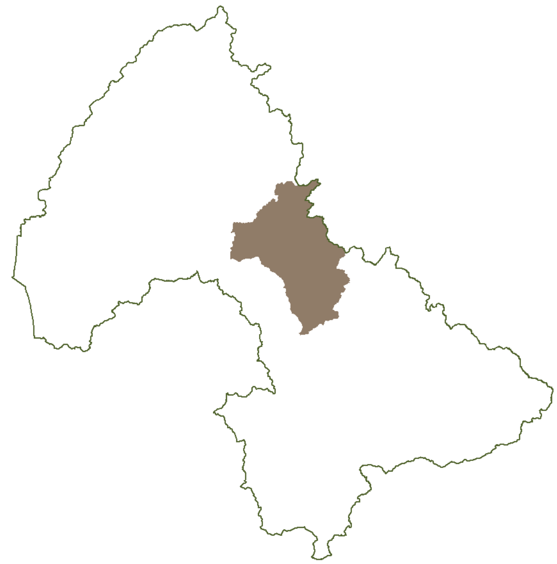
- Continue outreach, engagement, and involvement processes to incorporate landowner expertise into ASRP planning and local implementation efforts.
- Partner with and support the efforts of existing local organizations (see Appendix E for a list of potential partner organizations).

5.6.5.5 Institutional Capacity

The institutional capacity strategy is intended to build on and support the work of existing organizations, as well as support creativity in how local organizations approach working toward the goals of the ASRP. The actions described in Section 4.2.5 will be further evaluated for the Black River Ecological Region in Phases 2 and 3 based on the restoration and protection scenario selected. Based on the specific issues in this area, the following focused institutional capacity actions are recommended:

- Provide technical training on process-based restoration practices and principles.
- Provide funding for groups and individuals interested in restoration projects.
- Build on and support the work of existing organizations with missions that overlap with the ASRP vision (see Appendix E for a list of potential groups).

5.7 Black Hills Ecological Region



5.7.1 Overview

The Black Hills Ecological Region encompasses a number of independent tributaries to the Chehalis River that arise in the Black Hills, including Roundtree, Cedar, Gibson, Porter, Mox Chehalis, Wildcat, Cloquallum, Vance, and Newman creeks (Figure 5-13). All of these creeks arise in the glacially deposited Black Hills between Hood Canal and the Chehalis Basin, typically with headwaters dominated by wetlands and short drainages from about 150 to nearly 2,500 feet in elevation. The highest point in this region is also Capitol Peak at 2,659 feet in the Black Hills. This ecological region encompasses 215 square miles (greater than 137,000 acres) and represents approximately 8% of the overall Chehalis Basin.

The geologic landscape of the Black Hills Ecological Region was largely formed from the deposition of materials from continental glaciation. The Puget Lobe of the Cordilleran Ice Sheet extended into the Chehalis Basin at least twice, with the deposition of a terminal moraine north of Rochester (Gendaszek 2011). As the Puget Lobe retreated, meltwater channels drained south, creating a series of channels and valleys and depositing recessional glacial outwash in the Chehalis River and its tributaries (the Skookumchuck, Black, and Satsop rivers and Scatter Creek; Gendaszek 2011). The Black Hills Ecological Region has glacial lakes and relatively large areas of wetlands.

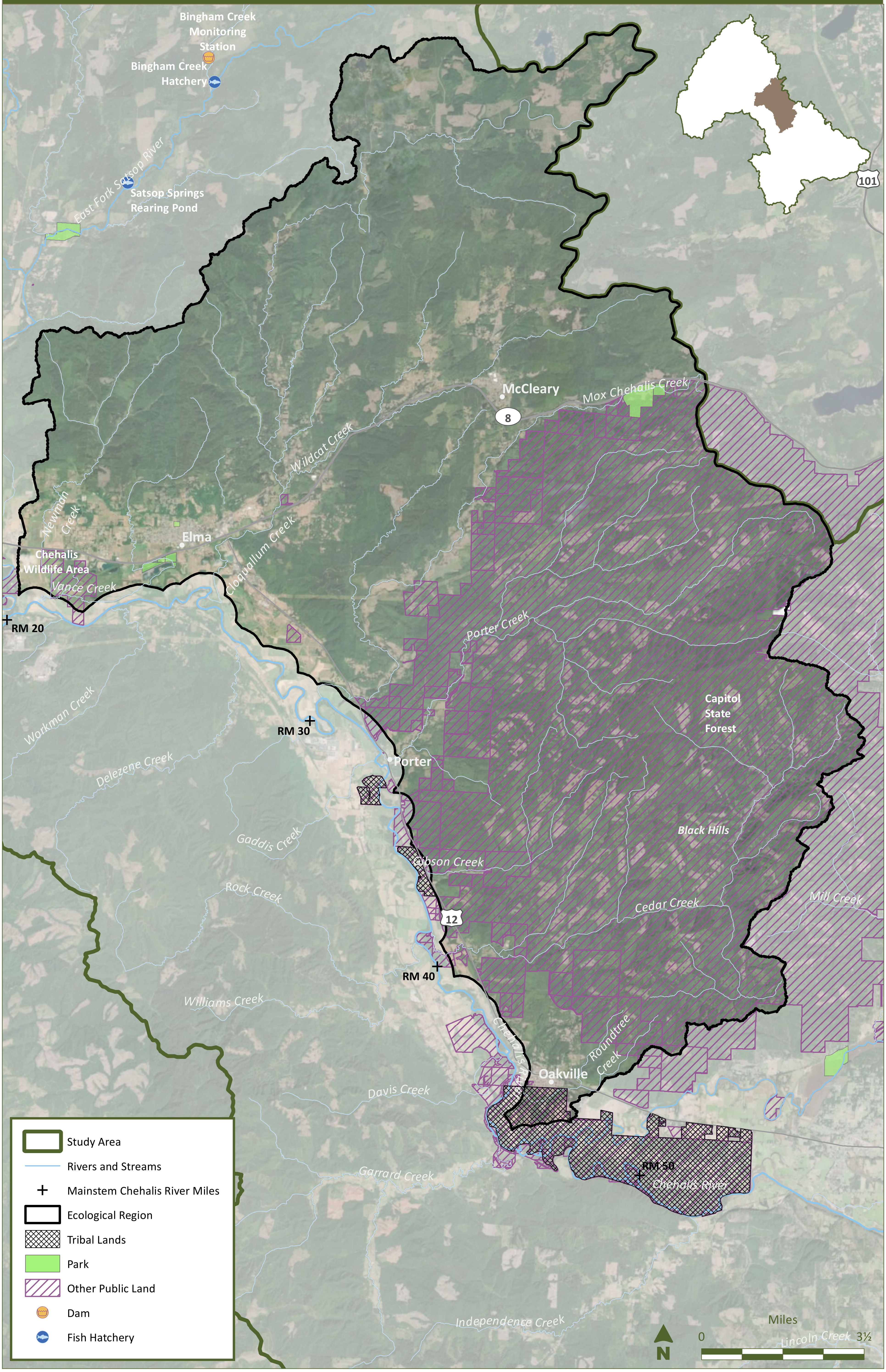
Precipitation in the Black Hills Ecological Region is dominated by rainfall, with 50 to 75 inches of average annual precipitation typically, but it features a convergence zone around the southeast corner of the Olympic Mountains and Hood Canal and can receive up to 200 inches of precipitation annually in the Porter, Mox Chehalis, and Cloquallum creek drainages.

Important Features and Functions

- This ecological region is composed of relatively short woodland tributaries flowing south from the Black Hills into the Chehalis River. The lower sections (typically less than 0.5 mile) of these tributaries are often slough-like with low-gradient, slow- or no-flow habitat that contrasts with the riffle/pool or plane bed habitat observed throughout much of the rest of the streams.
- Several of the streams (such as Porter and Cedar creeks) are within the Capitol State Forest managed by WDNR, which offers protection of stream and riparian habitat. Habitat Conservation Plans developed for the managed forests retain riparian buffers that are essential for shading and wood delivery to stream channels.
- Underlying glacial geology can supply spawning gravel and groundwater recharge, and these creeks are an important cold-water inflow to the Chehalis River.

The Black Hills Ecological Region is primarily within Grays Harbor County (97,561 acres, or 71%), with smaller portions in Mason County (20,536 acres, or 15%) and Thurston County (19,283 acres, or 14%). Cities and towns within this ecological region include McCleary, Elma, and Oakville.

Figure 5-13
Black Hills Ecological Region Map



Aerial Photo Source: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

5.7.2 Historical Conditions and Changes

Historical records for the pre-Euro-American settlement conditions are not available. GLO mapping from the late 1800s primarily shows steep timbered slopes, but survey notes indicate medium- to large-size cedar, fir, and hemlock present (considered first-rate timber). The Black Hills Ecological Region was likely historically dominated by old-growth Western hemlock and Douglas-fir forest on the hillslopes and cedar swamps and marsh wetlands in the headwaters of several creeks. It is likely there were abundant beaver and beaver ponds. Key changes that occurred in the Black Hills Ecological Region following Euro-American settlement were extensive timber harvest and agricultural development in the lower ends of the streams (primarily within the Chehalis River floodplain) and development of transportation corridors (including SR 12, SR 8, and railroad lines). Agricultural development as well as road, bridge, and residential construction likely also incrementally moved and straightened some of the rivers and creeks in the Black Hills Ecological Region over time.

To support the ASRP analysis and EDT modeling efforts, the SRT developed assumptions of the channel lengths and areas of floodplain habitat that were likely to be present in historical conditions. These assumptions were based on the GLO mapping from the late 1800s and interpretation of current LiDAR data that show remnant channels and other floodplain features. Streams in the Black Hills Ecological Region are unconfined to partly confined and low gradient within moderately sized valleys. Compared to historical conditions, the stream channel lengths do not appear to be significantly reduced, but side channels would have historically been more prevalent, and the streams could have had up to 3 times the area of frequently connected floodplain. Large wood has been removed from the channels throughout this region, and the streams are scoured to bedrock in some reaches.

5.7.3 Current Conditions

Current conditions reflect ongoing forest management, agricultural land uses, and residential and commercial development. Land cover in the Black Hills Ecological Region is approximately 47% coniferous forest, 18% scrub-shrub, 8% mixed forest, 7% developed, 6% grassland, 5% deciduous forest, 4% wetland, 4% agriculture, and small percentages of other cover[24] (Figure 5-14).

As noted previously, the Black Hills Ecological Region is primarily forested uplands, about half of which are contained within the Capitol State Forest. The remainder is a mix of small and large privately owned managed forest lands and rural residential or small agricultural properties. WDFW manages the Chehalis Wildlife Area along lower Vance Creek that is protected for waterfowl and other wildlife. An assessment of riparian conditions and functions by NOAA (Beechie 2018) found that levels of shading are only moderately reduced from the reconstructed historical conditions (i.e., in the managed forests), except on Vance and Newman creeks, where riparian conditions are poor, and in some reaches of Cloquallum and Wildcat creeks.

> **Black Hills Current Snapshot**
>
> **Condition of Watershed Processes:**
> Hydrology –impaired
> Floodplain connectivity – moderately impaired
> Riparian condition – moderately impaired
> Water quality – impaired
>
> **Restoration Potential**: High
>
> **Protection Potential:** Moderate
>
> **Geographic Spatial Units**: Cedar Creek, Porter Creek, Mox Chehalis Creek, Cloquallum-Wildcat Creek, and Newman-Vance Creek
>
> **Salmon Use and Potential**: Fall-run Chinook salmon, spring-run Chinook salmon (holding at tributary confluences), coho salmon, chum salmon, and steelhead
>
> **Non-Salmon Use and Potential:** Coastal tailed frog, Oregon spotted frog, northern red-legged frog, Western toad, North American beaver, Olympic mudminnow, largescale sucker, mountain whitefish, Pacific lamprey, riffle and reticulate sculpin, speckled dace, great blue heron, Barrow's goldeneye, common goldeneye, and wood duck

The stream channels were observed to lack wood in most reaches, and some reaches have been scoured to bedrock.

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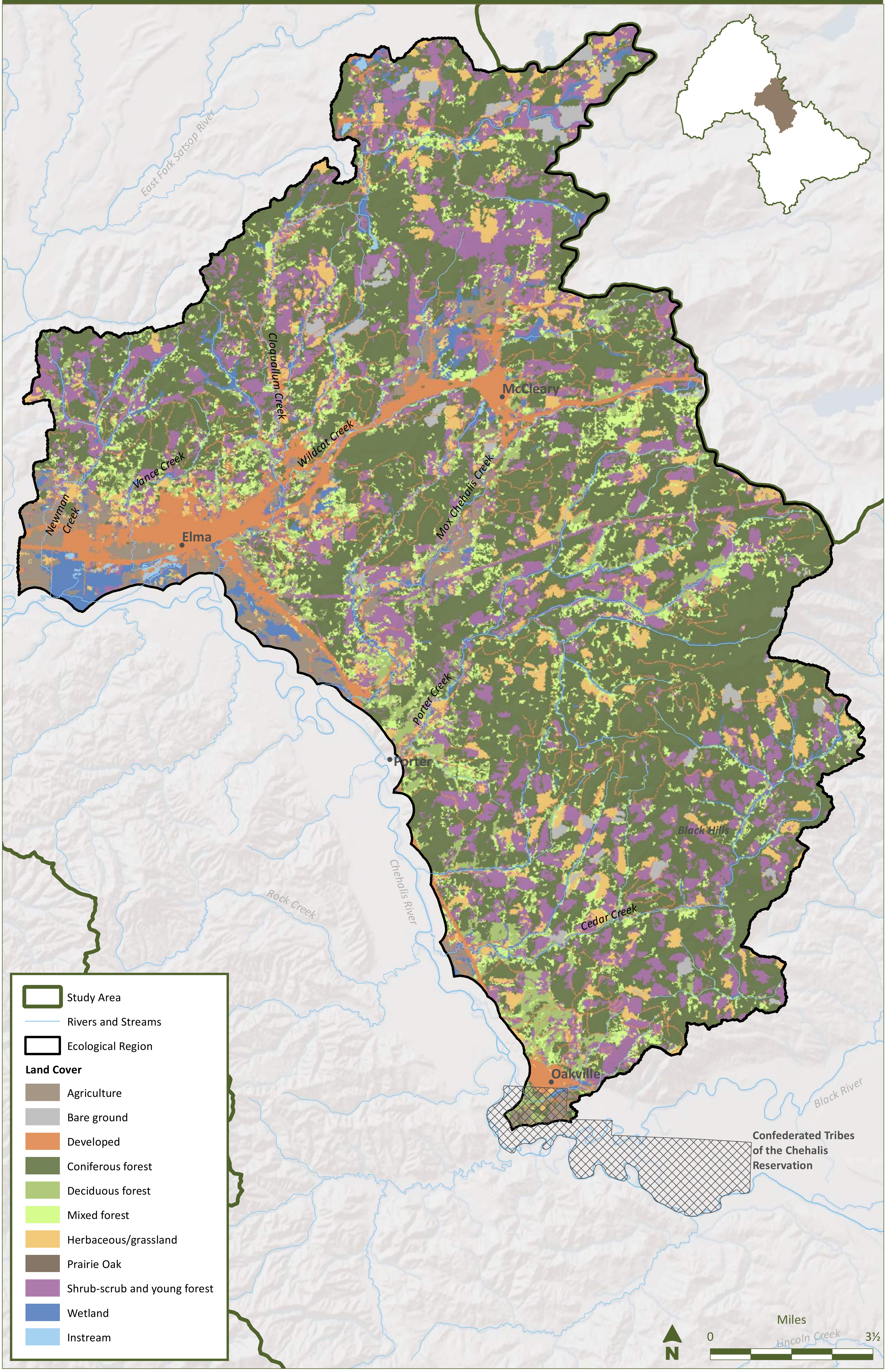
[24] Land cover data from Multi-Resolution Land Characteristics Consortium, National Land Cover Database 2011, augmented by WDFW Habitat Guild 2015 floodplain data where available.

Figure 5-14
Black Hills Ecological Region Land Cover



Water quality is impaired in multiple reaches in the Black Hills Ecological Region, primarily for temperature, low dissolved oxygen, and bacteria (Ecology 2018). Recent temperature monitoring in lower Cedar and Porter creeks by Ecology (2015 data) indicates that temperatures regularly exceed water quality standards (16°C [61°F] core summer salmonid habitat) from May through September, and they typically exceed the 13°C (55°F) supplemental spawning incubation criterion (September 15 to July 1) from May to July (Ecology 2016, 2011a).[25]

WDFW's Thermalscape model indicates that from 2013 to 2018, many stream reaches of the Black Hills Ecological Region (ranging from 39% [2018] to 91% [2014 to 2015] of reaches) had mean August temperatures equal to or exceeding 16°C (61°F) and are projected to increase to 98% and 99% of reaches in 2040 and 2080, respectively, without restoration actions (Winkowski and Zimmerman 2019).

The NOAA model that incorporates mature riparian conditions and anticipated climate change shows a likely future increase in summer water temperatures ranging from 1.5°C (2.7°F) to more than 2.5°C (4.5°F) by 2080 in the Black Hills Ecological Region, although some cooling potential exists for Vance and lower Newman creeks due to their current lack of riparian zone (Beechie 2018).

Existing wetland mapping (Ecology 2011b) indicates that many lowland or low gradient reaches along Mox Chehalis, Wildcat, and Cloquallum creeks and some of their smaller tributaries have a variety of associated wetlands, including emergent, shrub, and forested wetlands. No specific analysis of channel incision has been conducted for the Black Hills Ecological Region, but many of the streams have been scoured to bedrock or boulders, most likely due to removal of large wood and beaver dams from the channels. Approximately 100 fish passage barriers were incorporated into the EDT model[26] for the Black Hills Ecological Region, with the majority of those present in the Cloquallum Creek sub-basin. Vance, Newman, and McDonald creeks flow through urbanized areas of Elma; these creeks have been ditched and straightened and have numerous road crossings.

The salmonid species present in the Black Hills Ecological Region include fall-run Chinook salmon, coho salmon, chum salmon, and steelhead. Spring-run Chinook salmon hold at the confluence of some of these streams with the Chehalis River, as they provide cooler water (Holt 2018b). Non-salmon indicator species include Western toad, coastal tailed frog, northern red-legged frog, North American beaver, Olympic mudminnow, largescale sucker, mountain whitefish, Pacific lamprey, riffle and reticulate sculpin, and speckled dace. The bird indicator species present include great blue heron, Barrow's goldeneye, common goldeneye, and wood duck.

Occasionally, excess hatchery fish are released into Vance Creek Pond for sport fishing. Hatchery production in excess of program goals are released as fingerings into lakes without outlets.

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[25] Cedar Creek typically remains below 20°C (68°F), while Porter Creek regularly exceeds 20°C (68°F) during the June-to-August time period (Ecology gage data).
[26] Fish passage barrier data from WDFW processed through EDT model.

5.7.4 Limiting Factors

Limiting factors for salmonids have been identified in several assessments of the Chehalis Basin, including EDT (ICF 2019) and NOAA modeling (Beechie 2018) conducted for the ASRP and earlier studies (GHLE 2011; Smith and Wenger 2001). Additional limiting factors and a diagnosis of what is working and what is broken in the ecological region were determined by the SRT, drawing on local basin knowledge and reconnaissance conducted within the region.

The combined results of these assessments indicate that the major issues for salmonids in the region are as follows (in relative order of importance):

- Low habitat diversity (lack of side channels, large wood, floodplain connectivity, and significant loss of beaver ponds)
- Fish passage barriers
- Reduced quantity and quality of instream habitats
- High water temperatures
- Predation (non-native fish species)
- Sediment conditions (fine sediments)
- Channel instability (bed scour and sediment transport)
- Low flows

> **Diagnostic Snapshot**
>
> - Widespread loss of stable instream wood has resulted in extensive conversion of pool-riffle channels to plane bed channels. This has resulted in the loss of many miles of spawning habitat and hundreds of pools, as well as floodplain disconnection and the loss of floodplain habitat-forming processes.
> - Several of the streams (such as Vance, Newman, and McDonald creeks) are urbanized.
> - The existing riparian canopy provides good shading for smaller tributaries; species composition is primarily red alder, which provides shade but offers limited long-term large wood recruitment.
> - The lower portions of Cedar, Mox Chehalis, and Cloquallum creeks provide temperature refugia for spring-run Chinook salmon.
> - Substantial channel length lacks stable gravel.
> - Invasive plant species, including reed canarygrass, are present.

These identified issues for salmonids are consistent with earlier findings from Smith and Wenger (2001) and the Chehalis Basin Lead Entity (GHLE 2011),which indicated that the key limiting factors in this ecological region include lack of large wood, gravel (sediment) conditions, fish passage barriers, floodplain conditions, riparian conditions, water quality, and water quantity.

Limiting factors and threats to non-salmon indicator species are not well understood but may include high water temperatures, changes in flow conditions and water level variations, fine sediments, riparian conditions, and non-native predator species (as identified for Pacific lamprey by Clemens et al. [2017]).

5.7.5 Strategies and Actions in the Ecological Region

5.7.5.1 Habitat and Process Protection

Many of the protection actions described in Section 4.2.1 are appropriate in the Black Hills Ecological Region. Based on existing conditions, the following areas and actions are recommended for a protection focus:

- Ensure continued protection and management of riparian areas.
- Identify and protect areas with wetlands and cool-water inputs such as Cedar, Racoon, and Sand creeks.
- Protect areas with existing beaver ponds, such as Racoon Creek.

The majority of the Black Hills Ecological Region is within Grays Harbor County, which has regulations and policies in place to protect wetlands, floodplains, riparian areas, and fish and wildlife habitat conservation areas from degradation and development and manage invasive species. Grays Harbor County's draft SMP that is currently in final review with Ecology contains regulations to protect channel migration zones and riparian vegetation, along with general development regulations related to shoreline areas in the County (Grays Harbor County 2018).

The northern portion of the ecological region is in Mason County, which has regulations and policies in place to restore shoreline ecological functions and floodplain connectivity, improve habitat for salmon populations, and protect wetlands and groundwater. They also have objectives to coordinate with nearby counties on conservation plans and programs to ensure that protection measures occur at the watershed scale.

The eastern portion of the ecological region is in Thurston County, which has regulations in place to

Streams within the Capitol State Forest could be easily restored by adding wood.

Mox Chehalis Creek and other Black Hills streams could be enhanced for off-channel and beaver pond habitat for coho salmon.

Larger streams such as Porter and Cedar creeks—with areas of forested riparian and relatively intact habitat—could be easily enhanced with wood and supplemental tree plantings to increase habitat potential and long-term wood recruitment.

protect water quantity and quality; maintain or increase forest cover; establish and protect riparian habitat; protect streams, wetlands, floodplains, and prairies from development; limit impervious surfaces; and allow channel migration.

As part of the community planning strategy (see Section 5.7.5.3), funding support to align the counties' regulations with the ASRP and conduct enforcement will be considered.

5.7.5.2 Restoration

The restoration actions described in Section 4.2.2 are all appropriate in the Black Hills Ecological Region. Based on existing conditions, the following areas and actions are recommended for a restoration focus:

- Restore and manage riparian areas.
- Address fish passage barriers.
- Place extensive stable instream wood to capture alluvium (finer gravel), increase variations in bed textures, increase the number of pools and cover, raise streambeds, and increase floodplain and groundwater connectivity. Large-scale loss of gravel in many Black Hills channels is a substantial restoration opportunity.
- Construct beaver dam analogs and promote beaver use and creation of beaver ponds.
- Put immediate effort into restoring Porter, Cedar, and Sherman creeks with large wood augmentation.
- Protect and enhance areas around confluences with the mainstem Chehalis River to provide deep cold-water pools for spring-run Chinook salmon holding.
- Restore riparian and floodplain habitats along lower ends of streams where they enter the Chehalis River valley.

Priority areas for restoration in the Black Hills Ecological Region include Cloquallum, Porter, Cedar, and Sherman creeks.

5.7.5.3 Community Planning

As noted in Section 4.2.3, community planning actions would be coordinated with state and local governments, landowners, and other stakeholders to ensure the long-term success of the ASRP. Focus programs and policies that could be developed or investigated in the Black Hills Ecological Region include the following:

- Improve water typing for improved forest management around creeks.
- Discuss with Grays Harbor County additional planning measures that could effectively promote and protect the following:
  - Surface and groundwater supplies through reduction of withdrawals
  - Minimization of impervious surfaces
  - Improved wood recruitment for retention of spawning gravel and sources
  - Increasing channel migration

- Discuss with Thurston County additional planning measures that could effectively promote and protect the following:
  - Floodplain connectivity
  - Surface and groundwater supplies through reduction of withdrawals
  - Improved wood recruitment for retention of spawning gravel and sources
- As the Chehalis Basin Strategy becomes more integrated, coordinate the ASRP with the CFAR program to build habitat restoration and protection actions into community flood risk reduction efforts (such as restoring areas where structures and people have been relocated from floodplains).

5.7.5.4 Community Involvement

As noted in Section 4.2.4, community involvement and voluntary landowner participation are essential to the success of the ASRP, and the actions described in that section will be further evaluated for the Black Hills Ecological Region in Phases 2 and 3 based on the restoration and protection scenario selected. Based on the specific issues in this area, the following actions are recommended for focused community involvement:

- Continue outreach, engagement, and involvement processes to incorporate landowner expertise into ASRP planning and local implementation efforts.
- Partner with and support the efforts of existing local organizations (see Appendix E for a list of potential partner organizations).

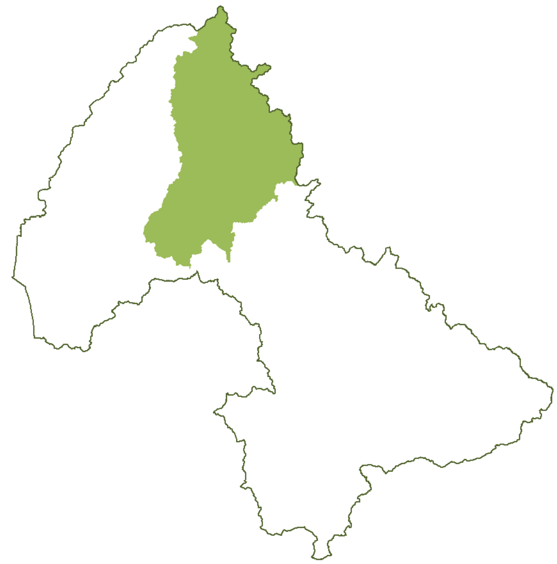
5.7.5.5 Institutional Capacity

The institutional capacity strategy is intended to build on and support the work of existing organizations, as well as support creativity in how local organizations approach working toward the goals of the ASRP. The actions described in Section 4.2.5 will be further evaluated for the Black Hills Ecological Region in Phases 2 and 3 based on the restoration and protection scenario selected. Based on the specific issues in this area, the following focused institutional capacity actions are recommended:

- Provide additional support for the small forest landowner program.
- Provide training on improved processes for water type-based decisions at the counties.
- Provide technical training on process-based restoration practices and principles.
- Provide funding for groups and individuals interested in restoration projects.
- Build on and support the work of existing organizations with missions that overlap with the ASRP vision (see Appendix E for a list of potential groups).

5.8 Olympic Mountains Ecological Region

5.8.1 Overview



The Olympic Mountains Ecological Region encompasses the northern part of the Chehalis Basin, including the Satsop and Wynoochee rivers and their tributaries (Figure 5-15). This region encompasses 496 square miles (greater than 317,000 acres) and represents approximately 18% of the overall Chehalis Basin. The Satsop and Wynoochee rivers arise in the Olympic Mountains. The highest point in this ecological region is Capitol Peak (different from the Black Hills Capitol Peak) at 5,054 feet. The Satsop River arises in three forks in distinctly different areas: the East Fork Satsop River arises in and flows through a series of wetlands and lakes in the low (approximately 110 feet in elevation) glacial moraine deposits west of Shelton; the Middle Fork Satsop River arises in the southern hills of the Olympic Mountains at approximately 2,000 feet in elevation; and the West Fork Satsop River arises in the higher elevations within the Olympic National Forest at Satsop Lakes near Chapel Peak at approximately 3,000 feet in elevation. The Wynoochee River arises in Olympic National Park near Wynoochee Point at approximately 4,000 feet in elevation.

The Olympic Mountains geology is predominantly volcanic and marine sedimentary rocks, including sandstone and siltstone, claystone, shale, mudstone, and locally derived conglomerates and breccias (WDNR 2010). Alpine glaciation from the Olympic Mountains advanced into the Chehalis Basin on multiple occasions (at least four times) with the deposition of glacial till and outwash across the northwestern portion of the Chehalis Basin (Gendaszek 2011).

Precipitation in the Olympic Mountains Ecological Region is dominated by rainfall, with higher

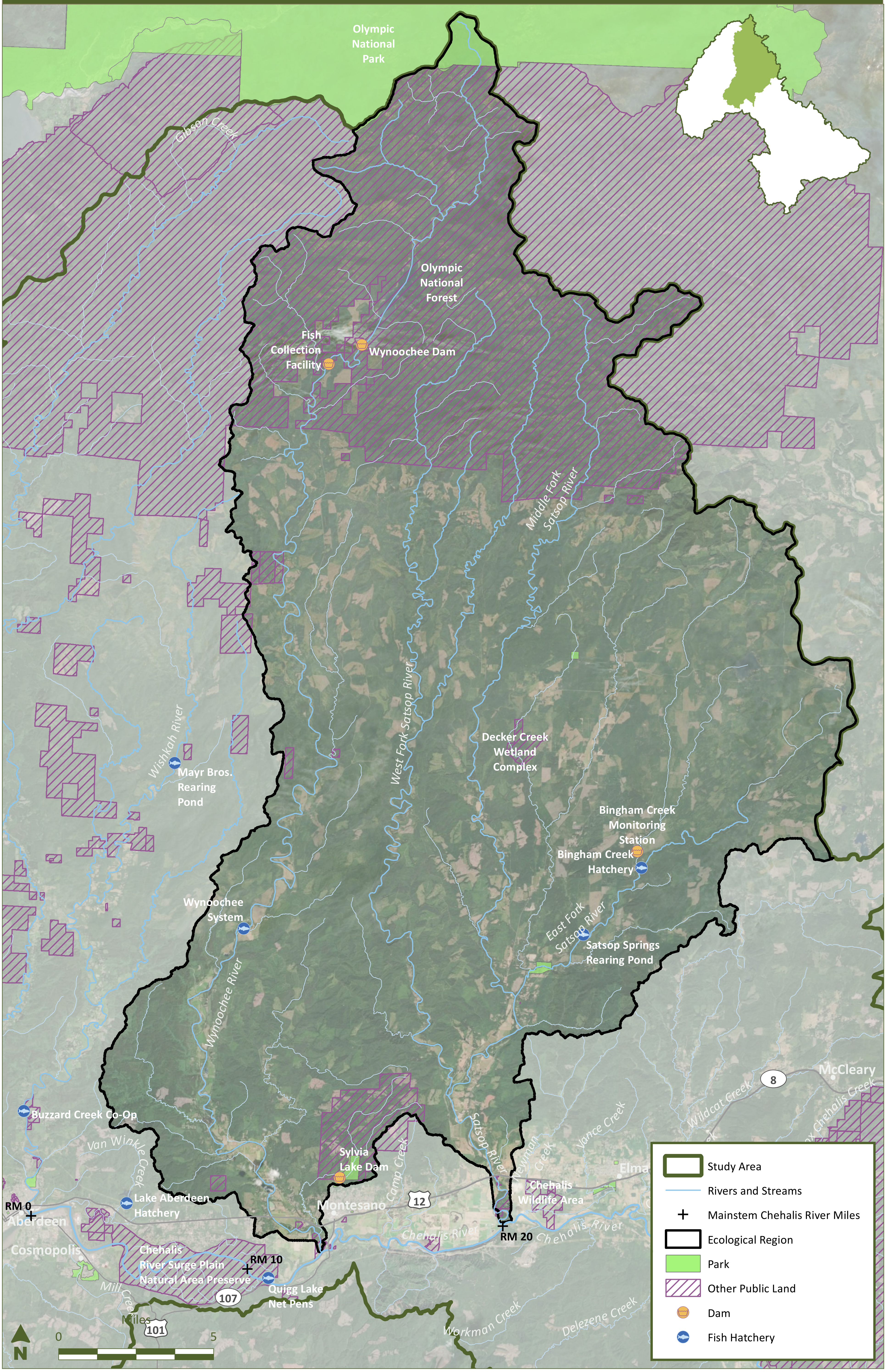
Important Features and Functions

- This ecological region is very productive for multiple salmonid species (steelhead and chum, coho, and fall-run Chinook salmon) and Pacific lamprey. The East Fork Satsop River is particularly productive for chum and coho salmon. Native char have been documented in both the Satsop and Wynoochee rivers.
- Glacial outwash gravel deposits with a large network of groundwater-fed streams in the East Fork Satsop River and tributaries are unique among all the ecological regions.
- Seasonally dry channels have extensive seasonal spawning use.
- This is one of only two ecological regions that still has significant old-growth forest.
- The West Fork Satsop and Wynoochee river systems have higher-elevation headwaters with rainfall-dominated hydrology and high sediment supply, characterized by active channel migration, major avulsions, and a lack of stable logjams.
- There are significant hatchery influences on wild fish that may include competition, genetics, predation, disease, and fish passage.
- There is more habitat for stream- and riparian-associated amphibians than any other ecological region.

elevations receiving snow. Average annual precipitation is 100 to 200 inches and can be as high as 250 inches in the upper mountain areas. Generally, this part of the Chehalis Basin receives the most precipitation out of all the ecological regions.

The Olympic Mountains Ecological Region is primarily within Grays Harbor County (204,387 acres, or 64%) and Mason County (111,656 acres, or 35%), and it is just touching the edge of Jefferson County (1,235 acres, or <1%). Cities and towns within this ecological region include Elma and Montesano.

Figure 5-15
Olympic Mountains Ecological Region Map



Aerial Photo Source: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

5.8.2 Historical Conditions and Changes

Historical records for the pre-Euro-American settlement conditions are not available, but available historical records and maps indicate that the Olympic Mountains Ecological Region was dominated by old-growth Western hemlock forest, including other important species such as Douglas-fir and Western red cedar. Several wetlands were present in the glacial deposits on the east and southeast side of the mountains. GLO maps show numerous and large wetlands associated with the upper East Fork Satsop River, Lake Nahwatzel, the Middle Fork Satsop River, and some wetlands along the West Fork Satsop River. Several major flow splits with side channels are shown for the lower to middle Wynoochee River, and a complex multithreaded channel with sloughs is shown on the lower 3 to 4 miles of the Wynoochee River.

Key changes that occurred in the Olympic Mountains Ecological Region following Euro-American settlement were extensive timber harvest and agricultural and residential development in the lower floodplains of the mainstem Satsop and Wynoochee rivers. Agricultural development as well as road, railroad, bridge, and gravel removal likely also incrementally moved and straightened many of the rivers and creeks in the Olympic Mountains Ecological Region over time.

Historical changes to the Satsop River included construction of the water diversion and hatchery facilities at Bingham Creek, construction of chum salmon spawning channels and hatchery facilities at Satsop Springs (RM 14.8), construction of small dams on several tributaries, and increased fine sediment delivery to the West Fork Satsop River and numerous tributaries. Additionally, the Middle Fork Satsop River was noted as going dry in the summer as early as the 1960s (WDF 1975).

This structure on Bingham Creek has a fish ladder and smolt trap that have provided approximately 40 years of wild coho salmon life-cycle monitoring information.

Wynoochee Dam is a fish passage barrier and affects gravel and wood loading downstream.

Historical changes to the Wynoochee River included a water diversion at RM 8.1 that occasionally diverted fish into Lake Aberdeen (WDF 1975), the construction of Wynoochee Dam in 1972 that eliminated approximately 9 miles of mainstem spawning habitat (including spawning habitat for the remnant spring-run Chinook salmon that were nearly extirpated from the river by the 1970s), and numerous areas of gravel mining in the middle and lower river and floodplain. Coho salmon and steelhead are now trapped at a fish collection dam downstream of Wynoochee Dam and hauled upstream past Wynoochee Dam, and smolts travel downstream during the 77 days when hydropower operations are suspended to allow passage through the dam (Tacoma Power 2018). Chinook salmon are not transported upstream of Wynoochee Dam.

To support the ASRP analysis and EDT modeling, the SRT developed assumptions of the channel lengths and areas of floodplain habitat that were likely to be present in historical conditions. These assumptions were based on the GLO mapping from the late 1800s, more recent historical aerial photographs, and interpretation of current LiDAR data that show remnant channels and other floodplain features. Rivers in the Olympic Mountains Ecological Region are unconfined to partly confined and low gradient within narrow valleys in the upper areas and large wide alluvial valleys in the lower extents. Compared to historical conditions, the stream channel lengths do not appear to be significantly reduced, but side channels would have historically been far more prevalent, particularly on the lower Satsop River; the rivers could have had 4 times or greater the area of frequently connected floodplain. Large wood has been removed from the channels throughout this region.

5.8.3 Current Conditions

Current conditions reflect ongoing forest management, agricultural land uses, and residential and commercial development. Land cover is 48% coniferous forest, 25% shrub, 8% grassland, 4% developed, 4% wetland, 4% bare ground, and small percentages of other cover[27] (Figure 5-16). Approximately one-third of this region is within the Olympic National Forest.

An assessment of riparian conditions and functions by NOAA (Beechie 2018) indicates that the majority of the riparian areas in the Olympic Mountains Ecological Region are either moderately impaired or impaired for wood recruitment, with only about 21% of reaches functional. These are substantially better conditions than most regions of the basin, but they are still impaired. Shading conditions are also only moderately changed from historical conditions, except in the lower reaches of both the Satsop and Wynoochee rivers.

Olympic Mountains Current Snapshot

Condition of Watershed Processes:
Hydrology – moderately impaired
Floodplain connectivity – impaired
Riparian condition – moderately impaired
Water quality – moderately impaired

Restoration Potential: High

Protection Potential: High

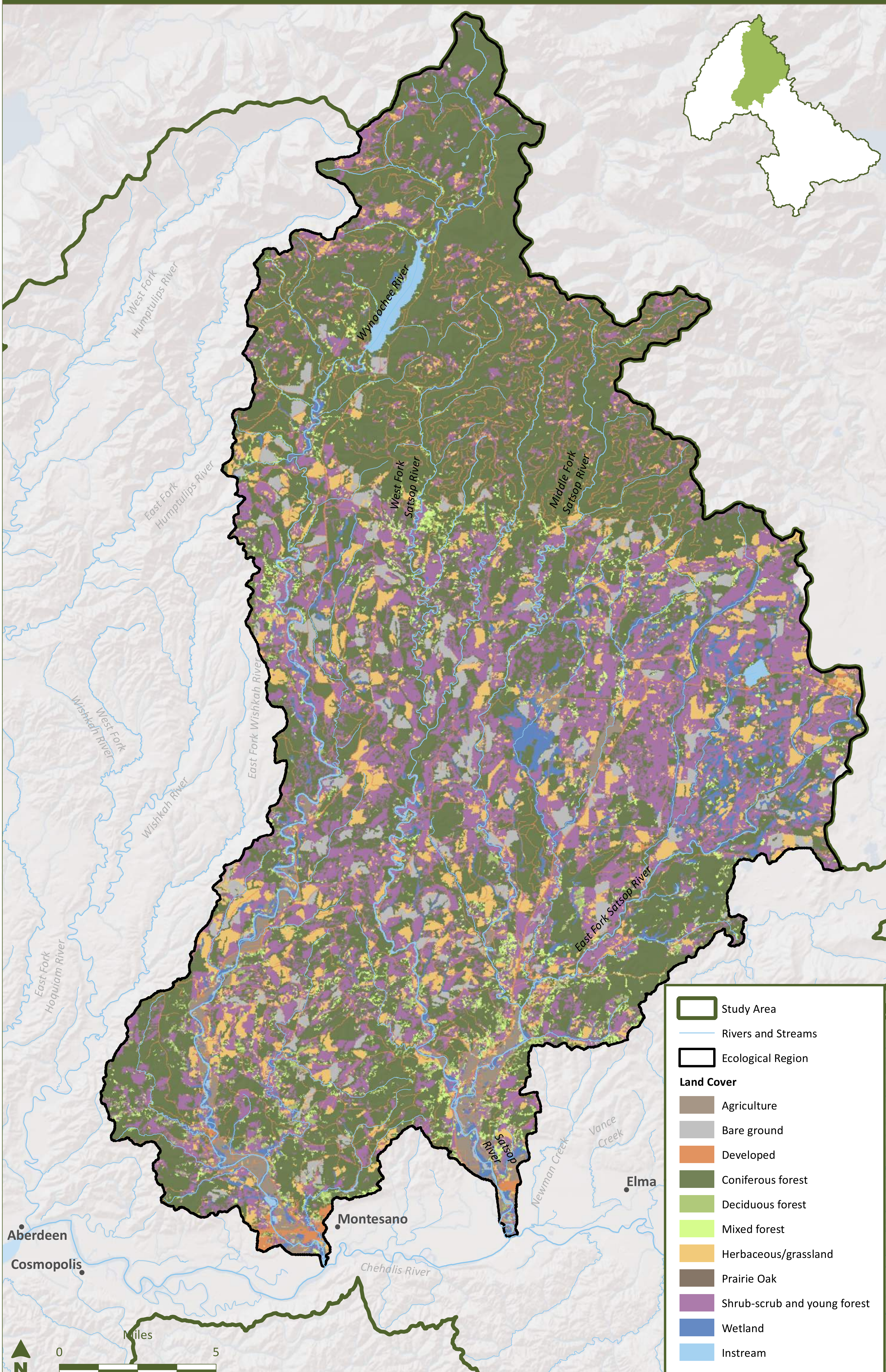
Geographic Spatial Units: East Fork Satsop River, Middle Fork Satsop River, West Fork Satsop River, Lower Satsop River, Lower Wynoochee River, and Middle Wynoochee River

Salmon Use and Potential: Fall-run Chinook salmon, chum salmon, coho salmon, and steelhead; spring-run Chinook salmon historically present

Non-Salmon Use and Potential: Western toad, coastal tailed frog, Van Dyke's salamander, northern red-legged frog, North American beaver, Olympic mudminnow, largescale sucker, mountain whitefish, Pacific lamprey, riffle and reticulate sculpin, speckled dace, common goldeneye, great blue heron, and wood duck

[27] Land cover data from Multi-Resolution Land Characteristics Consortium, National Land Cover Database 2011.

Figure 5-16
Olympic Mountains Ecological Region Land Cover



Water quality is impaired in multiple reaches of the Olympic Mountains Ecological Region, primarily for temperature, low dissolved oxygen, and bacteria (Ecology 2018). Recent temperature monitoring in the East Fork (RMs 10.8, 17.7, 22.5) and West Fork (RM 0 and 15) Satsop rivers by WDFW (2015 data) indicates that the East Fork Satsop River is substantially cooler than the West Fork Satsop River, although temperatures do occasionally exceed water quality standards (16°C [61°F] core summer salmonid habitat) in July and August (Ecology 2016). The West Fork Satsop River regularly exceeds water temperature standards and typically exceeds 20°C (68°F) in July and August.

WDFW's Thermalscape model indicates that from 2013 to 2018, many stream reaches of the Olympic Mountains Ecological Region (ranging from 25% [2018] to 46% [2014 to 2015] of reaches) had mean August temperatures equal to or exceeding 16°C (61°F) and are projected to increase to 59% and 77% of reaches in 2040 and 2080, respectively, without restoration actions (Winkowski and Zimmerman 2019).

The NOAA model that incorporates mature riparian conditions and anticipated climate change shows a likely future increase in summer water temperatures ranging from 1.5°C (2.7°F) to more than 2.5°C (4.5°F) by 2080 (Beechie 2018).

Existing mapping of wetlands (Ecology 2011b) shows large wetland areas, including the Decker Creek wetland complex, and significant areas of wetlands in the upper East Fork Satsop River area and along Bingham Creek. There are also several wetlands along both the lower Satsop and Wynoochee rivers and Sylvia and Black creeks (tributaries to the lower Wynoochee River).

These early action reaches on the Satsop and Wynoochee rivers have substantial channel migration and bank erosion occurring.

Historical and current areas of floodplain marsh and beaver pond habitats were documented by NOAA using GLO mapping (Beechie 2018). They found the Satsop River sub-basin has lost 20% of its historical marsh habitat and the Wynoochee River sub-basin has lost about 50%; however, the existing marshes have been modified. The Satsop River sub-basin has lost about 55% of its historical beaver pond habitat, and the Wynoochee River sub-basin has lost about 80%. Approximately 160 fish passage barriers were incorporated into the EDT model[28] for the Olympic Mountains Ecological Region, with a significant

[28] Fish passage barrier data from WDFW processed through EDT model.

number on tributaries to the Wynoochee River (Wynoochee Dam is the primary barrier on the mainstem rivers).

Several streams in this ecological region have highly porous glacial sediments and go dry or have very low flows in summer, including Dry Run, Dry Bed, and Decker creeks. This may mostly reflect natural conditions, but it creates a potential future risk for further dewatering from water withdrawals or loss of forest canopy and groundwater infiltration.

The percentage of fine sediment in streams was modeled by NOAA based on the density of roads and land uses; this modeling indicated about 16% fines in the Satsop River and 15 to 18% fines in the Wynoochee River, which is a substantial increase from modeled historical conditions (Beechie 2018) of 11% to 14% fines.

The salmonid species present in the Olympic Mountains Ecological Region include fall-run Chinook salmon, chum salmon, coho salmon, and steelhead. Spring-run Chinook salmon used and were historically present in the upper Wynoochee River but were nearly extirpated by the early 1970s from the river (WDF 1975). Non-salmon indicator species include Western toad, coastal tailed frog, Van Dyke's salamander, northern red-legged frog, North American beaver, Olympic mudminnow, largescale sucker, mountain whitefish, Pacific lamprey, riffle and reticulate sculpin, and speckled dace. The bird indicator species present include common goldeneye, great blue heron, and wood duck.

There are two hatchery facilities on the Satsop River; all programs are integrated broodstock, detailed as follows:

- The Satsop Spring facility is owned by WDFW but operated by the Chehalis Basin Task Force cooperative program. The annual production goals are 500,000 Chinook salmon, 450,000 normal-timed coho salmon, and 300,000 chum salmon released into the East Fork Satsop River. Chinook and coho salmon are all marked. The chum salmon are too small at release to clip the adipose fin, so they are unmarked. The Chinook and chum salmon programs are for supplementing the natural population and providing harvest opportunity, while coho salmon are for harvest.
- Bingham Creek Hatchery releases 150,000 each of normal and late-timed coho salmon and 55,000 winter-run steelhead into the East Fork Satsop River for harvest. All releases are marked. This hatchery also provides broodstock support for Satsop Springs when needed.

Lake Aberdeen Hatchery rears summer- and winter-run steelhead for release into the Wynoochee River to mitigate for lost harvest opportunity caused by Wynoochee Dam. Annual release goals are 60,000 summer and 170,000 winter-run steelhead that are all marked. The summer steelhead program is a segregated program, using hatchery-origin broodstock, while the winter-run steelhead program is integrated.

Additionally, there is one annual coho salmon fry release by Montesano Junior/Senior High School totaling about 275 fish. The size of these fish at release are less than 1 gram per fish. This program is too small to contribute to adult returns.

5.8.4 Limiting Factors

Limiting factors for salmonids have been identified in several assessments of the Chehalis Basin, including EDT (ICF 2019) and NOAA modeling (Beechie 2018) conducted for the ASRP and earlier studies (GHLE 2011; Smith and Wenger 2001). Additional limiting factors and a diagnosis of what is working and what is broken in the ecological region were determined by the SRT, drawing on local basin knowledge and reconnaissance conducted within the region.

The combined results of these assessments indicate that the major issues for salmonids in the region are as follows (in relative order of importance):

- High water temperatures (primarily lower rivers)
- Low habitat diversity (lack of side channels, large wood, floodplain connectivity, and beaver ponds)
- Reduced quantity and quality of instream habitats
- Channel lengths and widths
- Sediment load (fine sediments)
- Fish passage barriers
- Predation (non-native fish species)
- Channel instability (bed scour and sediment transport)
- Flow (primarily low flows)

Diagnostic Snapshot

- The ecological region is lacking wood nearly everywhere.
- Substantial channel length lacks stable gravel.
- Steep slopes are at risk of landslides.
- The East Fork Satsop River is highly productive and includes cold water and better conditions than other areas.
- These big rivers have very active channel migration that creates substantial risk for agriculture and residential land uses.
- Invasive plant species, including reed canarygrass, are present. The lower Satsop River, in particular, has extensive areas of knotweed.
- Wynoochee Dam affects gravel and wood loading downstream of the dam and inundated areas that may have been highly productive Chinook salmon spawning habitat. Chinook salmon are not transported above the dam.
- Lower watersheds include poor riparian conditions, excessive channel widths, and a lack of shade.
- Tributary channels are affected by incision.

These identified issues for salmonids are generally consistent with earlier findings from Smith and Wenger (2001) and the Chehalis Basin Lead Entity (GHLE 2011), which indicated that the key limiting factors in this ecological region include floodplain conditions, riparian conditions, water quality, sediment conditions, fish passage barriers, lack of large wood, channel stability, and water quantity. The ASRP assessment identified slightly different priorities focused on large wood, floodplain connectivity, beaver ponds, and riparian restoration.

Limiting factors and threats to non-salmon indicator species are not well understood but may include high water temperatures, migration barriers, changes in flow conditions and water level variations, fine sediments, riparian conditions, and non-native predator species (as identified for Pacific lamprey by Clemens et al. [2017]).

5.8.5 Strategies and Actions in the Ecological Region

5.8.5.1 Habitat and Process Protection

Many of the protection actions described in Section 4.2.1 are appropriate in the Olympic Mountains Ecological Region, particularly acquisitions and easements to protect high-quality riparian and floodplain wetland habitats. Based on existing conditions, the following areas and actions are recommended for a protection focus:

- Protect extensive wetland habitats and other aquifer recharge areas that support cold-water inputs in the upper East Fork and Middle Fork Satsop river sub-basins (including Dry Run and Dry Bed creeks).
- Protect estuary-adjacent areas at confluences with the Chehalis River to accommodate the processes by which sea level rise will cause estuary zones to shift upstream.
- Protect headwater lakes in the Wynoochee and West Fork Satsop river sub-basins for unique amphibian assemblages and species diversity.

The upper East Fork Satsop River includes headwater wetlands and cold water springs that are likely to be resilient to climate change effects on stream temperature, making this area a refuge and an important protection priority.

This seasonally dry channel, a tributary to the East Fork Satsop River, provides substantial chum and coho salmon habitat when wetted. Even ephemeral streams can add to the productivity of the system and should be protected.

The majority of the Olympic Mountains Ecological Region is within Grays Harbor County, which has regulations and policies in place to protect wetlands, floodplains, riparian areas, and fish and wildlife habitat conservation areas from degradation and development and manage invasive species. Grays Harbor County's draft SMP that is currently in final review with Ecology contains regulations to protect channel migration zones and riparian vegetation, along with general development regulations related to shoreline areas in the County (Grays Harbor County 2018).

The eastern portion of the ecological region is in Mason County, which has regulations and policies in place to restore shoreline ecological functions and floodplain connectivity, improve habitat for salmon populations, and protect wetlands and groundwater. They also have objectives to coordinate with nearby counties on conservation plans and programs to ensure that protection measures occur at the watershed scale.

As part of the community planning strategy (see Section 5.8.5.3), funding support to align the counties' regulations with the ASRP and conduct enforcement will be considered.

General protection priorities for Grays Harbor and Mason counties in the Olympic Mountains Ecological Region are as follows:

- Protect and increase forest cover.
- Protect wetlands from development and surface and groundwater withdrawals and minimize impervious surfaces.
- Protect spawning gravel sources and retain spawning gravels (protect/allow channel migration and improve wood recruitment).
- Protect key functioning floodplain and riparian areas from development and promote groundwater recharge.

5.8.5.2 Restoration

The restoration actions described in Section 4.2.2 are all appropriate in the Olympic Mountains Ecological Region. Based on existing conditions, the following areas and actions are recommended for a restoration focus:

- Restore riparian areas in the lower rivers to maintain cooler water temperatures and slow unnaturally high channel migration rates.
- Place extensive stable instream wood to improve channel stability, trap alluvium (finer gravel), increase variations in bed textures, increase the number of pools and cover, raise streambeds, and increase floodplain and wetland connectivity and promote groundwater recharge.
- Address fish passage barriers, particularly those associated with fish hatcheries and fish collection facilities.

A key Chinook salmon spawning reach is downstream of Wynoochee Dam in managed forest. No Chinook salmon are passed upstream of the dam, though areas upstream historically may have provided highly productive spawning habitat. The dam has effects on substrate and wood loading downstream (lack of gravels downstream of dam); this area could be restored and enhanced.

- Reconnect floodplains to restore and increase off-channel habitats that are particularly important for juvenile coho and Chinook salmon.
- Target estuary-adjacent areas at confluences with the Chehalis River for restoration to accommodate the processes by which sea level rise will cause estuary zones to shift upstream.
- Implement and monitor the early action restoration projects on the Wynoochee and East Fork Satsop rivers to evaluate the effectiveness of restoration techniques and identify opportunities for additional restoration projects.

Priority areas for restoration in the Olympic Mountains Ecological Region include the mainstem Satsop River and all forks; key tributaries such as Decker, Bingham, and Dry Run creeks; the lower and middle Wynoochee River; and Canyon River.

5.8.5.3 Community Planning

As noted in Section 4.2.3, community planning actions would be coordinated with state and local governments, landowners, and other stakeholders to ensure the long-term success of the ASRP. Focus programs and policies that could be developed or investigated in the Olympic Mountains Ecological Region include the following:

- WDFW could investigate the potential effects of hatchery fish on wild fish.
- Explore opportunities for Wynoochee Dam operational modifications that mimic natural flow patterns to benefit fish spawning and rearing in downstream reaches and improve fish transport and passage above the fish collection weir and dam.
- Discuss with Grays Harbor and Mason counties additional planning measures that could promote and protect the following:
  - Surface and groundwater supplies through reduction of withdrawals
  - Minimization of impervious surfaces
  - Riparian maturation and wood recruitment for retention of spawning gravel and sources
  - Natural channel migration
- As the Chehalis Basin Strategy becomes more integrated, coordinate the ASRP with the CFAR Program to build habitat restoration and protection actions into community flood risk reduction efforts (such as restoring areas where structures and people have been relocated from floodplains).

5.8.5.4 Community Involvement

As noted in Section 4.2.4, community involvement and voluntary landowner participation are essential to the success of the ASRP, and the actions described in that section will be further evaluated for the Olympic Mountains Ecological Region in Phases 2 and 3 based on the restoration and protection scenario selected. Based on the specific issues in this area, the following actions are recommended for focused community involvement:

- Seize on educational opportunities at the numerous public access recreation and fishing sites. Signage and/or community events at the access sites would present opportunities for communication and education regarding river restoration activities and connections to the fisheries that are supported by these activities.
- Continue outreach, engagement, and involvement processes to incorporate landowner expertise into ASRP planning and local implementation efforts, particularly timber landowners.
- Partner with and support the efforts of existing local organizations (see Appendix E for a list of potential partner organizations).

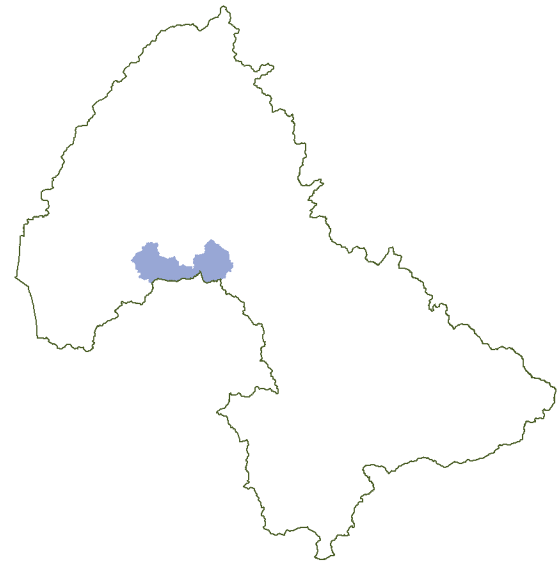
5.8.5.5 Institutional Capacity

The institutional capacity strategy is intended to build on and support the work of existing organizations, as well as support creativity in how local organizations approach working toward the goals of the ASRP. The actions described in Section 4.2.5 will be further evaluated for the Olympic Mountains Ecological Region in Phases 2 and 3 based on the restoration and protection scenario selected. Based on the specific issues in this area, the following focused institutional capacity actions are recommended:

- Provide technical training on process-based restoration practices and principles.
- Provide funding for groups and individuals interested in restoration projects.
- Build on and support the work of existing organizations with missions that overlap with the ASRP vision (see Appendix E for a list of potential groups).

5.9 Chehalis River Tidal Ecological Region

5.9.1 Overview



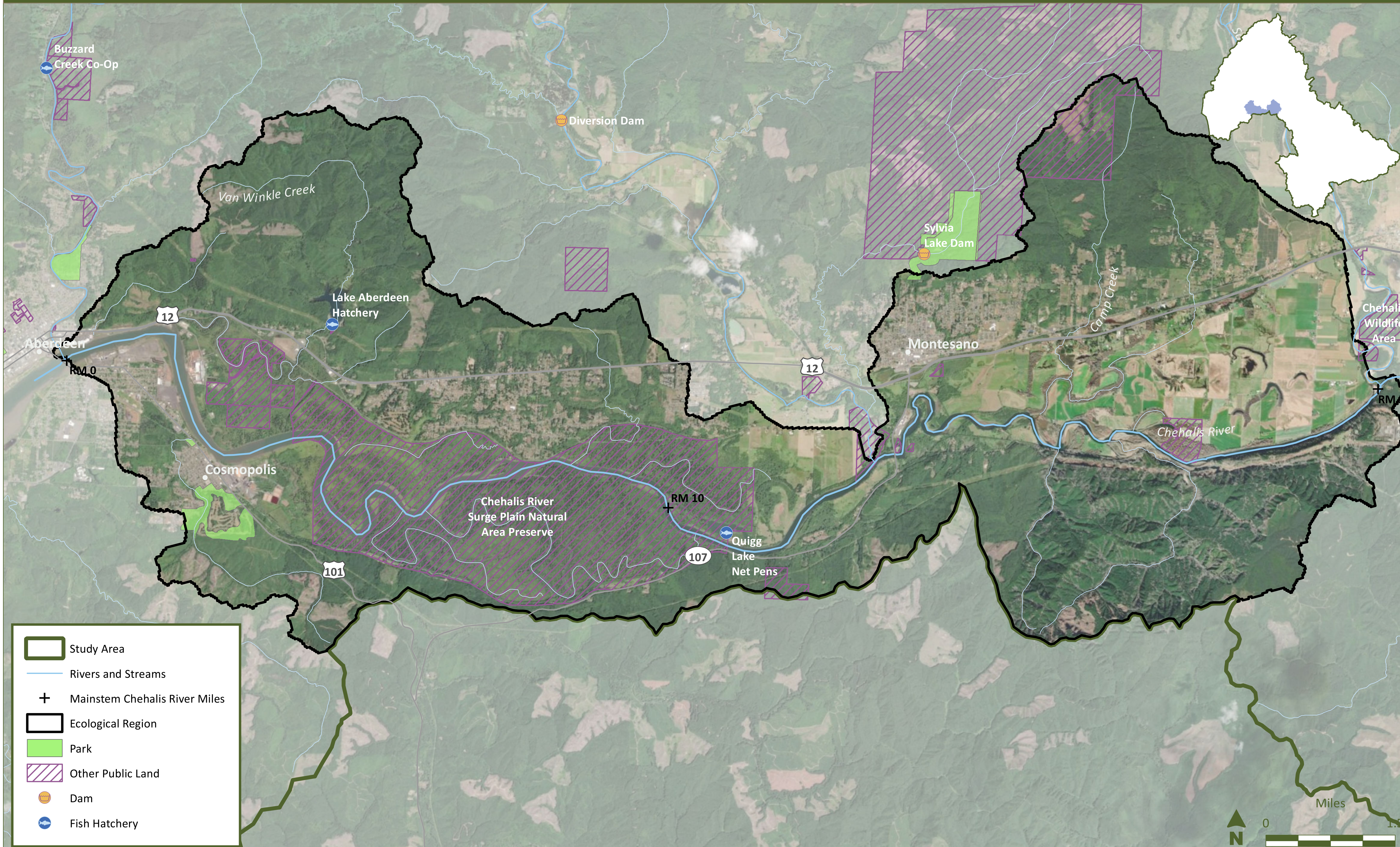
The Chehalis River Tidal Ecological Region encompasses the tidally influenced portion of the mainstem Chehalis River and its floodplain from approximately RM 0 to RM 20 (Satsop River confluence; Figure 5-17). It does not include Grays Harbor itself. This ecological region encompasses 59 square miles (greater than 37,000 acres) and represents approximately 2% of the overall Chehalis Basin. The entire Chehalis River Tidal Ecological Region is a low-elevation alluvial valley ranging from about 60 feet in elevation near Elma to about 20 feet in elevation in Aberdeen. The lower 3 miles of the river include a dredged navigation channel. A few small tributaries that enter the Chehalis River are included in the Chehalis River Tidal Ecological Region, including Van Winkle and Camp creeks. There is a very low drainage divide between the Chehalis River and the North River that drains to Willapa Bay. The floodplain geology is predominantly recent alluvium. Precipitation in the Chehalis River Tidal Ecological Region ranges from 75 to 100 inches (PRISM 2012).

Important Features and Functions

- All Chehalis Basin salmonids use or pass through this ecological region, making its function essential to their viability.
- The WDNR Surge Plain Natural Area Preserve provides protection for 5,500 acres of largely unaltered surge plain that includes expansive sloughs, mudflat, marsh, scrub-shrub, and forested wetlands. WDNR is working to acquire the remaining privately owned parcels surrounded by the preserve.

The Chehalis River Tidal Ecological Region is entirely within Grays Harbor County. The towns of Montesano and Cosmopolis are within this ecological region.

Figure 5-17
Chehalis River Tidal Ecological Region Map



Aerial Photo Source: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

5.9.2 Historical Conditions and Changes

Historical records for the pre-Euro-American settlement conditions are not available, but GLO maps from the 1860s indicate that the Chehalis River Tidal Ecological Region below the Satsop River was sinuous, with a number of sloughs and oxbows as well as prairies, brush, and wetlands. The Chehalis River below the Wynoochee River is not substantially changed in form from historical conditions, with many of the same sloughs present and slightly more sinuosity than shown in historical maps.

Key changes that occurred in the Chehalis River Tidal Ecological Region following Euro-American settlement were timber harvest and industrial, commercial, and residential development around Aberdeen and Grays Harbor and the major transportation corridors (including SR 12, SR 107, and railroad lines). Agricultural development as well as road, bridge, and industrial development likely also moved and straightened some areas of the Chehalis River. Much of the agricultural development occurred prior to 1938.

A recent study of floodplain land cover changes indicates that agricultural development continued very slowly from 1938 through the mid-1970s at a rate of approximately 6.6 acres per year converted to agriculture in the reach from the Satsop River to the Wynoochee River but less than 1 acre per year below the Wynoochee River (Pierce et al. 2017). Since the 1970s, there has been a decline in agricultural acreage (a loss of 8.8 acres per year) in the reach between the Satsop River and Wynoochee River and a loss of less than 1 acre per year below the Wynoochee River. Pierce et al. (2017) found there were larger declines in forest canopy from 1938 through the mid-1970s (approximate losses of 10 acres per year and 17 acres per year in the upper and lower reaches, respectively) and then an increase of about 5 acres per year in both reaches from the 1970s to 2013. However, overall there was a net loss of forest canopy over the entire time period (approximate losses of 2 acres per year and 6 acres per year in the two reaches, respectively).

The inner harbor of the estuary at the mouth of the Chehalis River near the cities of Aberdeen and Hoquiam was an area that was heavily altered when it was industrialized by pulp mills, sewage treatment plants, and other large facilities requiring access to the shoreline. A study of coho salmon smolt survival from the Chehalis River from 1987 to 1990 showed much lower survival compared to the Humptulips River; this lower survival rate was potentially related to industrial discharges in the lower river and a parasite (Schroder and Fresh 1992).

5.9.3 Current Conditions

Current conditions in the Chehalis River Tidal Ecological Region reflect ongoing agricultural land uses and residential and commercial development. Land cover is 23% coniferous forest, 21% wetland, 17% developed, 12% scrub-shrub, 10% agriculture, 4% herbaceous, 4% deciduous forest, 4% mixed forest, and small percentages of other cover[29] (Figure 5-18).

An assessment of riparian conditions and functions by NOAA (Beechie 2018) only included the portion of this region between the Satsop and Wynoochee rivers; however, the analysis indicated that the riparian zone is impaired for wood recruitment and provides moderate levels of shading.

Chehalis River Tidal Current Snapshot

Condition of Watershed Processes:
Hydrology – moderately impaired
Floodplain connectivity – impaired
Riparian condition – moderately impaired
Water quality – impaired

Restoration Potential: Moderate

Protection Potential: Moderate

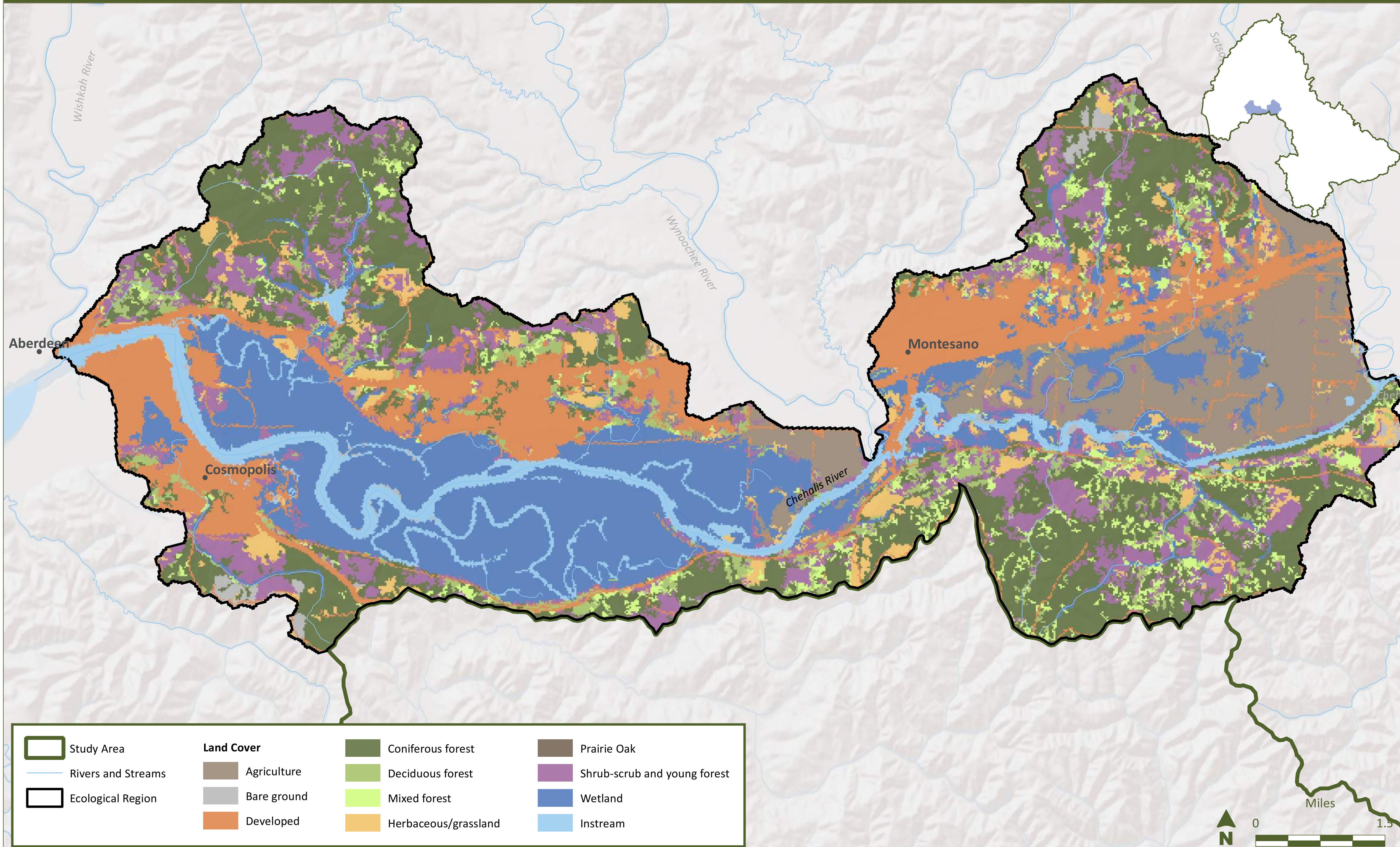
Geographic Spatial Units: Chehalis River from Wynoochee River to Mouth of the Chehalis River and Chehalis River from Satsop River to Wynoochee River

Salmon Use and Potential: Fall-run Chinook salmon, spring-run Chinook salmon, coho salmon, chum salmon, and steelhead

Non-Salmon Use and Potential: Northern red-legged frog, North American beaver, Olympic mudminnow, Pacific eulachon, largescale sucker, mountain whitefish, Pacific lamprey, riffle and reticulate sculpin, speckled dace, great blue heron, common goldeneye, and wood duck

[29] Land cover data from Multi-Resolution Land Characteristics Consortium, National Land Cover Database 2011.

Figure 5-18
Chehalis River Tidal Ecological Region Land Cover



Water quality is impaired in multiple reaches in the Chehalis River Tidal Ecological Region for numerous pesticides and toxic pollutants as well as temperature, low dissolved oxygen, and bacteria (Ecology 2018). Recent temperature monitoring by WDFW at RM 11 indicates that temperatures regularly exceed the 16°C (61°F) core summer salmonid habitat criterion from May through September and typically exceed the 13°C (55°F) supplemental spawning incubation criterion (September 15 to July 1) in September and May to July (Ecology 2016, 2011a).

WDFW's Thermalscape model indicates that from 2013 to 2018, many stream reaches of the Chehalis River Tidal Ecological Region (ranging from 30% [2018] to 89% [2015] of reaches) had mean August temperatures equal to or exceeding 16°C (61°F) and are projected to increase to 99% and 100% of reaches in 2040 and 2080, respectively, without restoration actions (Winkowski and Zimmerman 2019).

The NOAA model that incorporates mature riparian conditions and anticipated climate change shows a likely future increase in summer water temperatures ranging from 0.5°C (0.9°F) to 1.5°C (2.7°F) by 2080 in the Chehalis River Tidal Ecological Region (Beechie 2018).

Existing mapping of wetlands (Ecology 2011b) shows the majority of the floodplain is a mosaic of wetlands downstream of the Wynoochee River, as well as several large wetland areas between the Satsop and Wynoochee rivers. WDNR has preserved the Chehalis River Surge Plain Natural Area Preserve, which encompasses approximately 5,500 acres and includes a diverse complex of emergent, shrub, and forested wetlands; main river channel areas; and numerous sloughs. There are also a few private landholdings surrounded by the Chehalis River Surge Plain Natural Area Preserve (WDNR 2018).


Blue Slough is part of the Chehalis River Surge Plain Natural Area Preserve. It is not known to what extent historical piles affect habitat and natural processes.

The percentage of fine sediment in streams was modeled by NOAA based on the density of roads and land uses; this modeling indicated 17 to 18% fines in the Chehalis River below the Skookumchuck River to the estuary, which is a substantial increase from modeled historical conditions of 13% to 14% fines (Beechie 2018).

The salmonid species present in the Chehalis River Tidal Ecological Region include all species that migrate into the basin, including spring-run Chinook salmon, fall-run Chinook salmon, chum salmon, coho salmon, and steelhead. Non-salmonid indicator species include northern red-legged frog, Pacific eulachon, Olympic mudminnow, largescale sucker, mountain whitefish, Pacific lamprey, riffle and reticulate sculpin, and speckled dace, as well as North American beaver. The bird indicator species present include great blue heron, Barrow's goldeneye, common goldeneye, and wood duck. Floodplain habitats along the Chehalis River are of particular importance to northern red-legged frog as well as both native and non-native fish species.

There is a net pen located in Quigg Lake that raises 25,000 coho salmon annually from Lake Aberdeen Hatchery. Lake Aberdeen Hatchery has a production goal of 50,000 Chinook salmon and 30,000 coho salmon. All of these fish are integrated (i.e., wild-origin fish are integrated into the hatchery broodstock [adult fish used for production] for the production of hatchery fish) and for harvest opportunity. They are also released from the hatchery into Van Winkle Creek.

5.9.4 Limiting Factors

Limiting factors for salmonids have been identified in several assessments of the Chehalis Basin, including EDT (ICF 2019) and NOAA modeling (Beechie 2018) conducted for the ASRP and earlier studies (GHLE 2011; Smith and Wenger 2001). Additional limiting factors and a diagnosis of what is working and what is broken in the ecological region were determined by the SRT, drawing on local basin knowledge and reconnaissance conducted within the region.

The combined results of these assessments indicate that the tidal zone is a significant area affecting abundance of all salmonids throughout the basin. Major issues for salmonids in the region are as follows (in relative order of importance):

- Low habitat diversity (lack of side channels, large wood, floodplain connectivity, and beaver ponds)
- Flows
- Reduced quantity and quality of instream habitats
- Channel instability (bed scour and sediment transport)
- Channel width
- Predation (non-native fish species)
- Sediment load (fine sediments)
- High water temperatures
- Pathogens
- Fish passage barriers

Diagnostic Snapshot

- The ecological region is lacking wood.
- Invasive plant species, including reed canarygrass and purple loosestrife, are present. The New Zealand mud snail is present in the tidal surge plain.
- The lower 3 miles of the Chehalis River channel are dredged and largely industrial. Current pollution effects on aquatic species are not understood.
- The surge plain appears to be largely unaltered, including both the channel and floodplain upstream to the Wynoochee River.
- Above the Wynoochee River, floodplain alterations and land uses have reduced in-channel and floodplain habitats.
- Very little is known about aquatic species use in this ecological region other than known extensive use by waterfowl.

Preachers Slough is a lengthy slough providing diverse tidal slough and swamp habitat. Recent removal of barriers has reconnected more of this habitat.

These identified issues for salmonids are generally consistent with earlier findings from Smith and Wenger (2001) and the Chehalis Basin Lead Entity (GHLE 2011), which indicated that the key limiting factors in this ecological region include riparian conditions, floodplain conditions, lack of large wood, water quality, fish passage barriers, water quantity, and sediment conditions.

Limiting factors and threats to non-salmon indicator species are not well understood but may include high water temperatures, migration barriers, changes in flow conditions and water level variations, fine sediments, riparian conditions, and non-native predator species (as identified for Pacific lamprey by Clemens et al. [2017]).

5.9.5 Strategies and Actions in the Ecological Region

5.9.5.1 Habitat and Process Protection

Many of the protection actions described in Section 4.2.1 are appropriate in the Chehalis River Tidal Ecological Region. Based on existing conditions, the following areas and actions are recommended for a protection focus:

- Protect additional high-quality habitats adjacent to existing surge plain protected area.
- Protect estuary-adjacent areas to accommodate the processes by which sea level rise will cause estuary zones to shift upstream.

The Chehalis River Tidal Ecological Region is entirely within Grays Harbor County, which has regulations and policies in place to protect wetlands, floodplains, riparian areas, and fish and wildlife habitat conservation areas from degradation and development and manage invasive species. Grays Harbor County's draft SMP that is currently in final review with Ecology contains regulations to protect channel migration zones and riparian vegetation, along with general development regulations related to shoreline areas in the County (Grays Harbor County 2018).

In a portion of the surge plain habitat that is protected by WDNR, a barrier was replaced with a bridge to reconnect tidal channels. Additional similar restoration opportunities should be identified, and additional surge plain protection could be provided through the acquisition of remaining private lands.

As part of the community planning strategy (see Section 5.9.5.3), funding support to align the County regulations with the ASRP and conduct enforcement will be considered.

Protection priorities for Grays Harbor County within this ecological region include the following:

- Purchase surge plain properties not already protected.
- Protect floodplains from development.
- Manage invasive species.

5.9.5.2 Restoration

The restoration actions described in Section 4.2.2 are mostly appropriate in the Chehalis River Tidal Ecological Region. Based on existing conditions, the following areas and actions are recommended for a restoration focus:

- Restore riparian areas and control/manage invasive species such as reed canarygrass and purple loosestrife.
- Strategically place large wood to mimic natural tidal accumulations and form forested islands and cover.
- Evaluate effects of non-native predator species on native fish in the tidal zone.
- Reconnect floodplain and off-channel habitats, including gravel-mined pond restoration.
- Target estuary-adjacent areas for restoration to accommodate the processes by which sea level rise will cause estuary zones to shift upstream.
- Conduct barrier removals to restore tidal channel connectivity to primary sloughs and key tributaries, including tide gates.
- Opportunistically restore industrial portions of the estuary (e.g., through bank armoring removal or invasive species management).

Gravel ponds are prevalent in disturbed areas of the Chehalis River Tidal Ecological Region floodplain, which could be reconnected or restored.

Low-gradient freshwater tidal habitat could be enhanced by reconnecting forested and shrub-dominated sloughs and wetlands, such as through removal of tide gates and crossings.

Priority areas for restoration within the Chehalis River Tidal Ecological Region include the floodplain and major sloughs along the mainstem and key tributaries such as Van Winkle and Camp creeks.

5.9.5.3 Community Planning

As noted in Section 4.2.3, community planning actions would be coordinated with state and local governments, landowners, and other stakeholders to ensure the long-term success of the ASRP. Focus programs and policies that could be developed or investigated in the Chehalis River Tidal Ecological Region include the following:

- Discuss with Grays Harbor County additional planning measures that could effectively promote and protect the following:
  - Surface and groundwater supplies through reduction of withdrawals
  - Minimization of impervious surfaces
  - Riparian forest maturation and wood recruitment for retention of spawning gravel and sources
  - Natural channel migration
- As the Chehalis Basin Strategy becomes more integrated, coordinate the ASRP with the CFAR Program to build habitat restoration and protection actions into community flood risk reduction efforts (such as restoring areas where structures and people have been relocated from floodplains).

5.9.5.4 Community Involvement

As noted in Section 4.2.4, community involvement and voluntary landowner participation are essential to the success of the ASRP, and the actions described in that section will be further evaluated for the Chehalis River Tidal Ecological Region in Phases 2 and 3 based on the restoration and protection scenario selected. Based on the specific issues in this area, the following actions are recommended for focused community involvement:

- Seize on educational opportunities at the numerous public access recreation and fishing sites. Signage and/or community events at the access sites would present opportunities for communication and education regarding upriver restoration activities and connections to the fisheries that are supported by these activities.
- Develop partnering opportunities with Grays Harbor College to understand fish use patterns and natural processes within the tidally influenced area.
- Continue outreach, engagement, and involvement processes to incorporate landowner expertise into ASRP planning and local implementation efforts.
- Partner with and support the efforts of existing local organizations (see Appendix E for a list of potential partner organizations).

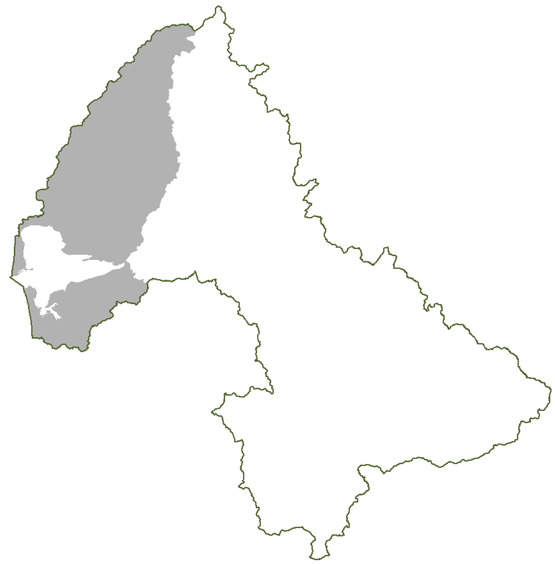
5.9.5.5 Institutional Capacity

The institutional capacity strategy is intended to build on and support the work of existing organizations, as well as support creativity in how local organizations approach working toward the goals of the ASRP. The actions described in Section 4.2.5 will be further evaluated for the Chehalis River Tidal Ecological Region in Phases 2 and 3 based on the restoration and protection scenario selected. Based on the specific issues in this area, the following focused institutional capacity actions are recommended:

- Work with local jurisdictions to identify any remaining water and sediment quality problems from industrial pollution that are affecting aquatic species.
- Provide technical training on process-based restoration practices and principles.
- Provide funding for groups and individuals interested in restoration projects.
- Build on and support the work of existing organizations with missions that overlap with the ASRP vision (see Appendix E for a list of potential groups).

5.10 Grays Harbor Tributaries Ecological Region

5.10.1 Overview



The Grays Harbor Tributaries Ecological Region encompasses the tributaries that directly enter Grays Harbor (other than the Chehalis River) and the Wishkah River that enters the Chehalis River at RM 0 (Figure 5-19). This ecological region encompasses more than 600 square miles (nearly 385,000 acres) and represents approximately 22% of the overall Chehalis Basin. The ecological region is diverse, with drainages from the Olympic Mountains and lower Coast Range areas. The highest point in this ecological region is Gibson Peak at 4,390 feet. The Humptulips River arises in two forks within the Olympic National Forest at about 3,000 feet in elevation and flows for 60 miles to Grays Harbor. The Hoquiam River arises in the low foothills of the Olympic Mountains in three forks at about 400 feet in elevation; the East Fork Hoquiam River is the longest and flows for 17 miles. A significant part of the Middle Fork and West Fork Hoquiam rivers are within the City of Hoquiam municipal watershed. The Wishkah River arises in the foothills of the Olympic Mountains at about 1,200 feet in elevation; the upper watershed of the Wishkah River is within the City of Aberdeen's municipal watershed, and a dam is located at RM 32.5 for water supply. In the South Bay, several tributaries arise in the low coastal foothills, the largest of which are the Elk and Johns rivers, which arise at about 500 feet in elevation and have a large percentage of the system within the tidally influenced range. All of the Grays Harbor tributaries are tidally influenced in their lower miles.

The Grays Harbor Tributaries Ecological Region geology is predominantly composed of volcanic and sedimentary rocks of the Olympic Mountains and Coast Range and recent alluvium in the larger valleys

Important Features and Functions

- The amount of tidally influenced freshwater wetland with Sitka spruce swamp in the ecological region is unique in the basin and much different from the deciduous-dominated forest in the Chehalis River Tidal Ecological Region.
- The maritime climate provides a year-round buffer to air (and water) temperatures.
- The Humptulips River sub-basin characteristics are important and unique: these feature a smaller percentage of the total length in tidewater, substantial spawning gravel, and close proximity to the ocean. Old-growth forest in the upper Humptulips River sub-basin has no duplicate in the Chehalis Basin except in small portions of the upper Wynoochee and Satsop rivers.
- This ecological region is characterized by several species that are either not seen or rarely seen elsewhere in the basin, including bull trout and eulachon, both of which are federally listed as threatened under the ESA.
- There are significant hatchery influences on wild fish that may include competition, genetics, predation, disease, and fish passage.

(continues on next page)

and lowlands. Part of the Humptulips River watershed is dominated by glacial deposits from the alpine glaciation in the Olympic Mountains (WDNR 2010).

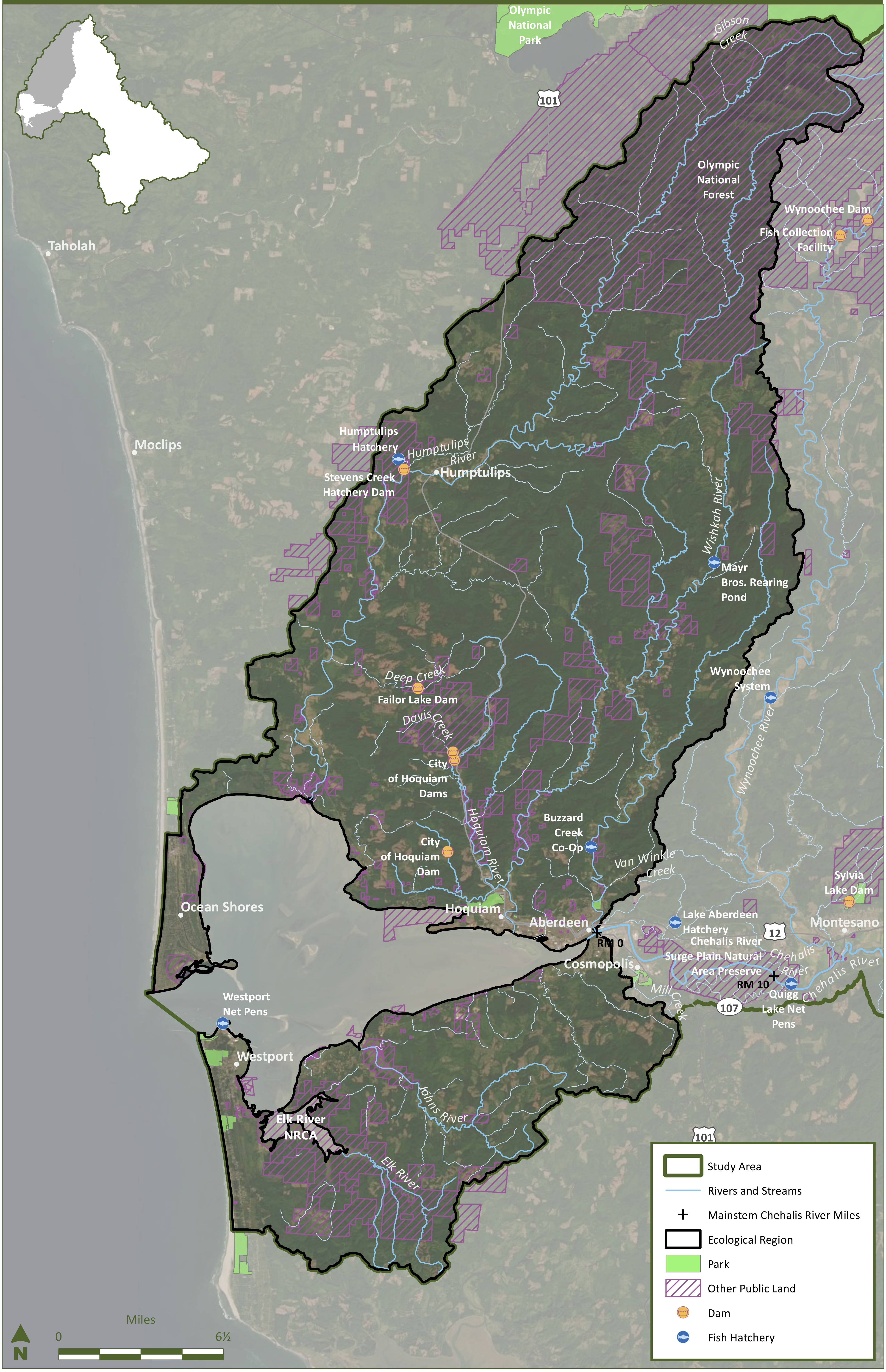
Precipitation is dominated by rainfall; however, average annual precipitation varies from 75 to 100 inches in Aberdeen and around the lowlands to 100 to 200 inches in the upper half of the Humptulips and Wishkah drainages (PRISM 2012).

The Grays Harbor Tributaries Ecological Region is almost entirely within Grays Harbor County (380,063 acres, or 99%), with a very small portion within Pacific County (4,638 acres, or 1%). Cities and towns in this region include Humptulips, Ocean Shores, Westport, Hoquiam, and Aberdeen.

Important Features and Functions (Continued)

- Stillwater-breeding amphibian habitats seem limited at all elevations. This ecological region has the largest distribution of Cascade frog. Some of the best stream-breeding and stream-associated amphibian habitats also occur in the headwaters of the Humptulips River.
- Forested tidal slough areas of this ecological region are important habitat for the bird indicator species—great blue heron, barrow's goldeneye, and wood duck.

Figure 5-19
Grays Harbor Tributaries Ecological Region Map



Aerial Photo Source: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

5.10.2 Historical Conditions and Changes

Historical records for the pre-Euro-American settlement conditions are not available, but available GLO maps indicate that the Grays Harbor Tributaries Ecological Region was dominated by sinuous rivers with wetlands along the lower Humptulips River and note a significant channel change along the Wishkah River in 1871.

Key changes that occurred in the Grays Harbor Tributaries Ecological Region following Euro-American settlement were timber harvest and industrial and urban development surrounding Grays Harbor (Aberdeen and Hoquiam) and the major transportation corridors (including Highway 101, railroad lines, SR 12, and SR 105). Similar to other parts of the basin, splash dams were used (see the description in Section 2.1). Several splash dams were known to have been used on both the East and West Fork Humptulips rivers and major tributaries such as Big Creek, and numerous splash dams were used on all forks of the Wishkah and Hoquiam rivers (Humptulips Historical Society 2018; WDF 1975; Wendler and Deschamps 1955). Numerous splash dams were also used on Newskah Creek. Road-, railroad-, bridge-, and timber-associated construction likely also moved and straightened some of the tributaries.

The Washington Department of Fisheries (1975) noted that gravel mining occurred regularly in and adjacent to the Humptulips River and there were low flows in several tributaries. A natural falls at about RM 18 on the East Fork Humptulips River had a fish ladder installed. Municipal water dams and diversion on the Hoquiam River and its tributaries have hindered fish passage and reduced flows. The water supply dam and reservoir at RM 32 on the Wishkah River was not installed with fish passage, although it is upstream of a natural falls. It appears that the dam blocks access for steelhead to upstream areas.

Natural and stable large wood is only present in a few protected locations in the upper West Fork Humptulips River. In the majority of the Grays Harbor Tributaries Ecological Region, the old-growth forest was logged, and splash dams were used extensively on the East and West Fork Humptulips rivers, the Wishkah Ricer, and Newskah Creek to facilitate moving timber to markets.

Modeling conducted by NOAA (Beechie 2018) for the ASRP indicated moderate losses (about 20%) in marsh habitats in the Humptulips and Hoquiam river floodplains and disturbance to many of the remaining marshes.

To support the ASRP analysis and EDT modeling, the SRT developed assumptions of the channel lengths and areas of floodplain habitat that were likely to be present in historical conditions. These assumptions were based on the GLO mapping from the late 1800s, more recent historical aerial photographs, and interpretation of current LiDAR data that show remnant channels and other floodplain features. The rivers in the Grays Harbor Tributaries Ecological Region are unconfined to partly confined and low gradient within narrow valleys in the upper areas and large, wide alluvial valleys in the lower extents.

Compared to historical conditions, the stream channel lengths do not appear to be significantly reduced, but side channels would have historically been far more prevalent, and the rivers could have had 3 to 8 times the area of frequently connected floodplain. Large wood has been removed from the channels throughout this region.

5.10.3 Current Conditions

Current conditions in the Grays Harbor Tributaries Ecological Region reflect ongoing agricultural land uses and residential and commercial development. Land cover is 53% coniferous forest, 19% scrub-shrub, 7% herbaceous, 7% developed, 6% wetland, and small percentages of other cover[30] (Figure 5-20).

An assessment of riparian conditions and functions by NOAA (Beechie 2018) indicates that the riparian areas in the Grays Harbor Tributaries Ecological Region are moderately impaired for wood recruitment, ranging from 13% to 34% functional (except in South Bay tributaries that are less than 5% functional), which is a much better condition than most other ecological regions within the basin. The assessment indicated the riparian areas are also relatively functional for shading.

Grays Harbor Tributaries Current Snapshot

Condition of Watershed Processes:
Hydrology – impaired
Floodplain connectivity – moderately impaired
Riparian condition – moderately impaired
Water quality – impaired

Restoration Potential: High

Protection Potential: Moderate

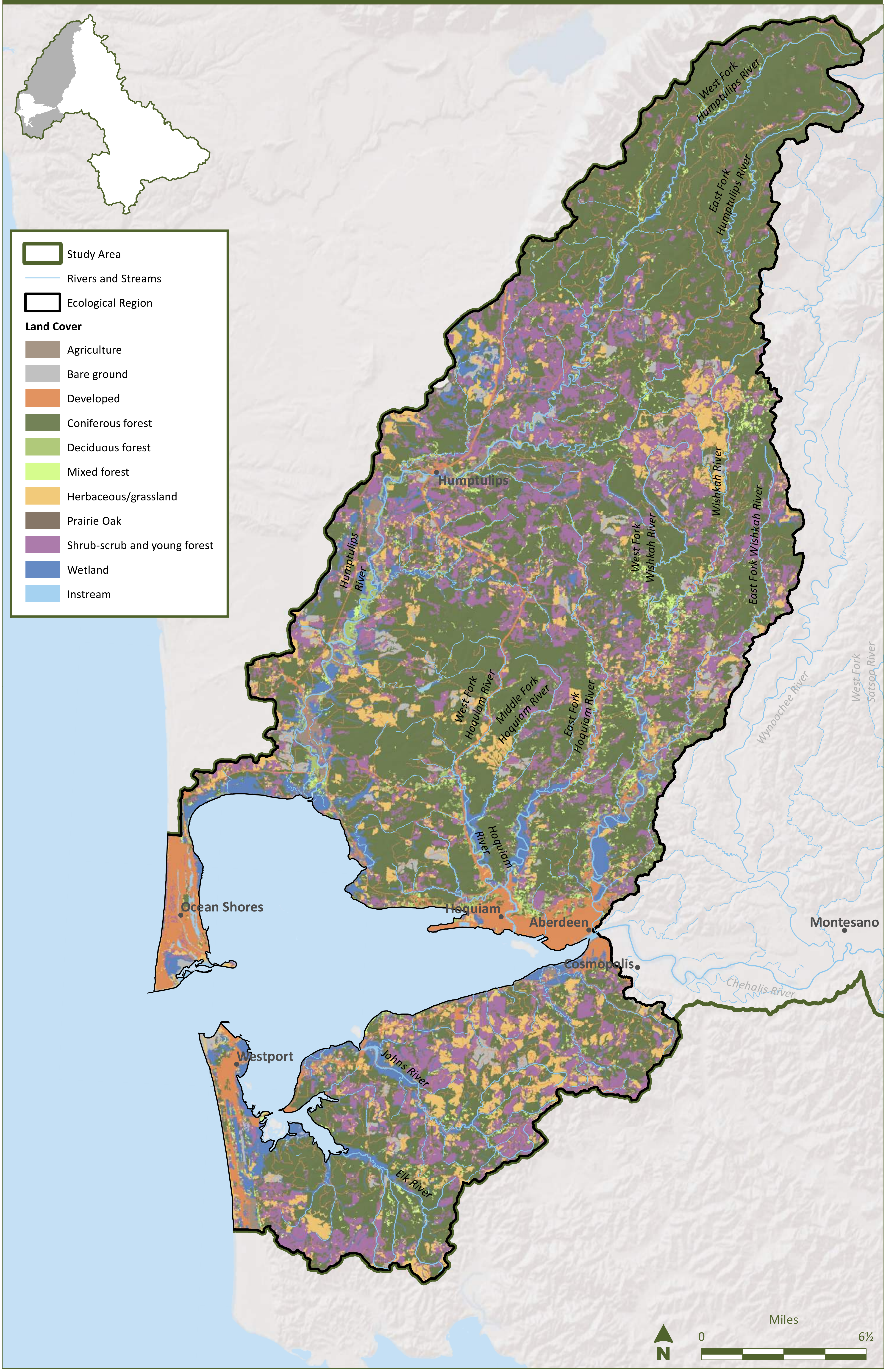
Geographic Spatial Units: East Fork Hoquiam River, Middle Fork Hoquiam River, West Fork Hoquiam River, Lower Humptulips River, Middle Humptulips River, East Fork Humptulips River, West Fork Humptulips River, Wishkah River, East Fork Wishkah River, West Fork Wishkah River, Elk River, and Johns River

Salmon Use and Potential: Fall-run Chinook salmon, coho salmon, chum salmon, and steelhead

Non-Salmon Use and Potential: Western toad, coastal tailed frog, Van Dyke's salamander, Northern red-legged frog, North American beaver, Olympic mudminnow, largescale sucker, mountain whitefish, Pacific lamprey, riffle and reticulate sculpin, speckled dace, great blue heron, Barrow's goldeneye, common goldeneye, and wood duck

[30] Land cover data from Multi-Resolution Land Characteristics Consortium, National Land Cover Database 2011.

Figure 5-20
Grays Harbor Tributaries Ecological Region Land Cover



Water quality is impaired in multiple reaches in the Grays Harbor Tributaries Ecological Region, primarily for temperature, low dissolved oxygen, and bacteria (Ecology 2018).

WDFW's Thermalscape model indicates that from 2013 to 2018, many stream reaches of the Grays Harbor Tributaries Ecological Region (ranging from 6% [2018] to 43% [2015] of reaches) had mean August temperatures equal to or exceeding 16°C (61°F) and are projected to increase to 78% and 95% of reaches in 2040 and 2080, respectively, without restoration actions (Winkowski and Zimmerman 2019).

The NOAA model that incorporates mature riparian conditions and anticipated climate change shows a likely future increase in summer water temperatures ranging from 1.5°C (2.7°F) to 2.5°C (4.5°F) in this region by 2080, with some reaches greater than 2.5°C (4.5°F), particularly in the Hoquiam and Wishkah rivers (Beechie 2018).

The tributaries to Grays Harbor are generally quite sinuous through low-gradient valleys. Existing mapping of wetlands (Ecology 2011b) shows relatively large wetland areas in the following locations:

- Lower Wishkah River floodplain
- East and West Fork Hoquiam rivers
- Chenois Creek, Grass Creek, and Grays Harbor shoreline
- Several locations along the lower and middle Humptulips River
- Johns River
- Elk River
- Lower Charley and Newskah creeks

This pond on a tributary to the Humptulips River is an example of high-quality ponded habitat for multiple species, including coho salmon and amphibian and bird indicator species.

Extensive tidal surge plain and swamp habitat is present along the lower Hoquiam River.

Extensive gravel is present on the Humptulips River, but substrate stability is an issue because the system is lacking in-channel wood to hold gravels in place.

In addition, there are protected areas and mitigation banks including the Elk River Natural Resources Conservation Area, the North Bay Natural Area Preserve, and the Weatherwax Wetland and Habitat Mitigation Bank.

Approximately 190 fish passage barriers were incorporated into the EDT model[31] for the Grays Harbor Tributaries Ecological Region.

The percentage of fine sediment in streams was modeled by NOAA based on the density of roads and land uses; this modeling indicated 16% to more than 20% fines in the Wishkah River, 15% to 18% fines in the Hoquiam and Humptulips rivers, and 18% to 23% fines in the South Bay streams, which is a substantial increase from modeled historical conditions that were generally 12% to 15% fines, although the South Bay streams had higher quantities of fines (Beechie 2018).

The salmonid species present in the Grays Harbor Tributaries Ecological Region include fall-run Chinook salmon, chum salmon, coho salmon, and steelhead. Non-salmon indicator species include Western toad, coastal tailed frog, Van Dyke's salamander, Northern red-legged frog, Olympic mudminnow, largescale sucker, mountain whitefish, Pacific lamprey, riffle and reticulate sculpin, and speckled dace. The bird and mammal indicator species present include great blue heron, Barrow's goldeneye, common goldeneye, wood duck, and North American beaver.

All hatchery releases into the Humptulips River sub-basin originate from WDFW-operated Humptulips Hatchery located on Stevens Creek. The hatchery steelhead programs are segregated for harvest opportunities. Annual production goals are 30,000 summer and 125,000 early-timed winter-run steelhead. Chinook and coho salmon production are integrated, marked, and provided for harvest opportunities. The annual release goals are 500,000 Chinook salmon and 100,000 late-timed and 400,000 normal-timed coho salmon. All releases are directly from the hatchery into Stevens Creek.

There are several cooperative programs in the ecological region that release fish originating from Wishkah Hatchery, a facility owned by WDFW but operated by fisheries cooperative groups. All fish produced from this facility are integrated and are for harvest opportunities. There is an annual production goal to release 25,000 marked coho salmon smolt into Buzzard Creek, a tributary to the Wishkah River. The cooperative facility annual production goal is 200,000 marked Chinook salmon, 300,000 normal-timed marked coho salmon, and 100,000 unmarked chum salmon released into the Wishkah River.

There is a cooperative program in the ecological region that rears and releases 100,000 normal-timed coho salmon from net pens located in the Westport Boat Basin. These fish are from Bingham Creek Hatchery and are Satsop River-origin fish. These fish are integrated, marked, and provided for harvest opportunity.

[31] Fish passage barrier data from WDFW processed through EDT model.

There are also three coho salmon fry releases by schools, totaling about 1,500 fish and sized less than 1 gram per fish. These programs are too small to contribute to adult returns.

5.10.4 Limiting Factors

Limiting factors for salmonids were identified in several assessments of the Chehalis Basin, including the EDT (ICF 2019) and NOAA modeling (Beechie 2018) conducted for the ASRP and earlier studies (GHLE 2011; Smith and Wenger 2001). Additional limiting factors and a diagnosis of what is working and what is broken in the ecological region were determined by the SRT, drawing on local basin knowledge and reconnaissance conducted within the region.

The combined results of these assessments indicate that the tidal zone is a significant area affecting abundance of all salmonids throughout the basin. Major issues for salmonids in the region are as follows (in relative order of importance):

- Low habitat diversity (lack of side channels, large wood and floodplain connectivity and particularly reduction of beaver ponds)
- Reduced quantity and quality of instream habitats
- High water temperatures
- Sediment load (fine sediments)
- Channel instability (bed scour and sediment transport)
- Flows
- Predation (non-native fish species)
- Fish passage barriers

Diagnostic Snapshot

- This ecological region is lacking wood and stable gravel. River habitat conditions are influenced by a legacy of logging, including splash dams that fundamentally altered instream habitat. In addition, local extraction of gravel occurred historically. This has resulted in many reaches that lack complexity.
- The lower tidal reach of the Humptulips River is in very good condition, except for invasive plant infestations. The condition of the delta of this watershed is an unusual feature; there has been essentially no agricultural conversion and little development. The availability of high-quality habitat could help magnify benefits associated with habitat improvements upstream.
- Lower tidal reaches of the Hoquiam and Wishkah rivers are within Aberdeen and Hoquiam and have been heavily modified.
- Sea level rise will significantly alter the lower reaches of all of these systems.
- Municipal and industrial water supply dams are on the Hoquiam (West Fork, Davis Creek) and Wishkah (Malinosky Dam) rivers that affect fish passage and water quality.
- Invasive plant species, including reed canarygrass, are present.

These identified issues for salmonids are generally consistent with earlier findings from Smith and Wenger (2001) and the Chehalis Basin Lead Entity (GHLE 2011), which indicated that the key limiting factors in this ecological region include riparian conditions, water quality, fish passage barriers, sediment conditions, floodplain conditions, lack of large wood, and water quantity, but have identified different priorities focused on large wood, beaver ponds, and floodplain connectivity.

Limiting factors and threats to non-salmon indicator species are not well understood but may include high water temperatures, migration barriers, changes in flow conditions and water level variations, fine sediments, riparian conditions, and non-native predator species (as identified for Pacific lamprey by Clemens et al. [2017]).

5.10.5 Strategies and Actions in the Ecological Region

5.10.5.1 Habitat and Process Protection

Many of the protection actions described in Section 4.2.1 are appropriate in the Grays Harbor Tributaries Ecological Region. Based on existing conditions, the following areas and actions are recommended for a protection focus:

- Protect high-quality habitats, including cold-water inputs, properly functioning riparian areas, and remaining old-growth forest, especially in the East Fork and West Fork Humptulips rivers. These areas provide critical summer rearing habitat for juvenile salmon and steelhead both currently and under future climate change scenarios.
- Protect intact tidal wetland habitats, particularly the tidal swamp (forested) habitats along the lower Humptulips River.
- Protect important holding and spawning areas for spring-run Chinook salmon in the Humptulips River.
- Protect the lower reaches of rivers in the ecological region to accommodate the processes by which sea level rise will cause estuary zones to shift upstream.

The Grays Harbor Tributaries Ecological Region is almost entirely within Grays Harbor County, which has regulations and policies in place to protect wetlands, floodplains, riparian areas, and fish and wildlife habitat conservation areas from degradation and development and manage invasive species. Grays Harbor County's draft SMP that is currently in final review with Ecology contains regulations to protect channel migration zones and riparian vegetation, along with general development regulations related to shoreline areas in the County (Grays Harbor County 2018).

As part of the community planning strategy (see Section 5.10.5.3), funding support to align the County regulations with the ASRP and conduct enforcement will be considered.

General protection priorities for Grays Harbor County within the Grays Harbor Tributaries Ecological Region include the following:

- Protect spawning gravel sources and retain spawning gravels (protect channel migration and improve wood recruitment).
- Maintain and increase forest cover and riparian cover.
- Protect from development.

5.10.5.2 Restoration

The restoration actions described in Section 4.2.2 are mostly appropriate in the Grays Harbor Tributaries Ecological Region. Based on existing conditions, the following areas and actions are recommended for a restoration focus:

- Add stable wood structures throughout the instream areas.
- Restore wider riparian buffers, especially in the lower and middle Humptulips Basin.
- Correct fish passage issues at water supply dams on the Hoquiam and Wishkah rivers.
- Develop demonstration projects for key restoration actions, such as instream wood and logjams and floodplain reconnections (see Section 5.10.5.4 for related recommendations).
- The Humptulips River has significant harvest and hatchery activities; any restoration actions will have to consider these activities.

Priority areas for restoration within the Grays Harbor Tributaries Ecological Region include the lower and middle Humptulips River, East Fork and West Fork Humptulips rivers, Johns River, East Fork Hoquiam River, the upper and lower Wishkah River, and key tributaries of the Humptulips River (such as Big and Stevens creeks).

Spawning habitat for fall-run Chinook, coho, and chum salmon is present in the middle reaches of the Wishkah River. Increasing in-channel structure would retain and sort river gravels.

The lower tidal reach of the Humptulips River is in good condition, except for significant invasive species issues. The Humptulips River estuary should be protected, and restoration should be conducted to address invasive species.

5.10.5.3 Community Planning

As noted in Section 4.2.3, community planning actions would be coordinated with state and local governments, landowners, and other stakeholders to ensure the long-term success of the ASRP. Focus programs and policies that could be developed or investigated in the Grays Harbor Tributaries Ecological Region include the following:

- WDFW could investigate effects of hatchery fish on wild fish populations.
- Develop a long-term strategy for managing knotweed.

- Discuss with Grays Harbor County additional planning measures that could effectively promote and protect the following:
  - Surface and groundwater quantities through reduction of withdrawals
  - Minimization of impervious surfaces
  - Riparian maturation and wood recruitment for retention of spawning gravel and sources
  - Natural channel migration
- As the Chehalis Basin Strategy becomes more integrated, coordinate the ASRP with the CFAR Program to build habitat restoration and protection actions into community flood risk reduction efforts (such as restoring areas where structures and people have been relocated from floodplains).

5.10.5.4 Community Involvement

As noted in Section 4.2.4, community involvement and voluntary landowner participation are essential to the success of the ASRP, and the actions described in that section will be further evaluated for the Grays Harbor Tributaries Ecological Region in Phases 2 and 3 based on the restoration and protection scenario selected. Based on the specific issues in this area, the following actions are recommended for focused community involvement:

- Develop demonstration projects for key restoration actions (such as instream wood and logjams and floodplain reconnections) that can also educate local populations.
- Work with local organizations—such as Grays Harbor Audubon Society , which engaged with the ASRP development for the Grays Harbor Tributaries Ecological Region at the 2018 Science Symposium—to develop educational opportunities. Signage and/or community events would present opportunities for communication and education regarding upriver restoration activities and connections to the habitats and species that are supported by these activities.
- Continue outreach, engagement, and involvement processes to incorporate landowner expertise into ASRP planning and local implementation efforts.
- Partner with and support the efforts of existing local organizations (see Appendix E for a list of potential partner organizations).

5.10.5.5 Institutional Capacity

The institutional capacity strategy is intended to build on and support the work of existing organizations, as well as support creativity in how local organizations approach working toward the goals of the ASRP. The actions described in Section 4.2.5 will be further evaluated for the Grays Harbor Tributaries Ecological Region in Phases 2 and 3 based on the restoration and protection scenario selected. Based on the specific issues in this area, the following focused institutional capacity actions are recommended:

- Support Grays Harbor County in enforcement of critical areas regulations.
- Develop partnering opportunities with Grays Harbor Audubon Society and other local organizations.

- Provide technical training on process-based restoration practices and principles.
- Provide funding for groups and individuals interested in restoration projects.
- Build on and support the work of existing organizations with missions that overlap with the ASRP vision (see Appendix E for a list of potential groups).

6 IMPLEMENTATION FRAMEWORK

6.1 Implementation Approach

The Implementation Plan framework in this section describes how the ASRP restoration and protection strategies and actions will be carried out in the various ecological regions throughout the Chehalis Basin. A complete Implementation Plan including design and funding guidance for projects will be developed during Phases 2 and 3 when a restoration and protection scenario is selected.

Sections 6.1.1 and 6.1.2 outline the frameworks for project implementation of the ASRP. The diagrams in Figures 6-1 and 6-2 show the overall process in which projects will be developed, selected for funding, and implemented. Two paths to implementation have been developed at this phase in the program to encompass the variety of project types and relative scales that the ASRP program will seek to fund. These pathways could evolve as the ASRP is adaptively managed to capitalize on efficiencies.

"Reach-scale projects" are defined as projects seeking to restore ecosystem processes over a large geographic area (longer than approximately 1 RM and typically 2 to 4 RMs in length). They are complex due to the sheer scale and application of restoration and protection treatments through a long stretch of river. Depending on dominant land use practices, reach-scale projects generally work with more than one landowner in a contiguous reach and have multiple restoration and protection treatments applied. An example of a reach-scale project could be a project sponsor working with six landowners over a 2.5 RM contiguous stretch, where a variety of protection actions including easements, fee-simple acquisitions, and voluntary participation create opportunities to implement large wood placements, side channel enhancements, and riparian plantings and enhancements.

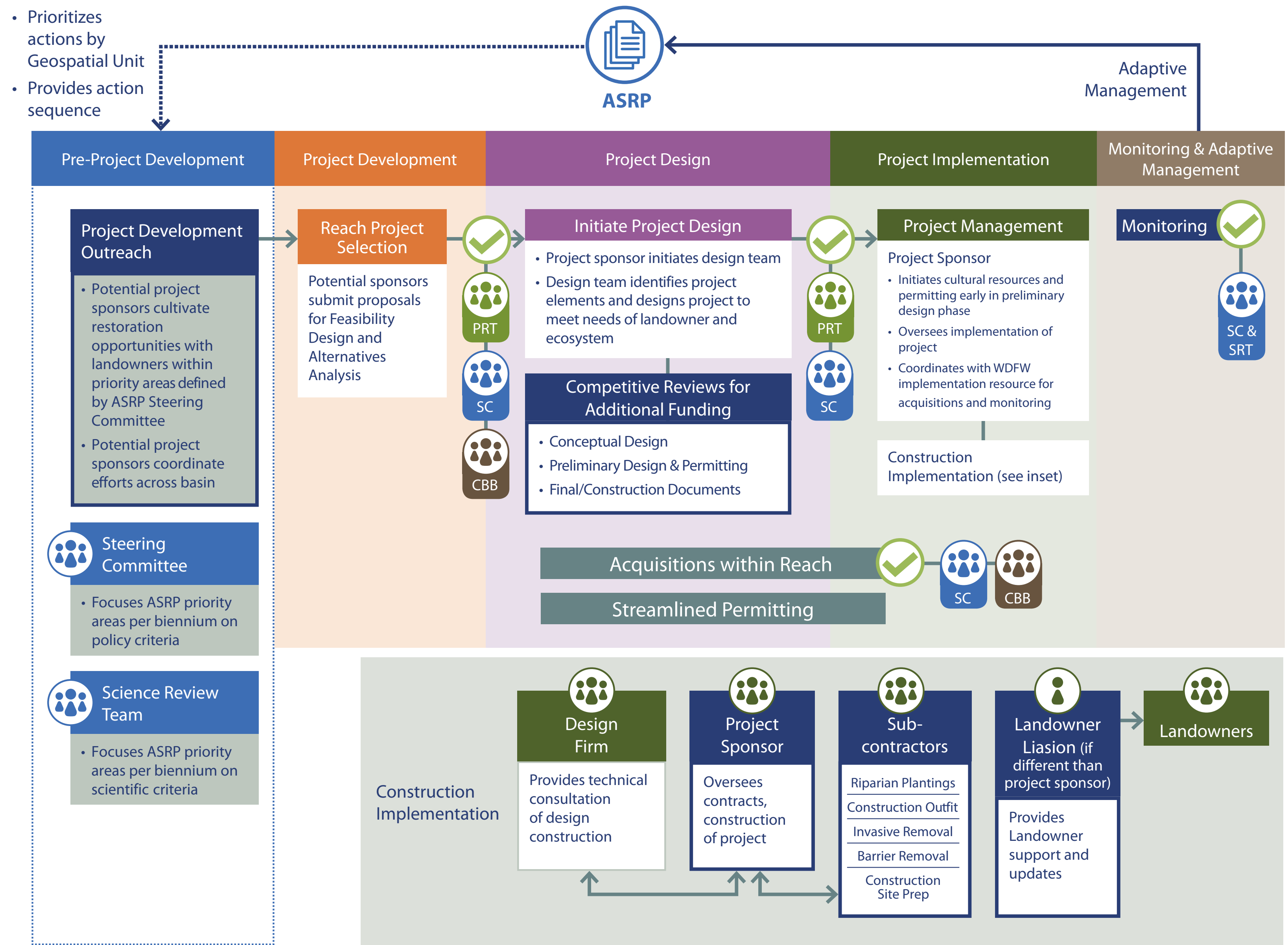
In contrast, "non-reach-scale projects" are those that may focus on restoring or protecting ecosystem function at a smaller scale and typically only apply one or two types of restoration treatments on site. Examples of non-reach-scale projects include fish passage barrier corrections, riparian plantings, or invasive species removal. In addition, single acquisitions of different kinds (e.g., fee-simple or water rights purchases) are considered non-reach-scale projects. For the 2019–2021 biennium, the ASRP will hold an ASRP projects grant round through WDFW and the Washington State Recreation and Conservation Office (RCO) to fund projects and project development aimed at immediate implementation priorities of the ASRP. This funding round will seek to fund high-quality projects that are both reach-scale (Figure 6-1) and non-reach-scale (Figure 6-2).

Factors that were considered when developing the approach for the Implementation Plan framework include regulatory processes, funding strategies, alignment with other programs and efforts, and design guidelines. Sections 6.2 through 6.4 provide an outline of the ASRP governance structure, how projects will be sequenced, and how the ASRP implementation will be aligned with other related programs and efforts.

6.1.1 Reach-Scale Implementation Process

The reach-scale implementation process framework (Figure 6-1) depicts the different stages of project implementation and the roles involved.

Figure 6-1
Reach-scale Implementation Process



Notes: CBB: Chehalis Basin Board; PRT: Project Review Team; SC: Steering Committee; SRT: Science and Technical Review Team

Reach-scale projects are complex, multifaceted endeavors. Having a framework for successful implementation helps relieve some of the complexities from taking on projects of this scale. The Steering Committee has developed these frameworks with the needs of the sponsors in mind, creating resources throughout the process to help each project be successful.

Each stage is predicated on a competitive funding process in which potential project sponsors would apply for ASRP funding to develop, design, or implement their project. These funding rounds will be operationally managed by WDFW and RCO on behalf of the Steering Committee. Competitive funding rounds are defined as follows:

1. Project development outreach
2. Conceptual design
3. Preliminary design and permitting
4. Final/construction documents

Timing of funding cycles and funding available for each phase of work per biennium will be determined by the Steering Committee in coordination with the Chehalis Basin Board and its long-term funding strategy determination, which will be further developed in 2020. While projects of this caliber historically have taken many years to develop and design, the ASRP is intended to capitalize on coordinated project development outreach as well as successes working with private landowners to understand project opportunities early and take advantage of them efficiently. A broad timescale for reach-scale project development and implementation is assumed to be 1 biennium for project development outreach, design, and permitting and 1 to 2 biennia for materials sourcing and construction.

Pre-Project Development

The pre-project development phase of reach-scale projects creates space to deliberately develop projects of high restoration and protection value as determined by the ASRP. Potential project sponsors can apply for capacity funding through an RFP to conduct targeted landowner outreach within larger priority geographic areas that the SRT and Steering Committee identify each biennium. Implementation priorities within priority geographic areas are further detailed in Section 6.3. The pre-project development outreach is intended to develop a reach (or more, depending on the funding guidelines) with preliminary landowner willingness secured in the form of RCO landowner acknowledgement forms, as well as conceptual ideas for restoration treatments within the project area. Having preliminary landowner willingness understood upfront allows the Steering Committee to provide informed recommendations on projects to enter design. The project development phase concludes with sponsors submitting a proposal for conceptual design and an associated budget for a reach. The Steering Committee, and by proxy a technical review team, will then review and recommend selected projects to enter the design phase. Project sponsors will be awarded funds through an administered RCO grant.

Design

Design of reach-scale projects is integral to the success of the ASRP when implemented across the basin and through diverse sponsorship. Design teams will be used in this phase of project implementation to foster a collaborative approach to project design. These teams are composed of the project sponsor, design lead, and WDFW implementation resource. The design team works together to ensure that all aspects of successful project development are integrated early. The successful project sponsor will develop and facilitate the design team for their project and work in partnership with the appropriate landowners to ensure project design meets the needs of both the landowners and the local ecosystem. A WDFW staff person will serve as an implementation resource on the design teams to provide guidance and aid sponsors in ensuring their project design is competitive for future funding rounds by meeting the goals of the ASRP. In addition, the WDFW implementation resource will provide standardized coordination among all reach-scale projects for acquisitions as needed within the project footprint as well as coordination with the M&AM Team to ensure programmatic monitoring will occur as designed to inform the basin-wide program. Acquisitions would be facilitated by partnered local land trusts in close coordination with the project sponsors and, if applicable, the landowner liaison. These land trusts would work in conjunction with the overall design and objectives of the project to complete any acquisitions needed within the project footprint to ensure project success and long-term protection. The WDFW implementation resource would manage these contracts in conjunction with RCO and facilitate coordination of land trusts with each respective design team as needed.

Implementation of reach-scale projects will be overseen by the project sponsor and include any necessary permitting, cultural resources consultation, and subcontracting as needed. The WDFW staff person serving on the design team will provide helpful resources and work to ensure permitting is as streamlined as possible. Permitting discussions should start early to accommodate scheduling complications and can start with funding granted toward preliminary designs. Finally, M&AM actions beyond permit-required monitoring, including potentially pre-and post-project monitoring, will be coordinated by the WDFW implementation resource, project sponsor, and appropriate landowners to systematically learn and adaptively manage implementation of the ASRP.

Reach-Scale Implementation Roles and Responsibilities

Several roles are inherent to the reach-scale implementation framework. The high-level process as depicted in Figure 6-1 shows the roles and responsibilities of several included parties. Table 6-1 further describes examples of the responsibilities for each role in the reach-scale project implementation process.

Table 6-1
Reach-Scale Implementation Roles and Responsibilities

PRE-PROJECT DEVELOPMENT	PROJECT DEVELOPMENT	PROJECT DESIGN CONCEPTUAL DESIGN	PRELIMINARY DESIGN	FINAL DESIGN	IMPLEMENTATION CONSTRUCTION
PROJECT SPONSOR					
• Conduct targeted outreach to build preliminary landowner willingness in priority reaches • Act as point-of-contact for landowner(s)	• Submit proposal for conceptual design with associated budget for reach (with preliminary landowner willingness secured) • If awarded funds, develop the design team through relevant subcontracts • Act as point-of-contact for landowner(s)	• Facilitate design team to produce concept level/feasibility designs for reach • Work with landowners to ensure participation and enthusiasm for project elements • Engage permitting staff to ensure elements are permit suitable and understand permitting timeline • Act as point-of-contact for landowner(s)	• Facilitate design team to produce preliminary designs for reach • Work with landowners to ensure participation and enthusiasm for project elements • Engage permitting staff to start the permitting process once funds are awarded for final design • Coordinate with WDFW implementation resource to identify and facilitate any necessary acquisitions within reach • Act as point-of-contact for landowner(s)	• Facilitate design team to produce final designs for reach • Work with landowners to ensure participation and enthusiasm for project elements • Apply for all necessary permits • Act as point-of-contact for landowner(s)	• Hold all permit documents • Hire subcontractors to prep, construct, and monitor project as needed • Coordinate with WDFW implementation resource • Act as point-of-contact for landowner(s)
WDFW IMPLEMENTATION RESOURCE					
• N/A	• Aid selected sponsors in developing design team as needed	• Serve on design team • Consult on design to ensure compatibility with ASRP goals	• Serve on design team • Consult on design to ensure compatibility with ASRP goals • Facilitate coordination with local land trusts for acquisitions within reach as needed • Consult on permitting needs and provide guidance as feasible	• Serve on design team • Consult on design to ensure compatibility with ASRP goals • Facilitate coordination with local land trusts for acquisitions within reach as needed • Facilitate coordination with M&AM Team for any pre-project monitoring needs	• Serve on design team • Facilitate coordination with M&AM Team for any pre-project monitoring needs
DESIGN FIRM					
• N/A	• Apply for participation on design team	• Serve on design team • Deliver conceptual designs	• Serve on design team • Deliver preliminary designs	• Serve on design team • Deliver final designs	• Serve on design team • Consult on design details during construction, as needed
LANDOWNER LIAISON (IF DIFFERENT THAN PROJECT SPONSOR)					
• Conduct targeted outreach to build preliminary landowner willingness in priority reaches	• Act as point-of-contact for landowner(s) • Convey landowner questions or concerns to design team	• Act as point-of-contact for landowner(s) • Convey landowner questions or concerns to design team	• Act as point-of-contact for landowner(s) • Convey landowner questions or concerns to design team	• Act as point-of-contact for landowner(s) • Convey landowner questions or concerns to design team	• Act as point-of-contact for landowner(s) • Convey landowner questions or concerns to design team

RCO, along with WDFW, will operationally manage ASRP annual RFP grant rounds. RCO will manage project contracts and invoicing and track project progress. The agency will also provide support for sponsors to set up and administer its grants according to RCO and ASRP guidelines.

Close coordination between the ASRP and Chehalis Basin Lead Entity is important, as potential sponsors are encouraged to vet project ideas and focus areas with other experts on the Chehalis Habitat Work Group. This forum provides coordination to ensure that potential sponsors are working in concert with each other in the basin and amplifying each other's projects. There is also the opportunity to leverage funding sources, particularly federal funds, as a mechanism to accomplish more through a project.

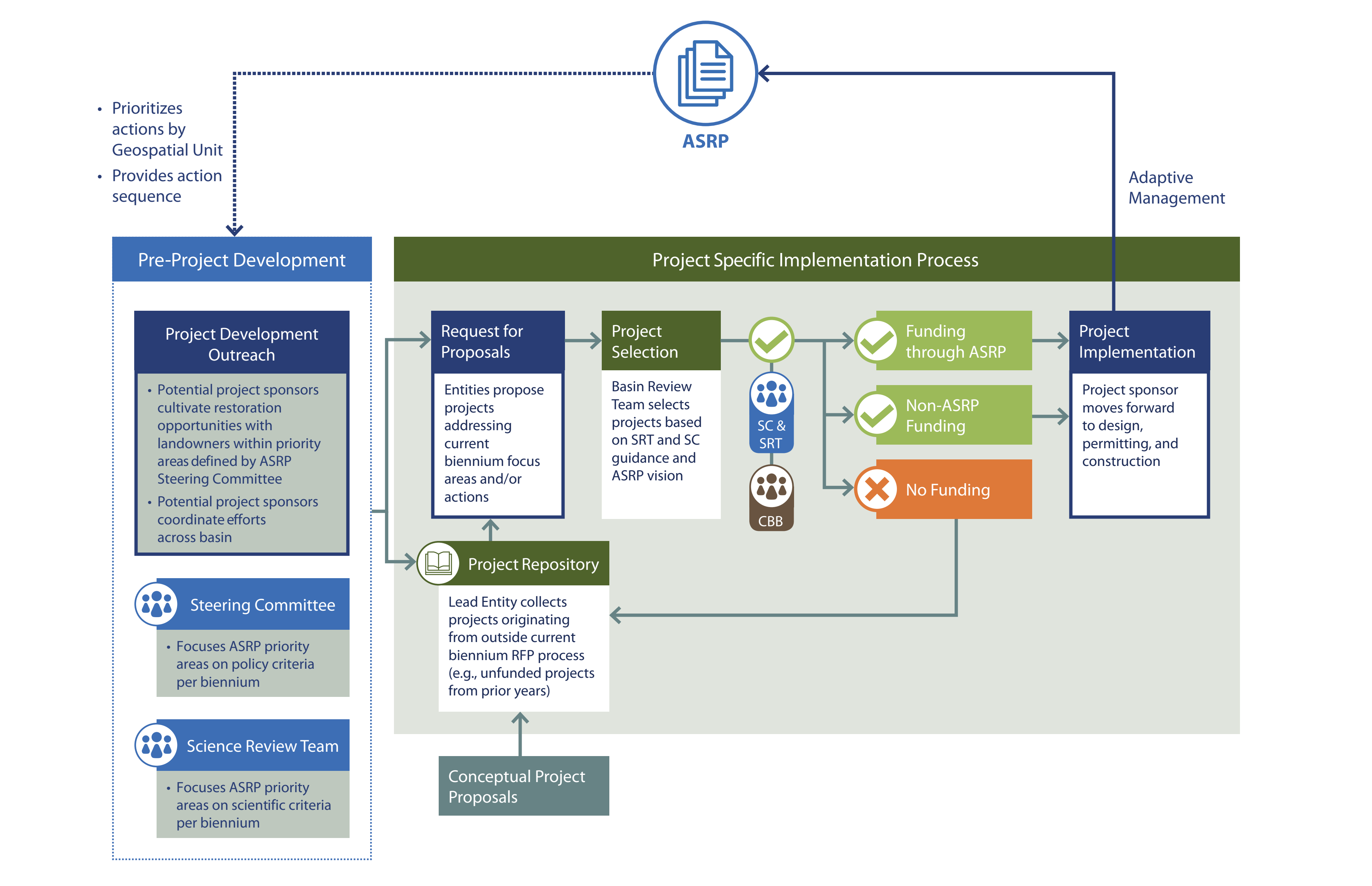
The SRT provides guidance to the Steering Committee on priority areas and actions for implementation based on sequencing plans, described as a framework in Section 6.3. The Steering Committee takes those scientific recommendations and communicates the ASRP priority geographic areas and actions through competitive RFP cycles in coordination with WDFW and RCO. The Steering Committee also provides budgetary recommendations to the Chehalis Basin Board on a biennial cycle based on implementation planning and expected project needs. These recommendations and the Board-approved budget will provide the basis for types of funding available for implementation of the ASRP.

The Chehalis Basin Board will provide timely, high-level guidance and strategic check-in support to the Steering Committee as projects are developed and designed and project costs are defined. This guidance will enable the Steering Committee to adjust implementation priorities depending on costs and associated benefits for reach-scale projects as they are developed. This type of guidance model fits the adaptively managed nature of the ASRP program.

6.1.2 Non-Reach-Scale Implementation Process

The non-reach-scale implementation process framework for smaller-scale projects such as fish passage barrier corrections, riparian plantings, invasive species removal, experimental restoration, and some acquisitions (Figure 6-2) depicts the different stages of project implementation and the roles involved.

Figure 6-2
Non Reach-scale Project Implementation Process



Notes: Non reach-scale projects that would be implemented under this process include more repetitive, widely applied actions such as removal of fish passage barriers, riparian planting projects, or invasive species management.

CBB: Chehalis Basin Board; SC: Steering Committee; SRT: Science and Technical Review Team

The non-reach scale process for implementation has been developed with efficiency in mind; it is meant to be opportunistic and encourage the rapid implementation of the ASRP at the local level. Not all implementation priorities of the ASRP will be reach-scale, and some will include smaller restoration treatments such as fish passage barrier corrections, parcel or water rights acquisitions, and riparian plantings. Non-reach-scale projects can also often build landowner support for potential larger reach-scale actions in the future. The Steering Committee developed this process to build upon previously successful ASRP RFP grant rounds as well as demonstrate successes of the Chehalis Lead Entity's Salmon Recovery Funding Board process. The associated funding cycle is annual in order to develop the significant number of projects needed to implement short-term priorities of the ASRP.

Similar to the reach-scale process, pre-project development includes targeted landowner outreach in the geographic priorities set for implementation by the SRT and the Steering Committee. Outreach funding will similarly be awarded through an RFP that has project development outreach as a viable funding type. Potential project sponsors are encouraged to share and vet project ideas through the Chehalis Lead Entity work group to have highly competitive project proposal applications. A formal RFP will be released each year, which will be staggered in timing with other grant programs in the basin and foster coordination of the different programs. Proposals for projects will then be weighed by a local project review team, comprising technical specialists appointed by the Steering Committee. This review team will rank projects against established criteria to measure the proposed projects relative to the goals, strategies, and implementation priorities of the ASRP. For those projects ranking above the set funding line established by the Steering Committee based on available funding each biennium, the Steering Committee will recommend a set of projects for funding authorization to the Office of Chehalis Basin, and funds will be released through a contract managed by RCO for project implementation.

Non-Reach-Scale Implementation Roles and Responsibilities

Many roles and responsibilities are the same in this process as those described in the reach-scale process in Section 6.1.1. Key differences include the absence of the WDFW implementation resource and the design teams. These smaller projects are inherently simpler in restoration treatments and therefore do not necessitate the more intensive design structure. To ensure efficiency in project design and implementation at this smaller scale, those roles are removed from this process. WDFW will still offer operational support to project sponsors, including responding to design questions to ensure compatibility with ASRP goals, as well as responding to permitting questions to help coordinate streamlined permitting as appropriate. RCO will still act as the RFP and contract manager for the non-reach-scale project grant rounds.

6.2 Governance Structure

The ASRP is operationally managed by WDFW on behalf of the Steering Committee and in coordination with the Office of Chehalis Basin and the Chehalis Basin Board. WDFW will continue to manage the funding programs in coordination with RCO as described previously for the implementation of the ASRP and will work closely with the Office of Chehalis Basin, the Chehalis Basin Board, and RCO to further develop and enact programs and implementation guidance.

The Chehalis Basin Board has spending authority of funds allocated to the Chehalis Basin Strategy. The Board routinely allocates funding to the ASRP, including amounts for overall ASRP implementation as recommended by the Steering Committee. The Steering Committee develops and manages the ASRP, including recommending how funding is allocated within the program. The Steering Committee is chartered to make recommendations to the Office of Chehalis Basin and the Board on specific funding dispersals to enact program priorities.

As the ASRP is further developed and transitions to implementation and M&AM, the governance needs of the program will likely evolve. A detailed organization chart of ASRP management for implementation and M&AM will be developed in Phases 2 and 3.

6.3 Prioritization and Sequencing Framework

While this plan contains a preliminary sequencing framework, it will be finalized based on the selected ASRP scenario. The intent of the prioritization and sequencing framework at this phase is to provide guidance to project sponsors and stakeholders in moving forward with the early actions and immediate priorities, as well as to set the stage for the medium- and long-term priorities. In future phases of the ASRP, the recommended Implementation Plan will support additional project development and funding needs. Guidance to practitioners regarding the sequencing and design of the projects will be developed as an appendix to the final ASRP but is not included in this ASRP Phase 1 document.

The sequencing priorities identified in Sections 6.3.1 through 6.3.3 are based on the protection and enhancement of core habitats included in Scenario 1. These represent preliminary sequencing of the areas and actions recommended in Section 5 of this document. This also includes the highest-priority areas and actions to improve the performance of spring-run Chinook salmon, a species of immediate implementation focus due to its sensitivities to ecosystem health and projected negative trend in population. This species is not federally listed under the ESA, and early implementation efforts could benefit spring-run Chinook salmon to help avoid those potential future declines from being realized. Priorities are organized by immediate priorities, medium-term priorities, and long-term priorities. The overall time frame for implementation of all identified restoration and protection projects is approximately 20 to 40 years. This is a very ambitious time frame considering the scale of proposed implementation, but it is necessary to begin to ameliorate the effects of climate change projected to occur by 2040 and to realize the projected outcomes. The urgency of implementation drives this timeline and is dependent on available funding and landowner willingness to succeed. Accountability of expenditures and transparency of actions is also built into this sequencing framework and will be further described in future phases of the ASRP.

The ASRP has developed implementation with an eye to successful existing restoration and protection processes in the state. The ASRP immediately looks to implement projects as the next phases of plan development are underway. The 2019 ASRP Implementation Grant Round RFP will be released broadly to potential project applicants by RCO on behalf of the Steering Committee in fall 2019. This RFP will seek to fund high-quality projects that address high-priority actions and areas identified in the ASRP.

6.3.1 Immediate Priorities

6.3.1.1 Early Action Projects

Starting in April 2016, Washington State provided approximately $6 million in grants to public and nonprofit organizations in Grays Harbor, Lewis, and Thurston counties for 28 habitat restoration projects in the Chehalis Basin. Most of the grant projects were designed to restore fish passage in streams where it is partially or fully blocked by culverts and other artificial structures. Altogether, these projects have opened more than 130 miles of streams to migrating salmon and other aquatic species.

The competitive grant process was conducted by WDFW and the Chehalis Basin Lead Entity's Habitat Work Group. Objectives for the selected early action projects included the following:

- Restore ecosystem processes to benefit salmon and other aquatic species.
- Partner with willing landowners to achieve goals and meet landowner needs.
- Demonstrate ASRP implementation across the basin and capture lessons learned.

Projects were evaluated based on their potential benefits to fish and other species and the likelihood that they could be implemented quickly and cost-effectively. This initial set of projects were implemented in 2017 and 2018. Projects that received funding included the following:

- Eight fish passage barrier corrections located on private property by the Lewis County Conservation District. The projects were designed to open 68 miles of streams to migrating coho salmon, steelhead, and cutthroat trout.
- A fish passage barrier removal project on Darlin Creek, a tributary of the Black River in Thurston County. The project, sponsored by the Capitol Land Trust, opened 2 miles of coho salmon and cutthroat habitat in a priority area of the Chehalis River watershed.
- The correction of three fish passage barriers in the Johns River watershed of Grays Harbor County, under the sponsorship of the Chehalis Basin Fisheries Task Force.

Starting in 2018, five early action reach-scale restoration projects began design in high-priority areas of the Chehalis Basin: the South Fork Newaukum, Skookumchuck, East Fork Satsop, and Wynoochee rivers and Stillman Creek. Early action projects are the first set of reach-scale projects that are being implemented as part of the ASRP. These projects are being developed in collaboration with willing landowners where there is a high likelihood that they will benefit multiple species of salmonids and other aquatic species.

6.3.1.2 Rapid Actions

Starting in late 2019, additional reach-scale projects could be initiated through the ASRP Implementation Grant Round that can demonstrate the relatively low-cost installation of large wood structures in managed forest areas where the riparian zone is already protected. It is anticipated that 3 to 5 miles of these projects could be implemented in the Willapa Hills, Black Hills, and Olympic Mountains ecological regions, as these are high-priority areas for this type of action. Additionally, one or more reach-scale designs will begin in high-priority areas (including the Newaukum, Skookumchuck, Satsop, and Wynoochee rivers) that either build on the existing early action designs or have been identified through cooperation with willing landowners. These new projects would require a project sponsor applying to manage the project through the ASRP Implementation Grant Round. Wood-loading rapid action-style projects in managed forests would require coordination with WDNR and the Forest Practices Act to ensure efficiencies in project timeline and permitting costs.

6.3.1.3 Immediate Priorities

Several immediate priorities are important to ensure the highest and most productive areas of the basin are protected and enhanced in the near term. These priority areas include the most productive and core areas of Scenario 1. It is of paramount importance to implement a significant number of projects in the near term to build capacity for designing and constructing projects and to achieve anticipated outcomes. Immediate priorities for the current and next biennium include those listed in Table 6-2.

> In the mainstem Chehalis River, lower South Fork Chehalis River, and other rivers and reaches in the basin where longer restoration reaches are not feasible due to intensive land uses, restoration is proposed to focus on “nodes” of habitat that would include a large floodplain site on one bank of the river and could include restoration of large remnant oxbows with instream habitat. Using the node concept, refuge areas would be spaced along the channel length and available to fish as they travel throughout the system.

Table 6-2
Immediate Priorities

IMMEDIATE PRIORITY AREAS	IMMEDIATE PRIORITY ACTIONS	PURPOSE
• Newaukum River forks • South Fork Chehalis River	Installation of beaver dam analogs	Improve floodplain connectivity and potential performance of spring-run Chinook salmon
• Areas with limited riparian buffers on south and/or west banks of the following: – South Fork Newaukum River – North Fork Newaukum River – Skookumchuck River	Implement riparian plantings with rapidly growing species (particularly cottonwood and willows)	Improve the performance of spring-run Chinook salmon by maintaining cooler temperatures in the rivers for a longer distance downstream

IMMEDIATE PRIORITY AREAS	IMMEDIATE PRIORITY ACTIONS	PURPOSE
• Elk Creek • Chehalis River tidal surge plain • Humptulips River tidal areas • Cold-water locations in the East Fork Satsop and South Fork Newaukum rivers • Cold-water tributary confluences to the mainstem Chehalis River	Protection/acquisition of the following: – Highly functional habitats – Cold-water holding pools – Cold-water springs or other inflows – Groundwater recharge areas	Initiate protection strategy of ASRP by protecting the following: – Cold-water holding areas and inputs – High-functioning intact habitats
Managed forest locations with a single timber landowner	In-channel wood installation over several miles of stream	Quickly design and implement projects to provide instream habitat and complexity
Mainstem lower Chehalis River below Skookumchuck River	Design large-scale floodplain reconnection node projects	Provide refuge habitat
• Skookumchuck River • South Fork Newaukum River • North Fork Newaukum River (in lieu of South Fork Chehalis River) • Satsop River • Wynoochee River • Humptulips River • Black River	Cold-water holding pool enhancement (such as large wood to maintain and expand holding pools or riparian plantings)	Provide immediate instream holding habitat
	Design-ready reach-scale projects that will build on or expand benefits of previous restoration efforts	Further implement large, reach-scale projects and scale up the implementation of the ASRP, starting in highest-priority sub-basins
	Riparian plantings	Maintain cooler temperatures in the rivers for a longer distance downstream
	Removal of invasive species	Provide opportunity for riparian planting of native species
	Remove fish passage barriers	Remove highest-priority barriers in priority sub-basins to provide immediate upstream habitat access
	Project development	Perform landowner outreach and assessment to identify additional reach-scale project opportunities

6.3.2 Medium-Term Priorities

Medium-term priorities are expected to be implemented in the years following implementation of the immediate priorities. These projects are intended to continue the momentum of the immediate priorities in the most productive sub-basins and core areas. These priorities also promote spreading the restoration and protection efforts to expand the spatial diversity of suitable habitats across the basin, including the removal of a large number of barriers that block fish passage. More significant efforts will focus on the nodes of the mainstem Chehalis River, and priorities will be adjusted as needed based on what was learned from restoration during the implementation of immediate priorities. Monitoring results will begin to have multiple years of data that can be analyzed to learn what have been the most effective restoration locations and measures, and adaptive management can be implemented as needed. The following medium-term priorities are anticipated:

- Continue numerous reach-scale restoration projects in the upper Chehalis, Newaukum, Skookumchuck, Black, Satsop, Wynoochee, and Humptulips rivers, including significant areas within managed forests.
- Explore the opportunity for the removal of Skookumchuck Dam.
- Restore six to eight nodes along the mainstem Chehalis and South Fork Chehalis rivers.
- Identify multiple opportunities for restoration in lowland streams such as Stearns, Lake, Bunker, Lincoln, Independence, Rock, Scatter, Porter, and Cloquallum creeks.
- Identify opportunities for restoration in key South Bay tributaries, such as Johns and Elk rivers.
- Develop water conservation opportunities in key sub-basins that already experience very low flows or are at risk due to ongoing development.
- Implement fish passage barrier removals in the highest-priority sub-basins.

6.3.3 Long-Term Priorities

Long-term priorities are expected to be implemented in the final years of the ASRP. These priorities include the conclusion of work in the designated scenario, including the completion of work in the largest and most productive sub-basins and core areas by finishing restoration of the lower reaches and tributaries, as well as the completion of the removal of fish passage barriers in those sub-basins. Work will also be completed in areas such as the middle and lower Chehalis, Cloquallum, Scatter, and Black rivers, because projects in these areas are more complicated and require more lead time due to existing development. Long-term projects will also occur in streams in the Central Lowlands and Black Hills ecological regions and tributaries to the upper Chehalis and South Fork Chehalis rivers. This phase may also include potential dam removal or modification. Adaptive management that began during the medium-term phase will continue and advance in this phase to adjust any priorities or techniques to ensure that the restoration is effective.

6.4 Alignment with Other Programs and Efforts

Developing and implementing successful partnerships in ecosystem restoration and salmon recovery efforts in the Chehalis Basin have been important to this process and are vital to the continued success of the ASRP. Alignment with the salmon recovery efforts in the Chehalis Basin is vital to success. The Chehalis Lead Entity has been a valued resource in helping to develop the ASRP into a program with synergistic benefits that complement Chehalis Lead Entity-funded and -implemented projects. Funding cycles will be staggered with the Salmon Recovery Funding Board process to capitalize on efficiencies and enhance coordination of projects between funding sources. ASRP funding cycles for projects were developed with many partner programs in mind in addition to the Salmon Recovery Funding Board process, including the Brian Abbott Fish Barrier Removal Board, the Family Forest Fish Passage Program, the Washington Wildlife and Recreation Program, and the Washington Coast Restoration and Resiliency Initiative.

In addition, state and tribal partners involved in the development of the ASRP have helped to ensure program compatibility with other successful habitat restoration and protection efforts. Examples of this are the coordinated efforts between the ASRP, WDNR, and Washington Department of Transportation to ensure fish passage barriers are comprehensively catalogued and distinctions are clear as to what types of funding are applicable to respective barrier correction programs. Another example is the coordinated operation of smolt traps between the Chehalis Tribe and WDFW. Leveraging expertise and funding, both groups are able to create more conclusive data by operating more smolt traps in key areas of the basin than they would by operating individually.

State, tribal, and federal coordination will also continue to leverage research and implementation efforts in the basin. In the 2019–2021 biennium, the ASRP has funded an in-depth analysis of freshwater mussels in the basin—a topic that can directly inform USFWS grant round priority areas into the future, as mussels are a species of focus for USFWS. As the ASRP planning and evaluation process moves forward, the Steering Committee will continue to coordinate with local groups and partner agencies to ensure the successful implementation and adaptive management of the program.

7 EXPECTED OUTCOMES

To help inform decision-making for the ASRP, this section summarizes the expected outcomes for the ASRP restoration scenarios. The outcomes presented here provide a larger range of potential benefits than were described in the *Initial Outcomes and Needed Investments for Policy Consideration* document (ASRP SC 2017). Following review of this document, development of a recommended restoration plan will occur. These outcomes and the level of proposed restoration represent the strategic prioritization and approach toward achieving the ASRP vision for the Chehalis Basin. The expected outcomes also consider the most recent modeled effects of climate change within the basin.

Expected outcomes for salmonids are presented from the EDT model results. Results from the NOAA model are not yet available for the restoration scenarios. Substantial additional field research and updated modeling has been conducted for the ASRP since the Initial Document (ASRP SC 2017) to help support the strategic prioritization and evaluation of potential outcomes. It is important to convey that the EDT model results make sense from a relative standpoint to the developers of the ASRP—the relative improvements in habitat and salmonid populations reflect the type and scale of actions and results of restoration in other watersheds. However, the results should not be viewed as an absolute number of fish that will return, only as a relative comparison to current salmonid habitat conditions and populations. The ASRP focuses on protecting and restoring aquatic species habitat and cannot guarantee that fish populations as modeled will utilize the habitats at any given time. The models and recent results are described in more detail in Appendix C; Sections 7.1 through 7.4 provide an overview of how the models have been used for the ASRP and how to understand the projected results.

7.1 EDT Model Overview

The EDT model is designed to assess the effects of habitat on salmonid species population performance. In other words, changes in habitat conditions affect a salmon population. The EDT model has three primary components: the system geometry (or river network), habitat attributes, and the life history elements of the salmonid species. The system geometry is specified by the number of stream reaches, their lengths, how reaches are connected to one another, and the locations of obstructions (if any). The habitat attributes describe how dozens of environmental and biological habitat descriptors (e.g., riparian condition, maximum temperature pattern, bed scour, habitat composition, predators) vary by reach and over time at a monthly time-step (attributes detailed by Lestelle [2005]). The life history component of the model describes and defines, for each species evaluated, where the species can spawn, the timing of life stage transitions, and the rate of movement through the system per each life stage. To evaluate changes from historical to current conditions or the benefits of restoration scenarios, the habitat attributes are modified to reflect the type of changes proposed. Each life stage is then affected in its productivity and capacity by the proposed changes to habitat attributes (conditions). Finally, this results in model outputs of population level estimates of capacity, productivity, and equilibrium abundance by restoration scenario. Productivity reflects the quality of the habitat, capacity reflects the quantity of the habitat, and equilibrium abundance combines productivity and capacity to yield an estimated abundance (EDT model outputs do not include harvest).

7.2 NOAA Model Overview

The NOAA model has three primary components: spatial analysis, habitat analysis, and life-cycle models for salmonid species. The model is built on inputs from multiple available sources of historic and current landscape and temperature data for a basin (spatial analysis), and then a detailed mapping and analysis of observable habitat characteristics (habitat analysis) is conducted that can then be changed for various scenarios. These data are then input into the life-cycle component of the model to evaluate which habitat factors have the most effect on fish species life-stage capacities and productivities. The model outputs include estimates of the equilibrium spawner abundance, as well as cumulative life-cycle productivity and cumulative life-cycle capacity. Harvest can be added to the NOAA model if data are available. The outputs can be compared and contrasted with the EDT model outputs to identify which habitat factors are most limiting the species and the life stages. The results for the NOAA model are not complete, and restoration scenario results are not presented in this document. Diagnostic information is detailed from both models in Section 7.3.1.

7.3 Expected Outcomes

The following notes provide important context for review of the expected outcomes:

- Expected outcomes based on the EDT model are only presented for salmon and steelhead species. Expected outcomes for other native species are described, but these were not derived from the EDT modeling effort or from other population modeling.
- The EDT-modeled outcomes assume all ASRP actions are implemented immediately and will be providing many functions by mid-century; if the implementation timeline is longer, outcomes will be reduced.
- Ocean conditions have a substantial effect on the survival of anadromous salmonids being targeted by the ASRP. The ASRP is focused on the freshwater environment and will help buffer effects from variability in ocean productivity. The ASRP will not affect ocean productivity, but it will influence the health, condition, and number of fish leaving the freshwater environment and entering the estuary and ocean.
- The Grays Harbor estuary is an important component of the ecosystem, particularly for Chinook and chum salmon. The estuary has not been evaluated for this Phase 1 of the ASRP but will be considered in future phases.

7.3.1 Expected No Action Outcomes

If no action is taken to restore or enhance aquatic species habitats, the cumulative research and both models indicate that water temperatures are likely to substantially increase, summer streamflows will likely decrease, and winter flooding could become more frequent and more extreme in magnitude due to climate change effects. These factors will further degrade aquatic habitats for native species and will likely favor invasive species that could replace some native species in some areas of the basin.

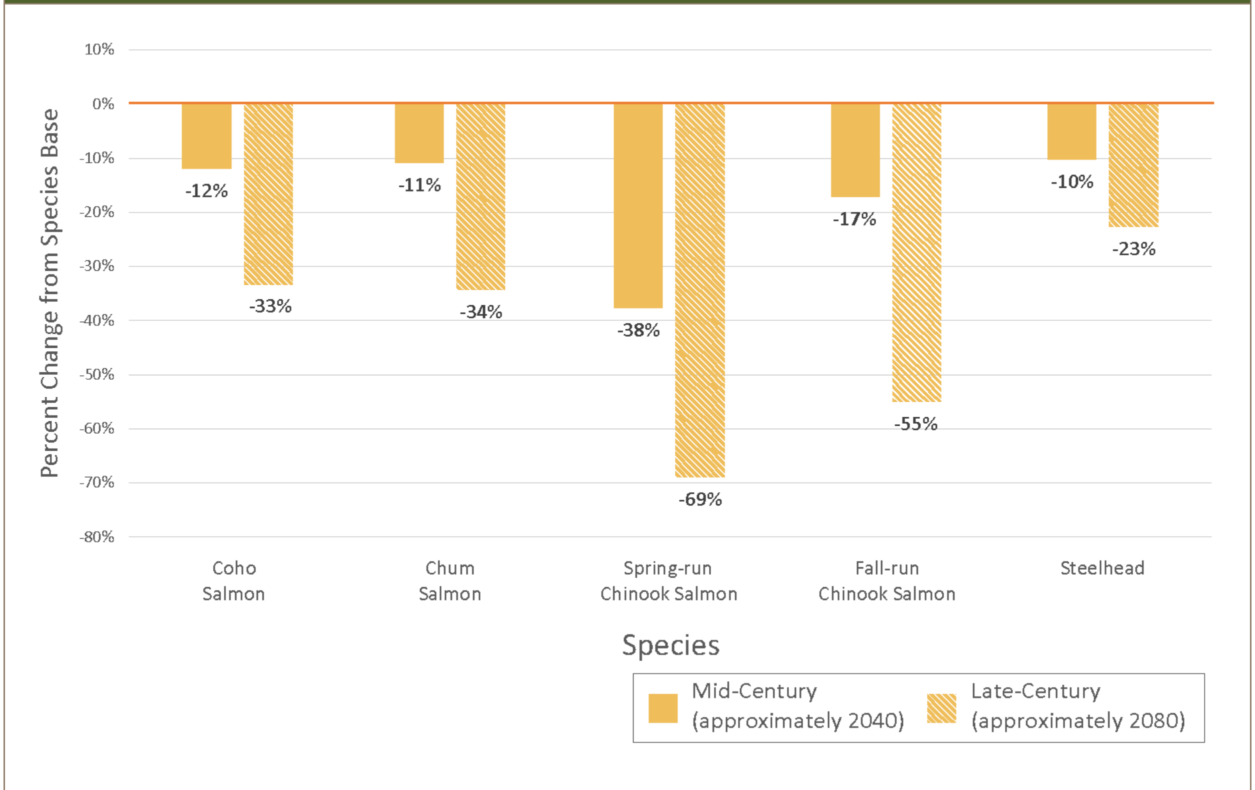
Development is also anticipated to continue in the basin, including the possible transition of many agricultural lands to more intensive agriculture such as high-value fruit crops or residential land uses. Development will place further pressure on surface and groundwater supplies and could also cause increased runoff of water and pollutants from impervious surfaces. This is anticipated to have adverse effects on aquatic habitats and species, including increasing water temperature, degrading other water quality parameters, reducing summer streamflows, and further reducing in-channel and off-channel habitat quantity and quality. It is important to emphasize that development has been projected following similar rates as the current trends. There is always the potential for much more significant development to occur as the overall Western Washington population increases.

For these reasons, salmon and steelhead are expected to substantially decline in number under the future No Action scenario. This is particularly the case for spring-run Chinook salmon that are most sensitive to increases in water temperature due to their need for extended holding as adults during the summer prior to spawning. The potential decline of spring-run Chinook salmon could render the species functionally extinct in the basin, with such low numbers that the run is not sustained. Additionally, salmonids and many of the other native aquatic species could experience substantial adverse effects from increased water temperatures. With no action, the ecosystem's ability to be resilient in the face of climate change would decline. Future unpredictable and extreme weather events could overwhelm the remaining functional habitats and cause local species extirpations and further declines.

> The EDT model projected outcomes indicate that if no action is taken, all salmon populations will decline substantially in the basin. Spring-run Chinook salmon are expected to be particularly affected by climate change.
>
> New genetic studies on spring-run Chinook indicate they are genetically distinct from fall-run Chinook (Prince et al. 2017; Thompson et al. 2019). This new information has prompted recent petitions to list spring-run Chinook salmon in Northern California and the Oregon coast under the ESA.

Figure 7-1 shows the EDT model projected declines, with future anticipated climate change, if the ASRP is not implemented. The existing habitat capacity is shown at the zero line, and all species would show substantial declines at the mid-century and late-century time period. If spring-run Chinook salmon were to be listed under the ESA in the Chehalis Basin, significant regulatory requirements would be placed on landowners and businesses and fishing would be curtailed for this run. Recovery actions would be required and could include many of the same elements as the ASRP, but they would be mandated across the basin.

Figure 7-1
No Action Change from Current



7.3.2 Expected Aquatic Species Restoration Plan Outcomes

7.3.2.1 Ecosystems and Habitats

Functioning ecosystem processes and habitats are a key factor in the long-term success of an aquatic species, which is manifested in the abundance and survival of the species. Restoration actions proposed under the range of scenarios (Section 4.2) would result in the restoration of impaired processes throughout the basin and the restoration and creation of habitat in strategic locations. These scenarios aim to build differing levels of ecosystem resiliency into the basin to combat future stressors. The following broad outcomes are projected to occur from the restoration of impaired ecosystem processes under each scenario:

- Restoration and protection of high-functioning riparian areas (that will provide large wood, nutrients to support the food web, shade, stream bank protection, and fish and wildlife habitat and migration corridors)
- Restoration and protection of high-functioning floodplain and off-channel habitats and wetlands that will improve watershed connectivity, water quality, water storage, highly productive food webs, and highly diverse fish and wildlife habitat

- Restoration of in-channel large wood to increase cover and roughness, decrease channel incision, retain and sort sediments, create deep pools, and improve channel complexity and floodplain connectivity in strategic locations
- Restoration of fish passage through current barriers to increase access to habitat that is currently inaccessible

The increased quantity, area, and spatial frequency of each of the habitats created or protected is an important outcome of restoration efforts. Expected habitat outcomes under the range of scenarios are shown in Table 7-1.

Table 7-1
Expected Habitat Outcomes

AQUATIC AND RIPARIAN ECOSYSTEMS	EXPECTED HABITAT OUTCOMES
Riparian Lands	The number of acres restored or protected would increase by 3,800 to 7,000 acres on large rivers, 5,000 to 7,100 acres on medium rivers, and 125 to 1,200 acres on small streams.
Floodplain Habitat	The number of restored or protected side channels or connected ponds would increase by approximately 200 to 500 features.
Wetland Habitat	The number of restored or protected wetlands would increase by approximately 200 to 500 features.
In-Channel Large Wood	The density of in-channel wood (jams of varying sizes per mile) would increase to approximately 12 to 18 jams on large and medium rivers, 20 to 28 multi-log clumps or beaver dam analogs, and 75 to 80 individual logs on small streams.
Aquatic Connectivity	Approximately 200 to 440 miles of currently inaccessible or partly inaccessible aquatic habitat would become accessible.
Critical Areas	Important aquifer recharge areas, cold springs, wetlands, stream-adjacent unstable slopes, and other critical areas would be identified and protected.
Unique Habitats	The number of depressional wetlands would be increased by approximately 10 sites, and the number of enhanced glacial outwash lakes would increase by approximately 5 sites.

Note:
Outcomes identified in this table were developed at specific treatment rates for costing purposes (see Appendix D for details on restoration action treatment rates) and were included as actions to support the salmonid modeling efforts.

7.3.2.2 Salmon and Steelhead

The modeling conducted for salmon and steelhead (EDT and preliminary baseline information from the NOAA model; see Appendix C) considered potential outcomes for mid-century (approximately year 2040) and late century (approximately year 2080), which allowed for incorporation of projected climate change and development effects in the basin. Several scenarios were modeled, including the following:

- Current baseline conditions
- Future No Action scenario (with climate change and development), as described in Section 7.1 and shown in Figure 7-1
- Scenario 1 (with climate change)
- Scenario 2 (with climate change)
- Scenario 3 (with climate change)

The analysis indicated the following key outcomes for salmon and steelhead:

- If no action is taken, model results project moderate to substantial declines for all salmon and steelhead species; these projected declines are so extensive that even the substantial restoration scenarios are only projected to result in modest gains over current conditions. This outcome is more dire than earlier projections and results from the climate change and other information that has been incorporated into the modeling.
- Scenario 1 would generally halt the potential declines in habitat capacity (represented by equilibrium abundance) that would begin to occur from climate change in the mid-century time frame and result in modest gains over current levels for coho salmon, spring-run Chinook salmon, chum salmon, and steelhead in mid-century and also sustain coho, spring-run Chinook salmon, and steelhead populations by late century (Figures 7-2 through 7-6). However, when compared to the future with the No Action scenario, Scenario 1 would provide moderate to substantial gains to all salmon species and steelhead by both mid-century and late century.
- Scenario 2 provides additional modest benefits beyond the Scenario 1 projections for coho salmon, chum salmon, and steelhead in mid-century and late century. Scenario 2 includes important smaller sub-basins that historically produced healthy runs of coho salmon, chum salmon, and steelhead. When compared to the future with the No Action scenario, Scenario 2 would provide modest additional gains to coho salmon, chum salmon, and steelhead by both mid-century and late century.
- Scenario 3 provides additional more substantial gains for coho salmon, spring-run Chinook salmon, chum salmon, and steelhead in mid-century and late century. Scenario 3 also increases spatial diversity for coho salmon, fall-run Chinook salmon, and steelhead. When compared to the future with the No Action scenario, Scenario 3 would provide substantial gains for coho salmon, spring-run Chinook salmon, chum salmon, and steelhead in mid-century and late century.
- EDT model projections for all three restoration scenarios indicate that fall-run Chinook salmon may experience an overall decline in both mid- and late century when compared to current

levels. However, when compared to the future with the No Action scenario, Scenario 1 provided appreciable gains by late century, while Scenarios 2 and 3 show slight or modest gains. This outcome needs further investigation; it is possible there is a modeling limitation that is affecting fall-run Chinook salmon more than spring-run Chinook salmon, and when compared to other species, the scenarios may not as successfully target fall-run Chinook salmon habitats and performance. This issue will be explored in more detail in the next phase of ASRP development.

- Modeling results do not account for harvest impacts on wild stocks. Ongoing harvest would reduce these potential outcomes. The ASRP does not include recommendations for harvest, which are under the authority of the fisheries co-managers.
- Modeling results account for changes in freshwater due to climate change but not changes to ocean conditions. In addition, the effects of non-native species on salmonids are minimally addressed by the EDT modeling. Non-native species could exert a much larger negative influence than understood at this time, both for current and future conditions.
- It is also important to note that equilibrium abundance is only one measure of salmonid population viability. Productivity and spatial and life history diversity are very important components that contribute to the long-term sustainability and resiliency of a population. Scenarios 2 and 3 aim to bring these factors into the restoration plan by restoring additional areas of the basin that could be highly productive (lowland, low-gradient streams with wide floodplains and beaver ponds) and are distributed throughout the basin. One of the key concerns with spring-run Chinook salmon is that their spatial distribution is so narrow that an extreme weather event could destroy an entire year class of fish. Providing high-quality habitats and refugia for all of the aquatic species of interest across the wide diversity of ecological regions in the basin provides much greater certainty of the long-term sustainability of the species.
- The modeling results are for wild fish. Restoration of habitat is also likely to benefit hatchery fish, but this is not accounted for in the results.
- Modeling results are based on the assumption that restoration actions are implemented immediately. As it will take 20 or more years to implement the ASRP, additional actions could be required to actually achieve the projected scale of results.

It is important to note that the ASRP aims to restore and protect aquatic species habitat and ecosystem resiliency; thus, increasing hatchery production in the Chehalis Basin is not a mechanism to achieve those goals. Hatcheries are a point source solution to production of a specific species, while habitat restoration is a much larger, integrated solution to a wider set of issues. Similarly, while restricting harvest of salmon and steelhead could result in improved escapement of wild fish, it does not address the limiting factors in the watershed that are significantly affecting salmonid productivity now and into the future.

Figures 7-2 through 7-6 show the EDT model-projected habitat capacity outcomes for the salmonid runs, shown as equilibrium abundance.

Figure 7-2
Coho Salmon Projected Habitat Capacity Outcomes

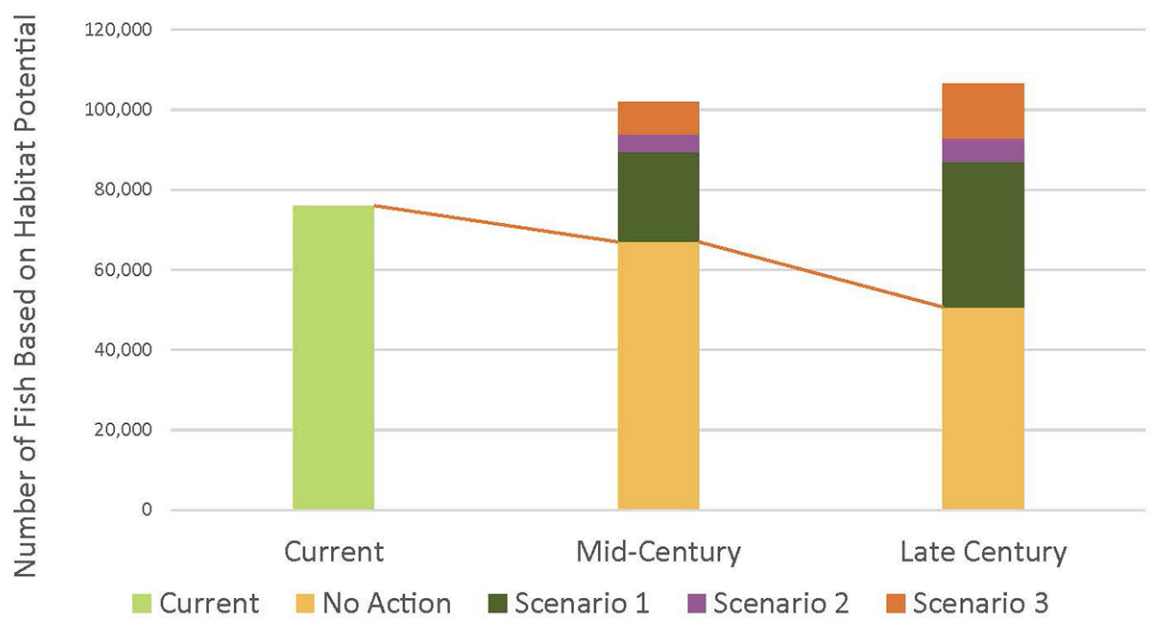


Figure 7-3
Chum Salmon Projected Habitat Capacity Outcomes

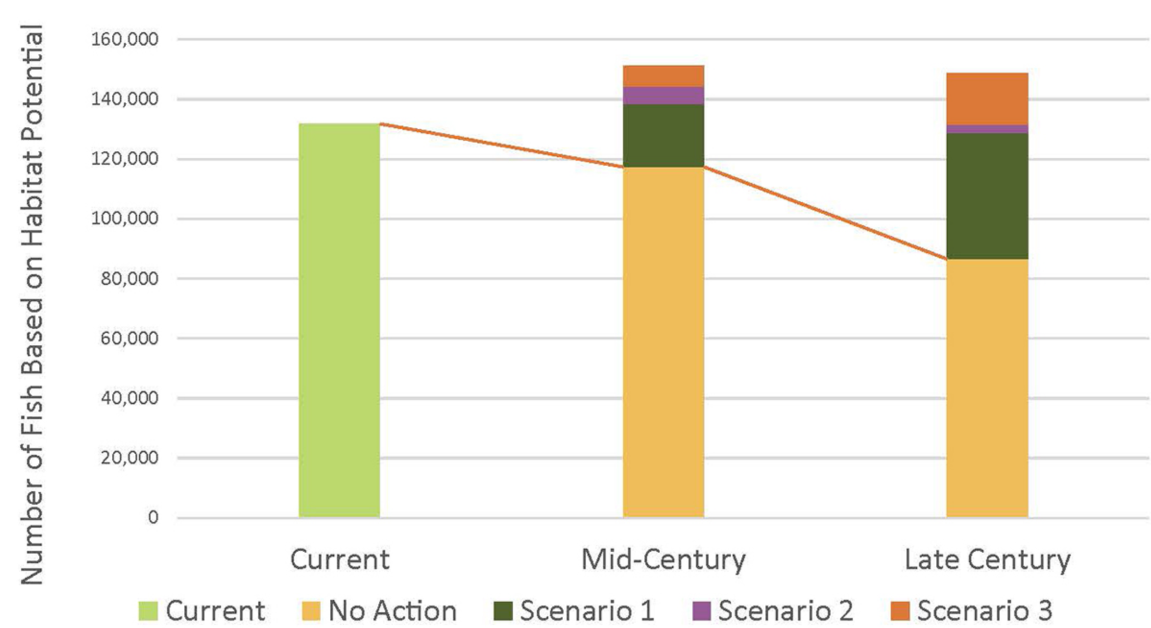


Figure 7-4
Spring-Run Chinook Salmon Projected Habitat Capacity Outcomes

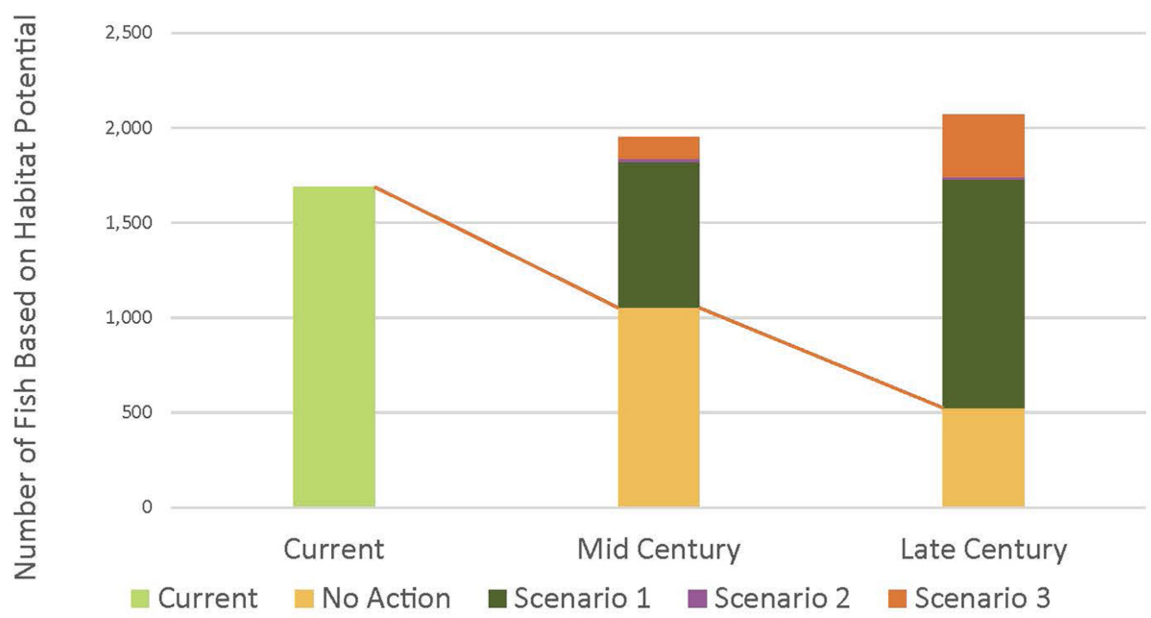


Figure 7-5
Fall-Run Chinook Salmon Projected Habitat Capacity Outcomes

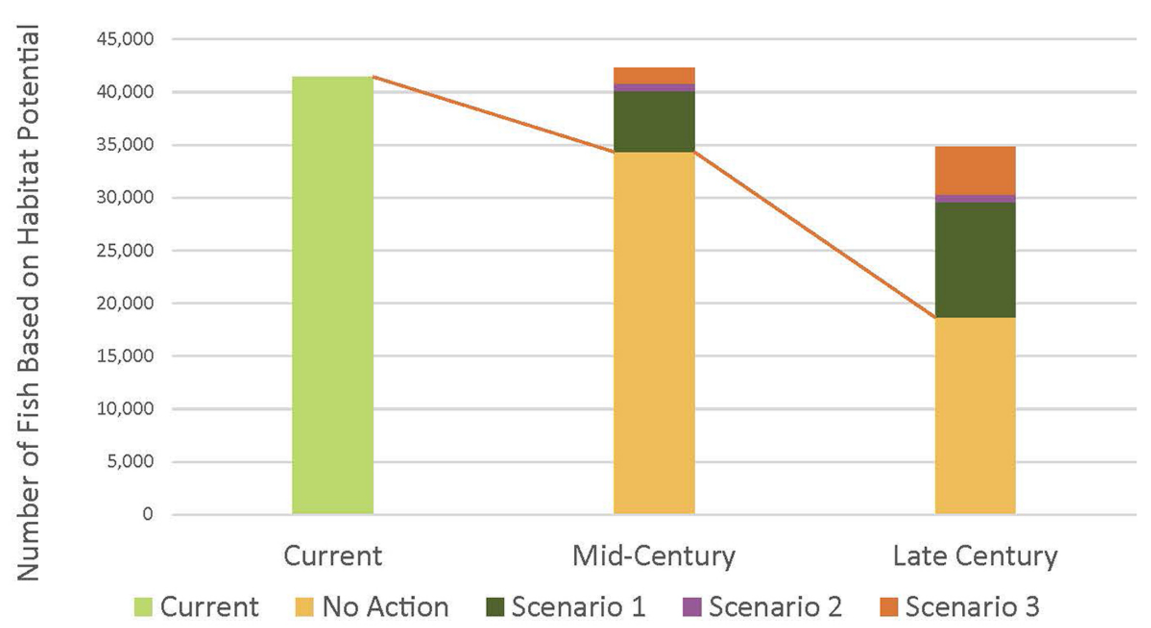
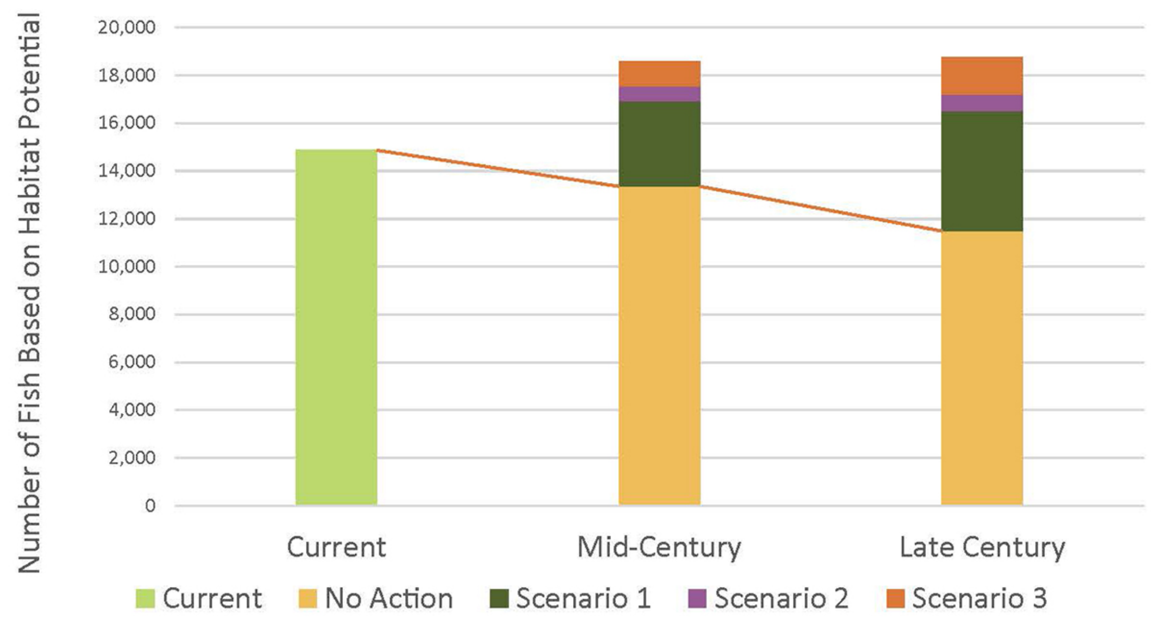


Figure 7-6
Steelhead Projected Habitat Capacity Outcomes



7.3.2.3 Other Native Species

The outcomes for aquatic species other than salmonids have not been quantified to the same extent at this time because there is much less information available about these species. An Amphibian Occupancy Model (Holgerson et al. 2019) was developed to identify which features associated with off-channel habitats influence the occupancy (positively, negatively, or no effect) of native stillwater-breeding amphibians and which can then be used to guide restoration. It is not a population model.

The restoration and protection actions in this document are likely to result in substantial positive outcomes for the range of aquatic species within the ASRP, building on resiliency throughout the system for all native species that use the basin. These outcomes will be assessed as part of the M&AM Plan for the ASRP. Monitoring will include investigating how salmonid-targeted restoration actions affect other native aquatic species. Of particular note, Oregon spotted frog has different habitat requirements than many of the other native aquatic species, using perennial emergent marshes with warmer water temperatures. These habitats are particularly susceptible to colonization by non-native fishes and bullfrogs, so these habitats will require more active protection to ensure expected outcomes.

Expected outcomes for native species other than salmonids are identified in Table 7-2, based on the anticipated installation of large wood, restoration and protection of riparian areas, and reconnection and restoration of floodplain habitats, including wetlands. Because data are limited relative to populations of these other species, outcomes in Table 7-2 should be interpreted as general outcomes for the scenarios.

Table 7-2
Expected Outcomes for Native Species from Restoration Scenarios

NATIVE FRESHWATER FISH	EXPECTED OUTCOMES
PACIFIC LAMPREY AND OLYMPIC MUDMINNOW	
Abundance	Densities of individuals in occupied sites would be maintained or increased; additional restored sites would be occupied.
Spatial Distribution	The number of occupied sites would be maintained or increased; fish passage barrier removal would provide access into currently inaccessible areas from 200 to 440 miles of additional habitat.
Habitats	Restoration actions would increase large wood for sediment retention and sorting; pool formation and hydraulic diversity are hypothesized to improve spawning and larval habitat for Pacific lamprey. Reconnection and enhancement of off-channel habitats and riparian/wetland communities are hypothesized to improve habitats for Olympic mudminnow.
BULL TROUT, CUTTHROAT TROUT, EULACHON, MOUNTAIN WHITEFISH, LARGESCALE SUCKER, RIFFLE SCULPIN, RETICULATE SCULPIN, AND SPECKLED DACE	
Spatial Distribution	The number of occupied sites and sub-basins would be maintained or increased.
Habitats	Restoration and protection actions to remove fish passage barriers, protect cold-water inputs, reduce water temperatures, and increase large wood, restore riparian areas, and reconnect floodplains are hypothesized to improve spawning, rearing, and holding habitats for all these native fish species.
AMPHIBIANS AND REPTILES	**EXPECTED OUTCOMES**
OREGON SPOTTED FROG	
Spatial Distribution	The number of Oregon spotted frog-occupied, secured, and managed freshwater wetlands would be increased.
Capacity	The area of suitable Oregon spotted frog freshwater wetlands and occupied sites would be increased.
Habitats	Protection and restoration of perennial freshwater marsh habitats are hypothesized to improve habitat for Oregon spotted frog.
WESTERN POND TURTLE	
Spatial Distribution	The ASRP program will work in cooperation with proposed reintroduction efforts at the state level to restore one or more suitable pond and/or off-channel habitats for reintroduction of Western pond turtle.
WESTERN TOAD	
Abundance	The densities of Western toad would increase in multiple instream habitats.
Spatial Structure	The number and total area of occupied sites would increase.
Habitats	Restoration actions including installation of large wood to promote channel migration and formation of shallow margin habitats and early successional riparian areas are hypothesized to increase the quantity and quality of habitats for Western toad.
NORTHERN RED-LEGGED FROG, LONG-TOED SALAMANDER	
Abundance	The densities of these species would increase in multiple off-channel habitats.
Spatial Structure	The number and total area of occupied sites would increase.
Habitats	Restoration actions including installation of large wood to promote channel migration and formation of (and seasonal connectivity of) off-channel habitats are hypothesized to increase the quantity and quality of habitats for these species.

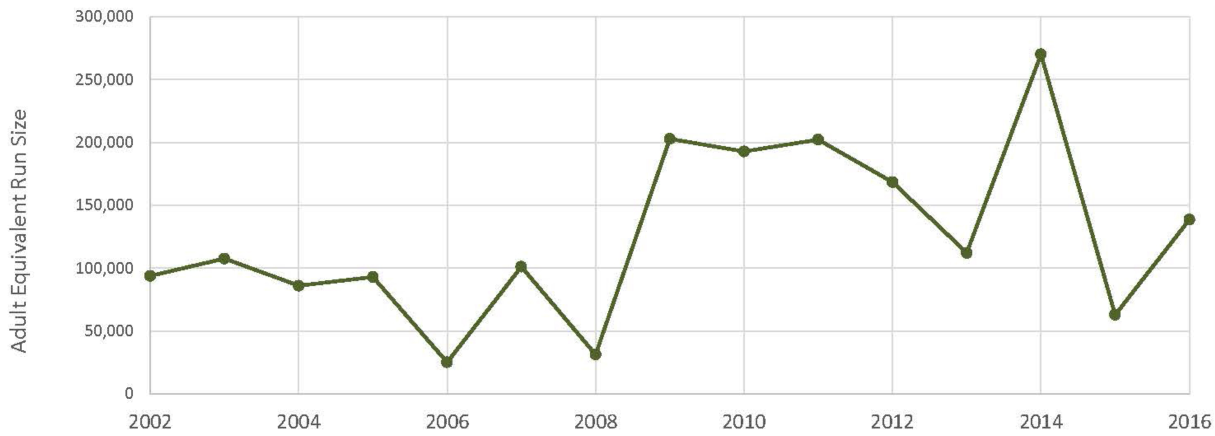
COASTAL TAILED FROG, VAN DYKE'S SALAMANDER	
Abundance	The densities of these species would increase in multiple headwater instream habitats.
Spatial Structure	The number and total area of occupied sites would increase.
Habitats	Restoration actions including protection of forest canopy and installation of wood to promote groundwater connectivity are hypothesized to increase the quantity and quality of habitats for these species.
NORTH AMERICAN BEAVER	
Abundance	The number of beaver-occupied reaches would increase.
Spatial Distribution	The locations and total area of beaver-occupied site would increase.
Habitats	Restoration actions including riparian and floodplain restoration are hypothesized to increase the quantity and quality of habitats for beaver.
INVERTEBRATES	**EXPECTED OUTCOMES**
WESTERN RIDGED MUSSEL	
Spatial Distribution	The number of Western ridged mussel-occupied and protected reaches would increase.
Habitats	Restoration actions such as installation of large wood to promote natural processes are hypothesized to increase the suitability of habitat for Western ridged mussels.

7.4 Uncertainty and Variability

Uncertainties and variability are inherent in ecosystem restoration. This stems from the complexity of natural systems, the limitations of current knowledge and simulation tools, and the inability to control all external factors. The recommended ASRP actions were developed with an understanding that adaptive management will be essential to respond to unavoidable uncertainty and variability factors. Through adaptive management, the uncertainty level can be expected to decrease and the ability to build system resilience to natural variability should increase. (Refer to the *Scientific Foundation* in Appendix A for additional detail on the high degree of natural variability and uncertainty in restoration planning.)

Variability is large in watershed and ecological processes. Examples include extreme flow and weather events, episodic events such as landslides that affect channel conditions, and ocean conditions that fluctuate widely. All of these can influence biological responses, such as salmon performance, making them subject to large fluctuations. As an illustration, the graph in Figure 7-7 shows how the coho salmon population has fluctuated from year to year in the basin in the recent past. This variability, whether caused by natural or unnatural influences, needs to be considered when assessing how well ASRP restoration goals and the vision are being achieved. Although the EDT model simulations produce specific expected outcome numbers for each restoration scenario, actual year-to-year salmon numerical performance will vary substantially because of the variability inherent in watershed and ecological processes and climatic conditions.

Figure 7-7
Illustration of Variability in Populations



Numerous uncertainties in the ASRP planning process have been reduced over the last few years through data gathering and modeling efforts. Additional uncertainties will be reduced through ongoing data gathering, additional modeling, and the M&AM program, which will be developed in Phase 2 of the ASRP. However, significant uncertainties will remain and need to be engaged through experimental and adaptive restoration design, as described in the following text.

Major remaining ASRP uncertainties include the following:

- Biological and physical responses of native aquatic species to restoration actions
- Scale and timeline for voluntary participation of public and private landowners
- Scale and timeline for ASRP implementation funding
- Potential confounding effects from invasive plant and animal species
- Impacts from future climate conditions, including their effects on ocean conditions
- Impacts from external factors, such as ocean conditions, that affect survival rates
- Limitations in modeling data, assumptions, and simulations
- Future human population growth and development in the basin

Uncertainty around the implementation timeline is an extremely important factor. The EDT simulations assume that all restoration actions are constructed and fully functioning on day 1. Riparian areas are assumed to be partially functioning on day 1 to represent their growth and maturation over a 40-year period or longer. In reality, restoration implementation will occur incrementally over a period of 20 years or more, meaning restored habitats will not be functioning for quite a while. Following construction, restoration function may take a decade or more to mature, especially for floodplain projects where vegetation growth must occur (Roni et al. 2019).

Perhaps the largest uncertainty the ASRP faces is around private and public landowner willingness and funding. Significant implementation delays, caused by lack of access to land for restoration sites or lack of funding to acquire land and construct restoration projects, compounds the uncertainty to achieve the modeled outcomes at mid- and late century because the effects of climate change and land use development will increase the degradation of aquatic resources. The bottom line is that the longer the time frame for ASRP implementation is, the longer it will take to achieve the outcomes presented in this ASRP Phase 1 document.

Uncertainties around non-native invasive animal and plant species are significant and will need to be engaged through experimental and adaptive restoration design. Non-native invasive species may confound restoration efforts, and based on current knowledge, selected restoration actions designed for native species are suspected to benefit some of the non-native invasive species. The fundamental unknown is that subtle aspects of the restoration actions proposed in the ASRP may benefit native species more than invasive species, and some may benefit native species to the detriment of invasive species, but knowledge of those subtleties is limited. The significance of invasive species impacts is expected to increase with warming associated with future climate conditions and should be a major focus for monitoring, experimental restoration designs, and adaptive management.

The following example is provided as an illustration of the complexity of this topic. Occupancy modeling for amphibians has indicated that the design and maintenance of long- and short-hydroperiod habitats will benefit different sets of amphibians while seasonally eliminating the production and/or entry of invasive fishes and bullfrogs. That knowledge is not the same for the native fishes because those fishes must occupy some aquatic habitat continuously; they cannot escape onto land (like amphibians), nor can any of the species (to current knowledge) cocoon in refugia. Emergent vegetation that reduces the negative effect of invasive fish species on amphibians may also benefit native fish species, but that pattern is also uncertain. Better knowledge of native fish refugia in both space and time is needed. Clearly, exploration in the area of what restoration actions will work best for native fishes in the presence of invasive fishes needs to be addressed so that protection and restoration for native fishes can be effectively accomplished.

Additional uncertainties are described more fully in the *Scientific Foundation* (Appendix A).

8 COST ESTIMATE

For this ASRP Phase 1 document, cost estimates were developed for the actions identified in Section 4, including restoration, protection, planning, institutional, and community involvement. The Steering Committee and SRT reached agreement on the approach for developing unit costs and general levels of treatment for the various restoration actions to significantly improve function. The restoration costs are the largest cost component of the ASRP and have been developed with additional input and review by the SRT. The other costs are preliminary and will be developed in greater detail during Phases 2 and 3 of the ASRP development. The estimated costs are intended to encompass the likely range of investment to achieve the outcomes for the ASRP scenarios, based on conducting substantial restoration activities throughout the Chehalis Basin. Descriptions of the costs for the major strategies and actions are summarized in Sections 8.1 and 8.2. More detail is provided in Appendix D.

It is important to note that these cost estimates have been prepared using current (2019) dollars and do not account for price inflation. Thus, the cost estimates have also been prepared using a wide cost range, from typically lower unit costs to a higher end of unit costs, in order to avoid underestimation of the total potential capital costs that could occur over 20 years or more. For example, cost savings could be achieved by using volunteer labor for riparian plantings, but these cost estimates currently assume commercial planting contractors would purchase and install all plantings.

8.1 Capital Costs

8.1.1 Restoration Costs

Restoration unit costs were developed based on the range of bid estimates and actual costs from recently constructed similar restoration features in Western Washington, particularly in rural areas and the Chehalis Basin, where available. The unit costs include restoration element construction, easement or land acquisition purchase, design, permitting, sales tax, and a contingency percentage. The unit costs were then applied to the actions and an average rate of treatment for each feature (as shown in Table 4-3). Restoration treatment rates (or densities) were developed for three size classes of rivers in coordination with the SRT, based on scientific literature and GIS analysis of Chehalis Basin characteristics, resulting in recommendations to achieve habitat, water quality, and other functions and natural wood loading rates.

The range of costs for each restoration scenario is shown in Table 8-1. Restoration of riparian corridors represents the biggest contributor to the restoration costs, as this is the largest element of the scenarios that would occur across several thousand acres of the basin. Riparian restoration includes pre-construction management of invasive species, plantings, short-term maintenance, and the purchase of lands or easements. Associated standard design and construction costs such as mobilization, clearing, and erosion control, along with design and permitting costs and an added contingency (typical for early project planning phases), are also major elements of the restoration costs and are necessary for the implementation of restoration projects. Table 8-2 provides more detailed costs per element for each restoration scenario.

The following key points should be considered when comparing the scenarios:

- No cost estimate has been developed for the No Action scenario. There could be substantial costs or lost revenue resulting from a possible ESA listing of one or more salmonid species in the basin that could require many of the proposed elements of the ASRP to recover a listed species, but with added regulatory restrictions and permitting hurdles. With no action, continued declines of salmonid runs would almost certainly lead to further reductions in commercial and recreational fisheries, as well.
- Cost estimates have been developed using a range of low to high unit costs. This is intended to account for future price escalation and likely variability of actual construction costs in more urbanized versus rural areas. It is important to note that the low end of cost estimates is very optimistic because it uses the lower end of material costs and land acquisition costs across the board; the average and high cost estimates are more likely to account for price variability and price escalation over time. If volunteer labor or donated materials are utilized, pricing could be less expensive for some projects.
- The restoration costs are based on the current stage of planning and could change for the final ASRP.
- Final sequencing and timing of restoration actions has not yet been developed (refer to Section 6 for the Implementation Plan framework), but capital investment dollars would not need to be appropriated in a single biennium and would likely occur over several biennia. More detailed analysis of inflation and price escalation will be included in the final ASRP.

Table 8-1
Range of Costs for Restoration Scenarios

RESTORATION SCENARIO	MILES OF CHANNEL RESTORED	RIPARIAN AND FLOODPLAIN ACRES RESTORED	COST RANGE		
			LOW	AVERAGE	HIGH
Scenario 1	222	9,027	$289,000,000	$439,000,000	$604,000,000
Scenario 2	316	10,245	$368,000,000	$547,000,000	$745,000,000
Scenario 3	450	15,323	$547,000,000	$812,000,000	$1,104,000,000

Note: Costs use 2019 dollars and do not account for price escalation over time. The cost ranges from low to high reflect material pricing and land acquisition costs under current conditions; the cost ranges do not reflect differing intensities of restoration.

Table 8-2
Cost Elements of Restoration Scenarios

RESTORATION ELEMENTS	COST RANGE[1] LOW	HIGH
SCENARIO 1		
Large Wood	$40,500,000	$65,400,000
Riparian Plantings	$62,200,000	$90,000,000
Riparian Easements/Acquisitions and Habitat Protection Acquisitions	$30,600,000	$124,700,000
Off-Channel Restoration	$12,600,000	$26,300,000
Excavation for Large River Nodes	$6,000,000	$10,500,000
Structure Removal/Relocation	$6,000,000	$11,900,000
Fish Passage Barrier Removal/Replacement	$45,000,000	$45,000,000
Associated Design and Construction Costs[2]	$86,500,000	$229,900,000
TOTAL	**$289,400,000**	**$603,700,000**
SCENARIO 2		
Large Wood	$58,400,000	$93,800,000
Riparian Plantings	$70,500,000	$101,900,000
Riparian Easements/Acquisitions and Habitat Protection Acquisitions	$35,900,000	$142,600,000
Off-Channel Restoration	$14,800,000	$30,600,000
Excavation for Large River Nodes	$6,000,000	$10,500,000
Structure Removal/Relocation	$8,000,000	$16,000,000
Fish Passage Barrier Removal/Replacement	$67,500,000	$67,500,000
Associated Design and Construction Costs[2]	$107,300,000	$281,700,000
TOTAL	**$368,400,000**	**$744,600,000**
SCENARIO 3		
Large Wood	$83,800,000	$133,800,000
Riparian Plantings	$106,100,000	$153,500,000
Riparian Easements/Acquisitions and Habitat Protection Acquisitions	$54,100,000	$215,400,000
Off-Channel Restoration	$18,300,000	$38,200,000
Excavation for Large River Nodes	$12,400,000	$21,800,000
Structure Removal/Relocation	$11,500,000	$22,900,000
Fish Passage Barrier Removal/Replacement	$101,300,000	$101,300,000
Associated Design and Construction Costs[2]	$159,700,000	$417,500,000
TOTAL	**$547,200,000**	**$1,104,400,000**

Notes:
1. Costs use 2019 dollars and do not account for price escalation over time. The cost ranges from low to high reflect material pricing and land acquisition costs under current conditions; the cost ranges do not reflect differing intensities of restoration.
2. Associated design and construction costs include standard construction elements such as erosion control, water diversions, mobilization/demobilization, sales tax, permitting, design, construction management, and contingency.

8.2 Ongoing Biennial Costs

In addition to capital costs for implementing the restoration elements of the ASRP, there will be substantial ongoing biennial costs for implementing the community planning, institutional capacity, community involvement, and habitat and process protection strategies (see Appendix D for additional details). Also, restored areas will require ongoing and periodic maintenance and stewardship. It is anticipated that some of these costs, over time, will become part of the operating budgets of various agencies and other organizations, and they could also be supplemented by grant funding or other fundraising efforts. However, at this time, to ensure the ASRP goals are achieved and maintained over the long term, ongoing stewardship funding will be required.

8.2.1 Monitoring and Adaptive Management Costs

A detailed M&AM Plan will be developed for the final ASRP, but for this ASRP Phase 1 document, the M&AM Team has recommended a preliminary range of costs of $4 million to $6 million for the 2021–2023 biennium after construction of the first restoration elements is complete. It is expected that monitoring would likely be more intensive for the first 10 or more years of ASRP implementation, with a reduced frequency of monitoring occurring in later years. However, species population monitoring would continue through the life of the ASRP to document if the anticipated scale of benefits expected are occurring. The adaptive management process will guide the implementation, monitoring, and possible further actions that could be required to ensure the success of the ASRP. Costs will be refined for full implementation of the M&AM Plan in the final ASRP.

8.2.2 Stewardship and Maintenance Costs

It is anticipated that multiple entities would own and manage the easements and lands acquired to implement the ASRP, including local land trusts, counties, tribes, and Washington State. Ongoing management and stewardship of these lands will be required, such as invasive species management, fencing, trash removal, and other maintenance activities. For other restoration features, such as replaced culverts or bridges, inspections and maintenance would need to be conducted periodically. Inspection of replaced culverts and bridges and periodic debris removal and minor repairs is estimated at $350,000 per year. Stewardship and maintenance costs will vary depending on the acreage acquired and quantity of other restoration features installed. Large wood structures typically function for 25 years or more and, as they naturally accumulate wood, can last much longer. Some maintenance or replacement of wood may be necessary in the future before riparian zones mature sufficiently to contribute large wood, but this has not been quantified at this time. Additionally, some activities, such as invasive species management, could be more intensive early on and could decline over time, whereas other costs could be unpredictable based on repairs needed after a major flood. For this ASRP Phase 1 document, invasive plant management costs have been estimated to total $1 million in the first biennium and $2 million in the second biennium. These costs will be refined for the final ASRP, including amortization of costs over the life of the ASRP.

8.2.3 Protection Costs

The protection strategy includes several potential elements that will help protect water quality and quantity, habitats, and watershed processes. Protection could occur via actions such as the transfer of development rights, purchase or transfer of water rights, tax abatement or other incentives to landowners to provide stewardship of forest and floodplain habitats, or acquisition of easements or lands to protect high-quality habitats and functions. In addition, staff time at basin jurisdictions (e.g., cities, counties) could be increased and funded through the ASRP to ensure floodplain and critical area requirements are enforced consistent with the ASRP. For this document, $3 million on a biennial basis is proposed. More details on the costs for this strategy will be developed for the final ASRP.

8.2.4 Community Planning, Institutional Capacity, and Community Involvement Costs

The community planning, institutional capacity, and community involvement strategies will support the Chehalis Basin communities by supporting staff to ensure consistency with the ASRP through integration of comprehensive plans and ordinances, development of sustainable economic programs (i.e., particularly agricultural and forestry programs) through a grant program, streamlining of state and local permitting, and provision of tax incentives and grants to foster local organizations to add capabilities to manage and monitor natural resources consistent with the ASRP. The anticipated costs for these types of actions are estimated at $4.5 million per biennium.

8.2.5 Summary of Ongoing Biennial Costs

Table 8-3 summarizes the potential ongoing biennial costs for the ASRP. Regardless of which ASRP scenario is ultimately selected, the ongoing costs would be largely similar, except for the potential for reduced stewardship costs for a smaller number of acres restored. More detailed costs will be developed in coordination with local jurisdictions and organizations for the final ASRP. Not all these biennial costs would continue for the lifetime of the ASRP; they could be one-time, periodic, or continuing costs.

Table 8-3
Summary of Ongoing Biennial Costs

STRATEGY	BIENNIAL COST	TIME PERIOD
Restoration Capital Costs[1]	$30M to $75M[2]	Estimated at 15 biennia
Restoration (Monitoring)	$4M to $6M	Up to 10 years, then reduced over time
Protection	$3M	For 10 biennia
Community Planning, Institutional Capacity and Community Involvement	$4.5M	Up to 4 years, then reduced over time
TOTAL	**$41.5M to $88.5M**	**$34M to $80M over time**

Notes:
1. Cost for implementing restoration scenarios
2. Cost range for average to high scenario costs across 15 biennia

9 MEASURING SUCCESS

9.1 Monitoring and Adaptive Management Process

The ASRP is a "living" plan, meaning it is intended to be updated, refined, and adaptively managed through time. An essential step toward adaptive management will be the completion of the M&AM Plan. The M&AM Plan will document how the ASRP will measure success of habitat restoration and protection of aquatic species, as well as inform and update project implementation to the learnings from ongoing adaptive management.

The *M&AM Framework* in Appendix B outlines the pathway to develop a comprehensive M&AM Plan as part of the ASRP. As developed for Phase 1 of the ASRP, the *M&AM Framework* includes sampling programs that strategically monitor ASRP efforts at different scales. Implementation monitoring will track project actions to ensure they were built as designed and intended. This type of monitoring is typically required for permit compliance. Project effectiveness monitoring will take implementation monitoring to the next level by evaluating whether the habitat and biological outcomes for each project were achieved on site. This type of monitoring will happen at a subset of locations where projects have been constructed. Finally, status and trends monitoring assesses the overall condition of the physical, biological, and chemical characteristics of the basin. This monitoring program will use a mix of random and fixed sample sites to understand both the spatial and temporal trends at the watershed scale.

When fully developed, the M&AM plan will include implementation strategies for each program as well as relevant protocols. The ASRP will utilize strategic monitoring at relevant spatial scales to understand the implementation successes of restoration and protection projects, as well as habitat benefits realized at a watershed scale. This information, along with lessons learned from landowner willingness on early implementation, will help the Steering Committee learn from early implementation and adapt to better direct, fund, and manage ongoing implementation. In addition, information from monitoring and its use in adaptive management will help the Steering Committee communicate the impacts, successes, and learning from ASRP implementation to the Chehalis Basin Board, key constituents, and outside groups looking to set up similar processes for habitat restoration throughout the region.

9.2 Process for Updating the Aquatic Species Restoration Plan

The ASRP will be updated and refined based on comments received during the public comment period after Phase 1 release in the fall of 2019. Comments collected through the public comment period will be compiled and reviewed to inform the next phase of development of this plan. In the current biennium, the ASRP will be fully developed and integrated with the other elements of the Chehalis Basin Strategy. After the Phase 3 ASRP is released, the Steering Committee and relevant technical advisory teams will work to update best available science as data gaps are researched, as well as document how management of the ASRP adapts and evolves through full implementation of the plan. Recurring (approximately annual) ASRP symposia and ongoing outreach events will provide forums to share best available science as it develops and allow for structured feedback points with implementers, key constituents, and landowners. The Steering Committee will release updated ASRP documents when priorities and implementation evolve enough to warrant the documentation of an adapted approach to integrated restoration and protection of aquatic species of the Chehalis Basin.

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Appendix A
Scientific Foundation for the Aquatic Species Restoration Plan

1 INTRODUCTION

> A central premise of the ASRP approach is that protecting or restoring **all** ecological regions to some degree is important to achieve the ASRP's vision, though restoration needs are not equal across all regions.

This document describes the Scientific Foundation used to develop the Chehalis Basin *Aquatic Species Restoration Plan* (ASRP). The Scientific Foundation encompasses the science-related principles, assumptions, concepts, and approaches used to develop the scientific conclusions that inform the ASRP decision-making process. Some of these are derived from research and monitoring specific to the Chehalis Basin, and some are derived from the more widespread body of scientific research. This document also presents the rationale for various parts of the plan and helps to ensure the plan is credible and effective.

This Scientific Foundation was developed recognizing the long-term vision of the ASRP for the Chehalis Basin: to utilize the best available scientific information to protect and restore habitat in the Chehalis Basin, in order to support healthy and harvestable salmon populations, robust and diverse populations of native aquatic and semi-aquatic species, and productive ecosystems that are resilient to climate change and human-caused stressors, while honoring the social, economic, and cultural values of the region and maintaining working lands.

The ASRP is based on the premise that ecological processes and functions within the Chehalis Basin can be protected and restored to meet this long-term vision by supporting and sustaining productive, diverse populations of native aquatic and semi-aquatic species. To be successful and accepted, the ASRP must be based on sound science. It must set appropriate priorities, incorporate successful strategies and actions, be appropriately scaled, and be fully implemented to meet the vision, even in the face of climate change.

Restoration cannot result in the same conditions that existed prior to large-scale human-caused watershed changes that began in the mid- to late-19th century, but it can achieve the vision by restoring ecological processes and functions to a "sustainable high-functioning condition"—that is, a partially restored state exhibiting the norms of conditions needed to support and sustain productive native species assemblages. For example, for salmon species this means that the range of life histories that were adapted to the basin prior to extensive habitat alterations would be supported and sustained at levels that ensure species viability and deliver ecosystem services. Under these conditions, natural and cultural elements would be integrated, supporting diverse native aquatic populations while society's present uses of the watershed continue, although not without modification (Liss et al. 2006). The specific mix of natural and cultural elements to be achieved is to be defined through policy-driven goals and objectives.

While the ASRP is called a restoration plan, protection of ecosystem processes and aquatic habitats is a vital part of the plan. For brevity, therefore, use of the word "restoration" in this document often refers to both restoration and protection. Also, for brevity, the word "salmon" refers to all species of anadromous salmonids; similarly, reference to "aquatic species" includes semi-aquatic species.

2 FOUNDATIONAL PRINCIPLES

The scientific principles on which the ASRP is based are grouped into the following two sets:

- Principles that govern scientific practice and the pursuit of knowledge necessary for developing, evaluating, and updating the ASRP (Section 2.1)
- Fundamental conservation principles of fish conservation and restoration ecology (Williams 2006) and the scientific literature associated with habitat restoration (Section 2.2)

2.1 Principles for Scientific Practice

For the ASRP to succeed, it must be based on the best available science. Moreover, that science needs to be understandable, credible, and relevant to the many participants engaged in development, management, and future updates of the ASRP. Relevant science is not done in a vacuum. The challenges of reversing declines of native aquatic species, then restoring them, require advancing scientific understanding of the factors that affect those species. That improved knowledge becomes relevant and useful to society as the public and governance accept it. Science and policy processes, working together, are essential for effective, sustainable management of natural resources (Lee 1993; Bocking 2006).

Principles for scientific practice within the context of the ASRP include the following:

- **Linkage Between Recommendations and Scientific Support:** Findings and recommendations must be transparent and supported by available data and the best available science determined through peer review or other credible processes.
- **Need to Identify Assumptions:** Assumptions must be clearly stated, along with information indicating their likely validity and impacts on findings and recommendations.
- **Need to Identify Uncertainties:** Uncertainties must be disclosed and addressed, including their potential consequences.
- **Criteria for Evaluating Effectiveness:** Criteria and measures to evaluate the effectiveness of the restoration plan (or its components) need to be provided. A Monitoring and Adaptive Management (M&AM) program will address this for the ASRP.
- **Time Frames for Outcomes Made Explicit:** Expected outcomes, including the time frame for restoration actions to become fully functional, need to be made explicit.

2.2 Conservation and Restoration-Related Principles

Conservation and restoration-related principles address restoration-focused concepts for aquatic ecosystems like the network comprising the Chehalis Basin. These principles, while especially applicable to migratory species like salmon, are also relevant to a broader suite of native aquatic species in the Chehalis Basin. The principles were largely developed for application to restoration planning in the

Columbia River system, but they are just as applicable for aquatic system restoration across the Pacific Northwest. The following principles are distilled from Zedler (2000), Williams (2006), and Lichatowich et al. (2017):

- **Defining the Ecosystem:** Restoration and management of wild, native aquatic species must address the ecosystem that encompasses their entire life history. This includes where life histories are affected by human development, as well as within habitats largely unaltered by humans. The ASRP addresses the freshwater portion of the ecosystem.
- **Linkage Between Life History Connectivity and Production:** Sustained production of wild, native species, such as salmon, requires a network of complex interconnected habitats, which are created, altered, and maintained by natural physical processes.
- **Importance of Diversity:** Genetic, life history, and population diversity are the basis of native wild aquatic species sustainability over time. Diversity contributes to the ability of these species to cope with variation typical of the environments they utilize (in the case of salmon, freshwater and marine environments). Habitats are the templates that organize life history traits (Southwood 1977) and similarly influence genetic structure (Waples et al. 2001). Knowledge about the genetic, life history, and population diversity needs of non-salmon species is growing but still limited at this time.
- **Viable Salmonid Population (VSP) Concept**: The VSP concept is a commonly used framework for defining the characteristics of a viable salmon population (i.e., one that has less than a 5% probability of extinction over the next 100 years [McElhany et al. 2000]). While it is often used in Endangered Species Act (ESA)-related recovery assessments for salmon, it also enables analysis of salmon populations regardless of ESA status. The VSP concept is incorporated into the ASRP to characterize performance for all salmon species in the Chehalis Basin under past, current, and future habitat conditions and applies a conceptual basis for assessing salmon performance that is widely understood and employed throughout the Pacific Northwest.
- **Public and Treaty Trust:** The participants in the ASRP have a collective legal and moral responsibility to ensure proper stewardship of wild salmon, other native aquatic species, and the aquatic environments they inhabit as part of our natural heritage.

3 FOUNDATIONAL ASSUMPTIONS

The process of building scientific knowledge invariably relies on the use of assumptions about the systems involved. Some assumptions are inferences based on well-established facts, theory, and knowledge or a body of related observations. In any scientific endeavor, all assumptions must be clearly defined and include reasoning and justifications. As long as assumptions are clearly defined, one can determine if and how they may affect outcomes. If assumptions are not stated, it can be impossible to understand why any particular outcome occurs.

The overarching assumption of the ASRP is that ecological processes and functions within the Chehalis Basin can be protected and restored to support and sustain productive, diverse populations of native aquatic species. Given this assumption, it is understood that the ASRP must be based on sound science and that a well-developed, appropriately scaled, and fully implemented ASRP can restore and protect ecological processes sufficiently to support these populations, even in the face of climate change. It is understood that such restored conditions would not be the same as those that existed prior to large-scale human-caused watershed changes that began in the mid- to late-19th century.

The premise asserts that ecological processes and functions can be restored to a “sustainable high-functioning condition”—that is, a partially restored state exhibiting the conditions needed to support and sustain productive native species assemblages. For native aquatic species, this means that the range of life histories that were adapted to the basin prior to extensive habitat alterations would be supported and sustained at levels to both ensure species survival and deliver ecosystem services. Under these conditions, natural and cultural elements are integrated, supporting diverse native aquatic populations while society’s present uses of the watershed continue, although not without modification (Liss et al. 2006).

The overarching assumption described in this section leads to 10 foundational assumptions about the past, present, and future states of the Chehalis Basin and the performance of certain native aquatic species relative to those conditions. These foundational assumptions shaped development of the ASRP and guided the selection and extent of restoration measures. Selected assumptions can be formulated as hypotheses for research questions testable as part of the ASRP. This implies that these assumptions may evolve over time as new information is developed.

The 10 foundational assumptions are as follows:

1. The viability and performance (e.g., abundance) of native aquatic species are largely controlled by habitat conditions experienced by these species across their full life histories. For salmon, this includes their life histories in freshwater, estuarine, and ocean environments.
2. In addition, abundance of native aquatic species is controlled by both the amount of suitable habitat (capacity) and by the quality of the habitat for the species (productivity). In many cases,

actions that address constraints on habitat quality will be more useful than those that address the quantity of habitats, unless the actions open access to high-quality habitat. It is imperative that streams and rivers have sufficient space to accommodate floodplains, wetlands, riparian forests, channel migration, and secondary channels. Process-based restoration is fundamentally dependent on space, as is habitat capacity and habitat quality; it must be ensured that sufficient space exists for habitat to form and change through time.

3. Salmon and selected co-evolved non-salmon species can serve as indicators of physical and biological processes operating at local, regional, and global scales affecting these species and co-evolved species. For example, habitats important to salmon species, such as streams and riparian wetlands, are critical to many other native aquatic species. It also needs recognition that some habitats, such as seeps, have non-salmon species indicators that important fish indicator species never use.
4. The abundance, productivity, and spatial distribution of salmon and non-salmon species in the Chehalis Basin have declined due to diverse environmental changes resulting from urbanization, agriculture, timber harvesting, channel and floodplain modifications, dam construction, and the spread of invasive plant and animal species.
5. Climate change in its current trajectory will affect temperature, precipitation, instream flow, and other factors that will further degrade habitat conditions and thus further reduce the abundance and survival of many native aquatic species in the Chehalis Basin. This is likely to jeopardize the continued existence of some species.
6. Based on the current approaches and patterns of human development, future human development of the Chehalis Basin will further degrade habitat conditions and further diminish the performance of native aquatic species.
7. Restoration actions, including engineering of specific environmental conditions, can improve watershed and ecological processes and attenuate the negative effects of climate change and past, current, and future development.
8. Historical conditions, when appropriately defined, provide a useful reference baseline to assess the intrinsic conditions of the Chehalis Basin defined by climate, geology, and biogeography against which to evaluate current and future habitat conditions, as well as the results of restoration actions.
9. If restoration actions are to succeed at reversing the effects of past habitat degradation and/or countering future adverse effects of climate change and new development in the basin, restoration actions will need to be extensive and effective over the long-term.
10. To be effective and long-lasting, restoration must be focused on correcting systemic causes of degradation. Restoration and protection of watershed and ecological processes at some level are essential for sustaining productive aquatic habitats that support native aquatic species in the face of continued human population growth in the basin, climate change, and proliferation of invasive plant and animal species.

4 FOUNDATIONAL CONCEPTS

4.1 Use of Potential Indicator Species

The ASRP is an ecosystem restoration plan. Given this ecosystem focus, the emphasis shifts away from assessing a single species toward the use of indicator species for assessing and monitoring the aquatic ecosystem conditions. Because it is not practical or feasible to monitor and assess all species, the use of appropriately selected indicator species addresses the problem of how to assess the condition of ecosystems, given their inherent complexity (Soule 1987; Karr 1992; Siddig et al. 2016). Indicator species are a shortcut to pursuing conservation objectives, given limited funding and time coupled with the complexities of species distributions and the various ways that different species respond to environmental change (Caro 2010).

Species that serve as useful indicators are ones that, because of their habitat utilization patterns or life histories, represent particular species assemblages or communities and indicate environmental changes or habitat conditions important to those species (McGeoch 1998; Carignan and Villard 2002; Niemi and McDonald 2004). Their use has been applied to diverse conditions, ranging from revealing patterns of pollution (Harlan 2008) to discerning patterns of spatial continuity (Rolstad et al. 2002) or species richness (MacNally and Fleischman 2004). In more recent years, indicator species have been used to monitor restoration success (Siddig et al. 2016). However, use of indicator species has also been criticized, particularly for vertebrates, based on lack of consensus of what the indicator should reveal, the difficulty in determining the best indicator (Simberloff 1998), and the inability of an indicator to reflect changes in the entire species suite of interest or having universal application (Caro 2010).

Landres et. al (1988) summarized the following eight criteria that can avoid most criticisms when using indicators:

1. Clearly state your assessment goals.
2. Use indicators only when other assessment options are not available.
3. Choose indicators by explicitly defined criteria in accordance with assessment goals.
4. Include all species that fulfill stated selection criteria.
5. Know the biology of the indicator well, and treat it as a formal estimator in conceptual and statistical models.
6. Identify and define sources of subjectivity in selecting, monitoring, and interpreting the indicator.
7. Submit assessment design, methods of data collection and statistical analysis, interpretations, and recommendations to peer review.
8. Develop an overall strategy for monitoring wildlife that accounts for natural variability in population attributes and incorporates concepts from landscape ecology.

The criteria of Landres et al. (1988) were used to develop a potential indicator species list for the ASRP. The overarching assessment goal is to identify positive changes in species responses to the ASRP's broad-based restoration effort. The ASRP avoids the further issues of having only one indicator species by identifying a suite of potential indicators under a scheme partly explained in the ASRP's precursor, the *Aquatic Species Enhancement Plan* (ASEP) drafted in 2014, where indicator species were labelled as key species (ASEPTC 2014). That scheme captured representation among all major vertebrate taxonomic groups with aquatic or semi-aquatic members except birds (namely amphibians, fishes, mammals, and turtles), and within taxonomic groups, the best representation within each guild.[1] Guilds were structured around life history similarities but often reflected systematic relationships and geographic patterns. Representation within guilds was determined from some combination of the best integrators among habitat compartments (aquatic, oceanic, or terrestrial) or their sub-compartments (pond, small river); having some local, state, or federal listing status; holding cultural or economic importance; and possessing an ability to engineer habitat (specifically, North American beaver).

The ASRP potential indicator list is more encompassing than the key species list in the ASEP in that it also includes birds species and one invertebrate (the Western ridged mussel), but the basis for potentially selecting these taxonomic groups was the same. Inclusion of the Western ridged mussel reflects a link to salmon species, on which its early life stages necessarily depend, and acts as a nod to recognizing the high importance of habitat water quality and conditions in the larger stream network.

The potential indicator species suite for the ASRP and basis for their potential selection are listed in Attachment 1. It is appropriate that the M&AM Team refine and select a suite of indicator species from the list in Attachment 1 to include in the comprehensive M&AM Plan.

4.2 Life History

Restoration activities need to consider the full life history of targeted species (Lichatowich et al. 1995). Life history is the entire developmental sequence of life stages that occur from birth through death, as they relate to survival and reproduction. Successful completion of a species' life history depends on the string of connected habitat conditions of suitable quality and quantity for each life stage at appropriate times and places. Over the course of its life history, a species encounters varying habitat conditions that ultimately determine its abundance and persistence.

Species life histories have evolved to exploit a range of expected habitat conditions. Life histories can vary greatly due to differences in where, when, and how individuals respond to environmental factors. For example, location within a species' geographic range can markedly influence variation in life history (Berven and Gill 2015).

Knowledge about the life history of indicator species like salmon in the Chehalis Basin is crucial in assessing watershed conditions and diagnosing habitat limiting factors. Habitat requirements can vary

[1] In ecology, a guild is a group of species that each exploit the same kinds of resources in comparable ways.

greatly between the life stages of a single species, as can the potential effects of habitat degradation or restoration. A species' response to degradation or restoration needs to be understood for each life stage and across its full life history.

Analytical models that include life stage responses and performance over a species' full life history can contribute to evaluating species performance in relation to degradation and restoration, and have been used to craft restoration programs for salmon species (Mobrand et al. 1997; Scheuerell et al. 2006; Thompson et al. 2009).

4.3 Population Structure

Animal populations typically are structured spatially across the landscape. This distribution reflects selection of key habitats (see the discussion about key habitats in Section 4.5) by different life stages as well as natural and artificial impediments to movement of different life stages. This structure is important to recognize in an effort like the ASRP because of implications on where the plan should focus, both for restoration and protection.

Across a geographic area the size of the Chehalis Basin, species like salmon frequently demonstrate genetic and life history variation within a single species (Waples et al. 2001, 2008) and in some cases may even exhibit multi-species differentiation, such as among torrent salamanders (Good and Wake 1992). Such differences are known to occur, for example, in river entry and/or spawning timing of both Chinook and coho salmon produced in different sub-basins of the Chehalis Basin (WDW and WWTIT 1993). This suggests that genetic differences exist among the various spawning aggregations within the Basin. The arrangement of these aggregations relative to one another (i.e., their proximity to one another and their overall distribution) is often referred to as spatial structure.

Some understanding of population structure in a basin the size of the Chehalis is essential for both conservation and management (Allendorf and Luikart 2007). The Washington Department of Fish and Wildlife (WDFW) continues to be engaged in assessing the genetic structure of the salmon species in the Chehalis Basin.

Although genetic studies are incomplete, the diverse nature of sub-basins in the Chehalis suggests that significant genetic structure should exist within the different salmon and other aquatic species. Lacking better knowledge, it is useful to recognize the differences among sub-basins based on patterns of environmental attributes such as topography, geology, flow regimes, water temperature, and other habitat characteristics (Waples et al. 2001). Distinct patterns, which exist among sub-basins in the Chehalis Basin, are informative about how ecological diversity within a basin of this size is likely to affect genetic and life history diversity. This approach is currently used in the Hood Canal watershed for recovery planning of ESA-listed summer chum salmon (Sands et al. 2009).

4.4 Viable Salmonid Population Concept

The VSP concept was developed by National Oceanic and Atmospheric Administration (NOAA) Fisheries to define the characteristics of a viable salmon population (i.e., one that has less than a 5% probability of extinction over the next 100 years [McElhany et al. 2000]). The concept provides a theoretical basis for describing salmon performance as it relates to long-term viability. In ESA-related recovery assessments for salmon, the concept serves as a framework to help determine if one or more populations should be ESA-listed and similarly when it is appropriate to delist.

The concept also enables analysis of salmon populations regardless of ESA status. It provides a useful framework to evaluate the potential of salmon populations to provide ecosystem services. As such, the concept provides a framework for analyzing potential changes in population performance in response to restoration or further habitat degradation. Analytical models are used for this purpose.

Table A-1
Definitions of the Characteristics (Parameters) Used to Assess the Performance of a Viable Salmonid Population

VSP CHARACTERISTIC OR PARAMETER	DEFINITION (MCELHANY ET AL. 2000).
Abundance	The size of the adult population, subpopulation, or other relevant demographic unit. Measured as adult spawners or total adults recruited to fisheries.
Productivity	Two definitions are used: 1) the population growth rate, which is the number of returning spawners produced per parent spawner calculated for each generation; or 2) the estimated average number of returning spawners produced per parent spawner at low population density. The second definition is also called intrinsic productivity, meaning that it is the number of surviving offspring in the absence of all competition with other members of the population.
Biological diversity	Diversity within the population in genetics, life histories, and physical traits (body size, age, run timing, migration patterns).
Spatial structure	The population's geographic distribution (population structure). Relevant distribution includes the areas of spawning and can also include the distribution of juveniles.

The four VSP characteristics (or parameters), defined in Table A-1, are all vitally important to the ASRP. Each provides needed information to evaluate how well a population can thrive; provide sustainable ecological services (such as harvest); and be resilient to environmental disturbances, land use, and climate change:

- **Abundance** is a key component of population viability**.** Small populations are at greater risk of extinction than large populations and provide fewer ecosystem services than larger ones. Both habitat quantity and quality in each life stage contribute to observed abundance. Habitat capacity, which determines maximum abundance, is the result of both habitat quantity and habitat quality (Moussalli and Hilborn 1986). This is a key concept in developing the ASRP.
- **Productivity, and specifically intrinsic productivity**, determines how rapidly a population can rebound when abundance is driven to low levels due to some form of disturbance (such as a

flood or inadvertent overharvest). Populations with low intrinsic productivity are at higher risk of extinction due to future degradation resulting from watershed development or climate change. Habitat quality, **not** habitat quantity, determines intrinsic productivity. Improvements made in habitat quality in any life stage will benefit intrinsic productivity and usually increase overall abundance regardless of the population's current status (Lestelle et al. 1996; Mobrand et al. 1997).[2]

- **Diversity** in genetic and life history characteristics provides resilience for a population to cope with short-term environmental disturbances or long-term changes over time. In this sense, these characteristics are similar to diversification in an investment portfolio—long-term success depends on this diversity.
- **Spatial structure** is a geographic analog to biological diversity (Kaje 2008; Lestelle et al. 2017) because it operates to diversify the spatial distribution of the population, protecting it against differential short- and long-term changes across the environment. Over long periods of time, diverse spatial structure leads to biological diversity through evolutionary processes. Spatial structure, which is a measurable characteristic, can therefore serve as an indicator of biological diversity, which changes slowly over time.

The VSP concept raises the following important questions for the ASRP:

- How should restoration efforts be balanced geographically to address the different VSP characteristics?
- Should efforts be aimed at increasing the performance of core production areas if restoration actions can make them even more productive?

Focusing restoration efforts in core production areas with the goal to quickly increase total salmon abundance could be an appealing idea, but this approach ignores the need to consider spatial structure of the aggregate population of the species in the Basin (termed metapopulation). Since it is important to improve both abundance and spatial structure, the ASRP is uses an approach that balances these two aspects of population performance while focusing on the core areas for spring-run Chinook salmon due to low run sizes and an elevated risk of extinction.

The ASRP approach, described in Section 5, establishes a spatial structure for the Chehalis Basin based on geological, topographical, and hydrological patterns. This structure recognizes ten ecological regions (see Section 5 of the ASRP Phase 1 document):

- Willapa Hills
- Cascade Mountains
- Middle Chehalis River
- Central Lowlands
- Lower Chehalis River

[2] There are certain situations where an increase in abundance will not occur, but this will typically not apply to this discussion.

- Black River
- Black Hills
- Olympic Mountains
- Chehalis River Tidal
- Grays Harbor Tributaries

The ASRP Science and Technical Review Team (SRT) believes that the population structure of most aquatic species is captured within this geographic organization.

4.5 Role of Habitats

In its simplest definition, the habitat of an organism is where it lives. But a more complete definition is necessary for the purposes of developing the ASRP. Habitat is the environment from the perspective of a specific species. It is a subset of environmental conditions that provides for occupancy, survival, and—at the appropriate time—reproduction by a given organism (Krausman 1999). It is the sum of all the resources needed by organisms, which include food, cover, space, and any special factors needed for survival and reproduction (Leopold 1933; Thomas 1979). These factors include chemical properties (e.g., oxygen) and temperature, among others.

Habitat requirements differ among species, even among closely related ones like salmon species. Habitat requirements also differ significantly among life stages for a single species, such as egg incubation, small juveniles, larger juveniles, and adults. The annual cycle of seasonal changes in habitat conditions often drives species- or life stage-specific patterns in habitat use.

Habitats are key determinants of species performance, and the abundance of a breeding population, such as the number of salmon that spawn in a river, is the cumulative result of all habitats experienced by the population over its full life cycle, as well as other factors (Mobrand et al. 1997).[3]

4.5.1 Habitat Formation and Degradation

Aquatic habitat in a watershed is created, maintained, and renewed by watershed processes that operate across various temporal and spatial scales (Benda et al. 1998; Waples et al. 2009; Beechie et al. 2010). Over long timescales (tens of thousands of years), glacial, fluvial, and mass wasting processes have shaped the landscape within which present-day riverine and floodplain habitats have formed (Beechie et al. 2010; Gendaszek 2011). In recent millennia, natural disturbance in watersheds due to fire, floods, and erosion have shaped the habitats and disturbance regimes to which aquatic species have adapted (Benda et al. 1998; Waples et al. 2008). Salmon life histories, for example, developed within these patterns in a watershed, resulting in life history patterns characteristic of that watershed (Stanford et al. 1996).

[3] In this case, fisheries that harvest some of the population prior to spawning can be thought of as predators, which in the strictest sense can be considered part of the habitat experienced by the population. Alternatively, the number of spawners that would be produced in the absence of all fishing would be the result of all habitat conditions (excluding fisheries) experienced over the life cycle.

With the recent more rapid alteration due to human activities, watershed processes were altered outside the range of their historic variation. Habitat conditions that had been more or less stable were changed in ways that adversely affected the abundance and survival of native aquatic species, like salmon (Beechie et al. 2003).

4.5.2 Habitat Restoration

Restoration ecology includes human efforts to restore the historical character of habitats usually with the intent to benefit specific species such as salmon. Restoration actions can deal with proximal or systemic issues in an environment. Proximal restoration attempts to restore specific local features, such as instream wood or riparian forests, that are lacking and thereby negatively affecting performance of the target species. Systemic restoration deals with the watershed processes responsible for formation and maintenance of habitat features. For example, a conclusion that the lack of large wood in a stream is detrimental to salmon might be addressed proximally by adding large wood or engineered wood structures. A systemic approach would identify the processes responsible for loss of large wood in the system, such as those resulting from logging or urbanization, and attempt to restore those processes by planting trees for long-term wood recruitment to the stream. The two approaches are not in conflict. A proximal solution can provide restoration in the short term while the longer-term systemic approach, such as restoration of riparian forests, can occur.

Process-based restoration aims to re-establish rates and magnitudes of physical, chemical, and biological processes that create and sustain the aquatic ecosystem (Beechie et al. 2010). Process-based restoration focuses on mediating anthropogenic disruptions to watershed processes, such that the river-floodplain ecosystem can adjust to ongoing human activities with minimal corrective intervention that otherwise might be needed to address specific habitat issues. This approach to restoration requires space for channel movement (to form multiple channels, wetlands, and floodplain habitats) and adjacent hillslope riparian forest, which allows the system to respond to future perturbations, such as climate change, through natural physical and biological adjustments. Such an approach is expected to enable the riverine ecosystem to evolve and continue to function through natural processes, though it would remain altered from pre-development conditions (Beechie et al. 2010).

Process-based restoration is complex. Different processes, including associated thresholds, and the strategies to restore them can require vastly different amounts of time to mature to full effectiveness, from less than a year to a century or more (Roni et al. 2002). Different strategies can also vary substantially in their effectiveness and the amount of uncertainty in projecting benefits over time.

4.5.3 Habitat Quantity, Quality, and Distribution

A basic consideration in developing a restoration plan is recognizing how habitat quantity, quality, and distribution in a watershed affect species performance. The following two questions are critical:

- Is it better to have a **greater quantity** of habitat or **higher-quality** habitat relative to the current condition?

- **Where** should habitat be restored in a watershed—for example, high in the watershed, in small streams, or within the floodplain (e.g., off-channel habitats)?

The short answer to both questions is that it depends on watershed-specific conditions. Such questions are essential to consider in developing and implementing an effective restoration plan.

It is important to recognize the differences in what is meant by habitat quantity and habitat quality. Each of these aspects of habitat has a different effect on species performance, detailed as follows:

- **Habitat quantity** is the amount of useable living space available to a species during a particular life stage. It is the living space that is selected (or used) by the species (Krausman 1999). Those physical features of the environment that are used in different life stages are often called **key habitats**. Examples for coho salmon would be the amount of spawnable area (pool tailouts and riffles) for spawners or the amount of slow-velocity water for young-of-the-year juveniles. The quantity of habitat affects the amount of competition that occurs between members of that species for the available habitat. Survival within a life stage is affected by the intensity of competition.
- **Habitat quality** is a more abstract term, but it is an essential concept to grasp. It is easiest to conceptualize with respect to a single animal (Johnson 2005). Habitat quality is defined by the characteristics of habitat that affect the probability of survival of an individual animal when competition for resources is absent. For example, fine-sediment sedimentation in spawning gravels affects all eggs even when the number of eggs is low, just as very high water temperature affects all juveniles equally when juveniles are at low abundance. Put simply, any factor that affects the survival of a species in the absence of competition among the members of the same species within a habitat is a characteristic of habitat quality. These factors can be structural (e.g., escape cover), chemical (e.g., toxic pollutant), thermal (e.g., water temperature), or biotic (e.g., invasive predator). All of these can affect survival in the absence of competition for resources by an indicator species. There is abundant evidence that larger portions of the Chehalis Basin channel network have experienced significant incision, which makes them prone to bed scour that can directly impact salmon egg survival and even reduce the extent of viable spawning gravels in the basin.
  Other aspects of habitat quality that merit consideration are as follows (Mobrand et al. 1997):
  - The effect of habitat quality on life stage survival occurs at all abundance levels of a species, whether abundance is low or high—this means that habitat quality is the primary determinant of survival at low population abundances (when competition for resources is minimal), which occurs when species are at critically low levels (ESA-listed or approaching listing).

- Improvements in habitat quality can result in substantial gains in population performance, as measured by abundance and survival, where quality has been reduced in the past by habitat degradation.[4]
- The need for improving habitat quality through restoration becomes greater as the threats of human activities in a watershed or climate change loom larger—these threats will have their greatest effects on species performance by impacting habitat quality characteristics.
- The distribution of key habitats within a stream system, particularly when they are limited or when they function as refugia during extreme environmental conditions, such as major freshets or periods of extreme temperatures, is an aspect of habitat quality. In these cases, the probability of individual animals finding the habitat they are searching for can have a strong effect on survival and population performance. Well-distributed habitats that act as refugia increase survival; shortage of refugia or an animal required to move long distances to locate a habitat type may decrease survival (Soto et al. 2016).

The quantity or quality issue is also raised when reconnecting habitats by removing or correcting fish passage barriers. The value of reconnecting habitat depends greatly on the quality and quantity of the habitat that is being connected. Opening fish passage into upstream habitat that is of poorer quality than the downstream habitat can actually decrease overall survival.[5] Similarly, the quantity of reconnected habitat is a key determinant of the value of enhancing fish passage at culverts and other blockages. In short, both habitat quality and habitat quantity need to be considered in prioritizing efforts to reconnect artificially disaggregated habitats (Roni et al. 2002; Beechie et al 2003).

[4] Abundance in this context refers to the abundance of an indicator species at the breeding stage or at an intermediate life stage for a large segment of the population. High density of a particular species in a life stage at a particular location may not reflect good habitat quality for various reasons (e.g., Van Horne 1983).
[5] A related issue is how culvert replacement can impact habitat quality. An impassable "perched" culvert may be maintaining channel grade in the vicinity of the culvert. Replacing the culvert with a larger culvert or bridge can cause the headcut to propagate upstream of the culvert, which in turn can convert a pool-riffle channel into a plane bed gully disconnected from its floodplain (reducing habitat quality). Understanding the science of how channels respond to particular disturbances is essential to assess the implications to habitat.

5 BASIS FOR DEVELOPING STRATEGIES AND ACTIONS

This section describes the approach for developing restoration strategies and prioritizing actions for the ASRP.

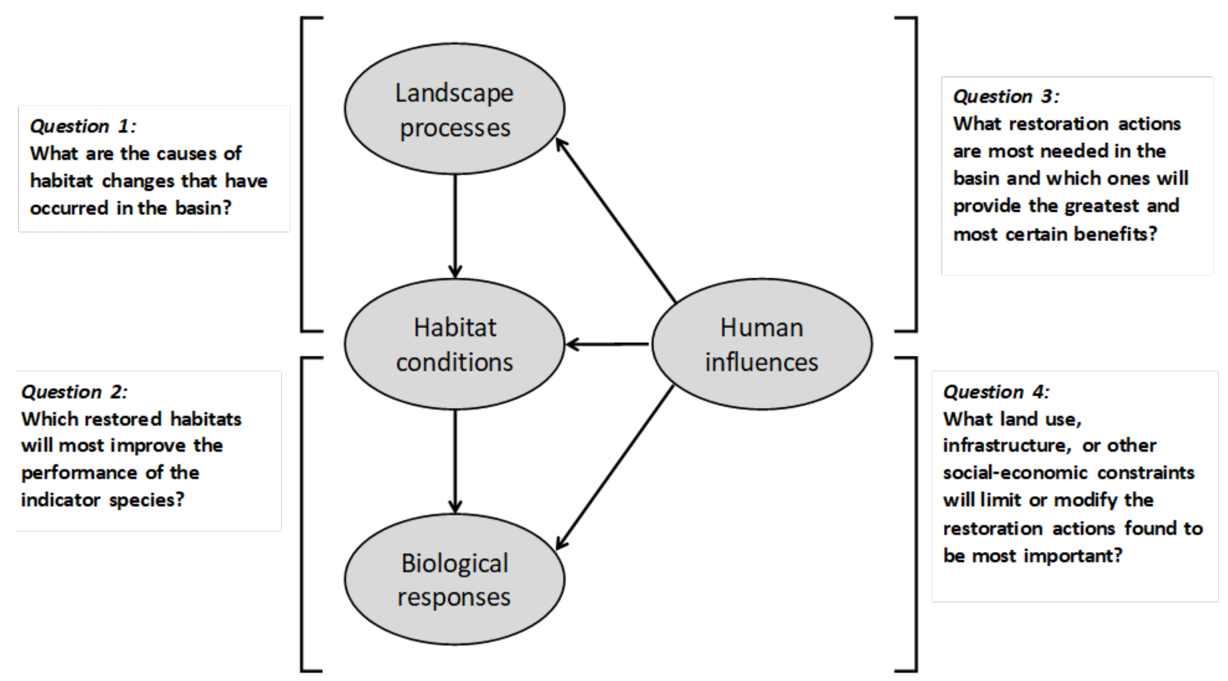
5.1 Assessment of the Aquatic Ecosystem

The restoration plan needs to be based on an assessment of the condition of the aquatic ecosystem sought to be restored to a more productive, sustainable state. That assessment diagnoses what could constrain achieving the plan vision. Without diagnosis, inadequate understanding exists of which watershed processes and habitat conditions need attention. In brief, the diagnosis asks: What is broken and what needs to be fixed?

Restoration strategies need to focus on key cause-effect linkages between watershed processes, habitat conditions, and biological responses of the indicator species, illustrated in Figure A-1. The figure, adapted from Beechie et al. 2013, is organized around the following four questions that need to be addressed to develop an effective restoration plan:

1. How has habitat changed from historic conditions, and what are the causes of those changes? Effective restoration can only be done after the causal mechanisms of habitat degradation have been clearly identified. Answering this question identifies the root causes of habitat changes, not merely their symptoms.
2. Which restored habitats will most improve the performance of indicator species (based on VSP characteristics or similar traits for other indicator species)? Answering this question identifies the relative importance of different habitats, including their locations, to the performance of the indicator species.
3. What restoration actions are most needed to address habitat changes in the watershed, and which ones will provide the greatest and most certain benefits? Answering this question identifies the actions—or treatments—deemed to be most important to include in the restoration plan.
4. What land use, infrastructure, or other socioeconomic constraints will limit or modify the restoration actions found to be most important? This question recognizes that human development and existing land uses will constrain what restoration actions may be feasible and their effectiveness. Scientists are responsible for evaluating these effects and constraints, but policy-makers and related governing bodies are responsible for decisions on land use, infrastructure, and social-economic constraints.

Figure A-1
Conceptual Diagram of Process Linkages Between Landscape Processes, Habitats, and Species Performance and Key Questions to Be Addressed in Identifying Restoration Actions to Be Implemented



Source: Adapted from Beechie et al. 2013.

Fundamental to the diagnosis is an assessment of how the watershed and its aquatic habitats have been changed over the past 200 years (Lichatowich et al. 1995). Its underlying assumption is that the intrinsic physical conditions of the Chehalis Basin and its habitats have been determined by natural geologic, climatic, and biogeographic interactions over millennia with lesser human populations. Before extensive human-caused disturbance, the aquatic environment had intrinsic limitations on what it could produce.

The overarching assumption of the diagnosis is that the aforementioned intrinsic conditions limit the performance of salmon and other species. The goal of restoration is not to restore the watershed to its intrinsic condition, which may be viewed as theoretically desirable but is not functionally possible within the backdrop of current human population activities and impacts. Rather, restoration aims to restore enough of the lost intrinsic potential consistent with achieving the ASRP vision.

Diagnosis assesses the degree to which changes have occurred to aquatic habitats from their intrinsic state and how these changes have impacted aquatic species performance. That said, development of the diagnosis is a set of serial steps, described in the following paragraphs.

Step One is to assess (or reconstruct) historic conditions of the entire watershed as it existed before extensive human-caused disturbance (Doppelt et al. 1993). This is done from old maps (such as those from the General Land Office), survey notes, aerial photos, miscellaneous documentation, and various scientific investigations done over time (Beechie et al. 2003). The purpose of this reconstruction is to develop a reasonable picture of how the relatively undisturbed system looked and, as a consequence, how it functioned compared to how it functions today.

Mobrand Biometrics (2003) developed an initial reconstruction of historic habitat for the entire basin. That reconstruction has been substantially updated and refined via recent work as part of the Chehalis Basin Strategy by Natural Systems Design, Inc., and NOAA Fisheries; however, historical conditions are still not fully understood. This reconstruction is the historical "template" used to evaluate the type and magnitude of habitat changes that have occurred.

Step Two is to assess the current state of the watershed and its habitats. In the Chehalis Basin, a substantial amount of information has been assembled over the past several decades to characterize the current condition of aquatic habitats across the basin. Notably, more recent assessments of habitat conditions have been done in large parts of the upper basin, including the mainstem Chehalis River, by WDFW, Anchor QEA, LLC, and Natural Systems Design, as described in McConnaha et al. (2017). NOAA Fisheries performed additional assessment work on current conditions. Important aspects of current conditions remain unknown. For example, no data collection or characterization has been done on the current extent of bedrock channels that were once likely alluvial or channels with unstable gravels where egg mortality is likely. Little data also exist regarding connectivity to coho salmon rearing areas in floodplains.

Step Three in the diagnosis compares the historic to current conditions across the basin to draw conclusions about the extent and distribution of changes that have occurred to watershed processes and habitat conditions. This step also then draws conclusions about the significance of these changes to species performance (Figure A-1). These conclusions are actually hypotheses about how the aquatic ecosystem is currently functioning and the factors that limit the performance of indicator species. These hypotheses are the basis for identifying and prioritizing strategies and actions for restoration.

An important part of the diagnosis is understanding geomorphic processes at work in the Chehalis Basin. For example, almost all stream channels of the basin have undergone large wood removal. Wood not only traps sediment but also partitions shear stress within the stream system, which reduces sediment transport capacity. Wood removal leads to bed coarsening (Manga and Kirchner 2000; Abbe et al. 2015) and channel incision[6] that increases sediment transport capacity and ultimately can convert a gravel-bedded channel to a bedrock channel (Stock et al. 2005). Incised channels also have a greater capacity to move wood; therefore, restoration of large, stable wood is important to reverse this pattern. Without addressing the root causes and creating stable instream structure to capture bed material, stream restoration will not be possible. Montgomery et al. (1996) show how wood removal converted gravel-bedded channels to bedrock in the Satsop River watershed.

[6] Incision is the process of downcutting into a stream channel leading to a lowering in the channel bed elevation. Incision is often caused by a decrease in sediment supply (e.g., from construction of a dam) and/or an increase in sediment transport capacity.

The analytical models—Ecosystem Diagnosis and Treatment (EDT) and NOAA Fisheries Life-Cycle Model (LCM)—have been used in Step Three to quantitatively assess the relative impacts to salmon performance by the changes from historic to current condition habitats (see Appendix C for details about EDT and LCM modeling). The models enable the quantification of a limiting factors analysis, enabling identification of the habitat factors (or stressors), and their geographic distributions, that have the greatest impacts on salmon performance. Analytical assessment for non-salmon species uses a combination of occupancy or simpler models combined with changes in historical versus current species-specific habitat footprints to assess the relative impact to non-salmon indicator species performance. The latter modeling provides a generalized sense of habitat loss rather than the sub-basin or geographically finer specificity of the modeling addressing salmon.

A high-level example of a diagnostic procedure applied to the Chehalis Basin is given in Attachment 2. The layout for the example is presented in the form of a process-based strategy framework. It illustrates the logic chain connecting the issues of concern (i.e., those environmental issues related to watershed alterations affecting species performance) to identification of strategies and actions. The framework is intended to help answer the question: What's broken and what needs to be fixed? The example is based on information summarized from the citations listed under Steps One and Two.

Step Four in the diagnosis provides a means to assess the future potential impacts of climate change on aquatic habitats and salmon performance (McConnaha et al. 2017). Projected increases in water temperature and peak winter flows have been translated into impacts on habitat conditions in the basin. These future changes, which are hypotheses, provide the basis for projecting effects on salmon performance using quantitative modeling and generalized impacts on non-salmon species given understanding of specific habitat conditions and physiological requirements, such as thermal requirements for selected amphibian species.

5.2 Strategies and Actions

The restoration plan consists of strategies and actions intended to mitigate human-related pressures on the Chehalis Basin aquatic ecosystem and restore processes and habitats sufficiently to achieve the goals and vision of the plan. A strategy is usually a bundle of actions that, when combined, are intended to achieve a common objective (PSP 2016). Strategies are usually developed with a long-term time horizon, such as 20 to 50 years or longer, with associated specific actions addressing nearer-term objectives.

Roni et al. (2002) and Beechie et al. (2013) organized commonly employed strategies into four categories, also used in WDFW's *Stream Habitat Restoration Guidelines 2012* (see Chapter 4 of Cramer 2012):

- Protect habitat
- Reconnect habitat
- Restore habitat-forming processes
- Recreate or enhance habitat

Certain aspects of each category merit highlighting here as follows:

- **Protection:** Protection of relatively intact, functioning parts of the ecosystem through legally binding actions to protect designated areas is often a far more cost-effective approach to conserving the integrity of biological communities than restoring an ecosystem after degradation. Habitat protection helps to conserve biodiversity and functioning habitats and processes, and it provides a source of locally adapted native plants, fish, and wildlife to recolonize nearby restored areas. Moreover, at-risk species frequently inhabit specific habitat types that are rare, and protection is a key strategy for these species.

Protection may also need to be combined with other strategies to sufficiently protect relatively intact habitats in a milieu of human-induced changes in adjacent habitats and the current climate change trajectory. These strategies include the following:

- **Reconnection of Habitats:** This strategy as presented here only includes those actions aimed at restoring passage of fish and other aquatic species within the aquatic environment. Issues of ecosystem connectivity that involve the flow, exchange, and pathways that move energy and matter through the system are included under habitat-forming processes (watershed processes). Dams, culverts, levees and road fill, floodplain fills, and channel incision are the principal ways that habitats become disconnected for fish passage. It is critical to recognize that reconnecting habitats for fish passage may not produce desirable benefits if the habitat being reconnected is poor quality, which may result in a decline of performance of indicator species following reconnection. In addition, creating connections between aquatic and terrestrial habitats or the presence of suitable migratory habitats among isolated aquatic sites, critical for most amphibians and other aquatic indicator species, is an important part of reconnecting habitat for those species but is not expressly addressed here.
- **Restoration of Habitat-Forming Processes:** Habitat is an outcome of inputs (e.g., large wood), physical processes (e.g., channel-forming floods), and other variables (e.g., tree growth increasing shade). Sustainable habitat restoration therefore requires the restoration of these inputs, processes, and variables that create, maintain, and periodically renew habitat. Restoration of degraded habitat requires that the root causes of degradation be identified and addressed at appropriate scales if the treatment is to provide long-term, sustainable results. In the Chehalis Basin, the issues causing degradation occur at a large scale and will require extensive, widespread treatment to be effective and take long periods of time to produce substantial benefits.
  One example of timescales with different treatment types is useful to make this point. Riparian vegetation restoration can require variable amounts of time to mature and provide benefits, depending on the situation, stream type, and strategy. Riparian zones along small streams flowing through wetlands only require a few years to be revegetated with willows using plantings and farm animal exclusion actions. In contrast, restoration of riparian corridors along larger streams that once flowed through old-growth riparian forests can require multiple decades (greater than 100 years) to mature and function in a manner needed to reform and

sustain important habitats. For example, the recruitment of large in-channel wood from large conifers within young riparian buffers is largely absent, and such recruitment to stream channels will require many decades to develop; thus, immediate actions to add functional in-stream wood would be required and would need to last as long it takes riparian areas to generate a sustainable supply of large functional wood.

For comparison, across managed forests in the Chehalis Basin—except for typically the upper portion of non-fish-bearing streams—policies to improve riparian buffers have been established to better enable passive restoration, but little scientific evidence exists to evaluate how well these new policies are working (both in terms of enforcement and effectiveness), partly due to the relatively short period of time these policies have been in place. Whether the current buffer policy will adequately address issues like wind throw or blow down remains unknown. Benefits from shading to cool water temperatures are occurring gradually. In this case, an active large wood-restoration strategy can be implemented in conjunction with the riparian strategy to accelerate the habitat-forming processes driven by large in-channel wood (Abbe and Brooks 2011). Island and secondary channel reformation can also be accelerated to provide high-quality spawning and rearing habitats for salmon. Large deep-pool habitat can be reformed by the scouring forces following the placement of large wood. These features, which form naturally as a function of large wood within the channel, also provide critically important cool temperature and slow-velocity refugia, especially with the advance of climate change.

- **Recreation or Improvement of Habitats:** This strategy involves restoring, creating, or improving specific habitat features at the site or reach scale. It is important to recognize that this category is not aimed at restoring habitat-forming processes, generally due to some human-caused constraint that exists or the very long periods of time (e.g., centuries) that would be needed to form these habitats. However, in situations where population performance is severely impacted by past habitat alterations, particularly if species viability is jeopardized, these strategies can be important where the benefits of restoring habitat forming processes would be realized in the distant future.

  Notably, this category of strategies has sometimes been ignored in restoration planning because it has been listed as the lowest priority of strategies (Beechie et al. 2003; Cramer 2012). However, it should be noted that those authors specifically stated that their prioritization was provided only as an interim recommendation when information on watershed-specific limiting factors is unavailable. Moreover, the general concern has been that actions aimed at recreating or creating specific habitats apart from restoring natural processes may be short-lived and not provide the needed benefits.

  An example of potential benefits of employing this category of strategies is seen in the creation of off-channel ponds, which are heavily used by juvenile coho salmon when available and are frequently the breeding habitat of primary importance to a number of stillwater breeding amphibians (Henning 2004; Henning and Schirato 2006; Henning et al. 2006, 2007). These habitats can significantly improve life cycle intrinsic productivity for coho salmon by improving overall habitat quality and diversity during winter (Lestelle 2007) and may be the critical

Chehalis River floodplain breeding habitat for the northern red-legged frog, an indicator species that is a probable umbrella species for the suite of stillwater amphibians that occur there (Hayes et al. 2019). Effective low-cost overwintering ponds have proven successful in rivers on the Olympic Peninsula (Cederholm et al. 1988) and in the Klamath River in Northern California (Soto et al. 2016). The ponds described in Cederholm et al. (1988) were created more than 30 years ago, and they remain in good condition and are heavily used by overwintering coho salmon. The relative importance of these ponds to coho salmon appears much greater in streams where natural wood loads have been reduced due to logging-related activities, such as in the Clearwater River on the Olympic Peninsula (Lestelle 2009). Most of the Chehalis River and its tributaries have severely reduced amounts of large wood compared to historical conditions.

5.3 ASRP Approach to Prioritization

Prioritization is the process of ranking watersheds (or sub-basins), habitats, and actions to determine their relative importance for funding and implementation for restoration work. Its overall purpose is to maximize the effectiveness of the restoration plan in achieving its goals while minimizing costs in time, resources, and efforts. Prioritization is an essential part of restoration planning.

Building on the fundamental assumptions that the current and historic patterns of habitat conditions over the Chehalis Basin create corresponding patterns of species performance (as abundance, productivity, or distributional extent) and population structure that are measurable (Fullerton et al. 2011), the ASRP approach to prioritization uses these measurements to estimate the degree to which restoration is possible using EDT and LCM model simulations, studies and monitoring data, and scientific judgments of the ASRP SRT and basin scientists.

5.3.1 Rationale for Prioritization Approach

A fundamental goal of ecosystem restoration is to protect and restore the biological diversity of native species, a condition essential to both ecosystem and population resilience (Schindler et al. 2010; Fleming et al. 2014). Focusing first on biological spatial structure (rather than population abundance) allows for more equitable allocation of restoration effort across the basin by weighing differences among sub-basins based on their size and degree of habitat degradation and, as a consequence, on their levels of restoration need.

The ASRP assumes that the spatial structure of habitats for salmon and non-salmon species in the Chehalis Basin environment reflects a hierarchical metapopulation organization. Thus, it is a key hypothesis that these biological patterns are adaptations to the underlying habitat template and have a genetic basis reflecting selection. As such, the pattern of species production across the basin is a critical piece of the ASRP for addressing species protection and restoration and habitat-forming processes. Ideally, the biological structure of species across the Chehalis Basin would be based on genetic information reflecting selection of behaviors, life history, and genomes across spatial scales. However, such data are currently limited for nearly all species in the Chehalis Basin.[7] Lacking detailed genetic information, it is assumed that the genetic structure reflects the structure of physical habitat across the basin and that the latter can be delineated based on available data.

The environmental characteristics of the Chehalis Basin—and the spatial pattern of conditions across the basin—are the templates that over millennia created the pattern and structure of species production across the basin that resulted in robust and resilient aquatic species populations. Human land use practices have altered the historic structure of habitat across the basin resulting in a change in species production. The maintenance of population structure is a critical component of the ASRP.

An approach that incorporates the concept of population structure was developed for salmon restoration by Waples et al. (2001) and Sands et al. (2009), but is equally applicable to non-salmon species (Murphy et al. 1990; Heppell 1998; Di Minin and Griffiths 2011). This approach places high importance on maintaining or restoring enough of the native species' spatial distribution by restoring or protecting enough of the spatial structure of the appropriate habitats. With sufficient habitat structure and distribution restored, it is anticipated those populations would be able to perform at levels that ensure long-term viability and deliver desired ecosystem services, including sustaining harvest, even in the face of climate change.

The ASRP references the spatial distribution of the aquatic populations and their habitats as spatial structure in the sense of the VSP concept for salmon (McElhany et al. 2000). This component of biological performance is also critically important in building a robust ASRP. Because the purpose of the ASRP is to guide restoration of physical habitat across the Chehalis Basin, it is important to address how the environment is structured spatially.

5.3.2 ASRP Spatial Structure

The ASRP prioritization is organized around the hierarchical spatial structure of species habitats described in this section based on geological, topographical, and hydrological patterns across the Chehalis Basin. It is hypothesized that the hierarchical structure described herein can capture the population structure of most aquatic species. The proposed structure is a nested hierarchy; that is, boundaries of the smaller units never overlap those of larger units. The proposed hierarchical spatial structure of species habitats for the ASRP is as follows:

- Chehalis Basin
  - Ecological regions
    - Sub-basins
      - Geospatial units

[7] Efforts are underway to address this need for salmon. Notably, the genetic data for salmon developed to date by WDFW generally supports the approach described here.

Within this spatial structure, the ASRP delineates 10 ecological regions, listed in Section 4.4. Non-mainstem ecological regions consist of collections of sub-basins down to the confluence with the mainstem Chehalis River. Mainstem ecological regions include the mainstem Chehalis River plus the associated floodplain features such as sloughs, side channels, and floodplain ponds as well as small, short tributaries not included in the other regions. The extent of tidal influence (near the entry to the Satsop River) or changes in gradient (near the confluence of the Skookumchuck River and at Rainbow Falls) delineate mainstem ecological regions. Delineation of these ecological regions agrees with the related concept of ecoregions developed by the U.S. Environmental Protection Agency (USEPA; Omernik and Griffith 2014). A full description of tributary ecological regions is shown in Table A-2.

The central premise of the approach is that protecting or restoring **all** ecological regions to some degree is important to achieve the ASRP's vision, although the restoration needs are not equal in every region. The long-term health of the basin requires restoration to improve ecological health within each ecological region. The level of effort in each ecological region will vary due to differences in land use and habitat degradation among ecological regions. Also, the potential gain in species performance from restoration will result in differences in restoration needs and strategic priorities among regions. Some level of restoration effort would be committed to each region, but the intensity of efforts will vary among regions.

5.3.3 Prioritization Tools and Methods

The ASRP SRT utilized available data, findings, and modeling tools, along with reconnaissance field assessment and consultation with basin researchers and field scientists to formulate priority strategies and actions for each ecological region, as well as priorities between ecological regions. Several analytical models have been applied in the basin, including habitat, fish performance, amphibian occupancy, temperature, hydraulic, and climate models, to simulate historical, current, and future conditions, and in some cases directly identify factors that limit distribution. Quantitative studies included genetic analysis, otolith chemistry, and native fish and amphibian studies. Numerous multi-year monitoring programs provided abundance and distribution data for all salmon species, native fish, and amphibians.

Attachment 2 provides a framework for the Chehalis Basin that describes the major process-based watershed and ecological issues affecting the performance of certain indicator species. Major processes include sediment, flow, riparian, and wood, among others. The framework presents a high-level description of the rationale for why these issues are important and for the potential solutions and actions that can reverse their effects. The ASRP SRT used the framework to support prioritizing issues and solutions within the Chehalis Basin for protection and restoration.

Table A-2
Description of Ecological Regions for the ASRP

ECOLOGICAL REGION	MAJOR SUB-BASINS OR CHEHALIS RIVER SEGMENTS	USEPA LEVEL III ECOREGION	USEPA LEVEL IV ECOREGION	COMMENT
Willapa Hills	Stearns Creek, South Fork Chehalis River, entire Chehalis River sub-basin upstream of Rainbow Falls	Coast Range	Willapa Hills, Volcanics	These sub-basins generally originate in the higher elevations of the eastern parts of the Willapa Hills and encompass the most southern portion of the Chehalis Basin.
Cascade Mountains	Skookumchuck River, Dillenbaugh Creek, Newaukum River	Puget Lowland and Cascades	Cowlitz/Chehalis Foothills, Cowlitz/Newaukum Prairie Floodplains, Western Cascades Lowlands and Valleys	These sub-basins originate in the foothills of the Cascade Mountains.
Middle Chehalis River	Mainstem Chehalis River from Skookumchuck to Rainbow Falls plus associated floodplain features			This is a very low-gradient section of the river characterized by low summer water velocities and high temperature.
Central Lowlands	Workman Creek, Delezene Creek, Rock Creek, Garrard Creek, Independence Creek, Lincoln Creek	Coast Range	Willapa Hills	All of these smaller sub-basins are located on the southwest side of the mainstem Chehalis River.
Lower Chehalis River	Chehalis River mainstem from Satsop River to Skookumchuck River plus associated floodplain features			The gradient of the mainstem Chehalis River increases downstream of the Black River. This section includes some side channels and floodplain features.

ECOLOGICAL REGION	MAJOR SUB-BASINS OR CHEHALIS RIVER SEGMENTS	USEPA LEVEL III ECOREGION	USEPA LEVEL IV ECOREGION	COMMENT
Black River	Black River, Scatter Creek	Puget Lowland	Southern Puget Prairies	Both sub-basins are almost entirely within the Level IV Southern Puget Prairies ecoregion. This low-gradient area historically drained southern Puget Sound rivers through the Chehalis Basin to the Pacific Ocean prior to the recession of the Continental Glacier. Extensive prairies and wetlands exist in these sub-basins.
Black Hills	Cloquallum Creek, Porter Creek, Cedar Creek	Coast Range	Willapa Hills, Volcanics	These sub-basins originate entirely or partially within the Black Hills, though the lower reaches flow through the Willapa Hills Level IV ecoregion.
Olympic Mountains	Wynoochee River, Satsop River	Coast Range and Puget Lowland	Central Puget Lowlands, Coast Range Outwash, Willapa Hills	Both major sub-basins originate in the southern parts of the Olympic Mountains, though both rivers flow through two or more Level IV ecoregions.
Chehalis River Tidal	Tidally influenced mainstem up to Satsop River plus associated floodplain features			The tidally influenced section of the mainstem includes sloughs (e.g., Preacher's Slough) and small tributaries.
Grays Harbor Tributaries	Humptulips River, Hoquiam River, Wishkah River, South Bay streams	Coast Range	Coastal Uplands, Coastal Lowlands, Coast Range Outwash	Lower reaches of these sub-basins are within the Coastal Lowlands Level IV ecoregion. Similarities exist in stream types among all of the sub-basins, though the forks of the Humptulips River differ substantially due to topography (canyons and steeper terrain transitioning to the Olympic Mountains).

6 UNCERTAINTIES

Most knowledge, and hence science, regardless of its quality, contains uncertainties (Sullivan et al. 2006). Scientific and other uncertainties are inherent in ecosystem restoration. Natural variability is large in watershed and ecological processes. Biological responses, such as salmon performance, are subject to a high degree of natural fluctuations, produced by external forcing factors (such as ocean conditions) and complex interactions within the Chehalis Basin's aquatic ecosystem. Restoration planning must identify the sources of variability in a system driven by natural or human actions. It must then develop recommendations that work within this variability to increase the probability of achieving goals and thereby minimizing uncertainty. Managing for uncertainty is discussed by Beechie et al. (2003), Darby and Sear (2008), and Skidmore et al. (2011). A major conclusion is that uncertainty should not halt or delay restoration actions. While not everything is known, sufficient information exists to make informed decisions that will benefit aquatic species.

6.1 Framework for Presenting Uncertainties

Diverse sources of uncertainty exist, and many frameworks have described them (see Hilborn 1987; Wynne 1992; and Elith et al. 2002 for frameworks applicable to the aquatic sciences). Morishima (2018) provides the following five-step framework that is useful to consider in the ASRP:

1. Determine the intended audience and most informative information.
2. Identify the specific content of the information to be conveyed.
3. Examine the source and nature of uncertainties and determine what to include in the analysis.
4. Perform the uncertainty analysis, which includes evaluating the degree of uncertainty and potential consequences of the uncertainty to the work
5. Present uncertainties, including their disclosure and documentation.

Details of the approaches that should be used for addressing uncertainties depends on characteristics of the uncertainties. Morishima (2018) advises that, at minimum, disclosure and documentation should be formalized, traceable, and capture the following six elements:

- Findings and assumptions (what relationships affecting uncertainty are assumed, hypothesized, or relied upon)
- Description of the evidence base relied upon in support
- Identification of sources of uncertainty in input data, analyses, and models and an understanding of how uncertainty can be reduced, along with the costs and benefits of doing so
- If possible, estimation of the magnitude of uncertainty in predictions (though this is often not possible because of the complexity of natural systems)

- Examination of the consequences of uncertainties in restoration decisions, either qualitatively or quantitatively, and the significance of a range of possible outcomes
- Statement of confidence and likelihood

M&AM is crucial for reducing uncertainty and risks as a restoration plan progresses. Therefore, it is imperative that explicit rationale for prioritization and decision-making be well documented to improve activities under the M&AM program in the future.

6.2 Recognized Uncertainties in the ASRP

In context of the ASRP, important sources of uncertainty are likely to include the following:

1. Lack of historical geomorphic and habitat information, including channel conditions through much of the drainage network (e.g., specific geographic extent of bedrock channels, spawning gravels, stability of spawning gravels)
2. Lack of basic biological information or information on functional relationships (e.g., between populations and environmental factors)
3. Precise timing and number of storms in a given year, which is difficult to predict
4. High variability in key parameter or variable estimates

This list is not exhaustive; it merely illustrates major categories. Importantly, an adequate understanding of uncertainties is also important for prioritization, as high levels of uncertainty could be viewed as a reason for either advancing or delaying projects if project results will substantially reduce uncertainty or if uncertainty puts the risk of project failure too high until better information becomes available, respectively.

Some additional elaboration on the nature of uncertainties in the ASRP is merited with regard to potential complications with invasive species. A large body of literature indicates that successful responses to restoration efforts can result from diverse structural changes in habitat due to restoration efforts (Roni et al. 2002, 2008; Wortley et al. 2013). This assumption is probably most valid, however, under those conditions where invasive species are absent. Under those conditions, one can have reasonably high confidence (low uncertainty) that the species for which restoration is targeted will respond in an expected and positive fashion. The ASRP makes the assumption that historic habitats were optimal to native species. The ASRP also assumes that current degraded conditions put native species at a disadvantage to invasive species, which are at an advantage in altered habitats. Science clearly does indicate that native species are impacted by existing degraded habitat. Science is also clear that native species will benefit from restoring historic habitat in the absence of invasive species. However, high uncertainty exists around how invasive species will respond in restored habitats and also how invasive species and invasive-native species interactions will respond to restoring historic habitats.

Studies integrating the potential effects of invasive species with structural habitat restoration that have actually examined the response are sparse. More specifically, since such studies are non-existent for salmonid species and other aquatic species in the Pacific Northwest, restoration conditions where invasive species are present should recognize either that uncertainty may be high or the range of uncertainty is broad enough to make accurate predictions about expected outcomes more difficult. Under such conditions, it may be necessary to approach the restoration in an experimental fashion—that is to say, by incorporating unmanipulated reference site or sites that are monitored in concert with the experimental site(s). This approach would better enable gauging species response to restoration in an adaptive fashion (i.e., it would be useful to future efforts to allow adjustments to the restoration approach likely to increase success). Whether an experimental approach is needed has to be gauged on the level of uncertainty faced; if uncertainty is judged to be high, an experimental approach is likely the more appropriate route.

6.3 Communicating Uncertainties with the Non-Science Audience

Uncertainty imposes a unique challenge for clear communication of study paths and results with non-scientists. Morishima (2018) states that uncertainty is best viewed from the systemic perspective of uncertainty analysis, which addresses the challenge of informing decision-makers of the limitations of data and methods of analysis so that study results and models can be properly understood and interpreted. He emphasized the critical need for uncertainty analysis to inform decision-making with ecological consequences and risk because of the challenge of clearly conveying the scope and magnitude of uncertainty to an audience with disparate backgrounds and experiences—and therefore perspectives, as well. Where uncertainty generates unacceptable risks, these risks must be diminished by reducing either the probability of undesirable outcomes or their consequences for people, species, or property. Recognition of the limitations of data and knowledge gaps (uncertainties) improves rather than diminishes the quality of scientific advice and can contribute to the development of trust between scientists, decision-makers, and stakeholders (Ryder et al. 2010).

7 ADAPTIVE MANAGEMENT, MONITORING, AND EVALUATION

Monitoring and adaptive management are essential components of ecosystem restoration. Adaptive management is an iterative process of decision-making in the face of uncertainty, with the intent of reducing uncertainty through monitoring and continually adapting implementation strategies and actions as knowledge that informs the best way to meet the stated goal (Skidmore et al. 2011).

Adaptive management is not managing by trial and error—it requires that purposeful actions be taken, then monitored and scientifically evaluated so that policy, management, and actions become more effective for restoration over time (Joint Natural Resources Cabinet 1999).

Adaptive management and monitoring are linked. Without monitoring, no scientifically valid way exists of assessing progress and knowing whether investments in actions are beneficial. Well-designed monitoring should do the following: 1) indicate whether the restoration measures were designed and implemented properly; 2) determine whether the restoration results met the objectives; and 3) provide new insights into ecosystem function and response (Kershner 1997). Hence, besides measuring progress of the plan, monitoring also serves a research role in addressing critical uncertainties.

For the ASRP Phase 1 document, an M&AM Framework (Appendix B) has been developed. Built on the ASRP vision statement components as well as this Scientific Foundation, the M&AM Framework describes the purpose, elements, and types of studies that will be included in the M&AM Plan (to be developed in Phase 2 of the ASRP). It also acknowledges the need for hypothesis testing and studies to fill critical data/knowledge gaps. The M&AM Plan will apply principles outlined in this foundation. This foundation underscores the basic principles on which the ASRP is developed and is a starting point for the M&AM Plan to be developed.

8 PLANNING FOR SCIENTIFIC CREDIBILITY

The scientific basis for decisions relating to the ASRP and the Chehalis Basin Strategy will assuredly be subjected to intense scrutiny as the components of plans are formulated and moved forward. It will be vital for decision-makers and the public to be confident that decisions and recommendations being contemplated and taken are based on the "best available science"—a term commonly used by management agencies and in the scientific literature (Sullivan et al. 2006; Ryder et al. 2010). The term "best available science" is commonly applied to engender credibility and trust among scientists, managers, stakeholders, governments, and the public. The ESA has been a focal point for defining best available science in the scientific literature, defining "best" as information that is collected by established protocols, properly analyzed, and peer-reviewed before its release to the public (Brennan et al. 2003; Ryder et al. 2010).

This Scientific Foundation incorporates a description of the guidance, principles, and processes that have been employed to ensure that best available science is utilized in the development of the ASRP. As implementation of the ASRP begins, ongoing standards and protocols will be needed to continue to guide the ASRP to maintain its scientific credibility; these will include the following:

1. Standardized terminology (e.g., habitat names, acronyms, symbols)
2. Continued scientific review to guide implementation and adaptive management actions
3. Development of criteria and standards for ASRP implementation projects
4. Regularly scheduled reviews by the sponsors and participants in the ASRP of all ASRP components and projects, including the Scientific Foundation, as a way of adapting and updating the plan and adjusting to new information
5. Procedures for record-keeping
6. A central location to facilitate data management

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Attachment 1
Potential Indicator Species for the ASRP

This attachment documents the rationale for potential indicator species for monitoring and adaptive management of the ASRP. Salmon are widely recognized as indicator species for watershed restoration in the Pacific Northwest (Lestelle et al. 1996; Hyatt and Godbout 2000). Their freshwater life history depends on streams, the arterial system of a watershed. The conditions of streams generally reflect overall watershed condition, since water drains downhill, bringing with it characteristics created upstream. Salmon are sensitive to these conditions, upon which their survival and abundance depends. Moreover, because some salmon species have complex life histories that utilize extensive parts of a river system, from estuary to headwaters, their life cycle acts to integrate the mosaic of conditions within an entire stream system. Salmon have another important, unique role—they connect ecosystems through their extensive migrations, connecting freshwater, estuarine, and oceanic systems (Irvine and Riddell 2007). In summary, salmon are the ideal taxa to gauge ecosystem health because they integrate across saltwater, freshwater, and terrestrial systems because of reciprocal subsidies.

Salmon are also recognized as being keystone species to watershed ecosystems. For example, they convey large quantities of marine nutrients from the ocean to watersheds as a result of their oceanic migrations and their return to their natal streams. In doing so, they are a key part of food webs for both aquatic and terrestrial ecosystems within a watershed (Cederholm et al. 2000).

Salmon have also been identified as a cultural foundation species. In ecology, the term "foundation species" refers to a species that has a strong role in structuring a community (Dayton 1972). Wild salmon are a cultural foundation species for Native American tribes throughout the Pacific Northwest (Hurlburt [unpublished]). The two indigenous peoples in the Chehalis Basin—Chehalis and Quinault—like other Northwest indigenous peoples, have viewed salmon as the symbol and lifeblood of their way of life (Capoeman 1990; DeLoria 2012).

Coho and spring Chinook are two species of salmon that are potential indicator species in the Chehalis Basin. Coho salmon have the greatest breadth of habitat use of the salmon species in the basin, spawning or rearing in virtually all streams of any notable size throughout the basin. They spawn in relatively steep headwater streams as well as on the margins of the largest rivers, extending to the head of tidewater. They rear in the smallest stream channels, in larger mainstem river channels, and in off-channel habitats on the floodplains. They spend approximately 1.5 years in the freshwater environment before migrating to the ocean as smolts, then return as mature adults after a comparable time spent in the ocean. Their time spent in freshwater as eggs or juveniles includes periods of the highest annual flows as well as the lowest annual flow. They experience the hottest times of the year and the coldest times. This diverse use of the basin exposes them to a wide variety of conditions and potential threats, which are also potential threats to many aquatic species.

The other potential salmon indicator species for the ASRP is spring Chinook. This race of Chinook salmon is particularly sensitive to habitat changes in a river basin like the Chehalis. These fish enter the river as immature adults (called premature migrating fish) in the spring and early summer, and then they ascend to the middle or upper reaches of the river and its largest tributaries. As a consequence, they experience the hottest part of the summer, often in very low flows when water withdrawals are highest for out-of-stream water uses, and when they are vulnerable to high rates of pre-spawning mortality if conditions are too severe (Quinn et al. 2016). Spring Chinook salmon populations are generally declining coast-wide due to their sensitivity to degraded habitats, as seen over the past 20 years in the Queets and Hoh rivers on the Washington coast. This species is especially valued by Native American tribes due to their early river entry timing and high fat reserves. The species is also an important food source for orca whales. There are growing conservation concerns about their future status, particularly in light of climate change (Prince et al. 2017).

Along similar lines, amphibians are widely recognized as potential indicator species (Welsh and Ollivier 1998; Adams 1999; Waddle 2006). Similar to salmon, the success of many amphibians depends on life history integration across ecosystem compartments. In the case of stillwater-breeding and stream-breeding amphibians (two-thirds of the amphibian species present in the Chehalis Basin), that integration occurs between freshwater and terrestrial habitats, which are utilized by aquatic obligate life stages (larvae or tadpoles) and post-metamorphic life stages that migrate seasonally between the aquatic (breeding) and terrestrial (non-breeding active season) compartments (Hayes et al. 2008; Semlitsch 2008). Amphibians are also unique among vertebrates in having a kidney physiology adapted to ridding themselves of fresh water, a condition they constantly face in the aquatic or moist environments they inhabit because they possess a water-permeable skin that doubles as a lung (Feder and Burggren 1992). This physiology has consequences that both limit the habitat conditions in which amphibians occur and make them more vulnerable than other vertebrates to selected environmental insults. These include the following: 1) their skin cannot function as a lung when dry, which restricts amphibians to either aquatic or relatively moist habitats; 2) maintaining a moist skin carries the cost of rapid water turnover (both rapid gain and loss), which makes them vulnerable to rapid absorption of water-soluble contaminants; and 3) their water-voiding kidney makes them capable of tolerating only the most dilute saltwater, which is reflected in the absence of truly marine amphibians (Feder and Burggren 1992). Amphibians are also key contributors to ecosystem services, especially through what can be labeled supporting services. In particular, amphibians can affect habitat structure through aquatic bioturbation, decomposition and nutrient cycling via waste excretion and indirectly through predatory changes in food webs, and primary production through consumption directly and nutrient cycling (Hocking and Babbitt 2014). Finally, also similar to salmon, several native amphibians in the Chehalis Basin are cool-adapted stenotherms for at least selected life history stages (Hayes et al. 2008).

The aforementioned features led to the identification of two amphibian species—northern red-legged frog and Oregon spotted frog– as potential indicator species in a manner similar to the two salmonids that were identified. The northern red-legged frog, a quasi-analog to coho salmon, is widespread in the basin. However, it can act as an umbrella species for most (four of the six) of the other native stillwater-breeding amphibian species because its presence increases the likelihood of occurrence of that segment of the native stillwater-breeding amphibian suite (Hayes et al. 2008). Northern red-legged frog is also a useful potential indicator species because its embryonic life stages have the lowest critical thermal maximum (approximately 20°C) of any North American frog, which restricts its breeding to the late winter interval, typically January to February (Licht 1971). The temperature requirements make it particularly useful for tracking changes that may result from climate warming. The second selection, the Oregon spotted frog, a quasi-analog to spring Chinook salmon, is a marsh habitat specialist that is currently only known from the Black River system in the Chehalis Basin (Hallock 2013). This completely aquatic frog was listed as threatened under the ESA in 2014 and is especially vulnerable to warm-water invasive predators, notably the American bullfrog and warm-water fishes (especially centrarchid fishes that include basses, crappies, and sunfishes; Hallock 2013). Its sensitivity to warm-water invasive species also make it useful for tracking changes that may result from climate warming, since warmwater invasive species are suspected to respond positively to climate warming. The Oregon spotted frog is an even better umbrella species than the northern red-legged frog because its presence increases the likelihood of occurrence of all six of the remaining native stillwater-breeding amphibians. However, its restricted distribution limits its utility as an umbrella species.

Besides fish and wildlife species, the variety of plants that occur in the aquatic, riparian, and floodplain habitats of the basin play a major role in providing the structure and function of the habitats. While not displayed as potential indicator species in this iteration, plant species are noted as key components of the habitats used by the fish and wildlife species. The widespread distribution of invasive plant, fish, and wildlife species also affects the structure and function of the ecosystem and the productivity and survival of fish and wildlife species. Inclusion of key plant species as selected indicator species could be incorporated into the comprehensive M&AM Plan.

Table A1-1
Potential Indicator Species for the ASRP

STANDARD ENGLISH NAME (COMMON NAME)	SCIENTIFIC NAME	STATUS[1]	HABITAT INTEGRATOR[2]
Winter-run steelhead	*Oncorhynchus mykiss*		AOT
Coho salmon	*Oncorhynchus kisutch*		AOT
Fall-run Chinook salmon	*Oncorhynchus tshawytscha*		AOT
Spring-run Chinook salmon	*Oncorhynchus tshawytscha*		AOT
Chum salmon	*Oncorhynchus keta*		AOT
Mountain whitefish	*Prosopium williamsoni*		AT
Eulachon	*Thaleichthys pacificus*	SGCN, FT, SC	AOT
Pacific lamprey	*Entosphenus tridentatus*	SGCN, FCO	AOT
Olympic mudminnow	*Novumbra hubbsi*	SS	AT
Speckled dace	*Rhinichthys osculus*		AT
Largescale sucker	*Catostomus macrocheilus*		AT
Riffle sculpin	*Cottus gulosus*		AT

STANDARD ENGLISH NAME (COMMON NAME)	SCIENTIFIC NAME	STATUS[1]	HABITAT INTEGRATOR[2]
Reticulate sculpin	*Cottus perplexus*		AT
Coastal tailed frog	*Ascaphus truei*	FFR	AT
Western toad	*Anaxyrus boreas*	SC,FCO	AT
Northern red-legged frog	*Rana aurora*		AT
Oregon spotted frog	*Rana pretiosa*	SE,FE	AT
Van Dyke's salamander	*Plethodon vandykei*	FFR	
Great blue heron	*Ardea herodias*	SGCN	AOT
Barrow's goldeneye	*Bucephala islandica*	SGCN	AOT
Wood duck	*Aix sponsa*	SGCN	AT
North American beaver[3]	*Castor canadensis*		AT
Western pond turtle	*Actinemys marmorata*	SE,FCO	AT
Western ridged mussel	*Gonidea angulata*		AT

Notes:

1. Key:
    - SS: state sensitive
    - SC: state candidate
    - SE: state endangered
    - SGCN: species of greatest conservation need (Washington 2015 State Wildlife Action Plan)
    - FCO: federal species of concern
    - FT: federal threatened
    - FE: federal endangered
    - FFR: Forests and Fish Law target species
2. Key:
    - AOT: aquatic-ocean-terrestrial
    - AT: aquatic-terrestrial
3. North American beaver is also a habitat engineer.

Attachment 2
Process-Based Strategy Framework

This attachment provides a framework and summary of the major process-based watershed and ecological issues affecting the performance of the indicator species used in the development of the ASRP. The framework presents a high-level description of the rationale for why these issues are important and for the potential solutions and actions that can mitigate their effects. Addressing watershed-scale processes rather than trying to restore specific habitats is more likely to be successful in restoring aquatic species populations and habitats over time (Beechie et al. 2010).

This summary is intended to provide the flow of logic necessary to link the issues to proposed strategies and actions.

Table A2-1
Watershed and Ecological Process-Based Strategy Framework

ISSUES OF CONCERN	RELEVANCE TO INDICATOR SPECIES	CAUSES	SOLUTIONS	STRATEGIES/ACTIONS
ECOSYSTEM COMPONENT: ACCESS TO INSTREAM AND OFF-CHANNEL HABITATS				
Access to instream habitats: The ability of juvenile and adult native fish species to move upstream and downstream to access spawning grounds and rearing areas and to migrate to the ocean (as applicable) is vital to species performance and long-term sustainability. Poorly designed or deteriorating culvert and bridge installations, as well as other barriers to passage, such as dams, can block or impede movements of juvenile and/or adult fish. **Access to off-channel (floodplain) habitats:** The availability and accessibility of off-channel habitats (ponds and wetlands) are important determinants of the performance of some salmon populations and other species such as Olympic mudminnow. Human-made structures, low flows, or other altered features can block access to these habitats.	Fish passage barriers block or limit access to upstream and downstream habitats that were used historically by a species, resulting in reduced population abundance due to loss in available habitat (quantity of habitat; Cramer 2012). Fish passage barriers block access to upstream cooler water habitats and refugia that will become more important with climate change (Beechie et al. 2012) Off-channel habitats are especially important to juvenile coho salmon for overwintering, which is a critical life stage to many coho salmon populations in the Pacific Northwest (Lestelle 2007). Accessibility and likelihood of juvenile coho salmon finding these habitats is a habitat quality characteristic, though these habitats also provide important habitat quantity (Lestelle 2009). Fish passage barriers can alter the spatial structure, life history diversity, and genetics of a population, thereby potentially impacting its long-term sustainability (Thompson et al. 2019).	Historically, culverts were simply designed to handle a given storm flow (e.g., 25-year flood event) with no regard to passing fish and other species. These culverts can cause perched outfalls or result in excessively high velocities that restrict passage. Concrete- or metal-bottomed culverts, particularly those with flat bottoms, can have shallow water or high-velocity conditions without hydraulic variation, thereby limiting the ability of fish to pass through. Old culverts can collapse or become plugged, restricting fish access. Dams, such as Skookumchuck Dam, can be a complete barrier to upstream and downstream passage. Small or seasonal channels or swales connecting off-channel ponds and wetlands to the main stream can be blocked by road or levee fills or poorly designed culverts and gates. Filling and drainage of wetlands to facilitate other land uses has reduced their availability. Invasive plants can choke access to off-channel habitats or within small streams.	Remove stream crossing structures on abandoned or closed roads. Redesign and rebuild stream crossing structures to accommodate flows and provide fish and other aquatic organism passage. Alter partial barriers to fish passage to maintain connectivity along the river as it supported fish populations historically. Restore, enhance, and maintain good access between stream channels and off-channel ponds and wetlands where infrastructure or other obstructions impede passage. Control invasive plant species while native plant revegetation is occurring.	**Road crossings:** Periodically evaluate stream crossing structures for passage effectiveness, maintain crossing structures consistent with best management practices, remove crossing structures on closed or abandoned roads, and replace or upgrade outdated structures on a priority basis. **Dam removal:** Remove dam that blocks upstream and downstream passage. **Improving access to off-channel habitat:** Improve access to off-channel habitats by removing obstructions, deepening connection channels, and/or adding structure where opportunities exist to improve access. Consider the presence of invasive species in the planning of this strategy/action. **Invasive species:** Inventory invasive plant species such as Japanese knotweed and reed canary grass. Identify methods of control and management to be implemented separately or in conjunction with native species revegetation. Periodic maintenance activities at prior restoration sites may be necessary to obtain adequate control. Activities listed for riparian protection and restoration can be important to help control invasive plant species.

ISSUES OF CONCERN	RELEVANCE TO INDICATOR SPECIES	CAUSES	SOLUTIONS	STRATEGIES/ACTIONS
ECOSYSTEM COMPONENT: SEDIMENT REGIME (SUPPLY, TRANSPORT, AND STORAGE)				
Excess sediment: Erosion and sediment transport is a natural process that shapes stream channels and floodplains, as well as associated habitats and aquatic biota. The sediment supply is produced from ongoing land erosion (e.g., landslides), as well as from the recapture of sediments (due to channel migration and avulsions) previously stored in flood plains and streambanks. Watershed alterations and management (such as forest practices, agriculture, and development) have disrupted the natural process, resulting in changes (often very significant ones) to the supply, storage, and transport of sediments. These changes had led to increased fine sediment levels within spawning gravels, channel and habitat instability, and in some cases, severe channel aggradation. **Sediment reduction:** Downstream of a dam (several exist in the Chehalis Basin), the channel can be sediment starved, leading to channel bed coarsening (armoring), incision, and/or a lack of stable spawning gravel. Bank armoring can reduce channel migration and the natural recruitment of sediment from floodplain deposits. Climate change is expected to increase sediment loading in many streams in Western Washington from increased landslides and erosion (Mauger et al. 2015; Beechie et al. 2012).	Increased sediment supply over levels typically found in old-growth forests or conditions prior to the modern era of watershed development results in increased mortalities of salmonid embryos and juveniles during egg incubation and overwintering life stages (Bjornn and Reiser 1991; Cederholm and Reid 1987). Increased sediment supply can cause channel aggradation (buildup of sediment in the channel), resulting in shallowing of pools and riffles (even dry channels), channel braiding, and greater habitat instability, thereby reducing population performance (SIT and WDFW 2010). Decreased sediment supply can cause channel incision and loss of suitable spawning habitat for salmon.	Runoff from road building and vehicular traffic on unpaved roads increases sediment delivery to streams. Landslides associated with roads, fires, and timber harvest increases sediment delivery. Blowouts and slides associated with undersized culverts increase sediment delivery to streams. Ongoing erosion associated with old road drainage networks due to failed culverts and unmaintained ditches increase sediment delivery to streams. Runoff from agricultural fields and farming activities increase fine sediment and pollutant delivery to streams. Removal of large wood and logjams during historic timber harvest and subsequent channel clearing or splash dam sluice activities, resulted in increased channel instability and loss of stored sediments. Runoff from land clearing for land conversion, including road building, increases fine sediment delivery to streams. Altered runoff and flow regimes due to land uses cause greater streambank erosion and recapture of stored sediments, thereby increasing sediment loading. Climate change is expected to increase sediment delivery to streams in Western Washington due to intensification of rainfall events and an associated increase in landslides and erosion (Mauger et al. 2015; Beechie et al. 2012).	Continue to improve forest management practices to reduce sediment yields from roads, clearcuts, and from areas prone to landslides. Close and obliterate unneeded roads (Roni et al. 2012; Beechie et al. 2010). Continue to upgrade and improve best management practices for managing sediment yield from all types of land uses. Improve opportunities for public education on ways of controlling sediment. Improve knowledge and understanding about sources of sediment produced in the watershed.	**Road Maintenance and Abandonment Plans:** Complete the development of Road Maintenance and Abandonment Plans on all forest lands, and implement steps for upgrading, maintaining, or decommissioning of roads and road crossings. **Non-forest roads:** Assess conditions of existing non-forest road systems that might contribute sediments, identifying risk levels for sediment contributions, and implement identified remedial measures. **Non-road sediment:** Assess non-road related sediment sources that contribute sediments, identifying risk levels for sediment contributions to adjacent streams, and implement remedial measures. **Protect riparian lands:** Increase protection of riparian lands through regulations, incentives (e.g., conservation easements), land purchases, and education and outreach programs. **Restore riparian forest:** Restore riparian forest characteristics using passive or active management methods. Activities listed for protection of riparian lands also apply here. **Large wood:** Construct engineered logjams or place large wood in appropriate locations of the river to facilitate sediment storage and processing and more natural channel patterns (including bed elevations) and, where appropriate, to recreate stable side channels, backwaters, or stable vegetated islands. **Sediment analysis:** Prepare watershed sediment budget and transport analysis for a sub-basin of concern. Such analysis will provide a landscape perspective for assessing the sediment budget, including rates of sediment supply and transport. Remedial measures can be formulated accordingly.

ISSUES OF CONCERN	RELEVANCE TO INDICATOR SPECIES	CAUSES	SOLUTIONS	STRATEGIES/ACTIONS
ECOSYSTEM COMPONENT: FLOW REGIME CHARACTERISTICS (MAGNITUDE, TIMING, FREQUENCY, DURATION, AND RATE OF CHANGE IN FLOW)				
The natural flow regime organizes and defines river ecosystems (Poff et al. 1997). The flow regime is defined by flow magnitude, duration, timing, frequency, and rate of change. The natural ranges of these attributes within the basin shaped the riverine environment and the populations of aquatic species that adapted to these conditions over millennia. **Altered flow regime (high-flow or low-flow aspects):** Conversion of upland mature forests to young, managed stands, combined with an extensive road network, alter the characteristics of the natural flow regime to varying extents. Land conversion in lowland from vegetation clearing and conversions to agriculture, residential areas, commercial and industrial uses, and urbanized areas. These changes decrease canopy cover and interception of rainfall, increase impervious surfaces, and decrease groundwater infiltration and water storage that supplement low flows. The flow regimes in certain rivers have also been altered by dams and reservoirs (Wynoochee and Skookumchuck). Flow regimes are also directly altered by channel incision. Floodplain disconnection alters flow regimes—the same flow magnitudes (Q) that once spread out slow-moving water onto floodplains are confined to deep, fast-moving water constrained within the channel. This also reduces the floodplain function of attenuating downstream flood peaks, thus not just altering flow regimes but also recurrence intervals. For example, urbanization does not change rainfall event, but it will increase the quantity of water entering the channel network due to impervious surfaces. This changes flood frequencies: a flow that naturally had a 0.01% probability of occurring in a given year can occur every year. This then changes flow regimes, which in turn change sediment and wood regimes. Climate change is expected to result in still further changes to the flow regime of the Chehalis Basin (Mauger et al. 2016; Beechie et al. 2012). Intensification of rainfall events are expected to increase peak annual flows significantly in some areas of the basin.	Life history patterns and associated life stage survivals of salmon and other native fish are strongly affected by characteristics of the flow regime in a stream system (Poff et al. 1997). Peak flow intensity, runoff volume and duration, and rate of change in flows during storm events can adversely affect egg to fry survival, emergent fry survival, and juvenile overwintering survival (Schuett-Hames and Adams 2003; Seiler et al. 2004). Diminished low flows in late summer or early fall as a result of changes in the flow regime will generally reduce the number of coho salmon smolts (and probably steelhead smolts) produced from tributary streams (Smoker 1953; Seiler 1999). Diminished low flows in late summer or fall can reduce connectivity and water storage of off-channel habitats and wetlands, reducing habitats for other aquatic species such as Olympic mudminnow and amphibians.	Extensive road networks through managed forests increase rate of runoff, which can produce greater instability of streams. Replacement of mature forests with managed forests of much younger stands increases runoff. Land clearing and land conversion create impervious surfaces in the watershed, altering runoff patterns and rates. Levees that prevent flooding onto the floodplains increase the volume and elevation of flow in the main channel. Channel incision reduces connectivity to floodplains and changes the volume of flow in the channels and increases delivery of water to areas downstream. Water withdrawals from surface water for the purpose of irrigation, domestic, and industrial use reduce low flow volumes. Groundwater pumping to support agricultural or residential uses can also reduce streamflow volumes.	Promote diverse stand age in the managed forest to increase retention of precipitation on the landscape. Reduce the footprint of roads in the managed forest areas of watersheds wherever possible. Restore connections to floodplains that provide for increased flood capacity and storage. Protect channel migration zones (CMZs) to maintain floodplain habitat formation and complex flow pathways. Restore flow regime characteristics by reducing the rate of storm runoff associated with developed areas. Restore riparian and floodplain vegetation communities.	**Channel pattern:** Strategically remove channel constrictions and impediments to meanders to restore channel capacity and develop more natural channel pattern and migration (e.g., by dike removal, use of setback levees, road relocations, lengthening and/or raising bridges, or rebuilding the channel pattern). **CMZ:** Protect and restore active channel migration zone (because it has been reduced by human activities) through regulations, incentives, education programs, or land acquisition. **Decommissioning:** Decommission or remove roads of little use on public lands, or ones whose services can be provided on alternative roads. **Forest maturity:** Manage for an increase in hydrologic maturity (older-age stands) of forested lands to the extent possible using incentives on private lands or through policy change on public lands. **Protect floodplains:** Protect existing riparian and floodplain lands from land conversions or loss of function through regulations, incentives, education programs, land acquisition, or land set-asides. **Restore floodplains:** Restore more natural floodplain characteristics and function by restoring wetlands, ponds, overflow channels, riparian forest, and/or size of floodplains; this includes connectivity of off-channel features. **Road Maintenance and Abandonment Plans:** Complete the development of Road Maintenance and Abandonment Plans on all forest lands, and implement steps for upgrading, maintaining, or decommissioning of roads and road crossings. **Stormwater management:** Update and enforce storm runoff management on agricultural, residential, commercial, or urbanized lands, including all transportation corridors that produce pollutants, promoting greater increases in stormwater infiltration using various methods and greater capacity for stormwater detention or retention. **Water rights:** Purchase water rights as available and dedicate those rights to conservation.

ISSUES OF CONCERN	RELEVANCE TO INDICATOR SPECIES	CAUSES	SOLUTIONS	STRATEGIES/ACTIONS
ECOSYSTEM COMPONENT: STREAM CHANNEL CONDITIONS (LARGE AND SMALL STREAMS)				
The river channels in the region have lost structural and habitat diversity compared to their historic condition to varying extents across the basin. Wood loads have been reduced to low levels throughout large portions of the basin (Smith and Wenger 2001; GHLE 2011). These changes have resulted in alterations to channel stability, changes in substrate stability, loss of pool habitat and other habitat types, and substrate sizes (Wendler and Deschamps 1955; Hiss and Knudsen 1993; Sullivan and Massong 1994; Smith and Wenger 2001; GHLE 2011). Smaller streams have been extensively channelized within urban and agricultural areas (Hiss and Knudsen 1993; GHLE 2011). Wood removal can trigger channel incision, which creates new sources of sediment by mining channel bed and destabilizing banks. Incision also increases sediment transport capacity, which has similar effects of a dam—bed coarsening and reduction of spawning gravel. Channel incision as a result of past land uses is widespread in large parts of the basin (Smith and Wenger 2001). Climate change may be exacerbating these issues (Clark 1999), seen in the dramatic increase in peak annual flows in the Newaukum River hydrograph.	The Chehalis Basin has experienced reductions of native fish migration, spawning, incubation, and juvenile rearing habitat quality (manifested in the frequency, stability, and structure of habitats) and quantity (Hiss and Knudsen 1993; Smith and Wenger 2001; Mobrand Biometrics 2003; GHLE 2011). Numerous river segments in the Chehalis Basin have experienced a loss of side channel habitats, which are particularly important for spawning and rearing by young juveniles. Reduced in-channel wood or increased flow can cause increased egg to fry mortality due to channel scour or sediment deposition. Reduced in-channel wood and loss of off-channel habitat can increase mortality of young fry due to loss of refuge habitat. Reduced in-channel wood and floodplain connectivity can increase mortality during summer and winter rearing stages due to loss of high-quality habitats. Reduced in-channel wood and riparian forest can result in reduced food diversity and quantity for juvenile salmon and other native fish. Reduced quality of in-channel habitats can result in declines in fish population performance at all freshwater life stages and over the entire life cycle, thereby reducing the probability of long-term sustainability and performance.	Intensive timber harvest in the early 20th century accompanied by log driving and splash damming resulted in large reductions to in-channel wood and channel incision (Wendler and Deschamps 1955). Removal of large and small logjams within the active channel migration zone has reduced riverine habitat quality and quantity. Stream channel straightening or channelization reduces habitat quantity and quality. Constriction of the active high-flow channel by roads, bridges, levees, or bank armoring reduces habitat quantity and quality. Increases (from various land uses) or decreases (due to a dam) in sediment loading to the stream change habitat-forming processes. Changes in the flow regime, particularly in the frequency, duration, and level of high-flow events, which is caused by various land and water use patterns, reduce habitat-forming processes. Disconnection from the river's floodplain or reductions in the water and/or sediment storage capacity of the floodplain reduces habitat quantity and habitat-forming processes. Gravel mining from the channel or the river bars reduces spawning habitats and modifies natural habitat-forming processes. Timber harvest or clearing within the riparian zone reduces wood recruitment to the river system and reduces nutrient cycling and foodweb productivity. Climate change effects (increasing peak flows in the Newaukum River) may be exacerbating these issues (Clark 1999).	Protect and restore active CMZs and restore meander patterns by reducing channel and flow constrictions and restoring channel migration zones. Restore large wood to the active channel and the active CMZ, and where appropriate, promote stable vegetated islands. Restore more natural flow regime characteristics by stormwater management and increasing forest cover. Restore connections to floodplains that provide for increased sediment storage and flood capacity and storage. Restore more natural flow regime in dammed rivers (Wynoochee and Skookumchuck rivers).	**Channel pattern:** Strategically remove channel constrictions and impediments to migration to restore channel capacity and develop more natural channel patterns (e.g., use of setback levees, road relocations, lengthening and/or raising bridges, or rebuilding the channel pattern). **CMZ:** Protect and restore the active CMZ (because it has been reduced by human activities) through regulations, incentives, education programs, or land acquisition. **Large wood:** Construct engineered logjams or place large wood in appropriate locations of the river to facilitate island formation, sediment storage, and processing and channel patterns (including bed elevations), and promote the formation of side channels, backwaters, or stable vegetated islands. **Invasive species management:** Inventory and manage invasive plant species such as Japanese knotweed and canary reed grass. **Protect riparian lands:** Increase protection of riparian lands through regulations, incentives (e.g., conservation easements), land purchases, and education and outreach programs. **Restore riparian forest:** Restore more natural riparian forest characteristics using passive or active management methods. Activities listed for protection of riparian lands also apply here. **Consider restoration corridor:** Consider a restoration corridor concept for restoration projects to identify channel migration hazards and provide space for a diversity of channel and floodplain habitats.

ISSUES OF CONCERN	RELEVANCE TO INDICATOR SPECIES	CAUSES	SOLUTIONS	STRATEGIES/ACTIONS
ECOSYSTEM COMPONENT: LARGE STREAM FLOODPLAIN CONDITIONS				
Loss of floodplain connectivity: Major parts of the floodplains of stream channels in the basin have been disconnected from the active channels within the alluvial valleys due to various types of channel alterations that have occurred over the decades, including channel incision (Smith and Wenger 2001; GHLE 2011). **Floodplain conversion:** Large areas of the floodplains have been converted to agriculture, residential, or urbanized areas. In the process, wetlands have been drained and filled (Clark 1999). Changes to the floodplains reduce their function including elements such as groundwater infiltration and storage, runoff volumes, and the amount and quality of off-channel habitat features used by native aquatic species.	Loss in floodplain function can further degrade in-channel conditions, affecting adult migration, spawning, incubation, and juvenile salmonid habitat quality (manifested in the loss of frequency, stability, and structure of habitats) and quantity. Loss in floodplain connectivity and function can diminish fish food diversity and quantity (Bellmore et al. 2013, 2017; Lestelle et al. 2005). Loss of side channel habitats is most significant for spawning and rearing by young salmon juveniles (Sedell et al. 1984). Loss of off-channel habitats are most important for summer and winter rearing of juvenile coho salmon, though juvenile Chinook salmon can also use these habitats (Lestelle et al. 2005; Lestelle 2007). Floodplain connectivity and seasonal timing affects the quality of habitat and presence of invasive species that affect the survival of stillwater breeding amphibians and native fish such as Olympic mudminnow (Hayes et al. 2019; Mongillo and Hallock 1999). All of these changes reduce fish population performance at various life stages and over the entire life cycle, thereby reducing the probability of long-term sustainability or recovery (citations as listed previously in this column). Loss of floodplain medium-hydroperiod habitats results in loss of breeding and rearing habitat for stillwater-breeding amphibians where these can breed and rear without high impact from invasive predator species.	Intensive timber harvest in the early 20th century accompanied by log driving and splash damming resulted in large reductions to in-channel wood and channel incision (Wendler and Deschamps 1955). Stream channel straightening or channelization can disconnect the active channel from its floodplains. Channel control measures, such as levees, and other types of bank armoring reduce channel migration and disconnect the active channel from its floodplain. Conversion of forested floodplains and floodplain intermediate-hydroperiod pond to agriculture, residential, and urban settings reduce floodplain habitats and functions. Drainage and filling of overflow channels, off-channel ponds, and wetlands and marshes located on the floodplains occur to convert these areas to simplified and/or upland habitats. Loss of floodplain medium-hydroperiod habitats results in loss of breeding and rearing habitat for stillwater-breeding amphibians where these can breed and rear without high impact from invasive predator species.	Restore connections to floodplains that provide for increased sediment storage, flood capacity and storage, and groundwater and hyporheic recharge (Roni et al. 2012). Restore wetland complexes and beaver pond complexes. Protect and restore CMZs and restore meander patterns by reducing channel and flow constrictions. Modify or remove levees, bank armoring, and other infrastructure that disconnects floodplains. Acquire floodplain lands and restore ecological functions of those lands. Create medium-hydroperiod pond to encourage stillwater amphibian breeding	**Transportation infrastructure:** Improve or remove transportation infrastructure within floodplains to restore channel and floodplain function and connectivity. **Protect floodplains:** Protect existing riparian and floodplain lands from land conversions or loss of function through regulations, incentives, education programs, land acquisition, or land set-asides. **Restore floodplains:** Restore floodplain characteristics and function by restoring wetlands, ponds, overflow channels, riparian forest, and/or size of floodplains; this includes connectivity of off-channel features. **Beaver management:** Develop and implement as warranted beaver management measures. Beaver activity is consistent with achieving floodplain, channel, and habitat characteristics, though private property protection and riparian protection (during re-establishment phase) may warrant active management of beaver. **CMZ:** Protect and restore active the CMZ (because it has been reduced by human activities) through regulations, incentives, education programs, or land acquisition. **Invasive species management:** Inventory and identify management measures for invasive plant species such as Japanese knotweed and canary reed grass. **Restore riparian:** Restore riparian forest characteristics using passive or active management methods. Activities listed for protection of riparian lands also apply here. **Consider restoration corridor:** Consider a restoration corridor concept for restoration projects to identify channel migration hazards and provide space for a diversity of channel and floodplain habitats.

ISSUES OF CONCERN	RELEVANCE TO INDICATOR SPECIES	CAUSES	SOLUTIONS	STRATEGIES/ACTIONS
ECOSYSTEM COMPONENT: RIPARIAN CONDITIONS				
Loss of riparian function: Riparian areas have been impacted to varying degrees throughout the basin by a wide variety of land use activities, which include timber harvest, land clearing, and land development. These activities have removed or altered the riparian plant communities, modified riparian soil conditions, and other associated land and water features, as well as modified natural ecological cycles, all of which affect riparian functions (Hiss and Knudsen 1993; Smith and Wenger 2001).	The ecological health of streams is closely linked to the watershed landscape by the biotic and physical-chemical properties of the riparian zone (Naiman et al. 2005; this citation applies to all following text also). Riparian forests affect stream and shoreline shading, influencing stream temperature, dissolved oxygen, and plant species composition (e.g., invasive species)—all of which affect salmonid and other aquatic species performance and habitat use. Riparian zones affect water quality by trapping suspended and fine sediments and pollutants. Riparian zones slow water velocities during high flows. Riparian zones stabilize streambanks and help maintain channel stability and bank cover for fish. Riparian zones add leaf matter, insects, and wood to the stream, providing nutrients, food, and structure to stream ecosystems. All of these functions directly and indirectly affect salmon and other aquatic species.	Timber harvest has occurred widely across the basin, including riparian areas, over the past 150 years, although only limited removal of trees is allowed within riparian forests in present day. Land conversion and vegetation removal has occurred within the riparian corridors of rivers across the basin for agriculture, residential, road systems, and urban areas. Streambank protection practices have been widely used to protect private property and infrastructure and have reduced riparian areas. The growth and spread of invasive plant species such as Japanese knotweed and reed canary grass has affected the growth and survival of native vegetation within the riparian corridor and can choke seasonal or small channels within the corridor.	Promote mature riparian forests by expanding widths where possible or by use of active management practices (e.g., thinning, planting). Manage Japanese knotweed and reed canary grass. Manage beaver populations to limit their adverse effects on riparian corridors while in the process of being restored to more natural conditions.	**Protect riparian lands:** Increase protection of riparian lands through regulations, incentives (e.g., conservation easements), land purchases, and education and outreach programs. **Restore riparian forest:** Restore riparian forest characteristics using passive or active management methods. Activities listed for protection of riparian lands also apply here. **Beaver management:** Develop and implement as warranted beaver management measures. Beaver activity is consistent with achieving floodplain, channel, and habitat characteristics, though private property protection and riparian protection (during re-establishment phase) may warrant active management of beaver. **Invasive Species Management:** Inventory and identify management measures for invasive plant species such as knotweed and reed canary grass.

ISSUES OF CONCERN	RELEVANCE TO INDICATOR SPECIES	CAUSES	SOLUTIONS	STRATEGIES/ACTIONS
ECOSYSTEM COMPONENT: WATER QUALITY				
Degraded water quality (temperature, oxygen, pollutants): Runoff developed lands can be sources of different types of pollutants, including fine sediment and various types of chemicals and heavy metals. Runoff from highways and major roads are particular sources of metals. Loss of forested riparian zones also cause elevated stream temperatures and sometimes reductions in dissolved oxygen, both of which reduce water quality. Low flows and lack of connectivity with floodplains can also increase water temperatures and subsequently reduce dissolved oxygen (Beechie et al. 2012).	Elevated stream temperatures can negatively affect native fish and amphibian population performance by limiting growth, prompting redistribution in search of cool water refuges, or in severe cases, causing direct mortality. Low dissolved oxygen levels in late summer and early fall when flows are at seasonal lows can adversely affect population performance by limiting growth or causing direct mortality. Increased sedimentation reduces habitat quality and can cause increased mortality or stress in certain life stages. Small amounts of chemical pollutants can adversely affect the physiology or behavior of both juvenile and adult salmon, leading to stress, mortality, reduced homing to spawning areas, or reproductive success.	Removal of forest cover affects the microclimate of stream systems and can elevate water temperatures. Loss of riparian trees along streams can directly lead to elevated water temperatures from solar radiation. Increased water temperatures, combined with low flows and high levels of organic material, can result in diminished dissolved oxygen levels. This condition can be particularly severe in off-channel habitats and wetlands and when flows are extremely low. Runoff from roads, highways, and parking lots is a source of metal and petroleum pollutants. Runoff from residential and agricultural areas is a source of nutrients, herbicides, and pesticides.	Continue to improve forest management plans to promote more diverse stand age across the landscape. Evaluate pre-filled sediment wedges to locally reduce water temperatures. Restore forested riparian corridors. Improve stormwater treatment measures. Improve education of the public on sources of pollutants and how to minimize these sources. Improve conservation and retention in fertilizer applications.	**Protect riparian lands:** Increase protection of riparian lands through regulations, incentives (e.g., conservation easements), land purchases, and education and outreach programs. **Restore riparian forest:** Restore riparian forest characteristics using passive or active management methods. Activities listed for protection of riparian lands also apply here. **Stormwater management:** Update and enforce storm runoff management on agricultural, residential, commercial, or urbanized lands, including all transportation corridors that produce pollutants, promoting greater increases in stormwater infiltration using various methods and greater capacity for stormwater detention or retention.

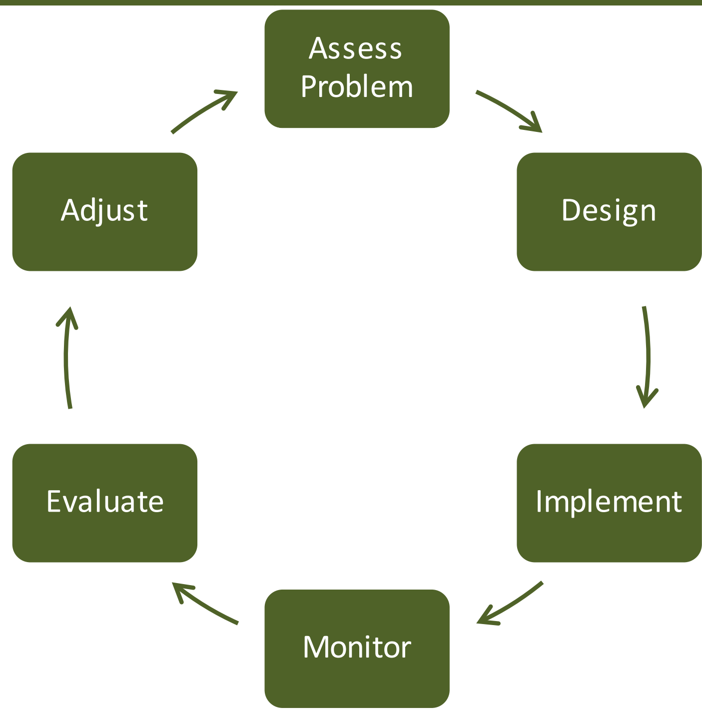
Appendix B
Monitoring and Adaptive Management Framework

1 OVERVIEW AND BACKGROUND

The Monitoring and Adaptive Management (M&AM) Team is a subcommittee of the Steering Committee, who in conjunction with the Science and Technical Review Team (SRT) recognized the need for a formal monitoring program evaluating the effects of restoration actions and an integrated adaptive management program to improve the restoration program. The formal monitoring program is meant to build off the foundations documented in the Scientific Foundation (Appendix A), as those principles are applicable in a robust and comprehensive M&AM Plan. The M&AM Team was tasked with developing the M&AM Framework for the Aquatic Species Restoration Plan (ASRP) Phase 1 document. This group includes SRT members, other regional experts, and practitioners of monitoring programs in Washington State that are appointed by the Steering Committee. The purpose of the framework is to lay the foundation for the overall M&AM Plan, which will provide a comprehensive approach to M&AM of the actions associated with the implementation of the ASRP.

Monitoring, in this context, is a key component of adaptive management of the ASRP. Adaptive management is defined as a "systematic approach for improving resource management by learning from management outcomes . . . [It] makes use of management interventions and follow-up monitoring to promote understanding and improve subsequent decision-making" (Williams et al. 2009; see Figure B-1). The components of the framework were selected to assess the outcomes of ASRP implementation at multiple scales and to provide relevant, timely feedback from which more informed management decisions could be made. This document will outline the framework elements, discuss the development of subprograms where applicable, and describe the applicable scales of monitoring to document the M&AM Team's approach to developing the full M&AM Plan as part of the ASRP. As a framework, this document does not include details about protocols or methods. The comprehensive M&AM Plan will be developed in a future ASRP phase.

Figure B-1
Adaptive Management Cycle



Note:
Adapted from Williams and Brown 2012.

1.1 Framework Development

The M&AM Team began developing this framework by reviewing the basic documents and observations that underpin and drive ASRP development, including the Chehalis Basin Strategy, the Scientific Foundation (see Appendix A of the ASRP Phase 1 document), and SRT observations from site tours. Building from the specific focus on the ASRP *Initial Outcomes and Needed Investments for Policy Consideration* (Initial Document; ASRP SC 2017) as well as the Scientific Foundation as updated for the ASRP Phase 1 document, the M&AM Team used the ASRP Initial Document's vision statement, approach description, and expected outcomes to identify elements critical to focusing monitoring efforts. The Scientific Foundation was a key resource for developing the monitoring program framework. Specific assumptions and uncertainties in the Scientific Foundation led to the development of hypotheses that require validation to assure ASRP benefits are realized and to adjust the ASRP if warranted. Input from SRT field visits in the Chehalis Basin helped inform testable hypothesis development.

The ASRP Initial Document's vision statement (ASRP SC 2017) was used to guide the M&AM Framework development. Four focus areas distilled from the ASRP Initial Document's vision statement are featured in Table B-1.

Table B-1
Monitoring and Adaptive Management Framework Focus Areas

FOCUS AREAS FROM THE ASRP INITIAL DOCUMENT VISION STATEMENT
1. Support healthy, harvestable salmon populations.
2. Maintain robust diverse populations of native aquatic and semiaquatic species.
3. Maintain productive ecosystems that are resilient to climate change and other anthropogenic stressors.
4. Honor the social, economic, and cultural values of the region.

These focus areas formed the basis for the development of monitoring programs, with different approaches and scales needed to address each monitoring program. M&AM Team members then integrated the first three focus areas into this M&AM Framework. The fourth focus area would be developed in a future phase by a policy- and community outreach-oriented team of experts.

2 PURPOSE

The overarching purpose of the M&AM Framework is to outline a monitoring program for the ASRP that can provide the information necessary to assure the success of the ASRP through adaptively managing its implementation. The M&AM Framework is designed to not only determine the effectiveness of the restoration in improving aquatic species habitat and population health but also serve as a course correction and feedback tool to assess progress. The monitoring program is intended to determine whether the level of effort, specific actions, and rate of restoration are sufficient to achieve the vision of the ASRP. An integrated array of monitoring approaches is needed to achieve that purpose. This M&AM Framework will ultimately guide development of a more detailed M&AM Plan to be completed in a future ASRP phase.

Building on the focus areas listed in Table B-1 and other supporting documentation, the M&AM Team identified the following management questions to guide framework development and link to specific sampling programs:

1. What is the current watershed condition in the Chehalis Basin?
2. What is the trajectory of change in watershed condition in the Chehalis Basin?
3. Will implementation of the ASRP restoration actions have a significant effect on the aquatic habitat in the Chehalis Basin?
4. What restoration is enough to improve aquatic habitats at a watershed scale?
5. What amount of restoration is necessary to benefit aquatic species at a watershed scale?
6. What is the project-level effect of restoration actions?
7. What can be learned from early action projects (see Section 6 of the ASRP Phase 1 document for project details) to inform subsequent reach scale actions?
8. Which of the hypotheses or assumptions included in the development of the ASRP have substantial uncertainty around them and have the potential to affect the implementation of the ASRP?
9. How would these hypotheses or assumptions be prioritized for additional study?
10. What are the known data gaps that are currently outside of the scope of this monitoring program that may affect the interpretation of the data collected (e.g., estuary conditions)?

> **Watershed scale** refers to a subdivision of the Chehalis Basin Ecological Regions that includes relevant sub-basins (e.g., approximately Hydrologic Unit Code [HUC] 10).
>
> **Project-level effects** are those effects that occur and are measured at the location of the project action.

These management questions naturally break out into different scales and approaches for monitoring. Some of the questions are at the project level, while others need to be assessed at the watershed scale. Hypothesis testing, given the variable nature of uncertainties, would need to be addressed at multiple scales. Using standard monitoring terminology from the Pacific Northwest, these questions can be grouped into the following four major monitoring types: implementation, project effectiveness, status and trends, and validation.

The M&AM Team recommends the following sampling programs (monitoring approaches or studies) to address differences in spatial scale, sampling approach, metrics, and analyses inherent in the questions and focus areas:

- **Implementation monitoring** tracks whether projects were constructed as planned (e.g., number of wood structures, acres of riparian planted, or length of side channel) (RCO 2019). Implementation monitoring should occur at all project locations to document construction and other project actions relevant to permit compliance. This monitoring could include as-built surveys of project topography, verification of quantities and specifications of wood placed, acres and quantities planted, measurements of habitat length and area constructed, and survivability of specified plantings.
- **Project effectiveness monitoring** evaluates whether the habitat and biological outcomes for each project were achieved (e.g., did wood structures scour pools, were floodplain habitats reconnected, or did the local abundance of Oregon spotted frogs increase) (RCO 2019). Under this framework, implementation monitoring would be included as part of project effectiveness monitoring at the locations where effectiveness monitoring is completed. Otherwise, implementation monitoring would be completed separately at each project site. To assess the effects of project actions on aquatic species and their habitat, it is recommended that effectiveness monitoring be conducted at a subset of the locations to assess the habitat outcomes (e.g., number and depth of pools created, area and survival of plantings, or floodplain connectivity of off-channel habitats). This monitoring could combine direct field sampling (e.g., pool measurements, wood counts, or crest gauges) and remote sensing (e.g., bathymetric light detection and ranging [LiDAR] and National Agriculture Imagery Program [NAIP] imagery). Limited information on biological community response would be collected (e.g., macroinvertebrate samples), but additional biological monitoring would not be conducted due to the high level of variability in biological sampling.
- **Status and trends monitoring** is a general approach to assessing the "status" or condition of the physical, biological, and chemical characteristics of a river or stream at a single point in time. These same locations are resampled at future time points to determine the "trend" in condition (Ecology et al. 2006). Under this framework, the status and trends approach is used to assess the change in habitat conditions at the watershed scale and to assess the impacts of actions that are outside the influence of the ASRP restoration efforts. Watershed scale refers to select sub-basins within the larger ecological regions defined in the ASRP Phase 1 document. An example of watershed scale could be the entire Newaukum River sub-basin.

> **Population health** is a combined assessment of abundance, distribution, diversity, and spatial structure.
>
> **Ecosystem resiliency** is the ability of an ecosystem to remain functional (provide the diversity and quantity of habitats needed to support healthy populations of the suite of native species) in the face of climate change and anthropogenic disturbance.

To assess the overall impact of restoration implementation and larger-scale elements—such as watershed condition and trajectory, aquatic species population health, and ecosystem resiliency—status and trend monitoring at a watershed scale is recommended. This sampling could include habitat monitoring using a network of sites and selected biological monitoring as follows:

- **Physical Habitat Sampling:** Habitat monitoring could include sampling sites across a spatially balanced network using varied critical indicators of watershed condition (e.g., water temperature, levels of large wood) as well as remote sensing data (e.g., NAIP imagery) to assess changes at a watershed scale.
- **Biological Sampling:** Biological sampling at the population scale occurs for selected salmon populations and for the diversity of selected native aquatic and semiaquatic species, as well as for macroinvertebrates. Population scale can differ depending on spatial distribution in the basin but informs watershed monitoring programs. Overlapping assessment strategies allow relationships between macroinvertebrate metrics, fish abundance, survival, and growth to be evaluated at multiple scales. Some salmon populations are currently being monitored using a "fish in/fish out" approach of spawner returns and smolt outmigration, and these efforts would continue under this framework. Aquatic species diversity could be measured across the suite of aquatic habitats (stillwater and flowing water habitats) present in the Chehalis Basin.

- **Validation monitoring** is recommended via hypothesis testing at case-specific scales. Validation monitoring is designed to evaluate the specific cause and effect relationships between habitat conditions resulting from the implementation of restoration actions and the populations the actions are intended to benefit (WDNR 2019). Under this framework, the validation monitoring is achieved via hypothesis testing, which looks at the underlying assumptions (i.e., cause and effect relationships between habitat conditions and species response) that have high levels of uncertainty and are likely to affect the interpretation of monitoring results.
  - **Case-Specific Sampling:** Focused case-specific sampling would be recommended to test hypotheses about species/habitat relationships that currently have high uncertainty and are likely to affect the implementation of the ASRP and the interpretation of other monitoring data. This sampling would be dependent on the specific hypotheses identified in future phases and is not further developed for this M&AM Framework stage. In addition, any data gaps (which are currently outside the scope of this framework) that are determined to be critical to implementation could be addressed under this type of sampling through coordination with the SRT and Steering Committee.

3 FRAMEWORK ELEMENTS

A framework element is a concept that the M&AM Team identified as being inherent across sampling programs that should be woven throughout the M&AM Plan in order to improve efficiency and effectiveness in sampling. These elements emerged throughout discussions of the M&AM team as "lessons learned" from the group's experience implementing other large-scale monitoring programs across the state.

3.1 Technical Elements of Sampling

3.1.1 Similar Protocols and Data Compatibility

It is important to have consistency in protocols and in how data are collected; this allows information to be compatible among different aspects of the monitoring program and increase cost efficiency by allowing for comparability between the different study designs and scales. Sampling programs included in this framework are designed to interact and complement each other in terms of the methods used to collect the data and the ability to share data across sampling programs described in this plan and other existing monitoring programs across the state. A basic principle would be to use consistent monitoring protocols so that information will be compatible across programs. Adhering to this principle would provide important overlap between the watershed status and trends and project effectiveness programs.

3.1.2 Remote Sensing

Remote sensing would complement field sampling and provide continuous imagery over large areas—for example, sub-basins targeted for multiple restoration actions. Remote sensing serves multiple purposes, including planning and design of restoration projects, evaluation of floodplain connections, analysis of changes in land use and performance of upland vegetation, and analysis of watershed condition on a broader scale than is possible with alternative methods. Remote sensing examples include analysis of NAIP imagery, LiDAR, bathymetric (green)-LiDAR, and varied georeferenced data to detect changes in landform, floodplain topography, channel migration and network (such as meanders and side channels), and riparian condition. Methods such as geomorphic change detection, hydraulic modeling, and habitat suitability modeling can be applied to these datasets and are often more efficient than field surveys for larger areas. Specifically, the use of hydraulic modeling could be key to evaluating floodplain connectivity, in conjunction with crest gauges in off-channel and side-channel habitats and drone-based video and images collected during high flows.

Importantly, remote sensing data with a history of regular periodic collection and high potential for continued collection should be selected for analysis. It is recommended that standardized methods such as high-resolution change detection methods developed by the Washington Department of Fish and Wildlife (Pierce 2019) and 2D hydraulic modeling that can describe past and current floodplain connection are selected for application to repeated data collection events.

3.1.3 Quality Assurance and Data Management

Data availability is critical for large, multifaceted monitoring efforts, as many groups need access to datasets for analysis and to use information for restoration and other types of work. Assuring that datasets are reliable, in terms of both precision and accuracy, is important across all the sampling programs. Data management systems are expensive, so partnerships across agencies, tribes, and other groups would ensure maximum data quality and accessibility. Online data management systems with automated quality assurance elements are helpful, but the management systems need to be flexible enough to store and organize multiple types of data that may be captured across sampling programs.

3.2 Consolidation of Data Within and Outside of the ASRP

Consolidation of existing data from studies conducted as part of the ASRP is needed to implement a cost-effective monitoring program, and it is a critical first step in program development. This would help to ensure that the M&AM Team and all parties involved in restoration are aware of available data sources and that M&AM Team members can integrate information needs associated with the monitoring program with existing data collection under other programs.

In alignment with that theme is the consolidation of information about active restoration and monitoring efforts that are outside of the ASRP programs entirely. Knowledge of locations, actions, and types of data being collected—similar to the consolidation of data from studies within the ASRP umbrella—helps to ensure cost effective implementation of the monitoring program. The Washington State Lead Entity Program Habitat Work Schedule is a useful tool to comprehensively track other restoration actions in the basin.

3.3 Timely Reporting of Information

In addition to collecting and consolidating data using consistent protocols, there is a need to ensure the data are analyzed and reported out in a timely, consistent manner in order to be useful to managers responsible for adaptive management. Timing and reporting formats will be further refined as part of the plan development process.

4 SAMPLING PROGRAMS

4.1 Project Effectiveness

Project effectiveness monitoring is the tracking of the response of habitats and their associated aquatic and semiaquatic species at the project level to restoration. This monitoring is used to determine the success of restoration actions at the project-level scale and whether actions are achieving their expected outcomes. The assumptions, objectives, and questions that are the basis of the project effectiveness monitoring program are described in the following sections.

Typically, a restoration plan or project includes several interacting treatments (e.g., placed large wood, channel reconfiguration, or levee removal). Monitoring should inform the long-term function of the following: 1) individual treatments (e.g., how are reconfigured channel sites changing and why?); and 2) the entire project (e.g., is the access to the floodplain improved and maintained throughout the reach?).

4.1.1 Key Assumptions

ASRP implementation will have a focus on conducting process-based restoration. Therefore, the following assumptions are maintained:

1. The process-based restoration approach would attempt to reestablish a semblance of functional rates and magnitudes of physical, chemical, and biological processes that create and sustain habitat-forming and riverine ecosystem dynamics (Beechie et al. 2010; Scientific Foundation).
2. The process-based restoration activities of the ASRP would be designed to do the following:
   - A. Reconnect off-channel and floodplain habitats.
   - B. Restore habitat-forming processes.
   - C. Restore habitat connectivity.
   - D. Restore self-sustaining riparian processes.
   - E. Re-create key habitat features.
   - F. Remove and/or relocate infrastructure at a high risk of flooding from restoration actions.
   - G. Integrate experimental design into restoration actions to evaluate outcomes for native species other than salmon and steelhead to ensure that successful outcomes have a higher probability in future efforts.

4.1.2 Monitoring Objectives

1. Track project implementation actions.
2. Determine the degree to which restoration projects achieve their expected outcomes by doing the following:
   - A. Use a standard monitoring approach to facilitate among-site and through-time comparisons.

   B. Include supplemental monitoring at projects (e.g., tracking channel development and measuring inundation timing and depths) to help determine how a project is functioning and to allow for adaptive management.

3. Evaluate the effectiveness of how restoration actions re-establish physical, chemical, and biological processes over time by tracking conditions.
4. Provide reliable information for scientifically based adaptive management decisions within a useful timeline. Reliable information should allow for the detection of differences between regional and local (project) trends in important conditions.

4.1.3 Monitoring Questions

1. To what degree are ASRP restoration projects achieving their expected outcomes and performance measures?
2. Are the restoration projects implemented through the ASRP creating the necessary physical, chemical, and biological conditions to achieve ASRP program goals?

4.1.4 Scale

Project-level effectiveness monitoring is designed to evaluate restoration projects implemented at the reach and site scales. Early Action Reach projects, described in Section 6 of the ASRP Phase 1 document, are considered reach-scale.

4.1.5 Spatial Design

Early Action Reaches and future project-level effectiveness monitoring could occur at the targeted fixed restoration locations.

4.1.6 Temporal Design

The temporal design addresses monitoring through a project's life (timeline). Pre-implementation monitoring ideally would occur in enough time before project implementation to capture between-year variability when applicable, though pre-implementation monitoring will be focused on the physical characteristics of the site. Post-implementation monitoring would occur immediately after treatment and subsequently on the most suitable year-scale rotation for each metric. Some metrics could be monitored more frequently, while other metrics could be monitored less frequently over a longer timeline. This sampling frequency would allow the detection of immediate responses and emerging trends in order to recommend adaptive management alternatives to design teams and restoration implementers.

4.1.7 Restoration Project Template

Templates similar to those used in the Lower Columbia River Estuary Program (USEPA 1999) could be used to document habitat restoration project information and existing data and integrated as part of the planning process for restoration project-level monitoring. These templates would be used to clearly document and communicate habitat project objectives and outcomes and identify the best methods to measure the achievement of quantifiable objectives and outcomes.

A standard form/questionnaire is expected to be used to collect consistent information about the restoration project site, design, and expected outcomes. Important uses include having the project sponsors (designers) identify the specific site characteristics that they intend to change; estimates of the types, locations, and quantities of changes; and the area affected by site changes or treatments. Such characteristics or attributes should be monitored to allow for adaptive management of the project and stronger inferences about the changes from the project. Specifically, the template would identify and quantify intended changes to habitats and help clearly specify objectives.

4.1.8 Native and Invasive Species Screen

An initial screen for native and invasive species should occur prior to the design process for each ASRP project. The purpose of the screen is to identify areas where the current diversity of aquatic species is potentially high (areas to protect), areas where restoration could improve habitats, and areas where invasive species could interfere with restoration or protection efforts. The native species screen has already occurred as part of the Early Action Reach design process. This step provided design teams with information about existing high-quality habitats for aquatic and semiaquatic species, known occurrences of rare species, sensitive areas that should not be further disturbed by restoration projects, and infestations of invasive species that should not be allowed to further proliferate in restored environments.

4.1.9 Example Metrics

Many metrics have been identified to be included as part of the Project Effectiveness Sampling Program. Table B-2 identifies some example metrics and associated protocols to give a sense of the type of habitat sampling that could be included as part of the program. Additional detail on protocols, methods, and selected priority metrics will be included in the M&AM Plan developed in Phase 2 of the ASRP.

Table B-2
Example Metrics for Project Effectiveness Monitoring

LOCATION	METRIC	METHOD/PROTOCOL
Channel	Channel dimensions	EAPSOP113, Channel Dimensions
	In-channel and side-channel habitat units	EAPSOP120, Habitat Units
	Thalweg profile	EAPSOP119, Thalweg Profile
	Large woody debris	EAPSOP121, Large Woody Debris Tally
	Fish cover	EAPSOP116, Fish Cover
	Riparian cover	EAPSOP115, Riparian Cover
	Substrate/embeddedness	EAPSOP114, Substrate
	Benthic macroinvertebrates	EAPSOP073, Benthic Macroinvertebrates
	Temperature (continuous)	EAPSOP80 Continuous Temperature (linked with ThermalScape modeling)

LOCATION	METRIC	METHOD/PROTOCOL
	Bank erosion	EAPSOP113, Bank Erosion
	Stream discharge	Continuous stream discharge
Riparian	Riparian structure	EAPSOP117, Riparian Vegetation Structure
	Riparian plantings	Survival, forest cover and function, invasive plant distribution and cover
Floodplain	Floodplain connectivity/water surface elevation	Hydraulic modeling using bathymetric LiDAR; measuring stage height with water loggers/crest gages; EAPSOP072, EAPSOP024, EAPSOP042
	Groundwater levels (continuous)	Piezometers, groundwater standard operating procedures (post-project only)
	Landscape changes such as land use, land cover, or vegetation	High-resolution change detection using LiDAR and NAIP imagery
Overall Project Reach	Project reach conditions	Photograph points at georeferenced locations

Note:
EAPSOP: Washington Department of Ecology Environmental Assessment Program Watershed Health Monitoring Program Standard Operating Procedure

4.2 Status and Trends Monitoring

Status and trends monitoring is a general approach to establishing the current condition (status) of a watershed and then repeat sampling to monitor the change in the condition (trend) through time. Under this framework, the monitoring could include both physical and biological sampling, and it could be distributed across appropriate subunits of the Chehalis Basin (e.g., HUC 10) that are denoted as watershed scale monitoring.

Status and trends monitoring of watershed conditions includes the physical, chemical, and selected biological conditions of aquatic and riparian habitats. This information would provide watershed-level and potentially ecological region- or basin-scale trends and health information to help interpret and provide context for reach- or project-level results. Reliable information about changes in watershed condition requires consistent long-term monitoring at a large number of representative (random) sites that can be used as references to detect treatment effects. The physical habitat sampling methods for the basin-wide efforts would be consistent with the project effectiveness monitoring program to facilitate reliable comparisons. Biotic sampling would also be included in status and trends monitoring, but it would be based on the distribution and habitat use of species. Salmonid sampling has an infrastructure in place to assess the migratory populations of Pacific salmon and steelhead in the Chehalis Basin (fish in/fish out where applicable, run size and escapement estimates). Monitoring of salmon and steelhead populations could be managed separately from the efforts to monitor the diversity of other indicator species.

4.2.1 Watershed Conditions Monitoring

Watershed condition monitoring of physical aspects of stream habitat for status and trends would either use a network of fixed stations from which basin-wide data are modeled (for example, temperature via ThermalScape from the modified Norwest model) or a network of spatially balanced sites to provide inferences over large spatial areas (for example, a Generalized Random – Tessellation Stratified [GRTS] application for selected watershed condition variables, such as large wood). Key assumptions, objectives, and questions that form the basis of the status and trends monitoring of watershed conditions are described in the following sections.

4.2.1.1 Key Assumptions

1. Basin-scale investment (e.g., hundreds of miles) in watershed restoration and protection would improve stream and riparian conditions at the reach scale and cumulatively result in a positive impact at the larger watershed scale.
2. The restoration and protection of natural watershed processes would allow the ecosystem to remain resilient to future perturbations, such as climate change and human stressors, through natural physical and biological adjustments (Beechie et al. 2010).

4.2.1.2 Objectives

1. Track and evaluate how the physical, chemical, and biotic conditions of aquatic and riparian habitats in the Chehalis Basin change over time.
2. Determine the key human and climate change stressors in the Chehalis Basin and impacts of these stressors to watershed conditions over time.
3. Provide the background basin conditions and context to use in interpreting the project-level effectiveness monitoring data.
4. Provide the least-biased, statistically valid, and reliable data on basin conditions, ultimately acting as a basis for determining whether restoration efforts are having a beneficial effect.

4.2.1.3 Monitoring Questions

1. Are watershed conditions in the Chehalis Basin improving, remaining the same, or declining over time?
2. Does the process-based restoration and protection approach of the ASRP attenuate human and climate change stressors to watershed processes?

4.2.1.4 Scale

Sampling may occur at the overall basin level and be stratified by selected watershed habitat categories or hydrologic unit codes (e.g., HUC 10), to be further described in the full M&AM Plan. Sampling and reporting by ecological region may occur depending on specific data needs and the patterns of restoration implementation.

4.2.2 Aquatic Species Diversity Monitoring

Aquatic species include both native and invasive fishes, amphibians, and plants as well as semiaquatic species that use aquatic habitats for a portion of their life cycle. Sampling for aquatic species diversity could provide baseline information on less-studied species and non-salmonid indicator species that can help provide context for reach- or project-level results. Aquatic species in the Chehalis Basin occur in a wide variety of habitat types. Different habitat types (strata), whether lotic (flowing) or lentic (stillwater), require varied sampling methods to evaluate their distinctive aquatic and semiaquatic species diversities (composition, richness evenness), although within a habitat type, methods and metrics would be consistent. Primary comparisons would be made within the same stratum, rather than across strata. Diversity metrics (alpha, beta, gamma, composition, richness, evenness) would be used to evaluate the health of the habitat and associated populations in each stratum.

4.2.3 Salmon and Steelhead Population Monitoring

The ongoing status and trends monitoring of salmon and steelhead populations is already providing useful information for interpreting fish responses at multiple scales. Salmon and steelhead population monitoring provides annual trends in salmon and steelhead abundance and harvest, describes a suite of viable salmonid population (VSP) metrics, and identifies whether trends in abundance are associated with changes in freshwater productivity. VSP metrics include spatial distribution, diversity, and productivity. Together, the VSP and freshwater productivity metrics can be used to interpret abundance trends and guide future restoration actions. Annual trends in salmon and steelhead abundance are the basic information used to evaluate fish responses to restoration and management practices. Sustained trends may trigger an adaptive response, specifically whether to stay the course (positive trends), make immediate changes (negative trends), or continue to evaluate (inconclusive trends). Harvest is an important indicator of long-term success of the ASRP, and the contributions of wild and hatchery production to harvest should be tracked over time. Additions to the sampling network for salmon and steelhead populations could be made in the 2019–2021 biennium, and the program would continue as part of the status and trends evaluation of populations at the watershed scale.

5 HYPOTHESIS TESTING AND DATA GAPS

An essential element of the M&AM Plan is to test key hypotheses to reduce uncertainty, otherwise known as validation monitoring. The M&AM Team identified an initial list of hypotheses, which was further refined into five categories deemed to have a large potential effect on the implementation and evaluation of the ASRP. Within these categories, the SRT identified multiple hypotheses that either underpin benefits of restoration that are assumed but need validation (uncertainty is relatively high) or represent fundamental questions where knowledge is needed. Validation is recommended to ensure that factors limiting the productivity of native species in the Chehalis Basin are clearly identified and restoration actions can be designed to effectively address them.

To address key hypotheses, the SRT developed a spreadsheet containing approximately 20 hypotheses linked to the ASRP Initial Document's vision statement (ASRP SC 2017), the Scientific Foundation, and Phase 1 approach and expected outcomes. Next, the SRT reviewed and ranked the hypotheses within the spreadsheet, which resulted in the following general categories of hypotheses being identified and prioritized:

1. Water Temperature
2. Wood
3. Off-Channel Habitat/Floodplains
4. Invasive Species
5. Poorly Acknowledged Factors Controlling Production (e.g., food)

Within each general category, several hypotheses were identified and reviewed, including the following:

1. **Water Temperature:** Can engineered logjams alter hyporheic flows and reduce water temperatures to the levels needed when combined with improving riparian shade?
2. **Wood:** Can engineered logjams adequately hold and maintain spawning gravels?
3. **Off-Channel Habitat/Floodplains:** Will the protection and creation of thermally suitable habitat, including localized cool-water refugia, result in the intended species assemblages and benefits (e.g., support summer rearing habitat for salmon and steelhead)?
4. **Invasive Species:** To what extent does the presence of predatory and competing fishes (invasive and native) in off-channel habitats limit their use by salmonids and other native aquatic species, or the survival of the latter?
5. **Poorly Acknowledged Factors Controlling Production (e.g., food):** Are actions available to increase food production in stream and off-channel habitats?

The SRT has not developed a finalized list of testable hypotheses. This will require additional discussion in the 2019–2021 biennium. However, the categories listed in this section (such as Water Temperature and Wood) provide an initial framework upon which to develop the key hypotheses component of the M&AM Plan.

Sampling methods for key hypotheses that are prioritized and selected for monitoring are anticipated to be case-specific to the habitats and species addressed in those studies. Some may be possible to address with the sampling programs or protocols previously described. The approach and effort for addressing the monitoring issues identified in these hypotheses would be designed to support the precision and accuracy needed for the results.

6 CONCLUSIONS

Collectively, programs included in the M&AM Framework provide a comprehensive basis from which to evaluate and enhance the ASRP effectiveness through the process of adaptive management. Project effectiveness monitoring will provide insight into physical changes that occur at the restoration sites themselves. Status and trends monitoring will provide information about watershed-scale changes that are occurring more generally throughout the basin for aquatic populations and their habitats. Given the diversity of the Chehalis Basin, the status and trends monitoring will focus on three key areas of watershed health—watershed conditions (physical chemical, and biotic), native species diversity, and salmon and steelhead populations. Finally, hypothesis testing would provide strategic information needed to adaptively manage the ASRP over time.

This document was developed through a collective and collaborative process across agencies, tribes, and other entities that will continue as the framework is refined and the M&AM Plan is developed and finalized. Continued work by the M&AM Team and input from the SRT and Steering Committee are expected in the 2019–2021 biennium. Next steps include additional detail development, prioritization of program elements for implementation, cost estimation, and full plan development in 2020.

7 REFERENCES

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Appendix C
Models and Analyses

MEMORANDUM

Date: October 1, 2019

To: Chehalis Aquatic Species Restoration Plan Development Team

From: Tim Beechie and Jeff Jorgensen, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northwest Fisheries Science Center, Fish Ecology Division
Colin Nicol and Caleb Fogel, Ocean Associates, Inc, under contract to U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northwest Fisheries Science Center, Fish Ecology Division

Re: Coho, Spring-Run Chinook, and Fall-Run Chinook Salmon and Steelhead Model Descriptions and Draft Diagnostic Scenario Results for Coho, Spring-Run Chinook, and Fall-Run Chinook Salmon

Introduction

Given the broad scope and importance of the *Aquatic Species Restoration Plan* (ASRP) to the Chehalis Basin Strategy, the Washington Department of Fish and Wildlife (WDFW) felt the National Oceanic and Atmospheric Administration (NOAA) Northwest Fisheries Science Center salmonid life-cycle model (NOAA model) was needed as a complement to information generated by the Ecosystem Diagnosis and Treatment (EDT) model. WDFW believes an additional, empirically based model was needed to do the following:

- Provide quantitative assessments of habitat change (e.g., measurements of historical and current floodplain habitat or riparian conditions) that can be linked to empirically based parameters of a life-cycle model.
- Incorporate stochastic or episodic habitat conditions into a life-cycle model when developing alternative restoration strategies.
- Evaluate changes in extinction risk under various habitat restoration scenarios and when incorporating annually varying habitat conditions.
- Assess specific ASRP restoration actions (e.g., wood addition) as compared to EDT's broader categories of habitat change (e.g., habitat complexity).
- Incorporate specific assessments of changes in habitat-forming processes when evaluating restoration needs, consistent with Beechie et al. (2013a, 2013b).
- Incorporate NOAA's extensive experience with life-cycle models into the ASRP.

To meet these needs, the NOAA Northwest Fisheries Science Center developed a suite of analyses and models to assess habitat changes from historical (pre-Euro-American settlement or natural potential) conditions to present. The results of those assessments were then used in a salmonid life-cycle model with nine diagnostic scenarios to determine which types of habitat changes have had the greatest impacts on salmon populations within the Chehalis Basin and how those impacts vary by sub-basin.

Three restoration scenarios that were developed through collaboration of the ASRP Science and Technical Review Team (SRT) and Steering Committee were also modeled to evaluate potential improvements in salmon and steelhead populations in the future. The results of the restoration scenario modeling are not presented in this memorandum as they are still in review; results will be available for future phases of the ASRP. These analyses are intended to help inform development of the ASRP for the Chehalis Basin, and further modeling will occur in future phases. A key element of the ASRP is habitat restoration for anadromous salmonids of economic and cultural significance, including spring-run and fall-run Chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (*O. kisutch*), steelhead (*O. mykiss*), and chum salmon (*O. keta*). The results are intended to diagnose physical constraints on salmonid populations and help prioritize restoration actions.

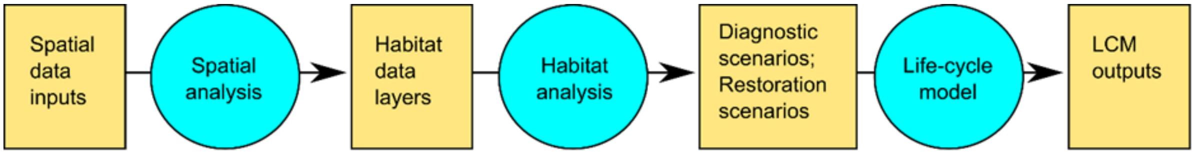
Model Overview

The NOAA analysis uses three separate models to take raw GIS data and ultimately produce results for each salmonid species under each diagnostic or restoration scenario (Figure 1). The three components of the model are the spatial analysis, the habitat analysis, and the life-cycle model (blue circles in Figure 1). This suite of models is referred to hereafter as the NOAA model. The spatial analysis processes the raw data files and produces five habitat data layers that contain current habitat areas and conditions, which are the inputs to the habitat analysis. In the habitat analysis, the five habitat data layers are used to estimate both historical and current life-stage capacities and productivities for each species and sub-basin[1] in each diagnostic or restoration scenario. That is, the outputs of the habitat analysis are individual data files for each diagnostic or habitat restoration scenario, with each file containing the life-stage and species-specific capacities and productivities used as the inputs to the life-cycle model.

The life-cycle model is then run with each diagnostic scenario for each species to diagnose the relative influences of past habitat changes on each species, as well as with each restoration scenario to assess potential improvements in each species in the future (including climate change and future development). The model outputs include estimates of the equilibrium spawner abundance (N_{eq}), as well as cumulative life-cycle productivity (P_n) and cumulative life-cycle capacity (C_n). The species currently modeled are fall-run Chinook salmon, spring-run Chinook salmon, coho salmon, and steelhead. The steelhead model diagnostic results are currently in review and are not presented here.

[1] There are 63 sub-basins, 51 tributaries, and 12 mainstem units used in the NOAA model (Figure 6).

Figure 1
Illustration of the Analysis Steps, Proceeding from the Raw Data Layers, to Habitat Data Layers, to Diagnostic and Restoration Scenarios, and Finally to the Life-Cycle Model Outputs



Raw data layers:
USGS 10-m DEM
C-CAP land cover raster
PRISM mean annual precip
Washington roads
Ecological Diversity Regions
SWIFD streamlines
WDFW Migration barriers
Summer water temperature
Riparian files
Floodplain habitat polygons
Large river edge habitat
Large river backwaters
Spawning riffles

Final habitat layers:
Large river edge habitat
Large river backwaters
Large river spawning riffles
Floodplain habitats
Attributed streamline

Diagnosis:
Migration barriers
Fine sediment
Wood loading
Shade (temperature)
Bank armor
Channel straightening
Beaver ponds
Floodplain habitats

Restoration:
Restoration actions
Climate change effects

LCM results
-Coho
-Spring Chinook
-Fall Chinook
-Steelhead

Notes:
C-CAP: NOAA's Coastal Change Analysis Program
DEM: digital elevation model
PRISM: Parameter-elevation Regressions on Independent Slopes Model
SWIFD: WDFW's Statewide Integrated Fish Distribution
USGS: U.S. Geological Survey

Diagnostic Scenarios

The diagnostic scenarios include scenarios for historical and current habitat conditions, as well as nine scenarios (listed here) in which each habitat factor is set to historical conditions independently (keeping all other factors in current conditions). This allows a comparison of which habitat factors have the most effect on abundance, productivity, and capacity of each species. The current conditions scenario sets all habitats to current conditions and therefore uses all of the current life-stage capacities and productivities for each species. The historical scenario sets all habitats to historical conditions and therefore uses all of the historical life-stage capacities and productivities for each species. The scenarios that use all current conditions except for one habitat component at a time set to historical conditions are used to help determine which types of habitat losses have most influenced salmon and steelhead populations originating in each sub-basin or ecological region. In these scenarios, the separate influences of changes in the following processes and habitat factors are each evaluated:

1. Migration barriers
2. Fine sediment in spawning gravels

3. Wood abundance change in small streams and large rivers[2]
4. Shade (temperature) changes in small streams and large rivers
5. Bank armor in large rivers
6. Large river channel straightening
7. Beaver pond changes in small streams
8. Floodplain habitat change (including all off-channel marshes, ponds, and lakes mapped in historical surveys or the most recent National Hydrography Dataset, and the influence of hyporheic exchange on stream temperature)
9. Wood abundance and floodplain habitat change combined

Tables 1 and 2 indicate which life-stage capacities and productivities are affected by each factor; details of how each habitat factor influences capacities and productivities will be included in the full report documenting the modeling that will be complete in December 2019.

Table 1
Checklist of Life-Stage Capacities (C) and Productivities (P) Affected by Each Habitat Factor in the Habitat Model and Life-Cycle Models for Coho Salmon and Steelhead

HABITAT FACTOR	C_{EGG}	P_{INCUB}	C_{SR}	P_{SR}	C_{WR}	P_{WR}
Barriers	X		X[1]	X	X[1]	X
Fine sediment		X				
Wood loading	X		X	X	X	X
Shade			X	X		
Channel length	X		X	X	X	X
Bank condition			X	X	X	X
Beaver pond area	X(neg)		X	X	X	X
Floodplain			X	X	X	X
Wood + floodplain	X		X	X	X	X

Notes:
1. Effect expressed only when barrier is 100% blocking.
C_{egg}: egg capacity
C_{sr} is summer rearing capacity
C_{wr} is winter rearing capacity
(neg): negative
P_{incub}: incubation productivity
P_{sr} is summer rearing productivity
P_{wr} is winter rearing productivity

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[2] Small streams are less than 20 meters bankfull width, and large rivers are greater than 20 meters bankfull width. Bank armor on large rivers was inventoried from aerial photography, but armored segments are not visible on small streams.

Table 2
Checklist of Life-Stage Capacities (C) and Productivities (P) Affected by Each Habitat Factor in the Habitat Model and Life-Cycle Models for Spring-Run and Fall-Run Chinook Salmon

HABITAT FACTOR	$P_{PRESPAWN}$	C_{EGG}	P_{INCUB}	C_{SUB}	P_{SUB}
Barriers		X		X[1]	X
Fine sediment			X		
Wood loading		X		X	X
Shade	X[2]			X	X
Channel length		X		X	X
Bank condition				X	X
Beaver pond area		X(neg)		X	X
Floodplain				X	X
Wood + floodplain		X		X	X

Notes:
1. Effect expressed only when barrier is 100% blocking.
2. Spring-run Chinook salmon only.
C_{egg}: egg capacity
C_{sub}: subyearling rearing capacity
(neg): negative
P_{incub}: incubation productivity
$P_{prespawn}$: prespawn productivity
P_{sub}: subyearling rearing productivity

Habitat Restoration Scenarios

A No Action future scenario and three restoration scenarios developed and agreed upon by the SRT were also run, which are intended to help evaluate the potential biological benefits of habitat restoration for each species modeled. The results of this analysis are not presented in this memorandum as they are currently under review and subject to change. Results will be available for future phases of the ASRP.

These scenarios are identified as the No Action scenario and restoration Scenarios 1, 2, and 3 by the SRT, and each scenario includes estimated changes in life-stage capacities and density-independent productivities for mid-century and late century. The No Action scenario includes riparian tree growth, removal of certain barriers, future development, and climate change. The three restoration scenarios represent low, moderate, and high levels of restoration effort, described as follows (more detail on the scenarios is provided in Section 4 of the ASRP Phase 1 document):

- Scenario 1 focuses restoration effort in 38 geospatial units (GSUs)[3]; within each GSU, barriers are removed and 20% to 50% of the stream length is treated.
- Scenario 2 adds on to Scenario 1 by restoring segments in 10 additional GSUs (48 GSUs total); within each GSU, barriers are removed and 20% to 50% of the stream length is treated.
- Scenario 3 adds on to Scenario 2 by restoration segments in 19 additional GSUs (67 GSUs total); within each GSU, barriers are removed and 20% to 75% of the stream length is treated.

The primary restoration actions proposed are barrier removal, wood addition, riparian planting, and floodplain reconnection. In all scenarios, riparian and floodplain restoration are applied only in GSUs outside managed forest lands. Barrier removal and wood placement are applied in GSUs both inside and outside managed forest lands. In GSUs inside managed forest lands, passive recovery of riparian conditions is modeled as the maturation of forested buffer zones required by the Forest Practices Act (Revised Code of Washington Chapter 76.09) mature. Each restoration scenario results in improvement in life-stage capacities and productivities, based on the percentage of improvement that the scenario creates from the current to the historical conditions.

Current water temperatures in the NOAA model are from the WDFW Thermalscape model and the Portland State University mainstem temperature model. Future water temperature scenarios are modeled using estimated temperature increases due to climate change, along with riparian and floodplain restoration scenarios to estimate future temperature reduction due to increased shade or increased hyporheic exchange due to floodplain reconnection. For the climate change increases, the U.S. Forest Service NorWeST stream temperature database (Isaak et al. 2017) was used, adjusted for a change in the baseline year from 2002 to 2015, resulting in final estimated changes of +1.0°C for mid-century and +2.0°C for late century. Climate change is also expected to increase peak flows in the Chehalis Basin, but while this effect is included in the model as a stochastic effect, it is currently under review and not included in future climate change scenarios.

Future urban development is included in the scenarios as a projected change in impervious area. In the NOAA model, future development is linked to a reduction in prespawn productivity for coho salmon (Feist et al. 2011, 2017).

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[3] GSUs are smaller units within a sub-basin and were used for the EDT modeling. The NOAA model results are presented by sub-basin and ecological region.

Life-Cycle Models

The NOAA Chehalis salmonid life-cycle models are population dynamics models driven by demographic rates, productivities, and capacities, where cohorts are tracked through life stages and space in an age-structured, stage-based approach. Through a series of computational loops, cohorts are moved through the life stages and ages with corresponding life-stage capacity and productivity parameters for each spatial unit. Each loop iteration represents a 1-year time step, transitioning fish from one age class to the next and applying as many intermediate life stages as necessary within a time step. That is, each time step in the model represents 1 year, and that year may include multiple life stages (e.g., fry colonization, summer rearing, and winter rearing).

The freshwater life stages are modeled in a sequence of either density-dependent or density-independent stages. Density-dependent stages use either the Beverton-Holt function or a hockey stick function, applying the life-stage capacities and productivities produced in the habitat analysis. The number and structure of life stages varies among species, but all of the salmon and steelhead modeled for the Chehalis Basin share certain stages or parameters in common (Table 3). Key differences among the species models include the following:

- The life-cycle model for coho salmon has six freshwater life stages that are influenced by freshwater habitat conditions: adult upstream migration, adult spawning, egg incubation, fry colonization, juvenile summer rearing, and juvenile winter rearing. A small percentage of fry move downstream to the mainstem Chehalis River after fry colonization, and another percentage move downstream after summer rearing. Smolts then leave the basin and experience emigration, delta-bay, and marine productivity. Most adults return to spawn at age 3, with a small percentage of jacks returning at age 2.
- The spring- and fall-run Chinook salmon models have five freshwater life stages that are influenced by freshwater habitat conditions: adult upstream migration, adult spawning, egg incubation, fry colonization, and subyearling rearing. Upstream migration productivity is a function of stream temperature for spring-run Chinook salmon but not for fall-run Chinook salmon. The remaining stages are modeled the same for both species. In the models, fry colonize natal sub-basin rearing habitats first, and fry exceeding the natal sub-basin rearing capacity move downstream through the mainstem to the bay as fry migrants. Fry migrants are assumed to be in freshwater for 2 to 4 weeks as they move to the delta-bay, and subyearling migrants are in freshwater for 12 weeks. Fry and subyearlings are assigned different productivity rates in the delta-bay and thereafter have similar ocean productivities. Most adults returning to spawn are ages 3 through 6 (a very small percentage return at age 2).
- The life-cycle model for steelhead has seven freshwater life stages that are influenced by freshwater habitat conditions: adult upstream migration, adult spawning, egg incubation, age 0+ summer rearing, age 0+ winter rearing, age 1+ summer rearing, and age 1+ winter rearing. A percentage of age-1 parr move downstream to the mainstem Chehalis River at the end of age 0+

winter rearing, and some age-1 smolts leave the basin. Some age-2 smolts leave the basin at the end of the second winter and experience emigration, delta-bay, and marine productivity, and the remaining age-3 smolts leave the basin at the end of the third winter and experience emigration, delta-bay, and marine productivity. Steelhead is the only species that has repeat spawners, with spawner ages ranging from 3 to 7.

Table 3

Overview of Common Life Stages and Calculations Used in the Life-Cycle Models of Chehalis River Spring- and Fall-Run Chinook Salmon and Coho Salmon

LIFE STAGE	MODEL CALCULATION	SPECIES
Spawning/eggs	Modeled with a hockey stick function using empirically estimated spawning capacities and fecundity values from literature. Varies with wood abundance.	All species
Incubation	Modeled using density-independent incubation productivity values. Varies with peak flow, fine sediment.	All species
Fry colonization	Density independent for coho salmon and steelhead. Modeled with a Beverton-Holt function for Chinook salmon using estimated fry-rearing capacity and density-independent productivity. For coho salmon, fry-rearing densities are not adequate to produce a density-dependent function. Varies with wood abundance.	All species
Juvenile rearing: fry-parr	Modeled with a Beverton-Holt function using empirically estimated rearing capacities and productivities. Varies with wood abundance, floodplain connectivity, temperature, beaver pond abundance, and other factors.	All species
Juvenile rearing: parr-smolt	Modeled with a Beverton-Holt function using empirically estimated rearing capacities and productivities. Varies with wood abundance, floodplain connectivity, beaver pond abundance, and other factors.	Coho salmon, steelhead
Delta-bay rearing	Density independent. Varies by species and by estuary-entry age.	All species
Ocean rearing	Density independent. Can vary by age and can be stochastic or fixed.	All species
Maturation	Adults in the ocean have age-specific maturation rates (i.e., a specified proportion of adults at each age return to spawn).	All species
Harvest	Optional. Harvest rates are currently not included.	All species
Upstream migration/holding	Density independent; empirical pre-spawn productivities based on literature values/functions for each species. Affected by temperature for spring-run Chinook salmon and impervious area for coho salmon.	All species

Note:
Additional stages and/or fish movement steps are included as needed for each species (e.g., steelhead repeat spawners or density-dependent movement of Chinook salmon fry migrants).

Diagnostic Results

The diagnostic results indicate that restoration of shade, wood, beaver ponds, and floodplain habitat provide the greatest opportunities to increase spawner abundances for coho, spring-run Chinook, and fall-run Chinook salmon in the Chehalis Basin (Table 4). Removal of migration barriers provide only a modest increase in coho salmon in the Chehalis Basin. The largest modeled restoration potentials for coho salmon are in overwinter habitats such as beaver ponds and floodplain habitats, whereas the largest modeled restoration potentials for spring-run Chinook salmon are restoring wood abundance, shade, and floodplain habitats. The largest modeled restoration potentials for fall-run Chinook salmon are restoring wood abundance and floodplain habitats. Reduction of fine sediment may also be important, but there is uncertainty in fine sediment levels and sources of fine sediment at this time, making it difficult to identify high-priority restoration actions and locations. The other factors all have explicit spatial data that help identify where restoration actions may provide significant benefits (i.e., riparian conditions, barriers, etc. have specific locations indicating where and what type of restoration should occur). The following subsections of this report describe the spatial distribution of restoration opportunities for each type of restoration activity.

Table 4

Modeled Estimates of Spawners in Each Diagnostic Scenario for Coho, Spring-Run Chinook, and Fall-Run Chinook Salmon for the Chehalis Basin

SCENARIO	COHO	SPRING-RUN CHINOOK	FALL-RUN CHINOOK
Current conditions	71,609	793	23,990
Historical shade	84,904 (19%)	1,111 (40%)	24,429
Historical beaver ponds	151,166 (111%)	820	26,178
Historical floodplain habitat	113,278 (58%)	1,112 (40%)	28,503 (19%)
Historical wood	88,814 (24%)	1,054 (33%)	30,879 (29%)
Historical wood and floodplain	132,791 (85%)	1,439 (81%)	36,491 (52%)
No barriers	78,116	793	24,501
Historical fine sediment	83,903 (17%)	1,223 (54%)	31,868 (33%)
Historical large riverbank condition	71,652	822	24,602
Historical large river length	71,717	852	24,907

Notes:
Estimates of spawners do not account for harvest.
Percent change in parentheses for all changes ≥10%; no color indicates changes <10%
Dark blue indicates changes >25%
Light blue indicates changes of 10% to 25%
Dark gray indicates changes >25% with high uncertainty
Light gray indicates changes of 10% to 25% with high uncertainty

Coho Salmon

The modeled estimates indicate coho salmon spawner abundance is most affected by beaver ponds and floodplains (Figure 2). The historical wood scenario increased modeled spawner abundance by only 24%, whereas the historical wood and floodplain scenario increased modeled spawner abundance by more than 80%. Historical shade, migration barriers, and fine sediment only increased spawner abundance by 8% to 19%, and all other scenarios produced less than 1% change. The diagnostic scenario with all historical conditions had a modeled spawner abundance more than 300% higher than the modeled current abundance.

Spring-Run Chinook Salmon

The modeled estimates indicate spring-run Chinook salmon spawner abundance is most affected by shade, floodplains, and fine sediment and moderately by wood abundance (Figure 3). The historical wood and floodplain combination scenario produced a 81% increase in spawner abundance. All other scenarios produced less than a 15% change in spawner abundance (no barriers, historical beaver ponds, historical large riverbank conditions, and historical large river length). The diagnostic scenario with all historical conditions had a spawner abundance of about 2,900 compared to modeled abundance under current conditions of about 800 (an increase of 259%).

Fall-Run Chinook Salmon

The modeled estimates indicate fall-run Chinook salmon spawner abundance is most affected by the wood and floodplain combination, but most of that increase was apparently from wood abundance (29% in the wood abundance scenario alone) (Figure 4). Modeled spawner abundance increased 33% in the historical fine sediment scenario, suggesting that fine sediment may be a significant issue, particularly for the fry migrant component of the population. All other scenarios produced a change in spawner abundance of 19% or less (no barriers, historical beaver ponds, historical large riverbank conditions, historical large river length, historical shade, and historical floodplain habitat). The diagnostic scenario with all historical conditions had a spawner abundance of about 56,000 compared to modeled abundance under current conditions of about 24,000 (an increase of 134%).

Figure 2
Results of the Coho Salmon Life-Cycle Model for All Diagnostic Scenarios, Without Harvest

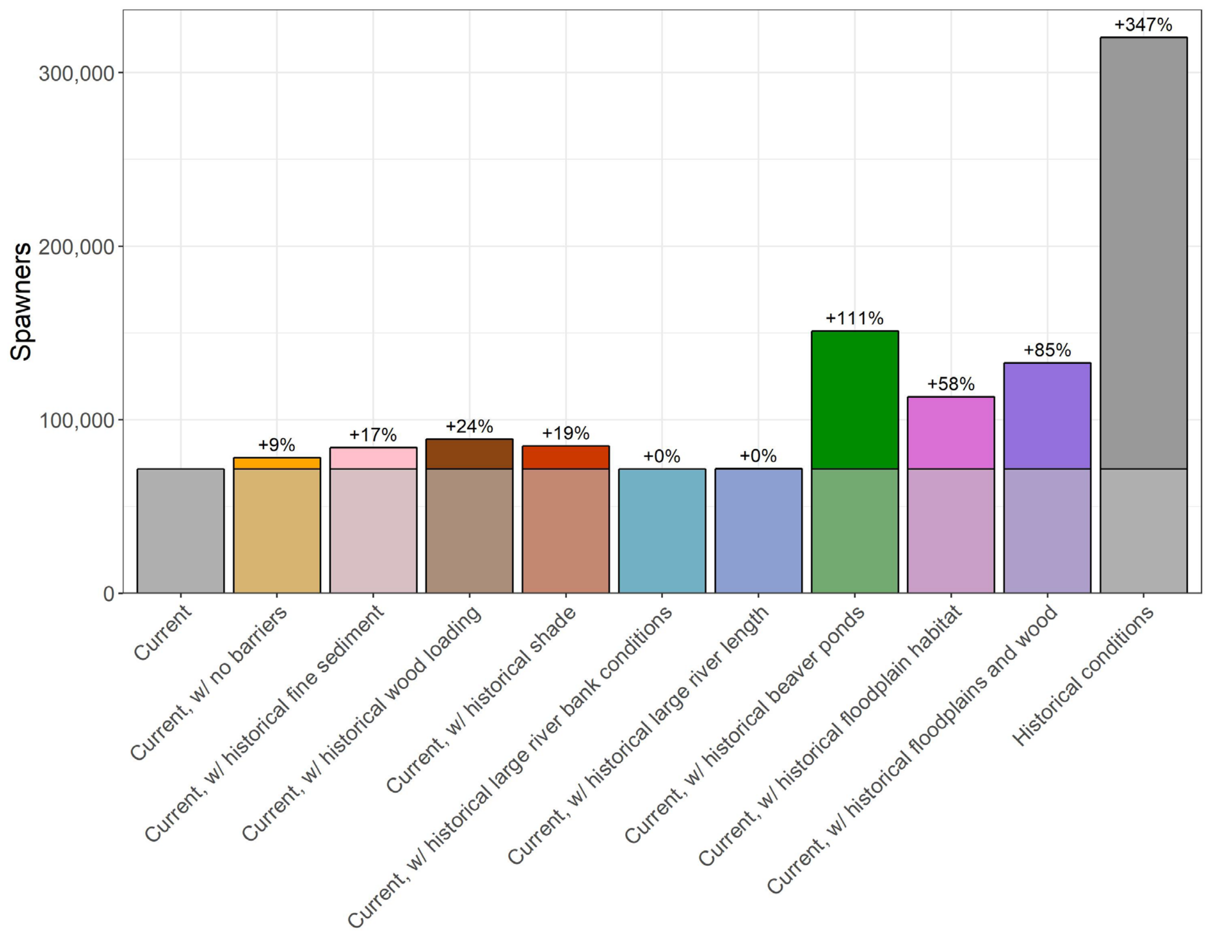


Figure 3
Results of the Spring-Run Chinook Salmon Life-Cycle Model for All Diagnostic Scenarios, Without Harvest

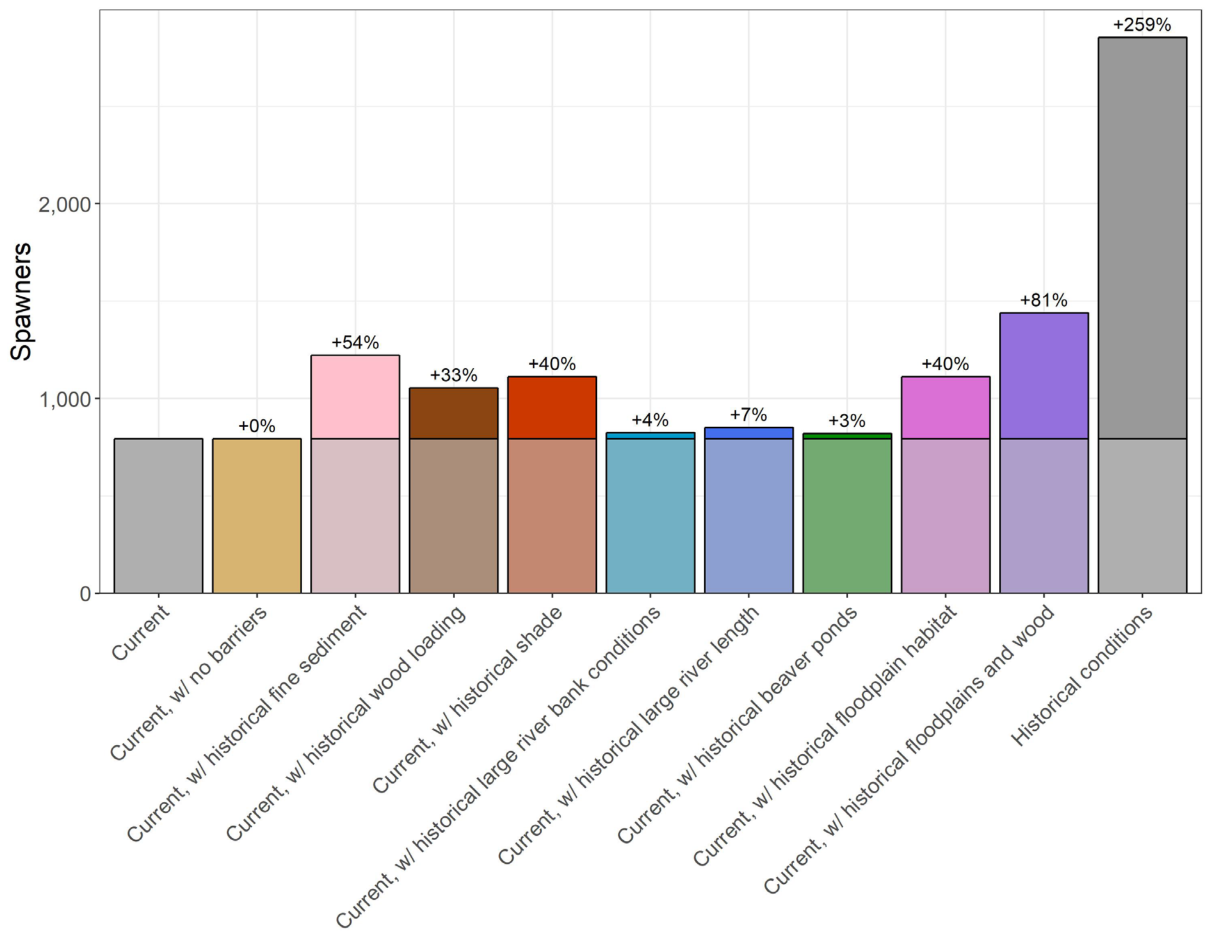
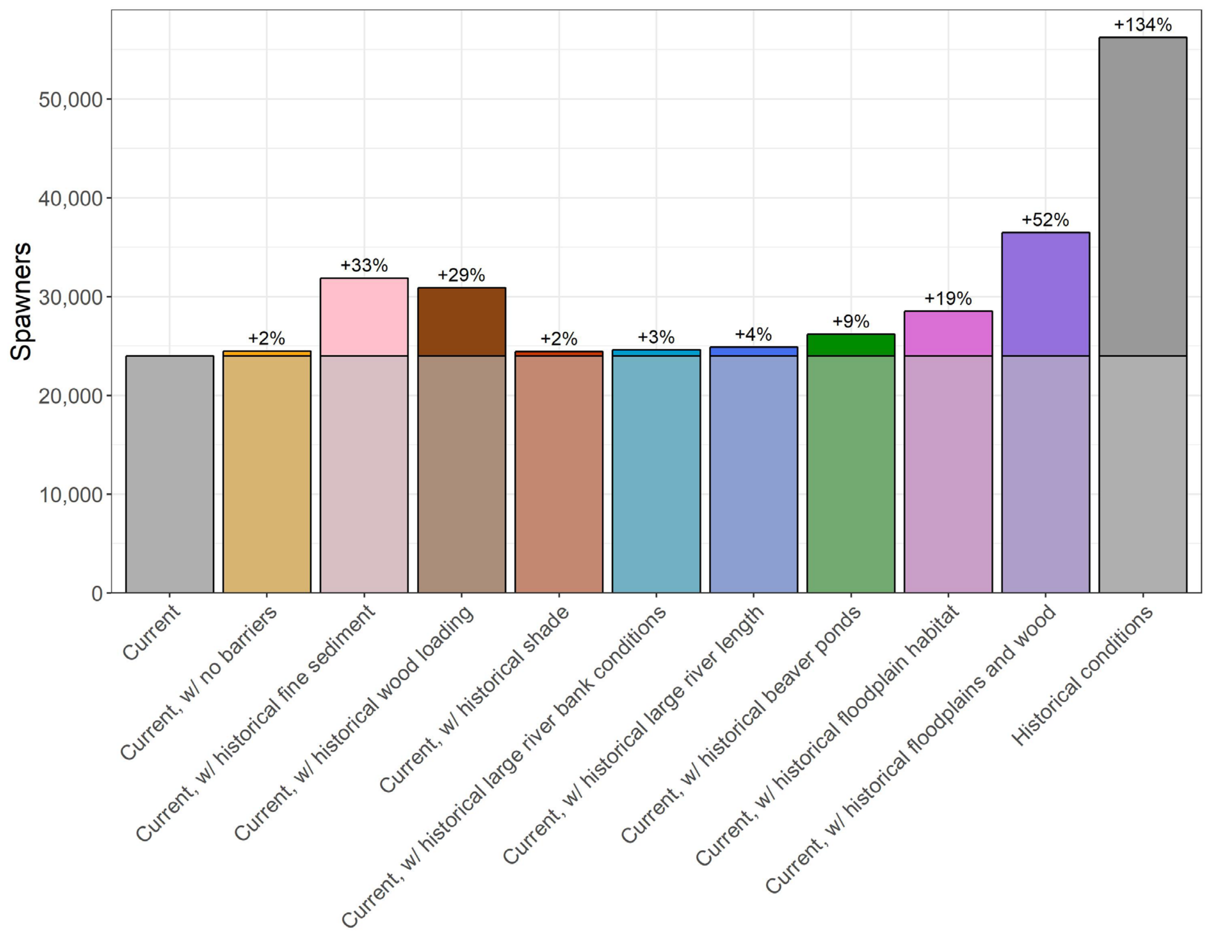


Figure 4
Results of the Fall-Run Chinook Salmon Life-Cycle Model for All Diagnostic Scenarios, Without Harvest



Diagnostic Results by Scenario and Ecological Region

The basin-level results indicate which types of habitat losses have most influenced the decline of salmon populations at the scale of Chehalis Basin, but the magnitude of each habitat loss varies spatially, as do the distributions of species within the basin. Hence, the relative importance of each factor varies among species and ecological regions. This section describes the spatial variation in modeled effects of each diagnostic scenario for each species (excluding diagnostic scenarios that produced little change for any species).

Historical Wood Abundance Scenario

The historical wood abundance scenario produced a moderate increase in modeled spawner abundance for all four species (Table 5). For coho salmon and fall-run Chinook salmon, modeled percent increases in spawner abundance relative to current conditions were similar across ecological regions (generally 20% to 40%). For spring-run Chinook salmon, the percent increase in spawner abundance was highest in the Mainstem: Upper Chehalis Ecological Region (70%), but the absolute abundance increase in that ecological region was very low (seven spawners). Most of the modeled increase in spring-run Chinook salmon spawner abundance in the historical wood scenario was in the Cascade Mountains Ecological Region (Skookumchuck and Newaukum rivers, 196 spawners).

Table 5

Modeled Increase in Spawner Abundance in the Historical Wood Abundance Scenario for Coho, Spring-Run Chinook, and Fall-Run Chinook Salmon by Ecological Region

ECOLOGICAL REGION	COHO	SPRING-RUN CHINOOK	FALL-RUN CHINOOK
Willapa Hills	1,749 (28%)	51 (29%)	296 (25%)
Mainstem: Upper Chehalis	0	7 (70%)	64 (30%)
Cascade Mountains	1,895 (30%)	196 (33%)	505 (30%)
Mainstem: Middle Chehalis	0	--	150 (37%)
Central Lowlands	1,494 (50%)	--	27 (57%)
Mainstem: Lower Chehalis	12	--	1,120 (21%)
Black River	977 (21%)	--	289 (27%)
Black Hills	2,137 (23%)	--	254 (42%)
Olympic Mountains	4,392 (21%)	--	2,404 (26%)
Grays Harbor Tributaries	4,549 (22%)	--	1,780 (43%)

Notes:
--: not applicable (spring-run Chinook salmon do not spawn in these ecological regions)
Percent change in parentheses for all changes ≥10%
Dark orange indicates changes >50%
Medium orange indicates changes of 25% to 50%
Light orange indicates changes of 10% to 25%
No color indicates changes <10%

Historical Floodplain Habitat Scenario

Percent change in spawner abundance under the historical floodplain habitat scenario was high across all ecological regions for coho salmon, except for the mainstem Chehalis River ecological regions (Table 6). However, increases in abundance from historical mainstem floodplain habitat show as zero because there are no spawners in those reaches; increased survival of juveniles from historical mainstem habitat are included in the tributary ecological region spawner abundance totals because all spawner abundance increases are reflected in the natal ecological region spawner abundance regardless of which life stage or location increases productivity. For coho salmon, floodplain habitat is important for the overwinter life stage, while for spring-run Chinook salmon, floodplains are most important for temperature reductions during the prespawn life stage. Because fall-run Chinook salmon are less dependent on floodplain habitats, percent increases in spawner abundance are generally low for those species, although modest increases may be gained in the Grays Harbor Tributaries and Olympic Mountains ecological regions.

Table 6
Modeled Increase in Spawner Abundance in the Historical Floodplain Habitat Scenario for Coho, Spring-Run Chinook, and Fall-Run Chinook by Ecological Region

SCENARIO	COHO	SPRING-RUN CHINOOK	FALL-RUN CHINOOK
Willapa Hills	2,986 (48%)	65 (38%)	88
Mainstem: Upper Chehalis	0	10 (100%)	7
Cascade Mountains	8,119 (128%)	253 (39%)	194 (11%)
Mainstem: Middle Chehalis	66	--	118 (29%)
Central Lowlands	2,084 (70%)	--	6 (13%)
Mainstem: Lower Chehalis	692 (315%)	--	329
Black River	5,659 (121%)	--	91
Black Hills	2,466 (27%)	--	91 (15%)
Olympic Mountains	11,199 (52%)	--	2,556 (28%)
Grays Harbor Tributaries	8,398 (41%)	--	1,033 (25%)

Notes:
--: not applicable (spring-run Chinook salmon do not spawn in these ecological regions)
Percent change in parentheses for all changes ≥10%
Dark orange indicates changes >50%
Medium orange indicates changes of 25% to 50%
Light orange indicates changes of 10% to 25%
No color indicates changes <10%

Historical Wood Abundance and Floodplain Habitat Scenario

The scenario that evaluates the combined effect of wood and floodplain habitat losses shows significant potential spawner abundance increases in all but the middle and upper mainstem ecological regions (Table 7). Based on effects of the individual wood and floodplain scenarios on each species, it is assumed that most of the change in coho salmon abundance is due to loss of floodplain habitat, whereas most of the change in spring- and fall-run Chinook salmon abundance is due to loss of wood.

Table 7
Modeled Increase in Spawner Abundance in the Historical Wood Abundance and Floodplain Habitat Scenario for Coho, Spring-Run Chinook, and Fall-Run Chinook Salmon by Ecological Region

ECOLOGICAL DIVERSITY REGION	COHO	SPRING-RUN CHINOOK	FALL-RUN CHINOOK
Willapa Hills	4,831 (78%)	127 (73%)	394 (33%)
Mainstem: Upper Chehalis	0	19 (190%)	71 (33%)
Cascade Mountains	10,922 (173%)	482 (81%)	733 (43%)
Mainstem: Middle Chehalis	88	--	292 (73%)
Central Lowlands	3,959 (133%)	--	37 (79%)

ECOLOGICAL DIVERSITY REGION	COHO	SPRING-RUN CHINOOK	FALL-RUN CHINOOK
Mainstem: Lower Chehalis	744 (338%)	--	1,487 (28%)
Black River	6,659 (143%)	--	386 (36%)
Black Hills	4,492 (49%)	--	352 (58%)
Olympic Mountains	16,014 (75%)	--	5,601 (60%)
Grays Harbor Tributaries	13,473 (65%)	--	3,148 (76%)

Notes:
--: not applicable (spring-run Chinook salmon do not spawn in these ecological regions)
Percent change in parentheses for all changes ≥10%
Dark orange indicates changes >50%
Medium orange indicates changes of 25% to 50%
No color indicates changes <10%

Historical Beaver Pond Scenario

Not surprisingly, the historical beaver pond scenario produces very large spawner abundance increases for coho salmon (Table 8). Beaver ponds are a preferred winter rearing habitat for coho salmon, and estimated juvenile survival through the winter is considerably higher in beaver ponds than in stream channels. The model also produces small increases in spawner abundance for fall-run Chinook salmon, but spring-run Chinook salmon show very little potential response to increased beaver pond habitat area.

Table 8
Modeled Increase in Spawner Abundance in the Historical Beaver Pond Scenario for Coho, Spring-Run Chinook, and Fall-Run Chinook Salmon by Ecological Region

SCENARIO	COHO	SPRING-RUN CHINOOK	FALL-RUN CHINOOK
Willapa Hills	10,635 (171%)	10	84
Mainstem: Upper Chehalis	0	0	0
Cascade Mountains	7,872 (124%)	17	395 (23%)
Mainstem: Middle Chehalis	0	--	0
Central Lowlands	4,095 (138%)	--	20 (43%)
Mainstem: Lower Chehalis	0	--	0
Black River	3,997 (86%)	--	0
Black Hills	7,594 (83%)	--	226 (37%)
Olympic Mountains	20,178 (94%)	--	950 (10%)
Grays Harbor Tributaries	25,225 (122%)	--	630 (15%)

Notes:
--: not applicable (spring-run Chinook salmon do not spawn in these ecological regions)
Percent change in parentheses for all changes ≥10%
Dark orange indicates changes >50%
Medium orange indicates changes of 25% to 50%
Light orange indicates changes of 10% to 25%
No color indicates changes <10%

Historical Shade Scenario

The historical shade scenario produces a relatively small change in coho salmon spawner abundance (19%), despite high summer stream temperatures in the Chehalis Basin. This is because the stream temperature *change* from current to historical shade is near 0°C in most ecological regions and less than 2°C in much of the remaining area (Figure 5). However, a few tributary ecological regions have relatively large percentage changes in modeled coho salmon spawner abundance, because shade conditions are locally very poor, notably the Cascade Mountains, Black River, and Central Lowlands ecological regions (≥38%) (Table 9). While the modeled percent increase in coho salmon spawner abundance was high in the Mainstem: Lower Chehalis Ecological Region, the absolute increase was small because coho salmon are modeled only spawning in side channels, and there are very few spawners there.

By contrast, spring-run Chinook salmon show large percent increases in modeled spawner abundance in the historical shade scenario in the Cascade Mountains, Willapa Hills, and Mainstem: Upper Chehalis ecological regions (Table 9). In these three ecological regions, modeled stream temperatures have increased significantly within holding and spawning reaches for spring-run Chinook salmon, and the historical shade scenario produced at least a 35% increase in each location. It is important to note that the spring-run Chinook salmon population in the entire basin is low and the Mainstem: Upper Chehalis Ecological Region currently has very few spawners.

Table 9

Modeled Increase in Spawner Abundance in the Historical Shade Scenario for Coho, Spring-Run Chinook, and Fall-Run Chinook Salmon by Ecological Region

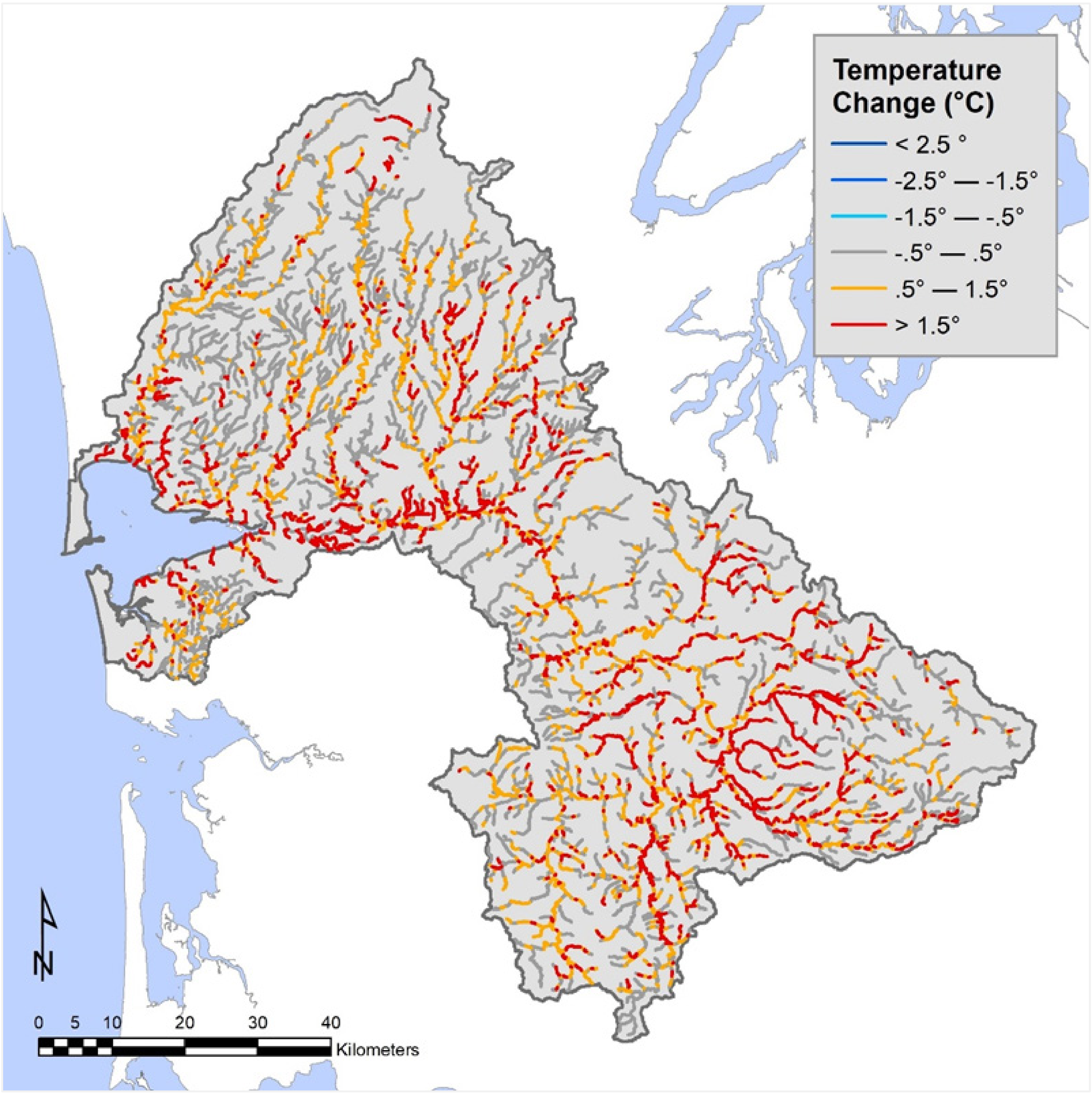
SCENARIO	COHO	SPRING-RUN CHINOOK	FALL-RUN CHINOOK
Willapa Hills	1,267 (20%)	64 (37%)	37
Mainstem: Upper Chehalis	0	8 (80%)	0
Cascade Mountains	4,873 (77%)	237 (40%)	51
Mainstem: Middle Chehalis	0	--	32
Central Lowlands	1,468 (49%)	--	1
Mainstem: Lower Chehalis	134 (61%)	--	176
Black River	1,756 (38%)	--	22
Black Hills	1,257 (14%)	--	13
Olympic Mountains	1,460	--	107
Grays Harbor Tributaries	1,080	--	0

Notes:
--: not applicable (spring-run Chinook salmon do not spawn in these ecological regions)
Percent change in parentheses for all changes ≥10%
Dark orange indicates changes >50%
Medium orange indicates changes of 25% to 50%
Light orange indicates changes of 10% to 25%
No color indicates changes <10%

Fall-run Chinook salmon are less sensitive to temperature changes because they enter the river after the high summer temperatures, and the historical shade scenario produced modeled increases in abundance of less than 10% in all ecological regions.

The comparison of current to historical shade levels in the Chehalis Basin shows that more than 60% of the basin has riparian shade conditions that are currently near their historical potential, mostly on small streams inside managed forests. Much of that stream length has a modeled temperature difference of <0.5°C, indicating very little potential for continued tree growth to improve temperature conditions in the future (Figure 5). However, most stream reaches in this condition are small streams occupied mainly by coho salmon. Areas with temperature change >2°C are most concentrated in the Cascade Mountains Ecological Region, and to a lesser extent in the Black River, Willapa Hills, Mainstem: Lower Chehalis, and Mainstem: Middle Chehalis ecological regions. This pattern reflects the following two dominant riparian situations in the basin: 1) the current shade condition in many small streams is a closed canopy due to maturing riparian forests; and 2) historical shade conditions in large river channels are relatively open due to wide channels and limited shading, even with tall trees adjacent to them. Areas with the largest modeled temperature changes are in small streams with little or no canopy currently and closed canopy under historical conditions (e.g., in the Skookumchuck River sub-basin).

Figure 5
Modeled Temperature Change due to Loss of Riparian Shade in the Chehalis Basin



No Barriers Scenario

The overall response of coho salmon was small for the diagnostic scenario with barriers removed (9% change), indicating that barriers have a relatively small impact on coho salmon at the scale of the entire Chehalis Basin. However, individual barriers have locally larger impacts when viewed at the ecological region scale (Table 10). This indicates that barriers have locally large effects on coho salmon but that a very small proportion of coho salmon habitat is blocked to adult migration. There is uncertainty associated with the passage rankings assigned to each barrier by WDFW, and because these were incorporated into the NOAA model as reductions in capacity and productivity, this uncertainty carriers over into the NOAA model outputs.

No migration barriers exist in the range of spring-run Chinook salmon spawning in the barrier database, so there is no response of spring-run Chinook salmon in the diagnostic scenario with barriers removed. However, one barrier on the West Fork Chehalis River was not included in the barrier database (West Fork Falls), and that will be added in future model runs. Fall-run Chinook salmon are exposed to a few barriers, but no significant impacts on abundance exist at the ecological region scale (overall response is a 2% spawner increase).

Table 10
Modeled Increase in Spawner Abundance in the No Barriers Scenario for Coho, Spring-Run Chinook, and Fall-Run Chinook Salmon by Ecological Region

SCENARIO	COHO	SPRING-RUN CHINOOK	FALL-RUN CHINOOK
Willapa Hills	355	0	0
Mainstem: Upper Chehalis	0	0	0
Cascade Mountains	707 (11%)	0	7
Mainstem: Middle Chehalis	0	--	0
Central Lowlands	1,345 (45%)	--	59 (126%)
Mainstem: Lower Chehalis	0	--	0
Black River	438	--	0
Black Hills	776	--	0
Olympic Mountains	1,619	--	412
Grays Harbor Tributaries	1,276	--	43

Notes:
--: not applicable
Percent change in parentheses for all changes ≥10%
Dark orange indicates changes >50%
Medium orange indicates changes of 25% to 50%
Light orange indicates changes of 10% to 25%
No color indicates changes <10%

Historical Fine Sediment Scenario

For fine sediment in spawning gravels, modeled changes in fine sediment are based on forest road density, resulting in relatively large declines in incubation productivity parameters for each species. Percent change in spawner abundance under the historical fine sediment scenario was most pronounced for spring- and fall-run Chinook salmon and was somewhat lower for coho salmon (Table 11). Little spatial variation exists in modeled abundance change for all species across the Chehalis Basin. Relatively high uncertainty exists in both the predicted fine sediment levels in the

NOAA model as well as in identification of sediment sources, because no data is available relating other fine sediment sources to fine sediment levels in streams.

Table 11
Modeled Increase in Spawner Abundance in the Historical Fine Sediment Scenario for Coho, Spring-Run Chinook, and Fall-Run Chinook Salmon by Ecological Region

SCENARIO	COHO	SPRING-RUN CHINOOK	FALL-RUN CHINOOK
Willapa Hills	1,691 (27%)	167 (97%)	779 (65%)
Mainstem: Upper Chehalis	0	29 (290%)	173 (80%)
Cascade Mountains	1,770 (28%)	214 (36%)	447 (26%)
Mainstem: Middle Chehalis	0	--	370 (92%)
Central Lowlands	973 (33%)	--	14 (30%)
Mainstem: Lower Chehalis	173 (79%)	--	1,599 (30%)
Black River	534 (11%)	--	218 (20%)
Black Hills	1,770 (19%)	--	201 (33%)
Olympic Mountains	2,691 (13%)	--	3,013 (32%)
Grays Harbor Tributaries	2,692 (13%)	--	1,064 (26%)

Notes:
--: not applicable
Percent change in parentheses for all changes ≥10%
Dark orange indicates changes >50%
Medium orange indicates changes of 25% to 50%
Light orange indicates changes of 10% to 25%
No color indicates changes <10%

Potential Restoration Actions

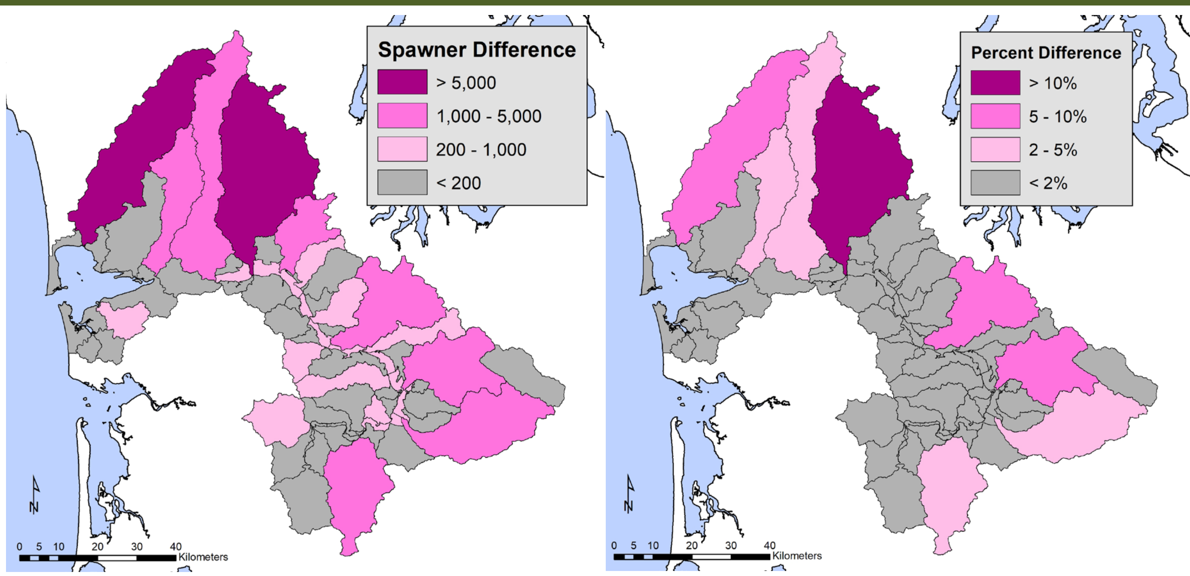
The diagnostic scenarios suggest that five types of habitat changes have had significant effects on salmon populations: loss of floodplain habitat, loss of wood from streams and rivers, loss of beaver ponds, loss or reduction of riparian forests, and, in some locations, migration barriers. Therefore, restoration of these habitats (or habitat attributes) and, to a lesser extent, removal of migration barriers have the potential to significantly improve salmon populations. A sixth potentially important habitat change—increased fine sediment and reduced incubation survival—has high uncertainty in the analysis, and it is currently not considered an important restoration action until its significance and causes are confirmed.

Floodplain and Wood Restoration

The diagnostic scenarios indicate that the combination of restoring floodplain habitat and wood abundance is likely to significantly benefit all three species, with reconnection of floodplain habitats most benefiting coho salmon and wood restoration most benefitting spring- and fall-run Chinook salmon. Importantly, diagnostic runs that separately track the benefit of restoring mainstem habitats at the sub-basin scale for each species indicate that floodplain habitat restoration in the lower mainstem (from the Skookumchuck River to the Wynoochee River) will increase multiple subpopulations of coho salmon upstream of the Wynoochee River, as well as improve spring- and fall-run Chinook salmon populations to a lesser degree. Among the tributary sub-basins, the Skookumchuck, Black, Humptulips, and Satsop rivers have large floodplain restoration potential, both when ranked by absolute abundance and percent increase (Figure 6). Each of those areas had significant historical marsh habitat that has been lost or degraded, likely due to channel incision resulting from channelization and wood removal. Only the Black River sub-basin has an appreciable portion of its historical marsh remaining today. Other sub-basins with relatively large potential absolute increases in coho salmon spawner abundance include the Wishkah, Wynoochee, Newaukum, and South Fork Chehalis river sub-basins.

By contrast, the potential benefits of wood restoration are more evenly distributed across the sub-basins, and the analysis does not indicate strong spatial priorities for wood restoration. However, the scientific literature generally indicates that wood restoration in small, moderate-slope reaches has the greatest potential to increase pool area (e.g., Montgomery et al. 1995), which benefits multiple species that occupy those reach types (primarily coho salmon and steelhead).

Figure 6
Map of Potential Coho Spawner Abundance Increase Through Floodplain Habitat Restoration, by Sub-Basin. Left Panel Is Absolute Change in the Total Chehalis Basin Abundance When Floodplain Habitat Is Set to Historical Condition in One Sub-Basin at a Time; Right Panel Is Percent Increase in the Total Chehalis Basin Abundance When Floodplain Habitat Is Set to Historical Condition in One Sub-Basin at a Time.

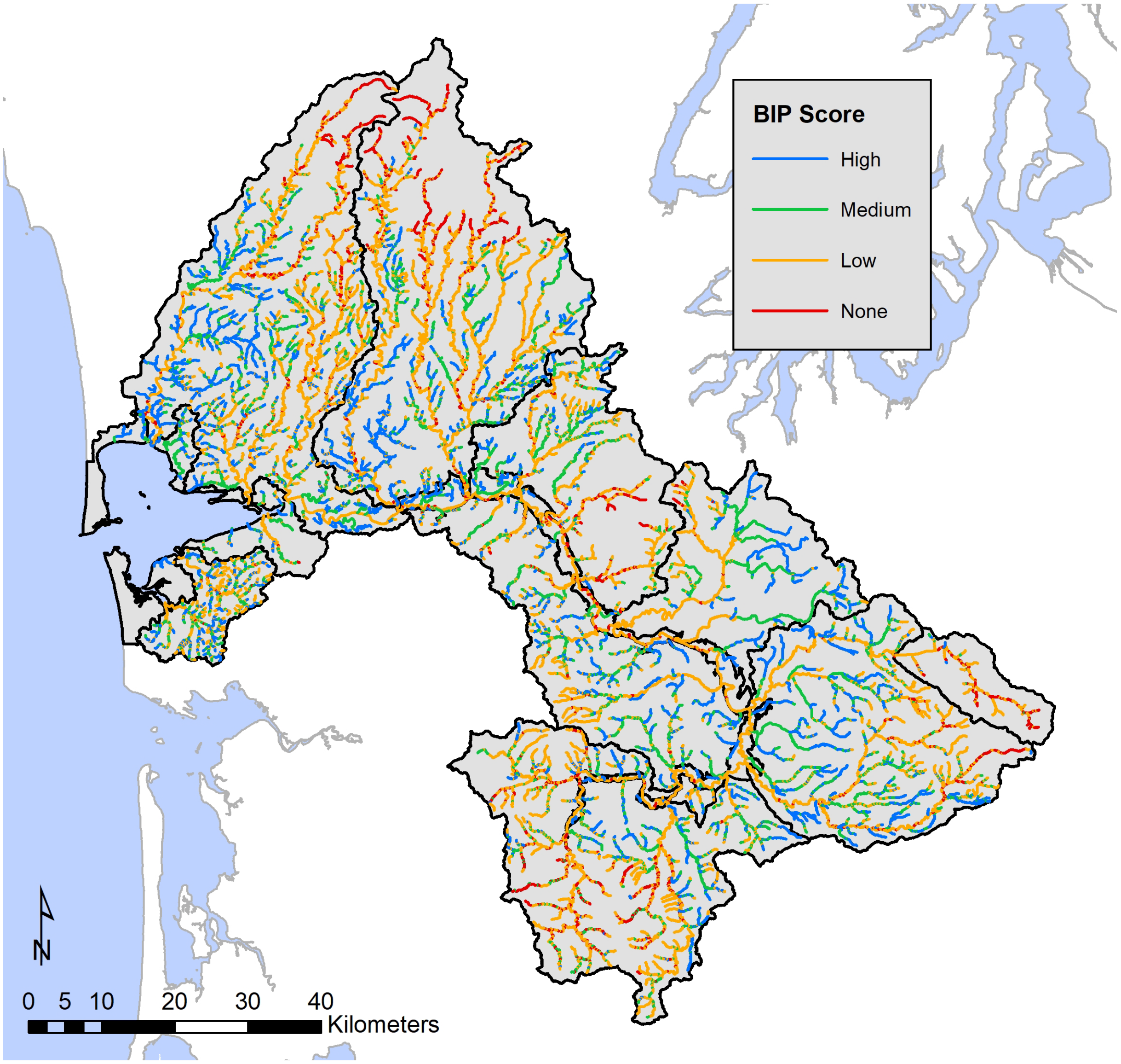


Beaver Pond Restoration

Restoring beaver ponds to small streams is likely to significantly benefit coho salmon (more than doubling the population in the historical beaver pond scenario), with relatively small effects on the other species. The potential for recovery of beaver ponds and beaver populations is greatest in small, low-slope channels with wide valleys[4] (Dittbrenner et al. 2018). A map of beaver restoration potential can help direct beaver restoration to the most suitable locations within the range of coho salmon in the Chehalis Basin (Figure 7). In general, areas with lower potential are in the upper Olympic Mountains, Black Hills, Cascade Mountains, and Willapa Hills, which are the four areas with predominantly volcanic lithology. Areas of alluvium, glacial deposits, and marine sedimentary rocks all contain significant stream length with high or medium beaver intrinsic potential (i.e., lower portions of Olympic Mountains, Grays Harbor Tributaries, Willapa Hills, Black Hills, and Cascade Mountains ecological regions, as well as the Black River and Central Lowlands ecological regions).

[4] Valleys >30 meters wide are considered wide. Channels <7 meters wide are considered small. Slopes <1% are considered low.

Figure 7
Map of Beaver Intrinsic Potential in the Chehalis Basin, Based on a Modified Version of the Beaver Intrinsic Potential Model of Dittbrenner et al. (2018)

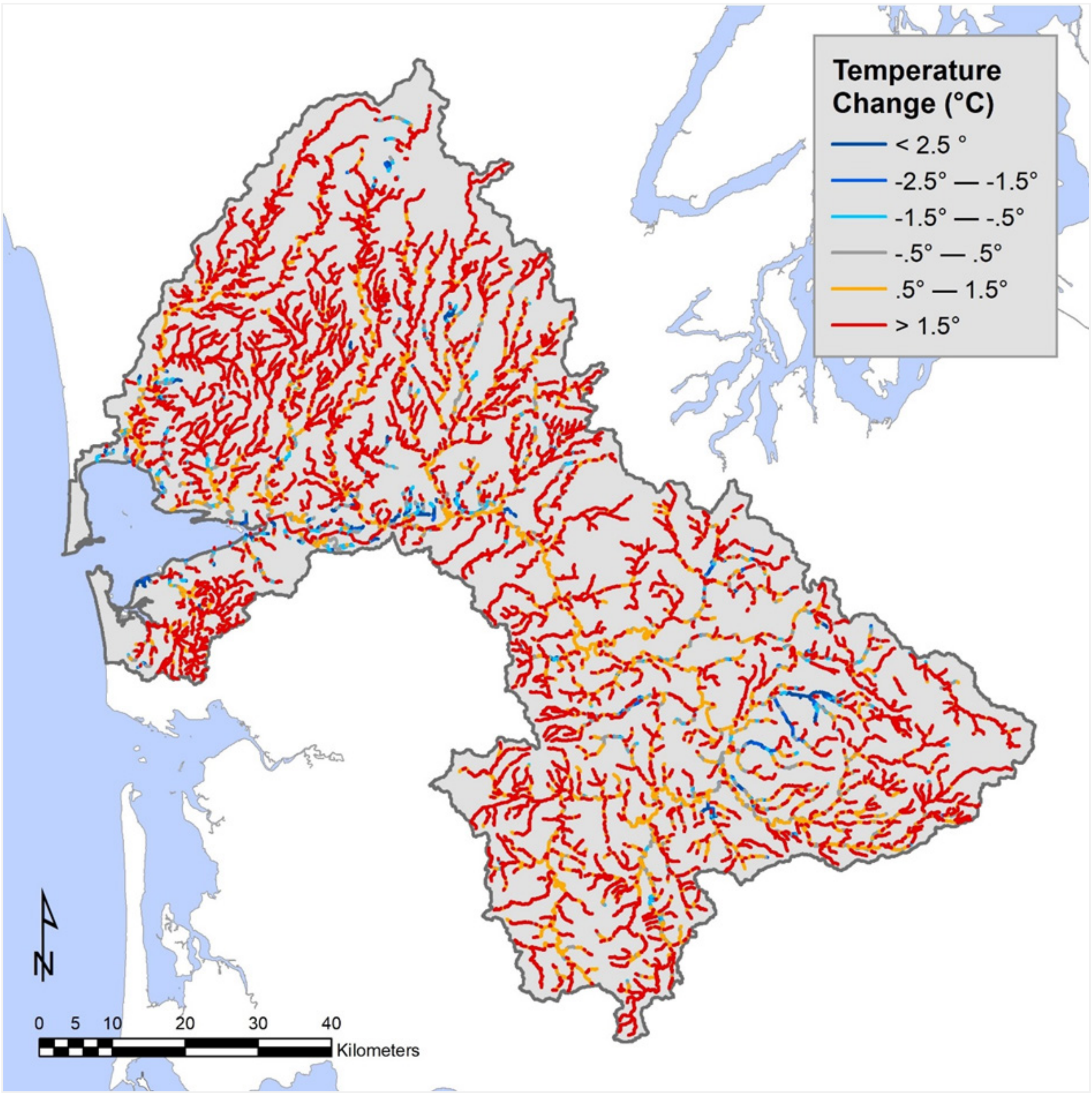


Riparian Restoration

Riparian restoration is both riparian planting and protection, and it is likely to significantly increase shade and reduce stream temperature in a few areas—some of which are very important to spring-run Chinook salmon. Modeling a historical shade scenario indicates that reduction of stream temperature in spring-run Chinook salmon holding and rearing areas can potentially increase the total spring-run Chinook salmon population by 40% under the current climate, as well as slightly increase coho salmon abundance (<10%). However, when projected temperature increases due to climate change are added, the model indicates that stream warming due to climate change will likely exceed cooling due to increased shade, and net warming is likely to occur in most of the stream network by late century. This is a result of the fact that much of the basin has shade levels at or near their historical potential, and continued tree growth does little to reduce stream temperature in the future. Figure 8 highlights areas that the riparian assessment indicates have the greatest potential for increasing shade and reducing stream temperature.

Riparian restoration may also increase wood recruitment in the future, although empirical studies and wood recruitment models both indicate that wood abundance in streams does not begin to increase until riparian forests are more than 60 years old. Currently, many riparian forests in the National Forest areas of the Olympic Mountains and Grays Harbor Tributaries ecological regions are functioning or only moderately impaired for wood recruitment (trees 75+ feet tall and riparian zone width >100 feet or trees 105+ feet tall and riparian zone width >50 feet), but in most other areas of the basin, riparian areas are impaired for the wood recruitment function. Significant increases in natural wood abundance are not expected until late century, and wood placement is recommended as an interim restoration solution, as there is limited stable wood currently in the river channels. However, riparian protection and restoration are important for assuring wood recruitment in the future.

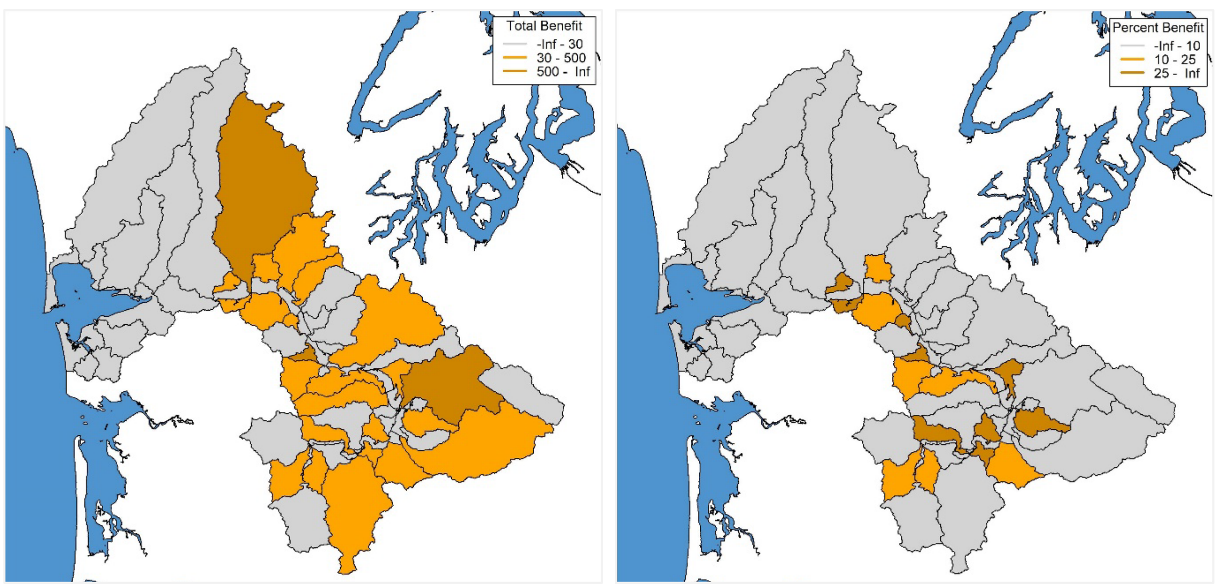
Figure 8
Areas of the Chehalis Basin with High Potential for Increasing Shade and Reducing Summer Stream Temperatures by Late Century. Blue-Colored Reaches Are Reaches in Which Riparian Restoration May Produce a Net Decrease in Stream Temperature by Late Century Despite Projected 2°C Warming due to Climate Change.



Barrier Removal

While the potential for barrier removals to benefit species is small overall (especially for spring-run Chinook salmon, which have no migration barriers within their range), specific sub-basins exist in which barrier removals can significantly improve local subpopulations of coho salmon and modestly improve local subpopulations of fall-run Chinook salmon (Figure 9). The no barriers diagnostic scenario indicates that barrier removals or passage improvements should provide the largest percent increases in coho salmon abundance in the small tributaries to the mainstem Chehalis River from Wynoochee River up to Crim Creek, but the largest potential absolute abundance increases are in the Satsop and Skookumchuck river sub-basins. A number of other large sub-basins may also have significant benefit, including Cloquallum Creek and Black, Newaukum, and South Fork Chehalis rivers. While barrier removals are not likely to provide the largest abundance increases among scenarios for any species, local benefits can be large and cost-effective to achieve.

Figure 9
Map of Sub-Basins with Highest-Potential Coho Salmon Improvement Through Barrier Removals in the Chehalis Basin. Left Panel Is Absolute Abundance Change When All Barriers Are Removed; Right Panel Is Percent Increase in Abundance When All Barriers Are Removed.



Fine Sediment Reduction

The diagnostic scenario for historical fine sediment indicates considerable potential exists to improve Chinook salmon subpopulations by reducing fine sediment levels in spawning gravels, but the model of fine sediment is based on data relating forest roads to fine sediment levels, with no other land uses considered. Moreover, limited data exists on fine sediment in the Chehalis Basin to confirm that fine sediment levels are in fact high relative to natural conditions. A reasonable conclusion from this analysis is that spring- and fall-run Chinook salmon subpopulations are very sensitive to fine sediment levels, but uncertainty exists if, or where, fine sediment levels are high within sub-basins. This suggests that field assessments of fine sediment levels and sources of fine sediment should be conducted to confirm where reducing fine sediment should be a restoration priority and which sediment sources are most important to address through restoration actions.

Summary

The NOAA model was used to evaluate nine diagnostic scenarios along with scenarios for current and historical conditions. The model results for these scenarios indicate that population declines for coho, spring-run Chinook, and fall-run Chinook salmon are most attributable to loss of beaver ponds, loss of floodplain habitats, loss of instream wood, reduced stream shade in some locations, and increased fine sediment. Migration barriers are a significant cause of decline in only a few sub-basins, and primarily for coho salmon. These diagnoses highlight that important restoration actions for salmonids include the following:

1. Reconnect floodplain habitats (side channels, marshes, and ponds) via levee setback and/or re-aggradate channels using instream wood or beaver dam analogs.
2. Restore instream wood to increase spawning and rearing habitat availability (i.e., increase gravel retention and pool formation).
3. Perform riparian restoration to increase stream shading and reduce stream temperature, as well as to provide long-term wood recruitment in the future.
4. Restore beaver populations to increase beaver pond abundance, or potentially use beaver dam analogs to mimic those features.
5. Perform targeted removal of migration barriers that block access to significant amounts of habitat.
6. Confirm areas with high fine sediment levels, identify sediment sources for those areas, and address sediment sources through restoration actions (e.g., by forest road reduction or remediation, or by reducing other sediment inputs such as agricultural or urban sources).

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MEMORANDUM

Date: October 25, 2019
To: Merri Martz, Anchor QEA, LLC
From: Laura McMullen, Chip McConnaha, Matt Yelin, Janel Sobota, and Jon Walker, ICF
Re: Aquatic Species Restoration Plan Phase 1 Ecosystem Diagnosis and Treatment Results

Introduction

The Chehalis River Basin is the largest river basin entirely within Washington State with a unique ecosystem supporting numerous anadromous salmonid species, additional native fish, amphibians, and other wildlife. As part of the Chehalis Basin Strategy, a basin-wide multi-stakeholder flood damage reduction and adaptive restoration plan—the *Aquatic Species Restoration Plan* (ASRP)—is being developed to provide the best guidance on restoring ecological health within the basin for multiple aquatic species (Chehalis Basin Strategy 2019). As part of the current (Phase I) ASRP development, ecosystem modeling specific to anadromous salmon habitat was performed to inform restoration planning.

The Ecosystem Diagnosis and Treatment (EDT) model (more details on the EDT model provided by Blair et al. [2009]) was used to evaluate No Action conditions and a sequence of restoration scenarios that increase in spatial extent and intensity throughout the basin. These scenarios were evaluated at mid- and late-century timepoints and were built off a changing future No Action baseline. The changing No Action baseline incorporates climate change elements, land-use degradation due to buildout outside of managed forests, and improvements in habitat inside managed forests over time due to riparian maturation, described further in the following text.

Modeled changes in habitat under future No Action and restoration scenarios were evaluated for the response of five salmonid runs: fall-run Chinook salmon (*Oncorhynchus tshawytscha)*, spring-run Chinook salmon (*O. tshawytscha)*, coho salmon (*O. kisutch)*, fall-run chum salmon (*O. keta*), and winter-run steelhead (*O. mykiss*). Salmonid habitat potential for these runs was developed for a historical pre-Euro-American settlement condition (hereafter referred to as the "Template" condition) and current conditions. The current condition was then compared to habitat potential under alternate future conditions. In addition, a geospatial unit (GSU)-level diagnostic run (restoration and protection) was conducted using the current scenario (described in the following sections; Figures 1 and 2). The diagnosis included a fish passage-specific restoration analysis that sequentially removed fish passage barriers at each GSU level to inform potential additional fish passage barrier removals in the mid- and late-century restoration scenarios.

Figure 1
Chehalis Basin Ecological Regions

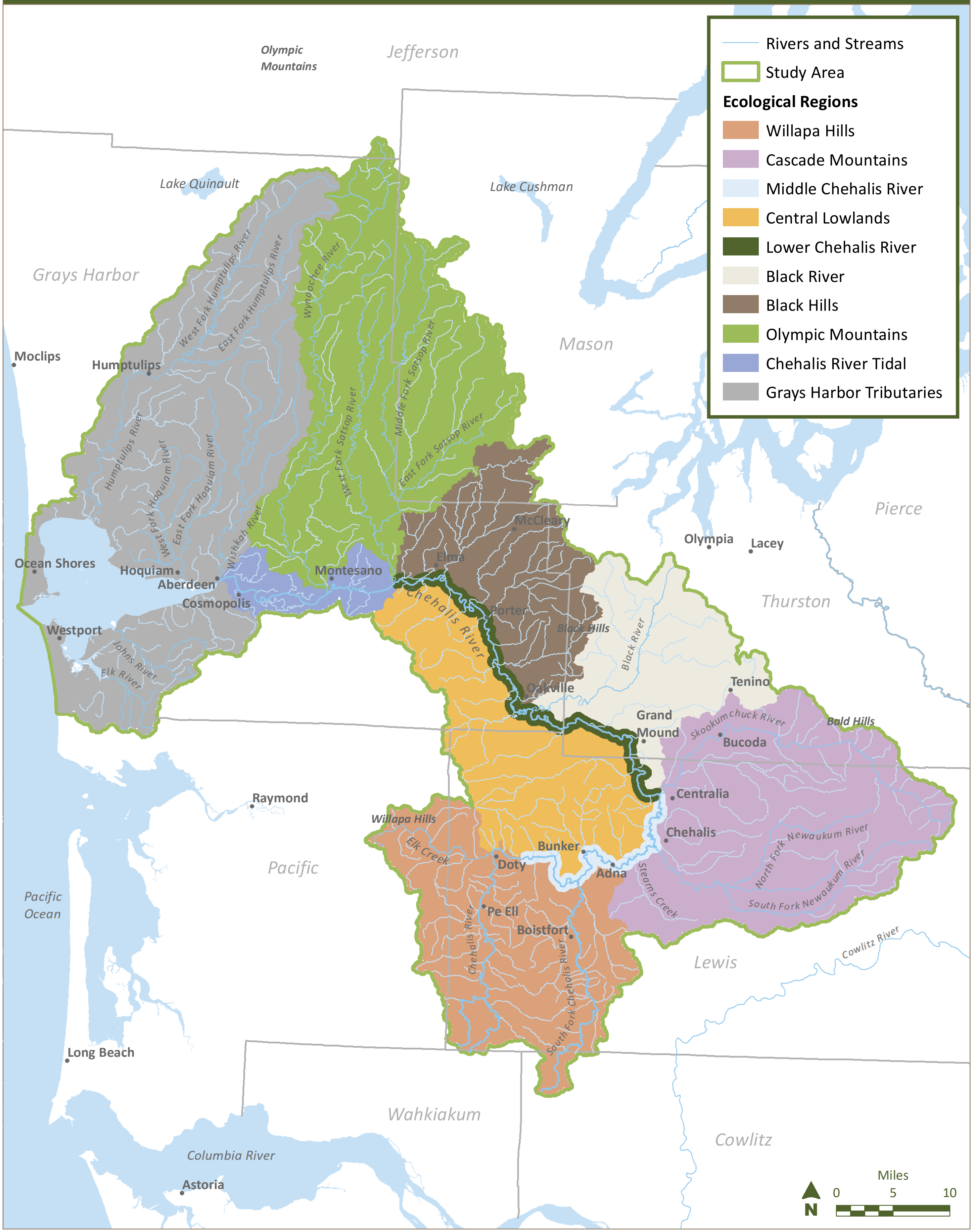
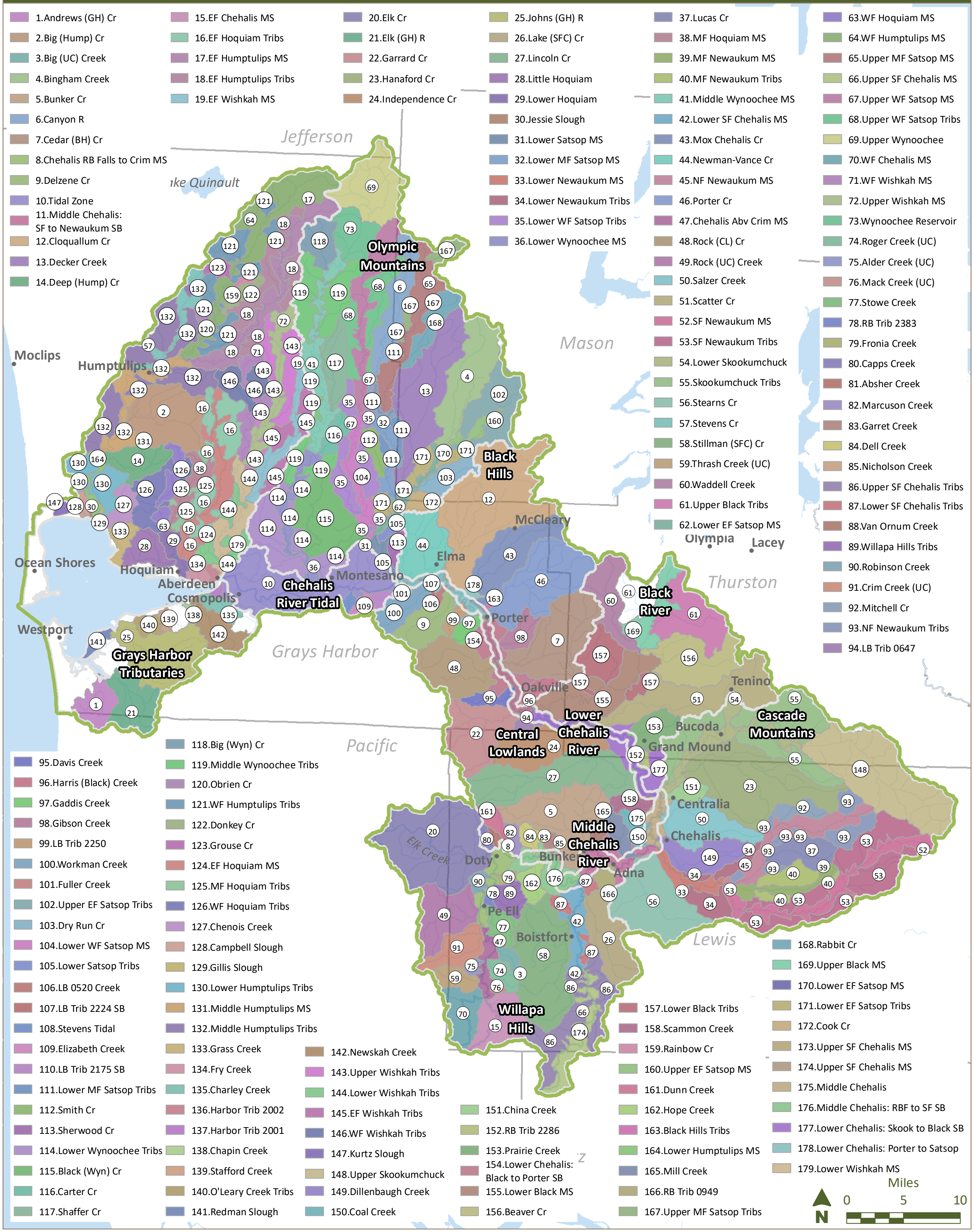


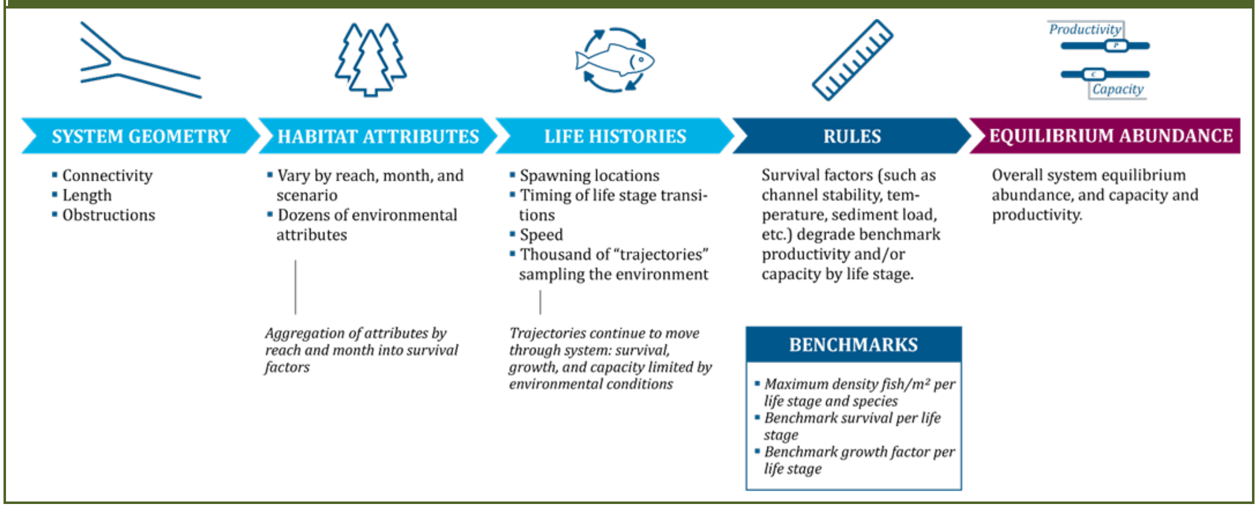
Figure 2
Chehalis River and Grays Harbor Geospatial Units



Ecosystem Diagnosis and Treatment Structure

EDT is a spatially explicit deterministic model used to evaluate habitat conditions relevant to the life stages of the modeled fish species in river reaches through time (Blair et al. 2009). It has been used throughout much of the Pacific Northwest of the United States (for example, Clearwater River, Washington [Dominguez 2006]; the White Salmon River watershed [Allen and Connolly 2005]; and the lower Columbia River [Rawding 2004]). EDT 3.0 is the current version used, and it is a modernized toolset based on public-facing web services and the Windows™ Presentation Foundation™ environment. Overall, three basic components are used that contribute to characterization of EDT for a watershed: the system geometry (a.k.a. river network), the habitat attributes, and the life histories of the fishes evaluated (Figure 3; see also Attachment 1 for the river network used in this model).

Figure 3
Ecosystem Diagnosis and Treatment Framework



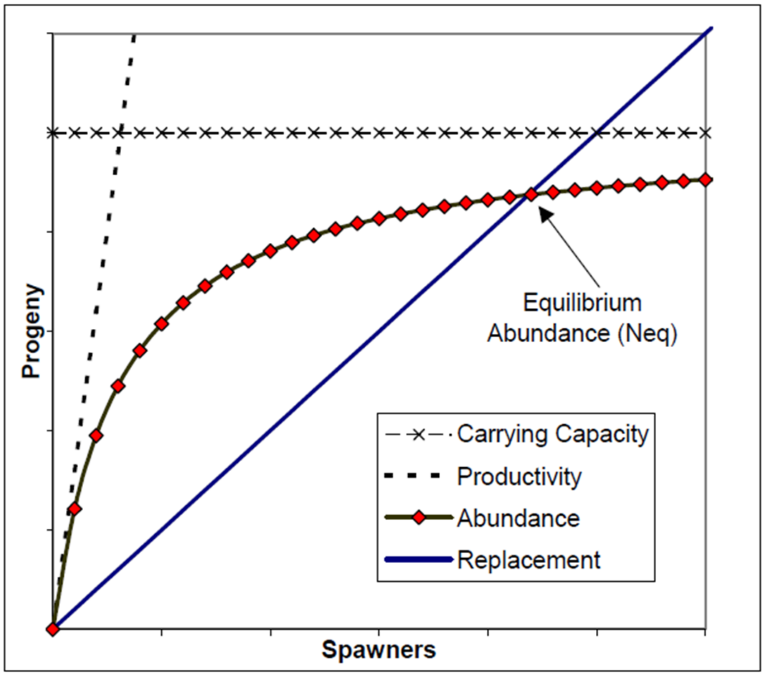
The system geometry allows for the user to specify the number of stream reaches, their lengths, how reaches are connected to one another, and the locations of obstructions. The habitat attributes component of an EDT model describes how dozens of environmental and biological habitat descriptors (e.g., riparian condition, maximum temperature pattern, bed scour, habitat composition, and predators) vary by reach and over time at a monthly time step (attributes detailed by Lestelle [2005]; see Attachment 2 for a glossary of terms).

The life history component of the model describes and defines, per species evaluated, where the species can spawn, the timing of life stage transitions, and the rate of movement through the system per life stages. Trajectories (of which there are hundreds to thousands per species) each demonstrate a specific and realistic life history pattern that could be expressed by that species in the system. Each trajectory starts in one spawning location, has a certain number of days in the egg life stage, a certain number of days until emergence to fry, and specific locations and timings for movements and transitions to additional life stages until returning as a spawner. For the Chehalis EDT model, 8,628 trajectories were run for fall-run Chinook salmon, 2,001 trajectories were run for spring-run Chinook salmon, 40,001 trajectories were run for coho salmon, 5,005 trajectories were run for chum salmon, and 20,003 trajectories were run for steelhead. Collectively, all the trajectories for each species evaluated (termed a "trajectory set") encompasses a full range of viable spawning locations and specific life history patterns throughout the Chehalis Basin.

Overall, system geometries and trajectory sets remain static among scenarios. Changes in model results among scenarios are thus not due to differences in life history configurations or changes to stream networks but to the habitat modeled. Habitat attributes vary among scenarios, and the interaction of the components of the model for different scenarios is what drives differences in population performance. Overall, the life history trajectories for species are affected in their productivity and capacity by life stage due to habitat conditions (e.g., temperatures that are too high, too much fine sediment, or not enough benthic invertebrates) as compared to benchmark values of productivity and capacity. Survival in Grays Harbor and the Pacific Ocean is entered as fixed survival rates to complete the species life history. Marine survival rates in EDT have been set to produce numbers that correspond with actual observations of Chehalis River run sizes.

Ultimately, this results in population level estimates of capacity, productivity, and equilibrium abundance (described more in the following text) by scenario. Productivity in EDT is calculated as survival without density-dependent effects (intrinsic productivity discussed by McElhany et al. [2000]). Productivity under a given set of conditions is the slope of the abundance line of a Beverton-Holt production function graph at its origin (Figure 4). Productivity reflects the quality of habitat in reaches and across months throughout the model, according to the life stages of the fish species being evaluated. Productivity is a function of habitat attributes such as temperature, large wood, and water quality that affect survival of life stages. Capacity in EDT describes how large a population can grow and reflects the quantity of habitat (Figure 4 shows capacity in EDT is the asymptotic limit to abundance reflecting habitat area, habitat type [e.g., pools, riffles], food, and productivity). Equilibrium abundance (Neq) is calculated based on productivities and capacities, and the Neq is the point where the abundance curve crosses the spawner-progeny replacement line (Figure 4; Lestelle et al. 2004). The estimate of potential fish performance in EDT reflects habitat conditions from spawning grounds all the way downstream and back up to spawning grounds as returning adults, spanning the entire life history of the species.

Figure 4
Example Beverton-Holt Production Function (Lestelle et al. 2004)



Beyond producing general population-level estimates of the capacity of habitat in a watershed under a particular scenario (e.g., current, mid-century with climate change) to support a fish species, EDT can also diagnose conditions in a watershed through evaluation of restoration and prioritization potential. In order to evaluate restoration and prioritization potential, two special-case scenarios must be developed for a watershed—a Template scenario and a fully degraded scenario.

Template scenarios are ideal, pristine habitat conditions that are representative of a pre-Euro-American settlement historic condition for a specific watershed. These scenarios are generally characterized by environmental attributes that would reasonably represent historical or undisturbed conditions. This does not mean that all environmental attributes would be set to perfect conditions for fish species; every system has its intrinsic limitations and characteristics that naturally vary in their ability to support fish species despite being undisturbed. Degraded scenarios are the opposite—they describe what a system would look like with a maximum amount of disturbance and degradation of habitat.

To prioritize areas and characteristics of a watershed that are important for restoration, a "splice analysis" is performed between a current or future scenario by sequentially splicing in Template conditions to each reach, sub-basin, or other spatial unit. To prioritize protection, a splice analysis is performed on the degraded condition. During a splice analysis, habitat attributes in a particular reach (or larger geographic area such as a sub-watershed) are replaced with either the degraded or Template attributes, while attributes in all other reaches stay the same. This replacement action is automatically performed over an iterative process throughout the geography of the system. For a fish-passage prioritization analysis, passage barriers are iteratively removed and the model is re-run to demonstrate benefit to fish populations of removing these barriers; for this analysis, the prioritization was performed at the GSU level. Results of a splice analysis show the number of fish that could potentially be gained (restoration splice) or lost (protection splice) if habitat attributes respectively got better or worse in a particular geographic area. This type of analysis has the power to quantify and rank restoration or protection priorities in a watershed from the perspective of each species modeled.

Chehalis EDT Model and Recent Updates

Ecosystem modeling using the EDT model to support planning for the ASRP in the Chehalis Basin has occurred over multiple years, with new iterations incorporating new and updated data as well as answering different, specific questions to aid in guidance of restoration for progress towards species recovery (McConnaha et al. 2017). The first iteration of the Chehalis EDT model was developed in 2001, with substantial revisions in 2003 to include more species and expanded to encompass the entire basin (Mobrand Biometrics 2003). The primary data sources used in 2003 to characterize habitat conditions are provided in Attachment 3, with more detailed description in the report from Mobrand Biometrics, Inc. (2003). In 2018 and early 2019, additional adjustments to the baseline ASRP EDT conditions included new spatial scale and spatial divisions within the model (Figures 1 and 2), obstructions, spawning distributions, floodplain area, lengths and gradient throughout the basin, and mid- and late-century temperatures based on climate predictions (Table 1).

Table 1
Updates to Baseline ASRP EDT Scenarios in 2018 and Early 2019

UPDATE	UPDATE DESCRIPTION
Spatial scale	New spatial scales were delineated for ecological regions, subregions, and GSUs.
Obstructions	Scenarios were updated to include everything from the April 2019 Washington Department of Fish and Wildlife (WDFW) inventory that intersected with known spawning habitat used in the EDT model; tribal injunction culverts in mid- and late-century No Action scenarios were removed (Mobbs 2019).
Spawning distribution	Spawning habitat of species of interest were updated based on recent WDFW data (Lestelle et al. 2019).
Floodplain	Scenarios were updated using hydraulic modelling from Watershed Science & Engineering for the mainstem Chehalis River and ASRP Science and Technical Review Team (SRT) hypotheses for elsewhere in the basin and EDT Template conditions (Dickerson-Lange and Abbe 2018).
Lengths and gradients	The model was rebuilt using latest National Hydrography Dataset flowline work (more accurate length/gradient estimates); the expanded network included updated 2018 Statewide Washington Integrated Fish Distribution (SWIFD) for species of interest.
Climate temperatures	Predicted climate change temperatures were added to mid- and late-century baseline No Action scenarios based on latest Portland State University-modeled mainstem data and a combination of WDFW Thermalscape and U.S. Forest Service NorWeST data.

Baseline Scenario Updates

In addition to the revisions outlined previously, several updates were added to the current, mid-century, and late-century baseline scenarios in the present iteration of EDT modeling for the Phase 1 ASRP (Table 2). In all scenarios, the West Fork Falls fish passage barrier in the West Fork Chehalis River was added, as it was not previously included in the model. Hatchery scores were adjusted throughout the basin in response to comprehensive, updated information on hatchery fish outplants in the basin. Fish species introduction ratings were revised based on invasive species information in all scenarios. The timing of Chinook salmon runs was changed to include the most recent knowledge. In future scenarios, updated climate change mainstem temperatures were added. Channel widths were adjusted in relation to both flow changes in the tributaries and adjusted bed scour ratings under climate change scenarios (see "Climate change widths," Table 2).

Table 2
Summer 2019 Updates Made to the Baseline ASRP EDT Scenarios

UPDATE	UPDATE DESCRIPTION
Climate change widths	Climate widths were updated (from low-flow predictions) in summer months for mid- and late century in tributaries; mainstem widths were updated from Hydrological Engineering Center's – River Analysis System (HEC-RAS) modeling (Hill 2019).
Mainstem temperatures	Mainstem temperatures were updated for all scenarios based on 2019 Portland State University-modeled temperatures (Van Glubt et al. 2017).
West Fork Falls barrier	The waterfall on the West Fork Chehalis River, a full passage barrier, was added to the model (was not in WDFW culvert database).
Bed scour	Predicted climate change impacts on bed scour were added due to increased winter flows.
Hatchery rating updates	Hatchery influence ratings were updated in key locations throughout the basin based on detailed information from WDFW on hatchery fish outplants (Scharpf 2019a).
Fish species introduction ratings	Ratings were updated based on invasive species data available from WDFW (Hayes 2019).
Fish passage barrier updates	Completed and in-progress fish passage barrier removals/corrections from the 2019 field season were added. Fish passage barrier layer updated to include those in new spatial network based on all WDFW inventoried culverts (WDFW 2018a).
Fish passage	Fish passage was updated based on the 2018 WDFW inventory (WDFW 2018b). Passage ratings were updated to reflect WDFW findings. All unrated barriers were given a 50% passage rating.
Chinook salmon run timing	Fall- and spring-run Chinook salmon arrival and emigration rates were changed to avoid the mid-summer period.

Channel Width with Future Climate

Mainstem widths for current, mid-century, and late-century scenarios were derived from HEC-RAS-modeled data for No Action, 2-year (normal year) flow scenarios provided by Anchor QEA, LLC (Hill 2019). On the advice of the ASRP Science and Technical Review Team (SRT), it was assumed that channel widths in the tributaries (not modeled by HEC-RAS) during summer would decline in the future based on lower summer flow with climate change. It was assumed that tributary summer flows would be reduced by the same percentage as mainstem flows from current to mid- and late century, and calculations were performed to estimate changes in summer tributary channel widths throughout the Chehalis Basin based on this. Note that this is a reduction in summer wetted channel width in every tributary reach in the model. Updated tributary widths under climate scenarios were derived using the following method:

1. Flow (Q) in tributaries was calculated from current widths based on Equation 1 and 2 derived from Lestelle (2004).
2. These flows were decreased for each month by the same average flow decrease demonstrated in climate flows derived by HEC-RAS for the mainstem Chehalis River by month (Mauger et al. 2016) and the most recent information from the University of Washington Climate Impacts Group.
3. These new flows were re-input into the equations to derive new climate widths for all tributary reaches.

Equation 1

$$\boldsymbol{Q} = \mathbf{0.004984} * \boldsymbol{w}^{\mathbf{2.299}}$$

Equation 2

$$\boldsymbol{Q} = \mathbf{0.06811} * \boldsymbol{w}^{\mathbf{1.767}}$$

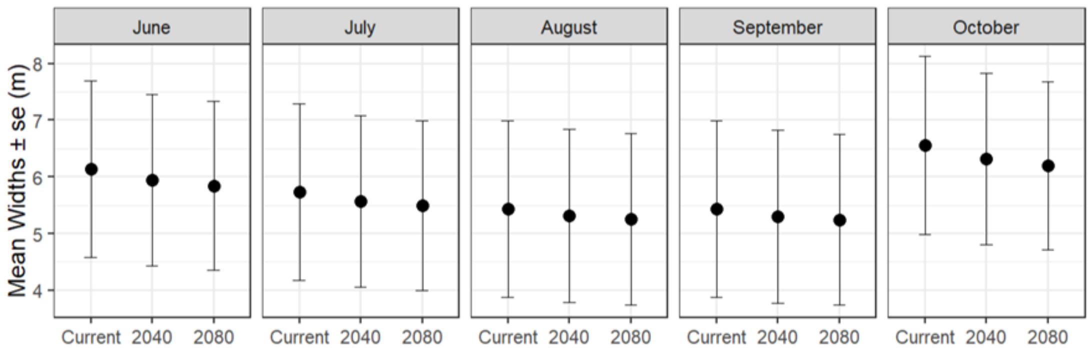
where:
Equation 1 used for unconfined reaches and Equation 2 used for confined reaches, where unconfined reaches are defined as having an EDT confinement rating of less than 3 and confined reaches are defined as having an EDT confinement rating of greater than or equal to 3.

Q	=	volumetric flow in cubic feet per second
W	=	maximum wetted width in feet

As stated by Lestelle (2005): "The equation for unconfined reaches [Equation 1] is based on data collected at 154 sites from a variety of rivers and tributaries in western Washington across a wide range of sizes. The equation for confined reaches [Equation 2] was developed with data from sites in the Wenatchee River system; that system contains a high degree of semi- or fully confined reaches."

The updated average tributary widths based on climate change are shown in Figure 5. Average widths decrease moving from current to mid- to late-century scenarios based on the assumed flow changes.

Figure 5
Average Tributary Summer Wetted Widths in Meters in the Chehalis Basin (June Through October) for Current, Mid-, and Late-Century Scenarios

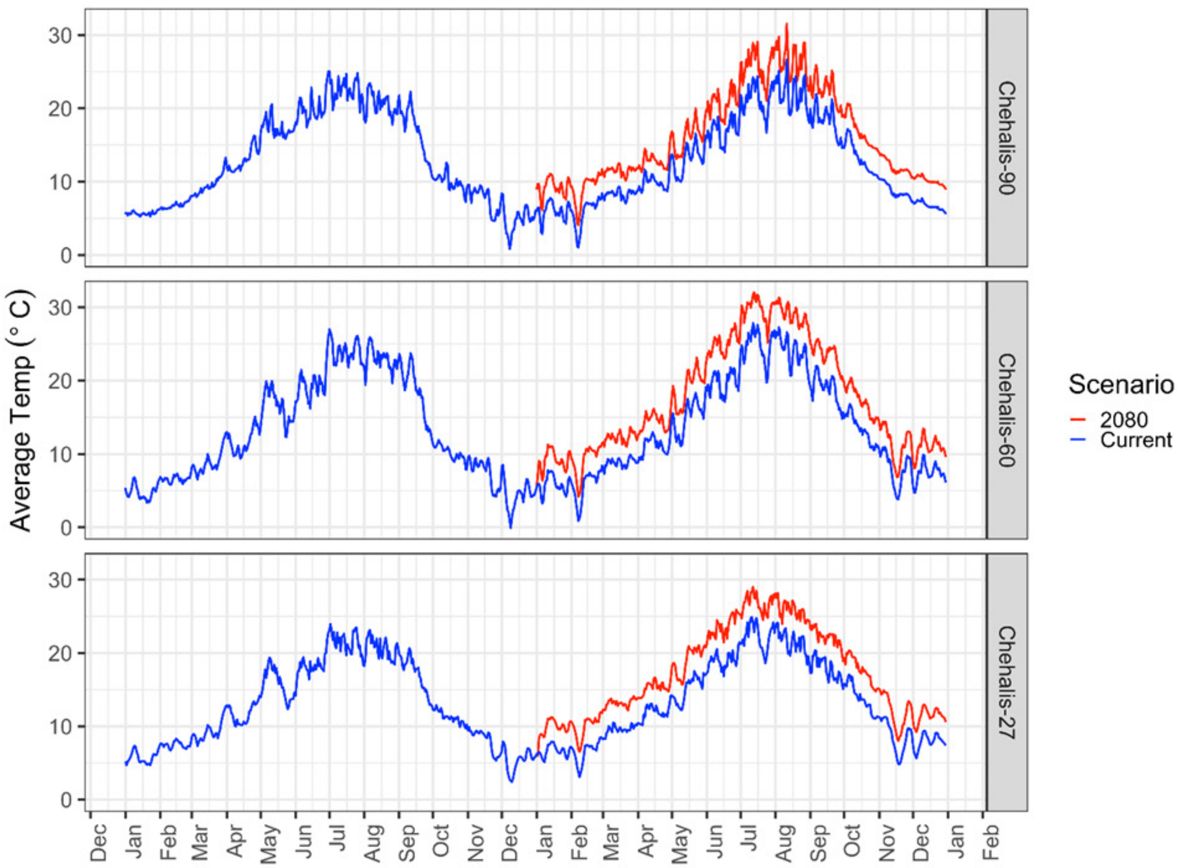


Note:
Whiskers show the standard error surrounding the mean of widths across all tributary reaches, indicating variability.

Water Temperature

Water temperature in the Chehalis River tributaries is based on the WDFW Thermalscape modeling (Winkowski and Zimmerman 2019). Future water temperatures in the tributaries were estimated by adjusting the Thermalscape data by the change in temperature in late century predicted by the U.S. Forest Service NorWeST system (Isaak et al. 2017). For temperature in the mainstem Chehalis River in the baseline current and late-century scenarios, updated results from the Portland State University CE-QUAL-W2-modeled data were used (Van Glubt et al. 2017). Portland State University-modeled water temperature in the mainstem Chehalis River for current and “future” conditions (taken to represent conditions in late century or 2080) (Figure 6) were used to derive mid-century (2040) temperatures by taking current daily temperatures 36.5% of the way towards late-century temperatures. 36.5% was calculated as the average point between current and late-century temperatures according to NorWeST predictions.

Figure 6
Portland State University CE-QUAL-W2-Modeled Temperature Data at Three Points in the Mainstem Chehalis River for Current and 2080

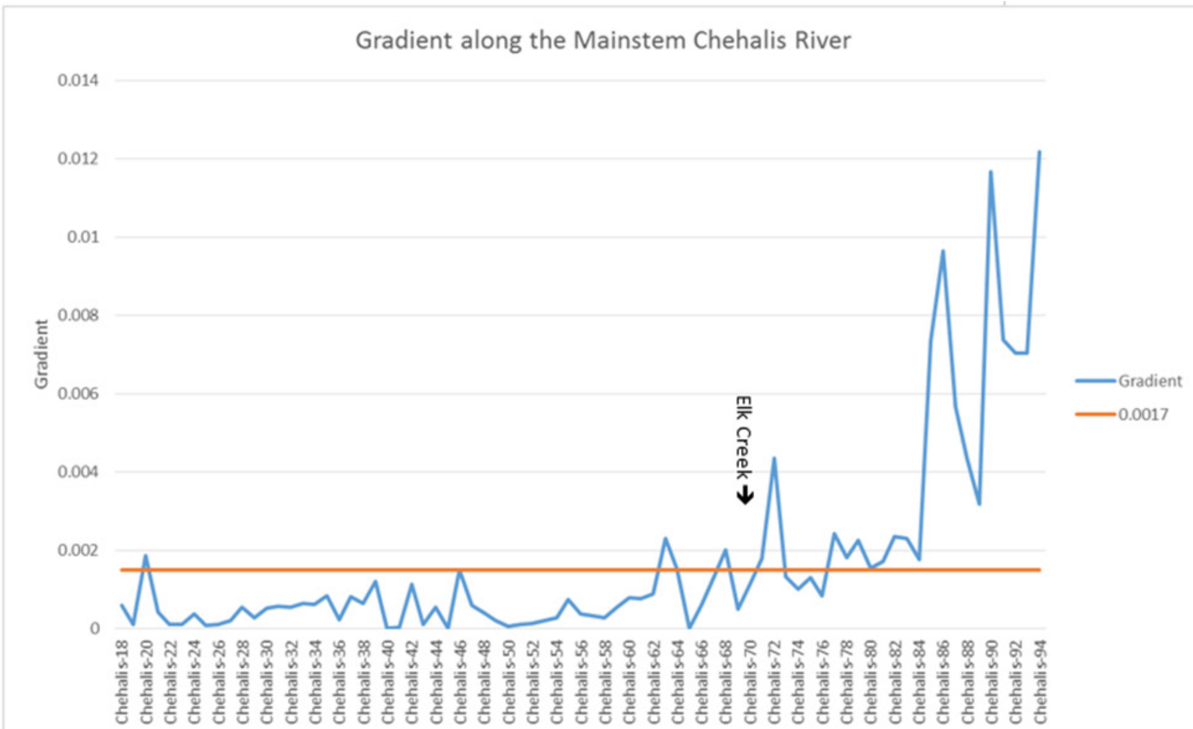


Note:
Current temperatures were based on 2013 and 2014 water years, and future conditions were based on the 2014 water year only. Chehalis-90 is near the inflow of Roger Creek, Chehalis-60 is just downstream of Van Ornum Creek confluence, and Chehalis-27 is near the inflow of Porter Creek.

Bed Scour

Bed scour in EDT reflects the average depth of bed scour in salmonid spawning areas (i.e., pool-tailouts and small cobble-gravel riffles) during peak flow events. High bed scour can affect salmonid egg survival and overwintering juveniles (Lestelle 2005). Climate change in the Chehalis Basin is expected to increase the frequency and intensity of winter storms (Mauger et al. 2016); this was assumed to increase bed scour throughout the basin in the future. Changes in bed scour were implemented in the mid- and late-century baselines based on an expert panel convened in 2016 as part of the Chehalis Basin Strategy and resulted in an adjustment (worsening) of bed scour of 8% in mid-century and 21% by late century; these methods are further described by McConnaha and Ferguson (2019). It is assumed that bed scour increases with gradient, and this hypothesis was implemented in reaches with a gradient exceeding 0.0017. This included reaches above the Elk Creek confluence in the mainstem Chehalis River (Figure 7), as well as the upper reaches of many tributaries.

Figure 7
Gradient of the Mainstem Chehalis River



Hatchery Locations

The hatchery fish outplants attribute was updated throughout the model based on information on hatchery and outplant locations provided by WDFW (Scharpf 2019). The hatchery fish outplants attribute in EDT represents the magnitude of hatchery fish outplants in the basin. It is meant as a general characterization and not a direct representation of magnitude, fish size, or species of the releases. Ultimately, it assesses the risk hatchery fish may cause to native fish through competition or predation (Lestelle 2005). For this update, the downstream influence of hatcheries was extended for approximately 4 to 6 kilometers, and the upstream influence was extended to one reach upstream of the hatchery reach. In the EDT model, systems with a Hatchery Fish Outplant rating of 0 have no hatchery influence, and those with a rating of 4 have fish releases every 1 to 3 years at multiple sites within the basin (Lestelle 2005). Hatchery and hatchery-influenced reaches received a rating of 3 in the EDT model; reaches upstream of Elk Creek received a rating of 0 (hatchery fish have not apparently been released into the upper Chehalis Basin); and all other reaches received a rating of 1 due to pervasive, low-level effects of hatchery fish throughout the majority of the Chehalis Basin.

Predation Effects

The fish species introductions attribute is used in EDT to account for increased predation on modeled species due to introduced exotic species (Lestelle 2004). The ratings for Fish Species Introductions were updated throughout the basin based on data collected by WDFW in recent years and a new rating system developed by Marc Hayes (Hayes 2019). Instead of only addressing fish species introductions, all invasive (non-native) animal species that may have a predatory, competitive, or food chain-altering influence were included in the rating system, with centrarchid fish species counting twice due to their substantial predatory influence (e.g., smallmouth bass) (Holgerson et al. 2019). The Holgerson et al. (2019) study examined predatory effects of fish and centrarchids specifically on amphibians; however, this effect is expected to be translated to fish prey and is currently being studied.

Fish Passage Updates

The Chehalis Basin Lead Entity identified fish passage barriers that were in the WDFW culvert inventory but had been recently replaced or improved or were likely to be replaced or improved from 2018 to 2019. A total of 26 culverts were set to 100% passage as a result of these updates. The update also included the previous step of removing the tribal injunction culverts at the No Action mid- and late-century scenarios (Table 1).

Chinook Life History Timings

Although fall- and spring-run Chinook salmon in the Chehalis Basin both have an ocean-type life history, fall-run Chinook salmon do not enter the system until fall and lack the summer holding life stage that limits spring-run Chinook salmon. Fall-run Chinook salmon are relatively abundant throughout the Chehalis River system, especially in the large, lower basin sub-basins and the mainstem Chehalis River. The EDT model had been applying life history specifications for both spring- and fall-run Chinook salmon that did not fully reflect current known life history patterns. The model had been applying life history patterns that assumed significant habitat use and movements of both juvenile and adult fish at times during mid-summer when water temperatures were at their extreme. Based on input from WDFW and Lestelle (2019), life history timings were revised to provide a more realistic depiction of Chinook salmon presence in the Chehalis River. The following adjustments were made:

- Adult fall-run Chinook salmon enter the Chehalis River starting August 21.
- Adult spring-run Chinook salmon complete their entry to the Chehalis River by June 30.
- Juvenile fall-run Chinook salmon enter the ocean (Grays Harbor) by July 15.

Baseline Results

Basin-wide EDT scenarios reflect the effects of the updates described in the previous section in current, mid-, and late century before evaluating the ASRP alternative restoration scenarios. Equilibrium abundance results for the updated baseline scenarios (current, mid-, and late-century baselines), including all subpopulations, are shown in Table 3 for coho salmon, fall-run Chinook salmon, spring-run

Chinook salmon, winter-run steelhead, and chum salmon. Equilibrium abundance region by region is shown in Figure 8.

Table 3
Equilibrium Abundance of Target Salmonid Species (Two Runs of Chinook) Modeled for Chehalis Basin Using EDT Under Three Baseline Scenarios

SPECIES/RUNS	CURRENT	MID-CENTURY	LATE CENTURY
Coho salmon	76,964	67,831	51,197
Fall-run Chinook salmon	41,658	34,484	18,730
Spring-run Chinook salmon	1,811	1,145	568
Winter-run steelhead	15,731	14,125	12,089
Chum salmon	131,755	117,428	86,597

Under the current baseline scenario, coho salmon were estimated to have a basin-wide equilibrium abundance of 76,964. In comparison, the average coho salmon total run size (including harvest) in the Chehalis Basin was estimated by WDFW from 2009 to 2018 was 71,787, with a maximum over the period of 128,525 (Scharpf 2019b). The EDT model predicts run sizes below the current average in mid- and late century without restoration (Table 3).

Under the current baseline scenario, fall-run Chinook salmon were estimated to have a basin-wide equilibrium abundance of 41,658. In comparison, the average fall-run Chinook salmon total run size (including harvest) in the Chehalis Basin from 2009 to 2018 was estimated by WDFW to be 13,782 with a maximum over the period of 21,474 (Scharpf 2019b). EDT predictions of fall-run Chinook equilibrium abundance are high as compared to current estimates, and EDT predicts decreases in run size by mid- and late century without restoration (Table 3).

Spring-run Chinook salmon are the least abundant of the species evaluated in the Chehalis Basin. Under the current baseline scenario, spring-run Chinook salmon were estimated to have a basin-wide equilibrium abundance of 1,811. By comparison, the average total spring-run Chinook salmon run to the Chehalis Basin (including harvest) from 2009 to 2018 was estimated by WDFW to be 1,749, with a maximum total run size of 3,495 (Scharpf 2019b). EDT predicts a decline of spring-run Chinook salmon to less than 600 individuals by late century without restoration actions (Table 3).

Under the current baseline scenario, steelhead were estimated to have a basin-wide equilibrium abundance of 15,731. The average winter-run steelhead total run size (including harvest) in the Chehalis Basin from 2009 to 2018 was estimated by WDFW to be 8,657, with a maximum over the period of 12,352 (Scharpf 2019b). EDT predicts a smaller decline of steelhead in the Chehalis Basin by mid- and late century as compared to some of the other evaluated species, with a late-century equilibrium abundance slightly lower than the current observed maximum run size (Table 3).

Under the current baseline scenario, chum salmon were estimated to have a basin-wide equilibrium abundance of 131,755. The average winter-run chum salmon total run size (including harvest) in the Chehalis Basin from 2009 to 2018 was estimated by WDFW to be 29,395, with a maximum over the period of 64,704 (Scharpf 2019b). EDT predicts a decline of chum salmon in the Chehalis Basin by mid- and late century without restoration (Table 3).

All species/runs are predicted to decline in abundance from current to mid- to late century in response to climate change if no restoration actions are implemented (Table 3). By late century, coho salmon would decline by 33%, fall-run Chinook salmon by 55%, spring-run Chinook salmon by 69%, steelhead by 23%, and chum salmon by 34%. The differences in percent decline by late-century baseline among species can be partly explained by differences in the diversity parameter (the percent of trajectories contributing to equilibrium abundance estimates; Table 4). Coho salmon and steelhead, the two species with the least percent reduction in predicted equilibrium abundance by late century, also are ranked first and third in least percent reduction in the combination of life histories and spawning areas (trajectories) contributing to results from current to late century (Table 4). On the other hand, the species/runs that exhibited the highest percent reduction in predicted equilibrium abundance from current to late century (spring-run Chinook and fall-run Chinook salmon) also demonstrated the highest reductions in diversity. Spring-run Chinook salmon already have a very low diversity predicted under current conditions (7%; Table 4). Not only are both spring- and fall-run Chinook salmon predicted to decline greatly in abundance by late century without restoration, but the combination of spawning areas and life history patterns that are able to persist also decreases greatly (Table 4).

Table 4
Diversity of Target Salmonid Species (Two Runs of Chinook) Modeled for Chehalis Basin Using EDT Under Three Baseline Scenarios

SPECIES/RUNS	CURRENT	MID-CENTURY	LATE CENTURY
Coho salmon	63%	59%	53%
Fall-run Chinook salmon	81%	69%	38%
Spring-run Chinook salmon	7%	4%	2%
Winter-run steelhead	42%	37%	33%
Chum salmon	73%	72%	61%

At an ecological region scale, all runs within each relevant region are also modeled to decline in abundance from current to mid- to late century (Figure 8). Climate and land use impacts overwhelm benefits due to riparian maturation in managed forests, although without the riparian maturation, the abundance of all subpopulations would be even lower by late century. In specific cases, mid-century results at a regional level for a species increase (e.g., coho salmon equilibrium abundance in the mid-century Olympic Mountains Ecological Region; Figure 8a). In this case, habitat benefits due to riparian maturation in matured forests are benefiting the region's subpopulation more than climate change and land use degradation are degrading it.

Figure 8
Equilibrium Abundance of Target Salmonid Runs Modeled for Chehalis Basin Using EDT Under Three Baseline (No Action) Time Periods

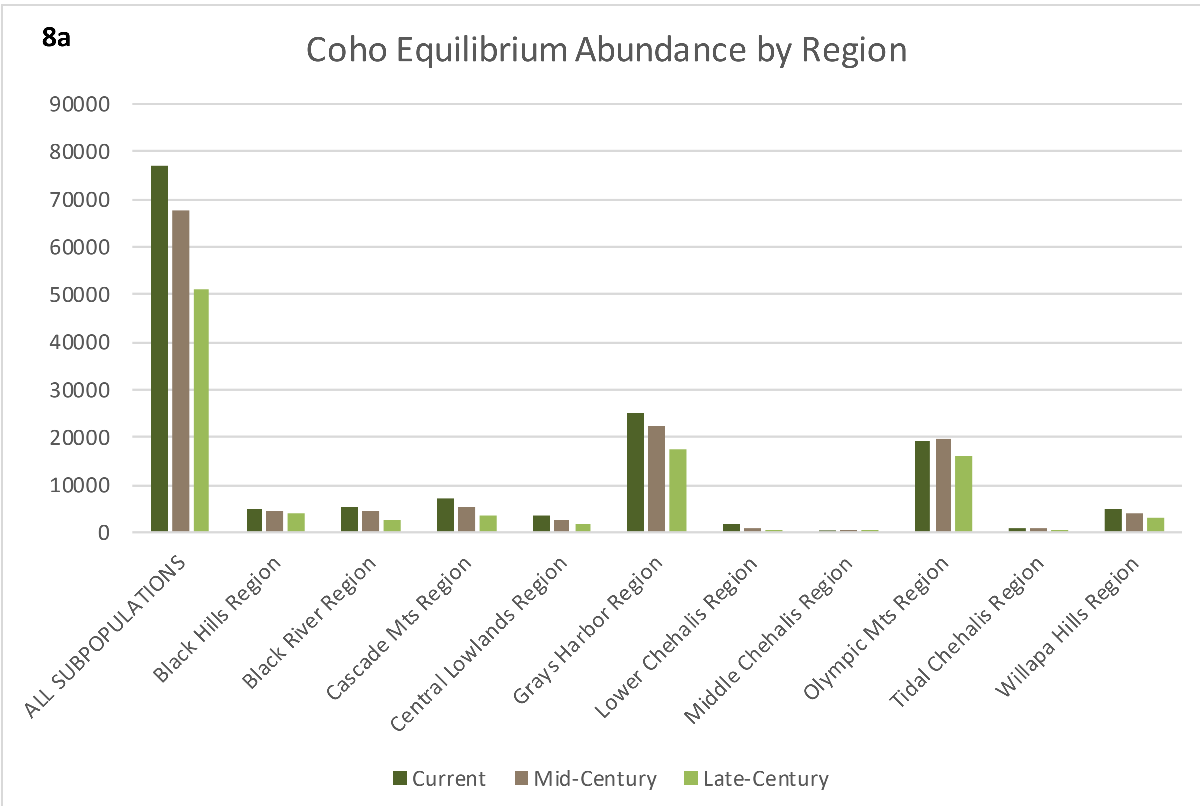
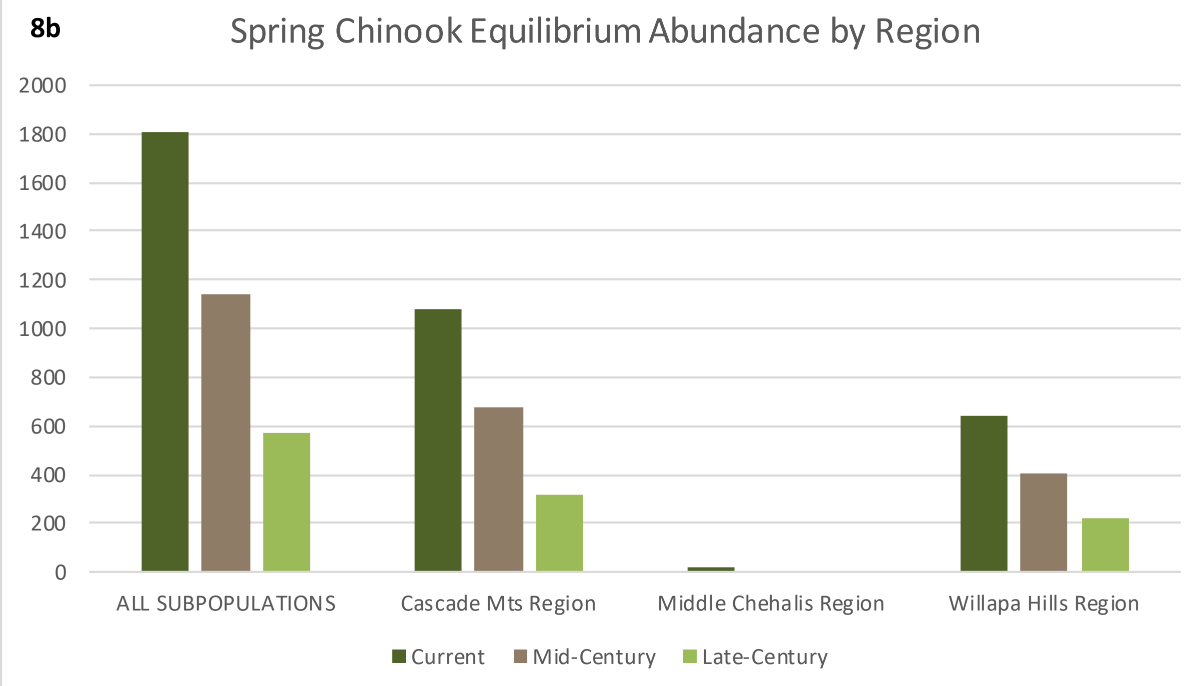


Figure 8
Equilibrium Abundance of Target Salmonid Runs Modeled for Chehalis Basin Using EDT Under Three Baseline (No Action) Time Periods



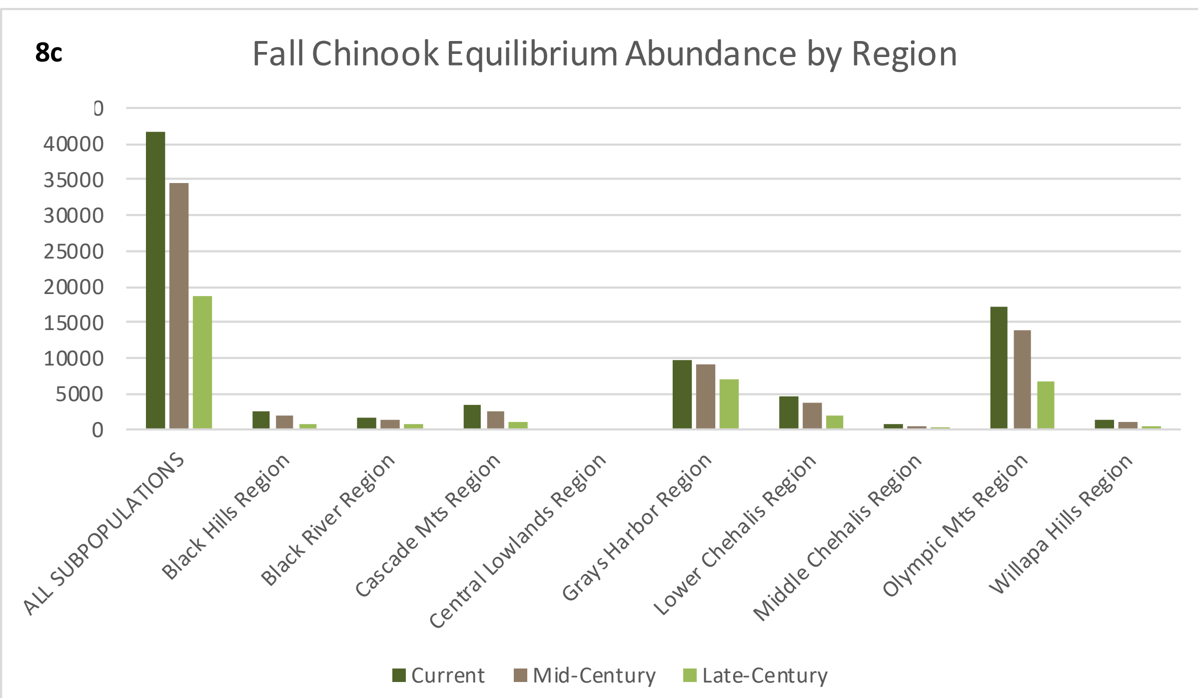
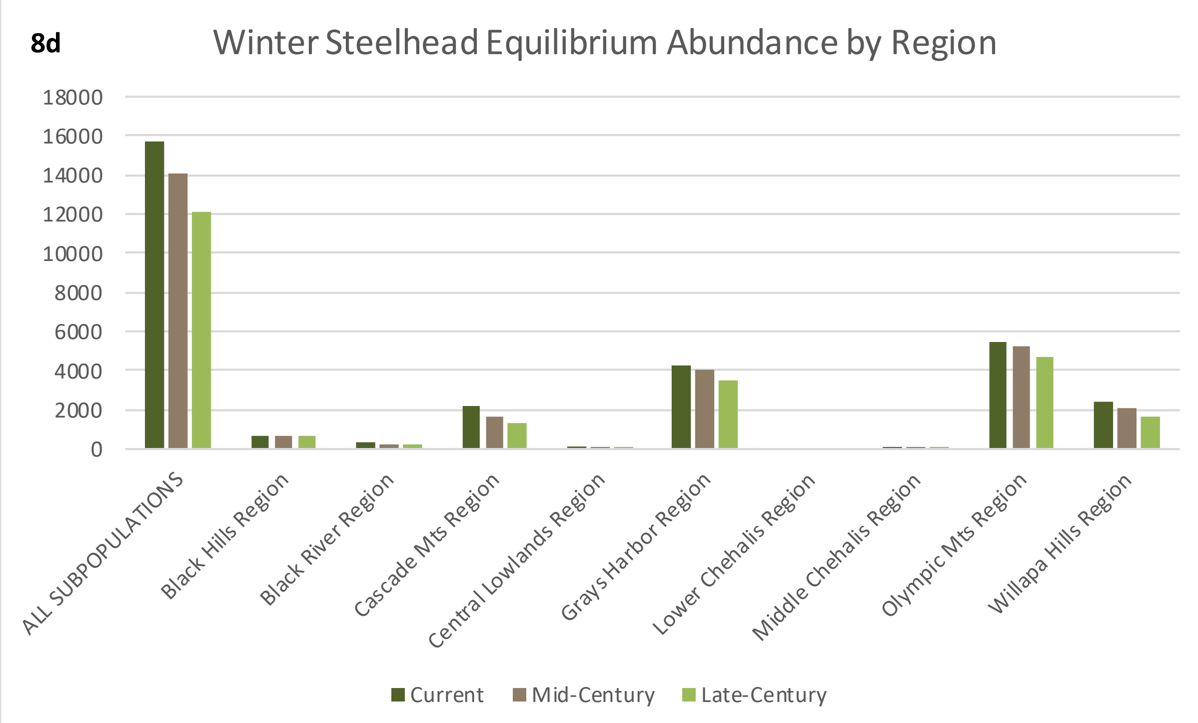
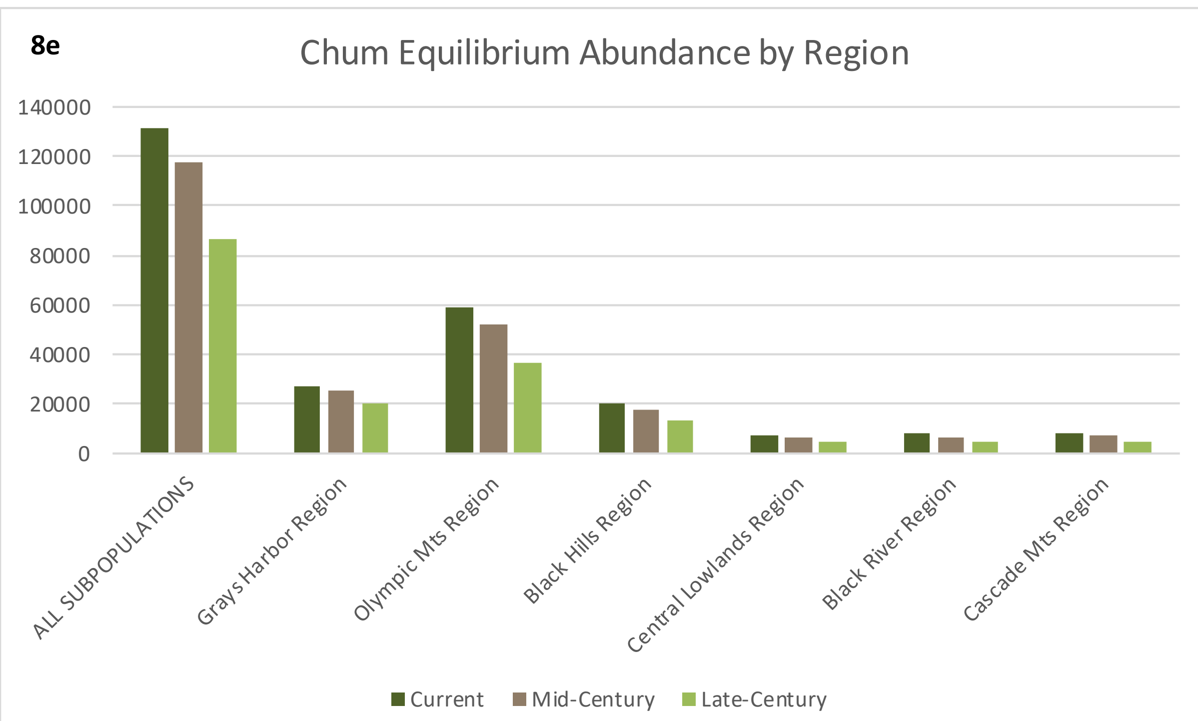


Figure 8
Equilibrium Abundance of Target Salmonid Runs Modeled for Chehalis Basin Using EDT Under Three Baseline (No Action) Time Periods



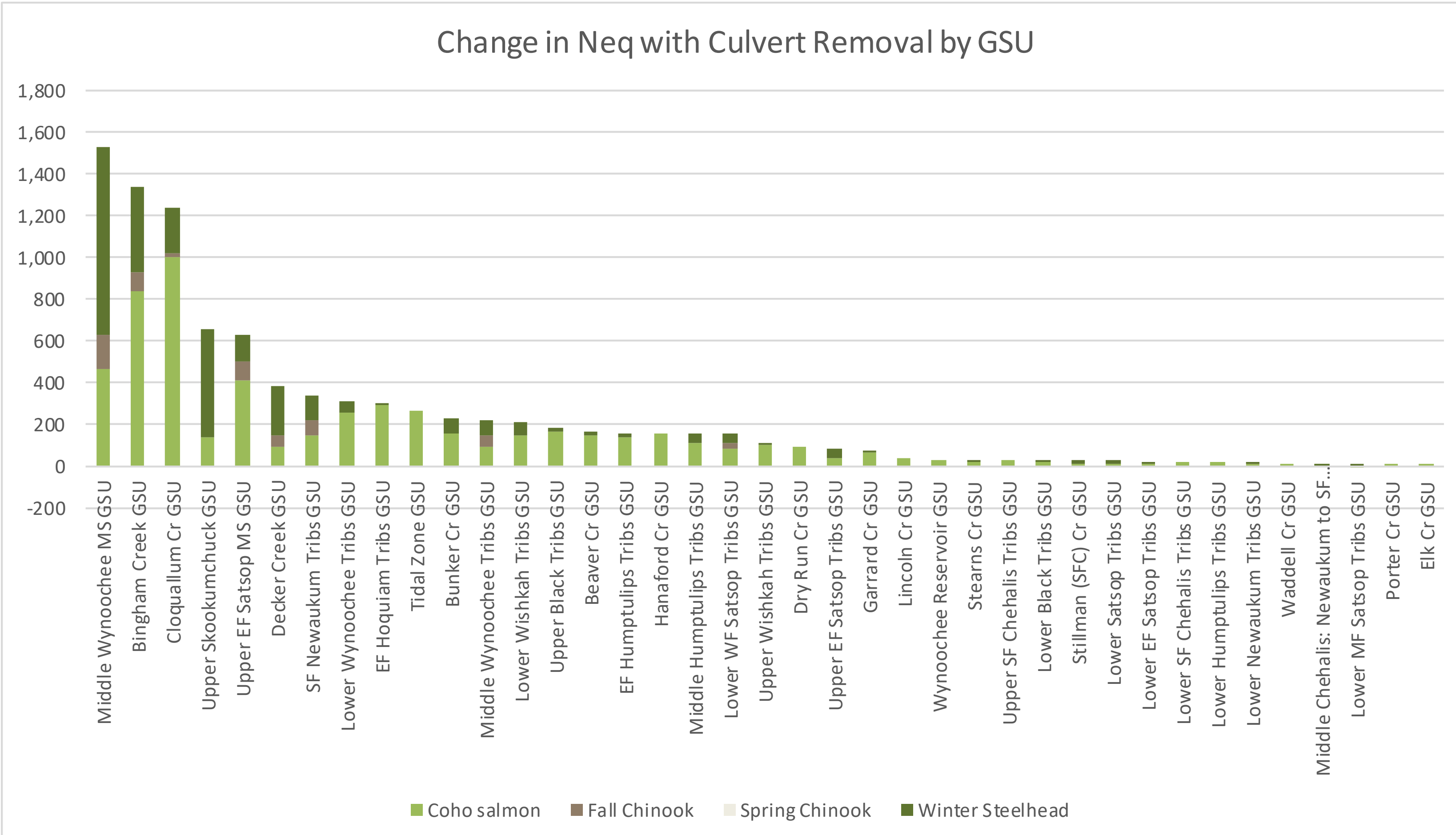


Fish Passage Analysis

A fish passage splice analysis at the GSU level was performed to rank GSUs in terms of the potential change in fish production based on the removal of fish passage impediments within the GSU; this analysis was performed for fall-run Chinook salmon, spring-run Chinook salmon, coho salmon, and steelhead. EDT evaluates barriers in terms of the potential production of target species originating in habitat above the barrier. Because salmon are anadromous and migrate downstream below the GSU as juveniles and upstream as adults, the evaluation of barriers reflects the quality and quantity of habitat both upstream and downstream of the obstruction. The ranking of obstruction impacts in EDT provides important information regarding potential benefits of barrier removal or repair. Figure 9 shows the ranking of GSUs by the sum of benefits of fish passage barrier removals across the species/runs evaluated here (coho salmon, fall-run Chinook salmon, spring-run Chinook salmon, and winter-run steelhead). With this ranking criteria, removing barriers within the middle Wynoochee River mainstem GSU had the greatest benefit for equilibrium abundance of all species combined, followed by the Bingham Creek GSU (which has a hatchery weir as a primary barrier with 67% passability) and the Cloquallum Creek GSU (Figure 9). The barriers present in the middle Wynoochee River mainstem GSU include Wynoochee Dam and the fish collection weir 2 miles downstream of the dam. Cloquallum Creek and its tributaries have the largest number of fish passage barriers of any sub-basin. For coho salmon, removing barriers in the Cloquallum Creek, Bingham Creek, and middle Wynoochee River GSUs provided the most benefit. For fall-run Chinook salmon, removing barriers in the middle Wynoochee River, Cook Creek, and upper East Fork Satsop River mainstem GSUs provided the most benefit. For steelhead, removing barriers in the middle Wynoochee River, upper Skookumchuck River, and Bingham Creek GSUs provided the most benefit. There was no significant benefit to removing barriers at any GSU level for spring-run Chinook salmon.

These results require supplementary analysis outside of the EDT model to identify which barriers are amenable to removal and restoration. For example, the partial obstruction on Bingham Creek that provides a potentially high value for coho salmon (Figure 9) is a counting station weir operated by WDFW that provides important information on abundance and survival for the region. Also, fish are passed above this structure to utilize upstream habitat. In this case, the value of the information may outweigh the benefit of increased production above the weir.

Figure 9
Increases in Equilibrium Abundance of Salmonids in the Chehalis River Basin with Removal of All Culverts by GSU



Analysis of Restoration Potential

Splice diagnoses were performed on the current condition baseline to identify areas with the most limiting habitat potential in the basin for the evaluated salmonid species and to help highlight areas that have high potential of increasing habitat with restoration. A restoration-splice evaluation is performed by splicing attribute values that are in the EDT Template into the current habitat condition for varying spatial scales within the entire basin (ecological regions, sub-basins, GSUs, or reaches). At the ecological region scale, a restoration splice was used to assess changes in species performance with full restoration measured by changes in performance attributes. The results in Tables 5 through 9 show the change in abundance in the 10 ecological regions at the basin level when different conditions (specific combinations of habitat attributes termed "survival factors") within each region were set to the EDT Template values. Survival factors are outlined and explained by Lestelle et al. (2004). For example, in Table 5, changing key habitat throughout the Black Hills Ecological Region to Template conditions increased the basin-wide abundance of coho salmon by 627, or about 0.80%, at the basin scale. For the ecological regions that contain mostly mainstem Chehalis River reaches (e.g., the Lower Chehalis River Ecological Region), the change in abundance with attribute restoration is due to increased production in the region itself (increased equilibrium abundance as calculated for fish that spawn in the region), as well as the contribution of that restoration to upstream subpopulation production (from increased abundance of fish that do not spawn in region but complete part of their life cycle in the region or must pass through the region).

By definition, the Template condition in the Chehalis EDT model does not always contain the best possible habitat for every species-life stage combination in every month and reach. It is a representation of historical conditions, in which some reaches had more spawning gravel and some less, some areas had naturally cooler or warmer water, and some reaches had less canopy cover and others more. It is possible under some scenarios for the current conditions to be "better" than Template conditions, especially when the habitat requirements for a particular life stage of a salmonid are very specific. Thus, there are some cases where changing a suite of habitat attributes in a region to Template conditions actually results in a basin-wide decrease in predicted equilibrium abundance for a species. In these cases, it may be inherently inappropriate to attempt to restore these particular habitat elements in this area.

Restoration of most GSUs makes small percent changes to abundance at the basin scale. However, these changes do make a larger difference at the regional, sub-basin, or GSU scale. The effect of restoration of the attributes can be ranked to show the relative value of restoration within a sub-basin, and this information can be used to guide selection of restoration actions.

Table 5

Basin-Level Splice Results for Coho Salmon Showing Change in Abundance with Restoration to Template Condition (Percentages Are Based on Percent Increase in Equilibrium Abundance at a Basin Scale)

	CHANGE IN ABUNDANCE WITH RESTORATION TO TEMPLATE (% CHANGE AT BASIN SCALE)										
ECOLOGICAL REGION	CHANNEL LENGTH	CHANNEL STABILITY	FLOW	HABITAT DIVERSITY	KEY HABITAT	OBSTRUCTIONS	PATHOGENS	PREDATION	SEDIMENT LOAD	TEMPERATURE	WIDTH
Willapa Hills	39(0.1%)	81(0.1%)	39(0.1%)	871(1.1%)	917(1.2%)	90(0.1%)	51(0.1%)	85(0.1%)	116(0.2%)	1,707(2.2%)	45(0.1%)
Cascade Mountains	527(0.7%)	181(0.2%)	79(0.1%)	1,277(1.7%)	1,803(2.3%)	989(1.3%)	136(0.2%)	189(0.2%)	233(0.3%)	1,444(1.9%)	275(0.4%)
Middle Chehalis River	56(0.1%)	41(0.1%)	2(0.0%)	642(0.8%)	490(0.6%)	41(0.1%)	123(0.2%)	164(0.2%)	73(0.1%)	811(1.1%)	97(0.1%)
Central Lowlands	0(0.0%)	37(0.0%)	16(0.0%)	143(0.2%)	923(1.2%)	398(0.5%)	39(0.1%)	61(0.1%)	47(0.1%)	240(0.3%)	19(0.0%)
Lower Chehalis River	394(0.5%)	286(0.4%)	277(0.4%)	2,373(3.1%)	1,748(2.3%)	0(0.0%)	738(1.0%)	1,551(2.0%)	356(0.5%)	1,006(1.3%)	544(0.7%)
Black River	0(0.0%)	91(0.1%)	32(0.0%)	238(0.3%)	485(0.6%)	423(0.5%)	1,51(0.2%)	428(0.6%)	191(0.2%)	738(1.0%)	27(0.0%)
Black Hills	0(0.0%)	78(0.1%)	40(0.1%)	429(0.6%)	627(0.8%)	1,134(1.5%)	77(0.1%)	236(0.3%)	113(0.1%)	702(0.9%)	16(0.0%)
Olympic Mountains	441(0.6%)	539(0.7%)	455(0.6%)	3,170(4.1%)	4,758(6.2%)	2,798(3.6%)	329(0.4%)	724(0.9%)	652(0.8%)	4,941(6.4%)	856(1.1%)
Chehalis River Tidal	0(0.0%)	2,949(3.8%)	3,120(4.1%)	12,333(16.0%)	2,184(2.8%)	323(0.4%)	358(0.5%)	1,495(1.9%)	1,215(1.6%)	569(0.7%)	1,599(2.1%)
Grays Harbor Tributaries	552(0.7%)	2,055(2.7%)	2,030(2.6%)	8,896(11.6%)	6,862(8.9%)	1,734(2.3%)	553(0.7%)	1,113(1.4%)	4,356(5.7%)	5,940(7.7%)	2,132(2.8%)

Table 6

Basin-Level Splice Results for Spring-Run Chinook Salmon Showing Change in Abundance with Restoration to Template Condition (Percentages Are Based on Percent Increase in Equilibrium Abundance at a Basin Scale)

	CHANGE IN ABUNDANCE WITH RESTORATION TO TEMPLATE (% CHANGE AT BASIN SCALE)										
ECOLOGICAL REGION	CHANNEL LENGTH	CHANNEL STABILITY	FLOW	HABITAT DIVERSITY	KEY HABITAT	OBSTRUCTIONS	PATHOGENS	PREDATION	SEDIMENT LOAD	TEMPERATURE	WIDTH
Willapa Hills	13(0.7%)	14(0.8%)	32(1.8%)	56(3.1%)	105(5.8%)	0(0.0%)	13(0.7%)	3(0.2%)	32(1.8%)	709(39.1%)	6(0.3%)
Cascade Mountains	180(9.9%)	24(1.3%)	103(5.7%)	431(23.8%)	309(17.1%)	0(0.0%)	31(1.7%)	7(0.4%)	67(3.7%)	984(54.3%)	8(0.4%)
Middle Chehalis River	2(0.1%)	13(0.7%)	10(0.6%)	34(1.9%)	125(6.9%)	0(0.0%)	41(2.3%)	17(0.9%)	4(0.2%)	145(8.0%)	35(1.9%)
Lower Chehalis River	0(0.0%)	18(1.0%)	3(0.2%)	38(2.1%)	238(13.1%)	0(0.0%)	162(8.9%)	56(3.1%)	6(0.3%)	248(13.7%)	87(4.8%)
Chehalis River Tidal	0(0.0%)	33(1.8%)	0(0.0%)	67(3.7%)	84(4.6%)	0(0.0%)	102(5.6%)	30(1.7%)	7(0.4%)	155(8.6%)	40(2.2%)

Table 7

Basin-Level Splice Results for Fall-Run Chinook Salmon Showing Change in Abundance with Restoration to Template Condition (Percentages Are Based on Percent Increase in Equilibrium Abundance at a Basin Scale)

	CHANGE IN ABUNDANCE WITH RESTORATION TO TEMPLATE (% CHANGE AT BASIN SCALE)										
ECOLOGICAL REGION	CHANNEL LENGTH	CHANNEL STABILITY	FLOW	HABITAT DIVERSITY	KEY HABITAT	OBSTRUCTIONS	PATHOGENS	PREDATION	SEDIMENT LOAD	TEMPERATURE	WIDTH
Willapa Hills	152(0.4%)	44(0.1%)	28(0.1%)	96(0.2%)	973(2.3%)	0(0.0%)	-18(0.0%)	0(0.0%)	41(0.1%)	-39(-0.1%)	21(0.1%)
Cascade Mountains	1,222(2.9%)	197(0.5%)	157(0.4%)	877(2.1%)	3,259(7.8%)	212(0.5%)	-49(-0.1%)	11(0.0%)	324(0.8%)	-72(-0.2%)	29(0.1%)
Middle Chehalis River	114(0.3%)	48(0.1%)	51(0.1%)	121(0.3%)	733(1.8%)	0(0.0%)	-144(-0.3%)	0(0.0%)	110(0.3%)	-202(-0.5%)	147(0.4%)
Central Lowlands	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)
Lower Chehalis River	2,235(5.4%)	148(0.4%)	179(0.4%)	854(2.1%)	2,036(4.9%)	0(0.0%)	-580(-1.4%)	6(0.0%)	893(2.1%)	-169(-0.4%)	1,694(4.1%)
Black River	0(0.0%)	64(0.2%)	21(0.1%)	81(0.2%)	711(1.7%)	0(0.0%)	-5(0.0%)	27(0.1%)	337(0.8%)	-14(0.0%)	0(0.0%)
Black Hills	0(0.0%)	60(0.1%)	28(0.1%)	221(0.5%)	1,290(3.1%)	56(0.1%)	8(0.0%)	16(0.0%)	59(0.1%)	8(0.0%)	0(0.0%)
Olympic Mountains	1,769(4.2%)	487(1.2%)	624(1.5%)	1,199(2.9%)	6,342(15.2%)	1,020(2.4%)	86(0.2%)	153(0.4%)	1,608(3.9%)	103(0.2%)	773(1.9%)
Chehalis River Tidal	0(0.0%)	1,062(2.5%)	166(0.4%)	2,566(6.2%)	12,833(30.8%)	0(0.0%)	986(2.4%)	631(1.5%)	306(0.7%)	1,233(3.0%)	4,984(12.0%)
Grays Harbor Tributaries	708(1.7%)	578(1.4%)	344(0.8%)	1,453(3.5%)	7,396(17.8%)	72(0.2%)	850(2.0%)	264(0.6%)	2,093(5.0%)	1,298(3.1%)	1,379(3.3%)

Table 8

Basin-Level Splice Results for Steelhead Showing Change in Abundance with Restoration to Template Condition (Percentages Are Based on Percent Increase in Equilibrium Abundance at a Basin Scale)

	CHANGE IN ABUNDANCE WITH RESTORATION TO TEMPLATE (% CHANGE AT BASIN SCALE)										
ECOLOGICAL REGION	CHANNEL LENGTH	CHANNEL STABILITY	FLOW	HABITAT DIVERSITY	KEY HABITAT	OBSTRUCTIONS	PATHOGENS	PREDATION	SEDIMENT LOAD	TEMPERATURE	WIDTH
Willapa Hills	7(0.0%)	100(0.6%)	257(1.6%)	330(2.1%)	123(0.8%)	18(0.1%)	48(0.3%)	49(0.3%)	39(0.2%)	402(2.6%)	23(0.1%)
Cascade Mountains	70(0.4%)	117(0.7%)	307(1.9%)	334(2.1%)	15(0.1%)	405(2.6%)	66(0.4%)	75(0.5%)	43(0.3%)	344(2.2%)	23(0.1%)
Middle Chehalis River	2(0.0%)	9(0.1%)	11(0.1%)	269(1.7%)	-12(-0.1%)	9(0.1%)	41(0.3%)	105(0.7%)	14(0.1%)	88(0.6%)	21(0.1%)
Central Lowlands	0(0.0%)	6(0.0%)	10(0.1%)	15(0.1%)	25(0.2%)	59(0.4%)	4(0.0%)	6(0.0%)	2(0.0%)	21(0.1%)	2(0.0%)
Lower Chehalis River	14(0.1%)	17(0.1%)	16(0.1%)	598(3.8%)	1(0.0%)	0(0.0%)	132(0.8%)	356(2.3%)	38(0.2%)	176(1.1%)	44(0.3%)
Black River	0(0.0%)	8(0.1%)	18(0.1%)	79(0.5%)	42(0.3%)	20(0.1%)	17(0.1%)	47(0.3%)	11(0.1%)	45(0.3%)	0(0.0%)
Black Hills	0(0.0%)	24(0.2%)	83(0.5%)	114(0.7%)	97(0.6%)	107(0.7%)	21(0.1%)	60(0.4%)	10(0.1%)	96(0.6%)	2(0.0%)
Olympic Mountains	39(0.2%)	156(1.0%)	342(2.2%)	894(5.7%)	401(2.6%)	1,009(6.4%)	122(0.8%)	335(2.1%)	147(0.9%)	766(4.9%)	464(3.0%)
Chehalis River Tidal	0(0.0%)	4(0.0%)	4(0.0%)	660(4.2%)	-1(0.0%)	0(0.0%)	45(0.3%)	251(1.6%)	81(0.5%)	261(1.7%)	2(0.0%)
Grays Harbor Tributaries	48(0.3%)	138(0.9%)	255(1.6%)	1,073(6.8%)	500(3.2%)	190(1.2%)	124(0.8%)	159(1.0%)	348(2.2%)	634(4.0%)	196(1.2%)

Table 9

Basin-Level Splice Results for Chum Salmon Showing Change in Abundance with Restoration to Template Condition (Percentages Are Based on Percent Increase in Equilibrium Abundance at a Basin Scale)

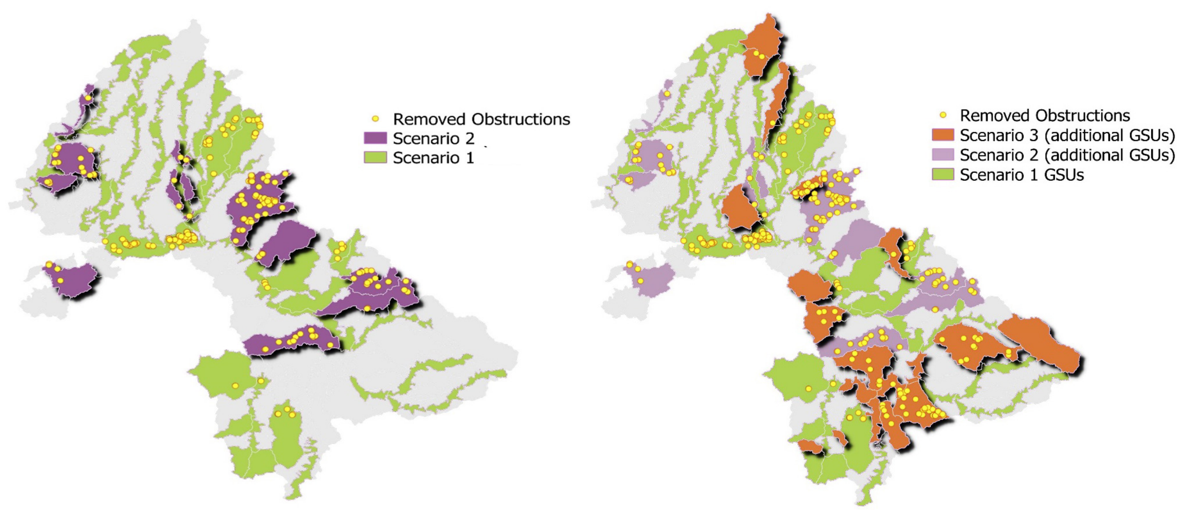
	CHANGE IN ABUNDANCE WITH RESTORATION TO TEMPLATE (% CHANGE AT BASIN SCALE)										
ECOLOGICAL REGION	CHANNEL LENGTH	CHANNEL STABILITY	FLOW	HABITAT DIVERSITY	KEY HABITAT	OBSTRUCTIONS	PATHOGENS	PREDATION	SEDIMENT LOAD	TEMPERATURE	WIDTH
Willapa Hills	0(0.0%)	5(0.0%)	1(0.0%)	13(0.0%)	50(0.0%)	0(0.0%)	1(0.0%)	0(0.0%)	38(0.0%)	0(0.0%)	12(0.0%)
Cascade Mountains	1,766(1.3%)	526(0.4%)	47(0.0%)	3,904(3.0%)	-951(-0.7%)	952(0.7%)	31(0.0%)	8(0.0%)	1,182(0.9%)	1(0.0%)	335(0.3%)
Middle Chehalis River	0(0.0%)	14(0.0%)	8(0.0%)	43(0.0%)	-1(0.0%)	0(0.0%)	5(0.0%)	12(0.0%)	4(0.0%)	0(0.0%)	-3(0.0%)
Central Lowlands	-1(0.0%)	264(0.2%)	18(0.0%)	431(0.3%)	2,194(1.7%)	315(0.2%)	12(0.0%)	4(0.0%)	457(0.3%)	-1(0.0%)	-1(0.0%)
Lower Chehalis River	0(0.0%)	533(0.4%)	268(0.2%)	2,188(1.7%)	-90(-0.1%)	0(0.0%)	484(0.4%)	930(0.7%)	260(0.2%)	89(0.1%)	587(0.4%)
Black River	0(0.0%)	217(0.2%)	28(0.0%)	289(0.2%)	-312(-0.2%)	215(0.2%)	45(0.0%)	40(0.0%)	1,277(1.0%)	0(0.0%)	0(0.0%)
Black Hills	1(0.0%)	537(0.4%)	83(0.1%)	2,258(1.7%)	-36(0.0%)	885(0.7%)	76(0.1%)	103(0.1%)	1,155(0.9%)	3(0.0%)	6(0.0%)
Olympic Mountains	2,247(1.7%)	2,031(1.5%)	1,293(1.0%)	6,294(4.8%)	-1,586(-1.2%)	4,202(3.2%)	254(0.2%)	525(0.4%)	6,437(4.9%)	126(0.1%)	2,647(2.0%)
Chehalis River Tidal	0(0.0%)	4,584(3.5%)	438(0.3%)	23,368(17.7%)	-1,026(-0.8%)	0(0.0%)	1,898(1.4%)	2,814(2.1%)	1,236(0.9%)	5,481(4.2%)	5,902(4.5%)
Grays Harbor Tributaries	1,122(0.9%)	1,455(1.1%)	346(0.3%)	7,056(5.4%)	-4,197(-3.2%)	695(0.5%)	643(0.5%)	628(0.5%)	4,556(3.5%)	984(0.7%)	2,913(2.2%)

Restoration Scenario Results

The following three restoration scenarios were developed through extensive discussions and individual ranking of initial EDT results within the SRT, SRT site visits throughout the basin, recent WDFW studies and data, local biologist input, and an iterative process of reviewing model results and ranking restoration actions and areas of focus. The scenarios are described in more detail in the ASRP Phase 1 document. The restoration scenarios (Figure 10) were developed with the following themes:

- **Scenario 1:** Protect and enhance core habitats for all aquatic species. Restoration is proposed to occur on approximately 222 miles of rivers.
- **Scenario 2:** Protect and enhance core habitats and restore key opportunities. Restoration is proposed to occur on approximately 316 miles of rivers.
- **Scenario 3:** Protect and enhance core habitats, restore key opportunities, and expand spatial distribution. Restoration is proposed on approximately 450 miles of rivers.

Figure 10
Geospatial Units Included in the Three ASRP Restoration Scenarios



The three scenarios were modeled for mid- and late century for all species. This analysis demonstrates the relative benefit of the alternative restoration scenarios on the salmonid species evaluated. Scenario 2 includes all geographic areas and restoration actions included in Scenario 1 and more, and Scenario 3 includes all geographic areas and restoration actions included in Scenario 2 and more. For each time period, these restoration scenarios were based on baseline conditions expected to be present at that time period (including riparian maturation, climate change, hypothesized culvert removals, and degradation due to buildout). Table 10 demonstrates the length in miles of spawning habitat restored under each scenario and the overall percent of spawning reaches treated. Scenario 1 restored a large percentage of spawning reaches for all species. Scenario 2 restored additional areas but a lesser percentage of all spawning reaches as compared to Scenario 1, and it restored no additional spawning reaches for spring-run Chinook salmon. Scenario 3 restored some additional spawning reaches for all species, especially focusing on additional coho salmon and steelhead spawning areas. Overall, spawning areas for spring-run Chinook salmon proportionally received the most treatment and coho salmon the least, although coho salmon have many more available spawning areas in the basin than the other species.

Figures 11 through 15 show predicted effects of these restoration scenarios on target species at a basin-wide scale. Coho salmon are predicted to decline in abundance from current to mid- to late century without restoration, but they are predicted to increase to numbers above current for all scenarios (Figure 11a). Coho salmon had similar responses across ecological regions (Figure 11b). Coho salmon greatly benefit from many of the restoration elements, especially those that enhance off-channel and floodplain habitats.

Figure 11
Effects of ASRP Restoration Scenarios on Coho Salmon in Chehalis Basin (11a) and Individual Ecological Regions (11b)

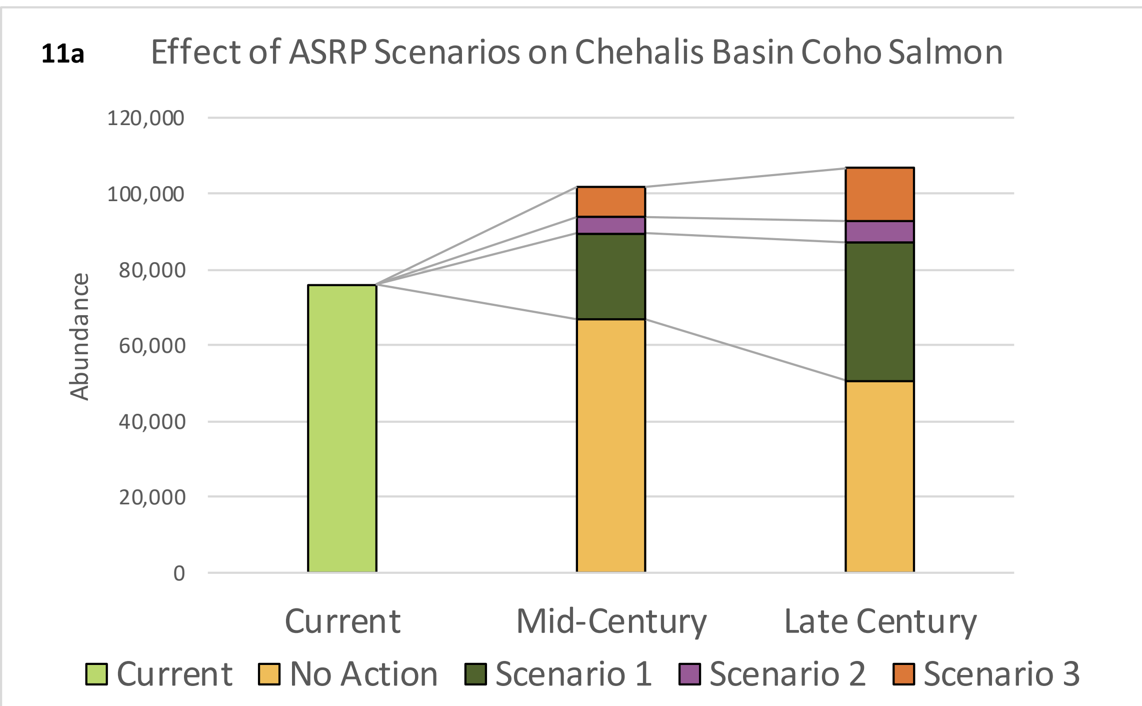
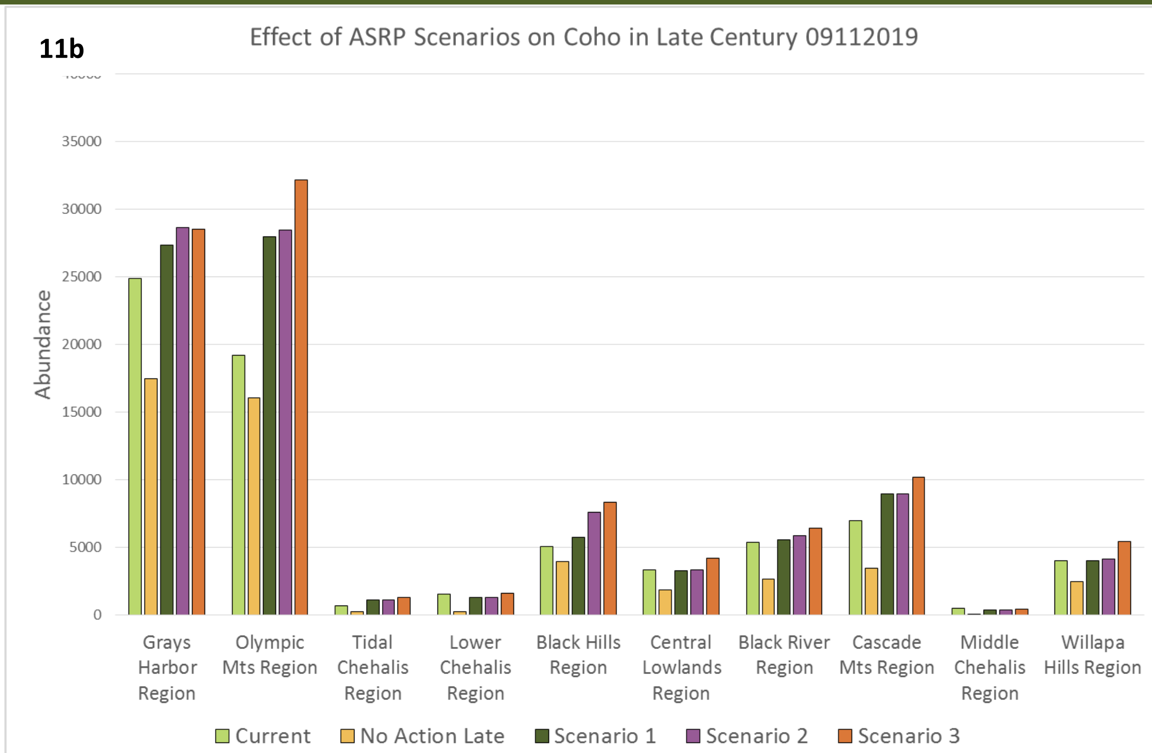


Figure 11
Effects of ASRP Restoration Scenarios on Coho Salmon in Chehalis Basin (11a) and Individual Ecological Regions (11b)



Notes:
Stacked results are additive (because each restoration scenario built upon the last), with predicted abundance of Scenario 3 always greater than Scenario 2. Note declining No Action baselines due to climate change but a predicted increase in abundance when restoration scenarios are modeled.

Fall-run Chinook salmon are predicted to decline in abundance from current to mid- to late century without restoration. In mid-century, with restoration Scenario 3, their numbers were predicted to increase to close to current levels, but in late century, their numbers were below current levels even with restoration Scenario 3. This is due to the detrimental climate temperature impacts as the juveniles outmigrate. Even though late-century numbers are predicted to be lower than current numbers, they are still predicted to be substantially higher with restoration actions than if no restoration actions occurred (Figure 12a). Fall-run Chinook salmon had similar responses across ecological regions (Figure 12b).

Figure 12
Effects of ASRP Restoration Scenarios on Fall Chinook Salmon in Chehalis Basin (12a) and Individual Ecological Regions (12b)

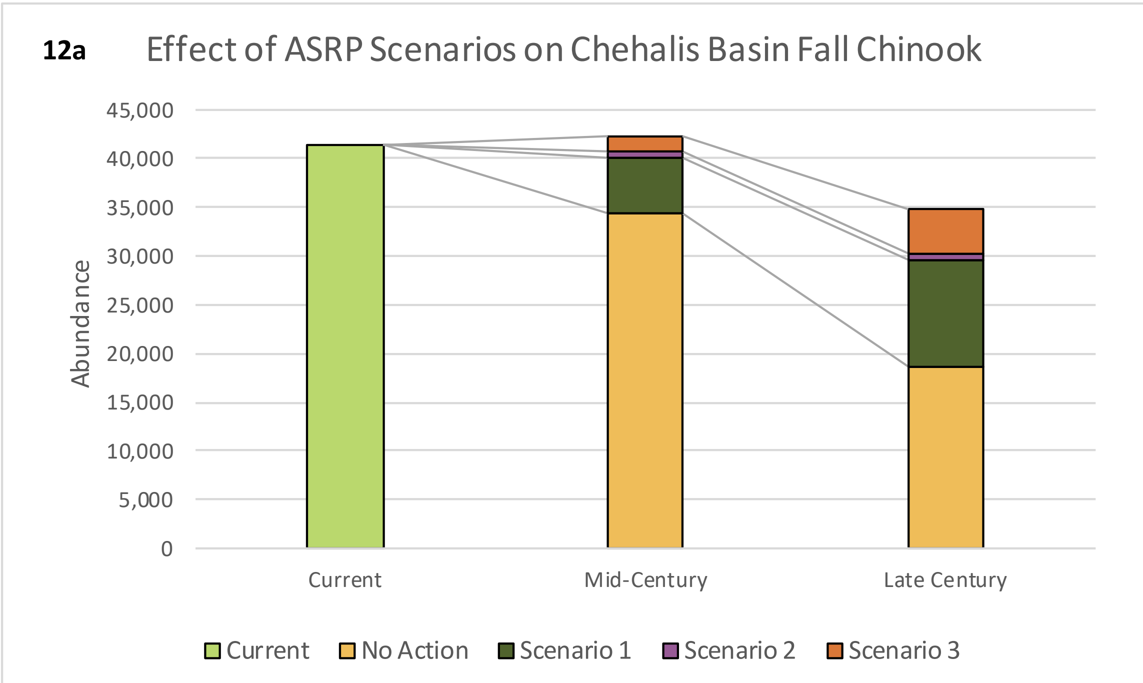
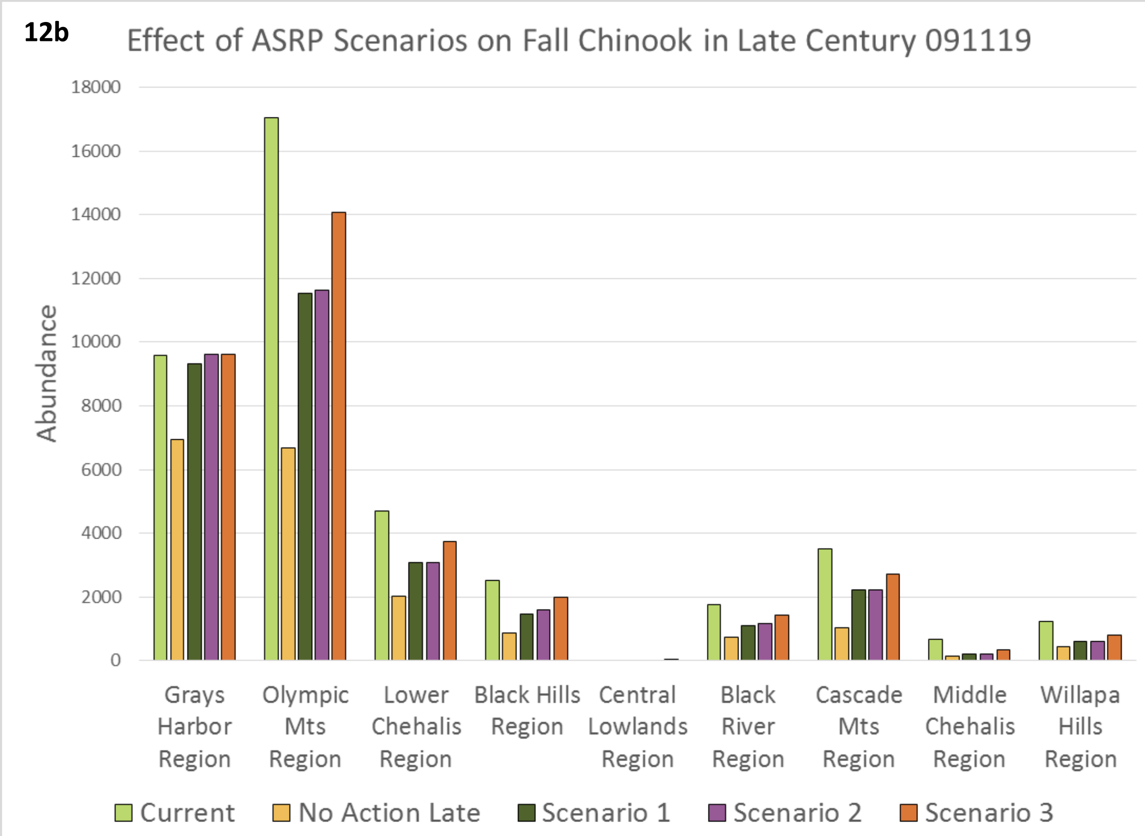


Figure 12
Effects of ASRP Restoration Scenarios on Fall Chinook Salmon in Chehalis Basin (12a) and Individual Ecological Regions (12b)



Notes:
Stacked results are additive (because each restoration scenario built upon the last), with predicted abundance of Scenario 3 always greater than Scenario 2. Note declining No Action baselines due to climate change. While modeling predicts increased abundance in mid-century as compared to current when restoration Scenario 3 is implemented, by late century the modeled restoration scenarios do not compensate for climate effects.

Spring-run Chinook salmon are predicted to decline in abundance from current to mid- to late century without restoration but increase to numbers above current with restoration (Figure 13a). Spring-run Chinook salmon most benefited from Scenario 1, which targeted their habitat as well as GSUs restored under Scenario 3. Spring-run Chinook salmon had similar responses across ecological regions (Figure 13b).

Figure 13
Effects of ASRP Restoration Scenarios on Spring Chinook Salmon in Chehalis Basin (13a) and Individual Ecological Regions (13b)

13a

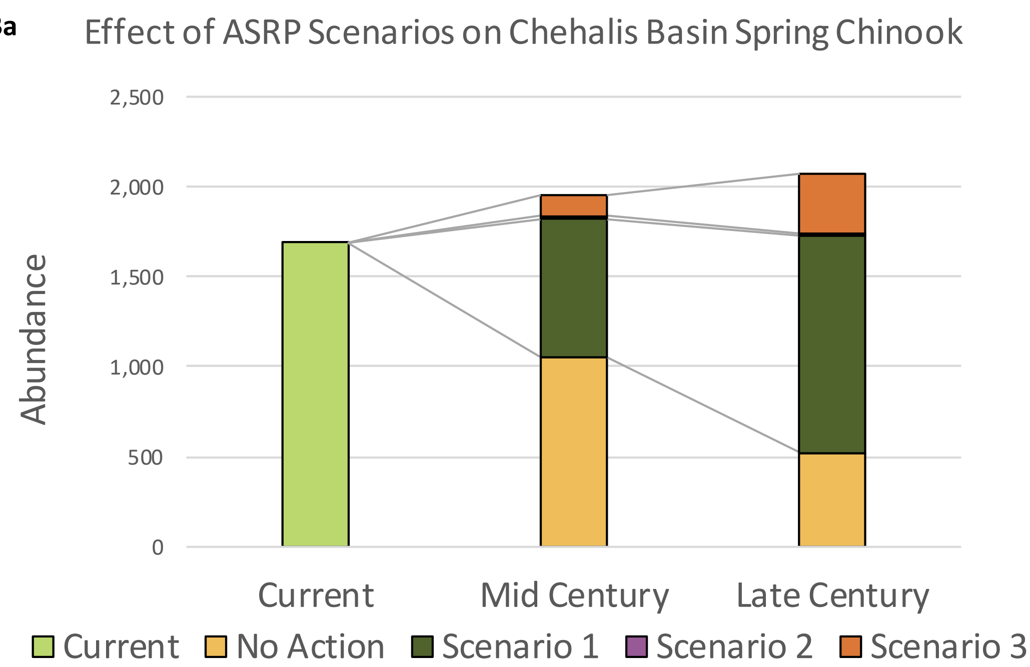
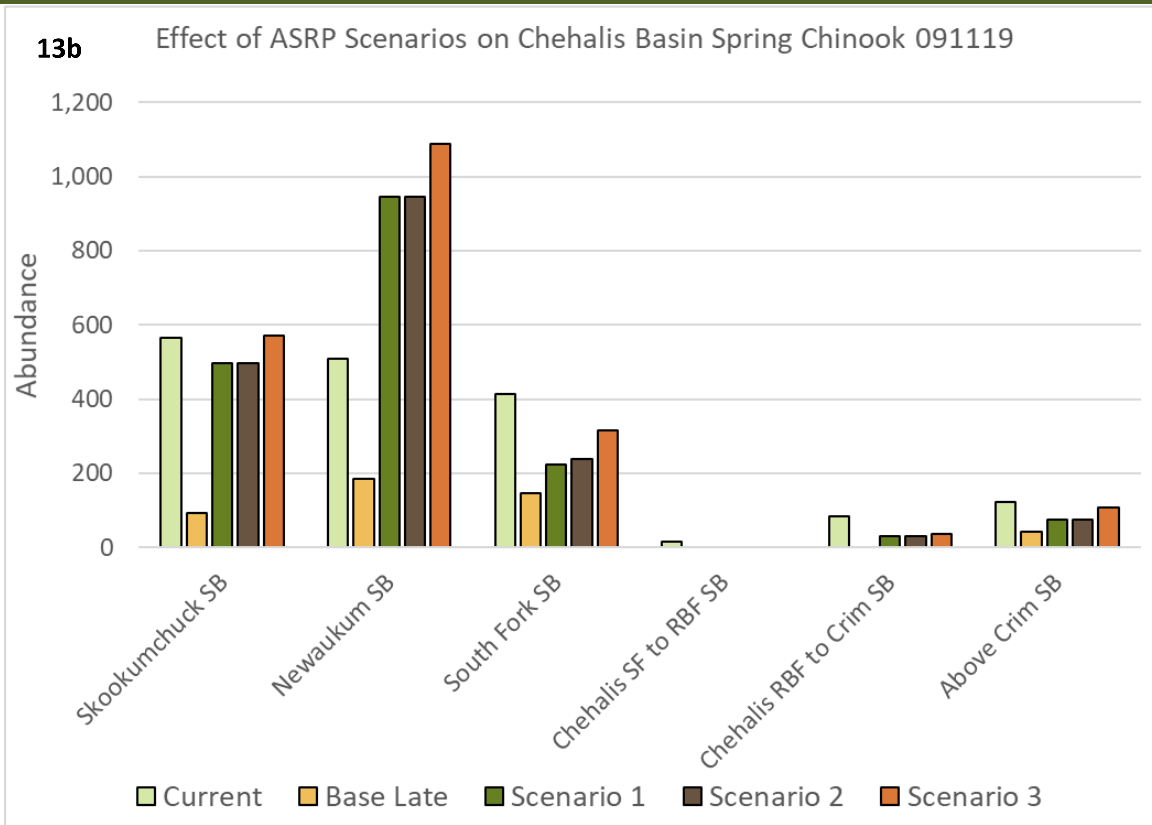


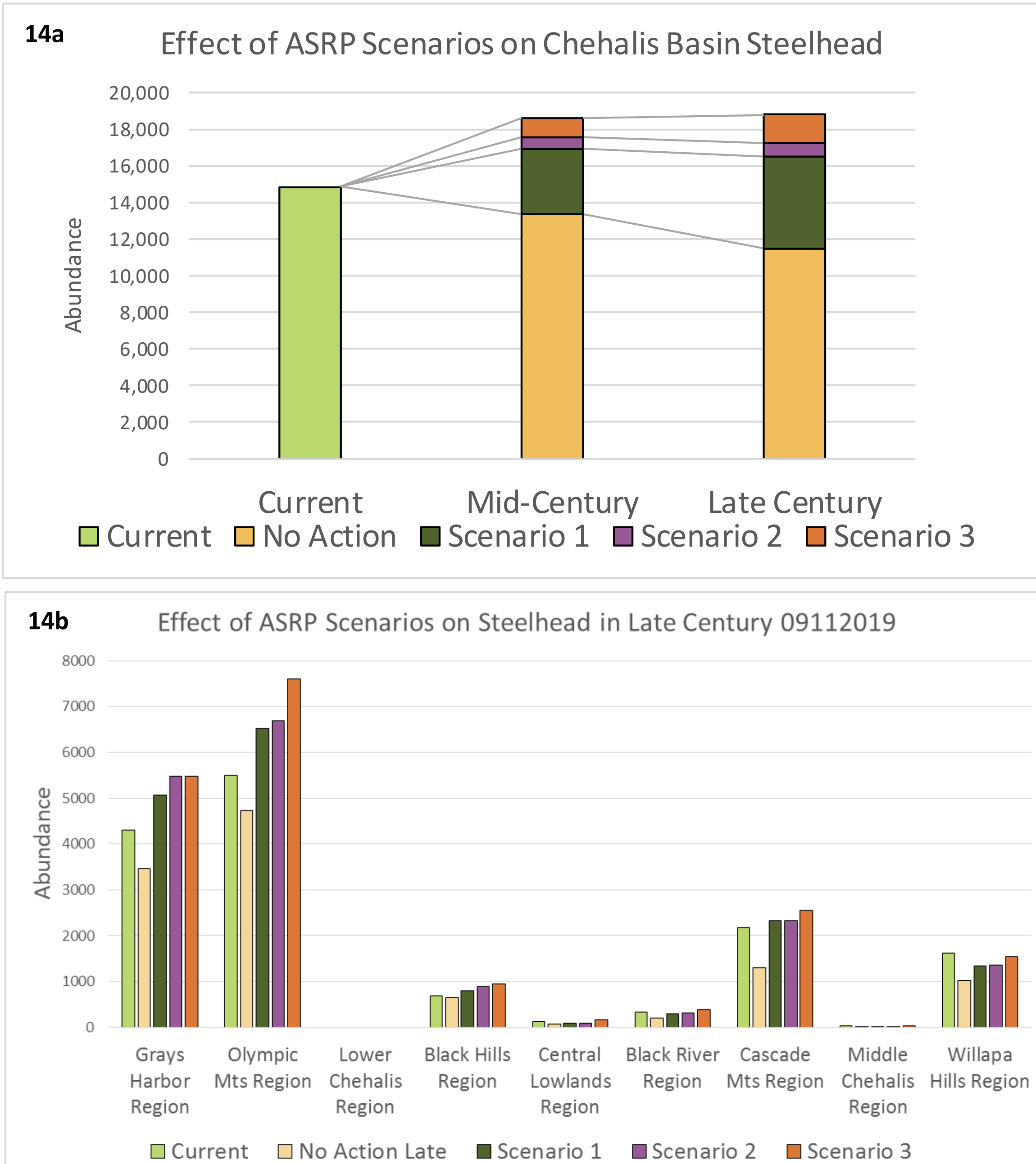
Figure 13
Effects of ASRP Restoration Scenarios on Spring Chinook Salmon in Chehalis Basin (13a) and Individual Ecological Regions (13b)



Notes:
Stacked results are additive (because each restoration scenario built upon the last), with predicted abundance of Scenario 3 always greater than Scenario 2. Note declining No Action baselines due to climate change but a predicted increase in abundance when restoration scenarios are modeled.

Steelhead are predicted to decline in abundance from current to mid- to late century without restoration but increase to numbers above current with restoration (Figure 14a). Steelhead had similar responses across ecological regions (Figure 14b).

Figure 14
Effects of ASRP Restoration Scenarios on Steelhead in Chehalis Basin (14a) and Individual Ecological Regions (14b)



Notes:
Stacked results are additive (because each restoration scenario built upon the last), with predicted abundance of Scenario 3 always greater than Scenario 2. Note declining No Action baselines due to climate change but a predicted increase in abundance when restoration scenarios are modeled.

Chum salmon are predicted to decline in abundance from current to mid- to late century without restoration but increase to numbers above current with restoration (Figure 15a). Chum salmon had similar responses across ecological regions in which they occur (Figure 15b).

Figure 15
Effects of ASRP Restoration Scenarios on Chum Salmon in Chehalis Basin (15a) and Individual Ecological Regions (15b)

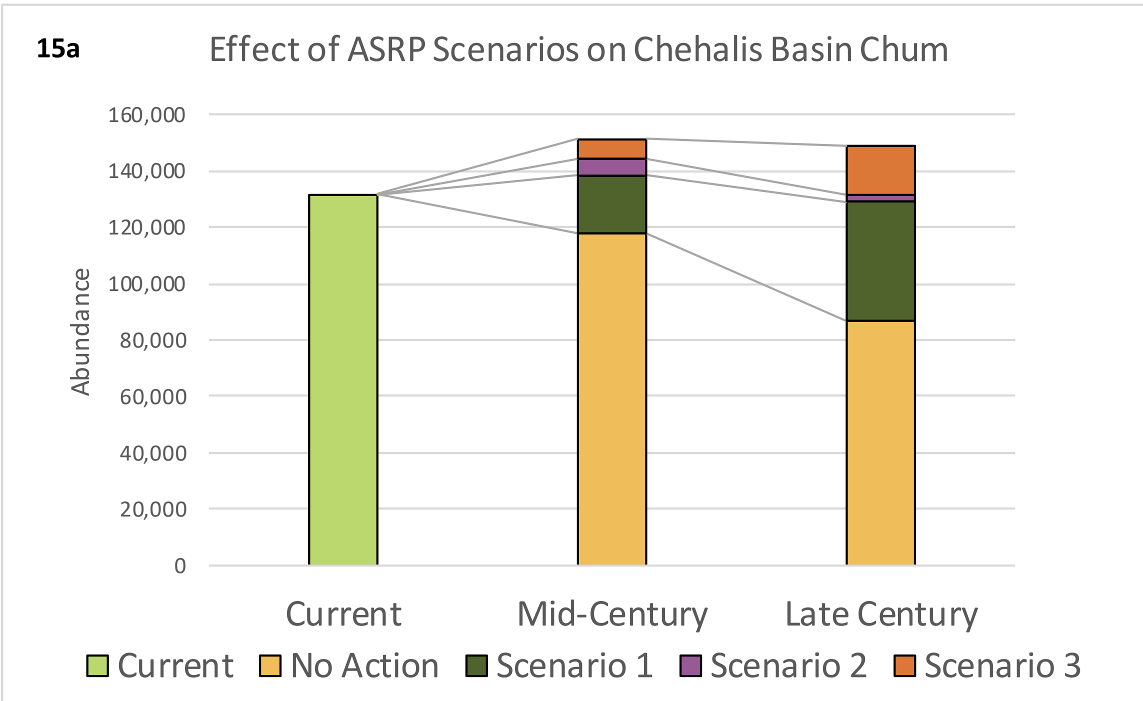
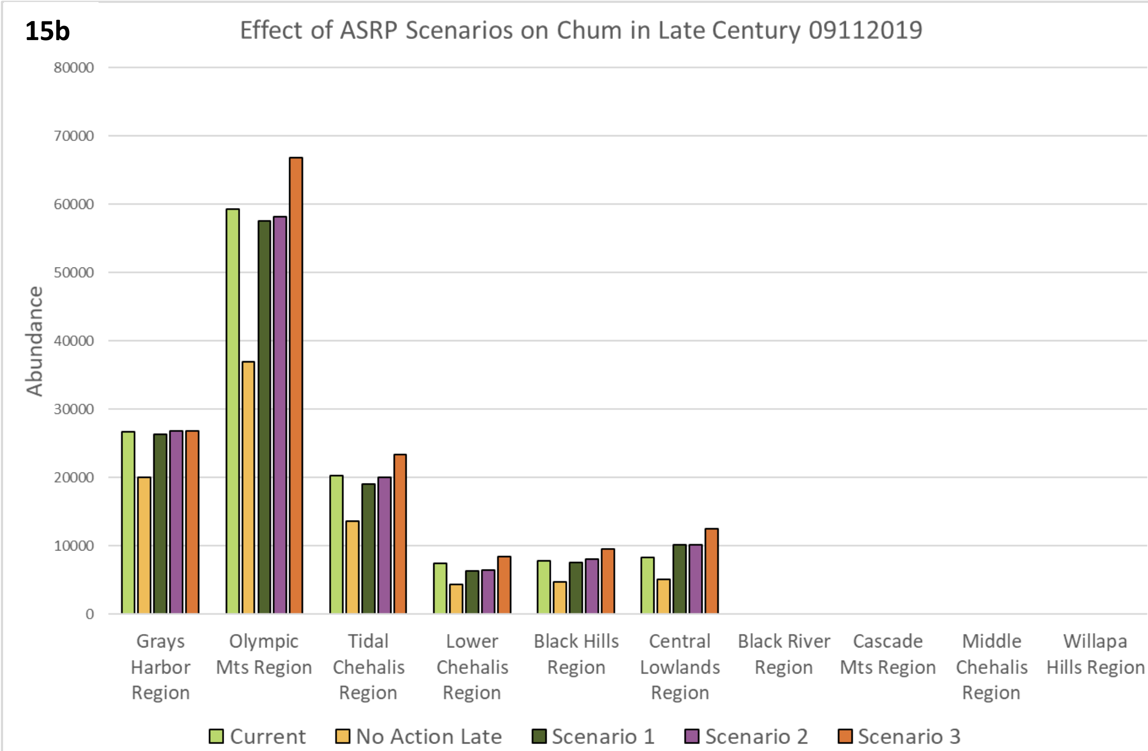


Figure 15
Effects of ASRP Restoration Scenarios on Chum Salmon in Chehalis Basin (15a) and Individual Ecological Regions (15b)



Notes:
Stacked results are additive (because each restoration scenario built upon the last), with predicted abundance of Scenario 3 always greater than Scenario 2. Note declining No Action baselines due to climate change but a predicted increase in abundance when restoration scenarios are modeled.

In conclusion, all species modeled were predicted to decline significantly by late-century with No Action. With the largest extent of restoration actions (Scenario 3), all species benefited as compared to the late-century baseline, and most species were predicted to increase as compared to the current condition population estimations.

These model results provide useful warnings about consequences of not conducting future restoration within the basin (baseline results) and guidance about where culverts should be removed and improved (fish passage analysis), which areas should be restored (restoration analysis) and how (splice analysis). Consideration into the details of these results should be taken to inform restoration goals. These results do not reflect the risks present in ocean changes (e.g., acidification), nor do they examine the implication of effects of varying water years or a shift in percentage of water year types over time. Ultimately these results should be used in conjunction with additional ecosystem-level analyses to inform the potential to restore habitat at a wholistic basin scale.

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Attachment 1
Chehalis Basin Ecosystem Diagnosis and Treatment River Network

Table C1-1
River Kilometers and Miles Associated with Chehalis Ecosystem Diagnosis and Treatment Model Geometry (River Network) at the Ecoregion, Sub-Basin, and Geospatial Unit Scales

RIVER DISTANCE INCLUDED IN ECOSYSTEM DIAGNOSIS AND TREATMENT		
ECOREGION/SUB-BASIN(SB)/GEOSPATIAL UNITS (GSU)	**KM**	**MILES**
WILLAPA HILLS	**561.4**	**348.8**
Absher SB	4.0	2.5
Absher Creek GSU	4.0	2.5
Alder Creek (UC) SB	1.8	1.1
Alder Creek (UC) GSU	1.8	1.1
Big Creek (UC) SB	5.3	3.3
Big (UC) Creek GSU	5.3	3.3
Capps SB	6.0	3.7
Capps Creek GSU	6.0	3.7
Chehalis RBF to Crim SB	20.5	12.8
Chehalis RB Falls to Crim MS GSU	20.5	12.8
Crim Creek (UC) SB	15.5	9.6
Crim Creek (UC) GSU	15.5	9.6
Dunn SB	11.4	7.1
Dunn Creek GSU	11.4	7.1
EF Chehalis River SB	29.7	18.5
EF Chehalis MS GSU	29.7	18.5
Elk Creek SB	89.8	55.8
Elk Cr GSU	89.8	55.8
Fronia SB	2.8	1.8
Fronia Creek GSU	2.8	1.8
Hope SB	7.9	4.9
Hope Creek GSU	7.9	4.9
Jones SB	11.7	7.3
Jones Creek GSU	9.3	5.8
Willapa Hills Tribs GSU	2.4	1.5
Mack Creek (UC) SB	2.0	1.2
Mack Creek (UC) GSU	2.0	1.2
Marcuson SB	5.8	3.6
Marcuson Creek GSU	5.8	3.6
RB Trib 2383 SB	1.3	0.8
RB Trib 2383 GSU	1.3	0.8
Robinson SB	2.2	1.3
Robinson Creek GSU	2.2	1.3
Rock(UC) SB	35.2	21.9
Rock (UC) Creek GSU	35.2	21.9
Roger Creek (UC) SB	3.8	2.4

RIVER DISTANCE INCLUDED IN ECOSYSTEM DIAGNOSIS AND TREATMENT		
ECOREGION/SUB-BASIN(SB)/GEOSPATIAL UNITS (GSU)	**KM**	**MILES**
Roger Creek (UC) GSU	3.8	2.4
South Fork SB	248.0	154.1
Lake (SFC) Cr GSU	41.9	26.0
Lower SF Chehalis MS GSU	23.1	14.3
Lower SF Chehalis Tribs GSU	9.9	6.1
Stillman (SFC) Cr GSU	85.4	53.0
Upper SF Chehalis MS GSU	30.3	18.8
Upper SF Chehalis Tribs GSU	57.4	35.7
Stowe SB	13.0	8.1
Stowe Creek GSU	13.0	8.1
Thrash Creek (UC) SB	9.2	5.7
Thrash Creek (UC) GSU	9.2	5.7
Upper Chehalis SB	18.5	11.5
Chehalis Abv Crim MS GSU	18.5	11.5
WF Chehalis River SB	15.9	9.9
WF Chehalis MS GSU	15.9	9.9
CASCADE MOUNTAINS	**718.5**	**446.4**
China SB	7.4	4.6
China Creek GSU	7.4	4.6
Dillenbaugh SB	28.5	17.7
Dillenbaugh Creek GSU	28.5	17.7
Newaukum SB	306.9	190.7
Lower Newaukum MS GSU	18.9	11.8
Lower Newaukum Tribs GSU	25.2	15.7
Lucas Cr GSU	26.0	16.1
MF Newaukum MS GSU	16.9	10.5
MF Newaukum Tribs GSU	23.1	14.3
Mitchell Cr GSU	8.3	5.2
NF Newaukum MS GSU	34.4	21.4
NF Newaukum Tribs GSU	27.2	16.9
SF Newaukum MS GSU	47.3	29.4
SF Newaukum Tribs GSU	79.5	49.4
Salzer SB	37.5	23.3
Salzer Creek GSU	37.5	23.3
Skookumchuck SB	275.7	171.3
Hanaford Cr GSU	104.3	64.8
Lower Skookumchuck GSU	37.3	23.2
Skookumchuck Tribs GSU	76.6	47.6
Upper Skookumchuck GSU	57.5	35.7
Stearns SB	62.6	38.9
Stearns Cr GSU	62.6	38.9

RIVER DISTANCE INCLUDED IN ECOSYSTEM DIAGNOSIS AND TREATMENT		
ECOREGION/SUB-BASIN (SB)/GEOSPATIAL UNITS (GSU)	**KM**	**MILES**
MIDDLE CHEHALIS RIVER	**70.6**	**43.8**
Middle Chehalis: Newaukum to SF SB	27.1	16.9
Middle Chehalis: Newaukum to SF GSU	27.1	16.9
Middle Chehalis: SF to Rainbow Falls SB	18.2	11.3
Middle Chehalis: SF to Rainbow Falls GSU	18.2	11.3
Middle Chehalis: Skook to Newaukum SB	14.3	8.9
Middle Chehalis: Skook to Newaukum GSU	14.3	8.9
RB Trib 0949 SB	10.9	6.8
RB Trib 0949 GSU	10.9	6.8
CENTRAL LOWLANDS	**396.9**	**246.6**
Bunker SB	55.0	34.2
Bunker Cr GSU	55.0	34.2
Coal SB	7.1	4.4
Coal Creek GSU	7.1	4.4
Davis SB	10.0	6.2
Davis Creek GSU	10.0	6.2
Dell SB	7.8	4.9
Dell Creek GSU	7.8	4.9
Delzene SB	19.4	12.0
Delzene Cr GSU	19.4	12.0
Fuller SB	2.3	1.4
Fuller Creek GSU	2.3	1.4
Gaddis SB	7.6	4.7
Gaddis Creek GSU	7.6	4.7
Garrard SB	58.4	36.3
Garrard Cr GSU	58.4	36.3
Garret SB	3.7	2.3
Garret Creek GSU	3.7	2.3
Independence SB	46.5	28.9
Independence Cr GSU	46.5	28.9
LB Trib 0520 SB	2.4	1.5
LB 0520 Creek GSU	2.4	1.5
LB Trib 0647 SB	3.4	2.1
LB Trib 0647 GSU	3.4	2.1
LB Trib 2250 SB	4.3	2.7
LB Trib 2250 GSU	4.3	2.7
Lincoln Cr SB	82.3	51.1
Lincoln Cr GSU	82.3	51.1
Mill SB	6.4	4.0
Mill Creek GSU	6.4	4.0
Nicholson SB	2.9	1.8

RIVER DISTANCE INCLUDED IN ECOSYSTEM DIAGNOSIS AND TREATMENT		
ECOREGION/SUB-BASIN (SB)/GEOSPATIAL UNITS (GSU)	**KM**	**MILES**
Nicholson Creek GSU	2.9	1.8
Rock (Central Lowlands) SB	43.5	27.0
Rock (CL) Cr GSU	43.5	27.0
Scammon SB	14.7	9.1
Scammon Creek GSU	14.7	9.1
Van Ornum SB	5.4	3.4
Van Ornum Creek GSU	5.4	3.4
Workman SB	13.8	8.5
Workman Creek GSU	13.8	8.5
LOWER CHEHALIS RIVER	**79.0**	**49.1**
LB Trib 2224 SB	1.2	0.7
LB Trib 2224 SB GSU	1.2	0.7
Lower Chehalis: Black to Skook SB	32.6	20.3
Lower Chehalis: Black to Skook GSU	32.6	20.3
Lower Chehalis: Porter to Black SB	21.8	13.6
Lower Chehalis: Porter to Black GSU	21.8	13.6
Lower Chehalis: Satsop to Porter SB	22.5	14.0
Lower Chehalis: Satsop to Porter GSU	22.5	14.0
RB Trib 2286 SB	0.9	0.6
RB Trib 2286 GSU	0.9	0.6
BLACK RIVER	**267.6**	**166.3**
Black River SB	189.1	117.5
Beaver Cr GSU	36.7	22.8
Lower Black MS GSU	30.5	19.0
Lower Black Tribs GSU	27.1	16.8
Upper Black MS GSU	17.4	10.8
Upper Black Tribs GSU	44.7	27.8
Waddell Cr GSU	32.7	20.3
Harris SB	6.4	4.0
Harris (Black) Creek GSU	6.4	4.0
Prairie SB	15.1	9.4
Prairie Creek GSU	15.1	9.4
Scatter SB	57.0	35.4
Scatter Cr GSU	57.0	35.4
Elk (GH) R GSU	67.5	41.9
Fry Creek GSU	2.6	1.6
Gillis Slough GSU	3.2	2.0
Grass Creek GSU	10.7	6.6
Grouse Cr GSU	2.5	1.6
Harbor Trib 2001 GSU	1.6	1.0
Harbor Trib 2002 GSU	2.3	1.4

RIVER DISTANCE INCLUDED IN ECOSYSTEM DIAGNOSIS AND TREATMENT		
ECOREGION/SUB-BASIN(SB)/GEOSPATIAL UNITS (GSU)	**KM**	**MILES**
Jessie Slough GSU	2.1	1.3
Johns (GH) R GSU	100.4	62.4
Kurtz Slough GSU	4.8	3.0
Little Hoquiam GSU	26.0	16.2
Lower Hoquiam GSU	15.0	9.4
Lower Humptulips MS GSU	14.6	9.0
Lower Humptulips Tribs GSU	23.5	14.6
Lower Wishkah MS GSU	29.6	18.4
Lower Wishkah Tribs GSU	27.3	17.0
MF Hoquiam MS GSU	17.6	10.9
MF Hoquiam Tribs GSU	12.8	8.0
Middle Humptulips MS GSU	37.6	23.4
Middle Humptulips Tribs GSU	73.0	45.3
Newskah Creek GSU	14.3	8.9
Obrien Cr GSU	4.1	2.6
O'Leary Creek Tribs GSU	3.3	2.0
Rainbow Cr GSU	4.3	2.7
Redman Slough GSU	5.3	3.3
Stafford Creek GSU	3.0	1.9
Stevens Cr GSU	23.6	14.7
Upper Wishkah MS GSU	34.5	21.5
Upper Wishkah Tribs GSU	52.0	32.3
WF Hoquiam MS GSU	18.7	11.6
WF Hoquiam Tribs GSU	37.5	23.3
WF Humptulips MS GSU	57.3	35.6
WF Humptulips Tribs GSU	40.6	25.2
WF Wishkah MS GSU	25.8	16.0
WF Wishkah Tribs GSU	27.8	17.3
BLACK HILLS	**329.0**	**204.5**
Cedar SB	50.6	31.4
Cedar (BH) Cr GSU	50.6	31.4
Cloquallum SB	150.2	93.3
Cloquallum Cr GSU	150.2	93.3
Gibson SB	5.7	3.5
Gibson Creek GSU	5.7	3.5
Mox Chehalis SB	43.8	27.2
Mox Chehalis Cr GSU	43.8	27.2
Newman SB	43.0	26.7
Newman-Vance Cr GSU	43.0	26.7
Porter SB	32.9	20.4
Porter Cr GSU	32.9	20.4

RIVER DISTANCE INCLUDED IN ECOSYSTEM DIAGNOSIS AND TREATMENT		
ECOREGION/SUB-BASIN (SB)/GEOSPATIAL UNITS (GSU)	**KM**	**MILES**
RB Trib 0542 SB	2.9	1.8
Black Hills Tribs GSU	2.9	1.8
OLYMPIC MOUNTAINS	**884.0**	**549.3**
Satsop SB	536.2	333.2
Baker Cr GSU	4.7	2.9
Bingham Creek GSU	51.0	31.7
Canyon R GSU	23.6	14.6
Cook Cr GSU	10.4	6.5
Decker Creek GSU	82.8	51.5
Dry Run Cr GSU	27.7	17.2
Lower EF Satsop MS GSU	19.5	12.1
Lower EF Satsop Tribs GSU	19.8	12.3
Lower MF Satsop MS GSU	35.5	22.1
Lower MF Satsop Tribs GSU	16.1	10.0
Lower Satsop MS GSU	11.4	7.1
Lower Satsop Tribs GSU	6.5	4.0
Lower WF Satsop MS GSU	31.4	19.5
Lower WF Satsop Tribs GSU	41.7	25.9
Rabbit Cr GSU	11.0	6.8
Sherwood Cr GSU	4.4	2.7
Smith Cr GSU	8.2	5.1
Upper EF Satsop MS GSU	14.2	8.8
Upper EF Satsop Tribs GSU	29.7	18.5
Upper MF Satsop MS GSU	18.9	11.8
Upper MF Satsop Tribs GSU	11.1	6.9
Upper WF Satsop MS GSU	34.6	21.5
Upper WF Satsop Tribs GSU	22.0	13.7
Wynoochee SB	347.8	216.1
Big (Wyn) Cr GSU	13.4	8.3
Black (Wyn) Cr GSU	44.2	27.4
Carter Cr GSU	10.8	6.7
Lower Wynoochee MS GSU	34.2	21.2
Lower Wynoochee Tribs GSU	58.1	36.1
Middle Wynoochee MS GSU	49.0	30.4
Middle Wynoochee Tribs GSU	64.0	39.8
Shaffer Cr GSU	38.1	23.7
Upper Wynoochee GSU	17.0	10.6
Wynoochee Reservoir GSU	19.1	11.9

RIVER DISTANCE INCLUDED IN ECOSYSTEM DIAGNOSIS AND TREATMENT		
ECOREGION/SUB-BASIN(SB)/GEOSPATIAL UNITS (GSU)	**KM**	**MILES**
CHEHALIS RIVER TIDAL	**133.9**	**83.2**
Elizabeth Creek SB	4.8	3.0
Elizabeth Creek GSU	4.8	3.0
LB Trib 2175 SB	2.3	1.5
LB Trib 2175 SB GSU	2.3	1.5
Stevens Tidal SB	2.6	1.6
Stevens Tidal GSU	2.6	1.6
Tidal Zone SB	124.1	77.1
Tidal Zone GSU	124.1	77.1
GRAYS HARBOR TRIBUTARIES	**1,215.7**	**755.4**
Andrews SB	17.5	10.9
Andrews (GH) Cr GSU	17.5	10.9
Campbell Slough SB	6.8	4.2
Campbell Slough GSU	6.8	4.2
Chapin Creek SB	4.1	2.5
Chapin Creek GSU	4.1	2.5
Charley Creek SB	6.0	3.7
Charley Creek GSU	6.0	3.7
Chenois Creek SB	16.4	10.2
Chenois Creek GSU	16.4	10.2
Elk River SB	67.5	41.9
Elk (GH) R GSU	67.5	41.9
Fry Creek SB	2.6	1.6
Fry Creek GSU	2.6	1.6
Gillis Slough SB	3.2	2.0
Gillis Slough GSU	3.2	2.0
Grass Creek SB	10.7	6.6
Grass Creek GSU	10.7	6.6
Harbor Trib 2001 SB	1.6	1.0
Harbor Trib 2001 GSU	1.6	1.0
Harbor Trib 2002 SB	2.3	1.4
Harbor Trib 2002 GSU	2.3	1.4
Hoquiam SB	219.9	136.6
EF Hoquiam MS GSU	37.4	23.2
EF Hoquiam Tribs GSU	54.8	34.0
Little Hoquiam GSU	26.0	16.2
Lower Hoquiam GSU	15.0	9.4
MF Hoquiam MS GSU	17.6	10.9
MF Hoquiam Tribs GSU	12.8	8.0
WF Hoquiam MS GSU	18.7	11.6
WF Hoquiam Tribs GSU	37.5	23.3

RIVER DISTANCE INCLUDED IN ECOSYSTEM DIAGNOSIS AND TREATMENT		
ECOREGION/SUB-BASIN (SB)/GEOSPATIAL UNITS (GSU)	**KM**	**MILES**
Humptulips SB	462.8	287.5
Big (Hump) Cr GSU	74.7	46.4
Deep (Hump) Cr GSU	34.8	21.6
Donkey Cr GSU	2.1	1.3
EF Humptulips MS GSU	48.5	30.1
EF Humptulips Tribs GSU	21.6	13.4
Grouse Cr GSU	2.5	1.6
Lower Humptulips MS GSU	14.6	9.0
Lower Humptulips Tribs GSU	23.5	14.6
Middle Humptulips MS GSU	37.6	23.4
Middle Humptulips Tribs GSU	73.0	45.3
Obrien Cr GSU	4.1	2.6
Rainbow Cr GSU	4.3	2.7
Stevens Cr GSU	23.6	14.7
WF Humptulips MS GSU	57.3	35.6
WF Humptulips Tribs GSU	40.6	25.2
Jessie Slough SB	2.1	1.3
Jessie Slough GSU	2.1	1.3
Johns SB	100.4	62.4
Johns (GH) R GSU	100.4	62.4
Kurtz Slough SB	4.8	3.0
Kurtz Slough GSU	4.8	3.0
Newskah Creek SB	14.3	8.9
Newskah Creek GSU	14.3	8.9
O'Leary Creek SB	3.3	2.0
O'Leary Creek Tribs GSU	3.3	2.0
Redman Slough SB	5.3	3.3
Redman Slough GSU	5.3	3.3
Stafford Creek SB	3.0	1.9
Stafford Creek GSU	3.0	1.9
Wishkah SB	261.4	162.4
EF Wishkah MS GSU	28.0	17.4
EF Wishkah Tribs GSU	36.3	22.6
Lower Wishkah MS GSU	29.6	18.4
Lower Wishkah Tribs GSU	27.3	17.0
Upper Wishkah MS GSU	34.5	21.5
Upper Wishkah Tribs GSU	52.0	32.3
WF Wishkah MS GSU	25.8	16.0
WF Wishkah Tribs GSU	27.8	17.3

Attachment 2
Ecosystem Diagnosis and Treatment Glossary

Ecosystem Diagnosis and Treatment Glossary

Abundance: The number of fish returning to spawn in a population. Abundance is one metric of the viable salmonid population (VSP) concept. Ecosystem Diagnosis and Treatment (EDT) computes the equilibrium abundance of the Beverton-Holt function as a function of the quantity and quality of habitat. See also *equilibrium abundance*.

Anthropogenic constraints: Constraints on a fish population that are caused by human alterations to the environment.

Bankfull width: The wetted width of a stream when the surface of the stream reaches the top of the banks.

Behavioral plasticity: The ability of salmon populations to modify their behaviors in order to compensate for changing environmental conditions change.

Benchmark density: The maximum density (in fish/m^2) that the EDT model allows for any given life stage.

Benchmark survival: The maximum density independent survival rate that the EDT model allows for any given life stage of a species.

Beverton-Holt production function: A mathematical relationship used in EDT between the number of spawning fish and their resulting progeny. The two parameters to the Beverton-Holt function are capacity and productivity. The relationship is disaggregated in EDT to relate fish in one life stage to surviving fish in the subsequent life stage.

Biological diversity: Biological diversity is the range of morphological and behavioral variation within a salmon population generally related to genetic diversity. EDT calculates a habitat analog to biological diversity based on the variation in fish production across the variation in habitat (see *diversity*). Biological diversity is an output parameter in EDT and is one of the metrics of the VSP concept.

Capacity: The maximum number of fish at a population or life stage that can be supported by a given environmental condition, measured by the number of individuals. Capacity is one of the two parameters to the Beverton-Holt production function. In a Beverton-Holt stock-recruit graph, capacity is the horizontal asymptote.

Carrying capacity: See *capacity*.

Density-independent survival: The inter-generational survival of a salmon population at in the absence of competition for space or resources measured as the ratio between spawners and progeny. In a Beverton-Holt model, the productivity parameter is calculated as the product of density-independent survival and eggs per spawner. Survival is an intra-generational parameter that describes the proportion of individuals within a cohort that survive from one life stage to the next, or from egg incubation to spawning. See also *productivity*.

Diversity: An index of biological diversity of life histories potentially expressed by a population in EDT as a function of the spatial and temporal diversity of suitable habitat. Diversity is the proportion of life history trajectories that have a productivity greater than 1 in a particular environmental condition.

Effectiveness: Restoration effectiveness is a scalar indicating how effective a particular type of restoration project is at restoring Template habitat conditions. The scalar is a number in the range from 0 to 1, with 0 indicating that an action is totally ineffective at restoring Template habitat conditions and 1 indicating that an action can completely restore Template habitat conditions.

Equilibrium abundance: The number of individuals in a salmon population where the ratio between spawners and progeny is exactly 1. In a Beverton-Holt production function, equilibrium abundance is calculated from productivity and capacity using the formula $N_{\text{eq}} = C \times (1 - P^{-1})$. In a Beverton-Holt stock-recruitment graph, the equilibrium abundance is the point at which the line $y = x$ intersects the stock-recruitment curve.

Environmental attributes: Fundamental physical and biological features of the environment that form the basin input to EDT and are entered as ratings (see *ratings*). Examples include water temperature, flow, and quantity of large wood. Survival resulting from one or more environmental attributes is merged in EDT as Survival Factors.

Estuary/Estuarine: The transitional environment between the freshwater, riverine environment used by juvenile salmon and the saltwater environment of the ocean. Estuarine environments are characterized by brackish water (intermediate between fresh and salty) and by tidally driven flow patterns.

Geospatial Unit (GSU): A spatial scale in the Chehalis EDT model that is composed of one or generally several reaches to form an ecologically useful component of a stream. An example is the South Fork of the Newaukum River Diagnostic Unit.

Habitat heterogeneity: The degree to which habitat conditions vary spatially and temporally within a river basin.

Habitat quality: Environmental attributes describing the quality of habitat available to a salmon population that affect survival and capacity in EDT. Examples include temperature, substrate, and large wood.

Habitat quantity: Environmental attributes describing the quantity of habitat (meters^2) available to a salmon population. In EDT, habitat quantity attributes are used to calculate capacity.

Intensity: Restoration intensity is a scalar on the implementation of a restoration project relative to the target habitat. The scalar is a number in the range from 0 to 1, with 0 indicating that a restoration project's footprint has no overlap with the target habitat and 1 indicating that a restoration project's footprint overlaps with the entire target habitat.

Intrinsic conditions: The condition of a watershed in the absence of anthropogenic constraints on salmon performance. Intrinsic conditions include factors such as geomorphology and historical climate.

Life history pathway: See *trajectory*.

Life history periodicity: The time of the year when each life stage of a salmon life history is present in a river system. For example, spring-run and fall-run Chinook salmon are characterized by a different periodicity: Spring-run adult migrants enter the river in the spring and hold over the summer, whereas fall-run adult migrants enter the river in the fall.

Limiting factor: See *survival factor*.

Marine: The ocean environment.

Normative condition: The condition of an ecosystem with a mix of natural and cultural features that allows the expression of a diverse and sustainable suite of desirable species and populations. The normative condition is not equivalent to the historic Template condition nor is it generally the current condition of most systems, but it is one in which natural ecosystem functions are allowed to shape the system in the context of human cultural activities.

Obstruction: A physical structure through which a stream flows, including artificial obstructions such as culverts, weirs, or dams, as well as natural obstruction like waterfalls that block or reduce upstream or downstream fish migration.

Ocean-type life history: A salmonid life history category characterized by downstream migration of juveniles to the ocean in the same year that they emerge from egg incubation, generally in the first spring. They do not overwinter in freshwater as juveniles. This contrasts with *stream-type life history*.

Productivity: The ratio between the number of recruits in a cohort and the number of recruits in the previous cohort in a salmon population without the effect of competition for space or resources. Productivity in EDT is calculated by multiplying the density-independent survival by the number of eggs per spawner. Productivity is one of the two parameters to the Beverton-Holt production function and is one of the metrics of the VSP concept used as output from the EDT model.

Progeny: The number of adult fish produced by a given number of adult spawners. See *recruits*.

Protection: The value of habitat to the current level of production and a measure of the impact of degradation of current conditions on current habitat potential.

Rating: Input data to EDT for most habitat quality attributes. Empirical and other data are standardized to a 0-to-4 scale that relates to the degree of degradation of life stage benchmark survival as a result of observed conditions in a reach. These ratings are defined on a 0-to-4 scale, with 0 meaning very favorable habitat conditions and 4 indicating very unfavorable habitat conditions.

Reach: A section of a river or stream that is used as EDT's most basic data management unit within which conditions are assumed to be homogeneous and defined by habitat quality and quantity ratings. Reaches are generally defined by geomorphic characteristics or by obstructions.

Recruits: The number of adult spawners that are the progeny of a previous cohort of spawners.

Restoration: The alteration of habitat conditions in a direction that favors production of a target species. In EDT, restoration implies movement of the current habitat condition toward the EDT Template condition.

Returns: The number of fish returning to a watershed.

Spatial structure: The distribution of populations of fish across a watershed (e.g., the Chehalis Basin) or other geographic delineation. Spatial structure describes the distribution of productive habitat across the area. In the Chehalis analysis, spatial structure refers to the distribution of production across sub-basins of the Chehalis Basin. Spatial structure is one of the metrics of the VSP concept used as output from the EDT model.

Spawners: Adult salmon that are digging redds and laying and fertilizing eggs.

Splice: An EDT model run in which the environmental conditions for a specific geographic area (reach, diagnostic unit, sub-basin) are changed in order to measure the sensitivity of the salmon population to conditions in that area. Splicing degraded river conditions into current river conditions is used to identify protection priorities. Splicing Template river conditions into current river conditions is used to identify restoration priorities.

Stock–recruitment relationship: A mathematical model describing the relationship between the number of individuals in a cohort of salmon and the number of individuals in the previous cohort. See *Beverton-Holt production function*.

Stream reach: See *reach*.

Stream-type life history: A salmonid life history category characterized by extended rearing in freshwater for the year following their emergence from egg incubation. Stream-type fish overwinter in freshwater and migrate to the ocean the following spring.

Sub-basin: A tributary sub-watershed that drains to the main Chehalis River (e.g., the Newaukum River sub-basin).

Survival: An intra-generational parameter that describes the proportion of individuals within a cohort that survive from one life stage to the next, or from egg incubation to spawning after experiencing the effect of one or more survival factors.

Survival factor: Physical parameters affecting the survival of a particular life stage, often referred to as *limiting factors*. Examples include flow, sediment, or temperature in EDT that are computed from relationships with one or more environmental attributes. The product of all EDT survival factors with the benchmark survival is the total survival for the life stage.

Template: EDT terminology for the watershed-specific reference condition that is used to diagnose current condition in a watershed. In the Chehalis analysis, Template is equivalent to the intrinsic condition of the watershed absent anthropogenic constraints. Template conditions were determined from reconstructed historical conditions.

Thalweg: The part of a stream with the greatest depth and greatest flow velocity.

Thalweg length: A measure of stream length arrived at by measuring the length of the thalweg between the points of interest.

Trajectory: A life history pathway of a fish population through space and time. Trajectories start and end with spawning in a specific reach and month and trace a potential migration path across the species life history. Each trajectory may vary in direction, rate of travel, and timing of life stages.

Viable salmonid population: A VSP is "an independent population of any Pacific salmonid (genus *Oncorhynchus*) that has a negligible risk of extinction due to threats from demographic variation, local environmental variation, and genetic diversity changes over a 100-year time frame" (McElhany et al. 2000). VSP metrics that describe the viability of fish populations are *abundance*, *productivity*, *biological diversity*, and *spatial structure* defined here. EDT uses the VSP metrics to describe potential fish production as a function of habitat.

Attachment 3
Primary Data Sources for Habitat Characterization from 2003 Iteration of the Chehalis Basin Ecosystem Diagnosis and Treatment Model[1]

[1] From Mobrand Biometrics 2003, Section 2.2.1.

In addition to extensive discussions with retired and current Washington Department of Fish and Wildlife (WDFW) staff and staff from the Quinault Indian Nation, site visits in many locations throughout the watershed, and sampling of fine sediments, the following data sources were also used to characterize habitat conditions:

- *A Catalog of Washington Streams and Salmon Utilization – Volume 2, Coastal Region* (Phinney and Bucknell 1975a)
- *Stream Catalog Supplement for Water Resource Inventory Areas (WRIA) 22 and 23* (an extensive work that includes photos, stream widths, habitat typing, and comments about various conditions for most streams, assembled by Phinney and Bucknell during the mid-1970s [Phinney and Bucknell 1975b])
- *Salmon and Steelhead Habitat Limiting Factors – Chehalis Basin and Nearby Drainages, Water Resource Inventory Areas 22 and 23* (an excellent, comprehensive compilation of environmental information for WRIAs 22 and 23 [Smith and Wenger 2001])
- *Chehalis River Basin Fishery Resources: Salmon and Steelhead Habitat Degradations* (U.S. Fish and Wildlife report and maps that summarize extensive surveys of many streams in the basin [Wampler et al. 1993])
- *Draft Environmental Impact Statement – Centralia Flood Damage Reduction Project, Chehalis River, Washington, General Evaluation Study* (Corps 2002)
- *Gravel Transport and Gravel Harvesting in the Humptulips, Wynoochee, and Satsop Rivers, Grays Harbor County, Washington* (summarizes historic and modern day conditions [i.e., in the mid-1980s] for area rivers [Collins and Dunne 1986])
- *East/West Humptulips Watershed Analysis* (including water temperature data files for the Humptulips River [USFS 2001])
- *Upper Humptulips River Watershed Temperature Total Maximum Daily Load* (Ecology 2001)
- Salmon Recovery Data Viewer CDs for WRIAs 22 and 23 (a comprehensive compilation of many GIS data layers relevant to the characterization, including ortho photos of the entire Chehalis Basin; compiled by Jay Roach and the Washington Department of Natural Resources in cooperation with other state agencies and independent entities [WDNR 2000, 2001])
- Long-term flow records at several sites within the Chehalis Basin (USGS flow records)
- Water temperature measurements at various sites in the basin collected by the U.S. Geological Survey and the Washington Department of Ecology (USGS [date unknown]; Ecology [date unknown])
- Fish passage barrier databases including the SSHEAR database (culvert, dam, and fishway database maintained by WDFW), Columbia Pacific RC and D inventory work done through Grays Harbor County (for the Humptulips, Wynoochee, and Satsop rivers), and data contained on the Salmon Recovery Data Viewer database
- *An Inventory of Off-Channel Habitat of the Lower Chehalis River with Applications of Remote Sensing* (includes an inventory of off-channel habitat in the lower Chehalis, Wynoochee, and Satsop rivers [Ralph et al. 1994])

- *Upper White Watershed Spring Chinook Redd Scour, and Cross-Section Assessments: 1995–2001* (streambed scour study applicable to the Chehalis Basin as a reference station because of its general conclusions regarding the effects of increased peak flows on scour [Schuett-Hames and Adams 2003])

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Appendix D
Derivation of Cost Estimates

This appendix provides a detailed description of the cost estimates developed for the Aquatic Species Restoration Plan (ASRP) Phase 1 document, including restoration, protection, planning, institutional, and community involvement costs. The restoration costs are the largest cost component of the ASRP and have been developed with input and review by the Science and Technical Review Team (SRT). The other costs are preliminary and will be developed in greater detail during Phases 2 and 3 of the ASRP development.

It is important to note that these cost estimates have been prepared using current (2019) dollars and do not account for price inflation. Thus, the cost estimates have also been prepared to be conservative by using a wide cost range, from typically lower unit costs to a higher end of unit costs, in order to avoid underestimation of the total potential capital costs that could occur over 20 years or more. For example, cost savings could be achieved by using volunteer labor for riparian plantings, but these cost estimates currently assume commercial planting contractors would purchase and install all plantings for a more conservative estimate.

CAPITAL COSTS

The ASRP will require a large capital investment in the near term to conduct the scale of restoration proposed. The restoration costs that comprise this capital investment are described in the following sections. In addition, there will need to be ongoing monitoring, stewardship, maintenance, and other actions that will continue for the lifetime of the ASRP. Those are described as ongoing biennial costs in the second section of this appendix.

Restoration Costs

Cost estimates were developed for the restoration components of the ASRP Phase 1 document by obtaining recent bid tabulations and actual costs to construct similar restoration features in Western Washington, and particularly in rural areas and the Chehalis Basin, where available. This information was obtained from the Washington Department of Transportation (WSDOT 2017), summaries of Salmon Recovery Funding Board projects (RCO 2019), current preliminary costs for the Early Action Reaches (Anchor QEA et al. 2019), and bid tabulations from a variety of recent projects where bidding and construction was supported by project team consultants (Anchor QEA 2019; Natural Systems Design 2017). This information was used to build a unit cost table, with ranges from low to high, based on the range of actual bids received and/or reported construction costs for these recent projects. Real estate values were obtained from recent reach-scale valuations prepared for the Early Action Reaches (Forterra 2019). All costs are in 2019 dollars.

Restoration treatment rates (or densities) were developed for three size classes of rivers (large, medium, and small[1]) in coordination with the SRT based on the following:

- Scientific literature regarding the effectiveness of various riparian buffer widths and natural wood loading rates for streams in Western Washington
- GIS analysis of Chehalis Basin characteristics such as valley width, floodplain width, and historical channel migration

The unit costs were then applied based on proposed restoration treatment rates (or densities) per mile for each of the active restoration scenarios that were modeled using the Ecosystem Diagnosis and Treatment (EDT) and National Oceanic and Atmospheric Administration (NOAA) Life-Cycle Models. The active restoration scenarios are shown in Table D-1.

Table D-1
Miles of Channel Treated for Active Restoration Scenarios

RESTORATION SCENARIO	LOCATION	LARGE RIVERS (MILES)[1]	MEDIUM RIVERS (MILES)	SMALL STREAMS (MILES)
Scenario 1	Outside Managed Forests	33	93	7
	Inside Managed Forests	10	70	9
Scenario 2	Outside Managed Forests	35	102	37
	Inside Managed Forests	14	103	25
Scenario 3	Outside Managed Forests	58	132	68
	Inside Managed Forests	17	122	52

Note:
1. Number of miles proposed for restoration on large rivers includes “nodes” on the mainstem Chehalis River and South Fork Chehalis River.

Tables D-2, D-3, and D-4 outline the costs for Scenarios 1, 2, and 3 based on the unit costs and treatment rates.

[1] Large rivers = >30 meters (97 feet) bankfull width (example rivers in this class are the middle and lower Chehalis River and the lower Humptulips River)
Medium rivers = >10 to 30 meters (>33 to 97 feet) bankfull width (example rivers in this class include the Skookumchuck and Newaukum rivers)
Small streams = 0 to 10 meters (0 to 33 feet) bankfull width (example streams in this class include Porter, Lincoln, and Bunker creeks)

Table D-2
Cost Summary for ASRP Scenario 1

RESTORATION ELEMENTS	MILES OF TREATMENT	RIPARIAN/ FLOODPLAIN ACRES	COST RANGE BY ELEMENT LOW	AVERAGE	HIGH
LARGE RIVERS (OUTSIDE MANAGED FORESTS)					
Large Wood	19		$4,848,800	$6,300,400	$7,752,000
Riparian Plantings		1,727	$11,659,091	$14,250,000	$16,840,909
Riparian Easements		1,157	$4,339,773	$8,534,886	$12,730,000
Riparian Acquisition		570	$3,705,000	$8,407,500	$13,110,000
Off-Channel Restoration			$1,757,500	$2,802,500	$3,800,000
Structure Removal/Relocation[1]			$950,000	$1,425,000	$1,900,000
Associated Costs[2]			$12,994,117	$22,639,799	$34,731,974
		Subtotal	**$40,300,000**	**$64,400,000**	**$90,900,000**
LARGE RIVERS (MANAGED FORESTS)					
Large Wood	10		$2,382,000	$3,171,000	$3,960,000
Habitat Protection Acquisition			$110,000	$135,000	$160,000
Associated Costs[2]			$1,688,802	$2,744,761	$4,064,233
		Subtotal	**$4,200,000**	**$6,100,000**	**$8,200,000**
LARGE RIVER NODES					
Excavation	14		$5,950,000	$8,225,000	$10,500,000
Large Wood	14		$1,890,000	$2,205,000	$2,520,000
Riparian Plantings		2,100	$15,424,500	$18,931,500	$22,438,500
Riparian Easements		1,050	$1,968,750	$5,578,125	$9,187,500
Riparian Acquisition		1,050	$4,856,250	$13,321,875	$21,787,500
Associated Costs[2]			$17,931,843	$30,709,781	$46,731,635
		Subtotal	**$48,100,000**	**$79,000,000**	**$113,200,000**
MEDIUM RIVERS (OUTSIDE MANAGED FORESTS)					
Large Wood	93		$15,977,400	$21,101,700	$26,226,000
Riparian Plantings		5,073	$34,240,909	$41,850,000	$49,459,091
Riparian Easements		3,399	$6,372,614	$18,055,739	$29,738,864
Riparian Acquisition		1,674	$7,742,250	$21,238,875	$34,735,500
Off-Channel Restoration			$10,802,500	$16,742,500	$22,450,000
Structure Removal/Relocation[1]			$4,650,000	$6,975,000	$9,300,000
Associated Costs[2]			$42,128,144	$75,012,952	$116,383,380
		Subtotal	**$122,000,000**	**$201,000,000**	**$288,300,000**
MEDIUM RIVERS (MANAGED FORESTS)					
Large Wood	70		$12,145,000	$16,047,500	$19,950,000
Habitat Protection Acquisition			$770,000	$945,000	$1,120,000
Associated Costs[2]			$8,662,909	$13,968,968	$20,584,991
		Subtotal	**$21,600,000**	**$31,000,000**	**$41,700,000**

RESTORATION ELEMENTS	MILES OF TREATMENT	RIPARIAN/ FLOODPLAIN ACRES	COST RANGE BY ELEMENT LOW	AVERAGE	HIGH
SMALL STREAMS (OUTSIDE MANAGED FORESTS)					
Large Wood	7		$1,243,900	$1,563,450	$1,883,000
Riparian Plantings		127	$859,091	$1,050,000	$1,240,909
Riparian Easements		85	$319,773	$628,886	$938,000
Riparian Acquisition		42	$273,000	$619,500	$966,000
Structure Removal/Relocation[1]			$350,000	$525,000	$700,000
Associated Costs[2]			$1,665,917	$2,758,750	$4,122,405
		Subtotal	**$4,800,000**	**$7,200,000**	**$9,900,000**
SMALL STREAMS (MANAGED FORESTS)					
Large Wood	9		$1,936,800	$2,520,900	$3,105,000
Habitat Protection Acquisition			$99,000	$121,500	$144,000
Associated Costs[2]			$1,383,274	$2,195,776	$3,204,451
		Subtotal	**$3,500,000**	**$4,900,000**	**$6,500,000**
FISH PASSAGE BARRIER REMOVAL/REPLACEMENT[3]			**$45,000,000**	**$45,000,000**	**$45,000,000**
		GRAND TOTAL (ROUNDED)	**$289,500,000**	**$438,600,000**	**$603,700,000**

Notes:
1. Structure removal/relocation will occur at the rate of one structure removed and one structure relocated per mile of other restoration.
2. Associated costs include standard construction elements such as erosion control, water diversions, mobilization/demobilization, sales tax, permitting, design, construction management, and contingency.
3. Cost for removal/replacement of 200 fish passage barriers is 50% farm/forest roads at $150,000 each and 50% city/county roads at $300,000 each.

Table D-3
Cost Summary for ASRP Scenario 2

RESTORATION ELEMENTS	MILES OF TREATMENT	RIPARIAN/ FLOODPLAIN ACRES	COST RANGE BY ELEMENT LOW	AVERAGE	HIGH
LARGE RIVERS (OUTSIDE MANAGED FORESTS)					
Large Wood	21		$5,359,200	$6,963,600	$8,568,000
Riparian Plantings		1,909	$12,886,364	$15,750,000	$18,613,636
Riparian Easements		1,279	$4,796,591	$9,433,295	$14,070,000
Riparian Acquisition		630	$4,095,000	$9,292,500	$14,490,000
Off-Channel Restoration			$1,942,500	$3,097,500	$4,200,000
Structure Removal/Relocation[1]			$1,050,000	$1,575,000	$2,100,000
Associated Costs[2]			$14,361,919	$25,022,936	$38,387,971
		Subtotal	**$44,500,000**	**$71,200,000**	**$100,500,000**
LARGE RIVERS (MANAGED FORESTS)					
Large Wood	14		$3,754,800	$4,859,400	$5,964,000
Habitat Protection Acquisition			$154,000	$189,000	$224,000
Associated Costs[2]			$2,657,248	$4,200,845	$6,115,042
		Subtotal	**$6,600,000**	**$9,300,000**	**$12,400,000**
LARGE RIVER NODES					
Excavation	14		$5,950,000	$8,225,000	$10,500,000
Large Wood	14		$1,890,000	$2,205,000	$2,520,000
Riparian Plantings		2,100	$15,424,500	$18,931,500	$22,438,500
Riparian Easements		1,050	$1,968,750	$5,578,125	$9,187,500
Riparian Acquisition		1,050	$4,856,250	$13,321,875	$21,787,500
Associated Costs[2]			$17,931,843	$30,709,781	$46,731,635
		Subtotal	**$48,100,000**	**$79,000,000**	**$113,200,000**
MEDIUM RIVERS (OUTSIDE MANAGED FORESTS)					
Large Wood	102		$17,523,600	$23,143,800	$28,764,000
Riparian Plantings		5,564	$37,554,545	$45,900,000	$54,245,455
Riparian Easements		3,728	$6,989,318	$19,803,068	$32,616,818
Riparian Acquisition		1,836	$8,491,500	$23,294,250	$38,097,000
Off-Channel Restoration			$12,835,000	$19,720,000	$26,350,000
Structure Removal/Relocation[1]			$5,100,000	$7,650,000	$10,200,000
Associated Costs[2]			$46,893,501	$83,429,753	$129,394,748
		Subtotal	**$135,400,000**	**$223,000,000**	**$319,700,000**
MEDIUM RIVERS (MANAGED FORESTS)					
Large Wood	103		$17,870,500	$23,612,750	$29,355,000
Habitat Protection Acquisition			$1,133,000	$1,390,500	$1,648,000
Associated Costs[2]			$12,746,852	$20,554,339	$30,289,344
		Subtotal	**$31,800,000**	**$45,600,000**	**$61,300,000**

RESTORATION ELEMENTS	MILES OF TREATMENT	RIPARIAN/ FLOODPLAIN ACRES	COST RANGE BY ELEMENT LOW	AVERAGE	HIGH
SMALL STREAMS (OUTSIDE MANAGED FORESTS)					
Large Wood	37		$6,574,900	$8,263,950	$9,953,000
Riparian Plantings		673	$4,540,909	$5,550,000	$6,559,091
Riparian Easements		451	$1,690,227	$3,324,114	$4,958,000
Riparian Acquisition		222	$1,443,000	$3,274,500	$5,106,000
Structure Removal/Relocation[1]			$1,850,000	$2,775,000	$3,700,000
Associated Costs[2]			$8,805,559	$14,581,964	$21,789,857
		Subtotal	**$25,000,000**	**$37,800,000**	**$52,100,000**
SMALL STREAMS (MANAGED FORESTS)					
Large Wood	25		$5,380,000	$7,002,500	$8,625,000
Habitat Protection Acquisition			$275,000	$337,500	$400,000
Associated Costs[2]			$3,842,427	$6,099,377	$8,901,253
		Subtotal	**$9,500,000**	**$13,500,000**	**$18,000,000**
FISH PASSAGE BARRIER REMOVAL/REPLACEMENT[3]			**$67,500,000**	**$67,500,000**	**$67,500,000**
		GRAND TOTAL (ROUNDED)	**$368,400,000**	**$546,900,000**	**$744,700,000**

Notes:
1. Structure removal/relocation will occur at the rate of one structure removed and one structure relocated per mile of other restoration.
2. Associated costs include standard construction elements such as erosion control, water diversions, mobilization/demobilization, sales tax, permitting, design, construction management, and contingency.
3. Cost for removal/replacement of 300 fish passage barriers is 50% farm/forest roads at $150,000 each and 50% city/county roads at $300,000 each.

Table D-4
Cost Summary for ASRP Scenario 3

RESTORATION ELEMENTS	MILES OF TREATMENT	RIPARIAN/ FLOODPLAIN ACRES	COST RANGE BY ELEMENT LOW	AVERAGE	HIGH
LARGE RIVERS (OUTSIDE MANAGED FORESTS)					
Large Wood	29		$7,400,800	$9,616,400	$11,832,000
Riparian Plantings		2,636	$17,795,455	$21,750,000	$25,704,545
Riparian Easements		1,766	$6,623,864	$13,026,932	$19,430,000
Riparian Acquisition		870	$5,655,000	$12,832,500	$20,010,000
Off-Channel Restoration			$2,682,500	$4,277,500	$5,800,000
Structure Removal/Relocation[1]			$1,450,000	$2,175,000	$2,900,000
Associated Costs[2]			$19,833,126	$34,555,483	$53,011,960
		Subtotal	**$61,500,000**	**$98,300,000**	**$138,700,000**
LARGE RIVERS (MANAGED FORESTS)					
Large Wood	17		$4,049,400	$5,390,700	$6,732,000
Habitat Protection Acquisition			$187,000	$229,500	$272,000
Associated Costs[2]			$2,870,964	$4,666,093	$6,909,196
		Subtotal	**$7,200,000**	**$10,300,000**	**$14,000,000**
LARGE RIVER NODES					
Excavation	29		$12,325,000	$17,037,500	$21,750,000
Large Wood	29		$5,220,000	$6,090,000	$6,960,000
Riparian Plantings		4,350	$31,950,750	$39,215,250	$46,479,750
Riparian Easements		2,175	$4,078,125	$11,554,688	$19,031,250
Riparian Acquisition		2,175	$10,059,375	$27,595,313	$45,131,250
Associated Costs[2]			$38,054,691	$64,911,521	$98,562,436
		Subtotal	**$101,700,000**	**$166,500,000**	**$238,000,000**
MEDIUM RIVERS (OUTSIDE MANAGED FORESTS)					
Large Wood	132		$22,677,600	$29,950,800	$37,224,000
Riparian Plantings		7,100	$47,925,000	$58,575,000	$69,225,000
Riparian Easements		4,757	$8,919,375	$25,271,563	$41,623,750
Riparian Acquisition		2,343	$10,836,375	$29,726,813	$48,617,250
Off-Channel Restoration			$15,610,000	$24,145,000	$32,350,000
Structure Removal/Relocation[1]			$6,600,000	$9,900,000	$13,200,000
Associated Costs[2]			$59,585,039	$106,060,564	$164,527,524
		Subtotal	**$172,200,000**	**$283,700,000**	**$406,800,000**
MEDIUM RIVERS (MANAGED FORESTS)					
Large Wood	122		$21,167,000	$27,968,500	$34,770,000
Habitat Protection Acquisition			$1,342,000	$1,647,000	$1,952,000
Associated Costs[2]			$15,098,212	$24,345,916	$35,876,699
		Subtotal	**$37,700,000**	**$54,000,000**	**$72,600,000**

RESTORATION ELEMENTS	MILES OF TREATMENT	RIPARIAN/ FLOODPLAIN ACRES	COST RANGE BY ELEMENT LOW	AVERAGE	HIGH
SMALL STREAMS (OUTSIDE MANAGED FORESTS)					
Large Wood	68		$12,083,600	$15,187,800	$18,292,000
Riparian Plantings		1,236	$8,345,455	$10,200,000	$12,054,545
Riparian Easements		828	$3,106,364	$6,109,182	$9,112,000
Riparian Acquisition		408	$2,652,000	$6,018,000	$9,384,000
Structure Removal/Relocation[1]			$3,400,000	$5,100,000	$6,800,000
Associated Costs[2]			$16,183,190	$26,799,285	$40,046,224
		Subtotal	**$45,800,000**	**$69,500,000**	**$95,700,000**
SMALL STREAMS (MANAGED FORESTS)					
Large Wood	52		$11,190,400	$14,565,200	$17,940,000
Habitat Protection Acquisition			$572,000	$702,000	$832,000
Associated Costs[2]			$7,992,249	$12,686,704	$18,514,605
		Subtotal	**$19,800,000**	**$28,000,000**	**$37,300,000**
FISH PASSAGE BARRIER REMOVAL/REPLACEMENT[3]			**$101,250,000**	**$101,250,000**	**$101,250,000**
		GRAND TOTAL (ROUNDED)	**$547,150,000**	**$811,550,000**	**$1,104,350,000**

Notes:
1. Structure removal/relocation will occur at the rate of one structure removed and one structure relocated per mile of other restoration.
2. Associated costs include standard construction elements such as erosion control, water diversions, mobilization/demobilization, sales tax, permitting, design, construction management, and contingency.
3. Cost for removal/replacement of 450 fish passage barriers is 50% farm/forest roads at $150,000 each and 50% city/county roads at $300,000 each.

ONGOING BIENNIAL COSTS

Restoration Costs

Monitoring and Adaptive Management

A detailed Monitoring and Adaptive Management (M&AM) Plan will be developed for the final ASRP, but for the ASRP Phase 1 document, the M&AM Team has recommended a range of costs for a comprehensive monitoring program. It is expected that monitoring would likely be more intensive for the first 10 or more years of ASRP implementation, with a reduced frequency of monitoring occurring in later years. However, species population monitoring would continue through the life of the ASRP to document if the anticipated scale of benefits expected are occurring. Depending on the frequency of monitoring, comprehensive programmatic costs could range from $4 million to $6 million for the 2021–2023 biennium after construction of the first restoration elements is complete. Costs will be refined for full implementation of the M&AM Plan in the final ASRP.

Stewardship and Maintenance

It is anticipated that multiple entities would own and manage the easements and lands acquired for the ASRP, including local land trusts, counties, and the state. Ongoing management, stewardship, inspections, and maintenance (i.e., for culverts or bridges) would need to be conducted. This cost will vary depending on the acreage acquired. For this document, the stewardship and maintenance cost has been estimated to include the following elements:

- Invasive plant management (e.g., spot spraying, mowing, and pulling of sparse invasive species) for one-half of the acreage of constructed riparian and floodplain projects at $300 per acre for the first 3 years following construction; this is estimated to total $1 million in the first biennium and $2 million in the second biennium
- Annual inspection of up to 100 replaced culverts or bridges at $50,000 per year
- Periodic debris removal and minor repairs at an average of 30 culverts or bridges per year (i.e., each would require maintenance on about a 10-year basis); this is estimated to total $10,000 per culvert or bridge, for $300,000 per year

Protection Costs

The protection strategy includes several potential elements that will help protect water quality and quantity, habitats, and watershed processes. Protection could occur via actions such as the transfer of development rights, purchase or transfer of water rights, taxes or other incentives to landowners to provide stewardship of forest and floodplain habitats, or acquisition of easements or lands to protect high-quality habitats and functions. In addition, staff time at basin jurisdictions (cities, counties) may need to be increased to ensure floodplain and critical area requirements are enforced consistent with the ASRP. For this document, $3 million on a biennial basis is proposed. More details on the costs for this strategy will be developed for the final ASRP.

Community Planning, Institutional Capacity, and Community Involvement Costs

The community planning, institutional capacity, and community involvement strategies will support the Chehalis Basin communities to ensure consistency with the ASRP through integrating comprehensive plans and ordinances, developing sustainable economic (particularly agricultural and forestry) programs, streamlining state and local permitting, and fostering local organizational capabilities to manage and monitor natural resources consistent with the ASRP. The types of actions and potential costs are shown in Table D-5.

Table D-5
Preliminary Community Planning, Institutional Capacity, and Community Involvement Costs

POTENTIAL BASIN-WIDE ACTIONS	EFFORT[1]	BIENNIAL COST
COMMUNITY PLANNING		
Assess consistency of floodplain regulations with ASRP; determine if updates are needed	Half full-time equivalent of staff time per county (2021–2023 biennium only)	$1,000,000
Assess consistency of critical areas ordinances with ASRP; determine if updates are needed		
Ensure best management practices and performance standards effectively protect species and habitats		
Create sustainable agriculture grant program to facilitate community and cooperative facilities, transportation, and training		$1,000,000
INSTITUTIONAL CAPACITY AND COMMUNITY INVOLVEMENT		
Develop streamlined permitting process for restoration projects (federal, state, local)	Half full-time equivalent of staff time at U.S. Army Corps of Engineers, U.S. Fish and Wildlife Service, NOAA, Washington Department of Fish and Wildlife, Washington Department of Ecology, Washington Department of Natural Resources, and four counties (2021–2023 biennium only)	$1,000,000
Provide technical training for process-based restoration practices and techniques	Professional training pool for periodic training sessions; two to three per biennium (2021–2023 and 2023–2025 biennia only)	$150,000
Continuation of ASRP SRT	Outside expert team to review ASRP monitoring results and recommend adaptive management actions (40 hours per year)	$200,000
Provide restoration staff within the Office of Chehalis Basin or Washington Department of Fish and Wildlife to manage project development and monitoring	Two full-time equivalent of staff time	$500,000
Provide tax incentives or grants to local jurisdictions to adopt ASRP recommendations		$250,000
Provide technical assistance for landowners	Restoration professional pool; one full-time equivalent at conservation districts	$350,000

Note:
1. Level of effort and cost has not yet incorporated local jurisdiction and organization input. This information will be further developed for the final ASRP.

Table D-6 outlines the total biennial cost estimate for this document. More detailed costs will be developed in coordination with local jurisdictions and organizations for the ASRP. Not all these biennial costs would continue for the lifetime of the ASRP; they could be one-time, periodic, or continuing costs.

Table D-6
Summary of Ongoing Biennial Costs

STRATEGY	BIENNIAL COST	TIME PERIOD
Restoration Capital Cost[1]	$30M to $75M[2]	Estimated at 15 biennia
Restoration (Monitoring)	$4M to $6M	Up to 10 years, then reduced over time
Protection	$3M	For 10 biennia
Community Planning, Institutional Capacity, and Community Involvement	$4.5M	Up to 4 years, then reduced over time
TOTAL	**$41.5M to $88.5M**	**$34M to $80M over time**

Notes:
1. Cost for implementing restoration scenarios
2. Cost range for average to high scenario costs across 15 biennia

ASSUMPTIONS FOR RESTORATION COSTS

Table D-7 provides the detailed unit costs and assumptions for the restoration costs. The unit costs have been informed by the Early Action Reach designs based on the width of riparian and floodplain restoration, types of large wood structures proposed, and the ongoing easement and acquisition process. As the Early Action Reach projects are implemented, additional information on actual costs will be incorporated. It is important to note that price escalation for materials and land is uncertain, so costs may change over time.

Table D-7
Unit Costs, Relative Costs, and Assumptions Used in Estimates for Restoration Cost Estimates

ITEM	UNIT COST ITEM	UNIT	UNIT COST RANGE[1]	LOW COST	AVERAGE COST	HIGH COST	NOTES[2,3]
1.01	Earthwork – Excavation	Cubic Yard	$17 to $30	$17	$24	$30	Assumes off-site haul and disposal of all material (less than 5 miles). Unit cost includes clearing and grubbing within excavation. To be used as minor component of large wood placement or major component of off-channel and wetland reconnection and restoration.
1.02	Earthwork – Placement	Cubic Yard	$26 to $50	$26	$38	$50	Unit cost includes import of select material, such as clean gravel and cobbles, from off-site source. Included with off-channel and floodplain restoration.
2.01	ELJs (Large Rivers, Mainstem Chehalis River Nodes Only)	Each	$60,000 to $80,000	$60,000	$70,000	$80,000	Assumes typical construction of a 50-foot-wide by 50-foot-long, eight-layer (15-foot-tall), gravity or pile-supported ELJ. Typical LWM specification; 30 18- to 24-inch DBH at 30 to 50 feet long (key pieces), plus pilings and slash of various lengths. Typical placement is 3 per mile, located with floodplain and off-channel restoration at nodes.
2.02	ELJs (Large Rivers, Wynoochee, Satsop)	Each	$30,000 to $50,000	$30,000	$40,000	$50,000	Assumes typical construction of a 50-foot-wide by 50-foot-long, three-layer (10-foot-tall), pile-supported ELJ. Typical LWM specification; 15- to 24-inch DBH at 30 to 50 feet long (key pieces), 15 key pieces, plus pilings and slash of various lengths. Typical placement rate is 6 per mile or located individually with floodplain and off-channel restoration at nodes.
2.03	ELJs (Medium Rivers)	Each	$25,000 to $45,000	$25,000	$35,000	$45,000	Assumes typical construction of a 40-foot-wide by 40-foot-long, 10-foot-tall gravity ELJ. Typical LWM specification; 18-inch DBH at 30 to 40 feet long (key pieces), 15 key pieces, plus pilings and slash of various lengths. Typical placement rate is 4 per mile or located individually with floodplain and off-channel restoration.
2.04	Large Wood Multikey Piece Structures (Medium Rivers)	Each	$6,500 to $9,000	$6,500	$7,750	$9,000	Assembly of average 5 key large wood pieces, plus 3 logs of varying lengths with ballast or pile supports. Typical key piece; 18- to 24-inch DBH 25-foot-long rootwad logs. Typical placement rate is 10 per mile.
2.05	Large Wood Multikey Piece Structures (Small Streams)	Each	$4,500 to $6,000	$4,500	$5,250	$6,000	Assembly of average 3 key LWM pieces plus 3 logs of varying lengths with boulder ballast for habitat and/or sediment and smaller wood retention. Typical key piece; 12- to 18-inch DBH 25-foot-long rootwad logs. Typical placement rate is 22 per mile.
2.06	Beaver Dam Analogs (Small Streams and Medium Rivers)	Each	$10,000 to $20,000	$10,000	$15,000	$20,000	Hand or small equipment placement of poles across channel with weaving of willow or cottonwood branches amongst poles. Typical placement rate is 2 per mile outside managed forests and 6 per mile inside managed forests.
2.07	Large Wood Key Pieces – Single Logs (Small Streams)	Each	$500 to $800	$500	$650	$800	Assumes placement and limited to no burial of 14- to 18-inch DBH 25-foot-long rootwad logs. No soil anchors or ballast blocks. Typical placement rate is 75 to 80 per mile.
3.01	Riparian Plantings	Acre	$8,500 to $12,500	$8,500	$10,500	$12,500	For areas with limited to no existing riparian trees. Cost assumes 6-foot on-center plant spacing and includes invasive species management (mowing, spraying, and/or disking). Low estimate assumes common plant types and easy site access. High estimate assumes a wider variety of plant types (higher cost) and more difficult site access. Cost includes temporary soil stabilization measures such as mulch and seeding.
3.02	Supplemental Riparian Plantings	Acre	$5,000 to $7,000	$5,000	$6,000	$7,000	Assumed to be required in areas of existing deciduous riparian vegetation. Cost assumes 16-foot on-center plant spacing and includes invasive species management. Low estimate assumes common plant types, easy site access, and limited clearing of existing vegetation. High estimate assumes a wider variety of plant types, more difficult site access, and clearing of existing vegetation.
3.03	Wetland Plantings	Acre	$10,000 to $18,000	$10,000	$14,000	$18,000	Adding native herbaceous seed plus shrubs and trees to wetland areas. Cost assumes 8-foot on-center woody plant spacing and includes pre-year of invasive species management before planting (i.e., mowing/spraying) plus 1 year post-construction invasive species management. Low estimate assumes common plant types and easy site access; high estimate assumes more diverse plant species, more difficult site access, and supplemental plantings 1 year after construction.
4.00	Restore Floodplain/Channel Nodes (Mainstem Chehalis River and South Fork Chehalis River Only)	Each	$2,400,000 to $5,700,000	$2,400,000	$4,300,000	$5,700,000	Large site nodes of restoration, such as at tributary confluences or areas of existing oxbows/channels. Includes installment of three ELJs (large rivers); excavation of channel connections totaling 1,000 linear feet, average 5-foot depth with 20-foot bottom width and 3:1 side slopes (average of 15,000 cubic yards); other bench excavation (10,000 cubic yards); riparian plantings on 100 acres; supplemental riparian plantings on 50 acres; acquisition of 150 acres with due diligence.

ITEM	UNIT COST ITEM	UNIT	UNIT COST RANGE[1]	LOW COST	AVERAGE COST	HIGH COST	NOTES[2,3]
4.01	Reconnect Side Channels or Oxbows	Each	$140,000 to $330,000	$140,000	$235,000	$330,000	Where opportunity exists and when needed for connectivity. Includes excavation for connection; assumes 500 linear feet of excavation, average 4-foot depth, with 10-foot bottom width and 3:1 side slopes (average of 1,500 cubic yards per site); placement of 200 cubic yards of gravel/cobble; placement of 30 single logs per site. No additional easements or acquisition within treated reaches.
4.02	Reconnect Floodplain Wetlands	Each	$45,000 to $70,000	$45,000	$60,000	$70,000	Where opportunity exists and when needed for connectivity. Includes excavation for connection; assumes 500 linear feet of excavation, average 4-foot-depth swale, 10 feet wide, and 4:1 slopes (2,000 cubic yards per site); placement of 10 single logs per site; wetland plantings on 5 acres. No additional easements or acquisition within treated reaches.
4.03	Create Depressional Wetlands	Each	$120,000 to $210,000	$120,000	$165,000	$210,000	For non-salmon species. Assumes creation of seasonally ponded depressional wetlands (open water and emergent) within riparian buffer areas. Includes excavation; assume 2 acres of excavation, average 2-foot depth (6,400 cubic yards per site); wetland plantings on 1 acre. No additional easements or acquisition.
4.04	Invasive Species Removal in Glacial Outwash Lakes	Each	$200,000 to $350,000	$200,000	$275,000	$350,000	Intensive removal of invasive fish and amphibians (netting, traps, etc.) for up to 3 years.
5.01	Land Acquisition – Easement	Acre	$1,250 to $8,000	$1,250	$4,625	$8,000	Assumes only an easement is purchased but 50% of land value.
5.02	Due Diligence for Land Acquisition – Easement	Each	$25,000 to $30,000	$25,000	$27,500	$30,000	Assumed to be required at a rate of 1 per 40 acres of easement area purchased (or per 5 miles treated in managed forest). Includes appraisals, surveys, and recording fees.
5.03	Land Acquisition – Purchase	Acre	$4,000 to $20,000	$4,000	$12,000	$20,000	Higher cost for residential or urban floodplain areas or for projects that will relocate/remove structures. Assumes entire parcel(s) is purchased. Only includes land and improvements cost; see due diligence costs. High end assumes improvements are present; low end assumes no improvements but zoned for development.
5.04	Due Diligence for Land Acquisition – Purchase	Each	$25,000 to $30,000	$25,000	$27,500	$30,000	Assumed to be required for each parcel individually identified for purchase in the project area, or where no individual parcel was identified, it was assumed to be required at a rate of 1 per 40 acres of land area purchased. Includes appraisals, surveys, and recording fees.
6.01	Road or Infrastructure Removal	Square Yard	$30 to $70	$30	$50	$70	Assumes demolition and off-site haul of asphalt, concrete, and piping and regrading, mulch, seed, and replanting. Low end represents removal of a paved road (~24 feet in width and excavation thickness of 4 feet); high end represents removal of buried pipelines and replacement/regrading of material.
6.02	Structure Demolition and Removal	Each	$10,000 to $25,000	$10,000	$17,500	$25,000	Assumes demolition and off-site haul of structures and foundations within the project area or on purchased lands. High range represents a large farm; low end represents a single-family home. Removals are as individually identified for specific projects.
6.03	Structure Relocation	Each	$50,000 to $80,000	$50,000	$65,000	$80,000	Assumes relocation of an existing structure (typically a large house) to a location outside the project area. Also includes removal of foundation at existing location. Relocations are as individually identified for specific projects.
7.01	Culvert Replacements	Each	$300,000		$300,000		Average from recent search of Salmon Recovery Funding Board-funded projects
ITEM	**RELATIVE COST ITEMS**	**UNIT**	**RELATIVE COSTS[2]**	**LOW COST**	**AVERAGE COST**	**HIGH COST**	**NOTES**
8.01	Temporary Erosion and Sediment Control – Plan and Measures	Lump Sum	1.5% to 2.5%	1.5%	2%	3%	Assumes site surface erosion and sedimentation control measures are permit requirements for all projects, including riparian and floodplain only projects. Includes development and approval of a Temporary Erosion And Sediment Control Plan. Taken only as a percentage of the work items; excludes property acquisition costs.
8.02	Care of Water – Diversion, Isolation, and Dewatering	Lump Sum	4% to 6%	4.0%	5.0%	6.0%	Assumes diversion of water and site isolation from the main channel is required. Assumes dewatering of excavations below the groundwater level during construction. Includes development and approval of a care of water plan. High estimate assumes high groundwater levels relative to excavation grades. Taken only as a percentage of the work items requiring excavation below the groundwater level; excludes property acquisition and planting costs.
8.03	Mobilization and Demobilization	Lump Sum	5% to 10%	5%	8%	10%	Assumes a regionally based contractor. Low estimate assumes minimal site access improvements and close proximity to an improved road. High estimate assumes major site access improvements and a more remote location. Taken only as a percentage of the work items; excludes property acquisition costs.
9.01	Lewis County Sales Tax	Lump Sum	7.80%		7.8%		Sales tax is for unincorporated areas. Applies to pre-tax project subtotal.
9.02	Grays Harbor County Sales Tax	Lump Sum	8.50%		8.5%		Sales tax is for unincorporated areas; the tax rate in Aberdeen is 8.63%. Applies to pre-tax project subtotal.
9.03	Thurston County Sales Tax	Lump Sum	7.90%		7.9%		Sales tax is for unincorporated areas. Applies to pre-tax project subtotal.

ITEM	UNIT COST ITEM	UNIT	UNIT COST RANGE[1]	LOW COST	AVERAGE COST	HIGH COST	NOTES[2,3]
9.04	Mason County Sales Tax	Lump Sum	8.50%		8.5%		Sales tax is for unincorporated areas. Applies to pre-tax project subtotal.
9.05	Pacific County Sales Tax	Lump Sum	7.80%		7.8%		Sales tax is for all areas. Applies to pre-tax project subtotal.
9.06	Cowlitz County Sales Tax	Lump Sum	7.70%		7.7%		Sales tax is for unincorporated areas. Applies to pre-tax project subtotal.
10.01	Permitting and Administration	Lump Sum	8% to 12%	8%	10%	12%	Applies to all projects. Does not account for very complicated cultural resources issues, but standard restoration site permitting. Does not apply to property acquisition costs or construction site preparation/plan costs.
10.02	Design and Engineering	Lump Sum	15% to 20%	15%	18%	20%	Applies to side channel development, floodplain reconnection, and LWM/ELJ projects. Assume 10% to 15% for design, 5% engineering during construction. Does not apply to planting, property acquisition, and construction site preparation/plan costs.
10.03	Contingencies	Lump Sum	25% to 35%	25%	30%	35%	Contingencies account for uncertainty in project scope, site conditions, material costs, and labor and equipment rates as no specific projects currently identified. Applies to pre-tax project subtotal.

Notes:
1. Unit cost ranges where shown represent variability in material costs, labor, land, and other values.
2. Relative costs are a percent of the project subtotals as specified in the notes.
3. ELJ and LWM placement rates are based on 75th percentile in Fox and Bolton (2007).
DBH: diameter at breast height
ELJ: engineered logjam
LWM: large woody material

Restoration Treatment Rate Assumptions

Installation of Large Wood

The treatment rate was based on the SRT recommendation and typical current standard practice in Western Washington to use the 75th percentile key piece loading rate from the Fox and Bolton (2007) research on natural wood loading in Washington State (Table D-8).

Table D-8
Proposed Wood Loading Rate

RIVER SIZE CLASS (BANKFULL WIDTH)	FOX AND BOLTON (2007)-RECOMMENDED 75TH PERCENTILE LOADING RATE FOR KEY PIECES	PROPOSED INSTALLATION FOR COST BASIS
OUTSIDE MANAGED FORESTS		
Large Rivers	Greater than 64 per mile	3 to 6 ELJ per mile with 15 to 30+ key pieces each
Large River Nodes	Greater than 64 per mile	3 ELJs per node of 1 mile with 20 to 30+ key pieces each
Medium Rivers	Greater than 64 per mile	4 ELJ per mile with 15+ key pieces each and 10 multikey piece structures with 5 key pieces each
Small Streams	Greater than 176 per mile	22 multikey piece structures with 3 key pieces each, 2 beaver dam analogs, and 80 single log key pieces
INSIDE MANAGED FORESTS		
Large Rivers	Greater than 64 per mile	6 ELJs per mile with 15 to 30+ key pieces each
Medium Rivers	Greater than 64 per mile	12 multikey piece structures with 5 to 6 key pieces each
Small Streams	Greater than 176 per mile	22 multikey piece structures with 3 key pieces each, 6 beaver dam analogs, and 75 single log key pieces

Notes:
Key pieces are defined as having the following minimum size:
1. Large rivers – Logs of 18- to 24-inch DBH with rootwad and length of 30 to 40 feet
2. Medium rivers – Logs of 18-inch DBH with rootwad and length of 30 to 40 feet
3. Small streams – Logs of 12- to 18-inch DBH and length of 25 to 30 feet, with or without rootwad
ELJ: engineered logjam

Riparian Buffer Restoration

Literature on recommended riparian buffer widths is typically based on the width that is necessary to provide a variety of functions including erosion protection, water quality, large wood recruitment, and habitat for wildlife. Literature recommendations include the following:

- 250-foot riparian width on each side of a river/stream is equivalent to the maximum site potential tree height of Douglas-fir (FEMAT 1993; Knutson and Naef 1997; Fischer and Fischenich 2000) and is commonly used for riparian buffer width recommendations.

- Hawes and Smith (2005) indicated buffer widths of up to 330 feet (each bank) could be necessary to fully provide pollutant removal, litter/debris inputs, and wildlife habitat (i.e., for mammals and songbirds).
- Wenger (1999) indicated that many functions could be achieved with buffers up to 100 feet in width; however, buffer widths from 220 to 574 feet would provide effective wildlife habitat, and widths up to 328 feet could be required for effective sediment control.
- Fischer and Fischenich (2000) indicated that most functions could be provided with buffer widths of 100 to 200 feet, but effective wildlife habitat could require buffer widths up to 1,640 feet.
- The Forest Practices Act requires a 200-foot buffer on each bank as measured from the bankfull channel edge or edge of the channel migration zone (Washington Administrative Code 220-30-021).

For the estimates in the ASRP Phase 1 document, the proposed width of riparian restoration was scaled based on river size classes, with consideration of historical channel migration, valley width, and provision of riparian functions. The width of riparian/floodplain restoration is informed by the width of riparian restoration proposed for the Early Action Reach designs and SRT recommendations—a riparian buffer width of 500 feet on each bank for large rivers, 300 feet for medium rivers, and 100 feet for small streams. It is not anticipated that the entire buffer can be restored due to infrastructure and other structures; it is assumed that 75% of this area would be treated. In practice, project implementation will not rely on meeting the minimum buffer widths that were used for costing and would instead vary depending on ecological, infrastructure, and/or landowner needs. Assumptions included the following:

- Historical migration width information (since 1938) is currently available for the mainstem Chehalis River. Median migration width from GIS analysis (comparison of 1938 to 2013 channel locations) is 356 feet (total width, 178 feet on each bank) or the 75th percentile channel migration width of 446 feet (total width, 223 feet on each bank). Adding a 200-foot buffer from this width of likely channel migration yields potential buffer widths of 378 feet or 423 feet, respectively. For the purposes of being conservative in the cost estimating, a width of 500 feet on each bank was used for the large river category.
- It is assumed that channel migration width and valley widths are proportionally narrower for medium rivers and small streams. This width was also informed by the actual widths of riparian restoration proposed for the predominantly medium river size category in the Early Action Reaches.

Floodplain Off-Channel Restoration

Reconnect Side Channels or Oxbows (Active Connection)

To account for the potential need for excavation to reconnect side channels or oxbows in multiple areas of the basin, the reconnection of one existing (but disconnected) side channel or oxbow per 2 miles was included in the cost estimates. Assumptions included the following:

- It is assumed that these sites are located within areas otherwise proposed for riparian restoration, so no additional acquisition is required.

- Reconnection would only be provided for sites that would likely remain disconnected until a greater than 5-year event after implementing other wood and riparian actions.
- It is assumed that placement of large wood and riparian actions will promote the formation of additional side channel habitats over time.

Reconnect Floodplain Wetlands

Similar to the potential need to excavate to reconnect side channels and oxbows, there may be opportunities to reconnect floodplain wetlands. Thus, one floodplain wetland reconnection per 2 miles of other restoration elements has been included in the cost estimates. Assumptions included the following:

- It is assumed that these sites are located within other areas proposed for riparian restoration, so no additional acquisition is required.
- Annual connections are not anticipated, but 2-year or 5-year connectivity would likely be provided.

Create Depressional Wetlands

The SRT recommended creating 10 depressional wetlands initially and monitoring for effectiveness at sustaining amphibian populations. Assumptions included the following:

- No additional acquisition would take place; the creation of depressional wetlands would occur within the riparian buffer.

Remove Invasive Species from Glacial Outwash Lakes

The SRT recommended selecting five lakes for the initial removal of invasive fish and amphibian species and monitoring for effectiveness at sustaining native fish and amphibian populations. Assumptions included the following:

- No additional acquisition would take place.

Fish Passage Barrier Removal/Culvert or Bridge Replacement

All fish passage barriers that are less than 100% passable within the geospatial units (GSUs) included in each scenario would be removed or replaced. Additional fish passage barriers from GSUs that provide the most benefit to coho salmon and/or steelhead would also be removed. A total of 200, 300, and 450 fish passage barriers are proposed for removal in Scenarios 1, 2, and 3, respectively.

Land Acquisition/Easements

Acquisitions and easements apply to the riparian restoration and floodplain restoration actions (other acquisition assumptions are included in the protection strategy costs). Assumptions relative to restoration acquisitions and easements included the following:

- It is assumed that 33% of the riparian buffer area will require acquisition and 67% of the riparian buffer area will require easements. This is a very conservative estimate, as not all areas of riparian restoration will require a real estate transaction.

- For the nodes on large rivers, 50% of the riparian/floodplain area will require acquisition and 50% of the riparian/floodplain area will require easements. A total of 150 acres per node site is assumed.

Structure Removal/Relocation

Structure removal and/or relocation could be required within restoration areas or purchased lands. Assumptions included the following:

- There will be one removal and one relocation per 1 mile of other treatments.
- It is assumed that 5,000 square yards of road or utility removal would be included per 10 miles of other treatments.

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Appendix E
ASRP Development Committees and Implementing Parties

STEERING COMMITTEE

Voting Members

- Dave Bingaman – Quinault Indian Nation
- Nicole Czarnomski – Washington Department of Fish and Wildlife
- Jason Gillie – Confederated Tribes of the Chehalis Reservation

Non-Voting Ex-Officio Members

- Chrissy Bailey – Washington Department of Ecology, Office of the Chehalis Basin
- Tom Gorman – Washington Department of Natural Resources
- Kirsten Harma – Chehalis Basin Lead Entity
- Mark Mobbs – Quinault Indian Nation
- Hope Rieden – Confederated Tribes of the Chehalis Reservation
- Adam Sant – Washington Department of Ecology, Office of the Chehalis Basin

Staff

- Emelie McKain – Washington Department of Fish and Wildlife

SCIENCE AND TECHNICAL REVIEW TEAM

The Science and Review Team is composed of the following scientists, researchers, and technical experts that have specific expertise in the Chehalis Basin:

- Tim Abbe – Natural Systems Design
- Tim Beechie – National Oceanic and Atmospheric Administration, Fisheries
- John Ferguson – Anchor QEA
- Marc Hayes – Washington Department of Fish and Wildlife
- Larry Lestelle – Biostream Environmental
- Marisa Litz – Washington Department of Fish and Wildlife
- Mark Mobbs – Quinault Indian Nation
- Chip McConnaha – ICF International
- Stacy Polkowske – Washington Department of Ecology
- Hope Rieden – Confederated Tribes of the Chehalis Reservation
- Mike Scharpf – Washington Department of Fish and Wildlife
- Colleen Suter – Confederated Tribes of the Chehalis Reservation

MONITORING AND ADAPTIVE MANAGEMENT TEAM

The Monitoring and Adaptive Management Team is composed of the following scientists, researchers, and technical experts that have specific expertise in the Chehalis Basin:

- Scott Collyard – Washington Department of Ecology
- John Ferguson – Anchor QEA
- Marc Hayes – Washington Department of Fish and Wildlife
- Kirk Krueger – Washington Department of Fish and Wildlife
- Mark Mobbs – Quinault Indian Nation
- Dale Norton – Washington Department of Ecology
- Miranda Plumb – U.S. Fish and Wildlife Service
- Stacy Polkowske – Washington Department of Ecology
- Hope Rieden – Confederated Tribes of the Chehalis Reservation
- Colleen Suter – Confederated Tribes of the Chehalis Reservation
- John Winkowski – Washington Department of Fish and Wildlife

COORDINATION TEAM

The Coordination Team is composed of the following staff and project management capacity:

- Celina Abercrombie – Washington Department of Fish and Wildlife
- Chrissy Bailey – Washington Department of Ecology, Office of the Chehalis Basin
- Cynthia Carlstad – Northwest Hydraulic Consultants
- Glen Connelly – Confederated Tribes of the Chehalis Reservation
- Jim Kramer – Ruckelshaus Center
- Merri Martz – Anchor QEA
- Emelie McKain – Washington Department of Fish and Wildlife
- Adam Sant – Washington Department of Ecology, Office of the Chehalis Basin
- Lynn Turner – Anchor QEA

PARTNERS IN ECOSYSTEM RESTORATION AND SALMON RECOVERY

Municipal Partners

- City of Aberdeen
- City of Centralia
- City of Chehalis
- City of Hoquiam
- City of McCleary
- City of Montesano
- City of Napavine
- City of Ocean Shores
- Grays Harbor County
- Grays Harbor Water District
- Lewis County
- Mason County
- Port of Centralia
- Port of Grays Harbor
- Thurston County
- Thurston Public Utility District

Agency Partners

- Washington Department of Ecology
- Washington Department of Fish and Wildlife
- Washington Department of Natural Resources
- Washington Department of Transportation
- Washington Recreation and Conservation Office
- U.S. Fish and Wildlife Service

Tribal Partners

- Confederated Tribes of the Chehalis Reservation
- Quinault Indian Nation

Implementation and Education Partners

- Adopt A Stream Foundation
- American Community Enrichment, Inc.
- Artic Community Association
- Association of Retired Fish and Wildlife Employees
- Capitol Land Trust
- Center for Natural Lands Management
- Centralia College
- Centralia Stream Team
- Chehalis Basin Education Consortium
- Chehalis Basin Fisheries Task Force
- Chehalis Basin Flood Authority
- Chehalis River Basin Land Trust
- Chehalis River Council
- Chehalis Small Forest Landowners Program
- Clean Streams and Memes
- Coast Salmon Partnership
- Coastal Community Action Program
- Conservation Northwest
- Creekside Conservancy (Heernet Environmental Foundation)
- Ducks Unlimited
- EarthCorps
- EarthShare Washington
- Environment Washington
- Experience Olympia & Beyond
- Forterra
- Friends of Grays Harbor

- Grays Harbor College Fish Lab
- Grays Harbor Community Foundation
- Grays Harbor Conservation District
- Grays Harbor Historical Seaport
- Grays Harbor Stream Team
- Grays Harbor Weed Board
- Indian Creek Homeowners Association
- Junior League of Olympia
- Kelsey Foundation
- Lake Arrowhead Community Club
- League of Women Voters
- Lewis County Conservation District
- Lincoln Creek Grange
- Local Chambers of Commerce
- Local Chapters of the American Legion, Benevolent and Protective Order of Elks, Fraternal Order of Eagles, Lions Clubs International, Masonic Grand Lodge, and Rotary International
- Long Live the Kings
- Marine Resources Committee
- Mason Conservation District
- Ocean Shores Community Club
- OlyMEGA
- Rachel Corrie Foundation for Peace & Justice
- Save Our Wild Salmon
- Sierra Club
- Star Lake Community Club
- The Nature Conservancy
- Thurston Conservation District
- Trout Unlimited
- Veterans Ecological Trades Collective
- Veterans of Foreign Wars Legion Club
- Washington Policy Center
- Washington Water Trust
- Washington Wild
- Westport Aquarium
- Wild Fish Conservancy
- Wild Salmon Center

Office of Chehalis Basin
Department of Ecology
State of Washington

The Chehalis Tribe

Washington Department of Fish and Wildlife

Department of Ecology
State of Washington

Quinault Indian Nation