Chehalis Basin Strategy

Aquatic Species Restoration Plan
— Initial Outcomes and Needed Investments — for Policy Consideration




Aquatic Species Restoration Plan Steering Committee

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ACRONYMS AND ABBREVIATIONS

ASRP	*Aquatic Species Restoration Plan*
BMP	Best Management Practice
CIG	Climate Impacts Group
EDT	Ecosystem Diagnosis and Treatment
EIS	Environmental Impact Statement
ESA	Endangered Species Act
I-5	Interstate 5
RCW	Revised Code of Washington
WDFW	Washington Department of Fish and Wildlife
WRIA	Water Resource Inventory Area

SUMMARY

Aquatic species habitat in the Chehalis Basin has been significantly modified and degraded from historical conditions. Estimates indicate that the potential of existing habitat to produce salmon has been reduced as much as 80% (ASEPTC 2014a) due to the loss or degradation of aquatic habitats. Without future significant protection and restoration actions, future human population growth, climate change, and resource use will continue to negatively impact aquatic species. If actions are not taken, climate change alone is predicted to have a devastating effect—for example, spring Chinook salmon are expected to decline by an additional 50% by the end of the century. An unprecedented level of commitment and action is required, which is being comprehensively analyzed through the *Aquatic Species Restoration Plan* (ASRP). The proposed vision of the ASRP is to provide for a future where the Chehalis Basin can support healthy and harvestable salmon populations, robust and diverse populations of native aquatic and semi-aquatic species, and productive, self-sustaining ecosystems that are resilient to climate change and other human stressors, while also honoring the social, economic, and cultural values of the Basin. The importance of community involvement in the ASRP cannot be understated—most of the actions in the ASRP would occur on private land, and would require landowners willing to collaborate in this important undertaking.

This initial document is intended to summarize progress to date and illustrate what the ASRP could achieve under different scenarios, along with associated costs for each scenario. The Chehalis Basin Board, tribes, and state agencies will use this initial document to develop guidance related to the desired outcomes and necessary level of investment. Depending on the feedback received, further discussion among the governments and organizations may be required to determine the science and policy work needed to develop and implement the full ASRP.

The 2,700-square-mile Chehalis Basin (Water Resource Inventory Areas [WRIAs] 22 and 23) has 3,353 miles of streams and rivers including the Chehalis River and its tributaries and all other tributaries to Grays Harbor (see Figure S-1 at the end of this summary). The wide variety of habitats within and adjacent to rivers and streams in the Basin support the most diverse amphibian population in Washington, the endemic Olympic mudminnow, and numerous other native fish and wildlife species. Existing anadromous and shellfish resources of the Chehalis Basin are of regional and national significance to tribal, commercial, and sport fishing.

The scope of the ASRP is focused on taking action in the freshwater environment where there is a potential to provide substantial gains for aquatic species, with an understanding of the dynamic conditions and uncertainties that accompany external factors such as climate change.

Scenarios Evaluated

This initial document presents two restoration scenarios, referred to as the Moderate and High scenarios. These are compared to a Base scenario—which reflects current conditions throughout the Basin—and a No Action scenario—which represents predicted future conditions. The modeled No Action scenario accounts for negative effects from climate change, positive effects from the maturation of riparian forests within managed forest lands under the Forest Practices Act, but no additional degradation or restoration of aquatic habitats from current conditions. The modeled Moderate and High scenarios incorporate these assumptions about climate change, riparian forests, and no additional degradation of aquatic habitats, and apply differing levels of restoration to estimate the costs and expected outcomes from the actions under the ASRP.

Accounting for Future Degradation

Although the modeled future conditions in this document do not account for additional ongoing degradation of aquatic habitats (except by climate change), it is assumed that degradation will continue to occur. This initial document includes a Habitat and Process Protection strategy (see Section 3.1), which will be further developed in the full ASRP. The modeled scenario will also be updated in the full ASRP to account for anticipated future degradation.

- The Moderate ASRP scenario would restore up to 164 miles of rivers and their riparian areas outside of managed forests and up to 130 miles of rivers inside managed forests.[1]
- The High ASRP scenario would restore up to 348 miles of rivers and their riparian areas outside of managed forests and up to 130 miles of rivers inside managed forests.
- Both the Moderate and High scenarios would improve fish passage at culverts and other barriers that are blocking aquatic species access to quality upstream habitats throughout the Basin.

The Base, No Action, Moderate, and High scenarios are being assessed through the Ecosystem Diagnostic Treatment (EDT) model to predict fish responses under the different scenarios; initial outcomes from the EDT model are presented in this initial document to outline the expected outcomes for salmonid[2] species (see Section 4 for details). The Moderate, High, and No Action scenarios are evaluated relative to mid-century (approximately 2040) and end of century (approximately 2080) conditions.

[1] "Managed forests" are defined as lands outside of federal management that are more than 80 contiguous forested acres. Managed forests 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 forestlands are downstream of the publicly and privately managed forest lands.
[2] "Salmonid" is the term for fish of the family *Salmonidae*, including salmon and trout.

Expected Outcomes and Associated Costs

The modeled outcomes in this initial document show that with no action and habitat degradation from anticipated future climate change, salmonid populations would decline significantly (see summary in Table S-1). This is especially notable for spring Chinook salmon, which are anticipated to decline by 50% by the end of the century, increasing the risk of extinction. Coho salmon, fall Chinook salmon, and steelhead would decline by 20% to 30% by the end of the century. Other aquatic species are expected to similarly decline with no action.

By mid-century, the expected outcomes for the Moderate and High scenarios do not show much change relative to the baseline conditions, and in the case of steelhead there could be an additional decrease relative to the baseline conditions. These mid-century outcomes show a larger change relative to No Action conditions at mid-century, and thus the restoration scenarios can be considered to be maintaining populations in the short-term with a changing climate.

Taking action under either the Moderate or High scenarios would result in substantial positive outcomes for salmonid and other aquatic species and natural processes by the end of the century, even with anticipated climate change conditions. EDT modeling showed a range of expected outcomes by the end of the century across the salmonid species—from a 20% increase for chum salmon under the Moderate scenario compared to No Action, to a more than 500% increase for spring Chinook salmon under the High scenario compared to No Action. Note that the percentages used to discuss expected changes in salmonid population outcomes represent a wide range of expected fish numbers, depending on the current relative abundance of the species (e.g., there are more than 100 times more chum salmon [approximately 195,200 fish] than spring Chinook salmon [approximately 1,800 fish] represented in the Base scenario). The expected outcomes would also show seasonal variability, but there is expected to be an increase across all the species by the end of the century. Spring Chinook salmon could increase by a range of 300% (Moderate scenario) to more than 500% (High scenario) and coho salmon could increase by 120% (Moderate scenario) to 180% (High scenario), as compared to the No Action scenario.

Understanding Expected Outcomes

It is important to note that the modeled outcomes do not include assumptions about the timeline for implementation of the ASRP actions. The longer the timeframe for ASRP implementation, the longer it will take to achieve the outcomes.

The model also does not account for additional degradation from present-day conditions (except from climate change); if habitat conditions degrade from other human activities before ASRP implementation, the expected outcomes of ASRP actions will also change. Further, the success of the ASRP is dependent on the voluntary participation of public and private landowners to achieve the substantial outcomes needed.

Uncertainties and variability are discussed further in Section 4.5. The sequence, timing, and pace of implementation will be accounted for during additional ASRP development in 2018.

The outcomes for aquatic species other than salmonids have not been quantified to the same extent at this time. However, the restoration and protection actions assessed in this initial document under both the Moderate and High ASRP scenarios are likely to result in substantial positive outcomes to the range of aquatic species identified for the ASRP, which will be further assessed during upcoming full ASRP development.

The estimated capital cost range is $400 million to $800 million for the Moderate scenario and $700 million to $1.3 billion for the High scenario. Costs are estimated for actions that include the protection of existing habitat conditions from human activities, removal of fish passage barriers, placement of large wood and log jams in stream channels, planting native trees and shrubs in riparian zones, reconnecting side channels and wetlands, and enhancing habitats for aquatic or semi-aquatic species. The largest cost in these estimates is compensating willing landowners for participating in the restoration plan. The Moderate scenario estimates the need to restore up to 11,700 acres of the riparian corridor and floodplain and the High scenario estimates up to 20,700 acres. The ongoing annual cost for monitoring and adaptive management, maintenance, land stewardship, and other activities is projected to be approximately an additional $9.5 million.

Table S-1
Expected Outcomes for Salmon and Costs

	SCENARIO	NO ACTION SCENARIO		MODERATE ASRP SCENARIO		HIGH ASRP SCENARIO	
SPECIES	TIMEFRAME	MID-CENTURY	END OF CENTURY	MID-CENTURY	END OF CENTURY	MID-CENTURY	END OF CENTURY
Coho Salmon	Change from Baseline	-22%	-30%	2%	55%	13%	97%
	Change from No Action			32%	119%	46%	180%
Spring Chinook Salmon	Change from Baseline	-22%	-50%	11%	106%	28%	239%
	Change from No Action			43%	311%	64%	578%
Fall Chinook Salmon	Change from Baseline	-9%	-26%	2%	12%	10%	40%
	Change from No Action			12%	51%	20%	88%
Steelhead	Change from Baseline	-10%	-23%	-3%	25%	0%	43%
	Change from No Action			8%	62%	11%	86%
Chum Salmon	Change from Baseline	0%	0%	7%	20%	9%	26%
	Change from No Action			7%	19%	8%	25%
			Range of Capital Costs[1]	$400 million to $800 million		$700 million to $1.3 billion	

Note:
1. Cost ranges identified in Table S-1 represent the expected costs to achieve the estimated outcomes, but were not assessed as part of modeling efforts. The primary difference in costs between the scenarios is due to the larger scale (approximately double the river length treated and 75% more riparian/floodplain areas restored for the High scenario).

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

The ASRP is the opportunity to reverse the trends of decline by using a collaborative, multi-government, science-based process to protect and restore aquatic species habitat, ecosystem processes, and riverine functions throughout the Chehalis Basin, now and into the future. Through investment, voluntary actions, political commitment, and community planning, implementation of the ASRP can not only halt the decline of native species, but also result in substantial gains to aquatic species in the long-term.

ASRP Development

This initial document and the Scientific Foundation (Appendix A) are the first step in creating the full ASRP, and provides a roadmap for the development of a comprehensive plan for restoration of aquatic species in the Chehalis Basin. The Chehalis Basin Board[3], tribal councils, state agencies, and Chehalis Basin Lead Entity participants will review this initial document from late 2017 through early 2018 and develop guidance related to the desired outcomes and necessary level of investment. Once a policy direction is provided on the outcomes desired for aquatic species, more detailed science and policy work will continue and provide specific information on priority river reaches to target for restoration, types of projects that should be a focus, cost refinements, an implementation schedule and sequence, a monitoring and adaptive management plan, and the relationship to other Chehalis Basin Strategy actions such as a potential dam, restorative flood protection, or land use management actions. The full ASRP will be developed during 2018. Other local groups and implementing parties will need to be intimately involved as the ASRP planning and evaluation process moves forward in 2018 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. The information that is contained in this initial document and information that will be contained in the full ASRP document is outlined in Table S-2.

[3] The Chehalis Basin Board was established, consistent with Revised Code of Washington (RCW) 43.21A.731, to evaluate the long-term strategy for the Chehalis Basin, including funding and timing of implementation of the various actions evaluated in the ASRP.

Table S-2
ASRP Development

INITIAL OUTCOMES AND NEEDED INVESTMENTS FOR POLICY CONSIDERATION DOCUMENT	FULL ASRP DOCUMENT
• Analysis of restoration potential at Basin-wide scale	• Analysis of restoration potential at reach scale • Information on key species, life histories, and habitat
• Expected outcomes for several scenarios	• Expected outcomes for final (selected) scenario • Refinements to outcomes incorporating additional data from ongoing studies and modeling efforts
• High-level Basin-wide strategies • Range of potential actions	• Actions developed to a more detailed geography (e.g., diagnostic unit, reach-scale, priority locations) and temporal scope (e.g., near-term, long-term) • Detailed objectives with metrics/indicators for measuring progress and/or a set of minimum policy objectives for abundance and other metrics that will serve as adaptive management targets
• Range of investments at Basin-wide scale	• Detailed costs, refined for reach-scale conditions • Cost efficiencies
• Document serves as roadmap for implementation • List of implementing partners in ecosystem restoration and salmon recovery efforts in the Chehalis Basin	• Phasing and plan for ASRP implementation including regulatory processes, funding strategies, alignment with other programs and efforts, and design guidelines
• Preliminary scale of monitoring and adaptive management costs	• Monitoring and adaptive management plan

Figure S-1
Chehalis Basin

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, and shellfish 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, the Basin's resources support the cultures of two federally recognized tribes in the area, 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 the most diverse amphibian population in Washington, the endemic Olympic mudminnow, and numerous other native fish and wildlife species. These aquatic resources are not boundless, however, and the Basin faces increasing threats to 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.

The Chehalis Basin Strategy 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. Over the past several years, the Governor's Chehalis Basin Work Group—working with a

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 Endangered Species Act (ESA) listings, causing federal government intervention into local actions and limitations on private landowners and the harvesting of salmon.

team of natural and water resource experts from federal and state agencies, tribes, and restoration practitioners and thought-leaders within the Basin—has overseen 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 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 2017 consistent with Revised Code of Washington (RCW) 43.21A.731, is currently evaluating a long-term strategy for the Chehalis Basin. Recommendations on a long-term Chehalis Basin Strategy are anticipated in late 2019/early 2020. The strategy will include two overarching types of actions: 1) habitat restoration and protection, and 2) flood damage reduction.

The *Aquatic Species Restoration Plan* (ASRP) is the component of the Chehalis Basin Strategy that focuses on habitat restoration and protection. Over the past 4 years, there has been a significant increase in research and collection of data to understand the aquatic species in the Basin and their habitats. The data, research, and analyses by numerous parties have been used by the ASRP Steering Committee (see Section 1.4) to develop a robust, collaborative, science-based understanding of the habitat and aquatic species in the Chehalis Basin. The Basin-wide ASRP seeks to design and encourage implementation of actions intended to:

- Protect and preserve important aquatic species and habitats
- Restore degraded ecosystems, reconnect habitat, and restore habitat-forming processes
- Reestablish natural ecosystem processes resilient to climate change and other human actions
- Foster organizations needed to implement and maintain the ASRP over the long term

In addition to the ASRP, a number of flood damage reduction actions are being further evaluated. These include changes to local floodplain management regulations and floodproofing of structures, the Aberdeen/Hoquiam North Shore Levee, restorative flood protection, and the dam 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 dam, new or improved levee systems, or local-scale flood damage reduction. If flood damage reduction actions are implemented, mitigation for these actions would be separate and independent of—though hopefully consistent with—the ASRP. The restorative flood protection action, also separate from the ASRP, is a flood damage reduction action intended to increase the flood storage capacity of the Chehalis Basin watershed. If implemented, the restorative flood protection action would be coordinated with and complement the ASRP within the treatment areas.

1.2 Purpose

The purpose of the ASRP is to use a collaborative, multi-government, science-based process to present a clear and comprehensive path to protect and restore aquatic species habitat, ecosystem processes[4], and riverine functions throughout the Chehalis Basin now and into the future. Restoring ecosystem processes will be more sustainable in the long term as compared to restoring discreet habitats, but involves a larger scale of actions and requires greater investment up front.

This initial document is intended to summarize initial expected outcomes and associated investments with regard to actions and costs. It provides options to the Chehalis Basin Board, tribes, and state for what the ASRP could achieve under different scenarios, along with associated estimated costs for each scenario. The Chehalis Basin Board, tribes, and state agencies will use this initial document to develop guidance related to the desired outcomes and necessary level of investment. Depending on the feedback received, further discussion among the governments and organizations may be required to determine the science and policy work needed to develop and implement the full ASRP. The full ASRP document will present refined models and analysis of the ASRP scenario that is chosen to be carried forward, and will provide the roadmap for implementation of the ASRP. 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[5]), which drains an area of approximately 2,700 square miles and contains 1,391 streams with 3,353 stream miles as originally surveyed in the Washington Stream Catalog (Phinney and Bucknell 1975)[6]. The scope of the ASRP is focused on conditions within the Basin that affect the survival of aquatic species. The ASRP does not include recommendations for harvest or changes in ocean conditions that also influence species survival. The modeled future conditions in this initial document also do not account for additional ongoing degradation of aquatic habitats from human development and other factors (except from climate change). It is assumed that degradation will continue to occur, and this initial document includes a Habitat and Process Protection strategy (see Section 3.1), which will be

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.

[4] Ecosystem processes are the physical, chemical, and biological cycles in a watershed that create habitats and conditions for the plant and animal species that live there. These cycles are shaped by the watershed's climate and geologic conditions and include water flows, energy cycles (such as hydraulic forces in rivers that transport sediment and wood and create habitats such as side channels), air and water temperatures, and biological cycles (such as nutrient processing and the aquatic food web).

[5] For the purposes of water resource planning under the Washington State Watershed Planning Act of 1998, 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 watersheds.

[6] Current GIS data, such as the National Hydrography Dataset from the U.S. Geological Survey, identifies more than 16,000 stream miles in the Basin, including all seasonal and perennial streams, non-fish-bearing streams, and artificially constructed or piped drainages.

further developed in the full ASRP. The modeled scenario will also be updated in the full ASRP to account for anticipated future degradation. 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 be engaged on a voluntary basis in future 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 supports 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.

Figure 1-1
Conceptual Process Diagram

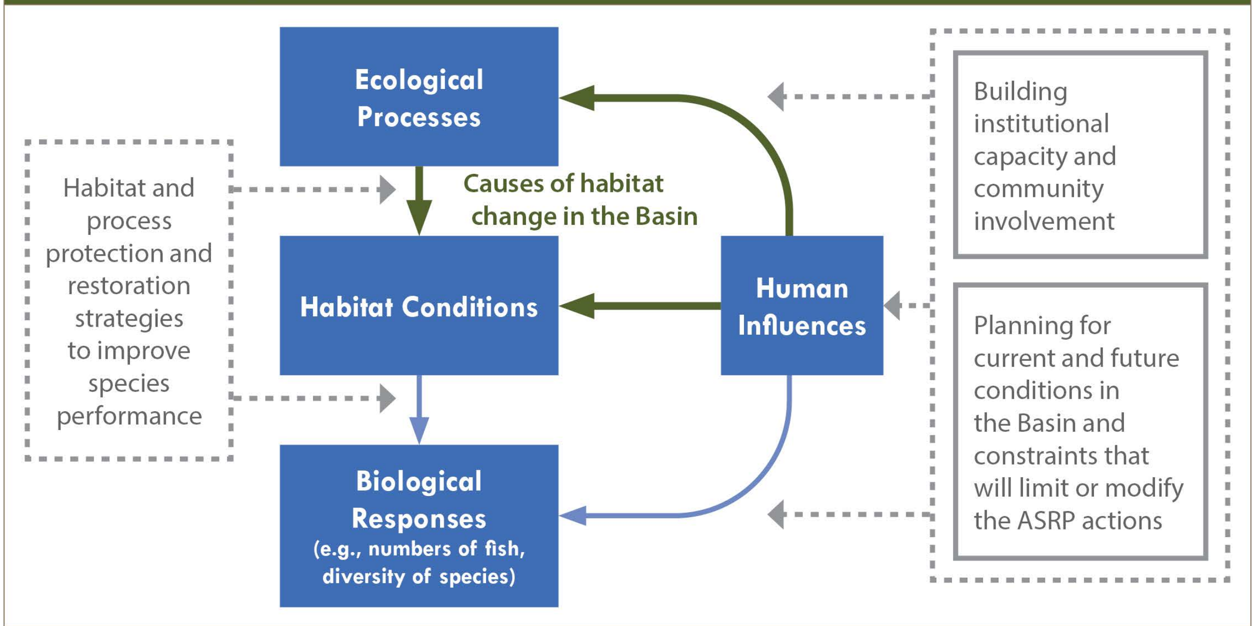
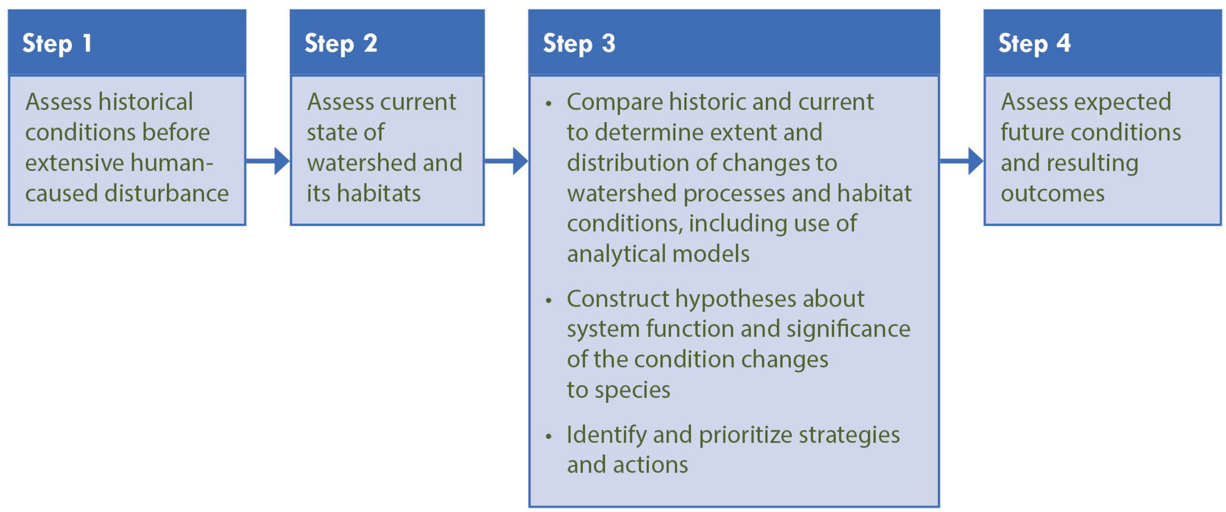


Figure 1-2 illustrates the diagnostic procedure used in the ASRP to assess changes to aquatic habitats from their historical state, how these changes have impacted aquatic species performance, and how future changes may affect habitats and species (refer to the Scientific Foundation in Appendix A for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

Figure 1-2
ASRP Diagnostic Procedure



This initial document provides predictions 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 resulting ASRP scenarios presented in this initial document are referred to as Moderate and High. The ASRP scenarios are compared to a Base scenario—which reflects current conditions including current conditions in the riparian areas and streams inside of managed forests, and barriers to aquatic species upstream habitat access—and a No Action scenario—which represents predicted future conditions based on current practices (no additional restoration or barrier correction outside of the requirements of existing forest practice regulations) and which includes climate change predictions and maturing of streamside buffers in managed forests. The Moderate, High, and No Action scenarios were evaluated relative to mid-century (approximately 2040) and end of century (approximately 2080). See Sections 3 and 4 for more details of the scenarios presented in this initial document.

The full ASRP document will present refined models and analysis of the ASRP scenario that is chosen to be carried forward. Note that this could be at the level presented in the Moderate or High scenarios in this initial document, or at a different level than these scenarios. In the full ASRP, refinements to actions, outcomes, and costs will be provided, analyses will be expanded to include more detail relative to the Basin's sub-watersheds, and efficiencies between projects will be identified.

1.4 ASRP Development

The ASRP is being developed by the Steering Committee and the Science and Technical Review Team (committee members of both groups are listed in Appendix C). The Steering Committee directs the staff and technical work to develop the ASRP. Steering Committee voting members are representatives from Washington Department of Fish and Wildlife [WDFW], Quinault Indian Nation, and Confederated Tribes of the Chehalis Reservation; non-voting ex-officio members are representatives from Washington State Department of Ecology, Washington Department of Natural Resources, and Chehalis Basin Lead Entity. The Steering Committee created the Science and Technical Review Team 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 ASRP builds on previous years of research, incorporating 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) into the framework and modeling efforts for the ASRP. Extensive research and modeling was also conducted to directly support development of the ASRP (the Scientific Foundation is provided in Appendix A).

The Science and Technical Review Team was formed in 2017 to advise the Steering Committee. Considerations for the Science and Technical Review Team 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 Science and Technical Review Team meetings are held to discuss issues and develop guidance. Science and Technical Review Team members were also part of a larger group that developed the Scientific Foundation for the ASRP.

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 full ASRP document). Researchers and other technical experts are called upon to provide input and modeling that contributes to Science and Technical Review Team 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 C). Additional information relative to implementation of the full ASRP will be developed during 2018. More detailed science and policy work will continue to provide specific information on priority river reaches to target for restoration, types of projects that should be a focus, cost refinements, an implementation schedule and sequence, a monitoring and adaptive management plan, and the relationship to other Chehalis Basin Strategy actions such as a potential dam or restorative flood protection actions. Other local groups and implementing parties will need to be intimately involved as the ASRP planning and evaluation process moves forward in 2018 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 late 2019/early 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.

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. Natural 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 the diagnosis of aquatic species habitat limitations (as presented in Section 1.3 and Appendix A) are 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. Even before extensive human-caused changes, there were inherent limitations on the aquatic species that could be produced and supported in the Basin, due to the natural geologic, climatic, and biogeographic conditions, as well as watershed process interactions, that shape and maintain landforms and habitat. Understanding those natural limitations is an important part of the ASRP diagnostic procedure (see Figure 1-2 in Section 1.3).

Comparison of historical and current conditions can be used to construct hypotheses about how the aquatic ecosystem is currently functioning and the factors and changes that limit the performance of aquatic species. Assessment focuses on key cause-effect linkages between watershed processes, habitat conditions, and biological responses of the focal species (see Figure 1-1 in Section 1.3). Understanding the factors that limit performance of aquatic species and the natural limitations on the system allows for an examination of where interventions are possible and likely to have the most success. These hypotheses then become the basis for identifying and prioritizing strategies and actions that compose the ASRP scenarios. An assessment of expected future conditions and resulting changes to aquatic habitats and species performance is also key to planning for a resilient system.

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 mature forests consisting primarily of maple, cedar, Douglas fir, willow, cottonwood, alder, ash, cherry, and dogwood.
- 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.
- Minor 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.

With the rapid alteration of watersheds in the Northwest beginning about 200 years ago due to land use and development, watershed processes began to change. Habitat forming processes that had been more or less stable were typically changed in ways that adversely affected the abundance and survival of native aquatic species, such as salmon (Beechie et al. 2003).

Methods Used to Assess Historical Conditions

General Land Office maps and notes from the mid- to late-1800s provide a key source of information about the historical conditions of the Basin. 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 Basin prior to widespread forest clearing, conversion to agriculture, and other impacts from settlement.

An initial reconstruction of historical habitat conditions for the entire Chehalis Basin was done by Mobrand Biometrics (2003). Further work to reconstruct historical conditions in the Basin upstream from Chehalis was done by Natural Systems Design (Abbe et al. 2016) and a Basin-wide reconstruction is ongoing by NOAA Fisheries.

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 its 3,353 miles of streams and rivers (Phinney and Bucknell 1975), the floodplain, and throughout the forestlands of the Chehalis 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). The Chehalis Basin is one of the few watersheds in Washington that does not have salmonid species (with the exception of bull trout) listed under the ESA. Additionally, the watershed still retains some connectivity with its floodplain, an essential component for the lifecycles 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 are of regional and national significance to tribal, commercial, and sport fishing.

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. 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. The *Aquatic Species Enhancement Plan* (ASEPTC 2014a) further details the current status of ecosystem structures, functions, and processes for the Chehalis Basin, including conditions for aquatic species in the Basin and habitat factors that are currently limiting for aquatic species populations of interest. The *Aquatic Species Enhancement Plan* is available online at: http://chehalisbasinstrategy.com/wp-content/uploads/2015/09/Aquatic-Species-Restoration-Program-Report_Final.pdf.

Assessing 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. 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, and Natural Systems Design, as described in McConnaha et al. (2017a). 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 Fisheries.

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 in 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[7] in the floodplain of the mainstem Chehalis River in 2013 was agriculture (47%), canopy (33%), and development (4%). In the upstream (southern) portion of the Chehalis Basin above Centralia/Chehalis, the Chehalis River valley is relatively narrow with less natural floodplain area, and land use is predominantly forestlands. Major transportation infrastructure of statewide importance, including Interstate 5 (I-5) and the BNSF Railway and Union Pacific Railroad lines, cut through the middle of the Basin within the floodplain. In the lower (northern) Chehalis Basin downstream of Centralia, the mainstem Chehalis River valley is much wider and more predominantly agricultural, except for Aberdeen, Hoquiam, and Cosmopolis at the Grays Harbor estuary.

[7] The Pierce et al. (2017) land cover assessment assumed that all vegetation in the floodplain is either agriculture or canopy. Agriculture included herbaceous and half of shrub/small trees. Canopy included forested and half of shrub/small trees. Development included built areas.

Current conditions related to quantity and quality of aquatic habitat in the Basin, that have changed from historical conditions, are as follows:

- In the last few decades, the Chehalis Basin has experienced flooding, which is damaging to human land uses, 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 generally moderate to poor (Anchor QEA 2014; Ecology 2015a). 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 has become disconnected from its floodplain in many areas. Incision (down-cutting of the river) is a naturally occurring process of erosion and stream evolution; however, it can also be exacerbated by land use actions such as forest practices, agricultural development, and actions that constrain the river's natural meandering process such as bank protection, concentrate its flow into a single channel, or remove fallen trees and wood from the channel.
- Naturally, most large wood that helps reduce channel incision, maintain side channels, pools, forested islands, and floodplains (Abbe and Montgomery 1996; Collins et al. 2002) would be supplied from local bank erosion and channel migration; however, with limited trees in the riparian zone and floodplain, minimal amounts of large wood are currently supplied from these sources. Recent flood events have recruited large wood from landslides and debris torrents in the upper Chehalis Basin and tributaries.
- Dams in rivers such as the Wynoochee and Skookumchuck have impacted the natural sediment and wood supply to downstream reaches, which alters the natural processes that form and sustain aquatic habitat.
- Land drainage (ditching), beaver hunting, and logjam removal vastly diminished 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 erosion and sedimentation, loss of channel complexity and floodplain and habitat connectivity, loss of riparian forests, land conversion, loss of in-channel large wood and log jams, drainage of wetlands and swamps, stream channelization, and water quality degradation (increased summer temperatures).
- The spread of non-native invasive species has impacted habitat, competition, predation, and species composition.

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. While settlers benefitted from the changes to the Chehalis Basin, 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 tribal cultures, communities, and economies.

2.3 Expected Future Conditions

Future conditions in the 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 continue to contribute to an uncertain future for aquatic species. Climate change is considered a significant driver of future conditions in the Basin and as a result, climate predictions have been incorporated into modeling outcomes in this initial document. Future development would be driven by human population growth. The outcomes presented in this initial document do not assess potential development; given the importance of future land use changes, the full ASRP will assess and incorporate the effects of land development.

Because watershed processes are directly tied to climate, a change in climate can affect many aspects related to where and how people, plants, and animals live (e.g., food production, availability and use of water, health risks). For example, a change in the usual timing and severity of rains or temperatures can affect when insects hatch, or when stream flows are highest. 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, which could cause changes in animal communities (DNR 2009).

Determining Expected Future Conditions and Resulting Impacts

Climate change projections for the region are available from the Climate Impacts Group (CIG) at the University of Washington (Mauger et al. 2016). CIG used multiple models to downscale global projections from the Intergovernmental Panel on Climate Change 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) over 100 years (for the periods of 1970 to 1999 and 2070 to 2099).

Projected increases in water temperature and peak winter flows, as described in McConnaha et al. 2017a, have been translated into impacts on habitat conditions in the Basin. These future changes, which are hypotheses, provide the basis for projecting effects on aquatic species performance using quantitative modeling. The future climate projections chosen for use in the models for the purpose of this analysis were agreed to by the Science and Technical Review Team.

Climate change has the potential to affect important variables throughout the Chehalis Basin. Some important predictions include:

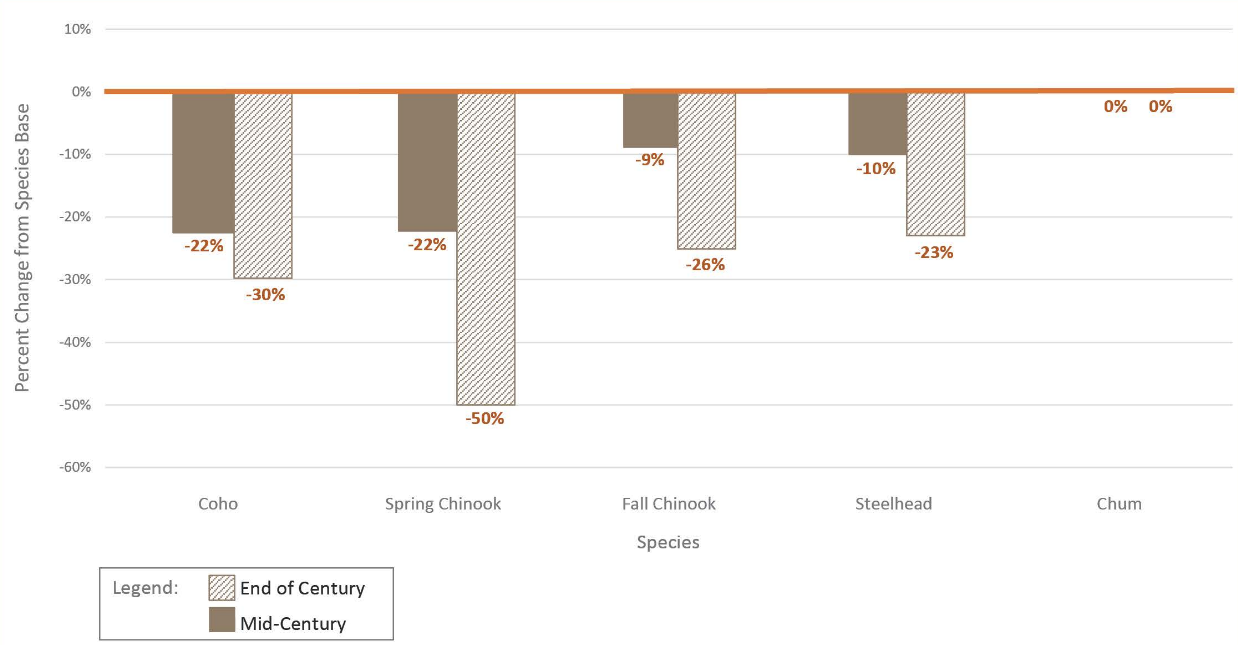
- Increases in annual air temperature of 3.3 to 9.7°F by 2070 to 2099 (compared to the period 1970 to 1999) are projected. These increases are projected to be the largest in the summer (Mote et al. 2014).
- Changes in quantity and timing of precipitation could translate into changes in streamflow magnitude, and perhaps 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 up to 66% (Mauger et al. 2016). Increased frequency and intensity of streamflow is likely to increase channel scour locally, which has a number of secondary effects (e.g., patterns of wood recruitment, stream substrate material distribution). Summer precipitation is projected to decrease in magnitude by as much as 30% (Mote et al. 2014). 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. 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 exotic species currently present in the Basin; this would cause additional stresses for native species.
- Changes in sea level would affect the low elevation wetlands and influence tidal exchange. 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 predicted to result in transitions from forested tidal swamp to irregularly flooded 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). Changes in habitat types and areas could reduce habitat for some native species and life history stages and favor other native or exotic species.
- Climate change would alter forests by increasing wildfire risk, increasing insect and tree disease outbreaks, and by 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.

Future climate change is predicted to affect temperature, precipitation, and other factors that will further degrade conditions and reduce the abundance of native aquatic species in the Chehalis Basin, which may jeopardize the continued existence of some species. These projected changes in climate were incorporated into the No Action scenario in order to predict future changes to salmonid populations. Modeling outcomes for the No Action scenario (Section 4) take into account the effects of future climate change, but do not account for future land use changes. Expected population declines for salmon species, as modeled, are shown in Figure 2-1.

Figure 2-1
No Action Scenario – Expected Change from Current Species Base



3 ASRP APPROACH

A vision for the ASRP was developed by the ASRP Steering Committee. This vision represents the desired outcome of actions to be undertaken as part of the ASRP.

> ASRP Vision Statement
>
> **The vision of the ASRP is to provide for a future where the Chehalis Basin can support healthy and harvestable salmon populations, robust and diverse populations of native aquatic and semi-aquatic species, and productive, self-sustaining ecosystems that are resilient to climate change and anthropogenic stressors, while also honoring the social, economic, and cultural values of the region.**

To achieve the ASRP vision, it is imperative that approaches be supported by landowners, tribes, and stakeholders and guided by best available science. Ensuring that science-based solutions are credible, transparent, and well-supported enables all stakeholders to have confidence that the proposed approaches have a high probability of success and that limited funding is utilized wisely. To this purpose, the ASRP Scientific Foundation (Appendix A) documents a set of science-related principles, assumptions, concepts, and primary approaches that inform the decision-making process for the ASRP effort. Some of the important assumptions considered for the ASRP include:

- The effects of climate change need to be factored into the ASRP to more accurately portray future scenarios for the Basin.
- Restoration efforts need to increase the productivity of aquatic species in the Basin by improving habitat quality and connectivity.
- Restoration and protection of watershed and ecological processes are essential for sustaining productive aquatic habitats that support native aquatic species.
- To be effective and long-lasting, restoration actions must be directed at restoring ecological and watershed processes.
- If restoration actions are to be successful, actions will need to be extensive and effective.

Through a careful review of the best available science, the Steering Committee, in coordination with the Science and Technical Review Team, has identified five high-level strategies to achieve the ASRP vision. These strategies achieved broad agreement and are intended to serve as the conceptual framework for future full ASRP development efforts. Each strategy is discussed in greater detail below, but broadly are as follows:

- Habitat and Process Protection

- Restoration
- Community Planning
- Community Involvement
- Institutional Capacity

These categories represent groups of actions the Steering Committee and the Science and Technical Review Team have determined important to the recovery of aquatic species. 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 dependent on community planning and community involvement. Successful protection of existing habitat will require intentional community planning and successful implementation of restoration will require voluntary actions of landowners. The ASRP would involve changes to the landscape 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 initial document. Initial efforts focused on identifying the restoration actions and the level of restoration necessary to achieve desired outcomes, including the Moderate and High restoration scenarios assessed. As such, the Steering Committee has yet to determine the mechanisms needed to fully implement the other strategies (Habitat and Process Protection, Community Planning, Community Involvement, and Institutional Capacity). The Science and Technical Review Team has identified and is assessing a diverse range of potential actions for these strategies. Additional discussion will be required to fully assess and refine the actions for each strategy in the full ASRP.

Each strategy category below is first described with a high-level overview statement (highlighted in a callout box) of what is included in the scenarios and the rationale behind the strategy. Major sub-strategies 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 sub-strategies would include a wide range of detailed actions and considerations that will receive further consideration during development of the full ASRP. A short description of what implementation of each strategy would be likely to entail within the Chehalis Basin under the full ASRP is also included with each of the strategy categories in Sections 3.1 through 3.5.

3.1 Habitat and Process Protection

> **Protect intact ecosystems, unique habitats, and strategic areas that support critical ecosystem functions and priority species.**

Additional work is needed to determine the appropriate habitat and process protection actions for the full ASRP, but initial discussions have identified the following potential actions:

- Encourage local governments to develop creative programs and policies that protect habitat and ecosystem processes
- Develop and promote voluntary residential stewardship planning and habitat protection
- Offer incentives to landowners to maintain forest cover on their lands
- Promote agriculture and forestry land uses and discourage intensive development within the floodplain
- Ensure that Best Management Practices (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
- Acquire rights or easements for areas that have unique or extremely high value for species or ecosystem processes
- Implement programs that protect and enhance river and stream flows

While the ASRP is called a restoration plan, it is important to understand that the protection of ecosystem processes and aquatic habitats is a vital part of the plan. Current modeling efforts (see Section 4 for outcomes) have not accounted for additional loss of habitat and ecosystem processes from population growth and human activities; any future loss of resources diminishes the ability of ASRP actions to achieve the predicted outcomes for aquatic species—thus the importance of protection actions.

There are many lands throughout the Chehalis Basin that provide important ecosystem processes and high-quality habitat for aquatic species, but could be subject to future land use changes. To see improvement for key aquatic species and avoid future declines, a focused protection effort would likely be needed to prevent the loss of existing habitats important to aquatic species and ecosystem processes. This effort would require close partnerships with landowners and multiple approaches could be used to ensure that the existing benefits are not lost. These actions could include voluntary stewardship planning, incentives to landowners, and revised BMPs as well as other creative programs devised by local governments. Habitat protection could also occur by working with land trusts and using a combination of easements, land acquisitions, and other tools. Protection actions, as with all ASRP actions, would occur in partnership with interested landowners.

Whenever feasible, protection actions would be implemented concurrently with restoration actions (see Section 3.2); however, additional protection actions beyond those identified for restoration would be required to protect the habitat of salmon and other aquatic species.

3.2 Restoration

Restore ecosystem functions to healthy and more sustainable levels for the benefit of native aquatic and semi-aquatic species.

Initial efforts have focused on identifying the restoration strategies necessary to achieve desired outcomes. These strategies were devised to address both short-term and long-term habitat needs. Short-term strategies 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 strategies assume that riparian function itself would continue to enhance the complexity and connectivity of the river channel through natural processes. Specific actions include:

- Remove human-caused barriers to fish passage
- Reconnect off-channel and floodplain habitats
- Restore habitat-forming processes
- Restore self-sustaining riparian processes
- Re-create key habitat features
- Remove and/or relocate infrastructure at a high risk of flooding from restoration actions
- Integrate experimental design into restoration actions to maximize positive outcomes for native species other than salmon and steelhead

In order to achieve sustained, long-term restoration of vital ecosystem functions throughout the Chehalis Basin with the future effects of climate change, the Moderate and High restoration scenarios have been evaluated, as follows:

- The Moderate ASRP scenario would restore up to 164 miles of rivers and their riparian areas outside of managed forests and up to 130 miles of rivers inside managed forests.
- The High ASRP scenario would restore up to 348 miles of rivers and their riparian areas outside of managed forests and up to 130 miles of rivers inside managed forests.

It is important to stress that the restoration would rely on the voluntary participation of public and private landowners to achieve the substantial outcomes needed. Specific restoration actions under this approach include the following elements (also see Table 3-1):

Removal of Fish Passage Barriers

An ongoing collaborative effort is identifying numerous human-caused barriers that are blocking fish access to substantial areas of quality upstream habitats throughout the Basin. Under the scenarios evaluated, approximately 400 of these barriers would either be removed or replaced with appropriately sized culverts or bridges to provide long-term fish passage for native fish at all life history stages, accommodate flood flows and sediment and wood transport, and prevent a barrier from reforming in the future (see Table 3-1).

Restoration of Floodplain Habitats

Due to historic land use changes, many floodplain habitats important to a range of aquatic species have become degraded and disconnected from rivers within the Chehalis Basin. Looking forward, it is anticipated that the natural migration of river channels and formation of floodplain habitats will continue to be constrained by other land uses over time. As a result, key floodplain habitats such as side channels, oxbows, and wetlands would be actively reconnected and restored in selected areas with the voluntary help of landowners. These actions are intended to substantially increase the quantity and quality of these important habitats. Under the evaluated scenarios, approximately one side channel or oxbow and one wetland habitat will be restored and reconnected per 2 miles of river that are restored with riparian and large wood elements (see Table 3-1). This would result in the restoration of approximately 150 to 350 of these habitats, depending on the scenario selected. The modeling analysis (see Section 4.3) did not assess benefits of the restoration of floodplain habitats; however, these benefits will be assessed for the full ASRP.

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 wildlife habitat. Riparian corridors would be restored by riparian plantings in priority areas outside of managed forests and widths would vary depending on the size of the river and the geomorphology of the restoration site, but would range from an average of 500 feet (per side) on large rivers to 150 feet (per side) on small rivers (see Table 3-1). Corridor widths are intended to encompass space for active channel migration and riparian growth. The restoration of riparian corridors would occur over a range from 150 to 350 miles of rivers, depending on the scenario selected.

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 large wood in priority river reaches to jump-start natural processes throughout the Basin. These actions would occur in conjunction with the restoration of riparian corridors. 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; traps and sorts sediments and smaller wood; and provides cover for aquatic species, nutrients to the food web, and habitat for invertebrates. Large and stable key pieces would be installed as engineered log jams, multi-piece structures, or single logs along approximately 150 to 350 miles of rivers, depending on the scenario selected (see Table 3-1).

Restoration of Other Aquatic Habitats

To specifically restore habitats for key life history stages of native amphibians and other semi-aquatic species in the short-term, creation of depressional wetlands in floodplain areas is included in this strategy. These wetlands provide seasonal habitat for amphibian egg-laying and juvenile development.

Removal of exotic aquatic 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 exotic aquatic species is expensive and labor intensive, this element will only be targeted for specific priority lakes where it is likely to be effective.

Table 3-1
Restoration Actions and Level of Treatment

ACTION	TREATMENT LEVEL[1] (APPROXIMATE)	MILES (APPROXIMATE)	ACRES (APPROXIMATE)
Remove Fish Passage Barriers	• 400 fish passage barriers	500 miles accessible	N/A
Restore Floodplain Habitats	Per 2 miles of other restoration elements: • One side channel/oxbow • One floodplain wetland	150 to 350	2,800 to 4,700
Restore Riparian Corridors and Processes	Average riparian width[2,3] (each bank) in feet: • Large rivers: 500 • Medium rivers: 250 • Small streams: 150	150 to 350	8,900 to 16,000
Install Large Wood	Key pieces per mile: • Large/medium rivers: 60 • Small streams: 180	200 to 480	N/A
Restore Other Aquatic Habitats	• Create depressional wetlands in the floodplain • Remove exotic species from glacial outwash lakes	N/A	N/A

Notes:
1. Treatment levels identified were developed to inform costing assumptions and are an estimate of the level of effort needed to achieve modeled outcomes.
2. Corridor widths are intended to encompass space for channel migration and riparian growth.
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

3.3 Community Planning

> Effectively plan for current and future conditions in the Chehalis Basin.

Community plans would likely need to be revised to align the needs of landowners, particularly those in the agricultural community, 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, and the needs of aquatic species in the Basin.

Additional work is needed to determine the appropriate planning actions for the full ASRP, but initial discussions have identified the following potential actions:

- 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

Within the Chehalis Basin, effective community planning will be important for the long-term success of the ASRP. The planning actions being considered 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 landscape 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 across state, county, and local jurisdictions. Similarly, for the ASRP to be successful, local government would need to assess existing comprehensive plans and see if adjustments would be needed to make them consistent with the approaches included in the ASRP.

3.4 Community Involvement

Engage landowners and Basin communities to ensure a successful plan and support implementation of actions.

The success of the ASRP is 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 understated—most of the actions in the ASRP will occur on private land, and would only occur if landowners are willing. Input will be sought to identify landowner needs in the Basin, to develop innovative approaches to implement the ASRP actions, and to plan for a future that provides benefits to both humans and aquatic species. 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 would need to occur early and often throughout the development process. Additional work is needed to determine appropriate community involvement actions for the full ASRP, but initial discussions have identified the following potential actions:

- Develop an ongoing process of landowner engagement to incorporate the initiative and expertise of landowners into ASRP planning and implementation efforts
- Develop a shared community vision for implementation of the ASRP
- 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
- Ensure that restoration and protection actions are developed in concert with landowners and meet their needs as well as aquatic species habitat needs

- Provide landowners with a timely and transparent process to develop and implement projects

Depending on the scenario selected, restoration would include 300 to 500 river miles and 11,700 to 20,700 acres of riparian and floodplain habitat, which will need to involve voluntary collaboration with landowners. 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 them.

3.5 Institutional Capacity

Build institutional capacity of existing organizations for restoration, protection, and planning processes to achieve the scale of actions required.

The ASRP scenarios would involve a level of protection and restoration actions never before seen in the Chehalis Basin. There is currently limited local existing capacity to design and implement these actions. 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 4). 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. Another key component of successful ASRP implementation would likely be enhanced and focused coordination between regional, tribal, state, and federal agencies, particularly as it relates to the permitting process.

Additional work is needed to determine appropriate institutional capacity actions for the full ASRP, but 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 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

4 EXPECTED OUTCOMES

To help inform decision-making for the ASRP, this section summarizes the expected outcomes and costs for the ASRP scenarios. The outcomes and costs presented here are preliminary and will change as additional data are available and assumptions are further refined for the ASRP. These outcomes and the level of proposed restoration represent the Science and Technical Review Team's agreement on an approach toward the ASRP vision for the Chehalis Basin. The expected outcomes also consider the modeled effects of climate change within the Basin. As the ASRP is developed, the expected outcomes will be improved by incorporating the results of various studies, including those related to spring Chinook salmon spawning distribution, and the prioritization of sub-basins and reaches.

The Steering Committee and Science and Technical Review Team also reached agreement on the methodology for developing cost estimates associated with the restoration actions outlined. Cost estimates were developed to help the Steering Committee and Chehalis Basin Board members to broadly assess the potential costs of the scenarios.

The ongoing research and modeling being conducted for the ASRP includes several models that assess habitat conditions. These models include an Ecosystem Diagnosis and Treatment (EDT) model, a Watershed Assessment model, and an Amphibian Occupancy Model. Initial outcomes from the EDT model are presented here to outline the expected outcomes for salmonid species from the ASRP scenarios. The Amphibian Occupancy Model is complete and provides information on off-channel habitat restoration potential, particularly with respect to connectivity and exotic species. The Amphibian Occupancy Model informs estimated outcomes for amphibian species assessed in this initial document. Initial results of the Watershed Assessment model are also complete, and also provide the expected outcomes for salmonid species from the ASRP scenarios, but have not yet been reviewed by the Science and Technical Review Team. Expected outcomes for other native fish species will be developed for the full ASRP.

The recent EDT modeling conducted for this initial document included refinements from previous modeling conducted for the Programmatic Environmental Impact Statement (EIS; Anchor QEA 2017a) including refined modeling assumptions, new temperature data, and a revised spawning distribution for spring Chinook salmon (McConnaha et al. 2017b). The actions and assumptions incorporated into the model were reviewed by the Science and Technical Review Team, with subsequent incorporation of feedback from the team into the modeling. The EDT outcomes for salmon and steelhead are presented in Sections 4.1 and 4.2.

It is important to note when reviewing the expected outcomes and costs that:

- 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.
- The EDT modeled outcomes do not include assumptions about the timeline for implementation of the ASRP actions.
- EDT outcomes use present-day conditions as the Base scenario and do not account for further degradation of existing habitat conditions, except by climate change, for the No Action or Moderate and High scenarios. The Habitat and Process Protection strategy in Section 3.1 will be further developed in the ASRP, and the modeled scenario will be updated at that time to account for anticipated future degradation.
- Ocean conditions can play a major role in salmon survival, but annual variability and future changes in ocean conditions due to climate change are not incorporated into the EDT modeling, as the ASRP cannot have any substantial effect on ocean conditions.
- Note that the percentages used to discuss expected changes in salmonid population outcomes represent a wide range of expected fish numbers, depending on the current relative abundance of the species (e.g., there are more than 100 times more chum salmon than spring Chinook salmon represented in the Base scenario).
- The current EDT modeling does not include the potential outcomes of reconnecting and restoring floodplain habitats, although the costs of these actions are included in cost estimates.
- Cost estimates have been developed for general river size classes within the Basin for this initial document, but will be refined for priority areas and reach-scale conditions for the full ASRP.
- Cost estimate input will be solicited more broadly from restoration groups and local governments for the full ASRP.

While the outcomes presented here are preliminary and will be revised for the ASRP in 2018, they are intended to serve as an important reference for the Steering Committee and Chehalis Basin Board members to broadly assess the potential outcomes and costs of the assessed scenarios. Concurrent with the modeling effort, cost estimates (see Section 4.6 and Appendix B) were developed in coordination with, and reviewed by, the Science and Technical Review Team based on recent projects with similar elements within the Chehalis Basin and nearby watersheds.

4.1 No Action

If no action is taken to restore or enhance aquatic species habitats, the analysis for this initial document indicates that water temperatures could substantially increase, summer streamflows will 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 exotic species that could replace native species in some areas of the Basin. For these reasons, salmon and steelhead are expected to decline in number under the No Action scenario (expected population declines for salmon species are shown in Figure 2-1 in Section 2).

The EDT model outcomes indicate that if no action is taken, all salmon populations except chum salmon will decline substantially in the Basin and the risk of extinction will increase (for example, spring Chinook salmon are expected to be particularly affected by climate change). With an increased risk of extinction, federal agencies may begin a review that could result in a future ESA listing.

4.2 Expected Outcomes for Ecosystem and Habitat

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 Moderate and High scenarios (Section 3.2) would result in the restoration of impaired processes throughout the Basin and the creation of habitat in strategic locations. The following broad outcomes are predicted to occur from the restoration of impaired ecosystem processes under both the Moderate and High scenarios:

- Restoration and protection of high-functioning riparian areas (that currently provide large wood, nutrients, shade, stream bank protection, and fish and wildlife habitat) and watershed connectivity
- Restoration and protection of high-functioning floodplain and off-channel areas that improve watershed connectivity, water quality, water storage, and fish and wildlife habitat
- Restoration of in-channel large wood to increase roughness, decrease channel incision, 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

Specific habitats created by these actions would include high-functioning riparian areas, off-channel floodplain features, wetlands, side channels, more in-channel pools and deepening of pools, thermal refugia, higher quality spawning habitats, and a greater abundance of in-channel large wood to supply cover habitat. These actions would also open up existing habitat that is currently inaccessible, but would have been historically accessible. The amount and spatial frequency of each of the habitats created or protected is an important outcome of restoration efforts. Expected habitat outcomes under both the Moderate and High scenarios are shown in Table 4-1.

Table 4-1
Expected Habitat Outcomes

AQUATIC AND RIPARIAN ECOSYSTEMS	EXPECTED HABITAT OUTCOMES
Riparian Lands	The number of acres restored or protected would increase by 5,200 to 7,400 acres on large rivers, 3,200 to 5,800 acres on medium rivers, and 540 to 2,800 acres on small rivers.
Floodplain Habitat	The number of restored or protected side channels or connected ponds would increase by approximately 70 to 120 features.
Wetland Habitat	The number of restored or protected wetlands would increase by approximately 80 to 130 features.
In-channel Large Wood	The density of in-channel wood (jams per mile) would increase to approximately 2 jams on large rivers, 3 jams on medium rivers, and 20 multi-log clumps on small rivers.
Aquatic Connectivity	Approximately 120 miles of currently inaccessible and 500 miles of partially accessible aquatic habitat would become accessible.
Critical Areas	Important aquafer recharge areas, 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 exotics-free glacial outwash lakes would increase by approximately 5 sites.

Note:
Outcomes identified in Table 4-1 were developed for costing purposes and were not assessed as part of modeling efforts.

4.3 Restoration Outcomes for Salmon and Steelhead

The EDT analysis for salmon and steelhead considered potential outcomes both in the near-term (year 2040) and in the long-term (year 2080), which allowed for incorporation of predicted climate change effects in the Basin. Several scenarios were modeled:

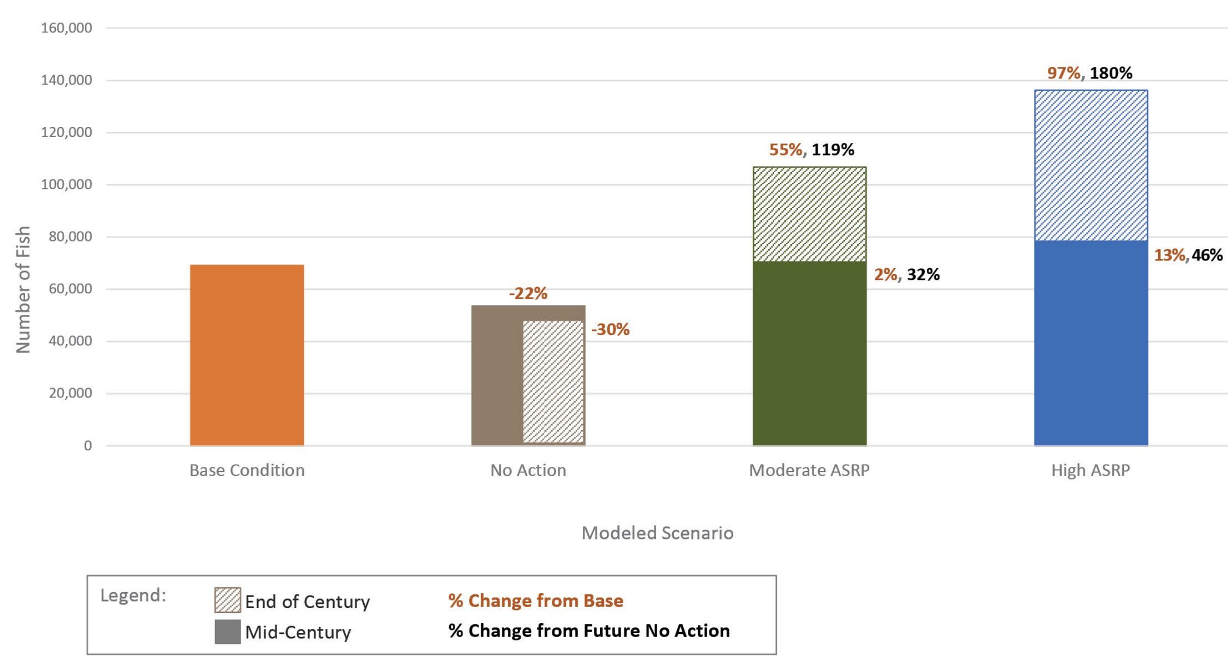
1. Current baseline conditions
2. Future No Action (with climate change), as described in Section 4.1 and shown in Figure 2-1 in Section 2
3. Moderate ASRP (moderate level of restoration both outside and within managed forests; with climate change)
4. High ASRP (high level of restoration both outside and within managed forests; with climate change)

The analysis shows the following key points:

- The Moderate ASRP scenario would generally halt the potential declines that would begin to occur from climate change in the near-term and result in substantial gains to all salmon species in the long-term, particularly for coho and spring Chinook salmon (30% to 40% in the near-term, respectively, and 120% to 300% in the long-term, respectively; see Figures 4-1 through 4-5).

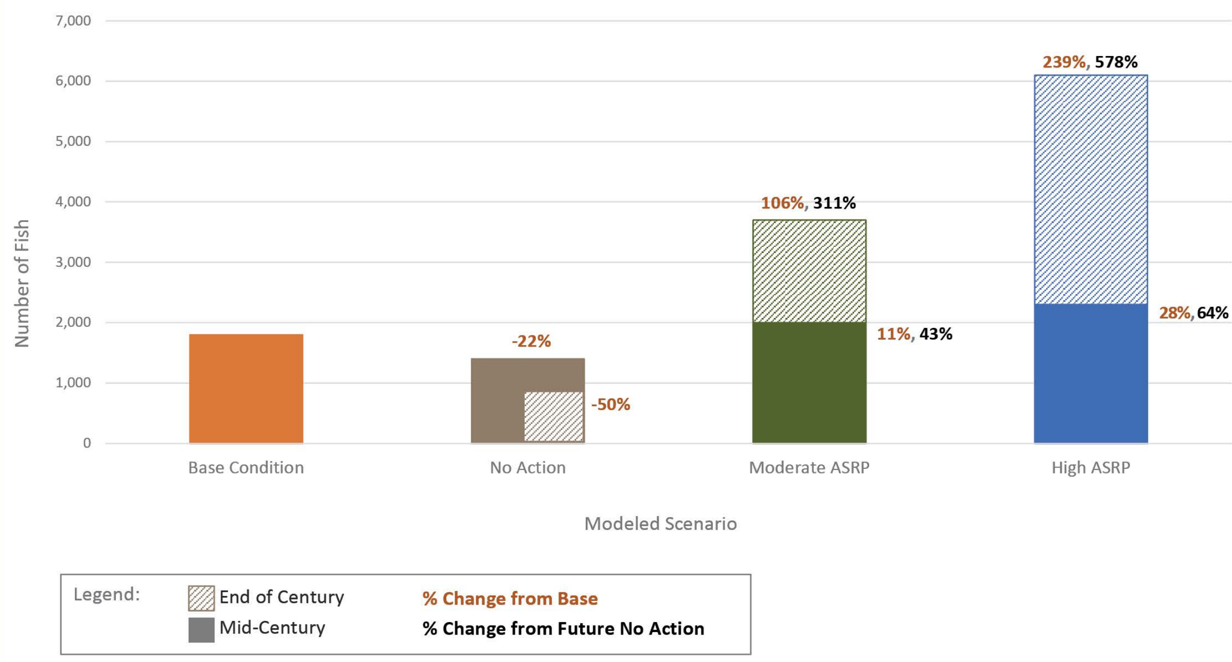
- The High ASRP scenario would result in even more substantial gains to all salmon species in both the near-term and long-term, particularly for coho and spring Chinook salmon (45% to 65% in the near-term, respectively, and 180% to 580% in the long-term, respectively; see Figures 4-1 through 4-5).
- The predicted outcomes for salmon have many uncertainties in the model results for all species. (Refer to Section 4.5 for additional discussion of uncertainty and variability.) Model results may underestimate or overestimate outcomes because the current analysis does not include:
  - Forthcoming data on additional fish barriers and expanded fish distribution
  - Increased quantity and quality of off-channel and floodplain habitats due to actions such as floodplain reconnection and habitat creation
  - Potential positive outcomes for natural processes, such as channel migration, sediment, and wood retention
  - Additional unquantified positive outcomes from halting further population declines (i.e., spatial and genetic diversity)
  - Continued degradation of habitats due to human population growth and development
  - Potential negative effects from flood damage reduction actions that may be implemented as part of the broader Chehalis Basin Strategy (see Section 1)
  - Worsening ocean conditions due to climate change

Figure 4-1
Coho Salmon Expected Outcomes



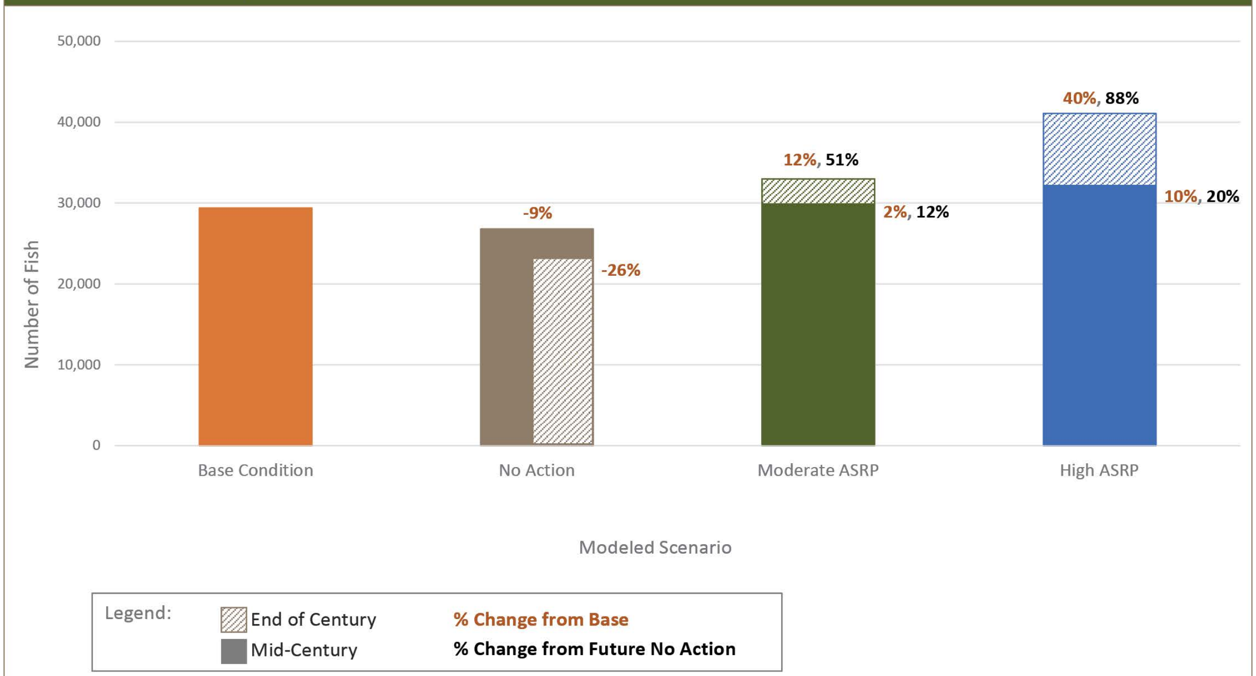
Note: Data from ASRP STRT 2017

Figure 4-2
Spring Chinook Salmon Expected Outcomes



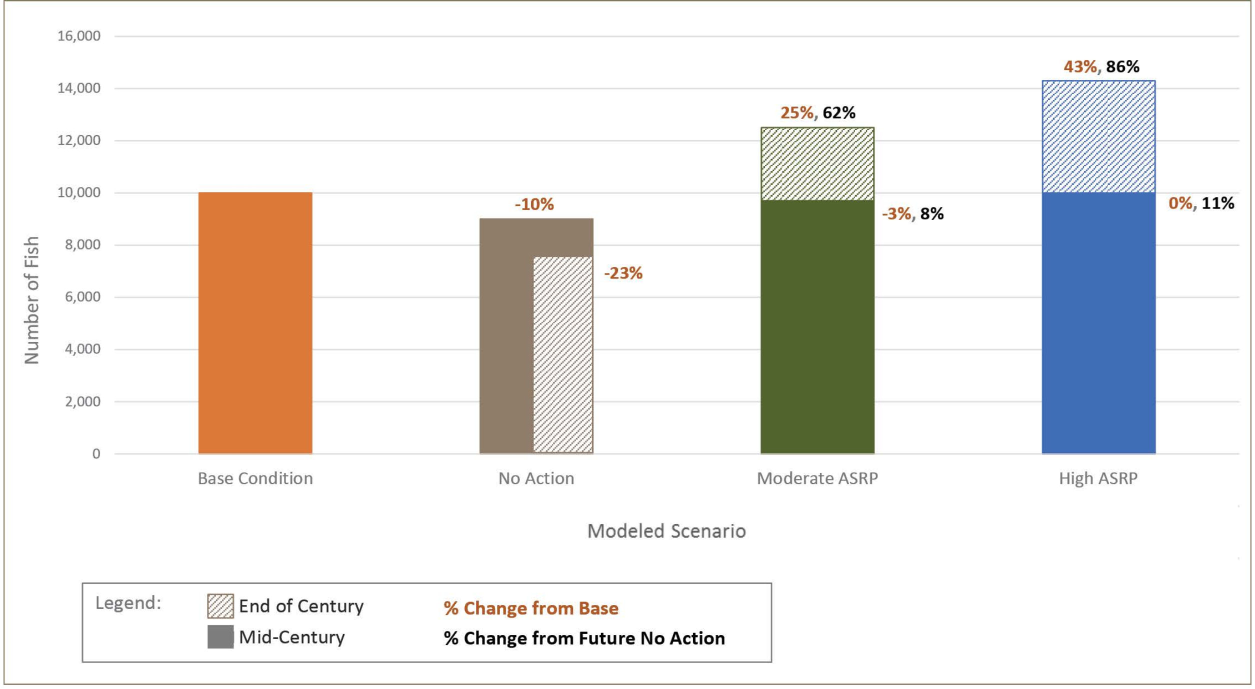
Note: Data from ASRP STRT 2017

Figure 4-3
Fall Chinook Salmon Expected Outcomes



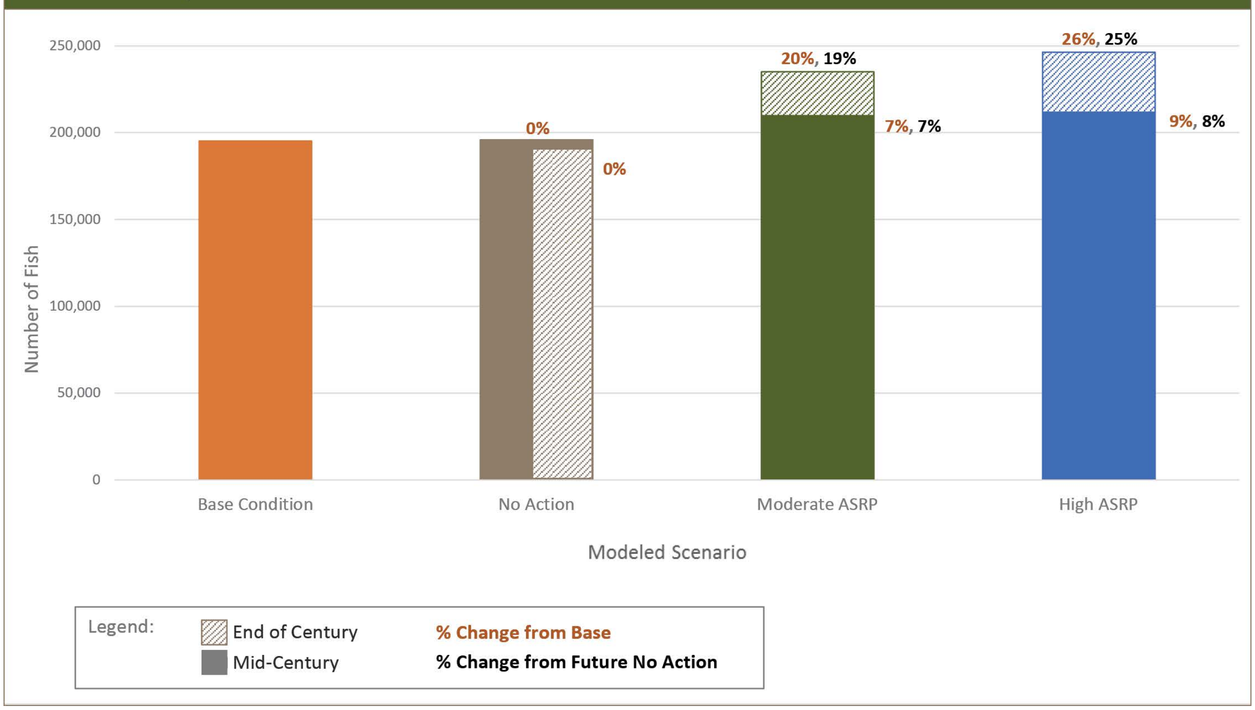
Note: Data from ASRP STRT 2017

Figure 4-4
Steelhead Expected Outcomes



Note: Data from ASRP STRT 2017

Figure 4-5
Chum Salmon Expected Outcomes



Note: Data from ASRP STRT 2017

4.4 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. While the Amphibian Occupancy Model currently provides information on the restoration potential of off-channel habitat, it is not designed to provide estimates of population abundance for aquatic species. Due to the life histories of these diverse species, this type of information is costly and difficult to obtain. The model does show that an increase in connected off-channel habitats favors two native amphibian species and strongly disfavors exotic centrarchid fishes, supporting the idea that improving the connection of floodplain off-channel habitat may be a useful restoration approach.

The restoration and protection actions in this initial document under both the Moderate and High ASRP scenarios are likely to result in substantial positive outcomes for the range of aquatic species identified for the ASRP. These outcomes will be assessed in greater detail for these other native species during the full ASRP development. Expected outcomes for native species other than salmonids are identified in Table 4-2, based on the anticipated restoration and protection of riparian corridors and the reconnection and restoration of floodplain habitats, including wetlands. Because data are limited relative to populations of these other species, outcomes in Table 4-2 should be interpreted as general outcomes of both the Moderate and High scenarios.

Table 4-2
Expected Outcomes for Native Species

NATIVE FRESHWATER FISH	EXPECTED OUTCOMES
PACIFIC LAMPREY AND OLYMPIC MUDMINNOW	
Abundance	Densities of individuals in occupied sites would be maintained or increased within 10 years of implementing initial restoration efforts.
Spatial Distribution	The number of occupied sites would be maintained or increased within 10 years of implementing initial restoration efforts.
BULL TROUT, CUTTHROAT TROUT, EULACHON, MOUNTAIN WHITEFISH, LARGESCALE SUCKER, RIFFLE SCULPIN, RETICULATE SCULPIN, AND SPECKLED DACE	
Spatial Distribution	The number of occupied sites would be maintained or increased by mid-century.
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 by 10% through ASRP actions within 10 years of implementing initial restoration efforts.
Capacity	The area of Oregon spotted frog-occupied freshwater wetlands would be increased by 10% through ASRP actions within 10 years of implementing initial restoration efforts.
Spatial Structure	At least three Oregon spotted frog secured and managed populations (≤100 egg masses) would be increased to consistently exceed 500 egg masses within 10 years of implementing habitat restoration.

WESTERN POND TURTLE	
Spatial Distribution	One occupied, secured, and managed site would be established through ASRP actions within 15 years of implementing initial restoration efforts.
WESTERN TOAD, NORTHERN RED-LEGGED FROG, LONG-TOED SALAMANDER, COASTAL TAILED FROG, AND VAN DYKE'S SALAMANDER	
Abundance	The densities of these amphibians would increase in at least five occupied, secured, and managed sites for each species within 10 years of implementing initial restoration efforts.
Spatial Structure	The number of occupied, secured and managed sites for these amphibians would increase within 10 years of implementing initial restoration efforts.
MAMMALS	**EXPECTED OUTCOMES**
BEAVERS	
Abundance	The number of beaver-occupied, secured, and managed reaches would increase by 10% through ASRP actions within 10 years of implementing initial restoration efforts.
Spatial Structure	The area of beaver-occupied freshwater wetlands would increase by 10% through ASRP actions within 10 years of implementing initial restoration efforts.
INVERTEBRATES	**EXPECTED OUTCOMES**
WESTERN RIDGED MUSSEL	
Spatial Distribution	The number of Western ridged mussel-occupied, secured, and managed reaches would increase by 10% through ASRP actions within 10 years of implementing initial restoration efforts.

4.5 Uncertainty and Variability

Scientific and other uncertainties are inherent in ecosystem restoration. Natural variability in watershed and ecological processes makes predictions of responses to restoration actions uncertain. Biological responses, such as salmon performance, are subject to large natural fluctuations produced by external factors (such as ocean conditions) and complex interactions within the Basin's aquatic ecosystem. (Refer to the Scientific Foundation in Appendix A for additional detail on the high degree of natural variability and knowledge uncertainty in restoration planning.)

Uncertainty refers to a lack of information, unreliable data, or an incomplete understanding of the variables and context. Uncertainty can be reduced, or sometimes eliminated, by gathering more information.

Variability refers to the range of results seen when evaluating present or historical conditions or when modeling future conditions. Variability cannot be reduced, but it can be defined at a finer scale through additional evaluation.

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 monitoring and adaptive management program, which will be developed in the full ASRP during 2018.

Uncertainties in this initial document include the following:

- The timeline and scale of response of habitats to restoration actions
- The biological and physical responses of species to environmental changes
- The voluntary participation of public and private landowners
- The effects of additional future degradation and other actions in the Basin
- The input data and conceptual assumptions in the EDT model

It is important to note that that the EDT modeled outcomes do not include assumptions about the timeline for implementation of ASRP actions. The longer the timeframe for ASRP implementation, the longer it will take to achieve the outcomes. The model also does not account for additional degradation from present-day conditions (except from climate change); if additional impacts to Basin conditions occur to change the baseline before ASRP implementation, the expected outcomes of ASRP actions will also change. Further, the success of the ASRP is dependent on the voluntary participation of public and private landowners to achieve the substantial outcomes needed. The sequence, timing, and pace of implementation will be accounted for during full ASRP development in 2018.

As noted above, salmon populations experience natural inter-annual variability, and biological responses are subject to a high degree of natural fluctuation. Figure 4-6 shows an example of how the coho salmon population has fluctuated in the recent past. This shows how salmonid populations can vary dramatically year-to-year, which results in a range of expected outcomes from the EDT model for each scenario. Thus, it is important to understand that the percentages shown in Figures 4-1 through 4-5 represent averages to be expected over time, but are presented as single numbers for simplicity of analyzing the scenarios in this initial document.

Figure 4-6
Illustration of Variability in Populations

4.6 Associated Costs

For this initial document, preliminary cost estimates were developed for the actions identified in Section 3. The Steering Committee and Science and Technical Review Team both reached agreement on the methodology used to identify unit cost assumptions and general levels of treatment for the various restoration actions to significantly improve function. 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 Basin. Descriptions of the costs for the major strategies and actions are summarized in Sections 4.6.1 and 4.6.2. More detail is provided in Appendix B.

4.6.1 Capital Costs

4.6.1.1 Restoration Costs

Restoration unit costs were developed based on the range of estimates and actual costs from recently constructed similar projects in the Chehalis Basin and similar rural watersheds. The unit costs include construction of the restoration elements, purchasing easements or land acquisition, design, permitting, sales tax, and a contingency percentage. The unit costs were then applied to the actions and the rate of treatment for each feature (as shown in Table 3-1). The rate of treatment was recommended by the Science and Technical Review Team based on literature regarding recommended riparian corridor widths to achieve habitat, water quality, and other functions and natural wood loading rates (also see Appendix B).

The range of costs for each restoration scenario is shown in Table 4-3. 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 management of invasive species, plantings, and limited 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 4-4 provides a more detailed delineation of costs per element for each restoration scenario.

Table 4-3
Range of Costs for Restoration Scenarios

RESTORATION SCENARIO	MILES OF CHANNEL RESTORED	RIPARIAN AND FLOODPLAIN ACRES RESTORED	COST RANGE		
			LOW	AVERAGE	HIGH
Moderate	300	11,700	$440,000,000	$603,000,000	$789,000,000
High	500	20,700	$685,000,000	$979,000,000	$1,300,000,000

Table 4-4
Cost Elements of Restoration Scenarios

RESTORATION ELEMENTS	COST RANGE	
	LOW	HIGH
MODERATE SCENARIO		
Large Wood	$41,900,000	$58,400,000
Riparian Plantings	$66,800,000	$93,500,000
Riparian Easements/Acquisition	$64,200,000	$174,100,000
Floodplain Restoration	$42,100,000	$71,400,000
Associated Design and Construction Costs[1]	$112,400,000	$281,100,000
Fish Passage Barrier Removal[2]	$110,000,000	$110,000,000
TOTAL	**$437,400,000**	**$788,500,000**
HIGH SCENARIO		
Large Wood	$71,200,000	$99,400,000
Riparian Plantings	$120,000,000	$168,000,000
Riparian Easements/Acquisition	$119,400,000	$320,100,000
Floodplain Restoration	$68,100,000	$115,600,000
Associated Design and Construction Costs[1]	$196,500,000	$492,900,000
Fish Passage Barrier Removal[2]	$110,000,000	$110,000,000
TOTAL	**$685,200,000**	**$1,306,000,000**

Notes:
1. 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
2. Cost for removal/replacement of up to 400 fish passage barriers

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 an increased risk of extinction of salmonids in the Basin or reductions in commercial and recreational fisheries as fish populations decline.
- The restoration costs are conservatively high at this conceptual stage and could change for the full ASRP. (Prioritization of sub-basins, reach-scale assessment, and riparian corridor width development will be developed relative to actual conditions for the full ASRP.)
- Sequencing and timing of restoration actions has not yet been developed, 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 ASRP.

4.6.2 Ongoing Annual Costs

In addition to capital costs used to design and construct restoration elements of the ASRP, there will be ongoing annual costs for implementing the community planning, institutional capacity, community involvement, and habitat and process protection strategies. 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 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 annual funding will be required.

4.6.2.1 Adaptive Management Costs

A detailed adaptive management plan and process will be developed for the full ASRP, but for this initial document, the Science and Technical Review Team has recommended that a preliminary cost of $4 million per year be identified for monitoring and adaptive management costs. Monitoring would likely be more intensive for the first 10 or more years for adaptive management, but aquatic species population monitoring would continue through the life of the ASRP, to document if the scale of expected outcomes is being achieved. The adaptive management process will guide the implementation, monitoring, and possible further actions that could be required to ensure the success of the ASRP.

4.6.2.2 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, and the state. Ongoing management and stewardship of these lands will be required, such as invasive species management, fencing, and maintenance. For other restoration features, such as replaced culverts or bridges, inspections and maintenance would need to be conducted periodically. Stewardship and maintenance costs will vary depending on the acreage acquired and quantity of other restoration features installed. 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 initial document, this cost has been estimated at $2 million per year. These costs will be refined for the full ASRP, including amortization of costs over the life of the ASRP.

4.6.2.3 Protection Costs

The protection strategy is likely to include several potential elements that will help to protect water quality and quantity, habitats, and watershed processes. Protection could occur via actions such as incentives to landowners to provide stewardship of forest and aquatic species habitats, programs that protect and enhance river and stream flows, acquisition of easements or lands to protect existing high-quality habitats and functions, and enforcement of floodplain and critical areas ordinances. This cost has been estimated at $1 million per year.

4.6.2.4 Planning, Institutional, and Community Involvement Costs

The planning, institutional, and community involvement strategies will support state and local planning, regulatory, and other local organizational capabilities to manage and monitor natural resources consistent with the ASRP. The anticipated costs for these types of actions are estimated at $2.5 million per year.

Table 4-5 summarizes the potential ongoing annual costs for the ASRP. Whether the Moderate or High 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.

Table 4-5
Summary of Ongoing Annual Costs

STRATEGY	ANNUAL COST
Adaptive Management	$4 million
Restoration Stewardship and Maintenance	$2 million
Protection	$1 million
Planning, Institutional and Community Involvement	$2.5 million
TOTAL	**$9.5 million**

5 SUMMARY OF OUTCOMES AND CONSIDERATIONS

Future human population growth, climate change, and resource use will continue to negatively impact aquatic species. The expected outcomes in Section 4 from the EDT model show that with no action and habitat modification from anticipated future climate change, salmonid populations would decline significantly, particularly spring Chinook salmon. It is anticipated that the average returns of spring Chinook salmon would decline by an additional 50% by the end of the century, which would increase the risk of extinction. Returns may be even lower in some years due to variability in environmental conditions. On average, the annual returns of coho salmon, fall Chinook salmon, and steelhead would decline by 20% to 30% by the end of the century. Other aquatic species are expected to similarly decline with no action. The No Action scenario is not consistent with the ASRP vision and is not an option if the Chehalis Basin Board wants to maintain sustainable populations of salmon, steelhead, and other aquatic species in the Basin.

Taking action under either the Moderate or High scenarios would result in substantial positive outcomes for salmonid and other aquatic species and natural processes by the end of the century, even with anticipated climate change conditions. Spring Chinook salmon could increase by a range of 300% (Moderate scenario) to more than 500% (High scenario) and coho salmon could increase by 120% (Moderate scenario) to 180% (High scenario), as compared to the No Action scenario. The outcomes shown in Section 4 do not include the expected benefits to commercial and recreational fisheries, increased education and recreation opportunities, and other economic development factors that could accrue from ASRP actions. Improvements to ecosystem services such as water quality and quantity—particularly benefitting low flows as a result of increased floodplain groundwater recharge and storage—are not quantified in this initial document, but are anticipated.

> To guide continuing analysis and further development of the ASRP, the following decision will need to be made:
>
> **What level of ASRP outcomes are desired and what corresponding level of investment should be made in aquatic species restoration?**
>
> This decision could be at the levels presented in the Moderate or High scenarios in this initial document, or at a different level. A lesser amount of restoration (below the Moderate scenario) might not result in sustaining salmonid populations into the future.

The estimated capital cost range is $400 million to $800 million for the Moderate scenario and $700 million to $1.3 billion for the High scenario. The ongoing annual cost for either scenario would likely be up to $9.5 million in the first one or more biennia, reducing over time. The actions assessed in the scenarios include removal of fish passage barriers, placement of large wood and log jams, planting native riparian trees and shrubs, reconnecting side channels and wetlands, and enhancing amphibian habitats. The largest cost in these estimates is compensating willing landowners for participating in the restoration plan. The Moderate scenario estimates the need to restore up to 11,700 acres of riparian corridor and floodplain habitat and the High scenario estimates up to 20,700 acres.

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Appendix A
Scientific Foundation for the Aquatic Species Restoration Plan

1 INTRODUCTION

This document provides a high-level description of the scientific foundation that undergirds the development of the Chehalis Basin *Aquatic Species Restoration Plan* (ASRP). The scientific foundation is the set of science-related principles, assumptions, concepts, and primary approaches used in developing the scientific conclusions that inform the decision-making process. Clarifying these elements as a foundational piece to the ASRP will foster a greater understanding of the rationale for various parts of the plan and how the plan is being developed. The scientific foundation helps ensure that the parts of the plan work cohesively together to produce a credible, well-integrated, internally consistent ASRP.

This document will inform the many participants in the ASRP about the foundational elements applied in the plan's development. It is written to be readable by the full range of participants, including policy-level decision makers, restoration practitioners, key support staffs, scientists, land managers, and stakeholders in the Chehalis Basin.

For the ASRP to succeed, it is imperative that it is guided by the best available science. Science as defined here includes: 1) the body of knowledge about one or more topics; and 2) the formal process of collecting information upon which a body of knowledge is based. Scientific information, along with other forms of information (e.g., economic and social) are needed to inform decision making. The decisions that steer the ASRP, as well as the broader Chehalis Basin Strategy, are made by the policy representatives for the parties to these efforts. Ultimately, those decisions will be based on various, frequently complex considerations.

The scientific foundation was developed recognizing the long-term vision of the ASRP for the Chehalis Basin. The ASRP vision is to provide for a future where the Chehalis Basin can support healthy and harvestable salmon populations, robust and diverse populations of native aquatic and semi-aquatic species, and productive, self-sustaining ecosystems that are resilient to climate change and anthropogenic stressors, while also honoring the social, economic, and cultural values of the region.

The ASRP is an ecosystem restoration plan. It aims to restore natural ecosystem processes and related habitats in the Chehalis Basin on which the native aquatic and semi-aquatic species depend. While the plan has a broad ecosystem perspective, it incorporates use of native indicator species to assess biological response to the restoration measures. These indicator species include salmon species, several amphibian species, and other species including birds and beaver. It bears noting that salmon are also highly valued both culturally and economically to human communities, especially to Native Americans. The two Indian tribes in the Basin—Chehalis and Quinault, like other Northwest tribes—have always seen the salmon as the symbol and lifeblood to their way of life (Capoeman 1990; Deloria 2012).

The overarching premise of the ASRP is that ecological processes and functions within the Chehalis Basin can be restored to support and sustain productive, diverse native aquatic species populations. Within this premise, it is understood that the ASRP must be based on sound restoration 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 watershed changes that began in the mid- to late-19th century.

The premise asserts that ecological processes and functions can be restored to a level sometimes referred to as "normative conditions" (Stanford et al. 1996; Liss et al. 2006)—that is, a partially restored state exhibiting the norms of conditions needed to support and sustain productive native species assemblages. 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 to both ensure viability and deliver ecosystem services. Under these conditions, both natural and cultural elements exist in a balance, supporting diverse native aquatic populations while society's present uses of the watershed continue, although not without modification (Liss et al. 2006). The mix of natural and cultural elements to be achieved is to be defined through policy-driven goals and objectives.

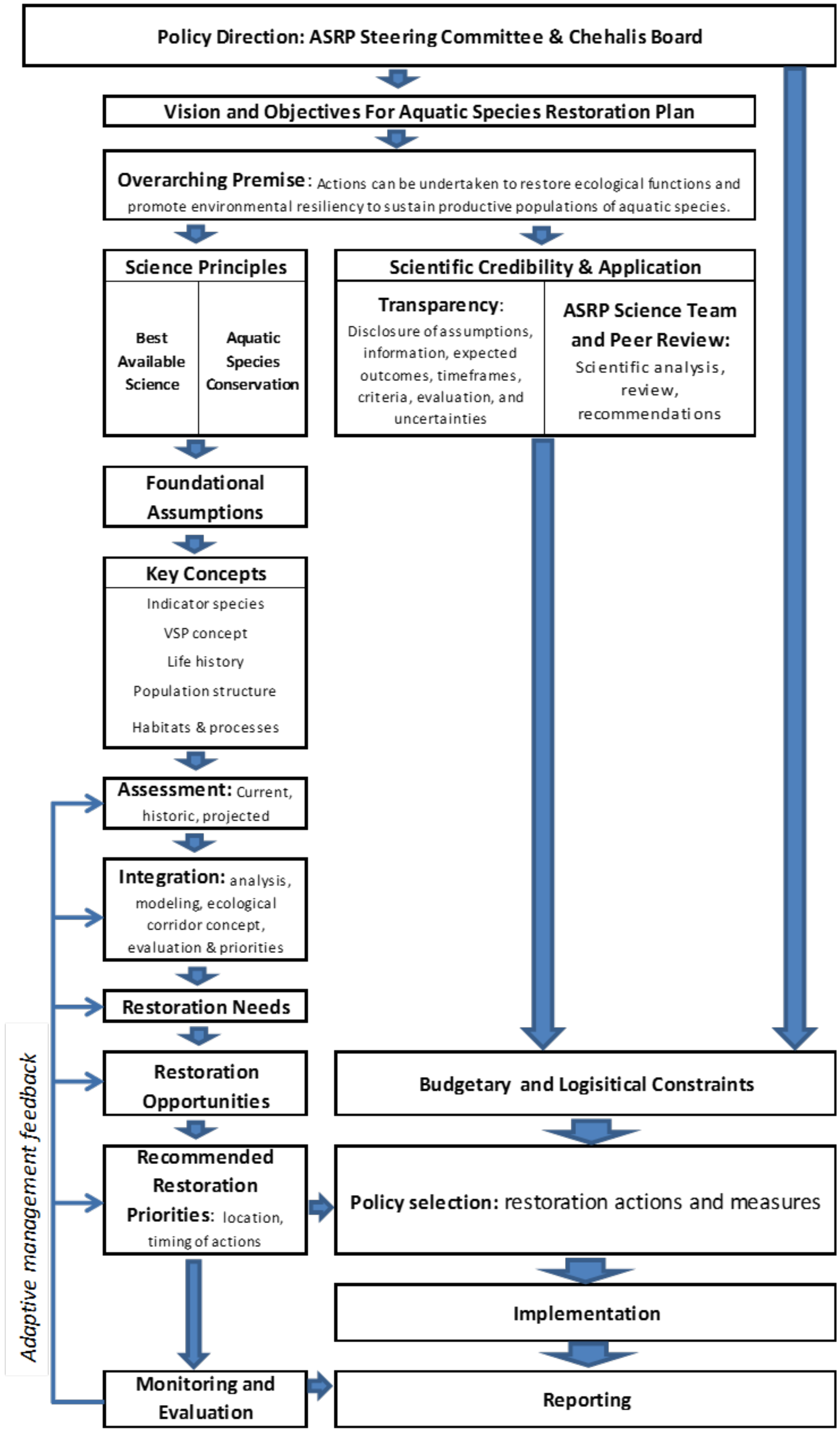
The scientific foundation needs to be seen as part of a framework in which the ASRP would be implemented and updated through time, illustrated in Figure A-1. The top three boxes in the figure identify policy direction within the plan, which sets forth the vision and objectives, and the overarching premise. The left side of the framework represents the elements of the scientific foundation, as described in this document. The right side represents the application of these elements through a process that involves the Science and Technical Review Team, the selection of restoration actions for the plan by the Steering Committee and Chehalis Basin Board, the plan's implementation, and reporting of results. Ongoing monitoring and associated adaptive management provide feedback and adjustment to the plan into the future.

It should be understood that 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, and similarly reference to aquatic species includes semi-aquatic species.

This document is organized into the following sections:

1. Introduction
2. Foundational Principles
3. Foundational Assumptions
4. Foundational Concepts
5. Basis for Developing Strategies and Actions
6. Adaptive Management, Monitoring, and Evaluation
7. Planning for Scientific Credibility

Figure A-1
Application Framework for the Scientific Foundation as Part of the ASRP



2 FOUNDATIONAL PRINCIPLES

Principles guide conduct, and they are generally seen as fundamentally true. The scientific principles on which the ASRP is based are grouped into two sets. The first set consists of those that govern scientific practice and the pursuit of knowledge necessary for developing, evaluating, and updating the ASRP. The second set consists of fundamental conservation principles recognized in fish conservation and restoration ecology (Williams 2006)—these are foundational to developing the ASRP.

For the ASRP to be successful, 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 management of the ASRP, including its development and future updates. Relevant science is not done in a vacuum. The challenges of reversing declines of native aquatic species, then restoring them, require advancing our 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 the democratic political process, working together, are both essential for effective, sustainable management of natural resources like wild salmon (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.
- **Criteria for evaluating effectiveness:** Criteria and measures to evaluate the effectiveness of the restoration plan (or its components) need to be provided.
- **Timeframes for outcomes made explicit:** Expected outcomes, including restoration time, need to be made explicit. Process-based restoration is inherently a long-term endeavor with long lag times between restoration projects implemented, maintenance of those projects through time until processes are restored, and realization of benefits (after Beechie et al. 2010).

Conservation related principles address restoration-focused concepts of aquatic ecosystems like the Chehalis River system. 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 originally 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 principles, listed below, are adapted from Williams (2006) and Lichatowich et al. (2017):

- **Defining the ecosystem:** Restoration and management of wild, native aquatic species must address their extended ecosystem defined by their entire life history. This consideration includes where life histories are affected by human development, as well as within habitats largely unaltered by humans.
- **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 in freshwater, estuarine, and ocean environments.
- **Importance of diversity:** Genetic, life history, and population diversity are the basis of native wild aquatic species sustainability over time, as demonstrated for wild salmon. Diversity contributes to the ability of these species to cope with environmental variation typical of freshwater and marine environments. Habitats are the templates that organize life history traits (Southwood 1977) and similarly influence genetic structure (Waples et al. 2001).
- **A public and treaty trust:** We have a collective 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 and applying it often relies on the use of assumptions about the systems involved. Some of these assumptions are inferences based on established knowledge or a body of related observations. Other assumptions are basic, but are generally accepted within the relevant discipline.

The scientific foundation for the ASRP makes explicit a set of ten 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 should shape the ASRP and guide the selection and extent of restoration measures. Certain assumptions can be formulated as hypotheses that can and will be tested as part of the ASRP. This implies that these assumptions may evolve over time as new information is developed. Some of the key concepts applied in developing the ASRP, which are described in the next section, are related to these assumptions. The descriptions of those concepts provide further explanation for some of the assumptions.

The ten foundational assumptions are:

1. The viability and performance (e.g., abundance) of native aquatic species are controlled to a large degree 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. Certain aquatic 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, habitat conditions important to salmon species, such as streams and riparian wetlands, are critical to many other native aquatic species.
3. The abundance, productivity, and spatial distribution of many native aquatic species in the Chehalis Basin have declined as a result of environmental changes due to urbanization, agriculture, timber harvesting, channel and floodplain modifications, dam construction, and the spread of invasive plant and animal species.
4. Climate change will affect temperature, precipitation, 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, which may jeopardize the continued existence of some species.
5. Future human development of the Chehalis Basin will further degrade habitat conditions and further diminish the performance of native aquatic species.
6. Restoration actions, including engineering of specific environmental conditions, can improve watershed and ecological processes and moderate the detrimental effects of climate change and past, current, and future development.

7. Historic conditions, when well 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.
8. If restoration actions are to be successful 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.
9. To be effective and long-lasting, restoration must be directed at 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 species.
10. Abundance of native aquatic species is controlled by 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 the quality of habitat will be more useful than those that address the quantity of habitats, unless the actions open access to high quality habitat.

4 FOUNDATIONAL CONCEPTS

4.1 Indicator Species

The shift toward ecosystem-based management that occurred in recent decades was a move away from a conventional single species approach to a whole system, multi-species framework (Grumbine 1994). This shift posed a problem: How do we assess the condition of ecosystems, given their inherent complexity? The use of appropriately selected indicator species provides a way of addressing the problem (Soule 1987; Karr 1992; Siddig et al. 2016). Indicator species are a necessary 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 indicator species are ones that, because of their habitat utilization patterns or life histories, represent particular species assemblages or communities and that 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, in particular 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 eight criteria that can avoid most criticisms when using indicators; these are:

1. Clearly state your assessment goals.
2. Use indicators only when other assessment options are unavailable.
3. Choose indicators by explicitly defined criteria in accord 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 that incorporates concepts from landscape ecology.

The criteria of Landres et al. (1988) were used in selecting and applying indicator species to develop the ASRP. The overarching assessment goal is to identify positive changes in species responses to the ASRP's broad-based restoration effort. We avoid the further issues of having only one indicator species by selecting a suite of indicators under a selection 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 2014a). 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, etc.); had some local, state, or federal listing status; cultural or economic importance and an ability to engineer habitat (specifically for North American beaver).

The ASRP indicator list is more encompassing than the key species list in the ASEP in that it also includes indicator birds, and one invertebrate, the Western ridge mussel; but selection basis for these taxonomic groups was the same as described above. Inclusion of the Western ridged mussel reflects a link to salmon species, on which its early life stages necessarily depend.

The indicator species suite for the ASRP and basis for their determination are listed in Attachment 1.

4.2 The Viable Salmonid Population Concept

The Viable Salmonid Population (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 the theoretical basis for describing salmon performance as it relates to long-term viability. In Endangered Species Act (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 gives a powerful way to analyze 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 helps to evaluate projected changes to future salmon population performance in response to restoration or further habitat degradation. Analytical models are used for this purpose.

The VSP concept is incorporated into ASRP as a way to characterize salmon performance in the Chehalis Basin under past, current, and future habitat conditions. This serves to apply a conceptual basis for

[1] In ecology, a guild is a group of species that exploits the same kinds of resources in comparable ways.

assessing salmon population performance that is widely understood and employed throughout the Pacific Northwest for salmon restoration work.

The four VSP characteristics (or parameters) are abundance and productivity among the populations that are produced in the geographic area of interest, biological diversity within and among the populations, and spatial structure of the populations within the relevant geographic area (McElhany et al. 2000).

All four of the VSP characteristics are 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.

Table A-1
Definitions of the Characteristics (Parameters) Used to Assess the Performance of a Viable Salmonid Population

VSP CHARACTERISTIC OR PARAMETER	DEFINITION
Abundance	The abundance of the adult population. 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. Relevant distribution includes the areas of spawning can also include the distribution of juveniles.

- **Abundance** is the size of a population, a subpopulation, or other relevant demographic unit. Small populations are at greater risk of extinction than large populations and provide less 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, <u>not</u> habitat quantity, determines intrinsic productivity. Improvements made in habitat quality in any life stage will benefit intrinsic productivity and also 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 provide 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** describes foremost how the spawning population is distributed, but also considers the dispersal and distribution of progeny. Spatial structure is a geographic analogue 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 an important question in developing 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? If the goal is simply to increase the total abundance of salmon in the Chehalis Basin, then restoring core production areas may be the best approach.

Such an approach would ignore the need to also consider spatial structure of the aggregate population for a species in the Basin (referred to as the metapopulation). Put simply, the question is how to balance the need for abundance versus diversity (or spatial structure)? Both are important to achieve the long-term vision for the Basin. The ASRP needs to consider a balance between these different aspects of population performance. However, if a particular species is at elevated risk of extinction, as spring-run Chinook salmon may be, particularly considering climate change, then it becomes more important to strengthen the core production area.

Analytical models are used to evaluate metrics for assessing changes in VSP characteristics under different possible scenarios considered under the ASRP. See Attachment 2 for further discussion on the abundance and productivity parameters.

4.3 Life History

Restoration activities need to take into account the full life history of indicator species (Lichatowich et al. 1995). Life history is the entire sequence of events related to survival and reproduction that occur from birth through death that encompasses all the life stages of a species. 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 their life history, the species

[2] There are certain situations where an increase in abundance will not occur, but this will typically not apply to this discussion.

encounters widely varying habitat conditions that ultimately determine the abundance and persistence of the species.

Species life histories have evolved to exploit a range of expected habitat conditions. The life history of individuals within a single population of a particular species can vary tremendously due to differences among individuals in where, when, and how they respond to environmental factors. Populations from different parts of the geographic range that a species inhabits may exhibit marked variations in their life histories.

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 greatly between the life stages of a single species, as can the potential effects of habitat degradation or restoration. The response of a species to either degradation or restoration, therefore, needs to be understood both at a life stage level and across the full life history.

Analytical models that include life stage responses as well as performance of a species across the full life history are useful for 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).

4.4 Population Structure

Animal populations typically are structured spatially across the landscape. This distribution reflects selection of key habitats by different life stages as well as natural and artificial impediments to movement of species life stages. This structure is important to recognize in an effort like the ASRP as it has implications for where the plan should give attention, both for restoration and protection.

Across a geographic area the size of the Chehalis Basin, species like salmon usually demonstrate substantial genetic and life history variation within a single species (Waples et al. 2001; Waples et al. 2008). 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 Basin is essential for both conservation and management (Allendorf and Luikart 2007). We note that the Washington Department of Fish and Wildlife (WDFW) is currently engaged in assessing the genetic structure of the dominant salmon species in the Chehalis Basin; some initial results will be reported at the end of September 2017.

While genetic studies remain underway, the diverse nature of sub-basins in the Chehalis Basin suggests that significant genetic structure should exist within the different salmon species. Lacking definitive genetic data, a surrogate approach to assess population structure is to recognize 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 the size of Chehalis 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).

4.5 Habitats

In its simplest definition, the habitat of an organism is where it lives. But a more complete definition is necessary for our purposes. 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 of 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—as well as seasonally due to changing conditions by season. Habitats are the key determinants of the performance of a species, 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]

Aquatic habitat within a watershed is created, maintained, and renewed by watershed processes that operate across various time and spatial scales (Benda et al. 1998; Waples et al. 2009; Beechie et al. 2010). Over long timescales (tens of thousands of years), glacial 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).

With the rapid alteration of watersheds due to human development activities, watershed processes were altered outside the range of natural variation. Habitat conditions that had been more or less stable were changed, typically in ways that adversely affected the abundance and survival of native aquatic species, like salmon (Beechie et al. 2003).

[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.

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 perceived to be 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 resulting from logging or urbanization, and attempt to restore these processes. The two approaches are not antithetical. 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 reestablish 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 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 remaining altered from pre-development conditions (Beechie et al. 2010).

Process-based restoration is not a simple affair. 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.

An important consideration in developing a restoration plan is recognizing the different ways that habitat quantity, quality, and distribution within a watershed affects species performance. Two questions are critical to consider:

- Is it better to have a <u>greater quantity</u> of habitat or <u>higher quality</u> habitat relative to the current condition?
- <u>Where</u> should restored conditions to habitat be located in a watershed: high in the watershed, low in the watershed, in small streams, in large streams, or within the floodplain (such as off-channel habitats)?

The short answer to both questions is: it depends on the situation. Questions like these are essential to consider in developing an effective 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.

- 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 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 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.

  Other aspects of habitat quality should be understood (see 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), such as occurs when a species when is 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 development 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

[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).

freshets or periods of extreme temperatures, is an aspect of habitat quality. In these cases, the probability of individual animals finding the habitat being searched for can have a strong effect on survival and population performance. Well distributed habitats that act as refugia increase survival; shortage of refugia or when an animal needs to move long distances to locate a habitat type may decrease survival (Soto et al. 2016).

The quantity or quality issue raises a question about reconnecting habitats by removing blocking culverts. 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).

Attachment 2 describes an analytical tool that accompanies this document to help the reader understand the different effects of habitat quantity and quality on salmon performance. A user-friendly Excel application is available to be used by the reader.

[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 strategies and types of actions that are incorporated into the ASRP and approaches being used to prioritize them for the plan.

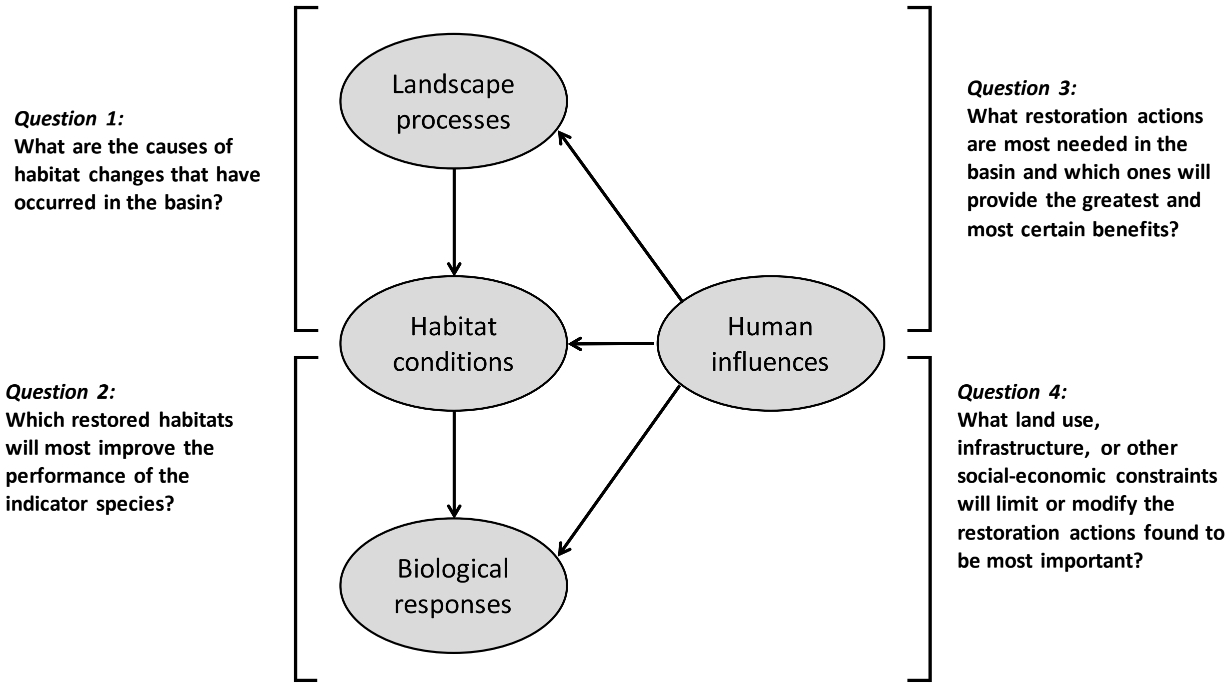
5.1 Assessment of the Aquatic Ecosystem

The restoration plan needs to be based on an assessment of the condition of the aquatic ecosystem we seek to restore to a more productive, sustainable state. The assessment is the diagnosis of what prevents us from achieving the vision of the plan. Without a diagnosis, we have an inadequate understanding of what watershed processes and habitat conditions need to be addressed in the plan. In colloquial terms, the diagnosis asks: What's broken and what needs to be fixed?

The restoration strategies that are implemented need to focus on key cause-effect linkages between watershed processes, habitat conditions, and biological responses of the indicator species, illustrated in Figure A-2. The figure, modified from (Beechie et al. 2013), is organized around 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 and not merely symptoms of those causes.
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 be included in the restoration plan.
4. What land use, infrastructure, or other social-economic 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. This question is not answered by scientists. Policy-related decision makers and related governing bodies are responsible, though informed with the answers to the other questions.

Figure A-2
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



Note: 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). The underlying assumption for this is that the intrinsic conditions of the Chehalis Basin and its habitats have been determined by natural geologic, climatic, and biogeographic interactions over the millennia. Before extensive human-caused disturbance, the aquatic environment had natural—or intrinsic—limitations on what it was capable of producing.

The performance of salmon populations and other species were limited by those intrinsic conditions. The goal of restoration is not to restore the watershed to its intrinsic conditions, which is not possible. Restoration aims to restore some part of the lost intrinsic potential in ways consistent with achieving the vision for the ASRP.

The diagnosis assesses the extent of changes that have occurred to aquatic habitats from their intrinsic state and how these changes have impacted aquatic species performance and proceeds through four steps, described below.

Step One is to assess (or reconstruct) the 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 Lands 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 functioned compared to how it functions today.

An initial reconstruction of historical habitat conditions for the entire Chehalis Basin was done by Mobrand Biometrics (2003). The historical reconstruction has been substantially updated and improved in recent work as part of the development of the Chehalis Basin Strategy by ICFI, Inc., Natural Systems Design, Inc. (NSD), and NOAA Fisheries; this work will be refined further in late 2017.

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. 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, and NSD, as described in McConnaha et al. (2017a). Additional assessment work on current conditions has been performed by NOAA Fisheries.

Step Three in the diagnosis procedure 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-2). 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 Basin. For example, almost all stream channels of the Chehalis Basin have undergone large wood removal. Wood not only traps alluvial sediment, but it partitions shear stress within the stream system, which reduces sediment transport capacity. Wood removal leads to bed coarsening (e.g., 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 (e.g., 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 watershed.

Analytical models are used in Step Three to quantitatively assess the relative impacts to salmon species performance by the changes in from historic to current condition habitats. The models provide the means to perform quantitative limiting factors analysis, enabling identification of the habitat factors (or stressors), and their geographic distributions, that have the greatest impacts on salmon performance.

[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.

A high-level example of a diagnostic procedure applied to the Chehalis Basin is given in Attachment 3. 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 questions: 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 above. To apply the framework, it needs to be expanded and reformulated into a spatially explicit format covering all geographic areas of the Chehalis Basin. This could then be used to identify the relative extent that each issue is relevant in each geographic area (using a simple scoring system). This kind of an approach can be useful in developing the spatially explicit diagnosis and in conveying conclusions (i.e., hypotheses).

It bears noting that a **Step Four** in the diagnostic procedure provides the means to assess the future expected impacts of climate change on aquatic habitats and salmon performance (McConnaha et al. 2017a). Projected increases in water temperature and peak winter flows, as described in McConnaha et al. 2017a, 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.

5.2 Strategies and Actions

The restoration plan consists of a set 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 for the plan. A strategy is usually composed of 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. The same categories and descriptions were employed in WDFW's "*Stream Habitat Restoration Guidelines 2012*" (Cramer 2012, see Chapter 4).

Table A-2 summarizes the four categories of strategies along with abbreviated descriptions of strategies and commonly applied actions that comprise them. The table is based largely on how the categories are presented in Cramer (2012) with some adaptations here in an attempt to distinguish more clearly differences among the categories.

Table A-2
Strategy framework identifying the major categories of protection and restoration strategies

PROTECT HABITAT	RECONNECT HABITAT	RESTORE HABITAT-FORMING PROCESSES	RECREATE OR ENHANCE HABITAT
Purpose: Protect areas with healthy, high-quality habitat (strongholds, refugia, and key sub-watersheds) to prevent further degradation. Secure, expand, and link protected areas. Dedicating land or water for stream conservation or restoration requires the integration of conservation planning with legal aspects of land ownership, land use, and water rights (Cramer 2012) • Land acquisition: Acquire and dedicate land in strategic locations to protect existing high-quality habitats from future degradation. • Conservation easements: Establish strategically located conservation easement to protect existing high-quality habitats from future degradation. • Zoning or regulatory: Enact regulatory reforms to recognize and protect high quality habitats of critical importance to key aquatic species. • Purchase or transfer of water rights: Purchase or provide incentives for dedicating existing consumptive water rights for conservation purposes. It should be noted that protection does not address changes upstream or downstream of a site that has been set aside for protection. Channel incision, for example, can propagates into a protected area and severely impact the site. Also, large increases in peak flows due to upstream watershed alterations, such as urbanization, can impact a protected site. Land disturbance increasing or decreasing sediment supply can also impact a protected site. Thus, an action to protect a site should include some form of active restoration if deemed needed, such as wood loading.	Purpose: Connect and provide access to isolated habitat, including instream, off-channel, and estuarine habitat made inaccessible by culverts, levees, or other man-made obstructions. Physical barriers to fish passage are only considered here. Processes of energy and nutrient flow are considered under habitat forming (and maintenance) processes. • Dams: Dam removal or provide for fish passage at the dam. • Culverts: Culvert removal or culvert upgrades to provide unimpeded passage. • Levees: Levee removal or levee breach for fish passage. • Floodplain fill: Remove floodplain fill (such as roadways or other sources of fill) blocking access to off-channel habitat. • Reconnect side-channels or off-channels: Reconnect historic side channel complexes or off-channel habitats that had become disconnected due to past floods or land use. • Incision: Restore channel bed elevation that has cut off access to tributary or off-channel habitat (e.g., placement of large wood to accumulate sediments and restore bed elevation). • Bank stabilization structures: Remove streambank stabilization structures blocking access to off-channel habitat. • Tide gates: Tide-gate removal or upgrade to improve fish passage.	Purpose: Employ land use recovery and watershed restoration actions to restore watershed and ecological processes that create, maintain, and connect habitats, including restoration of sediment dynamics, large wood dynamics, flow regimes, adequately sized healthy riparian zones, floodplain connectivity, water quality, and channel evolutionary processes. • Restore sediment supply and transport to conditions more like historic patterns: Excess sediment - Upland forestry and agricultural BMPs to reduce elevated rates of sediment supply; watershed assessment and diagnosis of sediment budget. Reduced sediment - Dam removal where channel sediment starved. Wood augmentation to retain sediments where supply sources interrupted. • Restore the flow regime to conditions more like historic patterns: Peak flows increased to higher than historic range – Reduce impervious surfaces, apply forest road BMPs, restore floodplain connectivity and/or CMZ. Peak flows decreased to lower than historic range – Dam removal. Low flows decreased to lower than historic range – Reduce water diversions, restore wetlands, reintroduce beavers, restore floodplain and riparian conditions. • Restore floodplain processes and function to conditions more like historic patterns: Restore floodplain connectivity and/or CMZ, restore wetlands, reintroduce beavers, restore floodplain and riparian conditions, remove streambank stabilization structures, land acquisition and conservation easements, remove roads and structures within the targeted floodplain area. • Restore riparian processes and function to those more resembling historic conditions: Restore riparian conditions with native vegetation, control invasive plants, exclude grazing by farm animals, remove streambank stabilization structures, land acquisition and conservation easements, remove roads and structures within a riparian forested corridor. • Restore instream wood load and related processes and function to conditions more like historic levels and patterns: Active placement of large wood to reactivate and reform channel conditions (such as island formation, width to depth ratios, deep pools, pool frequency, thermal refugia).	Purpose: Recreate lost habitat, modify existing habitat, or create new aquatic habitat by such measures as installing instream structures, reconfiguring channel planform, cross-section or profile, or constructing new habitat features such as side channel or off-channel ponds. • Recreate or create key habitat features: Key habitats to form are side-channels and off-channel habitats (such as overwintering ponds or spawning channels where groundwater exits-as in the Satsop). • Reconfigure channelized or simplified channels: Re-meander channels (where straightening or ditching had occurred in the past). • Enhance function of existing key habitats: Enhance cover in overwintering ponds (such as with "Christmas" tree bundles), large wood placement in channels with reduced wood loading. • Augment gravel quantities in gravel starved reaches: Add gravel to reaches that have become gravel starved due to dam operation (Wynoochee and Skookumchuck) or urbanization. • Enhance marine-derived nutrients: Add marine derived nutrients to streams where spawners have been severely diminished (as artificial supplements or hatchery carcasses). It should be noted that this category of strategies is not aimed at restoring habitat-forming processes. These strategies are generally intended to improve species performance in cases where other constraints may exist that prevent restoration of fully natural processes.

PROTECT HABITAT	RECONNECT HABITAT	RESTORE HABITAT-FORMING PROCESSES	RECREATE OR ENHANCE HABITAT
		• Restore incised channels: Active placement of large wood as above, watershed assessment and diagnosis of sediment budget. • Restore aggraded channels: Active placement of large wood as above, watershed assessment and diagnosis of sediment budget, other actions as listed for addressing excess sediment loading. • Restore water quality characteristics: Actions as listed for riparian restoration; actions as listed for increasing wood load to create more frequent thermal refuge sites along the channel; BMPs for managing agricultural, urban, and road runoff.	

Notes:
Under each category are listed common strategies (underlined) followed by types of actions that comprise them.
Table is adapted from Roni et al. (2002) and Cramer (2012; see Chapter 4).
BMP: best management practice
CMZ: channel migration zone

Certain aspects of each category bear highlighting here.

Protection: Protection of relatively intact, functioning parts of the ecosystem is often a far more cost-effective approach to conserving the integrity of biological communities than restoring an ecosystem after it has been degraded. Habitat protection helps to conserve biodiversity, reference conditions, and a source of locally derived native plants, fish, and wildlife to recolonize nearby restored areas.

Reconnect habitats: This strategy category as presented here only includes those strategies and 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 important to recognize that reconnecting habitats for fish passage may not produce desirable benefits if the habitat being re-connected is of poor quality. In that case, performance of indicator species may decline following reconnection.

Restore 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, 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. Issues causing degradation that occur at very large scales (such as at watershed or subwatershed scales) can require very extensive treatment to be effective and take long periods of time to produce substantial benefits. Other issues may occur primarily at the reach-scale and therefore may be addressed more effectively in shorter periods of time with smaller-scaled treatments.

One example of time scales with different types of treatment is useful here. Riparian 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.

The second case mentioned above is the situation that exists across managed forests in the Chehalis Basin. Policies to improve riparian buffers have been established to better enable passive restoration, but there is little scientific evidence to evaluate how well these new policies are working (both enforcement and effectiveness). 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).[7] Island and secondary channel reformation can be accelerated features that 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 large wood functions within the channel, also provide cool temperature and slow velocity refugia critically important, especially with the advance of climate change effects.

Recreate or enhance habitats: This strategy category involves restoring, creating, or enhancing specific habitat at the site- or reach-scale. It is important to recognize that this category is not aimed at restoring habitat-forming processes due generally to some constraint that exists, either human-caused or very long periods of time (e.g., centuries) needed to form these habitats. Still, in situations where population performance is severely impacted by past habitat alterations, particularly if species viability is jeopardized, these strategies can be of high importance where opportunities exist and/or where the benefits of restoring habitat forming processes are in the distant future.

It bears noting that this category of strategies has sometimes been ignored in restoration planning because it was listed as the lowest priority of strategies by Beechie et al. (2003) and Cramer (2012). It should be recognized, however, that those authors specifically stated that their prioritization was being given only as an interim recommendation when watershed-specific limiting factors information is unavailable. Moreover, in general the 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 benefits needed.

An example of potential benefits of employing this category of strategies is seen in the creation of off-channel ponds, which are used heavily when available by juvenile coho salmon. These habitats can significantly improve life cycle intrinsic productivity for coho salmon by improving overall habitat quality and diversity during winter (Lestelle 2007). Effective, low cost overwintering ponds have proven to be highly successful in rivers on the Olympic Peninsula (e.g., Cederholm et al. 1988) and in the Klamath River in Northern California (Soto et al. 2016). The ponds described in the Cederholm paper were created over 30 years and remain in good condition and heavily used by overwintering coho salmon. The importance of these ponds appears to be greatly increased in streams where natural wood loads have been reduced sharply due to logging-related activities, as seen in the Clearwater River on the Olympic Peninsula (Lestelle 2009). Large parts of the Chehalis Basin have conditions similar to those in the Clearwater River (e.g., Humptulips, Wynoochee, and Newaukum rivers).

[7] It is noted that placement of large wood into stream channels is listed in Roni et al. (2002) and Cramer (2012) as being a strategy to create or enhance habitat and therefore is given a low priority for implementation. A different perspective on importance is gained when this strategy is viewed as a way of jump-starting a key habitat forming process, particularly when seen in conjunction with riparian restoration. For this reason, it is listed under habitat-forming processes in Table A-2.

5.3 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.

Prioritization in the Chehalis Basin can be particularly challenging due to the Basin's very large size and its diverse sub-basins, which differ greatly in degree of habitat degradation and effects on indicator species. Key questions that need to be considered in prioritization include:

- What sub-basins are core production areas, or strongholds, for the indicator species being addressed? Attention should be given to ensuring that these areas continue to function in this manner in the future, particularly in the face of future watershed development and climate change.
- How should prioritization take into account the need to maintain core population areas versus the need to also maintain spatial structure of populations (i.e., population diversity and resilience)? The need to maintain or strengthen population resilience is expected to become more important with climate change.
- How should prioritization balance restoring habitat quality versus habitat quantity? This question will become more important as human development and climate change effects increase in the Basin.
- How should prioritization balance the needs of an indicator species like coho salmon that has broad distribution across the Basin and a highly sensitive species like spring-run Chinook salmon that has restricted distribution and may be subject to ESA-listing? Targeting areas that address the needs of both species may be considered.
- How should prioritization balance the need for both protection and restoration strategies? Some form of allocation of resources for each purpose might be considered.

Other questions that need to be considered as part of the overall prioritization process include action effectiveness and associated uncertainties, the time required to realize benefits (due to maturation of the action taken), longevity of the benefits of an action, scale of the action needed to address the problem, and cost. Each of these questions is relevant both in the technical (or scientific) forum and in the policy decision making process.

Roni et al. (2013) reviewed various approaches to prioritization used in restoration planning, which ranged from simple scoring procedures to the use of complex analytical models. Regardless of approach, the authors stressed that a consistent, repeatable, systematic, and well-documented approach for ranking and setting priorities was needed.

An integrated approach to prioritization is to be used for developing the ASRP. The approach will use a combination of analytical modeling and a qualitative assessment by scientists of the relative importance of different issues in the Basin. The two methods provide different ways of examining the relative needs and opportunities for restoration across the Basin, enabling the members of the science support team to bring their different areas of expertise to bear on the questions. These different perspectives, when integrated, can provide a more complete assessment of restoration needs and priorities than reliance on only one method.

Analytical models can be particularly useful in addressing ecological questions that involve large spatial scales and complex interacting components (McElhany et al. 2010). Salmon populations with diverse life histories and produced in a river basin as large and varied as the Chehalis Basin presents such a case. One of the models to be employed for developing the ASRP is the Ecosystem Diagnosis and Treatment (EDT) model (Blair et al. 2009). The model was used in the development of the Programmatic Environmental Impact Statement for the Chehalis Basin Strategy (McConnaha et al. 2017a). The model is populated with habitat characterization inputs for about 2,600 stream reaches in the Basin for both historic intrinsic and current conditions.

The EDT model is a salmon life cycle habitat model used to support watershed and salmon recovery planning. The model has been used throughout the Pacific Northwest including the Chehalis Basin. The Chehalis Basin version of the model has been developed over the past 14 years in collaboration with WDFW, the Quinault Indian Nation, other agencies, and stakeholders. The model was first developed for the Chehalis Basin in 2003 (Mobrand Biometrics 2003) with subsequent versions in 2014 and the current 2016 version (McConnaha et al. 2017a) intended to support the Chehalis Basin Strategy. The evolution of the model reflects improvements in knowledge and data and an evolving understanding of conditions in the Basin and the effects of future climate.

The model's outputs are salmon performance measures, expressed in the same terms of the VSP parameters described in Section 4.2. The model also provides quantitative limiting factors analysis for each salmon species being analyzed, identifying the relative importance of different habitat factors on performance. The limiting factors analysis gives results at various scales depending on need; for the Chehalis Basin, these scales can be at the level of the entire basin, a sub-basin (such as the Newaukum River), a diagnostic unit (such as the North Fork Newaukum River), or individual reaches. These outputs are the basis of diagnostic analysis produced with the model.

The model also provides an efficient way of ranking geographic areas (sub-basins, groups of reaches, or reaches) for their relative importance to either restoration or protection for a salmon species. The detailed reach structure within EDT gives a way to analyze geographic priorities, as well as priorities for habitat factors, for both restoration and protection actions. By systematically assuming either restored or fully degraded habitat conditions for a reach or a group of reaches and rerunning the model, changes in the performance of the species losses can be recomputed. The process is done repeatedly for all reaches or groups of reaches in the Basin. The results provide a list of priorities for both restoration and protection in the Basin relative to the species being modeled.

It is helpful to recognize how the model has been evaluated for use in prioritization. McElhany et al. (2010) performed a structured sensitivity analysis of the EDT model configured for several different sub-basins in the Columbia River Basin. Their purpose was to understand the sensitivity of the model to plausible ranges of values to the inputs to the model. They found that, as a consequence of internal parameter uncertainty, the model lacked needed precision for certain types of management applications, such as setting harvest exploitation rates. They concluded, however, that modeling outputs are robust for identifying priorities for both restoration and protection (i.e., prioritizations are relatively consistent, even in the face of sizeable input uncertainties). The authors also concluded that modeling outputs may be more useful as a relative measure of fish performance than as an absolute measure.

The second method for prioritization would engage members of the science support team to review the various watershed and ecological process-related issues and assess their likely importance to the indicator species. The procedure would allow different members of the team to examine the issues from different scientific perspectives to arrive at their conclusions about the relative importance of the issues. These perspectives, when integrated and brought together with the modeling results, can provide a more complete assessment of restoration needs and priorities than strict model reliance.

Attachment 3 provides an initial draft of a framework for the Chehalis Basin that describes the major process-based watershed and ecological issues affecting the performance of certain indicator species. 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. The framework is intended to engage the science team in clarifying the issues further as well as the flow of logic necessary to link the issues to potential solutions and actions.

The framework can be used to organize the issues spatially by sub-basins and potentially by diagnostic units identified for the Basin. Thirty-one separate sub-basins have been delineated, together with 107 diagnostic units (McConnaha et al. 2017a). A diagnostic unit is a spatial scale in the Chehalis EDT model composed of at least one, but usually multiple, reaches to form an ecologically useful component of a stream (e.g., the South Fork of the Newaukum River Diagnostic Unit).

Each sub-basin, or potentially each diagnostic unit, can be scored by members of the science team, or other knowledgeable experts on the conditions of the Basin, on the relative importance of each issue to the performance of the indicator species. This method is used commonly in restoration planning (Steel et al. 2003). The evidence and reason behind scores will be documented. All available information, including personal observations, can be used in the scoring. In addition, each score should also be given an uncertainty rating as to the level of confidence about the score (i.e., with respect to the importance of the issue to the indicator species). The results of this exercise would be used to also identify the strategies and actions that will most likely address the fundamental source of the issue. A synthesis of these conclusions would be used to help identify priority issues, geographic areas, and actions for the Basin.

5.4 Uncertainties

Scientific and other uncertainties are inherent in ecosystem restoration. Natural variability is large in watershed and ecological processes, making predictions of responses to restoration actions uncertain. 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. It is necessary to recognize the high degree of natural variability and knowledge uncertainty in restoration planning. Comprehensive discussions on managing for uncertainty are given in Beechie et al. (2003), Darby and Sear (2008), and Skidmore et al. (2011).

Only a brief listing of important aspects of dealing with uncertainty is warranted here and is as follows:

- Identify sources of uncertainty in input data, analyses, and models and strive to understand how uncertainty can be reduced, and the costs and benefits of doing so.
- If possible, estimate the magnitude of uncertainty in predictions, though this is often not possible because of the complexity of natural systems.
- Examine the consequences of uncertainties in restoration decisions, either qualitatively or quantitatively, and the significance of a range of possible outcomes.
- Clearly and honestly communicate uncertainties to decision makers and stakeholders—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 and decision makers and stakeholders (Ryder et al. 2010).

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 reasonable high confidence (low uncertainty) that the species for which restoration is targeted will respond in an expected, positive, fashion.

With the presence of invasive species (exotics), the nature of the expected response can change substantially, largely because the uncertainties in how native species may respond under such conditions. This increase in uncertainty is due to incomplete knowledge about how exotics may affect the target species. Studies that integrate the potential effects of exotics 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 exotics 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, by incorporating unmanipulated reference site or sites that are monitored in concert with the experimental site or sites. This approach would better enable gauging species response to restoration in an adaptive fashion, that is, 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.

Monitoring and adaptive management are 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 these activities in the future.

6 ADAPTIVE MANAGEMENT, MONITORING, AND EVALUATION

Monitoring and adaptive management are essential components of an ecosystem restoration initiative. Adaptive management is an iterative process of decision making in the face of uncertainty, with the intent of reducing uncertainty through monitoring, and continually moving toward a stated goal through ongoing actions informed by monitoring (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, there is no scientifically valid way of assessing progress and knowing whether investments in actions are beneficial. Well-designed monitoring should: 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.

7 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 these 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 release to the public (Brennan et al. 2003; Ryder et al. 2010).

The scientific foundation incorporates a description of the guidance, principles, and processes that are being employed to ensure that best available science is employed in the development and implementation of the ASRP. Ultimately, a high level, layperson-accessible document that describes the procedures and processes employed will offer assurance that the science underlying the development and implementation of the ASRP is solid and credible. Components of such a manual are conceptually described below:

1. Standardized terminology – e.g., habitat, acronyms, symbols
2. Mechanics for formatting
   - Style guide
   - Level of communication – dos and don'ts (e.g., use of jargon)
   - Reference citations should use a consistent style (likely the format recommended by the Council of Science Editors)
3. Scientific review guide
   - Use a format such as the U.S. Geological Survey Peer Review Checklist https://www2.usgs.gov/fsp/USGSPeerReviewChecklist.pdf
4. Context for application of the scientific foundation
   The general context within which the scientific foundation resides is schematically depicted in Figure A-1. The vision and goals for the ASRP are accompanied by a set of specific, measurable objectives for restoration. The environment and ecological processes are unstable and uncertain as they undergo constant change in response to local and global stressors. Sound science is needed to inform decision making regarding the measures and actions, evaluate effectiveness, and revise restoration objectives. This is an iterative, not a "one and done" process.
5. A set of core, high-level principles for transparency, credibility, and accountability. The following principles are provided as an example:

- Objectives must be clearly stated
- Transparency – models, methodology, and data sources must be clearly described, including selection of criteria and measures employed to evaluate performance and evaluation.
- Findings and recommendations must be supported by best available science.
- Documentation – Findings and recommendations must be clearly stated and accompanied by documentation sufficient to determine their scientific basis.
- Assumptions, caveats, and uncertainties must be fully disclosed, along with information indicating their likely validity, and implications for findings and recommendations. For example, use of traceable accounts used in the National Climate Assessments to document the basis for findings and recommendations. Where scientific evidence is not conclusive, traceable accounts provide documentation of uncertainties and confidence in expert judgements (See 5th order draft of Climate Science Special Report for examples).
- Terminology must be clearly defined and consistently employed.

6. These principles would be integrated within standard operating procedures and protocols to ensure that best available science is being employed, such as in the following examples:
   - <u>Describe requisite science foundation components</u> (or incorporate into contract provisions) to all contractors and staff involved in ASRP to inform them of requirements and expectations.
   - <u>Capital Budgeting.</u> Methods for prioritization and allocation of resources
     - An independent Science Review Team would be available on call to review proposed measures, actions, and projects and advise the ASRP Steering Committee. The Science Team would be comprised of members selected for situation-specific skill sets, requisite expertise, desired qualifications, and representational requirements.
       - A formal charter would provide terms of reference and specifics regarding operational details
         - Code of Conduct, including Conflict of interest to provide accountability
         - Selection and appointment of members
         - Decision making process
         - Reporting Responsibilities
     - The process to be employed by the Science Review Team is summarized as follows:
       - Identify ASRP-related research needs or review proposals by sponsors for initiation of research activity
       - Projects and specific studies
         - Identification of need and purpose
         - Advice on prioritization
         - Desired qualifications and selection of contractors
         - Study design (e.g., objectives; methods for data collection, selection, analysis, and interpretation; models and parameterization; criteria for evaluation of

results, guidelines for consideration of climate change trends, extreme events, alteration of ecological processes, pollutants such as pharmaceuticals, fertilizers, pesticides, infectious disease, risks, and uncertainties)

- Monitoring and oversight
- Adherence to core principles
- Review of results and reports
- Advice on requirements for operationalizing recommendations

– Communication protocols and editorial quality assurance review – ensure that science and information are accurately and appropriately conveyed to and accessible by decision makers, researchers, and the public.

7. Procedures for record keeping
   The Chehalis Basin Strategy and ASRP will be long-term efforts involving changing faces and circumstances. A system of record keeping – what has been or is being investigated and why, how studies are interconnected by subject and timing, methods for data collection, analysis, and reporting – is needed to support the capacity to make sound decisions and maintain some semblance of continuity over time. A "living" inventory (an indexed library) housing studies, reports, and data sources (as well as data archives for future reference and analysis), linked to findings and recommendations of the ASRP and Science Team should be considered. Such a system would track the status of ongoing studies and contain key technical concepts underlying the scientific foundation (e.g., Ecological floodplain processes and corridors tied to habitat requirements of focal species, life cycle models).

Attachment 1
Indicator Species for the ASRP

Table A-1-1
Indicator Species for the ASRP

STANDARD ENGLISH NAME (COMMON NAME)	SCIENTIFIC NAME	ASEP KEY SPP	ASRP INDICATOR	STATUS	CULTURAL OR ECONOMIC IMPORT	HABITAT ENGINEER	HABITAT INTEGRATOR
SALMONIDS							
Winter-run steelhead	*Oncorhynchus mykiss*	x	x		x		AOT
Coho salmon	*Oncorhynchus kisutch*	x	x		x		AOT
Fall-run Chinook salmon	*Oncorhynchus tshawytscha*	x	x		x		AOT
Spring-run Chinook salmon	*Oncorhynchus tshawytscha*	x	x		x		AOT
Chum salmon	*Oncorhynchus keta*	x	x		x		AOT
Mountain Whitefish			x				
OTHER FISH SPECIES							
Eulachon	*Thaleichthys pacificus*	x	x	x	x		AOT?
Pacific lamprey	*Lampetra tridentata*	x	x		x		AOT?
White sturgeon	*Acipenser transmontanus*	x	x		x		AOT?
Olympic mudminnow	*Novumbra hubbsi*	x	x				AT
Speckled dace	*Rhinichthys osculus*	x	x				AT
Largescale sucker	*Catostomus macrocheilus*	x	x				AT
Riffle sculpin	*Cottus gulosus*	x	x				AT
Reticulate sculpin	*Cottus perplexus*	x	x				AT
Smallmouth bass	*Micropterus dolomieu*	x					
Largemouth bass	*Micropterus salmoides*	x					
AMPHIBIANS							
Coastal tailed frog	*Ascaphus truei*	x	x	FFR			AT
Western toad	*Bufo boreas*	x	x	SC,FCO			AT
Northern red-legged frog	*Rana aurora*	x	x				AT
Oregon spotted frog	*Rana pretiosa*	x	x	SE,FE			AT

STANDARD ENGLISH NAME (COMMON NAME)	SCIENTIFIC NAME	ASEP KEY SPP	ASRP INDICATOR	STATUS	CULTURAL OR ECONOMIC IMPORT	HABITAT ENGINEER	HABITAT INTEGRATOR
Van Dyke's salamander	*Plethodon vandykei*	x	x	FFR			
BIRDS							
Great blue heron	*Ardea herodias*		x	SGCN			
Barrow's goldeneye	*Bucephala islandica*		x	SGCN			AOT?
Wood duck	*Aix sponsa*		x	SGCN			AT
MAMMALS							
North American beaver	*Castor canadensis*	x	x		x	x	AT
TURTLES							
Western pond turtle	*Actinemys marmorata*	x	x	SE,FCO	x		AT
INVERTEBRATES							
Western ridged mussel	*Gonidea angulata*		x		x		AT

Notes:
Preferred species for monitoring in gold.
AOT: Aquatic-Ocean-Terrestrial
AT: Aquatic-Terrestrial); for Status
FCO: Federal species of concern
FE: Federal endangered
FFR: Forest and Fish target species
SC: state candidate
SE: State endangered
SGCN: Species of greatest conservation need (linked to the WA wildlife plan)

Attachment 2
Coho Habitat Modeling Illustrator

COHO HABITAT MODELING ILLUSTRATOR

Purpose

The Coho Habitat Modeling Illustrator is a simple Excel application to illustrate how habitat characteristics can affect the performance of a coho salmon population. The tool is designed to show the relative effects of changing habitat characteristics in different coho salmon life stages and how those changes can affect population performance over the entire life cycle. In addition, the tool was designed so the user can better understand how habitat quality and habitat quantity combine to affect life cycle performance.

The tool allows the user to investigate the relative effects of habitat degradation as a result of land uses, effects due to future climate changes, and how restoration actions can reverse the effects of those changes to habitat conditions.

How the Tool is Configured

The tool is configured to very crudely approximate coho salmon performance in the Chehalis Basin, based on a very coarse use of the results of EDT modeling of the Basin in 2003 (Mobrand Biometrics, Inc. 2003). The model is configured in this manner to provide a relatable example, but the results are only for illustration and teaching about the concepts.

The equations that drive the tool are from Beverton and Holt (1957) and are applied in a life stage disaggregation of their well-known equation referred to as the Beverton-Holt stock-recruit equation. The disaggregated form (disaggregated to a life-cycle's life stages) was later elaborated on in Moussalli and Hilborn (1986) and Mobrand et al. (1997). These equations are at the core of the EDT model.

The tool is kept very simple and anyone involved in the development of the ASRP should be able to use it and understand it. Anyone who takes the time to work with it for only a short time will gain new insights into how habitat characteristics affect coho salmon population performance.

Use of the Tool

The charts that follow provide a very quick overview of the concepts and use of the tool. The flow of the charts is meant to show the basic concepts, with each subsequent chart building on the previous one. Once you go through these, you should be able begin using the tool. There are brief introductory explanations of the charts, but many charts are self-explanatory.

Chart A-2-1 (below) – The basic Beverton-Holt spawner to adult production curve (or called a spawner-recruit curve, where a recruit is the adult progeny of the spawners). This is meant to represent an underlying relationship between spawners and adult progeny, recognizing that if real data were to be plotted on the graph that some points would be above the curve and some below. The curve would represent the number of adults that would be produced, on the average, by a number of spawners shown on the x-axis.

The curve shown is what we would hypothesize about population performance based on habitat characteristics in the river system. In that sense, the curve represents habitat potential, but expressed in terms of population performance at different levels of spawner abundance.

The blue dashed straight line is the replacement line, meaning it defines the adult production that would just replace the number of spawners. Where the curved line exceeds the replacement line, the number of adults produced would be greater than (i.e., surplus) the number of spawners needed to replace the parent stock.

The intersection of the curved line with the dashed line defines what we call the equilibrium run size (Neq). This is the adult run size that we would tend to observe on the average in the absence of fishing mortality if environmental conditions remained more or less the same over a period of years—hence the run would tend to equilibrate to this point.

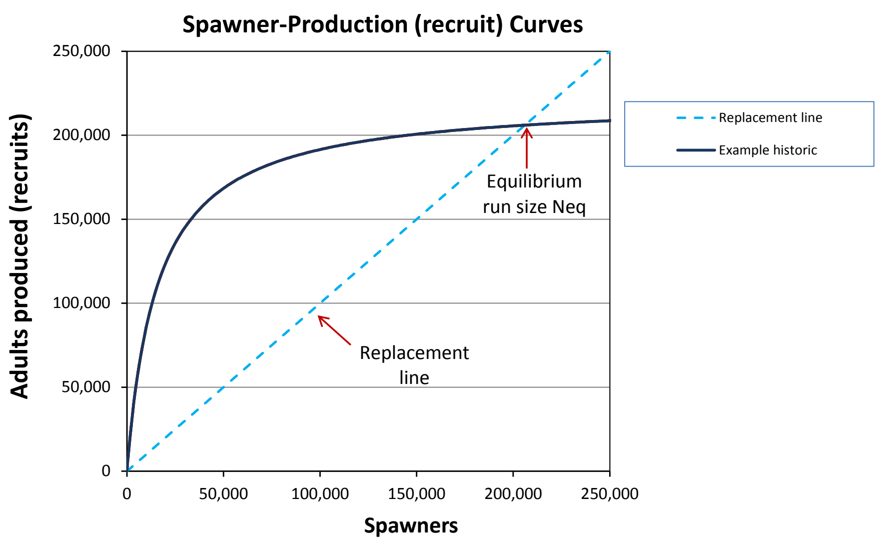


Chart A-2-1 (above)
Beverton-Holt Spawner-Production (S-P) Curve

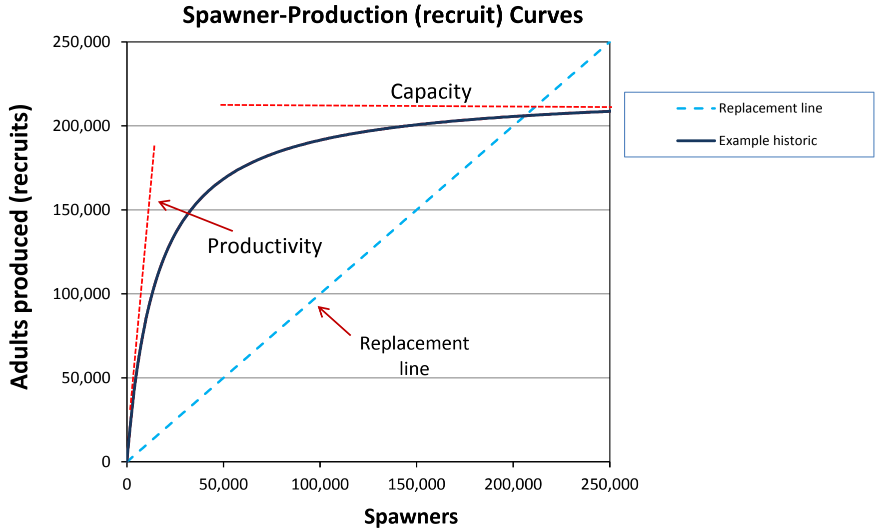


Chart A-2-2 (above)

The Two Parameters that Define the S-P Curve: Productivity and Capacity

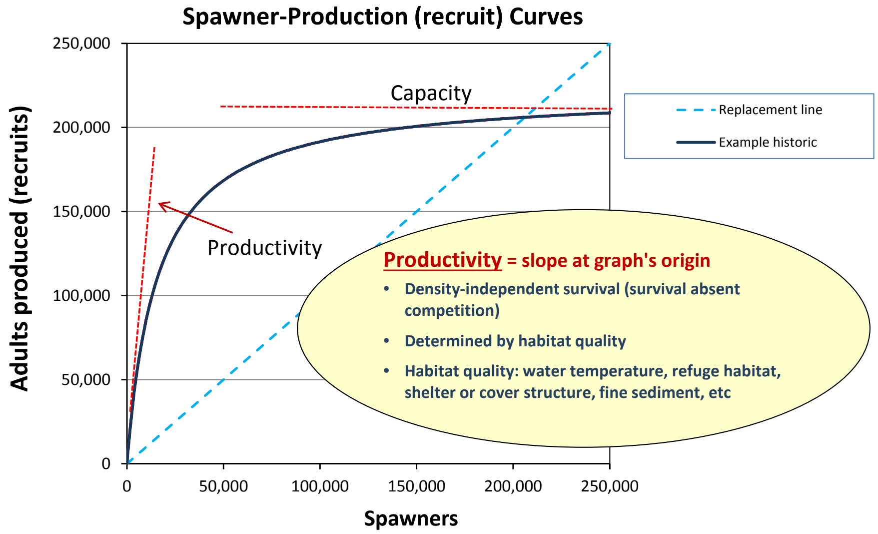


Chart A-2-3 (above)

Definition of the Productivity Parameter and How Habitat Affects the Parameter

Note: The slope of the curve at the origin (i.e., at very low population density) is seen in the angle of the red-dashed line. Degraded habitat quality will flatten the productivity slope. Improved habitat quality will steepen the slope. Examples of habitat quality are given.

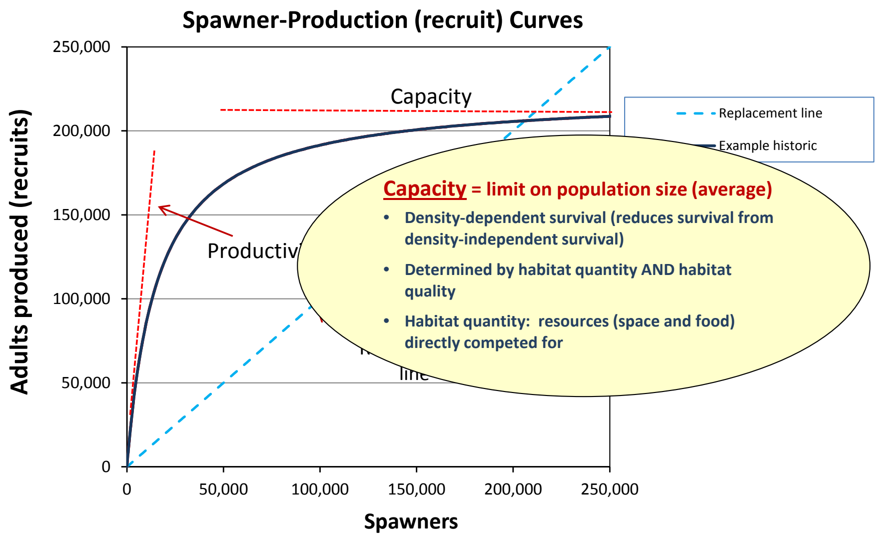


Chart A-2-4 (above)

Definition of the Capacity Parameter and How Habitat Affects the Parameter

Note: Population size is limited by this parameter. In general, increases in the quantity of habitat will increase the population size. Also, improvements in habitat quality will also often increase the population size.

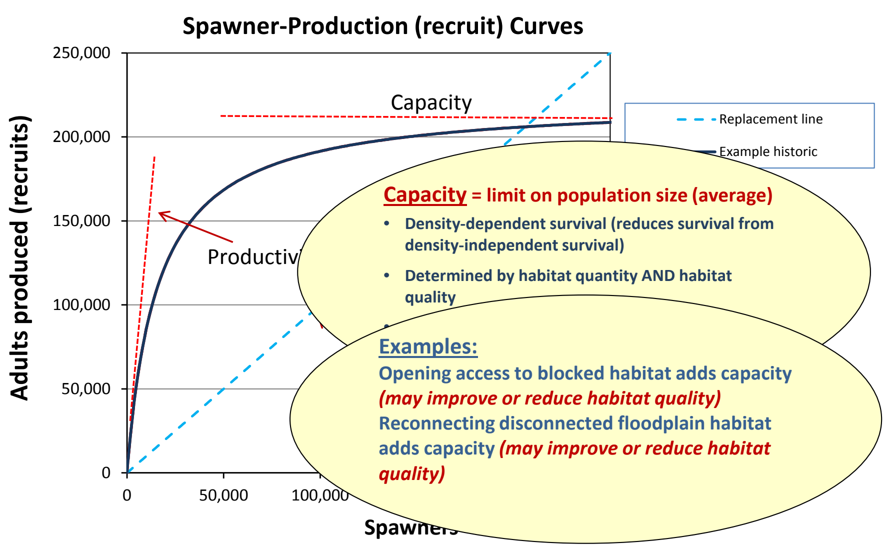
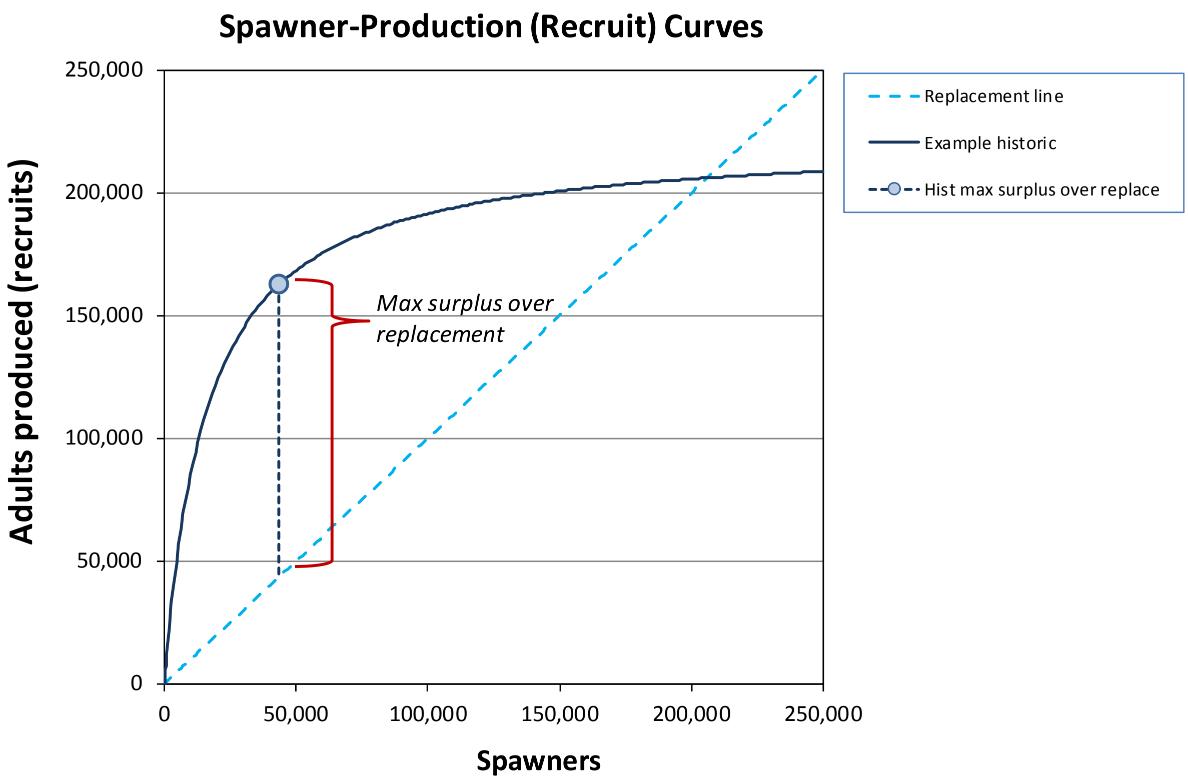


Chart A-2-5 (above)

Examples of Increasing Habitat Quantity to Increase Capacity

Chart A-2-6 (below) – Chart A-2-6 has two parts. The top part shows the same S-P curve used in the charts above. The vertical dashed line shows where the difference between the curved production line and the replacement line is greatest (labeled as max surplus over replacement). This is a very important point on the curve because it represents what is conventionally called the maximum sustainable yield (MSY) or maximum sustainable harvest (MSH) by fisheries scientists.



Performance measure	Scenario
	Historic
Spawner to smolt productivity	148.4
Smolt capacity	3,076,923
Smolt Neq	2,795,633
Life cycle productivity (recruits per spawner)	14.0
Life cycle capacity (spawners)	221,910
Life cycle Neq recruits	206,015
% change	0.0%
Max surplus over replacement (same as MSH)	119,022
% change	0.0%
Spawners at max surplus over replacement	43,496
Max sustainable harvest rate (MSH rate)	0.73

Chart A-2-6 (above)
Spawner-Production Recruit Curves

Note: Top – Point on the curve that shows the maximum surplus over replacement. Bottom – Summary of population performance measures associated with the S-P curve shown that are output from the illustrator tool.

Even though fisheries are normally managed today more conservatively than trying to achieve MSH (due to uncertainties), the point also has meaning to restoration scientists. The greater the “surplus” over replacement exists, the more capability the population has to respond to short-term disturbances to the system. We shall see that the amount of curve there is in the S-P relationship that the “surplus” over replacement is increased. This amount is affected by both capacity and productivity, but we shall see that productivity is particularly important in how "flat" the curve can become, that is how close it gets to the replacement line on its ascending limb.

The flatter the curve becomes to the replacement line, the easier it is for the population to be adversely affected by severe events (such as floods) or to climate change trends.

The bottom part of Chart A-2-6 is the summary table associated with the scenario that produced the S-P curve shown in the chart. Note that the S-P curve is meant to represent what can be considered as a crude representation of historic coho salmon performance in the Chehalis Basin (this is based on an out of date analysis so it is only meant here for the sake of illustration).

The table shows about 2.8 million smolts and an adult run size of about 206,000 fish. The maximum surplus over replacement is about 119,000 fish.

Table A-2-1 (below) – Table A-2-1 shows the inputs used in the illustrator tool that are built in. These are not meant to be changed by the user. These values are just meant to be rough approximations for reasonable values that might have existed in the river system like the Chehalis. The exact values are not important because this tool is meant only for illustration.

Seven life stages for the coho salmon life cycle are defined:

1. <u>Spn-incub</u> – Spawning and egg incubation life stage (combined). Begins at spawning and ends at fry emergence from the gravel. Spawning occurs in early winter typically and fry emergence in the spring.
2. <u>Colon-sum rear</u> – Fry colonization and summer rearing life stage (combined). Begins at fry emergence and ends in late early fall.
3. <u>Overwinter</u> – Juvenile overwintering life stage and transitions to early spring pre-smolt rearing. Begins in early fall and ends just prior to smoltification and seaward migration of smolts, usually in April and May.
4. <u>Smolt migration</u> – Smolt migration life stage in freshwater and upper estuary. This is a short life stage that may last about a month (little shorter or little longer).
5. <u>Ocean residency</u> – Ocean residency life stage. Begins when smolts enter the Grays Harbor and the ocean and ends when they come back as adults, about 18 months after leaving as smolts.
6. <u>Upst adult mig</u> – Upstream adult migration life stage. This period begins when adults reenter the Chehalis Basin as adults and takes them upstream for much of the distance to their spawning grounds.
7. <u>Prespawning</u> – The prespawning life stage. Begins as the prespawners approach their spawning areas where they tend to hold and sexually mature for spawning. This life stage may last from a couple of weeks to a month or longer.

The column labeled Capacity is the life stage capacity parameter value (c). Values shown are for the sake of this illustrator only. The three columns to the right of Capacity are elements of productivity. For the spawner-incubation stage, the eggs per spawner is a part of productivity. The column labeled "DI surv" is the density-independent survival value assumed for the historic condition. These are reasonable values for habitat in good condition. The far right column gives the actual productivity parameter (p) values for each life stage, which is obtained by multiplying the two previous columns together.

Table A-2-1
Input Values Used in the Illustrator Tool to Define the Historic Reference Condition

INITIAL (EXAMPLE HISTORIC)					
LS	STAGE	VALUES	VALUES	VALUES	FORMULAS
		CAPACITY C	EGGS/SPNER	DI SURV	P
1	Spn-incub	1,000,000,000	1,250	0.5	625
2	Colon-sum rear	15,000,000		0.5	0.5
3	Overwinter	6,000,000		0.5	0.5
4	Smolt migration	200,000,000		0.95	0.95
5	Ocean residency	5,000,000,000		0.1	0.1
6	Upst adult mig	20,000,000		0.95	0.95
7	Prespawning	1,000,000		0.99	0.99

Table A-2-2 (below) – User interface where the user enters scaler values into the white part of the table. These values will typically range from about 0.1 to 2.0 though the values can be greater than 2.0. The scalars are multipliers that are multiplied times the historic capacity (c) or productivity (p) values. Conditions cannot be improved better than the historic values.

Three scenarios can be evaluated. The first is to define the current condition (Historic to current). Values of 1 or less are entered under the columns marked c and p to show degradation. If for example, blocking culverts or dams were built that blocked have the historic area (or capacity) than scalers of 0.5 would be entered into the first three life stages. In this case productivity would remain the same.

The middle columns of the white section are to incorporate adverse changes that might be expected with climate change (CC). I believe that these will all affect productivity and not capacity (i.e., not quantity or the c parameter). The scalars entered here will further degrade the environment compared to the current condition.

The two columns on the far right are used to incorporate restoration actions. In this case, the scalars will all be greater than 1.0. You can enter a value simply by approximating what fraction of the loss you will restore for a given life stage. If you want to fully restore conditions for a life stage, then just enter a high number. The effect will be truncated once full restoration has been achieved.

You can skip over the Current to CC columns if you want and just let restoration work on the current condition by leaving all Current to CC numbers set at 1.

Table A-2-2

User Interface Table Where Multipliers (Scalers) Are Input that Degrade or Restore the Capacity and Productivity Values that Characterize the Historic Condition

Initial (example historic)						Multipliers to produce scenario shown (change values to examine effect) (degrades or restores)					
LS	Stage	values	values	values	formulas	Historic to current		Current to CC		Current to restored level	
		Capacity c	Eggs/spner	DI surv	p	c	p	c	p	c	p
1	Spn-incub	1,000,000,000	1250	0.5	625	1	1	1	1	1	1
2	Colon-sum rear	15,000,000		0.5	0.5	1	1	1	1	1	1
3	Overwinter	6,000,000		0.5	0.5	1	1	1	1	1	1
4	Smolt migration	200,000,000		0.95	0.95	1	1	1	1	1	1
5	Ocean residency	5,000,000,000		0.1	0.1	1	1	1	1	1	1
6	Upst adult mig	20,000,000		0.95	0.95	1	1	1	1	1	1
7	Prespawning	1,000,000		0.99	0.99	1	1	1	1	1	1

Note: The white sections of the interface are where the user enters values between 0.1 and 2 (or higher). These are scalar values only. Scalars are entered separately for c and p. Three scenarios can be evaluated. See text.

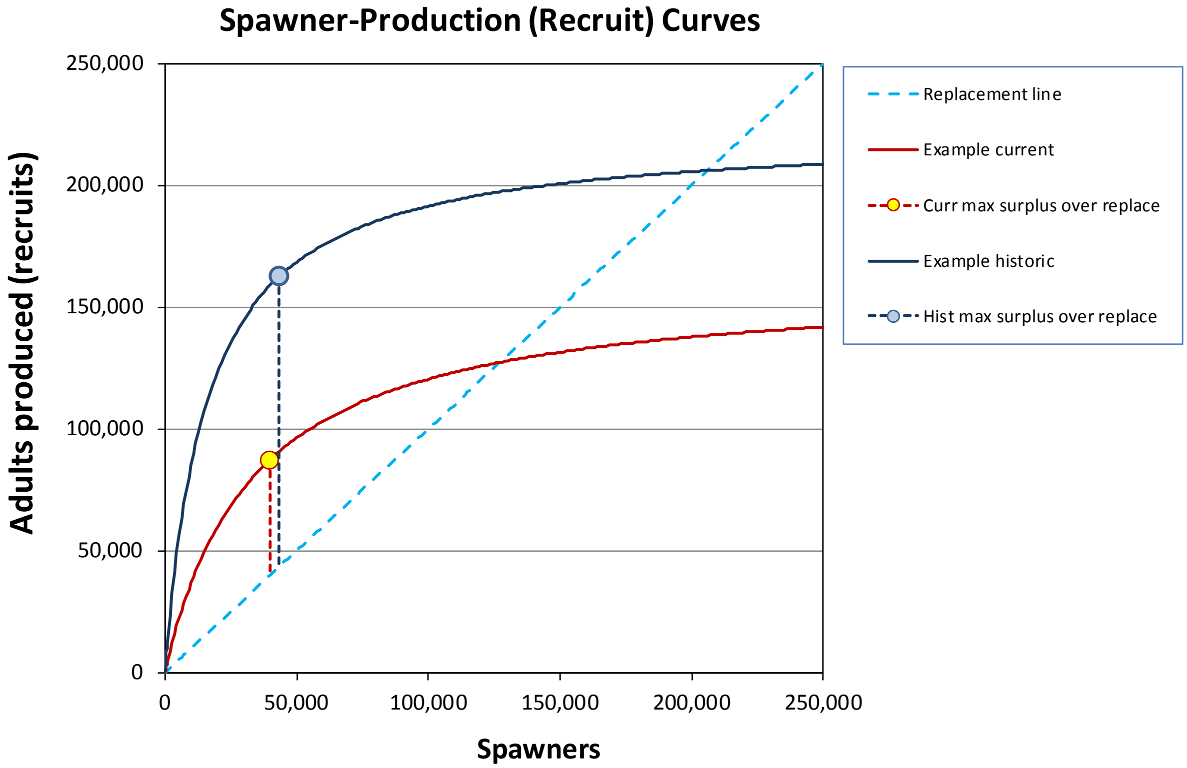
Table A-2-3 (below) – The table has scalars entered into it that might represent a reasonable characterization of the current condition. The capacity values are downgraded with scalars of 0.8 to represent dams and culvert installations that block passage. Freshwater habitat quality has been downgraded with scalers of 0.7. (Having worked with empirical survival values for coho salmon in many places and over many years, I consider these downgrades to be reasonable.)

Table A-2-3

User Interface Table Where Multipliers (Scalers) Have Been Entered to Represent Degraded Habitat in the Current Condition

Initial (example historic)						Multipliers to produce scenario shown (change values to examine effect) (degrades or restores)					
LS	Stage	values	values	values	formulas	Historic to current		Current to CC		Current to restored level	
		Capacity c	Eggs/spner	DI surv	p	c	p	c	p	c	p
1	Spn-incub	1,000,000,000	1250	0.5	625	0.8	0.7	1	1	1	1
2	Colon-sum rear	15,000,000		0.5	0.5	0.8	0.7	1	1	1	1
3	Overwinter	6,000,000		0.5	0.5	0.8	0.7	1	1	1	1
4	Smolt migration	200,000,000		0.95	0.95	1	1	1	1	1	1
5	Ocean residency	5,000,000,000		0.1	0.1	1	1	1	1	1	1
6	Upst adult mig	20,000,000		0.95	0.95	1	1	1	1	1	1
7	Prespawning	1,000,000		0.99	0.99	1	1	1	1	1	1

Chart A-2-7 (below) – Chart A-2-7 has two parts showing changes in the S-P curve with habitat degradation and a summary of performance measures.



Performance measure	Scenario	
	Historic	Current (degraded)
Spawner to smolt productivity	148.4	50.9
Smolt capacity	3,076,923	2,059,028
Smolt Neq	2,795,633	1,562,631
Life cycle productivity (recruits per spawner)	14.0	4.8
Life cycle capacity (spawners)	221,910	160,911
Life cycle Neq recruits	206,015	127,307
% change	0.0%	-38.2%
Max surplus over replacement (same as MSH)	119,022	47,447
% change	0.0%	-60.1%
Spawners at max surplus over replacement	43,496	39,930
Max sustainable harvest rate (MSH rate)	0.73	0.54

Chart A-2-7 (above)

Spawner-Production (Recruit) Curves

Note: Top – Changes in the maximum surplus over replacement with habitat degradation. Bottom – Summary of population performance measures associated habitat degradation using scalars shown in Table A-2-3.

Chart A-2-8 (below) – This is a screen capture of the tool configured to represent some example scenarios to show what can be done. Reset all the scalars to 1 to start fresh. Use the button "Restore Initial Values" to enter the scalars shown in the illustration. (You may need to activate your macros first.)

Coho Habitat Modeling Illustrator (NOTE: This simplified model does not enable life stage capacities to be affected by changes in productivity.)

Uses Beverton-Holt spawner-production functions disaggregated to life stages to illustrate effects of life-stage specific changes due to habitat degradation (current condition), climate change (CC) without restoration, and CC with restoration.

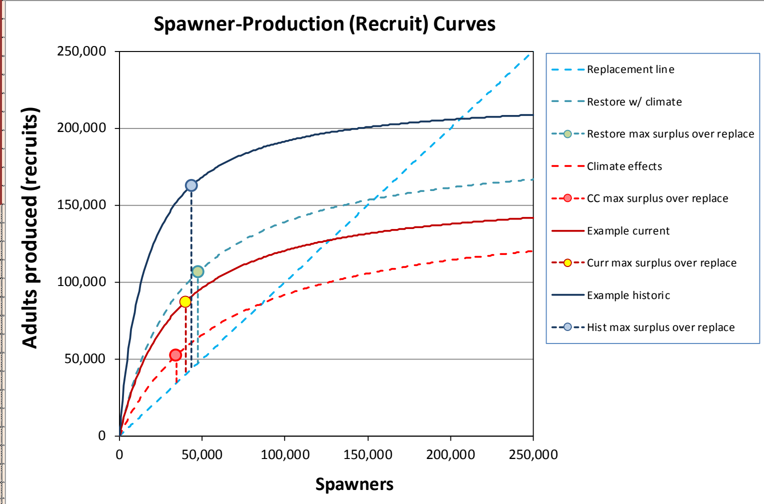
Purpose is to illustrate effects of degrading or restoring capacity (habitat quantity) or productivity (habitat quality) in different life stages.

Initial values for capacity and density-independent (DI) survival are meant to very crudely approximate a possible historic condition in the Chehalis Basin (based on EDT modeling-2003 version).

Instruction: Change values in white cells below to illustrate effect of degradation or restoration by life stage.

		Initial (example historic)				Multipliers to produce scenario shown (change values to examine effect) (degrades or restores)					
		values	values	values	formulas	Historic to current		Current to CC		Current to restored level	
LS	Stage	Capacity c	Eggs/spner	DI surv	p	c	p	c	p	c	p
1	Spn-incub	1,000,000,000	1250	0.5	625	0.8	0.7	1	0.9	1.2	1.2
2	Colon-sum rear	15,000,000		0.5	0.5	0.8	0.7	1	0.6	1.2	1.5
3	Overwinter	6,000,000		0.5	0.5	0.8	0.7	1	0.9	1.2	1.2
4	Smolt migration	200,000,000		0.95	0.95	1	1	1	1	1	1
5	Ocean residency	5,000,000,000		0.1	0.1	1	1	1	1	1	1
6	Upst adult mig	20,000,000		0.95	0.95	1	1	1	1	1	1
7	Prespawning	1,000,000		0.99	0.99	1	1	1	1	1	1

Performance measure	Scenario: Historic	Current (degraded)	CC no restore	CC & restoration
Spawner to smolt productivity	148.4	50.9	24.7	53.4
Smolt capacity	3,076,923	2,059,028	1,913,278	2,561,856
Smolt Neq	2,795,633	1,562,631	1,009,152	1,953,810
Life cycle productivity (recruits per spawner)	14.0	4.8	2.3	5.0
Life cycle capacity (spawners)	221,910	160,911	151,332	192,268
Life cycle Neq recruits	206,015	127,307	86,304	154,019
% change	0.0%	-38.2%	-32.2%	21.0%
Max surplus over replacement (same as MSH)	119,022	47,447	17,958	59,005
% change	0.0%	-60.1%	-62.2%	24.4%
Spawners at max surplus over replacement	43,496	39,930	34,173	47,507
Max sustainable harvest rate (MSH rate)	0.73	0.54	0.34	0.55



Restore Initial Values

Notes Neq is equilibrium abundance, i.e., abundance tending to be seen on the average. The Neq abundance is the point where the S-P curve crosses the replacement line.
MSH is maximum sustainable harvest.
MSH rate is the maximum sustainable harvest rate.

Chart A-2-8 (above)

Screen Capture of the Illustrator Tool Dashboard and Outputs Associated with Scalars Shown

Note: Four scenarios are shown in the chart with the S-P curves: historic, current, climate change incorporated, and partial restoration.

Attachment 3
Process-Based Strategy Framework

This appendix provides an initial draft of a framework for the Chehalis Basin that describes the major process-based watershed and ecological issues affecting the performance of the certain 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.

The framework is intended to engage the Science Review Team in clarifying the issues further as well as the flow of logic necessary to link the issues to potential solutions and actions.

One approach for using the framework is to organize the issues spatially by the sub-basins in the Chehalis Basin as well as by diagnostic units that have been identified for the Basin. Thirty-one separate sub-basins have been delineated, together with 107 diagnostic units (McConnaha et al. 2017a). A diagnostic unit is a spatial scale in the Chehalis EDT model composed of at least one, but usually multiple, reaches to form an ecologically useful component of a stream (e.g., the South Fork of the Newaukum River Diagnostic Unit).

Each sub-basin, or potentially each diagnostic unit, would be then scored by members of the Science Review Team, or other knowledgeable experts on the conditions of the Basin, on the relative importance of each issue to the performance of the indicator species. Brief documentation would be given on the evidence or reasoning for the score. All available information, including personal observations, could be used in the scoring. In addition, each score should also be given an uncertainty rating as to the level of confidence about the score (i.e., with respect to the importance of the issue to the indicator species). The results of this exercise would also be used to identify the strategies and actions that will most likely address the fundamental source of the issue. A synthesis of these conclusions would be used to help identify priority issues, geographic areas, and actions for the Basin.

Table A-3-1
Watershed and Ecological Process-Based Strategy Framework

ISSUES OF CONCERN	RELEVANCE TO SALMON AND OTHER SPECIES	CAUSES	SOLUTIONS	STRATEGIES/ACTIONS
ECOSYSTEM COMPONENT: ACCESS TO INSTREAM AND OFF-CHANNEL HABITATS				
Access to in-stream habitats: The ability of juvenile and adult salmon to move upstream and downstream to access spawning grounds and rearing areas and to migrate to the ocean is vital to salmon 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 adults. 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. Man-made structures or other altered features can block access to these habitats for seasonal rearing. Re-opening or improving the accessibility of 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). • 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 and life history diversity of a population, thereby potentially impacting its long-term sustainability.	• Historically, culverts were simply designed to handle a given storm flow (e.g., 50-year flood event) with no regard to passing fish and other aquatic organisms. These culvert installations can cause perched outfalls or result in excessively high velocities during elevated flows, resulting in passage restrictions. • Poorly designed culvert installations, particularly those with flat bottoms, can have particularly shallow water flowing through, 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 block to upstream and downstream passage. • Small channels or swales connecting off-channel ponds and wetlands to the main stream can be blocked by road fills or poorly designed culverts and other crossing structures. (Ponds and wetlands can be dry during summer, making them inconspicuous when roads were built, or even to technicians doing culvert inventories.) • Filling and drainage of wetlands, not uncommon in the past, has reduced their availability. • Invasive plants can choke access to off-channel habitats.	• Remove stream crossing structures on abandoned or closed roads. • Redesign and rebuild stream crossing structures to accommodate flows and fish and other aquatic organism passage. • Alter partial barriers to fish passage that are subject to the effects of climate change and associated changes in the flow regime to maintain connectivity along the river as it supported fish populations historically. • Restore, enhance, and maintain good access between main stream channels and off-channel ponds and wetlands where road structures impede passage. • Control invasives while native plant revegetation is occurring.	• Road crossings: Periodically evaluate stream crossing structures for passage effectiveness, maintain crossing structures consistent with BMPs, remove crossing structures on closed or abandoned roads, 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 deepening and/or adding structure where opportunities exist to improve access. (It is noted that accessibility to off-channel features can occur through very small rivulets of water during winter, connecting off-channel features to the main stream.) Consider presence of invasive species in the planning of this strategy/action. • Invasives: Inventory and control invasives such as knotweed and reed canary grass. Periodic maintenance activities at prior restoration sites may be necessary until invasives are controlled. Activities listed for riparian protection and restoration can be important to help control invasives.

ISSUES OF CONCERN	RELEVANCE TO SALMON AND OTHER 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, including salmon populations. 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. Prior to the rapid alteration of watersheds by Euro-Americans, sediment transport from rivers was generally in equilibrium with sediment supply. 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 sediments levels within spawning gravels, channel and habitat instability, and in some cases, to severe channel aggradation. Sediment reduction: Sediment Downstream of a dam (several exist in the Chehalis Basin), the channel can be sediment starved, leading to channel incision and/or a lack of stable spawning gravel. Climate change is expected to increase in sediment loading in many streams in Western Washington (Mauger et al. 2015).	• 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 et al. 1987). • Increased sediment supply can cause channel aggradation (buildup of sediment in the channel), resulting in egg smothering, 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 below dams can cause channel incision and loss of suitable spawning habitat for salmon.	• Runoff from road building and vehicular traffic on gravel roads increases sediment delivery to streams. • Landslides associated with roads and clearcutting increases sediment delivery. • Blowouts and slides associated with large road fills and undersized culverts. • On-going erosion associated with old road drainage networks due to failed culverts and unmaintained ditches. • Runoff from agricultural fields and farming activities increases sediment delivery. • Removal of old-growth large woody debris and wood jams during historic logging and subsequent channel clearing activities, resulting in increased channel instability and recapture of stored sediments. • Runoff from land clearing for land conversion, including road building. • Altered flow regimes due to land uses, causing 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).	• Continue to improve forest management practices to reduce sediment yields from roads, clearcuts, and from areas prone to landslides. • Close and obliterate unneeded roads. • Continue to upgrade and improve BMPs for managing sediment yield from all types of land uses. • Improve opportunities for public education on ways of controlling sedimentation. • Improve knowledge and understanding about sources of sediment produced in the watershed.	• Large wood: Construct ELJs 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. • 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: Increase protection of riparian lands through regulatory, incentive (e.g., conservation easements), land purchases, and education and outreach programs. • Restore riparian: Restore riparian forest characteristics (considering forest distribution, continuity, size, and stand composition) using passive or active management methods. Activities listed for protection of riparian lands also apply here. • 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. • Watershed analysis: Prepare watershed analysis of the primary watershed processes that are affecting a sub-basin of concern if such analysis has never been done, or prepare an updated analysis if warranted. 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. • Develop ecological corridor: Develop an ecological corridor strategy within the sub-basins to guide the prioritization of actions within the floodplain corridor of each sub-basin.

ISSUES OF CONCERN	RELEVANCE TO SALMON AND OTHER 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. <u>Altered flow regime – high flow or low flow aspects:</u> Conversion of old-growth forests to young, managed stands, combined with extensive road network altered to varying extents the characteristics of the natural flow regime. Land conversion in the sub-basin valleys caused further changes to flow regimes as lands were cleared and converted to agriculture, rural-residential areas, commercial properties, and urbanized areas. These changes increased impervious surfaces, changing runoff rates and patterns differently in different sub-basins. The flow regimes in certain rivers have also been altered by dams and reservoirs (Wynoochee and Skookumchuck). Climate change is expected to result in still further changes to the flow regime of the Chehalis Basin (Mauger et al. 2016). 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 stream dwelling salmon are strongly affected by characteristics of the flow regime in a stream system (Poff et al. 1997). • Peak flow intensity, runoff duration, and rate of change in flows during storm events can adversely affect egg to fry survival, emergent fry survival, and juvenile overwintering survival (Shuett-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).	• Extensive road networks through managed forests increase rate of runoff, which can produce greater instability of streams. • Replacement of old-growth forests with managed forests of much younger stands. • Land clearing and land conversion creating greater amounts of impervious surfaces in the watershed, altering runoff patterns and rates. • Levees in some areas of the Basin to prevent flooding onto the floodplains, thereby increasing the rate and height of flood runoff in the main channel. • Channel incision in many channels disconnecting the main streams to their floodplains and changing the rate of runoff in those areas and areas downstream. • Water withdrawals from the surface water of channels for the purpose of irrigation, domestic and industrial use. • Groundwater pumping to support agricultural or residential development (*to what extent is this happening and will it increase with climate change?)*.	• Promote diverse stand age in the managed forest to age a mixture of hydrologic maturity on the landscape. • Reduce the footprint of roads in the managed areas of watersheds wherever possible. • Restore connections to floodplains that provide for increased flood capacity. • Enlarge CMZs and restore meander patterns by reducing channel and flow constrictions. • Restore flow regime characteristics by reducing the rate of storm runoff associated with impervious surfaces. • Acquire floodplain lands and restore ecological functions of those lands.	• <u>Channel pattern:</u> Strategically remove channel constrictions and impediments to meanders to restore channel capacity and develop more natural channel pattern and avulsion pattern, e.g., by dike removal, use of setback levees, road relocations, lengthening and/or raising bridges, or rebuilding the channel pattern. • <u>CMZ:</u> Enlarge existing active channel migration zone (because it has been reduced by human activities) through regulatory, incentive, education programs, or land acquisition. • <u>Decommissioning:</u> Decommission or remove roads of little use on public lands, or ones whose services can be provided on alternative roads. • <u>Forest maturity:</u> 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. • <u>Protect floodplains:</u> Protect existing riparian and floodplain lands from land conversions or loss of watershed function through regulatory, incentive, education programs, land acquisition or land set asides. • <u>Restore floodplains:</u> 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<u>:</u> 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. • <u>Runoff BMPs:</u> Adopt or improve (i.e., update as needed) requirements for BMPs related to storm runoff management on agricultural, residential, commercial, or urbanized lands, including all transportation corridors that produce pollutants, promoting greater increases in storm-water infiltration using various methods and greater capacity for storm-water detention or retention. • <u>Water rights:</u> Purchase water rights and dedicate those rights to conservation. • <u>Develop ecological corridor:</u> Develop an ecological corridor strategy within the sub-basins to guide the prioritization of actions within the floodplain corridor of each sub-basin.

ISSUES OF CONCERN	RELEVANCE TO SALMON AND OTHER 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 depending on the sub-basin. <u>Wood loads</u> have been reduced to low levels throughout large portions of the Basin (Smith and Wenger 2001; John Ferguson, Anchor QEA (*personal communications*); Larry Lestelle, Biostream Environmental, *personal communications*). These changes have resulted in <u>alterations to channel stability</u>, <u>changes in substrate stability</u>, <u>loss of pool habitat and other habitat types</u>, and <u>substrate sizes</u> (Wendler and Deschamps 1955; Hiss and Knudsen 1992; Sullivan and Massong 1994; Weyerhaeuser 1994; Smith and Wenger 2001). Smaller streams have been extensively <u>channelized</u> within urban and agricultural areas (Hiss and Knudsen 1993; Larry Lestelle, Biostream Environmental, *personal communications*). <u>Channel incision</u> 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.	• Loss of adult migration, spawning, incubation, and juvenile salmonid habitat quality (manifested in the frequency, stability, and structure of habitats) and quantity (Hiss and Knudsen 1993; Smith and Wenger 2001; Mobrand Biometrics 2003). • Loss of side channel habitats, which are particularly important for spawning and rearing by young juveniles. • Increased egg to fry mortality due to channel scour or sediment deposition. • Increased mortality of young fry due to loss of refuge habitat. • Increased mortality during summer and winter rearing stages due to loss of high quality habitats. • Loss in food diversity and quantity for juvenile salmon. • 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 logging 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; Tim Abbe, NSD, *personal communications*). • Removal of large and small wood jams within the active channel migration zone (CMZ). • Stream channel straightening or channelization. • Constriction of the active high flow channel by roads, bridges, levees, or bank armoring. • Increases (from various land uses) or decreases (due to a dam) in sediment loading to the stream. • 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. • Disconnection from the river's floodplain or in the water and/or sediment storage capacity of the floodplain. • Gravel mining from the channel or the river bars. • Logging or clearing within the riparian zone. • Climate change effects (increasing peak flows in the Newaukum River) may be exacerbating these issues (Clark 1999).	• Enlarge CMZs and restore meander patterns by reducing channel and flow constrictions and restoring channel migration zones. • Restore large wood complexes to the active channel and the active CMZ, and where appropriate, promote the recreation of stable vegetated islands. • Restore flow regime characteristics by reducing the rate of storm runoff associated with impervious surfaces and wholesale clearcut logging. • Restore connections to floodplains that provide for increased sediment storage and flood capacity. • Restore a flow regime in dammed rivers (Wynoochee and Satsop rivers).	• <u>Channel pattern:</u> Strategically remove channel constrictions and impediments to meanders to restore channel capacity and develop more natural channel pattern and avulsion pattern, e.g., use of setback levees, road relocations, lengthening and/or raising bridges, or rebuilding the channel pattern. • <u>CMZ:</u> Enlarge existing active channel migration zone (CMZ) (because it has been reduced by human activities) through regulatory, incentive, education programs, or land acquisition. • <u>Large wood:</u> Construct engineered log jams (ELJs) 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 where appropriate, to recreate stable side channels, backwaters, or stable vegetated islands. • <u>Invasives:</u> Inventory and control invasives such as knotweed and canary reed grass. Periodic maintenance activities at prior restoration sites may be necessary until invasives are controlled. Activities listed for riparian protection and restoration also apply here. • <u>Protect riparian:</u> Increase protection of riparian lands through regulatory, incentive (e.g., conservation easements), land purchases, and education and outreach programs. • <u>Restore riparian:</u> Restore more natural riparian forest characteristics (considering forest distribution, continuity, size, and stand composition) using passive or active management methods. Activities listed for protection of riparian lands also apply here. • <u>Develop ecological corridor:</u> Develop an ecological corridor strategy within the sub-basins to guide the prioritization of actions within the floodplain corridor of each sub-basin. • <u>Eliminate gravel mining within bankfull.</u>

ISSUES OF CONCERN	RELEVANCE TO SALMON AND OTHER 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). Floodplain conversion: Large areas of the floodplains have been converted to agriculture, rural residential lands, or urbanized areas. In the process, wetlands have been drained and filled (Clark 1999). Changes to the floodplains have likely affected groundwater storage, runoff rates to the river, and the amount and quality of off-channel habitat features used by native aquatic species.	• Loss in floodplain function can significantly degrade in-channel conditions, adversely affect 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 function and its corresponding effects on active channel conditions can diminish fish food diversity and quantity (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 off-channel habitats are most important for summer and winter rearing of juvenile coho, though juvenile Chinook can also use these habitats (Lestelle et al. 2005; Lestelle 2007). • Features that limit floodplain connectivity affect the quantity and quality of aquatic habitat through direct manipulations to habitat as well as indirect effects on channel processes. • 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 above).	• Intensive logging 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; Tim Abbe, NSD, *personal communications*). • Stream channel straightening or channelization, which can act to disconnect the active channel from its floodplains. • Channel control measures, such as levees, and other types of bank armoring, which act to disconnect the active channel from its floodplains. • Conversion of forested floodplains to agriculture, rural residential areas, and urban settings create strong needs to control river channels and protect private property from flooding and channel migration. • Drainage and filling of overflow channels, off-channel ponds, and wetlands and marshes located on the floodplains occur to convert these areas to other uses besides ecological ones.	• Restore connections to floodplains that provide for increased sediment storage and flood capacity. • Restore wetland complexes and beaver pond complexes. • Enlarge CMZs and restore meander patterns by reducing channel and flow constrictions and restoring channel migration zones. • Restore flow regime characteristics by reducing the rate of storm runoff associated with impervious surfaces and wholesale clearcut logging. • Acquire floodplain lands and restore ecological functions of those lands.	• 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 some level of active management of beaver. • CMZ: Enlarge existing active channel migration zone (because it has been reduced by human activities) through regulatory, incentive, education programs, or land acquisition. • Transportation infrastructure: Improve or remove transportation infrastructure within floodplains to restore channel and floodplain function and connectivity. • Invasives: Inventory and control invasives such as knotweed and canary reed grass. Periodic maintenance activities at prior restoration sites may be necessary until invasives are controlled. Activities listed for riparian protection and restoration also apply here. • Protect floodplains: Protect existing riparian and floodplain lands from land conversions or loss of watershed function through regulatory, incentive, 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. • Restore riparian: Restore riparian forest characteristics (considering forest distribution, continuity, size, and stand composition) using passive or active management methods. Activities listed for protection of riparian lands also apply here. • Develop ecological corridor: Develop an ecological corridor strategy within the sub-basins to guide the prioritization of actions within the floodplain corridor of each sub-basin.

ISSUES OF CONCERN	RELEVANCE TO SALMON AND OTHER SPECIES	CAUSES	SOLUTIONS	STRATEGIES/ACTIONS
ECOSYSTEM COMPONENT: RIPARIAN CONDITIONS				
<u>Loss of riparian function:</u> Riparian zones in all sub-basins have been impacted to varying degrees by a wide variety of land and water-use activities, which include logging and all types of land clearing and land conversion to support societal needs. These activities have removed or altered the riparian plant communities, modified riparian soil conditions and other associated land and water features, and disrupted natural ecological cycles, all of which affect how riparian zones function in support of salmonid populations (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 below also). • Riparian forests affect stream and shoreline shading, influencing stream temperature, dissolved oxygen, and plant species composition (e.g., invasives) along the shorelines—all of which affect salmonid performance and habitat use. • Riparian zones affect water quality by trapping suspended and fine sediments and pollutants. • Riparian zones store water during high flows—to be released slowly to the stream over time. • Riparian zones stabilize streambanks and help maintain channel stability and bank cover for fish. • Riparian zones add leaf matter and wood for the stream, providing both nutrients and structure to stream ecosystems. • All of these functions directly and indirectly affect salmon.	• Wide scale logging of old-growth forests, including riparian forests, in sub-basin in the Basin over the past 150 years; logging continues to various degrees within existing riparian forests. • Land conversion within the riparian corridors of rivers and streams in the valleys of nearly every sub-basin, has turned riparian forested corridors into agriculture areas, rural residential areas, road systems, and urban areas. • Streambank protection practices to protect private property and infrastructure. • Growth and spread of invasive plant species such as Japanese knotweed and reed canary grass, which affect the growth and survival of native vegetation within the riparian corridor and can choke seasonal channels within the corridor.	• Promote diverse old-growth characteristics of riparian forests by expanding buffer widths where possible, or use of active management practices (e.g., thinning, planting, and shrub and herb control) to accelerate achievement of desired conditions within the riparian corridor. • Eradication of Japanese knotweed and management of 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.	• <u>Beaver management:</u> 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 some level of active management of beaver. • <u>Invasives:</u> Inventory and control invasives such as knotweed and reed canary grass. Periodic maintenance activities at prior restoration sites may be necessary until invasives are controlled. Activities listed for riparian protection and restoration also apply here. • <u>Protect riparian:</u> Increase protection of riparian lands through regulatory, incentive (e.g., conservation easements), land purchases, and education and outreach programs. • <u>Restore riparian:</u> Restore riparian forest characteristics (considering forest distribution, continuity, size, and stand composition) using passive or active management methods. Activities listed for protection of riparian lands also apply here.

ISSUES OF CONCERN	RELEVANCE TO SALMON AND OTHER SPECIES	CAUSES	SOLUTIONS	STRATEGIES/ACTIONS
ECOSYSTEM COMPONENT: WATER QUALITY				
<u>Degraded water quality – temperature, oxygen, pollutants:</u> Runoff from lands with many types of land management practices can be sources of different types of pollutants, including fine sediment and various types of chemicals and heavy metals. Runoff from highways and well-traveled roads are particular sources of substances of concern. Urbanized areas, where parking lots and densely populated areas, are also known sources of pollutants. Logging and land conversions are major sources of increased sediments to streams and rivers. Loss of high quality riparian zones also cause elevated stream temperatures and sometimes reductions in dissolved oxygen, both of which reduce water quality.	• Elevated stream temperatures can negatively affect salmon population performance by limiting growth, prompting juvenile redistribution in search of cool water refuges, or in severe cases, 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.	• Large scale clearcutting affects micro-climate of stream systems and can elevate water temperatures. • Loss of riparian trees along streams can directly lead to elevated water temperatures. • 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 are sources of chemical pollutants. • Runoff from residential and agricultural areas is a source of pesticides.	• Continue to improve forest management plans to promote more diverse stand age across the landscape (i.e., avoid cutting huge contiguous land parcels at the same time). • Promote diverse stand age in the managed forest. • Restoration of riparian corridors having old-growth characteristics. • Improved measures to capture runoff from sites likely to contain pollutants and routing into infiltration areas. • Improved education of the public on sources of pollutants and how the public can help to reduce these sources.	• <u>Protect riparian:</u> Increase protection of riparian lands through regulatory, incentive (e.g., conservation easements), land purchases, and education and outreach programs. • <u>Restore riparian:</u> Restore riparian forest characteristics (considering forest distribution, continuity, size, and stand composition) using passive or active management methods. Activities listed for protection of riparian lands also apply here. • <u>Runoff BMPs:</u> Adopt or improve (i.e., update as needed) requirements for BMPs related to storm runoff management on agricultural, residential, commercial, or urbanized lands, including all transportation corridors that produce pollutants, promoting greater increases in storm-water infiltration using various methods and greater capacity for storm-water detention or retention.

Appendix B
Derivation of Cost Estimates

This appendix provides a detailed description of the cost estimates developed for this initial 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. The other costs are preliminary and conceptual and will be developed in greater detail and with input from local restoration groups and other implementing parties for the full ASRP.

CAPITAL COSTS

The ASRP will require a large capital investment in the near-term to conduct the scale of restoration included in the scenarios. The restoration costs that comprise this capital investment are described below. In addition, there will need to be ongoing adaptive management, stewardship, maintenance, and other actions that will continue for the lifetime of the ASRP. Those are described as ongoing annual costs in the following section.

Restoration Costs

Cost estimates were developed for the restoration components of this initial 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[8]), summaries of Salmon Recovery Funding Board projects (RCO 2017), and bid tabulations from a variety of recent projects where bidding and construction was supported by project team consultants (Anchor QEA 2017b; Natural Systems Design 2017). This information was used to build a unit cost table (see Table B-7 in the last section of this appendix) 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 current listings and recent purchase prices from Zillow (Zillow 2017). All costs are in 2017 dollars.

Restoration treatment rates (or densities) were developed for three size classes of rivers (as defined in Table B-1) in coordination with the Science and Technical Review Team based on:

- Scientific literature regarding the effectiveness of various riparian corridor 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

[8] Note references for this appendix are included in Section 6 of the main document.

Table B-1
River Size Classes and Proposed Riparian Corridor Width for Active Restoration Scenarios

RIVER SIZE CLASS	BANKFULL WIDTH	RIPARIAN CORRIDOR WIDTH (EACH BANK)
Large Rivers	Greater than 97 feet (Greater than 30 meters)	500 feet
Medium Rivers	33 to 97 feet (10 to 30 meters)	250 feet
Small Streams	0 to 33 feet (0 to 10 meters)	150 feet

The unit costs were then applied based on restoration treatment rates (or densities) per mile for each of the active restoration scenarios that were modeled using the Ecosystem Diagnosis and Treatment (EDT) model. The estimated number of stream miles to be restored under each of the restoration scenarios are shown in Table B-2. Note that the miles shown are hypothetical for this initial document and do not reflect specific locations for restoration at this point.

Table B-2
Miles of Channel Estimated to be Treated for Active Restoration Scenarios

RESTORATION SCENARIO	LOCATION	LARGE RIVERS (MILES)	MEDIUM RIVERS (MILES)	SMALL STREAMS (MILES)
Moderate ASRP	Outside Managed Forests	64	78	22
	Inside Managed Forests	15	41	74
High ASRP	Outside Managed Forests	91	144	113
	Inside Managed Forests	15	41	74

Tables B-3 and B-4 outline the costs for the Moderate and High scenarios based on the unit costs and treatment rates.

Table B-3
Cost Summary for Moderate ASRP Scenario

MODERATE ASRP SCENARIO				COST RANGE BY ELEMENT		
RESTORATION ELEMENTS	MILES OF TREATMENT	RIPARIAN ACRES	FLOODPLAIN ACRES	LOW	MEDIUM	HIGH
LARGE RIVERS (OUTSIDE MANAGED FORESTS)						
Large Wood	64			$ 7,897,600	$ 9,260,800	$ 10,624,000
Riparian Plantings		5,198		$ 38,981,818	$ 46,778,182	$ 54,574,545
Riparian Easements		3,482		$ 19,153,067	$ 33,953,164	$ 48,753,261
Riparian Acquisition		1,715		$ 11,148,800	$ 25,299,200	$ 39,449,600
Floodplain Restoration			1,280	$ 17,920,000	$ 24,160,000	$ 30,400,000
Structure Removal/Relocation[1]				$ 4,800,000	$ 6,880,000	$ 8,960,000
Associated Costs[2]				$ 47,943,922	$ 81,161,825	$ 122,843,721
			Subtotal	**$ 147,900,000**	**$ 227,500,000**	**$ 315,700,000**
LARGE RIVERS (MANAGED FORESTS)						
Large Wood	15			$ 1,851,000	$ 2,170,500	$ 2,490,000
Associated Costs[2]				$ 1,290,961	$ 1,905,287	$ 2,644,828
			Subtotal	**$ 3,200,000**	**$ 4,100,000**	**$ 5,200,000**
MEDIUM RIVERS (OUTSIDE MANAGED FORESTS)						
Large Wood	78			$ 9,757,800	$ 12,249,900	$ 14,742,000
Riparian Plantings		3,167		$ 23,754,545	$ 28,505,455	$ 33,256,364
Riparian Easements		2,122		$ 11,671,400	$ 20,690,209	$ 29,709,018
Riparian Acquisition		1,045		$ 6,793,800	$ 15,416,700	$ 24,039,600
Floodplain Restoration			1,560	$ 24,090,000	$ 32,545,000	$ 41,000,000
Structure Removal/Relocation[1]				$ 5,850,000	$ 8,385,000	$ 10,920,000
Associated Costs[2]				$ 43,734,729	$ 74,293,451	$ 112,844,182
			Subtotal	**$ 125,700,000**	**$ 192,100,000**	**$ 266,600,000**
MEDIUM RIVERS (MANAGED FORESTS)						
Large Wood	41			$ 3,616,200	$ 4,391,100	$ 5,166,000
Associated Costs[2]				$ 2,522,083	$ 3,854,551	$ 5,487,222
			Subtotal	**$ 6,200,000**	**$ 8,300,000**	**$ 10,700,000**
SMALL STREAMS (OUTSIDE MANAGED FORESTS)						
Large Wood	22			$ 4,283,400	$ 5,045,700	$ 5,808,000
Riparian Plantings		536		$ 4,020,000	$ 4,824,000	$ 5,628,000
Riparian Easements		359		$ 1,975,160	$ 3,501,420	$ 5,027,680
Riparian Acquisition		177		$ 1,149,720	$ 2,608,980	$ 4,068,240
Structure Removal/Relocation[1]				$ 1,650,000	$ 2,365,000	$ 3,080,000
Associated Costs[2]				$ 6,818,929	$ 11,112,740	$ 16,449,075
			Subtotal	**$ 19,900,000**	**$ 29,500,000**	**$ 40,100,000**
SMALL STREAMS (MANAGED FORESTS)						
Large Wood	74			$ 14,407,800	$ 16,971,900	$ 19,536,000
Associated Costs[2]				$ 10,048,576	$ 14,898,104	$ 20,750,748
			Subtotal	**$ 24,500,000**	**$ 31,900,000**	**$ 40,300,000**
FISH PASSAGE BARRIER REMOVAL/REPLACEMENT[3]				**$ 92,950,000**	**$ 92,950,000**	**$ 92,950,000**
CONTINGENCY FISH PASSAGE BARRIERS[4]				**$ 17,050,000**	**$ 17,050,000**	**$ 17,050,000**
			Grand Total (Rounded)	***$ 437,400,000***	***$ 603,400,000***	***$ 788,600,000***

Notes:

1. Structure Removal/Relocation at 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 338 fish passage barriers in the long-term
4. Contingency for removal/replacement of additional fish passage barriers (up to 400 total) due to ongoing barrier identification effort

Table B-4
Cost Summary for High ASRP Scenario

HIGH ASRP SCENARIO				COST RANGE BY ELEMENT					
RESTORATION ELEMENTS	MILES OF TREATMENT	RIPARIAN ACRES	FLOODPLAIN ACRES		LOW		MEDIUM		HIGH
LARGE RIVERS (OUTSIDE MANAGED FORESTS)									
Large Wood	91			$	11,229,400	$	13,167,700	$	15,106,000
Riparian Plantings		7,390		$	55,427,273	$	66,512,727	$	77,598,182
Riparian Easements		4,952		$	27,233,267	$	48,277,155	$	69,321,042
Riparian Acquisition		2,439		$	15,852,200	$	35,972,300	$	56,092,400
Floodplain Restoration			1,820	$	25,480,000	$	34,352,500	$	43,225,000
Structure Removal/Relocation[1]				$	6,825,000	$	9,782,500	$	12,740,000
Associated Costs[2]				$	68,170,264	$	115,401,970	$	174,668,416
			Subtotal	**$**	**210,300,000**	**$**	**323,500,000**	**$**	**448,800,000**
LARGE RIVERS (MANAGED FORESTS)									
Large Wood	15			$	1,851,000	$	2,170,500	$	2,490,000
Associated Costs[2]				$	1,290,961	$	1,905,287	$	2,644,828
			Subtotal	**$**	**3,200,000**	**$**	**4,100,000**	**$**	**5,200,000**
MEDIUM RIVERS (OUTSIDE MANAGED FORESTS)									
Large Wood	144			$	18,014,400	$	22,615,200	$	27,216,000
Riparian Plantings		5,847		$	43,854,545	$	52,625,455	$	61,396,364
Riparian Easements		3,918		$	21,547,200	$	38,197,309	$	54,847,418
Riparian Acquisition		1,930		$	12,542,400	$	28,461,600	$	44,380,800
Floodplain Restoration			2,880	$	42,570,000	$	57,460,000	$	72,350,000
Structure Removal/Relocation[1]				$	10,800,000	$	15,480,000	$	20,160,000
Associated Costs[2]				$	79,413,219	$	134,854,576	$	204,777,588
			Subtotal	**$**	**228,800,000**	**$**	**349,700,000**	**$**	**485,200,000**
MEDIUM RIVERS (MANAGED FORESTS)									
Large Wood	41			$	3,616,200	$	4,391,100	$	5,166,000
Associated Costs[2]				$	2,522,083	$	3,854,551	$	5,487,222
			Subtotal	**$**	**6,200,000**	**$**	**8,300,000**	**$**	**10,700,000**
SMALL STREAMS (OUTSIDE MANAGED FORESTS)									
Large Wood	113			$	22,001,100	$	25,916,550	$	29,832,000
Riparian Plantings		2,753		$	20,648,182	$	24,777,818	$	28,907,455
Riparian Easements		1,845		$	10,145,140	$	17,984,566	$	25,823,993
Riparian Acquisition		909		$	5,905,380	$	13,400,670	$	20,895,960
Structure Removal/Relocation[1]				$	8,475,000	$	12,147,500	$	15,820,000
Associated Costs[2]				$	35,024,498	$	57,079,073	$	84,488,433
			Subtotal	**$**	**102,200,000**	**$**	**151,400,000**	**$**	**205,800,000**
SMALL STREAMS (MANAGED FORESTS)									
Large Wood	74			$	14,407,800	$	16,971,900	$	19,536,000
Associated Costs[2]				$	10,048,576	$	14,898,104	$	20,750,748
			Subtotal	**$**	**24,500,000**	**$**	**31,900,000**	**$**	**40,300,000**
FISH PASSAGE BARRIER REMOVAL/REPLACEMENT[3]				**$**	**92,950,000**	**$**	**92,950,000**	**$**	**92,950,000**
CONTINGENCY FISH PASSAGE BARRIERS[4]				**$**	**17,050,000**	**$**	**17,050,000**	**$**	**17,050,000**
			Grand Total (Rounded)	***$***	***685,200,000***	***$***	***978,900,000***	***$***	***1,306,000,000***

Notes:

1. Structure Removal/Relocation at 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 338 fish passage barriers in the long-term
4. Contingency for removal/replacement of additional fish passage barriers (up to 400 total) due to ongoing barrier identification effort

ONGOING ANNUAL COSTS

Restoration Costs

Adaptive Management

A detailed adaptive management plan and process will be developed for the full ASRP, but for this initial document, the Science and Technical Review Team has recommended that a preliminary cost of $4 million per year be identified for monitoring and adaptive management costs. Monitoring would likely be more intensive for the first 10 or more years, 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 scale of expected outcomes is being achieved. The adaptive management process will guide the implementation, monitoring, and possible further actions that could be required to ensure the success of the ASRP.

Stewardship and Maintenance

It is anticipated that multiple entities would own and manage the easements and lands acquired to implement the ASRP, including local land trusts, counties, and the state. Ongoing management and stewardship of these lands will be required such as invasive species management, fencing, and maintenance. For other restoration features, such as the replaced culverts or bridges, inspections and maintenance would need to be conducted periodically. Stewardship and maintenance costs will vary depending on the acreage acquired and quantity of other restoration features installed. 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 initial document, the stewardship and maintenance cost has been estimated to include the following elements:

- Land management and stewardship in perpetuity that would include invasive species management following construction (pre-treatment and 1-year post-construction invasive species management included in capital costs) and activities such as fencing repairs, signage repairs, site inspections, visitor management (on public lands), and other stewardship activities at $1.5 million per year
- Annual inspection of up to 100 replaced culverts at $50,000 per year
- Periodic debris removal and minor embankment repairs at an average of 40 culverts or bridges per year (i.e., each would require maintenance on about a 10-year basis); $10,000 per culvert, for $400,000 per year

Protection Costs

The protection strategy is likely to include several potential elements that will help to protect water quality and quantity, habitats, and watershed processes. Protection could occur via actions such as incentives to landowners to provide stewardship of forest and aquatic species habitats, programs that protect and enhance river and stream flows, 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 enforcement of floodplain and critical area requirements consistent with the ASRP. For this document, $1 million per year is included. More details on the costs for this strategy will be developed for the full ASRP.

Planning, Institutional, and Community Involvement Costs

The planning, institutional, and community involvement strategies will support the Chehalis Basin communities to ensure consistency with the ASRP through integration of comprehensive plans and ordinances, development of sustainable economic (i.e., particularly agricultural and forestry) programs, streamlined state and local permitting, and the fostering of local organizational capabilities to manage and monitor natural resources consistent with the ASRP. The types of actions and potential costs are shown in Table B-5.

Table B-5
Preliminary Planning, Institutional, and Community Involvement Costs

<table>
<tr><th colspan="3">BASIN-WIDE ACTIONS</th></tr>
<tr><th>POTENTIAL ACTIONS</th><th>EFFORT[1]</th><th>ANNUAL COST</th></tr>
<tr><td colspan="3">PLANNING</td></tr>
<tr><td>Assess consistency of floodplain regulations with ASRP, determine if updates are needed</td><td rowspan="3">Half FTE of staff time per county for up to 2 years</td><td rowspan="3">$500,000</td></tr>
<tr><td>Assess consistency of critical areas ordinances with ASRP, determine if updates are needed</td></tr>
<tr><td>Ensure best management practices and performance standards effectively protect species and habitats</td></tr>
<tr><td>Sustainable agriculture grant program to facilitate community and cooperative facilities, transportation, and training</td><td></td><td>$500,000</td></tr>
<tr><td colspan="3">INSTITUTIONAL AND COMMUNITY INVOLVEMENT</td></tr>
<tr><td>Develop streamlined permitting process for restoration projects (federal, state, local)</td><td>Half FTE of staff time at U.S. Army Corps of Engineers, U.S. Fish and Wildlife Service, National Oceanic and Atmospheric Administration, Washington Department of Fish and Wildlife, Washington Department of Ecology, Washington Department of Natural Resources, three counties up to 2 years</td><td>$500,000</td></tr>
</table>

BASIN-WIDE ACTIONS		
POTENTIAL ACTIONS	**EFFORT[1]**	**ANNUAL COST**
Provide technical training for process-based restoration practices and techniques	Professional training pool for periodic training sessions; 2 to 3 per year	$100,000
ASRP Science Review Team	Outside expert team to review ASRP monitoring results and recommend adaptive management actions	$150,000
Restoration office to manage project development and monitoring	2 FTE of staff time	$350,000
Incentives or grants to local jurisdictions to adopt ASRP recommendations		$150,000
Technical assistance for landowners	Restoration professional pool, 1 FTE at Conservation Districts	$250,000

Notes:
1. Level of effort and cost are conceptual and do not yet incorporate local jurisdiction and organization input. This information will be developed for the full ASRP.
FTE: full time equivalent

Table B-6 outlines the total annual cost estimate for this document. More detailed costs will be developed in coordination with local jurisdictions and organizations for the ASRP. Not all of the annual costs shown in Table B-6 would continue for the lifetime of the ASRP, but could be one time, periodic, or continuing.

Table B-6
Summary of Ongoing Annual Costs

STRATEGY	ANNUAL COST
Adaptive Management	$4 million
Restoration Stewardship and Maintenance	$2 million
Protection	$1 million
Planning, Institutional and Community Involvement	$2.5 million
TOTAL	**$9.5 million**

ASSUMPTIONS FOR RESTORATION COSTS

Table B-7 lists unit costs, relative costs, and assumptions with ranges from low to high that were used for restoration costs.

Table B-7
Unit Costs, Relative Costs, and Assumptions

ITEM	UNIT COST ITEMS	UNIT	UNIT COST RANGE[1]	LOW COST	MEDIUM COST	HIGH COST	NOTES[3]
1.01	Earthwork – Excavation	Cubic Yard	$17 - $30	$ 17	$ 24	$ 30	Assumes off-site haul and disposal of all material. 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 - $40	$ 26	$ 33	$ 40	Assumes import of select material, such as clean gravel and cobbles, from off-site source. Included with off-channel and floodplain restoration.
2.01	Engineered Log Jams (Large Rivers)[4]	Each	$60000 - $80000	$ 60,000	$ 70,000	$ 80,000	Assumes typical construction of a 60-foot-wide by 60-foot-long, 10-layer (15-foot-tall) gravity ELJ. Typical LWM specification; 24-inch DBH at 30 feet long (key pieces), 30 key pieces, plus 30 other 18-inch DBH logs of various lengths, >60 pieces. Typical placement rate is 2 per mile or located individually with floodplain and off-channel restoration.
2.02	Engineered Log Jams (Medium Rivers)[4]	Each	$40000 - $60000	$ 40,000	$ 50,000	$ 60,000	Assumes typical construction of a 40-foot-wide by 40-foot-long, 10 layer (15-foot-tall) gravity ELJ. Typical LWM specification; 18-inch DBH at 30 feet long (key pieces), 20 key pieces, plus 20 other 18-inch DBH logs of various lengths, >40 pieces. Typical placement rate is 3 per mile or located individually with floodplain and off-channel restoration.
2.03	Large Wood Multi-key piece Structures (Medium Rivers)[4]	Each	$6500 - $9000	$ 6,500	$ 7,750	$ 9,000	Assembly of average 5 key LWM pieces, plus 3 logs of varying lengths with boulder ballast for habitat and/or sediment and smaller wood retention. Typical key piece; 18- to 24-inch DBH 25-foot-long rootwad logs. Typical placement rate is 12 per mile.
2.04	Large Wood Multi-key piece Structures (Small Streams)[4]	Each	$4500 - $6000	$ 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.
2.05	Large Wood Key Pieces – Single Logs (Small Streams)[4]	Each	$700 - $900	$ 700	$ 800	$ 900	Assumes placement and limited to no burial of 12- to 18-inch DBH 25-foot-long rootwad logs. No soil anchors or ballast blocks. Typical placement rate is 110 per mile.
3.01	Riparian Plantings	Acre	$11000 - $15000	$ 11,000	$ 13,000	$ 15,000	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). The low estimate assumes common plant types and easy site access. The 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 and spot spraying of invasive species for 1 year following plantings.
3.02	Supplemental Riparian Plantings	Acre	$4000 - $6000	$ 4,000	$ 5,000	$ 6,000	Assumed to be required in areas of existing deciduous riparian vegetation. Cost assumes 16-foot on-center plant spacing and includes pre- and post-construction invasive species management. The low estimate assumes common plant types, easy site access, and limited clearing of existing vegetation. The high estimate assumes a wider variety of plant types, more difficult site access, and clearing of existing vegetation.
3.03	Wetland Plantings	Acre	$14000 - $24000	$ 14,000	$ 19,000	$ 24,000	Adding native herbaceous seed plus shrubs and trees to wetland areas. Cost assumes 8-foot on-center woody plant spacing and includes a previous year of invasive species management before planting (i.e., mowing/spraying) plus 1 year post-construction invasive species management. The low estimate assumes common plant types, easy site access; the high estimate assumes more diverse plant species, more difficult site access, and supplemental plantings 1 year after construction.
4.01	Reconnect Side Channels or Oxbows	Each	$320000 - $610000	$ 320,000	$ 465,000	$ 610,000	Assume 1 off-channel restoration site per 2 miles of other restoration elements. Includes excavation for connection, assume 500 linear feet of excavation, (average 6-foot depth, with 20-foot bottom width and 3:1 side slopes (average of 5,333 CY per site); placement of 500 CY gravel/cobble, placement of 30 single logs per site, full riparian plantings on 7.5 acres, supplemental riparian plantings on 7.5 acres. Easement for 20 acres.
4.02	Reconnect Floodplain Wetlands	Each	$240000 - $340000	$ 240,000	$ 290,000	$ 340,000	Assume 1 wetland restoration site per 2 miles of other restoration elements. Includes excavation for connection, assume 500 linear feet of excavation, average 4-foot-depth swale, 15 feet wide and 4:1 slopes (2,300 CY per site); placement of 10 single logs per site, wetland plantings on 5 acres and supplemental riparian plantings on 10 acres. Easement for 20 acres.
4.03	Create Depressional Wetlands	Each	$125000 - $220000	$ 125,000	$ 172,500	$ 220,000	Assume 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 CY per site); wetland plantings on 1 acre. No additional easements or acquisition.
4.04	Exotic Removal in Glacial Outwash Lakes	Each	$200000 - $350000	$ 200,000	$ 275,000	$ 350,000	Intensive removal of exotic fish and amphibians (netting, traps, etc.).
5.01	Land Acquisition - Easement	Acre	$3000 - $11000	$ 3,000	$ 7,000	$ 11,000	Assumes only an easement is purchased but 75% of land value.
5.02	Due Diligence for Land Acquisition – Easement	Each	$25000 - $30000	$ 25,000	$ 27,500	$ 30,000	Assumed to be required at a rate of 1 per 10 acres of easement area purchased. Includes appraisals, surveys, and recording fees.
5.03	Land Acquisition - Purchase	Acre	$4000 - $20000	$ 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	$25000 - $30000	$ 25,000	$ 27,500	$ 30,000	Assumed to be required at a rate of 1 per 10 acres of land area purchased. Includes appraisals, surveys, and recording fees.
6.01	Road or Infrastructure Removal	Square Yard	$30 - $70	$ 30	$ 50	$ 70	Assumes demolition and off-site haul of asphalt, concrete, piping and regrading, mulch, seed, replanting. Low end represents removal of a paved road (approximately 24 feet wide and excavation thickness of 4 feet), high end represents removal of buried pipelines and replacement/regrading of material.
6.02	Structure Demolition & Removal	Each	$10000 - $25000	$ 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.
6.03	Structure Relocation	Each	$50000 - $80000	$ 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.
7.01	Fish Passage Barriers Removal/Replacement	Each		$ 275,000	$ 275,000	$ 275,000	Average from recent search of Salmon Recovery Funding Board-funded projects, primarily in the Chehalis Basin.

Table B-7
Unit Costs, Relative Costs, and Assumptions

ITEM	RELATIVE COST ITEMS	UNIT	RELATIVE COST[2]	LOW COST	MEDIUM COST	HIGH COST	NOTES[3]
8.01	Temporary Erosion & Sediment Control – Plan and Measures	Lump Sum	1.5% - 2.5%	1.5%	2%	2.5%	Assumes site surface erosion and sedimentation control measures are permit requirements for all projects including riparian and floodplain projects. Includes development and approval of a Temporary Erosion & Sediment Control plan. Taken only as a percentage of the construction items, not applied to property acquisition.
8.02	Care of Water – Diversion, Isolation, and Dewatering	Lump Sum	4% - 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 or in-channel work. 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% - 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 sub-total.
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 sub-total.
9.03	Thurston County Sales Tax	Lump Sum	7.90%		7.9%		Sales tax is for unincorporated areas. Applies to pre-tax project sub-total.
9.04	Mason County Sales Tax	Lump Sum	8.50%		8.5%		Sales tax is for unincorporated areas. Applies to pre-tax project sub-total.
9.05	Pacific County Sales Tax	Lump Sum	7.80%		7.8%		Sales tax is for all areas. Applies to pre-tax project sub-total.
9.06	Cowlitz County Sales Tax	Lump Sum	7.70%		7.7%		Sales tax is for unincorporated areas. Applies to pre-tax project sub-total.
10.01	Permitting, Administration	Lump Sum	8% - 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 prep/plan costs.
10.02	Design and Engineering	Lump Sum	15% - 25%	15%	20%	25%	Applies to side channel development, floodplain reconnection, and LWM/ELJ projects. Assume 10% to 15% for design, 5% to 10% engineering during construction. Does not apply to planting, property acquisition, and construction site prep/plan costs.
10.03	Contingency	Lump Sum	25% - 35%	25%	30%	35%	Contingency accounts for uncertainty in project scope (components that have not yet been identified), site conditions, material costs, and labor and equipment rates. Applies to pre-tax project sub-total.

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. LF = linear feet, DBH = diameter at breast height, LWM = large woody material, ELJ = engineered log jam
4. ELJ and LWM placement rates are based on 75th percentile in Fox and Bolton 2007

Restoration Treatment Rate Assumptions

Installation of Large Wood

The treatment rate was based on the Science and Technical Review Team recommendation to use the 75th percentile loading rate from the Fox and Bolton (2007) research on natural wood loading in Washington State (Table B-8).

Table B-8
Wood Loading Rate Assumptions

RIVER SIZE CLASS (BANK FULL WIDTH)	FOX AND BOLTON (2007) RECOMMENDED 75TH PERCENTILE LOADING RATE FOR KEY PIECES	INSTALLATION FOR COST BASIS
OUTSIDE MANAGED FORESTS		
Large Rivers	Greater than 64 per mile	2 ELJ per mile with 30+ key pieces each
Medium Rivers	Greater than 64 per mile	3 ELJ per mile with 20+ key pieces each
Small Streams	Greater than 176 per mile	22 Multi-key piece structures per mile with 3 key pieces each, and 110 single log key pieces
INSIDE MANAGED FORESTS		
Medium Rivers	Greater than 64 per mile	12 Multi-key piece structures per mile with 5 key pieces each
Small Streams	Greater than 176 per mile	22 Multi-key piece structures per mile with 3 key pieces each, and 110 single log key pieces

Notes:
Key pieces are defined as having the following minimum size:
Large Rivers – Logs of 24-inch diameter at breast height with root wad and length of 30 feet
Medium Rivers – Logs of 18-inch diameter at breast height with root wad and length of 30 feet
Small Streams – Logs of 12- to 18-inch diameter at breast height and length of 25 feet, with or without root wad
ELJ: engineered log jam

Riparian Corridor Restoration

Riparian zones are transitional between aquatic and upland environments and provide numerous important functions for aquatic species as well as providing key elements to allow ecosystem processes to operate. Literature on recommended riparian corridor and buffer widths is typically based on the width that is necessary to provide a variety of functions and processes including channel migration, flood attenuation, sedimentation/erosion protection, protection of water quality, large wood recruitment, and habitat for fish and wildlife. Literature recommendations include:

- 250-foot riparian width on each side of 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 corridor width recommendations.
- Hawes and Smith (2005) indicated corridor widths 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 corridors up to 100 feet in width; however, corridor widths from 220 to 574 feet would provide the most effective wildlife habitat, and widths up to 328 feet could be required for effective nutrient control.
- Fischer and Fischenich (2000) indicated that most functions could be provided with corridor widths of 100 to 200 feet, but effective wildlife habitat could require corridor widths up to 1,640 feet.
- The Washington Forest Practices Act defines the Riparian Management Zone (RMZ), which is specific to regulating forest management operations. The RMZ for fish bearing waters ranges from 200 feet to 90 feet from bankfull channel width or channel migration zone, whichever is greater (Washington Administrative Code 220-30-021).

Assumptions used in this document include width of riparian restoration to be scaled based on river size classes, with initial consideration of historical channel migration, valley width, and provision of riparian functions. The Science and Technical Review Team recommended a riparian corridor width of 500 feet for large rivers, 250 feet for medium rivers, and 150 feet for small streams to ensure that corridor widths encompassed natural channel migration zones as well as additional riparian area. This document is not anticipating that the entire corridor can be restored (due to infrastructure and other structures), so to meet EDT effectiveness, it is assumed that 67% of this area would be treated.

- 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 corridor from this width of channel migration yields potential corridor widths of 378 feet or 423 feet, respectively.
- It is assumed that channel migration width and valley widths are proportionally narrower for tributaries.

Floodplain Restoration

Reconnect Side Channels or Oxbows (active connection)

In areas where channel incision or infrastructure/land uses may constrain the natural formation of side channels or oxbows, actively reconnecting these features can provide important habitats for aquatic species in the short-term and may be feasible to maintain over the long-term. The Science and Technical Review Team recommended one side-channel/oxbow restoration site per 2 miles of other restoration elements to meet desired EDT effectiveness. Assumptions included:

- Assume these sites are in addition to riparian corridor restoration actions
- Only for sites that would likely remain disconnected until a greater than 5-year event after implementing other wood and riparian actions

Reconnect Floodplain Wetlands

The Science and Technical Review Team recommended one wetland restoration site per 2 miles of other restoration elements to meet multi-species effectiveness. Assumptions included:

- Assume these sites are in addition to riparian corridor restoration actions
- Not including annual connections, but perhaps 2-year or 5-year connectivity

Create Depressional Wetlands

The Science and Technical Review Team recommended creating 10 wetlands initially and monitoring for effectiveness at sustaining amphibian populations. Assumptions included:

- No additional acquisition, would occur within riparian corridors

Remove Exotics from Glacial Outwash Lakes

The Science and Technical Review Team recommended selecting 5 lakes for initial removal of exotic fish and amphibians and monitoring for effectiveness at sustaining amphibian and native fish populations. Assumptions included:

- No additional acquisition

Fish Passage Barrier Removal/Replacement

- Remove or replace all that are currently in EDT database (338)
- Include contingency to account for additional barriers to be added from recent inventory into the full ASRP EDT analysis. Assumes that a revised selection of the high priority barriers to replace could range up to a total of 400 barriers to be removed or replaced that will provide equal or greater effectiveness and improvements to salmon populations

Land Acquisition/Easements

- Applies to riparian restoration and floodplain restoration actions
- Assume 33% of riparian corridor area will require acquisition and 67% of riparian corridor area will require easements
- Assume 20 acres of easement per floodplain restoration site

Structure Removal/Relocation

- Assume one removal and one relocation per mile of other treatments
- Assume 5,000 square yards of road/utility removal per 10 miles of other treatments

Appendix C
ASRP Development Committees and Implementing Parties

STEERING COMMITTEE

Voting members

- Washington Department of Fish and Wildlife
- Quinault Indian Nation
- Confederated Tribes of the Chehalis Reservation

Non-voting ex-officio members

- Washington State Department of Ecology
- Washington Department of Natural Resources
- Chehalis Basin Lead Entity

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 Quinn – Washington Department of Fish and Wildlife
- Marc Hayes – Washington Department of Fish and Wildlife
- Mara Zimmerman – Washington Department of Fish and Wildlife
- Larry Lestelle – Biostream Environmental
- Cynthia Carlstad – Carlstad Consulting
- Tim Abbe – Natural Systems Design
- Tim Beechie – National Oceanic and Atmospheric Administration, Fisheries
- John Ferguson – Anchor QEA
- Chip McConnaha – ICF International
- Hope Rieden – Confederated Tribes of the Chehalis Reservation
- Mark Mobbs – Quinault Indian Nation

PARTNERS IN ECOSYSTEM RESTORATION AND SALMON RECOVERY

Municipal partners

- Grays Harbor County
- Lewis County
- Mason County
- Thurston County
- Port of Centralia
- Port of Grays Harbor
- City of Aberdeen
- City of Centralia
- City of Chehalis
- Hoquiam
- McCleary
- Montesono
- Napavine
- Ocean Shores
- Thurston PUD
- Grays Harbor Water District

Agency partners

- Washington State Department of Ecology
- Washington Department of Fish and Wildlife
- Washington Department of Natural Resources
- U.S. Fish and Wildlife Service

Tribal partners

- Chehalis Tribe
- Quinault Indian Nation

Implementation and education partners

- Capitol Land Trust
- The Nature Conservancy
- Center for Natural Lands Management
- Heernet Foundation/Creekside Conservancy
- Chehalis Basin Education Consortium
- Chehalis Small Forest Landowners Program
- Centralia Stream Team
- Chehalis Basin Flood Authority
- Lewis County Conservation District
- Thurston Conservation District
- Mason Conservation District
- Grays Harbor Conservation District
- Chehalis River Basin Land Trust
- Chehalis Basin Fisheries Task Force
- Chehalis River Council
- Trout Unlimited
- Marine Resources Committee
- Wild Fish Conservancy
- Grays Harbor Stream Team
- Westport Aquarium
- Ducks Unlimited
- Forterra
- Grays Harbor College Fish Lab
- Grays Harbor Historical Seaport
- Grays Harbor Weed Board
- Clean Streams & Meme