Final

WRIA 9 Conservation Hypotheses Functional Linkages Phase 2

Prepared for:
WRIA 9 Steering Committee

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Prepared by:
Anchor Environmental
and
Natural Resources Consultants, Inc.

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FINAL

WRIA 9 CONSERVATION HYPOTHESES

FUNCTIONAL LINKAGES PHASE 2

Prepared for

WRIA 9 Technical Committee
c/o King County
Water and Land Resources Division
201 South Jackson Street, Suite 600
Seattle, Washington 98104

Prepared by

Anchor Environmental, L.L.C.
1423 Third Avenue, Suite 300
Seattle, Washington 98101
and
Natural Resources Consultants, Inc.
1900 West Nickerson Street, Suite 207
Seattle, Washington 98119

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EXECUTIVE SUMMARY

In response to the listing of Puget Sound Chinook salmon and bull trout as "threatened" under the federal Endangered Species Act, efforts were initiated in Water Resources Inventory Area 9 (WRIA 9) to develop a Salmon Habitat Plan to guide the protection and restoration of Chinook salmon in the Green/Duwamish and Central Puget Sound Watershed. Participants in WRIA 9 salmon recovery planning activities included representatives from local, state, and federal governments; the environmental community; and private industry.

A Technical Committee consisting of individuals with knowledge of the regional ecology was convened to conduct a Strategic Assessment intended to provide the scientific foundation for salmon recovery planning in WRIA 9. One of the seven projects undertaken in the Strategic Assessment is the Functional Linkages project. The Functional Linkages project began with a review of modeling approaches and other analytical tools that could be used to link quantity and quality of habitat to salmon abundance, productivity, and diversity in a spatially explicit way. The conclusions of that review were that, while all the tools reviewed added value to an analysis, no single model or tool was by itself sufficient (Anchor Environmental and Natural Resources Consultants 2003).

Informed by this initial review, WRIA 9 implemented an Ecological Synthesis Approach, which is described in this report. Rather than relying largely on a single model, the Ecological Synthesis Approach relies on information from as many diverse sources as possible, including information on current and historical habitat quality and fish use, limiting factors analyses, and statistical and scientific models, as available. Taking these sources of information into account, the WRIA 9 Technical Committee utilized a series of workshops to develop the Conservation Hypotheses that form the main body of this report. The Conservation Hypotheses are "best estimates" of how improvements in habitat conditions and habitat-forming processes will lead to changes in the four salmon population parameters critical to viability: abundance, productivity, spatial structure, and genetic and life history diversity. It is anticipated that these Conservation Hypotheses will provide the foundation from which to identify a cohesive suite of habitat preservation and restoration actions that will contribute to sustainable salmon populations in WRIA 9.

Conservation Hypotheses were developed both in small working group meetings and in two workshops that included members of the WRIA 9 Technical Committee, selected stakeholders, and the Anchor Consulting Team (Anchor Environmental and Natural Resource Consultants). Conservation Hypotheses were developed for each of the five habitat planning units, including the Upper, Middle, and Lower Green River; the Duwamish Estuary; and the Puget Sound nearshore, including Elliott Bay, Vashon Island, and Maury Island. WRIA-wide Conservation Hypotheses applicable to all five habitat planning units were also identified. In addition, a subset of non-habitat related (i.e., hatchery and harvest) Conservation Hypotheses that were deemed particularly critical to enable habitat-related actions to succeed were identified.

Thirty-two Conservation Hypotheses were identified, including seven that were applicable WRIA-wide, five in the Puget Sound nearshore, four in the Duwamish Estuary, four in the Lower Green River, six in the Middle Green River, three in the Upper Green River, and three that addressed non-habitat issues. The WRIA-wide Conservation Hypotheses contemplated a range of actions, including improved water quality, restored riparian zones, improved tributary conditions and access, high and low flow modifications, low impact watershed development, and reduced armoring and filling. The Puget Sound nearshore Conservation Hypotheses focused on improved sediment quality, protection of vegetated shallows, protection and restoration of sediment transport, protection of forage fish spawning habitat, and protection and restoration of "pocket estuaries." In the Duwamish Estuary, the Conservation Hypotheses included improved sediment quality, protection and restoration of vegetated shallows and marsh habitats, creation of an enlarged freshwater to saltwater "transition zone," and protection and restoration of refugia. The four Conservation Hypotheses developed for the Lower Green River focused on providing high flow/velocity refugia, improved fish passage at the Black River Pump Station, restoration of sediment recruitment processes, and protection of groundwater recharge via old White River channel. In the Middle Green River, the Conservation Hypotheses included protection and creation of refugia, restoration of sediment recruitment, restoration of spawning habitat in Soos and Newaukum Creeks, increased emphasis on low impact watershed development, improved groundwater recharge, and establishment of access above Tacoma Headworks. Restoring Chinook salmon and bull trout access to habitat above Howard Hanson Dam, and restoring and protecting spawning and rearing habitat were the primary Conservation Hypotheses for the Upper Green River. The non-habitat Conservation

Hypotheses address hatchery reform, modification of harvest techniques to include live capture gear, and reduction in the harvest of salmon prey items (e.g., Dungeness crab and forage fish).

A limited, preliminary attempt to inform future efforts to prioritize the Conservation Hypotheses was conducted by sorting them based on the expected effects on the four salmon population parameters critical to viability (McElhany et al. 2000): abundance, productivity, spatial structure, and genetic and life history diversity. Guidelines for research, monitoring, and evaluation needs related to the Conservation Hypotheses, as well as adaptive management, are presented.

1 INTRODUCTION

There are 27 species of Pacific salmon and trout listed as threatened or endangered under the Endangered Species Act (ESA) on the West Coast of North America. These species or evolutionarily significant units (ESUs) include four of the five biological species of Pacific salmon, steelhead, and bull trout. They range from the Southern California-Mexican border in the South to the Washington-Canadian border in the North, leaving virtually no geographic area untouched. Of the 27 ESA-listed species, three occur in the Puget Sound basin: Puget Sound Chinook salmon and bull trout throughout the basin, and Hood Canal summer chum salmon.

Recovering ESA-listed salmon ESUs will require action at multiple levels of governance—addressing the many and varied risks that salmon face—in a comprehensive, integrated way. In the Puget Sound basin, perhaps the most daunting challenge will be protecting, restoring, and rehabilitating habitat lost to urbanization. These activities will most effectively be planned and carried out at the watershed-wide scale by city and county governments.

Watershed-wide-scale planning for salmon conservation in Washington State is organized around Water Resources Inventory Areas or WRIAs. State-wide there are approximately 62 WRIAs, with 23 located in the Puget Sound basin. Although most of the Puget Sound WRIAs are to some degree urbanized, few are as urbanized as WRIA 9, which includes the Green/Duwamish River and the adjacent nearshore areas of Puget Sound, including Vashon and Maury Islands. From its headwaters in the Cascade Mountains about 30 miles north of Mount Rainier, the Green River flows 93 miles through a mix of forests, agricultural land, and urban development before entering Elliott Bay through the highly industrialized Duwamish River. Although the focus of the planning effort is on ESA-listed species, it is anticipated that actions that are beneficial for ESA-listed species will be beneficial in an ecosystem context for all species.

The Functional Linkages project is one of seven that comprise the WRIA 9 Strategic Assessment. The Strategic Assessment is designed to provide a comprehensive information base from which to build a conservation strategy. The Functional Linkages project was conceived of as a two phase process, with the first step focusing on a review of modeling approaches and other analytical tools that could be used to link quantity and quality of habitat to salmon abundance, productivity, and diversity in a spatially explicit way. The conclusions of that review were that, while all the tools reviewed added value to an analysis, no single model or tool was by itself sufficient (Anchor Environmental and Natural Resources Consultants 2003). One of the most common limitations of the models and tools reviewed was the failure to incorporate contemporary information on how salmon used existing habitat compared to historic use. Further, in WRIA 9 significant effort had already gone into a reconnaissance level survey and limiting factors analyses and none of the models or tools incorporated this knowledge. As a result, with the conclusions of the Functional Linkages Phase 1 Report in hand, the WRIA 9 Technical Committee adopted a method termed the Ecological Synthesis Approach to complete the second phase of the Functional Linkages Project. As the name implies, the Ecological Synthesis Approach does not contemplate the use of a single model, but relies on information from as many and as diverse sources as possible, including information on current and historical habitat quality and fish use, limiting factors analyses, and statistical and scientific models, as available. Taking these sources of information into account, the WRIA 9 Technical Committee utilized a series of workshops to develop the Conservation Hypotheses that form the main body of this report (Sections 3 and 4 and Appendices A, B, and C).

It is important to note that Conservation Hypotheses are not traditional scientific hypotheses that are stated in a null sense to be statistically accepted or rejected. Rather, they are a "best estimate" of how improvements in habitat conditions and habitat-forming processes will lead to changes in the four salmon population parameters critical to viability (McElhany et al. 2000): abundance, productivity, spatial structure, and genetic and life history diversity. Developing scientifically sound Conservation Hypotheses is the starting point for a comprehensive Salmon Habitat Plan. It is anticipated that these Conservation Hypotheses will provide the foundation from which to identify a cohesive suite of habitat preservation and restoration actions that will contribute to sustainable salmon populations in WRIA 9.

This report presents the Conservation Hypotheses developed for WRIA 9 by the Technical Committee and other regional participants. The main body of the report summarizes the process taken to develop the suite of Conservation Hypotheses and a summary matrix of the Conservation Hypotheses. Expanded descriptions of each Conservation Hypothesis were prepared by Technical Committee members and are provided in Appendix C.

2 THE ECOLOGICAL SYNTHESIS APPROACH

As noted above, the Ecological Synthesis Approach is a broad-based approach to habitat planning that embraces as many and as diverse sources of information as possible, while emphasizing a comparison of historic versus current habitat conditions and fish use. An initial description of the approach was included in a report by Anchor Environmental and Natural Resources Consultants (2003). In contrast to a scientific model-based approach, the Ecological Synthesis Approach represented an effort to use multiple sources of information, and to avoid some of the limitations introduced by pseudo quantification that plagues many expert opinion-type models (RSRP 2001).

2.1 Review of the Approach

As originally conceived, the Ecological Synthesis Approach was a workshop-based strategy that embraced the diversity of information often available to inform conservation decisions, and particularly the selection of spatially explicit protection and restoration actions. The approach was intended to maximize the technical input provided by the WRIA 9 Technical Committee and other regional experts. The general conceptual design and flow is shown in Figure 1.

For the WRIA 9 planning area, it was anticipated that information would be available from analyses of historical versus current habitat conditions and fish use, limiting factors analyses, and statistical and scientific models. The WRIA 9 Technical Committee would use information gathered from two workshops to develop common themes in how salmon were using the habitat, what processes and features were limiting, and what processes and features should be the focus of protection and restoration actions. Acknowledging that different life stages of salmon utilize different subareas of the watershed, and that different life stages utilize habitats differently, the expectation was that the Green/Duwamish River watershed would be divided into habitat planning units. From a comprehensive list of Conservation Hypotheses, it was anticipated that criteria would be developed to prioritize actions, with an emphasis on criteria that linked to the National Marine Fisheries Service (NMFS) viable salmonid population (VSP) guidelines (McElhany et al. 2000).

Step 1 Use WRIA 9 delineation of watershed into five habitat planning units.

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Step 2 Summarize status of individual habitat planning units, including current and historic habitat conditions and fish use.

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Step 3 Summarize the status of fish populations relative to the viable salmonid population (VSP) guidelines.

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Step 4 Trigger Question: What habitat actions or suite of actions in each habitat planning unit would be most effective in narrowing the gap between the current VSP status of the population and the desired future condition? (If multiple life stages make extensive use of a habitat planning units, then this question is answered for each life stage.)

↓

Step 5 Draft provisional Conservation Hypotheses for review, modification, and supplementation at **Workshop One.**

↓

Step 6 Based on the Conservation Hypotheses, identify classes of actions to implement and test Conservation Hypotheses.

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Step 7 Estimate the effectiveness of provisional conservation actions using available models and analytical tools (e.g., EDT SHIRAZ and matrix models)

↓

Step 8 Review, modify, and supplement classes of preservation and restoration actions at **Workshop Two.**

↓

Step 9 Final Conservation Hypotheses and associated classes of conservation actions, including guidelines for monitoring, evaluation and research.

ANCHOR ENVIRONMENTAL, L.L.C.

Figure 1
Strategy and Flowchart for Developing Conservation Hypotheses
Functional Linkages Phase 2

2.2 Definitions

The following definitions of key terms are used in this report. Although they are not unique to this project, they are used in specific ways. These key terms are provided to eliminate any ambiguity.

- Functional linkages are defined here as qualitative and quantitative relationships between habitat quality and quantity and the four parameters of VSP: abundance, productivity, genetic and life history diversity.
- A Conservation Hypothesis is a "best estimate" of how improvements in habitat conditions and processes will lead to improvements in the four salmon parameters critical to viability (McElhany et al. 2000).
- Habitat refers to the physical, biological, and chemical environment in which salmon reside, feed, grow, migrate, and reproduce. The sustainability of salmon populations is largely determined by quantity and quality of available habitat.
- Adaptive management is a systematic process for continually improving policies and practices by learning from the outcomes of operational programs and actions.

2.3 Sources of Data

The strength of the Ecological Synthesis Approach is the incorporation of information from diverse sources to construct Conservation Hypotheses. For the WRIA 9 Conservation Hypotheses, these sources included:

- Comprehensive reports comparing historic and current habitat conditions and salmon population condition (Gellenbeck 2004; KCWLRD 2004)
- *Habitat Limiting Factors and Reconnaissance Assessment Report, Green/Duwamish and Central Puget Sound Watersheds* (WRIA 9 and Vashon Island) (Kerwin and Nelson 2000)
- Recent multi-year investigations of fish use in the river (Nelson et al. 2004) and nearshore (Brennan and Higgins 2004)
- *Preliminary Conclusions Regarding the Updated Status of Listed ESUs of West Coast Salmon and Steelhead* (NMFS 2003)
- *Viable Salmonid Populations and the Recovery of Evolutionarily Significant Units* (McElhany et al. 2000).

3 USING THE ECOLOGICAL SYNTHESIS APPROACH TO DEVELOP CONSERVATION HYPOTHESES

3.1 General Strategy

The general approach used to develop Conservation Hypotheses is shown in step-wise fashion in Figure 1. All of the steps were carried out in working group meetings or more structured workshops that included members of the WRIA 9 Technical Committee, selected stakeholders, and the Anchor Consulting Team (Anchor Environmental and Natural Resource Consultants). The two formal workshops were facilitated by Brad Shinn of Norton-Arnold and Associates.

As outlined in Section 3.2, an initial working session was held in early March 2004 to initiate the project, and work through the details of steps 1 through 4 shown in Figure 1. Workshop One focused primarily on the crafting of Conservation Hypotheses (Section 3.3). Workshop Two served primarily as an opportunity for final review and discussion on how to proceed (Section 3.5).

Two areas where the actual process departed from what was anticipated should be noted. First, there was an expectation that draft reports on several of the other Strategic Assessment projects would be far enough along that they would be available in advance of the workshops. However, these reports were not available. Most notable in this regard were the analyses of historic versus current habitat conditions and fish use. Second, there was an expectation that there would be more input from groups using scientific models to inform their own planning efforts in the Green/Duwamish River watershed. Most notable in this regard was the Muckleshoot Indian Tribe's work with SHIRAZ and Washington Department of Fish and Wildlife's use of Ecosystem Diagnosis and Treatment (EDT). Neither modeling exercise was judged sufficiently complete by either entity when they were contacted by King County staff or the Anchor Consulting Team to warrant use at this time.

Although these were departures from what was planned, they were not considered "fatal flaws" that required altering the approach. Some of the data from the analyses were available and researchers were able to describe preliminary findings. Additionally, WRIA 9 Technical Committee members who were familiar with the various Strategic Assessment projects were able to bring some of the relevant information to the working sessions.

Moreover, there is every expectation that Conservation Hypotheses guiding WRIA 9 salmon recovery planning will be subject to ongoing, iterative review processes, and any relevant modeling results will be considered as they become available. As noted in Sections 5 and 6, monitoring, evaluation, and adaptive management are key features of the WRIA 9 Strategic Assessment approach.

3.2 Initial Working Session of WRIA 9 Technical Committee Subgroup

An initial working session was held March 8, 2004 with a subgroup of the WRIA 9 Technical Committee to agree on a geographic framework for habitat planning, review existing information, develop a template for detailed descriptions of Conservation Hypotheses, and develop some initial Conservation Hypotheses to serve as examples at Workshop One.

Although several possible modifications to the spatial delineation of subareas within WRIA 9 were discussed, the five subwatershed approach used in WRIA 9 as habitat planning units was agreed upon (Figure 2). As shown in Figure 2, the five habitat planning units are the Upper, Middle, and Lower Green River; the Duwamish Estuary; and the Puget Sound nearshore, including Elliott Bay, Vashon Island, and Maury Island.

Also agreed upon was the template for writing up detailed versions of the Conservation Hypotheses. Following a concise statement of the Conservation Hypotheses, identification of the habitat planning unit, and a physical description of the unit, it was agreed that the descriptions would include a summary of historic habitat, summary of historic fish use, summary of current habitat, summary of current fish use, anticipated effects on VSP, rationale and limiting factors addressed, research needs, class of actions and relative certainty guidelines for monitoring and evaluation, and references.

The balance of the working session was devoted to developing subwatershed-specific hypotheses to serve as examples to be provided to workshop participants prior to Workshop One. At the working session (and by follow up emails) the participants identified an initial group of 36 "example Conservation Hypotheses." These were summarized in spreadsheet format and distributed in advance to Workshop One participants.

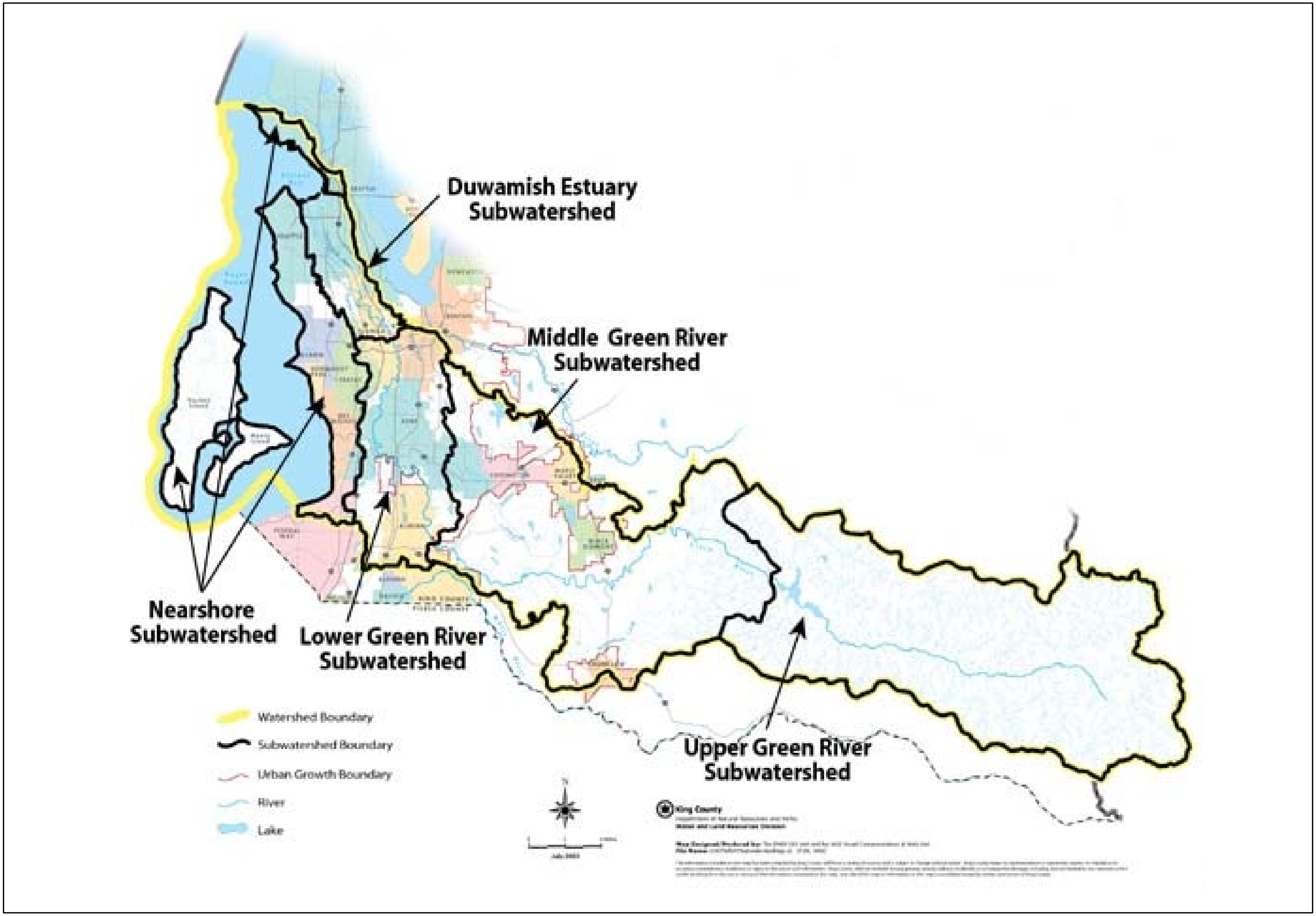

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Figure 2
WRIA 9 Habitat Planning Units
Functional Linkages Phase 2

3.3 Workshop One

Workshop One was held April 1, 2004 in Seattle, Washington. The workshop agenda, list of participants, handouts, and summaries of presentations and discussions are compiled in Appendix A. The main focus of the workshop was to present and review the draft Conservation Hypotheses, which were generated by the subgroup of the WRIA 9 Technical Committee, as described in Section 3.2. Several new hypotheses were proposed by workshop participants, and several "existing" Conservation Hypotheses were modified or combined. It was generally agreed that each of the hypotheses warranted detailed description, and as a followup to the workshop, the WRIA 9 Technical Committee Co-chair made assignments to selected Technical Committee members to complete the descriptions prior to Workshop Two.

3.4 Revising and Updating Conservation Hypotheses

In the time period between workshops, the Anchor Consulting Team worked with several members of the WRIA 9 Technical Committee and King County staff to develop detailed descriptions of each Conservation Hypotheses. These detailed descriptions are summarized in Section 4.

As noted above, it was anticipated that the time period between Workshops One and Two would also provide an opportunity for input from groups using scientific models to identify habitat actions. However, none of the existing modeling efforts were judged by their users to be developed sufficiently for these purposes. When they do become available, however, WRIA 9 is anxious to consider and incorporate their input.

3.5 Workshop Two

Workshop Two was held on May 18, 2004 in Seattle, Washington. The meeting agenda, list of participants, and summary of presentations and discussions are compiled in Appendix B

Workshop Two provided an additional opportunity for Technical Committee members and other participants to review both the spreadsheet summaries of the Conservation Hypotheses and, in most cases, the draft detailed descriptions and rationale. In the majority of cases, the Conservation Hypotheses and descriptions were accepted "as is;" however, several were identified as needing "clarification," and a few were combined or added.

A major goal of Workshop Two was to initiate discussion on how to prioritize the Conservation Hypotheses, then integrate the priorities with the necessary future conditions and associated "next steps." The results of that discussion are addressed in Section 7.

4 WRIA 9 CONSERVATION HYPOTHESES AND THEIR RATIONALE

The final list of Conservation Hypotheses is summarized in Table 1 presented at the end of this section. Detailed descriptions are compiled in Appendix C. A key section of the detailed descriptions is the rationale that provides evidence, based on WRIA 9 observations, that the action would affect Chinook salmon.

4.1 Summary of Conservation Hypotheses

The final list of 32 Conservation Hypotheses included seven that were identified in the WRIA-wide category, five in the Puget Sound nearshore, four in the Duwamish Estuary, four in the Lower Green River, six in the Middle Green River, three in the Upper Green River, and three that identified non-habitat issues. The WRIA-wide Conservation Hypotheses contemplated a range of actions, including improved water quality, restored riparian zones, improved tributary conditions and access, high and low flow modifications, low impact watershed development, and reduced armoring and filling. The Puget Sound nearshore Conservation Hypotheses focused on improved sediment quality, protection of vegetated shallows, protection and restoration of sediment transport, protection of forage fish spawning habitat, and protection and restoration of "pocket estuaries." In the Duwamish Estuary, the Conservation Hypotheses included improved sediment quality, protection and restoration of vegetated shallows and marsh habitats, creation of an enlarged freshwater to saltwater "transition zone," and protection and restoration of refugia. The four Conservation Hypotheses developed for the Lower Green River focused on providing high flow/velocity refugia, improved fish passage at the Black River Pump Station, restoration of sediment recruitment processes, and protection of groundwater recharge via old White River channel. In the Middle Green River, the Conservation Hypotheses included protection and creation of refugia, restoration of sediment recruitment, restoration of spawning habitat in Soos and Newaukum Creeks, increased emphasis on low impact watershed development, improved groundwater recharge, and establishment of access above Tacoma Headworks. Restoring Chinook salmon and bull trout access to habitat above Howard Hanson Dam, and restoring and protecting spawning and rearing habitat were the primary Conservation Hypotheses for the Upper Green River. The non-habitat Conservation Hypotheses address hatchery reform, modification of harvest techniques to include live capture gear, and reduction in the harvest of salmon prey items (e.g., Dungeness crab and forage fish).

The types of actions associated with each of the Conservation Hypotheses are also included in Table 1. These actions can be broadly grouped into the categories of protection, restoration, rehabilitation, and substitution (NRC 1992; TRT and Shared Strategy 2003). As summarized by the Puget Sound Technical Review Team[1] (TRT), associated with each of these categories of actions (in the order in which they are listed) is increasing uncertainty that they will succeed in moving the population closer to the desired state of viability. This is not to say we know one will "work" and another will not; rather that the protection of a habitat process or feature that is naturally functioning is more of a "sure thing" than the artificial construction (i.e., substitution) of a habitat feature where there is little opportunity to restore a habitat-forming process. The latter may function for some brief period of time, but is likely not sustainable.

4.2 Prioritizing Conservation Hypotheses

Although prioritizing the Conservation Hypotheses was not an objective of the Functional Linkages project (or a step based solely on technical considerations), at some point in the near term the Conservation Hypotheses or the actions they contemplate will need to be "ordered" for implementation. There are limits as to which actions can be implemented—some physical, some financial, and some political. Others factors that need to be considered include sequence of implementation, and the degree of "certainty" that a particular action will have the desired effect. However, perhaps most important of all considerations will be biological "bang for the buck."

Considering that a primary conservation goal for Puget Sound is to re-establish viable populations of Chinook salmon throughout the basin, and that the Green/Duwamish River is home to one of the 23 demographically independent populations in the Puget Sound Chinook ESU, the NMFS VSP guidelines (McElhany et al. 2000) should be an important criterion when determining priorities. Recognizing this, we took an initial step by tentatively sorting the Conservation Hypotheses based on their expected effect(s) on the four VSP parameters. The results are shown in Table 2 at the end of this section.

[1] The Puget Sound Technical Review Team is a group of regional experts convened by NOAA Fisheries to guide salmon restoration and work towards effective solutions that result in the delisting of the Puget Sound Chinook ESU.

Although sorting the Conservation Hypotheses by their expected affects on VSP using a qualitative “check system” is arguably subjective, if done by a panel of experts with their rationale clearly explained, such an exercise has no less scientific validity than the results of expert opinion models. Indeed, they are largely the same process.

Table 1
Summary of Conservation Hypotheses

	ID	Targeted River Miles (RM)	Conservation Hypothesis	Example Actions	Related Conservation Hypotheses	Lifestages Targeted	Targeted Functions	VSP Parameters Addressed	Key Assumptions	Data/References	Habitat Management Strategy Type/ Relative Certainty[1]
HABITAT-BASED CONSERVATION HYPOTHESES											
Applicable to entire WRIA	WRIA-wide-1	---	Protecting and improving water quality (e.g., temperature, dissolved oxygen, turbidity, and chemical contamination conditions) by addressing pollution sources. This will enhance habitat quality and lead to greater juvenile salmon growth, disease resistance, and survival. Improved water quality will also enhance survival of adult salmon, incubating salmon eggs, and salmon prey resources, such as forage fish.	• Retrofit stormwater detention and treatment facilities in urban and industrial areas • Reduce combined sewer outfall (CSO) discharges • Repair and replace failing septic systems • Remove creosote-treated wood • Protect groundwater sources that provide cold water (e.g., connection to White River and Deep/Coal Creek subbasins) • Protect tributaries and springs that provide cold water, particularly in the Lower and Middle Green River sections • Manage agricultural runoff to reduce nutrient and waste loading to streams • Restore freshwater and saltwater marshes that reduce runoff rates • Reduce non-point air pollution • Educate • Implement road setbacks	• WRIA-wide-2 • WRIA-wide-3 • WRIA-wide-6 • Low-3	• All lifestages	• Improve egg survival (both salmon and forage fish) • Increase food availability • Expand physiological refuge • Enhance resistance to disease • Enhance migration corridor • Enhance rearing habitat • Improve adult homing and upriver migration survival • Pollution abatement • Soil stability • Erosion control	• Abundance • Productivity	• Degraded water quality reduces the production of prey items consumed by juvenile salmon • Enhanced prey availability enhances growth and survival • Degraded water quality influences juvenile salmon fitness and disease resistance • Degraded water quality influences adult homing and upriver migration survival • Improved water quality contributes to adults having more energy for gamete development, upriver migration, and spawning that will lead to higher egg incubation survival	• Powell et al. (2002) • Arkoosh et al. (1999) • Stein et al. (1995) • Ecology (2002)	• Rehabilitate/ Low-Moderate • Preserve/High

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Summary of Conservation Hypotheses

	ID	Targeted River Miles (RM)	Conservation Hypothesis	Example Actions	Related Conservation Hypotheses	Lifestages Targeted	Targeted Functions	VSP Parameters Addressed	Key Assumptions	Data/References	Habitat Management Strategy Type/ Relative Certainty[1]
Applicable to entire WRIA	WRIA-wide-2	---	Protecting and improving riparian zone conditions by adding native riparian vegetation will enhance habitat quality by improving water quality, stabilizing streambanks, providing overhanging vegetation and large woody debris (LWD), and contributing organic matter, nutrients, and terrestrial prey items, thereby leading to greater juvenile salmon growth and higher survival.	• Restore native vegetation, including overhanging vegetation, in marine nearshore and freshwater riparian areas to provide shade, reduce runoff rates, and reduce contaminants entering waterways with functional buffers • Restore native vegetation in riparian corridor that improves water quality and contributes organic matter and terrestrial prey items • Reconfigure levees and bulkheads, particularly in the Lower Green River and marine shorelines, to allow restoration of riparian vegetation in more natural proximity to water to improve likelihood of vegetation survival and functional contribution to salmon habitat • Plant riparian vegetation to improve long-term potential for LWD recruitment • Provide riparian vegetated buffers • Remove and prevent armoring and fill • Maintain or restore riparian corridor conditions in tributaries • Allow flood events for germination and LWD recruitment • Add LWD in mainstem river and tributaries to provide habitat complexity, organic matter, and high-energy refuges	• WRIA-wide-1 • WRIA-wide-5	• Juvenile foraging/ rearing • Juvenile migration • Adult holding • Adult spawning	• Increase food availability • Improve predator refuge • Expand physiological refuge • Expand high energy/flow refuge • Enhance migration corridor • Enhance rearing habitat • Improve spawning ground quality for salmonids as well as forage fish in nearshore areas • Pollution abatement • Soil stability • Erosion control • Wildlife habitat • Organic/nutrient inputs • LWD inputs/habitat structure • Microclimate • Prey production	• Abundance • Productivity	• Improved riparian conditions will enhance prey availability • LWD recruitment will enhance pool and spawning habitat • Enhanced prey availability will enhance growth and survival • Juvenile salmon will use shade of improved riparian corridor; eventually LWD provided from riparian vegetation will provide refuge from fish and bird predators • Forage fish egg survival will be higher on shaded beaches • Salmon utilization of tributaries will increase with improved conditions	• Brennan and Higgins (2004) • Beschta et al. (1987) • Williams et al. (2001) • Kerwin and Nelson (2000)	• Restore/ Moderate • Rehabilitate/ Low-Moderate • Preserve/High
	WRIA-wide-3	---	Protecting and improving access to tributaries will increase the quantity of available habitat, particularly for juvenile Chinook and coho salmon, and lead to expanded salmon spatial distribution, greater juvenile salmon growth, and higher survival.	• Remove culverts and flapgates that are perched or otherwise limit fish access, particularly access to rearing areas for juvenile Chinook and coho salmon • Modify tributary mouth configuration to improve access over range of flow conditions • Restore natural sediment recruitment and reduce channel downcutting	• WRIA-wide-7 • Low-4	• All lifestages	• Increase food availability • Expand areas providing refuge from predators • Provide high energy/flow refuge • Enhance migration corridor • Expand rearing habitat • Expand spawning ground availability	• Abundance • Diversity • Spatial Structure	• Salmon utilization of tributaries will increase with improved access and habitat condition • Increased utilization will lead to longer residence times, higher survival, and greater distribution	• Kerwin and Nelson (2000)	• Restore/ Moderate

Table 1
Summary of Conservation Hypotheses

	ID	Targeted River Miles (RM)	Conservation Hypothesis	Example Actions	Related Conservation Hypotheses	Lifestages Targeted	Targeted Functions	VSP Parameters Addressed	Key Assumptions	Data/References	Habitat Management Strategy Type/ Relative Certainty[1]
Applicable to entire WRIA	WRIA-wide-4	---	Allowing natural disturbance-type flows in a relatively unconstrained river channel will enhance habitat diversity and will provide habitats that can support spawning and rearing salmon at a greater variety of flow conditions (compared with high flows in a constrained channel), thereby leading to expanded salmon spatial distribution, greater juvenile salmon growth, and higher survival.	• Implement a flow regime that more closely reflects the natural flow regime, including natural peak flows that create side channels, and enhance mainstem habitat in unconstrained portions of the river • Concurrently, set back levees to allow river to meander within the broader channel zone and to reduce scour-related impacts by allowing high flows to spill over banks to connected floodplain • If levees cannot be set back, then manage flow regime to prevent loss of a significant portion of year class due to redd scour	• WRIA-wide-2 • WRIA-wide-3	• Egg incubation • Juvenile freshwater rearing • Adult holding • Adult spawning	• Improve egg-to-fry survival • Enhance rearing habitat • Expand spawning ground availability • Improve spawning ground quality • Enhance rearing habitat	• Abundance • Productivity • Diversity • Spatial Structure	• Natural disturbance will create more diverse and complex habitat for salmon • Habitat complexity will enhance productivity and increase life history diversity • Scour impacts on redds will be excessive and limit egg-to-fry survival	• Franklin (1992)	• Rehabilitate/ Low-Moderate • Preserve/High
	WRIA-wide-5	---	Preserving and protecting against watershed and upland impacts by implementing Low Impact Development techniques, including minimizing impervious surfaces, will maintain habitat quality by helping maintain flow, maintain water quality, and reduce sedimentation, thereby leading to greater salmon survival.	• Maximize forest retention and minimize impervious surfaces through improved site design • Use pervious materials, such as pervious concrete, for hard surfaces, such as parking areas • Maintain and restore riparian area native vegetation • Maintain vegetation to the maximum extent practicable on all development sites • Purchase conservation easements • Implement stormwater management techniques that promote infiltration and reduce water quality impacts (especially temperature and turbidity)	• WRIA-wide-1 • WRIA-wide-2 • Low-3 • Mid-2 • Mid-5	• All lifestages	• Maintain food availability • Maintain physiological refuge • Maintain migration corridor • Maintain rearing habitat • Maintain adult homing and upriver migration survival	• Abundance • Productivity	• Degraded watershed conditions and functions will reduce the quantity and quality of instream habitat • Reduced quantity and quality of instream habitat will reduce productivity and diversity of salmon		• Restore/ Moderate • Preserve/High
	WRIA-wide-6	---	Preventing new bank and shoreline armoring and fill and removing existing armoring, fill, and other impediments (e.g., levees) will enhance habitat quality and quantity and lead to improved juvenile salmon survival, spatial distribution, and diversity.	• Use best management practices (BMPs) (e.g., setbacks and buffers) when developing in aquatic areas, especially flood and landslide hazard areas • Remove bulkheads, levees, and other impoundments • Remove fill and allow natural inundation by fresh and tidal waters to create wetlands, marshes, and side channels • Reconstruct estuaries, wetlands, flats, and beaches to expand spatial area and shallow habitats for refuge, prey production, migration, and physiological transition • Restore sediment transport processes	• WRIA-wide-2 • Near-2 • Near-3 • Near-4 • Mid-3	• All lifestages	• Increase prey production • Increase refuge • Provide high energy/flow refuge • Enhance migration corridor • Expand rearing habitat	• Abundance • Productivity • Diversity • Spatial Structure	• Increased habitat area, complexity, and diversity will result in increased species abundance, productivity, and diversity	• Williams et al. (2001) • Ecology (1994)	• Preserve/High • Restore/ Moderate

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	WRIA-wide-7		Maintaining adequate flows during low flow periods will improve water quality and enhance rearing and spawning habitat quality and quantity, and upstream migration and holding conditions for returning adults, thereby leading to greater survival.	• Implement a flow regime that augments base flows during low flow periods • Preserve inflow of groundwater from the White River and other sources	• WRIA-wide-1 • WRIA-wide-2 • WRIA-wide-3 • Low-1 • Mid-1 • Mid-5	• Adult migration • Adult spawning • Juvenile rearing • Juvenile migration	• Enhance rearing habitat • Improve spawning ground quality • Expand spawning ground availability • Improve adult migration	• Abundance • Productivity	• Low flows will reduce the quantity of habitat and limit the quality of habitat for spawning and rearing • Current baseflows will be inadequate for rearing juveniles, primarily coho and steelhead • Low flows will result in higher temperatures • Low flow will inhibit adult migration		• Preserve/High • Rehabilitate/ Low-Moderate
Nearshore (including Elliott Bay)	Near-1		Protecting and improving sediment quality, particularly in Elliott Bay, will enhance habitat quality and lead to greater juvenile salmon growth and higher survival.	• Remove or remediate contaminated sediments • Address non-point sources through stormwater management and riparian vegetation management • Repair and replace failing septic systems • Clean up contaminated sediments to remove from biologically active zone	• WRIA-wide-1 • Duw-2	• Juvenile foraging/ rearing • Juvenile migration	• Increase food availability • Enhance resistance to disease • Increase growth	• Abundance • Productivity	• Degraded sediment quality will reduce the production of prey items consumed by juvenile salmon • Enhanced prey availability will enhance survival	• Powell et al. (2002) • Arkoosh et al. (1999) • Stein et al. (1995)	• Preserve/High • Restore/ Moderate • Rehabilitate/ Low-Moderate
	Near-2	---	Protecting and increasing the availability of vegetated shallow nearshore and marsh habitats will enhance habitat quantity and quality and lead to greater juvenile salmon residence time, greater growth, and higher survival.	• Add material to dredged areas or remove fill to create shallow habitat with natural gradient and substrate sizes; replant and reseed with appropriate submerged aquatic vegetation • Replace or cap low quality fill material • Remove nearshore shoreline armor and overwater structures to allow access to upper intertidal zones and to reduce impacts to shoreline energy • Protect and restore shallow nearshore corridor	• WRIA-wide-6	• Juvenile foraging/ rearing • Juvenile migration • Juvenile predator avoidance	• Increase food availability • Improve predator refuge • Enhance migration corridor • Enhance rearing habitat	• Abundance • Productivity • Diversity	• Restoration of shallow water habitats will increase the production of prey items consumed by juvenile salmon • Enhanced prey availability will enhance survival	• Simenstad et al. (1982) • Brennan and Higgins (2004) • Phillips (1984) • Toft et al. (2004)	• Restore/ Moderate
	Near-3	---	Protecting and restoring nearshore sediment transport processes by reconnecting sediment sources and removing shoreline armoring that impacts sediment transport will lead to greater prey production, greater juvenile salmon growth, and higher survival.	• Reconnect beach feeding sources to intertidal zone and allow for bluff erosion; protect and restore low bank shorelines • Remove shoreline armor and fill • Undertake beach nourishment where above actions cannot be taken	• WRIA-wide-6	• Adult/subadult foraging • Juvenile foraging/ rearing	• Increase food availability • Enhance migration corridor • Enhance rearing habitat • Increase and enhance forage fish spawning habitat	• Abundance • Productivity	• Restoration of nearshore processes will increase the production of prey items consumed by juvenile salmon • Enhanced prey availability will enhance survival	• Dethier and Schoch (2000)	• Preserve/High • Restore/ Moderate

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Nearshore (including Elliott Bay)	Near-4	---	Protecting and expanding forage fish spawning areas by maintaining and increasing high intertidal zone access and availability of suitable substrate sizes will lead to greater juvenile salmon growth and higher survival.	• Protect existing shoreline sections with suitable substrate in the appropriate intertidal elevations for forage fish spawning • Remove shoreline armoring to expand availability of high intertidal areas and minimize scouring actions that remove suitably sized substrate from the armored shoreline reach • Restore native vegetation in riparian areas to provide overhanging vegetation to reduce possibility of egg desiccation, among other functions	• WRIA-wide-6 • Near-2 • Near-3	• Juvenile foraging/ rearing • Adult foraging	• Increase food availability • Enhance rearing habitat	• Abundance • Productivity	• Expanded forage fish spawning areas will lead to greater prey availability for juvenile and adult salmon • Enhanced availability of forage fish prey will enhance salmon survival	• Brennan and Higgins (2004) • Fresh et al. (1981)	• Preserve/High • Restore/ Moderate
	Near-5	---	Protecting and enhancing pocket estuaries (i.e., small non-natal smaller estuaries, lagoons, and spits) and salmon-bearing and non-salmon-bearing tributary mouths by maintaining and restoring tributary mouths will increase quantity of key habitat and lead to greater juvenile salmon growth and higher survival.	• Remove shoreline armoring around tributary mouths to widen small creek deltas • Remove armoring that channelizes the lower reaches of tributaries and along shorelines in order to expand the transition zone to salt water • Restore alongshore sediment processes • Protect and restore riparian vegetation along pocket estuaries	• WRIA-wide-3	• Adult foraging (cutthroat trout, and possibly others) • Prey production • Juvenile transition • Migration • Juvenile foraging/ rearing	• Increase food availability • Maintain or expand physiological transition zone	• Abundance • Productivity • Diversity • Spatial Structure	• Increasing spatial diversity of available habitats will support greater life history diversity • Enhancing pocket estuaries will lead to increased growth and higher survival	• Beamer et al. (2003) • Hirschi et al. (2003)	• Preserve/High • Restore/ Moderate
Duwamish Estuary (RM 0.0 11.0)	Duw-1	0 to 11	Expanding and enhancing the Duwamish Estuary (particularly vegetated shallow subtidal and intertidal habitats and brackish marshes) by restoring dredged, armored, and filled areas will enhance habitat quantity and quality and lead to greater juvenile salmon residence time, greater growth, and higher survival.	• Expand estuarine habitats • Provide off-channel habitats for early estuarine rearing • Add appropriately-sized, clean sediment material to dredged areas to create shallow habitat with natural gradient and substrate sizes • Remove fill material where appropriate to maintain spatial and structural complexity • Remove shoreline armoring and overwater structures • Re-establish marsh vegetation and mudflats • Restore riparian vegetation	• Near-2 • Duw-3	• Early estuarine rearing of subyearling and yearling outmigrants	• Increase food availability • Improve predator refuge • Enhance migration corridor • Enhance rearing habitat • Expand physiological transition zone	• Abundance • Productivity • Diversity • Spatial Structure	• Improved estuarine habitat will increase residence time, growth, and survival • Restoration of shallow water habitats will increase the production of prey items consumed by juvenile salmon • Enhanced prey availability will enhance survival	• Nelson et al. (2004) • Simenstad et al. (1982) • Ruggerone and Jeanes (2004)	• Restore/ Moderate • Rehabilitate/Low-Moderate • Substitute/Low
	Duw-2	0 to 11	Protecting and improving sediment quality will enhance habitat quality and lead to greater juvenile salmon growth, disease resistance, and higher survival.	• Remove or remediate contaminated sediments • Address non-point sources through stormwater management and riparian vegetation management • Repair and replace failing septic systems • Cleanup contaminated sediments and remove from biologically active zone	• WRIA-wide-1 • Near-1	• Early estuarine rearing of subyearling and yearling outmigrants • Adult migration • Adult holding	• Increase food availability • Enhance resistance to disease	• Abundance • Productivity	• Degraded sediment quality will reduce production of prey items consumed by juvenile salmon • Enhanced prey availability will enhance survival	• Powell et al. (2002) • Arkoosh et al. (1999) • Stein et al. (1995)	• Rehabilitate/Low-Moderate

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Summary of Conservation Hypotheses

	ID	Targeted River Miles (RM)	Conservation Hypothesis	Example Actions	Related Conservation Hypotheses	Lifestages Targeted	Targeted Functions	VSP Parameters Addressed	Key Assumptions	Data/References	Habitat Management Strategy Type/ Relative Certainty[1]
Duwamish Estuary (RM 0 11)	Duw-3	5.5 to 7	Enlarging the Duwamish River estuarine transition zone habitat by expanding the shallow water and slow water areas will enhance habitat quantity and quality of this key Chinook salmon rearing area, leading to greater juvenile salmon residence time, greater growth, and higher survival.	• Remove fill and provide large off-channel habitats for early estuarine rearing • Add riparian and wetland vegetation buffers • Add material to dredged areas to create shallow habitat with natural gradient and substrate sizes	• Duw-1	• Brackish water rearing of fry and fingerling life stages	• Increase food availability • Expand physiological transition zone • Increase refuge • Expand rearing habitat	• Abundance • Productivity • Diversity	• Fish will expand habitat use to areas that are newly available • The limited extent of the salinity transition zone due to modifications of the Lower Duwamish River will reduce salmon residence time and growth • Improved estuarine habitat will increase residence time, growth, and survival	• Nelson et al. (2004) • Congleton et al. (1981) • Weitkamp and Ruggerone (2000)	• Restore/ Moderate • Rehabilitate/Low-Moderate • Substitute/Low
	Duw-4	7 to 11	Protecting, creating, and restoring habitat that provides refuge (particularly side channels, off channels, and tributary access) and habitat complexity (particularly pools) for juvenile salmon over a range of flow conditions and at a variety of locations (e.g., mainstem channel edge, river bends, and tributary mouths) will enhance habitat quality and quantity and lead to greater juvenile salmon residence time, greater growth, and higher survival.	• Reconnect off-channel areas • Add LWD to provide a velocity break from high flow velocities	• WRIA-wide-3 • WRIA-wide-6 • Low-1	• Egg incubation • Freshwater rearing • Adult holding • Adult spawning	• Increase food availability • Improve predator refuge • Expand physiological refuge • Provide high flow refuge • Enhance migration corridor • Improve spawning ground quality	• Abundance • Productivity • Diversity • Spatial Structure	• Lack of refuge habitat in upper estuary will cause salmon to migrate downstream prematurely	• Nelson et al. (2004) • Ruggerone and Jeanes (2004)	• Restore/ Moderate
Lower Green River (RM 11 32)	Low-1	11 to 32	Protecting, creating, and restoring habitat that provides refuge (particularly side channels, off channels, and tributary access) habitat complexity (particularly pools) for juvenile salmon over a range of flow conditions and at a variety of locations (e.g., mainstem channel edge, river bends, and tributary mouths) will enhance habitat quality and quantity and lead to greater juvenile salmon residence time, greater growth, and higher survival.	• Reconnect off-channel areas and tributaries • Add LWD to provide low-velocity habitats during high flow events • Add riparian vegetation enhancement and buffers • Reduce steep riverbanks through levee setbacks • Protect cold water sources that can provide temperature refuge	• WRIA-wide-3 • WRIA-wide-4 • WRIA-wide-6 • Duw-4 • Mid-1	• Egg incubation • Freshwater rearing • Adult holding • Adult spawning	• Increase food availability • Improve refuge from predators • Expand physiological refuge • Provide high flow refuge • Enhance migration corridor • Improve spawning ground quality	• Abundance • Productivity • Diversity • Spatial Structure	• Loss of habitat that serves as refuge in the Lower Green River will limit freshwater productivity, diversity, and spatial structure • Lack of refuge habitat in upper estuary will cause salmon to migrate downstream prematurely, particularly during high flow events	• Nelson et al. (2004) • Ruggerone and Jeanes (2004)	• Restore/ Moderate • Rehabilitate/Low-Moderate
	Low-2	11 to 32	Restoring and enhancing sediment recruitment (particularly spawning gravels) by reconnecting sediment sources to the river will reduce channel downcutting, increase shallow habitats, improve access to tributaries, and improve spawning habitat, thereby leading to greater juvenile salmon residence time, greater growth, and higher survival.	• Set back levees to reconnect natural sediment sources • Set back levees to allow for side channel formation and LWD recruitment • Target sediment sources upriver • Add riparian vegetation enhancement and buffers	• WRIA-wide-3 • WRIA-wide-4 • Mid-3	• Freshwater rearing • Adult holding • Adult spawning	• Expand rearing habitat availability • Expand spawning ground availability • Improve spawning ground quality	• Abundance • Productivity • Diversity • Spatial Structure	• Reduced sediment recruitment will limit the availability of suitable spawning habitat • Improved spawning habitat in the Lower Green River will increase spawning • Natural sediment recruitment will improve access to tributaries	• Kerwin and Nelson (2000) • Nelson et al. (2004)	• Restore/ Moderate • Substitute/Low • Rehabilitate/Low-Moderate

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	Low-3	11 to 32	Preserving and maintaining groundwater inflow from the historical White River channel will contribute to maintaining river flows and good water quality, thereby leading to higher juvenile and adult salmon survival.	• Protect White River groundwater connection to Green River	• WRIA-wide-1	• Freshwater rearing • Adult holding	• Maintain rearing habitat • Enhance migration corridor	• Abundance • Productivity	• Degraded water quality downstream of the White River will limit productivity • White River groundwater will continue to provide a significant inflow during low flow periods		• Preserve/High
	Low-4	Black River	Modifying the Black River Pump Station to allow fish passage will increase habitat quantity and lead to greater juvenile salmon residence time and growth.	• Allow fish passage above the Black River Pump Station, particularly into Springbrook Creek	• WRIA-wide-3	• Freshwater rearing	• Expand rearing habitat	• Abundance • Productivity • Diversity • Spatial Structure	• Water quality and quantity will be adequate to support juveniles		• Restore/ Moderate
Middle Green River (RM 32 64.5)	Mid-1	32 to 64.5	Protecting, creating, and restoring habitat that provides refuge (particularly side channels, off channels, and tributary access) and habitat complexity (particularly pools) for juvenile salmon over a range of flow conditions and at a variety of locations (e.g., mainstem channel edge, river bends, and tributary mouths) will enhance habitat quality and quantity and lead to greater juvenile salmon residence time, greater growth, and higher survival.	• Reconnect off-channel areas • Improve riparian vegetation condition and buffers to provide a source of future LWD • Add LWD to provide a low velocity habitats during high flow events	• WRIA-wide-3 • WRIA-wide-6 • Duw-4 • Low 1	• Egg incubation • Freshwater rearing • Adult holding • Adult spawning	• Increase food availability • Improve predator refuge • Expand physiological refuge • Provide high energy/flow refuge • Enhance migration corridor • Improve spawning ground quality	• Abundance • Productivity • Diversity • Spatial Structure	• Lack of refuge habitat in upper estuary will cause salmon to migrate downstream prematurely	• Nelson et al. (2004) • Ruggerone and Jeanes (2004)	• Restore/ Moderate • Rehabilitate/Low-Moderate
	Mid-2	32 to 64.5	Protecting against watershed and upland impacts by implementing Low Impact Development techniques (see WRIA-wide-5) will be particularly beneficial in the subwatersheds of tributaries that provide spawning (e.g., Newaukum and Soos Creeks) and rearing habitat (e.g., Jenkins and Covington Creeks) will increase habitat quality and quantity and promote utilization of non-mainstem habitats and prevent creating additional stressors that limit survival.	• Use pervious materials, such as pervious concrete, for hard surfaces, such as parking areas • Maintain and restore native vegetation in riparian corridors and all development sites, particularly in rural areas • Create buffers on all wetlands, streams, and shorelines • Implement stormwater management techniques that promote infiltration and reduce water quality impacts (especially temperature and turbidity)	• WRIA-wide-1 • WRIA-wide-2 • WRIA-wide-5 • Mid-4 • Mid-5	• All lifestages	• Maintain food availability • Maintain physiological refuge • Maintain migration corridor • Maintain rearing habitat • Improve adult homing and upriver migration survival	• Abundance • Productivity • Diversity • Spatial Structure	• Degraded watershed conditions and functions will reduce the quantity and quality of instream habitat • Reduced quantity and quality of instream habitat will reduce productivity and diversity of salmon		• Preserve/High
	Mid-3	32 to 64.5	Protecting and restoring natural sediment recruitment (particularly spawning gravels) by reconnecting sediment sources to the river will help maintain spawning habitat.	• Add riparian protection and enhancement • Set back levees to reconnect natural sediment sources to allow for side channel formation and LWD recruitment • Add spawning gravels	• WRIA-wide-5 • Low-2	• Freshwater rearing • Adult holding • Adult spawning	• Expand rearing habitat availability • Expand spawning ground availability • Improve spawning ground quality	• Abundance • Productivity	• Improved spawning habitat in the Lower Green River will increase spawning and increase egg-to-fry survival • Natural sediment recruitment will improve access to tributaries	• Perkins (1993)	• Restor / Moderate • Substitute/Low

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	Mid-4	Newaukum Creek and Soos Creek	Preserving and restoring spawning and rearing habitat in lower Newaukum and Soos Creeks will increase habitat quality and quantity, thereby increasing productivity and spatial structure of Green River Chinook salmon.	• Add riparian protection and enhancement • Maintain and restore riparian vegetation • Limit development-related impacts, including levees • Protect cold water sources	• WRIA-wide-2 • WRIA-wide-3 • Mid-2	• Freshwater rearing • Adult holding • Adult spawning	• Increase food availability • Improve predation refuge • Provide high energy/flow refuge • Improve spawning ground quality	• Abundance • Productivity • Diversity • Spatial Structure	• Improved habitat quality in tributaries will lead to increased fish use, extended rearing time in freshwater, and higher survival • Newaukum and Soos Creeks will provide quality habitat for wild salmon	• Kerwin and Nelson (2000)	• Preserve/High • Restore/ Moderate
Middle Green River (RM 32 64.5)	Mid-5	45 to 58	Maintaining regional groundwater recharge and base flows to the mainstem Green River through forest retention and Low Impact Development techniques will maintain spawning and rearing habitat.	• Add riparian protection and enhancement • Protect natural hydrology • Protect cold water springs • Protect upland forest and wetlands	• WRIA-wide-1 • WRIA-wide-4 • WRIA-wide-5 • WRIA-wide-7 • Low-3 • Mid-2 • Mid-4	• Freshwater rearing • Adult holding • Adult spawning	• Increase food availability • Maintain holding area quality	• Abundance • Productivity	• Groundwater will provide an important source of cold water, which contributes to lower river temperatures • Degraded watershed conditions and functions will reduce the quantity and quality of instream habitat • Reduced quantity and quality of instream habitat will reduce productivity and diversity of salmon	• Kerwin and Nelson (2000)	• Preserve/High • Restore/ Moderate
	Mid-6	61 to 64.5	Restoring Chinook salmon access between the Tacoma Diversion Dam (TDD) and Howard Hanson Dam (HHD) by providing passage upstream and downstream at the TDD for natural-origin Chinook will increase habitat quantity and expand spatial structure.	• Construct fish ladder and collection facility to collect and selectively pass adult fish • Construct a downstream fish passage facility • Trap and haul around dam *Note: Tacoma Water is constructing an adult fish ladder, trap, sorting facility, and water-to-water transfer facility at the TDD to enable passage of adult fish into the Green River watershed upstream of HHD and constructing a juvenile bypass facility around the TDD for migrants from the upper watershed. Currently, there are no plans to provide adult salmon access between TDD and HHD due to concerns about the effects of decaying salmon carcasses on the municipal water supply.*	• Up-1	• All life stages	• Expand rearing habitat • Expand spawning habitat	• Abundance • Diversity • Spatial Structure	• Salmon will spawn in reach if allowed access		• Restore/ Moderate • Substitute/Low

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Upper Green River (RM 64.5 93)	Up-1	64.5 to 93	Establishing and restoring Chinook salmon access above HHD by providing passage upstream (trap and haul) beyond HHD and the reservoir for natural-origin Chinook salmon and downstream passage for their progeny, as well as first generation hatchery fry, will increase habitat quantity and expand salmon spatial structure. (Alternate Hypothesis: Augmenting restoration of salmon populations above HHD by re-introducing spring Chinook salmon from a neighboring river system (possibly White River) will expand Chinook distribution, diversity, and enhance abundance in the river.) (Alternate Hypothesis: Restoring salmon above HHD without the use of hatchery outplants or returning hatchery adults will recover Chinook salmon without bypassing important evolutionary processes (i.e., the selection of the fittest adults for spawning, and juveniles for incubation). *Note: Final decisions on which fish to pass upstream are dependent upon NMFS, USFWS, and the co-managers (WDFW and Muckleshoot Indian Tribe)*	• Construct fish ladder and collection facility to collect and selectively pass adult fish • Construct a downstream fish passage facility • Trap and haul around dam	• Mid-6	• All life stages	• Expand rearing habitat • Expand spawning habitat	• Diversity • Spatial Structure	• Availability of expanded habitats will lead to expanded salmon distribution and life history diversity	• Corps (2000)	• Restore/ Moderate • Substitute/ Moderate
	Up-2	64.5 to 93	Protecting, restoring, and enhancing habitat along the Upper Green River mainstem and major tributaries (e.g., North Fork River and Smay Creek) by restoring the riparian corridor and logging roads will enhance habitat quality and lead to greater residence time and higher survival (after the establishment of populations above HHD).	• Remove or repair failing logging roads • Restore native vegetation • Maintain wide riparian corridor • Add LWD • Tacoma Water continues to manage land holdings in upper watershed (approximately 10 percent of land) as a "natural" forest management zone, which will keep those areas largely intact • Trap and haul around dam	• WRIA-wide-2 • Up-1	• Egg incubation • Juvenile rearing • Adult holding • Adult spawning	• Improve egg survival • Increase food availability • Enhance rearing habitat • Improve spawning ground quality	• Abundance • Productivity • Diversity • Spatial Structure	• Improved habitat in upper watershed will enhance fish survival and lead to extended residence times and higher survival • Runs will be re-established in upper watershed	• Corps (2000)	• Preserve/High • Restore/ Moderate • Substitute/ Moderate

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	Up-3	64.5 to 93	Establishing and restoring bull trout population above HHD by providing passage upstream (trap and haul) beyond HHD and the reservoir for returning adults and downstream passage for their progeny, as well as hatchery fry, will increase habitat quantity and expand spatial structure. *Note: Final decisions on which fish to pass upstream are dependent upon NMFS, USFWS, and the co-managers (WDFW and Muckleshoot Indian Tribe)*	• Construct fish ladder and collection facility to collect and selectively pass adult fish • Construct a downstream fish passage facility • Trap and haul around dam		• All life stages	• Expand rearing habitat • Expand spawning habitat	• Diversity • Spatial Structure	• Upper watershed will provide habitat to support bull trout	• Watson and Toth (1994)	• Restore/ Moderate • Substitute/ Moderate
NON-HABITAT CONSERVATION HYPOTHESES											
	Non-Habitat-1	---	Employing live capture techniques to harvest hatchery salmon (marked) and release natural-origin salmon will reduce mortality of naturally-produced salmon while providing the opportunity to harvest a greater percentage of hatchery fish, thereby reducing straying of hatchery fish to the spawning grounds.	• Use non-lethal fishing gear to target hatchery fish • Increase harvest of hatchery fish		• Adult	• Increase adult survival • Reduce interbreeding	• Abundance • Productivity	• The ability to keep fish alive and distinguish between hatchery and natural-origin salmon will allow more natural-origin fish to be released • By limiting catch of natural-origin salmon, higher percentage of hatchery population will be harvested • Interbreeding will lead to decreased productivity, abundance, and diversity of natural-origin Chinook	• PSIT and WDFW (2001)	• N/A
	Non-Habitat-2	---	Modifying hatchery practices (e.g., more natural rearing conditions, smaller releases, release timing and location, genetic management, etc.) and improving the attractiveness of hatcheries to returning hatchery adults will lead to reduced interactions between hatchery- and naturally-spawned Chinook salmon, and enhance production of naturally-spawned Chinook.	• Retrofit hatcheries to allow for natural rearing conditions • Adjust release timing and release location to minimize overlap with natural population • Limit release numbers to carrying capacity • Use only natural-origin adults as broodstock • Enhance imprinting on unique odors prior to release • Add weir on mainstem upstream of Soos Creek to prevent hatchery straying		• All life stages	• Reduce hatchery and wild fish interactions • Increase spawning by natural-origin adults	• Abundance • Productivity	• Reducing difference between hatchery and natural salmon while also reducing spatial and temporal overlap will reduce negative interactions on wild fish survival	• HSRG (2003)	• N/A
	Non-Habitat - 3	---	Reducing harvest of nonsalmonid commercially and recreationally important species (e.g., Dungeness crab and forage fish) will lead to greater prey availability for juvenile and adult salmonids.	• Work with WDFW to reduce harvest of forage fish		• Adult foraging • Juvenile foraging	• Increase foraging	• Abundance • Productivity	• Forage fish are a primary component of Chinook diets as they get larger than 150mm. Reducing direct harvest of a prey item will increase its availability to Chinook and increase growth and survival	• Brennan and Higgins (2004) • Fresh et al. (1981)	• N/A

Note: 1) Strategy type and degree of certainty as defined in the "Integrated Recovery Planning for Listed Salmon: Technical Guidance for Watershed Groups in Puget Sound" by the Puget Sound Technical Recovery Team and Shared Strategy Staff Group (Draft February 3, 2003). Relative certainty was presented based on an increasing uncertainty of success in achieving VSP parameters in order of the strategy types from protect (least uncertainty), restore, rehabilitate, to substitute (most uncertainty).

Table 2
Preliminary Evaluation of Viable Salmonid Population Parameters Addressed By Conservation Hypotheses

ID	Brief Description	Viable Salmonid Population Parameter[1]			
		Abundance	Productivity	Spatial Structure	Genetic and Life History Diversity
WRIA-wide-1	Protect and improve water quality	✓	✓		
WRIA-wide-2	Protect and improve riparian zone	✓	✓		
WRIA-wide-3	Protect and improve tributary access	✓		✓	✓
WRIA-wide-4	Allow natural disturbance-type flows	✓	✓	✓	✓
WRIA-wide-5	Implement Low Impact Development techniques	✓	✓		
WRIA-wide-6	Prevent new and remove existing bank and shoreline armoring and fill	✓	✓	✓	✓
WRIA-wide-7	Maintain adequate flows during low flow periods	✓	✓		
Near-1	Protect and improve sediment quality	✓	✓		
Near-2	Protect and increase the availability of vegetated shallow nearshore and marsh habitats	✓	✓	✓	✓
Near-3	Protect and restore nearshore sediment transport processes	✓	✓	✓	✓
Near-4	Protect and expand forage fish spawning areas	✓	✓	✓	✓
Near-5	Protect and enhance pocket estuaries and salmon-bearing and non-salmon-bearing tributary mouths	✓	✓	✓	✓
Duw-1	Expand and enhance the Duwamish Estuary (particularly vegetated shallow subtidal and intertidal habitats and brackish marshes)	✓	✓		✓
Duw-2	Protect and improve sediment quality	✓	✓		
Duw-3	Enlarge the Duwamish River estuarine transition zone	✓	✓		✓
Duw-4	Protect, create, and restore habitat that provides refugia	✓	✓		✓
Low-1	Protect, create, and restore habitat that provides refugia and habitat complexity	✓	✓	✓	✓
Low-2	Restore and enhance sediment recruitment	✓	✓	✓	

ID	Brief Description	Viable Salmonid Population Parameter[1]			
		Abundance	Productivity	Spatial Structure	Genetic and Life History Diversity
Low-3	Preserve and maintain groundwater inflow from historical White River channel	✓	✓		
Low-4	Modify the Black River Pump Station to allow fish passage	✓	✓	✓	✓
Mid-1	Protect, create, and restore habitat that provides refugia and habitat complexity	✓	✓	✓	✓
Mid-2	Implement Low Impact Development techniques	✓	✓	✓	✓
Mid-3	Protect and restore natural sediment recruitment	✓	✓		
Mid-4	Preserve and restore spawning and rearing habitat in lower Newaukum and Soos Creeks	✓	✓	✓	✓
Mid-5	Maintain regional groundwater recharge and base flows to the mainstem Green River	✓	✓		
Mid-6	Restore Chinook salmon access between the Tacoma Diversion Dam and Howard Hanson Dam	✓		✓	✓
Up-1	Establish and restore Chinook salmon access above Howard Hanson Dam	✓		✓	✓
Up-2	Protect, restore, and enhance habitat along the Upper Green River mainstem and major tributaries (e.g., North Fork River and Smay Creek)	✓	✓	✓	✓
Up-3	Establish and restore bull trout population above Howard Hanson Dam	✓		✓	✓
Non-Habitat-1	Employ live capture techniques to harvest hatchery salmon and release natural-origin salmon	✓	✓		
Non-Habitat-2	Modify hatchery practices and improve the attractiveness of hatcheries to returning hatchery adults	✓	✓		
Non-Habitat - 3	Reduce harvest of nonsalmonid commercially and recreationally important species (e.g., Dungeness crab and forage fish)	✓	✓		

Source: McElhany et al. (2000)

5 GUIDELINES FOR RESEARCH, MONITORING, AND EVALUATION

Although a strong argument can be made for integrating research, monitoring, and evaluation, there are aspects of monitoring that are sufficiently distinct from research to warrant their separate treatment.

5.1 Research

In the process of developing Conservation Hypotheses, numerous questions arose that could not be answered with existing data. Although it was not an objective of the Functional Linkages project to develop a long list of research needs or a framework for research in the Green/Duwamish River, there were several issues that warrant noting. The following is a brief treatment of the questions and issues that should be addressed by research. They are organized by habitat planning unit beginning with the Upper Green River habitat planning unit and moving downstream. Some of these research topics are addressed in the WRIA 9 Research Framework (Ruggerone et al. 2004)

The primary focus of the Conservation Hypotheses developed for the Upper Green River involved fish passage at Howard Hanson Dam and questions about the adequacy of habitat upstream. Beyond these questions were issues of what would be the appropriate stocks or life histories to focus on, and what level of human intervention was appropriate. The latter was primarily a matter of whether the strategy should be a “hands off” approach of allowing natural-origin recruits access to the habitat above the dam, or using artificial propagation and a specific stock to “jump start” the recolonization. At Workshop One there was considerable discussion of the potential use of White River spring Chinook salmon to establish a spring Chinook population above the dam. The way in which these questions are addressed will depend on new technical information, as well as policy decisions made by the WRIA forum.

In the Middle Green River, the questions were largely about spawning and rearing habitats, and the hydrological processes that create and maintain them. Most of the questions are not unique to the Green River. Indeed, most are at the core of research involving the ecological linkages between habitat quantity and quality and freshwater productivity of salmon. To the extent that selected individual actions can be implemented as experiments (see Section

6), the WRIA 9 Salmon Habitat Plan can make a significant contribution to the state of knowledge in this important area.

Conservation Hypotheses in the Lower Green River were closely related to those in the Middle Green River, but with more emphasis on the role of and need for refugia. Current thinking is that the Lower Green River is potentially an important rearing habitat for stream-rearing juvenile Chinook salmon spawned in upriver reaches, but that limited areas to provide refuge during high flow evidently limits production. The creation of additional refugia through levee setbacks and riparian restoration, coupled with a comprehensive marking and monitoring program, could contribute to the greater understanding of the value of these habitats (see Ruggerone et al. 2004).

The Duwamish Estuary was historically a biologically productive, expansive tidal flat that provided important rearing habitats for fry migrants and a transition zone for smolts as they enter seawater. Conservation Hypotheses developed for this habitat planning unit focused on these roles, with particular emphasis on expanding the transition zone from freshwater to saltwater. Recent research suggests that the current area of habitat serving this vital ecological and physiological function is limiting, particularly during the period when both hatchery and natural-origin fish are present at the same time (Nelson et al. 2004). Creating additional transition zone habitat and then carefully monitoring fish use, growth, and survival would be an important test of the potential value of a larger scale program to expand this habitat (see Ruggerone et al. 2004).

The Puget Sound nearshore Conservation Hypotheses focused on several habitat features and processes, including sediment quality, vegetated shallow water habitats, sediment transport, forage fish production, and pocket estuaries. While all of these issues would benefit by more detailed understanding, they are part and parcel of the broader question of how salmonids use marine nearshore habitats, and the degree to which availability of marine nearshore habitats limit production. There are several Puget Sound-wide efforts underway to develop this more comprehensive understanding, and rather than launch yet another effort, the WRIA 9 forum might consider an increased role in an existing program. With possible exception of sediment quality, the research questions involving the Puget

Sound nearshore are not unique to WRIA 9, but are broad ecological issues that occur throughout Puget Sound.

5.2 Monitoring and Evaluation

Monitoring and evaluation will be a critical component of the WRIA 9 Salmon Habitat Plan. Because of the considerable uncertainty associated with such fundamental information as natural stock productivity, hatchery effects, and habitat use, WRIA 9 will need to place a high priority on the continued collection of information to fill the void. Without a monitoring program to systematically provide feedback on population status and population and life stage-specific responses to conservation measures and actions, there is little hope for a meaningful adaptive management program.

Monitoring can conveniently be divided into two broad categories: 1) implementation or compliance monitoring, and 2) effectiveness monitoring (Spence et al. 1996). Compliance monitoring tracks whether a proposed project was implemented and whether it was constructed as planned. In contrast, effectiveness monitoring addresses the question of whether the action is having its intended effect. This can be assessed in terms of a direct physical response (i.e., a habitat forming process re-established or an in-stream feature restored), or in terms of an effect on a targeted life stage (i.e., increase survival of fry), or at the population level (i.e., abundance, population growth rate, diversity, spatial distribution). The different types or levels of effectiveness monitoring are not mutually exclusive; they all provide important information that informs an adaptive management program.

There have been numerous documents written on various aspects of monitoring in recent years, including efforts by the States of Washington and Oregon, NMFS, the Environmental Protection Agency (E-Map), and others. Rather than start from "scratch," WRIA 9 would do well to review existing plans and programs, and build on those that are achieving their goals. This is particularly important in the case of population-level monitoring, which will necessarily need to be organized and implemented at the ESU level. Recent work by Nelson et al. (2004) and Brennan and Higgins (2004) can provide valuable baseline data for comparison to post-construction long-term monitoring efforts. The responsibility for monitoring and evaluation at the individual project level will likely be the responsibility of the WRIA 9 forum, and considerable effort will be required to develop a scientifically sound framework and approach. In anticipation of this need, project sponsors should consider setting aside a small portion of the project costs to cover monitoring and evaluation. At the same time, the WRIA 9 Forum should engage the appropriate state and federal agencies to begin planning and coordinating monitoring at the ESU level.

Despite the considerable importance of monitoring and evaluation to tracking the implementation and effectiveness of salmonid recovery actions, few monitoring and evaluation programs are currently operational. Moreover, where monitoring programs have been implemented, they have often been short-lived. For reasons that are not all together clear, long-term monitoring programs are often the first to be eliminated when budget constraints require reducing a program's size. This is not only unfortunate but very short-sighted on the part of decision makers who fail to recognize the critical importance of the feedback necessary to adaptively manage in the face of incomplete information and uncertainty.

6 GUIDELINES FOR ADAPTIVE MANAGEMENT

As noted in Section 2.2, adaptive management is a systematic process for continually improving policies and practices by learning from the outcomes of operational programs and actions. Stated more succinctly, it is a structured approach to learning by doing.

There have been several comprehensive volumes written on the subject of adaptive management in the past three decades (e.g., Holling 1978; Walters 1986; Lee and Lawrence 1986; Lee 1993). Virtually every one begins with the description of a simple and highly logical series of steps that starts with assessment, and then cycles through design, implementation, monitoring, evaluation, adjustment, and then back to assessment. These steps are shown diagrammatically in Figure 3.

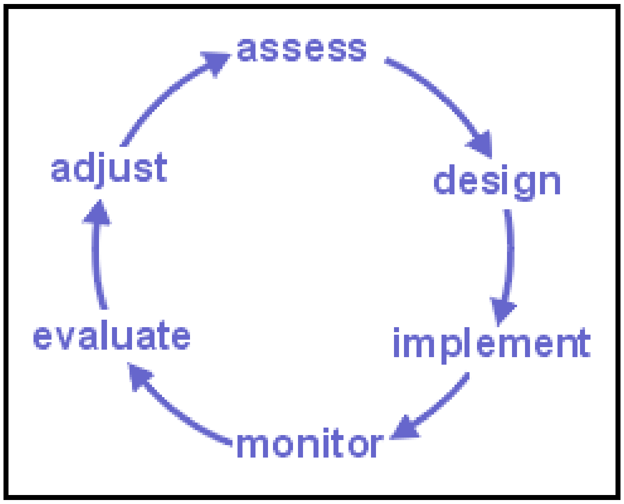

Figure 3
The Six Steps of Adaptive Management

In the arena of public policy, where the technical knowledge necessary to make a decision is often imperfect and there are numerous uncertainties, adaptive management is a way to move forward. Uncertainties are acknowledged and actions are viewed as experiments. In the field of salmon conservation a decision not to take an action until more data are available is in fact a decision of potentially enormous consequences. Extirpation of a salmon population and the accompanying loss of its genetic resources is a loss of its evolutionary legacy and potential contribution to the future biodiversity of the species.

Despite its simple and logical underpinnings, adaptive management does not have a strong track record of success in environmental planning (Lee 1999; Walters 1997). According to Lee, "it has been more influential as an idea than as a practical means of gaining insight into the behavior of ecosystems utilized and inhabited by humans." This is not to say it cannot work; however, it will require considerable time, funds, and commitment on the part of all involved to make it viable.

As was the case with monitoring and evaluation, the WRIA 9 forum would do well to consider reviewing several existing adaptive management programs and learn from their successes and failures. There is no reason an adaptive management program will not work if: 1) the actions are implemented as experiments that yield data (requires monitoring) that can be statistically interpreted, 2) the experiments are conducted at an appropriate scale (time and space), and 3) the affected parties commit to accepting the results and considering them in future decision making. Although it is highly desirable to have an agreed upon decision path in place before beginning an adaptive management program, it is often politically difficult to gain agreement. Acknowledging this, and placing a higher priority on obtaining sound technical data, it is perhaps better to separate formal decision making (policy) and the collection of data (science).

7 NEXT STEPS

Making the transition from Conservation Hypotheses that describe protection and restoration actions at a subwatershed scale to site-specific habitat-based actions is a critical next step in WRIA 9 salmon recovery planning. This is not a step that the Functional Linkages project can or should take in isolation. A key to the process will be completion of the Necessary Futures Project (Strategic Assessment – discussed in Section 1) and a strategy for linking habitat actions to changes in population viability. The latter is expected to include explicit assumptions about how habitat processes and physical attributes affect the four VSP parameters: abundance, productivity, spatial structure, and life history and genetic diversity. In Section 4.2, we provide an example of how the linkage between VSP and actions might be constructed. However, there are more formal models that could be used as well (e.g., EDT, SHIRAZ)

During Workshop Two, the WRIA 9 Technical Committee, along with other workshop participants, began the discussion of how the activities of the Strategic Assessment would coalesce, and specifically the question of how the Conservation Hypotheses would be matched up with the necessary future conditions. Toward that end, the following questions were devised as a means to move forward:

1. Which VSP parameter or parameters most threaten long-term sustainability and viability?
2. Which kinds of habitat actions most directly affect which VSP parameters? (Consider temporal and geographical scale)
   - Abundance: habitat quantity
   - Productivity: habitat quality
   - Spatial Structure: habitat distribution
   - Diversity: habitat complexity and distribution
3. Which Conservation Hypotheses include the action(s) most likely to affect the limiting VSP parameter(s)?
4. Which is expected to have the greatest effect?

Although simple in concept, answering these questions is a very direct and understandable way to make the transition from Conservation Hypotheses to specific actions that are expected to reduce risks to long-term viability.

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