Compilation of information to inform USFWS principals on the potential effects of the proposed Klamath Basin Restoration Agreement (Draft 11) on fish and fish habitat conditions in the Klamath Basin, with emphasis on fall Chinook salmon

Executive Summary

This document is a compilation and summary of various modeling exercises, analyses, and relevant information relating to the potential effects of implementing the proposed Klamath Basin Restoration Agreement (KBRA-Draft 11) on fish and fish habitat conditions in the Klamath Basin. The KBRA includes a water management regime, programs for fish habitat restoration, fish reintroduction, and an assumption that the PacifiCorp Hydropower dams (J. C. Boyle, Copco 1 and 2, and Iron Gate dams) will be removed in 2020 as specified in the Draft Klamath Hydroelectric Settlement Agreement (KHSA). The full text of the proposed KBRA and the Draft KHSA (collectively referred to hereafter as the Agreements) are available for review at: http://www.edsheets.com/Klamathdocs.html.

This report provides the U.S. Fish and Wildlife Service (Service) Principals involved in the Klamath settlement negotiations with supporting information and documentation of the technical staff analyses, data interpretations, and professional opinions based on relevant literature and available data relating to anticipated changes in environmental conditions, fish habitats, and anadromous fish production that would occur as a result of implementing the Agreements. The primary focus of this report is the effects of the proposed Agreements on anadromous fish species, and in particular, fall run Chinook salmon. The substantial body of existing information on fall run Chinook below Iron Gate Dam (IGD), as well as several existing peer-reviewed models that address flow habitat relationships and production of fall run Chinook salmon, provided the basis for considerable in-depth analysis of potential effects in the Klamath River downstream of IGD. Fewer tools are currently available for examining potential for successful re-occupancy of areas above IGD, but the existing information is sufficient for preliminary analyses. Analytical tools for coho salmon are more limited, and are virtually non-existent for spring run Chinook, steelhead, and lamprey. As such, this report offers little analysis of the outcomes of the proposed Agreements on those taxa.

A considerable amount of information exists relating to the life history of Lost River and shortnose sucker species in Upper Klamath Lake and its tributaries, but no available analyses or models exist that specifically correlate or predict population performance with environmental variables. Conclusions regarding the potential impacts of the Agreements on these two species are limited and general. The ongoing development of the Service's Recovery Plan for these two species should provide valuable additional information in the near future.

Information included in this document is not comprehensive, but may prove useful in developing the Fisheries Restoration Plan that will guide implementation of aquatic resource aspects of the KBRA. The Executive Summary provided below outlines key points contained in this report.

Water Quantity

The Water Resources Program in the KBRA consists of schedules, plans, and other provisions that would substantially change the management of the delivered water supply for irrigation and related uses in the Upper Klamath Basin, U. S. Bureau of Reclamation's (Reclamation) Klamath Irrigation Project, and the National Wildlife Refuges. Specific items listed in the KBRA include measures for reconnecting Upper Klamath Lake (UKL) wetlands, development of an Off-Klamath Project program aimed at increasing UKL inflows, formation of a structure to implement science-based adaptive water management, a water allocation plan for National Wildlife Refuges, and provisions for addressing drought, unexpected emergencies, groundwater withdrawals, and climate change. The KBRA also establishes limitations on the quantity of water diverted from UKL and the Klamath River for use by the Klamath Irrigation Project based a sliding scale that increases with increasingly wetter climatic conditions. The current management practice that provides higher water deliveries for agriculture in dry years than in wet years would be reversed, and water savings would be used to augment UKL elevations for listed suckers and flows in the Klamath River for anadromous and resident fishes.

At the request of technical staff representing participants in the settlement negotiations, the Klamath Tribes performed iterative hydrologic simulations using KPSIM and subsequently, WRIMS water balance models that incorporated differing flow and lake elevation targets, Klamath Irrigation Project delivery amounts, and model assumptions. Model runs performed during the early stages of the settlement negotiations using KPSIM, a Microsoft Excel based model initially developed in the late 1990's to address complex questions relating to relationships among flow requirements, minimum lake levels, inflow, agriculture, refuge demand, and management strategies for the Klamath Basin. To improve the performance and capabilities in modeling water balance in the Klamath Basin, the Water Resources Integrated Modeling System (WRIMS) was applied to the Klamath River Basin. WRIMS is generalized water resources simulation model specifically designed for evaluating alternatives in a Water Resources System and has been used extensively to simulate the State Water Project (SWP) and Central Valley Project (CVP) in California. The WRIMS model reconfigured for the Upper Klamath Basin has recently been referred to as KLAMSIM (Appendix E of the KBRA). This WRIMS application is a hydrologic model used to simulate flows in the upper Klamath River under various management scenarios and allows for comparison of alternatives. The period of record used in the Klamath WRIMS model analysis is water years 1961-2000. Outputs of the model simulate what would have happened in the 1961-2000 period of record if flows, lake levels, agricultural diversions, among other factors, are varied from what occurred historically.

Model simulations were done to evaluate the potential outcome of various water allocations being negotiated in the settlement process, with regard to deliveries to the Klamath Irrigation Project, UKL elevations, and Klamath River flows. Adequacy in meeting these water needs was determined by examination of deviations between model input targets and model outputs. The model run that most closely reflects the water terms of the KBRA is labeled "WRIMS Run-32 Refuge", which represents one possible hydrologic modeling scenario of KBRA implementation that includes a lake elevation schedule referred to as ALT-Y. More recent WRIMS model runs prepared by settlement parties are not included here, as they were completed after much of our analyses, which were completed primarily in late 2008 and early 2009, were finalized.

We compared model inputs and outputs of the WRIMS Run-32 Refuge simulation to a number of alternatives, including flow recommendations from the Hardy Phase II habitat modeling study (Hardy et al. 2006a) and historical flow records for IGD. Comparisons between alternatives were conducted for variety of exceedence year types (water year types) related to flow levels at the 10% (wetter) 30%, 50%, 70%, and 90% (dryer) exceedence levels for the period of record (water years 1961-2000 October 1, 1960 to September 30, 2000). In addition, we compared the alternatives based on our current understanding of fish habitat needs, derived from flow habitat relationships described previously in the Hardy et al. (2006a) “Phase II” instream flow report. Results of these comparisons and modeling results suggest the following:

- In general, WRIMS Run-32 Refuge output flows exceed historical IGD flows (water years 1961-2000) and were similar to the Hardy Phase II recommendations (Hardy et al. 2006a) for the 30% and greater exceedences during the critical Chinook salmon fry rearing (March-April) and Chinook (May) and coho salmon (June) juvenile rearing months.
- At a 10% exceedence, WRIMS Run-32 Refuge model flow outputs and historical IGD flows (water years 1961-2000) were generally similar, but the difference varied between time steps within the March - June period. WRIMS Run-32 Refuge output flows for this period were considerably higher than the Hardy Phase II baseflow recommendations (Hardy et al. 2006a) for a 10% exceedence, likely due to the Hardy baseflow recommendations not reflecting spill. We note that the Hardy et al. (2006a) Phase II flows were a baseflow regime target and that higher flows associated with pulse or overbank flows (i.e., spills) are also a component of the Hardy Phase II flow schedule.
- WRIMS Run-32 Refuge model output flows were lower than the Hardy et al. (2006a) Phase II recommendations in the fall and winter for dryer water years to help ensure that Upper Klamath Lake (UKL) would fill, as needed to meet lake elevation targets and the specified allocation to the Klamath Irrigation Project.
- Habitat values for WRIMS Run-32 Refuge model output flows were consistently higher than habitat values calculated for historical IGD flows (water years 1961-2000) for the March – June emergence and rearing life stages of Chinook and coho salmon for exceedences greater than 10%. At the 10% exceedence level, habitat values estimated for the WRIMS Run-32 Refuge output were higher than estimates for historical IGD flows during the October, November spawning period and during March of the rearing period, but were similar to one another for April-June.
- Chinook salmon spawning habitat values for October-November for the WRIMS Run-32 Refuge model outputs were generally higher for the 10% exceedence level, similar for the 30, 50, and 70% exceedences, and less at the 90% exceedence level than values calculated for historical IGD flows (water years 1961-2000) and the Hardy et al. (2006a) Phase II recommendations. However, habitat values calculated for the Hardy Phase II flow recommendations would be lower in wetter water years as result of higher flows associated with pulse or overbank flows (i.e., spills) that exceed flows corresponding to the maximum habitat value.
- WRIMS Run-32 Refuge model simulations predicted the lake to fill to the targeted lake elevation (4,143 feet) for the majority of exceedence year types (34 out of 39 simulated water years 1962-2000).

- There was a clear trend in the lake elevation outputs of the WRIMS Run-32 Refuge model run being higher than model input lake elevation targets (ALT-Y) throughout the fall and winter and during the majority of exceedences. This indicates that flexibility exists to adaptively manage lake elevations and river flows on a real-time basis.
- Outputs of the WRIMS Run-32 Refuge simulations also predicted that lake elevations would not drop below 4,139 feet during late summer/early fall, with the exception of September and October for a 90% exceedence year. This should facilitate refill of the lake by the following spring, thereby providing listed suckers unrestricted access to tributaries and spring refugia areas during periods of adverse water quality.
- Modeled shortages in Klamath River flows and UKL elevations at the 90% exceedence level (drought conditions like 1992 and 1994) demonstrate the need for a functional and effective drought plan, with particular emphasis given to the mid August through mid-October period to protect upstream migrant adult fall Chinook and coho salmon.

Water Quality

Our analysis of water quality effects was based primarily on results of temperature modeling reported by PacifiCorp and by the U.S.G.S. Fort Collins Science Center, various materials presented in the Klamath Hydropower FERC relicensing record, water quality data collected by the Service and by the Yurok and Karuk Tribes, and information presented in the literature. Based on analyses and review of these materials, we anticipate that potential changes in water quality conditions during the interim period prior to dam removal would be minor, as the continued operation of the PacifiCorp dams has the greatest single influence on water quality conditions and dynamics in the Klamath River below IGD. Removal of PacifiCorp Project reservoirs, restoration of the river channel in current hydropower reaches, and flows provided under the KBRA, are expected to contribute to restoration of the physical, chemical, and biological interactions that are critical to a functioning river ecosystem, primarily through nutrient assimilation, re-aeration and shifts in the thermal regime. Following removal of the PacifiCorp dams, improved water quality resulting from restoration actions within and upstream of the Keno reach would be realized in the former hydropower reaches and below IGD, rather than being altered within the existing reservoirs.

- In the interim period leading up to dam removal, water quality conditions in the Klamath River are likely to improve slightly in response to current and future regulatory and restoration actions, including interim measures proposed in the Draft KHSA, completion of wetland restoration projects and potential actions triggered by the Total Maximum Daily Load (TMDL) assessment and Clean Water Act Section 401 Certification process. Benefits would be achieved primarily through reductions in nutrient loading.
- Following removal of PacifiCorp's Klamath River dams, hydraulic residence time through reaches occupied by the dam complex would decrease from several weeks to less than a day. Conversion from a reservoir to riverine environment would also increase assimilation of nutrients, thereby improving water quality.
- Benefits of restoration efforts to improve water quality upstream of the PacifiCorp dam complex prior to and following dam removal would be fully realized in the

former hydropower reaches and below IGD with the removal of the dams. With the reservoirs in place, water quality improvements within and upstream of the Keno reach provided by the Agreements will be altered in the existing reservoir complex and therefore, will not be fully realized below IGD.

- Evaporation from the large surface area of existing reservoirs would be reduced to that which would occur on the reclaimed river channel; this volume of water would flow down the river.
- Water temperatures would change significantly following dam removal, resulting in a thermal regime that exhibits natural diurnal and seasonal fluctuations rather than the phase shift in thermal regimes that exists with the PacifiCorp Project reservoirs in place. Temperature reductions ranging between 2 and 10 ° C would occur from mid- to late August through mid-November, which will have a positive influence on adult salmon migration, holding, and spawning in reaches upstream of Seiad Valley.
- Removal of PacifiCorp Project reservoirs would allow important coolwater tributaries (e.g. Fall, Shovel, Spencer, and Jenny creeks) and cold water springs such as the 225 cfs that enter the mainstem Klamath River between J. C. Boyle Dam and the Powerhouse, to directly enter and flow unobstructed down the mainstem Klamath River. These cooler water inflows will create thermal diversity in the river in the form of intermittently-spaced patches of thermal refugia. Thermal diversity will benefit a variety of aquatic biota during warm summer months and warmer periods during adult fall and juvenile spring-summer fish migrations.
- The restored thermal regime will play a significant role in nutrient dynamics, as will other natural riverine processes like the re-aeration of water provided by a turbulent well-mixed river. In spite of the continued release of eutrophic water from Keno Dam, restoration of natural riverine processes below Keno Dam are expected to reduce nutrient concentrations and prevent low dissolved oxygen concentrations and high pH events from occurring in reaches currently inundated by reservoirs and below the current site of IGD.
- Water quality modeling performed by PacifiCorp and USGS for the without PacifiCorp Project dams alternative suggest that dissolved oxygen concentrations are likely to improve and be suitable for aquatic biota in restored river reaches previously inundated by reservoirs and below IGD. We do not expect pH to reach levels that are detrimental to river biota because of the high degree of mixing that would occur and its associated positive influence on limiting algae production.
- Algae blooms in the reservoirs serve as an added source of nutrients generated through the process of nitrogen fixation with atmospheric nitrogen, to the already eutrophic water of the Klamath River.
- In the absence of PacifiCorp Project reservoirs, conditions under which blue green algae (BGA) thrive will be significantly altered in reaches downstream of Keno Dam, resulting in fewer nutrients and a decrease in the alteration of water chemistry (pH and DO) associated with BGA blooms. Again, turbulent river conditions would prevent such blooms from occurring.

- BGA can release toxins that have been found to be harmful to fish and invertebrates; dam removal will likely eliminate or minimize this additional stressor to the biotic community.

Geomorphology and Channel Maintenance

Our analyses of geomorphology and channel maintenance relied extensively on recent and past studies specific to the Klamath River and on the Marmot dam removal on the Sandy River in Oregon. Studies cited in this report indicate that approximately 20.4 million cubic yards of sediment, primarily comprised of fines, are trapped behind the PacifiCorp complex of dams being considered for removal under the Agreements. Sediment in the path of reclaimed river channel would erode nearly instantaneously when exposed to moving water. Depending on discharge, suspended sediment would travel to the ocean within approximately four days after being eroded and mobilized. The overall geomorphic response to dam removal would depend on the magnitude and duration of high flows within a year, the sequences of these peak flow events across years, the composition and amount of bedload materials entering the river, and the effectiveness of flows at mobilizing and redistributing fine and coarse sediment throughout the river. Predicting the extent and length of time necessary for a complete geomorphic response, however, will be challenging due to the spatial and temporal scales in which the physical processes would occur following dam removal. This will be a subject of intensive study for the Secretarial Determination process specified in the Draft KHSA.

- Studies indicate that flows from IGD have been adequate for channel maintenance in most years and that fine sediments are regularly flushed from riffles and pools during average or wetter water years and under normal flow conditions.
- Low flows over extended period of drought, however, have increased deposition of silt and fine organics, allowing rooted aquatic vegetation to become well established. These conditions provide habitats preferred by polychaete worms, the intermediate host of myxosporean parasites of salmonids in the Klamath River.
- High late winter and spring flows that would result from the water allocation plan specified in the KBRA, in combination with tributary accretions below Keno Dam that are currently being regulated in PacifiCorp Project reservoirs, will increase the frequency of flows that mobilize sediment.
- Spill events and accompanying mobilization of bed materials are expected to decrease the retention of fines associated with establishment of aquatic vegetation, as well as adversely affect micro-habitats of the polychaete host of the fish pathogen *C. shasta* that is attributed to significant juvenile Chinook and coho salmon mortalities.
- Future peak flows in the Klamath River that would result from implementing the water allocation plan specified in the KBRA are expected to maintain channel maintenance functions. However, peak flow regimes can be altered by the creation of additional storage and out-of-basin water transfers, which differ in that stored water can be used to recreate peak flow events whereas water transferred out-of-basin cannot.

- Removing Marmot Dam on the Sandy River in Oregon demonstrated the ability of an energetic river like the Klamath to rapidly and efficiently redistribute expansive volumes of unconsolidated sediment given the right hydrologic conditions. This landmark restoration project exemplifies that dam removal can be an effective strategy for restoring ecosystem function and connectivity of a large river with minimal short-term impacts.

Fish Health

Our analyses of the potential effects of implementing the KBRA and removal of the PacifiCorp Project dams was conducted using disease incidence and outmigrant fish trapping data and a review of the current literature. We relied extensively on recent studies conducted by Dr. Jerri Bartholomew and her colleagues at Oregon State University and Dr. Scott Foott and staff of the Service's California/Nevada Fish Health Center. Dr.'s Bartholomew and Foott also provided specific text for, and extensively reviewed the Fish Health section of this report.

Fish diseases are widespread in the mainstem Klamath River during certain time periods and have been shown to adversely affect freshwater abundance of Chinook and coho salmon. In recent years, the Service, working collaboratively with its University, Tribal, and Agency partners, has documented high infection rates in emigrating juvenile Chinook and coho salmon, primarily by one or both myxozoan parasites – *Ceratomyxa shasta*, and *Parvicapsula minibicornis*. Fish health studies conducted from 1995 to present have consistently documented high infection incidence (up to 44% of natural origin juvenile fall Chinook salmon) in the Klamath River during the spring and summer. Abnormally high infection prevalence within the native salmon population indicates that a host-parasite imbalance exists below IGD.

- Polychaete worms, the alternate host for *C. shasta*, and *P. minibicornis*, are found throughout the mainstem Klamath River but are most prevalent in low velocity areas such as runs, pools, and riffle edge habitats, and inflow zones to reservoirs. Inflow zones of Klamath River reservoirs have exceptionally high densities of polychaetes, which is consistent with published literature. Converting the existing reservoir complex to a riverine system will eliminate these densely colonized areas.
- The KBRA provides flexibility to manage flows to respond to real-time climatic and biological conditions that will create variability in flows and resulting habitat conditions and reestablish natural instability and disturbance of microhabitats preferred by polychaetes. Disturbance of polychaete habitats is anticipated to reduce the abundance of polychaete populations and may reduce infection rates within remaining polychaete colonies.
- Stable, monotypic, nutrient- and diatom-rich flows that occur below IGD provide an optimal environment for production of filter-feeding benthic invertebrates like polychaete worms. Fluctuating flows that mimic, albeit to a lesser degree, conditions experienced under a natural flow regime, will eliminate the monotypic stable flow conditions in which polychaetes are known to proliferate.
- The greater thermal diversity that will be experienced following removal of the Klamath River dams and reservoirs is likely to result in greater invertebrate diversity and less favorable environmental conditions for production and survival of a single species such as the polychaete worms.

- Removal of the PacifiCorp Project dams is likely to alter the distribution of myxospores, an intermediate life stage of myxozoan parasites released from salmonids, by dispersing adult spawning salmon and resident trout found below IGD. The fish passage barrier created by IGD and the adjacent Iron Gate Fish Hatchery have concentrated the density of spawning adult salmon in the IGD to Scott River reach, thereby exacerbating release of infectious myxospores within this reach. The greater abundance of myxospores released by dense concentrations of spawning salmon within this reach results in higher infection rates in polychaetes, which proliferate in this relatively stable hydrologic reach.
- Removal of PacifiCorp Project dams would facilitate the occurrence of higher peak flows, restoration of mid-sized (gravel) sediment input below IGD, and result in variable flows that could intermittently scour and desiccate polychaete colonies and their habitats, resulting in reduced actinospore loads the following spring.

Anadromous Fish Production

Our analyses on potential changes in fish production focused primarily on juvenile fall Chinook salmon due to the availability of an existing production model developed for the Klamath River. To conduct the analyses, the Service requested USGS Fort Collins Science Center to implement the decision support system, Systems Impact Assessment Model (SIAM) to corroborate the information produced by the WRIMS model, Reclamation's water planning model for the Klamath Basin, and to predict changes in water temperature and production of juvenile fall Chinook salmon that would occur below IGD under various water management alternatives being evaluated in negotiations of the KBRA. SIAM is a multi-component planning model that was specifically designed to test performance of proposed water management alternatives as to their feasibility and effectiveness and its use been reported extensively in the peer reviewed literature.

Prior to dam removal, SAIM simulations predicted that production of fall Chinook salmon smolts below IGD would significantly improve in years resembling historical low and average production years in response to implementing the water allocation proposed in the KBRA. In years where modeled historical production was high, potential for improvement under both Run-32 Refuge and Hardy et al. (2006a) Phase II flow schedules was consistently low, because habitat availability was already at or near the maximum values possible given the existing channel configuration. Conversely, years where modeled historical production of fall Chinook salmon was low provided the greatest opportunity for improvement under any of the alternative flow schedules.

While opportunity exists to improve fall run Chinook salmon production prior to dam removal, removal of Klamath River dams has potential to greatly increase production potential over that experienced even in the historically highest production years based on quantitative estimates of miles of suitable habitat located upstream of IGD. Expansion of accessible habitats resulting from removal of Klamath River dams will greatly increase production potential over that which exists with the dams in place and augmented flows provided by the KBRA. In general, quantitative estimates of gains in habitat and associated production potential that would result from removal of the Klamath River dams, including the reestablishment of spring and fall Chinook and coho salmon, steelhead, and Pacific lamprey upstream of IGD exceed gains that could be achieved below IGD through manipulation of flows alone with the dams in place.

Pre Dam Removal

- In general, years where modeled historical (water years 1961-2000) production of fall Chinook salmon was low provided the greatest opportunity for improvement under any of the alternative flow schedules. Conversely, for years where modeled historical production was high, there was little difference in the change in production between the alternatives.
- Percent change in production from the historical water years 1961-2000 baseline and Run-32 Refuge simulation for the 10 highest historical production years (upper 25th percentile) averaged about +6 % and for the 10 lowest historical production years (lower 25th percentile), about +45 %. Percent change in production from the historical baseline and the Hardy et al. (2006a) Phase II simulations for the 10 highest historical production years averaged about -7% and about +50 % for the 10 lowest historical production years.
- In years when modeled fish production increased significantly over historical (water years 1961-2000) baseline predictions (>10 % over baseline), improvements in production often occurred as a result of increased flows in the spring and/or reduction in intensity and/or frequency of fall spills. Early fall spills reduced estimates of adult spawning habitat availability, while increases in spring flows over historical baseline conditions resulted in increased fry and juvenile rearing habitat availability.
- Implementing either the WRIM Run-32 Refuge model outputs or Hardy et al. (2006a) Phase II flow recommendations was predicted to decrease the occurrence of poor production years in the future by about 2/3. Reducing the average occurrence of low production years from 1 out of every 4 years downward to 1 out of every 10 years is significant given the dominant 3 to 4 year life cycle of fall Chinook salmon in the Klamath Basin.
- SIAM simulations predicted Upper Klamath Lake water surface elevations to be substantially higher for the WRIMS Run-32 Refuge model run than elevations predicted for the Hardy et al. (2006a) Phase II simulation. This, however, should be expected as Hardy et al. (2006a) characterize their flow recommendations as being *"made based on the ecological needs of the Lower Klamath River and anadromous fish in particular"* and that the Hardy Phase II study was *"not commissioned to undertake any 'optimization' or flow balancing to meet competing water demands*".

Post Dam Removal

- An estimated 676 linear km (420 miles) of habitats suitable for anadromous fish would become available in the Upper Klamath Basin upon removal of the PacifiCorp Project dams. In addition, an estimated range of 98-379 km (60-235 miles) of potential habitat exists in the Upper Basin that could be rehabilitated into a functional condition for use by anadromous fish species.
- Dam removal provides opportunity for spring Chinook salmon to become established in the upper Klamath River. Under the KBRA, suitable stocks will be identified and a reintroduction plan will be implemented. We anticipate that any increase in adult returns would generate increased harvest opportunities.
- Removal of the dams would provide access to a diversity of habitats within their historical range, such as intermittent streams and thermal refugia. This added

diversity in fish habitats will benefit various life stages and species of anadromous fish and will contribute to their ability to thrive in variable and challenging environments by providing opportunities to increase genetic variation.

- Changes in water temperatures that more closely resemble the thermal regime experienced prior to the development of the PacifiCorp Hydropower Project are anticipated to increase the average size of juveniles at ocean entry, which has been widely shown in the literature to increase estuary/ocean survival. Adult salmon would also benefit from a colder thermal regime in the late summer and fall in the upper river, which may reduce disease incidence, increase swimming performance, and increase gamete viability.
- Following removal of the Klamath dams, key historical spawning areas would become available in mainstem reaches such as Iron Gate and Copco and in numerous tributaries such as the Williamson and Sprague rivers and Jenny, Fall, Spencer, and Shovel creeks.
- Access to additional spawning habitats would disperse spawning, which would minimize the unnaturally high levels of redd superimposition that currently occurs below IGD, even in years of low adult spawning escapement. Decreased redd superimposition would increase adult to juvenile production ratios.
- Dispersion of the concentrated spawning and resulting high fry and juvenile densities that currently occurs in the Klamath River between IGD and the Shasta River may benefit outmigrant fry and juvenile salmonids from the Shasta River and potentially, Scott River, by reducing competition for food and space.

Implementing the Water Allocation in Real Time

Under the KBRA, a Technical Advisory Team will develop an Annual Water Management Plan and make recommendations to the Secretary of the Interior that rely on science-based, adaptive management in real time that adjusts to changing environmental and biological conditions. In this report, we provide an example of a real-time management (RTM) application for managing the water allocation specified in the KBRA. The goals of the RTM application are 1) to provide a feasible method for implementing the water allocation proposed in the KBRA and 2) to reestablish important processes and function of the natural hydrograph. The proposed RTM process described in this report would eliminate the need for water year types and fixed flow schedules by using real-time daily discharge of the Williamson River, an unregulated reference stream, to inform daily flows at IGD as recommended by the National Research Council (NRC 2008). This concept was an essential aspect of the Hardy et al. (2006a) Phase II flow regime and is strongly supported by instream flow practitioners and stream ecologists because it results in flow patterns that mimic the shape and function of the natural hydrograph under which the aquatic biota evolved.

- The RTM process would restore the natural flow paradigm under which aquatic biota evolved and that is inherent in unregulated, natural river systems.
- The RTM process proposed in this report has been demonstrated to be a potential tool for implementing the water allocation proposed in the KBRA. The Service is currently working with the Stockholm Environment Institute to refine this methodology.

- The KBRA includes provisions to adaptively manage the division of water between the lake and the river based on real-time environmental and biological conditions. This progressive and strategic approach to managing water would be new to the Klamath Basin.

Conclusions

Under implementation of the Fisheries Program specified in the KBRA, scientific efforts and funding would emphasize restoration, reintroduction, and adaptive management. A unified approach to science in the Basin that aligns funding and technical efforts to meet a common purpose identified in and supported by the Agreements, will benefit fish and fish management in the Basin. This unified approach needs to be well defined in the Fisheries Restoration Plan required under the KBRA, a concept supported by the NRC (2008).

As described in Section 9.1.1 of the KBRA, the purpose of the defined Fisheries Program is to restore and sustain natural production of fish species throughout the Klamath River Basin. Specifically, this program,

> *"...establishes conditions that, combined with effective implementation of the Water Resources Program in Part V, will contribute to the natural sustainability of fisheries and full participation in harvest opportunities, as well as the overall ecosystem health of the Klamath River Basin…"*

Our analyses indicate that implementing the KBRA's water allocation plan would benefit the restoration of anadromous salmonids prior to the removal of PacifiCorp Project dams. However, quantitative gains in fish habitat and associated production potential that would result from dam removal, including the reestablishment of spring and fall Chinook and coho salmon, steelhead, and Pacific lamprey upstream of IGD, exceed gains that could be achieved below IGD through manipulation of flows alone. The water allocation plan specified in the KBRA would also contribute to maintaining water levels in Upper Klamath Lake that, in combination with restoration activities listed in the KBRA, will benefit listed sucker populations. Removal of PacifiCorp Project dams and subsequent reestablishment of Basin connectivity and variable stream flows in the Klamath River are expected to contribute significantly towards restoration of the physical, chemical, and biological processes and interactions that are essential to a functional aquatic ecosystem. When viewed in combination with the implementation of an effective drought plan, dam removal, and other restoration actions identified Table 1, it is the professional judgment of the authors that the KBRA water and fish programs, would over time, achieve the Agreement's stated goal of restoring the "*natural sustainability of fisheries and full participation in harvest opportunities, as well as the overall ecosystem health of the Klamath River Basin*". The timing and magnitude of improvements, however, will largely depend on the time required to implement the full suite of restoration and management actions identified in the KBRA (Table 1).

Table 1. Status of various activities that influence fish production in the Klamath River under current conditions, the FERC relicensing process, and under the Klamath Basin Restoration Agreement (no= will not occur, yes = will occur, ? = likelihood of occurrence unknown).

Activity	Status Quo	Dams Remain Fish Passage Installed	Restoration Agreement
Basin-wide Restoration Plan	?	?	Yes
Increased Funding, Scope, and Pace of Restoration Actions	No	No	Yes
Reintroduction Plan above IGD	No	Yes	Yes
Reintroduction of Anadromy to Upper Klamath Basin	No	Yes [a]	Yes
HCP Above UKL	No	?	Yes
Acquisition of Water Rights above UKL	No	No	Yes
Increased Storage and Restoration in UKL Wetlands	Yes	Yes	Yes
Capped Allocation of Water to KIP & Increased Environmental Water	No	No	Yes
No Adverse Impact from KIP Groundwater use	No	No	Yes
Drought Management Plan	?	?	Yes
Real-time Management of Environmental Water	No	?	Yes
Funding for Water Quality Work in Keno Reservoir	No	No	Yes
Removal of PacifiCorp Project Dams	No	No	Yes
Anadromous Fish Habitat at Present Reservoir Sites	No	No	Yes
Improved Water Quality in Lower Klamath River	Limited	Limited	Yes

[a] Excludes mainstem Klamath River and tributary habitats inundated by PacifiCorp Project reservoirs.

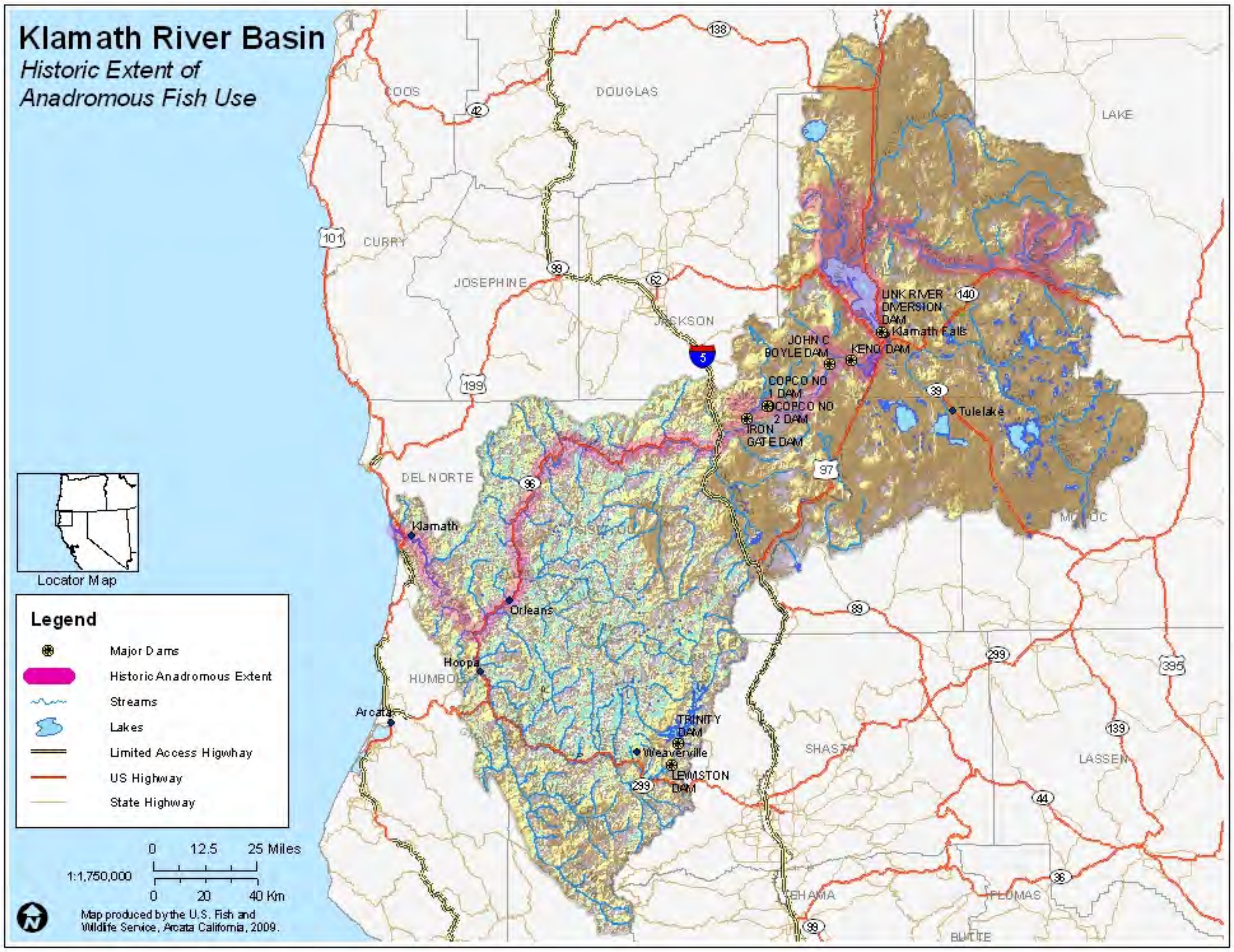

Figure 1. Location of mainstem Klamath River dams and the historic extent of anadromy within the Klamath Basin. The first upstream passage barrier to anadromous salmonids and Pacific lamprey on the mainstem Klamath River was Copco 1 Dam constructed in 1918, followed by Copco 2 Dam in 1925, and Iron Gate Dam in 1962.