Synthesis of the Effects to Fish Species of Two Management Scenarios for the Secretarial Determination on Removal of the Lower Four Dams on the Klamath River

FINAL

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Prepared by the Biological Subgroup (BSG) for the Secretarial Determination (SD) Regarding Potential Removal of the Lower Four Dams on the Klamath River

John Hamilton, United States Fish and Wildlife Service (Service)
Dennis Rondorf, United States Geological Survey (USGS)
Mark Hampton, National Marine Fisheries Service (NMFS)
Rebecca Quiñones, United States Forest Service (USFS)
Jim Simondet (NMFS)
Terry Smith (USFS)

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Contents

Acronyms and Abbreviations

AF = Acre Feet
AFA = Aphanizomenon flos-aquae
BLM = Bureau of Land Management
BO = Biological Opinion
BOD = Biological Oxygen Demand
BSG = Biological Subgroup
CDFG = California Department of Fish and Game
CEQA = California Environmental Quality Act
cfs = cubic feet per second
DO = Dissolved Oxygen
DPS = Distinct Population Segment
ESA = Endangered Species Act
ESU = Evolutionarily Significant Unit
FEIS = Final Environmental Impact Statement
FERC = Federal Energy Regulatory Commission
HRT = Hydraulic Residence Time
IGD = Iron Gate Dam
IGH = Iron Gate Hatchery
KBRA = Klamath Basin Restoration Agreement
KDD = Klamath Drainage District
KFMC = Klamath Fisheries Management Council
KHSA = Klamath Hydroelectric Settlement Agreement
MGD =Million gallons per day
MSAE =*Microcystis aeruginosa*
N = nitrogen
NEPA = National Environmental Policy Act
NMFS = National Marine Fisheries Service
NPDES = National Pollutant Discharge Elimination System
NWR = National Wildlife Refuge
Service = U.S. Fish and Wildlife Service
NRC = National Research Council
NRCS = National Resource Conservation Service
ODEQ = Oregon Department of Environmental Quality
ODFW = Oregon Department of Fish and Wildlife
OSU = Oregon State University
P = phosphorus
PFMC = Pacific Fisheries Management Council
Project = Klamath Hydroelectric Project
PR = Project Reach
Reclamation = USDI Bureau of Reclamation
RM = river mile
Secretary = Secretary of Interior
SD = Secretarial Determination

SOD = Sediment Oxygen Demand
SONCC = Southern Oregon Northern California Coast (coho salmon)
SRFCF = Shasta River Fish Counting Facility
Task Force = Klamath River Basin Fisheries Task Force
TID = Tule Lake Irrigation District
TMDL = Total Maximum Daily Load
UKL = Upper Klamath Lake
U.S. = United States
USDI = U.S. Department of the Interior
USFS = U.S. Forest Service
USGS = U.S. Geological Survey
VSP = Viable Salmonid Population
YOY = Young of the Year

EXECUTIVE SUMMARY

For decades the long-standing conflict in the Klamath River Basin over water and fish resources has persisted. In an effort to resolve these disputes, PacifiCorp and interested parties negotiated, wrote, and signed the Klamath Hydroelectric Settlement Agreement (KHSA) in 2010, calling for the potential removal of the four lower dams on the Klamath River mainstem. The KHSA established a process known as the Secretarial Determination, which includes 1) conducting new scientific studies and a re-evaluation of existing studies found in the FERC record and from other sources, and 2) evaluating the potential environmental and human effects of such an action pursuant to National Environmental Policy Act, California Environmental Quality Act, and other applicable laws. In March 2012, the Secretary of the Interior will decide whether removal of these dams on the Klamath River: 1) will advance salmonid fisheries, and 2) is in the public interest.

In this report, we summarize anticipated effects to fish resources under two management scenarios: 1) current conditions with dams in place and without the programs and actions in the Klamath Basin Restoration Agreement (KBRA), and 2) removal of the lower four dams plus programs and actions called for in the KBRA and KHSA. This information will aid the Secretary of the Interior in determining whether dam removal and implementation of KBRA will advance restoration of salmonid (salmon and trout) fisheries.

Due to the complexity of interactions and responses of fish populations, some uncertainty is inherent in our conclusions, as in all projections into the future. Every effort has been made to use the most current and accurate information available in our analysis. Our findings are based on reasonable projections of possible future management under the two scenarios. The descriptions in this report of management actions under KHSA and KBRA (scenario 2 above), are not management decisions, and they are not recommendations. They are simply reasonable representations of actions that could be taken in order to provide a basis for this analysis. In the case of a positive Secretarial Determination, more planning and environmental compliance analysis would be needed to determine exact methods for dam removal and types and locations of restoration activities.

Current conditions with dams (and no KBRA): Under conditions with dams in place (and no KBRA), the Project Reach and downstream will continue to be characterized by unnatural shifts in water temperature and flow patterns, exacerbating seasonal poor water quality. The thermal regime of the mainstem river is influenced under certain conditions for up to 120 miles below Iron Gate Dam (IGD). Reservoirs would continue to prevent important cold-water inputs from reaching mainstem habitats. Total Maximum Daily Load (TMDL) implementation and interim KHSA measures would improve water quality but there is less certainty regarding when TMDL targets (e.g., nutrients, dissolved oxygen, and water temperature) would be achieved. Conditions suitable for the growth of blue green algae in these reservoirs (warm, quiescent, and nutrient-rich water), which produce toxins harmful to fish and other biota, would likely persist. However, current conditions would provide some benefits in maintaining cooler temperatures below IGD during spring and early summer.

In general, the diversity, productivity, and abundance of most aquatic organisms in the Klamath River will continue to be restricted as a result of conditions with dams. Dams will continue to block fish migration to over 420 miles of historical habitat. Resilience and potential for salmonid stocks to be restored would be limited, with some runs (e.g., spring-run Chinook salmon)

remaining at significantly suppressed levels over the years of analysis (50 years). Coho salmon populations in the Klamath River Basin would likely continue to require protection under the state and federal Endangered Species Acts. Redband trout movements would continue to be restricted and the populations negatively impacted by Project hydropower peaking. The status of two federally listed suckers above IGD will be less likely to improve without KBRA and declining populations of Pacific lamprey will be unable to use habitat above IGD. In particular, migrating salmon and steelhead will continue to be blocked from significant groundwater inputs in the upper basin which would provide thermal refugia and habitat resistant to climate change.

If the dams remain, Iron Gate Hatchery operations (mitigating for the loss of salmonid habitat between the lower two dams) would continue to supplement salmon to commercial, Tribal, and recreational fisheries. Continued reliance on hatchery production, however, will likely suppress wild population recovery, contribute to disease problems below the Project, and increase the risk of sudden fishery collapse. Sport fisheries for steelhead, once thriving, would likely remain depressed. With dams in place, existing warm-water fisheries in the reservoirs would likely be maintained.

Conditions with dams in place (and no KBRA) would continue to disrupt natural flow patterns and riverine processes below IGD. Natural flow variability and the amount of summer base flows would continue to be reduced overall. Even with adherence to the 2010 National Marine Fisheries Service Biological Opinion, flows would be less variable (and less beneficial) than they would be without dams and the actions in KBRA. In combination with changes in flow patterns, the disruption of sediment supply would continue to limit riparian plant succession, channel formation, and spawning gravel recruitment. The reduction of spawning gravels has been identified as a principal cause of declining salmonid recruitment downstream from IGD. Conditions conducive to salmon disease will also persist below IGD with these disrupted flow patterns.

Conditions with dam removal and KBRA: Water quality and habitat condition are expected to improve in the Klamath River Basin under conditions without dams and with KBRA. Klamath Basin National Wildlife Refuges would receive a certainty of water delivery. TMDL targets would be reached sooner with KBRA funding and implementation, improving dissolved oxygen, pH, and nutrient concentrations upstream and downstream of the Project Reach. Removal of dams and associated reservoirs would substantially reduce the growth of blue-green algal blooms that are deleterious to fish and other biota.

Reservoir drawdown and dam removal would have short-term adverse effects to aquatic habitats in the Project Reach and downstream. Dam removal would adversely affect dissolved oxygen immediately after removal as resuspended bottom sediments would exert an oxygen demand while being transported. The amount of sediment supply to the ocean due to dam removal would be less than the average annual sediment supply of the river under current conditions. Suspended sediment levels would be relatively high from the Project Reach to the ocean, for up to eight months. These concentrations would minimally impact spawning migration, but may impact spawning gravels below IGD for up to several years. Populations of fall-run Chinook salmon are expected to recover within five years of dam removal. Eventually, the channel would reach its original form, reestablishing processes that provide habitat, spawning gravels, and would likely reduce salmon mortality associated with *C. shasta*.

Although restoration of a more natural flow regime would result in warmer spring and early summer temperatures below IGD, without dams there would be cooler temperatures in the late summer and fall when migration, spawning, and incubation occur for fall-run Chinook salmon.

Juvenile salmon may compensate for warmer spring and early summer temperatures by growing faster and outmigrating earlier. Adult spring-run Chinook salmon are expected to synchronize their life history and migration timing with the more natural flow and temperature regime as likely occurred historically. More normative river and KBRA pulse flows would increase the survival of salmon during outmigration by disrupting the protozoan fish pathogen *C. shasta* life cycle and result in more ecosystem benefits. Gravel delivered by tributaries would no longer be retained behind dams and therefore contribute to mainstem spawning. Provisions within KBRA (drought plan), when implemented, should minimize the risk of extended low flows.

Species viability would improve for most native anadromous and resident species with dam removal and KBRA implementation. Habitat above IGD historically supported between 10 and 149 thousand naturally spawning Chinook salmon. This range was from 18 to 30 thousand for naturally spawning steelhead. Removal of the dams, in conjunction with KBRA, would provide salmon and steelhead access to over 420 miles of this historical habitat, increasing production in the Klamath River Basin. Dam removal would benefit other species by providing additional habitat, increasing genetic diversity, and increasing habitat connectivity. In particular, for salmon and steelhead, dam removal would provide access to cold-water habitats buffered from climate change and would restore processes that encourage species resiliency. Until water quality is improved, however, some anadromous fish will be dependent on seasonal transport around Keno reservoir. While coldwater would be somewhat diluted by higher flows, fish would have access to significant thermal refugia in the J.C. Boyle Bypassed Reach.

Impacts to federally listed suckers from dam removal would be minimal because reservoirs contribute little to recovery of the species; however, suckers may benefit from improved water quality in the upper basin, and specifically in Upper Klamath Lake, from the programs and actions in KBRA. Resident fish would not be entrained in turbines or stranded by Project operations. Resident fish would also be able to move upstream and downstream more freely, increasing their ability to search for optimal habitats that favor survival. Proposed habitat improvements, including water quality and quantity and riparian corridor improvements and protection, are anticipated to increase redband/rainbow trout productivity.

Salmon fisheries would likely benefit from dam removal coastwide, since the abundances of Klamath River salmon would be less likely to reach levels that restrict commercial fishing through weak-stock management. Eventually, harvest of Pacific lamprey and redband trout would be greater assuming a relatively high success rate of KBRA measures. The increase in abundance of redband/rainbow trout in the project reach (where the dams currently exist) could provide significantly more recreational fishing opportunities than the current trophy trout fisheries. While the recreational fishery for native steelhead would improve, removal of dams would eliminate the locally popular warm-water fishery for non-native resident species in Project reservoirs.

1. INTRODUCTION

1.1. Document Purpose

The United States (U.S.) has a strong interest in addressing long-standing disputes over scarce water resources and fisheries restoration in the Klamath River Basin[1]. Decades of water conflicts in the Klamath River Basin between conservationists, tribes, farmers, fishermen, and state and federal agencies have recently devolved into a "rotating crisis" for Klamath River Basin communities.

On April 6, 2001, the federal government shut off irrigation water to approximately 1,400 family farms and ranches covering 220,000 acres within the Klamath Reclamation Project and to two wildlife refuges. Limited water was restored for irrigation in late August. The following year, during late September 2002, an estimated 33,000 adult salmon (primarily Chinook salmon), steelhead trout and other fish species died in the lower 36 miles of the Klamath River. Low flows and other flow related factors (e.g., fish passage and fish density) contributed to the die off. In 2006, the commercial salmon fishing season was closed along 700 miles of the West Coast for much of May, June, and July, the most productive months of the season, to protect a weak return of Klamath River Chinook salmon stocks.

The U.S. since 2002 has spent over $500 million in the Klamath River Basin, including funds for lake and river restoration and habitat improvement projects (California Farm Bureau Federation 2008). Klamath River Basin restoration activities are supported by a variety of federal, state, private, and local sources including the National Oceanic and Atmospheric Administration Restoration Center, National Marine Fisheries Service (NMFS)-Southwest Region, NMFS Pacific Coastal Salmon Recovery Fund (PCSRF), California Department of Fish and Game (CDFG), California Coastal Conservancy, USDI Bureau of Reclamation (Reclamation), U.S. Fish and Wildlife Service (Service), and the U.S. Forest Service (USFS).

Concurrent with the rotating crisis of resource issues during the past decade, PacifiCorp, the owner of the Klamath River Hydroelectric Project (Project), submitted an application for a hydropower relicensing to the Federal Energy Regulatory Commission (FERC). However, PacifiCorp and interested parties have since signed an agreement (the Klamath Hydroelectric Settlement Agreement (Klamath Hydroelectric Settlement Group (KHSA) 2010) to move forward with consideration of removal of the lower four Project dams. In this review, we present some of the biological information associated with two conditions, with and without the dams, under a time horizon of 50 years starting in 2012.

[1] The 'Klamath River Basin' referred to here is the entire Klamath River watershed; 'basin' as used herein refers to a portion of the watershed . The 'lower basin' refers to the watershed generally from IGD downstream.

1.2. Secretarial Decisions to be Made

The two management scenarios we will analyze and compare in this paper are:

> **Conditions with Dams:** For purposes of this paper, conditions with dams will assume no change from current management, which includes on-going programs under existing laws and authorities that contribute to the continued existence of listed threatened and endangered species and Tribal Trust species. This is one representation of what could happen for multiple years following a negative Secretarial Determination. Other representations could have been chosen for this analysis, but that would have required considerable speculation as to the outcome of a FERC relicensing process or additional negotiations among the KHSA settlement parties.
>
> **Conditions without Dams and Klamath Basin Restoration Agreement (KBRA):** Under this condition the lower four Klamath River dams will be removed in the year 2020 and the full range of actions/programs described in KBRA (Klamath Basin Restoration Agreement (KBRA) 2010) implemented; the KBRA is a connected action to the KHSA and for this analysis will be assumed to go forward with dam removal and a positive Secretarial Determination.

The KBRA Fisheries Programs were designed to: 1) restore and maintain ecological functionality and connectivity of historical fish habitats; 2) re-establish and maintain naturally sustainable and viable populations of fish to the full capacity of restored habitats; and 3) provide for full participation in fish harvest opportunities for local communities. The process to restore fish in the Klamath River Basin consists of Phase I and Phase II.

Phase I would establish restoration priorities and criteria selecting restoration projects between 2012 and 2021. Specific elements would include, but may not be limited to, restoration and permanent protection of riparian vegetation, restoration of stream channel functions, remediation of fish passage problems, and prevention of entrainment of fish into diversions.

Within seven years of finalizing Phase I, the managers would initiate Phase II by developing a long-term plan based on the monitoring results of Phase I actions. Phase II would implement elements, restoration priorities, and an adaptive management process for the remainder of the KBRA. Managers would revise the plan as appropriate.

The focus of KBRA restoration would be the Klamath River Basin, excluding the Trinity River watershed above its confluence with the Klamath River. The focus of anadromous salmonid reintroduction would be the Upper Klamath Basin, excluding the Lost River or its tributaries and the Tule Lake Basin. KBRA programs would restore fish passage and water quality; reintroduce fish to the areas currently blocked by the hydroelectric dams; increase the amount of water to improve instream flows and maintain the elevation of Upper Klamath Lake; and provide specific allocations and delivery obligations for water to the Lower Klamath and Tule Lake National Wildlife Refuges. A Drought Plan would be developed to ensure increasingly intensive water management for agriculture, National Wildlife Refuges, and in-lake and in-river fishery, and avoid or minimize impacts to upper Klamath basin communities and natural resources during drought years. The KBRA would establish a process to resolve specific claims in the Klamath Basin Adjudication, as well as maintain the economic character of the off-project agricultural community.

The Secretary, in cooperation with the Secretary of Commerce and other federal agencies, will use existing studies, appropriate data, and further studies if necessary to determine whether, in his or her judgment, the conditions of the KHSA, and concurrent execution of the KBRA, have been satisfied, and whether Facilities Removal: 1) will advance restoration of the salmonid fisheries of the Klamath River Basin; and 2) is in the public interest, which includes but is not limited to consideration of potential impacts on affected local communities and Tribes. The Secretary will use best efforts to complete this determination by March 31, 2012.

1.3. Background

The Klamath River Basin (Figure 1) was once the third-largest producer of salmon in the United States (Institute for Fisheries Resources and Pacific Coast Federation of Fishermen's Associations 2006). The 10-million acre Klamath watershed once produced substantial runs of steelhead (*Oncorhynchus mykiss*), Chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (*Oncorhynchus kisutch*), green sturgeon (*Acipenser medirostris*), eulachon (*Thaleichthys pacificus*), coastal cutthroat trout (*Oncorhynchus clarki clarki*), and Pacific lamprey (*Entosphenus tridentatus*). These anadromous fish runs have contributed substantially to commercial, recreational, and Tribal fisheries (Gresh et al. 2000; U.S. Department of the Interior 1985; USDI Klamath River Basin Fisheries Task Force 1991). Iron Gate Dam (IGD), at river mile (RM) 190, currently blocks upstream fish passage. Historically, the Klamath River drainage above IGD provided spawning and rearing habitat for large populations of anadromous salmon and steelhead (Federal Energy Regulatory Commission 1990; Lane and Lane Associates 1981; Snyder 1931).

Anadromous fish populations within the Klamath River Basin have declined to levels substantially below historical abundance, and many species continue to decline. Although not presently listed[2] under the federal Endangered Species Act (ESA), spring-run Chinook salmon in the lower Klamath River drainage are subject to a high risk of extinction (Nehlsen et al. 1991), and fall-run Chinook salmon and summer steelhead as being under moderate risk of extinction. The abundance of anadromous lampreys appear to have also declined to low levels (Larson and Belchik 1998). Eulachon are now believed to be extirpated from the Klamath River. These long-term declines have been

[2] On April 12, 2011, NMFS announced a 90-day finding for a petition to list the Chinook salmon in the Upper Klamath and Trinity Rivers Basin as threatened or endangered and designate critical habitat under the ESA. NMFS found that the petition presents substantial scientific information indicating the petitioned actions may be warranted and will conduct a status review to determine if the petitioned actions are warranted (76 FR 20302).

caused by the cumulative effects from a variety of activities, including the construction of dams that block access to upstream spawning and rearing habitat, agricultural development, timber harvesting, and mining (USDI Klamath River Basin Fisheries Task Force 1991). Changing ocean conditions have also contributed to declines.

Overharvest has also contributed to these declines. Chinook salmon populations south of Cape Blanco, which include both the Klamath and Sacramento rivers, share the same marine habitat and primarily remain off the Oregon and California coasts (Myers et al. 1997). Because the two stocks mingle in the ocean, protection of one (often the Klamath River stock) means restricted harvest on both.

In 2003-2006, West Coast ocean salmon fishing was severely restricted as a result of the low abundance forecasts (Klamath Fisheries Management Council 2004, 2005, 2006); (KFMC). The restrictive season in 2006 led to the Secretary of Commerce making a fishery resource disaster determination under section 308(b) of the Interjurisdictional Fisheries Act and a subsequent fishery failure determination, commonly referred to as a "disaster declaration," under section 312(a) of the Magnuson-Stevens Act. More recently, the Pacific Fishery Management Council (PFMC) has closed salmon fishing in waters south of Cape Falcon, Oregon, to protect the declining population of Sacramento River Chinook salmon.

In April 2008, in response to the "collapse" of Sacramento River fall Chinook salmon and the poor status of many west coast coho salmon populations, the PFMC adopted the most restrictive salmon fisheries in the history of the West Coast. The regulations included a complete closure of commercial and recreational Chinook salmon fisheries south of Cape Falcon, Oregon. NMFS determined that "[t]he evidence pointed to ocean conditions (weak upwelling, warm sea surface temperatures, and low densities of prey items) as the proximate cause" of the collapse (Lindley et al. 2009) in conjunction with decreases in life history diversity.

Only a century ago native people in the Klamath River Basin could rely on healthy salmon populations to support subsistence and a variety of cultural uses. Fishing communities once thrived on the large production of salmon from the Klamath River. Developing rural, agricultural, and timber communities could depend on the resources of the Klamath River Basin for economic and social stability. These uses are now often in conflict as salmon runs decline and communities compete for limited supplies of water and other natural resources.

1.4. Past and Present Federal and State Programs Specific to the Klamath Basin

In 1986, the U.S. Congress passed the Klamath River Basin Fishery Resources Restoration Act (Klamath Act; PL-552), which provided for a 20-year program within the Department of the Interior (Department) to restore the anadromous fisheries of the Klamath River Basin. The Klamath Act noted the need to improve and restore habitat, promote access for anadromous fish to blocked habitat, rehabilitate watersheds, and improve upstream and downstream migrations by removal of obstacles to fish passage. The Klamath Act established two Federal Advisory Committees (the Klamath River

Basin Fisheries Task Force (Task Force) and the KFMC, to guide fishery restoration and harvest management of Klamath River anadromous fish. The Task Force and Department subsequently developed the *Long Range Plan for the Klamath River Basin Conservation Area Fishery Restoration Program*[3] (Long Range Plan) to guide fishery and habitat restoration (USDI Klamath River Basin Fisheries Task Force 1991). The Long Range Plan generally directs that fishery restoration is to be achieved through fish habitat protection and restoration from a total watershed perspective, not simply an in-stream perspective. The Long Range Plan also advocates access to habitats above Iron Gate and Copco Dams.

In addition to creating a fishery restoration plan, the Task Force also encouraged local watershed groups to develop restoration plans for each of the five sub-basins of the lower Klamath River Basin. These groups included the Shasta River Coordinated Resource Management Planning Group (Shasta sub-basin), Scott River Watershed Council (Scott sub-basin), Klamath National Forest and Salmon River Restoration Council (Salmon sub-basin), Karuk Tribe and Mid-Klamath Watershed Council (mid-Klamath sub-basin), and the Yurok Tribe (lower-Klamath sub-basin). Since 1991, over $1.3 M has been invested in these groups to develop the sub-basin plans, sub-basin assessments, and conduct restoration activities. Funds from the Klamath Act are often leveraged to develop broader restoration programs and projects in conjunction with other funding sources, including CDFG restoration grants. As an example, nearly $1.9 M of CDFG restoration funding was spent on a variety of Klamath River Basin restoration projects during the 2002-2006 period alone. While the Klamath River Basin Conservation Area Restoration Program ended in 2006, federal funds have been authorized each fiscal year since, and the Service continues to administer funds in the near term consistent with the goals of the program.

The Trinity River Restoration Program was created as part of the 1984 Trinity River Basin Fish and Wildlife Management Act. This Act authorized the Secretary to develop and implement a management program to restore fish and wildlife populations in the Trinity River Basin to levels which existed prior to construction of the Trinity and Lewiston Dams. The program is focused on improving habitat conditions for salmonid fry by increasing channel complexity and restoring river-floodplain connectivity.

Implementation of Total Maximum Daily Loads (TMDLs) Action Plans addressing temperature, dissolved oxygen (DO), nutrient, and microcystin impairments in the Klamath River are calculated to protect and restore beneficial uses (North Coast Regional Water Quality Control Board 2010). These beneficial uses including cold freshwater habitat, fish migration, fish spawning, and preservation of rare and endangered species are expected to improve with implantation of TMDLs.

Restoration activities are expected to benefit salmon, steelhead, and their habitat. They are also anticipated to benefit other endemic species. These effects are expected to

[3] The Department of the Interior's Long Range Plan for the Klamath River Basin Conservation Area Fishery Restoration Program was accepted on January 15, 2004 by the Federal Energy Regulatory Commission as a Comprehensive Plan as provided by Section 10(a) of the Federal Power Act.

continue throughout the duration of the action, possibly increasing during that time period. Passage improvements have reintroduced salmon to critical habitat. Restoration activities are expected to improve upon one or more of the Viable Salmonid Population (VSP) parameters (abundance, population growth rate, population spatial structure, and diversity) for the interior Klamath populations.

Considerable efforts are on-going to restore habitat in the upper Klamath River Basin. Although many of these restoration efforts have targeted habitat for sucker species listed under the ESA, these efforts would also benefit anadromous species. Since the early 1990's, the Service, Reclamation, State of Oregon, Klamath Tribes, National Resources Conservation Service (NRCS), other partners, and private landowners have been working to recover the Lost River sucker and the shortnose sucker. The Service and its partners have supported approximately 400 habitat restoration projects in the upper Klamath River Basin, including over 50 wetland and 150 riparian projects. The cost of these restoration projects has been shared by many entities, including state and federal programs such as Partners for Fish and Wildlife, Hatfield Restoration, Jobs in the Woods, and Oregon Resources Conservation Act programs as well as private grant programs and contributions from private landowners.

Major habitat restoration projects that have been completed in the upper basin include: 1) screening of the main irrigation diversion on the Klamath Reclamation Project[4] (A-Canal); 2) screening of the outlet at Clear Lake Dam; 3) construction of a new fish ladder at Link River Dam; 4) restoration of over 25,000 acres of wetlands adjacent to Upper Klamath Lake (UKL) and in the watershed above the lake; 5) 13 fish passage improvement projects, including screening and fish ladders; 6) restoration of the lower three miles of the Wood River; 7) fencing along about 200 miles of streams (D. Ross, Service, pers. comm.); 8) removal of Chiloquin Dam; and 9) reconnection of the Williamson River Delta (over 4,000 acres).

In 2004, the National Academy of Sciences concluded that a lasting resolution of Klamath River Basin water issues will require an integrated and comprehensive effort (National Research Council 2004a). That type of effort is now being pursued through KBRA programs and cooperative agreements. For example, representatives of the states of California and Oregon, the President's Klamath River Basin Working Group, and the Environmental Protection Agency have signed the Klamath River Watershed Coordination Agreement. They agreed to place a high priority on their Klamath River Basin activities and to coordinate and communicate with one another and with Tribal governments, local governments, private groups, and individuals to resolve water quantity/quality problems in the basin (U.S. Department of the Interior et al. 2004).

[4] The Klamath Reclamation Project is located in Klamath County, Oregon, and Siskiyou and Modoc Counties in northern California. The project includes facilities to divert and distribute water for irrigation, National Wildlife Refuges, and control of floods in the area. Water storage and diversion facilities in northern California include: Clear Lake Dam and Reservoir; Tule Lake; and, the Lower Klamath Lake National Wildlife Refuge. Gerber Dam and Reservoir, Upper Klamath Lake, Link River Dam, and the Lost River, Miller, Malone, and Anderson-Rose Diversion Dams are located in Oregon.

In 2008, Oregon Department of Fish and Wildlife (ODFW) amended its 1995 Klamath River Fish Management Plan for Oregon waters to include anadromous fish (Oregon Department of Fish and Wildlife 2008). Under the management plan, they intend for anadromous fish to recolonize historically occupied habitat in the upper Klamath River upstream from the California border.

1.4.1. Klamath Basin Restoration Agreement (KBRA) and Klamath Hydroelectric Settlement Agreement (KHSA)

Discussions associated with FERC relicensing of the PacifiCorp Hydroelectric Project brought together for the first time a diverse group of interests to resolve some of the Klamath Basin's longstanding disputes related to the allocation of water resources. The group consists of three counties, several irrigation districts, three tribes, conservation and fishing organizations, and federal and state agencies. Released in March 2010, the KBRA would both rebuild fisheries and sustain agricultural communities consistent with environmental laws.

Although a fundamental assumption of the KBRA is the removal of the lower four PacifiCorp dams, dam removal negotiations with PacifiCorp occurred separately. In November 2008, PacifiCorp, the U.S., the state of Oregon and the California Resources Agency agreed to broad principles to move forward with removal of the lower four Klamath River dams and to promote good-faith negotiations to reach a KHSA that will minimize adverse impacts of dam removal on affected human communities.
Klamath River Basin stakeholders negotiated and signed the KBRA and KHSA in February 2010. The parties entered into these final agreements to resolve longstanding disputes between them regarding a broad range of resource issues. The Agreements, in combination and totality, are intended to result in effective and durable solutions which:

1. restore and sustain natural production, and provide for full participation in ocean and river harvest opportunities, of fish species throughout the Klamath River Basin;
2. establish reliable water and power supplies which sustain agricultural uses, communities, and National Wildlife Refuges (NWRs); and
3. contribute to the public welfare and the sustainability of agricultural uses, local communities and Tribes, along with public trust resources of the Klamath River Basin.

The two agreements are designed to be implemented together as negotiated to ensure these longstanding disputes are resolved.

1.4.2. Economic Team's Non-use Survey and National Environmental Policy Act

To help inform the Secretarial Determination (SD) process, a federal team is analyzing the economic effects of maintaining the current condition versus the removal of dams simultaneous with KBRA implementation (an action connected to dam removal and

KHSA). To strengthen the economic analysis, the Office of Management and Budget has requested and authorized a non-use valuation survey to assess the economic value the nation places on implementing KHSA and KBRA in order to improve the Klamath River Basin fisheries and its ecosystem. Non-use value is the value attached to environmental changes associated with dam removal, and connected actions, by members of the public who do not consume Klamath fish or visit the Klamath River Basin. Non-use values, by definition, cannot be inferred from observed behavior but must be estimated using stated preference methods.

The information that follows herein will be used to inform the non-use valuation survey. The non-use valuation survey is intended to evaluate and measure the "existence value" of species or resources even though respondents may never experience or make any use of these species or resources. Existence values, although often difficult and controversial to measure, are legitimate and important economic values because people are willing to pay for the continued existence of species or landscapes. Existence values also affect the way people behave, and anything that changes human behavior has economic consequences (National Research Council 2004b). It is anticipated that this report will also be referenced in the National Environmental Policy Act (NEPA) and California Environmental Quality Act (CEQA) document generated for the Secretarial Determination.

The primary focus of this document is a comparison of conditions under the two management scenarios after implementation of potential dam removal, not necessarily a comparison during the interim period leading up to potential removal (e.g., the present through 2012). The conclusions reached by the authors are based on what we believe to be the most reasonable projections and an accurate representation of future conditions under the management scenarios presented in the settlement agreements. However, the findings herein are not management decisions nor are they intended to determine management decisions.

2. WATERSHED CONDITION, EXISTING AND UNDER TWO FUTURE MANAGEMENT SCENARIOS

2.1. Above Iron Gate Dam

Many of the necessary components of the aquatic ecosystem above IGD appear to be present and functional, or are restorable to functional form (California Department of Fish and Game 2005; USDI Fish and Wildlife Service 2004a).

2.1.1. Existing Hydrology and Water Quality Above Link River Dam

The reach of the Klamath River from the headwaters to Link River Dam (the water control structure at the outlet to Upper Klamath Lake (UKL)) is over 300 miles from the mouth of the river at Requa, California. Vegetation and climate here differ greatly from conditions in the lower Klamath watershed. Nevertheless, portions of the watershed located above and below Link River Dam are strongly interconnected.

Water quality conditions in UKL greatly influence water quality conditions in the Klamath River downstream of the lake. The 2002 TMDL and water quality management plan developed by Oregon Department of Environmental Quality (ODEQ) provides targets and guidance to improve water quality in the river and UKL (Oregon Department of Environmental Quality 2002). The 2002 Upper Klamath Lake TMDL allocation calls for a 40 percent reduction of phosphorus (P) loading to achieve pH targets (Oregon Department of Environmental Quality 2002). (For complete discussion on water quality parameters, impairments, and TMDL allocations for Klamath and Agency lakes, their tributaries and the Klamath River in Oregon see ODEQ website (Oregon Department of Environmental Quality 2011). As a result, many wetland and riparian restoration projects are now designed to improve water quality. The conditions and aquatic biota of the upper Klamath basin are discussed below, beginning with upstream and ending with downstream locations.

2.1.1.1. Williamson River: The Williamson River originates from springs just east and south of Taylor Butte. Most tributaries to the upper Williamson River originate along the flanks of Yamsay Mountain and the ridge to the south and are ephemeral, with flows occurring during spring snowmelt. Significant springs contribute water directly to the upper Williamson River, resulting in seasonally robust base flows and strong hydrograph runoff signals. Although the river provides irrigation for agriculture and ranching through a network of ditches, the natural hydrograph has been minimally altered. Williamson River water quality is generally good. The Williamson River supports a world class fishery for redband trout and historically supported anadromous fish (Hamilton et al. 2005).

2.1.1.2. Wood River: The Wood River Valley supplies 25 percent of the water to UKL. Springs contribute considerable amounts of water directly to the Wood River resulting in a strong base flow. While flow is diverted for grazing and agriculture from the Wood River, the natural hydrograph has been minimally altered. Water temperatures and DO[5] levels are generally good for coldwater fish.

The Wood River Valley supports much of the cattle in the upper Klamath basin and is the source of 19 percent of the external Phosphorus (P) loading to UKL (Oregon Department of Environmental Quality 2002)[6]. A nutrient that is limiting in most ecosystems, P contributes to overabundance of aquatic plants and eutrophic (nutrient rich) conditions when in excess. The Wood River is an important P source and has a high export of P per unit area of watershed (National Research Council 2004a). Because of this, the Wood River Valley was identified by ODEQ as a significantly water quality impaired area. The

[5] DO concentration is the amount of oxygen that is dissolved in water and is essential to healthy aquatic life in streams and lakes. The DO level can be an indication of how well the water can support aquatic plant and animal life. Generally, a higher DO level indicates better water quality. If DO levels are too low, some fish and other organisms may not be able to survive. The optimal level for salmon is 9 mg/L. A level of 6 mg/L is acceptable for adult migration while 3.5-6 mg/L is considered poor (California North Coast Regional Water Quality Control Board 2007) . Levels below 3.5 mg/L are likely fatal to salmon. A level below 3 mg/L is stressful to most vertebrates and other forms of aquatic life.

[6] Waters in the Upper Klamath basin are naturally high in P.

Klamath Basin Rangeland Trust has been active in the Wood River Valley, encouraging landowners to adopt sustainable land and water management practices. Since 2002, 12,000 acres have been enrolled in a program to reduce water use and the program has resulted in a reduction of approximately 1.1 acre-foot (AF) of water per acre of land (S. Peterson, Klamath Basin Rangeland Trust, pers. comm.). The Wood River supports a blue ribbon fishery for brown and redband trout. Historically, the river supported anadromous fishes (Hamilton et al. 2005)

2.1.1.3. Sprague River: The Sprague River originates along the flanks of Gearhart Mountain and Coleman Rim in the highlands along the central-eastern edge of the upper Klamath River Basin. From these highlands, the North and South Forks gain water from numerous tributaries as they flow down mountain canyons to the upper Sprague River Valley, above Beatty Gap. The hydrologic regimes of the North and South Forks have a pronounced runoff component and similar hydrographs near the uplands, with peaks occurring during snowmelt in the spring. However, above the Sprague River Valley, the North Fork gains significant groundwater, reflected in the hydrograph as higher flows, whereas the South Fork does not.

From the confluence of the North and South Forks, the Sprague River meanders downstream through the narrowing upper Sprague River Valley, until it passes through Beatty Gap into the lower valley. Gains due to groundwater inflow occur in the upper valley, which contains both drained and undrained wetlands. More groundwater discharge occurs at a spring complex (locally known as Medicine Springs) just downstream of Beatty Gap. From here, the Sprague River meanders through the lower Sprague River Valley for 75 miles, to its confluence with the Williamson River.

The Sprague River is the largest tributary to the Williamson River. It is listed as water-quality impaired for nutrients, temperature, sediment, pH, and DO under section 303(d) of the Clean Water Act (Oregon Department of Environmental Quality 2002). Upper Klamath Lake receives most of its water from the Williamson River (including its largest tributary, the Sprague River) and the Wood River (National Research Council 2004a). The Williamson and Sprague Rivers together provide over half of the water reaching Upper Klamath Lake (Kann and Walker 2001 in National Research Council 2004a). In 2004, the Oregon State University (OSU) Agricultural Extension Service and the Klamath Watershed Council began a series of monthly meetings with rural landowners in the Sprague River Valley to discuss watershed restoration goals. With the help of the Service, NRCS, Klamath Basin Ecosystem Foundation, and Klamath Soil and Water Conservation District, this effort has effectively connected landowners with appropriate state and federal resource conservation programs. As a result, more than 70 percent of the private land owners in the Sprague River Valley are partnering with local, state, and federal agencies on land conservation and natural resource actions (D. Ross, Service, pers. comm.). The efforts of the Watershed Council and Klamath Basin Ecosystem Foundation have resulted in the addition of fiscal partners (e.g., Oregon Department of Agriculture, Klamath County, and Oregon Watershed Enhancement Board) to the conservation partnership. These partnerships will continue, enabling more restoration in the future.

Historically, the Sprague River provided excellent habitat for anadromous fish and the primary salmon fishery for the Klamath Tribe (Fortune et al. 1966; Hamilton et al. 2005; Lane and Lane Associates 1981). While habitat is degraded in some areas, the Sprague River continues to support fish production and provide habitat for cold water species.

2.1.1.4. Upper Klamath Lake: UKL is located in southern Oregon; about 16 miles north of the California-Oregon border and 11 miles east of the crest of the Cascade Range. It is a large, relatively shallow lake with a surface area of 57,329 acres and an average depth of approximately nine feet at full pool. Most of the lake (92 percent) is shallower than approximately 13 feet, with the exception of a narrow trench running parallel to Eagle Ridge, on the lake's western shore. This trench contains the deepest waters of the lake, approaching approximately 49 feet. UKL is located in the Klamath Graben structural valley, and much of its 2,326,497 acre drainage basin is composed of P-rich volcanically derived soils. The largest single contributor of inflow to the lake is the Williamson River, which enters the lake near its northern end (Johnson et al. 1985).

Agency Lake, just north of UKL, is connected to UKL and has 9,143 acres of surface area and an average depth of approximately seven feet. Agency Lake and UKL have been distinct from one another hydrologically and in terms of water quality. However, with the recent removal of dikes associated with the restoration of wetlands at the mouth of the Williamson River, there is greater connection between Agency Lake and UKL. While historically eutrophic, blooms of blue-green alga *Aphanizomenon flos-aquae* (AFA) during the summer and autumn have now resulted in a hypereutrophic UKL.

UKL is a natural water body, but lake surface elevations have been regulated since 1921, when Link River Dam was completed at the southern outlet of the lake. Link River Dam, owned by Reclamation, controls the water level of UKL. PacifiCorp operates Link River Dam under an annual contract, renewable at the parties' discretion. Reclamation specifies that PacifiCorp operate and maintain Link River Dam in a manner consistent with the Klamath Reclamation Project's annual operation plans. Reclamation also specifies that PacifiCorp develop, in consultation with Reclamation, operational criteria for the coordination of Link River and IGD to allow Reclamation to meet its ESA responsibilities.

The UKL is the principal water source for the Klamath Reclamation Project, an irrigation system developed to supply water to 239,692 acres of farm and ranch land and two National Wildlife Refuges in the upper Klamath basin. During the summer months there are several demands on the water stored within the UKL, which include requirements of Biological Opinions (BOs) to meet: 1) minimum UKL elevations as required for the federally listed endangered Lost River sucker (*Deltistes luxatus*) and endangered shortnose sucker (*Chasmistes brevirostris)*; and 2) minimum flows immediately below the IGD for ESA-listed coho salmon. Water is also lost from the lake through evaporation.

There has been a recent decline in UKL outflows since the 1960s, which may be due to increasing diversions, decreasing net inflows, or other (Mayer and Naman 2011b, In Press). There have been declines in winter precipitation in the upper Klamath basin in recent decades and declines in upper-Klamath Lake inflow and tributary inflow, particularly base flows (Mayer and Naman 2011b, In Press). Declines in tributary base flow could be due to increased consumptive use, in particular, groundwater utilization, and/or climate change. Agricultural diversions from the lake have increased over the 1961 to 2007 period, particularly during dry years. Declines in Link River and Klamath River (at Keno) flows in the last 40-50 years have been most pronounced during base flows in the summer season (Mayer and Naman 2011b, In Press), the time when Klamath Reclamation Project demands are the greatest. It is well known that Klamath Reclamation Project demands in the past have increased in dry years (Mayer and Naman 2011b, In Press). Given warmer temperatures associated with climate change, effects to salmon are expected to increase due to increasing water demand, expected reduced snowpack and water availability, and increasing evapotranspiration rates.

Based on historical reports, UKL has been eutrophic since at least the mid-1800s, but wetland drainage and agricultural development beginning in the late-1800s and accelerating through the 1900s is strongly implicated as the cause of its current hypereutrophic character (Bortleson and Fretwell 1993; Snyder and Morace 1997). Each summer, the lake experiences extremely high water temperature and pH, broad daily shifts in DO (anoxic to supersaturated), and high ammonia (Kann 1998; Lindenberg et al. 2008; Morace 2007; Wood et al. 1996; Wood et al. 2006). Occasional summer fish kills of variable magnitude have been noted in areas of poor water quality in Upper Klamath Lake since the late 1800s; however, in recent years, fish kills have occurred more frequently, with substantial die-offs of chubs and suckers (Perkins et al. 2000a).

Besides being implicated in the mortality of federally ESA-listed suckers, poor water quality also decreases the health of fish by suppressing growth, reducing reproductive success, and reducing resistance to disease or parasitism.

2.1.2. Conditions with Dams - Hydrology and Water Quality above Link River Dam

Under this management scenario, hydrology would generally remain the same, subject to the influence of climate change. Unlike hydrology, water quality would be expected to improve over the course of the analysis period. Implementation of activities supporting the TMDL and Non-Point Source (NPS) reduction programs are two such programs that would continue under both alternatives. However, under the "conditions with dams" alternative water quality improvement projects would likely occur at a reduced pace and scale, as compared with conditions without dams and with KBR, resulting in less potential for water quality improvement (Dunne et al. 2011; USDI Secretarial Determination Water Quality Subgroup In Review).

2.1.3. Conditions without Dams and with KBRA - Hydrology and Water Quality above Link River Dam

If there is an affirmative Secretarial Determination leading to removal of the lower four dams, flow releases to the Klamath River would be controlled by operation of the Klamath Project through management actions at Link River Dam and Keno Dam. Section 20 of the KBRA establishes a process for development and management of environmental water for the benefit of fisheries and other aquatic resources. A Technical Advisory Team shall be established to advise the Secretary on the management of environmental water no later than March 15 of each year. The guiding principles for the management of environmental water as described in the KBRA are:

1. Replicating the natural hydrologic regime under which the fish species evolved likely represents the best flow regime to conserve and recover Klamath River anadromous fish stocks and listed suckers in Upper Klamath Lake;
2. Flow and lake level management should strive to achieve existing habitat-based flow and lake elevation recommendations that would likely increase survival of salmonids and suckers, and potentially improve other important ecological, chemical, physical, and biological processes; and
3. Flow and lake level management should strive to meet lake level and flow outputs from simulations presented in Appendix E-5, recognizing that such simulations do not necessarily reflect either overall water availability at any given time, or the actual water management strategy that will be employed in the future.

We cannot predict with certainty future management decisions regarding water under either management scenario. KBRA plans have yet to be developed and ESA consultation on either scenario has yet to take place. However, up to 30,000 AF of additional water would be acquired for flows if land owners are willing to sell this water. In simulations, we assumed that this 30,000 AF was available.

A previous retrospective analysis of KBRA water management was based on water years from 1961 through 2000 (Hetrick et al. 2009). The prospective analysis of water management scenarios for the SD in this document is based on water years through 2009 which increases the period of record for the analysis by an additional nine years, many of which were dry in comparison to the historical record. Examination of river flows and lake levels from the hydrology model outputs that used the longer period of record revealed several issues that needed correction to improve conditions for anadromous fishery resources in the river and for listed suckers in Upper Klamath Lake. Therefore, in addition the parameters that were imposed to the WRIMS Run-32 Refuge model run, the federal team imposed following additional changes to the KBRA hydrology outputs presented here.

1. Incorporation of a minimum flow of 100 cfs at Link River to provide adequate passage through the fish ladder and stream channel.

2. Incorporation of a minimum flow at Keno Dam of 300 cfs to provide adequate fish passage.

3. Minor adjustment of KBRA flow targets for use in the hydrology model for the time steps from July 1 through the end of September to improve flow conditions for adult migration and reduce the potential for fish die off. The changes that are suggested include reducing the target from 921 to 840 cfs for July 1 to 15, increasing the target from 806 to 840 cfs for July 16 to 31, increasing the target from 895 to 1,110 cfs in August, and increasing the targets from 1,010 to 1,110 cfs in September.

4. Incorporation of minimum Ecological Base Flow (EBF) levels during the periods from March 1 through June 30 and during the months of August and September. The EBF volumes would be represented by the Hardy Phase II 95 percent exceedence flow levels.

5. Incorporation of pulse flows into the disaggregated daily data to realize potential benefits of these flows to reduce disease infection rates through disruption of the parasite's life cycle.

6. Minor adjustment to the flow targets for the month of March for water years represented by the 70 percent Exceedence and drier. These adjustments include reductions in the targets from 2,358 to 2,085 cfs (March 1-15) and from 2,343 to 2,149 cfs (March 16-31). The change is consistent with rate of change for wetter water years.

7. Incorporation of minimum base flows of 800 cfs below IGD during the months of October through February.

These changes for the analysis of hydrology under KBRA are documented (Greimann 2010).

In Figure 2, lake level simulations under the Dams out with KBRA management scenario are compared with the management scenario of continuing current operations with the Project managed under the NMFS' 2010 BO. Lake levels may still be influenced by the Klamath Reclamation Project as operated under the Service's 2008 Biological Opinion (BO) or a future Service BO.

In 1998, 7,100 acres at Agency Lake Ranch was converted from a previously drained wetland for cattle grazing to a water-storage area. Agency Lake Ranch was expanded in 2005 to include an additional 2,700 acres at Barnes Ranch. Although Agency Lake Ranch and Barnes Ranch were not restored to a typical vegetated wetland habitat, the area that was flooded is likely to attract wetland plants and animals (Lindenberg and Wood 2009). If KBRA is enacted, Agency Lake Ranch and Barnes Ranch lands will be transferred from Reclamation to the Service upon written mutual agreement within one year of the effective date. The Service, with technical assistance from Reclamation, will make best efforts to reconnect the land to Agency Lake, to provide restoration, wildlife, fisheries, and water management benefits (M. Barry, Service, pers. comm.).

A large set of potential measures or actions have been identified as potentially occurring under KBRA, KHSA, and/or TMDL and NPS reduction programs to improve water quality (USDI Secretarial Determination Water Quality Subgroup In Review). Specifically, the KBRA identifies a host of restoration activities in the Klamath River Basin above Link River Dam under the Fisheries and Water Resource Programs that are likely to improve the water quality. Example actions include riparian restoration and protections, and aquatic and upland habitat restoration. Additionally, with the complementary actions and goals of the KBRA, KHSA, and TMDL, it is anticipated that sufficient federal and state funding opportunities will be available to support improvements to water quality. As such, it is expected that implementation of these actions would occur at an accelerated pace and scale as compared to the No-Action alternative.

2.1.4. Existing Hydrology and Water Quality in the Project Reach

The Link River flows about two miles from the Link River Dam into Lake Ewauna, the upper end of an impounded reach of the Klamath River (also known as Keno reservoir), which is controlled by Keno Dam. Hydrology in the Project Reach (PR) (between Link River Dam and IGD) is influenced by hydropower operations, Lost River stream flow and flow diversions, as well as water returns from the Klamath Reclamation Project. Water quality in this reach of the Klamath River is also influenced by these same operations.

The reservoirs and tributaries in the Project Reach (PR) are described below:

2.1.4.1. Keno Reservoir - Keno reservoir is approximately 18 miles long and 300 to 2,600 feet wide; maximum depths range from nine to 20 feet. Keno reservoir extends from RM 252 to RM 233. The current hydrology and hydraulics of the reach have been modified by anthropogenic activity. In the late 19th-century and early 20th-century, levees, canals, and dams were built and wetlands drained to support irrigated agriculture (Stene 1994).

Summer water quality is extremely poor in Keno reservoir, with heavy AFA[7] growth and die off, low DO concentrations, and high[8] pH and water temperature[9] (National Research Council 2004a; Deas and Vaughn 2006).

[7] *Aphanizomenon flos-aquae* (AFA) is a type of blue green algae that grows worldwide. The category "blue-green algae" is a misnomer as the 'algae' is not a plant at all but part of the cyanobacteria phylum in the Bacteria kingdom.
[8] The pH test measures the hydrogen ion concentration of water. Values of pH between 7 and 8 are optimal for supporting a diverse aquatic ecosystem. A pH range between 6.5 and 8.5 is generally suitable.
[9] While the recommended maximum temperature for adult salmon migration is 18° C (U.S. Environmental Protection Agency 2003) and temperatures over 21° C are usually considered unacceptable, Klamath River Chinook migrate at temperatures up to 24° C (Strange 2010).

Keno reservoir experiences seasonal poor water quality during summer months with water temperature exceeding 25º C, pH approaching 10 units, dense algal blooms, and DO concentrations below 4 mg/l (hypoxia) (Sullivan et al. 2009). Like UKL, dense blooms of AFA affect water quality within Keno reservoir. Persistent hypoxic events in this reach of the Klamath River can last for several days or even weeks and are associated with high levels of unionized ammonia (Deas and Vaughn 2006). The most persistent hypoxic conditions are typically observed at river mile 246, near the Miller Island State Wildlife Area, where DO can drop in early July and remain less than 6 mg/l until November (Reclamation, unpublished data). Within year variation of temperature and DO at river mile 246 (USDI Geological Survey 2010) is shown in Figure 3 for 2005. The degree to which this happens varies annually and spatially within the reservoir. Studies have observed higher DO in other parts of Keno reservoir during the summer months (PacifiCorp 2004a, 2011).

The severe and persistent hypoxia observed in Keno reservoir is likely due to poor quality water entering from UKL containing large amounts of organic matter with an associated high biological oxygen demand[10] (BOD) (Deas and Vaughn 2006; Doyle and Lynch 2005) . In addition to the high BOD rates of source water from UKL, the bed sediments have high sediment oxygen demand (SOD)[11] rates which further exacerbate the hypoxic conditions. Doyle and Lynch (2005) found that SOD rates in Keno reservoir ranged from 0.3 to 2.9 grams of oxygen per square meter per day (O_2/m^2/day) with a median value of 1.8 O_2/m^2/day. Taken together, the SOD and BOD can more than account for the severe hypoxia that develops in the reach of the Klamath River from July into October of most years (Doyle and Lynch 2005).

While water quality is poor during summer months during most years, generally, the Lake Ewauna to Keno reservoir section of the Klamath River (Link River Dam to Keno Dam) has DO concentrations greater than 6 mg/L and temperatures less than 20^{o}C from mid-November through mid-June (USDI Geological Survey 2010). These conditions are within the criteria for migration for these months if adult anadromous salmonids have access to habitats above IGD (Oregon Department of Environmental Quality 2007, 2010; U.S. Environmental Protection Agency 2003). Nevertheless, because of seasonal poor water quality in Keno reservoir, FERC concluded that this water body presents a potential (but not necessarily insurmountable) impediment to unaided anadromous fish migration (Federal Energy Regulatory Commission 2007). See further discussion on this topic under *Section 2.1.13.3*.

Reclamation specifies that PacifiCorp operate Keno Dam so the water level does not fall below elevation 4,085.0 feet, as measured at or near the present location of the Highway 66 Bridge at Keno, and that PacifiCorp operate Keno Dam to accommodate a discharge

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[10] BOD is a measure of the oxygen used by microorganisms (e.g. bacteria) to decompose organic waste. When organic matter, such as dead plants, is present in water, bacteria will begin breaking down this waste, consuming much of the available dissolved oxygen. Consequently, other aquatic organisms are robbed of the oxygen they need to live.

[11] Sediment Oxygen Demand (SOD) is the sum of all biological and chemical processes in sediment that utilize (take up) oxygen.

of 3,000 cubic feet per second (cfs) from the Lost River diversion channel and 600 cfs from the Klamath Straits drain.

Reclamation operations provide UKL and Klamath River water to approximately 180,000 acres of cropland and two National Wildlife Refuges. Klamath Project water is diverted from UKL above Link River Dam and from other locations on the Klamath River above Keno. The Lost River Diversion Channel carries water in either direction between Klamath and Lost Rivers while the Klamath Straits Drain carries water only from Lower Klamath Lake to the Klamath River (Dave Mauser, Service, pers. comm.). The Lost River sub-basin, formerly a closed basin, is now connected to the Klamath River via the Lost River Diversion Channel.

Major sources of nutrient reductions and additions are related to the Klamath Reclamation Project. Klamath Straits Drain discharges consist of irrigation return flows and return flows from two National Wildlife Refuges that flow into Keno reservoir. The Lost River Diversion Channel generally provides inflows to the Keno reservoir during the wet season and diverts water from the Klamath River during the growing season. Additional canals and pumps also divert water. The operation of Keno reservoir, especially reservoir levels, is vital for the operation of pumps and canals/drains within the Klamath Reclamation Project. Keno reservoir levels are also key to the supply of water to the Service's Lower Klamath Lake Refuge complex and the Tule Lake National Wildlife Refuge through the Lost River Diversion Channel.

There are four point sources which discharge into Keno reservoir. Two domestic wastewater treatment plants, City of Klamath Falls and South Suburban, discharge approximately three million gallons per day (MGD) and two MGD, respectively. Collins Forest Products and Columbia Plywood also contribute 0.9 MGD and 9,000 gallons per day, respectively. A water quality model was developed for Keno reservoir to link sources to impairments and to predict water quality improvements. This modeling effort is part of a larger model framework being developed to support TMDL development for the entire Klamath River. In the BO on the proposed relicensing of the Klamath Hydroelectric Project (USDI Fish and Wildlife Service 2007a), the Service specified wetland restoration adjacent to Keno reservoir to improve water quality as a reasonable and prudent measure necessary and appropriate to minimize incidental take of federally listed suckers. The Service also specified that Reclamation develop and implement a water quality improvement plan, including Keno reservoir, in conservation measures in its BO for the Klamath Reclamation Project (USDI Fish and Wildlife Service 2008).

2.1.4.2. Mainstem Klamath River – Keno Reach– The Keno Reach of the Klamath River extends from Keno Dam down to the upstream end of J.C. Boyle reservoir (also known locally as Topsy reservoir), a distance of approximately 4.7 river miles (RM 233 to RM 228.3) (PacifiCorp 2004b). The river channel has a steep gradient and is generally broad with rapids, riffles and "pocket water" among the rubble and boulders (Oregon Department of Fish and Wildlife 1997). Water quality at the top of this reach is poor because it is immediately downstream of Keno reservoir (Lake Ewauna). As the water proceeds downstream, it is aerated by turbulence and water quality is slightly improved before it reaches J.C. Boyle reservoir (Oregon Department of Fish and Wildlife 1997). Nonetheless, summer water quality problems include low to adequate DO, high nutrient levels, and warm water temperatures.

The nutrient rich water supports a productive and popular wild redband/rainbow trout fishery throughout the Keno Reach. However, fishing on the Keno Reach is closed during the summer months because poor water quality would cause excessive mortality in a catch and release fishery (Oregon Department of Fish and Wildlife 1997). Most spawning habitat for the Keno Reach redband/rainbow trout is in Spencer and Shovel creeks (Oregon Department of Fish and Wildlife 1997). Adults from the Keno, and J.C. Boyle bypassed and peaking reaches migrate to these tributaries for spawning (Fortune et al. 1966) or did so historically. Fish passage at J.C. Boyle Dam has been reduced to a fraction of what it was immediately after construction (USDI Fish and Wildlife Service 2004b). The average size trout ascending the ladder has decreased in size from 12 to 7 inches in the period between 1961 to 1990 (Hanel and Gerlach 1964; Hemmingsen et al. 1992).

2.1.4.3. Spencer Creek, RM 229.5 - Spencer Creek enters the Klamath River at the upper end of J.C. Boyle reservoir. Its headwaters are at 8,000 feet elevation in the Mountain Lakes Wilderness. The creek is approximately 15 miles long, but fish passage is blocked by a barrier falls approximately nine miles upstream from the mouth. Good quality spawning habitat with gravel is reported for the nine miles below the barrier, but only marginal habitat for above the barrier (Fortune et al. 1966). Springs, seeps, and wet meadows are scattered throughout the watershed, but none of these flow consistently year round into Spencer Creek.

Historically, a 1,500 acre wetland system of marshes and springs at the head of Spencer Creek, named Buck Lake, functioned to stabilize flows throughout the year by providing water storage. The wetlands were drained and channels were constructed for irrigation and grazing purposes in the 1940's, removing this hydrologic function. Most of Buck Lake is in private ownership, but significant adjacent areas are in Bureau of Land Management (BLM) and USFS ownership. The upper third of the Spencer Creek watershed is mostly in USFS ownership, and some private ownership. The middle third of the watershed is mostly in BLM and private ownership, and the lower third is mostly privately owned (USDI Bureau of Land Management et al. 1995).

The draining of Buck Lake and grazing impacts to riparian vegetation along Spencer Creek have increased water temperatures and caused sedimentation of the streambed (USDI Bureau of Land Management et al. 1995). The macroinvertebrate community is characterized by taxa that are tolerant to environmental degradation (USDI Bureau of Land Management et al. 1995). BLM analysis (USDI Bureau of Land Management et al. 1995) described the road system in the watershed as poorly designed from a hydrologic perspective and in need of rehabilitation. In subsequent years, roads have been blocked or closed, culverts removed and allotment fences realigned to reduce impacts to streams and riparian areas on both private and federally managed lands in this watershed. In 2005, the BLM completed a $250,000 culvert improvement project in the Spencer Creek watershed (A. Hamilton, BLM, pers. comm.).

Recently, water temperatures exceeded goals for salmonids several times in 1992, 1993, and 1994 (USDI Bureau of Land Management et al. 1995). However, temperature and DO from June through October were excellent for salmonids (Fortune et al. 1966). More recent data indicate that the temperatures that exceed criteria occur during summer months (T. Smith, USFS, pers. comm.); a period when fall-run Chinook salmon would not need to occupy the tributary habitat in Spencer Creek to complete their life cycle.

Miners and Clover creeks, tributaries to Spencer Creek, are small streams with flows that become subsurface in the summer prior to their confluence with Spencer Creek in most years (USDI Bureau of Land Management et al. 1995). Clover Creek has less connectivity to Spencer Creek than Miners Creek, though the degree of connectivity of either is unclear due to conflicting reports. The lack of consistent connectivity between streams likely caused reproductive isolation and contributed to the large degree of genetic divergences in the redband/rainbow trout populations in the Klamath River Basin (Buchanan et al. 1989; Buchanan et al. 1990, 1991).

2.1.4.4. Mainstem Klamath River – J. C. Boyle Bypassed Reach - The J.C. Boyle Bypassed Reach is the portion of the mainstem Klamath River between J.C. Boyle Dam and its Powerhouse, located from approximately RM 224 to RM 220. The J.C. Boyle Powerhouse is operated on a peaking schedule, with most of the river flow being diverted through a penstock around the Bypassed Reach for hydroelectric power generation. When river flows are 3,000 cfs or less, per the KHSA Interim Measures 13[12] a minimum flow of 100 cfs is discharged to the Bypassed Reach from J.C. Boyle Dam. When river flows are above 3,000 cfs, the excess water is spilled to the Bypassed Reach (PacifiCorp 2004b). The diverted flow is returned to the river at the powerhouse above the J.C. Boyle Peaking Reach.

Water coming from J.C. Boyle reservoir is high in nutrients, making it productive for resident trout, but it is also warm during summer (with temperatures greater than 21^{o}C at times), limiting its capacity as habitat for trout (Oregon Department of Fish and Wildlife 1997). Beginning about 0.5 mile below the dam, additions of cool spring flows (referred to as Big Springs) gradually augment instream flow to about 350 cfs just above the powerhouse and cooling instream temperatures to about 18^{o}C during summer (Oregon Department of Fish and Wildlife 1997; USDI Bureau of Land Management 2003). This reach has a steep gradient, characterized by a series of large rapids, runs, and pools among large boulders. Spawning habitat for trout is limited to small pockets of gravel. Surrounding upland areas in this reach are primarily in BLM ownership. For a more detailed description of the J.C. Boyle Bypassed Reach and Big Springs, see USDI Bureau of Land Management (USDI Bureau of Land Management 2003).

[12] USDI Fish and Wildlife Service (2011). Klamath Hydroelectric Settlement Agreement 02-18-10, signed. Available on-line at: http://klamathrestoration.gov/sites/klamathrestoration.gov/files/Klamath-Agreements/Klamath-Hydroelectric-Settlement-Agreement-2-18-10signed.pdf.

2.1.4.5. Mainstem Klamath River – J. C. Boyle Peaking Reach - The J.C. Boyle Peaking Reach is about 17 miles long, from the J.C. Boyle powerhouse (RM 220) to the upper end of Copco reservoir (RM 203). Flows in this reach are heavily influenced by the hydroelectric power generating operations. Flows can exceed 3,000 cfs (U.S. Department of the Interior 2008) during periods of spring run-off when water is available and power is in demand. When power is not being generated, flows are generally about 350 cfs, and of higher water quality due to Big Springs inputs. Peaking, or changing from 350 to 3,000 cfs in one day, is common in the summer months when power demands are high. Daily temperature fluctuations of up to 12°C occur in this reach during the middle of the summer (City of Klamath Falls 1986) and are associated with peaking.

Extreme flow fluctuations impact aquatic invertebrate production because the river substrate gets exposed on a daily basis (including some salmonid spawning gravels (City of Klamath Falls 1986), yet aquatic invertebrates are still considered numerous and the redband/rainbow trout fishery considered productive (PacifiCorp 2004c, 2011).

Dunsmoor (2006 in (Federal Energy Regulatory Commission 2007)) conducted a series of surveys in the J.C. Boyle peaking reach to assess biota stranding rates during the first several peaking cycles that occurred in 2006. His survey during the first peaking cycle found large numbers of stranded juvenile sculpin, smaller numbers of juvenile and larval suckers and minnows, and many dead aquatic insects and crayfish. No dead fish were found during the later surveys and the number of dead crayfish and insects was lower. Based on transect sampling conducted on July 7, Dunsmoor estimated that the density of stranded crayfish was 0.37 per square foot.

Some site specific studies show limited effects of peaking to aquatic biota (PacifiCorp 2005a). However, peaking at J.C. Boyle has been determined to reduce the production of sessile organisms, like macroinvertebrates, by ten percent to twenty-five percent (Administrative Law Judge 2006). Macroinvertebrate drift rates, a measure of food availability for trout, in the non-peaking Keno Reach were five to six times greater than in the peaking reach. Fluctuations in the peaking reach are undoubtedly a contributing factor to the lower macroinvertebrate drift rates (Administrative Law Judge 2006). Peaking operations that cause high mortality likely only happen a few times a year, following the first peaking event after several months of steady flow (Administrative Law Judge 2006).

In the Frain Ranch Reach (approximately RM 218); portions of the channel are low gradient. Further downstream in the Caldera reach, the channel is steep and confined to a canyon. There is a predominance of good riparian bank cover, but cover in some areas is affected by cattle grazing. This reach of the river has both state and federal Scenic River designations due to its undeveloped nature and remarkable qualities (USDI National Park Service - Pacific Northwest Region 1994). In addition, the lower 6.2 miles of this reach are designated as a Wild Trout Area by the state of California (California Department of Fish and Game 2005). Most of the surrounding land in this reach is owned by BLM (75 percent) and PacifiCorp (15 percent) (U.S. National Park Service - Pacific Northwest Region 1994).

2.1.4.6. Shovel Creek - Shovel Creek enters the Klamath River at RM 206.3 from the south and approximately three miles downstream from the California/Oregon state line. It is an important spawning tributary for redband/rainbow trout in the J.C. Boyle Peaking Reach (California Department of Fish and Game 2005). Shovel Creek is approximately 12.7 miles long but only the lower 2.7 miles are accessible to fish due to a natural barrier (California Department of Fish and Game 2005). Stream flow is predominantly from precipitation and snowmelt, with some contributions from springs. During storms, flows can get up to 175 cfs, and during summer, irrigation diversions in the lower mile can reduce flows to 2 cfs (Beyer 1984); (D. Maria, former CDFG Biologist, pers. comm.). These diversions are strictly for agricultural (pasture) use and do not operate in the fall, winter, and early spring. Thus, diversions would not affect salmon spawning. Flows should be adequate for salmon spawning (D. Maria, former CDFG Biologist, pers. comm.). Rearing habitat is good to excellent as the cattle exclusion fencing in the lower mile has created a riparian strip with an abundance of woody and other vegetative instream cover (D. Maria, former CDFG Biologist, pers. comm). Flows and water quality in Shovel Creek are probably adequate to maintain a run of fall-run Chinook salmon (Fortune et al. 1966).

Habitat projects have improved trout production and survival in Shovel Creek for redband/rainbow trout (California Department of Fish and Game 2000). However, spawning success may be limited by the low amount of spawning gravels (Beyer 1984). Shovel Creek supported about 250 to 300 adult pairs of redband/rainbow trout during 1985 – 1990, and most juveniles emigrate from Shovel Creek to the Klamath River in late summer and fall as young of year (YOY) rather than as newly emerged fry in spring (California Department of Fish and Game 2000), suggesting a healthy spawning and rearing environment.

2.1.4.7. Copco Reservoirs - Near RM 209, the Klamath River crosses into California, and enters Copco 1 reservoir near RM 204. Copco 1 reservoir is about 4.5 miles long. Copco reservoir is impounded by Copco No.1 Dam at RM 198.7, where flow is diverted into the adjacent Copco No. 1 Powerhouse. About one-half mile below this powerhouse, Copco No. 2 Dam diverts almost the entire flow from Copco No. 2 reservoir into a penstock (a very large pipe directing flow to a turbine) around the 1.4-mile Copco bypassed river reach to Copco No. 2 powerhouse at RM 196.8. Copco reservoirs have poor water during summer months and contribute to degradation of downstream water quality (Federal Energy Regulatory Commission 2007; USDI Klamath River Basin Fisheries Task Force 1991). Copco dams have no upstream or downstream fishways.

2.1.4.8. Mainstem Klamath River – Copco No. 2 Bypassed Reach - The Copco No. 2 Bypassed Reach is about 1.4 miles long. It extends from the Copco No. 2 Dam (RM 198.3) to the Copco No. 2 powerhouse (RM 196.9). A minimum flow of 5 cfs is currently discharged into the Copco No. 2 Bypassed Reach, while the rest of the river flow (up to ~3,000 cfs) is diverted to the powerhouse. This reach is in a steep, narrow canyon with bedrock, boulders, large rocks, and occasional pool habitat. Water quality is likely poor in summer because its source, Copco No. 2 reservoir, has high temperatures and AFA blooms in summer (PacifiCorp 2004b). The powerhouse discharges directly into a short reach of river just above Iron Gate reservoir.

FERC noted that Chinook salmon occurred in this reach historically and that they outmigrate after rearing in freshwater for several months, so if this species is reintroduced to the Copco No. 2 Bypassed Reach, it may emigrate from the reach before water temperatures become severely stressful in July and August. The ability to develop a self-sustaining run would depend on successful passage through Iron Gate reservoir, past IGD, and through the lower Klamath River (Federal Energy Regulatory Commission 2007).

2.1.4.9. Fall Creek - Fall Creek is a small tributary of the Klamath mainstem that enters the river below Copco No. 2 powerhouse and at the upstream end of Iron Gate reservoir. Springs in the upstream reaches feed the creek year round producing relatively uniform flow of good quality water for anadromous fish. Minimum flows are rarely less than 30 cfs (Coots 1957), and are typically above 40 cfs (PacifiCorp 2004b). Approximately 1.15 miles upstream from the Klamath River, a small powerhouse and a water fall block access upstream to anadromous fish (Wales and Coots 1954). The Fall Creek powerhouse is operated without storage, as a run-of-river facility (PacifiCorp 2004b). The City of Yreka diverts up to their water right of 15 cfs downstream of the powerhouse for drinking water purposes. Just downstream, an additional diversion of 10 cfs may go to the Fall Creek fish-rearing facility (not operated in all years) and then is returned to the creek a short distance downstream (PacifiCorp 2004b).

Before construction of IGD in 1960, Fall Creek supported Chinook and coho salmon, both resident and anadromous steelhead rainbow trout, Pacific lamprey, Klamath smallscale suckers (*Catostomus rimiculus*), and Klamath sculpins (*Cottus klamathensis*) (Coots 1957). The creek has a steep gradient, and is about 14 feet in width. Some aspects of the creek are not typical of quality spawning habitat, but spawning efficiency was well documented in 1954 (Wales and Coots 1954). This predominantly spring-fed tributary may provide refuge for redband/rainbow trout from Iron Gate reservoir during the summer when water quality conditions are poor.

2.1.4.10. Jenny Creek - Jenny Creek flows approximately 25 miles from Oregon to Iron Gate reservoir on the Klamath River in California (Oregon Department of Fish and Wildlife 1997). The watershed has numerous springs and small tributaries. Portions of the creek are grazed by livestock. Jenny Creek was excluded from consideration as salmonid habitat because "of limited spawning areas and blockage of fish passage by two falls, 20 feet and 60 feet high" (Fortune et al. 1966). However, about 250 Chinook salmon were estimated to have spawned in the lower mile of Jenny Creek (Coots and Wales 1952). Little spawning habitat and no salmon were reported above the first mile.

Some of Jenny Creek water is diverted into the Rogue River Basin at Howard Prairie and Hyatt reservoirs. BLM (USDI Bureau of Land Management 1995) estimated this export to be 30,000 AF annually. The diversions have apparently taken place from this stream since the 1920's. Currently, nearly all of the western side of the Jenny Creek watershed between these two reservoirs and the California border is now within the Cascade-Siskiyou National Monument; thus, future diversions in this significant portion of the watershed are not likely to increase.

2.1.4.11. Iron Gate Reservoir - Below Copco 2 powerhouse, the river flows into Iron Gate reservoir, impounded by IGD at RM 190. Iron Gate reservoir is approximately 6.8 miles long. This is the furthest downstream of the Project facilities. Here, the flow passes through the Iron Gate powerhouse, and then continues in the Klamath River for 190 miles to the Pacific Ocean. IGD has no upstream or downstream fishways. Iron Gate reservoir has poor water during summer months and contributes to degradation of downstream water quality (Federal Energy Regulatory Commission 2007; USDI Klamath River Basin Fisheries Task Force 1991).

2.1.5. Conditions with Dams in the Project Reach - Hydrology and Water Quality

Below Keno Dam, current project reservoirs would continue to contribute to low DO, downstream thermal phase shift (Bartholow et al. 2005), nutrient effects on algal abundance, and exacerbation of algal toxins. Copco 1 and Iron Gate reservoirs in particular would most likely continue to degrade temperature and DO (Federal Energy Regulatory Commission 2007; PacifiCorp 2004b) of downstream habitats for decades to come. Inputs of important coldwater tributaries (e.g., Fall Creek and Shovel Creek,) and springs would continue to be overwhelmed by thermal mass and long hydraulic residence time (HRT) in the reservoirs. The thermal regime of the river downstream of the reservoirs would continue to be out of phase with the natural temperature regime. The coldwater inflow to the J.C. Boyle Bypassed Reach (Big Springs) would continue to influence the Bypassed Reach until mixed with powerhouse flows.   Downstream from this point the mixture of coldwater inflow from Big Springs and the warmer water discharge from the J.C. Boyle powerhouse would continue to create unnatural temperature fluctuations (USDI Bureau of Land Management 2003).

The effects of ongoing and future upstream water quality improvements under TMDL would likely improve water quality over the period of analysis, but there is less certainty as to when TMDL targets (e.g., nutrients, DO, and water temperature) would be achieved (USDI Secretarial Determination Water Quality Subgroup In Review).

2.1.6. Conditions without Dams and with KBRA in the Project Reach - Hydrology and Water Quality

Without J.C. Boyle, Copco 1, Copco 2, and Iron Gate Dams, Klamath River hydrology would no longer be dominated by hydropower peaking events. Although, the hydrograph would still be influenced by the Klamath Reclamation Project, flows would more closely mimic the natural hydrograph. Evaporation and solar warming associated with the surface area of existing reservoirs would be reduced to that occurring from the reclaimed river channel, most of this recovered water (estimated to be conservatively as 5,780

AF/annually[13]; T. Mayer, Service, pers. comm.) would be assumed to flow down the river.

Initial analysis of KBRA flows show they would provide additional habitat in the PR for anadromous fish when needed for migration (Hetrick et al. 2009). Water quality would be improved more readily (Dunne et al. 2011), and TMDL targets would be reached sooner, (USDI Secretarial Determination Water Quality Subgroup In Review) with KBRA habitat restoration. Both KBRA and TMDL water quality improvements within and upstream of the Keno reservoir would propagate downstream and, therefore, would likely be more fully realized below IGD in the absence of Project reservoirs. Increased topographic shading and reduced solar surface warming resulting in cooler water temperature would more likely be realized under dam removal.

Water quality would no longer be influenced by J.C. Boyle, Copco 1, Copco 2, and Iron Gate reservoirs. Under conditions with the lower four dams removed, HRT through the river where reservoirs currently exist would decrease from several weeks to less than a day.

Some have pointed to net annual retention in the reservoirs as evidence that nutrient concentrations may increase in the river downstream of Keno Dam if the downstream dams are removed (PacifiCorp 2006). However, overall net retention at Iron Gate and Copco reservoirs accounted for a relatively low percentage (11 percent for Total Phosphorous (TP), and 12 percent for Total Nitrogen (TN)) of inflow on an annual basis for the three year period from May 2005 through December 2007 (Asarian et al. 2009). While it is evident that the reservoirs do retain nutrients on an annual basis consistent with reservoir functions globally (Harrison et al. 2009), the importance of this concept is probably overshadowed by the importance of intra-annular dynamics of nutrients that show the reservoirs retain nutrients primarily in the winter months by capturing particulate matter from upstream. During the summer and fall months the reservoirs can release nutrients that helps stimulate primary productivity (Asarian et al. 2009). There would likely be more nutrient assimilation in a riverine environment (dams removed) than reservoir environment (with dams), thereby improving water quality.

Removal of Project reservoirs would allow important coldwater tributaries (e.g., Fall Creek and Shovel Creek) and springs to directly enter and flow undiluted down the mainstem Klamath River, thereby providing 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 salmon migrations. Without the dams, the thermal regime of the river downstream of the reservoirs would be in phase with the natural temperature regime.

With higher flows, the coldwater influence from Big Springs would be diminished in the current Bypassed Reach (Bartholow and Heasley 2005) but not eliminated. FERC

[13] Based upon an annual evaporation rate of 4 ft/yr and an average total surface area of 1,445 acres for the four reservoirs.

concluded that the high degree of turbulence in this reach would cause a high degree of mixing of warm and cool water (Federal Energy Regulatory Commission 2007). Simulated water temperatures within the J.C. Boyle Bypassed Reach indicate that removal of the project dams would reduce daily minimum and mean water temperatures from April through October within the reach upstream of the spring inflows, but would increase daily minimum, mean, and maximum water temperatures downstream of the springs (Dunsmoor and Huntington 2006). Lowered water temperatures upstream of the springs would improve conditions for rearing, migrating, and spawning salmonids in this relatively short (0.5 mile) reach, but daily mean temperatures would still exceed 20°C during July and August, which may limit the value of this upstream habitat for supporting rainbow trout and as holding habitat for spring-run Chinook salmon and summer steelhead. Downstream from the springs, FERC concluded that increased water temperatures could adversely affect the suitability of habitat in this reach for salmonid rearing and as holding habitat for adult spring Chinook salmon and summer steelhead (Federal Energy Regulatory Commission 2007).

However, dilutive flows downstream from the springs are less likely to occur at the time of year that cool water areas are functioning as thermal refugia. Access under this management scenario would still mean additional habitat for spring-run Chinook salmon and summer steelhead provided by groundwater in the Bypassed Reach. Below the location of the powerhouse temperatures would no longer be subject to extreme and unnatural fluctuations as they are under current conditions (City of Klamath Falls 1986; USDI Bureau of Land Management 2003).

The restored channel and thermal regime will play a significant role in nutrient dynamics as will other natural riverine processes; most notably re-aeration of water provided by a turbulent well-mixed river. Under dam removal, an additional approximately 23 miles of free flowing river (Cunanan 2009) would assimilate nutrients. The additional assimilative capacity is expected to reduce nutrient concentrations as well as minimize low DO concentrations and high pH events. In addition, the assimilative capacity for nutrients of the Klamath River would likely be further elevated over the current regime because of increased flows in the bypassed reaches.

It has been pointed out that, while dam removal may increase supply of marine derived nutrients provided by the carcasses, eggs, and young of anadromous fish, increasing the supply of nutrients could adversely affect water quality conditions which currently are subject to elevated nutrient loads in the upper basin (Federal Energy Regulatory Commission 2007). At the same time, salmon smolts have been identified as important exporters of nutrients, in particular phosphorous (P), from freshwater ecosystems (Scheuerell et al. 2005). Elevated levels of P in the Klamath ecosystem have been identified as a significant problem. Further analysis of this uncertainty is beyond the scope of this report.

2.1.7. Existing Riverine and Geomorphic Processes Above Iron Gate Dam

PacifiCorp (PacifiCorp 2004a) provides the following description of the geology of the PR: "From Keno downstream, the Klamath River flows in a steep bedrock channel to approximately the California line, interrupted only by a short alluvial reach above J.C. Boyle Dam. In the California reach above Copco reservoir, the Klamath River is alluvial, though with occasional bedrock controls. The short reach of river between Copco and Iron Gate reservoirs is steep and bedrock-controlled."

Physical, chemical, and biological processes of the Klamath River have been significantly diminished above IGD (National Research Council 2004a). As discussed in the Hydrology and Water Quality section above, the Klamath River hydrology has been altered, resulting in a reduction of the duration and magnitude of high flows from historical levels and shifting of the seasonality of flows (Balance Hydrologics Inc. 1996) to provide fewer ecosystem benefits. Water quality also has been degraded. UKL has moved from eutrophic to a hypereutrophic state, with profound negative effects for fish in the lake and downstream ecosystem (Kann 1998; Oregon Department of Environmental Quality 2002).

Geomorphic and vegetative processes that form channels and provide habitat and create spawning gravels have been disrupted by Project dams (California Department of Water Resources 1981; PacifiCorp 2004a; USDI Klamath River Basin Fisheries Task Force 1991). Because of the small size of Project reservoirs relative to the Klamath River's annual runoff, the Project reservoirs are unlikely to significantly affect high flows, but they trap all bed load sediment, resulting in some coarsening of the bed downstream of Project dams (PacifiCorp 2004a).

Fish studies have shown considerable biological impacts due to Project peaking (City of Klamath Falls 1986; Federal Energy Regulatory Commission 2007; USDI Bureau of Land Management 2002; Wales and Coots 1950). From June 1948 to May 1949, prior to the construction of IGD, Project peaking operations resulted in the loss of over 1.8 million salmonid fingerlings below Copco 1 Dam (Wales and Coots 1950). While the completion of IGD in 1962 reregulated Copco flows, these peaking impacts continue for resident fish in the PR. Daily extreme flow fluctuations such as those that occur in the PR during peaking operations (City of Klamath Falls 1986; Federal Energy Regulatory Commission 2007) result in high mortalities of many aquatic populations from physiological stress, wash-out during high flows, and stranding during rapid dewatering (Cushman 1985; Petts 1984). It is likely that trout have significantly increased energetic costs due to movements required to adjust to extreme flow fluctuations from hydroelectric peaking operations. These conditions reduce the diversity, productivity, and abundance of riverine organisms (Cushman 1985). However, on the Klamath River, some site specific studies show limited effects to aquatic biota (PacifiCorp 2005a).

Current flow fluctuations have adversely affected riparian resources in both the bypassed and peaking reaches by supporting the perpetuation of reed canary grass and by affecting the structure, size, and nature of depositional features (Administrative Law Judge 2006).

Project operations have reduced the number of flow events that can scour established reed canary grass (Administrative Law Judge 2006), an ecologically undesirable species that provides little habitat for native fauna (Federal Energy Regulatory Commission 2007). Approximately two-thirds of the riparian habitat in the J. C. Boyle Bypassed Reach is riparian grassland, which is predominately reed canary grass (Federal Energy Regulatory Commission 2007). Reed canary grass can adversely affect downstream channel formation (Slemmons 2007) by effectively trapping sand, gravel, and small cobble in its dense root mass. Such material would otherwise have been transported downstream where it would replenish similar sized bed material scoured by floods. This may adversely affect abundance and quality of fish and terrestrial habitat (Federal Energy Regulatory Commission 2007). Reed canary grass is adapted to survive in frequently inundated coarse substrate and is capable of out-competing woody riparian vegetation, however, Project operations continue to maintain, to a certain degree, woody vegetation in the by-pass reach (Administrative Law Judge 2006).

2.1.8. Conditions with Dams - Riverine and Geomorphic Processes Above Iron Gate Dam

With dams in place, the ecosystem and aquatic habitat conditions available upstream of IGD are likely to remain similar as those described above. The effects of ongoing and future upstream water quality improvements under TMDL would improve water quality (although it is possible that water temperature standards would not be met). However, these conditions are unlikely to affect flows or geomorphic and vegetative processes that would form channels to provide fish habitat and spawning gravels above IGD.

From a geomorphic perspective, the continued elimination of the upstream sediment supplies in this system would be the primary Project impact on Klamath River geomorphology (Federal Energy Regulatory Commission 2007; PacifiCorp 2004a). Because of sediment starvation, bed material has coarsened and active features (e.g., point bars, islands) are made up of less fine sediment (Administrative Law Judge 2006). These impacts would continue under this scenario.

2.1.9. Conditions without dams and with KBRA - Riverine and Geomorphic Processes Above Iron Gate Dam

Higher seasonal flows, such as those under KBRA, will improve the quality of riparian habitat in the J.C. Boyle Bypassed Reach. Seasonal high flows in the Bypassed Reach would create more frequent and larger magnitude flow events, mobilizing and transporting wider ranges of sediment deposition (Administrative Law Judge 2006). High flows can scour encroaching reed canary grass (Administrative Law Judge 2006) and encourage establishment of willow in riparian areas. Willow is a desirable riparian plant that germinates and establishes itself on freshly deposited alluvium (material transported and deposited by river flows) (Administrative Law Judge 2006).

KBRA flows, dam removal, and KBRA restoration would improve water quality and restore assimilative capacity of the river to process nutrients. KBRA type flows would move the hydrograph toward a duration, timing, and magnitude of flows that provide more ecosystem benefits above IGD than have been provided in recent years (Hetrick et al. 2009). These flows are expected to meet channel maintenance needs to route coarse sediments, build bars, erode banks, flush fine sediments, scour vegetation and undercut and topple large woody riparian vegetation (National Research Council 2007). The removal of Project dams would reestablish geomorphic and vegetative processes that form channels that provide fish habitat and spawning gravels in the PR above IGD, especially in the former bypassed reaches (Federal Energy Regulatory Commission 2007).

In the first few years following removal, the evolution of the new channel within reaches previously impounded would likely initiate with multiple braids of channel degradation and widening, followed by lateral movement and incision until the time required for the channel to reach equilibrium condition (months, years, or decades) (Randle and Greimann 2004). Because the reservoirs are wider than the natural stream channel, some of the sediment along reservoir margins may remain for a long period of time and perhaps indefinitely. The river may migrate over the former reservoir area and eventually erode most of the stored sediment, but this process may be slow, and it is possible that much of the sediment would become stabilized by woody vegetation, such as willow, before a large flow erodes the sediment (Randle and Greimann 2004).

Tributaries that flow into Project reservoirs will deliver coarse bed materials in sufficient quality and quantity to restore habitat in the mainstem Klamath River, rather than these materials remaining trapped upstream of the dams. Sediment delivery with seasonal high flows would likely result in deposition of gravel in low velocity pockets on the bed and fine sands on the banks. These deposits would have ecological benefits including creating spawning pockets around boulders and in pools. Flows of adequate duration and frequency can clean and redeposit gravel to provide quality spawning habitat (Administrative Law Judge 2006). The more natural flow regime under KBRA would mean a greater likelihood of flows of adequate duration and frequency to achieve this.

2.1.10. Existing Klamath Basin National Wildlife Refuges

Tule and Lower Klamath Lakes, located in southern Oregon and Northern California historically comprised approximately 187,000 acres of open water, emergent marshes and seasonally flooded wetlands (USDI Fish and Wildlife Service 1956). Tule Lake was primarily maintained through inflows from the Lost River with periodic overflow from the Klamath River during high flow events. During the late 1800s (prior to the Klamath Project), the lake ranged in size from 53,000 acres to slightly over 100,000 acres (Abney 1964). Lower Klamath Lake fluctuated much less than Tule Lake and received nearly all its water from the Klamath River through a narrow channel called the Klamath Straits. Lower Klamath Lake was comprised of approximately 80,000 acres, with that acreage expanding and contracting through the year based on fluctuating water levels in the Klamath River (Weddell 2000).

Wildlife resources of the historic lakes and marshes were truly spectacular. Early naturalist and photographer William Finely noted in a tour of Lower Klamath Lake in 1905:

> "We cruised over a large part of the lake, and found that the large rookeries of cormorants, grebes, white pelicans, great blue herons, California gulls and Caspian terns form one of the most extensive bird colonies we have ever seen. Doubtless this locality has never been disturbed to any extent by Man. This is the great breeding ground of that whole region." (William Finley as reported in (Dutcher 1905)).

In addition to colonial nesting waterbirds, waterfowl populations were especially large and supported a robust market hunting economy. During the fall/winter of 1903-04, 120 tons of wild ducks were shipped to the markets in San Francisco (Finley and Finley 1925). In addition to the market hunting of waterfowl, large numbers of waterbirds were shot for their skins and feather. One of the principal reasons for the establishment of Lower Klamath NWR was to protect wetland birds from excessive commercial exploitation (Weddell et al. 1998).

In 1905, the historical hydrology of the Lower Klamath and Tule Lake Basins began to change with creation of the Klamath Reclamation Project. The purpose of the Project was to develop irrigation infrastructure to allow for the agricultural development of the basin. Lower Klamath and Tule Lake NWRs were established on lands already withdrawn for reclamation. Lower Klamath NWR was established in 1908 via Executive Order 928 and Tule Lake NWR was created in 1928 Executive Order 4975. Presently, Tule Lake NWR is comprised of 39,117 acres and Lower Klamath NWR consists of 53,600 acres. Although these Executive Orders protected wildlife from illegal shooting and other activities, reclamation and irrigation remained the primary focus of land management.

Plans to homestead lands within both Refuges in the 1950's resulted in intense debate between agricultural interests and conservationists over the future of the Refuges. After more than a decade of debate, the Kuchel Act (Public Law 88-567) was enacted on September 2, 1964. The Act declared that the lands within Tule Lake and Lower Klamath NWRs were dedicated to wildlife conservation for the major purpose of waterfowl management, but with full consideration to optimum agricultural use that is consistent with waterfowl management. The Act permanently placed the Refuges in governmental ownership and allowed for the continued leasing of specific refuge lands for agricultural use, consistent with waterfowl management.

The upper Klamath basin forms a natural funnel for the Pacific Flyway as migratory waterfowl transition from northerly breeding areas to major wintering sites in the Central Valley of California and Mexico (Gilmer et al. 1982). Lower Klamath and Tule Lake NWRs represent key migrational spring and fall staging areas in upper Klamath basin and the larger Pacific Flyway (Gilmer et al. 2004). Although Flyway waterfowl numbers have declined from the mid-20th Century, the importance of both refuges to waterfowl in the Flyway has remained unchanged. The following narrative was written by the Service during planning activities prior to enactment of the Kuchel Act in 1964:

> "Adequate lands, water, and food for waterfowl in the Upper Klamath River Basin are indispensable to the welfare of the Continental waterfowl population. About 80 percent of all the waterfowl of the Pacific Flyway funnel through the Upper Klamath River basin in their annual migrations. In the fall of 1955, for example, there were at one time upwards of 7,000,000 birds on the Lower Klamath and Tule Lake National Wildlife Refuges in the Basin. This is the greatest concentration of waterfowl in North America and probably in the world (USDI Fish and Wildlife Service 1956)."

Both refuges are particularly important to certain species of waterfowl, supporting significant proportions of Pacific Flyway populations. Fleskes and Yee, in an assessment of spring waterfowl use of the Southern Oregon and Northeastern California (SONEC) region, determined that 50.3 percent of the waterfowl wintering in California utilized this area during spring migration (Fleskes and Yee 2007). Sixty-six percent of the total use in the SONEC region occurred in the Lower Klamath basin (defined as most of the Klamath Project area east to Goose Lake, California) with the Klamath Basin NWR Complex supporting most of these birds. Especially notable was use by pintails (*Anas acuta*), a species of continental concern. Fleskes and Yee (Fleskes and Yee 2007) concluded that the SONEC region is a critical spring staging area for waterfowl that winter in the Central Valley of California and other Pacific Flyway regions and should be a major focus area for waterfowl-habitat conservation efforts.

The refuges, and fish and wildlife, are not included as a purpose of the Klamath Reclamation Project. As such, the refuges have a relatively low priority for water delivery and cannot receive water until irrigation and other Reclamation obligations needs are met. Water shortages of varying magnitude to Lower Klamath NWR occurred frequently through the 1990's and 2000's. During the fall of 2010, the refuge was the driest it has been in over 70 years (D. Mauser, Service, pers. comm.).

Tule Lake NWR water needs are met via return flows from agricultural lands surrounding and within the refuge. This includes water to maintain elevations within the Sumps (13,000 acres of wetland habitats), consistent with current operating rules and regulations and BOs, as well as water needed to serve the agricultural lease lands. Currently, Refuges have no allocation of water and only receive water in excess of BO, Tribal Trust, and Project Irrigator needs.

"Walking Wetlands", the practice whereby wetlands are inserted into commercial rotations, can be denied water if the Klamath Project deems water delivered to agricultural crops is a better use of water resources. The Refuge Manager has no authority to direct water to Walking Wetlands.

The lease land farming program is subject to the National Wildlife Refuge System Improvement Act of 1997 as well as the Kuchel Act and will be evaluated in the upcoming Comprehensive Conservation Plan as it relates to the primary purpose of waterfowl management and other applicable laws, regulations and policy. The Refuge receives no funds from the current leasing program.

All refuge outflows, as well as drainage water from the Klamath Project, enter Keno reservoir via the Klamath Straits Drain. One of the main water quality concerns in the Klamath River Basin is the impact of Klamath Project returns on water quality and salmon in the Klamath River (Mayer 2005). Studies of return flows from Lower Klamath NWR determined that the ultimate effect of refuge wetland management is to decrease net nitrogen (N) and P loads but increase the ratio of bioavailable P to bioavailable N in the refuge outflow (Mayer 2005). All N and P forms showed net retention over the irrigation season, indicating that the refuge wetlands are retaining N and P and improving outflow water quality in terms of nutrients (Mayer 2005).

2.1.11. Conditions with Dams- Klamath Basin National Wildlife Refuges

The refuges, fish, and wildlife would continue to not be included as a purpose of the Klamath Reclamation Project. As such, the refuges would have no priority for water delivery and cannot receive water until irrigation needs are met. The refuges would continue to have no water management flexibility and will remain unable to adapt to drought year extremes.

Management of Refuge lease lands would remain subject to the Refuge System Improvement Act, the Kuchel Act, and all other applicable laws, regulations and policies.

2.1.12. Conditions without dams and with KBRA- Klamath Basin National Wildlife Refuges

If the KBRA is enacted, the refuges would, for the first time in over 100 years, receive a certainty of water delivery. If the KBRA had been in place in 2009, the summer water delivery to Lower Klamath NWR would have been 48,000 AF, about twice as much water as what the refuge actually received in 2009.

KBRA would provide for modification of Klamath Project Purpose so that Refuge purposes would be added to assure that the refuge water allocation is equal in priority to the irrigator's allocation. This provision also would allow the Refuge to enter into contracts with irrigation districts and/or Reclamation for the delivery of Refuge water through Klamath Reclamation Project facilities. The Refuges would receive sufficient water for wildlife purposes in nine of ten years. A Drought Plan would be developed to address the occasion when water is in extremely short supply. Refuge managers would have the ability to call for water when it is needed which gives them the flexibility to create optimum habitat conditions. Without dams and with KBRA, Lower Klamath NWR would be provided with a Water Allocation (Apr-Oct): 48,000 AF in dry years increasing incrementally to 60,000 AF in wet years. Even this dry year allocation of 48,000 AF would provide for full refuge needs 88 percent of years. This dry-year wet-year approach is similar to that used by Klamath Reclamation Project water users. Reductions in allocation would not be imposed disproportionately to Tule Lake NWR.

Walking Wetlands would receive water from both the Lower Klamath allocation (1 AF/acre) and the irrigator's available supply (2 to 2.5 AF/acre). The refuge would gain additional wetland habitat for a relatively minor cost in terms of water allocation, and the Klamath Reclamation Project irrigators would not be penalized for using additional water to provide wetlands on private lands. This provision would apply to "walking wetlands" on both private lands and lease lands on Tule Lake NWR. The use of Lower Klamath allocation on walking wetlands must be approved by the Refuge Manager.

KBRA would provide the refuge authority to order water delivery through Klamath Reclamation Project pumping facilities including D-Plant and several pumping plants on the Straits Drain. Management of Refuge lease lands would remain subject to the Refuge System Improvement Act, the Kuchel Act, and all other applicable laws, regulations and policies. The parties agree to pursue collaborative conservation measures on the lease lands, including walking wetlands, as well as other practices beneficial to wildlife. The Service would maintain the ultimate administrative control over the lease lands; however, Tule Lake Irrigation District (TID) and Klamath Drainage District (KDD) would become the leasing agent for those lands. The lands would be managed consistent with the Kuchel Act. Because of the close proximity of TID and KDD, lease administration and coordination with the Service would be much improved. Under this provision, the Refuge would receive 20 percent of net lease revenues for implementation of conservation practices on the Refuge. In 2009, the Refuge share would have been $640k.

Frequent drought conditions experienced in the Refuges will likely be exacerbated by the effects of climate change. While KBRA provides a suite of management changes and water allocations to mitigate currently inadequate supplies of water under drought conditions, these have yet to be specified.

2.1.13. Existing (Historical) Anadromous Fish Species Above Iron Gate Dam

Access for all anadromous salmonid species is blocked above IGD. Based on the historical range of anadromous fish in the watershed (Butler et al. 2010; Hamilton et al. 2005) and assessment of the current condition of that habitat (Huntington 2006), this would total over 420 miles of habitat currently unused by anadromous fish, including 81 miles of habitat in the PR (Administrative Law Judge 2006; Cunanan 2009). This total includes the mainstem Klamath River, Jenny, Fall, Shovel, and Spencer creeks, as well as numerous smaller tributaries. Habitat under the lower four Project reservoirs is also currently unused. Cunanan (Cunanan 2009) estimated this to be approximately 23 miles of river mainstem, river side channel, and tributary habitat.

Table 1 summarizes the historical and potential population estimates of anadromous fish in the Klamath River Basin associated with this habitat. These estimates provide a range of numbers of natural anadromous spawners potentially supported by access to historical habitat upstream from the current location of IGD based upon information to date. In some respects, the historical estimates are conservative because the estimated run sizes were already reduced at the time estimated. Reductions were due to overfishing, mining, and land use degradation of the habitat early in the 20th century. Although, the restoration effects of KBRA and access to historical habitat are expected to have positive effects, they will likely be accompanied by the uncertainty of conditions beyond the scope of this endeavor such as ocean conditions and climate change. There will continue to be uncertainty around all approaches to determining impacts of dams and anadromous salmonid production gains if dams are removed. The summary in Table 1 needs to be considered as a context for other analyses of anadromous fish gains if dams are removed.

2.1.13.1. Existing (Historical) Chinook Salmon Above Iron Gate Dam

NMFS, in its administration of the ESA, defines Chinook salmon and other anadromous species by Evolutionarily Significant Units (ESUs). An ESU is a population or group of populations of salmon that are substantially reproductively isolated from other populations and contribute substantially to the evolutionary legacy of the biological species. As defined by NMFS, the Upper Klamath and Trinity Rivers Chinook Salmon ESU includes all populations from the Trinity and Klamath rivers upstream from the confluence of the Trinity River. These populations include Chinook salmon that enter the Klamath River upstream of the Trinity River from March through July (spring-run) and July through October (fall-run), and spawn from late August through early January. Chinook salmon in the Klamath River are not currently listed under the ESA.

NMFS determined that, within the Klamath River upstream of the Trinity River, there are statistically significant, but fairly modest, genetic differences between the fall and spring runs. Fall-run Chinook salmon generally emigrate as sub-yearlings. However, some fall-run Chinook salmon migrate as yearling smolts. They have the ability to adapt to changing thermal conditions and delay emigration until their second spring in freshwater, as they have done in Snake River reservoirs (Connor et al. 2005). Spring-run Chinook salmon generally outmigrate at age 1. Recoveries of coded wire tags (CWT) indicate that both runs have a coastal distribution off California and Oregon. NMFS determined that there was no apparent difference in the marine distribution of CWT recoveries from fall-run (Iron Gate and Trinity River hatcheries) and spring-run populations (Trinity River Hatchery) (Myers et al. 1997).

NMFS also determined that fall-run populations in this ESU were at relatively high abundances, near historical levels, and trends were generally stable (Myers et al. 1997). However, the status of natural spawning fall-run Chinook salmon is on a downward trajectory in the Klamath River (R. Quiñones, USFS, pers. comm). Basin wide escapement is staying close to consistent, even with natural-spawning fall Chinook salmon continuing to decline over time, due to an increasing proportion of hatchery fish (R. Quiñones, USFS, pers. comm); Figure 4. Some argue that the majority of the returning Klamath River Basin salmon are now hatchery reared fish (Institute for Fisheries Resources and Pacific Coast Federation of Fishermen's Associations 2006).

Chinook salmon populations were extirpated with the construction of Project dams. Historically, the range of this species included tributaries to UKL (Butler et al. 2010; Hamilton et al. 2005). In past decades, managers have depended on hatcheries to make up for the loss of Chinook salmon production in habitats above the dams and the production of hatchery fish to supplement harvest remains a management tool. However, times and conservation strategies have changed with an increased emphasis on the goal of restoring natural runs (National Marine Fisheries Service 2009; USDI Klamath River Basin Fisheries Task Force 1991; Williams et al. 2008). Reliance on hatchery production can make populations of Chinook salmon in the Klamath River more vulnerable to sudden collapse due to environmental changes (Independent Scientific Advisory Board 2005; Lindley et al. 2009).

The Upper Klamath and Trinity Rivers Chinook Salmon ESU, as a whole, has not been at significant risk of extinction, but there is substantial concern for the status of spring-run populations (Myers et al. 1997). Historically, spring-run Chinook salmon in the Klamath River Basin were very important (Myers et al. 1997; National Research Council 2004a; Snyder 1931) and, according to some sources, substantially outnumbered fall-run Chinook salmon (Gatschet 1890; Spier 1930). Currently, in contrast to fall-runs, spring-run abundance is at only 10 percent of historical levels (Myers et al. 1997). Huntington (Huntington 2006) reasoned that they likely accounted for the majority of the upper basin's actual salmon production under pristine conditions, but were apparently in substantial decline by the early 1900s. The cause of the decline of the Klamath River spring-run Chinook salmon prior to Copco 1 Dam has been attributed to dams, overfishing and irrigation, and largely to hydraulic mining operations (Coots 1962; Snyder 1931). Dam construction eliminated much of the historical spring-run spawning and rearing habitat and was partly responsible for the extirpation of at least seven spring-run populations from the Klamath-Trinity River system (Myers et al. 1997). The disappearance of the large run in the Shasta River coincided with the construction of Dwinnell Dam in 1926 (Moyle et al. 1995 in National Research Council 2004a). With hydraulic mining operations now outlawed, spring-run Chinook salmon would no longer be subject to one of their most significant threats in the Klamath River.

Restoration under KBRA provides considerable potential to increase spring-run abundance. However, Huntington (2006) cautioned that the existing potential for Chinook salmon production within the basin above UKL is clearly much lower than his estimate of historical potential. While significant restoration has taken place throughout the Klamath watershed, and there are extensive opportunities for rehabilitating habitat above and in UKL, Huntington (2006) notes it is important to recognize that significant portions of the historical production potential are unlikely to be recovered due to habitat degradation in the last ~100 years. Similarly, rehabilitation of anadromous fish habitat between IGD and UKL may fall short of pre-settlement conditions during the period of analysis because some of the habitat restoration may take longer than 50 years.

2.1.13.2. Conditions with Dams – Chinook Salmon Above Iron Gate Dam –

Under conditions with dams, Chinook salmon will remain extirpated in the Klamath River above IGD.

Under this scenario, considerable efforts to improve habitat are underway (National Marine Fisheries Service 2010b) toward the goal of recovery of salmon and steelhead stocks. Once implemented, TMDLs and associated Implementation Plans are expected to improve water quality, reduce stress on salmonids from pollution, and contribute to their recovery (National Marine Fisheries Service 2010b). However, without access to appropriate habitat, spring-run Chinook salmon runs will likely remain at a fraction of historical levels; it is possible that Klamath River spring-run Chinook salmon runs may become extinct (Moyle et al. In Press; Nehlsen et al. 1991) over the period of analysis.

Table 1. Estimates by various authors of the historical and current potential annual adult returns of anadromous fish in the Klamath River Basin. Methodologies differ by author therefore, please refer to reference for details.

Species Run Type	Actual Post Project Counts and Surveys*			Historical and Potential Production Estimates*			Source: Notes
	Min	Mean	Max	Min	Mean	Max	
Upper Basin, UKL and Upstream							
Chinook (all runs)					15,052 (H)		Chapman (Chapman 1981): Based on relationship between rearing Weighted Usable Area (WUA) and Habitat Capacity. Author believes that estimate is conservatively low.
Chinook (all runs)						111,230 (H)	Huntington (2006): The 2004 estimates were revised based on new watershed areas that better represent potential habitat conditions in the upper basin.
Chinook (all runs)					6,260 (P)		Fortune (1966): Estimated that 3,130 Chinook salmon pairs could be supported in this reach.
Chinook (spring-run)				10,000 (H)			California Department of Fish and Game (1990): Based on a minimum number of 5,000 spring-run Chinook ea. in the Williamson and in the Sprague Rivers.
Steelhead					8,447 (H)		Chapman (1981): Based on relationship between rearing Weighted Usable Area (WUA) and Habitat Capacity. Author believes that estimate is conservatively low.
Steelhead				6,852 (H)		20,044 (H)	Huntington (2004): Lower estimates are based on relationship between watershed area and population estimates for Shasta River and higher estimates are based on mean annual discharge and population estimates for the Shasta River.

Copco Dam to Upper Klamath Lake							
Chinook (fall-run)					19,207 (H)		Chapman (1981): Based on relationship between rearing Weighted Usable Area (WUA) and Habitat Capacity[14]. Author believes that estimate is conservatively low.
Chinook (fall-run)					2,920 (P)		Fortune (1966): Estimated that 1,460 Chinook salmon pairs could be supported in this reach.
Chinook (fall-run)					10,000 (P)		Based on FERC (2007)[15]
Steelhead					9,550 (H)		Chapman (1981): Based on relationship between rearing Weighted Usable Area (WUA) and Habitat Capacity[16]. Author believes that estimate is conservatively low.
Downstream of Copco Dam							
Chinook (fall-run)				175,000 (H)			Coots (1977): Based on estimates and counts of historical average annual spawning escapements.
Chinook (fall-run)		168,000					California Department of Fish and Game (1965): Based on spawning surveys 1962-63.
coho				20,000 (H)		70,000 (H)	Coots (1977): Based on estimates and counts of historical average annual spawning escapements.
coho		15,400					California Department of Fish and Game (California Department of Fish and Game 1965): Based on spawning surveys 1962-63.
Steelhead				300,000 (H)		750,000 (H)	Coots (1977): Based on estimates and counts of historical average annual spawning escapements.
Steelhead		221,000					California Department of Fish and Game (1965): Based on spawning surveys 1962-63.
Klamathon Racks (~RM 180) to Copco Dam							
Chinook (fall-run)	2,392	12,628	33,144				Wales (1951): Chinook salmon counts at Klamathon Racks from 1925 to 1950.

[14] Chapman's estimates were for IGD to UKL. This estimate was adjusted using the proportions of fish from IGD to Copco Dam and Copco Dam to UKL in FERC (2007).

[15] FERC (2007) estimates did not take into consideration habitat under the dams.

Iron Gate Dam to Copco Dam							
Chinook (fall-run)	1,113	6,026	18,925				Based on (FERC 1963; Fortune et al. 1966; and Coots 1977).
Chinook (fall-run)					1,200 (P)		Based on FERC (2007)[14]
Chinook (fall-run)					2,301 (H)		Chapman (1981): Based on relationship between rearing Weighted Usable Area (WUA) and Habitat Capacity[16]. Author believes that estimate is conservatively low.
Steelhead					1,144 (H)		Chapman (1981): Based on relationship between rearing Weighted Usable Area (WUA) and Habitat Capacity[16]. Author believes that estimate is conservatively low.
Downstream of Iron Gate Dam							
Chinook (fall-run)				21,120 (P)		80,810 (P)	Hubbell, P. M. and L.B. Boydstun (Hubbell and Boydstun 1985): Based on currently available run size data, available habitat, and professional judgment.
Chinook (fall-run)	4,889	25,145	83,918				California Department of Fish and Game (2010): Estimate derived from Fall-Run Chinook Mega-Table for natural adult spawners 1978 through 2009. Excludes runs size estimates for Trinity River fall Chinook salmon.
Shasta River							
Chinook (fall-run)	2,037	27,537	81,844				Wales (Wales 1951): Chinook salmon run size estimates conducted in the Shasta River from 1925 to 1950.
Chinook (spring-run)				5,000 (H)			(California Department of Fish and Game 1990): Based on a minimum number of 5,000 spring-run Chinook in the Shasta and Scott Rivers.
Scott River							
Chinook (spring-run)				5,000 (H)			California Department of Fish and Game (1990): Based on a minimum number of 5,000 spring-run Chinook in the Shasta and Scott Rivers.
Salmon River							
Chinook (spring-run)	166	732	1,721				Based on snorkel survey counts conducted between 1980 and 2009. Population estimates were expanded based on number of fish observed per mile of available habitat.

Klamath & Trinity Rivers							
Chinook (fall-run)					500,000 (H)		Moyle (2002)
Chinook (fall-run)				205,000 (P)		410,000 (P)	Institute for Fisheries Resources (Institute for Fisheries Resources and Pacific Coast Federation of Fishermen's Associations 2006)
Chinook (spring-run)					100,000 (H)		Moyle (2002)
Chinook (spring-run)				160,000 (P)		320,000 (P)	Institute for Fisheries Resources (2006)
Coho Salmon					75,000 (P)		Institute for Fisheries Resources (2006)
Steelhead Trout					150,000 (P)		Institute for Fisheries Resources (2006)

* 'Actual Post Project Counts and Surveys' are those for after the Project construction in 1918; 'Historical and Potential Production Estimates' are estimates, using various methods, of 1) the runs before the Project construction in 1918 (H); and 2) the estimated potential runs in the future (P). KlamRas model results by Oosterhout (2005) were excluded because they are only suitable for ranking. Ecosystem Diagnosis and Treatment (EDT) model estimates were excluded because of concerns about EDT modeling applications to the Klamath (USDI Fish and Wildlife Service 2005) and pending further review by the Service.

2.1.13.3. Conditions without dams and with KBRA – Chinook Salmon Above Iron Gate Dam

FERC concluded that successful fish passage through the Project has the potential to increase fish production by allowing anadromous fish to use historical production areas within and upstream of the project. Successful passage would provide access to important thermal refugia, most notably in the J.C. Boyle Bypassed Reach and in tributaries upstream of Upper Klamath Lake (Federal Energy Regulatory Commission 2007). Dam removal would make habitat accessible to both spring-run and fall-run Chinook salmon above IGD (Federal Energy Regulatory Commission 2007) and likely reestablish Chinook salmon above IGD in a short period of time, as observed after barrier removal at Landsburg Dam in Washington (Kiffney et al. 2008). A ranking level model comparison of fall-run Chinook spawners in the upper watershed predicts that numbers will likely be higher with dam removal than under conditions where the dams remain (Figure 5), over a 50-year period (Oosterhout 2005)[16].

[16] KlamRas modeling was a ranking level comparison of fall run Chinook production and returns to the upper watershed based for numerous alternatives over a 50 year period. These projections were completed as part of the FERC relicensing process. This modeling was done without projections of harvest because modeling of assumptions using harvest were considered to be too complex. Figure 5 compares the four dams out scenario to a dams in and volitional passage scenario. Oosterhout did not analyze the Current Condition scenario.

For the IGD to Copco Dam reach of the mainstem Klamath above IGD there are historical counts (with harvest) of Chinook salmon from 1925 to 1961 (Coots 1977; Federal Energy Regulatory Commission 1963; Fortune et al. 1966) enabling a comparison of conditions under the two management scenarios. These counts ranged from 1,113 to 18,925 Chinook salmon, averaging 6,026 per year. While habitat and conditions that supported runs in this reach have changed, with KBRA restoration and reduction in harvest to rebuild runs[17], it is not unreasonable to expect future returns in this reach to be within this range.

In addition to fall-run Chinook salmon, the dam removal management scenario would benefit spring-run Chinook salmon. Historically, adult spring-run Chinook salmon migrated upstream of the current location of IGD, perhaps as early as February and March (Klamath Republican articles in (Fortune et al. 1966)) and likely held over in large holding pools in the mainstem, in tributaries fed by cool water, and in headwater habitat above UKL (California Department of Fish and Game 1990; Moyle 2002; Snyder 1931). Precise details of the life history of spring-run Chinook salmon in the Klamath River Basin are unavailable (National Research Council 2004a).

Following construction of Project Dams, summer holding habitats for adult spring-run Chinook salmon in the mainstem Klamath River were restricted to a few large confluence pools fed by cold tributaries. Iron Gate Hatchery (IGH) maintained a remnant spring-run Chinook salmon population for a short period of time after construction of IGD. However, the lack of adequate holding facilities and high water temperatures resulted in unsuccessful spawning of the last 17 adults in 1978 (Catalano et al. 1997).

Dam removal provides an opportunity for spring-run Chinook salmon to become reestablished in the upper Klamath River. Holding areas with suitable temperatures currently exist above the Project such as Big Springs in the J.C. Boyle Bypassed Reach (USDI Bureau of Land Management 2003), groundwater influenced areas on the west side of UKL (Gannett et al. 2007), the Wood River (Gannett et al. 2007), and the Williamson River. The Williamson River both above and below its confluence with the Sprague River continues to provide deep, coldwater holding habitat (Hamilton et al. 2010). It is also possible that holding habitat exists under Project reservoirs, especially where tributaries join the mainstem. Dam removal would make these habitats available to migrating spring-run Chinook salmon adults. The removal of dam structures and improvement of water quality would likely improve conditions for outmigrating juveniles. However, the restored water temperature regime may change upstream migration timing of adult spring-run Chinook salmon because of the shift in water temperatures below IGD (Bartholow et al. 2005).

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[17] To the extent possible, adult salmon returning to Upper Klamath Lake and tributaries from Phase I Reintroduction efforts will be protected to minimize their harvest in sport, commercial, and Tribal fisheries until the phase II Reintroduction Plan is adopted." (see Section 11.3.1 C of KBRA).

Above UKL, KBRA implementation would reintroduce Chinook salmon in Phase 1 (KBRA section 11.3.1.A) – no sooner than one year[18] after the KBRA Effective Date. Even without supplementation, it is likely that Chinook salmon recolonization would occur as it did following barrier removal at Landsburg Dam in Washington (Kiffney et al. 2008).

One of the uncertainties associated with potential reintroduction is seasonal passage through UKL and Keno reservoir (Dunne et al. 2011). In its analysis, FERC did not include the 360 miles of habitat in the upper basin that would be made available if anadromous fish are able to migrate successfully through UKL and Keno reservoir (Federal Energy Regulatory Commission 2007). According to FERC, both of these water bodies present potential (but not necessarily insurmountable) impediments to migration due to adverse water quality conditions during part of the year (Federal Energy Regulatory Commission 2007). According to FERC, successful restoration of anadromous fish to habitat above Keno would be dependent on the timing of migration and on future changes in water quality (Federal Energy Regulatory Commission 2007).

Studies published after FERC's analysis suggest that UKL habitat is presently suitable to support fall-run Chinook salmon for at least the October through May period (Maule et al. 2009). The life history of fall-run Chinook salmon generally does not include a freshwater phase from June through September and spring inputs on the west side of UKL likely provide some thermal refuge year round for migrants. Thus, conditions for fall-run Chinook migration appear favorable (at least through UKL). It is possible that some fall-run Chinook salmon juveniles would spend their first winter in UKL and resume emigration the following spring at age 1, as they do in Snake River reservoirs (Connor et al. 2005).

Water quality in Keno reservoir would be improved more readily under this scenario (Dunne et al. 2011), and TMDL targets are expected to be reached sooner with dam removal and KBRA habitat restoration (USDI Secretarial Determination Water Quality Subgroup In Review). Thus, impediments identified by FERC would be reduced over time. In addition, not all life histories of anadromous fish would be impacted by the impediments that FERC has identified. Seasonal trap and haul of adults and juveniles, (National Marine Fisheries Service 2007a; U.S. Department of the Interior 2007) provided by KBRA would reduce impacts for remaining life histories, but there would be some level of associated mortality. The seasonal trap and haul program will require an adaptive approach and additional study to better understand the boundaries by which this program would operate.

Below UKL, lower harvest rates from 2012 to 2020[19] would contribute to rebuilding of local populations and reestablishment of populations into areas where they have been extirpated.

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[18] The most likely date for Phase I Plan completion would be 1 year after the KBRA Effective Date (see Section 10.1.1 of KBRA). For purposes of analysis, we consider 2012 to be the effective date.
[19] See Section 11.3.1 C of KBRA

2.1.13.4. Existing (Historical) Coho Salmon Above Iron Gate Dam

Coho salmon populations in the Klamath River above IGD were extirpated with the construction of the Project dams. The National Research Council (2004a) states that IGD blocks substantial amounts of coho habitat. The extent of the loss of their habitat is apparently less than the loss of habitat for Chinook salmon and steelhead. While Huntington (Huntington 2004) found no records or anecdotal accounts "that suggest coho [salmon] were ever present above UKL," their upstream distribution did extend at least to Spencer Creek (Hamilton et al. 2005).

Coho salmon are both state (California) and federally listed as threatened. The Southern Oregon/Northern California Coast coho salmon (SONCC) ESU includes all natural-origin populations in coastal streams between Cape Blanco, Oregon, and Punta Gorda, California. The SONCC ESU includes the Klamath River drainage up to IGD. Three artificial propagation programs are considered to be part of the ESU: the Cole River Hatchery, Trinity River Hatchery, and IGH. The Trinity River and Iron Gate hatcheries are within the Klamath River Basin. NMFS has determined that these artificially propagated stocks are currently no more divergent relative to the local natural-origin population(s) than what would be expected between closely related natural-origin populations within the ESU (70 FR 37160). Additional discussion of the Upper Klamath Coho Population Unit is provided in Section *2.2.8.4 Existing Coho Salmon Below Iron Gate Dam*.

2.1.13.5. Conditions with Dams – Coho Salmon Above Iron Gate Dam

Under conditions with dams, coho salmon will remain extirpated in the Klamath River above IGD. Under this scenario, considerable efforts to improve habitat are underway (National Marine Fisheries Service 2010b) toward the goal of recovery of salmon and steelhead stocks. Once implemented, TMDLs and associated Implementation Plans are expected to improve water quality, reduce stress on salmonids from pollution, and contribute to their recovery (National Marine Fisheries Service 2010b).

2.1.13.6. Conditions without dams and with KBRA – Coho Salmon Above Iron Gate Dam

Dam removal would result in an increase in habitat and coho salmon would likely access these habitats above IGD in a short period of time, as observed after barrier removal at Landsburg Dam in Washington (Kiffney et al. 2008) and dam removal at Little Sandy Dam in Oregon (B. Strobel, Portland Water Bureau, pers. comm.). Assuming coho salmon distribution up to Spencer Creek after dam removal, coho salmon will have an additional 68 miles of habitat, including approximately 45 miles of habitat in the mainstem Klamath River and tributaries (National Marine Fisheries Service 2007a; U.S. Department of the Interior 2007), as well as an additional 23 miles of habitat currently inundated by the reservoirs (Cunanan 2009). From 2012 to 2020 sport, commercial, and Tribal harvest will be held at minimal levels to rebuild runs under KBRA[20].

[20] See Section 11.3.1 C of KBRA

Consequently, incidental coho salmon harvest would be reduced. After 2020 coho incidental harvest would likely increase due to the increased effort directed at Chinook salmon.

Benefits of dam removal for coho salmon go beyond the accessibility of additional habitat. In general, as habitat availability and diversity increase for an ESU, the risk of extinction to the species is reduced. Reestablishing coho salmon to the upper Klamath basin would considerably increase the quantity and diversity of habitats available. These actions are likely to improve persistence of a population within an ESU, and the ESU as a whole (McElhany et al. 2000).

The quality and quantity of instream habitat for juvenile coho salmon will vary temporally and spatially above the current location of IGD. Accretions of cool spring water (Big Springs) in the J.C. Boyle reach (USDI Bureau of Land Management 2003) will provide important thermal refugia throughout the critical warm period of the year. However, some areas of poor water quality may degrade further with warmer spring and summer water temperatures. Overall, dam removal and associated KBRA actions will accelerate water quality improvement (Dunne et al. 2011) and the effectiveness of TMDL actions which should provide benefits to this species (USDI Secretarial Determination Water Quality Subgroup In Review).

The conclusion of the Coho/Steelhead Expert Panel was that the difference between the without dams and with KBRA management scenario versus the Current Condition is expected to be small for the entire coho salmon population within the entire basin, especially in the short term (0-10 years after dam removal) (Dunne et al. 2011). However, benefits specific to access to the upper Klamath River watershed will improve the viability of the species (Administrative Law Judge 2006). Larger (moderate) responses would be possible under the Proposed Action if the KBRA is fully and effectively implemented and mortality caused by the pathogen *C. shasta* is reduced (Dunne et al. 2011).

2.1.13.7. Existing (Historical) Steelhead Above Iron Gate Dam

Steelhead populations in the Klamath River above IGD were extirpated with the construction of Project dams. Historically, the range of this species included the tributaries of UKL (Butler et al. 2010; Hamilton et al. 2005).

2.1.13.8. Conditions with Dams – Steelhead Above Iron Gate Dam

Under conditions with dams steelhead will remain extirpated in the Klamath River above IGD. Absent additional habitat, runs will likely continue to decline. Klamath River summer steelhead in particular appear to be in decline as data for the Salmon River (Figure 6) indicate.

Under the dams in scenario, considerable efforts to improve habitat are underway (National Marine Fisheries Service 2010b) toward the goal of recovery of salmon and steelhead stocks. Once implemented, TMDLs and associated Implementation Plans are expected to improve water quality, reduce stress on salmonids from pollution, and contribute to their restoration (National Marine Fisheries Service 2010b).

2.1.13.9. Conditions without dams and with KBRA – Steelhead Above Iron Gate Dam

Conditions without dams would enable reestablishment of steelhead above IGD and result in an increase in the amount of habitat for this species (Federal Energy Regulatory Commission 2007). Because of their ability to navigate steeper gradient channels and spawn in smaller and intermittent streams (Platts and Partridge 1978), steelhead would realize the extent of anadromous habitat gain to a greater degree than other species.

Based on accounts in other systems, steelhead are expected to recolonize the area between UKL and IGD quickly after dam removal without human intervention.
Data collected from a smolt trap located 200 feet above where the Little Sandy Dam in Oregon stood (removed fall 2008) captured steelhead smolts passing the trap site in 2009. In 2010, the trap captured steelhead smolts, as well as a large number of one-year old *O. mykiss* juveniles (B. Strobel, Portland Water Bureau, pers. comm.). The Gifford Pinchot National Forest 'Hemlock Dam Removal and Trout Creek Restoration Project' website shows an adult steelhead swimming through the project reach just hours after Trout Creek was rewatered, post dam removal (U.S. Forest Service - Gifford Pinchot National Forest 2010).

One uncertainty regarding the potential success of steelhead reintroduction cited by the Coho/Steelhead Expert Panel was unfavorable water quality conditions in Keno Reservoir and upper Klamath Lake (Dunne et al. 2011). However, evidence indicates that UKL habitat is presently suitable to support less thermally tolerant fall-run Chinook salmon for at least the October through May period (Maule et al. 2009). Summer poor water quality conditions, may necessitate seasonal trap and haul around Keno reservoir for some life stages of steelhead until KBRA and TMDL implementation improve water quality. Overall, dam removal and associated KBRA actions will accelerate water quality improvements (Dunne et al. 2011) and TMDL water quality benefits to steelhead (USDI Secretarial Determination Water Quality Subgroup In Review).

The conclusion of the Coho/Steelhead Expert Panel was that the without dams and with KBRA management scenario could result in increased spatial distribution and numbers of steelhead, and in the long term (decades), increased numbers relative to those under Current Condition (Dunne et al. 2011).

2.1.13.10. Existing (Historical) Pacific Lamprey Above Iron Gate Dam

The historical upstream distribution of Pacific lamprey was likely to at least Spencer Creek above IGD (Hamilton et al. 2005), although there is some uncertainty in this regard (Administrative Law Judge 2006). Pacific lamprey in California have been in decline (Moyle et al. 2009). However, there are no current status assessments for any Klamath lampreys and little is known of their biology or sensitivity to environmental changes in the Klamath drainage (S. Reid, Western Fishes, pers. comm.).

2.1.13.11. Conditions with Dams – Pacific Lamprey Above Iron Gate Dam

Under conditions with dams, Pacific lamprey will be unable to access suitable habitat for spawning and juvenile rearing within tributaries and stream reaches above IGD. TMDL implementation will benefit this species.

2.1.13.12. Conditions without dams and with KBRA – Pacific Lamprey Above Iron Gate Dam

Pacific lamprey are found in tributaries near IGD (Administrative Law Judge 2006). Resident lamprey ammocoetes already rear in tributaries within the PR and ammocoetes of both resident and anadromous Pacific lamprey have similar habitat requirements. Although the historical upstream distribution of Pacific lamprey is unknown, suitable habitat for spawning and juvenile rearing is available within tributaries and stream reaches in the PR. Pacific lamprey below IGD would migrate above the dam if access was provided through fishways (Administrative Law Judge 2006), however, dam removal would be more conducive to the reestablishment of anadromous Pacific lamprey above IGD (Federal Energy Regulatory Commission 2007). It is expected that adult Pacific lamprey would recolonize the newly opened habitat after dam removal but natural colonization may take decades (Close et al. 2010). Capacity for Pacific lamprey in the Klamath River system is predicted to increase by a maximum of 14 percent (based on analysis of mainstem habitat), with potentially more if habitat in the upper Klamath River Basin is accessible and suitable (Close et al. 2010). Full implementation of KBRA could potentially increase the capacity of Pacific lamprey habitat upstream from Keno Dam (Close et al. 2010).

Access to habitat would benefit Pacific lamprey by increasing their viability through: 1) extending range and distribution of the species; 2) providing additional spawning and rearing habitat; 3) increasing genetic diversity of the species; and 4) increasing the abundance of the Pacific lamprey (Administrative Law Judge 2006). Removal of dams is considered to be the only feasible step that could be expected to expand the current range of Pacific lamprey to areas upstream of IGD (Federal Energy Regulatory Commission 2007).

Overall, dam removal and associated KBRA actions will accelerate water quality improvements (Dunne et al. 2011) and TMDL water quality benefits to this species (USDI Secretarial Determination Water Quality Subgroup In Review).

2.1.14. Existing Fish Disease Above Iron Gate Dam

Disease occurs when conditions for the pathogen are conducive and infection results in damage or death to the host. Baseline information on the distribution and occurrence of most salmonid pathogens is limited. Existing data and observations in the Klamath River indicate that the most common pathogens of concern can be grouped into four categories: 1) viral pathogens such as Infectious Haematopoietic Necrosis (IHN), 2) the bacterial pathogens *R. salmoniranrum* (bacterial kidney disease, BKD), *Flavobacterium columnare* (columnaris), and *Aeromonas hydrophila*; 3) external protozoan parasites *Ichthyophthirius* (Ich), *Ichthyobodo,* and *Trichodina*; and 4) the myxozoan parasites *Ceratomyxa shasta* (causes ceratomyxosis) and *Parvicapsula minibicornis*. There is a lack of information concerning the presence of IHN and BKD either above or below IGD (Administrative Law Judge 2006). *Columnaris* is common worldwide and present at all times in the aquatic environment. *Columnaris* disease in cold water fishes is generally seen at water temperatures above 15°C. In natural infections, the disease is often chronic to subacute, affecting skin and gills (California Department of Fish and Game 2003). Ich infestation of gill tissue results in hyperplasia, a condition that reduces the ability of the fish to obtain oxygen. Death is by asphyxiation. Ich can be found on any fish at any temperature, but typically only cause disease and mortality at water temperatures above 14°C and in crowded conditions (California Department of Fish and Game 2003). Other common pathogens are likely present in the Klamath River, but are reported rarely.

The life cycles of both *P. minibicornis* and *C. shasta* involve an invertebrate and a fish host, where these parasites complete different parts of their life cycle. In the Klamath River, *P. minibicornis* and *C. shasta* share the same invertebrate host: an annelid polychaete worm, *Manayunkia speciosa* (Bartholomew et al. 2006; Bartholomew et al. 1997). Once the polychaetes are infected, they release *C. shasta* actinospores into the water column. Temperature and actinospore longevity are inversely related. In one study, actinospores remained intact the longest at 4°C, but were short-lived at 20°C. Actinospores are generally released when temperatures are above 10°C. Actinospores remain viable (able to infect salmon) from 3 to 7 days at temperatures ranging from 11 to 18ºC (Foott et al. 2006). They are viable for shorter periods of time when temperatures are outside of this range. As actinospores viability increases, actinospore distribution may increase, raising the infectious dose for salmon over a larger area of the river (Bjork and Bartholomew 2010). Actinospore abundance is controlled by the number of infected polychaetes and their infection levels (prevalence and severity), and actinospore abundance is a primary determinant of infectious dose.

Salmon become infected when the actinospores enter the gills, eventually reaching the intestines. At that point, the parasite replicates and matures to the myxospore stage. Myxospores are shed by the dying and dead salmon, and the cycle continues with infection of polychaete worms by the myxospores (Bartholomew and Foott 2010). Transmission of the *C. shasta* and *P. minibicornis* parasites is limited to areas where the invertebrate host is present.

Susceptibility to *C. shasta* is also influenced by the genetic type of *C. shasta* fish encounters. Atkinson and Bartholomew (Atkinson and Bartholomew 2010a, 2010b) conducted analyses of the genotypes of *C. shasta* and the association of these genotypes with different salmonid species, including Chinook and coho salmon, steelhead, rainbow trout, and redband trout. In the Williamson River, although parasite densities had been found to be high, Chinook salmon were resistant to infection because the genotype specific to Chinook salmon was absent. In a genetic analysis, the *C. shasta* genotypes were characterized as Type 0, Type I, Type II and Type III:

> The Type 0 genotype occurs in both the Upper and Lower Klamath Basin and native rainbow/redband trout and steelhead are susceptible to infection with Type 0. However, in most situations, this genotype occurs in low densities and it is not very virulent. Infection generally leads to minimal or no mortality.
>
> The Type I genotype of *C. shasta* occurs in the Lower Klamath Basin and affects Chinook salmon. This genotype causes significant mortality to Chinook salmon below IGD. However, if it were to move above IGD, it would affect only Chinook salmon.
>
> The Type II genotype occurs in and above UKL and below IGD, and at low levels between the dams, and affects coho salmon and nonnative rainbow trout. However, it appears that the biotype of this parasite in the upper basin does not affect coho salmon. Risks to native rainbow/redband trout from this genotype are low (J. Bartholomew, Oregon State University, pers. comm.).
>
> Type III appears widespread based on fish infections, but was not detected in water samples. Type III appears to infect all salmonid species (Atkinson and Bartholomew 2010b). Prevalence of this genotype is low and it infects fish but does not appear to cause mortality.

The invertebrate host for the parasite is present in a variety of habitat types, including runs, pools, riffles, edge-water, and reservoir inflow zones, as well as sand, gravel, boulders, bedrock, aquatic vegetation, and is frequently present with a periphyton species: *Cladophora* (Bartholomew and Foott 2010). Slow-flowing habitats may have higher densities of polychaetes, and areas that are more resistant to disturbance, such as eddies and pools with sand and *Cladophora*, may support increased densities of polychaete populations (Bartholomew and Foote 2010), especially if flow disturbance events are reduced or attenuated.

Numerous factors are causes of disease, but how all of them interact is a complex situation not fully understood. Understanding how pathogens and hosts evolve is critical to predicting the effectiveness of management and regulatory decisions. Human actions and disturbance can affect this balance, leading to artificially increased mortality (severity, distribution, and timing) from naturally occurring disease. What we do know is that environmental variables that affect the host-pathogen balance vary between the different pathogens and in some cases spatially within riverine habitats.

2.1.15. Conditions with Dams – Fish Disease Above Iron Gate Dam

Under conditions with dams there would be fewer options to change the status of fish disease in the Klamath River. The existing salmonid host-pathogen relation for *C. shasta* genotypes described above will remain relatively stable with minimal change in distribution. Continued interruption of salmonid hosts migration to habitat above IGD may exacerbate salmonid-pathogen relations downstream of IGD. The infectious nidus (breeding place) for *C. shasta* and *Parvicapsula minibicornis* that currently occurs below IGD would likely persist. This will continue to cause significant mortality in salmon downstream from IGD (see sections 2.2.9 through 2.2.11).

2.1.16. Conditions without dams and with KBRA – Fish Disease Above Iron Gate Dam

Poor water quality in Upper Klamath Lake has been implicated in the mass mortality of federally listed suckers, and may suppress their growth, reproductive success, and resistance to disease or parasitism (Federal Energy Regulatory Commission 2007). KBRA will accelerate TMDL water quality benefits and, thus, reduce disease above IGD (USDI Secretarial Determination Water Quality Subgroup In Review).

Historically, anadromous fish and their associated pathogens migrated to the upper Klamath Basin and available information suggests that the likelihood of introducing new pathogens that would affect existing populations is minimal (Bartholomew 1998; Bartholomew and Courter 2007; Stocking and Bartholomew 2007). Columnaris and Ich are ubiquitous in freshwater systems, and both are present throughout the Klamath River system above and below IGD. Removal of dams would reduce or eliminate populations of warmwater fish associated with existing reservoirs that are potential hosts to columnaris and Ich. Generally, with the exception of columnaris and Ich, pathogens associated with anadromous fish do not impact non-salmonids, including federally listed suckers (Administrative Law Judge 2006). Whirling disease, another myxozoan parasite spreading in the West in recent decades, is absent from the Klamath River (S. Foott, Service, pers. comm.) and sampling has found no evidence of the disease in the upper Klamath watershed streams (C. Banner, ODFW, pers. comm.).

Since a majority of the pathogens currently found in the lower basin also exist in the upper basin of the Klamath River system, a logical conclusion is that migration of anadromous fish above IGD would not be a significant factor contributing to disease for resident fish (Administrative Law Judge 2006). FERC concluded there is a slight risk of transmission of disease IHN to upper watershed (Federal Energy Regulatory Commission 2007). Because of its low levels, *R. salmoniranrum*, the causative agent of bacterial kidney disease in salmon, does not appear to pose a significant risk of disease in the salmonid population in the Klamath River system, and consequently the bacteria will not pose a significant threat to fish in the upper basin (Administrative Law Judge 2006). Similarly, parasitic *trematode metacercaria* of *Nanophyetus salminicola*, the host to the Rickettsia bacterium that causes salmon poisoning in canines, is present in many juvenile and adult salmon. However, they do not appear to present a significant health threat to resident fish in the upper Klamath Basin.

Observations below IGD indicate *C. shasta* has the potential to infect large portions of salmonid populations and cause significant mortality. If salmon spawning migrations were to occur above IGD, an upriver infectious nidus for *C. shasta* may be created similar to the one that currently occurs below IGD where spawning congregations occur. The likelihood of this happening is unknown. While *C. shasta* has been detected above

IGD in the lower Williamson River (a tributary of Upper Klamath Lake) and in areas below IGD in nearly equal levels, the effects on fish have differed between these two areas. Results from the pathogen exposure portion of a study (Maule et al. 2009) demonstrate that *C. shasta* was present in the Williamson River and abundant. However, experimental exposures of Chinook salmon in the upper Klamath Basin have never resulted in the detection of the pathogen in the fish (Stocking et al. 2006). Juvenile Chinook salmon exposures conducted in the upper Williamson River, lower Williamson River, and Upper Klamath Lake suggest that Chinook salmon are sufficiently resistant to survive exposure at these sites during the spring.

2.1.17. Existing Resident Fish Species Above Iron Gate Dam

2.1.17.1. Existing Bull Trout Above Iron Gate Dam

Bull trout are currently listed as threatened under federal ESA. The current abundance, distribution, and range of bull trout in the Klamath River Basin are greatly reduced from historical levels due to habitat loss and degradation caused by reduced water quality, timber harvest, livestock grazing, water diversions, roads, and the introduction of non-native fishes (USDI Fish and Wildlife Service 2002). Bull trout populations in the Klamath interim recovery unit face a high risk of extirpation (USDI Fish and Wildlife Service 2002). Bull trout are considered extinct in California (Moyle et al. In Press).

In the upper Klamath basin, this species is confined to the far upper reaches of the watershed. Although the status of specific local populations has been slightly improved by recovery actions, the overall status of Klamath River bull trout continues to be depressed (USDI Fish and Wildlife Service 2002).

Factors considered threats to bull trout in the Klamath River Basin at the time of listing — habitat loss and degradation caused by reduced water quality, past and present land use, water diversions, roads, and non-native fishes — continue to be threats today.

2.1.17.2. Conditions with Dams – Bull Trout Above Iron Gate Dam

Under conditions with dams the status of federally listed bull trout will likely continue to improve on its current trajectory. Water quality improvements associated with TMDL implementation will likely benefit bull trout.

2.1.17.3. Conditions without dams and with KBRA – Bull Trout Above Iron Gate Dam

Under conditions without dams, the status of federally listed bull trout would likely continue on its current trajectory. There may be some loss of federally listed bull trout as reintroduced anadromous salmonids prey upon bull trout fry and juvenile (USDI Fish and Wildlife Service 2007a). This loss may be offset by increased food availability as bull trout prey upon salmonid eggs, fry, and juveniles (Beauchamp and VanTassell 2001; Dunham and Rieman 1999; Fraley and Shepard 1989). KBRA would likely accelerate TMDL water quality benefits to bull trout (USDI Secretarial Determination Water

Quality Subgroup In Review). This management scenario provides promise for increasing overall population abundance and distribution of bull trout (Buchanan et al. 2011).

2.1.17.4. Existing Lost River and Shortnose Suckers Above Iron Gate Dam

Shortnose (*Chasmistes brevirostris*) and Lost River (*Deltistes luxatus*) suckers are endemic to the Upper Klamath basin of southern Oregon and northern California. Historically, these species were not known to, and likely did not, occupy riverine habitat below Keno reservoir. Both sucker species were listed as endangered under the ESA in 1988.

Lost River suckers may survive up to 57 years while shortnose suckers may live as long as 33 years (Scoppettone and Vinyard 1991). Reproductive maturity for female shortnose suckers may be attained as early as four years of age while Lost River suckers typically reach reproductive maturity at six to nine years of age (Buettner and Scoppettone 1990; Perkins et al. 2000b). Adult Lost River and shortnose suckers primarily occupy lake habitats of the Upper Klamath basin. Most adult suckers migrate into tributaries to spawn, while others spawn in suitable near-shore lake habitats, primarily spring influenced areas (National Research Council 2004a).

Spawning generally occurs from February-June and peaks in April and May (USDI Fish and Wildlife Service 2007b, 2007c). Larvae produced in UKL tributaries migrate to the lake shortly after emergence from natal gravels (Cooperman and Markle 2003). Seasonal timing of larval sucker migration from natal areas is determined by the timing of adult spawning and is variable between sites (Tyler et al. 2004). The number of larval suckers peaked earliest at sites in the upper Sprague River, typically from late March through April. Larval numbers in the lower reaches of the Williamson and Sprague rivers peaked during mid-May, but larvae were present in the drift as early as March and as late as early July (Ellsworth et al. 2009).

Larval suckers begin to appear in the lake in late March to early April, with peak abundance occurring in mid-May to mid-June. Larvae transform to juveniles by mid to late July. Larval habitat is generally along the shoreline, in water 4 to 20 inches deep and associated with emergent aquatic vegetation, such as bulrush (*Scirpus spp.*) (Buettner and Scoppettone 1990; Cooperman and Markle 2004). Lake fringe emergent vegetation is the primary habitat used by larval suckers and, to a lesser extent, by juvenile suckers (USDI Fish and Wildlife Service 2007b, 2007c). Juvenile suckers also utilize non-vegetated near shore areas with a variety of substrates types.

Larvae grow into YOY juveniles typically by mid-summer. YOY suckers utilize a wide variety of near-shore habitat including emergent wetlands, non-vegetated areas and off-shore habitat (Hendrixson et al. 2007; Terwilliger et al. 2004; VanderKooi et al. 2006). As they grow during the summer many move offshore. Subadult and adult suckers are found in open water areas of the lake typically at depths of greater than three feet in the northern half of UKL (Banish et al. 2009; Peck 2000).

At the time of listing in 1988, the identified threats to Lost River and shortnose suckers included: loss of historical populations; contraction of range; habitat loss, degradation, and fragmentation; drastically reduced adult populations; overharvesting by sport and commercial fishing; large summer fish die-offs caused by declines in water quality; lack of significant recruitment; hybridization with the other two sucker species native to the Upper Klamath basin; potential competition with introduced exotic fishes; and the inadequacy of existing regulatory mechanisms to provide for the conservation of these species (53 FR 27130).

The state of California designated shortnose and Lost River suckers as fully protected on January 1, 1974, prohibiting the take or possession of these fish. The sport fishery for suckers in Oregon was closed prior to federal ESA listing in 1988, and has not been reopened.

2.1.17.5. Conditions with Dams – Lost River and Shortnose Suckers Above Iron Gate Dam

FERC concluded that removal of the mainstem dams would also eliminate existing habitat for adult shortnose and Lost River suckers in the project reservoirs (Federal Energy Regulatory Commission 2007). However, given existing information, the Service does not consider reservoir populations and habitat below Keno Dam as contributing significantly to sucker recovery (USDI Fish and Wildlife Service 2006). Analysis by FERC suggests that the population of Lost River and shortnose suckers in Copco reservoir is supported primarily by the downstream movement of juvenile and adult suckers from Upper Klamath Lake and J.C. Boyle reservoir (Federal Energy Regulatory Commission 2007).

Under conditions with dams there is likely to be less improvement in the status of federally listed suckers than under the dams out with KBRA alternative because KBRA will accelerate water quality improvements (Dunne et al. 2011) and TMDL water quality benefits to this species (USDI Secretarial Determination Water Quality Subgroup In Review). Conditions with dams and without KBRA would provide fewer opportunities for water quality and habitat improvements in the upper basin areas where Lost River and shortnose suckers reside.

2.1.17.6. Conditions without dams and with KBRA – Lost River and Shortnose Suckers Above Iron Gate Dam

Under conditions without dams and power generation, federally listed suckers would no longer be entrained in Project turbines (Gutermuth et al. 2000). Suckers (likely to include federally listed suckers) would no longer be stranded following spill reductions at Link River, Eastside, Westside, or J.C. Boyle project facilities as reported (Oregon Department of Fish and Wildlife 2006; Tinniswood 2006a) or in the peaking reach below J.C. Boyle Dam powerhouse. On July 5, 2006, a severe stranding along 225 feet of the peaking reach was documented near Frain Ranch. About 5,000 fish of various species, more crayfish, and an order of magnitude more aquatic insects perished in a single peaking cycle

(Administrative Law Judge 2006). Peaking operations that cause high mortality likely only happen a few times a year, following the first peaking event after several months of steady flow (Administrative Law Judge 2006). However, some site specific studies show limited stranding effects to aquatic biota (PacifiCorp 2005a).

In regard to KBRA water management and federally listed suckers, the goal of the lake elevation targets in the fall and winter months is to fill the lake. For most water years, the lake would reach its maximum elevation of 4,143 feet by April or May (Figure 2). Historically, February through June was the peak runoff period and high lake elevations were inherent. This hydrologic regime directly corresponds with the timing of the spawning migration of adult Lost River and shortnose suckers to shoreline habitats near the eastside spring areas of UKL and to tributary spawning streams, particularly the Williamson and Sprague rivers (Perkins et al. 2000b). Filling the lake early in the water year ensures access to suitable lakeshore spawning habitats in addition to increasing the probability of achieving adequate lake levels through the summer (Shively et al. 1999; USDI Bureau of Reclamation 2001).

KBRA elevations target lake levels from falling too quickly in June and July and to meet a minimum lake level of 4,140 feet at the end of July (Figure 2). When lake elevations drop below about 4,140 feet, vegetated habitats preferred by larval suckers and to a lesser extent, juvenile suckers, become dewatered and they must move to less desirable habitats. In late summer, the elevation of UKL at or above 4,138 feet allows juvenile suckers access to near shore non-vegetated habitat. This elevation also allows adult suckers access to offshore open water habitat with adequate depth (> six feet deep) and refugia areas, particularly Pelican Bay (Buettner and Scoppettone 1990). These habitats typically have better water quality than the main body of the lake at this time of year. This also facilitates the likelihood of refilling the lake by the following winter/spring. Lake levels would be higher in more years (in April, 26 out of 50 years, and in July, 30 out of 50 years) under KBRA than under the NMFS 2010 BO (Figure 2).

Overall, dam removal and associated KBRA actions will accelerate water quality improvements (Dunne et al. 2011) and TMDL water quality benefits to this species (USDI Secretarial Determination Water Quality Subgroup In Review).

Water quality in streams is expected to improve in response to greater instream flows (purchase of water rights) and to revegetation of the degraded riparian corridors. Water quality should increase in lake fringe areas adjacent to improved wetlands, which are important for survival of larval and juvenile suckers. Water quality of open water areas such as Agency Lake may improve, but the Resident Fish Expert Panel does not anticipate improvement in water quality in most open water areas of Upper Klamath Lake (Buchanan et al. 2011). This management scenario provides promise for preventing extinction of sucker species and for increasing overall population abundance and productivity (Buchanan et al. 2011).

2.1.17.7. Existing Redband Trout Above Iron Gate Dam

The UKL basin supports the largest and most functional adfluvial redband trout populations of Oregon's interior basins. However, some populations are severely limited in distribution and abundance by low habitat quality and interactions with non-native species. There is no proposal for federal listing for redband trout. Fishing is allowed but the ODFW considers the Redband Species Management Unit to be vulnerable (Oregon Department of Fish and Wildlife 2005).

According to FERC, the J.C. Boyle bypassed and peaking reaches support good fisheries for rainbow (or redband) trout (Federal Energy Regulatory Commission 2007). However, under existing operations, peaking in the reach from the J.C. Boyle powerhouse to the California state line eliminates effective habitat for redband trout fry (USDI Bureau of Land Management 2002). The temperature fluctuations of up to 12°C that occur in the J.C. Boyle peaking reach during the middle of the summer (City of Klamath Falls 1986) impact redband trout and peaking dewaters the river bed (including some spawning gravels) on a daily basis (City of Klamath Falls 1986).

While other site specific studies show more limited temperature impacts and fewer effects to aquatic biota (PacifiCorp 2005a) it has been determined that Project peaking operations cause high mortality to fish and other aquatic organisms through stranding (Administrative Law Judge 2006). Project peaking operations kill, through stranding, large numbers of young fish and aquatic invertebrates that are the primary prey food for trout (Administrative Law Judge 2006).

2.1.17.8. Conditions with Dams – Redband Trout Above Iron Gate Dam

Under conditions with dams the status of redband trout will likely continue on its current trajectory. Water quality improvements from TMDL implementation would provide benefits to redband trout.

Redband trout need to migrate among habitats between the dams, mainstem tributaries and reservoirs to meet their life history requirements. Under the conditions with dams, redband trout will continue to be blocked from these migrations by the lower three Klamath River dams and be greatly impaired in their movements by J.C. Boyle Dam (Jacobs et al. 2008).

Migration impairment and hydropower peaking has apparently altered redband trout life history and abundance and led to the decline in size and abundance of adult redband trout migrating upstream over J.C. Boyle Dam (Jacobs et al. 2008). Other site specific studies show more limited effects to redband trout (PacifiCorp 2004c, 2005a). However, it has been determined that flushing of juvenile salmonids downstream is likely in the peaking reach and very few salmonid fry or other fish species are observed in the margins of the peaking reach (Administrative Law Judge 2006). There was no evidence of delay or deterrence of redband trout at the J.C. Boyle Powerhouse or fish ladder (PacifiCorp 2004c).

Adverse effects of flow peaking were evident among redband/rainbow trout found to be smaller in size and significantly lower in overall condition factors when trout sampled from the peaking reach were compared to trout from the Keno Reach (Oregon Department of Fish and Wildlife 2003). However, other site specific studies show much more limited effects to redband/rainbow trout (PacifiCorp 2004c, 2005a). According to FERC, the J.C. Boyle peaking reach supports a good fishery for redband/rainbow trout (Federal Energy Regulatory Commission 2007). It has been determined that flow fluctuations from peaking operations increase energetic demands on salmonids, decreasing energy available for overall health, growth, and reproduction (Administrative Law Judge 2006).

2.1.17.9. Conditions without dams and with KBRA – Redband Trout Above Iron Gate Dam

Under dam removal and KBRA, redband trout would be able to migrate volitionally, as observed after a similar dam removal in Michigan (Burroughs et al. 2010). This study also attributed the more than twofold increase in abundance of primary sport fish (trout) to dam removal, indicating that the productivity of the fish community increased as fish were able to choose and access those habitats that best fulfill their life history requirement.

Removal of J.C. Boyle Dam and restoration of a more natural flow regime would likely reverse the decline in abundance and size of adult redband trout migrating upstream over J.C. Boyle Dam and reestablish diverse life histories conducive to the conservation of this stock and associated redband fishery. With dam removal and no power generation, redband trout would no longer be entrained in turbines (Gutermuth et al. 2000). Stranding following spill reductions at Link River, Eastside, Westside, or J.C. Boyle Project facilities, as reported by (Oregon Department of Fish and Wildlife 2006; Tinniswood 2006b), would no longer occur for redband trout.

Effective habitat for redband trout (USDI Bureau of Land Management 2002) would be increased in the reach from the J.C. Boyle powerhouse to the California state line under the flows associated with dam removal and KBRA. The extreme daily temperature fluctuations in the J.C. Boyle peaking reach during the middle of the summer and the riverbed dewatering (City of Klamath Falls 1986) would be eliminated.

There is conflicting information on the nature of any potential competitive interactions between anadromous fish and resident trout in the Klamath basin. Information indicates that, in some circumstances, resident trout may have a competitive edge over steelhead trout (Administrative Law Judge 2006). There are many examples from nearby river systems in the Pacific Northwest that show naturally spawned anadromous steelhead trout and resident rainbow/redband trout can co-exist and maintain abundant populations without adverse consequences. The Deschutes River in Oregon, the Yakima River in Washington (Sheely 2008), and the river systems in Idaho are examples. However, a recent study showed that hatchery salmon supplementation negatively impacted resident trout abundance and salmonid biomass in a Washington watershed (Pearsons and Temple 2010).

The Oregon Department of Fish and Wildlife Draft Reintroduction Plan states that impacts to other indigenous species from recolonization of steelhead trout into the Oregon portion of the Klamath River Basin are unknown at this time and that investigations into native fish interactions will be initiated as part of the Reintroduction Plan (Oregon Department of Fish and Wildlife 2008). Competition between steelhead and currently present indigenous species such as redband trout are not assumed to be a major limiting factor since these species historically co-evolved (Oregon Department of Fish and Wildlife 2008). Existing redband trout and colonizing anadromous steelhead are expected to co-exist, as they do in other watersheds, although there may be shifts in abundance related to competition for space and food (Buchanan et al. 2011).

Resident trout have the genetic capacity to adopt anadromy and some may outmigrate to the ocean if passage exists (Administrative Law Judge 2006). While residualization (tendency to remain in freshwater) is common in juvenile hatchery steelhead trout, there is an absence of evidence of high levels of residualization in juvenile naturally-spawned steelhead trout (as could potentially occur above IGD). The potential for residualization is largely dependent on environmental conditions (Administrative Law Judge 2006; Busby et al. 1994; Courter et al. 2009). There are no scientific studies of the Klamath River Basin demonstrating that reintroduction of anadromous steelhead trout would detrimentally affect the genetic makeup of the resident trout fishery (Administrative Law Judge 2006). Redband trout are not susceptible to *C. shasta* or other disease that would potentially be brought upstream by anadromous fish (Bartholomew and Courter 2007).

Overall, dam removal and associated KBRA actions will accelerate water quality improvements (Dunne et al. 2011) and TMDL water quality benefits to this species (USDI Secretarial Determination Water Quality Subgroup In Review). The Resident Fish Expert Panel concluded that this management scenario is expected to increase redband trout populations. The abundance of redband/rainbow trout in a free-flowing reach between Keno Dam and IGD could increase significantly. Recreational fishing opportunities would be expected to increase in proportion to the increase in trout abundance. The Resident Fish Expert Panel estimates a seven fold increase in harvest of assuming spawning habitat does not limit the population increase. It is possible that the trophy fishery will likewise expand in this reach (Buchanan et al. 2011).

2.1.17.10. Existing Klamath Largescale Suckers Above Iron Gate Dam

In Oregon, the populations of Klamath largescale suckers are relatively abundant compared with the status of Lost River and shortnose suckers because they do not depend on lakes for rearing and they are able to ascend barriers, especially if fish ladders are present. California populations, on the edge of the range, are recommended for listing as endangered (Moyle et al. In Press).

2.1.17.11. Conditions with Dams – Klamath Largescale Suckers Above Iron Gate Dam

Under conditions with dams the status of Klamath largescale suckers will likely continue on its current trajectory. Implementation of TMDL would likely have benefits for this species.

2.1.17.12. Conditions without dams and with KBRA – Klamath Largescale Suckers Above Iron Gate Dam

Klamath largescale suckers would no longer be entrained in Project turbines (Gutermuth et al. 2000) and would no longer be stranded following spill reductions at Link River, Eastside, Westside, or J.C. Boyle Project facilities. Removing the dams with KBRA may also increase populations as physical, chemical, and biological processes of the Klamath River are restored. Overall, dam removal and associated KBRA actions will accelerate water quality improvements (Dunne et al. 2011) and TMDL water quality benefits to this species (USDI Secretarial Determination Water Quality Subgroup In Review).

2.1.17.13. Existing Klamath Smallscale Suckers Above Iron Gate Dam

This species is common in the Trinity, Klamath, and Rogue rivers. If anything, dams and diversions have increased its habitat by providing more lacustrine, warm water habitats (Moyle 2002).

2.1.17.14. Conditions with Dams – Klamath Smallscale Suckers Above Iron Gate Dam

Under conditions with dams the status of Klamath smallscale suckers will likely continue on its current trajectory. Implementation of TMDL would likely have benefits for this species.

2.1.17.15. Conditions without dams and with KBRA – Klamath Smallscale Suckers Above Iron Gate Dam

Dam removal with KBRA would eliminate reservoir habitat for Klamath smallscale suckers, but may also increase populations as physical, chemical, and biological processes of the Klamath River are restored. Klamath smallscale suckers would no longer be entrained in Project turbines (Gutermuth et al. 2000) and would no longer be stranded following spill reductions at Link River, Eastside, Westside, or J.C. Boyle Project facilities. Overall, dam removal and associated KBRA actions will accelerate water quality improvements (Dunne et al. 2011) and TMDL water quality benefits to this species (USDI Secretarial Determination Water Quality Subgroup In Review).

2.1.17.16. Existing Endemic Species of Klamath Lamprey Above Iron Gate Dam

There are six species native to the Klamath basin above IGD:

Pacific Lamprey, *Entosphenus tridentatus* (extirpated by dams)

Pit/Klamath Brook Lamprey, *Entosphenus lethophagus*
Modoc Brook Lamprey, *Entosphenus folletti*
Miller Lake Lamprey, *Entosphenus minimus*
Klamath River Lamprey, *Entosphenus similis*
"Klamath Lake Lamprey", *Entosphenus* sp.

Populations of the Miller Lake lamprey and the two brook lampreys appear to be secure in the upper Klamath basin, and Klamath River lampreys are numerous in the Klamath River. The undescribed "Klamath Lake Lamprey" population is apparently dependent on lacustrine habitat (except for spawning) and, due to this, has probably been adversely impacted by habitat (water quality) and prey population declines in UKL. This population is not known to inhabit the Project reservoirs.

Lamprey in California have been in decline (Moyle et al. 2009). However, there are no current status assessments for any Klamath lampreys and little is known of their biology or sensitivity to environmental changes in the Klamath drainage (S. Reid, Western Fishes, pers. comm.).

<u>2.1.17.17. Conditions with Dams – Endemic Species of Klamath Lamprey Above Iron Gate Dam</u>

Under conditions with dams, hydroelectric power peaking effects to the endemic Klamath lamprey species in the PR would continue. Implementation of TMDL would likely have benefits for this species.

<u>2.1.17.18. Conditions without dams and with KBRA – Endemic Species of Klamath Lamprey Above Iron Gate Dam</u>

Under dam removal, peaking effects on the endemic Klamath lamprey species in the PR would be eliminated. Conditions without dams and with KBRA would likely increase populations as physical, chemical, and biological processes of the Klamath River are restored. Overall, dam removal and associated KBRA actions will accelerate TMDL water quality benefits (Dunne et al. 2011; USDI Secretarial Determination Water Quality Subgroup In Review) to these species. Capacity for the freshwater-resident lamprey species in the upper Klamath River Basin is not expected to change significantly with dam removal, but may increase somewhat with implementation of the KBRA aquatic habitat restoration measures (Close et al. 2010).

2.1.18. Existing (and Historical) Human Use Above Iron Gate Dam

The decline of salmon populations, as well as the decline of other fish species (lamprey and some species of suckers) has impaired the availability of these fishes for Tribal cultural uses. The elimination of the spring-run Chinook salmon above the Salmon River has resulted in the elimination of cultural ceremonies associated with this run. Declines in fish populations, especially salmonids, have also resulted in decreased use and value of subsistence fishing locations, an altered daily diet that has been linked to health issues for Tribal members (Norgaard 2004), and increased poverty.

History tells us that there was significant use of anadromous fish above the current location of IGD. The recorded historical harvest of salmon and steelhead includes the following:

- *"My husband fished salmon in all the fishing spots at Sprague River... He particularly fished at the fishing holes where Spring Creek empties into Sprague River two miles north of Beatty... He speared salmon during the runs each year from 1901 until the runs stopped... He would take between 3-400 salmon a year."* Bertha Lotches, born 1889, member of the Klamath Tribes. <u>In:</u> (Lane and Lane Associates 1981), p 58.

- *"The Indians obtained a large part of their livelihood from the salmon fish they caught…The fish were pretty well distributed to all Indian families. At the Baking Powder Grade in the Sprague River, 20 men on average would fish daily throughout the summer months. They would spear and take out of the river approximately 100 fish a day, averaging 30 pounds a fish. I would say that approximately 3,000 pounds of salmon fish were taken out at Baking Powder Grade each day for 90 days."* Victor Nelson, member of the Klamath Tribes. <u>In:</u> (Lane and Lane Associates 1981), p 58.

- *"In explaining the fishery methods used by the Klamath tribe, Spier wrote that fishing with nets was the primary method. Spears were not used much because the dark water of the Williamson River and Klamath Lake, other than the Pelican Bay area. Salmon were sometimes speared from river banks and from the rocks at Klamath Falls. Hooks were used chiefly for large fish like salmon and "salmon trout."* <u>In:</u> (Fortune et al. 1966), p 6.

- *"The largest village of all, named Eulalona, on the banks of the Link River immediately below upper Klamath Lake, was the central point of the tribe and the scene of winter fishing grounds, unexcelled for salmon.*" <u>In</u>: Good (Good 1941), p 32.

- *Lobo'kstsoksi,* [Klamath Tribal name for an Indian village] [is] *on the bluff on the left bank of the Sprague River at the railroad bridge, with a few houses on the opposite side. There is a dam for salmon here.* <u>In</u>: (Spier 1930), p 14.

- *The Takelma descended upon bezukse'was* [Klamath Tribal name for the large Indian village on the Williamson River below the confluence with the Sprague River] *in the middle Williamson valley at salmon fishing time.* <u>In</u>: (Spier 1930), p 28.

- *"I know from my own knowledge...The salmon taken out by Indian members of the Klamath Tribe of Indians provided approximately one-half of the food that all of the Klamath Indians used from 1898 to the time when the fish were stopped by the dam of the California Oregon Power Company in 1910."* Delford Lang, member of the Klamath Tribes. <u>In:</u> (Lane and Lane Associates 1981), p 58.

- *"There were ten of us in the family and I supplied the salmon for the use of my family. What salmon I caught I did not need, my family would give to their friends. I would take between 300 to 400 salmon out of the reservation streams each and every fall during the salmon runs….Sprague River is one of the fine spawning streams of the reservation."* James Johnson, born 1887, member of the Klamath Tribes. In: (Lane and Lane Associates 1981), p 60.

- *"The Indian name for the falls [on Link River] was 'tiwishkeni' which translated means 'rush of falling waters place.' Around this location enormous quantities of salmon, steel-head [sic], and mullet were taken each year by the Indians who dried them for their winter food supply. The construction of Copco Dams upon the Klamath in California stopped the annual migration of salmon and steelhead…"* In: (Wynne 1967), p 16.

While it is prudent to use caution in making extrapolations from numbers presented in anecdotal information, these historical accounts demonstrate that there was considerable harvest of anadromous fish above the current location of IGD. Several accounts in Lane and Lane Associates (Lane and Lane Associates 1981) document the dependence of Tribes on salmon for up to one half of their annual food supply prior to the construction of Copco 1 Dam. Howe (Howe 1968), in speaking of the Indians of Modoc and Siskiyou counties in California and Klamath and Lake counties in Oregon, characterized salmon runs as an important source of wealth and stability to those Indians whose villages enabled them to take the fish.

Currently there is no commercial harvest of fish above IGD although historically, salmon and steelhead were harvested commercially at Link River and other locations (Duncan 1948; Frain 1948).

In addition to salmon and steelhead above IGD, the Tribes also relied on lamprey for food although it is uncertain which species of lamprey were consumed. Both Lost River and shortnose suckers were once abundant and were critical food resources for Native Americans and white settlers in the upper Klamath River basin (Gilbert 1898; Howe 1968). It was estimated that the aboriginal harvest at one site on the Lost River may have been 50 tons annually (Stern 1966). Settlers built a cannery on the Lost River to process suckers for oil and prepare salted suckers for shipment. In 1900, the Klamath Republican newspaper reported that "mullet", as suckers were referred to, were so thick in the Lost River that a man with a pitch fork could throw out a wagon load in an hour. Since ESA listing, the Klamath Tribes, who historically relied on the Lost River suckers and shortnose suckers for food, no longer harvest these species. Now the only utilization of suckers is for scientific purposes, and the Service and state of Oregon closely monitor take through a carefully managed permit process.

To a diminished degree, the Klamath watershed continues to provide fishery resources for Indian subsistence and ceremonial purposes, ocean commercial harvest, recreational fishing, and the economic health of many local communities (USDI Klamath River Basin

Fisheries Task Force 1991). These activities now occur primarily below IGD as a result of effects of the Project on fishery resources both upstream and downstream of the Project.

In terms of recreational fisheries for resident fish, the Williamson and Wood rivers support blue ribbon fisheries for trout. According to (Huber 1998), the Williamson River's trout are the basis for its national reputation. It contains some of the biggest redband/rainbow trout in the state and, as far as rivers go, some of the biggest in the lower 48 states. The Wood River also supports a superb fishery for both redband and non-native brown trout (Huber 1998).

The Sprague River, while degraded habitat in some areas, continues to support populations of redband trout and other coldwater species. UKL continues to have a reputation for producing enormous redband trout (Huber 1998). The Keno Reach of the upper Klamath River above J.C. Boyle reservoir offers anglers a great opportunity to catch trophy trout (Huber 1998).

The Project reservoirs currently provide a recreational fishery for largemouth bass (*Micropterus salmoides*), trout, catfish (*Ictalurus punctatus*), crappie (*Pomoxis* sp.), and panfish. Fishing for these species is especially popular in Copco 1 and Iron Gate reservoirs (Freeman 1984; Shaffer 2005).

2.1.19. Conditions with Dams – Human Use Above Iron Gate Dam

Under conditions with dams there will likely be few if any changes in human use of fish resources in the Klamath River above IGD. Implementation of TMDL would likely have benefits for human use fisheries.

2.1.20. Conditions without dams and with KBRA – Human Use Above Iron Gate Dam

With over 420 additional miles of habitat available without dams, more adult fall-run Chinook salmon would return to be harvested after the four dams are removed (Oosterhout 2005) than under the condition where the dams remain. Returning fall-run Chinook salmon from above IGD would be available for Tribal, commercial, and recreational fishers.

For the first eight years[21] after KBRA effective date sport, commercial, and Tribal harvest will be at held minimal levels to rebuild runs. After that, the state of Oregon anticipates that self-sustaining populations of Chinook salmon and steelhead returning to the Oregon portion of the Klamath River will be integrated into Tribal, recreational, and commercial fisheries (Oregon Department of Fish and Wildlife 2008). The Klamath Tribe would again be able to harvest anadromous fish in locations where they fished

[21] "To the extent possible, adult salmon returning to Upper Klamath Lake and tributaries from Phase I Reintroduction efforts will be protected to minimize their harvest in sport, commercial, and Tribal fisheries until the phase II Reintroduction Plan is adopted." (see Section 11.3.1 C of KBRA).

historically. Dam removal and the success of the KBRA in the upper Klamath basin could potentially lead to some increases in the capacity and productivity of Pacific lamprey, but the Expert Panel did not know to what extent or over what time frame such increases could translate into increased harvest potential (Close et al. 2011).

Overall, dam removal and associated KBRA actions will accelerate TMDL water quality benefits to human use fisheries (USDI Secretarial Determination Water Quality Subgroup In Review).

<u>*2.1.20.1. Recreational*</u>

In 1971-1974, ODFW released adult steelhead at J.C. Boyle Dam (Tinniswood 2006b). Anglers caught few of the transplanted steelhead. At least for one of these years, poor angler success was attributed to low water temperatures during the majority of the season (Tinniswood 2006b).

Despite this attempt, it is likely that access under the without dams and with the KBRA management scenario would create a sport fishery for anadromous species, in particular steelhead, above IGD. When passage for salmon and steelhead was created around dam sites on the St. Joe River in Michigan and Indiana, a significant fishery developed, resulting in a doubling of angler hours (Brian Gunderman, Michigan Department of Natural Resources–Fisheries Division, pers. comm.; Taylor and Wesley 2009).
A similar fishery developed when passage for salmon and steelhead was created around dam sites on the Grand River in Michigan, although creel data are not yet available (Taylor and Wesley 2009). On the Sandy River in Oregon, removal of Marmot Dam allowed expansion of an existing fishery for salmon and steelhead[22] and created additional access for bank anglers (T. Alsbury, ODFW, pers. comm.).

The effects of reintroduction on resident trout fisheries are unclear, however, in the Yakima River, anadromous fish reintroduction is believed to have had a positive effect on the resident trout fishery (Sheely 2008).

Removing the dams would result in the loss of the locally popular fishery for yellow perch in Copco 1 and Iron Gate reservoirs. One source considers this the best yellow perch fishery in California and possibly the western U.S. (Shaffer 2005). Without the dams, fishing for largemouth bass and other warm water species would also be lost. Determining cultural values associated with trading a nonnative species fishery for native species fishery is beyond the scope of this project, but for example, largemouth bass tournaments in the PR reservoirs would no longer occur. After dam removal, habitat would change from lake to a river, and flatwater lake recreational opportunities would be eliminated at these four facilities (Camp Dresser McKee 2008).

In the event of the removal of one or more of the four mainstem project dams, visitors would still be able to access the area for recreational pursuits, assuming most of the roads would likely remain. However the visitors' activities would be focused on a

[22] http://www.dfw.state.or.us/fish/docs/2011_Willamette_Zone_Fish_Regs.pdf

river setting rather than large bodies of a lake or reservoir. The three most likely activities affected by dam removal would be flatwater recreation, river-based angling, and whitewater boating use (Federal Energy Regulatory Commission 2007).

2.1.20.2. Commercial

While this management scenario would not create a commercial fishery above IGD, anadromous salmonid access to habitat above IGD would benefit commercial salmon fisheries. For these commercial fisheries, any increases in the abundance of natural Klamath River Chinook salmon stocks from habitat above IGD (as well as below) would not just be limited to the Klamath River and associated fisheries. There are multiplier benefits to Chinook salmon fisheries coastwide from increases in the abundance of these natural Klamath River Chinook salmon. In many years, the abundance of Klamath River Chinook salmon can directly affect the coastal mixed stock fisheries. When Klamath abundance is low, overall fishing effort is restricted to protect those fish. For example, in 2000, the ratio of Klamath River Chinook salmon to Chinook salmon harvest in other fisheries was projected to be approximately 1:25 fish (A. Grover, CDFG, pers. comm.). An increase in the abundance of Klamath River fall-run Chinook salmon in that year would have resulted in substantial multiplier benefits to overall Chinook salmon harvest, if other harvest restrictions had not been in place (e.g., to protect federally listed coho salmon and CA Coastal Chinook salmon).

In years 2003-2005, the low abundance of Klamath salmon stocks was again a factor in the restriction of coastal Chinook salmon fisheries south of the Columbia River and in 2005 there was also a request for disaster relief associated with the restricted fisheries due to the low abundance of Klamath stocks (Pacific Fishery Management Council 2006a). In 2006, a forecast for low abundance of Klamath stocks required a restricted season for salmon (Pacific Fishery Management Council 2006b).

2.2. Below Iron Gate Dam

2.2.1. Existing Hydrology Below Iron Gate Dam

The historical flows of the Klamath River provided the conditions under which species evolved prior to anthropogenic alterations to the hydrological regime (hydrograph). The annual historical hydrograph of the Upper Klamath River was relatively smooth, with high flows in winter and spring that declined gradually during summer until increasing again in the fall (Balance Hydrologics Inc. 1996). This pattern reflected the seasonal cycle of fall and winter precipitation and spring rainfall and snowmelt in the Klamath River Basin (Risley and Laenen 1999). Farther downstream in the coastal zone of the Lower Klamath River basin, the hydrologic pattern of the Klamath River was primarily dominated by rainfall events in the fall and winter which affected discharge. Spring peaks from snowmelt in tributary basins provided a predictable increase in discharge, typically near the end of April (National Research Council 2004a), with base flows reaching a minimum in the beginning of September. In the middle and lower portions of the Klamath River, discharge responded rapidly to rainfall events due to the relatively short length of lower tributary sub-basins (e.g., Salmon River). Historical Klamath River hydrology was diverse, with a range of hydraulic conditions and habitats which in turn likely supported varied life histories of salmonids.

Balance Hydrologics Inc. (Balance Hydrologics Inc. 1996) analyzed hydrologic records and concluded that the timing of peak and base flows changed significantly after construction of the Klamath Reclamation Project. The Klamath Reclamation Project operation increased flows in October and decreased flows in the late spring and summer as measured at Keno, Seiad, and Klamath USDI Geological Survey (USGS) gage sites. Their report also noted that water diversions in areas outside the Klamath Reclamation Project boundaries occur as well (Balance Hydrologics Inc. 1996).

IGD was completed in 1962 to re-regulate flow releases from the Copco facilities. Reregulation was not intended to restore the "pre-project" hydrograph. Upstream diversions and return flows continued to influence flows. USGS records indicate base and peak flows were altered compared to pre-development flows of the upper basin. Fall base flows were slightly increased while spring, summer, and winter base flows were reduced. The USGS records for IGD also show a decrease in the magnitude of peak flows, a two-month shift in timing of flow minimums from September to July, as well as reduction in the amount of discharge in the summer months (USGS, Fort Collins, CO, unpublished material, 1995 in (National Research Council 2004a)).

By truncating the range of flows that led to diverse life history strategies, changes in the annual hydrology have influenced populations of fish that have evolved under the natural flow regime. These changes included effects on the environmental cues used to trigger anadromous salmonid migrations (outmigration, spawning) and the availability and quality of habitat necessary to meet the life history needs of species (National Marine Fisheries Service 2002).

In accordance with the NMFS 2002 BO, minimum flows below IGD were increased gradually in three phases over an eight year period. Actual daily flows during the period of Phase III (final phase) implementation (March 27, 2006 through March 15, 2010) varied from minimums to over 10,000 cfs as a result of spill events due to additional water availability. Since March 2006, extended periods of steady state flows in all seasons have occurred and are indicative of the loss of flow variability under current water operations. However, an injunction by a district court in 2006 ordered NMFS to issue a new BO that took into account the latest scientific information as well as impacts to all coho life stages. Prescriptions in the new BO (National Marine Fisheries Service 2010a) called for greater flow variability.

2.2.2. Conditions with Dams – Hydrology Below Iron Gate Dam

Under conditions with dams flows would be controlled and continue to be regulated. The lost influence of accretions between Keno Dam and IGD would continue, reducing flow variability. Evaporation within PacifiCorp's reservoirs would continue (estimated to be conservatively 5,780 AF/annually; T. Mayer, Service, pers. comm.), resulting in lower flows below IGD.

In the future, water releases at IGD are expected to be consistent with NMFS' 2010 proposed instantaneous minimum flows (National Marine Fisheries Service 2010a). NMFS' BO concluded that the prescribed flows to increase fall and winter flow variability and increased spring discharge in select average and wetter exceedences will avoid jeopardizing the existence of the SONCC coho and avoid destroying or adversely modifying their critical habitat.

2.2.3. Conditions without dams and with KBRA – Hydrology Below Iron Gate Dam

The guiding principles for the management of environmental water in the KBRA are described in Section 2.1.3. When modeled KBRA type flows were compared to both the historical flow releases at IGD as well as those flow recommendations presented in the Hardy Phase II Report (Hardy et al. 2006). They concluded that KBRA type flow simulations exceeded historical flow volumes downstream of IGD during spring and early summer months which are critical to fry and juvenile salmon rearing (Hetrick et al. 2009). In dryer water years, KBRA type flows were typically lower than Hardy Phase II flows during the fall and early winter to encourage filling of UKL to meet lake level targets for listed suckers and provide for allocation of project water to the Klamath Irrigation Project. However, during years of extreme drought, such as occurred in 1992 and 1994, severe water shortages are still evident, particularly during the late summer and fall months when adult salmon are staging in the estuary and beginning to migrate upstream to spawn. These shortages highlight the need for development of a Drought Plan as described in Section 19 of the KBRA.

Again, the period of record that was retrospectively analyzed was based on water years from 1961 through 2000 (Hetrick et al. 2009). Prospective analysis of water management scenarios for the SD was based on water years through 2009 which increases the period of record for the analysis by an additional nine years (see section 2.1.3 for description). Given these changes, and the others described in Section 2.1.3 above, flow projections at IGD under the dams out with KBRA management scenario are compared with the management scenario of continuing current operations with the Project managed under the NMFS' 2010 BO in Figure 7.

2.2.4. Existing Water Quality Below Iron Gate Dam

The diverse geography of the Klamath River Basin is the predominant influence on the basin's water temperature regime. The Klamath River Basin is sometimes referred to as being an "upside down" system, given that the system's low gradient, dry upper watershed and steep, high-rainfall lower portion are inverted from classic watershed structure. As a result, the maritime climate and cool tributary inflow emanating from heavily forested tributaries can moderate water temperatures in the lower Klamath River basin, often leaving water temperatures slightly cooler than those further upstream. However, summer meteorological conditions can be severe throughout the basin for extended periods from June through September, and water temperatures will rise appreciably as ambient air temperatures rise. Ambient air temperatures tend to be highest upstream of the Trinity River confluence, which, when combined with limited tributary accretion, can produce daily average temperatures near 26°C during summer months (P. Zedonis, Service, pers. comm.).

With existing dams, the temperature effects and their contributions to poor water quality will persist (Figure 8). The thermal regime of the Klamath River within PacifiCorp's project boundaries and below IGD has been considerably altered as a result of Project reservoir operations. Simulations indicate the primary influence of Project reservoirs on water temperature results from increased hydraulic residence time HRT and thermal mass (Bartholow et al. 2005; Deas and Orlob 1999). Project reservoirs result in delay of seasonal thermal signature by approximately 18 days (Bartholow et al. 2005). PacifiCorp's modeling (PacifiCorp 2004b) also showed a similar phase shift in water temperatures that can be attributed to operation of Project reservoirs (Figure 9).

With climate change, minimum water temperatures will become increasingly important for salmonids. Appropriate minimum temperatures provide rearing anadromous fish with relief from thermal stress during the summer diurnal temperature cycle. An increase in minimum temperatures may adversely affect Chinook that are at their limit of thermal tolerances (National Research Council 2004a). Minimum daily temperatures likely dictate forays of rearing fish away from refugia to feed. Current Project management and summer flows from IGD would continue to increase July and August minimum temperatures by reducing the effects of nocturnal cooling (Figure 8; (National Research Council 2004a)).

DO concentrations vary considerably both spatially and temporally within the Klamath River mainstem, and are influenced primarily by high nutrient levels emanating from the upper basin (PacifiCorp 2004b). PacifiCorp's reservoirs appear to be a net sink on an annual basis, but can act as both a source and sink for these nutrients, based largely upon the time of year and the cycling mechanisms occurring at that time (Asarian et al. 2009). Highly enriched water also likely arises from mainstem tributaries that support large agricultural operations (e.g. Scott and Shasta rivers). Currently (and perhaps historically), the Klamath River mainstem supports a significant benthic algae community as a result of warm water, abundant solar input, and highly nutrified water chemistry. As the large aquatic plant community undergoes complex diel cycles of photosynthesis and respiration during summer months, instream DO concentrations can vary greatly through the day and may at times be reduced to approximately 6 mg/L (P. Zedonis, Service, pers. comm.), which may be stressful to adult and juvenile salmonids (California North Coast Regional Water Quality Control Board 2007).

Given that the Klamath River below IGD remains in a weakly buffered state, pH levels throughout the river can experience diel fluctuations between ~7.5 to 8.5 pH units (P. Zedonis, Service, pers. comm.) as a result of high primary production (i.e., algae and benthic macrophyte growth) during summer months. Photosynthesis and associated uptake of carbon dioxide by aquatic plants result in high pH (i.e., basic) conditions during the day, whereas respiration at night decreases pH to more neutral conditions.

Ammonia toxicity can be a concern in aquatic environments, like the Klamath River, where high nutrient concentrations coincide with elevated pH and water temperature, and low dissolve oxygen concentrations and stream flow that allows rapid oxidation. Ammonia toxicity is more of a concern within upstream reaches (e.g., IGD to Seiad Valley (RM 128)) where these variables, as well as macrophyte and algae concentrations, are appreciably higher than those common to the lower river (PacifiCorp 2004b).

2.2.4.1. Conditions with Dams – Water Temperatures Below Iron Gate Dam

If dams remain, the unnatural temperature regime resulting from the phase shift in seasonal water temperature patterns below IGD will continue. These phase shifted patterns include cooler temperatures in spring and early summer and elevated July and August minimum temperatures. The extent of the phase-shifted temperatures is about 18 days (Bartholow et al. 2005). Water temperatures would remain up 2 to 4^{o}C cooler during spring and early summer than predicted under free-flowing conditions with dams removed.

The biological consequence of cooler spring temperatures for juvenile salmonids is an opportunity for continued growth at more moderate water temperatures downstream of IGD compared to conditions without dams. Stress and disease impacts would be reduced for later outmigrants. For adult salmon, the consequences of the phase shifted temperatures with dams is relatively high temperatures in late summer and fall (Bartholow et al. 2005) that may delay migration and increase prespawning mortality of adult salmon.

The effects of ongoing and future upstream water temperature improvements under TMDL would likely improve water quality over the period of analysis, but there is uncertainty as to when TMDL targets would be achieved (USDI Secretarial Determination Water Quality Subgroup In Review).

2.2.4.2. Conditions without dams and with KBRA – Water Temperatures Below Iron Gate Dam

In the absence of Project reservoirs, HRT would be shortened from several weeks to less than a day. In addition, the thermal lag (phase shift) resulting from storage of water in reservoir and associated increased thermal mass would be eliminated. A free-flowing river would have temperatures that would emulate variability inherent in local unregulated river systems, would experience natural diurnal variations, and become warmer earlier in the spring and early summer as well as cooler earlier in late summer and fall (Figure 7). With this phase shift eliminated, the timing of water temperatures would be more synchronous with historical migration and spawning periods for Klamath River anadromous fishes. However, maximum recommended temperatures for juvenile rearing of fall Chinook salmon between February 1 and July 1, 1962-2001 were exceeded

49 days with dams and 60 days without dams (Bartholow et al. 2005). Warmer temperatures in the spring and early summer may diminish mainstem thermal refugia (Belchik 1997; Sutton and Soto 2010) downstream from IGD during this time of the year, although juvenile anadromous fish also find refuge in lower portions of tributaries that provide cold-water (Sutton and Soto 2010).

The effects of IGD on mainstem flow and temperature vary spatially, temporally, and by water year. Modeling suggests that from approximately the Scott River downstream to the mouth of the Klamath River, tributary inputs and meteorological conditions are the primary temperature drivers throughout the year (Bartholow et al. 2005). Thus, the temperature difference between the with and without dams condition is greatest just below IGD, but can extend to 120 to 130 miles downstream of the present-day location of IGD (Bartholow et al. 2005; Deas and Orlob 1999).

Bartholow et al. (2005) showed a marked reduction of 4 to 5°C in mean daily water temperatures in October to early November without dams near the present day location of IGD and progressively smaller reductions down to Seiad Valley (RM 128). This is the time period when fall-run Chinook salmon spawn. Under the dams out with KBRA management scenario, temperatures are better for adult migration, spawning, and egg incubation (Figure 10, Figure 11, and Figure 12, and Figure 13)[23].

Without the dams there are more miles of rearing habitat below IGD during April than under either of the dams-in scenarios (Figure 14)[21]. During the month of May, however, the dams out scenario has more rearing habitat than the dams-in scenario (Bartholow et al. 2005), but not as much as under the dams in scenario with 2010 BO flows. Simulations of dam removal in other locations have shown similar reductions in temperature associated with dam removal, but effects may differ seasonally (Risley et al. 2010).

2.2.4.3. Conditions with Dams – Dissolved Oxygen Below Iron Gate Dam

The effects of ongoing and future upstream DO concentrations under TMDL would likely improve over the 50 year period of analysis, but the there is uncertainty as to when TMDL targets would be achieved.

PacifiCorp has been attempting to increase DO levels downstream of IGD through various engineering and operational changes, such as turbine venting (U.S. Department of the Interior 2008), and has demonstrated some potential improvement in DO (L. Prendergast, PacifiCorp, pers. comm.). However, the efficacy of these measures when fully implemented at different flows, and the persistence of the benefit downstream, have yet to be fully documented.

[23]Water temperatures under the hydrology for the two management scenarios are compared to temperatures under the original hydrology for Bartholow et al. (2005) in Figures 10-14.

2.2.4.4. Conditions without dams and with KBRA– Dissolved Oxygen Below Iron Gate Dam

Over the long term (more than 2 years), DO concentrations would be greater under the dam removal management scenario (Federal Energy Regulatory Commission 2007; PacifiCorp 2004b) and be suitable for aquatic biota in restored river reaches previously inundated by Project reservoirs, and below IGD. Based upon stream channel changes alone, these simulations by PacifiCorp (as shown in (Federal Energy Regulatory Commission 2007)) show substantial improvements in DO with dam removal immediately downstream from IGD (Figure 15). Simulations indicate DO concentrations could be increased by 3 to 4 mg/l during the summer and early winter (PacifiCorp 2005b), a time when DO concentrations in water released from IGD can be substandard (e.g.,<7 mg/L). Reaeration afforded by a turbulent free flowing river has been identified as a key factor related to these improvements.

Yet, while reaeration of the river water is a critical factor preventing frequent low DO conditions in the Klamath River below IGD, in spite of relatively high nutrients in the river system, a reduction in nutrient concentrations would also likely improve DO conditions further. Existing conditions of DO in the Klamath River suggest that there can still be times when daily DO minimums as low as 5.5 mg/l and daily pH maximums approaching 9.0 can occur[24], although infrequently (Campbell 2001). These data suggest that under certain environmental conditions the current nutrient concentrations are ample to support high primary productivity with substantial photosynthesis and respiration. Examination of general trends of DO in the river system also suggest a positive association of reduced nutrient concentrations and reduced diel fluctuations in DO with distance from IGD (California North Coast Regional Water Quality Control Board 2010). Therefore, if nutrient reductions were to occur, there would be a positive influence on the DO regime of the river.

Restoration actions associated with the KBRA, such as stream bank and upland sediment stabilization and wetland reconstruction are two of many possible restoration actions that would reduce nutrients from entering the river system. Thus, TMDL DO targets would likely be reached sooner with KBRA habitat restoration (USDI Secretarial Determination Water Quality Subgroup In Review). Both KBRA and TMDL water quality improvements within and upstream of the Keno reservoir would propagate downstream and, therefore, would likely be more fully realized below IGD in the absence of Project reservoirs.

2.2.4.5. Existing Nutrients Below Iron Gate Dam

Except in extreme cases, nutrients alone do not impair beneficial uses. Rather, they cause indirect impacts through their biostimulatory effect on algal growth, low DO, and extreme pH conditions that can impair uses.

[24] Refer to criteria as described in U.S. Environmental Protection Agency 2003.

On an annual basis, there is typically a small net retention of total P and N in the project reservoirs. However, Project reservoirs can act as sources during the critical summer growing season (Kann and Asarian 2005, 2007). Kann and Asarian (Kann and Asarian 2005, 2007) found the combined Copco and Iron Gate reservoirs can act as sources of N during the spring/summer months, a critical time for rearing and outmigration of juvenile salmonids. The seasonal timing of the reservoirs functioning as a nitrogen source is important because during this period, nutrients can drive primary productivity and elevate diel fluctuations in DO and pH, which in turn, can harm aquatic biota as well as contribute to fish disease problems.

2.2.4.6. Conditions with Dams – Nutrients Below Iron Gate Dam

Under conditions with dams, project reservoirs would continue to be potential seasonal nutrient sources to the river system below. Implementation of TMDL would have benefits for water quality below IGD.

2.2.4.7. Conditions without dams and with KBRA – Nutrients Below Iron Gate Dam

Under the conditions without dams, HRT through reaches occupied by the PacifiCorp dam complex would decrease from several weeks to less than a day, with the added benefit of nutrient assimilation (river versus reservoirs) - thereby improving water quality. After dam removal, restored hydrological and thermal regimes would play a significant role in nutrient dynamics as will other natural riverine processes; most notably re-aeration of water provided by a turbulent well-mixed river. In spite of the continued release of eutrophic water from Keno Dam, albeit at a continually reduced load through time as a result of KBRA-related actions and TMDL implementation (California North Coast Regional Water Quality Control Board 2010), natural riverine processes in the river downstream would likely further reduce the nutrient concentrations (Armstrong and Ward 2008), thus assisting in meeting state standards for DO and pH. Nutrient reduction goals of the TMDLs will likely require several decades to meet the targets (Also see *2.1.3. Conditions without Dams and with KBRA - Hydrology and Water Quality above Link River Dam*).

While nutrient concentrations observed in Klamath basin may support ammonia levels hazardous to salmonids in slow moving, stratified environments such as the Project reservoirs, levels hazardous to salmonids in a riverine setting like the Klamath River likely do not exist. High ammonia levels in the river would be avoided by high turbulence that re-aerates water and oxidizes ammonia to nitrate and by use by autotrophs (Campbell 2001; National Research Council 2004a). Furthermore, it would be expected that KBRA-related restoration actions as well as the TMDL implementation plan for the mainstem Klamath River would likely have a synergistic effect resulting in reducing nutrients in the river system over time (probably decades) that thereby improve water quality (See *2.1.3. Conditions without Dams and with KBRA - Hydrology and Water Quality above Link River Dam*). As such, it would be expected that reductions in nutrients of upstream water would also translate to improved water quality conditions in downstream reaches (California North Coast Regional Water Quality Control Board 2010).

2.2.4.8. Existing Water Quality and Blue Green Algae Species Below Iron Gate Dam

Blue green algae (BGA) known as cyanobacteria, are microscopic organisms that are found throughout the world. In the Klamath River Basin, there are several toxic forms of BGA, but *Microcystis aeruginosa* (MSAE) appears to be the predominant species of concern (Kann and Corum 2009). The toxin associated with MSAE has been shown to pose a health risk to people and animals (e.g., dogs, fish, and invertebrates) when exposed in sufficient quantities. In most years, this species is found in great abundance in Copco and Iron Gate reservoirs beginning in July and persists through October, exceeding World Health Organization Moderate Probability of Adverse Health Effect Levels (WHO MPHAEL) for both cell density and toxin by 10 to over 1000 times (Kann and Corum 2009). Reasons for MSAE's great abundance in these reservoirs is believed to be associated with limited mixing of surface water (thereby allowing stratification), a good nutrient source, and abundant solar radiation, and warm water temperatures (Kann and Corum 2009). Since MSAE persists in great concentrations in these reservoirs for a relatively long time period, its toxins have been found to bioaccumulate in resident fish (Kanz 2008). MSAE and toxins are also eventually transported through the dams to areas downstream. Downstream transport has been shown to be substantial and, in some locations (backwater areas), at times exceed public health guideline values 40,000 cells/ml MSAE or 8 µg/L (Kann and Corum 2009).

2.2.4.9. Conditions with Dams – Water Quality and Blue Green Algae Species Below Iron Gate Dam

BGA blooms of *Microcystis aeruginosa* and AFA have been documented in Copco and Iron Gate reservoirs from 2005 to 2007 and would persist if the dams remain (Kann 2007; Kann and Corum 2007).

Algal blooms documented in the Klamath River in the past few years have been large, with toxin levels very high relative to the WHO MPHAEL standards, often exceeding them by 10 to over 100 times (Kann and Corum 2006; Kann and Corum 2007). In addition to representing a public health hazard in the reservoirs, high concentrations of BGA and toxins eventually are transported downstream as drift and have been reported to exist throughout the mainstem Klamath River below IGD (Kann and Corum 2006; Kann and Corum 2007).

Kanz (Kanz 2008) conducted a screening level analysis of accumulation of microcystin in yellow perch (*Perca flavescens*) from the reservoirs, Chinook salmon from IGH, and freshwater mussels (*Gonidea angulata*) from the Klamath River below IGD. He found bioaccumulation of the toxin in tissue to be transitory in nature, present in tissues when the toxin and algal blooms were present and that depuration occurred in the absence of the toxin in the water. Other species tested did not have detectable concentrations of the toxin suggesting that there may be species-specific differences in uptake and/or retention.

Kanz (Kanz 2008) suggested the toxin could have negative effects on fishes as well as mammals that consume the contaminated tissues. Landsberg (Landsberg 2002) reviewed the historical literature on the effects of harmful algal blooms on aquatic organisms and reported that *M. aeruginosa* can be toxic to fish and zooplankton. However, later bioaccumulation studies of yellow perch in 2009 found no detectable quantities of toxin (PacifiCorp 2009). Nevertheless, concentrations of BGA and attendant toxins may be yet another stressor to the biotic community in the Klamath River. Conditions with dams would maintain conditions under which toxic blue green algae thrive and produce toxins.

2.2.4.10. Conditions without dams and with KBRA – Water Quality and Blue Green Algae Species Below Iron Gate Dam

In the absence of Project reservoirs, conditions under which BGA thrive will be greatly diminished, resulting in fewer nutrient issues and a decrease in the alteration of water chemistry (pH and DO) associated with algae blooms. Again, turbulent river conditions that would occur after dam removal would contribute to conditions adverse to BGA.

2.2.5. Existing Riverine and Geomorphic Processes Below Iron Gate Dam

To help understand the hydrologic implications of the geology of the Klamath River, PacifiCorp (PacifiCorp 2004a) provides the following description of the Klamath River below IGD. Below IGD, the river has alluvial features, but with frequent bedrock outcrops in the bed, and it flows through a narrow valley cut into the Cascade volcanics. The valley widens near Hornbrook and the Cottonwood Creek confluence, then narrows again as it flows along the boundary between the Cascade and Klamath Provinces. From I-5 downstream, the river cuts across the Klamath Province, and the channel is steep and bedrock-controlled, with limited accumulations of alluvium. The alluvial accumulations increase in extent with distance downstream, and they are more abundant in reaches with locally wider valley bottoms. Near Seiad Valley, the valley is considerably wider than elsewhere, and the alluvial character is most pronounced (PacifiCorp 2004a).

The Project dams have disrupted geomorphic and vegetative processes that form channels and create spawning gravels below IGD (California Department of Water Resources 1981; PacifiCorp 2004a; USDI Klamath River Basin Fisheries Task Force 1991). Since the construction of the Project, sediment and spawning gravel has been intercepted by Project reservoirs and cut off just below IGD. The reduction in spawning gravels below IGD has been identified as one of the chief causes of the decline in salmonid recruitment and the California Department of Water Resources has invested considerable resources in planning for gravel augmentation for salmon spawning below IGD (California Department of Water Resources 1981).

Further downstream, tributaries to the Klamath River contribute significant flows and sediment and reduce the extent of downstream impacts from the Project (PacifiCorp 2004a). PacifiCorp (PacifiCorp 2004a) concluded that Project impacts on river corridor geomorphology downstream of IGD are probably no longer significant near the confluence with the Shasta River and almost certainly are no longer significant near the confluence with the Scott River.

2.2.6. Conditions with Dams –Riverine and Geomorphic Processes Below Iron Gate Dam

With Project dams in place, bed mobilization from IGD to Cottonwood Creek is expected to continue to decrease in the future as sediment is trapped by reservoirs (USDI Bureau of Reclamation 2011). The lack of a sediment supply associated with a natural flow regime prevents adequate riparian sediment deposit and scour, limits riparian plant succession, and reduces substrate movement below IGD. If the upstream dams remain, channel forming flows and processes will remain minimal or absent. Spawning gravel inputs from tributaries in the PR and upstream processes will remain trapped in reservoirs. Under the Conditions with Dams scenario, the sediment size below IGD will remain similar to the existing sediment size or may increase slightly (Blair Greimann, Reclamation, pers. comm.).

2.2.7. Conditions without dams and with KBRA –Riverine and Geomorphic Processes Below Iron Gate Dam

Over the long term, KBRA flows would move the hydrograph toward duration, timing, and magnitude of flows that provide more ecosystem benefits than water management has provided in recent years (Hetrick et al. 2009). Under natural, unregulated conditions, a spring flow pulse occurred in the Klamath River and in its tributaries (National Research Council 2004a). This feature of the hydrograph is thought to increase the survival of juvenile salmon outmigrants through several mechanisms, including decreased infection of disease among juveniles, decreased residency time in the mainstem prior to smolting, and increased habitat availability in the mid-Klamath River (Hardy et al. 2006). The dam removal scenario with KBRA implementation would restore the assimilative capacity of the river to process nutrients, resulting in water quality benefits downstream from IGD.

Based on the most recent analysis, drawdown of the four dams will release approximately one third to two thirds of the estimated 15 million cubic yards of sediment that will be stored in the reservoirs by 2020 (USDI Bureau of Reclamation 2011). The amount of sediment supply to the ocean due to dam removal would be less than the average annual sediment supply of the river under current conditions (USDI Bureau of Reclamation 2011). Earlier analyses indicated that there would be a greater sediment release into the downstream reaches of the Klamath River (Stillwater Sciences 2009a). Thus, the following impacts on aquatic habitat from dam removal due to the release of sediment as predicted by Stillwater Sciences (2009a) should be considered to be on the high side.

The removal of Project dams will cause sediment in the path of the river flow to erode nearly instantaneously when exposed to moving water (Hetrick et al. 2009; Stillwater Sciences 2009a). Not all of the sediment trapped in the reservoirs will erode. Most of the sediment outside of the river channels in Copco 1 and IGD reservoirs will remain in place (Gathard Engineering Consulting 2006). Downstream sediment delivery will occur as a series of pulses of sorted material starting with fines, then sand, followed by coarse material driven by the occurrence and magnitude of storms upriver (Hetrick et al. 2009). The drawdown of the reservoirs is expected to take up to nine months, depending upon when the drawdown starts and the particular reservoir (USDI Bureau of Reclamation 2011).

The material in the reservoirs is primarily silt and clay and a significant portion of the reservoir material will erode during the drawdown period and will remain in suspension all the way to the ocean (Stillwater Sciences 2009a). The primary impact on aquatic habitat from dam removal is predicted to result from the release of this fine sediment when the reservoirs are drawn down in preparation for their eventual removal; there would be relatively little sediment release after draw down is complete (Stillwater Sciences 2009a). During the drawdown period, suspended concentrations will be extremely high in the PR and below. The concentrations will decrease in the downstream direction as tributary flows dilute the high concentrations, but the higher than normal concentrations will persist all the way to the ocean. The travel time from the PR to the ocean is about four days (Gathard Engineering Consulting 2006; Stillwater Sciences 2009a).

Small amounts of fine sediment would settle along stream margins and other low-velocity areas within the active channel. It is anticipated that sediment would move down the river in waves following successive storms as the channel, currently inundated by the reservoirs, reoccupies its original planform and grade. Sediments will distribute both longitudinally and horizontally as a function of discharge and river channel velocities. The distribution of fine and coarse sediment will be highly dependent upon the frequency, magnitude, duration, and rate of change of hydrologic events during and immediately following drawdown of the reservoirs. Coarse materials will follow the fines, covering up many of the areas that were inundated, and this process will sequentially continue down the river until the river cuts back to its original channel form (Hetrick et al. 2009).

Simulations of sediment transport following removal of the lower four dams on the Klamath River indicate that there would be a maximum of two to four feet of primarily silt and sand sized sediment deposition downstream of the dam and upstream of RM 183 (Stillwater Sciences 2009a; USDI Reclamation 2011). All the excess silt and sand sized sediment is expected to be flushed out of the reach downstream of IGD once a flow greater than an average annual flood occurs (USDI Bureau of Reclamation 2011). After the initial flush of fine sediment through the system, there will be a resupply of gravel to the reach downstream of IGD that will permanently raise bed elevations by one to two feet in the reach from Bogus Creek to Willow Creek and about one foot from Willow Creek to Cottonwood Creek. No significant sediment deposition is expected downstream of RM 183, near Cottonwood Creek (USDI Bureau of Reclamation 2011).

Potential adverse effects include increased fine sediment in spawning gravels, pool filling, and increased levels of suspended sediment and turbidity. Most of these effects are predicted to be of relatively short duration (Stillwater Sciences 2009a). Based on the available information and modeling, the downstream effects of sediment on resources is likely to be minimal, and relatively short term—particularly if dam removal occurs during a wet year (Federal Energy Regulatory Commission 2007). However, FERC estimated that adverse effects from high silt loads in mainstem spawning habitat would persist for a longer time period, perhaps for several years (Federal Energy Regulatory Commission 2007). It will take one wet year to flush the fine sediment from the river bed. If dam removal occurs during a dry year followed by several dry years, the river bed may remain clogged with fine sediment until a flood that is approximately as large as the average annual flood occurs (USDI Bureau of Reclamation 2011).

Adverse effects from high silt loads that occur to spawning fall Chinook salmon would be limited to fish that spawn in the mainstem Klamath, and not the majority of fall Chinook salmon that spawn in its tributaries, although depending on the timing of any dam removals, adult upstream migration to those tributaries could be slowed by increased turbidity and suspended solids (Federal Energy Regulatory Commission 2007). See *Section 2.2.8.3. Conditions without Dams with KBRA – Chinook Salmon Below Iron Gate Dam for more discussion on impacts of fine sediment release.*

Eventually, downstream sediment delivery would reestablish geomorphic and vegetative processes (American Rivers 2002; Bednarek 2001; Stanley and Doyle 2003) forming channels that provide fish habitat and spawning gravels below IGD (Hetrick et al. 2009). Spawning gravel that has been intercepted by Project dams and reservoirs would be restored throughout the PR and downstream of IGD under conditions without dams and with KBRA. This gravel recruitment and the reestablishment of a mobile stream bed below IGD (Varyu and Greimann 2010) would have substantial benefits for spawning habitat for salmon and steelhead. The quantity and quality of available spawning habitat would likely increase in the long term by restoring the transport of spawning gravels from areas upstream of IGD (Federal Energy Regulatory Commission 2007; Blair Greimann, Reclamation, pers. comm.).

Sediment transport below IGD would be greater under the dams out scenario (Stillwater Sciences 2010a). The removal of the dams would resupply gravel to the reaches downstream of IGD and this would reduce the median substrate size from IGD to the Shasta River, meaning that lower flows are required not only for bed mobilization but for sediment transport as well. The increased sediment transport and the reestablishment of a mobile stream bed would likely have benefits in the reduction of fish disease (Bartholomew and Foott 2010; Hetrick et al. 2009) (see section on Fish Disease below). The differences between the two alternatives in terms of effects on bed mobilization decrease below the Shasta River (USDI Bureau of Reclamation 2011). This is a function of very coarse bed material and bedrock substrate in this reach. However, there would still be an increase in the amounts of gravel transport through this reach after dam removal.

Case histories also provide examples of the rate of sediment movement after dam removal. On Idaho's Clearwater River nearly all of the sediment that had been stored behind the Grangeville Dam was flushed downstream within eight months (American Rivers et al. 1999). After removal of the Marmot Dam, Sandy River, Oregon, was complete, about 20 percent of the stored sediment was exported within the first 48 hours (Major et al. 2008; Parks 2009). However, on a lower gradient (0.47 percent) stream in Michigan, increased sediment downstream from dam removal degraded habitat for at least 4 years after dam removal (Burroughs et al. 2010). The authors were of the opinion that excess sediment deposition should decline after erosion in the former impoundment ceased. The higher gradient Klamath River (0.8 percent, Keno Dam to IGD; (Federal Energy Regulatory Commission 2007)) would likely move sediment downstream more quickly.

2.2.8. Existing Anadromous Fish Species Below Iron Gate Dam

2.2.8.1. Existing Chinook Salmon Below Iron Gate Dam

Chinook salmon in the Klamath River Basin are not listed under the state or federal ESA, but low abundance predictions of Klamath River Fall Chinook salmon in recent years have forced restrictions to West Coast commercial and recreational fisheries. Klamath River fall-run Chinook salmon enter the Klamath River in August through October of each year, spawning shortly thereafter in the lower reaches of rivers and streams. These runs are substantially lower than historical levels. Recent natural adult spawner escapement has ranged from 16,064 (in 1984) to 161,794 (in 1995) (S. Borok, CDFG, pers. comm.). Fall-run Chinook salmon are distributed throughout the Klamath River downstream of IGD and in its tributaries. Typically only a small portion of the Chinook run spawns in the mainstem Klamath River.

Spring-run Chinook salmon currently enter the Klamath River from April to June of each year before migrating to smaller headwater tributaries. Historically, populations may have returned earlier, perhaps as early as February and March (Klamath Republican articles in (Fortune et al. 1966)). They require cold, clear rivers and streams with deep pools to sustain them through the warm summer months (McCullough 1999). These areas have been greatly reduced in the basin due to dams and degradation of habitat. Naturally-spawned spring-run Chinook salmon populations are now a remnant of their historical abundance and primarily occur in the South Fork Trinity River and Salmon River basins.

There is evidence that fall-run Chinook salmon in the Klamath River are more tolerant of warm water temperatures than other Chinook stocks. For Klamath River adult fall-run Chinook salmon mean daily river temperatures upon initiation of upriver migration range from 21.8 to 24°C and upper thermal limits are substantially higher than previously reported in the literature (Strange 2010). Likewise, fall-run Chinook salmon fry rear in the mainstem Klamath River at temperatures of 19 to 24°C (National Research Council 2004a).

2.2.8.2. Conditions with Dams – Chinook Salmon Below Iron Gate Dam

Under this scenario, considerable efforts to improve habitat are underway toward the goal of recovery of salmon and steelhead stocks (National Marine Fisheries Service 2010b). Once implemented, TMDLs and associated Implementation Plans are expected to improve water quality, reduce stress on salmonids from pollution, and contribute to their recovery (National Marine Fisheries Service 2010b).

However, under conditions with dams, the status of naturally spawning fall-run Chinook salmon may continue on its current trajectory (R. Quiñones, USFS, pers. comm.; Figure 4). With minimal access to appropriate habitat, spring Chinook salmon runs will likely remain at a fraction of historical levels; it is possible that Klamath River spring-run Chinook salmon may become extinct over the period of analysis (Moyle et al. In Press; Nehlsen et al. 1991).

Project reservoirs are likely to continue to contribute to the population of exotic predators of anadromous fish below IGD. Both yellow perch and largemouth bass in reservoirs are species not native to Oregon or California. Largemouth bass are known predators of native fishes, including salmon and trout (Moyle 2002; Moyle et al. In Press). In addition to Upper Klamath Lake, the project reservoirs are believed to be a source of these non-native species in the Klamath River below IGD (T. Shaw, Service, pers. comm.).

2.2.8.3. Conditions without Dams with KBRA – Chinook Salmon Below Iron Gate Dam

For fall-run Chinook salmon, analysis of effects of dam removal below IGD is based on the current dam removal plan as described (Stillwater Sciences 2009a) and the assumption that this plan will be implemented[25]. As a short-term (1-2 years) result of dam removal, total suspended sediments (TSS) concentrations may become quite high (e.g., 14,000 mg/L under a dry year scenario) (Stillwater Sciences 2009b; USDI Bureau of Reclamation 2011). Concentrations of suspended sediment are expected to be higher in reaches closer to the point of origin of the sediment (the former dam sites) and to decline in a downstream direction. Concentrations would be further reduced at confluences of major tributaries such as the Scott, Salmon, and Trinity rivers (Stillwater Sciences 2009a). Release of sediment from behind IGD during reservoir drawdown is expected to result in increases in suspended sediment and turbidity for approximately nine months following initial reservoir drawdown (USDI Bureau of Reclamation 2011).

Based on redd surveys using a mark and re-sight methodology from 2001 through 2009 (California Department of Fish and Game, unpubl. data) around 8 percent (range from 5.3 to 13.5 percent) of the total escapement in the Klamath River basin spawns in the mainstem downstream of IGD. Because they migrate upstream during fall and typically finish spawning by late November and because increases in suspended sediment and

[25] Some specifics of the dam removal plan have been refined (USDI Reclamation 2011). Drawdown start dates of January 1 2020, November 1, 2019, and January 1, 2020, are now most likely for J.C. Boyle, Copco 1, and Iron Gate dams (USDI Reclamation 2011); drawdown of Copco 1 reservoir would be accomplished through both the low level outlet and notching of the dam (USDI Reclamation 2011).

turbidity would be limited (USDI Reclamation 2011), impacts to fall-run adults associated with drawdown would be minimized or avoided.

Chinook salmon in the mainstem below IGD would also be impacted by downstream oxygen demand associated with dam removal. Oxygen demand per unit mass of wet sediment may also be relatively high over the short term (Stillwater Sciences 2010b). Preliminary calculations in a spreadsheet model that used these analytical results suggests that a load of this magnitude, likely representing a near worst case scenario, could result in near anoxic water (i.e., no oxygen in the water column) for 10's of miles downstream of the dam, and possibly for a few days following the elevated sediment concentrations, before recovery. It is expected that this effect would be temporary, and could be the largest if high suspended sediment concentrations occur shortly after initial drawdown. Once the remnant sediments along the margins of the reservoir have been exposed to air following drawdown, the oxygen demand of those sediments would be expected to decrease, possibly reducing the impact during later sediment flushes (C. Anderson, USGS, pers. comm.). Future modeling of a variety of TSS loads under different environmental conditions (e.g. weather, hydrology) will aide in describing the potential influences on DO concentration in the river in both space and time (P. Zedonis, Service, pers. comm.).

For Chinook salmon and the biota immediately downstream of the PR, it is likely that oxygen demand impacts would subside more rapidly than TSS impacts both longitudinally and temporally. However, results of studies currently underway as part of the Secretarial Determination process will provide additional information regarding short-term dissolved oxygen concentrations in the river downstream of IGD following dam removal (P. Zedonis, Service, pers. comm.).

For other life stages of Chinook salmon, 'worst-case scenario' exposures to excess suspended sediments following reservoir drawdown are predicted to range from sublethal avoidance behavior and physiological stress to high direct mortality for some life-stages (e.g., incubating eggs in the mainstem), depending on durations and concentrations of exposure (Stillwater Sciences 2009a). Fine sediment infiltration of Chinook salmon redds is expected to be limited to shallow depths near the bed surface, which can be readily flushed during a high flow event after the fine sediment supply in the former reservoir is exhausted, or would be removed by the redd construction of spawning fish in subsequent years (Stillwater Sciences 2008). Beyond the first year the effect of fine sediment on spawning success is believed to be unlikely to persist (Stillwater Sciences 2008). However, FERC estimated that adverse effects from high silt loads in mainstem spawning habitat would persist for a longer time period, perhaps for several years (Federal Energy Regulatory Commission 2007).

For fall-run Chinook salmon smolts the impact from dam removal due to suspended sediment is expected to be minor. Variable life histories result in many age 0+ juveniles rearing in tributaries and migrating to the mainstem only later in the spring and summer. Many of the fry outmigrating to the mainstem come from tributaries in the mid- or lower Klamath, where TSS concentrations will be diluted (Stillwater Sciences 2008).

Overall, cumulative impacts on multiple life stages were considered to result in no production from redds in the mainstem during the year of dam removal (Stillwater Sciences 2009a). The reduction in the number of fall-run Chinook salmon spawners that would occur under the worst-case scenario would be evident for three years of direct impact from a given sediment pulse (Stillwater Sciences 2009a). In a worst-case scenario, the average percent reduction in escapement for the three simulations is 33 percent three years after dam removal, 32 percent four years after dam removal, and around 1 percent five years after dam removal (Stillwater Sciences 2008). Overall, it appears that the impacts on fall-run Chinook salmon due to suspended sediments will be short-term, and that the population will fully recover within five years after dam removal (Stillwater Sciences 2008).

For spring-run Chinook salmon, because no spawning occurs in the mainstem Klamath River, spawners, incubation, eggs and fry would not be affected by dam removal (Stillwater Sciences 2009a). The overall effect of dam removal to the spring-run Chinook population is not anticipated to be considerable (Stillwater Sciences 2009a).

KBRA flows are intended to benefit fall-run Chinook salmon. Hetrick's analysis of KBRA type[26] flows showed the greatest benefits of would be in years when production was low (Hetrick et al. 2009). For years where modeled historical production was high, there was little difference from KBRA management. The percent change in production between the historical water years 1961-2000 baseline and KBRA type flows for the 10 highest historical production years (upper 25th percentile) averaged about +6 percent and for the 10 lowest historical production years (lower 25th percentile), about +45 percent. A similar comparison of percent change in production between the historical water years 1961-2000 baseline and the Hardy Phase II simulations showed -7 percent and +50 percent for the 10 highest and lowest historical production years respectively (Hetrick et al. 2009). Implementing either the KBRA type flows or the Hardy et al. (Hardy et al. 2006) Phase II flow recommendations was predicted to decrease the occurrence of poor production years in the future by two-thirds. This would have significant positive consequences for Chinook salmon given their life cycle in the Klamath River (Hetrick et al. 2009).

Overall, dam removal and associated KBRA actions will accelerate TMDL water quality benefits to this species (USDI Secretarial Determination Water Quality Subgroup In Review). The restored temperature regime would mean varied and differing effects to anadromous fish below IGD.

For adult fall-run Chinook salmon during upstream migration, the dams out management scenario would cool thermal habitat[27] and benefit mainstem spawning and egg incubation

[26] This analysis assumed that low flows in water years 2012 to 2020 would resemble low flows in water years 1961 to 2000. The Hetrick et al. (2009) analysis was based on a period of record 1961-2000; thus we refer to these as 'KBRA type' flows.

[27] No Action/Current Dams includes NMFS 2010 BO flows; Dams Out with KBRA includes dams in 2012 through 2020 with KBRA flows, dams removed in 2020 with KBRA flows.

(Figure 11). The miles of habitat below IGD with suitable temperatures for Chinook salmon migration during August 15 to September 15 would increase from 20 miles with dams in to more than 100 miles with dams out (Figure 12). The miles of habitat with suitable temperatures below IGD with Chinook salmon spawning and egg incubation during October would be slightly greater under conditions without dams and with KBRA (Figure 13).

For juvenile fall-run Chinook salmon, Bartholow et al. (Bartholow et al. 2005) reported far greater acute degree days (a degree day was defined as an aggregate measure of thermal stress, here calculated as the sum of the differences of mean daily temperature above 20^{o}C below IGD) under conditions without dams. However, Bartholow et al. (Bartholow et al. 2005) also suggest that earlier warming of the river system is likely to trigger juvenile salmonids to out migrate earlier as did FERC (Federal Energy Regulatory Commission 2007). If so, this would mean emigrants would avoid unsuitably warm water temperatures that are presently reached in late spring to midsummer in most years. This is consistent with findings that accumulated temperature units are more important predictors of migration of juvenile Chinook salmon than flow or photoperiod (Sykes et al. 2009). A predicted earlier outmigration in response to elevated water temperatures in the spring is also supported by a vast body of literature relating to increased growth rates and thermal response of emigrating salmonids (Hoar 1988). Similarly, FERC concluded that the shift in thermal phase would likely result in earlier spawning, a longer incubation period, earlier emergence and growth, and encourage earlier emigration of fall-run Chinook salmon (Federal Energy Regulatory Commission 2007).

Dunsmoor and Huntington (Dunsmoor and Huntington 2006) analyzed conditions with dams and conditions without dams using the Klamath River Water Quality Model developed for Link River Dam to the estuary. Specifically they compared the impacts on temperature, and to a lesser extent DO. They also applied life stage-specific criteria to model results to evaluate impacts on salmon. Under conditions without dams, Dunsmoor and Huntington (Dunsmoor and Huntington 2006) showed a net reduction in the duration of highly stressful conditions as well as the frequency of the need for thermal refugia in most of the river reaches outside of the J. C. Boyle Bypassed Reach and at the dams.

While their results were consistent with those of Bartholow et al. (Bartholow et al. 2005), at least for fall-run Chinook salmon regarding a restored or more natural thermal regime for adult migration, Dunsmoor and Huntington's (Dunsmoor and Huntington 2006) analysis also suggested that dam removal may provide thermal benefits to juvenile Chinook salmon downstream of IGD. Among the four reasons cited for disagreeing with Bartholow et al. (Bartholow et al. 2005) on this point, they believe that the Bartholow et al. (Bartholow et al. 2005) use of a degree day metric was somewhat unrealistic in its assessment of likely impacts to juveniles. This was because it assumes juveniles to be occupying the river regardless of temperature. Thus, Figure 14 may have limited meaning for rearing Chinook salmon because most juveniles have already outmigrated during the period when the greatest number of degree days accumulated. Dunsmoor and Huntington (Dunsmoor and Huntington 2006), however, did suggest that further study was warranted regarding whether Chinook production in the lower mainstem would be increased, decreased, or remain the same.

Warmer temperatures during spring and early summer could impair migration of adult Chinook salmon during these periods and may inhibit restoration of spring-run Chinook salmon unless returning adults migrate earlier before the onset of unsuitable temperatures. However, in this regard, the immigration timing attributed to spring-run Chinook salmon is generally based on observations after runs were blocked from habitat above IGD and likely does not reflect the timing of historical runs to the upper Klamath Basin. The 1901 Klamath Republican reported salmon at Klamath Falls in February and March (Fortune et al. 1966; Lane and Lane Associates 1981). This would mean even earlier entry into the Klamath River from the ocean. Snyder (1931) reported the timing of spring-run Chinook salmon entering the Klamath as late February and March, with entry completed by the last of May. These accounts indicate immigration and a life history that likely avoided periods of poor water quality.

If dams were removed it is reasonable to expect reestablished spring-run Chinook salmon to synchronize their upstream migration with more natural flows and temperatures. The removal of Project reservoirs would also contribute important coldwater tributaries (e.g., Fall Creek, Shovel Creek) and springs, such as the coldwater inflow to the J.C. Boyle Bypassed Reach, to directly enter and flow unobstructed down the mainstem Klamath River, thereby providing thermal diversity in the river in the form of intermittently-spaced patches of thermal refugia. These refugia would be useful to migrating adult spring-run Chinook salmon by extending opportunities to migrate later in the season. The thermal diversity would also benefit juvenile salmon.

After dam removal, water temperatures would return to more normal day diurnal variability similar to that in unregulated river systems. While the river would experience higher maximum temperatures with dam removal, it would also experience lower minimum temperatures and associated benefits to rearing salmonids (National Research Council 2004a). While average and daily maximum water temperatures would also increase to stressful levels earlier in the summer than currently occurs (Federal Energy Regulatory Commission 2007), the increase in average and maximum daily temperatures may be compensated for by lower temperatures at night, which the National Research Council (National Research Council 2004a) concluded may allow rearing fish to move out of temperature refugia to forage at night, allowing growth to occur even when ambient temperatures are above optimal (Federal Energy Regulatory Commission 2007). Conditions without dams would allow the ecosystem's historical thermal dynamics to be restored between February and June. Thus, conditions supporting diversity in life history strategies inherent in viable salmon populations (Poff et al. 1997; Poole et al. 2001) would likely occur.

Dam removal would reestablish connectivity of resident and anadromous fish to habitat currently blocked by the dams (Burroughs et al. 2010). Connectivity is important for enabling organisms to travel throughout a riverine system. Continuous passage through a river enables organisms to migrate up and downstream, search for optimal sediment sizes and water levels for spawning, or find areas of greater food availability, or lower predation (Bednarek 2001). In the Klamath River watershed, connectivity to additional, groundwater areas with cooler summer and warmer winter temperatures would mean that populations increase their likelihood of persistence under climate change. Fish passage at the locations of the lower four dams would be generally unhindered upon dam removal and KBRA implementation. The fishway at Link River dam is presently suitable for passage of all fish species. The fishway at Keno Dam currently complies with passage criteria for salmonid fish, but plans are being developed to have the fishway rebuilt to criteria for lamprey and for greater anadromous salmonid runs if the Keno facility is transferred to the government as part of settlement (T. Hepler, Reclamation, pers. comm.).

Once Chinook salmon could migrate to groundwater areas in the tributaries to UKL (Federal Energy Regulatory Commission 2007) the likelihood of restoring spring-run Chinook salmon to the Klamath River would be greater. Access to these additional habitats in the Klamath River watershed would not only benefit Chinook salmon life histories but other anadromous salmonid runs as well.

Modeling for fall-run Chinook salmon showed the chance of getting substantially more fall-run Chinook salmon spawners is much better with the dams removed than with the dams remaining, over a 50-year period (Oosterhout 2005). Oosterhout's results also suggested that returns would also be greater for steelhead and coho salmon; however, further analysis is needed.

The monitoring and adaptive management elements of KBRA would shift the focus of Klamath restoration to identification of limiting factors and reestablishing critical riverine processes, rather than single species management. This would add ecological insurance to restoration projects and align efforts with current approaches to watershed restoration (Palmer 2008).

2.2.8.4. Existing Coho Salmon Below Iron Gate Dam

Coho salmon were once abundant in the Klamath River. This section will detail the current condition of the three mainstem Klamath River population units and two tributary population units (i.e., the Shasta and Scott) most affected by Klamath River conditions with or without dams.

Historically, coho salmon inhabited an expansive range of the Klamath River Basin, including habitat upstream of current dams - Iron Gate, Lewiston (Trinity River), and Dwinnell (Shasta River). Coho salmon populations within the Klamath River watershed have declined dramatically and currently exist only within a limited portion of their historical range. NMFS determined that coho salmon populations throughout the SONCC coho salmon ESU continue to be depressed relative to historical numbers, and strong indications exist that breeding groups have been lost from a significant percentage of streams within their historical range.

Based on precipitation and flow patterns, among other factors, Williams et al. (Williams et al. 2006) identified the distribution of Upper Klamath River Population Unit as extending from Portuguese Creek to Spencer Creek (inclusive). The historical upstream distribution of coho salmon in the watershed extended at least to Spencer Creek (Hamilton et al. 2005). Although it may seem intuitive to describe the status of the species separately above and below IGD, they are combined in the Upper Klamath River reaches (Table 2) in order to maintain consistency with the historical population structure identified by Williams et al. (Williams et al. 2006).

Within the California portion of the SONCC coho salmon ESU, estimating the risk of extinction of a given coho salmon population is difficult since longstanding monitoring and abundance trends are largely unavailable. Williams et al. (Williams et al. 2008) proposed biological viability criteria, including population abundance thresholds as part of the ESA recovery planning process for the SONCC coho salmon ESU. The viability criteria developed by Williams et al. (Williams et al. 2008) address and incorporate the underlying viability concepts (e.g., abundance, productivity, diversity, and spatial structure) outlined in McElhany et al. (McElhany et al. 2000), and are intended to provide a means by which population and ESU viability can be evaluated in the future when robust population data become available. Comparing rough population estimates recently derived through Klamath coho salmon life-cycle modeling (Ackerman et al. 2006) against population viability thresholds proposed by Williams et al. (Williams et al. 2008) allowed NMFS to make conservative assumptions concerning the current risk of extinction of Klamath River mainstem and tributary population units (Table 2).

None of the population units of Klamath River coho salmon are considered viable at this point in time. Even the most optimistic estimates from Ackerman et al. (Ackerman et al. 2006) indicate each population falls well short of abundance thresholds for the proposed viability criteria that, if met, would suggest that the populations were at low

Table 2. Estimated abundances versus various abundance thresholds of coho salmon populations in the Klamath River Basin (from (Williams et al. 2008)).

Stratum	Population Unit	Approximation of run size estimates from 2001-2004 (from Ackerman et al. 2006)	High Risk Annual Abundance Level[a]	Low Risk Annual Abundance Level[b]
Central Coastal Basins	Lower Klamath	0 – 2,000	205	5,900
Interior – Klamath	Middle Klamath	0 – 1,500	113	3,900
Interior – Klamath	Upper Klamath	100 – 4,000	425	8,500
Interior – Klamath	Scott River	10 – 4,000	441	8,800
Interior – Klamath	Shasta River	100 - 400	531	10,600
Interior – Klamath	Salmon River	50	115	4,000
Interior – Trinity	South Fork Trinity River	500-9,000[c]	242	6,400
Interior – Trinity	Lower Trinity River		112	3,900
Interior – Trinity	Upper Trinity River		64	2,400

[a] High risk annual abundance level corresponds to a population threshold below which there exists a high risk of depensation (e.g., decreasing productivity with decreasing density). Depensatory processes at low population abundance result in high extinction risks for very small populations because any decline in abundance further reduces the population's average productivity, resulting in a steep slide toward extinction (McElhany et al. 2000).
[b] Low risk annual abundance level represents the minimum number of spawners required for a population to be considered at low risk for spatial structure and diversity threshold.
[c] Ackerman et al. 2006 produced single estimates for the Trinity River from 2001-2004; they did not distinguish between the population units identified by Williams et al. (2008).

risk of extinction for this specific criterion. In some years, populations have fallen below the high risk abundance level (such as the Shasta River population).

A population is considered by NMFS at low risk of extinction if all criteria are met, therefore failure to meet any one specific criterion would result in the population being at an elevated risk of extinction (e.g., not viable). Furthermore, the Shasta River coho salmon population abundance is critically low and likely experiencing depensation pressures. With regard to spatial structure and diversity, (Williams et al. 2008) abundance thresholds were based upon estimated historical distribution and abundance of spawning coho salmon, and thus capture the essence of these two viability parameters. None of the abundance estimates for the five Population Units along the mainstem Klamath River, which include the Upper Klamath, Middle Klamath, Lower Klamath, Shasta River, Scott River, and Salmon River, currently meet or exceed the low risk annual abundance threshold and fail to meet spatial structure and diversity conditions consistent with viable populations. Therefore, all five of these Population Units have a high risk of extinction under current conditions.

NMFS 2005 status review concluded the effect of hatchery programs on the spatial structure, productivity and diversity within the SONCC coho salmon ESU is uncertain (70 FR 37160). More recently, the specific viability criterion proposed by Williams et al. (Williams et al. 2008) considers the influence of hatchery fish within a population. Hatchery fish can affect natural salmon populations through increased competition, disease introgression, and genetic dilution (National Research Council 1996). To limit these effects, Williams et al. (Williams et al. 2008) propose that the fraction of naturally spawning fish within a given population that are of hatchery origin not exceed five percent. Populations within both the Klamath River and Trinity River are influenced by hatchery fish, with native coho salmon present only in small numbers (California Department of Fish and Game 1994, 2004a; Good et al. 2005; Weitkamp et al. 1995). The high proportion of hatchery-reared coho salmon within the Trinity and Klamath rivers would suggest the Klamath River meta-population is at least at a moderate risk of extinction with regard to its genetic diversity.

2.2.8.5. Conditions with Dams – Coho Salmon Below Iron Gate Dam

Activities to aid recovery of salmonid populations within the Klamath River Basin, including coho salmon, will continue through flow management and habitat restoration. Several notable restoration and recovery actions were implemented in 2009 (National

Marine Fisheries Service 2010b). Water quality and habitat problems under conditions with dams will continue to result in impacts to listed coho below IGD (National Marine Fisheries Service 2008). Actions are currently being taken under PacifiCorp's Interim Conservation Plan, including efforts to improve DO levels below IGD. In addition, habitat restoration projects are also being implemented under the Coho Enhancement Fund as part of PacifiCorp's Interim Conservation Plan. However, the efficacy of these efforts remains unknown at this time.

There are other, ongoing efforts underway that are intended to contribute to the recovery of SONCC coho salmon. The NMFS BO proposes increasing fall and winter flow variability with expectation of improving water quality conditions and expanding complex side channel habitat used by coho salmon for spawning (National Marine Fisheries Service 2010a). To avoid jeopardy the BO also proposed increased spring flows to provide sufficient flow, depth, velocity, substrate, and cover for critical habitat and sufficient water velocities to enable juvenile coho to outmigrate. However, current populations of Klamath River coho may remain depressed, and therefore, not at a point where genetic integrity of populations are capable of contributing to resiliency when challenged by additional environmental stressors, including climate change.

2.2.8.6. Conditions without dams and with KBRA – Coho Salmon Below Iron Gate Dam

Coho salmon are distributed throughout the Klamath River downstream of IGD and its tributaries with most spawning, fry and juvenile rearing occurring in tributaries. Coho salmon adults entering the lower Klamath tributaries are not likely to be significantly affected by dam removal, since most will be out of the mainstem by the start for drawdown. It appears that less than 12 percent of the total Klamath River Basin coho escapement will not have reached a tributary, will still be in the mainstem, and be directly affected by sediment release during dam removal (Stillwater Sciences 2009a). Based on an analysis combining both hatchery and naturally produced coho salmon, less than 1 percent of the total escapement spawns in the mainstem (Stillwater Sciences 2009a).

For the coho salmon in the mainstem during dam removal the cumulative impacts on multiple life stages are anticipated to result in no production (Stillwater Sciences 2009a). The effect of dam removal on the coho salmon population is not expected to be significant, despite direct mortality to a proportion of some life stages (Stillwater Sciences 2009a). A decrease in coho salmon production is likely for two year classes (Stillwater Sciences 2009a).

Overall, dam removal and associated KBRA actions will accelerate TMDL water quality benefits to this species (USDI Secretarial Determination Water Quality Subgroup In Review). Over the long term, water quality and habitat would improve for coho salmon downstream from IGD with dam removal. Populations of coho salmon that make up the SONCC ESU need to have diverse habitats available when challenged with abiotic and biotic change.

Warmer temperatures in spring and early summer would degrade mainstem habitat and mainstem thermal refugia. However, juvenile coho salmon apparently migrate up tributary streams to escape high temperatures rather than remain in the mainstem (Sutton and Soto 2010). This study found that coho counts in the studied thermal refugia significantly decreased at temperatures >22–23°C, suggesting that this is approximately the upper thermal tolerance level for Klamath coho salmon.

Access to habitat above IGD would provide connectivity across historically accessible habitats and allows fish to respond to changing environmental conditions, including temperatures and flows associated with climate change. As portions of the historical range of coho were made inaccessible by Project dams, the abilities of populations and the ESU to persist were constrained. Reestablishing access to historically available habitat above IGD will benefit recovery of coho salmon by providing opportunities for the local population and the ESU to meet the various measures used to assess viability (e.g., abundance, productivity, diversity, and spatial structure) (Williams et al. 2006). Thus, there would be less risk of extinction when more habitat is available across the ESU.

2.2.8.7. Existing Steelhead Below Iron Gate Dam

Steelhead are widely distributed throughout the Klamath River watershed below IGD. Populations, including summer, fall, and winter steelhead, are considered part of the Klamath Mountains Province ESU. Even though NMFS found that listing of the Klamath Mountain Province Steelhead Distinct Population Segment (DPS) was not warranted, NMFS expressed concerns about the status of steelhead within this DPS, and identified the DPS as a candidate species, which the agency would continue to monitor and re-assess (66 FR 17845).

While Klamath steelhead populations have been difficult to accurately estimate due to their diverse life history and broad distribution, there is evidence of a declining trajectory. Busby et al. (Busby et al. 1994) reported that summer-run counts have been declining three percent per year since 1980. Shasta River weir counts showed a strong decline (average 15 percent per year) since 1977; Bogus Creek counts were low, possibly with a slight decline (~ one percent per year, but not significantly different from zero) (Busby et al. 1994).

Hardy et al. (Hardy et al. 2006) report that historical run sizes for steelhead trout in the Klamath River Basin were estimated at "400,000 fish in 1960 (USFWS 1960 as cited by (Leidy and Leidy 1984)); 250,000 in 1967 (Coots 1967 in (Hardy et al. 2006)); 241,000 in 1972 (Coots 1972 in (Hardy et al. 2006)); 135,000 in 1977 (Boydston 1977 in (Hardy et al. 2006)); and 103,000 in the early 1980's (Hopelain 1998)".

The limited data on summer steelhead abundance indicates this run is depressed, with an average of less than 600 summer steelhead surveyed per year in ten Klamath River tributaries on lands administered by the Klamath National Forest (R. Quiñones, USFS, pers. comm.). Klamath Mountain Province summer steelhead populations are in decline

(Figure 6 and Figure 16) (R. Quiñones, USFS, pers. comm.). Hundreds of miles of historical habitat were lost to steelhead in 1918 with the construction of the first Copco Dam on the mainstem Klamath River. In 1963, hundreds of additional miles of habitat were lost with the construction of Lewiston Dam on the Trinity River. Hatcheries at the Iron Gate and Lewiston Dams currently produce fall steelhead as mitigation for habitat loss upstream of these facilities. Summer steelhead are not part of the hatchery production program in the Klamath River Basin. However, NMFS reviewed the status of Klamath Mountains Province steelhead and determined the ESU is not currently at risk of extinction (National Marine Fisheries Service 2001).

2.2.8.8. Conditions with Dams – Steelhead Below Iron Gate Dam

Under this scenario, considerable efforts to improve habitat are underway (National Marine Fisheries Service 2010b) toward the goal of recovery of salmon and steelhead stocks. Once implemented, TMDLs and associated Implementation Plans are expected to improve water quality, reduce stress on salmonids from pollution, and contribute to their recovery (National Marine Fisheries Service 2010b).

2.2.8.9. Conditions without dams and with KBRA-Steelhead Below Iron Gate Dam

Summer and winter steelhead are currently distributed throughout the Klamath River downstream of IGD and its tributaries, spawning primarily in tributaries such as Trinity, Scott, Shasta, and Salmon rivers. Reservoir drawdown impacts are predicted to be greatest for the portion of the steelhead adults migrating to spawn in tributaries upstream of the Trinity River confluence, and are anticipated to affect at least six year classes of this group (Stillwater Sciences 2009a). Much of the population will avoid severe impacts of suspended sediments by remaining in tributaries for extended rearing, or using the Klamath River mainstem farther downstream where suspended sediment concentrations are anticipated to be more dilute. Life history variations mean that although numerous year classes will be affected, not all individuals in any year class will be affected (Stillwater Sciences 2009a). Overall summer and winter steelhead populations are predicted to be impacted by removal over the short-term, but have life history characteristics that should allow strong recovery (Stillwater Sciences 2009a).

Access to additional habitat in the upper Klamath River watershed would benefit steelhead runs. In general, dam removal with KBRA would likely result in the restoration of more reproducing populations, higher genetic diversity, and the opportunity for variable life histories and use of new habitats.

In addition to Chinook salmon, Dunsmoor and Huntington (Dunsmoor and Huntington 2006) analyzed conditions for juvenile steelhead with dams versus conditions without dams. Assuming that juveniles will seek thermal refugia when daily maximum temperatures exceed 22°C, they determined 1) frequency (number of days) with which juveniles would require thermal refugia, and 2) average minimum daily river temperatures for periods when thermal refugia would be occupied. They concluded that removal of the lower four dams provides a net benefit to use of refugia, because of the combined effects of decreased need for refugia in many reaches with the tendency for cooler daily minima in reaches where dam removal increases the need for refugia (Dunsmoor and Huntington 2006). They also concluded that severely stressful thermal conditions for juvenile steelhead would be reduced by 2-3 weeks below IGD under the dam removal scenario.

Overall, dam removal and associated KBRA actions will accelerate TMDL water quality benefits (USDI Secretarial Determination Water Quality Subgroup In Review) to this species. The restored temperature regime means varied and differing effects to anadromous fish below IGD. After dam removal, water temperatures would return to variability inherent in local unregulated river systems. While the river would experience higher maximum temperatures, it would also experience lower minimum temperatures and associated benefits to rearing salmonids (National Research Council 2004a). Conditions without dams would allow the ecosystem's historical thermal dynamics to be restored. Thermal dynamics, including daily fluctuations and seasonal phase shift, would change for all or most months. Thus, conditions supporting diversity in life history strategies inherent in viable populations (Poff et al. 1997; Poole et al. 2001) would likely occur.

2.2.8.10. Existing Pacific Lamprey Below Iron Gate Dam

There is little data on historical abundance or distribution of Pacific lamprey in the Klamath River Basin, however anecdotal evidence suggests stocks have been in decline since the late 1980s (Larson and Belchik 1998; Moyle et al. 2009) and are currently on a status "Watch List" (Moyle et al. In Press). FERC believes this decline may be part of a coastwide trend (Federal Energy Regulatory Commission 2007). In Oregon, the Pacific lamprey was listed as a sensitive species in 1993, followed with protected status in 1996 (Bayer et al. 2001). The American Fisheries Society lists Pacific lamprey as "vulnerable" throughout its range (Jelks et al. 2008). Causes of Pacific lamprey decline include: 1) flow regulation, which can impede passage at dams and dewater rearing habitat; 2) river channelization, which can negatively impact larvae habitat by increasing water velocity and reducing depositional areas; and 3) susceptibility to the toxicological effects from contaminants due to their sedentary life (Close et al. 2002).

Pacific lamprey are present in the mainstem Klamath River and tributaries below IGD and the Trinity, Salmon, Shasta, and Scott River basins. Most ammocoete rearing likely occurs in the Salmon, Scott, and Trinity rivers, as well as the mainstem Klamath River, but Pacific lamprey are currently not regularly observed in the mainstem upstream of the Shasta River (Stillwater Sciences 2009a). This may be due to the lack of suitable sediment (see below). Lamprey have been observed on salmon at the Klamathon Racks (~RM 180) and they have been collected from Cottonwood Creek near Hornbrook (Coots 1962).

2.2.8.11. Conditions with Dams – Pacific Lamprey Below Iron Gate Dam

Under conditions with dams, anadromous Pacific lamprey populations may remain at status quo or continue to decline below IGD. TMDL implementation for the Klamath River will likely benefit Pacific lamprey.

2.2.8.12. Conditions without dams and with KBRA – Pacific Lamprey Below Iron Gate Dam

Because adult lamprey migrate upstream throughout the year, with multiple year classes of ammocoetes remaining in the substrate for multiple years, overall effects of increased sediments during dam removal could be severe (Stillwater Sciences 2009a). However, a lamprey distribution survey conducted by the Karuk Tribe in 2002 captured no lamprey ammocoetes in the reach below IGD to Cottonwood Creek (Karuk Tribal Fisheries 2010). Crews noted that "ideally suitable" habitat with substrate consisting of soft (easy to push your finger into) sand and fine silt material was almost entirely absent within the reach (Karuk Tribal Fisheries 2010). Lamprey ammocoetes were captured directly below Cottonwood Creek, one of the first sediment contributing tributaries below the dam (Karuk Tribal Fisheries 2010). With few ammocoetes directly below IGD, removal effects are unlikely to impact the Pacific lamprey population as a whole.

Due to their wide spatial distribution in the Klamath River Basin, straying behavior, and high fecundity, Pacific lamprey are anticipated to recover relatively quickly from dam removal impacts (Stillwater Sciences 2009a). Should mortality occur downstream of IGD from increased sediment load and deposition, it is expected that populations of larval lamprey found in the unaffected tributaries would recolonize these areas during normal lifecycle movements (Close et al. 2010). In addition, increased habitat availability and reestablishment of natural sediment dynamics following dam removal are likely to help reduce the impacts of dam removal for any Pacific lamprey in the mainstem that survive initial sediment releases (Stillwater Sciences 2009a). Pacific lamprey larval rearing capacity downstream of IGD will be increased during the short-term after dam removal and with implementation of the KBRA because of the added fine sediment loading following dam removal. The available burrowing habitat for larvae will subsequently decrease through time, but will likely remain higher than current conditions (Close et al. 2010).

The return to a temperature regime and flows that more closely mimic historical patterns would likely benefit Pacific lamprey. Overall, dam removal and associated KBRA actions will accelerate TMDL water quality benefits to this species (USDI Secretarial Determination Water Quality Subgroup In Review). Under the Condition without Dams and with the KBRA Alternative, increases in dissolved oxygen levels are expected to improve habitat productivity for Pacific and other Klamath River Basin lamprey species (Close et al. 2010).

In the conditions without dams and with the KBRA Alternative, higher temperatures in the spring and summer with dam removal could constrain lamprey productivity. Larval survival would be expected to be reduced and developmental abnormalities increased in some years. With dam removal, however, over-summering lamprey may make use of thermal refugia in tributaries upstream of the current location of IGD, thus potentially mitigating the effect of higher spring and summer temperatures (Close et al. 2010).

In response to climate change, the Lamprey Expert Panel expects the conditions without dams alternative to have a slight positive effect on lamprey habitat and lamprey inhabiting areas downstream of IGD, including effects on spawning and rearing conditions when compared to the conditions with dams alternative (Close et al. 2010).

2.2.8.13. Existing Green Sturgeon Below Iron Gate Dam

Green sturgeon are long-lived, slow-growing fish that are able to spawn multiple times. Early life-history stages reside in freshwater or estuarine habitat, with adults returning to freshwater to spawn when they are more than 15 years of age and more than 4 feet (1.3 m) in size. Green sturgeon are thought to spawn every two to four years (74 FR 52300). They are believed to spend the majority of their lives in nearshore oceanic waters, bays, and estuaries. Green sturgeon spawn primarily in the mainstem Klamath River downstream of Ishi Pishi Falls, in the Trinity River downstream of Grey's Falls, and potentially in the lower Salmon River.

The northern green sturgeon DPS includes all green sturgeon populations starting with the Eel River and extending northward. The northern green sturgeon DPS includes the green sturgeon spawning within the Klamath River drainage. In 2005, NMFS concluded that green sturgeon in the Northern DPS were not in danger of extinction now or likely to become endangered in the foreseeable future throughout all of its range (National Marine Fisheries Service 2005). However, the Northern green sturgeon DPS is considered a Species of Concern (69 FR 19975). Green sturgeon populations in this DPS face a number of potential threats including concentration of spawning, lack of population data, harvest concerns, and loss of spawning habitat. The Klamath River drainage is thought to contain most of the total spawning population of green sturgeon (Adams et al. 2002). Green sturgeon are known to occupy the mainstem Klamath River to Ishi Pishi falls and the lower portions of the Salmon River. Green sturgeon also occupy the Trinity River. Each year juveniles are captured in outmigrant traps at Willow Creek. Green sturgeon are regularly harvested by Hoopa Valley Tribal members.

2.2.8.14. Conditions with Dams – Green Sturgeon Below Iron Gate Dam

Under this scenario, considerable efforts to improve habitat are underway (National Marine Fisheries Service 2010b) toward the goal of recovery of salmon and steelhead stocks. Once implemented, TMDLs and associated Implementation Plans are expected to improve water quality, reduce stress on salmonids from pollution, and contribute to their recovery (National Marine Fisheries Service 2010b). These efforts may benefit green sturgeon as well.

2.2.8.15. Conditions without dams and with KBRA– Green Sturgeon Below Iron Gate Dam

Although green sturgeon in the mainstem Klamath River at the time of dam removal could be severely affected, much of the spawning and rearing habitat occurs downstream of the Trinity River confluence where sediment concentrations are predicted to be lower. The majority of the green sturgeon population will be in the ocean during dam removal. Any impacts to green sturgeon life stages in the mainstem Klamath River during dam removal will have little influence on the population as a whole over time (Stillwater Sciences 2009a). The return to a temperature and flow regime that more closely mimic historical patterns would likely benefit green sturgeon. Overall, dam removal and associated KBRA actions will accelerate TMDL water quality benefits to this species (USDI Secretarial Determination Water Quality Subgroup In Review).

2.2.8.16. Existing Eulachon Below Iron Gate Dam

Eulachon (commonly called smelt, candlefish, or hooligan) are a small, anadromous fish from the eastern Pacific Ocean. Eulachon typically spend three to five years in saltwater before returning to fresh water to spawn from late winter through early summer. Spawning grounds are typically in the lower reaches of larger rivers fed by snowmelt (Hay and McCarter 2000). Spawning typically occurs at night. Eggs are fertilized in the water column, sink, and adhere to the river bottom typically in areas of gravel and coarse sand. Most eulachon adults die after spawning.

There has been no long-term monitoring program targeting eulachon in California, making the assessment of historical abundance and abundance trends difficult (Gustafson et al. 2008). Based on the best available scientific and commercial information on eulachon, NMFS (75 FR 13012) listed the Southern DPS of eulachon as threatened under the ESA in March 2010. The Southern DPS includes all populations within the states of Washington, Oregon, and California and extends from the Skeena River in British Columbia south to the Mad River in Northern California.

Changes in ocean conditions due to climate change are believed to be the most significant threat to eulachon and their habitats. Eulachon generally inhabit cool to cold ocean waters and feed on cold water assemblages of copepods and other marine invertebrates (Willson et al. 2006). Increases in ocean temperatures off the coast of the Pacific Northwest could alter the abundance and composition of copepod communities, thus reducing the amount of food available for eulachon, warming ocean temperatures could also facilitate the northward expansion of warm-water eulachon predators and competitors for food resources, such as Pacific hake (Phillips et al. 2007; Rexstad and Pikitch 1986). Eulachon are likely extinct in California except for strays (Moyle et al. In Press).

2.2.8.17. Conditions with Dams – Eulachon Below Iron Gate Dam

Under this scenario, considerable efforts to improve habitat are underway (National Marine Fisheries Service 2010b) toward the goal of recovery of salmon and steelhead stocks. Once implemented, TMDLs and associated Implementation Plans are expected to improve water quality, reduce stress on salmonids from pollution, and contribute to their recovery (National Marine Fisheries Service 2010b). If eulachon runs are restored, these efforts may benefit this species as well.

2.2.8.18. Conditions without dams and with KBRA– Eulachon Below Iron Gate Dam

There will be short-term suspended sediment impacts to eulachon under dam removal conditions (Stillwater Sciences 2009a). Eulachon are likely extinct in California except for strays (Moyle et al. In Press), thus, impacts in any particular year are likely to be minimal. Overall, dam removal and associated KBRA actions will accelerate potential TMDL water quality benefits to this species (USDI Secretarial Determination Water Quality Subgroup In Review).

2.2.9. Existing Fish Disease Below Iron Gate Dam

The ability of the mainstem Klamath River to support the rearing and migration of salmon is constrained, in part, by high water temperatures, poor water quality, and disease outbreaks, especially during the summer months (Federal Energy Regulatory Commission 2007). Certain fish pathogens are widespread in the mainstem Klamath River below IGD and there is increasing evidence to suggest that disease levels are adversely affecting freshwater production of Chinook and coho salmon (Nichols and True 2007; Nichols et al. 2007), particularly during periods of high ocean productivity. Disease-induced mortality of juvenile downstream migrant salmon may not have a significant population level effect during years of diminished ocean productivity that limits ocean carrying capacity for salmonids. Under poor ocean conditions, density-dependent survival in the ocean may limit salmon populations rather than freshwater production. Conversely, for years where ocean productivity is high and does not create density-dependent survival conditions, significant losses of juvenile salmon in the river due to infectious diseases directly affect the size of the ocean salmon population, resulting in decreased harvest opportunity and potentially, decreased spawning escapement to the Klamath River Basin.

The most noted fish health incident in the Klamath River was an adult fish die-off that occurred in September 2002 in the lower river. A minimum of 32,533 fall Chinook salmon, 629 steelhead, and 344 coho salmon perished during this event as a result of poor environmental conditions, high escapement, and an epizootic outbreak of columnaris and Ich (California Department of Fish and Game 2004b; USDI Fish and Wildlife Service 2003b). It is important to note that estimates from the Service mortality report "should be viewed as a minimum number of fish killed" (USDI Fish and Wildlife Service 2003a).

The first extensive surveys for *C. shasta* occurred in the Klamath River basin in the late 1980s; (Buchanan et al. 1989; Hendrickson et al. 1989) although its presence had been documented as early as 1968 (Schafer 1968). No information exists on how prevalent these parasites were immediately before and immediately after construction of Project dams. Recent information however, has documented abnormally high infection prevalence in native salmon below IGD, which indicate that a host-parasite imbalance exists in that area (Stocking et al. 2006). Studies employing caged sentinel fish at fixed locations (Stocking et al. 2006; J. Bartholomew, OSU, pers. comm.) and quantification of the parasite in water samples (Hallett and Bartholomew 2006) have narrowed the focus of the area most affected by disease to approximately the reach between I-5 and Seiad Valley in the lower Klamath River.

In recent years, the Service working collaboratively with its many partners, has documented high infection rates in emigrating juvenile Chinook and coho salmon, primarily by one or both myxozoan parasites – *C. shasta*, and *P. minibicornis*. Fish health studies (Foott et al. 1999; Nichols and Foott 2005; Nichols et al. 2007) and Oregon State University (Stocking and Bartholomew 2007; Stocking et al. 2006) have consistently documented high infection incidence in the Klamath River during the spring and summer. For example, Nichols and Foott (Nichols and Foott 2005) estimated that up to 45 percent of natural origin juvenile fall-run Chinook salmon passing by the Big Bar outmigrant trap during certain months were infected with *C. shasta* and 94 percent with *P. minibicornis*. Ceratomyxosis has been identified as the most significant disease for juvenile salmon in the Klamath Basin and salmon which become infected with *C. shasta* (the pathogen causing ceratomyxosis) are not likely survive to adulthood (Foott et al. 2003).

Downstream of IGD, the polychaete host for *C. shasta* and *P. minibicornis* is aggregated into small, patchy populations mostly concentrated between the Interstate 5 and the Trinity River confluence, and especially above the Scott River (Stocking et al. 2006). The reach of the Klamath River from the Shasta River to Seiad/Indian Creek is known to be a highly infectious zone with high actinospores exposure, particularly from May through August (Beeman et al. 2008; Beeman et al. 2007). This portion of the river contains areas of dense populations of polychaetes within low-velocity habitats with *Cladophora* (a type of green algae), sand-silt, and fine benthic organic material in the substrate (Stocking and Bartholomew 2007). High parasite prevalence in the Lower Klamath River is considered to be a combined effect of high spore input from heavily infected, spawned adult salmon that congregate downstream of IGD and IGH and the proximity to dense populations of polychaetes (Bartholomew et al. 2007). The highest rates of infection occur in the Lower Klamath River downstream of IGD (Stocking and Bartholomew 2007; Bartholomew and Foott 2010).

Not all Klamath River anadromous fish are at the same risk. Within the system steelhead trout are resistant to *C. shasta* (Administrative Law Judge 2006). Salmon that emigrate earlier in the spring or that emigrate more rapidly are likely to experience a lower risk than those rearing in specific reaches of the mainstem Klamath River where high infection rates have been documented (S. Foott, Service, pers. comm.). However, while native salmon exposed to low doses of *C. shasta* (and presumably *P. minibicornis*) exhibit some degree of resistance (Bartholomew et al. 2001), even they can become overwhelmed by the presence of high infectious doses, resulting in a diseased state (Bartholomew 1998; Foott et al. 2006; Ratliff 1981; Stone et al. 2008). Salmon that display clinical symptoms of disease are more prone to perish due to increased susceptibility to other pathogens, greater susceptibility to predation, and a compromised osmoregulatory system that is critical for successful entry into seawater (S. Foott, Service, pers. comm.).

Results from exposure studies of salmonids to naturally occurring *C. shasta* in the Klamath River suggest that the freshwater polychaete intermediate host is largely confined to the mainstem (Stocking and Bartholomew 2007). The polychaete has been found throughout the Klamath River, often located in slow flowing depositional habitats such as pools. However, large populations were consistently present and spatially structured at the inflow to the mainstem reservoirs indicating preference for this habitat (Stocking and Bartholomew 2007). In J.C. Boyle reservoir, where a large number of samples were collected, population densities rapidly increased with distance from the inflow into the reservoir and then steadily decreased (Stocking and Bartholomew 2007). Stagnant or non-flowing habitats generally lacked evidence of *M. speciosa* (Stocking and Bartholomew 2007). We are not aware of information on the effects of DO concentrations on the polychaete.

C. shasta, and *P. minibicornis*, are assumed to have co-evolved with the salmon species they infect in the Klamath River. This co-evolution of parasites and their salmon hosts should persist over time at a relatively low level virulence equilibrium, given relative consistency in the environmental conditions in which this equilibrium evolved (Esch and Fernandez 1993; Toft and Karter 1990). When environmental conditions are significantly altered, however, the abrupt change typically favors the parasite because of its shorter generation time and greater genetic variation as compared to that of the host (Webster et al. 2007). In other words, the parasite is quicker to adapt to environmental changes than the host, causing the parasite-host equilibrium to become out of balance. This imbalance in the parasite-host equilibrium may be expressed as elevated infection rates in the host organisms over naturally-occurring equilibrium (background) levels, similar to the high infections levels that have been observed in juvenile Chinook salmon populations in the lower Klamath River below IGD.

2.2.10. Conditions with Dams – Fish Disease Below Iron Gate Dam

Below IGD the current stable flows, substrate, concentration of spawners and carcasses, temperatures, and plankton rich discharge from reservoirs have created ideal conditions for disease (Hetrick et al. 2009). There is some evidence that the density of spawning adults plays an integral part of the life history of *C. shasta* (Bartholomew and Foott 2010). Continued operation of the hatchery is more likely to continue the spawning aggregation. In addition, under the current conditions with dams, the seasonal temperature shift caused by the Project reservoirs would continue to lower water temperatures downstream in the spring through most of July in low flow years, but increases water temperatures below IGD starting in late July. This shift likely would reduce vulnerability to disease for early-migrating smolts, but would increase stress and disease for the later migrating fish. Other than TMDL implementation, under conditions with dams there will be limited opportunity to change the status of salmon disease below IGD.

2.2.11. Conditions without dams and with KBRA – Fish Disease Below Iron Gate Dam

The positive and negative effects regarding disease under the two alternatives are listed in Table 3. In general, habitat issues such as water quality, diversity of flows, thermal phase synchrony, sediment movement, and reduced planktonic drift from reservoirs without dams and with KBRA would favor the salmonid host and not the disease pathogen *C. Shasta*. Consideration of these factors in total indicates that dam removal and KBRA would alleviate many of the conditions conducive to disease below IGD.

The condition with dam removal and with KBRA is anticipated be less conducive to *C. shasta* for several reasons. First, a mobile bed with dam removal (Varyu and Greimann 2010) and with KBRA will displace present substrate and will consist of finer material than is currently present below IGD. This substrate, and habitat for the polychaete intermediate host of *C. shasta*, will turn over and be more frequently disrupted at lower flows than under the current condition with dams in place (Varyu and Greimann 2010).

Second, more variable flows resulting from KBRA management will cause further habitat disruption for the polychaete, the intermediate host. Third, under the condition with dam removal and with KBRA, reservoirs will no longer provide planktonic drift for the polychaete intermediate host. Fourth, access to additional habitat above IGD will disperse salmonid carcasses and decrease the likelihood of conditions necessary for *C. shasta* to complete its life cycle.

FERC concluded that removal of dams would enhance downstream water quality and reduce cumulative effects that contribute to downstream fish kills caused by disease and poor water quality, eliminating likely Project-related downstream fish disease (Federal Energy Regulatory Commission 2007).

2.2.12. Existing Resident Fish Species Below Iron Gate Dam

The federally listed suckers and Bull trout do not occur below IGD. They do not occupy habitats downstream of IDG due to their specific habitat requirements. Lost River suckers are native to the Lost River and upper Klamath River systems, especially large lakes in these systems (Tule Lake, Upper Klamath Lake and Lower Klamath Lake) (Moyle 2002). Shortnose suckers are native to upper Klamath River and Lost River basins in Oregon and California (Moyle 2002).

Table 3. Positive and negative effects on fish disease occurring on the Klamath River under proposed conditions without dams and with KBRA.

Effect	*Rationale for Dam Removal Reducing Disease*	*Rationale for Dam Removal not reducing Disease*
More natural hydrologic regime/more diverse flows	Would create instability and disturbance in microhabitat that will reduce polychaete populations (Stocking and Bartholomew 2007) and presumably reduce infection rates within those populations Would also increase dispersion of actinospores.	
Restored sediment transport	Removal of Project dams would increase of mid-sized (gravel) sediment transport through the reach directly below IGD (Federal Energy Regulatory Commission 2007) and a more mobile stream bed below IGD (Varyu and Greimann 2010). Restoring natural sediment transport processes would likely contribute to the scour of attached algae downstream of the current site of IGD, and deposited gravel and sand would provide a less favorable substrate for attached algae because of its greater mobility during high flow events than the existing armored substrate. The reduction in attached algae would provide less habitat for the polychaete intermediate host of *C. shasta* and *P. minibicornis*, which should reduce the infection rate of juvenile salmonids downstream of IGD. (Federal Energy Regulatory Commission 2007).	Cladophora attached to bedrock and boulders may temper disease reductions (J. Bartholomew, pers. comm.)
Reduction of planktonic drift	Drifting plankton from reservoirs contribute to downstream food webs and alter community structures below dams (Hideyuki Doi et al. 2008). Absence of reservoirs would likely reduce and change species composition of planktonic drift used by filter feeding polychaetes.	
Increased thermal diversity	Greater thermal diversity 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.	
Restored thermal phase (the delay in the progression of water temperatures is eliminated)	Cooler water temperatures during the early fall and winter would likely result in reduction of polychaete colonization rates and a shortened period of actinospore release.	When water temperatures approach 10°C in spring, replication and release of actinospores increases. Earlier warming in the spring could stimulate early actinospore release from polychaetes however, increased spring temperatures mean fish outmigrate earlier and move to downstream areas with lower spore concentrations.

Table 3. (Continued)

Reduced temperatures from mid-July to end of year	Actinospore production and release into the environment is positively associated with water temperature. Udey (Udey et al. 1975) found disease replication to be temperature dependent; when water temperatures decrease, replication of parasites decrease.	These benefits may be minimal for juvenile outmigrants but reduce the concentrations of myxospores shed from adults.
Dispersal of adult salmon and trout	Concentrations of adult salmon and resident trout found below IGD function as reservoirs of myxospores. Foott (2007 unpublished data) found adult Chinook salmon to have a high level of parasite infection (>70 percent) below the dam[28]. Stocking et al. (2006) also found that polychaetes residing below IGD also exhibited high infection prevalence (4.9 to 8.3 percent) as compared to polychaetes above IGD (0.27 percent). FERC's analysis is that restoring access to reaches above IGD for anadromous fish would allow adult fall Chinook salmon to distribute over a greater length of the river, reducing crowding and the concentration of disease pathogens that currently occur in the reach between IGD and the Shasta River (Federal Energy Regulatory Commission 2007).	
Increased DO	DO concentrations would increase immediately below IGD (PacifiCorp 2004b) resulting in potentially less stress to the biotic community and improved health of salmonids (efforts are underway to improve DO in powerhouse releases from IGD, but the efficacy of these efforts is unclear).	

In Oregon, bull trout generally reside in restricted habitat primarily in the upper reaches of tributaries to the Columbia, Snake, and Klamath rivers (Ratliff and Howell 1992). In California, bull trout were historically found in the McCloud River, a 60 mile tributary of the Sacramento River. The last reported capture of a bull trout there was in 1975 (Buchanan et al. 1997).

2.2.12.1. Existing Klamath Largescale Suckers Below Iron Gate Dam

Klamath largescale suckers are found or have been found in the Klamath River downstream to Iron Gate reservoir (Moyle 2002), but California populations of Klamath largescale suckers, on the edge of their limited range, are recommended for listing as endangered (Moyle et al. In Press).

Removing the dams with KBRA will provide more riverine habitat and may increase populations as physical, chemical, and biological processes of the Klamath River are restored. Overall, dam removal and associated KBRA actions will accelerate TMDL water quality benefits to this species (USDI Secretarial Determination Water Quality Subgroup In Review).

[28] The infectious nidus is located over 10 miles downstream of IGD.

2.2.12.2. Conditions with Dams - Klamath Largescale Suckers Below Iron Gate Dam

The Klamath largescale sucker appears to be resident of large rivers, although a small population exists in Upper Klamath Lake (National Research Council 2004a). The status of the Klamath largescale sucker is poorly understood; the status of the stream populations are unknown, although they are assumed to be widespread and abundant (Reiser et al. 2001 in National Research Council 2004a). Under conditions with dams, the status of the Klamath largescale suckers will likely continue on its current trajectory. Implementation of TMDL would likely have benefits for this species.

2.2.12.3. Conditions without dams and with KBRA - Klamath Largescale Suckers Below Iron Gate Dam

In Upper Klamath lake, the Klamath largescale sucker is found mainly near inflowing streams, suggesting a low tolerance for lake conditions (National Research Council 2004a). Removing dams with KBRA will provide more riverine habitat and may increase populations as physical, chemical, and biological processes of the Klamath River are restored. Overall, dam removal and associated KBRA actions will accelerate TMDL water quality benefits to this species (USDI Secretarial Determination Water Quality Subgroup In Review).

2.2.12.4. Existing Klamath Smallscale Suckers Below Iron Gate Dam

The Klamath smallscale sucker appears to have a life history similar to other species of suckers. The Klamath smallscale suckers are confined to the Trinity River system, the Klamath River below Klamath Falls and the Rogue River in Oregon (Moyle 2002). Klamath smallscale suckers are found primarily in deep, slow pools of major rivers, and are quite common in the river and its tributaries of low gradient (National Research Council 2004a). Dams and diversions may have increased its habitat by providing more lacustrine, warm water habitats (Moyle 2002).

2.2.12.5. Conditions with Dams – Klamath Smallscale Suckers Below Iron Gate Dam

Under conditions with dams there will be no change in the status of Klamath smallscale suckers. Implementation of TMDL would likely have benefits for this species.

2.2.12.6. Conditions without dams and with KBRA – Klamath Smallscale Suckers Below Iron Gate Dam

Dam removal with KBRA would eliminate reservoir habitat for Klamath smallscale suckers, but may also increase populations as physical, chemical, and biological processes of the Klamath River are restored. Overall, dam removal and associated KBRA actions will accelerate potential TMDL water quality benefits to this species (USDI Secretarial Determination Water Quality Subgroup In Review). Dam removal would allow Klamath smallscale suckers from the lower Klamath River to have access to habitats above IGD.

2.2.12.7. Existing Endemic Species of Klamath Lamprey Below Iron Gate Dam

Only Pacific lamprey and Klamath River lamprey are found downstream of IGD. Pacific lamprey is discussed above in the Anadromous Fish Species section. There is no specific information on the biology of Klamath River lamprey, although the adults seem to live in the Klamath River itself, as well as in lakes and reservoirs, where they prey on native suckers and cyprinids. Klamath River lamprey appear to be widespread in the lower Klamath River, Trinity River, and tributaries. However, there are no current status assessments for any Klamath lampreys and little is known of their biology or sensitivity to environmental changes in the Klamath drainage (S. Reid, Western Fishes, pers. comm.).

2.2.12.8. Conditions with Dams – Endemic Species of Klamath Lamprey Below Iron Gate Dam

Under conditions with dams the status of Klamath River lamprey will likely continue on its current trajectory. Implementation of TMDL would likely have benefits for this species.

2.2.12.9. Conditions without dams and with KBRA – Endemic Species of Klamath Lamprey Below Iron Gate Dam

Dam removal with KBRA may increase populations of Klamath River lamprey as physical, chemical, and biological processes of the Klamath River are restored. Overall, dam removal and associated KBRA actions will accelerate TMDL water quality benefits to this species (USDI Secretarial Determination Water Quality SubGroup In Review). Endemic lamprey species in the Klamath River Basin (e.g., the Klamath lamprey in tributaries downstream of IGD and the western brook lamprey in tributaries near the mouth of the Klamath River) are not expected to be affected by water quality changes under the condition without dams given their locations (Close et al. 2010).

2.2.13. Existing (and Historical) Human Use Below Iron Gate Dam

While Klamath River fall-run Chinook salmon runs are diminished, commercial, recreational and Tribal fisheries are able to harvest fish produced below IGD, including those produced from IGH.

Norgaard (2004) reports that salmon were the most important food and the basis of the prosperous subsistence economy of the Karuk people. Interviews with traditional Karuk Tribal fishermen indicate dramatic reductions in fishery harvests since construction of the Klamath River dams (Norgaard 2004). Norgaard (2004) describes the lack of access to and availability of traditional food sources, specifically salmon, as being directly responsible for a host of diet related illnesses among Native Americans including diabetes, obesity, heart disease, tuberculosis, hypertension, kidney troubles, and strokes.

2.2.13.1. Chinook Salmon Harvest

Klamath River fall-run Chinook salmon stocks contribute to ocean salmon fisheries from central Oregon to central California, as well as in-river Tribal and recreational fisheries. With the exception of a 50 percent allocation to the Tribes, based on age-3 to age-5 fish, harvest allocation decisions for Klamath River fall-run Chinook salmon in ocean and in-river recreational fisheries are based on annual negotiations and preseason PFMC recommendations.

The Yurok and Hoopa Valley Tribes have a federally protected right to the fishery resource of their reservations sufficient to support a moderate standard of living or 50 percent of the total available harvest of Klamath-Trinity basin salmon, whichever is less. The Karuk Tribal fishery is limited to a site at Ishi-Pishi Falls under sport harvest regulations and possession limits as per CDFG regulations. The only exception given to the Karuk Tribe is related to gear which allows Tribal Members to use dip nets.

2.2.13.2. Coho Salmon Harvest

Excess fishing is believed to have been a factor in the decline of coho salmon until the early 1990s when harvest was substantially curtailed (62 FR 24588).

Coho salmon originating from the Klamath River Basin are intercepted by ocean fisheries primarily off the coast of California. Coded wire tagged coho salmon released from hatcheries south of Cape Blanco have a southerly migration pattern, primarily to California (65 to 92 percent), with some recoveries in Oregon (7 to 34 percent), and (1 percent) in Washington or British Columbia (Weitkamp et al. 1995). Marine exploitation rates for coho salmon of less than or equal to 13 percent, are indicated by Rogue River and Klamath River hatchery-origin salmon stocks.

In recent years the PFMC has recommended regulations that do not allow directed coho salmon fisheries or the retention of coho salmon south of Humbug Mountain in Oregon. Harvest of coho salmon has been prohibited in the Klamath River since 1994, with the exception of sanctioned Tribal harvest for subsistence, ceremonial, and commercial purposes by the Yurok, Hoopa Valley, and Karuk Tribes.

2.2.13.3. Steelhead Harvest

At one time, recreational fishing in the Klamath River, in particular for steelhead, was nationally renowned. Adventurists were transported to the Klamath River lodges after taking commercial flights to the Montague Airport near Yreka. Numerous angling books and guides note the Klamath attracted steelhead and salmon anglers (Albert 2003; Burdick 1990; Combs 1991; Freeman 1984; Kreider 1948; Shaffer 2005). Several authors (California Department of Fish and Game 1965), Combs 1991, and Freeman 1984) classified the Klamath as a great steelhead river. Some considered the Klamath steelhead fishery to be world famous (Quinn and Quinn 1983). In the context of salmon and steelhead angling on the Klamath River, Albert (Albert 2003) noted that fishing is a primary industry in the Klamath River Basin, with numerous campsites, R.V. parks, motels, lodges, drift boat services, tackle stores, launching sites, gas stations, and restaurants, with most concentrated in or near small river communities. Burdick (Burdick 1990) recognized some of the lodges and guides that were dependent on this industry. The Klamath River below IGD continues to provide some (albeit reduced) recreational fishing for salmon and especially steelhead.

Despite declines of runs, the Klamath-Trinity River is the number one producer of steelhead trout in California (Hopelain 1998). There is limited information on harvest trends for Klamath River steelhead. Harvest trends likely mimic Klamath Steelhead population declines discussed above in *Section 2.2.8.7, Existing Steelhead Below Iron Gate Dam*. Barnhart (Barnhart 1994) noted that recent Klamath steelhead catch rates (fish per angler-hour) showed significant downward trends.

2.2.13.4. Eulachon Harvest

In Oregon, commercial fishing for eulachon is allowed in the Pacific Ocean. However, in practice, little to no fishing is taking place because so few fish return each year (74 FR 10857).

Historically, members of the Yurok Tribe harvested eulachon in the Klamath River in California for subsistence purposes. The Yurok Tribe does not have a fishery management plan for eulachon at this time, and eulachon abundance levels on the Klamath River are too low to support a fishery (74 FR 10857).

2.2.13.5. Green Sturgeon Harvest

Green sturgeon harvest is limited to direct harvest by Tribes and out of basin bycatch from white sturgeon commercial and sport fisheries. Coastwide, green sturgeon harvest has decreased from a high of 9,065 in 1986 to 862 in 2001, the last year in the previous status review, to 512 in 2003. Yurok and Hoopa Valley Tribal harvest accounted for 59 percent of the total green sturgeon catch in 2003 (National Marine Fisheries Service 2005).

2.2.13.6. Pacific Lamprey Harvest

Harvest of Pacific lamprey is an important cultural fishery to the Tribes of the Klamath River. Lamprey are harvested by the Karuk and Yurok Tribes and have sustained Tribal fisheries for millennia. Lamprey are also common in the Trinity River. Harvest of lamprey continues today with Hoopa Tribal members fishing with “eel baskets” of traditional as well as modern construction. Harvest of Pacific lamprey in the lower Klamath River is reported to be less than two percent of its historical level (Petersen

Lewis 2009). The Tribes continue to harvest this species and rely on healthy Pacific lamprey populations to support subsistence and a variety of cultural purposes.

2.2.14. Conditions with Dams – Human Use Below Iron Gate Dam

Under conditions with dams there will be few changes in human use in the Klamath River below IGD. Commercial, recreational, and Tribal harvest of Chinook salmon produced at IGH will continue. If anadromous fish production from the Klamath River continues on its current trajectory, human use would be anticipated to decline as well. Additionally, the Klamath Tribes will continue to be without a harvest site for anadromous fish. TMDL implementation and ongoing restoration efforts will likely provide some improvement to human use fisheries.

2.2.15. Conditions without dams and with KBRA – Human Use Below Iron Gate Dam

For the first eight years after the KBRA effective date sport, commercial, and Tribal harvest will be constrained to allow upriver stocks to rebuild (KBRA)[29]. However, after this period, appreciable increases in abundance of fish relative to the conditions with dams would be anticipated to provide additional harvest and fishing opportunities.

2.2.15.1. Tribal Fisheries

The increase of salmon populations associated with dam removal, as well as an increase in other populations of native fish species, would restore cultural use by the Tribes. In particular, the restoration of the spring Chinook run above the Salmon River would reestablish cultural ceremonies associated with the migration of this species through the length of the Klamath River. Increases in fish populations, especially salmonids, would also resulted in increased use, abundance, and value of subsistence fishing locations, and increased consumption of fish that would improve the health of Tribal Members (Norgaard 2004). Furthermore, with restoration, more diverse and robust runs would likely give Tribal fisheries more options for harvest. For example, recent increases in sockeye salmon returns to the Columbia River resulted in the expansion of harvest by Tribal and recreational fishers in time and space (Smith 2010).

The KBRA will establish a harvest site between IGD and the I-5 bridge for the Klamath Tribes during an interim period until dams are removed. Spring-run Chinook salmon restoration would result in commercial harvest that is more valuable on a per fish basis to Tribal fishers than harvest of fall-run Chinook salmon. Eventually, harvest of Pacific lamprey would increase from 1 to 10 percent downstream from IGD under the without dams and with KBRA scenario (Close et al. 2010).

[29] Section 11.3.1 C of KBRA

2.2.15.2. Commercial Fisheries

Over the long term, appreciable increases in abundance under the dam removal condition are likely to provide additional opportunities for commercial fisheries. Commercial fishery opportunities for salmon may be impeded by stock abundance other than Klamath River fisheries in some years; however it is reasonable to assume commercial fisheries will improve under conditions without dams corresponding to increased returns. Again, in years when Klamath Chinook salmon abundance limits other fisheries, the increases in the abundance of natural Klamath River Chinook salmon stocks will mean greater ocean harvest opportunities for mixed stock fisheries due to multiplier benefits (see discussion of multiplier benefits in Section 2.1.20.2). More diverse and robust runs would likely extend commercial fishing seasons.

Increased fall-run Chinook harvest in the ocean may need to be constrained to encourage restoration of other anadromous salmonid runs (such as spring-run Chinook) harvested for commercial purposes because ocean harvest does not discriminate between spring- and fall-run Chinook salmon.

2.2.15.3. Recreational Fisheries

The recreational fishery response would be similar to the commercial fishery response in terms of providing additional fishing opportunities. More diverse and robust runs would likely extend recreational fishing seasons. Restoration would likely result in harvest of spring-run Chinook salmon that may be of more value on a per fish basis (due to their higher fat content) than fall-run Chinook. Increased fall-run Chinook harvest in the ocean may need to be constrained to encourage restoration of other anadromous salmonid runs (such as spring-run Chinook) harvested for recreational purposes because ocean harvest does not discriminate between spring- and fall-run Chinook salmon.

2.2.16. Existing Hatcheries Below Iron Gate Dam

Two anadromous fish hatcheries operate within the Klamath River Basin, Trinity River Hatchery near the town of Lewiston and IGH on the mainstem Klamath River near Hornbrook, California. Both hatcheries mitigate for anadromous fish habitat lost as a result of the construction of dams on the mainstem Klamath and Trinity rivers, and production focuses on Chinook and coho salmon, and steelhead. Trinity River Hatchery releases about 4.3 million Chinook salmon, 0.5 million coho salmon and 0.8 million steelhead annually. IGH releases approximately 6.0 million fall-run Chinook salmon, 75,000 coho salmon, and 200,000 steelhead annually, for a total of roughly 11,875,000 hatchery anadromous salmonids released into the Klamath River annually.

IGH releases Chinook salmon from the middle of May to the end of June, a time when discharge from IGD is in steep decline and water temperatures are rapidly rising. This timing may create competition between hatchery and natural fish for food and limited resources (NMFS 2006 in Federal Energy Regulatory Commission 2007), especially limited space and resources for naturally spawned coho salmon in thermal refugia. These releases may also have negative fish health consequences (Federal Energy Regulatory Commission 2007). Hatchery operations may have a suppressive effect on wild populations of salmonids through predation and competition, and it should not be assumed that hatchery operations are beneficial to salmonids (Independent Scientific Advisory Board 2005; National Research Council 2004a). When released into the freshwater, hatchery fish may compete with naturally produced fish for food and habitat (Fleming et al. 2000; Kostow et al. 2003; Kostow and Zhou 2006; McMichael et al. 1997).

Pearse et al. (2007) found that hatchery steelhead adults sampled from IGH in 2001 clustered strongly (genetically) with smolts sampled by screw trap in the Shasta and Scott rivers, suggesting that significant gene flow has occurred between IGH and these nearby tributaries, presumably due to ‘straying’ of returning hatchery adults. Outmigrating hatchery smolts are also known to use the Shasta River, so it is likely that some may return to spawn there as well (Pearse et al. 2007). This straying has the potential to reduce the reproductive success of the natural population (Araki et al. 2007; Araki et al. 2008; McLean et al. 2004) reduce local adaptability, negatively affect the diversity of populations via outbreeding depression (Reisenbichler and Rubin 1999), and reduce life history diversity (Lindley et al. 2009).

Hatchery programs have also been described as an important component of healthy salmon fisheries serving to enhance production for natural stock recovery, coded-wire tag indicator stock, or mitigation. To assure the effectiveness and maximize the benefits of artificial production programs, the PFMC recommends to “[m]aximize the continued production of hatchery stocks consistent with harvest management and stock conservation objectives” (Pacific Fishery Management Council 2003).

2.2.16.1 Existing Iron Gate Hatchery Production

Production from IGH contributes to commercial, Tribal, and recreational fisheries in the Klamath River and the Pacific Ocean. In the mixed-stock coastal fisheries of the Pacific Ocean, the presence of hatchery fish allows for higher harvest levels than if there were no hatchery stocks in the fishery (Federal Energy Regulatory Commission 2007). IGH is designed to mitigate for the loss of approximately 16 miles of habitat from the site where IGD was constructed to Copco 2 Dam (Federal Energy Regulatory Commission 1963). If IGH mitigation were to be discontinued after dam removal, it would be offset by the production of 81 miles of habitat in the PR (Administrative Law Judge 2006; Cunanan 2009) and more than 360 miles of habitat above the Project (Huntington 2006).

Current total returns from IGH releases are estimated to be 0.48 percent and 1.78 percent for fingerling and yearling fall-run Chinook salmon (M. Hampton, CDFG, pers. comm.). Over the last 31 years, adult returns of fall-run Chinook salmon to IGH have ranged from 2,228 (in 1979) to 72,474 (in 2000) (California Department of Fish and Game 2009; U.S. Forest Service - Klamath National Forest 2006).

For steelhead, Busby et al. (1994) reports steelhead returns to IGH exhibited a strong decline in 1987. In many recent years, returns of adults to IGH have been insufficient to meet the 200,000 yearling release goals (Chesney 2000). During the 1970's and 1980's returns to IGH ranged from 832 to 4,411 steelhead. From 2005 to 2009 the peak return was in 2006-2007 with 212 steelhead; 140 fish returned in 2008-2009 (California Department of Fish and Game 2010). The downward trend in steelhead escapement to IGH is illustrated Figure 16.

2.2.16.2. Conditions with Dams – Iron Gate Hatchery Production

If the dams remain, IGH is anticipated to continue operation (Federal Energy Regulatory Commission 2007). Annual IGH production would be 5,100,000 Chinook salmon fingerlings, 900,000 Chinook salmon yearlings, and 75,000 yearling coho salmon (M. Hampton, CDFG, pers. comm.).

IGH Chinook salmon production supports recreational, commercial, and Tribal fisheries in the Klamath River and the Pacific Ocean (Federal Energy Regulatory Commission 2007). However, salmon production of this magnitude may have negative impacts on natural salmon populations (NMFS 2006 in Federal Energy Regulatory Commission 2007) and contribute to the Klamath River fish health problems for salmon below IGD (Federal Energy Regulatory Commission 2007). For steelhead, returns of adults produced at IGH may continue on their downward trajectory.

2.2.16.3. Conditions without dams and with KBRA – Iron Gate Hatchery Production

Under conditions without dams, IGH operations will continue for at least eight years following dam removal assuming that an alternate water supply is secured. Currently a study is underway to evaluate hatchery production options that do not rely on the current IGH water supply. Based on the study findings, PacifiCorp will provide one-time funding to construct and implement the measures identified as necessary to continue to meet the current mitigation production objectives for a period of eight years following the removal of IGD (U.S. Department of the Interior 2008). After eight years hatchery production levels may cease or be reduced resulting in reduced hatchery fish.

Three scenarios are envisioned under conditions without dams with KBRA for the eight years after the dams are removed. Scenario 1) continued IGH operation would result in current Chinook and coho salmon production (see above); Scenario 2) expanded Fall Creek Hatchery operation would result in annual production anticipated to be 3,600,000 Chinook salmon fingerlings, 425,000 Chinook salmon yearlings, and 75,000 yearling coho salmon; and Scenario 3) existing Fall Creek Hatchery operation would result in annual production anticipated to be 1,800,000 Chinook salmon fingerlings, 125,000 Chinook salmon yearlings, and 75,000 coho salmon yearlings (M. Hampton, CDFG, pers. comm.)[30].

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[30] As outlined in Interim Measure 19: Hatchery Production Continuity in the KHSA. a post-Iron Gate Dam Mitigation Hatchery Plan must be submitted 6 months following an Affirmative Determination

For steelhead, habitat above IGD has the potential to increase returns by 6,800 to 20,000 spawners (Table 1). Disease problems in the Klamath River are far less likely to interfere with steelhead returns than with salmon returns, as Klamath steelhead trout are resistant to *C. shasta* (Administrative Law Judge 2006).

3. CLIMATE CHANGE

3.1 Existing Conditions – Climate Change

The range of anadromous fish populations is restricted in large part by climate. Salmonid restoration efforts in the Klamath watershed cannot ignore the effects of climate change. The Intergovernmental Panel on Climate Change concluded that warming of the climate is unequivocal (Intergovernmental Panel on Climate Change 2007). The global average temperature since 1900 has risen by about 0.9°C. By 2100, global average temperature is projected to raise another 2 to 11.5°F. The U.S. average temperature is likely to rise more than the global average over this century, with some variation from place to place (USDI Geological Survey 2009).

The effects of climate change on coldwater fishes (i.e., salmonids) are likely to be especially severe in the southern part of their ranges, such as in the Klamath River watershed. Increasing temperatures will change conditions in all aquatic habitats, from rivers to estuaries to the Pacific Ocean. In rivers, climate change is expected to alter flow patterns, including the seasonality and magnitude of droughts and floods. Consequently, the suitability of rivers in the United States for supporting salmon and trout is expected to decrease four to 20 percent by 2030 and by as much as 60 percent by 2100 (Eaton and Scheller 1996), with the greatest losses projected for California and Oregon (O'Neal 2002).

Water temperatures in the Pacific Northwest warmed by approximately 0.72°C in the 20th century (based on conversions by Eaton and Scheller 1996 and see (Mote et al. 2003)). Anadromous salmonids, depending on the species and location, tolerate water temperatures in the range of 0 - 25°C (Brett 1971; Richter and Kolmes 2005). However, salmonid survival and reproduction may become impaired by water temperatures higher than 18°C (U.S. Environmental Protection Agency 2003)[31]. Thus, although the increase in water temperature seems small, it can result in water temperatures that are suboptimal or lethal to salmonids already residing in rivers where summer temperatures often exceed 20°C (McCullough 1999).

Streams are also expected to be warmer and drier during the summer and fall months due to a reduction in snowpack levels and seasonal retention. Elevations below 9,900 ft. will

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incorporating the results of a study on the viability of Iron Gate Hatchery following dam removal. This study has not yet been conducted and the plan has not yet been developed. Continued operation would likely require a revision to the existing NPDES permit for hatchery discharge under the new flow scenario. (C. Creager, California NCRWQCB, pers. comm.).

[31] See footnote in Section 2.1.4.1.

suffer the most (~80 percent) reduction in snow pack (Hayhoe et al. 2004). In California, losses are expected to be most significant in the southern Sierra and Cascade Mountains (Mote et al. 2005), the source of snowmelt for most streams in the lower Klamath River Basin. Increased temperatures also will increase the incidence of winter floods and summer droughts (Anderson et al. 2008; Edwards 1991; Field et al. 1999). Peak flows have already shifted to earlier in the year by 10 to 30 days in much of the western U.S. (Stewart et al. 2004). Predictions are that future peak flows may shift even earlier in the year by 30 to 40 days (Stewart et al. 2004). In the Klamath River Basin, these impacts will be more marked in streams which are primarily fed by snow-melt (i.e., Salmon and Scott Rivers) than those fed by springs (the Williamson and Wood rivers in the upper basin; the Shasta River below IGD).

The hydrologic characteristics of the Klamath River mainstem and its major tributaries are dominated by seasonal melt of snowpack (National Research Council 2004a). Van Kirk and Naman (Van Kirk and Naman 2008) found statistically significant declines in April 1 Snow Water Equivalent since the 1950s at several snow measurement stations throughout the Klamath River Basin, particularly those at lower elevations (<6,000 ft.). There is strong evidence that winter precipitation in the upper Klamath River Basin has declined (Mayer and Naman 2011b, In Press). Climatic factors are likely responsible for much of the decline in long-term UKL net inflows during the period 1961 to 2007 (Mayer 2008).

Bartholow (2005) found that the Klamath River is increasing in water temperature by 0.5°C/decade, which may be related to warming trends in the region (Bartholow 2005) and/or alterations of the hydrologic regime resulting from the Klamath Reclamation Project, logging, and water utilization in Klamath River tributary basins. Particularly, changes in the timing of peak spring discharge, and decreases in water quantity in the spring and summer may affect salmonids of the Klamath River. Rain on snow events may increase the frequency of late winter and early spring flooding causing destruction of salmonid redds and thereby reducing survival of salmonids.

The Klamath estuary will likely be impacted by more frequent and extreme tides and storms (Cayan et al. 2008), and likely will experience altered salinity concentrations as sea level rises (Scavia et al. 2002). These changes, in combination with increasing temperatures, can result in seasonally anoxic conditions (Moore et al. 1997) and altered food availability in at least some parts of the estuary. Impacts to salmonids using the Klamath estuary may be modulated by their rearing strategy. For example, impacts to juvenile Chinook salmon in the Klamath River may not be significantly impacted as they do not appear to use the estuary extensively for rearing (Sullivan 1989).

In the Pacific Ocean, localized increases in California Current primary productivity may favor growth for some salmonids, but benefits to populations will largely depend on movement patterns dictated by currents (Brodeur et al. 2007; Huyer et al. 2007; Wells et al. 2008). The California Current is a Pacific Ocean current that moves south along the western coast of North America, beginning off southern British Columbia, and ending off southern Baja California. The movement of northern waters southward makes the coastal waters cooler than the coastal areas of comparable latitude on the east coast of the United States. The cold water is highly productive due to the upwelling, which brings to the surface nutrient-rich waters, supporting marine life and important fisheries. Furthermore, recent research estimates that upwelling has been delayed by as much as one month, perhaps disrupting predator-prey relationships and adversely impacting food availability to juveniles at ocean entry (Di Lorenzo et al. 2008; Scheuerell et al. 2009).

A connection between salmon abundance and a North Pacific climate variation, named the Pacific Decadal Oscillation (PDO), has been demonstrated (Mantua and Hare 2002). Warm phase PDO is generally associated with reduced abundance of coho and Chinook salmon in the Pacific Northwest, while cool phase PDO is linked to above average abundance of these fish. The El Niño Southern Oscillation (ENSO) and North Pacific Gyre Oscillation (NPGO) (Di Lorenzo et al. 2008) also influence habitat quality in the Pacific Ocean (Garcia-Reyes and Largier 2010), as well as inland aquatic habitats by influencing precipitation events. Unfavorable ocean conditions (e.g., warm phase PDO) are believed to be partially responsible for the poor survival of salmon stocks in California in 2006 (National Marine Fisheries Service 2007b) and 2008 (Lindley et al. 2009).

In a paper published in The National Academy of Sciences of the USA, Battin et al. (Battin et al. 2007) used a series of linked models of climate, land cover, hydrology, and salmon population dynamics, to investigate the impacts of climate change on the effectiveness of proposed habitat restoration efforts designed to recover depleted Chinook salmon populations in a Pacific Northwest river basin. Model results indicated that climate change will have a large negative effect on freshwater salmon habitat. Additionally, (Battin et al. 2007) concluded that climate change will make salmon recovery targets much more difficult to attain.

These changing conditions have profound implications for restoration of anadromous fish populations over the next 50 years. Water temperature in all habitats is predicted to steadily increase throughout the 21st century, perhaps beyond salmonid tolerances. As a result, the abundance of some salmonid populations in the Klamath River Basin may decrease by as much as 60 percent by 2100 (based on estimates in (Chatters et al. 1992), unless climate change is actively incorporated into conservation efforts.

As adverse as climate change predictions appear for the future of anadromous fish habitat, there are mitigating circumstances associated with the upper Klamath basin. Contrary to the commonly accepted view that snowpack storage is the dominant source of late summer water, recent research has revealed that the source of late summer water in western and central Oregon and northern California is almost exclusively immense groundwater storage in the Cascade Range. The volume of water stored as groundwater in permeable lava flows in the Cascade Range is seven times that stored as snow (Thompson 2007). Under a climate change scenarios, streams fed by groundwater are predicted to continue to flow in the summer, due to an extended storage effect, but at a reduced volume (Tague et al. 2008; Thompson 2007). The hydrograph of groundwater fed systems is expected to reflect higher winter flows and decreased spring and summer flows as snowmelt peaks earlier in the year and flows are mediated by geologic drainage rates (Thompson 2007; Jefferson et al. 2007; Tague et al. 2008). Flow in streams fed by springs should continue to be more stable (less interannual variability) than streams dominated by surface runoff (Jefferson et al. 2007).

While the hydrology and temperature regime of the Klamath River generally is dominated by surface water runoff, the upper Klamath basin (as well as the Shasta River) have substantial regional groundwater flow. Much of the inflow to UKL can be attributed to groundwater discharge to streams and major spring complexes within a dozen or so miles from the lake. This large component of groundwater buffers the lake somewhat from climate cycles (Gannett et al. 2007). In absolute terms, decreases in summer base flows may be greater in groundwater basins than in surface dominated basins (Mayer and Naman 2011a; Thompson 2007). However, this does not change the fact that these groundwater basins, such as the upper Klamath, will have under climate change, more streamflow in late summer than those basins with little sub surface flow (Thompson 2007).

In terms of temperature, groundwater is generally cooler in the summer and warmer in the winter than surface water. Because of the groundwater influence, stream water temperatures in the upper Klamath basin are less likely to be altered than those in the lower basin in response to climate change over the 50 year time scale of this analysis. Temperatures of springs generally reflect the temperature of their water source (aquifer). Consequently, spring water in the summer is farther from equilibrium with air temperature than ambient stream water, taking it longer (in time and distance) to warm (Tague et al. 2007).

Groundwater temperatures respond to climate change to a lesser degree than groundwater flows. While hydraulic pulses can move through a groundwater system relatively rapidly, on the time scale of months or years, the actual advective travel time of water is much longer (Gannett 2010). Large scale springs, such as in the Cascades, with travel times on the order of decades to centuries, can be expected to damp climatic temperature variations on the order of decades (Manga 1999). Large amounts of groundwater discharge into the Wood River subbasin, the lower Williamson River area, and along the margin of the Cascade Range (Gannett et al. 2007). Temperature benefits to the mainstem Klamath River below UKL from upper Klamath basin groundwater inputs would continue to be diminished as water passes through UKL, where it can warm before flowing downstream. However, Big Springs provides significant high quality water below J.C. Boyle Dam and the Shasta River was historically a groundwater-dominated system (National Research Council 2004a) with considerable potential to provide groundwater benefits currently.

Under climate change, late summer drought conditions will likely increase in frequency, further restricting the suitable rearing habitat of juvenile salmonids and the holding waters of adult spring Chinook without thermal refugia. These late summer drought conditions may further restrict the distribution and abundance of salmonids in currently marginal habitats near the southern limit of the range. Climate change is likely to have deleterious effects on salmonid populations and consequently an undesirable effect on harvest of salmonids during the 50-year period of interest. Carefully planned habitat restoration projects (such as conservation and acquisition of groundwater) offer one of the few strategies that will be likely to mitigate the short-term effects of climate change (i.e., decades) (Independent Scientific Advisory Board 2007).

3.1.1. Conditions with Dams – Effects of Climate Change

The synergistic effects of dams, reservoirs, and climate change are likely to be deleterious to salmonid populations. Dams will continue to block access of anadromous salmonids to habitat in the PR and to upper Klamath tributaries with important groundwater resources. Inasmuch as these groundwater resources can mitigate the effects of climate change to some extent, continued blockage will not be advantageous to restoration of salmonids. With dams, the benefits of substantial groundwater resources in the PR will not be realized because they are inundated by reservoirs or occur in bypassed reaches. Salmonids may be extirpated from currently marginal habitats as a result of future climate change and these extirpations will further aggravate salmonid population viability be reducing abundance and spatial diversity of the populations. Furthermore, increasing air temperatures and water temperatures associated with climate change will likely exacerbate the effects of reservoirs on lower Klamath River temperatures and water quality. Further diminished water quality has uncertain consequences for fish diseases in the mainstem Klamath River. Ongoing efforts to restore habitat for salmonids will continue under this alternative, but there is more uncertainty regarding whether the combined effects of dams, migration barriers, and climate change will preclude further declines in salmonid populations.

3.1.2. Conditions without dams and with KBRA – Effects of Climate Change

Under the without dams and KBRA management scenario, the hydrograph and seasonal water temperature regime would more closely mimic conditions under which native salmonid species evolved. Dam removal and KBRA would enable salmonids to fully realize the benefits of groundwater sources and the associated thermal refugia above UKL, in the PR reach, and downstream of the PR reach. The groundwater and thermal refugia will to some extent mitigate climate change effects in late summer for rearing juvenile salmonids and for adult salmonids, particularly upstream migrating or holding spring Chinook salmon. In addition, under the voluntary water purchase programs made possible with KBRA funding, there will be an opportunity to return to fish habitat groundwater currently diverted from below IGD. In a review of climate change impacts on salmonids, the Independent Scientific Advisory Board for the Columbia River Basin (Independent Scientific Advisory Board 2007) identified carefully planned habitat restoration as the only practical way to mitigate the effects of climate change in the short-term (e.g., decades). Therefore, the combination for providing access to habitat for salmonids through dam removal and restoration of habitat for salmonids on the scale proposed in KBRA is the alternative most likely to mitigate the effects of climate change over the 50- year period of interest.

4. ECOSYSTEM SCALE EFFECTS OF TWO MANAGEMENT SCENARIOS

4.1 Resilience as a Concept

In previous sections of this review and the summary below (Table 4) we described species-specific responses to the two proposed alternatives. We addressed many of the likely species-specific responses at spatially restricted scales such as individual river reaches and tributaries. However, the positive gains in fish abundance through large-scale dam removal projects may depend on a number of incalculable elements at a larger ecosystem scale. Large-scale dam removal is a fairly new concept and there is limited experience and literature to draw upon to predict how the ecosystem will respond. Furthermore, the proposed action alternative is not limited to simple dam removal. The proposed action to remove dams is accompanied by the KBRA restoration projects, and the combined effect may significantly increase the overall impact of the action on the ecosystem. Although it may be difficult to estimate the quantitative response in salmonid abundance to the action alternative, we recognized that dam removal would provide resiliency to the ecosystem.

Ecological resilience can be defined as the extent to which ecosystems can recover from natural and human disturbances without losing their functions or shifting into alternate states. An ecosystem is a community of organisms that are dependent on each other and on their environment. According to resilience theory, ecosystems can exist in multiple ‘stable states’ and shift from one to the other (‘phase shifts’) when certain tolerance thresholds are crossed. The ability to have multiple stable states is what makes natural systems inherently resilient.

The concept of resilience in ecological systems was first introduced by C.S. Holling to describe the persistence of natural systems in the face of changes in ecosystem variables due to natural or anthropogenic causes (Holling 1973). Walker et al. (Walker et al. 2004) further defined resilience in ecological systems as "the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks." In other words, a resilient ecosystem resists damage and recovers quickly from stochastic disturbances such as the introduction of exotic species or catastrophic floods. Resilient salmon populations will have similar attributes.

To strengthen resiliency in salmon populations, habitat opportunities need to be expanded to allow maximum expression of life-history variation. This conclusion is in agreement with the viability concepts of abundance, productivity, diversity, and spatial structure discussed earlier (McElhaney et al. 2000; Williams et al. 2008). A dam disrupts river connectivity and can block or delay passage both up- and downstream for migrating fish. Dam removal would contribute to the resiliency of the salmon population by re-connecting important seasonal fish habitat, normalizing temperature regimes and sediment transportation, and improving biological diversity. However, we recognize that biodiversity and ecosystem integrity are difficult to describe and so complex that a single measure or four measures cannot be expected to express relations in a functioning ecosystem (De Leo and Levin 1997; Loreau et al. 2001; Thompson and Starzomski 2007). Lotic models and concepts of how riverine ecosystems function across space and time continue to evolve in science (Thorp et al. 2006; Ward et al. 2002).

Salmon have phenotypic plasticity and a high reproductive capacity that will contribute to the resilience of Klamath River populations (Healy 2009). Increasing the resiliency of a population is one way to increase the likelihood that the salmon population will survive under future conditions with climate change. For example, Hilborn et al. (Hilborn et al. 2003) describes how the high level of what he termed "biocomplexity" in the stock structure of sockeye salmon (*O. nerka*) enabled it to sustain the consistent harvest of the fishery in Bristol Bay, Alaska despite major changes in climate conditions in the last century. Hilborn et al. (2003) reviewed the record catches of Bristol Bay sockeye during a 20-year period and concluded that a complex amalgamation of several hundred discrete spawning populations contributed to the stability of the fishery. Different geographic and life history components of sockeye salmon dominated in the fishery as the climatic regime of the area changed over decades.

4.2 Dams and Habitat Connectivity

In regulated rivers with multiple dams, several options to restore habitat connectivity for salmonids exist. Two dams are planned to be removed on the Elwha River, Washington, the Elwha and Glines Canyon dams. The removal of these dams is expected to restore habitat connectivity and anadromous salmon runs (Bednarek 2001; Gregory et al. 2002). Inasmuch as about 90 percent of the Elwha River Basin will continue to be managed under the Olympic National Park, restoring connectivity will be a step toward restoring the natural state of the ecosystem in the Park. On the Columbia River, an independent review group advocated restoration of the river to a more normative ecosystem (Williams 2006). They referred to a normative river ecosystem as one with both natural and cultural elements, including dams, in a balance that allows salmon to thrive and many of society's present uses of the river to continue, although not without modification (Williams 2006). They emphasized that the entire natural ecosystem and cultural systems, including the continuum from natal freshwater salmon rearing areas to the estuary and ocean environment, should be considered. In the Klamath River Basin the proposed action retaining the Link River and Keno mainstem dams, and making substantial changes to the water conveyance infrastructure, appears to be an intermediate path compared to proposals for restoring salmon on the Columbia River and the Elwha River, Washington.

Dams have an obvious effect on anadromous salmon by inundation of habitat, impacting water temperatures, and precluding successful upstream migration and reproduction for adult salmon. However, some more subtle effects include sediment starvation of downstream reaches, regulation of flows, temperature phase lag, and a discontinuity distance downstream. The serial discontinuity concept (Stanford and Ward 2001; Ward and Stanford 1983; Ward and Stanford 1995) predicts the distance downstream required for the stream to recover from the effects of the dam and impoundment. Downstream of the dam, sediment starvation changes the geomorphic structure resulting in larger bed sediment size. As the bed shifts from sand, gravel, and cobble to sediment domination by coarse gravels and cobbles, the flood flows required to move the bed increases progressively. With the bed dynamics decreased, the channel becomes less dynamic and increasingly incised with a bed at a lower elevation than expected under natural conditions. When dams are removed, the effects of sediment accumulation in the reservoirs and sediment starvation downstream are mitigated as a new longitudinal profile is established and the aquatic community returns (Gregory et al. 2002). Similar discontinuity reaches downstream of IGD for temperature and water quality parameters will be minimized (effects of Keno Dam and upstream water quality degradation will still exist) in the Klamath River after dam removal (Bartholow et al. 2005; Federal Energy Regulatory Commission 2007).

Restoring access to reaches above IGD will increase the diversity of thermal regimes and habitats available to Chinook, coho and steelhead populations. We have described how coldwater refugia and groundwater in the Wood and Williamson rivers provide thermal diversity. Chinook salmon will benefit from a diversity of temperature regimes associated with the higher elevations above UKL and the potential rearing habitat in UKL. Thermal refugia available after dam removal between Keno Dam and IGD will provide more diverse thermal environments. The close relation between temperature and growth rates of juvenile salmonids will result in a variation in size of juvenile salmonids. Juvenile steelhead are well known for their diversity in life history strategies and range in age and size at the time of their seaward migration (Peven et al. 1994).

Habitat reconnected by dam removal provides salmon populations the opportunity to use riverine habitats that are spatially diverse over a range of elevations and gradients across a landscape with different land use and ecological communities. Resilience in groups of salmon populations can result from spatial, temporal, and genetic diversity. The stabilizing effect of groups of diverse populations is known as the "portfolio effect" because it is analogous to the effects of asset diversity on the stability of financial portfolios (Schindler et al. 2010). The biology of salmon with the homing behavior of returning to natal streams encourages discrete salmon populations adapted to natal streams and supports the portfolio effect. Moore et al. (Moore et al. 2010) described how asynchronous population dynamics among groups of salmon populations have the portfolio effect and how this stabilizes long-term production. Historically the Klamath River Basin had high levels of spatial diversity with salmon distributed in the low-rainfall tributaries above UKL as well as high-rainfall tributaries in the lower Klamath River. Earlier in the report we described how the anthropogenic activities have been accompanied by declines or complete extirpation of salmonid populations in some areas of the Klamath River Basin since historical times. If dam removal and KBRA enables salmon to use streams where they have been extirpated, then the portfolio effect should increase resilience of Klamath River Basin salmon populations.

4.3 Natural Flows and Disturbance

Restoration of regulated rivers to normative conditions requires restoring peak flows to reconnect and periodically reconfigure channel and flood-plain habitats, stabilizing base flows to reestablish food-webs, and reconstituting seasonal temperature patterns

(Stanford et al. 1996). Galat and Lipkin (Galat and Lipkin 2000) reviewed the historical hydrographs of the Missouri River and recommended periodic controlled flooding, increased magnitude, frequency, and duration of annual high-flow pulses. Occasional managed floods have been implemented on the Colorado River to improve sediment deposition and alter ecological attributes of the river ecosystem (Patten et al. 2001). Pulse flows and floods have numerous desirable effects on the geomorphology, floodplain, riparian habitat, and ecology (Benke et al. 2000; Junk et al. 1989; Junk and Wantzen 2004; Middleton 2002; Poff et al. 1997). Although such floods may be considered destructive when the havoc they bring to a floodplain is considered, occasional floods are one of the natural disturbances that salmon populations are well adapted to survive in the long term. Although dam removal may restore the Klamath River hydrograph to a more normative state, we recognize dam removal will not remove the effects of alterations to Lower Klamath Lake, diverting winter flows from the Lost River, and drawing UKL down during winter on the natural hydrograph.

The natural resiliency of salmon populations is partially the result of adaptations to disturbance regimes across their distribution. Disturbance events and environmental gradients result in connectivity and spatio-temporal heterogeneity that leads to high biodiversity and resilience in salmon communities (Ward 1998). Disturbance regimes in habitat used by Pacific salmon are characterized by four attributes: 1) frequency, 2) magnitude, 3) duration, and 4) predictability (Waples et al. 2009). Often, anthropogenic activities such as flow regulation by dams result in disrupting natural disturbance regimes, truncating environmental gradients, and severing interactive pathways thereby interfering with habitat diversification, migratory pathways, and other riverine processes (Ward 1998). In general, anthropogenic activities create disturbance regimes that are different from the natural range of disturbances for which salmon are adapted. Although the role of disturbance regimes in the resiliency of salmon populations have been developed by experts from across the distribution of Pacific salmon, they are generally applicable to the Klamath River Basin. The need for ecosystem management to restore resilience of salmon populations at a landscape scale is universal.

The importance of natural flows and their effect on the geomorphology of the Klamath River is closely linked to the relation between substrate and the life history of salmon. For example, in freshwater salmon use gravels for spawning, relatively clean sediments for incubation, and complex habitats to support food and rearing. Both coho and Chinook salmon select spawning sites partially based on gravel/cobble substrate size (Groves and Chandler 1999; Mull and Wilzbach 2007). Excessive fines in the redds during incubation are well known to reduce survival of salmon prior to emergence. Diversity in habitat for rearing enables multiple species and life history stages to use the appropriate habitat niche. Lister and Genoe (Lister and Genoe 1970) described this habitat segregation among juvenile fall Chinook salmon and coho salmon in the Big Qualicum River. Flow improvements and habitat restoration proposed in the KBRA is a strategy that will enable juvenile salmonids of all species to spatially segregate resulting in increased production, enhanced growth, and better survival.

The natural hydrograph of the Klamath River Basin and tributaries is a worthy reference point when considering ecosystem function and restoration of salmon. The National Research Council of the National Academies (National Research Council 2007) reviewed the Natural Flow Study (Perry et al. 2005) and the Instream Flow Study Phase II (Hardy et al. 2006) and described the shortcomings of the studies and the implications of the results for anadromous fishes in the Klamath River. The National Research Council (2007) concluded the prescribed flows in Hardy et al. (2006) would probably have beneficial effects on the suite of anadromous fishes in the Klamath River, but did not specify the specific benefits likely for each anadromous species. Higher and more natural spring flow levels and fall and winter flow variability prescribed in the BO (National Marine Fisheries Service 2010a) are expected to benefit coho salmon rearing, outmigration, and reproduction. A drought plan for allocating scarce water supplies during drought years is proposed for preparation in the KBRA (Section 19). These flow prescriptions will have broad positive effects across numerous levels in the aquatic ecosystem, and support a diversity of size and life history patterns among salmonids.

4.4 KBRA and Resilience

The predicted response of salmon species to the action alternative, four dams removed with KBRA, assumes some restoration at the ecosystem level. The removal of four lower river dams would, to some extent, mitigate the current ecosystem scale footprint of anthropogenic effects that we have described. That footprint extends from the effects of extirpation of salmon in the headwaters tributaries to the discontinuity distance downstream of IGD where fish disease reduces the survival of juvenile salmon. The KBRA provides for flow allocation, inseason management, and a drought plan that we expect will improve the ecosystem services sought by society and the attributes of natural flow that will benefit the ecosystem. The numerous habitat projects described in KBRA address the landscape scale issues of degraded tributaries that should, over a 50- year period, increase the resilience of salmon populations.

The challenge for KBRA will be to recreate complex ecosystem components from simple and degraded resources (see Jansson et al. 2007). Palmer et al. (Palmer et al. 2005) recognized that another challenge is that restoration of river systems must be mostly self-sustaining and resilient to external perturbations so that minimal follow-up maintenance is needed in the long term. For example, caution will need to be exercised to minimize the opportunities for benefits to invasive exotic species (Jansson et al. 2007). Entities in the Klamath River Basin have expertise associated with recently implemented restoration projects described by the National Marine Fisheries Service (2010b). In addition, a considerable body of knowledge has developed on restoring riverine connectivity in both longitudinal and lateral directions in other river basins (Jansson et al. 2007; Katz et al. 2007; Kondolf et al. 2006; Lake et al. 2007; Montgomery 2006). Both restoration projects from within the Klamath River Basin and other drainages offer the opportunity to learn in order to inform future efforts (Kondolf et al. 2007; Palmer et al. 2007). A recent survey of stream restoration projects in the Pacific Northwest found about 70 percent of all respondents reported their projects were successful. The advantage KBRA will have over many other restoration activities is the framework for monitoring and evaluation. Another advantage will be the large scale of KBRA that is necessary to affect change at the ecosystem scale.

Dam removal and habitat restoration associated with the KBRA will likely lead to an increase in spatial and temporal diversity for returning salmon. Habitat restoration will be more likely to foster salmon resilience if it considers processes that generate and maintain natural variability in freshwater environments (Bisson et al. 2009). Restoration of as much of the lost resilience of salmon populations as possible appears to offer the best hope of sustaining both salmon and their fisheries (Healy 2009). Restoration may be an important strategy to allow salmon populations to cope with climate change. These conclusions are in general agreement with the findings of a review on the Columbia River Basin that concluded that selective habitat restoration offered the most promise for salmon to cope with climate change (Independent Scientific Advisory Board 2007).

Restoring salmonid populations to the Klamath River Basin will likely be associated with restoring their diversity and resilience. Restoration of salmon populations will depend on multiple species of salmon and variable life histories (i.e., spring and fall-run Chinook salmon) to provide the relatively stable opportunities to harvest salmon across a range of locations and different times of the year. Historically, the Klamath River Tribes harvested salmon at various locations throughout much of the year and as far upstream as tributaries to UKL (Hamilton et al. 2005). This is evidence that the salmon populations at the time had a high level of temporal and spatial diversity that contributed to their resilience. Restoring resilient salmon fisheries will reconnect the fishery resource to the communities resulting in increased social resilience (Bottom et al. 2009; Healy 2009; Martin 2008). Martin (2008) described how weakened salmon stocks and a reduced Columbia River gillnet fishery harvest associated with the Endangered Species Act listing of some salmon species has affected the strategies for coping and reduced social resilience in Lower Columbia River salmon dependent communities. At the broadest scale, natural resource dependent rural areas and communities, including west coast salmon fisheries and Klamath River Basin communities, appear most likely to benefit, along with salmon, from a resilient ecosystem associated with dam removal and habitat benefits of KBRA.

5. SUMMARY

The following matrix (Table 4) provides a summary of benefits and risks under the two management scenarios (current conditions with dams versus conditions without dams and with KBRA).

Table 4. Comparison of benefits and risks to fisheries resources and habitat conditions under two Klamath River scenarios (current conditions 'with dams' versus conditions 'without dams and with KBRA').

Issue	Conditions with Dams	Conditions without Dams with KBRA
Hydrology		
Risks	**Continued artificially stable flows from IGD downstream to**	**Low flows in dry years may pose risks but drought plan is**

Issue	Conditions with Dams	Conditions without Dams with KBRA
	Seiad Valley[32]. **Low flows in dry years may pose risks to fish populations.**	**expected to reduce this risk relative to current condition.**
Benefits	**Continued implementation of NMFS' Long Term recommendations provide flows below IGD sufficient to avoid jeopardizing SONCC coho salmon.**	**Restore flows to a more natural flow regime downstream of Keno to the estuary.** **Evaporation losses are reduced.** **Eliminate adverse effects from extreme peaking operations in the PR.** **Provide flows above and beyond avoiding jeopardy for SONCC coho salmon.**
Thermal Refugia		
Risks	**No access for anadromous fish to thermal refugia upstream of IGD.**	**Currently used thermal refuge within mainstem below IGD will be used earlier and longer and the size of current thermal refugia will be diminished when flows are greater during summer months.**
Benefits	**To the degree that juvenile salmon below IGD are present, they will experience cooler temperatures in the spring and early summer due to the continued effects of the dams, possibly improving growth and survival.**	**Anadromous fish will have access to extensive thermal refugia in tributaries upstream of the current location of IGD, especially extensive groundwater influenced areas in tributaries to UKL. Groundwater areas will be buffered from climate change.** **Additional refugial areas will be available to fish in PR, providing diverse habitat over wider spatial areas .**
Geomorphic Processes		
Risks	**Continued cut off of gravel in PR and below IGD.** **Continued disruption of channel forming flows and processes both above and below**	**Possible flooding in near term.** **Release of fine sediment during drawdown predicted to have short term impact to aquatic**

[32] Current stable flows below IGD are not solely the result of Project dams but are influenced by storage and flow regulation that occurs at Upper Klamath Lake from Link River Dam flow releases and as a result of flow requirements below IGD dictated by the NOAA BO on operation of the BOR project (NMFS 2010).

Issue	Conditions with Dams	Conditions without Dams with KBRA
	IGD Perpetuation of reed canary grass in by-pass reach	habitats. Short term potential adverse effects include increased fine sediment in spawning gravels, pool filling, and increased levels of suspended sediment and turbidity. NONE apparent over long term.
Benefits	NONE	Reestablishment of total spawning gravels in PR and below IGD (Keno Dam to Shasta River). Fluvial mechanisms will be restored; Transitory habitat will increase under variable flows; riparian restoration and instream habitat complexity will increase. Higher seasonal flows can scour encroaching reed canary grass.
Temperature		
Risks	Current phase shift and lack of temporal diversity will persist. Current warm temperatures in late summer and fall will persist. Spawning below IGD will continue to be delayed and prespawn mortality will remain high (Hetrick et al. 2009).	Water temperatures would be up 2 to 4°C warmer during spring and summer for rearing fish resulting in stress and disease for late outmigrants.
Benefits	Current cooler temperatures in spring and early summer reducing stress and disease for late outmigrants.	Reduction of the thermal lag (phase shift); water temperatures would return to variability inherent in local unregulated river systems. Reduction of 4 to 5°C in water temperature in October to early November to at least 60 miles below IGD, resulting in improved temperatures for adult migration and spawning phases. Spawning below IGD will no longer be delayed and

Issue	Conditions with Dams	Conditions without Dams with KBRA
		prespawn mortality will diminish. **Earlier spawning of natural fall-run Chinook salmon, a longer incubation period, earlier emergence and growth, would encourage earlier emigration thus reducing stress and disease.**
Dissolved Oxygen		
Risks	**Currently DO falls below 6 mg/L below IGD, a minimum for migration. These negative impacts will persist.**	**In the short term, removal may result in near anoxic water downstream.**
Benefits	**NONE**	**DO would increase by 3 to 4 mg/L immediately downstream of IGD when DO concentrations in water released can be substandard.**
Nutrients		
Risks	**Reservoirs would continue to be potential seasonal nutrient sources to the river downstream of IGD.**	**Nutrients released during dam removal operations may impact the river and estuary in the short term.** **Additional marine-derived nutrients may exacerbate elevated P levels in Klamath ecosystem.**
Benefits	**Actions consistent with TMDLs are anticipated to reduce nutrient levels.**	**There would be increased assimilation of the river's nutrient load.** **Actions consistent with TMDLs are anticipated to reduce nutrient levels sooner than with the Dams In Alternative.** **HRT downstream of Keno would decrease greatly reducing primary productivity and improving water quality.** **Anadromous fish may export excess P from the Klamath ecosystem.**
Toxic Blue Green Algae (BGA)		
Risks	**Conditions under which BGA blooms of *Microcystis aeruginosa* and *Aphanizomenon***	**NONE apparent**

Issue	Conditions with Dams	Conditions without Dams with KBRA
	***flos-aquae* (AFA) thrive will very likely continue.**	
Benefits	**Anticipated to be NONE or minimal**	**Conditions under which *Microcystis aeruginosa* and AFA thrive will be greatly reduced, along with this additional stressor to the downstream biotic community and human users of the fishery resources.**
Anadromous Fish Habitat		
Risks	**Long term continued degradation of water quality and habitat complexity/suitability, increased disease, degraded spawning gravel, and impaired riverine functions below IGD.**	**Below IGD, short term impacts to habitat may occur as a result of dam removal.**
Benefits	**NONE**	**Restoration of anadromous fish runs to more than 420 miles of historical habitat upstream from IGD.** **Coarse sediment transport will be restored;** **Fluvial mechanisms will be restored;** **Transitory habitat will increase under variable flows;** **Riparian restoration and instream habitat complexity will increase.** **Spawning and rearing habitat under reservoirs and downstream of IGD would ultimately be improved.**
Habitat Restoration Activities		
Risks	**While there are extensive opportunities for rehabilitating habitat, significant portions of the historical production potential are unlikely to be recovered.**	**While historical production potential may not be recovered, conditions without dams are expected to move production closer to potential.**
Benefits	**PacifiCorp funding of restoration actions under coho and sucker conservation strategies may continue to occur.**	**KBRA resources will be directed toward restoration of habitat.** **Adequate funding to address physical, chemical, and biological problems in a**

Issue	Conditions with Dams	Conditions without Dams with KBRA
		comprehensive manner.
Keno Reservoir Passage		
Risks	Continued decline of runs in the watershed that use Keno ladder.	NONE
Benefits	NONE	Passage will be provided for fish species of interest. KBRA includes water quality improvements to Keno reservoir and trap and haul efforts around the reservoir when water quality conditions are likely to be poor.
Spring-run Chinook Salmon Restoration		
Risks	Continued depressed status and loss of historical habitat. Increased risk of listing or up-listing under federal and state ESAs	Impacts to survival in mainstem likely to occur for one year due to sediment release. Supplemental source of spring-run Chinook salmon uncertain at this time.
Benefits	NONE	Potential for restoration of spring-run Chinook salmon. This will provide access to extensive holding areas buffered from climate change.
Federally and State Listed Coho Salmon		
Risks	Continued depressed status and low viability of Klamath populations. Coho salmon populations continue short of abundance thresholds for viability.	Short term impacts to survival due to sediment release.
Benefits	Habitat availability in the mainstem Klamath Rivers sufficient to avoid jeopardy of SONCC coho salmon.	Reduced risk of extinction across the ESU. Provide flows above and beyond avoiding jeopardy for SONCC coho salmon.
Federally Listed Eulachon		
Risks	NONE	Unknown level of risk to spawning populations (if not already extirpated) the year of removal.
Benefits	NONE	NONE
Federally Listed Suckers		

Issue	Conditions with Dams	Conditions without Dams with KBRA
Risks	**Continued poor water quality in Keno reservoir and UKL.** **Without screens, continued operation of the hydropower project will result in entrainment and continued stranding.**	**Reservoir removal will result in some minor loss of insignificant sucker populations.**
Benefits	NONE	**Improved water quality in Keno reservoir and UKL is anticipated to result from restoration efforts.** **Population benefits are anticipated from the lake levels in more years under KBRA** **Potential for reducing extinction risk and for increasing overall population abundance and productivity.**
Federally Listed Bull Trout		
Risks	NONE	**Predation on fry and juveniles.**
Benefits	NONE	**Additional prey.** **Potential for increasing overall population abundance and distribution.**
Redband Trout		
Risks	**Continued poor water quality in Keno and UKL.** **Without screens, continued operation of the hydropower project will result in entrainment.** **Continued dewatering of habitat and spawning gravel in peaking reach.** **Continued extreme summer temperature fluctuations in peaking reach.**	**Reservoir removal will result in some loss of trout from reservoirs.**
Benefits	**Reservoirs provide lake habitat for some trout.**	**Improved water quality in Keno reservoir and UKL.** **Improved migration to habitat and refugia.**

Issue	Conditions with Dams	Conditions without Dams with KBRA
		Entrainment will be eliminated. Suppress extreme summer temperature fluctuations in peaking reach. Eliminate dewatering of habitat and spawning gravel in peaking reach. Substantial increase in harvest assuming spawning habitat does not limit the population increase. Trophy fishery may expand.
Disease		
Risks	See Section 2.2.10	See Table 3
Benefits	See Section 2.2.10	See Table 3
Recreational, Tribal and Commercial Harvest of Chinook Salmon		
Risks	Continued risk of fishing closures, disaster payments to Klamath salmon fisheries. Continued decline of the Tribal fishery.	Short term fishing closures may be required to protect stocks following dam removal. Unless protective measures are put into place, increased Chinook salmon harvest may limit restoration of other anadromous salmonid runs.
Benefits	Continued augmentation through hatchery production to mitigate for loss of 16 miles of habitat.	1) Production benefits from 100s miles of additional habitat 2) Over the long-term, greater harvest numbers and fishing opportunities 3) There would be additional opportunities for recreational fishers in the PR 4) Multiplier benefits to West Coast salmon fisheries in many years 5) Expansion of the period of harvest 6) Restoration of harvest by Klamath Tribe
Steelhead Abundance and Harvest		
Risks	Continued decline of steelhead populations, in particular, summer steelhead below IGD.	Short term impacts to survival due to sediment release.

Issue	Conditions with Dams	Conditions without Dams with KBRA
	Increased risk of listing under federal and state ESAs **Continued decline of the Tribal fishery.**	
Benefits	**Continued fishing opportunities likely to remain.**	**1) Increased abundance of steelhead over the long term** **2) under the current management plan, harvest would be similar to current conditions** **3) expansion of the period of harvest** **4) there would be additional opportunities for recreational fishers in the PR and upstream**
Pacific Lamprey Abundance and Harvest		
Risks	**Increased risk of listing under federal and state ESAs.** **Continued decline of the Tribal fishery.**	**Impacts to survival likely to occur for one year due to sediment release. Several year classes may be lost.**
Benefits	**NONE**	**Appreciable increases in abundance and Tribal harvest relative to current conditions.** **Increased sediment in the mainstem may increase ammocoete habitat.**
Green Sturgeon Abundance and Harvest		
Risks	**NONE apparent**	**Impacts to survival likely to occur for one year due to sediment release.** **Impacts likely reduced over long term.**
Benefits	**Similar abundance and harvest to current conditions**	**Similar abundance and harvest to current conditions**
Recreational Reservoir Fisheries		
Risks	**NONE**	**Warm water sport fisheries would be eliminated from the reservoirs.**
Benefits	**Reservoir warm water sport fisheries would be maintained.**	**Potential to reduce population of exotic predators of anadromous fish in the lower river.**

Issue	Conditions with Dams	Conditions without Dams with KBRA
		Additional opportunities for anadromous species recreational fishers in the PR
Hatchery Operations		
Risks	**Continued hatchery impacts (degradation of genetic diversity, loss of local adaptations, contribution of hatchery fish to reduced fish health) to naturally-spawned Chinook salmon, coho salmon, steelhead, and fish health below IGD.**	**Hatchery production levels may cease or be reduced after eight years following dam removal resulting in reduced hatchery fish harvest.**
Benefits	**Hatchery production would likely continue to contribute to commercial, Tribal, and recreational fisheries in the Klamath River Basin and the Pacific Ocean. In the mixed-stock coastal fisheries of the Pacific Ocean, the presence of hatchery fish allows for higher harvest levels than if there were no hatchery stocks in the fishery.**	**Hatchery production at an unknown level would continue at least eight years following dam removal.** **Reduced hatchery impacts to naturally-spawned Chinook salmon, coho salmon, steelhead, and fish health below IGD upon cessation of hatchery production.**
National Wildlife Refuges		
Risks	**Refuges continue with no priority for water delivery for wetland functions and waterfowl.**	**NONE apparent**
Benefits	**NONE**	**KBRA would provide modifications of Klamath Project Purposes for refuge water allocation for wetland functions and waterfowl.** **Flexibility to call for water would allow refuge managers to create optimum habitat conditions for wetland functions and waterfowl.**
Likelihood of Long-term Population Resilience Associated with Climate Change		
Risks	**Limited resilience of populations under climate change.** **Increased likelihood of listing of species or stocks.**	**NONE apparent over the long term.**
Benefits	**Hatchery populations may**	**Improved access to habitat that**

Issue	Conditions with Dams	Conditions without Dams with KBRA
	persist.	**will be buffered from climate change. Resilience of populations under climate change more likely.**

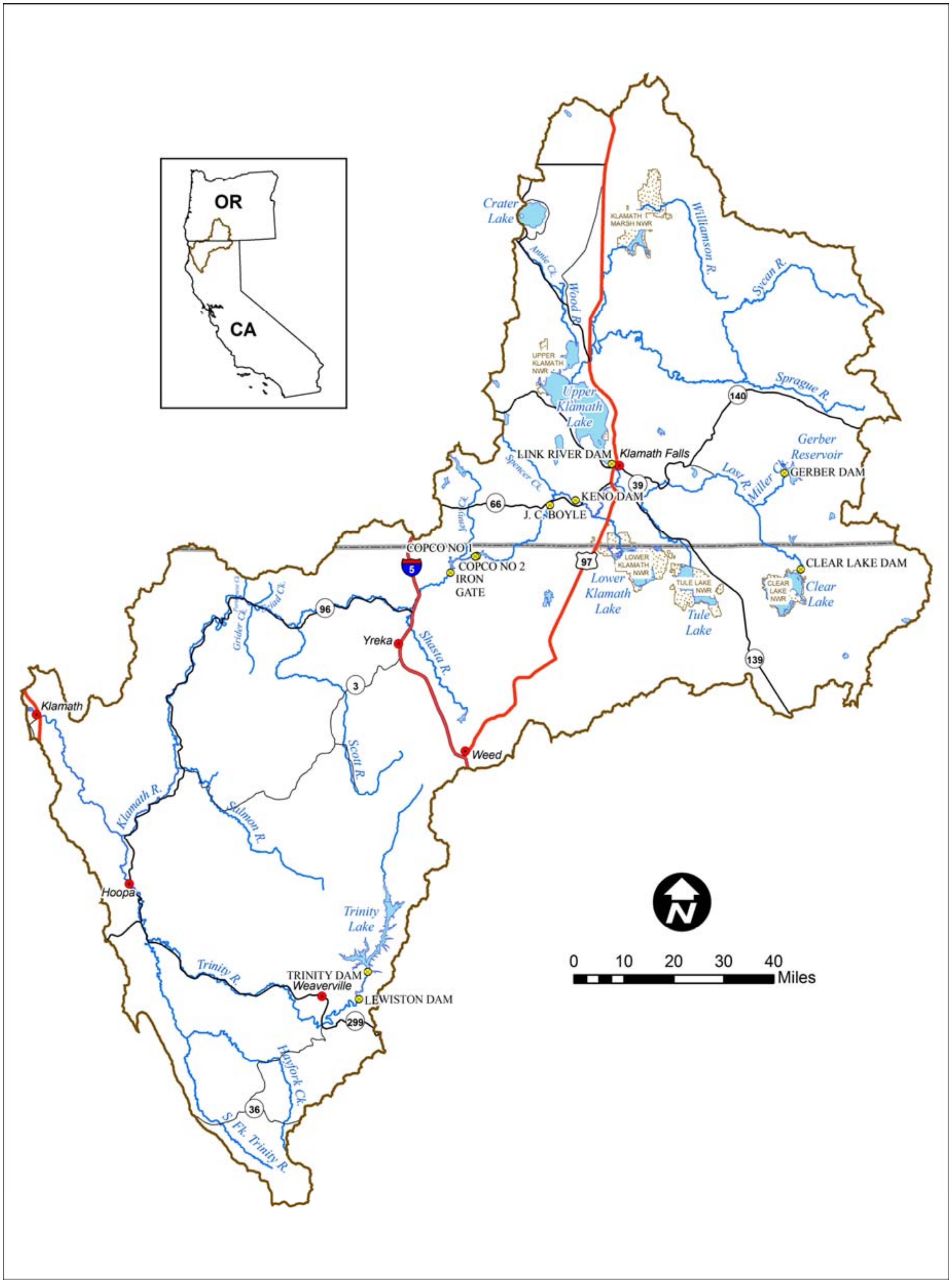


Figure 1. Klamath River Basin Map.

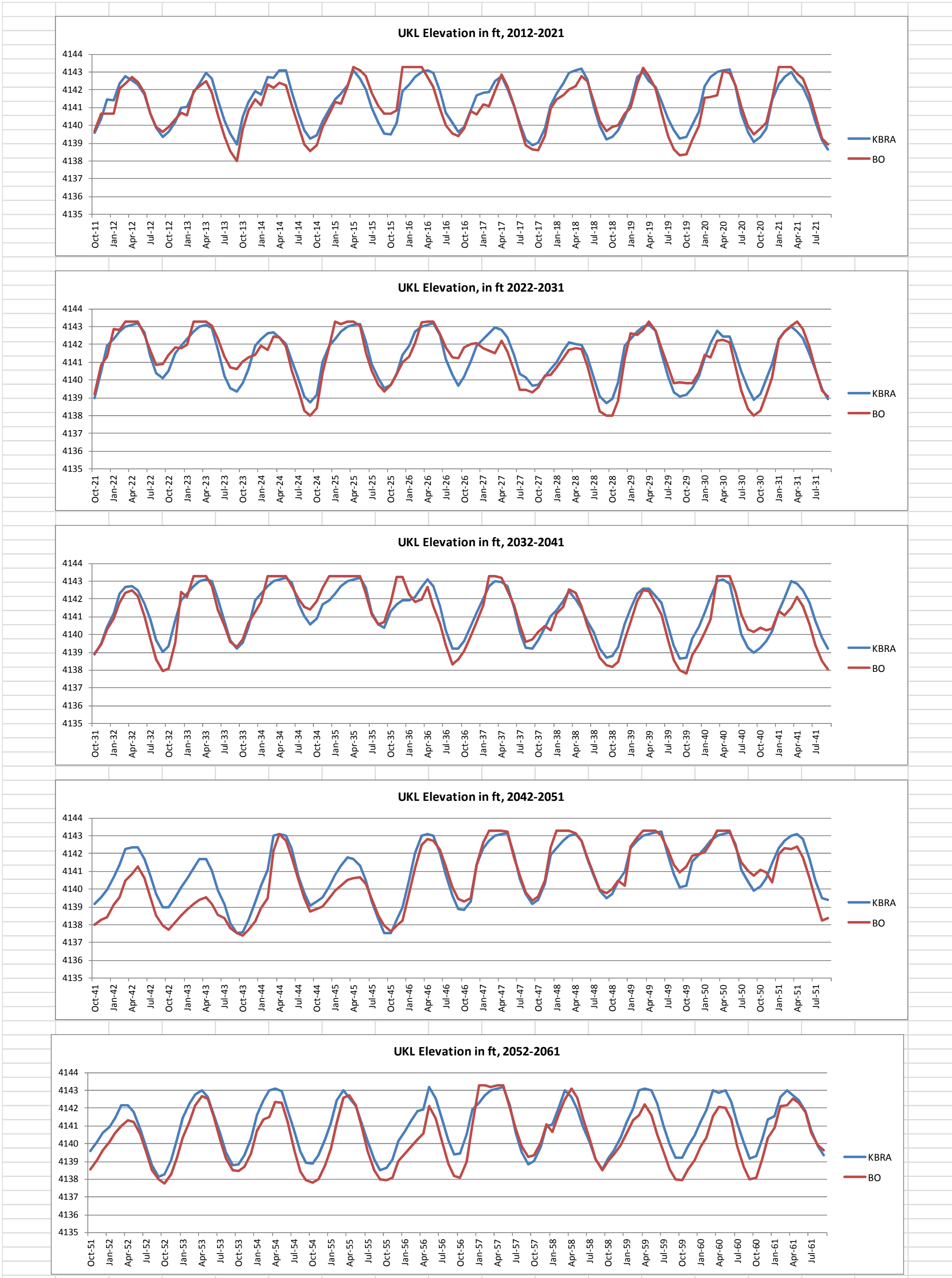
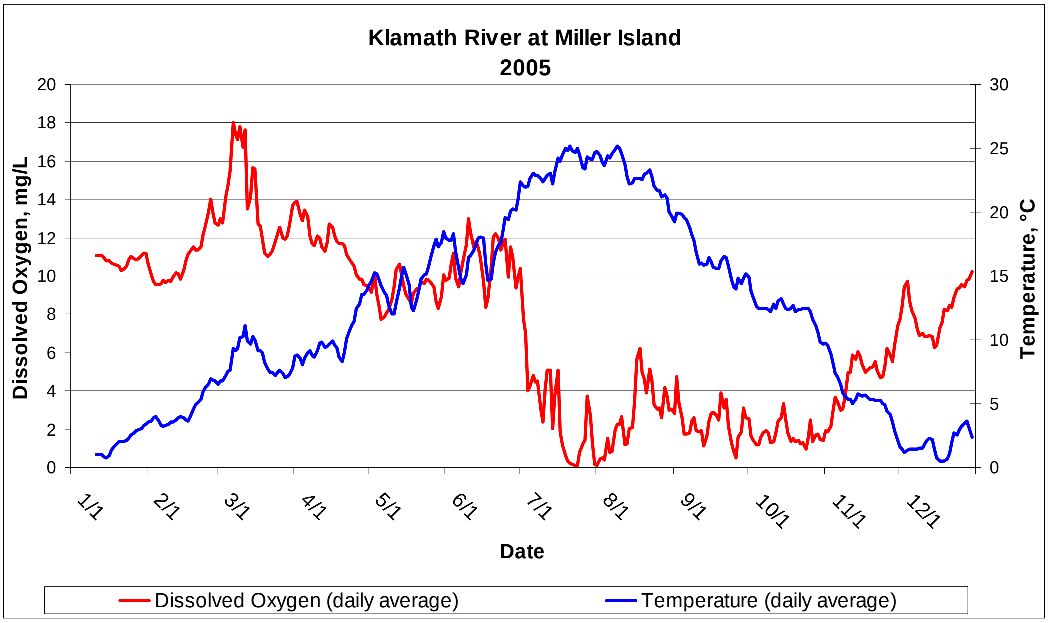


Figure 2. A comparison of simulated UKL lake levels from 2012-2061 for the two management scenarios: current conditions (with 2010 BO flows) versus dams out with KBRA (USDI Bureau of Reclamation 2010).



Source: http://or.water.usgs.gov/proj/keno_reach/monitors.html

Figure 3. Graph of DO (mg/L) and temperature (°C) in the Klamath River near Miller Island boat ramp, river mile 246 (Keno reservoir).

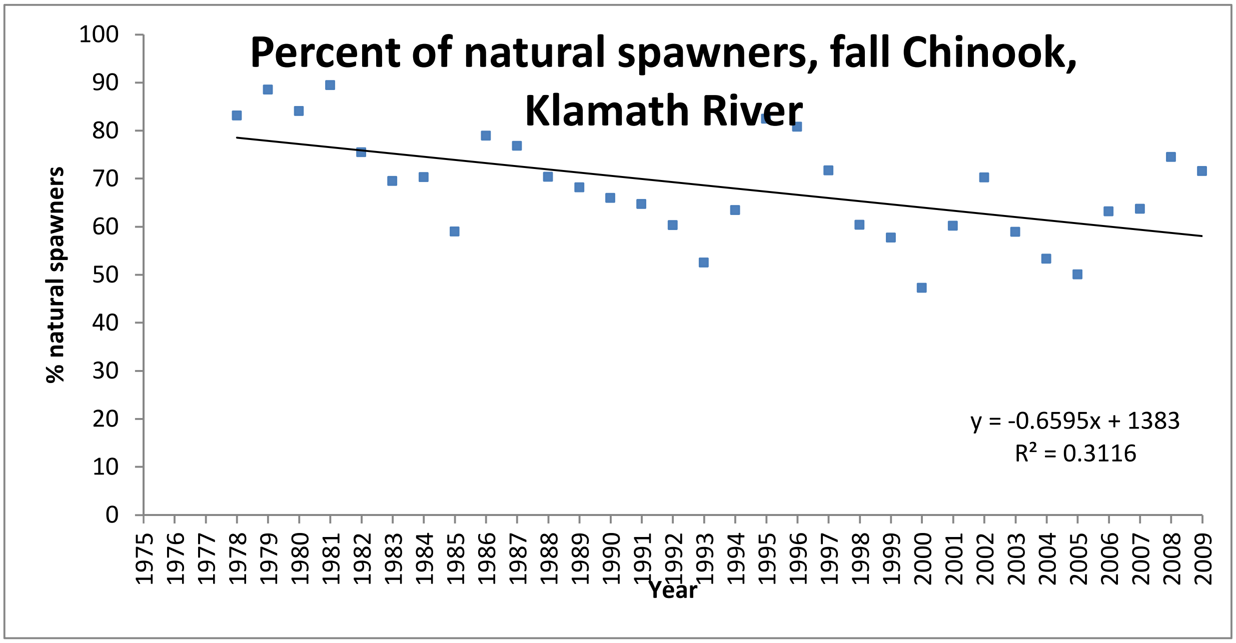


Figure 4. Percent natural spawners, Klamath River fall-run Chinook salmon, 1975-2009 (R. Quiñones, USFS, pers. comm.).

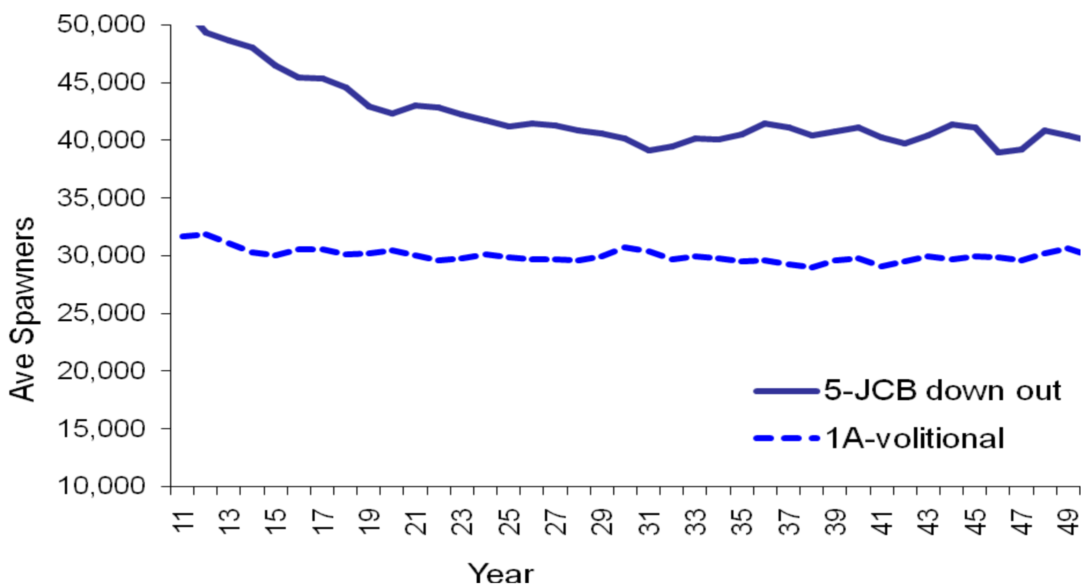


Figure 5. Ranking of average fall-run Chinook salmon spawners under existing Upper basin habitat conditions over 500 replications, out to 50 years with lower four dams out (#5) and volitional passage (#1A) (From Oosterhout 2005; courtesy of PacifiCorp). Volitional passage information is provided here because it is the closest projection to the with dams alternative. Oosterhout (2005) did not analyze existing conditions.

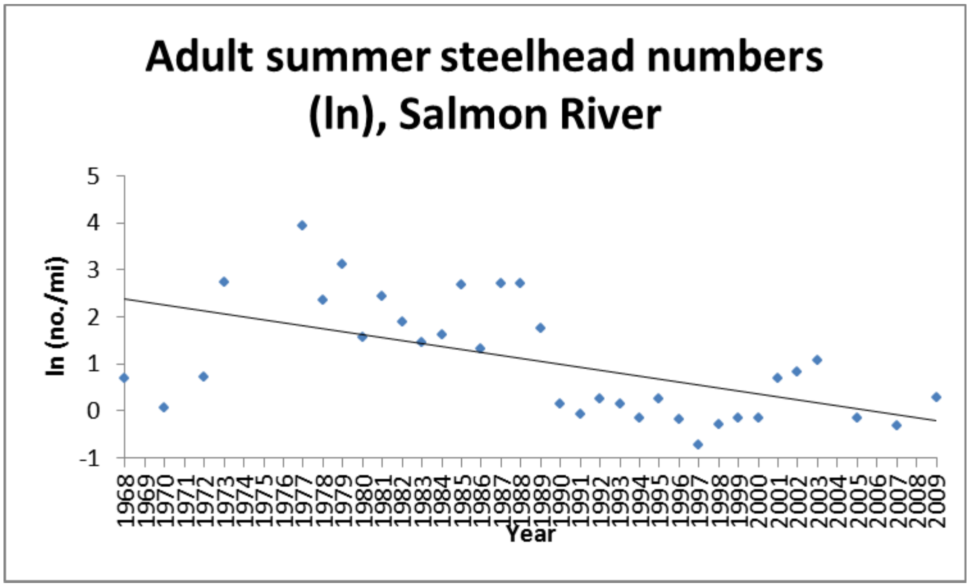


Figure 6. Summer steelhead adult returns (ln (abundance)), 1968-2009, Salmon River California (R. Quiñones, USFS, pers. comm.).

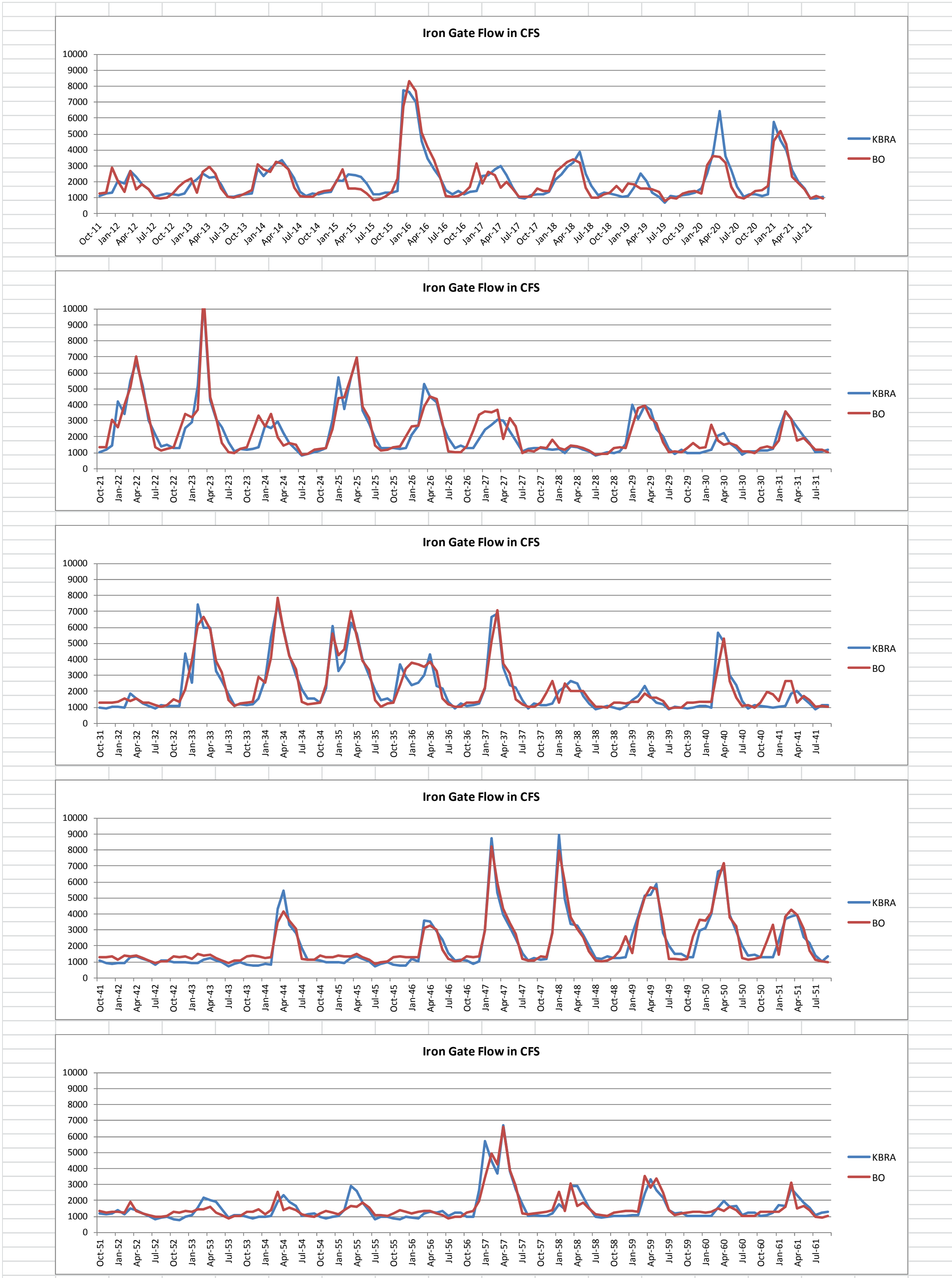


Figure 7. A comparison of simulated hydrology from 2012 to 2061 below IGD for the two management scenarios: current conditions (with 2010 BO flows) versus dams out with KBRA (USDI Bureau of Reclamation 2010).

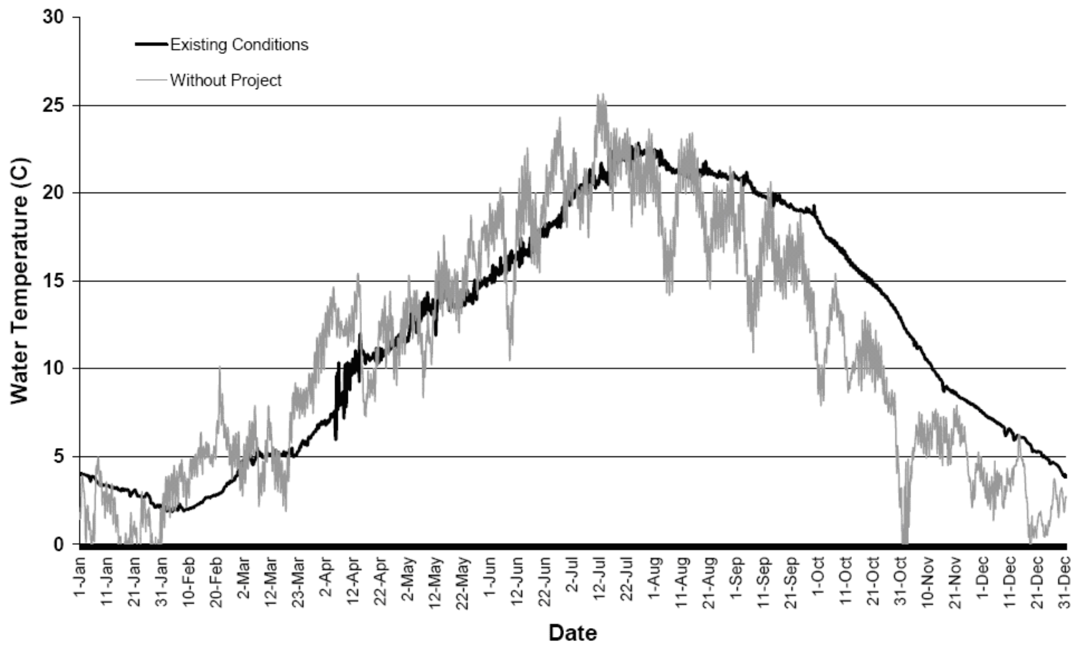


Figure 8. Simulated hourly water temperature below IGD (RM 190.5) based on 2002 (defined as a dry water year) for existing conditions compared to hypothetical conditions without the existing Klamath Hydroelectric Project dams. (Source: Federal Energy Regulatory Commission 2007; Figure 3-50, and PacifiCorp, response to AIR-AR-2, dated October 2005).

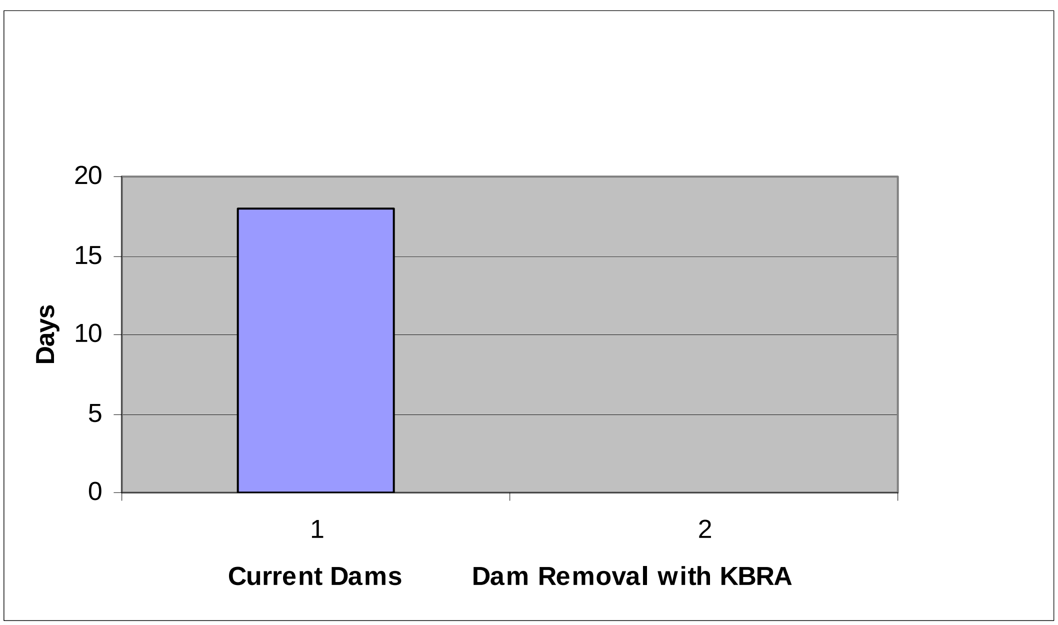


Figure 9. Delay in the normal progression of water temperatures below IGD (or Phase Shift from historical timing) (Bartholow et al. 2005).

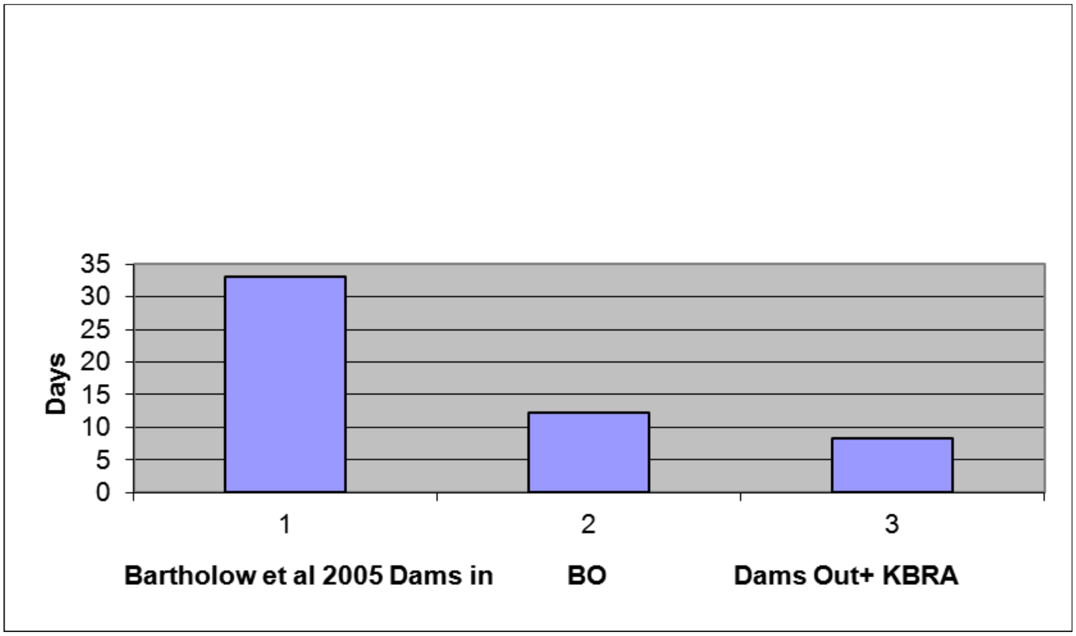


Figure 10. Average annual number of days that temperatures exceed maximum recommended temperature for migrating Chinook salmon immediately below IGD (Based on flows from 1. Bartholow et al. (2005) Dams-in; vs. 2. Dams-in with 2010 NMFS BO; vs. 3. Dams out + KBRA with Agency Lake and Barnes Ranch).

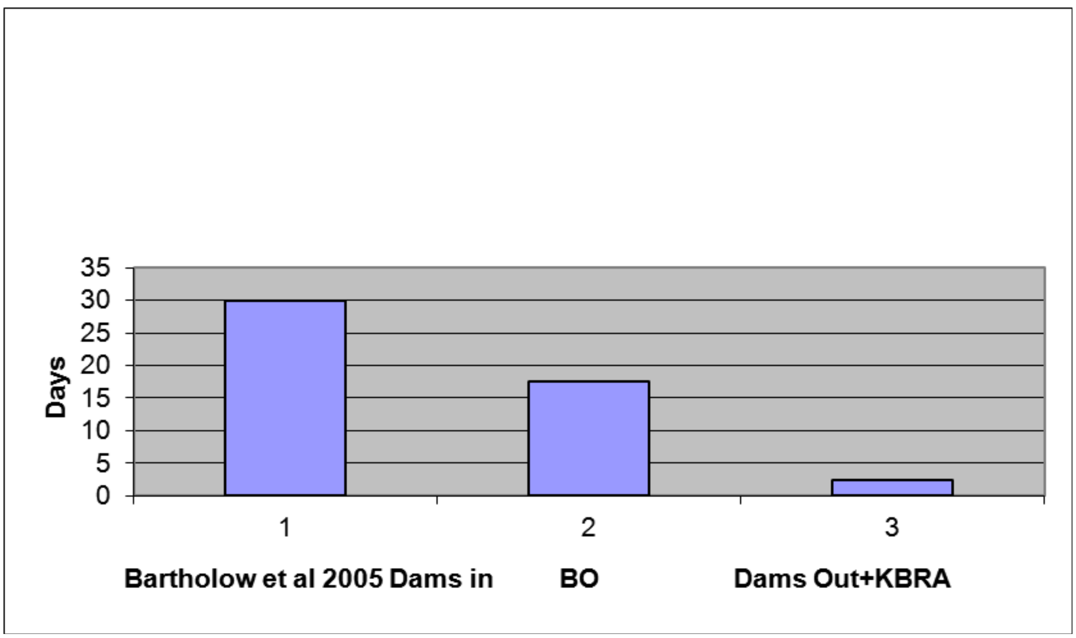


Figure 11. Average annual number of days that temperatures exceed maximum recommended temperature for Chinook salmon spawning and egg incubation immediately below IGD (Based on flows from 1. Bartholow et al. (2005) Dams-in; vs. 2. Dams-in with 2010 NMFS BO; vs. 3. Dams out + KBRA with Agency Lake and Barnes Ranch).

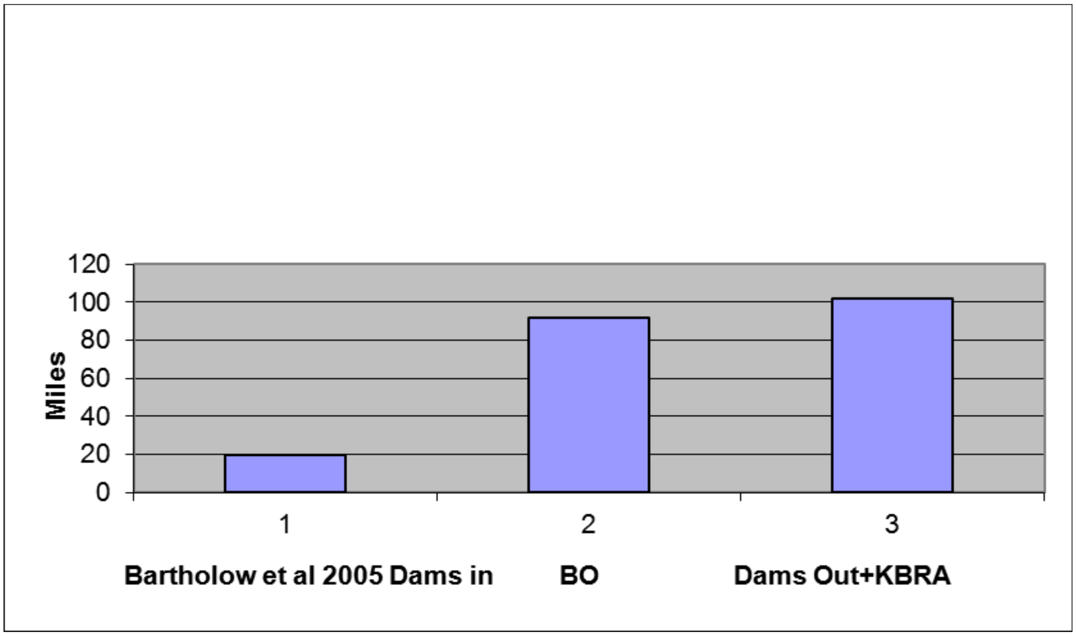


Figure 12. Miles of habitat downstream from IGD with suitable temperatures for Chinook salmon migration during August 15 to September 15 (Based on flows from 1. Bartholow et al. (2005) Dams-in; vs. 2. Dams-in with 2010 NMFS BO; vs. 3. Dams out + KBRA with Agency Lake and Barnes Ranch).

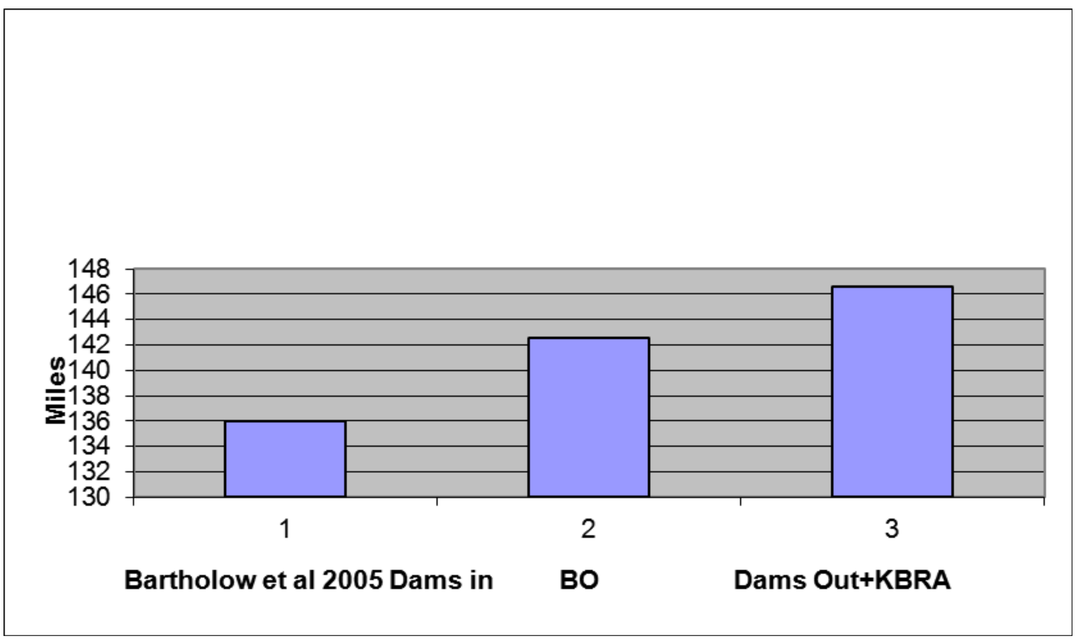


Figure 13. Miles of habitat below IGD with Chinook salmon spawning and egg incubation during October (Based on flows from 1. Bartholow et al. (2005) Dams-in; vs. 2. Dams-in with 2010 NMFS BO; vs. 3. Dams out + KBRA with Agency Lake and Barnes Ranch) (Note scale of Y axis).

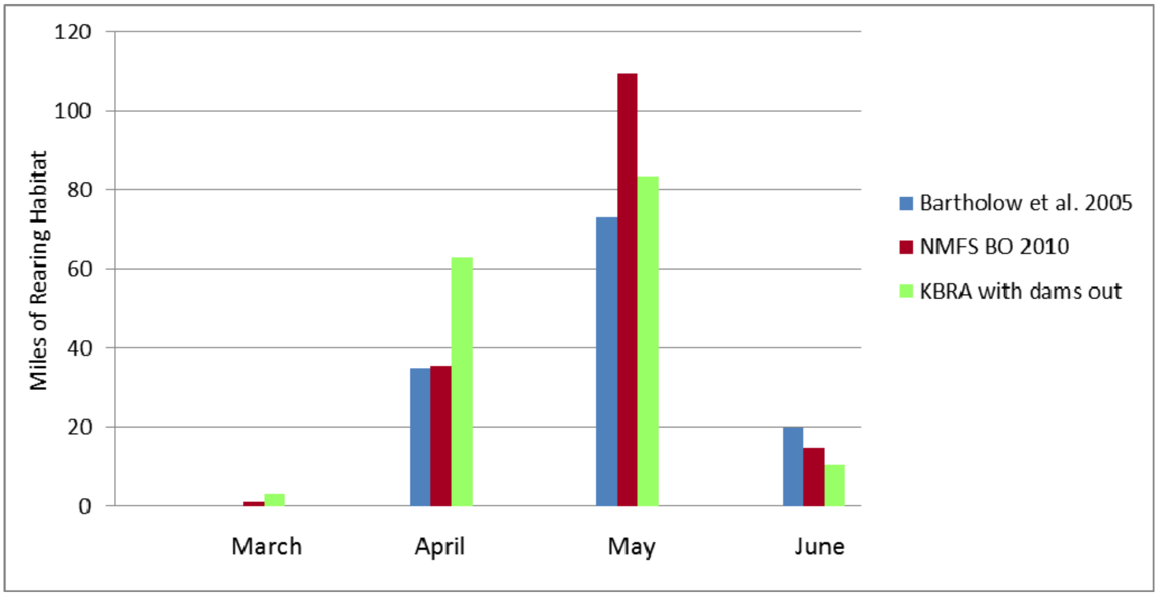


Figure 14. Miles of habitat below IGD with suitable temperatures for Chinook salmon rearing (Based on flows from 1. Bartholow et al. (2005) Dams-in; vs. 2. Dams-in with 2010 NMFS BO; vs. 3. Dams out + KBRA with Agency Lake and Barnes Ranch).

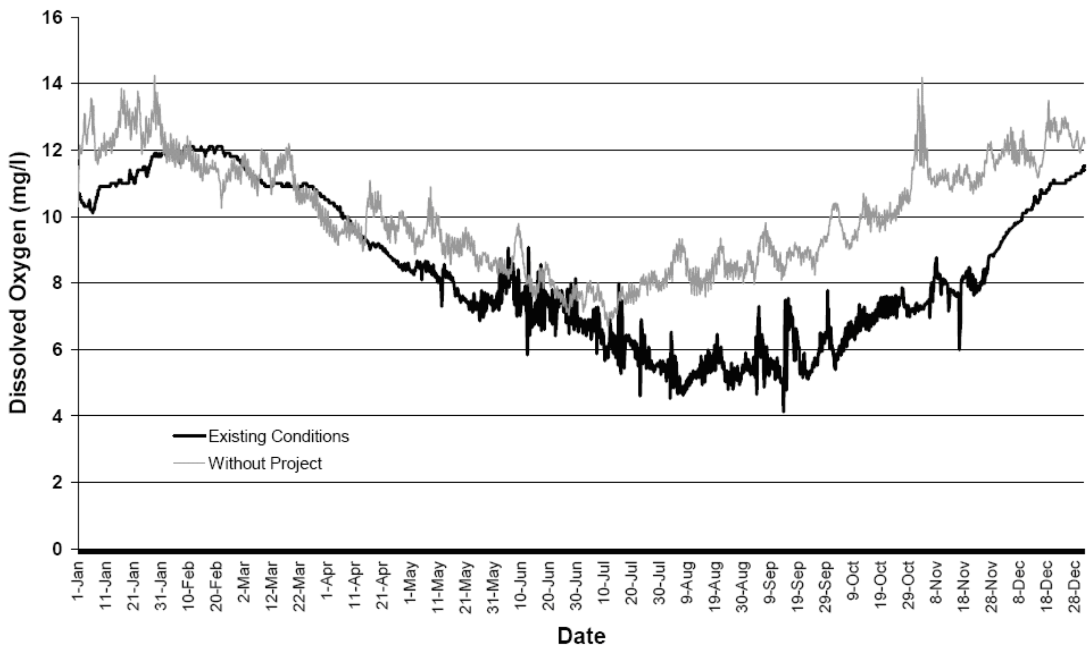


Figure 15. Simulated hourly DO levels below IGD based on the year 2002 (a dry year) for existing conditions compared to hypothetical conditions without the Klamath Hydroelectric Project dams (Source: Federal Energy Regulatory Commission 2007; Figure 3-51 and PacifiCorp, response to AIR AR-2, dated October 17, 2005).

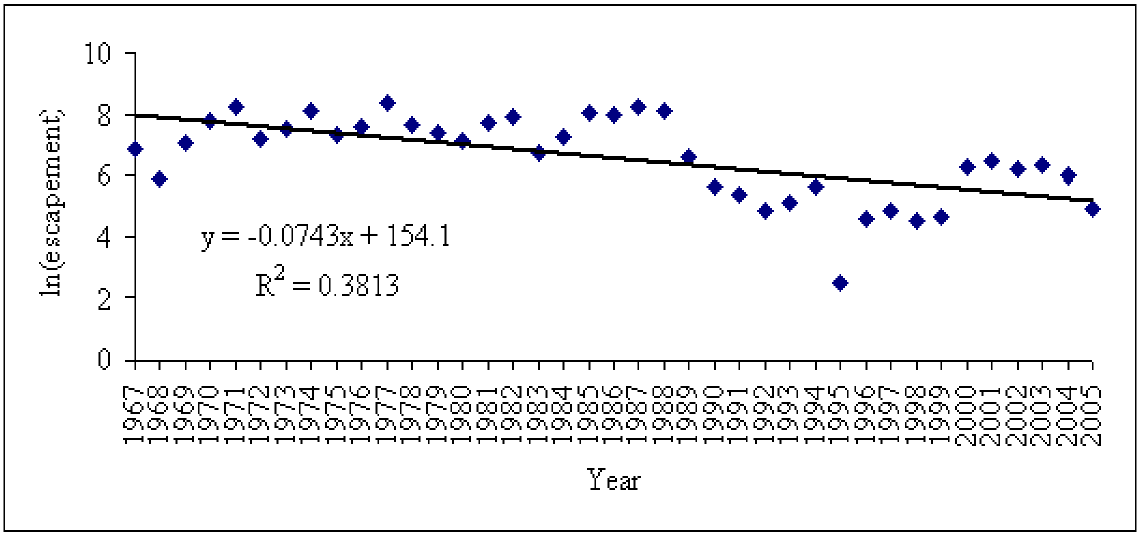


Figure 16. Steelhead escapement (ln(escapement)), Iron Gate Hatchery, Klamath River, California, 1967 to 2005 (Quiñones 2006).

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7. PERSONAL COMMUNICATIONS

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Chauncey Anderson, USGS, 2010

Craig Banner, ODFW, 2010

Jerri Bartholomew, OSU, 2009, 2010

Matthew Barry, Service, 2010

Sara Borok, CDFG, 2009

Clayton Creager, California NCRWQCB, 2010

Scott Foott, Service, 2009, 2010

Blair Greimann, Reclamation, 2011

Brian Gunderman, Michigan Department of Natural Resources –Fisheries Division, 2010

Allen Grover, CDFG, 2006

Andy Hamilton, BLM, 2008

Mark Hampton, CDFG, 2009; NMFS, 2011

Tom Hepler, Reclamation, 2010

Dennis Maria, former CDFG Biologist, 2005

Dave Mauser, Service, 2010

Tim Mayer, Service, 2009, 2010

Shannon Peterson, Klamath Basin Rangeland Trust, 2005

Linda Prendergast, PacifiCorp, 2010

Rebecca Quiñones, USFS, 2009, 2010

Stewart Reid, Western Fishes, 2009

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Tom Shaw, Service, 2009

Terry Smith, USFS, 2005

Burke Strobel, Portland Water Bureau, 2010

Paul Zedonis, Service, 2010

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