Aquatic Species Enhancement Plan Data Gaps Report

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Chehalis Basin Strategy: Reducing Flood Damage and Enhancing Aquatic Species

Prepared for

Chehalis Basin Work Group

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LIST OF ACRONYMS AND ABBREVIATIONS

ASEP	Aquatic Species Enhancement Plan
BACI	Before-After-Control Impact
Basin	Chehalis Basin
cfs	cubic feet per second
EDT	Ecosystem Diagnosis & Treatment
GLO	General Land Office
HEC	Hydrologic Engineering Center
HSC	Habitat Suitability Criteria
HSI	Habitat Suitability Index
PHABSIM	Physical Habitat Simulation
PIT	passive integrated transponder
Project	Chehalis Basin Strategy: Reducing Flood Damage and Enhancing Aquatic Species Project
PTAGIS	Columbia Basin PIT Tag Information System
RAS	River Analysis System
RM	River Mile
Strategy	Chehalis Basin Salmon Habitat Restoration and Preservation Strategy
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Service
VSP	viable salmonid population
WDFW	Washington Department of Fish and Wildlife
WUA	weighted usable area

Introduction

The Chehalis Basin Strategy: Reducing Flood Damage and Enhancing Aquatic Species Project (Project) is a feasibility-level study of the benefits and impacts of alternatives for flood hazard mitigation and enhancement of aquatic species in the Chehalis Basin (Basin). The purpose of the Project is to provide information for the Chehalis Basin Work Group and stakeholders in the region that will be used to decide whether to advance the Project to the next phase (Phase 2) of the feasibility study and project permitting. Flood hazard mitigation alternatives included in the Project's scope are as follows:

- A water retention structure on the Upper Chehalis River
- Levees, berms, and other water retention structures along Interstate 5
- A suite of smaller water retention projects throughout the Basin
- A survey of the number and elevation of structures in the Upper Chehalis floodplain and the potential effects that various projects and flood events would have on those structures

Categories of enhancement alternatives included the following:

- Removal of fish barriers (e.g., culverts)
- Enhancements to in-channel and floodplain (side-channel) habitats for Key Species (e.g., in-channel wood placement and reconnecting side channels to the main river channel)
- Riparian corridor enhancement and restoration

In addition to these categories, the Project also evaluated several future climate scenarios and estimated the potential effects of climate variability on flooding, flood hazard mitigation alternatives, and aquatic species.

A significant component of the Project is the Aquatic Species Enhancement Plan (ASEP). The ASEP includes studies to characterize key aquatic resources in the Basin, identify habitat enhancement strategies and actions, and evaluate the potential effects of flood hazard mitigation alternatives and climate variability on these resources.

This Data Gaps Report identifies data gaps that emerged as habitat enhancement, flood hazard mitigation, and climate studies were implemented. These gaps reflect a lack of data, situations where data were too sparse to support a robust analysis, data needed to improve model studies and reduce model uncertainty, and aspects of analyses that would benefit from a detailed review of the scientific literature. For example, a critical analysis of the benefits and impacts associated with dams on aquatic resources would help direct future analyses. The gaps identified in this report should be considered if a decision is made to advance the Project to Phase 2. Gaps were identified for key habitat and species, physical modeling, climate change, and watershed restoration planning categories.

The information provided in this report was compiled by staff from the Washington Department of Fish and Wildlife (WDFW), Washington Department of Ecology, and the Anchor QEA consulting team (Anchor QEA, ICF International, Confluence Environmental Company, and BioAnalysts, Inc.). Data gaps will be prioritized in the future based on discussions of the gaps and their importance to increasing the certainty of results of model studies and analyses.

Key Habitat and Species Data Gaps

1 Introduction

Key Habitat and Species that could be affected by proposed flood hazard reduction alternatives and habitat enhancements were reviewed. The process used to select species for analysis is described in the ASEP report and its appendices. The process resulted in a list of approximately 70 Key Species being incorporated into the ASEP analytical framework. Of these, 46 Key Species of selected fish, invertebrates, mammals, and birds were addressed in the text and 23 had sufficient information to support model studies of the effects of water retention and habitat enhancement alternatives on them. In addition, five non-native species were selected to be analyzed, because these species may either alter habitat suitability for native species or benefit directly or indirectly from habitat changes resulting from Project alternatives in ways that impact either a group or association of species (guild) or individual Key Species. In general, the most information available for use in analyses pertained to four salmon species (or runs) that were previously assessed using salmon habitat models.

Key Species in the Basin were organized into guilds that use the same habitat types or habitat features. The responses of Key Species in each guild to flood hazard mitigation alternatives were analyzed using models appropriate for the available data. Models used varied from single-variable models, such as Habitat Suitability Indices (HSIs), to models that incorporated multiple factors and how the factors interacted with different life history stages and species, such as the Ecosystem Diagnosis & Treatment (EDT) model. The detail available to characterize model results varied with the model used.

Specific data gaps identified for Key Habitats and Species were grouped into four categories: Key Habitats, Salmonid Species, In-channel Other Fish and Non-fish Species, and Off-channel Other Fish and Non-fish Species.

In general, for the habitats and habitat features modeled, additional information is needed to improve confidence in the predicted future effects of flood hazard mitigation and habitat enhancement actions. For species lacking information, the gathering of information needed for improving the interpretation of effects of flood hazard mitigation and habitat enhancement alternatives should be prioritized based on a cost-benefit analysis to identify the most appropriate species to target. To increase the confidence in the estimated potential for restoration actions to enhance a suite of species, studies should be conducted to identify the factors that limit species and enhancement actions and strategies to address those limiting factors.

2 Identifying and Quantifying Key Habitats

Habitat types were organized to help assign species to guilds through a coarse-filter/fine-filter approach. Macrohabitat represented the coarse-filter and was the initial habitat level used to assign species into macroguilds. The fine-filter component of the habitat organization included two levels of guilds that were defined as representing groups of species or certain life stages of particular species that use the same category of habitat or habitat components. Macrohabitats included instream and off-channel/low-flow habitats. The instream macrohabitat was divided into major guilds including mainstem, medium river, and small stream guilds. These major guilds were further divided into six guilds based on substrate and summer water temperatures. All of the species or life stages of species using the off-channel/low-flow macrohabitat were grouped into one macroguild due to limited data on the macrohabitat. Data gaps identified for the Key Habitats during are described in Sections 2.1.1 and 2.1.2.

2.1.1 MACROHABITATS

2.1.1.1 Survey or Review of Existing Information of Terrestrial Habitat Features and Small-scale Priority Habitats

A survey or review of existing information of selected terrestrial habitat features (e.g., wetlands, caves, cliffs, and talus) or of small-scale priority habitats (e.g., bogs) is needed. These features were either not mapped in the Basin or the resolution of their mapping was so poor that additional mapping is needed. Given a general lack of information on these habitats, these habitats were assumed to occur in most of the three terrestrial macrohabitat categories: coniferous forest, prairie/oak woodland, or riparian forest. This mapping is needed to understand whether these habitat features may be altered by changes in hydrology (inundation) as a consequence of water retention alternatives.

2.1.1.2 Additional Data and Mapping of Off-channel/Low-flow Habitat

Additional data and mapping are needed for the off-channel/low-flow macrohabitat. Data are limited for Key Other Fish and Non-fish Species that inhabit off-channel/low-flow habitat, especially in comparison to the instream macrohabitat. This limitation led to all the species or life stages of species using that habitat being grouped into one macroguild. In addition, existing aquatic off-channel/low-flow habitat mapping underestimates the actual extent of this habitat because of concealing vegetation. Efforts to map off-channel/low flow habitat in vegetated areas is needed to determine its true extent, how the extent may be altered by flood retention alternatives, and how any alterations may affect the suite of species occupying that habitat. In the absence of more specific information on the species' life history and population dynamics, the off-channel/low-flow habitat was assumed to limit the organisms in this guild in proportion to habitat area. The degree and timing of connectivity between the flowing channels of the Chehalis River and its tributaries and off-channel/low-flow habitats are also likely limiting to species in this macrohabitat. This connectivity may be affected by habitat enhancement or flood retention measures, which can be better assessed by establishing baseline conditions through thorough mapping.

2.1.1.3 Relationship Between Hydrology and Habitat Creation and Maintenance

The relationship between hydrology and wood availability and the creation and maintenance of off-channel habitat is not known. Specifically, the pattern of flooding (inundation frequency, periodicity, and flow magnitude) that results in habitat being created is unknown. While it is currently believed that a 2-year flood acting on large woody debris jams in the Basin triggers channel forming processes, how bigger floods with the same levels of wood in the channel might result in channel habitat formation has not been quantified. Therefore, a need exists to model or estimate the amount of off-channel habitat creation and maintenance at various flow levels and wood loadings. Also, any interaction between groundwater and surface waters (floods) that maintain off-channel aquatic habitat and affect the area, timing, and duration of off-channel habitat formation is poorly understood. This data gap is further discussed in the "Physical Modeling Data Gaps" section below.

2.1.1.4 Historical Aerial Photograph Analysis

A need exists to confirm the assumption that prairie/oak woodland, riparian, and off-channel/low-flow habitats have been converted to agricultural land by comparing mapped habitat with historical aerial photographs or General Land Office (GLO) survey data. The agricultural macrohabitat dominates the floodplain, whereas prairie/oak woodland is the most limited terrestrial floodplain macrohabitat. Current mapping data suggest that agriculture has replaced prairie/oak woodland and riparian forests as well as possibly off-channel/low-flow habitat. This needs to be confirmed to determine whether the suite of off-channel habitat-occupying species are constrained by current conditions and whether water retention alternatives alter those constraints. If much of the historical alteration of habitat occurred before the first aerial photographs became available and earlier losses of habitat were considerable, the use of historical GLO survey data might be important to establishing the baseline habitat condition in the Basin.

2.1.1.5 Literature Review of Effects of Temperature on Primary and Secondary Productivity

Because temperature appears to be an important aspect of aquatic specifies distributions and habitat characteristics in the Basin, and water retention alternatives may alter temperature profiles, a detailed review of the scientific literature on the effects of temperature on primary and secondary productivity in aquatic ecosystems would help direct future ASEP analyses.

2.1.2 GUILDS

2.1.2.1 Seasonal Use of Mainstem River by Cold-water Fish

Use of the mainstem river by cold-water fish is likely often limited to the colder season when river temperatures are lower, but information on colder season (mostly during late fall and winter) use patterns is limited. During warm seasons, cold-water fish use of the river is better known, but fish may use reaches differently in different seasons. It would be premature to assume that summer non-use implies winter non-use and apparent low habitat value. For example, most of the limited information on bull trout (*Salvelinus confluentus*) in the Chehalis River is based on winter use. Information on the seasonal use of mainstem habitats by cold-water fish is needed to determine whether these species are constrained by current conditions, and whether flood retention alternatives alter those constraints.

2.1.2.2 Extent of Small-stream and Medium River Habitat

All tributaries to the Chehalis River in the proposed reservoir footprint can be categorized as small-stream habitat, but the point at which small-stream habitat changes to medium-river habitat cannot be precisely defined with the current physical and biotic data, though this transition appears to occur within the proposed reservoir footprint. This issue is important because fish guilds for small and medium stream habitats differ, and the expected effects to these two guilds may be quantified based on the area affected. Therefore, delineation of the boundary is needed to determine whether these species are constrained by current conditions and how flood retention alternatives may alter those constraints.

2.1.2.3 Current and Historical Off-channel Habitats in Small-streams

A need exists to determine whether off-channel habitats in the small streams are less common now than in the past. The horizontal separation between off-channel habitats and their parent small streams is usually much less than what is found in medium or mainstem rivers. Because large wood is typically a key element needed to form off-channel habitat in small streams and large wood is thought to be limited in the Basin, it is unclear whether off-channel habitats in the small streams are less common now than in the past. This information is needed to determine whether the species occupying off-channel habitats in small streams are constrained by current conditions and whether flood retention alternatives alter those constraints.

3 Salmonid Species

Salmon species status and population parameters for current and historical time frames were compiled and summarized in the ASEP report. This effort focused primarily on spring-run Chinook salmon (*Oncorhynchus tshawytscha*), fall-run Chinook salmon (*O. tshawytscha*), winter-run steelhead (*O. mykiss*), and coho salmon (*O. kisutch*) populations. This information was used to evaluate viable salmonid population (VSP) parameters, including abundance, productivity, diversity, and spatial structure as well as input parameters for biological models used to evaluate effects of water retention alternatives, habitat enhancement, and future climate scenarios on these four species or runs of salmon. These was also sufficient information to assess the current population status of chum salmon (*O. keta*) in the Basin and VSP parameters for this species. Also, the effects of potential changes in flow associated with water retention alternatives on chum salmon habitat were modeled using Physical Habitat Simulation (PHABSIM). During ASEP implementation and discussions at workshops to identify habitat enhancement needs, the following data gaps for salmonid species were identified.

3.1.1 ADDITIONAL SPECIES DATA GAPS

Coastal cutthroat trout (*O. clarki clarki*) occur throughout much of the Basin. On June 10, 1998, bull trout were listed as threatened under the Endangered Species Act by the U.S. Fish and Wildlife Service. Portions of the Lower Basin were designated as critical bull trout habitat by the USFWS on September 30, 2010 (USFWS 2010). Bull trout have been documented in Grays Harbor and throughout the Chehalis River from the mouth to its confluence with Garrard Creek. However, detailed life history, distribution, and abundance information on these two species in the Basin is not available. This information is needed to assess the potential effects of dam alternatives and climate change and to develop habitat enhancement strategies for these species. Similarly, this same information needs to be collected on summer steelhead (*O. mykiss*) and mountain whitefish (*Prosopium williamsoni*).

3.1.2 HARVEST DATA GAPS

In general, harvest data related to focal salmonid species was adequate at the Basin scale. Several decades of systematic fisheries stock monitoring data were available and used to depict trends and patterns across historic and contemporary management periods. The only Basin-wide data deficiency related to salmon population estimation was the availability of complete harvest data for certain species (i.e., spring-run Chinook salmon and winter-run steelhead as indicated by WDFW staff [Phillips pers. comm. 2014]). These data are needed to develop reliable estimates of total run size and population productivity.

3.1.3 JUVENILE SALMON DATA GAPS

Most juvenile salmonid data collections to date have been limited in scope and collected on the mainstem Chehalis River to address specific fish harvest management questions (e.g., measuring marine survival of coho salmon) and not to evaluate differences in the life history diversity, population structure, or behavior. Most existing juvenile life history information is broadly inferred from analysis of scales and otoliths of adult fish returning from the ocean. Important behavioral patterns exist that are only evident when juveniles are examined directly through focused studies. Specific gaps for juvenile salmon life history data needed to improve EDT model parameterization and test assumptions are as follows:

- **Juvenile salmon life histories and movement patterns.** Information is needed on the timing, behavioral responses to flow events, and habitats occupied as juvenile salmonids migrate from tributaries and into the mainstem Chehalis River. Studies to determine the movement and migration patterns of juvenile

Chinook salmon, coho salmon, and steelhead in the Upper Basin are ongoing and will continue through July 2014. Juveniles from the Upper Basin and Elk Creek, South Fork Chehalis, and Newaukum sub-basins are being evaluated using a combination of radio telemetry and passive integrated transponder (PIT) tag methods. These studies are investigating whether fish move upstream past the proposed dam site, their downstream migration timing and behavior, movement from the mainstem into tributaries and off-channel habitats, and survival. Analysis of the potential effects of flood hazard mitigation alternatives will be improved by incorporating additional juvenile rearing data. For example, the following information should be gathered:

- Understanding when juvenile coho salmon and winter-run steelhead enter the mainstem river from various tributaries, travel downstream, and occupy overwintering habitats. Recent information from other systems suggests that a relatively large proportion of juvenile coho salmon may leave natal streams and enter marine waters 6 to 8 months before becoming smolts. The extent to which juvenile steelhead use habitats throughout the Basin during freshwater residence is unknown. Understanding this type of information would inform the selection of mainstem habitat restoration actions that address factors limiting productivity and improve EDT model study results. Information on the seasonal connectivity of these habitats is also needed. This connectivity allows coho salmon and other juvenile salmonids to access the habitats and can also affect their survival. This information would support assessment of potential effects of proposed enhancement measures and flood hazard mitigation alternatives.
- Further investigation of the spring-run Chinook salmon yearling life history is needed to understand its potential to support population resiliency in the future and any potential effects water retention alternatives may have on the expression of this life history, for example by altering water temperatures. Salmon population modeling conducted in Phase 1 assumed all spring-run Chinook salmon juveniles out-migrated as sub-yearlings. However, yearling migrants have been observed in the smolt trap located in the Upper Chehalis River and operated by the Chehalis Tribe. Thus, yearling migrants remain an active life history strategy for spring-run Chinook salmon in the Basin, although WDFW analyses of scales on returning adult spring-run Chinook salmon suggest that this life history may not be contributing to adult returns. Determining whether the yearling life history strategy contributes to adult returns under various environmental conditions would allow habitat enhancement actions that support this life history strategy to be prioritized.
- In general, a better understanding of the proportion and age at which various species migrate from the freshwater environment to the ocean is needed to improve assessments of project-related benefits and impacts.

- **Movement patterns of juvenile salmonids relative to instream temperature and flow.** During development of the ASEP report, substantial gaps were identified in the understanding of in-Basin movements and use of habitat by pre-spawning adults and other life stages and a lack of understanding of how juvenile salmonid movement patterns relate to environmental conditions, particularly water temperature and flow. This information is needed to improve analyses of the potential benefits and impacts of flood hazard mitigation alternatives, habitat enhancement, and future climate scenarios on salmonid species because high temperatures rank importantly among the factors thought to limit salmonid survival in the Basin. Summer movement patterns of juvenile salmonids associated with their use of cool water refugia are being determined as part of WDFW's 2013/2014 studies using PIT-tag detection arrays and Riverscape Survey, but these studies were spatially restricted to the upper portion of the Basin (mainstem river channel above the mouth of the Newaukum River). Movement patterns are also being investigated using radio telemetry techniques during the winter rearing and spring migration periods by the U.S. Geological Survey (USGS). Depending on the results of these studies, additional information may be needed to improve the understanding of how adjustments to flow and temperature from water retention structures may affect salmon populations in the mainstem river below the dam. A more complete understanding of juvenile movements (timing and location) would improve estimates of how fish might benefit from restoration investments.

- **An Upper Basin, pre-dam baseline condition for juvenile salmonid rearing and juvenile survival at the reach scale.** Salmon models included in this phase of the study incorporated critical assumptions about the current condition of habitat within the reservoir footprint area. Habitat assessments in 2013 were conducted above the proposed dam site as part of WDFW's Riverscape Survey, and the condition of the habitat appears to have changed significantly when compared to conditions observed prior to the 2007 flood event. Assessing how habitat in the reservoir footprint area changes over time and in response to major flood events would reduce uncertainty associated with estimating baseline habitat conditions in model studies.
- **Fish passage at flood retention structures**. Additional data are needed to further assess the potential impact of water retention structures on the downstream passage survival and delay of salmon parr and smolts to improve estimates of overall impacts associated with these structures. This could be accomplished through a literature review or possibly field studies of fish movement during the parr stage. For the current feasibility study, an analysis of the amount of time fish passage would be blocked with the Flood Retention Only (FRO) alternative was performed. For current conditions it was estimated that fish passage would be blocked 0.9% of the time assuming the reservoir can be drained quickly after a flood. Recent reviews of debris management in other western Washington reservoirs led to the conclusion that an extra two week reservoir pool holding period would be necessary to manage and remove debris after about a ten-year recurrence interval flood. Assuming those operations, it is estimated fish passage would be blocked 1.5% of the time, calculated on an annual basis. For both scenarios, fish passage was blocked in 9 years out of the 22 year period of record used in the hydrologic modeling. During the years in which the reservoir was utilized for flood storage, fish passage was blocked for an estimated 3-6% of the year for the first scenario and 6-8% of the year for the second scenario. In addition, fish passage will be impaired when flows exceed 2,000 cfs when the reservoir is not impounding water (the fish passage design flow is 2,000 cfs). Under existing conditions 2,000 cfs is exceeded 2.7% of the time. For the current feasibility study, the survival of juvenile and adult fish passing the FRO Alternative and the effectiveness of fish passage facilities associated with the alternative were estimated and incorporated into model studies of the effects of the FRO on salmon. However, the lack of passage when water was impounded was considered to be small and not incorporated into the analyses. Also, the time required to manage debris was not determined until late in the study and was not incorporated into model studies of the effects of the FRO on salmon. Both of these scenarios (impounding water and a two week reservoir pool holding period for debris management) should be incorporated into future analyses of the effects of the FRO Alternative on aquatic resources in the Basin.

3.1.4 ADULT SALMON DATA GAPS

Specific gaps for adult salmon data are summarized as follows:

- **Water temperature**. Temperature is thought to limit the survival of pre-spawn spring-run Chinook salmon in the Chehalis River, but between-year variability in the temperature footprint could greatly alter pre-spawn survival among years. Hence, studies of summer/fall movement and holding locations of spring-run Chinook salmon relative to mainstem and tributary instream temperatures are needed over several years to improve analyses of potential effects of water retention and habitat enhancement alternatives on this run of salmon.
- **An Upper Basin, pre-dam baseline for adult salmonid spawning habitat**. The salmon population models used in ASEP analyses included assumptions about the current condition of the habitat within the reservoir footprint area, but the area needs to be surveyed and models updated to reduce

uncertainty associated with the potential effects of flood hazard mitigation and habitat enhancement alternatives on salmon spawning habitat.

- **Movement patterns of adult salmonids relative to instream temperature and flow.** The modeling studies assume that after adult salmonids enter the Basin, they migrate to their spawning reach and hold before spawning in the same area where they spawn, especially spring-run Chinook salmon. In the model, this leads to pre-spawning mortality due to high temperatures because the model assumes the fish are exposed to high water temperatures and do not find or hold in thermal refugia. Because of these assumptions, spring-run Chinook salmon benefit from cooler water released from the multi-purpose dam water retention alternative. However, observations in other systems and the scientific literature suggest that salmon often hold in thermal refugia before they spawn, moving into spawning areas only shortly before spawning commences. Detailed information on this behavior in the Basin would improve future assessments of the effects of water retention alternatives on pre-spawn mortality.

3.1.5 STOCK ASSESSMENT DATA GAPS

Overall, population patterns and trends within the Basin are limited to the lens through which data needed to support stock assessment efforts have been gathered. Available stock assessments have characterized abundance at a spatial scale and resolution that is appropriate for managing harvest of affected salmon and steelhead stocks and not necessarily for the evaluation of Project alternatives.

For example, stock assessments conducted to date have not focused on delineating population trends or differences between areas above or below the location of the proposed water retention structure (River Mile [RM] 108). Therefore, estimates presented in the ASEP report are based on data collected to inform questions at a larger spatial scale. While the existing stock assessment data are the best available, the collection of spawner abundance and distribution data in the Upper Basin at a level consistent with currently funded activities in fall/winter of 2013/2014 should be continued for several years to understand the impact of inter-annual variability (which is frequently high) on spawner abundance and habitat use. This would enable a more detailed understanding of how salmon populations are distributed and use habitats relative to potential Project-related effects. In addition, a need exists to use genetic-based analysis of existing data to evaluate the temporal and spatial separation of spring-run and fall-run Chinook salmon, the population structure of Chinook salmon in general in the Basin, and whether the spring-run and fall-run are genetically distinct.

3.1.6 SALMON POPULATION-HABITAT MODEL DATA GAPS

The effects to salmon from changes captured in physical models were evaluated using population-habitat models. These relate habitat conditions to quantitative measures of species' performance such as fish abundance. These models require considerable physical data and knowledge of species-habitat relationships, life history patterns, and population structure. Population, life history, and habitat data for salmon species were input into two population-habitat models: EDT and SHIRAZ. Both the EDT and SHIRAZ models share a common mathematical basis that relates habitat to fish performance. The EDT model was used to evaluate changes in habitat associated with various alternatives (habitat enhancement, water retention structures, and future climate scenarios) at specific points in time and throughout the entire Basin upstream of and including the Wynoochee River. The SHIRAZ model was used to simulate population trends over time associated with a smaller subset of alternatives (water retention structures and a future climate scenario), on a smaller number of species and for the mainstem Chehalis River only.

Refinement of several data gaps would enhance the ability of the EDT and SHIRAZ models to predict impacts to salmon populations from flood hazard mitigation alternatives and benefits from habitat enhancement actions and their priorities. These are described in the following sections.

3.1.6.1 Ocean Survival

Anadromous salmonids spend the majority of their lives in the ocean where conditions are strong controllers of abundance and population fluctuations. Survival rates of salmonids once they leave the Chehalis River system are not completely known, and values derived from other systems were used for ASEP analyses. The salmon population-habitat models do not estimate ocean survival but rather use a set of assumptions to scale abundance to reflect ocean survival and harvest. Estimates of smolt-to-adult rates for winter-run steelhead, coho salmon, and fall-run and spring-run Chinook salmon for various spawning aggregations are needed to understand how annual variation in returns to the Basin are affected by marine and freshwater environmental conditions each year. This would help improve the understanding of the role flood events and thus water retention alternatives have on salmon productivity. It would require that out-migrating smolts be collected at traps and tagged or sampled from various locations and tagged, and returning adults monitored for their tags.

3.1.6.2 Historical Habitat Conditions

The effect of habitat condition on fish population performance can only be understood in the context of the intrinsic character of a watershed and its inherent ecological potential. Little detailed information exists for the historical habitat condition of the Basin. To identify the intrinsic restoration potential of the watershed, historical habitat conditions in the Basin need to be determined. While some sources of information and data exist that provide a partial understanding of the historical context (e.g., GLO plat maps, USGS flow data, and air temperature and precipitation data), little data are available that describes habitat conditions prior to increased logging and land development that occurred in the nineteenth century. For the ASEP report, authors characterized the Basin's history and development based on a review of literature and estimated the intrinsic potential of the habitat in the Basin using the EDT model. To run the EDT model, in the absence of specific information, assumptions were made regarding the pre-development habitat conditions. In addition, a starting point for watershed restoration planning is to characterize the pre-development condition of a watershed. Defining the potential geomorphic, aquatic habitat, or biological conditions that may exist within each reach independent of human impacts would provide an understanding of the watershed's inherent productivity potential, intrinsic constraints, and restoration potential limits (Roni and Beechie 2013).

Several studies could be conducted to fill this data gap. One would be to conduct an analysis using GLO plots in a manner analogous to the Willamette River analysis (Hulse et al. 2002). Understanding the watershed template also requires studying the large-scale features that define the channel forms of the Basin, including the geology, topography, and valley form (Montgomery 1999). This characterization could be conducted and combined with a more in-depth description of the aquatic resources that historically occupied the habitat, and then incorporated into the EDT model to estimate of the intrinsic habitat potential of the Basin. This would allow restoration goals to be related to that potential.

3.1.6.3 Culverts

Culvert and fish passage surveys have identified numerous barriers to upstream fish migration in the Basin. Often, culverts and other barriers to fish passage are not complete barriers, but rather, allow some proportion of passage above or below particular streamflow levels. Also, these barriers continue to be improved and/or removed by local entities and many fail once improved, which creates a constantly changing situation that must be regularly updated in order for model results to be accurate. ASEP analysis estimated benefits associated with 169 culverts identified in previous surveys as being high-priority blockages. However, these surveys were not conducted with ASEP objectives in mind, the culverts modeled were not selected based on any species-specific or sub-basin specific enhancement goals, and assumptions associated with the culvert analysis may have resulted in the estimated benefits being both over- or under-estimated. In future phases of the Project, it will be important to make sure that barriers analyzed accurately reflect on-the-ground conditions. Therefore, all culverts should be surveyed and accurately georeferenced. This will allow their status to be tracked over time and a determination made on whether the barrier meets the minimum fish passage criteria established by WDFW. This would allow barrier removal and repairs to be prioritized based on modeled responses of fish populations to various actions.

3.1.6.4 Tributary Water Temperature

Temperature is a key parameter incorporated into numerous relationships in the model. Lacking sufficient empirical information on temperatures in tributaries, EDT modelers made assumptions about water quality that affected the ecological function ratings in the model for mainstem and tributary habitats, which influenced the model outputs in terms of salmon movement and survival. Additional water temperature data in the major tributaries in the Basin are needed to support the evaluation of limiting factors and habitat enhancement strategies using the EDT model in the future.

3.1.6.5 Tributary Habitat Conditions and Fish distributions by Life Stage and Species

Habitat conditions and fish distribution patterns in Chehalis River tributaries have been described in the EDT model using expert opinion from WDFW biologists and habitat surveys where they exist. No systematic measurement of habitat attributes or fish distributions in most of the tributaries was available. Better information on these systems would enhance the accuracy of EDT model results and the utility of using the model to prioritize restoration actions.

3.1.6.6 Species Modeled

Salmon species and runs modeled using EDT included winter-run steelhead, coho salmon, and fall-run and spring-run Chinook salmon. Salmon species and runs modeled using SHIRAZ included mainstem populations of winter-run steelhead, coho salmon, and spring-run Chinook salmon. For future phases of analysis, it would be beneficial to expand the coverage of salmonid species modeled using EDT by adding chum salmon and cutthroat trout. This would allow two very different species to be included in future analyses of flood hazard mitigation and habitat restoration actions, and would result in a more comprehensive evaluation of potential effects of these actions on the aquatic ecosystem. Because of their unique life histories and use of very different habitats within the Basin, these species differ from each other and salmon species currently incorporated into salmon population-habitat models.

3.1.6.7 Life History Models

Satterthwaite et al. (2012) state that conceptual and computational theory exists that describes variation in age-specific movements by salmonids between freshwater and ocean environments and that models developed based on this theory allow predictions of life history patterns on the basis of tradeoffs between opportunities for growth and survival. These types of models should be developed for the Basin and used to assess potential effects of changes in water temperature and hydrology associated with water retention structures on salmonid life histories, especially spring-run Chinook salmon in the mainstem Chehalis River.

3.1.6.8 Literature Review of Utilization of Reservoir Habitat by Juvenile Salmon

Current modeled results for a multipurpose dam alternative were based on the assumption that coho salmon would receive a benefit from rearing in a reservoir compared to existing (river) rearing conditions. This assumption is based on limited examples, with the most relevant being long-term observations of coho salmon use of the Cowlitz Falls Dam reservoir in Lewis County. The implications of this assumption effect the modeled change of abundance for coho salmon with a multipurpose dam, yet are not well validated. A literature review or analysis of empirical information from existing facilities is needed to establish the validity of this assumption for coho salmon. Additional information on how juvenile salmon use reservoir habitats would improve future model studies of the effects of water retention alternatives on salmon production.

3.1.6.9 Benefits of Riparian Restoration

Further sensitivity analyses are needed using the EDT model to identify how much of the response to riparian restoration alternatives modeled was from temperature effects versus other attributes. Other attributes include, for example, large wood entering the instream channel and creating habitat or influencing habitat-forming processes. Understanding the contribution various parameters in the model have on the outcome will help inform and guide future analyses and restoration efforts.

3.1.6.10 Fish Passage Assumptions

The fish passage survival and collection efficiency values developed for the various types of upstream and downstream fish passage facilities at water retention alternatives were based on best professional judgment and knowledge of similar facilities installed at other dams. However, since the values affect EDT and SHIRAZ model results and in some cases the facilities are experimental, a literature review of studies of similar facilities would be useful to refine, or bracket, the survival and efficiency estimates. Preliminary results for downstream passage at existing facilities in Washington state reveal lower passage rates for certain species (Allegro pers. comm. 2014). Additional information on how adult and juvenile salmon pass dams through the proposed facilities would improve future model studies of the effects of water retention alternatives on salmon production.

4 In-channel Other Fish and Non-fish Species

Similar to salmon species, species status and population parameters were compiled and summarized for current and historical time frames in the ASEP report for In-channel Other Fish and Non-fish Species, including the following:

- Pacific lamprey (*Entosphenus tridentatus*)
- White sturgeon (*Acipenser transmontanus*)
- Chum salmon
- Eulachon (*Thaleichthys pacificus*)
- Speckled dace (*Rhinichthys osculus*)
- Largescale sucker (*Catostomus macrocheilus*)
- Riffle sculpin (*Cottus gulosus*)
- Reticulated sculpin (*Cottus perplexus*)
- Smallmouth bass (*Micropterus dolomieu*)
- Largemouth bass (*Micropterus salmoides*)
- Coastal tailed frog (*Ascaphus truei*)
- Van Dyke’s salamander (*Plethodon vandykei*)
- Freshwater mussels

The availability of population, life history, and habitat data for all key In-channel Other Fish and Non-fish Species is limited in the Basin, and more information is needed to better assess potential effects of enhancement and flood hazard mitigation actions on these species. Specific data gaps that became apparent during development of the ASEP report are provided in the following sections.

4.1.1 SPECIES-SPECIFIC LIFE HISTORY AND POPULATION DATA GAPS FOR IN-CHANNEL SPECIES

Much of the available information on these species is limited or anecdotal, and most of it comes from areas outside of the Basin. Basin-specific information on In-channel Other Fish and Non-fish Species is arguably one of the largest Key Habitat and Species data gaps hindering development of a robust ASEP. This is especially the case in the context of determining what is truly limiting, the scope and extent of the limiting factors, and the identification of specific restoration targets that will reduce the effects of those limiting factors and enhance populations of In-channel Other Fish and Non-fish. Basin-specific surveys and research would increase the understanding of potential effects associated with the implementation of proposed flood reduction alternatives and allow for more resolved analyses of habitat restoration actions on each species' limiting factors.

Two types of information are needed: 1) comprehensive data on the distribution of In-channel Other Fish and Non-fish Species; and 2) species-specific life history, population, and habitat information. These data gaps are summarized by species as follows:

- **Pacific lamprey**—From redd surveys in the Basin, Pacific lamprey are known to spawn in many of the sub-basins, including the Upper Chehalis River. More information is required on adult and juvenile Pacific lamprey use of this sub-basin to identify potential passage impacts that may be created if a water retention structure was constructed. In addition, surveys are required to better understand adult and juvenile migration and use of off-channel habitat throughout the Basin. Ideally, growth rates, survival to maturity, and fecundity should also be determined to assess the effects of proposed water retention and habitat enhancement alternatives on lamprey.
- **White sturgeon**—Tagging studies indicate that from 1-8% of Columbia River origin white sturgeon travel from the Columbia River to Oregon and Washington coastal estuaries and river systems. The magnitude of the segment that ends in the Chehalis River is unknown, but recreational fishery catch records suggest that approximately 1% of the number residing in the Lower Columbia River enter the Basin (Langness pers. comm. 2014). Although white sturgeon enter the Basin in part to forage, stomach content analyses are lacking but are needed to understand sturgeon diet and which species comprise the prey of white sturgeon. Moreover, modeling techniques used for the ASEP report currently do not capture white sturgeon life stages believed to enter the Basin. HSIs are available for rearing and spawning but not for older-age juvenile, sub-adult, and adult fish habitat preferences. Establishing adult HSIs would allow PHABSIM modeling to be conducted.
- **Riffle sculpin and reticulated sculpin**—Sculpin species are difficult to survey and identify without more comprehensive techniques (e.g., electrofishing and using fyke nets and emigrant traps). Survey data are needed to understand their species-specific distribution in the Basin relative to habitat parameters, including water depth and velocity, and substrate characteristics. Sculpins were found in three of the seven off-channel sites sampled by WDFW in fall 2013; however, sampled fish were not identified to the species level due to a lack of resources.
- **Eulachon**—Eulachon (or candlefish) use of the Basin is poorly understood. Their distribution is outlined by historic and current catch records, but research is required to understand their response to potential changes in flow, sediment, and temperature. Moreover, impacts to eulachon from climate change and changes to sea level especially require further understanding because of dynamic aspects of their estuarine life history. Modeling techniques used for the ASEP report were not able to analyze eulachon. Examining the extent of their use of the Basin, their role in local food webs, and factors limiting their distribution are required to develop a model to begin to explain impacts from water retention and habitat enhancement alternatives. Developing eulachon HSIs and extending PHABSIM modeling to the mouth of the Chehalis River would be needed to support PHABSIM modeling for eulachon.
- **Smallmouth bass and largemouth bass**—Non-native smallmouth and largemouth bass prey on many species in the Basin. Basin-specific diet analyses are lacking but are needed to understand the contribution of native fish and non-fish to bass diets both within in- and off-channel habitat areas. In

addition, their response to environmental changes (such as changes in connectivity and area of off-channel habitats, temperature, and prey) should be investigated to effectively predict their responses to flood hazard mitigation and habitat enhancement alternatives.

- **Largescale sucker and speckled dace**—Largescale sucker and speckled dace habitat preferences in the Basin need to be better understood. Surveys measuring depth, substrate, and velocity should be completed to support more robust analysis of the effects of flood retention and habitat enhancement alternatives on these species using PHABSIM modeling. Additionally, HSIs should be verified to ensure they represent Basin-specific habitat preferences for both species.
- **Coastal tailed frog**—A few coastal tailed frog life stages were recorded incidentally during WDFW Riverscape Survey sampling for fish within the proposed dam footprint. However, the WDFW Riverscape Survey was a visual-based survey that does not involve moving stream substrates (Winkowski pers. comm. 2014). Furthermore, instream surveys designed to identify western toads are ineffective in recording coastal tailed frog life stages. Because coastal tailed frog life stages exploit the interstitial spaces of coarse instream substrates, those survey approaches cannot detect the true distribution of coastal tailed frog in this system. Water retention alternatives will result in altering much of the aquatic habitat within the proposed reservoir footprint, and to evaluate the true extent of habitat potentially lost to coastal tailed frog by these alternatives, instream rubble-rousing surveys (Quinn et al. 2007) will be needed.
- **Van Dyke's salamander**—Only two historical records for Van Dyke's salamander exist in the Basin, but WDFW stream-margin surveys conducted in 2014 recorded one location for Van Dyke's salamander in the proposed dam footprint. However, limitations in sampling that year due to the available time window during spring and fall prevented adequate surveys for this terrestrial species within the footprint of the proposed dam and its adjacent area from occurring during this phase of the Project. Surveys within the proposed dam footprint conducted at the appropriate time are needed to establish the level of potential loss of this species with inundation as a consequence of dam alternatives.
- **Freshwater mussels**—Studies to identify the distribution and species diversity of freshwater mussels need to be conducted to gather basic information on these species.
- **Impact of forestry practices on fish (especially juvenile salmonids) and amphibians**—Though a recent study of forestry practices revealed that current practices appear to have little effect on the occupancy and abundance of instream-breeding amphibians, studies on how a lack of groundwater may constrain the instream temperature requirements of instream-breeding amphibians is needed.
- **Ecological role of chum salmon**—Chum salmon can contribute large amounts of marine-derived nutrients to parts of the Basin's aquatic ecosystem, and the need for enhancing this major ecological factor for all aquatic species should be investigated.
- **Chum salmon spawning data**—Additional spawning habitat surveys are needed to identify key habitats (upwelling), especially in the Black River. Further, a study of the benefits to chum salmon from improving the quantity and quality of spawning habitat within the Basin is needed.

4.1.2 IN-CHANNEL HABITAT LIMITING FACTORS DATA GAPS

The ASEP report identifies potential limiting factors for each species included in the In-channel Other Fish and Non-fish Species groups. Determining species-specific (and life-stage-specific) limiting factors requires knowledge from field surveys to establish population size and trends over time and/or experimentation. Even though a population may be abundant under current conditions, it still may be limited by ecological constraints. Determining whether this is the case requires studies to identify any limiting factors.

While challenging, identifying limiting factors with some confidence is critical to evaluating water retention alternatives and developing habitat enhancement strategies. Data describing aquatic habitat conditions (e.g., proportion pool, riffle, run; temperatures; wood quantity; and riparian condition) within the Basin are needed to identify limiting factors, enhancement opportunities, and reaches that would benefit from protection. In addition, studies of wood depletion rates following large flood events, and evaluation of wood recruitment processes and wood dynamics in the Basin are needed along with how those processes may be affected by water retention alternatives. The benefits from large woody material recruiting into the stream channel from riparian buffers can only be realized if the material stays in channel or on the floodplain.

As stated above, a need also exists to collect comprehensive distribution data on In-channel Other Fish and Non-fish Species. Further, there is a need to understand those habitats sufficiently enough to be able to confidently identify what is limiting the species population patterns and responses, especially in the context of exotic predators and inundation-connectivity patterns. That information can then be used to identify habitat restoration actions that have the potential to enhance this suite of species. Because habitats and interactions among these species are complex and the attempts to apply actions to enhance this suite of species are a nascent field, it will be critical that such attempts be applied in an adaptive management, scientific manner to provide information useful for future efforts. Specifically, this means that the application of enhancements should incorporate monitoring designs, such as Before-After Control Impact (BACI) designs, which include a monitoring component implemented both prior to and after the application of the enhancement to gauge the species' responses. Monitoring of control or reference sites to which no enhancement is applied should also be considered to enable the species' responses to be distinguished from localized environmental effects and the implementation of the enhancement action. Failure to implement enhancements under an adaptive science protocol will result in critical knowledge being lost and the potential misinterpretation of the effects of flood hazard mitigation alternatives. This is especially the case if enhancement actions fail, because the basis of the failure will be misunderstood and unavailable to inform future efforts.

4.1.3 IN-CHANNEL HABITAT MODEL DATA GAPS

The effects to In-channel Other Fish and Non-fish Species from changes captured in physical models were evaluated using species-habitat models. However, the availability of population, life history, and habitat data for In-channel Other Fish and Non-fish Species is limited in the Basin. Because of this and because PHABSIM and HSI models are available for a wide array of terrestrial and aquatic species, species-habitat models with fewer data requirements than the salmon population-habitat models were used to evaluate effects of flood reduction and climate change alternatives on In-channel Other Fish and Non-fish Species. This included Pacific lamprey, chum salmon, smallmouth bass, largemouth bass, speckled dace, largescale sucker, and mountain whitefish. Data gaps that limit the ability of the PHABSIM and HSI models to predict the effects of flood hazard mitigation and climate alternatives on In-channel Other Fish and Non-fish populations are described in the following sections.

4.1.3.1 Validation Studies

PHABSIM models calculate an index of habitat quality and quantity as an estimate of weighted usable area (WUA). Habitat Suitability Criteria (HSC) are the standards for each life stage and species. HSIs rate different stream depths, velocities, and substrates or other habitat components or attributes in regard to their habitat value on a scale of 0 (not preferred) to 1.0 (most preferred). These values are referred to as HSIs.

Specific validation activities needed to fully interpret the PHABSIM and HSI model results include the following:

- HSIs for velocity preferences used in the PHABSIM model. Additional HSIs are required for adult white sturgeon and spawning eulachon habitat preferences. In addition, to cover their geographic distribution, PHABSIM should be extended to include mainstem river habitat downstream of Porter Creek to the mouth of the Chehalis River.

- ASEP authors compared monthly flows that maximized WUA for a species to median monthly flows at cross sections of the river that corresponded to PHABSIM reaches. For some species, flows were only compared for months that were most applicable to a given species at a suitable life stage. Validation should be completed to verify specific seasonality. For example, validation should be completed for Pacific lamprey and largescale sucker spawning during April through June in the Chehalis River.
- For those species with life histories that include a full year or longer in freshwater (i.e., Pacific lamprey, largemouth bass, smallmouth bass, speckled dace, and largescale sucker), information is lacking on their use of over-winter habitat. Surveys or tagging studies are required to fully understand their habitat use during winter months.

4.1.3.2 Changes in Flow Above Proposed Water Retention Structures

ASEP authors evaluated changes in flow downstream of the proposed water retention alternatives but did not consider changes resulting from the proposed water retention structure's inundation pool, which would change or eliminate habitat used by Other Fish and Non-fish Species. As several Key Species in the Other Fish species group use the Upper Chehalis River, effects on migration, rearing, and spawning as well as marine-derived nutrient dynamics are needed in Phase 2 to improve estimated responses to changes in habitat.

4.1.3.3 Literature Survey of Habitat Inundated by Flood Retention Only Dams

A review of the scientific literature pertaining to how habitat within the reservoir footprint of the FRO Alternative is affected during water retention events, how quickly the habitat recovers, and whether aquatic species occupy these habitats between impoundment events is needed to reduce the uncertainty associated with how this alternative affects aquatic species.

4.1.3.4 Temperature Considerations

Temperature should be incorporated into PHABSIM analyses because cold-blooded organisms roughly double their metabolic rate for every 10 degrees Celsius increase in temperature (within the range of tolerable temperatures) and become more active with increased temperature and will require proportionally more habitat or WUA. Incorporating temperature effects into future PHABSIM modeling is needed to improve the assessment of this important ecological parameter on Other Fish and Non-fish Species in the Basin.

5 Off-channel Other Fish and Non-fish Species

Similar to In-channel Other Fish and Non-fish Species, species status and population parameters were compiled and summarized for current and historical time frames in the ASEP report for Off-channel Other Fish and Non-fish Species, including the following:

- Olympic mudminnow (*Novumbra hubbsi*)
- Northern red-legged frog (*Rana aurora*)
- Western toad (*Anaxyrus boreas*)
- Oregon spotted frog (*Rana pretiosa*)
- Western pond turtle (*Clemmys marmorata*)
- North American beaver (*Castor canadensis*)

The availability of population, life history, and habitat data for all key Off-channel Other Fish and Non-fish Species is limited in the Basin, and more information is needed to better assess potential effects of enhancement and flood hazard mitigation actions on these species. Specific data gaps that became apparent during development of the ASEP are provided in the following paragraphs.

5.1.1 SPECIES-SPECIFIC LIFE HISTORY AND POPULATION DATA GAPS FOR OFF-CHANNEL SPECIES

Much of the available information on Off-channel Other Fish and Non-fish Species is limited or anecdotal, and most of it comes from areas outside of the Basin. Basin-specific information on these species is one of the largest Key Habitat and Species data gaps hindering development of robust ASEP analyses. This is especially the case in the context of determining what is truly limiting, the scope and extent of the limiting factors and the identification of specific restoration targets that will reduce the effects of those limiting factors to provide populations of Off-channel Other Fish and Non-fish with a significant boost. Basin-specific surveys and research is needed to increase the understanding of potential effects associated with the implementation of proposed flood hazard mitigation alternatives and allow for more resolved analyses of habitat restoration actions on each species' limiting factors.

Two types of information are needed: 1) comprehensive data on the distribution of Off-channel Other Fish and Non-fish Species; and 2) species-specific life history, population, and habitat information. These data gaps are summarized for off-channel species as follows:

- **Olympic mudminnow**—Limited information is available on Olympic mudminnow habitat use and distribution. In particular, available information consists of anecdotal data from a handful of off-channel habitats along the middle mainstem Chehalis River and few systematic data from a very small number of locations along the lower mainstem Chehalis River (i.e., below Porter). As a consequence, basic data on Olympic mudminnow occupancy and abundance are especially deficient for off-channel habitats over most of the floodplain. Occupancy and abundance patterns of Olympic mudminnow need to be evaluated in context of the entire assemblage of co-occurring aquatic species to identify habitat factors that limit them, such as why do Olympic mudminnow not occupy areas with ideal habitat? Is this related to the presence of exotic aquatic predators or water quality parameters? Why do they appear to have a preference for right bank, off-channel habitat in the Basin system? As a species that seems specialized for certain types of off-channel habitats, it is one species that would most benefit from systematic sampling of that habitat. This sampling should be expressly designed to ascertain habitat use, explain regional distribution patterns, and identify habitat preferences and its role as a prey species to native and non-native predator species in the Basin.
- **Western pond turtle**—Western pond turtle is another species that appears to use certain types of off-channel habitats and would benefit from systematic sampling of that habitat. Western pond turtle differ markedly from off-channel resident species like Olympic mudminnow, because they requires the complementary coupling of their suitable aquatic habitat with proximate terrestrial habitat suitable for nesting. As a member of the suite of species using off-channel habitats, systematic sampling of off-channel habitat should be expressly designed to include western pond turtle, explain their regional distribution and habitat preferences, and their role in the food webs of this system. That analysis should also determine the likelihood of western pond turtle occupancy as a function of habitat being complementary with suitable proximate terrestrial nesting habitat. These data needed to evaluate western pond turtle responses to flood hazard mitigation alternatives and identify potential habitat enhancement actions, because no data currently exist.
- **Northern red-legged frog**—Northern red-legged frog appear to be widespread in the Basin, but systematic surveys for the species have not been conducted. As yet another species that appears to use off-channel habitats (for breeding), it is another species that would benefit from systematic sampling of that habitat. Similar to the western pond turtle, the northern red-legged frog differ from most off-channel resident species in that they requires the complementary coupling of suitable aquatic and terrestrial habitats. However, in the case of the frog, the breeding habitat is aquatic and suitable terrestrial habitat must be forested uplands with a relatively dense understory. As a member of the suite species using off-channel habitats, systematic sampling of off-channel habitat should be expressly designed to include the northern red-legged frog and explain their regional distribution, especially in context of exotic aquatic predators and water quality in their aquatic breeding habitat. Sampling should assess the scale of movement into terrestrial uplands associated with their breeding habitat and their role in local food webs. That analysis should determine the likelihood of northern red-legged frog occupancy as a function of the degree to which their aquatic breeding and terrestrial non-breeding habitats complement each other. The results would be used to assess how water retention alternatives

may alter habitat occupancy and population abundance patterns and identify potential habitat enhancement actions.

- **Western toad**—Gaining an understanding of the process that creates and ultimately limits the quantity and quality of western toad breeding habitat is a data gap that needs to be filled to understand the western toad's current population status and the potential of the Basin to support western toad. Although it is known that western toads use unvegetated, shallow stillwater aquatic habitat for depositing eggs (Crisafulli et al. 2005), no western toad life stages were recorded in stillwater habitat during seven off-channel (oxbow) habitats sampled during WDFW surveys conducted in 2013. Examination of the surveyed oxbow habitat indicated that it lacked the required barren shallow areas for toad egg deposition, which was frequently being choked with the invasive exotic, reed canarygrass. Because habitat-renewing (high) flows that set back vegetation succession may be the process through which toad breeding habitat is created in oxbows and other off-channel/low-flow habitats, the lack of toad breeding habitat in these oxbows may reflect the interruption or limitation of this process. As another species that may use off-channel habitats for breeding, western toad would benefit from systematic sampling of that habitat designed to explain their regional distribution, movement into terrestrial uplands associated with their breeding habitat, and their role in local food webs. Systematic sampling of off-channel habitat should also determine the likelihood of western toad occupancy as a function of the degree to which their aquatic breeding and terrestrial non-breeding habitats complement each other and how water retention alternatives may, or may not, alter this relationship, and potential changes in western toad occupancy and abundance.

  Western toad were extensively recorded during the in-channel WDFW amphibian surveys as breeding within the mainstem of the Chehalis River and also during WDFW Riverscape Surveys. However, the in-channel WDFW amphibian surveys were restricted to the vicinity of the proposed dam footprint, which makes the true extent of the species' distribution within the mainstem unclear. In particular, based on present surveys, it is uncertain whether most instream breeding of western toad occurs within the proposed dam footprint or there is significant western toad breeding further downstream.

  Further, modeling of changes in western toad habitat in the mainstem Chehalis River using PHABSIM was designed for fish and does not extend into the late-season (instream) off-channel breeding and rearing habitat used by western toad. To adequately model western toad response to changes in instream habitat associated with water retention alternatives, PHABSIM transects should be surveyed at locations where western toad breeding actually occurs, and riverscape-type surveys should encompass the range of instream habitats where toads occur.
- **Oregon spotted frog**—Other than knowledge of habitat requirements that enable modeling (Pearl and Hayes 2004), no data exist to evaluate Oregon spotted frog responses to flood hazard reduction alternatives. Similar to Olympic mudminnow, the federal candidate Oregon spotted frog reside exclusively in off-channel habitats. Hence, this species is one of a suite of species occupying off-channel habitat that would benefit most from systematic sampling of that habitat. Systematic sampling of off-channel habitat should be designed to include the Oregon spotted frog, define their regional distribution in off-channel habitats (particularly with regard to the likely effects of exotic aquatic predators in these habitats), and support assessment of how water retention alternatives may alter those distributions. Additionally, exploring the relationship between off-channel habitat size (all known occupied sites are all greater than 10 acres [four hectares]; Hayes 1997) and adult survival for the Oregon spotted frog is a data gap that should be addressed to allow the effects of flood hazard mitigation alternatives on these parameters to be assessed.
- **North American Beaver**—North American beaver is yet another species that not only uses off-channel habitat extensively but is critical to maintaining the quality of selected off-channel habitats for a suite of fish and amphibians that use off-channel habitats. A basic understanding of both beaver distribution in

off-channel habitats and how beaver presence may be influencing the suite of native off-channel species is lacking. That understanding is fundamental to evaluating how water retention alternatives may affect the North American beaver and potentially the suite of off-channel species for which beaver create habitat. Hence, systematic sampling of off-channel habitat should be expressly designed to include beaver. In addition, a better understanding is needed of the effects water control structures have on North American beaver population abundance, because the species can have a dramatic effect on the formation of habitat used by beaver and other species and stream hydrology.

5.1.2 OFF-CHANNEL HABITAT LIMITING FACTORS DATA GAPS

The ASEP report identifies potential limiting factors for each of the Off-channel Other Fish and Non-fish Species. As with the in-channel species, determining species-specific (and life-stage specific) limiting factors requires field surveys to establish population size and trends over time and/or experimentation. Even though a population may be abundant under current conditions, it still may be limited by ecological constraints. Determining whether this is the case requires studies to identify any limiting factors. While challenging, identifying limiting factors with some confidence is critical to evaluating water retention alternatives and developing habitat enhancement strategies. Data describing off-channel aquatic habitat conditions within the Chehalis River floodplain is needed to enhance the ability to identify limiting factors and enhancement opportunities. In addition, studies of wood depletion rates following large flood events and evaluation of wood recruitment processes and wood dynamics in the Basin are also needed. The benefits from large woody material recruiting onto the floodplain can only be realized if the material stays on the floodplain.

A need also exists to collect comprehensive distribution data on Other Fish and Non-fish Species, especially in off-channel habitats of the main channel Chehalis River floodplain. Further, there is a need to understand those habitats sufficiently enough to be able to confidently identify what is limiting (especially in the context of exotic predators and inundation-connectivity patterns), by assessing species population patterns and responses. The information can then be used to identify habitat restoration actions that have the potential to enhance this suite of species. Because habitats and interactions among these species are complex and the attempts to apply actions to enhance this suite of species are a nascent field, it will be critical that such attempts be applied in an adaptive management, scientific manner to provide information useful for future efforts. Specifically, this means that the application of enhancements should incorporate monitoring designs, such as BACI designs, which include a monitoring component implemented both prior to and after the application of the enhancement to gauge the species' responses. Monitoring of control or reference sites to which no enhancement is applied should also be considered to enable the species' responses to be distinguished from localized environmental effects and the implementation of the enhancement action. Failure to implement enhancements under some sort of adaptive science protocol will result in critical knowledge being lost and the potential misinterpretation of the effects of flood hazard mitigation alternatives. This is especially the case if enhancement actions fail, because the basis of the failure will be misunderstood and unavailable to inform future efforts.

5.1.3 OFF-CHANNEL HABITAT MODEL DATA GAPS

The effects to Off-channel Other Fish and Non-fish Species of changes captured in physical models were evaluated using correlative analyses. Data gaps that limit the ability of correlative analyses to predict the effects of flood hazard mitigation alternatives on Off-channel Other Fish and Non-fish populations are described below.

5.1.3.1 Habitat Use

Off-channel habitat use by the Other Fish was assumed to occur for all species with life histories that may include use of off-channel habitat. Basic surveys of off-channel habitats for the suite of species that use that habitat are a fundamental data gap. Such surveys need to be species-specific to address the patterns of differential use of those habitats by different species, variation in off-channel habitat conditions that may influence patterns of use by different species (e.g., presence of exotic aquatic predators), and potential changes in off-channel habitat characteristics and use that may arise due to flood reduction alternatives being implemented.

5.1.3.2 Literature Review of Hyporheic Exchange on Water Quality and Quantity in Connected Versus Disconnected Floodplains

A review of the scientific literature pertaining to how hyporheic exchange effects water quality and quantity in connected versus disconnected floodplains would improve future model studies of the effects of water retention alternatives on aquatic species.

5.1.3.3 Changes in Inundation Above Proposed Flood Reduction Structures

ASEP authors evaluated changes in inundation downstream of the proposed dam site but did not consider potential changes resulting from the flood retention structure's inundation pool on habitat use by Other Fish species that inhabit the Upper Basin. Baseline information is needed for migration, rearing, and spawning requirements of these species to assess the effects of flood retention alternatives.

5.1.3.4 Conditions Not Analyzed

The correlative analysis conducted under the ASEP could not account for several factors due to a lack of information. In the future, data need to be collected in the following ways to allow more detailed assessment to be conducted:

- Identify and map connections of off-channel habitats to the main channel, including three dimensional models that will accurately translate floods into acres inundated through time.
- Determine which off-channel aquatic habitats are maintained by upland drainage or groundwater, independent of river flooding.
- Determine the length of time off-channel habitats are inundated in relation to the duration and frequency of flood events and the water outflow/infiltration patterns following flood events.

Floodplain inundation areas were estimated for no-dam and dam scenarios at 500-, 100-, 20-, 10-, and 2-year flood events by ASEP authors. The two water retention alternatives were not compared at this stage of the analysis, because both were assumed to have a maximum discharge of 10,000 cubic feet per second (cfs) after flooding based on dam operations studies. However, this analysis did not account for potential changes in the hydrographs created by truncating flows from the Upper Chehalis region under the two alternatives or augmented summer flows associated with the multi-purpose dam alternative. In the future, more detailed analyses of dam operations should be conducted to understand their effects on floodplain inundation and the formation of off-channel habitat and to develop operations that support habitat formation processes. In particular, the inundation period at different flood levels should be modeled (i.e., the amount of time that floodplain areas are inundated during different flood events and under various under dam operation scenarios). This would require daily flow information for flood events and inundation modeled at a daily time step (or even finer resolution). In addition, a literature review on how inundation periods affect (creates or maintains) off-channel habitat is needed to better understand the dynamics of the processes and interpret the effects of changes on off-channel habitat formation.

6 Data Archive System

Over time, data will be gathered by various research groups implementing a variety of surveys and research studies to achieve multiple objectives. For fish tagging studies, sharing of tag codes, tags, receivers, and other equipment among research groups is encouraged. A central database for aquatic species life history, population, and habitat usage data should be developed and be accessible to all users. In addition, a centralized system for housing models—EDT, SHIRAZ, PHABSIM, and others—is needed.

The Columbia Basin PIT Tag Information System (PTAGIS) is one of many examples of a centralized database for PIT-tagged fish. PTAGIS provides contributors that collect tagging and interrogation data with custom software and standardized data protocols, manages a central database, and coordinates among fishery agencies and organizations. PTAGIS also collects and stores data automatically detected by specially designed equipment. Importantly, all data contributed to and collected by PTAGIS are freely available through a website to registered users. This type of data housing and access should be considered for the Chehalis River.

Physical Modeling Data Gaps

1 Introduction

For ASEP analyses, physical model outputs were used as inputs to biological models to evaluate the impacts of potential flood retention and restorative actions on aquatic species in the Basin. Flood hazard mitigation alternatives may affect species by altering essential habitat forming processes such as flow, channel form, and the movement of large wood and sediment through the system. The essential habitat forming processes involving flow were analyzed for the Project using the River Analysis System (RAS) developed by the Hydrologic Engineering Center (HEC) located in Davis, California, or the HEC-RAS model.

2 Flow (HEC-RAS)

To characterize changes in habitat across a range in river hydrology (driest to wettest) and water retention alternatives (base case, flood retention only dam, and multi-purpose dam), various water years were input into the HEC-RAS model. The model was run and estimates of average depth, channel width, and velocity at cross sections that extend throughout the longitudinal gradient of the mainstem Chehalis River were developed. Model results (monthly averages) were then converted into GIS layers of inundation. Inundation data were input into the EDT model to estimate the amount of habitat (average channel width) for each diagnostic unit for the mainstem Chehalis River to evaluate effects of changes in river hydrology on salmon habitat. Results were also used to evaluate changes in off-channel floodplain habitat inundation associated with water retention alternatives.

The HEC-RAS model used for ASEP analyses (and updated for the Project) was calibrated to peak flow events. Typically the model was run as an unsteady state model. However, ASEP authors were especially interested in the effects of changes in river hydrology across all water years and months, including low-flow conditions. To enable the HEC-RAS model to run in an unsteady state, an artificial lower limit of 150 cfs was set. For flows less than 150 cfs, the model was run in a steady state because it was unstable otherwise.

It is difficult to assess the accuracy of the HEC-RAS model for low-flow simulations at this time. Watershed Science and Engineering's analyses of simulated stage-discharge relationships at the Doty and Grand Mound gage sites indicated that low-flow model runs required a significantly lower Manning's *n* value to match gage site rating curves, and without these changes, the model simulations of water surface elevations at lower flows were consistently high to very high (by up to 1 foot or more). Manning's *n* value is a roughness coefficient used in Manning's formula for calculating flow in open channels. For ASEP analyses, reduced Manning's *n* values were used in the HEC-RAS model, but the accuracy of the model at low flow is unknown. In the future, water surface elevation data for lower flows will need to be collected to calibrate (or at least validate) the HEC-RAS model to lower flows, which will reduce the uncertainty associated with HEC-RAS (and thus ASEP) model outputs.

HEC-RAS model outputs were also used to assess changes in floodplain inundation patterns and the effects of water retention alternatives on off-channel habitat used by Other Fish and Non-fish Species. There are four important aspects to these analyses. Filling these gaps will result in more accurate assessments of flood hazard mitigation and habitat enhancement alternatives on Other Fish and Non-fish Species that occupy off-channel habitats.

- **Whether changes in hydrology associated with flood retention alternatives affect off-channel and floodplain habitat-forming processes.** Effects are likely, but estimating those effects on geomorphic processes in relation to these habitats was not assessed in this phase of the Project. A river channel that becomes less dynamic due to water retention and more prone to bank armoring and has fewer large wood inputs may be less capable of creating floodplain habitats. Therefore, future studies should evaluate the potential effects changes in river hydrology may have on riparian zone vegetation patterns and the processes that create floodplains and off-channel habitats.
- **The connectivity of off-channel habitats to the main channel during flood events.** A major impediment to interpreting species responses in off-channel habitats to water retention alternatives is a lack of understanding of the dynamics of the habitat with respect to inundation (hydroperiod) and its connectivity to the stream network. The one-dimensional, relative-elevational modeling done to date provided a crude surrogate for estimating the effects of water retention alternatives on Other Fish and Non-fish Species in off-channel habitat. At this stage of the analysis, shortcomings in the available spatial data were recognized. When HEC-RAS data were converted into floodplain inundation area using GIS, the GIS polygons could both over- and under-estimate the actual amount of area inundated due to uncertainty in surface elevations and connectivity under roads and bridges. In future feasibility studies, the inundation area data should be thoroughly reviewed to produce a more accurate estimate. High (daily) resolution modeling using two- or three-dimensional hydrological models is necessary to determine hydroperiod and the patterns of seasonal connectivity. These data are critical to identifying local habitat availability and projects for enhancements of off-channel habitats. No data exist on either hydroperiods or patterns of seasonal connectivity for off-channel habitats, but these periods and patterns likely represent aspects of off-channel habitat dynamics to which these species respond.
- **Temporal and spatial aspects of how water retention alternatives may affect floodplain inundation.** Aquatics species that require suitable off-channel habitats need these habitats to be present at the right time of year to meet reproduction and rearing requirements. The habitats also need to be at locations in the Basin where they can be accessed and occupied by the species that require the habitats. In other words, suitable habitat that is formed at the wrong time and in the wrong location for a species to use provides no benefit to that species. Therefore, studies that integrate data on species' distribution throughout the year with flood inundation patterns (frequency, timing, and location) are needed.
- **The relationship between overbank flooding events and hyporheic exchange.** In particular, how floodplain inundation frequency, hydroperiod, and flood aerial extent affects hyporheic conditions including groundwater recharge and ultimately mainstem and off-channel aquatic habitat based flows (levels) during summer months

3 Water Temperature

Flood hazard mitigation alternatives may also affect species by altering water temperature. Water quality and riparian shading studies in Phase 1 were designed to fill several data gaps identified during earlier studies of the Chehalis River. Previously developed models for the water retention reservoir and the Chehalis River downstream of the dam were developed using a limited dataset. In the future, these models need to be re-evaluated and modified or replaced with better modeling frameworks, to provide the predictive accuracy needed to answer questions regarding the impacts of proposed flood retention structures on downstream temperatures, water quality, and aquatic habitats. Temperature data collected from the Phase 1 study should be used to calibrate and validate the temperature models. The models could then be used to simulate different management alternatives under consideration, evaluate the impacts of different operational scenarios, and identify optimal reservoir operations under a variety of flow and climatic conditions that meet flood control and aquatic habitat objectives. The models would help relate observed behaviors of tagged fish to environmental conditions, help identify areas of cooler water that could be protected, and improve estimates of how riparian restoration actions may reduce thermal inputs and water temperatures. The models could also be used to quantify the frequency, duration, and spatial extent of temperatures above thermal limits of various aquatic species and state water quality standards.

Three additional data gaps associated with water temperature modeling were identified:

- A need exists to evaluate potential increases in temperature associated with the FRO Alternative due to increased thermal inputs in the inundation pool area from a lack of riparian shading. Water temperature modeling should be used to determine solar heat loads from a projected decrease in effective shade in the reservoir reach to better understand how this might affect water temperatures downstream of the inundation pool reach. The ongoing riparian density work could provide additional data to enhance this type of analysis.
- An analysis of existing precipitation and flow data is also needed to verify whether wet winters increase summer base flow and decrease water temperatures during the summer period.
- Finally, temperature models for key tributaries and off-channel habitats need to be developed.

Climate Change Analysis Data Gaps

Climate change was analyzed for salmon species using two models: EDT and SHIRAZ. For Other Fish and Non-fish Species, the effects of climate change were assessed using PHABSIM and HSI analyses, and a correlative approach. The scientific understanding of climate change and its potential repercussions is continually developing. For this Project, ASEP authors relied upon the best available information on changes to environmental conditions such as streamflow, temperature, and sea level rise that were projected to occur in the Basin. However, several key data gaps were identified:

- Predicted changes in air temperature in the Basin through time were converted to changes in instream aquatic habitats. In any future phases of study, an improved correlation analysis to estimate how air temperature changes affect water temperatures should be completed, including the effects of flow. In addition, no data existed to estimate future temperature profiles for off-channel habitats at any level of resolution and represents a major data gap.
- Available hydrology projections are not satisfactorily calibrated at this time, which is a significant data gap that limits the ability to more fully analyze how climate change may affect the Basin. This finding was based on the fact that the model projections for stream flow did not satisfactorily correspond to stream gage observations recorded during the 1958 to 2006 period. The modeled climate change stream flow projections vastly underestimated stream flows compared to observed conditions. The modeled historic data showed maximum daily discharges at Grand Mound (USGS gage 12027500) ranging from 17,000 to 22,000 cfs for the 20- to 100-year events, respectively (CIG 2010). In contrast, historical data showed the actual daily flow rates ranged from 47,000 to 64,000 cfs at these same recurrence intervals (USACE 2013). This data gap should be addressed in the future by working with the Climate Impacts Group at the University of Washington to improve the calibration of available models used to project future stream flows.
- Information on the interaction between the effects of climate change and flood hazard mitigation alternatives on flows that create new channels and the availability of wood to initiate or support channel creation is missing and is a significant data gap. This information is needed to address how climate and flood retention alternatives may change the dynamics of off-channel habitat formation in the system and affect the associated suite of species that occupy and depend on these habitats.
- Results of EDT and SHIRAZ model studies revealed that future climate scenarios can have a dramatic effect on salmon populations in the Basin. For example, spring-run Chinook salmon may be extirpated from the Basin or specific river reaches. Based on analyses completed to date, water temperature is anticipated to change as a result of future climate scenarios, which was thought to be a primary driver of these model results. However, the EDT model analysis has not been subjected to formal sensitivity analyses. Therefore, a more thorough examination of the effects of climate change on water temperature in the Basin should be conducted. This should include a review of the literature on heating budgets for small and large streams and climate change downscaling methods used on streams with different characteristics (flow, hydrology, substrate geomorphology, etc.). As discussed above in sections 3.1.3 and 3.1.6.4, temperature monitoring in the smaller streams and aquatic habitats in the system where those data do not exist (e.g., channel habitats) should be conducted, and variation in summer temperatures along the mainstem and along select tributaries should be documented. These studies will allow for improved model studies of the potential effects of future climate scenarios on aquatic resources in the Basin. The studies should result in more realistic estimates of how climate change may affect instream and off-channel temperatures and ultimately cold water-adapted fish like salmon and their thermal refugia.

- A better understanding of how off-channel aquatic habitat may affect summer stream water temperatures is needed, because research suggests that off-channel water interacts with instream water via hyporheic exchange, and this connection may provide a critical source of cool water to the mainstem Chehalis River during summer.
- Salmon spawning distributions need to be modeled and related to changes in flow associated with climate change.
- An analysis of extreme flow events (frequency, duration, and magnitude) to inform habitat formation modeling is also needed.
- Additional data gaps for the PHABSIM and correlative climate change analyses include completing analyses of predicted changes in flow during spring and fall using the PHABSIM model.
- High uncertainty exists with the high and low climate change sensitivity scenarios modeled for the ASEP using EDT. This uncertainty is associated with whether the projected increases in peak flows are accurate, how these projected increases were translated into high and low flow scenarios for the mainstem and then applied to tributaries, and how climate change conditions can be combined with habitat enhancement and flood reduction alternatives in the future. Simply stated, results of current studies lack resolution to allow absolute values to be used with high confidence. The results represent patterns and trends that result from assumptions made to conduct the analyses. Additional model studies of climate variability and its potential effects on aquatic species in the Basin are needed in future phases of the Project to increase the confidence decision makers have when using the information to address management and policy questions.
- As discussed above in Section 3.1.3, an analysis of the amount of time fish passage would be blocked with the FRO Alternative under current conditions was performed, including the time required to remove large woody debris. Under future climate change conditions, two additional scenarios were analyzed. The first used a 18% increase in peak flows in the Chehalis River and the second a 90% increase. For the 18% climate change scenario, it was estimated that the reservoir will be closed to fish passage 13 times in the 24 year period of record and the closures represent 3.4% of the total time during the period of record. For the 90% climate change scenario, it was predicted the reservoir will be closed to fish passage 31 times in the 24 year period of record and the closures represent 9.7% of the total time during the period of record. During the years in which the reservoir is utilized for flood storage, fish passage was blocked for an estimated 6-13% of the year for the 18% climate change scenario and 2-29% of the year for the 90% climate change scenario. In addition to the fish passage blockage, passage will be impaired about 3% of the year for the 18% climate change scenario and about 5% of the year for the 90% climate change scenario. That compares to about 4% and 9% for the two scenarios without the FRO dam. Factors that resulted in the increased period of time fish passage would be blocked under the future climate change conditions modeled were the increased volume of runoff and the number of times the reservoir would be used. The greater volume of runoff causes the reservoir to empty more slowly than compared to current hydrologic conditions. The assumptions for future climate change included increases in peak flow for the Chehalis as well as all tributaries, meaning the Chehalis River would reach flood stage much more often, triggering the reservoir to be operated more frequently than it would be under current hydrologic conditions. The FRO Alternative operations under these future climate scenarios were not evaluated as to their potential effects on aquatic resources in the Basin. This is a key data gap that should be addressed in future feasibility studies.
- Also, an analysis is needed to determine if the frequency and duration of water storage events in these climate change scenarios will affect the ability of reservoir margins to support vegetation, and how much food and thermal shading the vegetation provides to the stream channel under these scenarios.
- Similarly, analysis of modified water retention duration and frequency and debris management activities required under climate change scenarios is necessary to determine for future model studies whether the complete degradation of habitat conditions above an FRO dam is the most appropriate assumption to make when evaluating future climate change scenarios. Currently, to analyze the effects of the FRO

Alternative on salmon, three alternatives were evaluated using EDT. Designated as FRO25, FRO50, and FRO100, these alternatives represented the assumption that 25%, 50% or 100% of the habitat upstream from the FRO dam, respectively, would be degraded as a result of impounding flood flows. These alternatives were developed to evaluate uncertainty associated with how the frequency of FRO use within and between years impacted habitat conditions for salmon above the dam. If under future climate change scenarios the complete degradation of habitat conditions above the FRO dam occurs, then the (FRO100) scenario would be the most appropriate assumption to use in future analyses.

- As discussed in Section 3.1.4, the current model studies assumed that after adult salmonids enter the Basin, they migrate to their spawning reach and hold before spawning in the same area where they spawn, especially spring-run Chinook salmon. In the model, this leads to pre-spawning mortality due to high temperatures because the model assumes the fish are exposed to high water temperatures and do not find and hold in thermal refugia. Because of these assumptions, spring-run Chinook salmon benefit from cooler water released from the multi-purpose dam alternative. However, observations in other systems and the scientific literature suggest that salmon often hold in thermal refugia before they spawn, moving into spawning areas only shortly before spawning commences. This gap also applies to effects of climate change on salmonids. Detailed information on this behavior in the Basin would improve future assessments of the effects of climate change alternatives on pre-spawn mortality rates.

Watershed Restoration Planning Data Gaps

Local organizations, tribes, and state and federal agencies have dedicated a large amount of effort to identify limiting factors and habitat restoration sites in the Basin. A list of restoration actions that have resulted from these efforts can be found in Appendix D of the Draft ASEP. Additional actions were identified in the *Chehalis River Basin Comprehensive Salmonid Habitat Enhancement Plan* (Anchor QEA 2012) and through the current Project on habitat limiting factors and the effects of various restoration strategies on aquatic species (see Draft ASEP). In recent decades, the science surrounding restoration has improved greatly, including taking a holistic approach to restoring watersheds (Roni and Beechie 2013). Roni and Beechie (2013) identified the major steps in the restoration planning process required to develop a comprehensive program and well-designed restoration projects. These include the following, in sequential order:

1. Set watershed restoration goals.
2. Assess and inventory watershed conditions.
3. Identify problems and potential actions.
4. Review and select appropriate restoration techniques.
5. Prioritize restoration actions.
6. Design restoration project and monitoring.
7. Implement restoration and monitoring.
8. Publish results and modify goals and management.

Along these lines, the Grays Harbor County Lead Entity Habitat Work Group prepared the *Chehalis Basin Salmon Habitat Restoration and Preservation Strategy* (Strategy; Grays Harbor County 2011). The Lead Entity adopted seven strategies, all equal in value, for addressing the most pressing limiting factors identified within the Basin. Salmon habitat projects and activities must meet one or more of these strategies for inclusion on the Habitat Project List for Salmon Recovery Funding Board consideration. These guiding strategies include the following:

- Attain a healthy and diverse population of wild salmonids.
- Restore, enhance, and protect the Grays Harbor Estuary.
- Restore and preserve properly functioning riparian areas.
- Restore habitat access.
- Restore properly functioning hydrology.
- Restore floodplain and stream channel function.
- Prioritize habitat projects and activities within sub-basins that provide the highest benefit to priority stocks.

In Section 3 of the Strategy, the Lead Entity describes a conceptual model for sub-basin profiles. The goal of the conceptual model is to identify short- and long-term voluntary restoration and protection actions that improve or protect natural processes within sub-basins that create healthy habitat for salmonids. In the Strategy, the Lead Entity identifies the different kinds of limiting factors in Water Resource Inventory Areas 22 and 23 and describes their effects on physical processes and salmon. In addition, for each sub-basin profile, they assign each limiting factor to one of three tier concerns. Tier 1 Concerns represent the most pressing limiting factors affecting the VSP salmonid population parameters of abundance, productivity, diversity, and spatial structure. The preference of the Lead Entity is that Tier 1 Concerns would be considered first for implementation, because of their potential effect in providing the greatest benefit to fish. Tiers 2 and 3 Concerns are similar, although decreasingly reduced in priority because of their lesser benefit to fish. The strategy notes that even though Tier 1 Concerns will scientifically render the greatest benefit to fish, community values may not always endorse them as a priority. In some sub-basins or along certain reaches, it may be possible only to implement Tier 2 and 3 general recovery actions.

At the completion of this current phase of the Project, many of the steps identified in this section are well underway. For example, a 3-day workshop was conducted in March 2014 to discuss habitat conditions for salmon in each sub-basin and the mainstem Chehalis River to identify limiting factors. A summary of the findings from the workshop can be found in Appendix F of the ASEP report. In addition, a 2-day meeting of ASEP authors was held in April 2014 to discuss the types of habitat restoration actions needed to address the limiting factors and how to prioritize among sub-basins and salmon species and estimate benefits to salmon populations.

To summarize, while seven equally weighted strategies for addressing the most pressing limiting factors were identified within the Basin, specific restoration goals have not been established for the Basin. Given the results presented in the ASEP report on the benefits associated with the different enhancement strategies modeled, a watershed restoration plan for the Basin can now be developed that identifies a suite of priority actions that are linked to expected biological responses and management objectives for various species and sub-basins.

For example, habitat restoration actions could focus on improving coho salmon abundance to address harvest management objectives by removing barriers. The actions could also be prioritized to benefit spring-run Chinook salmon, because these populations appear to be at greater risk compared to other salmonids. They could address impacts associated with climate change or flood hazard mitigation alternatives. They could also be focused on species listed under the Endangered Species Act or that are State of Washington species of concern, such as the Oregon spotted frog, Olympic mudminnow, and eulachon.

In other words, the broad strategies and types of projects identified in the ASEP report for addressing habitat restoration and species enhancement could guide more detailed discussions of specific Basin goals, objectives, projects, and locations. These discussions would involve knowledgeable experts within the Basin and result in development of a comprehensive watershed restoration plan that relies less on projects of opportunity to achieve the restoration goals, and more on the implementation of strategic projects selected to meet specific biological and management objectives. The watershed restoration plan could also identify any social issues potentially limiting implementation of a restoration plan.

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