TECHNICAL MEMORANDUM 2

Date: December 11, 2017
To: Aquatic Species Restoration Plan Steering Committee
From: Aquatic Species Restoration Plan Science and Technical Review Team[1]
Re: Final ASRP Phase 1 Analytical Structure and EDT Results

Keywords: ASRP, EDT, Phase 1, Salmonid habitat

This memorandum describes the evaluation of the effect of habitat change in the Chehalis Basin on five salmonid species that could occur as a result of climate change and actions developed in Phase 1 of the Aquatic Species Restoration Plan (ASRP). The Chehalis ASRP Science and Technical Review Team (STRT) developed the analysis to support ASRP Steering Committee (SC) development of the Phase 1 ASRP report. This memorandum describes the analytical scheme developed by the STRT and includes results from the Phase 1 analysis using the Chehalis Ecosystem Diagnosis & Treatment (EDT) model. The analysis estimated the change in the potential of habitat in the Chehalis Basin to support Coho salmon, fall-run Chinook salmon, spring-run Chinook salmon, winter steelhead, and Chum salmon as a result of climate change and ASRP habitat restoration actions. Habitat potential was assessed as adult equivalent abundance of the species (abundance without harvest).

The analysis evaluated the impact of habitat change on Chehalis Basin anadromous salmonids over the course of the 21st century starting with the base condition that depicts current conditions. Over that period, habitat conditions for the modeled species are expected to change due to environmental conditions (climate change) and habitat restoration that could result from the ASRP. Habitat change evaluated in this analysis was limited to the restoration of the riparian corridor and the installation of large instream wood.

General Strategy

The restoration scenarios for the Phase 1 analysis were defined with respect to the parameters and alternative conditions shown in Table 1. Detailed discussions of the parameters follow the table.

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Table 1
Parameters and Alternatives Defining Strategies for the Phase 1 ASRP Analysis

PARAMETER	ALTERNATIVE CONDITIONS	
Location	Inside managed forest	Outside managed forest
Restoration strategy	Future No-Action	ASRP
Time period	Mid-century (~2040)	Late century (~2080)
Reach selection for restoration	Cumulative restoration potential (several alternatives)	
Habitat restoration treatment	Restoration of riparian forest	Placement of large wood or wood structures
Effectiveness of treatment	Effectiveness multipliers (several alternatives)	
Future climate	Low (36% of PSU projection)	High (PSU projection)

Note:
PSU: Portland State University

Location. For this analysis, the Chehalis Basin was divided into stream reaches inside and outside managed forest. These land-use categories are approximately sub-equal in area in the Basin. Managed forest refers to areas of large- and small-scale commercial forestry on private and public lands and are mainly in the upper portions of the watershed. Importantly, managed forests are regulated by the Washington Forest Practices Act (WFPA), which has mandated protection of riparian buffers along streams within harvested areas since 1988 and non-fish-bearing streams since 2000. Based on the WFPA protection, most trees within fish-bearing streams in managed forests are at least 30 years old and will continue to grow and add to riparian function over time. Areas outside managed forest are generally at lower elevations dominated by agricultural and urban land use where the WFPA does not apply. The riparian corridor outside managed forest varies in width and age and is generally less robust than that inside managed forest reflecting different land use regulations.

Restoration strategy. Future conditions in the Chehalis Basin were depicted under two strategies: Future No-Action (FNA) and ASRP restoration treatments. The FNA strategy assumed no human-caused changes to the aquatic environment over the study period as a result of development within the watershed or restoration of aquatic habitat. Conditions were assumed to change due to growth of riparian trees in managed forest areas and climate change; except for climate change, conditions outside managed forest did not change under the FNA.

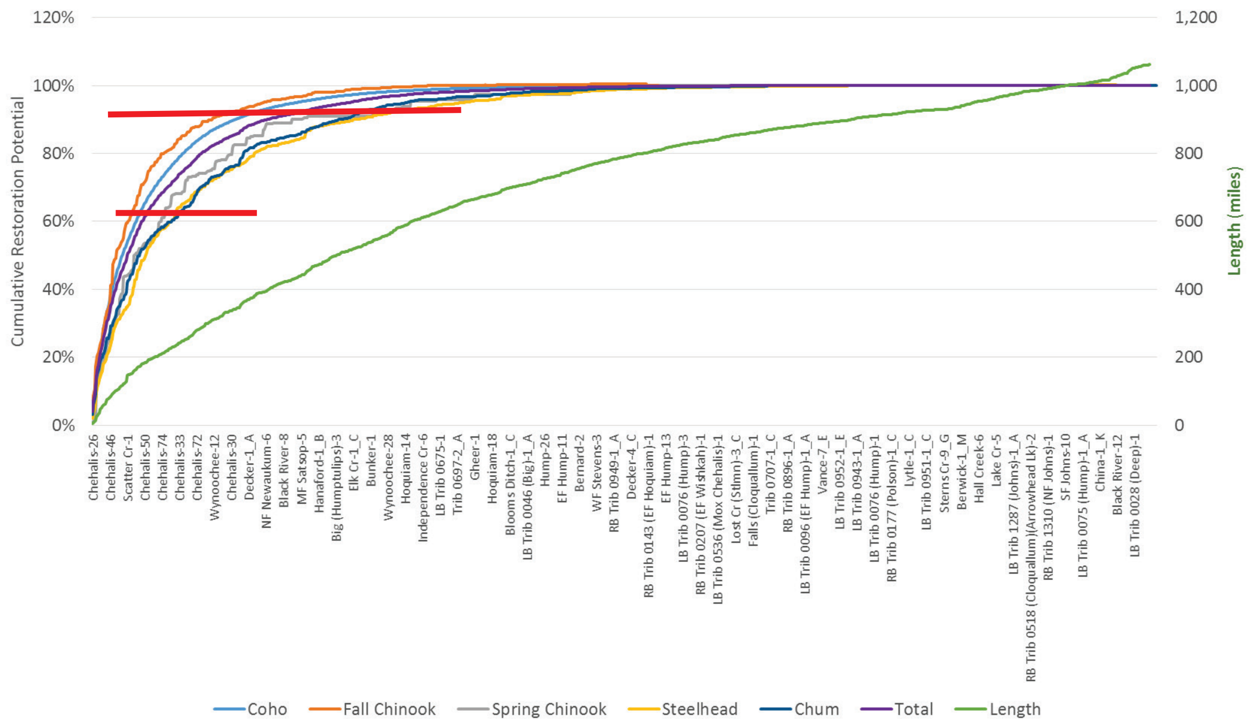
The ASRP strategy included an initial combination of active restoration and tree growth, culminating in passive maintenance of restored habitat conditions as riparian forests are restored and mature. Six ASRP restoration scenarios were analyzed for Phase 1 that varied by time period, restoration treatment, spatial extent of the treatment, and the effectiveness of the treatment to change aquatic habitat conditions.

Time period. The analysis evaluated habitat change in the Chehalis Basin during the 21st century at three points in time. The baseline for the analysis was the EDT depiction of the current condition (2017) of the Chehalis Basin. Modeling of the current condition was based on available empirical, modeled, and expert-derived data described in McConnaha et al. (2017). Future conditions were depicted at mid-century and late century. These future periods roughly correspond to projections of climate conditions in 2040 and 2080 (Mauger et al. 2016).

Reach selection. Habitat restoration treatments were applied to a subset of reaches inside and outside managed forest. Reaches were selected using a "bottom-up" approach to establish the level of restoration effort for Phase 1. For each reach within the EDT model, we computed the change in abundance of each of the five modeled salmonid species with full restoration[2] (referred to as restoration potential). The restoration potential by reach was then ordered by the change in abundance of Coho salmon; Coho salmon were chosen for this ordering because of their broad distribution throughout the Chehalis Basin and overlap with all modeled species. The ranked restoration potential for each reach was then added sequentially to create a cumulative curve of restoration potential. Figure 1 shows the procedure used to select two levels of spatial application of restoration treatments outside managed forest. A similar procedure was used to select reaches that received active restoration treatment inside managed forest. Various levels of cumulative reach selection were used to depict alternative restoration scenarios based on the cumulative potential for Coho salmon. The cumulative restoration potential by reach corresponded to miles of stream restoration used to estimate the cost of ASRP restoration. The SC will select the appropriate level of effort for the Phase 1 ASRP.

[2] Full restoration was assumed to be the historic template condition.

Figure 1
Cumulative Restoration Potential by Reach Outside Managed Forests for Chehalis Salmonids, Plus Cumulative Stream Length



Note: Two levels of reach selection are shown in red based on the 60% and 90% cumulative potential for Coho salmon. Note that because of the large number of reaches (2,208) only a sub-set of reach labels appear. A similar procedure was followed to select reaches for active restoration inside managed forests.

Effectiveness of habitat restoration treatments. The habitat restoration treatments were shaped to reflect changes over time using effectiveness scalars (Box 1). We used the scalars to construct a narrative regarding how the ASRP actions might be implemented over time and to reflect our synthesis of the available scientific literature regarding the interaction between riparian forests and instream habitat conditions for salmonids. The scalars captured our assumptions regarding the effectiveness of the treatments to affect instream conditions over time as well as social and legal considerations.

Artificial obstructions. The current Chehalis EDT model contains 338 culverts that restrict the upstream passage of anadromous salmonids to varying degrees. The current array of culverts in the model was derived by intersecting the assumed salmon spawning distribution with the most recent culvert inventory from the Washington Department of Fish and Wildlife (WFDW; designated FPDSI_WRIA22and23_08012017). The spawning distribution of the five species is documented in McConnaha et al. (2017) and was based on the current Washington State-Wide Integrated Fish Distribution (SWIFD). The SWIFD maps for the Chehalis Basin are undergoing review and modification by

WDFW and the tribes. The updated fish distribution will be incorporated in future updates of the Chehalis EDT model.

The STRT has modified the distribution of spring-run Chinook salmon spawning described in Technical Memorandum 1 (STRT 2017) to be used in this analysis. Relative to the original SWIFD distribution used in the model, the adopted distribution of spring-run Chinook salmon is more spatially restricted and excludes the mainstem Chehalis River below the South Fork Chehalis River and the lower reaches of the major tributaries.

We assumed that by mid-century, culvert restoration would focus on those culverts with the greatest impact on salmonid habitat and that it would not be feasible to address all 338 culverts currently in the model (which are themselves a subset of a greater number of culverts throughout the Chehalis Basin). To identify the key culverts for restoration by mid-century, each of the 338 culverts was ranked in regard to its impact on restoration potential using the Chehalis EDT model.[3] In most sub-basins, a small number of key culverts have the greatest impact on habitat potential; presumably these higher impact culverts would be the target of restoration in the near term. Those culverts that cumulatively added up to 50% of the total impact of culverts in the sub-basin were assumed to be removed (set to 100% passage) by mid-century in the EDT model. Typically, this resulted in less than 50% of the total number of modeled culverts in a sub-basin being removed.

Box 1: Effectiveness Scalars

Scenarios evaluated in the Phase 1 analysis were defined by the application of generalized conceptual models (Figure 2) for two categories of restoration actions: 1) restoration of riparian forest corridor; and 2) the addition of large wood to the stream channel. The conceptual models defined the maximum effectiveness of the actions to change instream habitat conditions. Effectiveness scalars were used to reduce the maximum effectiveness to capture hypotheses about the growth of riparian forests and their effectiveness to provide shade and to contribute structural elements to stream channels. The scalars were also used to capture assumptions regarding the feasibility of restoration across the Basin given differences in social and legal constraints. The scalars were arrived at through the deliberations of the STRT to construct a narrative that described the expected sequence of actions in the ASRP. The values were based on our synthesis of the scientific literature and knowledge of the Chehalis system.

<u>Future climate</u>. Over the course of the 21st century, the climate of the Chehalis Basin is expected to change, increasing water temperature and winter peak stream flows while reducing summer stream flows (Mauger et al. 2016). The expected change in water temperature under future climate was estimated by Portland State University (PSU) (Van Glubt et al. 2016). PSU used a CE-QUAL-W2 model to estimate future water temperature in the mainstem Chehalis River based on projections of air temperature from the University of Washington Climate Impacts Group for the 2040–2090 period under the Representative Concentration Pathways (RCP) 8.6 warming assumptions (Mauger et al. 2016). These model results, used

[3] https://public.tableau.com/profile/jon.walker5889#!/vizhome/CulvertRemovalPrioritiesintheChehalisBasin/Dashboard

for the late-century climate condition, are referred to as “high” climate change. PSU has not evaluated future conditions in other years. Therefore, the mid-century climate condition was estimated for Phase 1 by adjusting the PSU high climate change temperature values. Most projections of climate change over this period describe a roughly linear increase in air temperature between 2017 and 2080 (Mauger et al. 2016). The year 2040 was picked to represent mid-century condition and is 36% of this 63-year period. Therefore, assuming a linear relationship between climate change and time, the projected 2080 increase in water temperature from the PSU modeling was reduced by 64% to represent the effect of climate change around 2040 or mid-century; this condition is referred to as “low” climate change.

Description of Scenarios

For Phase 1 of the ASRP analysis, the parameters described in Table 1 were combined to create nine scenarios that were evaluated using the Chehalis EDT model (current plus two FNA scenarios and six restoration scenarios). The defining features and assumptions of each scenario are shown in Table 2. The label applied to each scenario in the analysis is listed in the column labeled “EDT Code.” This labeling shows first the strategy (FNA or ASRP), followed by the cumulative reach assumption outside managed forest/inside managed forest, and finally the time period (mid- or late century). For example, ASRP60/30-Mid refers to a scenario with ASRP restoration applied to the reaches providing 60% of the restoration potential outside managed forest (Figure 1) and 30% cumulative restoration potential inside managed forest, in the mid-century time period. The SC has applied an alternative nomenclature to the scenarios that is shown in the column labeled “SC Code.”

Three habitat restoration treatments were adjusted using the effectiveness scalars (Box 1) and applied to the selected reaches at the appropriate time period in Table 2. “Riparian including LWD” is a long-term treatment in which trees along the riparian corridor have matured and potentially provide full riparian functionality including the effects of large woody debris (LWD). “Riparian without LWD” is a shorter-term treatment in which trees have increased in height and provide shade but are too small to provide instream wood. “LWD addition” is a shorter-term strategy to put wood or wood structures into streams pending full maturation of riparian forests. The habitat restoration treatments are shown in colors in Table 2 that correspond to the conceptual models in Figure 2 that describe how the treatments were linked to changes in aquatic habitat in the modeling.

Table 2

Features and Assumptions of Scenarios Evaluated for the Phase 1 ASRP

					OUTSIDE MANAGED FOREST					INSIDE MANAGED FOREST				
EDT CODE	SC CODE	ACTION	CLIMATE CHANGE	CULVERTS	CUMULATIVE REACH SELECTION	TREATMENT WITHIN SELECTED REACHES	EFFECTIVENESS SCALAR APPLIED TO TREATMENT	TREATMENT TO NON-SELECTED REACHES	EFFECTIVENESS SCALAR APPLIED TO TREATMENT	CUMULATIVE REACH SELECTION	TREATMENT WITHIN SELECTED REACHES	EFFECTIVENESS SCALAR APPLIED TO TREATMENT	TREATMENT TO NON-SELECTED REACHES	EFFECTIVENESS SCALAR APPLIED TO TREATMENT
Base	Base	None	Current	Current	Current					Current				
MID-CENTURY														
FNA-Mid	NoActMid	No-Action	Low	Current	None	None	NA	None	NA	100%	Riparian without LWD	0.20	NA	NA
ASRP60/ 30-Mid	Mod1Mid	ASRP	Low	Top 50% Fixed	60%	LWD Addition	0.20	None	NA	30%	Riparian including LWD	0.20	Riparian without LWD	0.20
ASRP90/ 30-Mid	High1Mid	ASRP	Low	Top 50% Fixed	90%	LWD Addition	0.20	None	NA	30%	Riparian including LWD	0.20	Riparian without LWD	0.20
ASRP60/ 60-Mid	Mod2Mid	ASRP	Low	Top 50% Fixed	60%	LWD Addition	0.20	None	NA	60%	Riparian including LWD	0.20	Riparian without LWD	0.20
ASRP90/ 60-Mid	High2Mid	ASRP	Low	Top 50% Fixed	90%	LWD Addition	0.20	None	NA	60%	Riparian including LWD	0.20	Riparian without LWD	0.20
LATE CENTURY														
FNA-End	NoActEnd	No-Action	High	Current	None	None	NA	None	NA	100%	Riparian including LWD	0.40	NA	NA
ASRP60-End	Mod1End &Mod2End	ASRP	High	100% Fixed	60%	Riparian including LWD	0.40	None	NA	100%	Riparian including LWD	0.60	NA	NA
ASRP90-End	High1End &High2End	ASRP	High	100% Fixed	90%	Riparian including LWD	0.40	None	NA	100%	Riparian including LWD	0.60	NA	NA

Base Condition

The base condition for the analysis depicted the current condition of the watershed. The EDT base condition scenario characterizes the current condition of the stream based on empirical data collected from around 1975 to 2016 (McConnaha et al. 2017).

Mid-Century

All mid-century scenarios incorporated the "Low" climate change assumptions.

FNA-Mid. The FNA scenario assumed no future modification of habitat conditions in the Chehalis Basin as a result of human actions by mid-century. This includes improvement in adult fish passage—all obstructions were set to current levels of fish passage impairment through mid-century. Except for climate-related attributes, conditions in reaches outside managed forest did not change over the study period in the FNA-Mid alternative. We assumed that riparian forests inside managed forest areas would be protected by the WFPA and grow over the study period. However, we concluded that the trees would be relatively small by mid-century and unlikely to be large enough to provide LWD and affect the structure and habitat composition of the stream. To provide LWD and structural elements, riparian trees need to be in excess of 100 years old (Box 2). However, tree height should be sufficient by mid-century to provide shade and moderate stream temperature. Based on these considerations, we used the "Riparian without LWD" restoration treatment (Figure 2) and applied a 0.20 scalar to all reaches inside managed forest in mid-century to reflect limited tree growth.

Box 2: Impact of Tree Growth and Size on the Contribution of Large Wood to Streams

Riparian forests affect many instream conditions including providing shade, large wood structure, and other key salmonid habitat features (Bilby and Ward 1991; McConnaha et al. 2016). Accumulation of wood to provide habitat features and affect channel conditions requires larger anchor pieces to limit downstream movement of downed wood. Studies indicate that tree growth would increase shade in the near and long term, but in the near term would not increase wood abundance because trees would be too small to remain in the channel and form pools, and the rate of recruitment would not overcome the depletion rate by 2040 (McHenry et al. 1998; Beechie et al. 2000). Wood abundance may just begin to increase by 2080, but the change in abundance would not likely be significant, especially in larger streams and rivers where only older and larger pieces of wood will anchor wood jams or form pools (Beechie and Sibley 1997). Until trees fully mature (are greater than 100 years old), the effect of riparian recovery would largely be limited to the effect of shade on water temperature.

ASRP60/30-Mid. This scenario envisions active restoration outside managed forest in those reaches providing 60% of the restoration potential outside managed forest. We assumed that riparian tree plantings would occur immediately after implementation of the ASRP, but that relatively little growth of trees would occur by mid-century. Instead, LWD and engineered wood structures would be added to "jump-start" restoration ("LWD

Addition"). Because of logistical, legal, and other challenges to restoration outside managed forest, we concluded that this active restoration of LWD should have a relatively low effectiveness scalar of 0.20.

ASRP60/30-Mid also assumed limited active restoration inside managed forest by mid-century in addition to continued growth of existing riparian forest. Active restoration, which was envisioned to include installation of large wood anchor pieces to collect wood provided by the riparian forest, was applied to reaches providing 30% of the cumulative restoration potential inside managed forest area ("Riparian including LWD"). Because of the short time period and the limited time for growth of riparian trees, an effectiveness scalar of 0.20 was applied to this active restoration. In the reaches inside managed forest that were not selected for active restoration, continued growth of trees was assumed, but trees were assumed to be too small by mid-century to contribute to LWD recruitment ("Riparian without LWD"). Because of the small size of trees by mid-century, we concluded that an effectiveness scalar of 0.20 was appropriate.

The ASRP60/30-Mid scenario also assumed that the culverts providing 50% of the restoration benefits in a sub-basin would be removed or repaired to provide 100% adult upstream passage.

<u>ASRP60/60-Mid</u>. This scenario was identical to ASRP60/30-Mid except that restoration was applied to reaches inside managed forest providing 60% of the cumulative restoration potential inside managed forest.

<u>ASRP90/30-Mid</u>. This scenario was identical to ASRP60/30-Mid except that restoration was applied to reaches outside managed forest providing 90% of the cumulative restoration potential.

<u>ASRP90/60-Mid</u>. This scenario was identical to ASRP60/30-Mid except that restoration was applied to reaches providing 90% of the cumulative restoration potential outside managed forest, while active restoration was applied to reaches providing 60% of the cumulative restoration inside managed forest.

Late Century

All late century scenarios incorporated the "high" climate change assumptions.

<u>FNA-Late</u>. The FNA-Late scenario assumed no future modification of habitat conditions in the Chehalis Basin by late century as a result of human actions. All obstructions remained at current levels of passage impairment through the end of the century. Riparian forests inside managed forest areas were assumed to recover over the study period to a substantial degree because of continued tree growth. However, we concluded that tree growth by the end of the century would still likely not be large enough to provide full functionality including LWD and affect the structure and habitat composition of the stream (Box 2). Later in the century, tree height should increase and create enough shade to moderate temperature. Based on these considerations, we applied the "Riparian without LWD" restoration treatment (Figure 2) at a 0.40 scalar to all reaches inside managed forest by late century.

<u>ASRP60-Late</u>. By late century, we assumed that riparian forest in restored reaches outside managed forest and all reaches inside managed forest would be substantially restored and that creation and maintenance of instream habitat conditions would be largely controlled by natural processes with little or no active restoration. This scenario assumed that restoration outside managed forest would focus on those reaches that provide 60% of the restoration potential. We concluded that restoration would be more challenging outside managed forest and that riparian conditions outside managed forest would start out in a more degraded condition than reaches inside managed forest that have benefited from application of the WFPA since 1988 to fish-bearing streams, and since 2000 to non-fish-bearing streams. Based on this we applied a moderate effectiveness scalar of 0.40 to the “Riparian including LWD” restoration treatment for this scenario.

Inside managed forest, no selection of reaches for restoration occurred by the end of the century. All reaches inside managed forest were assumed to be substantially functional and provide shade, wood structure, and other attributes influenced by riparian forest. However, we did not assume full functionality of the riparian forest by the end of the century because of limited tree growth (Box 2). We applied the “Riparian including LWD” restoration model, but assumed an effectiveness multiplier of 0.60, higher than that assumed for outside managed forest.

<u>ASRP90-Late</u>. This scenario is identical to the ASRP60-Late except that restoration is applied to reaches providing 90% of the restoration potential outside managed forests.

Habitat Restoration Effectiveness Conceptual Models

The effectiveness of the restoration treatments in Table 2 to modify instream conditions was assessed based on conceptual models developed by an expert panel in 2016 (discussed in McConnaha et al. 2017) and recently reviewed and updated by the STRT. These conceptual models (Figure 2) describe the maximum effectiveness of the restoration action to change attributes in the EDT model based on growth and maturity of riparian trees and the addition of LWD. To create the scenarios discussed in the previous section, the maximum effectiveness from the conceptual models was reduced by the effectiveness scalars shown Table 2 (see also Box 1).

Conceptual models were developed for three restoration treatments that were applied to selected reaches as shown in Table 2:

- Riparian including LWD
- Riparian without LWD
- LWD addition

We concluded that the effect of the three restoration actions depended on stream size (Figure 2). In general, the effect of wood and riparian condition on stream attributes was judged to be less in large streams than in smaller streams (Vannote et al. 1980). For the Phase 1 analysis, large streams were defined as having a summer stream width larger than 18.5 meters, and small streams were defined as having a summer stream width smaller than 18.5 meters. This value was chosen based on the summer width of the Newaukum River at the confluence of the North, Middle, and South forks. Based on this delineation, the lower reaches of the major tributaries and the mainstem Chehalis River below the South Fork Chehalis River are designated as "large."

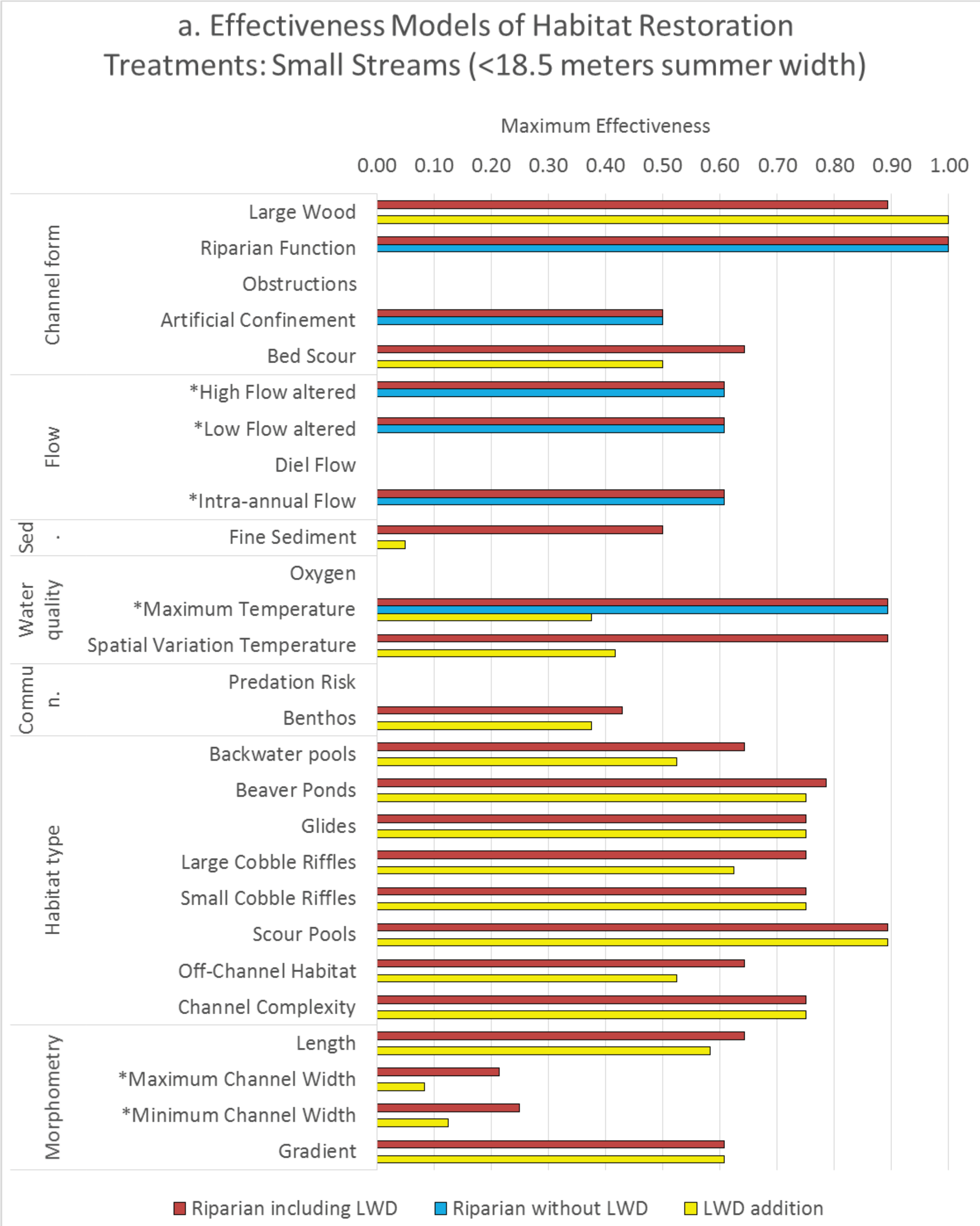
"Riparian including LWD" addresses the effect of a fully functional riparian forest on the associated aquatic environment (Figure 2). This condition is characterized as old-growth forest with trees older than 100 years old (Box 2). Few areas of the Chehalis Basin presently have fully functioning, old-growth riparian forest. Large old-growth trees that eventually fall into the stream create anchor pieces that can remain for several hundred years. These trap smaller pieces and have a major impact on channel form and habitat formation (Beechie and Sibley 1997). On the Olympic Peninsula, functional riparian areas have trees typically older than 100 years old (McHenry et al. 1998). Most of the upper Chehalis watershed is managed for commercial timber and has been rotated several times following cutting of the original old-growth. Riparian forests on fish-bearing streams within these areas have been protected by the WFPA since 1988 and have trees that are now around 30 years old. By the end of the century these areas should have trees of sufficient size and age to provide substantial riparian functions (Box 2).

"Riparian without LWD" refers to riparian conditions in mid-century or in areas outside managed forest that have little or no riparian forest (Figure 2). Trees are not expected to be of sufficient size by mid-century to provide appreciable riparian function other than shade. We constructed the "Riparian without LWD" model in Figure 2 by removing all wood-related connections between riparian forest and instream conditions.

"LWD addition" includes active addition of large wood either as wood pieces or as more elaborate engineered wood structures (Figure 2). This type of active restoration can provide some of the function of large wood provided by a fully functional riparian forest, but does not provide shade and temperature moderation and other factors included in the "Riparian including LWD."

The conceptual models depict the maximum effectiveness of an action to address the restoration potential of attributes in the model. The maximum effectiveness of an action displayed in Figure 1 was reduced using scalars to reflect specific assumptions and conditions in Table 2. The resulting adjusted effectiveness is applied to the restoration potential for each affected attribute in the appropriate reaches and months (Figure 3). Restoration potential is the difference between habitat potential under fully restored (historic) conditions and the current condition at attribute, reach, sub-basin, or basin scales.

Figure 2
Effectiveness Assumptions Regarding the Maximum Effectiveness of Restoration Actions on Attributes in the EDT Model



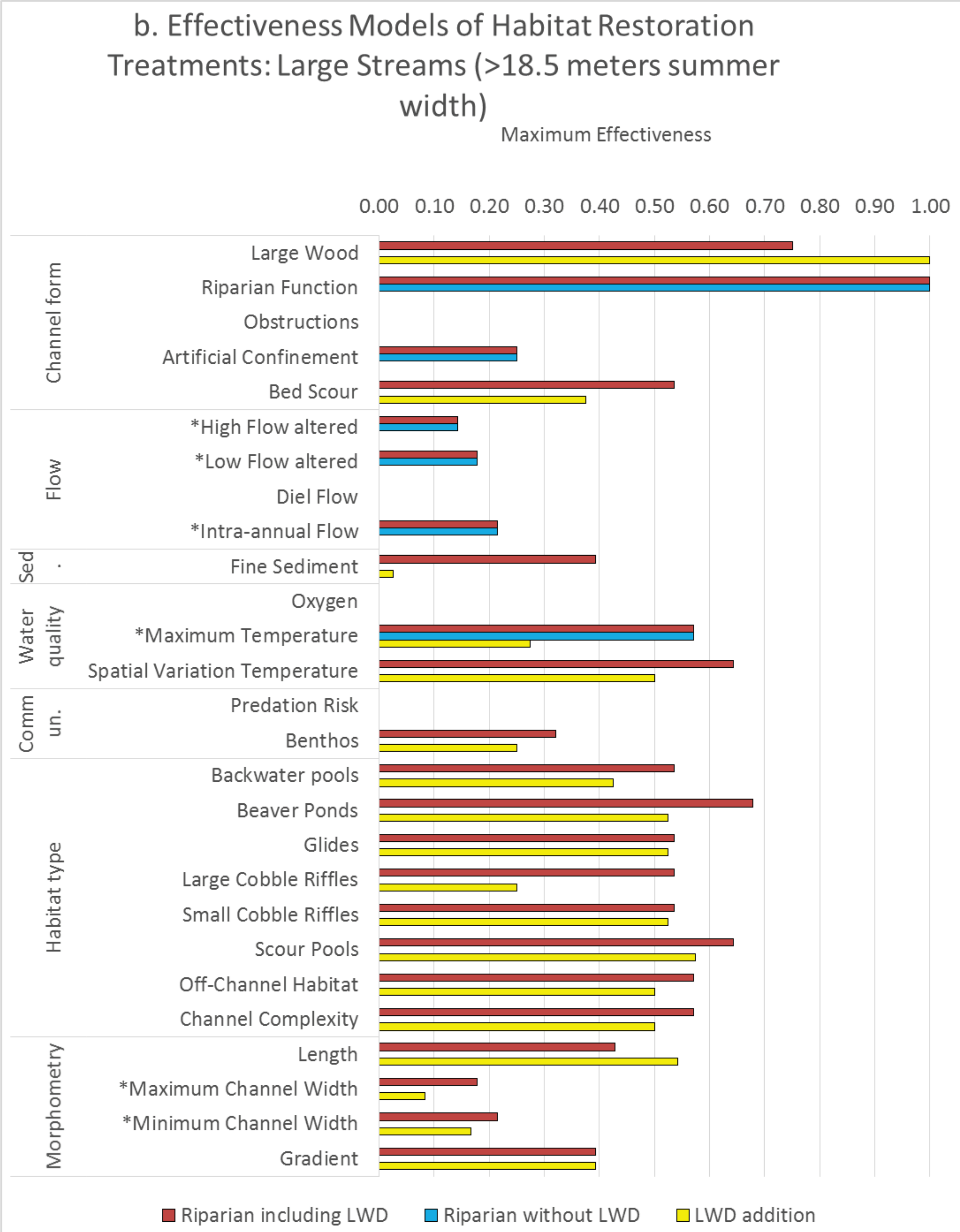
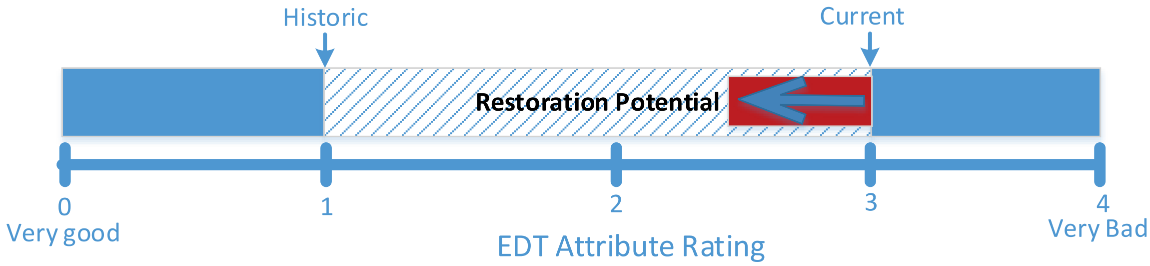

b. Effectiveness Models of Habitat Restoration Treatments: Large Streams (>18.5 meters summer width)
Maximum Effectiveness
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
Channel form
Large Wood
Riparian Function
Obstructions
Artificial Confinement
Bed Scour
Flow
*High Flow altered
*Low Flow altered
Diel Flow
*Intra-annual Flow
Sed.
Fine Sediment
Water quality
Oxygen
*Maximum Temperature
Spatial Variation Temperature
Commun.
Predation Risk
Benthos
Habitat type
Backwater pools
Beaver Ponds
Glides
Large Cobble Riffles
Small Cobble Riffles
Scour Pools
Off-Channel Habitat
Channel Complexity
Morphometry
Length
*Maximum Channel Width
*Minimum Channel Width
Gradient
Riparian including LWD
Riparian without LWD
LWD addition

Figure 3
Procedure for Capturing Change in EDT Attributes as a Result of Restoration Actions



Note:
Change is bounded by the Current condition of the attribute in a reach and the Historic condition of the attribute. Actions move the setting toward the Historic condition based on the effectiveness of the action to change the attribute.

Results

The impact of the eight ASRP scenarios on the five Chehalis River salmonid species was evaluated using the Chehalis EDT model (McConnaha et al. 2017). The model estimated the change in the potential of habitat in the Chehalis Basin to support the five species measured as the change in potential abundance (fish returning to the Chehalis River without harvest) relative to baseline conditions. Species in the model were broken down into spawning aggregations referred to as geospatial units that roughly correspond to sub-watersheds (e.g., the Newaukum River). Change in potential abundance was computed for each geospatial unit and rolled up to the basin scale.

Two baseline conditions were used to compute change in abundance potential in this analysis. The current condition baseline was used to evaluate how habitat potential will change in the future compared to the habitat potential that currently exists in the Basin, and to compute change resulting from the FNA scenario as well as the ASRP restoration scenarios described above. The second baseline was the FNA scenario. This baseline was used to evaluate how future changes due to the ASRP habitat restoration compares to the future if nothing is done to restore aquatic habitat. This accounts for expected change in climate as well as the continued growth of trees within managed forest areas. Using the current condition as the basis for computing change assumes a flat baseline into the future while using the FNA assumes a declining baseline over time due to climate change and forest growth. Given the likelihood that future climate in the Chehalis Basin will degrade habitat for the five species, the use of FNA baseline is probably more realistic.

The discussion here will focus on the Basin-level results shown in Figures 4 through 7. Results for the eight scenarios in each geospatial unit for all five species are shown in Tables 3 through 8.

With no restoration actions by mid-century (FNA-Mid), climate change is projected to decrease the abundance of Coho salmon, spring-run Chinook salmon, fall-run Chinook salmon, and steelhead compared to the abundance under current habitat conditions (Figure 4). Chum salmon were the least responsive species to habitat change in the model and abundance showed no response to the mid-century no-action scenario. Chum salmon spend the least amount of time in freshwater of the five species and only experience conditions in the Chehalis Basin during fall and winter when temperatures are moderate and flows high. As a result, they were generally insensitive to habitat changes compared to other species. The moderate ASRP habitat restoration scenarios (ASRP60/30-Mid and ASRP60/60-Mid) substantially reduced the effect of future climate, but still resulted in a decrease in potential abundance by mid-century compared to abundance under the current base condition. Chum salmon abundance showed a small increase under the moderate ASRP scenarios by mid-century. The high ASRP scenarios (ASRP90/30-Mid and ASRP90/60-Mid) resulted in greater potential abundance for all modeled species by mid-century compared to abundance under the current base condition (Figure 4). Potential abundance of spring-run Chinook salmon increased under these scenarios by about 12% relative to current abundance.

Compared to the response with no restoration action at mid-century (FNA-Mid), the increase in potential abundance with the ASRP restoration for all five species was uniformly greater and positive (Figure 5). Spring-run Chinook salmon and Coho salmon potential abundance increased about 25% under the moderate ASRP treatments and by about 43% under the high ASRP treatments compared to their expected condition by mid-century with no restoration actions. Potential abundance of fall-run Chinook salmon, steelhead, and Chum salmon increased about 8% under the moderate ASRP and by 8 to 14% under the high ASRP compared to their abundance by mid-century with no restoration actions.

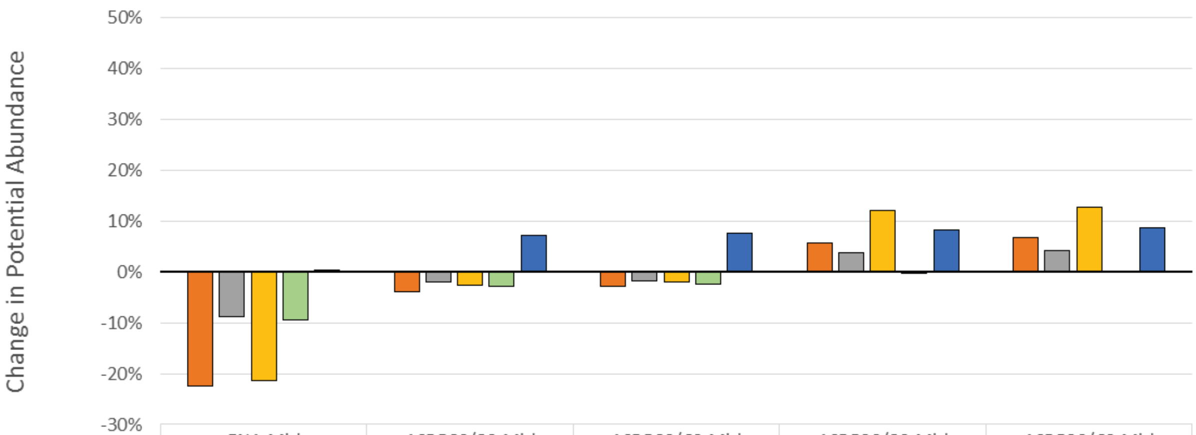
By late century the negative effect of doing nothing (FNA-Late) reduced spring-run Chinook salmon abundance by about 50% and reduced the abundance of Coho salmon, fall-run Chinook salmon, and steelhead by about 23% compared to their abundance under current habitat conditions (Figure 6).[4] However, the moderate ASRP scenario (ASRP 60-Late) counteracted the negative effects of future climate and more than doubled the abundance of spring-run Chinook salmon compared to their abundance under current habitat conditions. Other species showed lesser but still significant change by late century under the moderate ASRP scenario compared to the current condition. The positive effects of the high ASRP scenario were even greater, increasing spring-run Chinook salmon abundance by a factor of 2.5 by late century compared to the current abundance. Abundance of Coho salmon almost doubled under the high ASRP scenario while fall-run Chinook salmon and steelhead abundance increased by about 43% compared to current abundance.

Without any restoration actions (FNA-Late) the abundance of all five species was projected to decline considerably by late century relative to their current abundance (Figure 6). Using FNA-Late as the base, the increase due to the ASRP scenarios was appreciably greater than the change relative to the current habitat condition (Figure 7). The increase was pronounced for spring-run Chinook salmon. Abundance of

[4] Note that the vertical scale is considerably expanded in Figures 5 and 6 compared to Figures 3 and 4.

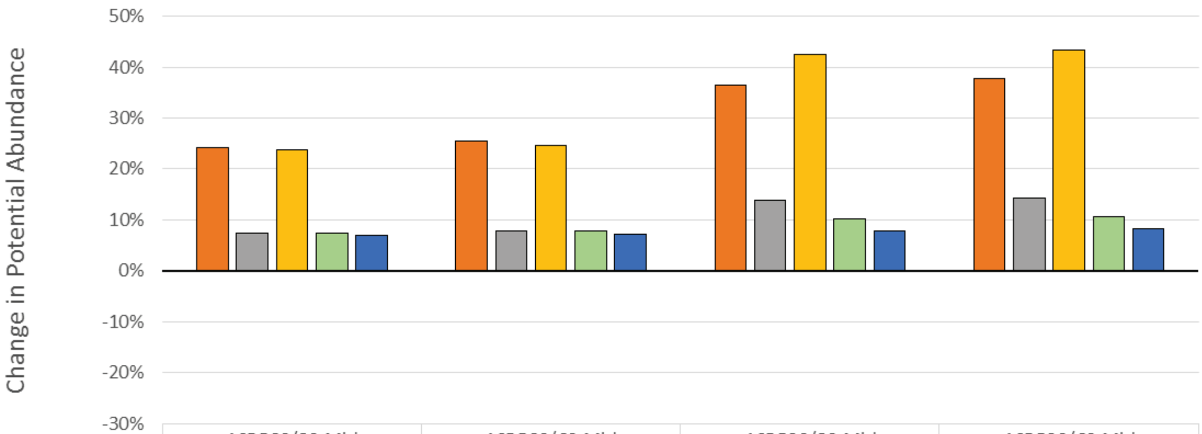
this species more than tripled under the moderate ASRP scenario compared to the expected abundance by late century with no action. With the high ASRP scenario spring-run Chinook salmon abundance increased more than six fold by late century compared to the no action scenario. Potential abundance of Coho salmon increased by a factor of 1.8 by late century while fall-run Chinook salmon and steelhead increased by about 85% compared to the projected abundance by late century with no further actions.

Figure 4
Condition of Chehalis Basin Salmonids by Mid-Century Under ASRP Alternatives Compared to the Current Base Scenario



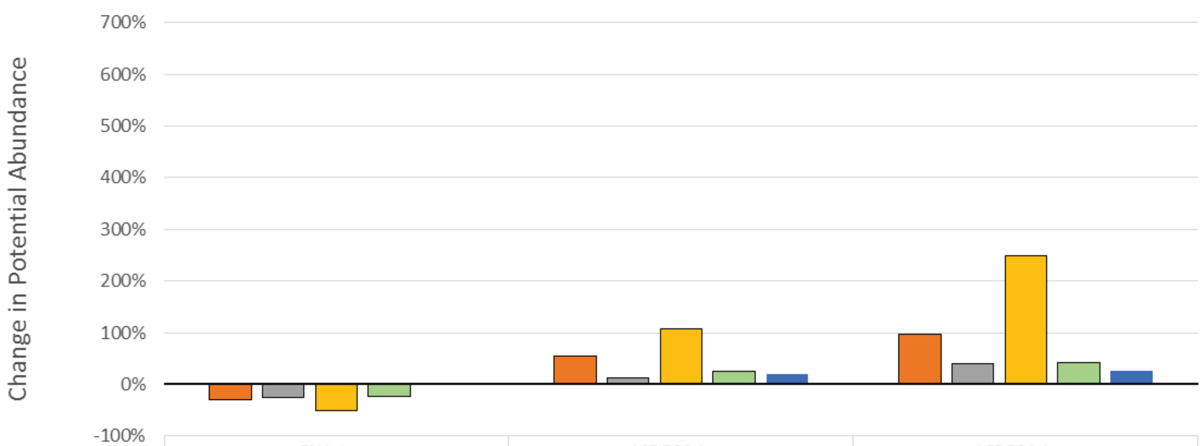
	FNA-Mid	ASRP60/30-Mid	ASRP60/60-Mid	ASRP90/30-Mid	ASRP90/60-Mid
Coho	-22%	-4%	-3%	6%	7%
Fall Chinook	-9%	-2%	-2%	4%	4%
Spring Chinook	-21%	-3%	-2%	12%	13%
Steelhead	-10%	-3%	-2%	0%	0%
Chum	0%	7%	8%	8%	9%

Figure 5
Condition of Chehalis Basin Salmonids by Mid-Century Under ASRP Alternatives Compared to the No-Action Scenario



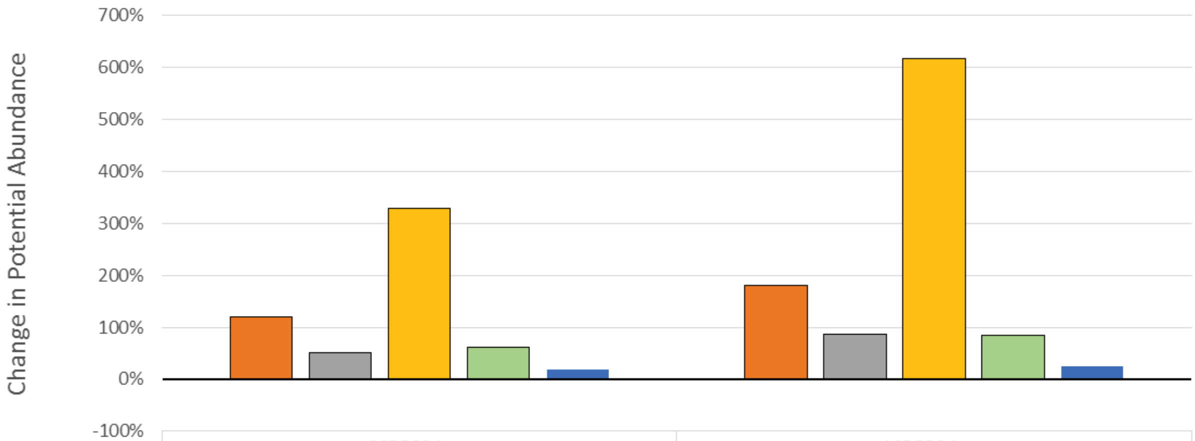
	ASRP60/30-Mid	ASRP60/60-Mid	ASRP90/30-Mid	ASRP90/60-Mid
Coho	24%	25%	36%	38%
Fall Chinook	7%	8%	14%	14%
Spring Chinook	24%	25%	42%	43%
Steelhead	7%	8%	10%	11%
Chum	7%	7%	8%	8%

Figure 6
Condition of Chehalis Basin Salmonids by Late Century Under ASRP Alternatives Compared to the Current Base Scenario



	FNA-Late	ASRP60-Late	ASRP90-Late
Coho	-30%	55%	97%
Fall Chinook	-25%	12%	40%
Spring Chinook	-51%	108%	249%
Steelhead	-23%	25%	43%
Chum	1%	20%	26%

Figure 7
Condition of Chehalis Basin Salmonids by Late Century Under ASRP Alternatives Compared to the No-Action Scenario



	ASRP60-Late	ASRP90-Late
Coho	119%	180%
Fall Chinook	50%	87%
Spring Chinook	328%	618%
Steelhead	62%	85%
Chum	19%	25%

Coho Fall Chinook Spring Chinook Steelhead Chum

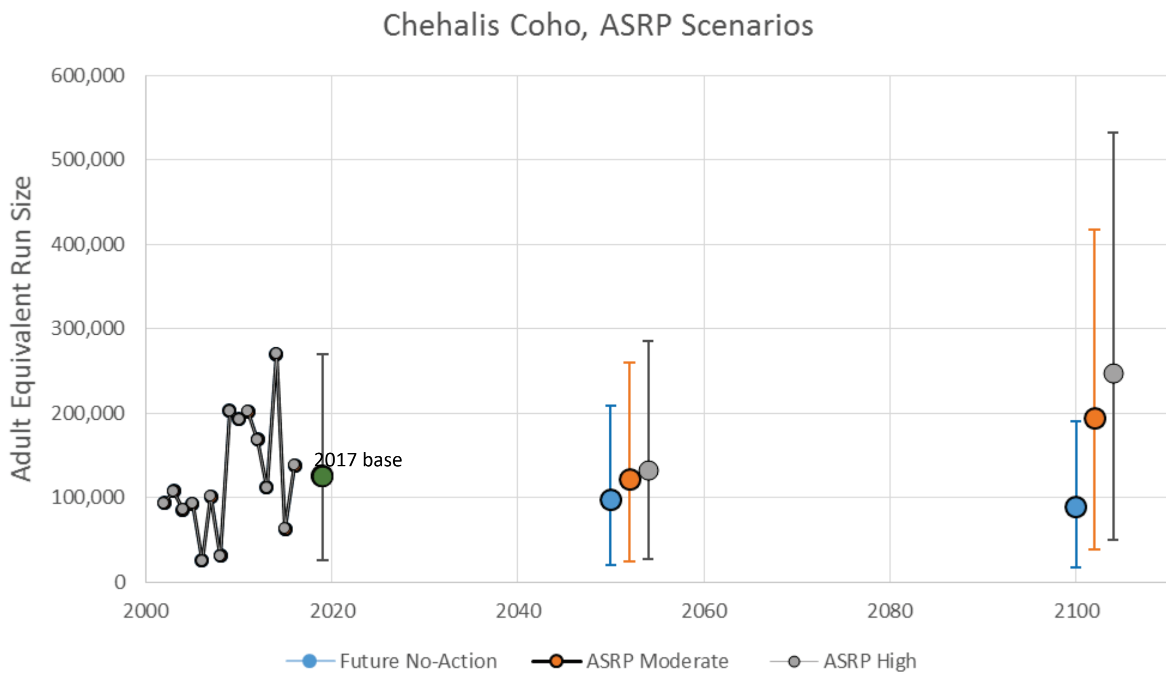
Change with Variation

EDT is a deterministic model, meaning that it does not address random environmental or biological variation. The model computes potential average performance for the modeled species under a static set of habitat conditions. In this analysis, we have modeled habitat conditions as they exist currently and as they might exist at mid- and late century. The deterministic value provided by EDT allows decision makers to compare alternatives in regard to their potential impact on salmonids. However, it is important to bear in mind that the abundance and returns of salmonids to the Chehalis River will vary greatly based largely on conditions outside the control of the ASRP, especially changes in survival conditions in the Pacific Ocean (Zimmerman et al. 2015).

To emphasize this point, we arrayed the modeled change in Chehalis River habitat potential along a timeline in the context of expected natural variability in the abundance of Chehalis River Coho salmon (Figure 8). The purpose was to illustrate the effect of natural year-to-year variation and provide reasonable expectations of future annual variation in abundance of Coho salmon for each EDT projection under the ASRP. The potential variability in fish response to habitat change illustrated in Figure 8 is based on estimates of the total annual Coho salmon smolt production from the Chehalis system and annual marine survival rate developed by WDFW (Zimmerman 2017). This information was developed by WDFW as a basis for setting ocean harvest rates and is only available for Coho salmon.

Figure 8 starts with adult equivalent abundance of Chehalis Coho salmon from 2002 to 2016. Forward projections for 2017, mid-century, and late century used the EDT results from Figures 4 through 7. Whiskers around these forward projections illustrate the potential annual variation in abundance based on the observed variation in fish abundance in the 2002 to 2016 period. Data comparable to that in Zimmerman (2017) is not available for other species; however, the impact of natural variability on fish response to habitat change is equally valid for the other modeled species. The results provide reasonable expectations of the year-to-year range in abundance that could be expected in the future based on past variability in abundance.

Figure 8
Historic and Projected Abundance of Chehalis River Coho Salmon



Note:
Annual variation (whiskers) around the projected abundance (filled circles) is based on the variation in the 15-year period from 2002 to 2016.

Discussion

Phase 1 analysis focused on the effect of restoration of the riparian corridor and the addition of large wood in selected areas of the Chehalis Basin. We evaluated eight alternative future conditions ranging from no-action (climate change and tree growth only) to scenarios that assumed extensive restoration of the riparian corridor and large wood. The ASRP restoration strategy in the near term emphasized land management (acquisition and easements) coupled with active restoration in areas outside and inside managed forest. This active restoration was assumed to consist of addition of large wood and installation of engineered wood structures. By late century, however, the strategy would shift to more passive restoration with increasing reliance on natural processes to create and maintain riparian habitat. Importantly, the positive changes in habitat potential seen by late century are dependent on the success of land management and active habitat restoration measures taken in the shorter term. The key role of these early actions to the ultimate success of the program belies the relatively modest restoration benefits calculated for the mid-century conditions. The benefits seen by late century also depend on the continued protection of riparian zones in managed forest areas by the WFPA and the resulting growth and maturation of riparian forests throughout the Basin.

The purpose of the Phase 1 analysis has been to “size” the ASRP in terms of expectations of benefits and to estimate the spatial extent of restoration in order to estimate the cost of the program. Rather than guide actual restoration projects, this exercise was intended to provide a perspective on scope and costs. During subsequent phases of the ASRP, the STRT will work with the SC to craft a more strategic approach to restoration. We anticipate that the more top-down approach will reveal important synergisms and opportunities to increase the efficiency and effectiveness of restoration.

The results of this analysis highlight key concerns regarding the future status of Chehalis salmonids without significant restoration. The abundance of all modeled species was greatly reduced as a result of future climate conditions. Spring-run Chinook salmon under the no-action alternative were projected to be particularly reduced in the future and are likely to be functionally extinct (meaning unable to be self-sustaining over longer time periods) within the model by late century as a result of increased water temperature due to climate change. By late century, four of the seven spring-run Chinook salmon geospatial units are calculated to have an abundance potential of less than 50 fish (Table 5). Abundance potential of habitat in the Newaukum River for spring-run Chinook salmon (the most productive geospatial unit) was reduced from about 890 fish under current habitat to about 480 by late century under the FNA strategy. This reduction in abundance reflects decreased productivity and capacity of the species under future climate and habitat conditions. Given normal variation in survival conditions between years, many years would likely see an abundance of appreciably less than is calculated by the EDT model under the average condition. Results for other species, while not as extreme as for spring-run Chinook salmon, indicate concerns for all species under future climate without the support of significant restoration.

Notably, the estimated impact of climate change on spring-run Chinook salmon is more optimistic than reported previously (McConnaha et al. 2017). Previous analysis did not assume continued growth of trees within managed forest areas, which somewhat moderated the projected effect of future climate in this analysis. More significantly, however, is the effect of the revised spawning distribution for spring-run Chinook salmon (STRT 2017). The previously assumed distribution of spring-run Chinook salmon included spawning in the mainstem Chehalis River that was not included in the revised spawning distribution. Given their size, the mainstem reaches contributed appreciably to the previous estimate of potential production of spring-run Chinook salmon under the current condition (McConnaha et al. 2017). At the same time habitat potential in these reaches was greatly reduced or eliminated under future climate as a result of the projected water temperature increase. The loss in habitat potential in the mainstem reaches in the previous analysis resulted in a large overall reduction in abundance of spring-run Chinook salmon as a result of climate change. Eliminating the mainstem reaches from the distribution in the current analysis removed the portion of the modeled distribution most affected by climate change and thereby reduced the estimated overall impact of climate change on spring-run Chinook salmon in the model. However, this does not make the future condition of Chehalis River spring-run Chinook salmon any less dire. The elimination of habitat potential for the species in several sub-basins and the small remaining abundance potential raise significant questions regarding the viability of the species under future climate conditions.

The following limitations to this analysis should be considered:

1. The analysis evaluated the restoration program as three snapshots of conditions that might develop in the future as a result of the ASRP. In reality, the restoration program would be a continuous effort intended to achieve the long-term goal. Shorter term actions may not provide impressive short-term benefits, but are pivotal to the ultimate success of the program.
2. Future climate in this analysis addressed changes in the Chehalis Basin watershed and did not capture changes that may occur in Grays Harbor or the ocean due to climate change that could negatively affect Chehalis Basin salmonids. Changes in ocean temperature, pH, and other factors are likely to decrease ocean survival for salmonids in the future (Abdul-Azia et al. 2011) making the results reported here optimistic with regard to climate change impacts.
3. The analysis assumed that the effects of human development on modeled habitat will remain at the current level into the future. This will almost certainly not be the case given projections of population increase in the south Puget Sound (Bolte and Vache 2012; Lackey 2017). The effects of future development will be evaluated in subsequent phases of the ASRP and may be incorporated into the baseline condition in the future.
4. Selection of reaches in which to apply the restoration treatments for the analysis did not reflect a systematic approach to restoration, but instead was done by a simple ranking of all reaches in the Chehalis Basin in regard to the potential gains from full restoration of the reach in isolation (Figure 1). This means that a single reach would be restored to its historic condition but reaches upstream and downstream would remain in their current condition. Experience with the EDT model indicates that important synergisms exist with regard to restoration benefits between reaches. Restoring multiple adjoining reaches usually provides a greater benefit to fish abundance than does the sum of restoring each reach in isolation.
5. The reach-selection process favored Coho salmon over other species. The restoration proportions in each scenario described in Table 2 were chosen based on the cumulative restoration potential for Coho salmon (Figure 1). Because each species has a distinct distribution across the Basin in the model, a different proportion of restoration potential was chosen for each of the other species. This is illustrated in Table 3.

Table 3
Cumulative Restoration Potential for Chehalis River Reaches Ordered by Coho Salmon

LENGTH	COHO	FALL CHINOOK	SPRING CHINOOK	STEELHEAD	CHUM	TOTAL
OUTSIDE MANAGED FOREST						
163 miles	60%	65%	51%	43%	48%	60%
345 miles	90%	92%	83%	76%	76%	90%
INSIDE MANAGED FOREST						
42 kilometers	30%	37%	0%	18%	31%	28%
129 kilometers	60%	68%	18%	37%	52%	56%

In the area outside managed forest, choosing 60% of the cumulative restoration potential for Coho salmon meant that reaches providing only 51% of spring-run Chinook salmon, 43% of steelhead, and 48% of Chum salmon cumulative reach potential was selected (Table 3). Even more striking, choosing 30% cumulative restoration for Coho salmon inside managed forest meant that no spring-run Chinook salmon spawning reaches benefited from active restoration in the mid-century ASRP restoration measures (though they did benefit from forest growth). Choosing 60% of the cumulative habitat potential for Coho salmon inside managed forest meant that only 18% of the spring-run Chinook salmon restoration potential benefited from the mid-century restoration measures.

The reason for this discrepancy is that even though Coho salmon are distributed throughout the Chehalis Basin, the bulk of the Coho salmon habitat potential is in the lower sub-basins such as the Satsop and Wynoochee rivers. Spring-run Chinook salmon, however, are found (at least in the model) only in sub-basins above and the Skookumchuck River. This meant that when reaches were selected for restoration based on the cumulative restoration potential for Coho salmon, restoration was tipped in favor of the lower Chehalis Basin with less benefit going to upper sub-basins where spring-run Chinook salmon are found.

The more strategic approach to restoration planned for subsequent phases of the ASRP should address this and use a more equitable selection of restoration priorities.

Table 4

Results of the Phase 1 Analysis for Coho Salmon in Individual Sub-Basins

			MID-CENTURY										LATE-CENTURY					
	BASE	TEMPLATE	FNA-MID	ASRP60/30-MID	ASRP90/30-MID	ASRP60/60-MID	ASRP90/60-MID	FNA-MID	ASRP60/30-MID	ASRP90/30-MID	ASRP60/60-MID	ASRP90/60-MID	FNA-LATE	ASRP60-LATE	ASRP90-LATE	FNA-LATE	ASRP60-LATE	ASRP90-LATE
South Bay Streams	635	3,967	562	564	564	564	564	-11%	-11%	-11%	-11%	-11%	409	445	445	-36%	-30%	-30%
Humptulips River	7,988	34,596	7,584	7,840	8,077	7,950	8,186	-5%	-2%	1%	0%	2%	7,089	8,630	9,836	-11%	8%	23%
Hoquiam River	1,960	4,473	1,662	1,695	1,801	1,695	1,801	-15%	-14%	-8%	-14%	-8%	1,032	1,146	1,756	-47%	-42%	-10%
Wishkah River	4,816	10,024	4,023	4,341	4,711	4,341	4,711	-16%	-10%	-2%	-10%	-2%	2,675	4,421	6,190	-44%	-8%	29%
Wynoochee River	5,616	24,143	4,899	5,558	6,331	5,571	6,343	-13%	-1%	13%	-1%	13%	5,138	7,682	10,605	-9%	37%	89%
Satsop River	11,058	33,071	10,053	11,425	11,775	11,654	11,999	-9%	3%	6%	5%	9%	11,038	15,271	17,086	0%	38%	55%
Satsop to Skookumchuck	9,705	67,659	6,036	8,100	9,502	8,170	9,571	-38%	-17%	-2%	-16%	-1%	4,386	14,187	19,089	-55%	46%	97%
Black River	8,098	24,003	4,595	6,812	7,623	6,845	7,656	-43%	-16%	-6%	-15%	-5%	4,111	9,342	11,499	-49%	15%	42%
Scatter Creek	1,201	4,605	711	1,272	1,280	1,272	1,280	-41%	6%	7%	6%	7%	328	1,847	1,901	-73%	54%	58%
Skookumchuck River	4,520	34,263	3,497	5,038	5,520	5,079	5,561	-23%	11%	22%	12%	23%	1,675	8,405	11,186	-63%	86%	147%
Skookumchuck to South Fork	1,753	35,386	828	1,248	1,349	1,248	1,349	-53%	-29%	-23%	-29%	-23%	771	4,257	5,656	-56%	143%	223%
Newaukum River	4,173	37,962	2,568	4,059	4,737	4,059	4,737	-38%	-3%	14%	-3%	14%	2,040	13,037	15,866	-51%	212%	280%
South Fork Chehalis	4,041	34,647	3,308	4,594	5,585	4,718	5,722	-18%	14%	38%	17%	42%	4,080	10,603	14,334	1%	162%	255%
South Fork to Elk	581	9,726	421	531	616	531	616	-28%	-9%	6%	-9%	6%	395	1,354	2,181	-32%	133%	276%
Elk Creek	1,758	10,625	1,673	1,874	2,032	1,958	2,119	-5%	7%	16%	11%	21%	1,967	3,060	4,193	12%	74%	139%
Elk to Crim	432	7,695	270	525	570	525	570	-38%	22%	32%	22%	32%	197	634	1,600	-54%	47%	271%
Above Crim	777	6,983	881	1,015	1,020	1,015	1,020	13%	31%	31%	31%	31%	1,379	2,497	2,735	78%	221%	252%
Total	69,111	383,829	53,570	66,493	73,091	67,195	73,806	-22%	-4%	6%	-3%	7%	48,707	106,817	136,158	-30%	55%	97%

Table 5

Results of the Phase 1 Analysis for Spring-Run Chinook Salmon in Individual Sub-Basins

			MID-CENTURY										LATE-CENTURY					
	BASE	TEMPLATE	FNA-MID	ASRP60/30-MID	ASRP90/30-MID	ASRP60/60-MID	ASRP90/60-MID	FNA-MID	ASRP60/30-MID	ASRP90/30-MID	ASRP60/60-MID	ASRP90/60-MID	FNA-LATE	ASRP60-LATE	ASRP90-LATE	FNA-LATE	ASRP60-LATE	ASRP90-LATE
South Bay Streams																		
Humptulips River																		
Hoquiam River																		
Wishkah River																		
Wynoochee River																		
Satsop River																		
Satsop to Skookumchuck																		
Black River																		
Scatter Creek																		
Skookumchuck River	240	4,065	199	266	322	266	322	-17%	11%	34%	11%	34%	0	506	863	-100%	111%	259%
Skookumchuck to South Fork																		
Newaukum River	890	14,100	650	845	954	845	954	-27%	-5%	7%	-5%	7%	438	2,003	2,982	-51%	125%	235%
South Fork Chehalis	322	6,235	248	301	373	309	383	-23%	-6%	16%	-4%	19%	216	683	1,303	-33%	112%	304%
South Fork to Elk	96	2,393	88	94	96	94	96	-9%	-2%	0%	-2%	0%	1	93	326	-99%	-3%	240%
Elk Creek	55	828	41	42	53	45	56	-26%	-23%	-4%	-18%	1%	42	87	165	-24%	58%	199%
Elk to Crim	47	904	32	33	36	33	36	-33%	-30%	-23%	-30%	-23%	0	16	110	-99%	-67%	133%
Above Crim	109	1,292	128	133	139	133	139	17%	21%	27%	21%	27%	158	276	389	45%	152%	256%
Total	1,760	29,817	1,384	1,714	1,972	1,725	1,985	-21%	-3%	12%	-2%	13%	855	3,665	6,137	-51%	108%	249%

Table 6

Results of the Phase 1 Analysis for Fall-Run Chinook Salmon in Individual Sub-Basins

			MID-CENTURY										LATE-CENTURY					
	BASE	TEMPLATE	FNA-MID	ASRP60/30-MID	ASRP90/30-MID	ASRP60/60-MID	ASRP90/60-MID	FNA-MID	ASRP60/30-MID	ASRP90/30-MID	ASRP60/60-MID	ASRP90/60-MID	FNA-LATE	ASRP60-LATE	ASRP90-LATE	FNA-LATE	ASRP60-LATE	ASRP90-LATE
South Bay Streams	473	942	469	469	469	469	469	-1%	-1%	-1%	-1%	-1%	460	463	463	-3%	-2%	-2%
Humptulips River	8,252	18,834	8,172	8,294	8,399	8,329	8,440	-1%	1%	2%	1%	2%	6,742	7,790	8,604	-18%	-6%	4%
Hoquiam River	1,456	1,603	1,426	1,426	1,425	1,426	1,425	-2%	-2%	-2%	-2%	-2%	1,332	1,334	1,413	-8%	-8%	-3%
Wishkah River	3,859	4,645	3,692	3,769	3,829	3,769	3,829	-4%	-2%	-1%	-2%	-1%	3,148	3,650	4,167	-18%	-5%	8%
Wynoochee River	2,956	11,483	2,657	2,776	3,095	2,779	3,098	-10%	-6%	5%	-6%	5%	2,074	2,972	4,847	-30%	1%	64%
Satsop River	4,767	10,192	4,381	4,810	4,893	4,856	4,940	-8%	1%	3%	2%	4%	3,715	5,497	6,075	-22%	15%	27%
Satsop to Skookumchuck	3,794	20,890	3,013	3,422	4,047	3,424	4,049	-21%	-10%	7%	-10%	7%	2,446	5,125	6,562	-36%	35%	73%
Black River	882	3,690	431	800	901	804	907	-51%	-9%	2%	-9%	3%	336	1,213	1,499	-62%	38%	70%
Scatter Creek																		
Skookumchuck River	517	4,102	479	590	688	590	688	-7%	14%	33%	14%	33%	326	859	1,276	-37%	66%	147%
Skookumchuck to South Fork	401	4,505	379	444	491	444	491	-6%	11%	22%	11%	22%	231	691	959	-42%	72%	139%
Newaukum River	1,082	11,942	868	1,058	1,172	1,058	1,172	-20%	-2%	8%	-2%	8%	536	2,088	2,990	-50%	93%	176%
South Fork Chehalis	517	5,043	446	522	635	535	656	-14%	1%	23%	4%	27%	309	764	1,391	-40%	48%	169%
South Fork to Elk	187	1,983	172	187	210	187	210	-8%	0%	12%	0%	12%	139	274	443	-26%	46%	136%
Elk Creek	19	180	16	17	20	17	20	-15%	-10%	5%	-10%	5%	8	17	41	-55%	-9%	119%
Elk to Crim	85	878	70	74	81	74	81	-17%	-12%	-4%	-12%	-4%	44	86	155	-48%	2%	83%
Above Crim	113	721	98	100	105	100	105	-13%	-11%	-7%	-11%	-7%	82	137	200	-27%	22%	78%
Total	29,358	101,633	26,770	28,760	30,460	28,862	30,579	-9%	-2%	4%	-2%	4%	21,928	32,960	41,084	-25%	12%	40%

Table 7

Results of the Phase 1 Analysis for Steelhead Salmon in Individual Sub-Basins

			MID-CENTURY										LATE-CENTURY					
	BASE	TEMPLATE	FNA-MID	ASRP60/30-MID	ASRP90/30-MID	ASRP60/60-MID	ASRP90/60-MID	FNA-MID	ASRP60/30-MID	ASRP90/30-MID	ASRP60/60-MID	ASRP90/60-MID	FNA-LATE	ASRP60-LATE	ASRP90-LATE	FNA-LATE	ASRP60-LATE	ASRP90-LATE
South Bay Streams	71	615	68	68	68	68	68	-4%	-4%	-4%	-4%	-4%	58	70	70	-18%	-2%	-2%
Humptulips River	892	3,715	789	808	823	813	827	-12%	-9%	-8%	-9%	-7%	712	846	948	-20%	-5%	6%
Hoquiam River	260	598	197	197	203	197	203	-24%	-24%	-22%	-24%	-22%	165	197	218	-36%	-24%	-16%
Wishkah River	285	722	247	252	260	252	260	-13%	-11%	-9%	-11%	-9%	241	290	330	-15%	2%	16%
Wynoochee River	1,670	4,895	1,413	1,475	1,581	1,477	1,583	-15%	-12%	-5%	-12%	-5%	1,395	1,787	2,211	-16%	7%	32%
Satsop River	3,006	6,541	2,679	2,783	2,830	2,806	2,852	-11%	-7%	-6%	-7%	-5%	2,775	3,401	3,725	-8%	13%	24%
Satsop to Skookumchuck	725	3,052	677	917	933	920	936	-7%	27%	29%	27%	29%	610	1,172	1,346	-16%	62%	86%
Black River	238	975	201	242	246	245	249	-16%	1%	3%	3%	4%	212	362	398	-11%	52%	67%
Scatter Creek																		
Skookumchuck River	165	586	153	162	171	162	171	-7%	-1%	4%	-1%	4%	41	188	255	-75%	14%	55%
Skookumchuck to South Fork	90	1,261	70	90	92	90	92	-22%	0%	2%	0%	2%	63	214	260	-30%	138%	189%
Newaukum River	1,288	4,363	1,236	1,374	1,405	1,374	1,405	-4%	7%	9%	7%	9%	1,146	1,941	2,185	-11%	51%	70%
South Fork Chehalis	520	1,497	481	480	487	485	491	-7%	-8%	-6%	-7%	-5%	574	794	873	11%	53%	68%
South Fork to Elk	164	904	172	178	180	178	180	5%	9%	10%	9%	10%	172	274	347	5%	68%	112%
Elk Creek	305	863	312	308	312	308	312	2%	1%	2%	1%	2%	333	419	476	9%	37%	56%
Elk to Crim	35	333	29	53	54	53	54	-16%	53%	58%	53%	58%	16	38	55	-54%	9%	59%
Above Crim	253	1,094	292	289	291	289	291	15%	14%	15%	14%	15%	369	495	554	46%	95%	119%
Total	9,965	32,014	9,016	9,677	9,936	9,717	9,976	-10%	-3%	0%	-2%	0%	7,706	12,489	14,251	-23%	25%	43%

Table 8

Results of the Phase 1 Analysis for Chum Salmon in Individual Sub-Basins

			MID-CENTURY										LATE-CENTURY					
	BASE	TEMPLATE	FNA-MID	ASRP60/30-MID	ASRP90/30-MID	ASRP60/60-MID	ASRP90/60-MID	FNA-MID	ASRP60/30-MID	ASRP90/30-MID	ASRP60/60-MID	ASRP90/60-MID	FNA-LATE	ASRP60-LATE	ASRP90-LATE	FNA-LATE	ASRP60-LATE	ASRP90-LATE
South Bay Streams	2,091	5,558	2,096	2,096	2,096	2,096	2,096	0%	0%	0%	0%	0%	2,113	2,149	2,149	1%	3%	3%
Humptulips River	18,894	38,606	18,880	19,091	19,193	19,163	19,264	0%	1%	2%	1%	2%	18,491	20,063	20,730	-2%	6%	10%
Hoquiam River	6,519	8,053	6,499	6,499	6,545	6,499	6,545	0%	0%	0%	0%	0%	6,405	6,454	6,746	-2%	-1%	3%
Wishkah River	10,585	13,508	10,551	10,763	10,906	10,763	10,906	0%	2%	3%	2%	3%	10,406	11,293	11,981	-2%	7%	13%
Wynoochee River	26,422	39,092	26,797	28,176	28,354	28,180	28,358	1%	7%	7%	7%	7%	27,310	30,390	31,907	3%	15%	21%
Satsop River	44,833	66,379	45,371	46,553	46,767	46,918	47,131	1%	4%	4%	5%	5%	47,715	51,818	52,874	6%	16%	18%
Satsop to Skookumchuck	54,432	106,503	54,584	62,261	62,739	62,387	62,865	0%	14%	15%	15%	15%	54,777	71,390	74,065	1%	31%	36%
Black River	8,398	12,799	8,315	8,692	8,727	8,692	8,727	-1%	4%	4%	4%	4%	8,045	9,505	9,754	-4%	13%	16%
Scatter Creek	2,154	5,060	2,126	2,283	2,288	2,283	2,288	-1%	6%	6%	6%	6%	2,038	2,978	3,008	-5%	38%	40%
Skookumchuck River	6,524	16,688	6,472	6,841	7,280	6,841	7,280	-1%	5%	12%	5%	12%	6,254	7,997	10,077	-4%	23%	54%
Skookumchuck to South Fork	5,965	20,154	5,904	6,956	7,111	6,956	7,111	-1%	17%	19%	17%	19%	5,685	8,932	9,768	-5%	50%	64%
Newaukum River	5,372	12,684	5,327	6,056	6,128	6,056	6,128	-1%	13%	14%	13%	14%	5,177	8,679	9,014	-4%	62%	68%
South Fork Chehalis	566	1,054	560	574	601	574	601	-1%	2%	6%	2%	6%	540	615	723	-5%	9%	28%
South Fork to Elk	2,405	5,169	2,377	2,451	2,613	2,451	2,613	-1%	2%	9%	2%	9%	2,259	2,757	3,543	-6%	15%	47%
Elk Creek																		
Elk to Crim																		
Above Crim																		
Total	195,158	351,306	195,860	209,294	211,347	209,860	211,912	0%	7%	8%	8%	9%	197,215	235,021	246,339	-100%	20%	26%

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