REINTRODUCTION OF ANADROMOUS FISH TO THE UPPER KLAMATH BASIN:

AN EVALUATION AND CONCEPTUAL PLAN

Prepared for:

Klamath Tribes
POB 436
Chiloquin, OR 97624

--- and ---

Yurok Tribe
POB 1027
Klamath, CA 95548

Prepared by:

Charles W. Huntington
Clearwater BioStudies, Inc.
Canby, Oregon

Errol W. Claire
Canyon Mountain Technical Services
Canyon City, Oregon

F. Al Espinosa, Jr.
Espinosa Consulting
Moscow, Idaho

Robert House
BioHouse
Eagle, Idaho

March 2006

EXECUTIVE SUMMARY

Klamath Basin Tribes have expressed two primary goals for an effort to reintroduce anadromous fish to areas above Iron Gate Dam on the Klamath River. These goals include (1) restoring native fish access to historical habitats, and (2) reestablishing upper basin runs of anadromous fish that are self-sustaining and can support some level of tribal harvest. Attainment of these goals would require that either dams be removed from the mainstem Klamath or that effective fish passage be provided at or around multiple dams that currently block fish migration.

The following plan was prepared for the Klamath and Yurok Tribes, both of whom have strong interests in restoring anadromous fish runs to the upper basin. However, it is not intended to advocate for or against a decision to embark upon the reintroduction effort. Responsibility for that decision rests with tribal, federal, state, and local decision-makers, and ultimately the public. Instead, the authors have made an effort to take an objective look at existing conditions in the Upper Klamath Basin, to consider the prospects for reintroducing anadromous fish, and to identify an approach to reintroduction that would make sense should it go forward. This document provides the general outlines of such an approach, but recognizes that additional details would need to be developed by a multi-agency and Tribal team of experts specifically assigned the task. It emphasizes areas above Upper Klamath Lake most strongly, because this was the focus first requested by the Tribes. Prior to actual fish reintroduction, the plan would need to be expanded to include a more explicit course of action for areas between the site of Iron Gate Dam and the lake.

If effective fish passage (with high migrant survival and minimal delay) is provided along the river corridor between Iron Gate Dam and Upper Klamath Lake, the authors think available habitat provides a reasonable opportunity to re-establish fish runs in the Williamson and Wood River systems. Re-establishing significant salmon runs in much of the Sprague system would first require a concerted, comprehensive, and effective effort to rehabilitate damaged habitats.

Conditions in the lower Klamath River today should be a concern both to those managing existing runs of anadromous salmonids and to those who want to re-establish runs in the upper basin. Efforts to improve these conditions, through dam removals, changes in water management, watershed rehabilitation, and/or other measures, should be a very high priority.

TABLE OF CONTENTS

INTRODUCTION

The purpose of this plan is to outline an adaptive program for reintroducing anadromous fish into the drainage basin above Iron Gate Dam (IGD) on the Klamath River, California, with a strong emphasis on restoring fish runs to historic areas above Upper Klamath Lake (UKL), Oregon (Figure 1). It was prepared under contract to the Klamath and Yurok tribes, both of whom have strong interests in restoring these runs, but is not intended to advocate for or against a decision to embark upon the reintroduction effort. Responsibility for that decision rests with tribal, federal, state, and local decision-makers, and ultimately the public. Instead, it identifies the opportunities and challenges that a successful reintroduction program will encounter, approaches to addressing the challenges, and a structured process for making adaptive adjustments to the program as (or if) efforts to reestablish the runs move forward. Prior to actual fish reintroduction, the plan would need to be expanded to include an explicit course of action for areas between IGD and UKL.

The plan has been developed by a team of four consulting biologists, each of whom has multiple decades of experience working with the anadromous species and the kinds of aquatic habitats that are at the center of discussions as to whether fish reintroduction efforts above Iron Gate, and particularly above UKL, will be successful. This experience has been brought strongly into play as the group has reviewed key areas of the UKL drainage basin, refined hypotheses, and developed species-specific fish reintroduction strategies that account for existing conditions, fish passage needs, and opportunities for rehabilitating key streams and habitats.

The plan builds upon a variety of analyses of recent aquatic environmental conditions within the Klamath Basin, including several conducted as part of an ongoing federal relicensing process for the Klamath Hydroelectric Project (KHP). The KHP is a multi-dam system (including Iron Gate) that currently lacks the kind of fish passage facilities needed to make fish reintroduction possible.

GENERAL GOALS AND OBJECTIVES

The Tribes have expressed two primary goals for an anadromous fish reintroduction effort, several rationales, and the intention to advocate for an adaptive, hypothesis-driven program that will take existing environmental conditions and potential improvements into account as (or if) fish reintroductions move forward. The two Tribal goals for the effort are (1) to restore native fish access to historical habitats, and (2) to reestablish runs of anadromous fish in the Upper

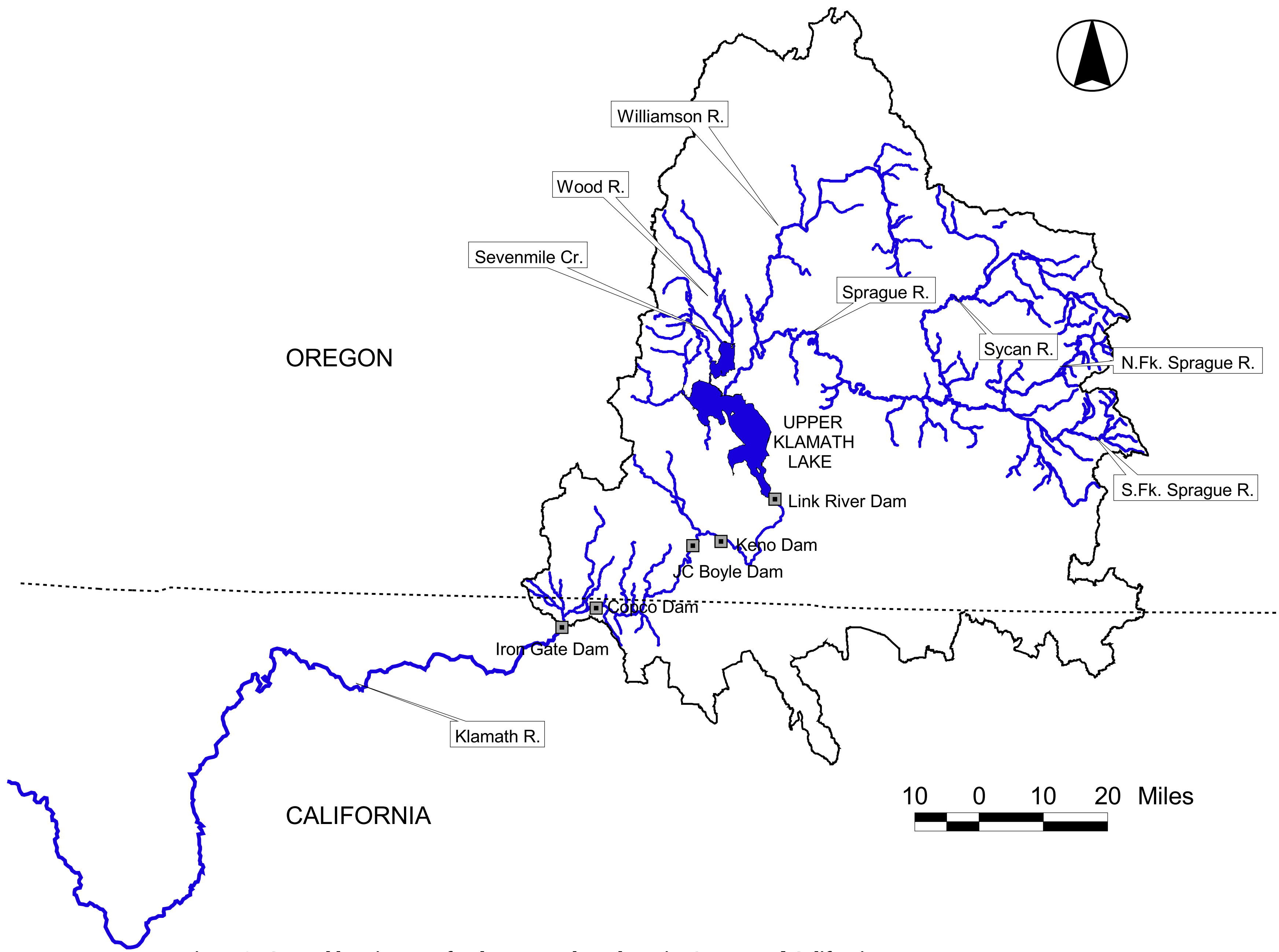

Figure 1. General location map for the Upper Klamath Basin, Oregon and California.

Klamath Basin (the area above Iron Gate Dam [IGD], including UKL and its tributaries) that are self-sustaining and can support some level of tribal harvest. Rationales for the effort include:

- Meeting treaty and federal Executive Order obligations to the Tribes.

- Enhancing the ecological diversity and distribution of Klamath River anadromous fish in order to increase the likelihood that they will persist over the long term.

- Restoring anadromous fish access to some of the most thermally stable aquatic environments in the Klamath Basin (i.e., a multitude of spring-dominated streams above UKL).

- Regaining the potentially high productivity of upper basin fish runs.

- Maximizing the benefits that will accrue from environmental restoration in the Upper Klamath Basin, and particularly in and above UKL.

The Tribal goal of restoring native anadromous fish to historically used habitat in the Upper Klamath Basin is generally consistent with the stated goals or objectives of federal and state resource managers, and with a long-range plan for restoring Klamath Basin fisheries that a multi-party task force completed under authority of a law passed by the U.S. Congress in 1986 (P.L. 99-552; the Klamath Act). For example, federal and state policies require that under most circumstances, safe and effective up- and downstream fish passage be provided at or around dams, including those originally constructed without functional passage facilities. Consistent with these policies, the fishery restoration plan developed by the Klamath River Basin Fisheries Task Force, mentioned above, includes identifying and implementing solutions to fish passage and water quality problems associated with the KHP as an important objective (USFWS 1991). More recently, Oregon has adopted a Native Fish Conservation Policy that provides statewide management goals intended to ensure the conservation and recovery of native fish (ODFW 2003). This policy places emphasis on restoring and maintaining native fish at population levels that provide ecological and societal benefits, but has yet to be fully incorporated into Oregon's Klamath River Basin Fish Management Plan (ODFW 1997), which will be undergoing a 10-year update soon (R. Smith, ODFW, pers comm.; A. Stuart, ODFW, pers comm.). Oregon's existing basin plan takes a precautionary view of anadromous fish reintroductions, emphasizing the need to consider the uncertainties or potential risks of such an effort, as well as the potential benefits. California's policies on the management of native fish in the Klamath Basin are not inconsistent with those of Oregon.

CONTEXT FOR ANADROMOUS FISH REINTRODUCTIONS

Basin-wide Conditions

The Klamath Basin encompasses an ecologically diverse landscape of more than 31,000 km^2 in southern Oregon and northern California (NRC 2004) that supports anadromous runs of spring- and fall-run chinook salmon *(Oncorhynchus tshawytscha)*, coho salmon (*Oncorhynchus kisutch*), steelhead (Oncorhynchus mykiss), Pacific lamprey *(Entosphenus tridentata)*, eulachon *(Thaleicthys pacificus)*, and green sturgeon *(Acipenser medirostris)*. It is also home to a variety of resident native fishes that are of regional significance, including bull trout *(Salvelinus confluentus)*, redband trout *(Oncorhynchus mykiss newberrii)*, and several species of suckers. Collectively, these fish are highly valued and have played an important role in sustaining the Tribes for thousands of years. The basin's salmon are found in marine waters off California, Oregon, and Washington, and provide opportunities for commercial and recreational fishing, as well as fishing-based tourism, to coastal as well as Klamath River communities.

Progressive degradation of ecological conditions and losses of functional habitat have been common contributors to declines in the abundance of many Klamath Basin fishes, and to listings of its coho salmon, Lost River sucker *(Deltistes luxatus)*, shortnose sucker *(Chasmistes brevirostris)*, and bull trout under the U.S. Endangered Species Act (ESA). The basin's history of aquatic degradation and habitat loss has been reviewed by USFWS (1991) and the NRC (2004). Over the last 100-150 years, the basin's annual salmon runs have declined to levels far below historic abundances that, based on rough estimates for specific species and runs (Moyle 2002), were probably between 500 thousand and a million adult fish. Anadromous lampreys appear also to have experienced substantial declines (Larson and Belchik 1998). The declines in fish populations reflect the cumulative effects of a variety of activities, including the construction of dams that blocked access to upper portions of the basin, agricultural development (including irrigation demands and riparian grazing by livestock), timber harvesting, mining, and historical over-harvest by commercial and recreational fisheries (USFWS 1991; NRC 2004).

Efforts to recover the Klamath Basin's native fishes, and particularly its anadromous and ESA-listed populations, have been growing over the last few decades and will continue into the foreseeable future. Despite degradation of habitats, blockage of fish passage, and the loss of several anadromous fish runs, there remain significant and important opportunities to restore the system.

The Upper Klamath Basin

Expansive bottomland areas with abundant low-gradient channels often provide preferred salmon habitats and are substantially more common in the Upper Klamath Basin than they are in most of the remainder of the Klamath system. Such areas are particularly extensive above Keno and UKL, where spring-fed streams include the Williamson and Wood rivers, smaller springbrooks flowing into these two rivers, Sprague River, and many other streams. As noted earlier, many of these streams have been affected by historic land and water use practices. UKL itself is generally shallow (mean depth ~2.7 m), warm in summer, and affected by seasonal water quality problems related to massive seasonal blooms of *Aphanizomenon flos-aquae*, a nitrogen-fixing blue green algae. The abundance of this alga was relatively low into approximately the mid-1900s, but has grown dramatically in response to ecological disturbances that have included removal of lake-fringe and other wetlands, hydrologic alterations, and elevated nutrient loading (NRC 2004).

Efforts are now underway to restore riparian areas and wetlands associated with the Sprague, Williamson, and Wood rivers in order to improve water quality and aquatic habitat (NRC 2004). A completed Total Maximum Daily Load (TMDL) regulatory process has identified some important goals and targets forthese restoration efforts. Regional scientists have identified the Sprague River system, and particularly the upper reaches of the mainstem, as being of high priority for ecological restoration (USFWS 2006). A large (1335 hectare) riverine wetland restoration project has been completed in the lake delta area of Wood River by the Bureau of Land Management, and The Nature Conservancy is restoring wetlands and reconnecting them to UKL on its 2995 hectare Williamson River Delta Preserve.

Anadromous fish were once abundant in Upper Klamath Basin. Historical records indicate that spring- and fall-run chinook, coho, steelhead, and Pacific lamprey were all present (Hamilton et al. 2005), but their precise geographic distributions within the area remain somewhat uncertain. This reflects that fish runs into the area were blocked in the early 1900s, before there was any substantive effort to catalog freshwater production areas (Huntington 2004a). However, recent evaluations of potential anadromous fish habitat above IGD, conducted by multiple parties involved in the FERC relicensing process for the Klamath Hydroelectric Project (KHP), have developed a list of 676.6 kilometers of streams that still provide habitat that appears suitable for use by these fish and an additional 97.5-379.0 km that could be rehabilitated to a sufficient degree to support them (Huntington 2006; Table 1). The list is imperfect, because of uncertainties about which streams might actually become rehabilitated, but reasonable. The streams identified are more extensive above UKL than they are below the lake, and reflect that

Table 1. Estimates of the quantity (in kilometers) of recent and restorable habitat for anadromous fish in the drainage basin above the site of Iron Gate Dam.

Stream	Estimates of potential anadromous fish habitat (km)		Comments
	Existing	Existing plus recoverable	
Areas below Upper Klamath Lake (UKL)			
Klamath R.	44.6	44.6 (109.9?)	Value in parentheses includes habitat now inundated by slackwater.
Spencer Cr. *	23.6	23.6	
Shovel Cr. *	5.3	5.3	
Fall Cr.	1.4	1.4	
Jenny Cr.	1.8	1.8	
Others	21.1	21.1	
Total	**97.8**	**97.8 (163.1?)**	
Westside tributaries to UKL			
Wood R.	32.5	32.5	
Annie Cr.	---	19.9	Alterations and diversions affect access at present.
Sun Cr.	---	21.4	Alterations and bull trout barrier affect access at present; rehabilitation planned.
Fort Cr.	6.1	6.1	
Crooked Cr.	15.7	15.7	
Agency Cr.	1.3	1.3	
Sevenmile Cr.	30.4	30.4	Water diversions affect passage and would need to be modified.
Short Cr.	2.8	2.8	
Fourmile Cr.	---	16.7	
Cherry Cr. *	---	15.5	
Threemile Cr. *	---	8.1	
Recreation/Crystal Cr.	13.1	13.1	
Fourmile (Lake) Cr. *	---	---	Water exported to Rogue R. Basin.
Denny Cr.	---	---	Upper reaches suitable for use; bottomland reaches dysfunctional.
Total	**101.9**	**183.5**	
Williamson R. system (excluding Sprague)			
Williamson R.	37.4	37.4	
Larkin Cr.	6.4	6.4	
Sunnybrook Cr.	1.1	1.1	
Spring Cr.	4.0	4.0	
Total	**48.9**	**48.9**	
Sprague R. system			
Sprague R.	136.1	136.1	Much of mainstem strongly in need of rehabilitation.
N.Fk. Sprague R.	57.9	57.9	Lower-most reaches strongly in need of rehabilitation.
Dead Cow Cr. *	6.9	6.9	
School Cr.	6.1	6.1	
Cold Cr.	3.3	3.3	
Gearhart Cr. *	4.8	4.8	
Boulder Cr.	4.8	4.8	Steep and cold stream; will get only limited use (ODFW).
Sheepy Cr.	1.8	1.8	Steep and cold stream; will get only limited use (ODFW).
Meryl Cr. *	---	14.0	In need of substantial rehabilitation.
Fivemile Cr.	22.4	22.4	Lower-most reaches strongly in need of rehabilitation.
S.Fk. Sprague R.	55.5	55.5	Lower reaches very strongly in need of remedial actions.
Corral Cr.	2.5	2.5	
Camp Cr.	2.9	2.9	
Buckboard Cr.	6.6	6.6	
Whitworth Cr. *	17.4	17.4	
Brownsworth Cr. *	20.8	20.8	
Ish Tish Cr.	---	10.9?	Potential for rehabilitation uncertain.
Paradise Cr.	---	---	Rehabilitation appears infeasible.
Fishhole Cr. *	---	51.5?	Flow enhancement and other rehabilitation would be needed here.
Deming Cr.	---	---	ODFW considers the stream naturally isolated from the South Fork.
Sycan R. (above and within Sycan Marsh)	---	68.4?	Use of this habitat would require passage through Sycan Marsh.
Skull Cr.	---	10.3?	Use of this habitat would require passage through Sycan Marsh.
Paradise Cr. *	---	34.4?	Use of this habitat would require passage through Sycan Marsh.
Long Cr. *	---	45.2?	Use of this habitat would require passage through Sycan Marsh.
Sycan R. (below Sycan Marsh)	53.7	53.7	Strongly in need of rehabilitation.
Brown Springs Cr.	---	1.9	Rehabilitation of this small springbrook is in process.
Snake Cr. *	---	6.8	Rehabilitation may be infeasible.
Others	---	---	Multiple intermittent streams have uncertain anadromous potential.
Whisky Cr.	---	7.2	Rehabilitation of part of this springbrook will require major investments.
Rock Cr.	---	8.4	Lower-most reach of stream may be dysfunctional.
Trout Cr. *	11.3	11.3	
Whitehorse Cr.	---	3.2?	Rehabilitation of this small springbrook will be difficult but not infeasible.
Copperfield Cr.	---	---	Rehabilitation appears infeasible.
Others	---	---	Rehabilitation appears infeasible.
	421.4	**453.1 (669.3?)**	Value in parentheses includes areas within/above Sycan Marsh.
All Streams Above Iron Gate	**676.6**	**774.1 (1055.6?)**	Value in parentheses includes inundated areas and sites within/above Sycan Marsh.

* Streams that include additional unnamed tributaries with potential habitat.
? Kilometers of streams that may or may not be recoverable as habitat, depending on the circumstances.

despite losses of several anadromous fish runs due to blockages at dams, and the degradation of habitats in many areas, the upper basin still has potential for producing anadromous fish.

Brief discussions of where within the Upper Klamath Basin each species of anadromous fish is known or thought to have been present at one time are given below.

Chinook salmon. The diversity of stream conditions present, Tribal accounts (e.g., see Lane & Lane Associates 1981), and historical information reported by Snyder (1931) suggest chinook salmon that once returned to areas above IGD included both spring and fall-run fish (Huntington 2004a). This assessment is consistent with results of a regional review by Nehlsen et al. (1991) that indicated historic populations of both spring-run and fall-run chinook were extirpated from the Sprague, Williamson, and Wood rivers above UKL. Spring-run chinook apparently began disappearing early in the development of the Klamath Basin, most likely due to a combination of over-fishing, migratory impediments, and early habitat degradation. This was a pattern repeated in many areas of the Pacific Northwest and reflects that this race of fish was a primary focus of early Euro-American fisheries and highly sensitive to environmental disturbance. Substantial numbers of what were apparently fall-run chinook were still being harvested in the Sprague River up until about 1910 (Lane & Lane Associates 1981), the year in which the U.S. Bureau of Fisheries began blocking fish runs at Klamathon in anticipation of construction of Copco 1, the first KHP dam.

After reviewing a considerable quantity of information on existing environmental conditions and hypothesizing on the conditions that likely existed prior to development, we strongly suspect that much of the historic success of fall chinook salmon in the drainage basin above UKL was associated with one or both of two components of the system. The first of these components was the thermally moderate spawning and egg incubation environments associated with spring-fed streams or areas of strong groundwater input. Such environments, still present in several areas above UKL today, would have allowed (and could still allow) these fish to spawn somewhat later, and emerge as fry earlier, than would otherwise be expected for chinook salmon in streams more than 4,000 feet above sea level. The second element was eutrophic (now hyper-eutrophic) UKL itself, and the very productive rearing environment its warming, nutrient-rich waters could provide during spring to sub-yearling chinook expressing an ocean-type (<1 yr in freshwater) life history. So far as we know, this combination of environmental elements is unique in the Pacific Northwest.

Steelhead. The anadromous form of this species was once present in upper basin streams both above and below UKL (Fortune et al. 1966; Chapman 1981; Hamilton et al. 2005) but information on how it partitioned available habitat with redband trout, particularly the large adfluvial fish associated with UKL, is lacking (Huntington 2004a). Buchanan et al. (1994) reported strong genetic similarity between redband/rainbow trout found in Spring and Trout creeks (above UKL), those in Spencer Creek and the Klamath River (within the project-bounded area), and the steelhead found in Bogus Creek (below IGD). Their work suggests that the four upper basin populations mentioned were once associated with runs of anadromous rainbow trout.

Coho salmon. Historic egg collection records for the Klamathon Racks, compiled by CDFG (2002), suggest that in at least some years a run of coho exceeding about 2000 adult fish returned to areas now blocked by the KHP. This species was once present in streams in the lower portions of the drainage basin above IGD, up to and including Spencer Creek. There are no records or anecdotal accounts of coho having once been present above UKL (Hamilton et al. 2005), although early Euroamerican residents of the area often had difficulty distinguishing among species of salmon (Snyder 1931; Fortune et al. 1966). Given that it is not clear that the fish were once present farther upstream, fish managers apparently do not intend to make efforts to actively introduce the species to areas above Keno.

Pacific lamprey. Streams above IGD undoubtedly provided important habitat for Pacific lamprey prior to dam construction, and the species was once present in the drainage network between IGD and Keno Dam (Hamilton et al. 2005). The preferred habitat of juvenile lampreys is found in low-gradient channels with an abundance of fine sediments in the streambed, habitat that is abundant above UKL.

The Klamath Hydroelectric Project

The KHP began with the completion of Copco 1 Dam in 1918, which blocked anadromous fish from upstream areas despite assurances to the Klamath Tribes that the power company would construct a fishway (Lane and Lane Associates 1981). The project has since grown to include six mainstem dams (Table 2), three of which lack fish passage facilities and are located in California (Copco 2 and IGD, in addition to Copco 1). The other KHP dams (J.C. Boyle, Keno, and Link River) are all in Oregon and provide fish passage of variable effectiveness (FishPro 2000). Collectively, the six dams are situated from 306-409 km up the Klamath River and vary from 4.6-52.7 m in height. Other than Link River Dam, which is owned by the U.S. Bureau of Reclamation but has powerhouses operated as part of the KHP, the dams are all owned by PacifiCorp and impound relatively narrow reservoirs. These reservoirs range from 0.5-36.2 km long, and have varying capacities for water storage. Those immediately upstream of Copco 1 and IGD are deepest, and have the greatest water volumes and retention times.

Table 2. Dams within the project-bounded river corridor. Sources: FishPro (2000), and Dunsmoor and Huntington (2006).

Dam	River kilometer	Year completed	Dam height (m)	Reservoir length (km)	Maximum surface area (hectares)	Mean water retention time for spring (April-May) flows during 20th-80th percentile water years
Link River	409	1927	4.6	---	36,422	---
Keno	371	1931 (replaced in 1966)	7.6	36.2	1,002	3.2-11.3 days
J.C. Boyle	362	1958	20.7	5.8	170	0.6-1.6 days
Copco 1	320	1918	38.4	7.2	405	7.3-20.8 days
Copco 2	319	1925	10.1	0.5	16	negligible
Iron Gate	306	1962	52.7	10.9	382	7.4-23.0 days

No effort was made to provide fish passage when the lower-most KHP dam, Iron Gate, was completed in 1962. Instead, a hatchery was constructed immediately downstream to mitigate for the loss of anadromous fish production between it and the two Copco dams. Iron Gate hatchery now releases fall-run chinook, coho, and steelhead under the terms of its existing hydropower license with the FERC. Spring chinook salmon were last recorded at the hatchery site in 1978 (USFWS 1998).

The Klamath Irrigation Project

Although not shown earlier in Figure 1, the U.S. Bureau of Reclamation's Klamath Irrigation Project (KIP) was developed in the early to mid-1900s to provide water to approximately 97,100 hectares of land in south-central Oregon and northern California. The KIP diverts water at Link River Dam, and from several locations in Keno Reservoir, for conveyance to irrigators and to the Lower Klamath National Wildlife Refuge. A fishway was recently completed at the dam to improve passage for federally listed suckers and the basin's migratory redband trout. The KIP's withdrawals of water at the dam and reservoir, and return of lesser volumes of irrigation return flow, have ecological ramifications downstream (NRC 2004). This does not make the KIP unique in the upper basin, however, as a diversity of past and ongoing land and water management activities continue to affect streamflows and water quality.

KEY ISSUES

Multiple issues have been identified by fish managers as central to decisions about how (or whether) to reintroduce anadromous fish to the Upper Klamath Basin. If a decision is made to remove dams within the project-bounded migratory corridor, or to provide effective up- and-downstream fish passage at these dams, managers of the fish reintroduction program that follows will face a number of issues and questions that will have to be addressed through a combination of structured decision-making and adaptive implementation. This section of the reintroduction plan describes some of these key issues:

- Fish passage through the project-bounded area
- Habitat suitability in upper basin streams
- Fish migration and seasonal rearing in Upper Klamath Lake
- Potential direct interactions with resident fishes
- Fish diseases
- Conditions in the mainstem Klamath River downstream of IGD
- Stock selection

FISH PASSAGE THROUGH THE PROJECT-BOUNDED AREA

Providing effective fish passage through or around the dams and artificial reservoirs now found along the river corridor between UKL and IGD will be essential if the objectives identified by the Tribes are to be met. While active reintroduction efforts and measures that improve habitat conditions in strategically selected areas will also be required, success in re-establishing anadromous fish runs that can sustain themselves in the Upper Klamath Basin through time will be dependent upon high levels of survival and low levels of unnatural delay as fish migrate through this corridor.

As part of the ongoing relicensing process for the KHP, Oosterhout (2005) and PacifiCorp (2005) modeled 13 distinct fish passage options with the intent of rank-ordering the relative abilities of these options to support populations of anadromous fish above Iron Gate Dam. Neither modeling effort was intended to produce reliable estimates of the absolute abundance of fish that might return to areas above the dam (Oosterhout 2005, PacifiCorp 2003). Instead, each effort predicted general patterns of relative fish production in the Upper Klamath Basin, something that may be helpful in sorting through the potential performance of fish passage options or in discriminating among geographic areas where future fish runs appear more or less likely to be successful.

Oosterhout (2005) used KlamRAS, a stochastic life-cycle model for fall chinook, stream reach and lifestage-specific survival values predicted by the Ecosystem-Diagnosis-and-Treatment (EDT) model (Mobrand Biometrics 2005), and a variety of documented assumptions to simulate how fish might respond to the options. She found that fall chinook exhibiting an ocean-type juvenile life history would benefit most from removal of 4-5 KHP dams, that these fish would benefit less from volitional fish passage at the dams, and that options relying on volitional passage to allow migration of juvenile and adult fall chinook past dams not removed generally ranked higher than those that relied on trapping and hauling fish around the dams. Dr. Oosterhout found one exception to this pattern, however. Her model suggested that a fish passage option that collected and transported adult and juvenile fish around the entire KHP would improve fish passage survival for ocean-type fall chinook originating above UKL to such an extent that more adults would result than from a purely volitional fish passage alternative at the KHP. The implications of the full collect-and-transport option for other types of fish that would be excluded from the project-bounded area by this option were not addressed by Dr. Oosterhout's modeling.

More recently, PacifiCorp (2005) used the EDT model and many but not all of the same inputs relied upon by Oosterhout (2005) to rank-order KHP fish passage options for ocean-type fall chinook, stream-type spring chinook, and steelhead. While information required for a thorough review of this modeling has not been released as of March 2006, the model output tends to suggest some of the same basic patterns for all three modeled species that Oosterhout (2005) found for fall chinook. Specifically, that dam removal options would be most beneficial to upper basin fish and that options relying on fish screens to collect juvenile fish will outperform those that depend upon gulpers to do so. The volitional (ladder and screen) option that left all dams in place performed relatively more poorly in PacifiCorp's (2005) EDT modeling than it did in Oosterhout's (2005) KlamRAS modeling, for reasons that are not entirely clear.

The net result of the modeling performed to date on KHP fish passage options is a clear indication that dam removal would be the option most beneficial to Upper Klamath Basin fish. This would be true for each of the three types of anadromous fish modeled, as well as for coho and Pacific lamprey, which have not been modeled.

The model results are somewhat mixed for KHP passage options other than dam removals, although an emphasis on volitional up- and downstream fish passage facilities at KHP dams not removed appears conceptually to offer the only one of these options that might fully meet the Tribes' objectives for <u>all</u> anadromous species. For example, the relative abundances of future runs modeled by Oosterhout (2005) and PacifiCorp (2005) suggest that a system that collected and transported anadromous fish completely around the project-bounded area might be effective for chinook runs returning to areas above UKL. However, there are several reasons that this option would not meet Tribal goals identified early in this document. First, it would preclude expansion of Klamath River chinook, coho salmon, steelhead, and Pacific lamprey into project-bounded areas that they occupied prior to dam construction. Second, efforts to actually reintroduce steelhead under this option would be confounded (i.e., prevented even above UKL) by an inability to distinguish and differentially pass non-anadromous but migratory (fluvial and adfluvial) redband trout toward their intended destinations when collected at fish passage facilities. Finally, collection difficulties associated with the option of hauling fish completely around the KHP might preclude reintroductions of Pacific lamprey, although experience at Columbia River dams suggest that these fish may also have difficulty with fish ladders (Moser et al. 2002).

Despite the potential drawbacks of a KHP-wide fish transportation system (see above), we think the downstream migrant component of this approach (with collection at Link River Dam and release below IGD) might prove beneficial if coupled with other fish passage measures. Experiences at hydropower dams elsewhere in the region have shown that passing juvenile chinook downstream through or around a series of multiple dams and artificial reservoirs can be challenging (Peters and Marmorek 2001; Peters et al. 2001). If juvenile chinook survival rates through the project-bounded river corridor constrain the ability to sustain runs above UKL after a new passage system is deployed, and assuming the system does not already include juvenile transportation originating at Link River Dam, the possibility of transporting chinook collected at the dam's facilities to below IGD should be given consideration. Delayed effects that such transport may have on juvenile chinook have become recognized as a potential problem in the Columbia River Basin (Peters and Marmorek 2001; Peters et al. 2001), with the most recent analyses suggesting that the effects may be partly related to premature releases of juvenile fish into an estuarine environment (Williams et al. 2005). Such timing difficulties would seem unlikely to affect the survival of juvenile chinook released near IGD, approximately 306 km upriver from the ocean, but delayed effects following transport may still occur.

Two additional aspects of the migratory corridor between Link River Dam and IGD seem particularly worthy of note. Fish passage conditions within Keno Reservoir are severely affected during the summer and fall by extended periods of high water temperatures, low levels of dissolved oxygen, or both (Dunsmoor and Huntington 2006). Conditions are severe enough in Keno Reservoir that EDT modeling by PacifiCorp (2005) suggests significant unfavorable effects on future runs of adult fall chinook and steelhead migrating through the area unless the problem is addressed. Similarly, hydropower peaking operations below JC Boyle Dam result in rapid flow shifts (Huntington 2004b) that would need to be reduced substantially in order to make them consistent with regional norms for the avoidance of stranding sub-yearling salmon (e.g., Hunter 1992).

Although removal of most or all of the dams within the project-bounded river corridor above IGD appears to offer the clearest and surest benefits in terms of reestablishing self-sustaining populations of anadromous fish to historic areas above IGD, it is not clear that a decision will be made to remove the dams. Whatever initial fish passage measures are ultimately implemented within this corridor, there will be a strong need to (1) establish explicit performance objectives for these measures with regard to fish passage survival and potential delay, (2) monitor how well the measures meet the objectives, and (3) to make adaptive adjustments to the fish passage system as needed if the objectives are not met.

HABITAT SUITABILITY IN UPPER BASIN STREAMS

Our team has reconnoitered potential salmon streams within the drainage basin above UKL and individual team members (particularly CWH) have reviewed a variety of data on the aquatic habitat conditions there and downstream. We have also examined general patterns in recent EDT model output (PacifiCorp 1995) suggesting how chinook salmon and steelhead might perform in the aquatic habitat upstream of IGD. Results of our effort, and observations we have about existing habitat conditions and specific habitat rehabilitation or enhancement opportunities, are summarized here. A brief but more detailed summary of available information on the quantity and quality of potential anadromous fish habitat in the Upper Klamath Basin, developed by Huntington and Dunsmoor (2006a), is given in Appendix A.

Stream conditions within the Upper Klamath Basin provide a variety of opportunities and challenges for anadromous fish reintroduction. Many upper basin streams have been affected by a combination of riparian and/or wetland alterations, channel simplification (a reduction in desirable habitat structure), water withdrawals, or introductions of non-native fish. However, such alterations have not been universal, and the degree to which streams appear to have been changed from a natural condition is highly variable. Some upper basin areas continue to provide high-quality aquatic habitat, many have been moderately to substantially degraded, and some of the smaller tributary streams have been modified to the point that they are barely recognizable as historic channels. Overall, it is clear that recognition of spatial patterns evident within this mix of conditions, patterns that reflect both the distribution and connectivity of relatively higher quality habitats, should form the basis of any reintroduction effort.

An Overview of Species-specific Opportunities

Fall chinook. Streams in four watershed areas within the upper basin offer what appear to us to be the best near-term opportunities for the active reintroduction of fall chinook. These include the hydroproject-bounded area (PRJ), Lower Williamson River (LWR), Wood River (WDR), and to a lesser extent Lower Sprague River (SPL). Habitat in the lower Williamson and Wood river systems may well be some of the best remaining in the entire Klamath Basin. Near-term chinook use of patches of relatively better habitat upstream of Lower Sprague River (i.e., above Trout Creek) appears likely to be constrained by current conditions within the long (up to 92 km) stretches of severely damaged lowland river corridors immediately downstream from them. The damaged corridors, including the upper Sprague River itself, are impaired by riparian degradation, reduced channel complexity, sedimentation, reduced flows, and altered temperature regimes. An experimental release of fish into selected areas above Lower Sprague River might prove otherwise, but we suspect that efforts to reintroduce fall chinook salmon to them will achieve limited success until the riverine corridors are significantly rehabilitated. Such rehabilitation will require a sustained, long-term effort.

Recent output from an Ecosystem-Diagnosis-and-Treatment (EDT) model (PacifiCorp 2005), which should still be reviewed in detail and refined as necessary, suggests a relatively similar pattern to that we have seen from ground level, at least in terms of habitat for fall chinook (Figure 2). The model suggests relatively higher spawner densities (fish utilization levels) following reintroduction along the mainstem Klamath, a few tributaries within the project-bounded area, and in the Williamson, Wood, and lower Sprague rivers. It also suggests low to negligible densities across much of the rest of the Sprague system. Segments of the lower Sycan (SYL) and S.Fk. Sprague rivers (SFS) that the model suggests might receive relatively heavier use by spawning fall chinook are situated farther upstream than we think these fish might actually go under existing conditions.

Although it has very little effect on the existing production potential found in the Williamson and Wood river systems, the current condition of the upper mainstem Sprague, and the lower-most reaches of its larger tributaries (particularly the North and South forks) will likely impose a significant constraint on total chinook production above UKL. Tribal accounts and our thinking on how the system once functioned leads us to conclude that a large portion of the historic abundance of these fish above UKL was once linked to these areas. We believe, and the EDT modeling suggests, that there are significant though challenging opportunities to rehabilitate habitat in these areas (Figure 3). Meeting these challenges will require action on recommendations the NRC (2004) has already made for recovering ESA-listed suckers,

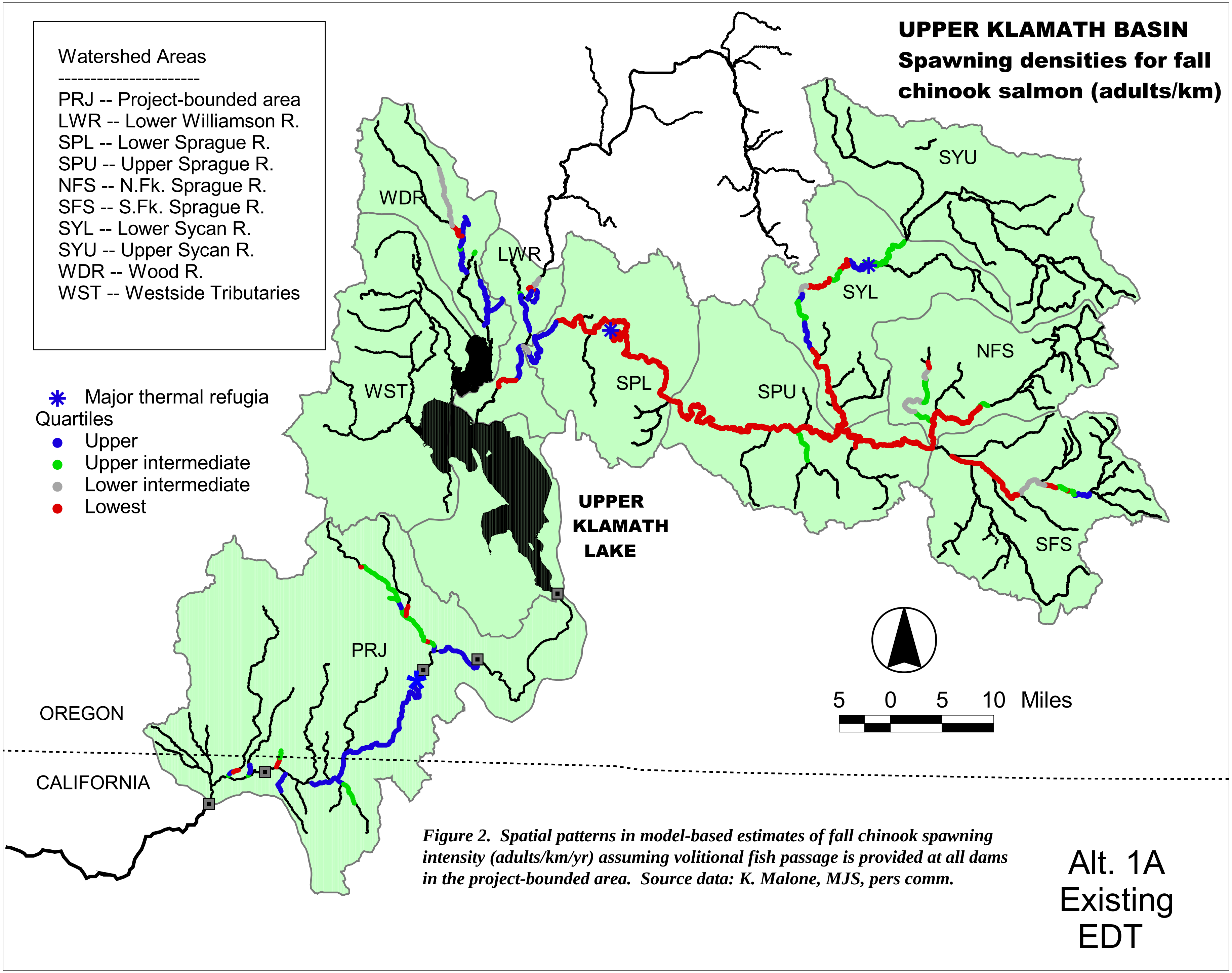

Figure 2. Spatial patterns in model-based estimates of fall chinook spawning intensity (adults/km/yr) assuming volitional fish passage is provided at all dams in the project-bounded area. Source data: K. Malone, MJS, pers comm.

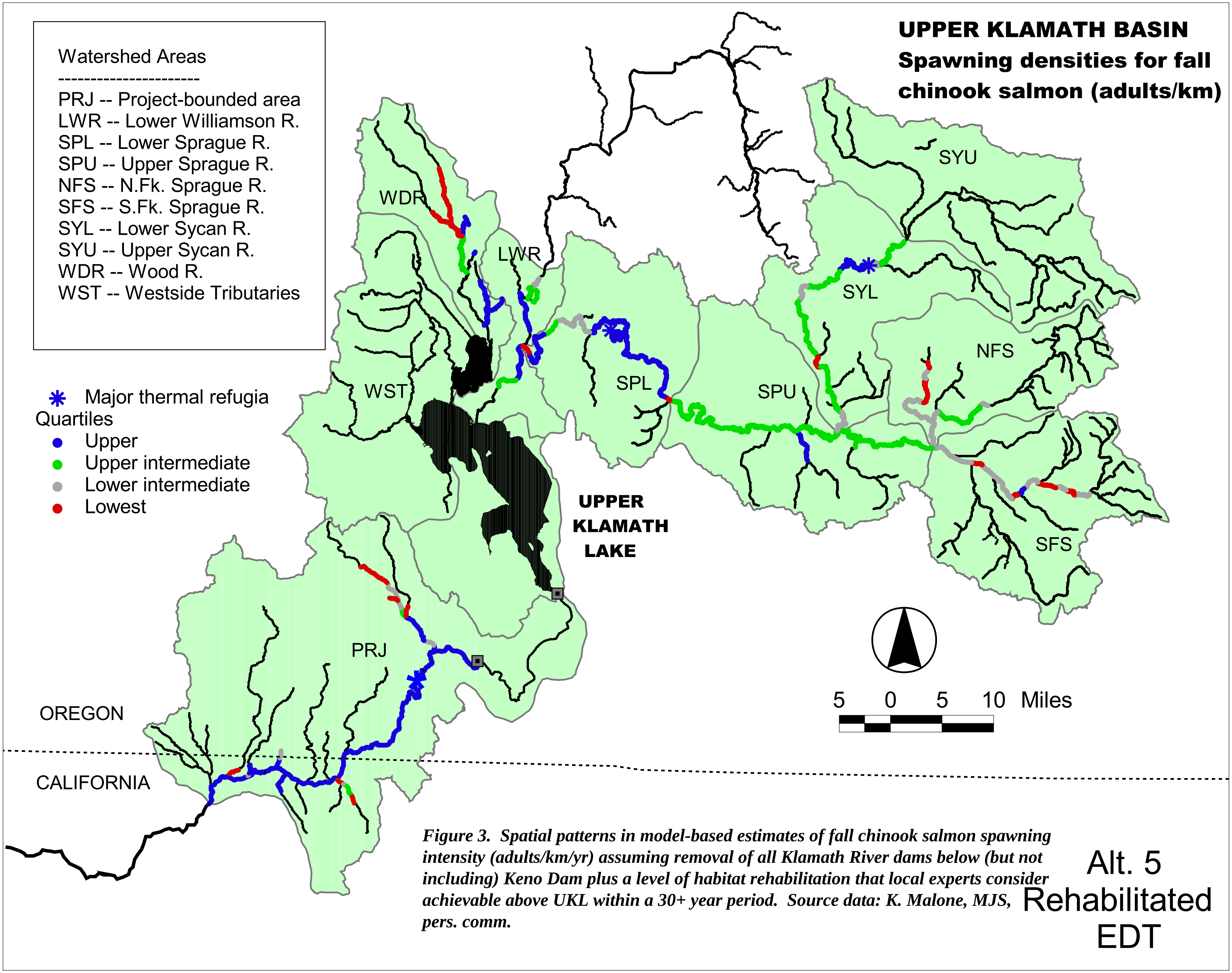

Figure 3. Spatial patterns in model-based estimates of fall chinook salmon spawning intensity (adults/km/yr) assuming removal of all Klamath River dams below (but not including) Keno Dam plus a level of habitat rehabilitation that local experts consider achievable above UKL within a 30+ year period. Source data: K. Malone, MJS, pers. comm.

including implementation of the recent TMDL and Water Quality Management Plan for the UKL drainage (Boyd et al. 2002), changes in water management, and the cooperation of private landowners.

Spring-run chinook. There may be better physical opportunities for producing spring chinook than fall chinook in those areas above UKL where adult fish can find summer holding areas with suitably cool water temperatures. Reasons for this include the possibility of earlier spawn timing, which may be critical for producing ocean-type juveniles in certain areas, and a propensity for exhibiting stream-type (≥1 freshwater year) juvenile life-histories in areas where they are advantageous. Spring-run fish are known to exhibit a diversity of juvenile life-history patterns elsewhere in the Klamath Basin (Olson 1996; NRC 2004) as well as in the nearby Rogue River (Schluchter and Lichatowich 1977), with both stream and ocean-type juveniles found in both systems.

We view existing habitat conditions within two of the watershed areas in the upper basin, Lower Williamson River and Wood River, as having clear near-term potential for producing spring-run chinook and a third area, North Fork Sprague, as having significant potential if effective habitat rehabilitation first occurs there and along the mainstem Sprague River downstream. There is also some potential, albeit lower, to produce these fish in Sevenmile Creek if serious rehabilitation efforts are undertaken in that area. With habitat rehabilitation and flow augmentation, the mainstem South Fork Sprague and Sycan rivers might also produce these fish, although these opportunities seem less certain than do some of the others.

Judgments that local experts have made on the existing condition of summer rearing habitat for juvenile spring chinook are generally consistent with our observations (Figure 4). The best habitat for these fish is concentrated in the Williamson and Wood River systems, with suitable habitat in the North Fork Sprague River isolated above a long stretch of severely degraded river corridor.

Steelhead. Habitat that is at present physically suitable for use by steelhead is more widespread in the upper basin than is habitat suitable for chinook (Figure 5), and is already used to varying degrees by resident or migratory trout. Many streams or segments of streams contain fair to good steelhead habitat, but the connectivity of this habitat is a frequent issue. As was noted for both races of chinook, much of what appears to be the better habitat for steelhead in the Sprague system is situated above long stretches of severely degraded river corridor. However, we think that re-introduced steelhead would be more likely than chinook to find near-term ways to utilize habitats in, for example, the North Fork Sprague River.

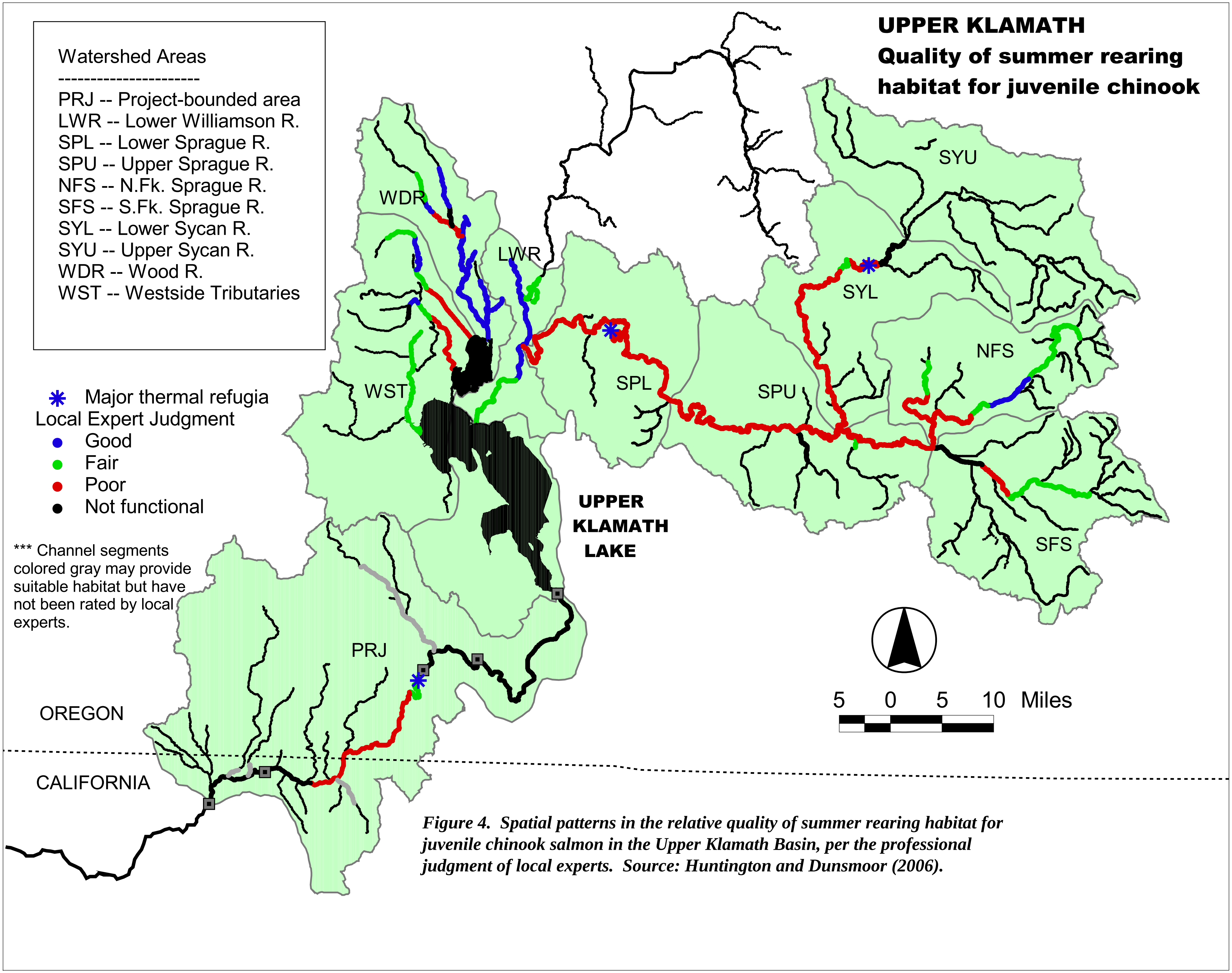

Figure 4. Spatial patterns in the relative quality of summer rearing habitat for juvenile chinook salmon in the Upper Klamath Basin, per the professional judgment of local experts. Source: Huntington and Dunsmoor (2006).

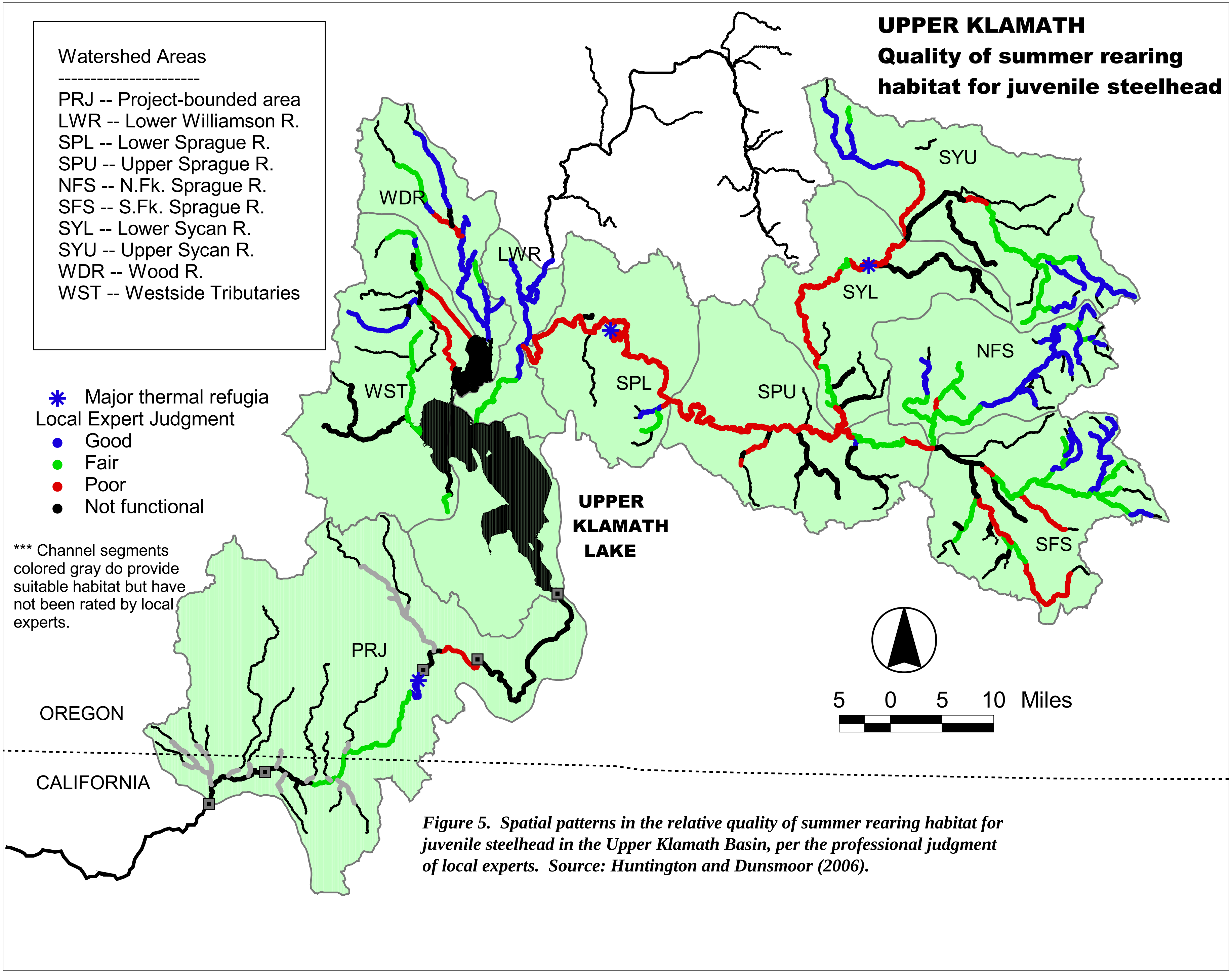

Figure 5. Spatial patterns in the relative quality of summer rearing habitat for juvenile steelhead in the Upper Klamath Basin, per the professional judgment of local experts. Source: Huntington and Dunsmoor (2006).

Opportunities Within Specific Watershed Areas

Descriptions of the reintroduction opportunities present within specific areas of the Upper Klamath Basin, based on our own field reconnaissance and examinations of selected data, are summarized in this section of the plan. For greater detail, readers should refer to Huntington and Dunsmoor (2006a).

The Project-bounded area (PRJ). Although not a focus of our field reconnaissance, the area between IGD and Link River Dam provides habitat that available information suggests is still suitable for use by chinook, steelhead, and probably coho. Potential anadromous fish streams present include the mainstem Klamath River, 6 major and multiple minor tributaries. The major tributaries include Fall, Jenny, Scotch, and Camp creeks flowing into Iron Gate Reservoir, Shovel Creek flowing into Copco 1 Reservoir, and Spencer Creek flowing into J.C. Boyle Reservoir.

EDT modeling by PacifiCorp (2005) suggests that if fish passage were provided, a large, spring-fed thermal refuge in the mainstem Klamath below J.C. Boyle Dam might combine with cool areas in Fall, Shovel, and Spencer creeks to support a small run of stream-type spring chinook (Huntington and Dunsmoor 2006a). However, habitat in much of the mainstem within the project-bounded area appears best suited to fall chinook that will migrate downstream as ocean-type juveniles before water temperatures rise to undesirable levels during summer. The modeling by PacifiCorp (2005) suggests very low survival rates for juvenile salmonids in the KHP reservoirs during winter (Huntington and Dunsmoor 2006a; see Appendix A), a pattern that seems anomalous to us and that should be re-examined.

Lower Williamson River (LWR). This area includes the mainstem Williamson up to a barrier falls below Upper Klamath Marsh and three springbrooks that are tributary to the mainstem (Larkin, Spring, and Sunnybrook creeks). It provides an abundance of good spawning and rearing habitat for both spring and fall-run chinook salmon, and steelhead trout. Spring Creek and the Williamson River above its confluence with Sprague River also offer significant opportunities for enhancing spawning habitat by adding gravel if needed. Below the Sprague River confluence, the Williamson provides habitat that appears to be of very good quality, including high-volume pools that contain cool water during summer (good holding areas for adult spring chinook) and multiple large spawning areas that appear best suited to use by fall chinook.

Our overall assessment of the habitat here does not differ in many ways from that of the EDT model (PacifiCorp 2005). However, we are somewhat skeptical that (as the model suggests) the presence of the disease *Ceratomyxa shasta* in the Williamson below the Sprague River will make habitat that otherwise appears to be some of the best in the upper basin a mediocre to poor place for juvenile anadromous salmonids to rear. It would be our assumption that stocks of anadromous fish selected for reintroduction would be fairly resistant to the disease. This is clearly a situation that will warrant further evaluation.

Lower Sprague River (SPL). Habitat in the mainstem Sprague River below Trout Creek is generally of moderately low to low quality, and found within a channel often influenced by historic splash damming, livestock grazing, and a variety of watershed disturbances farther upstream. Although it currently experiences high water temperatures and reduced water quality during summer, this section of the mainstem does provide a few spawning areas of variable quality and appears to have some potential as an early rearing area for ocean-type juvenile chinook.

In contrast to the conditions found in the lower mainstem, Kamkaun Springs tributary offers spawning habitat and a critical thermal refuge of considerable quality and size that is heavily used at present by adfluvial redbands and suckers from UKL. The springs were an historic fishing site (C. Case, Klamath Tribes, pers comm.) and would provide key adult holding, spawning, and juvenile rearing opportunities for reintroduced anadromous fish. Lalo Springs, a smaller springbrook located several kilometers downstream of Kamkaun, presents an important opportunity to rehabilitate similar habitat. Additional small springbrooks within the area, including Whitehorse Springs Creek, have been modified to the point they are barely recognizeable as streams, and no longer provide habitat or production potential for resident or anadromous salmonids. Data available on Trout Creek, a tributary we were unable to visit, suggest that it provides habitat suitable and once used by steelhead.

Riparian conditions along the lower mainstem Sprague River and its lowland tributaries are variable, with multiple channel segments responding to changes in livestock management. Continued and more widespread improvements here will be important to the reintroduction effort, as will the planned removal of Chiloquin Dam. Strategic gravel additions would appear feasible in the functional springbrooks, and could be used to increase the availability of high-quality spawning habitat for migratory fish (including anadromous ones), if needed.

Upper Sprague River (SPU). With few exceptions beyond areas within or near Beatty Gap and the town of Beatty, the mainstem Sprague River above Trout Creek is currently in very poor condition. This reflects a history of channelization, wetland removal, diking, water management, and heavy riparian grazing by livestock. Long sections of the river are characterized by severely damaged habitat structure, high water temperatures, and reduced water quality during summer. Rehabilitation of the upper Sprague would involve substantive changes in riparian area and water management, strategic reconfiguration of the channel where it has been most altered, and reconnecting historic floodplains and wetlands. Such actions are technically feasible and would require implementation of a strategic, long-term program that informed and worked with private landowners on the opportunities and incentives available to them.

In the near-term, one of the most important opportunities to protect and restore critical habitat along the upper Sprague River appears to be associated with Spring Creek, a springbrook near Beatty still used as a spawning area by adfluvial redband trout from UKL. It has stable flows, moderate temperatures during summer and winter, and intact riparian vegetation along its lower-most reach. In combination with groundwater-influenced mainstem areas within Beatty Gap, the stream likely provides critical thermal refuge for salmonids. If historically damaged portions of its riparian corridor are rehabilitated and gravel is added at selected locations to improve available spawning habitat, these actions would benefit the redband trout currently using the stream and improve conditions for reintroduced anadromous fish.

Another springbrook tributary to the upper Sprague River, Whiskey Creek, is currently in very poor condition but was once a major fishing site (Lane and Lane Associates 1981) and a likely producer of both salmon and steelhead (Huntington 2004a). Rehabilitating the stream would take a substantial effort involving channel reconditioning, riparian restoration, and flow augmentation. It would also require willing participation in the effort by stream-adjacent landowners.

Lower Sycan River (SYL). In their current condition, the lower Sycan River and its tributaries are unlikely to be major producers of anadromous salmonids due to low streamflows, poor riparian conditions, and high summer water temperatures. Progress is being made in restoring riparian conditions on Forest Service lands and along a few segments of private land, but much work remains to be done before this watershed area will be capable of supporting significant numbers of salmon or steelhead. Habitat on the mainstem Sycan River upstream of the Forest Service boundary, including that in or near Teddy Powers Meadow, appears to hold promise.
There are several springbrooks that have the potential to offer thermal refuge to fish along the lower Sycan. One of these, Brown Springs Creek, is in the process of being restored.

Upper Sycan River (SYU). Available data and the judgments of local experts (Huntington and Dunsmoor 2006a) indicate that the highest quality habitat in the Sycan system is situated upstream of Sycan Marsh, much of it on Forest Service land. This habitat appears suited to steelhead production, but fish access to the area will depend upon the ability of adult and juvenile fish to consistently pass through the marsh, which we view as questionable at present but worthy of further examination.

<u>North Fork Sprague River (NFS)</u>. Within the agricultural lowlands, much of the mainstem North Fork and two of its larger tributaries, Fivemile and Meryl creeks, have been affected by water diversions, cumulative riparian damage from livestock grazing, and streambed sedimentation. The mainstem and its tributaries are generally in better physical condition farther upstream, providing habitats that local experts consider to be of fair to good suitability for steelhead (Huntington and Dunsmoor 2006a). Habitat that to us appears suitable for use by chinook salmon is found primarily in the mainstem North Fork, with lesser use of Fivemile Creek a possibility.

Available data reflect that water temperatures along the North Fork are influenced by variable riparian conditions, inputs of cold water from streams draining the Gearhart Mountain Wilderness, and high levels of groundwater influence along several portions of the lower river (Watershed Sciences 2000). Temperatures prevailing along the mainstem today are elevated as a consequence of diminished riparian function, but not nearly to the levels seen along the Sycan or South Fork Sprague rivers. When combined with channel conditions, the North Fork's temperature regime suggests to us three potential patterns of chinook use of the river if problems in downstream migratory corridors can be addressed. First, fall chinook might spawn within groundwater-influenced channel segments along the lower river, possibly up to and including Bailey Flat. Second, spring-run fish might hold during summer in thermal refugia (e.g., in the mainstem Williamson River, at Kamkaun Springs, or other areas of groundwater influence), then move varied distances to spawning areas in the lower North Fork as temperatures drop in the late summer. Third, spring chinook may hold in refugial areas within the North Fork itself, including cold pools in the canyon above the lowlands, and migrate upstream out of the canyon as temperatures drop in the late summer to spawn in Lee Thomas Meadows. Spring chinook spawning in the lower North Fork might express both ocean- and stream-type life histories. Colder temperature regimes in the upper North Fork would limit fish spawned there to a stream-type life history.

The potential for future chinook use of the North Fork will be enhanced by riparian improvements anticipated to occur as the TMDL and Water Quality Management Plan for the UKL drainage (Boyd et al. 2002) is implemented. Along the lower mainstem and Fivemile Creek, a few private landowners have begun to improve riparian and channel conditions by constructing fences to exclude livestock from near-stream areas. Water diversion screening and remediation of any (uncataloged) barriers to upstream fish migration on private agricultural lands will be critically important. A large culvert through which the mainstem passes beneath Forest Service Road 3411, upstream of the agricultural lowlands, will need to be evaluated as a potential high-flow fish barrier.

EDT modeling (PacifiCorp 2005) suggests that with rehabilitation, the North Fork would be one of the most productive areas above UKL for spring chinook. Interactions with brook trout present in the stream's upper-most reaches might affect chinook potential in that area.

South Fork Sprague River (SFS). The upper reaches of the South Fork, above the agricultural lowlands, and several forested tributaries (including Whitworth and Brownsworth creeks) are considered by local experts to provide habitat of fair to good suitability for steelhead trout (Huntington and Dunsmoor 2006a). Within the lowlands, the mainstem South Fork and its other tributaries (Ish Tish, Paradise, and Fishhole creeks) are in poorer condition and appear to have limited potential for producing anadromous fish at present. The lower-most South Fork has been channelized, diverted, and disconnected from extensive floodplain wetlands and marshes that have been converted to pastureland. We think this lower section of the river was historically a major salmon producer. Today, it has reduced flows and multiple unscreened water diversion dams that would need to be modified in order to assure that anadromous fish could migrate to and from the more functional parts of the drainage basin upstream.

Future significant use of the South Fork by chinook salmon would require considerable rehabilitation of the stream and its watershed. EDT modeling by PacifiCorp (2005) suggests that the stream would have the potential to produce both spring- and fall-run chinook salmon if migration impediments along the lower South Fork were fixed and feasible rehabilitation measures were implemented. Such measures would include the types of actions identified earlier for the upper Sprague River.

Wood River (WDR). The Wood River is spring-fed and, like the lower Williamson River, a key spawning area for UKL's adfluvial redband trout. It has stable flows, cool temperatures, and significant potential for producing anadromous salmonids. Upper portions of the mainstem Wood, particularly above Annie Creek, are in the best condition, with lower sections of the river exhibiting increased levels of fine sediment as a consequence of contributions from Annie Creek and the cumulative effects of riparian grazing. Potential spawning sites for spring or fall chinook, and for steelhead, could accommodate significant numbers of fish. Future spawning by anadromous fish, and particularly chinook, would likely cleanse riverbed substrates in multiple areas and increase the abundance of sites that offer suitable habitat. Results from EDT modeling suggest that anadromous fish performance in multiple reaches of the river could be substantially improved by rehabilitation measures.

Three sizeable springbrooks tributary to Wood River (Crooked, Agency, and Fort creeks) also provide accessible habitat capable of supporting anadromous fish. Each has an abundance of rearing habitat but relatively lesser amounts of spawning habitat. ODFW and local landowners have placed gravels into these springbrooks at multiple locations, to create new spawning sites that have since been well used by adfluvial redband trout. A large water diversion from Fort Creek requires fish screens.

Two Wood River tributaries that flow from the Cascades and Crater Lake National Park, Annie and Sun creeks, have habitat that may be suitable for use by anadromous fish but are largely blocked to migratory fish by water diversions and channel alterations. Upper reaches of both streams are in good condition, with Annie Creek larger and potentially suited to use by spring chinook as well as steelhead. Cold temperatures combine with high loads of volcanic fines within that stream to make early spawning and fry emergence prior to spring runoff (and associated bedload movement) important to successful use by chinook. Sun Creek contains abundant spawning habitat but appears better suited to steelhead due to its relatively smaller size. Both streams contain brook trout.

Efforts to reconnect Sun Creek directly to Wood River via its historic channel alignment are underway, as a measure to strengthen that stream's at-risk bull trout population (B. Tinniswood, ODFW, pers comm.). Rehabilitation of the lower Annie Creek corridor is technically feasible and will require the cooperation of private landowners. Anadromous fish use of upper Annie Creek would depend upon passage improvements at one or more large diversions near the upper end of the Wood River Valley that redirect a significant portion of stream runoff to pasturelands.

Westside Tributaries (WST). Multiple tributaries to the west sides of Agency and Upper Klamath lakes contain habitat that appears suitable for use by limited numbers of steelhead, and one, Sevenmile Creek, might support a modest population of spring chinook with rehabilitation and fish passage improvements at water diversions. All of these streams have cool water temperatures in their upper reaches during summer, and most have altered or disconnected channels that lie between their source areas and natural discharge points into the lakes. Water diversions completely de-water the lowermost segments of some of these streams at certain times of the year.

One westside tributary to UKL is of particular ecological significance and worthy of note. Crystal Creek and an associated segment of Recreation Creek form a high-volume springbrook that combines with Pelican Bay to offer relatively cooler water and a thermal refuge to fish that might otherwise be exposed to lethally high summer temperatures in the main body of UKL. The stream appears naturally to offer little in the way of spawning habitat for anadromous fish, but may be of critical importance as a summer rearing area for salmon or anadromous trout. In combination with Pelican Bay, it is already quite important to the area's adfluvial redband trout.

FISH MIGRATION AND SEASONAL REARING IN UPPER KLAMATH LAKE

One of the most critical issues affecting anadromous fish reintroduced to areas above UKL will be the degree to which high percentages of both juvenile and adult fish are able to move through the lakes during critical migratory periods. Also of importance will be how well some of the juvenile fish are able to use the lakes as seasonal rearing areas during periods of better water quality. Historic but now extirpated runs of chinook salmon and steelhead were clearly able to use and migrate through the lakes. However, those runs consisted of the offspring of fish that fit the system, both physiologically and behaviorally, and experienced different lake environments than are now present.

We do not point to uncertainties about how well reintroduced anadromous fish will negotiate the lakes to indicate skepticism that they will be able to do so. For reasons that will soon be outlined, it is likely that a portion of the first fish reintroduced to areas above UKL will move through the lakes at appropriate times and exhibit behaviors favoring survival and successful migration. The big question is how large that portion will be, and how many linked generations of fish will need to be challenged by this environment before selection against fish exhibiting ineffective behaviors in the lakes yields runs of fish that are as effective as possible at moving through the area***. The only sure answer to this question will be gained through an adaptive reintroduction program.***

There are several reasons for optimism that anadromous fish reintroduced to areas above UKL will be able to negotiate the lakes with a reasonable level of success (Dunsmoor and Huntington 2006):

- The previously mentioned success of historic runs.
- Documented rearing and successful migrations by anadromous fish through other natural lakes, including runs of ocean-type chinook in Lake Washington, a large waterbody in a highly developed urban environment within the Puget Sound area, Washington (Meyers et al. 1998; Warner and Fresh 1999).

- The presence of persistent, wind-driven natural currents along the eastern shoreline of UKL (PWA 2001; T. Wood, USGS, pers comm.) that will likely help guide outmigrant salmon and steelhead to Link River Dam (Figure 6). These currents already appear to guide juvenile suckers, fish with weaker swimming abilities than juvenile salmonids, to this area of the lake during summer (NRC 2004).

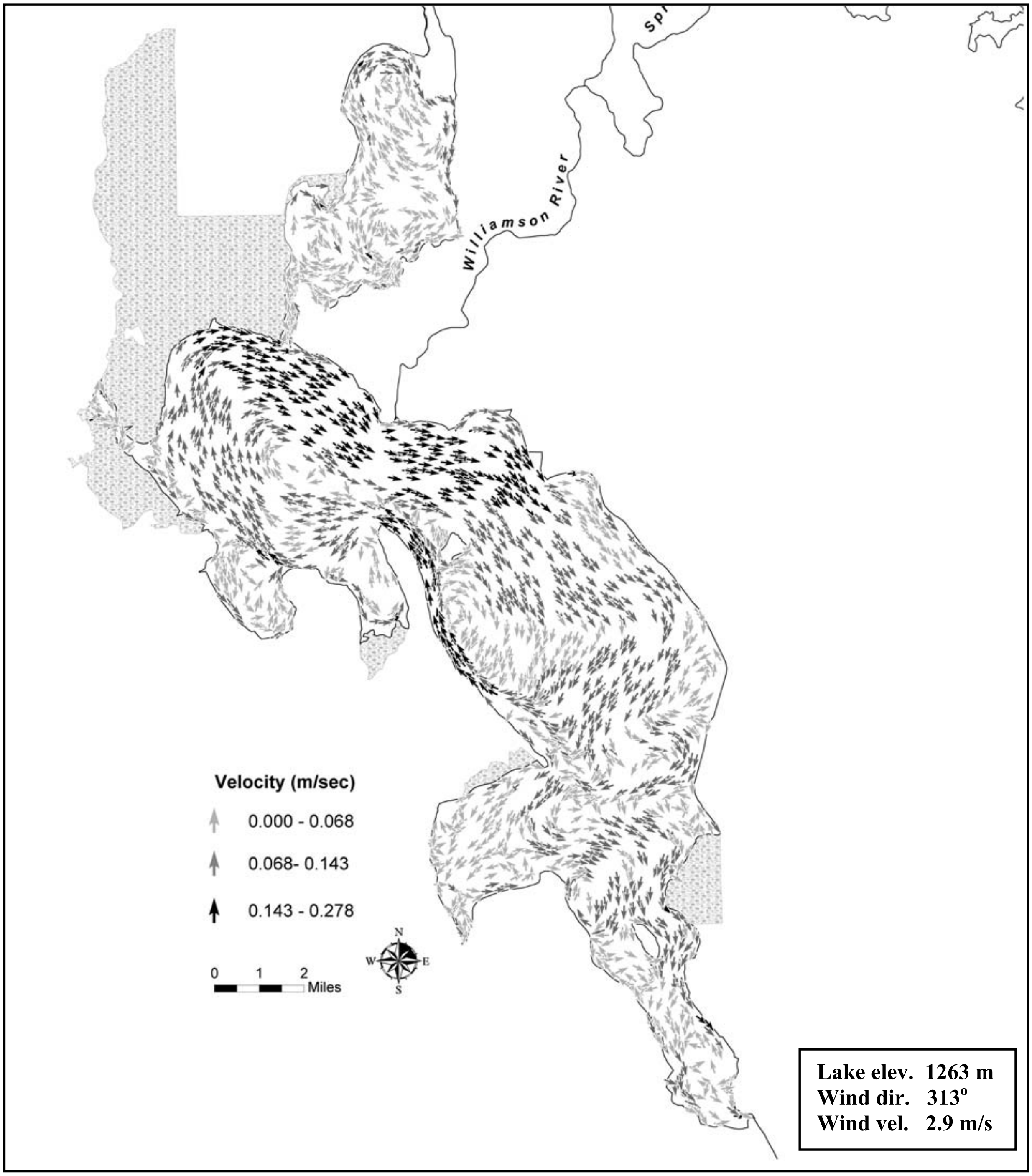

Figure 6. Currents prevailing in Upper Klamath Lake under a set of typical spring-time conditions (source: T. Wood, USGS Oregon Water Science Center, Portland, OR, pers comm.).

- Lake temperatures and water quality that from fall through spring are tolerable to ideal for the species to be reintroduced. This includes much of the upstream migration period that USFWS (1998) describes for adult chinook and steelhead below IGD. It also covers the primary outmigration period for stream-type chinook and steelhead smolts in areas below IGD (USFWS 1998), and provides a window of opportunity for fast growing ocean-type chinook juveniles to exit the area before lake conditions become highly stressful or lethal.

- Strong seasonal use and rapid growth in the lakes by adfluvial redband trout indicate that the lake continues to provide a quality rearing environment with abundant food resources during much of the year.

- The presence of sizeable areas along the westside of UKL (Pelican Bay and associated Crystal Creek) that serve now as thermal and water quality refugia for lake-dwelling fish during summer (NRC 2004) and that might, if used, sustain significant numbers of juvenile salmon or steelhead when unsuitable conditions prevail across most of the lake.

- Recent and ongoing efforts to restore wetland fringe and river delta habitats on the periphery of UKL. These habitats are likely to be important to juvenile anadromous fish, particularly juvenile chinook salmon, as they rear or migrate through the lakes.

There are also reasons to be concerned about conditions in UKL, and that they may hamper a successful reintroduction effort above the lakes. These include:

- A lake environment that has changed during the years since the historic anadromous fish runs were extirpated, and that now includes substantially reduced wetland and river delta areas, and blue-green algae blooms that periodically create lethal water quality conditions during summer.

- Potentially narrowed opportunities for lake rearing and successful migration due to the severely poor water quality conditions now found across most of UKL during summer. The consequences of this situation will be high mortality rates for any fish whose timing or behavior in the lakes miss these narrowed opportunities.

- The potential that predatory fish will elevate mortality rates of juvenile anadromous fish while they rear or move through UKL.

Key elements in dealing with the issues outlined above will include selecting stocks of fish that fit the upper basin environment as well as possible, reintroducing the fish in ways that allow poorly adapted individuals to fail while well adapted individuals succeed, and providing sufficient opportunity for the prevailing environment to shape the dominant life history strategies of new upper basin runs. Ultimately, the new runs will have to spawn, emerge fry, recruit juveniles to appropriate rearing habitats, migrate downstream through UKL as juveniles, and migrate upstream as adults, at the right times. Progress in this direction will need to be monitored, evaluated, and used as a basis for making appropriate adjustments to the reintroduction program as it moves forward.

POTENTIAL DIRECT INTERACTIONS WITH SENSITIVE RESIDENT FISHES

Although the species of anadromous fish being considered for reintroduction above IGD and UKL were once present in these areas, the native fish populations with which they once shared upper basin habitats are today in far poorer than historic condition. Federally listed suckers and bull trout, as well as redband trout populations that ODFW (2005) identifies as being vulnerable and at-risk, will need to be taken carefully into account as any reintroduction program moves forward. However, consideration of these resident fishes includes more than simply focusing on the potential for what could be important, direct species interactions that might warrant adjustments to the reintroduction program. The current status of these resident fishes is caused by degraded habitat conditions found in many upper basin areas, conditions that multiple ongoing agency, Tribal, and private programs are attempting to address. Success in these programs depends strongly on support from both private landowners and the general public. An indirect beneficial effect of the reintroduction program, and one important to at-risk native fishes, may well be that placing salmon back into the upper basin increases interest and support for rehabilitating existing habitats.

Redband Trout. Oregon has identified 10 populations of redband rainbow trout in the Upper Klamath Basin and recognizes that these fish are a regionally significant resource (ODFW 2005). Available genetic data are not definitive, but suggest that some of these populations had varied levels of interaction with coastal steelhead trout prior to dam construction. The populations appear to be highly variable with regard to their life histories and disease resistance (Buchannan et al. 1994), although fish closely associated with the Klamath River and Upper Klamath Lake apparently share a very high resistance to the myxosporean pathogen *Ceratomyxa shasta* native to the system. Additional genetic and life history studies of these fish are needed (ODFW 2005), to better understand both how the populations are structured and how they are using or partitioning the existing environment.

Based on studies conducted elsewhere, direct interactions with chinook salmon would be unlikely to have unfavorable effects on these native trout and might increase their prey base. Rearing habitats of chinook salmon tend to have little overlap in time and space with rainbow trout (Chapman and Bjornn 1969; Everest and Chapman 1972). As a consequence, studies on tributaries to the Yakima River, Washington, showed that the presence of juvenile chinook did not adversely affect the growth, abundance, or biomass of resident rainbow trout (McMichael and Pearsons 1998).

In contrast to juvenile chinook, hatchery steelhead may have unfavorable effects on wild rainbow trout populations (McMichael and Pearsons 2001). For example, after 10 years of intensely supplementing Big Springs Creek, Idaho with hatchery steelhead, Bjornn (1978) found that only ~20% of the stream's resident rainbow trout population remained. In theory, these same types of negative interactions might also occur between wild steelhead and resident rainbow, because their juveniles have similar rearing habitat requirements and could compete for food and space. The intensity of such competition would depend on several factors, including the densities of steelhead and resident trout (Hunter et al. 1989).

Under natural conditions, however, the nature of interactions between steelhead and resident rainbow trout is not necessarily clear. In the Deschutes (OR) and Yakima (WA) rivers, strong natural populations of wild resident redbands and steelhead trout with redband heritage coexist without problems. There is little information, however, on situations such as that in the Upper Klamath Basin where the interactions might be between non-anadromous redbands and coastal strain steelhead (i.e., from below IGD). We suspect that in multiple areas, particularly where highly fecund populations of adfluvial fish spawn during much of the year in areas dominated by groundwater, or where water temperatures are particularly high, there may be substantial competitive advantage for redband trout over coastal steelhead. If so, steelhead might have low success in these areas.

We are unaware of information on interactions between coho salmon or anadromous Pacific lamprey with the at-risk species of native fish present above IGD. However, since records of coho or anadromous lamprey having been present above UKL are lacking (Hamilton et al. 2005), it seems that active placement of them into that area would be unlikely to occur anyway.

Bull Trout. The potential for hatchery steelhead to harm bull trout has been identified (McMichael and Pearsons 2001), but the likelihood of this occurring in the Upper Klamath Basin seems quite small if or when steelhead are reintroduced. Reintroducing juvenile chinook salmon into areas above UKL might at some point reestablish predator-prey relations between the two species, to the natural disadvantage of the salmon.

Endangered Suckers. UKL is the primary habitat of Lost River and shortnose suckers (Cooperman and Markle 2003). These suckers spawn in the gravel of tributary streams like the Williamson or Sprague Rivers, or in areas of groundwater upwelling, during spring.

Although the species co-evolved with chinook salmon and migratory rainbow trout, the introduction of abundant salmon or steelhead to the lake and its tributaries could lead to incremental increases in what is already a very high level of larval mortality in the shallow, nearshore, and vegetated habitats along the lower rivers and lake. The risk that a significant predation problem might develop seems quite small, particularly in relation to other difficulties these suckers face and opportunities to ameliorate them through habitat rehabilitation (L.K. Dunsmoor, Klamath Tribes, pers comm.). However, the issue has been raised (P. Moyle, UC Davis, pers comm.) and should be addressed in an adaptive reintroduction program.

Conclusion. Future interactions between introduced anadromous fish and the existing, resident fish fauna will occur. Specific results will often be benign, but may be positive or negative depending on the species involved and how the reintroduction program is managed. In order to effectively manage the reintroduction program, species interaction issues must be addressed and resolved. Interactions identified as being of concern must be monitored and analyzed.

Recent risk containment protocols incorporated into a large-scale salmon supplementation program on the Yakima River, Washington provide an example of how a monitoring and evaluation program might be used to guard against unwanted side effects from fish reintroductions to the Upper Klamath Basin. In order to assess changes in the status of non-target taxa (existing fish fauna including natives), the Yakima program monitored and evaluated the abundance, size structure, and distribution of 16 non-target taxa before and multiple years after annual spring releases of juvenile salmon (Ham and Peterson 2001). The explicit intent was to contain risks to non-target taxa during the supplementation effort. According to the approach used, if a detected change in status was greater than an explicit containment objective, then further evaluations were conducted to determine if the program caused the change.

FISH DISEASES

The reintroduction of anadromous salmonids into the Upper Klamath Basin will pose two key issues related to fish diseases. First, the potential vulnerability of fish reintroduced to the upper basin to *Ceratomyxa shasta*, a myxosporean parasite that is present in multiple important areas and tends to be lethal to non-resistant strains of fish at high temperatures. The second issue is the potential for introducing new diseases to areas above IGD and transferring them into existing salmonid populations in the upper basin. Both issues must and can be addressed. Concern about *Ceratomyxa* can be addressed by selecting resistant stocks of fish for the reintroduction program. Avoiding introductions of new diseases will require careful stock selection and precautionary fish management practices that minimize the risk of such introductions.

There are currently six at times virulent fish pathogens found in the Klamath Basin below IGD, including *C. shasta*, infectious hematopoietic necrosis (IHN), *Parvicapsula minicornus*, *Renibacterium salmonarium* (BKD)*, Flexibacter columnaris*, *and Ichthyopthirius multifilis* (ICH). IHN is a viral disease and of particular concern to fish managers in Oregon, because it can be quite virulent and represents the greatest risk of introducing new strains of disease to areas above IGD (T. Amandi, OSU, pers comm.; J. Kaufman, ODFW, pers comm.). BKD, *Parvicapsula,* ICH*,* and (as noted) *C. shasta* are already present in the upper basin, but not known to be causing virulent outbreaks within native populations of trout. *F. columnaris* has been involved in sucker kills within UKL and contributed to the deaths of a few adult redband trout in Pelican Bay (of UKL) during the mid-1990s (USFWS 2002).

Ceratomyxa shasta. This is currently the most common and virulent fish pathogen in the Klamath Basin. A myxosporean protozoan, it reproduces within the fish and can cause substantially elevated rates of fish mortality at temperatures above about 15.6^{o}C (S. Foott, USWFS, pers comm.). Salmon and steelhead populations native to basins within which the protozoan is endemic, such as the Klamath, tend to have developed significant immunity to its effects (Buchanan 1989). For example, Stocking et al. (2005) note that native steelhead appear to be at low risk for ceratomyxosis, the disease caused by this protozoan, when rearing or migrating in the Klamath River. However, conditions in the mainstem Klamath are no longer as they were historically and *C. shasta* has now become a major disease issue for outmigrant juvenile chinook salmon in the river. This protozoan is also known to be present in the lower reaches of Williamson River up to Kirk Springs and in the Sprague River up to Trout Creek (Hendrickson et al. 1989), areas where adfluvial redband trout are highly resistant to infection. The infectious stage of this myzozoan parasite is not found in the Trinity River (Hendrickson et al. 1989; Bill Cox, CDFG, pers comm.).

Infectious hematopoietic necrosis (IHN). The IHN virus is known to attack the liver of salmonids, especially when water temperatures are cold. Chen (1984) suggests that salmonids can evolve resistance to native strains of the virus, but that non-native strains to which fish can be exposed following inter-basin transfers can be highly virulent. IHN infection does not occur in nature at water temperatures above about 15°C, but if juvenile rainbow trout are infected at temperatures below 15°C and transferred to warmer water, the course of the disease to death is more rapid. IHN was a problem at the Trinity River Hatchery in the early 1990's (S. Foott, USFWS, pers. comm.). No viral diseases have been detected at Iron Gate Hatchery since testing began in about 1968 (B. Cox, CDFG, pers comm.).

***Parvicapsula minibicornus*.** This is a myxozoan parasite that infects the kidneys and gills of salmon, destroying the fish's ability to maintain its proper water and salt balance. Temperatures of 16°C or higher stimulate full development of the disease. In 2002, *P. minibicornus* was observed in 23% of juvenile chinook sampled from the Klamath River estuary and 95% of juvenile chinook examined in the main river (Nichols 2003). Bartholomew et al. (2005) mention severe infections of *P. minibicornus* in seaward migrations of juvenile chinook in the Klamath River during recent years. These have co-occurred with outbreaks of *C. shasta* (J. Bartholomew, OSU, pers. comm.).

***Renibacterium salmonarium*.** This is a bacterial kidney disease (BKD) that is most pathogenic in very cold waters. It infects the kidney of salmonids and is then transmitted from fish to fish and one generation to the next through fecal material. The disease has been detected at Trinity River Hatchery in steelhead and spring chinook salmon, as well as in natural steelhead (Foott and Walker 1992). Antibiotic injections of juvenile fish are the best way to prevent spread of the disease. BKD has recently been a major problem for hatchery chinook salmon in the Rogue River Basin (T. Amandi, OSU, pers. comm.).

***Flexibacter columnaris*.** *Columnaris* is a bacterial skin and gill infection common in hatchery fish that is usually treatable unless warm water temperatures or other stressors are present. In rivers, it becomes a problem when fish are highly stressed from elevated water temperatures. In September 2002, an unusual combination of factors, including low flows, warm temperatures, a high density of congregating fish, and a delayed upstream migration, sparked a disease epidemic of this bacterium that (along with ICH, another disease organism, see below) contributed to the loss of more than 34,000 adult salmon in the lower Klamath River (S. Foott, USFWS, pers. comm.).

***Ichthyopthirius multifilis*.** ICH, a ciliated protozoan, is a common fish parasite found worldwide and present at all times in the Klamath River and other aquatic systems (CDFG 2003). It has a lifecycle in which adult protozoans (trophozoites) reside on fish, leave the fish to form cysts in streambed substrates, and cysts yield up to a couple of thousand infective, immature protozoans (tomites) which then find and attach to fish to repeat the parasitic cycle. ICH and *Columnaris were the* key disease agents in the 2002 kill of tens of thousands of adult salmon, mostly chinook, in the lower-most reaches of the Klamath River (CDFG 2003).

Conclusion. In order to ensure the health of redband and other native trout above IGD, as well as of native mid-Klamath fish that might be affected by the potential peripheral effects of a reintroduction program, protective measures should be taken by fish managers. The surest way to avoid introducing new strains of disease into the Upper Klamath Basin, or spreading disease in the mid-Klamath, will be to select chinook salmon and steelhead stocks from the mid-Klamath basin and to initiate upper basin runs using disease free-eggs or juveniles (C. Banner ODFW, pers comm.; S. Foott, USFWS, pers comm.; B. Cox, CDFG, pers comm.). Placing disease-free eggs in artificial redds at selected sites, using similar eggs in streamside incubators, or raising pathogen-free juveniles and releasing them into appropriate acclimation areas would be safe approaches. Starting the program by passing adults to selected areas above the dams would maximize natural recolonization processes while minimizing unwanted artificial selection, but may not be an acceptable option because of disease transmission risks. Whatever disease management protocols are followed to initiate new runs, a panel of experts on fish diseases should be consulted, and appropriate research conducted, so that at the earliest reasonable opportunity adult fish of upper basin origin can pass upstream through the project-bounded area and into all of the areas where they reared as juveniles.

CONDITIONS IN THE LOWER KLAMATH RIVER

Conditions in the lower mainstem Klamath River, below IGD, are a widespread concern and will ultimately affect the degree to which any reintroduction program within the upper basin will be successful. Poor lower river conditions related to environmental degradation in the upper basin, agricultural water management, KHP dams and reservoirs, and altered conditions in many lower river tributaries, are affecting the seasonal suitability of existing mainstem conditions for salmon. This situation affects existing runs of fish in the mid-Klamath basin, and will affect any future upper basin runs unless remediated. For example, migrations of adult fall chinook now arrive several weeks later to areas below IGD than they did in the mid-1900s (USFWS 1998) and may be doing so as a result of elevated river temperatures (NRC 2004; Dunsmoor and Huntington 2006). A major kill of these fish, experienced low in the river during 2002 due to a confluence of multiple factors (NRC 2004), has dramatically raised concern about the situation, as has a recent rise in disease infection rates among juvenile salmon in the lower river.

Concerns about conditions in the lower Klamath are a reason the NRC (2004) suggested that removal of at least one of the KHP dams (Iron Gate) should be seriously examined. Recent water quality modeling (PacifiCorp 2005) reveals the extent to which KHP reservoirs and operations have altered the river's thermal regime, and the significant improvements that might accompany dam removals (Dunsmoor and Huntington 2006). Efforts to provide better conditions in the lower river should be viewed not as separate from the reintroduction effort, but as a key part of it.

STOCK SELECTION

Huntington and Dunsmoor (2006b) reviewed available information, conferred with knowledgeable individuals in the Klamath and adjacent Rogue River basin, and ranked available stocks of chinook salmon for potential use in the reintroduction effort above UKL. The ranking was performed by evaluating each candidate stock against six explicit criteria intended to advance candidates that were more likely to perform well biologically during the reintroduction program and to screen out those less suited to the task (Table 3). The criteria took key ecological issues and a variety of considerations identified by interested agencies and Tribes into account. A similar process could be followed for anadromous fish that might be reintroduced into other areas above IGD, with the specific criteria adjusted if appropriate.

The review of stocks available for the reintroduction program showed that chinook have been extirpated from several areas of the Klamath Basin, not simply above IGD, but that they continue to spawn in a diversity of locations still accessible to them (Huntington and Dunsmoor 2006b; Figure 7). Some of these locations are at higher elevations and greater distances from the ocean than IGD. For fall chinook, the candidate stock holding the most promise from a biological standpoint spawns in the Shasta River, but it has low abundance and appears to be in decline. Fall chinook that spawn in the mainstem Klamath below IGD scored well and may slowly recolonize the upper basin naturally if (when) fish passage is provided, but will be difficult to collect from the river for an active reintroduction effort. Fall chinook in Bogus Creek and Scott River appear to provide the most realistic near-term sources of fish for active reintroduction, with those returning to Bogus Creek having what appears to be better migration and spawn timing.

For spring chinook, no wild population in the Klamath Basin is sufficiently large and productive to warrant unquestioned selection as a near-term source stock for a reintroduction effort. Spring chinook in the Salmon River offer the only alternative for using wild fish. However, they are not highly abundant and are considered to be at risk (Moyle 2002; NRC 2004). Strongly hatchery-influenced runs in the Trinity River have sufficient abundance to provide fish for reintroduction, but have disease histories, and very high stray rates (Hankin 1985), that make them less than ideal candidates (Huntington and Dunsmoor 2006b). Fish from Cole Rivers Hatchery on the nearby Rogue River might be an option if disease and genetic concerns could be addressed to the satisfaction of fish managers, but whether this might be possible is unclear. Further discussions on the potential and appropriate use of available spring chinook stocks in an effort to reintroduce this race of fish to the Upper Klamath Basin are warranted.

Table 3. Stock selection criteria used to rate chinook stocks for near-term use in the reinstroduction effort.

Selection Criterion***	Scoring of metric(s)
Criterion 1 – Size and run strength of the donor population/stock.	
Population/stock is either (1) a "large" naturally spawning group of fish (1000 fish/yr) with a lambda >1 (see FCRPS BiOP 2000, Apdx. A) or (2) a hatchery population.	1 if true, 0 if false
Criterion 2 – Disease concerns.	
Candidate population/stock (1) is resistant to Ceratomyxa shasta, (2) lacks viral diseases, and (3) will not contribute to outbreaks of new diseases in the upper basin if properly managed.	assigned score will integrate all three elements and fall within a range of 0 (false) to 1 (true)
Criterion 3 – Ecological goodness-of-fit.	
Candidate population/stock is suited to the aquatic environment found in the upper basin, based on an assessment of (1) the basic habitat requirements of the species, (2) migration length, (3) migration and spawn timing, (4) ecological similarity between the source and receiving watersheds, and (5) juvenile life-history patterns. For elements 4 and 5, a hatchery stock will be evaluated on the basis of conditions in the source watershed(s) of its founding population(s).	assigned score will integrate all five elements and fall within a range of 0 (false) to 1 (true)
Criterion 4 – Evolutionary/genetic relatedness.	
Candidate population/stock is from the same ESU as the extirpated upper basin population or other populations that may be affected by future fish releases, and reflects an emphasis on using geographically proximate versus distant stocks in the fish reintroduction effort.	assigned score will integrate both elements and fall within a range of 0 (false) to 1 (true)
Criterion 5 – History of hatchery influence.	
Candidate population/stock consists of fish adapted to their home watershed and unaffected, directly or indirectly, by conventional fish culture. Scores for hatchery stocks will reflect the number of fish generations cultured by conventional methods.	assigned score will integrate both elements and fall within a range of 0 (false) to 1 (true)
Criterion 6 – Rates at which adult fish stray.	
Candidate population/stock strays at a low rate that reflects good homing.	Assigned score will integrate both elements and fall within a range of 0 (false) to 1 (true)

*** For each candidate stock, a final overall rating was calculated by multiplying the score on Criterion 1 by an integrated score for criteria 2 through 6. A candidate scoring "0" for Criterion 1 but scoring well on the other five criteria was not considered suitable for unquestioned use in near-term reintroduction efforts, but may become suitable if it responds to future restoration efforts or if agency and Tribal fish managers identify ways in which the stock can be used in a 'safe' manner.

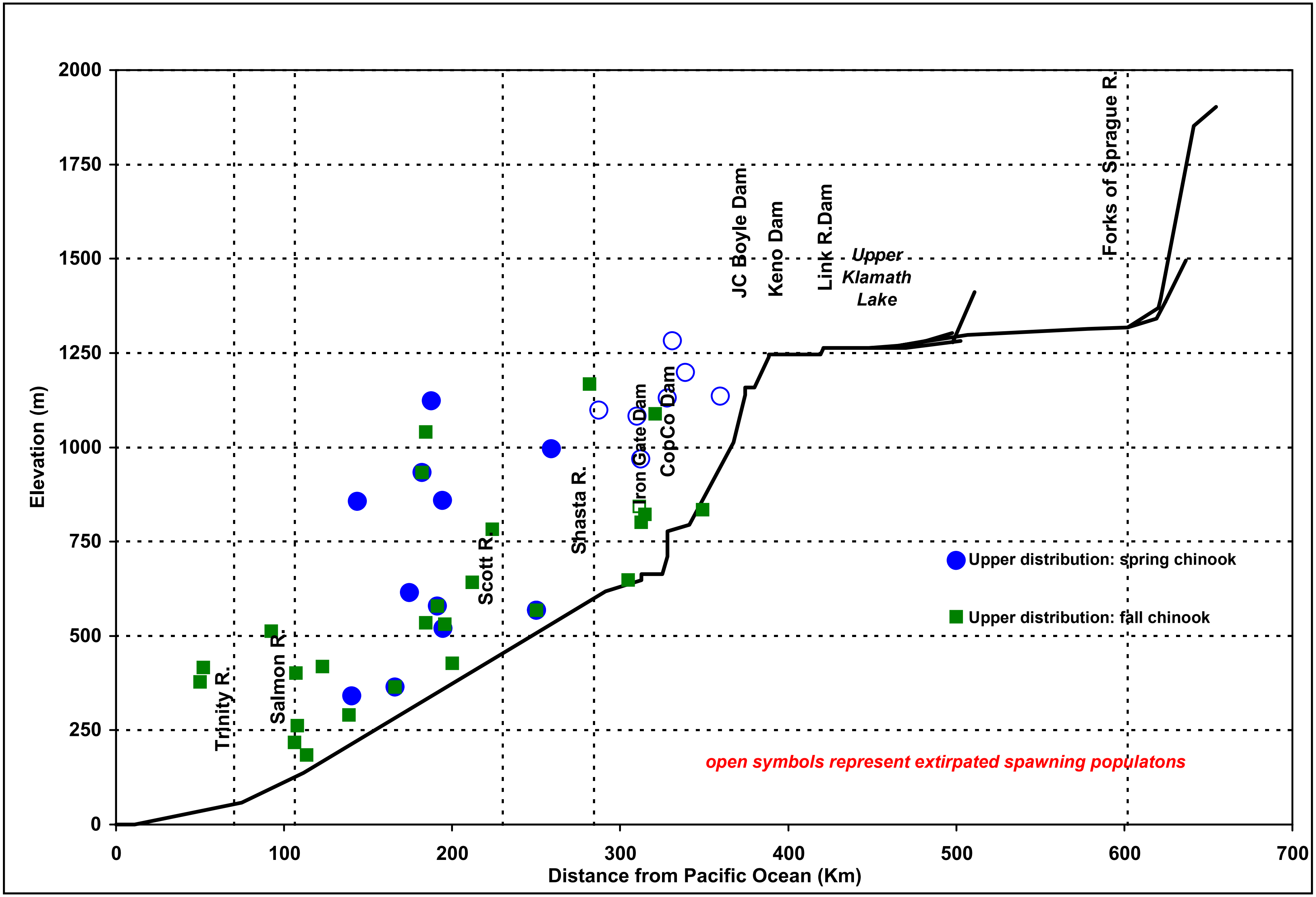

Figure 7. Elevation above sea level and distance upstream from the ocean for the upper limits of spawning by existing and historic stocks of chinook salmon in the Klamath Basin below Iron Gate Dam.

ELEMENTS OF AN ADAPTIVE REINTRODUCTION PROGRAM

The overarching goal the Tribes have established for a program to reintroduce anadromous fish to the Upper Klamath Basin is to restore self-sustaining populations of these fish to historic areas. The ultimate level of program success will depend on the degree to which there are KHP dam removals, effective fish passage at varied migratory impediments, substantive changes to water management practices in the basin, provision of adequate streamflows, and/or other major environmental improvements. Accepting the Tribes' expectation that treaty and Executive Order obligations to provide meaningful fishery resources will be met, we suggest an approach that focuses first on what we think (hypothesize) are the best near-term opportunities for reintroducing fish to the upper basin. These initial opportunities would be tested, the hypotheses underlying them adjusted or revised as appropriate, and the effort expanded to the degree practicable through a process of informed hypothesis generation, strategic habitat rehabilitation, experimentation, monitoring, and adaptive program management.

The process of generating and refining hypotheses for fish reintroduction efforts is typically structured around analytical (life-cycle) models. However, no such model has been applied to the Upper Klamath Basin and agreed upon by those with a stake in fish reintroduction above IGD. PacifiCorp (2005) has used an EDT model to estimate probable fish performance in the upper basin but has not released information underlying its model results for a thorough external review. We have used a combination of EDT model output (which had anomalies), varied data, and our own professional judgments to assess the relative magnitudes of fish reintroduction opportunities available in the upper basin, but have relied primarily on our own judgments when there were conflicts. Before any reintroduction effort moved forward, it would be critical that one or more analytical models be agreed upon and adopted as part of the framework for peoples' thinking and decision-making. These models should be transparent and available for use by all participants in the effort.

A STRUCTURED APPROACH

We suggest that a reintroduction effort should begin with early experimentation, before dam removals occur or functional fish passage facilities are provided within the KHP-bounded area. The intent of this early experimentation would be to study test groups of anadromous fish released into areas above Link River Dam that are still isolated from the remainder of the Klamath Basin by the lack of dam passage. Such experimentation could focus on confirming or refining hypotheses about how the younger freshwater life-stages of the fish to be reintroduced will perform in differing areas, on whether performance differences among particular candidate stocks are as anticipated, or on addressing other issues. Whatever the focus, it would provide an opportunity to test several assumptions and narrow a few uncertainties. The opportunity might be particularly important to future efforts toward spring chinook reintroduction, because selection of a donor stock for this race of fish may come from what appears to be a group of less-than-optimal candidates. Selection from among these candidates might be aided by tests of fish that managers might initially be hesitant to release into the area unless they are confident that minimal numbers of the fish might end up in the mid-Klamath basin.

Once permanent fish passage is provided, whether by dam removals or through the construction of fish passage facilities, the reintroduction effort could shift from a purely experimental exercise toward one designed to systematically develop locally adapted populations above the current site of IGD. Active efforts within the project-bounded area should begin with a focus on fall chinook and coho salmon, while those farther upstream should initially emphasize fall chinook and move to include spring-run chinook at the earliest reasonable opportunity. Assuming fish passage measures implemented within the project-bounded area will allow volitional fish passage, we would recommend a “wait-study-and-see” approach be taken with steelhead for a number of years to see whether (1) coastal steelhead begin colonizing the area naturally, (2) redbands from the upper basin begin expressing anadromy, or (3) improved understanding is developed of a coastal steelhead niche in the upper basin.

The different approach suggested for steelhead as opposed to chinook or coho reflects that we are concerned that an aggressive, near-term reintroduction effort focused on these fish would be a mistake. Little is known at present about the steelhead once found in the upper basin or of the early life histories of the unique redband populations found in the area. This makes it difficult to know how best to plan an introduction that will both avoid unwanted outcomes for the redbands and/or have a good probability of success for the steelhead. The lack of knowledge on how redbands and steelhead once partitioned habitat and co-existed in the upper basin is a very important issue. Future life-history and genetic work could help clarify this situation, or at least narrow the uncertainty to the point that an active yet cautionary steelhead program can be developed and move forward.

If or when initiated, an active steelhead reintroduction program, or one for Pacific lamprey, would follow patterns similar to those of the efforts with chinook and coho. The programs would first focus on reintroducing the fish into areas where the latest thinking or modeling indicated the greatest likelihood of success. Further efforts would build on the results of the initial reintroduction.

HOW THE PROCESS WOULD MOVE FORWARD

We suggest that the reintroduction program be organized around a technical team with expertise in decision analysis, the ecology of salmon and other fishes found in the Klamath Basin, progressive fish culture techniques, fish passage engineering, study design, aquatic biological field research, habitat restoration, hydrology, water quality, and other appropriate disciplines. Guided by objectives set by policy-makers, the team would be responsible for refining initial reintroduction concepts and plans, overseeing modeling efforts, formulating explicit hypotheses, guiding field studies and monitoring efforts, revising hypotheses, anticipating difficulties, and making adaptive decisions intended to help move the overall program toward pre-defined measures of success. Studies overseen by the team would address uncertainties inherent in decisions that had to be made during reintroductions. Each step in the program would need to be designed in such a way that it ensured not only that reasonable actions were taken, but also that the right information was gathered and available to help resolve difficulties before or as they developed.

Actual implementation of the reintroduction effort would seem to be the responsibility of the fish agencies and Tribes, with policy and regulatory approval required by multiple entities at varied points in the process. The agencies and Tribes will need to agree in advance upon exactly how their respective roles in the effort will be defined, to avoid potential confusion or disagreements during implementation, and to assure an organized effort. This will be particularly important given that the affected area will span two states and the territories of multiple Tribes.

AN EXAMPLE: FISH REINTRODUCTION TO AREAS ABOVE LINK RIVER DAM

When initially contracted by the Tribes, we were asked to suggest a plan for reintroducing anadromous fish to areas above Link River Dam, at the upstream end of the project-bounded area. The species of primary (but not sole) interest were the spring and fall chinook, and steelhead trout. In this section we describe approaches to reintroducing these species above the dam.

Steelhead. We have already given our general thoughts on reintroducing steelhead to the area if fish passage is provided. Basically, we encourage the Tribes to support genetic and life history research on the upper basin's redband trout and a wait-study-and-see approach that gives steelhead an opportunity to show up in the area naturally. This could be coupled with a clear process for measuring threshold conditions that would lead to an active reintroduction effort appropriate to the situation as it is understood when the conditions were met. Reasonable threshold conditions might be some combination of the rated status of Oregon's SMU for Klamath River redbands, the availability of a truly appropriate stock of fish for reintroduction, and/or the passage of some specified period of time (e.g., 10 years after volitional fish passage is provided?) without detection of some certain number of steelhead. Monitoring would need to occur at a Link River Dam fish collection facility so that movements of potential steelhead, whether of coastal or redband strain, could be detected. Detailed planning of an active reintroduction effort would need to await results of the genetic and life-history research.

Chinook salmon. As for chinook, an active reintroduction program for the area above Link River Dam would include provision of fish passage through the KHP-bounded area, as well as the structure and process-related elements outlined earlier. Studies conducted above the dam during an "experimental phase" that could occur prior to provision of functional fish passage through the project-bounded area would be intended to fine-tune the reintroduction strategy and set the stage for a concerted effort to reestablish fish runs. Key elements of the effort will include:

- Its conceptual foundation
- The reintroduction strategy
- Performance metrics, standards, and incremental measures of success
- Fish collection facilities on streams supporting the selected source stocks
- Fish culture facilities or structures
- Operating protocols for fish collection and culture operations
- Fish releases
- Fish monitoring
- Environmental improvements and monitoring

Conceptual foundation

We do not know whether dams will be removed or the exact configuration of the fish passage system to be deployed within the KHP-bounded area, but assume that the method chosen will either (1) have a reasonable chance of sustaining runs of fish above Link River Dam without additional substantial improvements, or that (2) such additional improvements will be possible.

The lower Williamson and Wood systems are in relatively good condition and are far more intact than is the Sprague River system. They offer good near-term opportunities for the reintroduction of anadromous fish to the area above Link River Dam. Early fish reintroduction efforts focused on the Williamson and Wood would allow resolution of uncertainties related to fish rearing and movements through Upper Klamath Lake, Agency Lake, and areas farther downstream. Near-term activities in the Sprague River system should probably emphasize habitat restoration rather than fish reintroduction.

The mainstem Sprague River has been severely altered and will require substantial restoration efforts to regain anything close to its historic importance as a producer of anadromous salmonids. While the mainstem's lower-most reaches offer reduced potential for anadromous fish production, conditions along most of the remainder of its length appear on the ground to be a major problem.

The North Fork Sprague River, as well as the larger springbrooks along the mainstem Sprague (the smaller ones all seem to have been altered to the point that they are almost unrecognizable), appear to have existing potential for producing chinook salmon, but their functionality in this regard is hampered by currently degraded conditions along the mainstem. Any fish introduced to the Sprague system with the intent of capturing the production potential of these tributaries will need to have migration timing very carefully matched to periods of suitable water quality conditions in the mainstem.

If chinook salmon are reintroduced to the Williamson River, some may enter the lower Sprague to spawn. However, it seems uncertain to doubtful that under existing habitat conditions these fish will volitionally recolonize areas that are substantial distances up the mainstem Sprague, such as the Sycan River or either of the two forks of the Sprague.

The springbrooks at Kamkaun and Spring Creek (near Beatty) offer near-term potential to rear or acclimate large numbers of juvenile chinook along the middle reaches of the mainstem Sprague whenever it is decided to make a concerted effort to reintroduce anadromous fish to the Sprague system.

Some level of salmon production might be achieved by a major effort to put chinook into the Sprague system before much habitat restoration has occurred. This would be a "go for broke" strategy with a significant risk of fish returns so low that the reintroduction program would be subject to early claims that it was a failure.

Use of appropriate stocks will be critical to the success of any reintroduction effort, and will need to place strong emphasis on matching the timing of life history events to the thermal regimes found in streams above UKL, in the lakes, and in the Klamath River below the lakes.

Programs involving active releases of anadromous salmonids into new areas can have an inherent tension between desires for large annual releases of smolts that will quickly return large adult runs and claims of "success", and releases of younger fish less influenced by artificial selection that will suffer higher mortality but better reflect the selective pressures of the receiving waters when they do return as adults. A similar tension exists between a desire to keep runs high with continued large releases of juvenile fish rather than tapering off on releases so that a burgeoning localized population of fish can express itself. **Because developing chinook stocks effective at rearing and/or migrating through UKL will be critical to reintroduction over the long term, the use of progressive fish culture techniques and multiple release strategies designed to encourage development of locally adapted populations of fish should be a key emphasis of the program.** Put simply, development of local stocks should be given a priority equal to or greater than that placed on the magnitude of early returns of adult chinook.

Initial mortality of chinook introduced to habitat above Link River Dam may be quite high due to strong natural selective pressures that may affect them as they enter and pass through Upper Klamath Lake as juveniles. If so, a key indicator of project success will be an increasing trend in through-lake survival across linked generations of fish. This is because the central near-term goal of the reintroduction effort is to develop a well-adapted chinook stock for the area, and an improving trend in through-lake survival would indicate that one was being developed.

Watershed and habitat rehabilitation, including water quality improvements, have the potential to greatly increase the success of the reintroduction program, both in terms of how well fish will perform in specific areas and in the geographic extent of areas that will produce fish.

Reintroduction strategy

A reasonable strategy for a chinook reintroduction program above Link River Dam would be to focus in the near term on the Williamson and Wood River systems, with fish releases used to test hypotheses, to identify productive life-histories and habitat limitations, to re-establish locally adapted populations above the lake, and to build toward a possible long-term effort to repopulate one or more portions of the Sprague system. The intent would be to work at developing a record of success, both in reintroducing fish to the Williamson and/or Wood, and at rehabilitating the Sprague. Unless an experimental release into the lower or North Fork Sprague River or some other area showed substantial near-term potential for chinook production, movement into the Sprague system would be deferred until the beneficial results of significant rehabilitation efforts were evident.

The strategy would also include a continuing focus on conditions downstream of Upper Klamath Lake, both within the project-bounded area and in the basin below the site of Iron Gate Dam. As noted previously, river conditions in those areas will have a strong influence on the ultimate success of the reintroduction effort.

Performance metrics, standards, and incremental measures of success

Performance metrics and standards. Overall performance metrics for the reintroduced populations should be those McElhaney et al. (2000) have developed to help evaluate and describe viable salmonid populations. These metrics would be used to judge the degree to which chinook populations were making progress toward becoming self-sustaining, or if it had already become so, and include:

- Population growth rate (also known as lambda; McClure et al. 2003)
- Abundance (spawning stock size)
- Genetic diversity
- Life history diversity
- Geographic distribution

Specific standards for these population metrics, and for finer scale life-stage specific metrics, would be based in part on agreed-upon analytical (life-cycle) modeling that suggested values needed to sustain a population. The standards would provide a basis of determinations of when the program was being successful and when or where it was falling short. Identification of instances in which the program was falling short would give the technical team a basis for making adjustments to the program.

Incremental measures of success. Other measures of success, beyond those outlined above, will help the technical team and others track incremental progress in moving the program forward. These might be viewed as "milestones", and would give the public at large some easily identified indicators of how the reintroduction effort was proceeding:

- Successful development of a more detailed reintroduction plan, with a work schedule consistent with the highest reintroduction priorities.
- Successful identification of sources of funding for implementation and monitoring of the reintroduction effort, and said funding secured.
- Priority measures in the reintroduction plan are being funded and implemented.
- Successful spawning (indicated sequentially by: fish use of spawning habitat, abundant and dispersed redds, successful fry emergence)
- Successful juvenile rearing above the lakes (indicated sequentially by: juveniles rearing in one type of ecological setting, juveniles rearing in multiple types of ecological settings)

- Successful juvenile rearing in Upper Klamath and Agency lakes, including the river delta areas and/or westside thermal refugia
- Successful emigration (indicated sequentially by: fish reaching Link River Dam, fish reaching the site of Iron Gate Dam, fish reaching Big Bar, fish reaching the Klamath estuary)
- Progress in rehabilitating habitat (indicated by: the number of diversions screened or laddered, the length of riparian corridors fenced, measurable improvements in channel condition or water quality, etc.)

Fish collection facilities on streams supporting the selected source stocks

If not already present, adult collection facilities will need to be constructed so that chinook from the source stocks can be collected, handled, held, and spawned using progressive techniques.

Fish culture facilities or structures

Existing facilities and temporary structures should be used where possible to culture fish for release into areas above Link River Dam. In-basin facilities that may be available include Iron Gate Hatchery, Fall Creek Hatchery, the facility on Crooked Creek in the Wood River system, and the Klamath Tribes' hatchery at Braymill on the lower Sprague River. Temporary structures might include streamside incubators, egg boxes (for use primarily by citizen volunteers), small circular rearing tanks, or others.

Operating protocols for fish collection and culture operations

Fish collection and culture operations will follow approved plans for disease and genetic management, and for operating in a progressive manner. Incubation and rearing techniques will be intended to produce fry or juveniles as similar as possible to those known or expected to be in the receiving waterway at the time of release, per assessments made by biologists involved in the reintroduction program. Success in achieving this goal will be one of the primary criteria by which the performance of fish culture personnel will be evaluated. Records will be kept as to the exact disposition of all adults, eggs, and juveniles handled. All eggs or juvenile fish actively introduced to the upper basin will first have been screened for viral and other diseases.

Fish releases

Fish will be released at times, sizes, and locations that they might naturally be found if spawned in the system. Preliminary calculations of the numbers of fish that might be released early in the full reintroduction phase of the program are based on conservative interpretations of available data and fall within the range of 250,000-500,000 chinook fry (or the number of eggs necessary to produce this many fry) into each of two systems above UKL: the lower Williamson River and the Wood River system. Multiple release strategies will be employed, including volitional drift from streamside incubators, releases of fed (40-50 mm) fry, releases of larger juvenile fish, and possibly others.

Fish monitoring

Monitoring will occur in spawning areas, rearing areas, and migratory corridors. The intention of this effort will be to acquire data on performance metrics and measures of success, as well as to develop a better understanding of juvenile and adult distribution, abundance, habitat utilization, growth, health, genetics, and interactions with other species. Ultimately, the effort will help identify key bottlenecks and allow the technical team to assess how best to establish and maintain a sustainable population. Fish monitoring will:

- Assess adult passage timing through the lower Klamath River
- Assess adult passage efficiencies and potential delays within the project-bounded area
- Assess the health of resident and introduced populations in the upper basin
- Assess effectiveness of upstream passage at potential barriers above Link River Dam
- Assess spawning distribution, timing, and abundance in the upper basin
- Assess distribution and abundance of rearing juveniles
- Assess juvenile migration patterns, timing, and rates
- Assess effectiveness of juvenile passage and level of entrainment into diversions
- Assess juvenile movement within and through the lakes and reservoirs
- Assess juvenile passage efficiencies and potential delays at hydropower dam
- Assess juvenile migration and movement through the lower Klamath River
- Assess mortality associated with fisheries

Fish, both juveniles and adults, will need to be monitored following their release into the upper basin. Elastomer tags, PIT-tags, radio tags, and/or other marks may be necessary in combination with multiple collection/detection sites to the monitoring their timing, rate of growth, and general health within the upper basin and at selected locations along the migratory corridor downstream. Sampling may occur via formal collection facilities, rotary screw traps, trap nets, seining, or snorkeling.

A risk management program similar to that used during salmon supplementation in the Yakima River (WA) system (Ham and Pearsons 2001) will be employed to keep the reintroduction program's peripheral effects on native species within pre-defined limits. In addition, special attention and research will be devoted to potential interactions between chinook fry or fingerlings and ESA-listed suckers. This effort should probably be an expansion of research the USGS is already doing on UKL's suckers.

Environmental improvement and monitoring

- Continue to monitor water quantity and quality in Upper Klamath Lake, Agency Lake, principal test streams, and the migration corridor.
- Continue to emphasize monitoring of temperatures and dissolved oxygen.
- Continue to acquire good, accurate, and comprehensive flow data for test streams and their principal tributaries.
- Restore watershed integrity, riparian, water quality, and habitat integrity/quality in the Sprague River system and selected tributaries of the Wood and Williamson Rivers.
- Document trends of improvement, degradation, or *status quo* condition in project watersheds—especially the Sprague River.
- Continue to monitor eutrophication trends or recovery in Upper Klamath and Agency lakes.
- Monitor TMDL development and accountability. Identify limiting factors and agency failures in implementation.
- Monitor and evaluate watershed/habitat restoration programs and efforts in the Upper Klamath Basin and in areas below IGD.
- Monitor the acceleration and efficacy of watershed restoration in the Sprague River system.
- Evaluate the effectiveness of completed watershed projects in the Wood River and Williamson River systems.
- Identify the backlog of restoration projects proposed for the Upper Klamath Basin that have not been funded or implemented. Identify limiting factors.
- Identify additional opportunities for watershed/habitat restoration above UKL.
- Identify "restoration" programs that are ineffectual and wasting funds.
- Identify and secure additional sources of funding.

THE AUTHORS' COLLECTIVE VIEW ON THE REINTRODUCTION EFFORT

Throughout this document we have made an effort to take an objective look at existing conditions in the Upper Klamath Basin, to consider the prospects for reintroducing anadromous fish, and to identify an approach to reintroduction that would make sense should it go forward. We have provided the general outlines of such an approach, but recognize that additional details would need to be developed by a multi-agency and Tribal team of experts specifically assigned the task. If effective fish passage (with high migrant survival and minimal delay) is provided in the project-bounded area, we think available habitat provides a reasonable opportunity to re-establish fish runs in the Williamson and Wood River systems. Re-establishing significant salmon runs in much of the Sprague system will first require a concerted, comprehensive, and effective effort to rehabilitate damaged habitats.

Conditions in the lower Klamath River today should be a concern both to those managing existing runs of anadromous salmonids and to those who want to re-establish runs in the upper basin. Efforts to improve these conditions, through dam removals, changes in water management, watershed rehabilitation, and/or other measures, should be a very high priority.

REFERENCES CITED

Bjornn, T.C. 1978. Survival, production, and yield of trout and chinook salmon in the Lemhi River, Idaho. Bulletin No. 27, College of Forest, Wildlife, and Rangeland Sciences, University of Idaho, Moscow. 57 p.

Boyd, M., S. Kirk, M. Wiltsey, and B. Kasper. 2002. Upper Klamath Lake Drainage Total Maximum Daily Load (TMDL) and Water Quality Management Plan (WQMP). Oregon Department of Environmental Quality, Portland. May 2002.

Buchanan, D. V., A. R. Hemmingsen and K. P. Currens. 1994. Oregon native trout project. Annual Progress Report. Oregon Department of Fish and Wildlife, Portland, Oregon**.** 36 pages.

Buchanan, D. 1989. Klamath Basin trout. ODFW studies on diversity within and between rainbow trout in Oregon's Klamath River Basin. Oregon Department of Fish and Wildlife, Research Section, Corvallis, Oregon.

California Department of Fish and Game (CDFG). 2003. 2002 Klamath River fish kill: Preliminary analysis of contributing factors. State of California, The Resources Agency, Department of Fish and Game, Northern California – North Coast Region. Redding, California. January 2003.

Chapman, D.W., and T.C. Bjornn. 1969. Distribution of salmonids in streams, with special reference to food and feeding. p. 153-176 in T.G. Northcote (ed.), Symposium on Salmon and Trout in Streams. H.R. MacMillan Lectures in Fisheries, Univ. of British Columbia, Vancouver.

Chapman, D.W. 1981. Pristine production of anadromous salmonids – Klamath River. Final report to the Bureau of Indian Affairs, U.S. Department of the Interior, Portland, Oregon. 08 July 1981.

Chen, M. 1984. Comparative susceptibility of salmonid fishes and salmonid fish cells to five isolates of infectious hematopoietic necrosis and biological properties of two plaque variants. PhD dissertation, Oregon State University, Corvallis, OR.

Cooperman, M.S., and D.F. Markle. 2003. Endangered species, the Endangered Species Act and the National Research Council's interim judgment in the Klamath Basin. Fisheries 28(3):10-19.

Dunsmoor, L.K., and C.W. Huntington. 2006. Suitability of environmental conditions within Upper Klamath Lake and the migratory corridor downstream for use by anadromous salmonids. Technical memorandum to the Klamath Tribes. March 2006.

Everest, F. H., and D. W. Chapman (1972). Habitat selection and spatial interaction by juvenile chinook salmon and steelhead trout in two Idaho streams. J. Fish. Res. Bd. Canada 29: 91-100.

FishPro. 2000. Fish passage conditions on the upper Klamath River. Consultant report to the Yurok Tribe and PacifiCorp. FishPro, Port Orchard, Washington. July 2000.

Foott, J., and R. Walker. 1992. Disease survey of Klamath River salmonid smolt populations. U.S. Fish and Wildlife Service, California-Nevada Fish Health Center, Anderson, CA.

Fortune, J. D., A. R. Gerlach and C. J. Hanel (1966). A study to determine the feasibility of establishing salmon and steelhead in the Upper Klamath Basin. Oregon State Game Commission and Pacific Power and Light Company, Portland, Oregon.

Ham, K. D., and T. N. Pearsons. 2001. A practical approach for containing ecological risks associated with fish stocking programs. Fisheries 26(4): 15-23.

Hamilton, J. B., G. L. Curtis, S. M. Snedaker, and D. W. White. 2005. Distribution of anadromous fishes in the upper Klamath River watershed prior to hydropower dams - a synthesis of the historical evidence. Fisheries 30(4):10-20.

Hankin, D. 1985. Analysis of recovery data for marked chinook salmon released from Iron Gate and Trinity River hatcheries, and their implications for management of wild and hatchery stocks in the Klamath River system. Report to the US Department of Interior, Bureau of Indian Affairs. Contract No. 100-FISH-513.

Hendrickson, G., A. Carleton, D. Manzer. 1989. Geogrphic and seasonal distribution of the infective stage of *Ceratomyxa shasta* (Myxozoa) in northern California. Diseases of Aquatic Organisms 7: 165-169.

Hunter, M.A. 1992. Hydropower flow fluctuations and salmonids: A review of the biological effects, mechanical causes and options for mitigation. State of Washington. Technical Report No. 119. Olympia, Washington.

Hunter, M. A., Washington Department of Fisheries, U. S. Fish and Wildlife Service, National Marine Fisheries Service and Washington Department of Wildlife. 1989. The White Salmon River anadromous fish productivity potential. Washington Department of Fisheries, Olympia, Washington. 36 p.

Huntington, C. W. 2004a. Preliminary estimates of the recent and historic potential for anadromous fish production in the Klamath River above Iron Gate Dam. Technical memorandum to the Klamath Tribes, Chiloquin, Oregon. Clearwater BioStudies, Inc., Canby, Oregon. 15 January 2004.

Huntington, C.W. 2004b. Klamath R. flows within the JC Boyle Bypass and below the JC Boyle Powerhouse. Technical memorandum to the Klamath Tribes, Chiloquin, Oregon. Clearwater Biostudies, Inc., Canby, Oregon. 15 April 2004.

Huntington, C.W. 2006. Estimates of anadromous fish runs above the site of Iron Gate Dam. Technical memorandum to the Klamath Tribes, Chiloquin, Oregon. Clearwater BioStudies, Inc., Canby, Oregon. 15 January 2006.

Huntington, C.W., and L.K. Dunsmoor. 2006a. Aquatic habitat conditions related to the reintroduction of anadromous salmonids into the Upper Klamath Basin, with emphasis on areas above Upper Klamath Lake. Technical memorandum to the Klamath Tribes, Chiloquin, Oregon. Clearwater BioStudies, Inc., Canby, Oregon. 27 March 2006.

Huntington, C.W., and L.K. Dunsmoor. 2006b. Stock selection issues related to the reintroduction of anadromous salmonids into the Upper Klamath Basin, with emphasis on areas above Upper Klamath Lake. Technical memorandum to the Klamath Tribes, Chiloquin, Oregon. Clearwater BioStudies, Inc., Canby, Oregon. 27 March 2006.

Lane and Lane Associates (1981). The Copco Dams and the fisheries of the Klamath Tribe. Portland, OR, USDI Bureau of Indian Affairs.

Larson, Z. S. and M. R. Belchik. 1998. A Preliminary status review of eulachon and Pacific lamprey in the Klamath River Basin. Yurok Tribal Fisheries Program, Klamath, California. 23 p.

McClure, M., E. E. Holmes, B. L. Sanderson, and C. E. Jordan. 2003. A large-scale, multi-species status assessment: anadromous salmonids in the Columbia River basin. Ecological Applications 13:964-989.

McElhany, P., M. Ruckelshaus, M. J. Ford, T. Wainwright, and E. Bjorkstedt 2000. Viable salmonid populations and the recovery of evolutionarily significant units. National Marine Fisheries Service, Seattle, WA.

McMichael, G. A. and T. N. Pearsons. 1998. Effects of wild juvenile spring chinook salmon on growth and abundance of wild rainbow trout. Trans. Amer. Fish. Soc. 127: 261-274.

McMichael, G. A. and T. N. Pearsons. 2001. Upstream movement of residual hatchery steelhead into areas containing bull trout and cutthroat trout. North American Journal of Fisheries Management (21): 943-946.

Meyers, J.M., R.G. Cope, G.J. Bryant, D. Teel, L.J. Lierheimer, T.C. Wainwright, W. S. Grant, F.W. Waknitz, K. Neely, S.T. Lindley, and R.S. Waples. 1998. Status review of chinook salmon from Washington, Idaho, Oregon, and California. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-35, 443 p.

Mobrand Biometrics. 2005. Documentation of the mathematical algorithms within EDT. Consultant report to NOAA Fisheries. Mobrand Biometrics, Vashon Island, Washington. March 2005.

Moser, M.L., P.A. Ocker, L.C. Stuehrenberg, and T.C. Bjornn. 2002. Passage efficiency of adult Pacific lampreys at hydropower dams on the lower Columbia River, USA. Trans. Amer. Fish. Soc. 131:956-965.

Moyle, Peter B. 2002. Inland Fishes of California. University of California Press, Berkeley.

National Research Council (NRC). 2004. Endangered and Threatened Fishes in the Klamath River Basin - Causes of Decline and Strategies for Recovery. Report by the National Academy of Sciences' Committee on Threatened and Endangered Fishes of the Klamath River Basin. National Acadamies Press, Washington, D. C. 397 p.

Nehlsen, W., J. E. Williams and J. A. Lichatowich. 1991. Pacific salmon at the crossroads: Stocks at risk from California, Oregon, Idaho, and Washington. Fisheries 16(2): 4-21.

Oregon Department of Fish and Wildlife. 1997. Klamath River Basin Fish Management Plan. Oregon Department of Fish and Wildlife, Portland. 176 p.

ODFW. 2003. Oregon Native Fish Conservation Policy. Oregon Department of Fish and Wildlife, Salem. 12 September 2003.

ODFW. 2005. Oregon Native Fish Status Report, 2005. DRAFT. Oregon Department of Fish and Wildlife, Salem.

Olson, Alan D. 1996. Freshwater rearing strategies of spring chinook salmon (Oncorhynchus tshawytscha) in Salmon River tributaries, Klamath Basin, California. Master's Thesis. Humboldt State University, Arcata, California. 63 p.

Oosterhout, G. 2005. KlamRAS results of fish passage simulations on the Klamath River. Final consultant report to PacifiCorp and the Habitat Modeling Group. Decision Matrix, Inc., Eagle Point, OR.

PacifiCorp. 2003. Study plan 1.10: Fish passage planning and evaluation. Revised final working draft study plan, Klamath Hydroelectric Project (FERC Project No. 2082). PacifiCorp, Portland, Oregon. July 2003.

PacifiCorp. 2005. Response to November 10, 2005, FERC AIR AR-2 Ecosystem Diagnosis and Treatment (EDT) analysis. Submission to FERC for the relicensing of the Klamath Hydroelectric Project (Project No. 2082). PacifiCorp, Portland, Oregon. 16 December 2005.

Peters, C.N., and D.R. Marmorek. 2001. Application of decision analysis to evaluate recovery actions for threatened Snake River spring and summer chinook salmon (Oncorhynchus tshawytscha). Can. J. Fish. Aquat. Sci. 58:2431-2446.

Peters, C.N., D.R. Marmorek, and R.B. Deriso. 2001. Application of decision analysis fot evaluate recovery actions for threatened Snake River fall chinook salmon (Oncorhynchus tshawytscha). Can. J. Fish. Aquat. Sci. 58:2447-2458.

Philip Williams & Associates (PWA). 2001. Evaluation of proposed lake management hydrodynamics, water quality and eutrophication in Upper Klamath Lake. PWA Report No. 1412. Consultant report to the U.S. Bureau of Reclamation, Klamath Falls, Oregon.

Schluchter, M.D., and J.A. Lichatowich. 1977. Juvenile life histories of Rogue River spring chinook salmon Oncorhynchus tshawytscha, as determined by scale analysis. Information Report 77-5. Oregon Department of Fish and Wildife, Research Section, Corvallis. June 1977.

Snyder, J. O. 1931. Salmon of the Klamath River, California. Division of Fish and Game of California. Fish Bulletin 34:1-130.

Stocking, R, R. Holt, S. Foott, J. Bartholomew. 2005. Ecology of the salmonid parasite *Ceratomyxa shasta* in the Klamath River Basin. 46th Western Fish Disease Workshop, American Fisheries Society, Fish Health Section, June 27-29, 2005, Boise, ID.

USDI Fish and Wildlife Service (USFWS). 1991. Long range plan for the Klamath River Basin Conservation Area fishery restoration program. Yreka, CA, prepared by the Klamath River Basin Fisheries Restoration Task Force with the assistance of William M. Kier Associates, U. S. Fish and Wildlife Service.

USFWS. 1998. Klamath River (Iron Gate Dam to Seiad Creek) life stage periodicities for chinook, coho, and steelhead. United States Fish and Wildlife Service, Arcata Office, Arcata, California. 51 p.

USFWS. 2002. Biological/Conference Opinion Regarding the Effects of Operation of the U. S. Bureau of Reclamation's Proposed 10-Year Operation Plan for the Klamath Project and its Effect on the Endangered Lost River Sucker (*Delistes Luxatus*) Endangered Shortnose Sucker (*Chasmistes brevirostris*) Threatened Bald Eagle (*Haliaeetus leucocephalus*) and Proposed Critical Habitat for the Lost River and Shortnose Suckers. USDI Fish and Wildlife Service, Klamath Falls, Oregon. 204 p.

Warner, E., and K. Fresh. 1999. Technical Review Draft: Lake Washington chinook salmon recovery plan. Muckleshoot Indian Tribe (Auburn, WA) and the Washington Department of Fish and Wildlife, Fish Management, Olympia, Washington. 141 p.

Watershed Sciences. 2000. Remote sensing survey of the Upper Klamath River Basin – thermal infrared and color videography. Consultant report to the Oregon Department of Environmental Quality. Watershed Sciences, Corvallis, Oregon. 10 May 2000.

Williams, J.G., S.G. Smith, R.W. Zabel, W.D. Muir, M.D. Scheuerell, B.P. Sandford, D.M. Marsh, R.A. McNatt, and S. Achord. 2005. Effects of the federal Columbia River power system on salmonid populations. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-63. 150 p.

APPENDIX A

BRIEF SUMMARY OF HABITAT QUANTITY AND QUALITY INFORMATION FOR POTENTIAL ANADROMOUS FISH STREAMS IN THE UPPER KLAMATH BASIN

Brief, species-specific summaries of the quantity and quality of aquatic habitat potentially available to spring chinook, fall chinook, and steelhead, if they are reintroduced to the Upper Klamath Basin are given in tables A1 through A3. The summaries for chinook salmon are more comprehensive than those for steelhead due to a greater availability of data on stream channels with current or historic potential for producing these fish. More detailed discussions of these data, and of the aquatic habitat available in the upper basin, are available in Huntington and Dunsmoor (2006a).

Information provided in tables A1 and A2 on the numbers of salmon that might be accommodated by existing spawning habitat indicates how many fish the best available data (which are not perfect) suggest could spawn in specific areas of the stream network above Iron Gate Dam without superimposing their redds (gravel nests). These numbers represent something of an upper limit on how many adult fish could spawn effectively in the area **if** their abundance was not constrained by other factors. ***Given the existing condition of their rearing habitats, fish passage issues, and other factors, it seems likely to certain (depending on location) that the actual abundance of adult chinook salmon would be lower in the upper basin after reintroduction than the tables suggest could be accommodated by available spawning habitat. This would be true until or unless there was a substantial improvement in stream and migratory corridor conditions.***

Table A1. Summary of information on the quantity and quality of existing habitat potentially available for ocean-type (Type-1) fall chinook salmon in the Upper Klamath Basin. Source: Huntington and Dunsmoor (2006a).

	Kilometers of potential	Estimated quantity of available spawning habitat (adults accomodated)		Estimated quality of available spawning habitat (percent of habitat providing specific levels of survival-to-emergence, as predicted by EDT)				Estimated quantity of low-flow rearing	Estimated quality of available rearing habitat (percent of habitat in specific quartiles for EDT-predicted subyearling survival during spring)				EDT-predicted[3] spawner use: Percent of all adults spawning abv IGD		EDT-predicted[3] spawner use: Rank order for intensity (#/km)	
										Upper	Lower		Alt 1A	Alt 5	Alt 1A	Alt 5
Stream/waterbody[1]	habitat	Surveys	EDT	>45%	31-45%	15-30%	<15%	habitat (m^2)	Upper	intermediate	intermediate	Lowest	no rehab	w/ rehab	no rehab	w/ rehab
Iron Gate to Link River Dam																
Klamath R. (riverine reaches)	42.5	---	7,768	100	0	0	0	1,453,700	0	0	0	100	46	32	2	2
Existing Reservoirs	24.3	---	0	---	---	---	---	9,362,300	0	0	0	100	---	---	---	---
Jenny Cr.	1.8	---	57	54	0	0	46	16,085	23	77	0	0	<1	<1	11	13
Fall Cr.	1.4	---	5	7	0	0	93	6,313	7	8	85	0	<1	<1	6	3
Shovel Cr.	4.7	---	160	100	0	0	0	22,860	14	0	63	24	1	<1	5	14
Spencer Cr.	20.4	652	---	60	40	0	0	152,312	0	33	11	56	3	3	9	10
Keno Reservoir/Lake Ewauna	31.9	---	0	---	---	---	---	7,383,000	0	100	0	0	---	---	---	---
Link R.	1.9	---	0	---	---	---	---	233,000	0	100	0	0	---	---	---	---
Above Link River Dam																
Upper Klamath/Agency Lks	---	---	0	---	---	---	---	229,695,000	16	84	0	0	---	---	---	---
Williamson R.	33.5	4,576	---	29	37	35	0	1,452,050	47	0	19	34	10	7	4	8
Springbrook tributaries	1.9	103	---	100	0	0	0	41,922	100	0	0	0	3	2	1	1
Sprague R. below Trout Cr.	54.6	1,475	---	11	30	0	59	1,680,370	0	55	43	3	10	12	8	7
Springbrook tributaries	1.2	32	---	100	0	0	0	28,475	100	0	0	0	0	0		
Sprague R. above Trout Cr.	82.7	152	---	0	0	8	92	2,736,020	0	7	66	26	0	13		9
Springbrook tributaries	9.7	12	---	25	0	0	75	47,821	25	0	0	75	1	2	12	4
Sycan R.[2]	20.5	262	---	0	0	65	35	403,571	0	12	61	27	7	10	10	5
Springbrook tributaries	1.9	0	---	---	---	---	---	24,829	---	---	---	---	---	---	---	---
N.Fk. Sprague R.	19.6	5,129	---	7	59	0	34	268,284	0	0	93	7	<1	2	15	11
Springbrook tributaries	22.4	142	---	100	0	0	0	122,025	44	56	0	0	<1	2	13	15
S.Fk. Sprague R.[2]	23.9	1,106	---	37	24	39	0	296,124	0	13	43	44	2	3	14	15
Wood River	32.5	1,022	---	56	44	0	0	751,783	63	6	31	0	7	4	7	11
Springbrook tributaries	17.6	201	---	18	82	0	0	228,345	100	0	0	0	8	4	3	6
Other tributaries	25.5	---	---	0	61	39	0	139,075	0	34	15	50	<1	<1	15	17
Sevenmile Cr.	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Crystal/Recreation Cr.	13.1	---	0	---	---	---	---	249,365	---	---	---	---	---	---	---	---
Other westside UKL tributaries	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
TOTAL	489.3															

[1] Dashed lines in habitat columns represent a lack of data for the stream/waterbody if potential habitat is identified as present.
[2] Use of this system by chinook will be substantially constrained without habitat rehabilitation and some level of flow enhancement.
[3] Draft (initial) model output from EDT; review dependent on release of modeling files that will allow examination of model behavior.

Table A2. Summary of information on the quantity and quality of existing habitat potentially available for stream-type spring chinook salmon in the Upper Klamath Basin. Source: Huntington and Dunsmoor (2006a).

		Estimated quantity of available spawning habitat (adults accomodated)		Estimated quality of available spawning habitat (percent of habitat providing specific levels of survival-to-emergence, as predicted by EDT)				Estimated quantity of low-flow rearing habitat (m²)	Estimated quality of available summer rearing habitat (percent of habitat in specific quartiles for EDT-predicted subyearling survival during summer[3])				EDT-predicted[3] spawner use: Percent of all adults spawning abv IGD		EDT-predicted[3] spawner use: Rank order for intensity (#/km)	
Stream/waterbody[1]	Kilometers of potential habitat	Surveys	EDT	Upper	Upper intermediate	Lower intermediate	Lowest		Upper	Upper intermediate	Lower intermediate	Lowest	Alt 1A no rehab	Alt 5 w/ rehab	Alt 1A no rehab	Alt 5 w/ rehab
Iron Gate to Link River Dam																
Klamath R. (riverine reaches)	42.5	---	7,768	16	24	38	22	1,453,700	0	16	0	84	0	0		
Klamath R. Reservoirs	24.3	---	0	---	---	---	---	9,362,300	0	0	0	100	---	---	---	---
Jenny Cr.	1.8	---	57	0	0	100	0	16,085	0	0	100	0	0	0		
Fall Cr.	1.4	---	5	100	0	0	0	6,313	92	0	0	8	<1	<1	5	9
Shovel Cr.	4.7	---	160	0	100	0	0	22,860	0	100	0	0	<1	<1	10	16
Spencer Cr.	20.4	816	---	6	64	30	0	152,312	6	64	30	0	3	1	6	12
Keno Reservoir/Lake Ewauna	31.9	---	0	---	---	---	---	7,383,000	0	0	0	100	---	---	---	---
Link R.	1.9	---	0	---	---	---	---	233,000	0	0	0	100	---	---	---	---
Above Link River Dam																
Upper Klamath/Agency Lks	---	---	0	---	---	---	---	229,695,000	0	0	1	99	---	---	---	---
Williamson R.	33.5	5,720	---	27	35	38	0	1,452,050	34	9	22	34	62	27	1	2
Springbrook tributaries	10.5	129	---	39	61	0	0	302,411	39	61	0	0	12	6	3	4
Sprague R. below Trout Cr.	54.6	1,844	---	0	0	0	100	1,680,370	0	0	0	100	0	1		15
Springbrook tributaries	1.2	42	---	100	0	0	0	28,475	100	0	0	0	2	1	2	3
Sprague R. above Trout Cr.	82.7	190	---	0	0	29	71	2,736,020	0	17	0	83				
Springbrook tributaries	9.7	14	---	25	0	0	75	47,821	25	0	0	75	<1	8	12	1
Sycan R.[2]	44.6	4,428	---	0	26	20	54	993,018	40	0	33	26	0	8		10
Springbrook tributaries	1.9	0	---	---	---	---	---	24,829	0	0	0	100	---	---	---	---
N.Fk. Sprague R.	52.5	10,180	---	13	43	44	0	535,812	13	68	19	0	3	19	9	6
Springbrook tributaries	22.4	178	---	0	23	77	0	122,025	0	57	43	0	0	7		7
S.Fk. Sprague R.[2]	34.4	5,557	---	0	9	51	40	413,276	0	27	29	44	0	3		11
Wood River	32.5	1,278	---	63	6	31	0	751,783	100	0	0	0	14	10	4	8
Springbrook tributaries	17.6	252	---	100	0	0	0	228,345	100	0	0	0	1	6	7	5
Other tributaries	25.5	1,818	---	81	19	0	0	139,075	81	19	0	0	2	1	7	14
Sevenmile Cr.	29.8	260	---	66	0	0	34	588,874	66	0	34	0	1	2	11	13
Crystal/Recreation Cr.	13.1	---	0	---	---	---	---	249,365	100	0	0	0	---	---	---	---
Other westside UKL tributaries	0.0	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
TOTAL	595.1															

[1] Dashed lines in habitat columns represent a lack of data for the stream/waterbody if potential habitat is identified as present.

[2] Use of this system by chinook will be substantially constrained without habitat rehabilitation and some level of flow enhancement.

[3] Draft (initial) model output from EDT; review dependent on release of modeling files that will allow examination of model behavior.

Table A3. Summary of information on the quantity and quality of existing habitat potentially available to fall-winter steelhead in the Upper Klamath Basin. Source: Huntington and Dunsmoor (2006a).

Stream/waterbody[1]	Kilometers of potential habitat	Estimated quantity of low-flow rearing habitat (m^2)	Estimated quality of available rearing habitat: Summer habitat (percent of habitat in specific quality classes, per local experts)				Winter habitat (percent of habitat in specific quartiles for EDT-predicted juvenile survival[2])			
			Good	Fair	Poor	Not functional	Upper	Upper intermedia	Lower intermedia	Lowest
Iron Gate to Link River Dam										
Klamath R. (riverine reaches)	42.5	1,453,700	13	51	36	0	0	39	38	23
Existing Reservoirs	24.3	9,362,300	0	0	0	100	0	0	0	100
Jenny Cr.	1.8	16,085	---	---	---	---	100	0	0	0
Fall Cr.	1.4	6,313	---	---	---	---	13	88	0	0
Shovel Cr.	4.7	22,860	---	---	---	---	33	43	0	24
Spencer Cr.	20.4	152,312	---	---	---	---	0	40	30	30
Other tributaries	24.9	---	---	---	---	---	---	---	---	---
Keno Reservoir/Lake Ewauna	31.9	7,383,000	0	0	0	100	0	0	0	100
Link R.	1.9	233,000	0	0	0	100	0	0	0	100
Above Link River Dam										
Upper Klamath/Agency Lks	---	229,695,000	0	1	0	99	0	0	0	100
Williamson R. (excluding Sprague)	37.4	1,528,870	69	31	0	0	79	0	0	21
Springbrook tributaries	11.5	302,411	100	0	0	0	100	0	0	0
Sprague R. below Trout Cr.	54.6	2,736,020	0	0	100	0	11	89	0	0
Trout Cr.	11.3	16,149	39	48	13	0	---	---	---	---
Springbrook tributaries	1.2	28,475	54	46	0	0	53	0	0	47
Sprague R. above Trout Cr.	82.7	2,736,020	0	17	83	0	0	45	8	48
Springbrook tributaries	9.7	47,821	100	0	0	0	0	100	0	0
Other tributaries	8.4	7,286	0	0	51	49	---	---	---	---
Sycan R. below Sycan Marsh	53.7	993,018	0	21	79	0	14	49	29	9
Springbrook tributaries	1.9	24,829	0	100	0	0	0	0	0	100
Sycan R. incl./above Sycan Marsh	68.4	394,518	25	42	6	27	---	---	---	---
Tributaries	89.9	220,329	58	25	17	0	---	---	---	---
N.Fk. Sprague R.	57.9	589,095	64	36	0	0	19	13	54	15
Fivemile Cr.	22.4	122,025	31	69	0	0	31	69	0	0
Other tributaries	27.7	127,505	55	38	8	0	---	---	---	---
S.Fk. Sprague R.	55.5	504,293	35	44	4	16	12	23	49	16
Tributaries	50.2	82,958	20	39	35	5	---	---	---	---
Wood River	32.5	751,783	100	0	0	0	17	12	0	71
Springbrook tributaries	23.1	244,983	76	24	0	0	13	0	0	87
Other tributaries	41.3	193,914	51	22	23	4	17	30	52	0
Sevenmile Cr.	30.4	590,309	8	59	34	0	12	7	5	75
Recreation/Crystal Cr.	13.1	249,365	0	100	0	0	0	0	0	100
Westside tributary streams	21.8	---	29	19	23	30	---	---	---	---

[1] Dashed lines in habitat columns represent a lack of data for the stream/waterbody if potential habitat is identified as present. For the identified Klamath R. tributaries between Iron Gate Dam and Link River Dam, habitat suitable for steelhead production is considered to be present (B. Tinniswood, ODFW, pers comm.).

[2] Draft (initial) model output from EDT; review and adjustment (if appropriate) dependent on release of modeling files that will allow a thorough examination of model behavior.