

Table of Contents

ACRONYMS AND ABBREVIATIONS	xvi
EXECUTIVE SUMMARY	1
ES.1 Introduction	1
ES.1.1 Purpose of this Report	2
ES.1.2 Klamath Basin Background.....	3
ES.1.3 The KSHA and KBRA	4
ES.2 Will Dam Removal and KBRA Implementation Advance Restoration of Salmonid and Other Fisheries of the Klamath Basin Over a 50-Year Time Frame?	6
ES.2.1 Short-Term Effects of Dam Removal	7
ES.2.2 Long-Term Effects of Dam Removal	9
ES.3 What Would Dam Removal Entail, What Mitigation Measures May Be Needed, and What Would These Actions Cost?	13
ES.3.1 Mitigation Measures	15
ES.3.2 Estimated Dam Removal Costs	15
ES.4 What Are the Major Potential Risks and Uncertainties Associated with Dam Removal?	17
ES.4.1 Effects to Aquatic Species and Fisheries from Extended Downstream Sediment Transport.....	17
ES.4.2 Cost Exceedence to a Federal DRE	17
ES.4.3 Short-term Flooding	18
ES.4.4 Cultural and Historic Resources	18
ES.5 Is Facilities Removal in the Public Interest, Which Includes, But is Not Limited to, Consideration of Potential Effects on Local Communities and Tribes?	19
ES.5.1 Summary of Effects to National Economic Development (NED)	19
ES.5.2 Summary of Effects to Regional Economics (RED)	23
ES.5.3 Tribal	27

	ES.5.4 Previous PacifiCorp Analyses of Relicensing versus Removal of the Four Facilities and Public Utility Commission Rulings	28
	ES.6 Other Social and Environmental Effects from Dam Removal.....	29
SECTION 1	INTRODUCTION	33
	1.1 Purpose and Scope of this Report.....	34
	1.2 Background	35
	1.2.1 Hydrologic Setting.....	36
	1.2.2 Historical Changes.....	37
	1.2.3 Existing Biological and Physical Conditions.....	38
	1.2.4 Regulatory Conditions.....	39
	1.2.5 Conditions Leading to the Development of the KHSA	40
	1.2.6 Public Utilities Commission Rulings on the KHSA	42
	1.2.7 Klamath Basin Restoration Agreement (KBRA)	43
	1.2.8 Summary and Path Forward	45
SECTION 2	TECHNICAL INPUT AND PUBLIC OUTREACH PROCESSES.....	47
	2.1 Stakeholders and the Public	47
	2.2 Indian Tribes.....	47
	2.3 Technical Coordination Committee.....	48
SECTION 3	DATA COLLECTION PROCESS.....	51
	3.1 Technical Management Team.....	51
	3.2 Guidance on Scientific Integrity and Review Process	53
	3.2.1 Scientific Review	53
	3.3 List of Technical Studies Developed for the Secretarial Determination Process	56
SECTION 4	SECRETARIAL DETERMINATION FINDINGS OF TECHNICAL STUDIES	59
	4.1 Expected Effects of Dam Removal and KBRA on Physical, Chemical, and Biological Processes That Support Salmonid and Other Fish Populations	61
	4.1.1 Fish Population Factors Affected by Dam Removal and KBRA.....	63
	4.1.2 Species-Specific Effects	84
	4.1.3 Short Term Effects on Fisheries from Dam Removal	93
	4.1.4 Summary of Effects on Fisheries and Fish Species.....	101
	4.2 Dam Removal Detailed Plan and Estimated Cost	103
	4.2.1 Dam Removal Engineering and Construction	104
	4.2.2 Summary of Costs	127

- 4.3 Risks and Uncertainties of Dam Removal 129**
 - 4.3.1 Affects to Aquatic Species and Fisheries from Extended Downstream Sediment Transport..... 129
 - 4.3.2 Cost Exceedence to a Federal DRE 130
 - 4.3.3 Short-term Flooding 131
 - 4.3.4 Cultural and Historic Resources 133
- 4.4 Analysis of Information to Inform a Decision on Whether Dam Removal and KBRA are in the Public Interest 135**
 - 4.4.1 Economic Analysis 135
 - 4.4.2 Tribal 199
 - 4.4.3 Prehistoric and Historic Cultural Resources 219
 - 4.4.4 Previous Analyses of Relicensing versus Removal of the Four Facilities – Implications for PacifiCorp Customers and Public Utilities Commission Rulings 221
 - 4.4.5 Wild and Scenic River 227
 - 4.4.6 Recreation 231
 - 4.4.7 Real Estate..... 239
 - 4.4.8 Refuges..... 243
 - 4.4.9 Chemicals in Reservoir Sediments 247
 - 4.4.10 Algal Toxins 253
 - 4.4.11 Greenhouse Gases 257
 - 4.4.12 Societal Views on Dam Removal and the KBRA 261
- SECTION 5 SUMMARY AND FINDINGS 267**
 - 5.1 Will Dam Removal and KBRA Advance Restoration of Salmonid and Other Fisheries of the Klamath Basin Over a 50 Year Time Frame? 268**
 - 5.2 What Would Dam Removal Entail, What Mitigation Measures May Be Needed, and What Would These Actions Cost? 272**
 - 5.3 What are the Major Potential Risks and Uncertainties Associated With Dam Removal? 275**
 - 5.4 Is Facilities Removal in the Public Interest, Which Includes But is not Limited to Consideration of Potential Impacts on Affected Local Communities and Tribes? 277**
- SECTION 6 REFERENCES 291**

LIST OF TABLES

ES-1	Four Questions of the Secretarial Determination	2
ES-2	Declines in Klamath River Anadromous Fish.....	3
ES-3	General Information on the Four Facilities on the Klamath River	5
ES-4	Major Long-Term Benefits for Salmonid Restoration from Dam Removal and Implementation of the KBRA	11
ES-5	Benefits to Other Fish Species from Dam Removal and KBRA Implementation	12
ES-6	Dam Removal Mitigation Measures.....	15
ES-7	Summary of Costs for Full Removal of all Four Facilities	16
ES-8	Summary of Costs for Partial Removal of all Four Facilities.....	16
ES-9	Total Net Benefits and Costs Summary for Dam Removal and Implementation of the KBRA	22
ES-10	Benefit Cost Analysis Summary for Dam Removal and Implementation of the KBRA	23
ES-11	Average Annual Change in Jobs (Full Time, Part Time, or Temporary), Regional Labor, Income, and Regional Output for Dam Removal and Implementation of the KBRA (by Region, Activity, and Timeframe).....	25
ES-12	Common Benefits to all Indian Tribes with Dam Removal and Implementation of the KBRA.....	27
ES-13	Operations, Costs, Risks, and Liabilities for FERC Relicensing and Removal of the Four Facilities, Based on PacifiCorp Analyses	29
ES-14	Summary of Other Social and Environmental Effects of Dam Removal and KBRA Implementation	30
1-1	List of Major KBRA Programs, Plans, and Commitments	44
2-1	Partial List of Coordination Meetings with the TCC, Stakeholders, Tribes, and Public	48
3-1	List of Studies and Reports Developed or Reviewed for the Secretarial Determination Overview Report	57
4-1	Organization of Chapter 4 of the Overview Report	60
4.1-1	Declines in Klamath River Anadromous Fish.....	61
4.1-2	Projected Increases in Average Annual Air Temperature	68
4.1-3	Projected Seasonal and Annual Changes in Precipitation.....	69
4.1-4	Estimated groundwater discharge (springs) into upper Klamath River systems	73
4.1-5	Summary of Model Predictions for SSCs in the Klamath River Downstream of Iron Gate Dam	96
4.2-1	General information of Four Facilities on the Klamath River.....	104
4.2-2	Partial Removal of J.C. Boyle Dam	105
4.2-3	Existing Recreational Facilities Adjacent to J.C. Boyle Reservoir	106
4.2-4	Estimated Costs for the Full Removal of J.C. Boyle Dam.....	109
4.2-5	Estimated Costs for the Partial Removal of J.C. Boyle Dam	109
4.2-6	Partial Removal of Copco 1 Dam.....	111

4.2-7 Existing Recreational Facilities Adjacent to Copco 1 Reservoir 112

4.2-8 Estimated Costs for the Full Removal of Copco 1 Dam 114

4.2-9 Estimated Costs for the Partial Removal of Copco 1 Dam 114

4.2-10 Partial Removal of Copco 2 Dam 116

4.2-11 Estimated Costs for the Full Removal of Copco 2 Dam 117

4.2-12 Estimated Costs for the Partial Removal of Copco 2 Dam 118

4.2-13 Partial Removal of Iron Gate Dam 119

4.2-14 Existing Recreational Facilities Adjacent to Iron Gate Reservoir 120

4.2-15 Estimated Costs for the Full Removal of Iron Gate Dam 124

4.2-16 Estimated Costs for the Partial Removal of Iron Gate Dam 125

4.2-17 Estimated Costs for the Modification of the Yreka Pipeline 126

4.2-18 Summary of Costs for Full Removal of the Four Facilities 127

4.2-19 Summary of Costs for Partial Removal of the Four Facilities 128

4.4.1-1 Annual and Total Discounted Net Economic Value of the Chinook Troll Fishery (all stocks) Under Dams Out with KBRA and Dams In, by Management Area 140

4.4.1-2 Annual and Total Discounted Net Economic Value of the Ocean Recreational Chinook Fishery (all stocks) Under Dams Out with KBRA and Dams In, by Management Area 144

4.4.1-3 Total Discounted Economic Value of Irrigated Agriculture Under Dams Out with KBRA and Dams In 145

4.4.1-4 Total Discounted Net Economic Value of Refuge Recreation Under Dams Out with KBRA and Dams In 146

4.4.1-5 Klamath Survey Response Rates 148

4.4.1-6 Survey Results Regarding Respondents’ Use of Their Local Rivers 149

4.4.1-7 Survey Results Regarding Respondents’ Concern for Species in Klamath Basin 150

4.4.1-8 Respondents’ Opinions Regarding Klamath River Basin Dam Removal Plans 151

4.4.1-9 Vote on Action Plan Scenarios, by Sample Area 152

4.4.1-10 Vote by Annual Cost of Plan to Household 152

4.4.1-11 Extent of Respondents’ Agreement with Statements Regarding the Survey and the Choices Provided in the Survey 153

4.4.1-12 Average Household Annual WTP Values with 95% Confidence Interval 154

4.4.1-13 Aggregate Present Value of Household WTP Over 20 Years, with 95% Confidence Interval 156

4.4.1-14 Agency Base Funding and KBRA Program Costs 157

4.4.1-15 Full Four Facilities Removal and Total Site Mitigation Costs for Full Facilities Removal 158

4.4.1-16 Partial Four Facilities Removal and Total Site Mitigation Costs for Partial Facilities Removal 158

4.4.1-17 Average Annual and Total Discounted Value OM&R Costs 159

TABLE OF CONTENTS

4.4.1-18	Total Discounted Value of Forgone Hydropower Economic Benefits of Dams Out Relative to Dams In	160
4.4.1-19	Total Discounted Value of Forgone Whitewater Boating Benefits of Dams Out Relative to Dams In	161
4.4.1-20	Effects of Dam Removal and KBRA on Tribal Harvest Opportunities, by Geographic Area	165
4.4.1-21	Effects of Dam Removal and KBRA on Standard of Living and Engagement in Resource Stewardship, by Tribe	166
4.4.1-22	Estimated benefit-cost comparison of proposed scenarios.....	170
4.4.1-23	Regional Economic Impacts from Dam Decommissioning Expenditures with Facilities Removal Relative to the Dams In	175
4.4.1-24	Annual Ex-Vessel Revenue for Most Impacted Management Areas with Dams Out Relative to the Dams In	175
4.4.1-25	Annual Regional Economic Impacts from Commercial Fishing with Facilities out Removal and KBRA Relative to the Dams In	176
4.4.1-26	Annual Regional Economic Impacts from Reservoir Recreation with Facilities Removal Relative to the Dams In.....	177
4.4.1-27	Annual Regional Economic Impacts from Ocean Sport Salmon Fishing with Facilities Removal Relative to the Dams In	178
4.4.1-28	Annual Regional Economic Impacts from In-River Sport Salmon Fishing with Facilities Removal Relative to the Dams In	179
4.4.1-29	Annual Regional Economic Impacts from Whitewater Boating with Facilities Removal Relative to the Dams In	180
4.4.1-30	Regional Economic Impacts of KBRA Fishery Program Actions Relative to Base Funding Over a 15-year period.....	182
4.4.1-31	Regional Economic Impacts of KBRA Water Resource Program Actions Relative to Base Funding over a 15-year period.....	184
4.4.1-32	Gross Farm Revenue by IMPLAN Crop Sectors Between the Dams In and Dam Out with KBRA for Drought Years	185
4.4.1-33	Regional Economic Impacts from Gross Farm Revenue between Dams In and Dams Out with KBRA for Drought Years	186
4.4.1-34	Regional Economic Development Impact Analysis Summary Table	190
4.4.1-35	KBRA Program Regional Economic Development Impact Analysis Summary Table	196
4.4.2-1	Effects of the Current Conditions and Projected Changes with KHSA and KBRA Implementation Common to all Tribes	203
4.4.2-2	Effects of the Current Conditions and Projected Changes with KHSA and KBRA Implementation Common to all Tribes	205
4.4.4-1	Operations, costs, risks, and liabilities for FERC relicensing and for removal of the Four Facilities, Based on PacifiCorp analyses.....	224

4.4.5-1 Changes Expected to WSR Resources as a Result of Dam Removal230

4.4.6-1 Comparison of Klamath Hydroelectric Project Reservoirs and Regional Low and Moderate Visitor Use In Reservoirs and Lakes Providing Comparable Recreational Opportunities232

4.4.6-2 Recreation Facilities Removed as Part of Dam Removal.....232

4.4.6-3 Estimated Change in Number of Days Meeting the Range of Acceptable Flows for Recreational Activities on Klamath River Reaches234

4.4.6-4 Regional Rivers with Whitewater Boating Opportunities236

4.4.6-5 Expected Changes to Recreational Resources as a Result of Dam Removal238

4.4.7-1 Land Use Designations of Privately Owned Parcels around Copco 1 and Iron Gate Reservoirs240

4.4.12-1 Klamath Nonuse Value Survey Response Rates262

5-1 Long-Term Benefits for Salmonid Restoration from Dam Removal and KBRA Implementation269

5-2 Benefits to Other Fish Species from Dam Removal and KBRA Implementation272

5-3 Dam Removal Mitigation Measures.....273

5-4 Summary of Costs for Full Removal of all Four Facilities274

5-5 Summary of Costs for Partial Removal of all Four Facilities.....274

5-6 Total Net Benefits and Costs Summary for Dam Removal and Implementation of the KBRA279

5-7 Benefit Cost Analysis Summary for Dam Removal and Implementation of the KBRA281

5-8 Average Annual Change in Jobs (Full Time, Part Time, or Temporary), Labor income, and Output for Dam Removal and KBRA Implementation (by Region, Activity, and Timeframe)283

5-9 Common Benefits to all Indian Tribes with Dam Removal and Implementation of the KBRA285

5-10 Operations, Costs, Risks, and Liabilities for FERC Relicensing and Removal of the Four Facilities, Based on PacifiCorp Analyses.....286

5-11 Summary of Other Social and Environmental Effects of Dam Removal and KBRA Implementation ...287

LIST OF FIGURES

ES-1 Klamath River Basin Map. The Klamath Basin covers over 12,000 square miles and includes PacifiCorp’s J.C. Boyle, Copco 1, Copco 2, and Iron Gate dams on the main stem of the Klamath River 1

ES-2 Thousands of adult salmon died in the lower Klamath River during September 2002. Causative factors included low flows, high concentration of returning Chinook salmon, warm water temperatures, and disease..... 2

ES-3 J.C. Boyle Dam and Powerhouse 5

ES-4 Copco 1 Dam and Reservoir 5

ES-5 Copco 2 Dam and Downstream Powerhouse 6

ES-6 Iron Gate Dam and Powerhouse 6

TABLE OF CONTENTS

ES-7 Modeled suspended sediment concentrations (SSC) immediately downstream of Iron Gate Dam for dam removal in dry, median, and wet water years. Background concentrations are modeled using data from all water year types for 1961–2008. 7

ES-8 Estimated mortality impacts on basin-wide production (number of adults or juveniles) resulting from dam removal for key salmonid species for both median (most likely) and low flow (worst case) water years. 7

ES-9 Timeline depicting the timing of migratory fish lifecycles in the mainstem of the Klamath River coinciding with dam removal plans. 8

ES-10 Increased salmon and steelhead distribution in Klamath Basin under current conditions (with dams) compared to historical conditions (without dams) 9

ES-11 Modeled water temperatures during the fall Chinook salmon migration period for the Klamath River indicate that future (2020–2061) water temperatures will be 1–3°C greater than historical (1961–2009) temperatures due to climate change. Dam removal would decrease summer and fall temperatures downstream of Iron Gate Dam, with diminishing effects further downstream. Water temperatures in the Keno Reach would not be affected by dam removal. Simplified patterns from Perry et al. (2011) use standard “GFDL” Global Climate Model output. 10

ES-12 Fish diseases are widespread in the mainstem of the Klamath River during certain time periods and in certain years and have been shown to adversely affect freshwater abundance of Chinook and coho salmon, which are an intermediate host to one prevalent Klamath River fish disease caused by the myxozoan *C. Shasta*. Habitat conditions which support *C. Shasta* and its polychaete host caused by the dams include: stable river flows; relatively stable streambed; crowding of adult salmon at barriers to fish passage; and plankton-rich discharge from reservoirs 11

ES-13 Chart of the median monthly flows in the Klamath River at specific USGS gages. Reservoir drawdown is planned to occur from January through March 15 (2020), coinciding with typically high flows in the Klamath River. 13

ES-14 Partial removal of J.C. Boyle Dam would include removal of embankment dam and fish ladder, providing a free flowing river and allowing full volitional fish passage. However, certain structures, including the steel pipeline and supports, would be retained. 13

ES-15 Partial removal of Copco 1 Dam would include removal of the concrete dam, providing a free flowing river and allowing full volitional fish passage. Certain structures, including the penstocks and powerhouse, would be retained. 14

ES-16 Partial removal of Copco 2 Dam would include removal of spillway gates, providing a free flowing river and allowing full volitional fish passage. Certain structures, including the water intake and embankments, would be retained. 14

ES-17 Partial removal of Iron Gate Dam would include removal of embankment dam, providing a free flowing river and allowing full volitional fish passage. Certain structures, including the spillway and powerhouse, would be retained. 14

ES-18 On the Lower Klamath NWR, the fall carrying capacity for dabbling and diving ducks (migratory waterfowl) would be greater with dam removal and implementation of the KBRA in both wet and dry years although the difference is more pronounced in dry years. 20

ES-19 Jobs and Regional Economic Output would increase in all of the five Commercial Fishing Management Areas with Dam Removal. 23

ES-20 Dense summer and fall blue-green algae (Cyanobacteria) blooms in Iron Gate Reservoir produce toxic microcystin resulting in poor water quality for fish and public health posting by the State of California. Known and/or perceived concerns over health risks associated with seasonal algal toxins have resulted in the alteration of traditional cultural practices, such as gathering and preparation of basket materials and plants, fishing, ceremonial bathing, and ingestion of river water 27

1-1 Klamath River basin map. J.C. Boyle, Copco 1, Copco 2, and Iron Gate dams would be removed under the KHSA. 33

1-2 The Klamath River is a unique river system with a flat topography as its headwater with a steeper downstream portion beginning near the dams. In addition the basin receives widely varying precipitation. 36

1-3 Klamath Basin wetland acreage over time (1905-2011). 37

1-4 Copco 1 Dam, powerhouse, and downstream area of the Klamath River. This facility would be removed under the KHSA. 40

1-5 The Copco 2 powerhouse. The CPUC approved the rate increases that capped rate payer exposure at \$200 million (in 2020 dollars) as defined in the KHSA. 42

1-6 Agriculture is one of the many resources in the Klamath Basin that would benefit from more water delivery certainty with the implementation of the KHSA and KBRA. 45

2-1 Coordination for the Secretarial Determination process as outlined in the KHSA among the TMT and the tribes, stakeholders, and public. 47

2-2 Public meetings were frequently held throughout the basin to inform stakeholders and public groups on the progress of the project. 48

3-1 The Sediment Chemistry Investigation: Sampling, Analysis, and Quality Assurance Findings for Klamath River Reservoirs and Estuary, October 2009-January 2010 (Reclamation 2011n) was one of the many peer reviewed reports developed for the Secretarial Determination. Two independent experts in reservoir sediment chemistry reviewed the report. These reviewers were not associated with the TMT or the Klamath Basin. The comments were forwarded to the TMT authors without modification, and the authors responded to these reviews independently. 55

4.1-1 Wild (naturally spawning) Chinook salmon in the Klamath Basin are in decline. 61

4.1-2 Coho salmon in the Klamath Basin are threatened with extinction. 62

4.1-3 Summer and winter steelhead in the Klamath Basin are in decline. 62

4.1-4 Increased salmon and steelhead distribution in the Klamath Basin under current conditions (with dams) compared to historical conditions (prior to dam construction). 63

4.1-5 Historical water deliveries to Reclamation’s Klamath Project relative to the maximum water allocation that would be provided under the terms of the KBRA. 64

4.1-6 USGS graph of flows below Iron Gate Dam (July 1, 2009 through June 30, 2010). Flows below Iron Gate Dam typically do not vary from day to day or month to month, particularly during dry periods 65

TABLE OF CONTENTS

4.1-7 Climate change projections indicate that by the end of the 21st century, more precipitation will fall as rain than snow throughout northern California and the Pacific Northwest, affecting seasonal hydrology in the Klamath River Basin... 67

4.1-8 Wildfire incidence in the Klamath Basin will increase under climate change..... 68

4.1-9 Simulated annual precipitation and temperature averaged over Klamath River subbasins. 70

4.1-10 Re-vegetation projects under KBRA would help to replace large woody debris in riparian zones, improving fish habitat and ecosystem resilience to climate change... 71

4.1-11 Map of the Klamath River indicating the rivermile markers. 72

4.1-12 Dam removal would increase available rearing habitat upstream of Iron Gate Dam including area like this, in the Wood River upstream of Upper Klamath Lake 72

4.1-13 Dam removal would also provide access to cold water tributaries upstream of the Four Facilities (Tecumseh Springs). 73

4.1-14 Removing J.C. Boyle Dam would increase summer water temperatures in the 4-mile reach just downstream of J.C. Boyle Dam, but it would not affect groundwater springs that would continue to serve as refuge habitat for coldwater fish. 75

4.1-15 Modeled water temperatures during the fall Chinook salmon migration period for the Klamath River indicate that future (2020–2061) water temperatures will be 1–3°C greater than historical (1961–2009) temperatures due to climate change. Dam removal and KBRA implementation would decrease summer and fall temperatures downstream of Iron Gate Dam, with diminishing effects further downstream. Water temperatures in the Keno Reach would not be affected by dam removal. Simplified patterns from Perry et al. (2011) use standard “GFDL” Global Climate Model output. 76

4.1-16 Schematic of general nutrient Inputs, internal loading, and algal growth in Upper Klamath Lake. As the lake is relatively shallow (mean depth = 8 feet at mean summer elevation [Wood et al. 1996]), seasonal separation of warmer surface waters from colder bottom waters (thermal stratification) is typically intermittent. 77

4.1-17 Total phosphorus and total nitrogen concentrations tend to decrease from upstream to downstream in the Klamath River, with the most pronounced peaks occurring downstream of Keno Dam during summer and fall months. Simplified spatial and temporal patterns illustrate generalized trends reported for 2001-2005 in Asarian et al. (2010). 78

4.1-18 Summertime blooms of cyanobacteria (blue-green algae) can produce toxins that bioaccumulate in aquatic biota..... 79

4.1-19 Optimum levels of dissolved oxygen for fish range from 8 to 10 mg/L. 80

4.1-20 The relatively deep Copco 1 Reservoir experiences thermal stratification and results in low dissolved oxygen (from less than 1 mg/L to 5 mg/L) in reservoir bottom waters during summer and fall months. This poor water quality affects the Klamath River downstream of Copco 1 Dam. 81

4.1-21 With dam removal, dissolved oxygen in the Klamath River downstream of Iron Gate Dam would consistently achieve North Coast Basin Plan percent saturation objectives and would be greater than dissolved oxygen under existing conditions from April through November. Dam removal may also result in greater variability in dissolved oxygen during June through October due to

photosynthesis and respiration of attached algae (periphyton) that establish in the free-flowing river. Lines represent simplified TMDL model output of hourly values from NCRWQCB. 82

4.1-22 Salmon are an intermediate host within the myxozoan life cycle. 83

4.1-23 Thousands of adult salmon in the lower Klamath River died during 2002. Causative factors were low September flows, high concentration of returning Chinook salmon, warm water temperatures, and disease. 84

4.1-24 Chinook salmon would benefit from the increase in habitat and improved water quality as a result of the removal of the Four Facilities. 85

4.1-25 EDRRA Chinook salmon model results showing the relative percent increase in annual median escapement provided under the Dam Removal and Implementation of KBRA scenario versus the dams remain scenario in the absence of hatcheries for the years immediately following dam removal (2021 to 2061). 86

4.1-26 Coho salmon are expected to recolonize upstream habitat with the removal of the Four Facilities. 87

4.1-27 With dam removal steelhead trout would have increased habitat to spawn. 88

4.1-28 Pacific Lamprey Expert Panel (Close et al. 2011) predicts increased carrying capacity for Pacific lamprey with dam removal. 89

4.1-29 Habitat for the green sturgeon, a species of concern, would improve in the Klamath River with the removal of the Four Facilities. 90

4.1-30 Stranded fish and macroinvertebrates in the J.C. Boyle Peaking Reach. 90

4.1-31 Redband trout, a native species in the Klamath River, would benefit from the a free-flowing river with dam removal. 91

4.1-32 Both Lost River (below) and shortnose suckers are endangered species that would likely benefit from KBRA habitat and water-quality improvements in the upper Klamath Basin. 92

4.1-33 Modeled suspended sediment concentrations immediately downstream of Iron Gate Dam for dam removal in dry, median and wet water years. Background concentrations are modeled using data from all water year types for 1961–2008. 93

4.1-34 Modeled suspended sediment concentrations at Klamath, CA (river mouth) for dam removal in dry, median and wet water years. Background concentrations are modeled using data from all water year types for 1961–2008. 93

4.1-35 Timeline depicting the timing of salmon lifecycles in the mainstem of the Klamath River coinciding with dam removal plans. 95

4.1-36 Estimated mortality impacts on basin-wide production (number of adults or juveniles) resulting from dam removal for key salmonid species (Stillwater Sciences 2011a) for both median (most likely) and low flow (worst case) water years. 96

4.1-37 Comparison of Suspended Sediment Concentrations at Iron Gate Dam With and without Sediment Dredging. 98

4.1-38 Comparison of Estimated Fish Mortality Impacts With and Without Sediment Dredging. 98

4.1-39 Fish rescue locations to mitigate for potential impacts from sediment release with dam removal. ...100

TABLE OF CONTENTS

4.1-40 Fish rescue operations would include out-migrant traps such as these two operating in the Shasta River..... 100

4.2-1 Chart of the median daily flows in the Klamath River at specific USGS gages. Reservoir drawdown and is planned to occur from January through March 15 (2020), coinciding with typically high flows in the Klamath River.. 103

4.2-2 Photos of J.C. Boyle Dam and Reservoir with specific components labeled. With full facilities removal, all visible components would be removed. With partial facilities removal, certain components (e.g., steel conveyance pipe) would be retained. 104

4.2-3 Partial removal would provide a free flowing river and allow full volitional fish passage. However, certain structures would be retained. 105

4.2-4 Potential locations for revegetation in J.C. Boyle Reservoir. Revegetation efforts would be focused as shown below. 106

4.2-5 Photo of Copco 1 Dam and Reservoir with specific components labeled. With full facilities removal, all visible components would be removed. With partial facilities removal, certain components (e.g., penstock) would be retained. 110

4.2-6 Partial removal would provide a free flowing river and allow full volitional fish passage. However, certain structures would be retained. 111

4.2-7 Potential locations for revegetation in Copco 1 Reservoir. Revegetation efforts would be focused as shown below..... 112

4.2-8 Photo of Copco 2 Dam and Reservoir with Specific Components Labeled. With full facilities removal, all visible components would be removed. With partial facilities removal, certain components (e.g., penstock) would be retained. 115

4.2-9 Partial Removal Would Provide a Free Flowing River and Allow Full Volitional Fish Passage. However, certain structures would be retained. 116

4.2-10 Photo of Iron Gate Dam and Reservoir with Specific Components Labeled. With full facilities removal, all visible components would be removed. With partial facilities removal, certain components (e.g., penstock) would be retained. 118

4.2-11 Partial removal would provide a free flowing river and allow full volitional fish passage. However, certain structures would be retained or retained and buried..... 119

4.2-12 Potential locations for revegetation in Iron Gate Reservoir. Revegetation efforts would be focused as shown below. 120

4.2-13 The 100-year floodplain could change between RM 190 and 172 due to dam removal, with no discernable effects below RM 172..... 121

4.2-14 Hydrographs immediately below Iron Gate Dam for a 100-years flood event with and without removal of the Four Facilities..... 122

4.2-15 Close up of one or two structures potentially affected by the change in the 100 year Floodplain – comparison of dams in and dams out floodplain..... 122

4.3-1 The timing of J.C. Boyle and Iron Gate dam excavation and removal has been designed to occur when river flow is at its lowest point beginning in June, greatly reducing the probability of embankment overtopping. 132

4.4.1-1 Total Economic Value: Typology and Valuation Methods 146

4.4.1-2 Economic Regions for Regional Economic Benefits 172

4.4.1-3 2009 Regional economy for Siskiyou and Klamath counties, the location of the Four Facilities. 172

4.4.1-4 Commercial fishery management areas included in the analysis 175

4.4.1-5 Recent ocean commercial fishing in the area of analysis.. 176

4.4.1-6 Reservoir based recreation occurs in the region. 177

4.4.1-7 Ocean sport fishing contributes to the regional economy..... 178

4.4.1-8 In-river sport fishing angler days and expenditures..... 179

4.4.1-9 Whitewater boating user days and expenditures. 180

4.4.1-10 Irrigated Agriculture Acreage and Revenue in the Area of Analysis 185

4.4.2-1 Map of Current Tribal Reservation Locations, Other Features, and Reserve Areas 200

4.4.2-2 Historical tribal photo of dip net fishing on the Klamath River..... 202

4.4.2-3 Sampling an algal bloom in Copco 1 Reservoir. The State of California regularly posts public health warnings for these algal blooms due to the presence of the algal toxin microcystin..... 204

4.4.2-4 Klamath Tribal Elder, Betty Blackwolf, prays for the c'waam at the Annual Return of the c'waam Ceremony on the banks of the Sprague River. Creator-(G'mokumpk) told the Native people to honor the c'waam after the first snow of each year and that if the fish are healthy, the people and the land will be healthy. 206

4.4.2-5 Fire and blessings at Klamath Tribes return of the c'waam Ceremony. Once an important part of the Klamath Tribes' diet, the c'waam (Lost River sucker) fishery was closed in 1986 due to severe population declines and was listed as endangered under the ESA in 1988. 208

4.4.2-6 The Klamath Tribes taking part in a traditional Powwow. Improved fish abundance with dam removal would strengthen ceremonial practice improving tribal identity. 208

4.4.2-7 Members of the Karuk Tribes still use traditional dip net fishing at Ishi Pishi Falls on the Klamath River 209

4.4.2-8 Traditional Karuk tribal smokehouse. Greater fisheries abundance would bolster transmission of traditional knowledge to youth, including the important practice of giving fish to elders. 209

4.4.2-9 Resigmini Rancheria members eel fishing at the mouth of the Klamath. An important part of traditional tribal diet is Pacific lamprey (eels). Tribes have reported eel catch reductions down by 98 percent from historic level 216

4.4.5-1 Location of Wild and Scenic River segments in the Klamath Basin..... 227

4.4.6-1 An overview of recreational activities at regional reservoirs and lake. 231

4.4.6-2 Comparison of Average Number of Days per Year with Acceptable Flows for Whitewater Boating and Fishing in the Hell's Corner Reach – Damslin Compared to Dams Out. 234

4.4.6-3 Whitewater boating opportunities in the Klamath Basin and in the region 235

4.4.7-1 The parcels around Copco 1 Reservoir, shown below, would be affected from changes to water access and/or views. 242

TABLE OF CONTENTS

4.4.8-1 The Lower Klamath NWR would receive more water (measured in acre-feet) through the Refuge Allocation under KBRA than under dams remaining without the KBRA in both summer and winter seasons. Water deliveries with the KBRA would also vary less between wet and dry years than under existing conditions. 243

4.4.8-2 With implementation of the KBRA, the Lower Klamath NWR would be able to provide more acres of permanent wetland habitat during dry years and the same number of acres during the wettest years as under existing conditions. With the KBRA, the number of acres of fall and spring seasonal wetlands would be greater than without the KBRA in both wet and dry years. More acres of wetland habitat would result in larger numbers of waterfowl and other wetland species supported by the NWR. 244

4.4.8-3 On the Lower Klamath NWR, the fall carrying capacity for dabbling and diving ducks (migratory waterfowl) would be greater with dam removal and implementation of the KBRA in both wet and dry years although the difference is more pronounced in dry years. 245

4.4.8-4 Late summer (August) carrying capacity for nongame waterbirds on the Lower Klamath NWR would be greater with implementation of the KBRA during dry and average years. The carrying capacity would be about the same as currently exists during wet years. 245

4.4.9-1 Multiple exposure pathways are present in the lower Klamath River, the Klamath estuary and the near shore of the Pacific Ocean that may allow contaminated sediments to cause adverse ecological or human health effects. 248

4.4.9-2 Summary results of the screening-level evaluation that was performed to identify potential adverse effects from exposures to reservoir sediments. 250

4.4.9-3 Sediment chemistry sampling in J.C. Boyle Reservoir, Oregon, during October, 2009. 251

4.4.9-4 A large bullhead sampled for contaminants in fish tissues from Iron Gate Reservoir during September, 2010. 251

4.4.9-5 Yellow perch sampled for contaminants in fish tissues from Copco 1 Reservoir during September, 2010. 251

4.4.10-1 Biologist collects water samples from Iron Gate Reservoir during a summer algae bloom... 253

4.4.10-2 Dense summer and fall blue-green algae (Cyanobacteria) blooms in Iron Gate Reservoir produce toxic microcystin resulting in poor water quality for fish and public health posting by the State of California. 253

4.4.10-3 Median chlorophyll-a concentrations in Copco 1 and Iron Gate reservoirs are two to ten times greater than those documented in the mainstem river and exceed the threshold for potentially impaired beneficial uses for biota and humans, including aquatic habitat, recreation, agricultural supply, and fishing. Keno Impoundment (including Lake Ewauna) concentrations are similarly high. 254

4.4.10-4 Health advisory postings can occur in June–October during intense blue-green algal blooms in Copco 1 and Iron Gate reservoirs. These blooms can be transported into downstream reaches of the Klamath River. 254

4.4.11-1 PacifiCorp Power Control Area Generation Resource Mix (as of 2007). 258

4.4.12-1 Survey results regarding concern about the declines in Chinook salmon and steelhead that return to the Klamath Basin. 263

4.4.12-2 Survey results regarding concern about the shortnose and Lost River suckers that are at very high risk of extinction.....263

4.4.12-3 Survey results regarding concern about the Klamath coho salmon that are at high risk of extinction264

4.4.12-4 Survey results regarding an Action plan for dam removal and Basin Restoration.....264

ABBREVIATIONS AND ACRONYMS

BCA	Benefit Cost Analysis
BIA	Bureau of Indian Affairs
BLM	Bureau of Land Management
BT	benefits transfer
CARB	California Air Resources Board
CDFG	California Department of Fish and Game
CEQA	California Environmental Quality Act
CESA	California Endangered Species Act
cfs	Cubic feet per second
CH ₄	Methane
CO ₂	Carbon Dioxide
CPUC	California Public Utilities Commission
CWA	Clean Water Act
DDT	dichlorodiphenyltrichloroethane
DOC	US Department of Commerce
DOI	United States Department of the Interior
DRE	Dam Removal Entity
EDRRA	Evaluation of Dam Removal and Restoration of Anadromy
EIS/EIR	Environmental Impact Statement/Environmental Impact Report
eGRID	Emissions & Generation Resource Integrated Database
ESA	Federal Endangered Species Act
ESU	Evolutionary Significant Unit
FERC	Federal Energy Regulatory Commission
FHWA	Federal Highway Administration
GHG	Greenhouse gases
GWP	Global warming potential
IMPLAN	IMpact analysis for PLANning
IPCC	Intergovernmental Panel on Climate Change
KBRA	Klamath Basin Restoration Agreement
KHSA	Klamath Hydroelectric Settlement Agreement
km	Kilometer
KMZ	Klamath Management Zone
mg/L	milligrams per liter
MTCO ₂ e	Metric tons of carbon dioxide equivalent
MW	Megawatts
MWh	Megawatt hours
NCRWQCB	North Coast Regional Water Quality Control Board

NED	National Economic Development
NEPA	National Environmental Policy Act
NH_4^+	ammonia
NHPA	National Historic Preservation Act
NOAA Fisheries Service	National Oceanic and Atmospheric Administration Fisheries Service
N_2O	Nitrous Oxide
NPS	National Park Service
NRC	National Research Council
NWR	National Wildlife Refuge
NWSRA	National Wild and Scenic Rivers Act
O&M	Operations and Maintenance
OM&R	Operations, Maintenance, and Replacement
OCCRI	Oregon Climate Change Research Institute
ODEQ	Oregon Department of Environmental Quality
OMB	Office of Management and Budget
OPCC	Opinion of Probable Construction Cost
OPUC	Oregon Public Utilities Commission
ORV	Outstanding remarkable value
OWRD	Oregon Water Resources Department
PCA	Power Control Area
PCBs	polychlorinated biphenyls
PO_4^{3-}	Ortho-phosphate
PUC	Public Utilities Commission
PV	Present Value
Reclamation	Bureau of Reclamation
RED	Regional Economic Development
RP	revealed preference
RPS	Renewable portfolio standard
RM	River Mile
SEF	Sediment Evaluation Framework
SONCC	Southern Oregon Northern California Coast
SP	Stated preference
SSC	suspended sediment concentration
taf	Thousand Acre-Feet
TCC	Technical Coordination Committee
TMDL	Total Maximum Daily Load
TMT	technical management team
TN	total nitrogen
TP	Total Phosphorous

TABLE OF CONTENTS

µg/L	micrograms per liter
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
USGCCRP	United States Global Climate Change Research Program
USGCRP	United States Global Change Research Program
USGS	United States Geological Survey
WHO	World Health Organization
WQST	Water Quality Sub-team
WSR	Wild and Scenic River
WSRA	Wild and Scenic River Act
WTP	Willingness to Pay
WURP	Water Use Retirement Program
WY	Water year
°C	Celsius
°F	Fahrenheit