INDEPENDENT MULTIDISCIPLINARY SCIENCE TEAM (IMST)

State of Oregon

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October 7, 2003

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Enclosed is Technical Report 2003-1, the Independent Multidisciplinary Science Team's (IMST) report entitled "IMST Review of the USFWS and NMFS 2001 Biological Opinions on Management of the Klamath Reclamation Project and Related Reports".

Different community and environmental goals and conflicting information in the Klamath Basin became a major concern for citizens of Oregon and California, Klamath Basin Tribes, and agencies responsible for managing natural resources. In an April 25, 2001 letter, Governor John Kitzhaber asked the IMST to "review the information and offer an independent assessment of the science used to establish lake levels and instream flow targets for suckers and coho." The IMST agreed to conduct the review because the IMST was charged to advise the State on matters of science related to the Oregon Plan for Salmon and Watersheds. Questions about 1) status and management of coho salmon in the Klamath River and 2) management of Upper Klamath Lake and its watershed directly relate to the responsibilities of IMST.

The IMST reviewed the Biological Assessments of the USBR, Biological Opinions of USFWS and NMFS, scientific literature, and scientific reviews of the Klamath Basin environmental issues. As with all IMST reports, this report results from evaluation of the best available science. The report has been subjected to intense technical review by more than 20 scientists and agency representatives. The final report was adopted with full consensus of the Team at our April 2003 meeting.

The report includes answers to science questions about Upper Klamath Lake and Klamath River, conclusions on lake and river management, and recommendations to the State of Oregon. The issues and reviews surrounding Upper Klamath Lake and Klamath River have been confusing for the public and resource professional alike. The IMST developed matrices that summarize and quote the findings of the major reviews of Upper Klamath Lake and Klamath River to help the State and readers of this report better understand these complex resource issues.

There were 14 major conclusions and 10 formal recommendations generated in this report. Recommendations are directed at one or more State of Oregon agencies or entities that the IMST believes have the ability to implement, or to affect changes in management or regulation that are needed for implementation. Senate Bill 924 requires the designated agencies to respond to each IMST recommendation. Agencies are expected to respond to the Oregon Plan Manager and IMST within six months of the release of the report. IMST then evaluates the responses for scientific merit, and forwards the evaluations to you and Jim Myron, Governor's Natural Resource Office.

In making its recommendations, the IMST did not consider the *current* legal, regulatory, or funding situation under which the responding agencies operate; nor does the IMST imply any sort of "performance evaluation" associated with these agency assignments. The IMST's responsibility is to identify issues that we believe are critical to the health and recovery of salmonids, and to advise the State of Oregon. While agency response may, under some circumstances, be that there is no legal authority and/or funding to implement certain recommendations, the IMST believes that these recommendations should be incorporated into long-range planning and impediments to implementation removed.

We hope that this report will be helpful as work on the Oregon Plan for Salmon and Watersheds continues.

Sincerely,

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encl.

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IMST Review of

the USFWS and NMFS 2001 Biological Opinions on

Management of the Klamath Reclamation Project

and Related Reports

A report of the Independent Multidisciplinary Science Team,

Oregon Plan for Salmon and Watersheds

Technical Report 2003-1

April 16, 2003

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Citation: Independent Multidisciplinary Science Team. 2003. IMST Review of the USFWS and NMFS 2001 Biological Opinions on Management of the Klamath Reclamation Project and Related Reports. Technical Report 2003-1 to the Oregon Plan for Salmon and Watersheds, Oregon Watershed Enhancement Board, Salem, Oregon.

ACKNOWLEGEMENTS

The IMST would like to thank former IMST members Logan Norris and Jim Lichatowich on their contributions on the early draft versions. We also thank the IMST technical support staff, Ellen Deehan, Leah Gorman, Kathy Maas-Hebner, and Suzie Peck for their contributions to writing and producing this report and to Kelly Wildman for assistance on graphics. We are also grateful to IMST administrative staff, Glenda Serpa, for her support in the production of the final report. Finally, we wish to thank the following technical reviewers: William Bennett, Matt Boyd, Mike Cooperman, Guillermo Giannico, Ron Larson, Jim Lecky, Doug Markle, Paul Measles, Jeff Mount, Peter Moyle, Terry Nelson, David Policansky, Meg Reeves, Rip Shively, Mark Stern, and four anonymous reviewers who commented on earlier drafts**.**

LIST OF ACRONYMS

CDFG - California Department of Fish and Game
cfs - cubic feet per second
CPUE - catch per unit effort
EPA - (United States) Environmental Protection Agency
ESA - Endangered Species Act
ESU - evolutionary significant unit
IFIM - Instream Flow Incremental Methodologies
IMST - Independent Multidisciplinary Science Team
INSE - Institute for Natural Systems Engineering
NMFS - National Marine Fisheries Service (now NOAA Fisheries)
NOAA - National Oceanic and Atmospheric Administration
NRC - National Research Council
OSU - Oregon State University
Oregon Plan - Oregon Plan for Salmon and Watersheds
PHABSIM - Physical habitat simulation
SONCC - Southern Oregon/Northern California Coasts
UC - University of California
USBR - United States Bureau of Reclamation
USFWS - United States Fish and Wildlife Service
USGS - United States Geological Survey
YOY - young-of-the-year

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PREFACE

The Independent Multidisciplinary Science Team (IMST) was established by the 1997 Oregon Legislature via Senate Bill 924, signed by Governor John Kitzhaber on March 25, 1997. The IMST is to advise the State on matters of science related to the Oregon Plan for Salmon and Watersheds. The Governor, the Senate President and the Speaker of the House jointly constituted the 7-member Team October 10, 1997. The establishment of the Team reflected the 1997 agreement between Oregon and the National Marine Fisheries Service (NMFS) concerning coho salmon. This agreement has been terminated, but Executive Order 99-01, which expanded the scope of the Oregon Plan, specifies the continuing role of the Team in the recovery of wild salmonids in Oregon.

IMST Operational Framework

The operational framework of the IMST is summarized in the Team Charter (available at http://www.fsl.orst.edu/imst/). The primary means of communicating results of the IMST's work is through written reports. In IMST reports, the Team assesses the best available science as it pertains to salmonid and watershed recovery and the management of natural resources. Based on these assessments, the IMST makes recommendations to Oregon state agencies or entities.

Recommendations are directed to one or more agencies or entities that have the ability to implement, or to affect changes in management or regulation that are needed for implementation. It should be noted that the IMST looks beyond an agency's *current* ability to implement the recommendations because current legal, regulatory, or funding situations may need to change to accomplish the goals of the Oregon Plan. It is the belief of the IMST that if an agency agrees that a recommendation is technically sound and would aid the recovery of salmonid stocks and watersheds, the agency would then determine what impediments might exist to prevent or delay implementation and work toward eliminating those impediments. The IMST also assumes that each agency has the knowledge and expertise to determine how best to identify and eliminate impediments to implementation and to determine appropriate time frames and goals needed to meet the intent of the recommendation. In addition, the IMST recognizes that an agency may already have ongoing activities that address a recommendation. Our inclusion of such an "overlapping" recommendation should be seen as reinforcement for needed actions.

Senate Bill 924 specifies that agencies are to respond to the recommendations of the IMST, stating "(3) If the Independent Multidisciplinary Science Team submits suggestions to an agency responsible for implementing a portion of the Oregon Plan, the agency shall respond to the Team explaining how the agency intends to implement the suggestion or why the agency does not implement the suggestion." Once agency responses are received, the IMST reviews the scientific adequacy of each response and whether further action or consideration by the agency is warranted. IMST reviews of responses are forwarded to the Governor and the State Legislature. State agencies are expected to respond to IMST recommendations within six months after a report is issued.

Rationale for IMST Review of Klamath Basin Issues

Different community and environmental goals and conflicting information in the Klamath Basin became a major concern for citizens of Oregon and California, Tribes, and agencies responsible for managing natural resources. During an April 12, 2001 visit to Klamath Falls, Oregon, Governor John Kitzhaber agreed to ask the Independent Multidisciplinary Science Team (IMST) to review the reports written by the US Bureau of Reclamation (USBR), US Fish and Wildlife Service (USFWS), and National Marine Fisheries Service (NMFS). In an April 25, 2001 letter, the Oregon Governor's Office asked the IMST to "review the information and offer an independent assessment of the science used to establish lake levels and instream flow targets for suckers and coho."[1] The IMST agreed to conduct the review because the IMST was charged to advise the State on matters of science related to the Oregon Plan for Salmon and Watersheds. Questions concerning 1) status and management of coho salmon in the Klamath River and 2) management of Upper Klamath Lake and its watershed directly relate to the responsibilities of the IMST.

Conceptual Scientific Framework

The IMST developed the following conceptual scientific framework for the recovery of depressed stocks of wild salmonids in Oregon. It was originally developed as we evaluated Oregon's forest practices (IMST 1999a). Since then, it has been expanded to cover all land uses and fish management. Although not testable in a practical sense, we believe this conceptual framework is consistent with generally accepted knowledge and scientific theory.

The recovery of wild salmonids in Oregon depends on many factors, including the availability of quality freshwater and estuarine habitats, ocean conditions, the management of fish harvest, and the adequacy of natural and artificial propagation. Freshwater habitat extends across all the lands of the state, and includes urban areas and lands devoted to agriculture, forestry, and other uses. Estuaries provide a transition between fresh water and the ocean, and are a critical part of the habitat of wild anadromous salmonids. The ocean on which salmonids depend extends well beyond Oregon and is subject to fluctuations in productivity that markedly affect adult recruitment. Fish propagation and fish harvest are critical activities in which humans are directly involved with anadromous fish. The IMST is evaluating the science behind the management practices and policies that affect all of these freshwater and estuarine habitats and the management of fish and fisheries.

We have divided our work into a series of reports that focus on major types of land use (forestry, agriculture, and urban land uses) and fish management (artificial propagation, harvest, and habitat) that impact salmonid recovery in Oregon at the landscape level. The land use subdivisions correspond to the different policy frameworks within which these lands are managed. Although the policies differ, these land uses interface and intermingle, and the aquatic environments on which the fish depend traverse and link them all; therefore, the boundaries we make in our reports are artificial. In addition to these broad scale reports the IMST also reviewed ongoing or proposed state programs, activities, or policies that could also affect salmonid recovery. These reviews are often requested by the State or its agencies.

Concepts

IMST conducts its analysis of land use practices and fish management within a framework made up of the following three fundamental concepts. Although we developed these concepts to apply to wild salmonids, we believe that most of these concepts apply to other native fish species as well. While we do not specifically address sucker populations in Upper Klamath Lake in this

[1] April 25, 2001 letter to Logan Norris, IMST Chair, from Louise Solliday, Governor's Natural Resource Advisor, Salem, Oregon.

section, the populations and their habitats have undergone significant changes and harvesting pressures since Euro-American settlement.

1. **Wild salmonids are a natural part of the ecosystem of the Pacific Northwest, and they have co-evolved with it.** The contemporary geological landscape of the Pacific Northwest was established with the formation of the major river/stream basins of the region, approximately two to five million years ago. The modern salmonids of the region largely developed from that time (Lichatowich 1999). The abundance of these species at the time of Euro-American migration to Oregon is a reflection of more than 10,000 years of adaptation to the post-glacial environment and 4,000 to 5,000 years of adaptation to contemporary climatic and forest patterns. There is some indirect evidence from anthropological studies that salmon in Oregon's coastal streams may not have reached the high levels of abundance that the first Euro-Americans saw until about 1,000 to 2,000 years ago (Matson and Coupland 1995). The point is that the salmonid stocks of today co-evolved with the environment over a relatively long period compared with the length of time since Euro-Americans entered this landscape.

2. **High quality habitat for wild salmonids was the result of naturally occurring processes that operated across the landscape and over time.** These same processes occur today, but humans have altered their extent, frequency, and to some degree, their nature. Humans will continue to exert a dominant force on the terrestrial, freshwater, and estuarine landscape of the Pacific Northwest, but current ecosystems need to better reflect the range of historical conditions (Benda 1994, Reeves et al. 1995).

3. **The environment and habitat of these species is dynamic, not static.** At any given location, there were periods of time when habitat conditions were better and times when habitat conditions were worse. At any given time, there were locations where habitat was better and locations where it was worse. Over time, the location of better habitat shifted, both in fresh water and the ocean.

   Fresh water and estuarine salmonid habitat in the Pacific Northwest has been a continuously shifting mosaic of disturbed and undisturbed habitats. One of the legacies of salmonid evolution in a highly fluctuating environment is the ability to colonize and adapt to new or recovered habitat.

   The ocean habitat also fluctuates and is dynamic, changing over several time scales. There are inter-decadal variations in climate called regimes (as well as shorter term variations) that affect the ocean productivity for salmonids. One regime that resulted in a shift from favorable to unfavorable ocean conditions, especially for coho salmon, occurred in 1977. Some believe that we are entering a more favorable regime that began with the 1998 La Niña. However, it is important to realize that full recovery of salmonid populations is a long-term process. A major assumption is that improved conditions of freshwater and estuarine habitat are buffers to poor ocean conditions. Without improvement of the condition of these habitats, the return to poor ocean conditions in the future will be more devastating to salmonids than what was experienced in the early 1990s (Lawson 1993).

These concepts apply regardless of the land use or fish management strategy and are the basis for the evaluations in this report.

Operation of the Concepts in Salmonids

Wild salmonid stocks historically accommodated changes in their environment through a combination of three strategies. ***Long-term adaptation*** produced the highly varied life history forms of these species, providing the genetic diversity needed to accommodate a wide range of changing conditions. ***High fish abundance distributed in multiple locations (stocks)*** increased the likelihood that metapopulations and their gene pools would survive. ***Occupation of refugia*** (higher quality habitat) provided the base for recolonization of poor habitat as conditions improved over time.

History

Since the mid 1850s, the rate and extent to which habitat conditions have changed has sometimes exceeded the ability of these species to adapt; therefore, abundance currently is greatly reduced. Although refugia exist (at a reduced level) today, population levels of wild salmonid stocks are seriously depressed because of other factors (ocean conditions, fisheries and hatchery management, land-use patterns and practices) that limit habitat productivity and the rate and extent to which recolonization can occur. In addition, some harvest and hatchery practices may have diminished the genetic diversity of salmonids (reviewed in Allendorf and Waples 1996, NRC 1996), potentially limiting their ability to cope with climate fluctuations. It is the combination of these factors and their cumulative effects since 1850 that have produced the depressed stocks of today.

The historical range of ecological conditions and the diversity of salmonid stocks in the Pacific Northwest are important because they provide a framework for developing policy and management plans for the future. The persistence and performance of salmonids under historical ecological conditions is evidence that these habitats were compatible with salmonid reproduction and survival. Prior to European settlement of the western United States, artificial propagation was not practiced, yet the level of harvest by Native Americans may have reached the levels of peak harvests by Euro-Americans (Beiningen 1976; Schalk 1986).

Conclusions

Land uses and fish management strategies resulting in non-historical ecological conditions may support productive salmonid populations, but the evidence for recovery of fish populations under these circumstances is neither extensive nor compelling. Recovery also requires fish management (artificial propagation and harvest) strategies that are consistent with the goals of recovery and are compatible with the condition of the terrestrial and ocean landscape within which they operate. We conclude that:

- The goal of land use management and policy should be to emulate (not duplicate) natural processes within their historical range.
- The goal of fish management and policy should be to produce and take fish in a manner that is consistent with the condition of the environment and how it changes with time.
- Recovery of fish stocks is an iterative and a long-term process. Just as policy and management have changed in the past, they will continue to change in the future, guided by what we learn from science and from experience.

EXECUTIVE SUMMARY

Different community and environmental goals and conflicting information in the Klamath Basin became a major concern for citizens of Oregon and California, Klamath Basin Tribes, and agencies responsible for managing natural resources. In an April 25, 2001 letter, Governor John Kitzhaber asked the IMST to "review the information and offer an independent assessment of the science used to establish lake levels and instream flow targets for suckers and coho." Questions concerning 1) status and management of coho salmon in the Klamath River and 2) management of Upper Klamath Lake and its watershed directly relate to the responsibilities of the IMST.

The Klamath Reclamation Project is operated by the US Bureau of Reclamation (USBR) and supplies irrigation water to approximately 220,000 acres of farmland. As a federal project, the Klamath Reclamation Project is required to follow national laws for resource protection, including the Endangered Species Act (ESA). The US Fish and Wildlife Service (USFWS) and National Marine Fisheries Service (NMFS) are required by the Endangered Species Act to review the effects of Klamath Reclamation Project operations on the endangered and threatened species, Lost River suckers *(Deltistes luxatus*), shortnose suckers (*Chasmistes brevirostris*), and coho salmon (*Oncorhynchus kisutch*).

In 2001, a severe drought occurred in the Klamath Basin. USFWS and NMFS reviewed the USBR's 2001 Biological Assessments and operations plans for the Klamath Reclamation Project based on drought forecasts. Both USFWS and NMFS issued Biological Opinions that stated the Klamath Reclamation Project's proposed operations for 2001 were likely to jeopardize the endangered species of the Klamath Basin.The USFWS and NMFS and subsequent reviews raised several major questions about:

- The status of sucker populations,
- Factors responsible for fish kills,
- Use of lake levels as a management tool for protecting sucker populations, and
- Instream flow requirements for coho salmon in the Klamath River.

The IMST reviewed the Biological Assessments of the USBR, Biological Opinions of USFWS and NMFS, scientific literature, and scientific reviews of the Klamath Basin environmental issues. In this Summary, we list our conclusions, followed by brief explanations, specific to Upper Klamath Lake, management of the Klamath River below Iron Gate Dam, and broad landscape-level conclusions. IMST developed eight specific recommendations to the State of Oregon and their cooperators in co-management of the Klamath Basin and its resources.

IMST Conclusions Specific to Upper Klamath Lake

Conclusion 1: Sucker populations may have declined in the last decade, particularly in response to three major fish kills and several low water years, though population sizes are difficult to accurately estimate and are subject to many sources of error. Long-term declines over the last century have been substantial.

Conclusion 2: Between 1991 and 2001, abundance of juvenile suckers was lowest in the years of lowest lake levels.

Conclusion 3: Availability of spawning areas and access to refuges in Upper Klamath Lake are greater during high than low water.

Conclusion 4: IMST concludes that factors involved in fish kills are complex and difficult to predict. They involve lake levels, phytoplankton blooms, stratification, winds, mixing, and bottom sediments. We also agree with the NRC that there is no strong scientific data to link fish kills with lake levels between 1990 and 2000. Typically, from such a short time series it is difficult to determine scientifically whether a relationship does or does not exist.

Conclusion 5: Regulating lake levels is one of the few options available to management agencies to protect sucker populations. IMST agrees with USFWS that lake level management is one of several appropriate management tools to reduce conditions that may lead to fish kills, but lake level management alone will not prevent sucker die-offs. The minimum lake levels required for protection of suckers are not exact.

Conclusion 6: Wetland and riparian restoration could lower the risk of sucker die-offs and provide additional benefits to the Upper Klamath Lake and Klamath River system.

Conclusion 7: Management of tributary spawning habitat, using a watershed approach, will be important to survival of sucker populations.

IMST Conclusions Specific to the Klamath River

Conclusion 8: Review of the literature indicates that the scientific basis for NMFS (2001) decision requiring minimum instream flows at Iron Gate Dam for coho salmon in the Klamath River is conceptually sound.

Conclusion 9: Data on distribution of coho salmon and habitat use in the mainstem Klamath River throughout the year are scarce and incomplete. Decisions about management actions are limited by the timeframe and spatial extent of existing data.

IMST Conclusions for Broader Landscape-level Issues

Conclusion 10: The 2001 Biological Opinions prepared by USFWS and NMFS were based on the best available science. The types of data and information used in the Biological Opinions are appropriate and technically sound.

Conclusion 11: Upper Klamath Lake, the Klamath River and Klamath Basin watershed have been changed by many factors (e.g., land use, erosion, nutrient loading, wetland destruction, and introduction of non-native species), which have all contributed to decline of shortnose and Lost River suckers and coho salmon.

Conclusion 12: The IMST recommends that future research and management include lake stratification and stability, weather, historical precipitation levels and streamflow, and historical fish distributions.

Conclusion 13: The IMST finds that a high degree of uncertainty is related to complex phenomena and/or scarce empirical information. In the face of uncertainty, a precautionary approach to management is warranted.

Conclusion 14: Interstate coordination and an active negotiation process are needed for management of Upper Klamath Lake and the Klamath River.

Recommendations

Recommendation 1: The IMST recommends that the State of Oregon work with the State of California and the federal agencies and tribal co-managers to develop an integrated long-term management program for the entire Klamath River Basin.

Recommendation 2: The IMST recommends that the State of Oregon consult with the State of California and the federal and tribal co-managers to develop a program for collecting relevant data on sucker populations and lake habitats and salmonid populations and river habitats in the Klamath River Basin.

Recommendation 3: The IMST recommends the Department of Fish and Wildlife of the State of Oregon to collaborate with the State of California and the federal and tribal co-managers to develop monitoring data needed on salmonid use of the mainstem Klamath River throughout the entire year, including summer and autumn.

Recommendation 4: The IMST recommends that the State of Oregon collaborate with the State of California and the federal and tribal co-managers to develop and test a model that relates the influence of management actions on Upper Klamath Lake, on the long-lived sucker species in the lake, and flows in the Klamath River.

Recommendation 5: The IMST recommends that the State of Oregon work with the State of California and the federal and tribal co-managers to resolve the debate about the historical climate and streamflow in the Klamath River Basin and develop a common framework for determining appropriate instream flow in the mainstem Klamath River.

Recommendation 6: The IMST endorses efforts to restore the wetlands around Upper Klamath Lake and recommends that the State of Oregon place high priorities on opportunities to restore wetlands and riparian areas along streams and lakes within the Klamath River Basin.

Recommendation 7: The IMST recommends that the State of Oregon, State of California, and federal agencies increase technical assistance to land owners along streams, rivers, and lakes in the Klamath River Basin restore riparian areas, wetlands, and streamflows to the degree possible.

Recommendation 8: The IMST recommends that the State of Oregon develop explicit, measurable benchmarks for environmental conditions that represent periods of high ecological risk. State policies could be refined to identify precautionary actions that would be triggered during periods of high risk and greater uncertainty.

Recommendation 9: The IMST recommends that the Oregon Water Resources Department resolve and complete the on-going adjudication process in the Klamath River basin. The previous IMST recommendations require active water resource management in the Klamath River Basin, and adjudication is essential before implementing these recommended actions.

Recommendation 10: The IMST recommends that in tributaries and springs of Upper Klamath Lake, ODFW, in collaboration with other state agencies, should assess water quality and fish passage problems that potentially limit sucker recovery. The IMST recommends that ODFW assess effectiveness of the existing fish ladder for passage of adult suckers at the Chiloquin Dam. ODFW and DEQ should assess and improve water quality in spawning areas.

INTRODUCTION

The Klamath Reclamation Project is operated by the US Bureau of Reclamation (USBR) and supplies irrigation water to approximately 220,000 acres of farmland. As a federal project, the Klamath Reclamation Project is required to follow national laws for resource protection, including the Endangered Species Act (ESA). Therefore, operation of the project -- including delivery of water to farmers -- is legally subject to a review process by the US Fish and Wildlife Service (USFWS) and National Marine Fisheries Service[2] (NMFS). These two agencies are obligated by the Endangered Species Act to review the effects of Project operations on endangered and threatened species: in this case, Lost River suckers *(Deltistes luxatus*), shortnose suckers (*Chasmistes brevirostris*), and coho salmon (*Oncorhynchus kisutch*). The USBR prepares a Biological Assessment of their proposed project operations. USFWS and NMFS use the Biological Assessment to base their analyses and presents these analyses in technical documents called Biological Opinions.

In 2001, a severe drought occurred in the Klamath Basin. USFWS and NMFS reviewed the USBR's 2001 Biological Assessments and operations plans for the Klamath Reclamation Project based on drought forecasts. Both USFWS and NMFS issued Biological Opinions that stated the Klamath Reclamation Project's proposed operations for 2001 were likely to jeopardize the endangered species of the Klamath Basin.In response to these decisions and the worsening conditions of the drought, several independent reviews have been conducted to evaluate the science and technical information used by NMFS and USFWS in their 2001 Biological Opinions. In the ensuing debate, citizens and politicians raised questions about the scientific validity of the measures USFWS and NMFS proposed to protect Lost River and shortnose suckers in Upper Klamath Lake and coho salmon in the Klamath River. Major questions were raised about:

- The status of sucker populations,
- Factors responsible for fish kills,
- Use of lake levels as a management tool for protecting sucker populations, and
- Instream flow requirements for coho salmon in the Klamath River.

Conflicting information became a concern to citizens of Oregon and California, including Tribes, in the Klamath Basin. During an April 12, 2001 visit to Klamath Falls, Oregon Governor John Kitzhaber agreed to ask the Independent Multidisciplinary Science Team (IMST) to review the reports written by the USBR, USFWS, and NMFS. In an April 25, 2001 letter, the Oregon Governor's Office asked the IMST to "review the information and offer an independent assessment of the science used to establish lake levels and instream flow targets for suckers and coho."[3] The IMST agreed to conduct the review, and we present our assessment in this report.

In this introductory section, we:

- Define the scope of this report.
- Clarify the major documents that IMST reviewed in preparing this report.
- Give a brief overview of the geography and natural resources of the Klamath Basin, land use and hydrologic change in the Klamath Basin, the Klamath Project, the Endangered Species Act, and recent actions by the federal agencies concerning management of the

[2] Now known as NOAA Fisheries.
[3] April 25, 2001 letter to Logan Norris, IMST Chair, from Louise Solliday, Governor's Natural Resource Advisor, Salem, Oregon.

Klamath Project. We provide this information in order to put our evaluation of the science questions in context.
- Describe the organization of this report.

Scope of this Report
This report evaluates the technical basis for the 2001 Biological Opinions prepared by USFWS and NMFS:

> National Marine Fisheries Service (NMFS). 2001. Biological Opinion, ongoing Klamath Project operations. April 6, 2001. National Marine Fisheries Service, Southwest Region. 60 pp.
>
> US Fish and Wildlife Service (USFWS). 2001. Biological Opinion and conference report for the continued operations of the Bureau of Reclamation's Klamath Project as it affects endangered Lost River sucker (*Deltistes luxatus*), endangered shortnose sucker (*Chasmistes brevirostris*), threatened bald eagle (*Haliaeetus leucocephalus*), and proposed critical habitat for the suckers. April 5, 2001. Fish and Wildlife Service, California/Nevada Operations Office, Sacramento California. 188 pp.

As part of the review, we closely examined the 2001 Biological Assessments by USBR:

> US Bureau of Reclamation (USBR). 2001a. Biological Assessment of the Klamath Project's continuing operations on Southern Oregon/Northern California ESU coho salmon and critical habitat for Southern Oregon/Northern California ESU coho salmon. Prepared by US Bureau of Reclamation, Mid-Pacific Region, Klamath Area Office, Klamath Falls, Oregon. 54 pp.
>
> US Bureau of Reclamation (USBR). 2001b. Biological Assessment of Klamath Project's continuing operations on the endangered Lost River sucker and shortnose sucker. Prepared by US Bureau of Reclamation, Mid-Pacific Region, Klamath Basin Area Office, Klamath Falls, Oregon. February 13, 2001. 112 pp.

We also attempt to resolve some of the confusion that has been created by multiple reviews of these documents (see following section, and Tables 9 and 16 on pages 55 and 92, respectively). In this report, we consider issues related to sucker populations in Upper Klamath Lake, limnological factors related to fish kills in Upper Klamath Lake, wild coho salmon in the Klamath River mainstem, and the watershed conditions and processes that contribute to these issues.

Sources of Information for this Report
This report does not represent independent analytical research, but rather scientific review of work done by other researchers. In preparing this report, we reviewed existing analyses published in the primary literature, other technical literature reviews, and technical documents.

<u>Federal Biological Assessments and Biological Opinions</u>
A major source of information for this report were technical documents describing federal actions released by USBR, USFWS, and NMFS. In addition to the 2001 Biological Opinions (USFWS 2001, NMFS 2001), the IMST reviewed the following Biological Assessments and Biological Opinions:

US Bureau of Reclamation (USBR). 2002. Final Biological Assessment: The effects of proposed actions related to Klamath Project operation (April 1, 2002 – March 31, 2012) on federally-listed threatened and endangered species. Prepared by US Bureau of Reclamation, Mid-Pacific Region, Klamath Basin Area Office, Klamath Falls, Oregon. February 13, 2001. 103 pp.

National Marine Fisheries Service (NMFS). 2002. Biological Opinion, Klamath Project operations. Final Version. May 31, 2002. National Marine Fisheries Service, Southwest Region. 102 pp.

US Fish and Wildlife Service (USFWS). 2002. Biological /Conference Opinion regarding the effects of operation of the U.S. Bureau of Reclamation's Proposed 10–year operation plan for the Klamath Project and its effects on the endangered Lost River sucker (*Deltistes luxatus*), endangered shortnose sucker (*Chasmistes brevirostris*), threatened bald eagle (*Haliaeetus leucocephalus*), and proposed critical habitat for the Lost River and shortnose suckers. May 31, 2002 Final Version. Fish and Wildlife Service, California/Nevada Operations Office, Sacramento California. 204 pp.

Interdisciplinary Reviews of the Management of Klamath Lake and Klamath River

There are three other major interdisciplinary reviews of Klamath Issues. These were a major focus of our report.

Braunworth, W.S., Jr., Welch, T., and Hathaway, R. (eds). 2002. Water Allocation in the Klamath Reclamation Project, 2001: An Assessment of Natural Resource, Economic, Social, and Institutional Issues with a focus on the Upper Klamath Basin. Special Report 1037. Oregon State University Extension Service, Corvallis, Oregon. 401 pp.

National Research Council (NRC). 2002. Scientific evaluation of Biological Opinions on endangered and threatened fishes in the 0

Klamath River Basin: Interim Report. National Academy Press, Washington, D.C. 37 pp.

University of California. 2001. University of California Peer Review of: Biological Opinion and Conference Report for the continued operations of the Bureau of Reclamation's Klamath Project as it affects endangered Lost River sucker (*Deltistes luxatus*), endangered shortnose sucker (*Chasmistes brevirostris*), threatened bald eagle (*Haliaeetus leucocephalus*), and proposed critical habitat for the suckers. On file at Klamath Falls Fish and Wildlife Office, USFWS, Klamath Falls, Oregon. 15 pp.

Braunworth et al. (2002), also referred to as the OSU-UC Davis report in our report, is a report jointly issued by Oregon State University (OSU) and the University of California Davis (UC Davis), and represents a multidisciplinary, multi-state effort to synthesize information on the Klamath Basin. The OSU-UC Davis report addresses wildlife, suckers, and coho salmon, as well as social, economic, and policy issues in the Klamath Basin resulting from water management decisions in 2001 (http://eesc.orst.edu/Klamath).

The National Research Council (NRC) formed a committee to review the Biological Opinions related to the management of Upper Klamath Lake in fall of 2001. The Committee met once in December 2001 and produced a prepublication version of their interim report in February 2002. The Committee released a final interim report in June 2002 (NRC 2002) and will release a final report in 2003.

University of California (2001) is a peer review conducted by four anonymous University of California faculty members. This report reviewed the 2001 USFWS Biological Opinion and related scientific issues.

Other literature considered by the IMST is listed in the reference section at the end of the report. The IMST asked for 21 technical reviews of the science and management information in this report from scientists in the following agencies and institutions:

- National Marine Fisheries Service
- US Fish and Wildlife Service
- US Bureau of Reclamation
- USDA Natural Resources Conservation Service
- US Geological Survey
- Upper Klamath Basin Working Group
- Oregon Department of Water Resources
- Oregon Department of Agriculture
- Oregon Department of Fish & Wildlife (two reviewers)
- Oregon Department of Environmental Quality
- Oregon Department of Justice, Natural Resources Section
- California Department of Water Resources
- Oregon State University (three reviewers)
- National Research Council
- University of California, Davis (two reviewers)
- University of California, Berkeley
- Two other groups who submitted anonymous reviews

The IMST appreciates the information and technical advice provided by these reviewers (see Acknowledgements for list of reviewers' names). The listing of these reviewers is simply an acknowledgement of the sources of review of this report and does not represent an endorsement of this report by either the individuals or the institutions or agencies they represent.

Geography and Natural Resources of the Klamath River Basin

The Klamath River basin in Oregon and California encompasses a total area of 9.4 million acres (Figure 1). The major tributaries (Wood, Sprague, Williamson, and Lost Rivers) of the upper Klamath Basin (in Oregon) flow into Agency Lake or Upper Klamath Lake and do not directly enter the mainstem Klamath River (2). Link River connects the southern end of Upper Klamath Lake to Lake Ewuana. The Klamath River begins at Lake Ewuana immediately below Upper Klamath Lake (Figure 2). Four major tributaries (Shasta, Scott, Salmon, and Trinity rivers) enter the Klamath River in California at river miles 176, 143, 66, 43, respectively (USGS 7.5 minute topographic map; Figure 1).

Upper and Lower Klamath Lakes, two of the major lakes in the basin, are large, shallow, and eutrophic. Upper Klamath Lake has a mean depth ranging from 5.8 feet to 9.7 feet, depending on lake elevation (Table 1; Figure 3). Both lakes are lined with large marshes (Table 2; Figure 4), which were quite extensive historically (Figure 5). Most of these marshes are remnants of Pleistocene lakes that dried up or were filled in gradually with soil, peat, and volcanic pumice and ash (Snyder and Morace 1997; Boyd et al. 2002).

Table 1. Physical characteristics of Upper Klamath Lake and Agency Lake, Oregon. Modified from Table 1 in Snyder and Morace (1997). Source of data: US Army Corps of Engineers (1979, p.43).

Lake surface elevation		Average Depth	Surface Area	Volume
Minimum*	4137.0 ft	5.8 ft	60,000 acres	350,000 acre-feet
Mean summer	4141.3 ft	8.0 ft	77,500 acres	620,000 acre-feet
Maximum	4143.3 ft	9.7 ft	90,000 acres	875,000 acre-feet

* In 1994, the lake surface elevation was 4,136.8 ft (Mark Buettner, USBR, written communication cited in Snyder and Morace (1997).

Table 2. Comparison of two major lakes in the Klamath Basin: Upper Klamath Lake, Oregon and Lower Klamath Lake, California (Johnson et al. 1985; USBR 2002).

Lake	*Total Historical Area (acres)**	*Total Current Area (acres)**	*Historical lake area in wetlands (acres)*	*Current lake area in wetlands (acres)*
Upper Klamath Lake	111,510	61,543	51,510	17,370
Lower Klamath Lake	85,000-94,000	4,700	55,000-64,000	2,225

*Total area includes open water and wetlands.

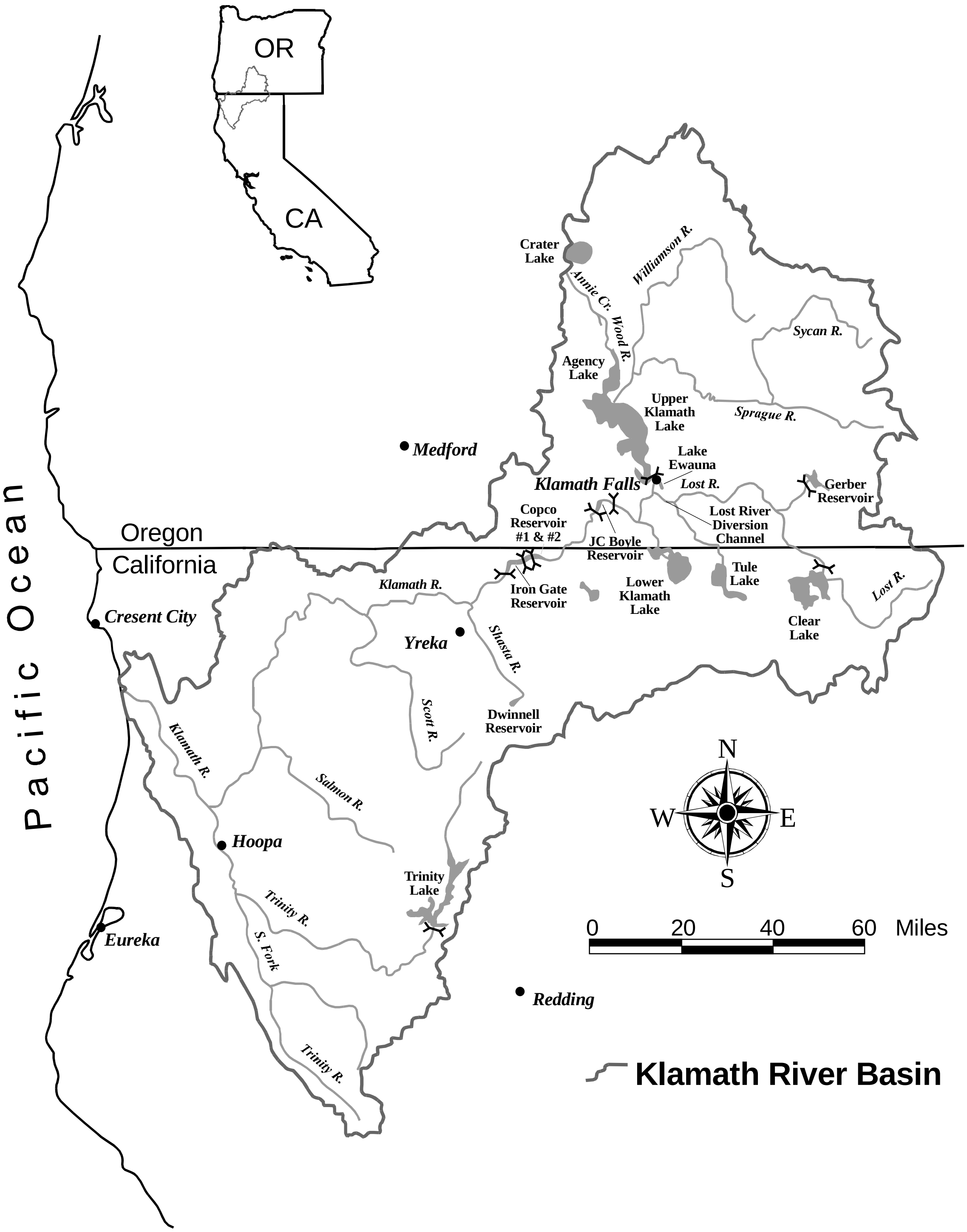

Figure 1. Klamath Basin in Oregon and California showing USBR Klamath Reclamation Project (figure modified from file produced by USBR).

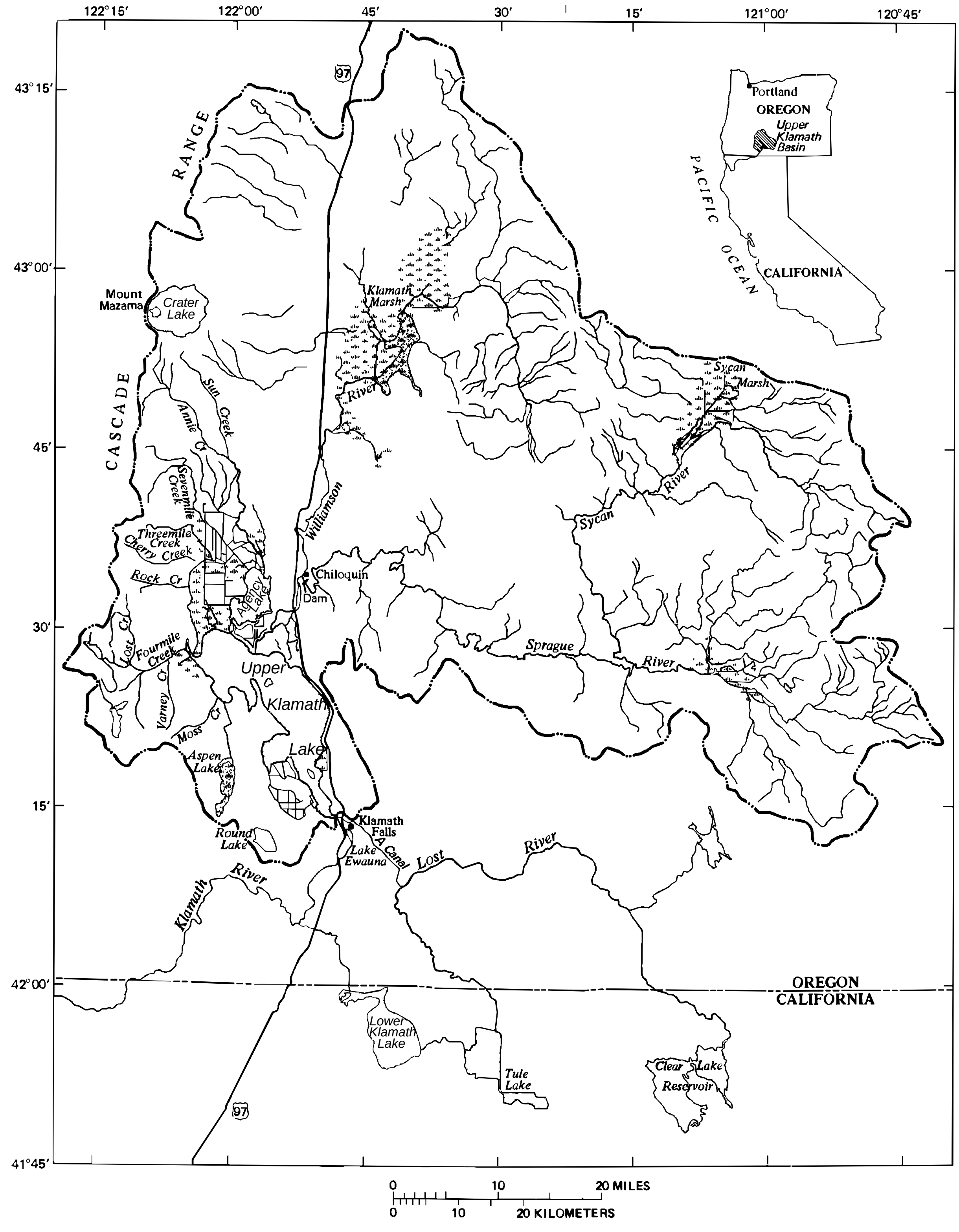

Figure 2. Upper Klamath Lake basin and vicinity, indicating current location of marshes. Klamath Marsh is located in the Williamson drainage upstream from Upper Klamath Lake. Reproduced from Bortleson and Fretwell (1993).

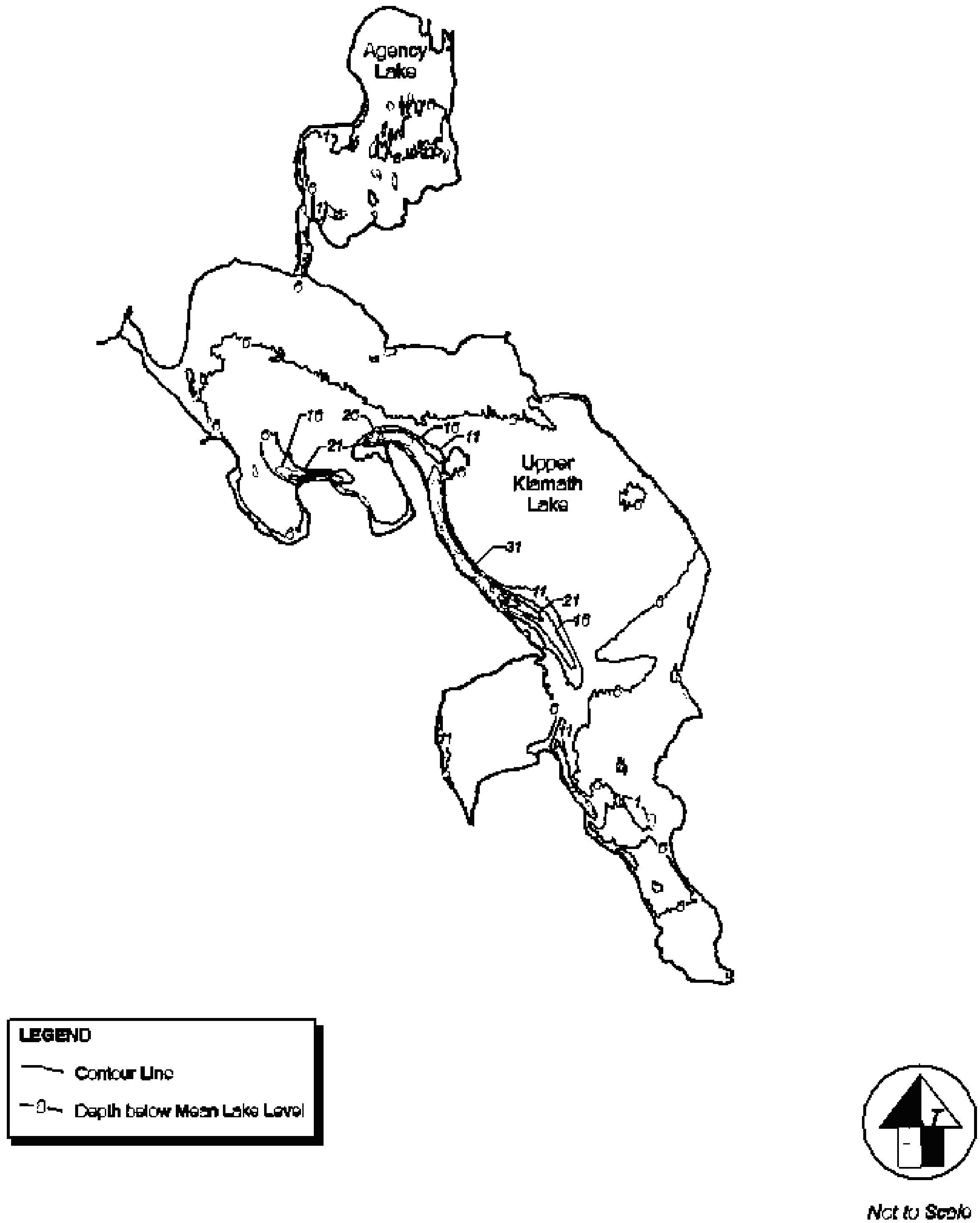

Figure 3. Bathymetric map of Upper Klamath Lake and Agency Lake, Oregon. The depth contours (ft) are based on the mean summer lake elevation of 4,141.3 feet above mean sea level. Reproduced from Welch and Burke (2001). Data source: USBR (1999) Bathymetry of Upper Klamath and Agency Lakes provided to Welch and Burke.

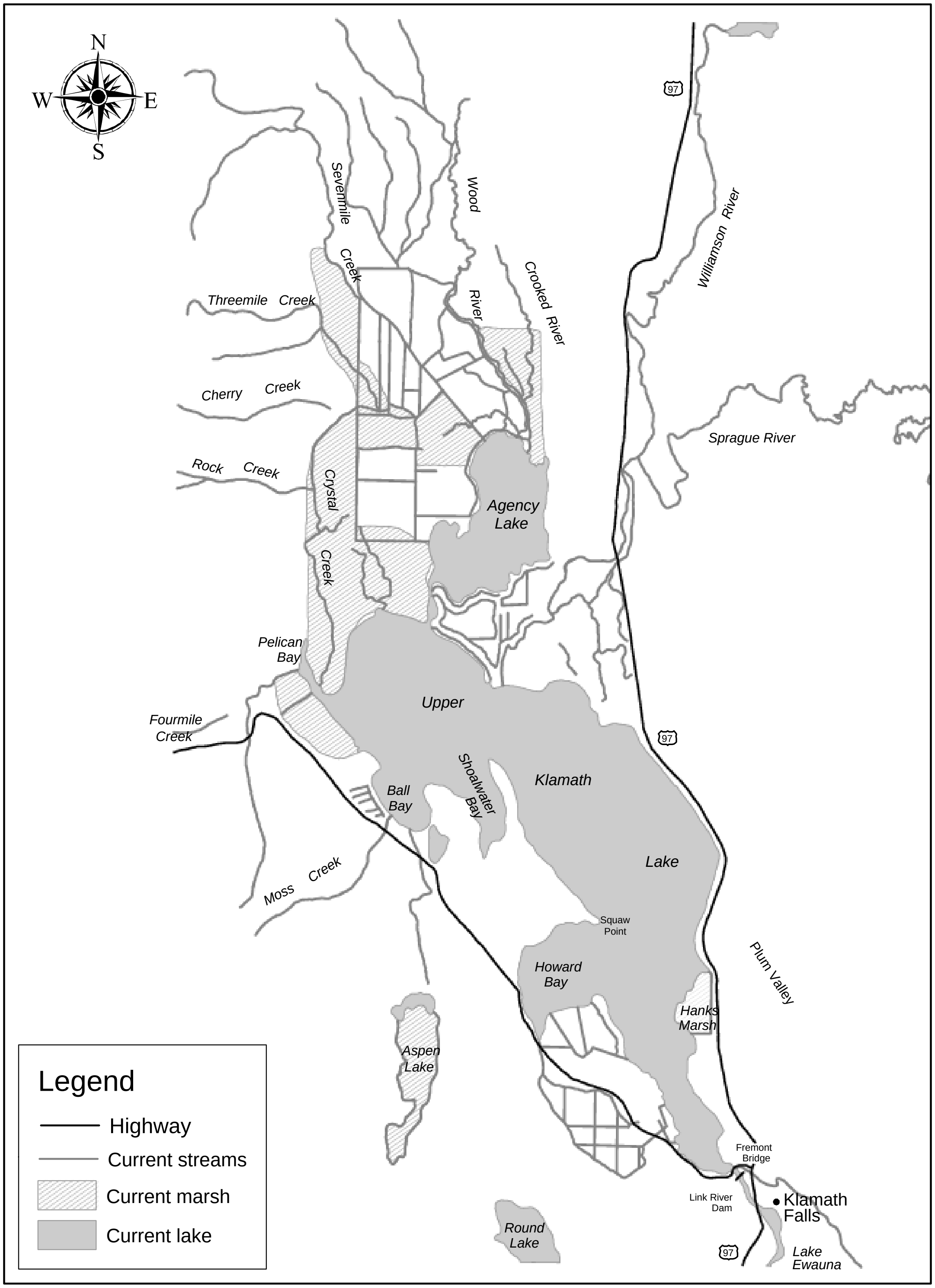

Figure 4. Current distribution of marshes around Upper Klamath and Agency Lakes. Modified and reproduced from color image in Bortleson and Fretwell (1993).

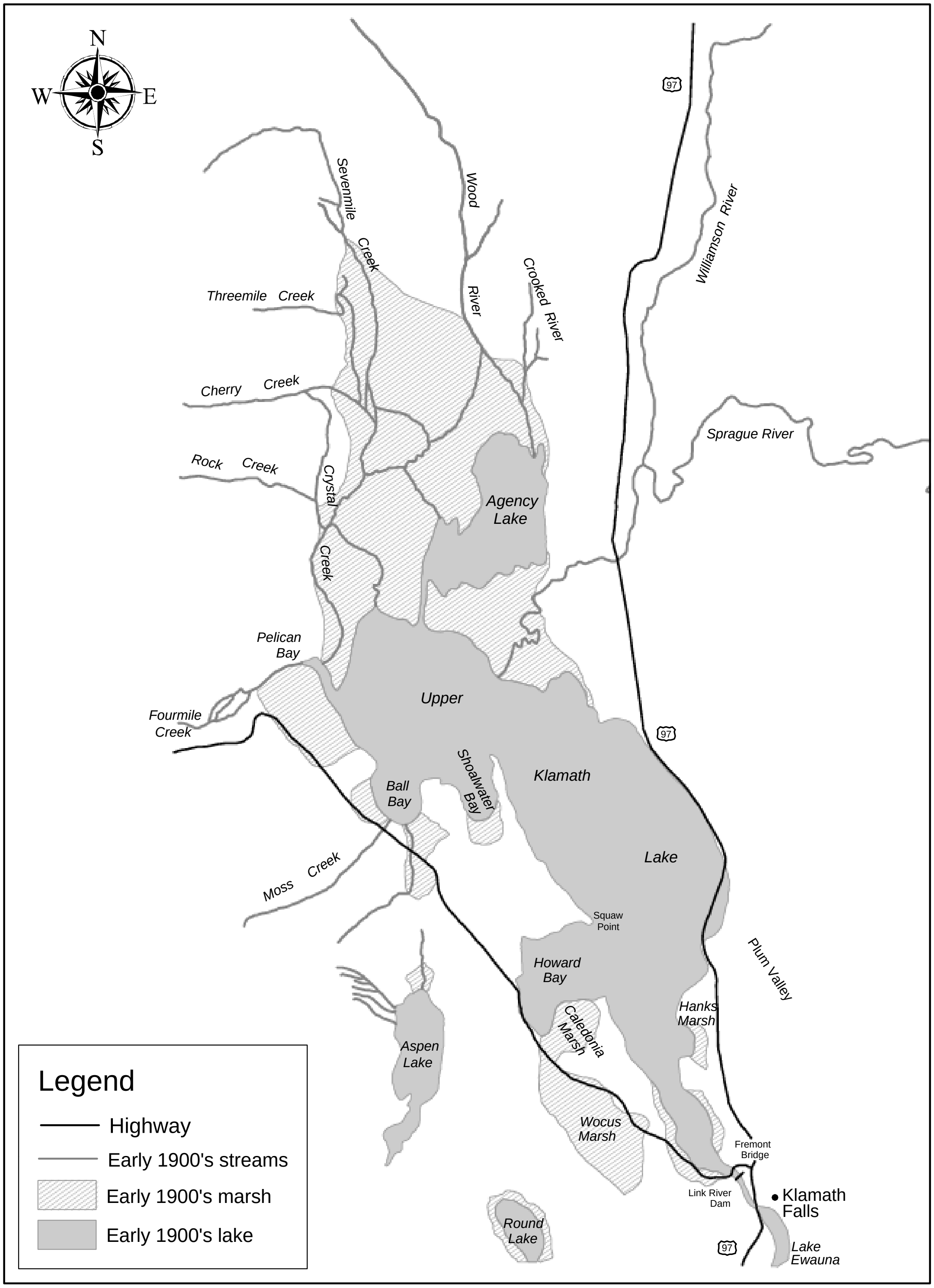

Figure 5. Marshes surrounding Upper Klamath and Agency Lakes in the early 1900's. Modified and reproduced from color image in Bortleson and Fretwell (1993).

Fishes of the Klamath Basin

The Klamath Basin contains five species of anadromous salmonids: coho salmon, chinook salmon (*Oncorhynchus tshawytscha*), chum salmon (*O. keta*), steelhead (*O. mykiss*), and coastal cutthroat trout (*O. clarkii*). Several other anadromous fish species—green sturgeon (*Acipenser medirostris*), eulachon (*Thaleichthys pacificus*), shad (*Alosa sapidissama*), river lamprey (*Lampetra ayersi*) and Pacific lamprey (*Entosphenus tridentatus*)—migrate from the Klamath River to the Pacific Ocean and back (Deas and Orlob 1999). Spring chinook, fall chinook, and chum salmon are still present in the Klamath River in California; however, spring chinook salmon are no longer found in the Klamath River in Oregon as a result of dam construction (NMFS at website http://www.nwr.noaa.gov). In the Klamath River basin, coho salmon [Southern Oregon/Northern California Coasts (SONCC) Evolutionary Significant Unit] are listed as threatened, and the Lost River sucker and shortnose sucker are listed as endangered under the federal ESA. Historically, Lost River and shortnose suckers occupied Clear Lake, Tule Lake, Upper Klamath Lake, and Lower Klamath Lake and their tributaries (USBR 2002). Both sucker species have been extirpated from Lower Klamath Lake since the Klamath Reclamation Project was developed.

Land Use and Hydrologic Change in the Klamath Basin

Snowmelt directly and indirectly recharges groundwater in the Klamath River basin. Historically, many sources—groundwater, Upper Klamath Lake, Lower Klamath Lake, tributaries, marshes and wetlands—contributed substantially to flows in the mainstem of the Klamath River (Boyle 1976; Hecht and Kamman 1996). Current flows in the mainstem Klamath River are substantially less than historical flows during some seasons (see Figures 24 and 25 on p. 76).

Human activities have modified streams, rivers, marshes, riparian areas, and lakes in the Klamath River basin for more than 150 years. Wetlands adjacent to Upper Klamath Lake and adjacent Agency Lake were drained throughout the first 80 years of the 20th century to provide agricultural crop lands and livestock pastures (Figures 4 and 5). At least 110,000 acres of the watershed for Upper Klamath Lake have been converted to irrigated pasture and other agricultural uses (1998 EPA Index of Watershed Indicators data as reported in Eilers et al. 2001). Permitted irrigated land acreage increased 11 fold between 1900 and present day (Risley and Laenen 1999). Most of the 110,000 irrigated acres occur in riparian areas, floodplains, and lakeshore and river deltas connected to the lake (Boyd et al. 2002)**.** The changes in land use observed in the watershed are consistent with those types of activities that have been identified that would cause changes in hydrologic regimes and nutrient loading to tributaries and Upper Klamath and Agency Lakes (Boyd et al. 2002).

The USBR Klamath Reclamation Project has been a major source of land use and hydrologic change in the upper Klamath River basin. These changes are detailed in the following section on the Klamath Reclamation Project and management of Upper Klamath Lake. Other major projects have also greatly altered the hydrology of the Klamath Basin. Four dams (J.C. Boyle, Copco I, Copco II, and Iron Gate) were constructed on the mainstem Klamath River between 1917 and 1962 (Figure 1).

Additionally, lower sections of the Klamath River have been affected by the completion of the Trinity River Diversion Project in 1964, approximately 46-91% (average of 75%) of the instream flow of the Trinity River had been diverted into the Sacramento River from 1964 through 1994 (USFWS and Hoopa Valley Tribe 1999).

The Klamath Reclamation Project

In 1905, Congress authorized the formation of the Klamath Reclamation Project, with the aim of converting wetlands in the Klamath and Lost River systems to farmland and wildlife refuges (Hathaway and Welch 2002). By 1921, the Klamath Reclamation Project increased the water storage capacity of Upper Klamath Lake to deliver water to agricultural water-users beyond the shoreline of the lake. The Klamath Reclamation Project supplies irrigation water to approximately 220,000 acres of farmland. The project area and water distribution system is illustrated in Figure 6.

<u>Upper Klamath Lake, Oregon</u>

Upper Klamath Lake is the main water storage area for the Klamath Reclamation Project. Water is withdrawn from Upper Klamath Lake, diverted through a series of canals to agricultural water users, and then enters Lower Klamath Lake, Tule Lake, and Lost River (Figure 6). While historically a natural lake, Upper Klamath Lake has been modified for use as a water reservoir. A natural rock reef at the south end of the lake impounds water. In 1921, the California-Oregon Power Company (Copco) constructed (and later transferred ownership to the federal government) Link River Dam at the mouth of Upper Klamath Lake, approximately 0.4 miles downstream from the reef (USFWS 2001).

During the construction of Link River Dam, a 100-foot wide channel was cut through the reef. Construction of the dam and modification of the rock reef provided more control over the volume of water that could be stored in and released from Upper Klamath Lake (USFWS 2001). Before the dam was constructed, lake levels were related to inflow into Upper Klamath Lake (USFWS 2002). Construction of the dam has allowed for the manipulation of the hydrologic schedule and as a result, water storage and release can alter the seasonal patterns of lake levels. In general, water storage has caused lake levels to be higher than historical levels from February through June, and controlled releases and withdrawals for irrigation have caused lake levels to be lower than historical levels from July through January (Figure 7).

Prior to modification, the lowest point on the natural reef was 4137.8 ft, and September lake levels in Upper Klamath Lake averaged 4140.5 ft (USFWS 2002). Since the construction of the Link River Dam, water can be released from the lake until the lake level drops to 4136.0 ft, the bottom of the Link River Dam (Rykbost and Todd 2002). After dam construction, September lake levels decreased to an average of 4139.5 ft -- a difference of one foot in elevation (Figure 7). Historical lake level fluctuation was between 4140.0 and 4143.0 ft above sea level (USBR 2002). Since completion of the dam, lake levels have ranged 6.5 feet (from 4,136.8 to 4143.3 ft above sea level; USBR 2002), having large effects on lake volume and lake surface area (Table 1). The recent history of water management under the Klamath Reclamation Project is presented in a following section.

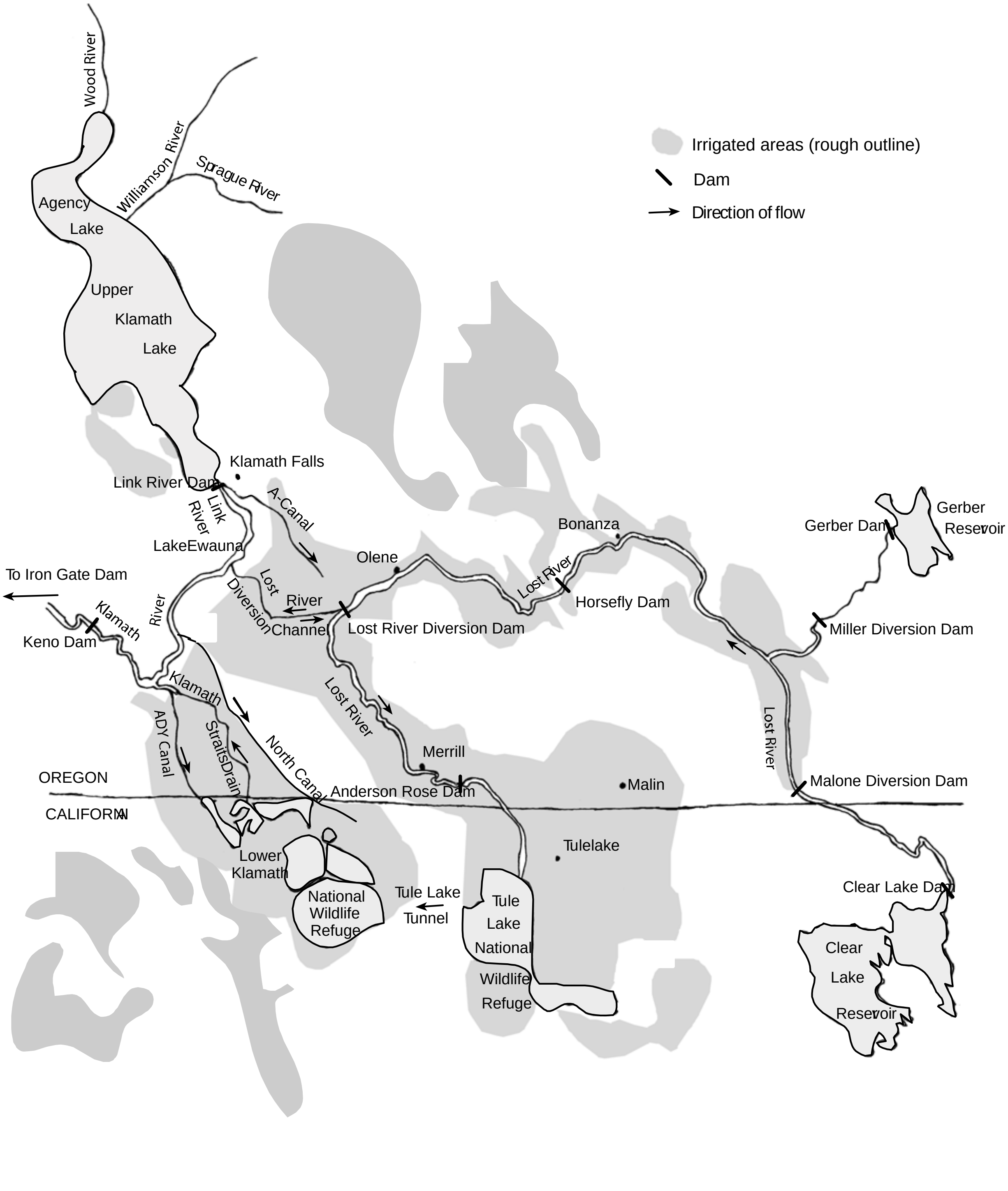

Figure 6. Water distribution system of the Klamath Project and of associated water managers. Arrows indicate direction of flow in rivers and irrigation canals. Water bodies are not drawn to scale. Figure reprinted from Braunworth et al. (2002) with permission from Oregon State University Extension Service.

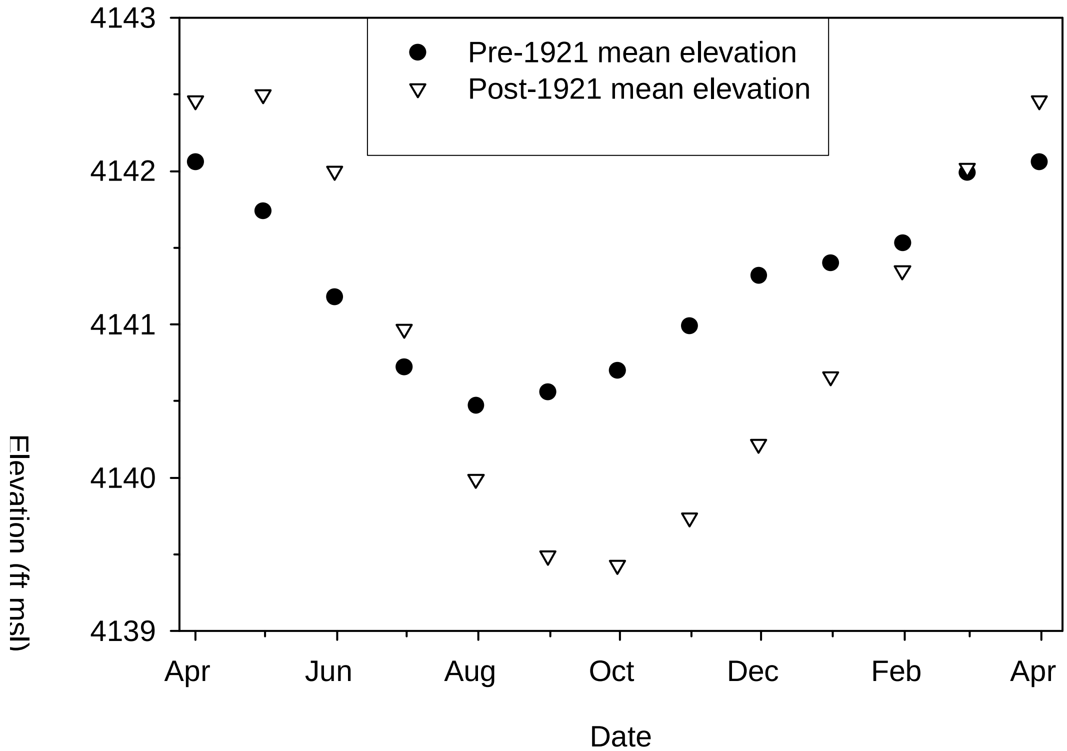

Figure 7. Monthly elevations of the surface of Upper Klamath Lake, Oregon before and after construction of the Link River Dam in 1921. Reproduced from Cooperman and Markle (2003).

Lower Klamath Lake, California

Before the Klamath Reclamation Project was completed, Upper Klamath Lake in Oregon and Lower Klamath Lake in California were hydrologically connected. During high water events, water from the upper reaches of the Klamath River entered Lower Klamath Lake via over-bank flow. This supported a broad basin marsh or tule lands around Lower Klamath Lake (Sisemore 1941).

Lower Klamath Lake was originally formed by a rock reef (located at Keno, Oregon) that backed up the Klamath River. The Klamath Reclamation Project constructed a dike to isolate Lower Klamath Lake from the River and to serve as a railroad bed. Efforts then began to drain the lake and convert the wetlands to agricultural land and a wildlife refuge (Rykbost and Todd 2002).

Lost River Basin

The Klamath Reclamation Project impacted other water bodies in the region as well, including the Lost River basin. Prior to the Klamath Reclamation Project, the Lost River basin was a closed system and had no outlet to the ocean (Rykbost and Todd 2002). Water was diverted from Lost River, Tule Lake, and Clear Lake to the Klamath River through the Lost River Diversion Channel.

History of Federal Management Actions Regarding the Klamath Reclamation Project

As a federal project, the Klamath Reclamation Project falls under national laws for resource protection, such as the Endangered Species Act. As a consequence, USBR has interacted with other federal agencies, including USFWS and NMFS to operate the project.

The Endangered Species Act (ESA)

The ESA of 1973 states that the United States pledged to conserve to the extent practicable the various species of fish or wildlife and plants facing extinction [ESA 1973: Section 2 (a) 4]. Section 7 of the ESA states that all Federal agencies shall use their authorities to further the purposes of the act by carrying out programs for the conservation of endangered and threatened species [ESA 1973: Section 7 (a) 1]. Within the ESA, the term **conservation** (and the words conserve and conserving) means to use all methods and procedures which are necessary to bring any endangered or threatened species to the point at which the measures provided for under the ESA are no longer needed [ESA 1973: Section 3 (3)].

Under Section 7, federal agencies conducting operations that may affect listed species or critical habitat enter into **consultation** with the USFWS or NMFS. As part of the consultation process, an agency proposing management actions that may impact endangered or threatened species must submit a **Biological Assessment** to USFWS or NMFS. Contents of the Biological Assessment are not mandated by statute but typically include:

- Description of the proposed operation,
- Information regarding the listed species in the affected areas,
- How the operation may affect the species, and
- Proposals on how the agency may avoid or minimize adverse effects on the species.

In response to the Biological Assessment, the USFWS or NMFS issues a **Biological Opinion**, determining if the actions proposed in the Biological Assessment would be sufficient to protect the listed species or would cause additional harm, in which cases a **jeopardy** decision is made. Jeopardy has been legally defined as “to engage in an action that reasonably would be expected, directly or indirectly, to reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing the reproduction, numbers, or distribution of that species” (50 CFR 402.02). As part of a jeopardy decision in the Biological Opinion, the USFWS or NMFS presents **reasonable and prudent alternatives** to the proposed operation plan to protect the listed species. These typically include management and/or mitigation activities.

Congress has directed the USFWS and NMFS to give the benefit of the doubt to the species of concern in developing their Biological Opinion (H.R. Conf. Rep. No. 697, *supra*, at 12 as cited in USFWS 2001 Section III, Part 2; Page 125). Additionally, the intent of the ESA has been interpreted by courts as “Congress has spoken in the plainest of words, making it abundantly clear that the balance has been struck in favor of affording endangered species the highest of priorities, thereby adopting a policy which it described as ‘institutionalized caution’.” [Tennessee Valley Authority v. Hill, 437 US 153, 194 (1978): accord Sierra Club v. Marsh, 816 F2d 1376, 1383-84, 1387 (9th Cir. 1987) as cited in Kandra et al. v. US et al., US District Court of Oregon, Civ. No. 01-6124-AA (2001)].

Consultation History

USBR operates the Klamath Reclamation Project based on an operations plan and as required in the consultation process, USBR produces a Biological Assessment that evaluates the expected effects of its proposed operations. In 1992, USFWS released a Biological Opinion on the Klamath Reclamation Project’s long-term operations. This Biological Opinion provided the basis for water management in Upper Klamath Lake throughout the 1990’s, although USFWS and USBR continued consultation on various aspects of project operations during this time period

(USFWS 2001). Consultation between NMFS and USBR began in 1998, after coho salmon in the Klamath River were listed as Threatened under the ESA on May 6, 1997.

For Project operations during 2001, the USBR issued a final Biological Assessment about the potential consequences of the Klamath Reclamation Project operation plans on coho salmon in February 2001 (USBR 2001a) and shortnose and Lost River suckers in March 2001 (USBR 2001b). As part of the Biological Assessments, the USBR also released a 2001 Operation Plan for the Klamath Project. In response, the USFWS and NMFS produced separate Biological Opinions in April 2001 examining the Biological Assessments and Project Operation Plan (USFWS 2001; NMFS 2001). The USFWS Biological Opinion addressed the consequences of surface water management on endangered suckers and threatened bald eagles (*Haliaeetus leucocephalus*), and the NMFS Biological Opinion addressed the consequences of surface water and groundwater management on Klamath River flows necessary for threatened coho salmon. The USFWS and NMFS included jeopardy decisions in their Biological Opinions.

In 2002, USBR released a new Biological Assessment covering a 10-year time period (April 1, 2002 through March 31, 2012) that included operations affecting the Upper Klamath Lake and the Klamath River, and USFWS and NMFS responded by issuing 2002 Biological Opinions as well. We do not evaluate the decisions made in these 2002 documents but do briefly discuss how water management differs from the 2001 documents. In the following section, we describe water management of Upper Klamath Lake under these plans in more detail.

Recent History of Water Management under the Klamath Reclamation Project

The challenge of lake level management discussed in this report is to concurrently:

- Provide sufficient instream flows for the Klamath River below Iron Gate Dam, and
- Provide sufficient lake levels in Upper Klamath Lake.

In 2001 and 2002, USBR used one classification system to define types of “water years” for managing water in both Upper Klamath Lake and the Klamath River. This system classifies years into four categories based on precipitation: above average, average, dry, and critically dry years (Table 3). Classification is based on the Natural Resource Conservation Service forecasts of net inflow to the lake between April and September, expressed in acre-feet (Table 3). Initial forecasts are made on April 1 and revised monthly thereafter. Beginning in 2003, USBR will continue to use the four category system described above to manage Upper Klamath Lake but will use a five-category system to manage the Klamath River: wet, above average, average, below average, and dry years (Table 4; Rasmussen, J., pers. comm. [5]). These five categories were originally defined by NMFS (2002) and are based on exceedence values for inflow volume into Upper Klamath Lake.

Table 3. Definition of water years used by USBR (2001a and 2001b), USFWS (2001), and NMFS (2001) for both Upper Klamath Lake and Klamath River during 2001 and 2002. Net inflow into Upper Klamath Lake is predicted for the period from April through September. Beginning in 2003, these four water year types will only be used to manage Upper Klamath Lake by USBR and USFWS.

Water Year Type	Net inflow into Upper Klamath Lake (acre-feet)
Above-average	> 500,400
Below-average	312,800 to 500,400
Dry	185,000 to 312,000
Critical Dry	<185,000

Table 4. Five-category system to define water year types for managing flows in the Klamath River as recommended by NMFS (2002)[1]. Beginning in 2003, USBR will use this system to manage flows in the *Klamath River*, in contrast with a four-category system (Table 3) to manage *Upper Klamath Lake* [2].

Water Year Type	Upper Klamath Lake Inflow Volume
Wet	10%
Above-average	30 %
Average	50 %
Below-average	70 %
Dry	90 %

[1] Water year categories are based on monthly exceedence flows in Hardy and Addley (2001a). NMFS (2002) selected exceedence flows that typified unimpaired monthly flows during each water year type.
[2] Rasmussen, John. Personal Communication. 2003. USBR Klamath Falls, Oregon.

Water management levels for Upper Klamath Lake are based on elevation of the lake's water surface and are reported in feet above mean sea level not as lake depth. As we discussed previously, construction of Link River Dam allows the level of Upper Klamath Lake to be controlled. Water management is the quantity of water discharged from Iron Gate dam, expressed in cubic feet per second (cfs). The year 2001 was classified as "critical dry". The range of Upper Klamath Lake end-of-month elevations in feet above mean sea level for "critical dry" years are portrayed in Figure 8. The range of Klamath River discharge statistics in cubic feet per second for "critical dry" years are portrayed in Figure 9.

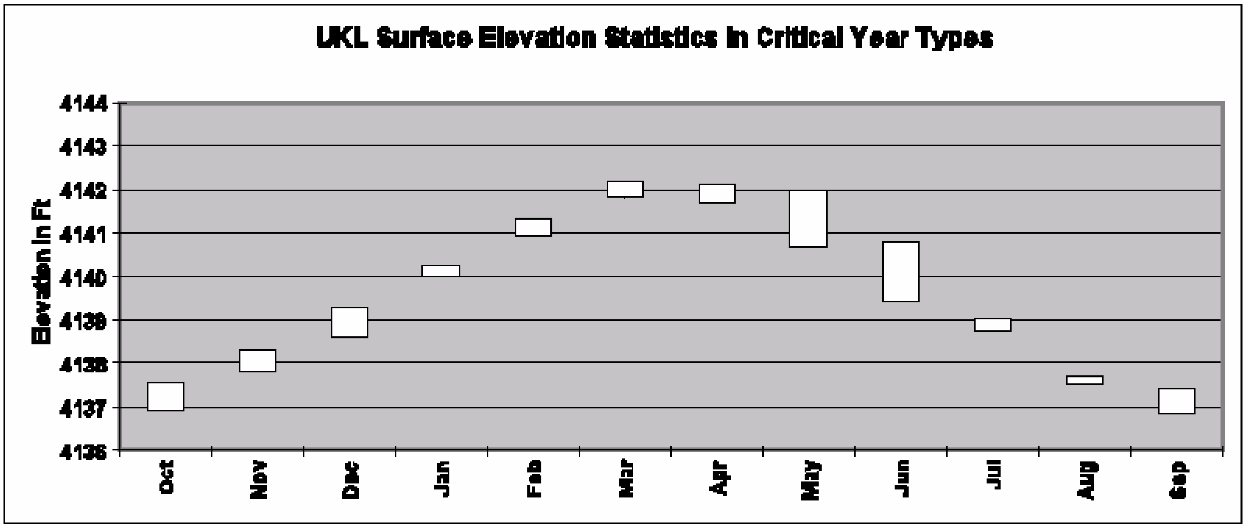

Figure 8**.** Upper Klamath Lake end-of-month elevations for critical years, which were less than 6% of the record from 1960-1998. A "critical" water year type is defined as having inflow less than 185,000 acre-feet. The upper and lower bounds of the boxes represent the average +1 standard deviation and the average -1 standard deviation respectively. From USBR (2001b).

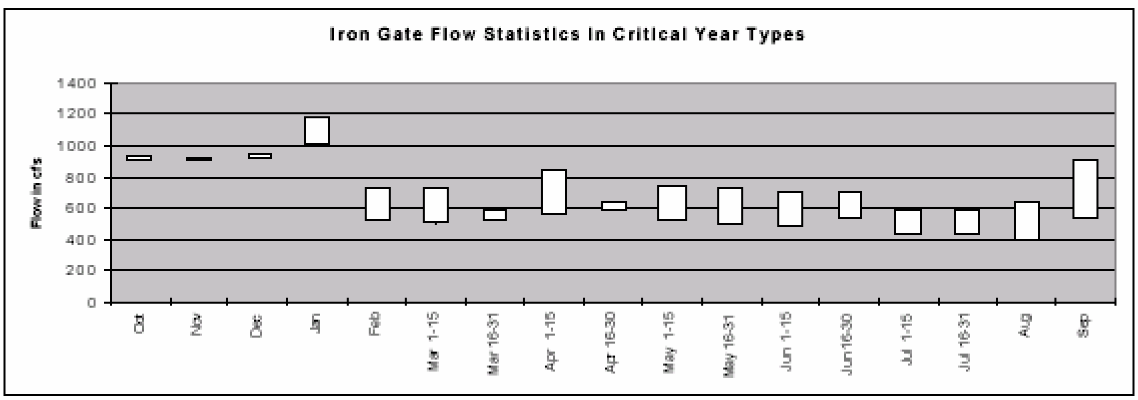

Figure 9. Instream flow (discharge) statistics at Iron Gate dam for critical dry water years. The upper and lower bounds of the boxes represent the average +1 standard deviation and the average -1 standard deviation respectively for years between 1968 - 1998. From USBR (2001b).

The USBR, USWFS, and NMFS released several management documents since 1990. In the following sections, we briefly describe some key features of these plans with respect to Upper Klamath Lake and the Klamath River. These sections emphasize water management in 2001. The chronology of recommended lake levels for Upper Klamath Lake is listed in Table 5 and the chronology of recommended flows for the Klamath River is listed in Table 6.

Upper Klamath Lake

For critical dry years such as 2001, the USBR proposed a minimum lake level of 4,136.8 (USBR 2001b). In their 2001 Biological Opinion, USFWS determined that this minimum lake level was too low for operations in 2001. The minimum lake level proposed by USBR was also lower than called for in an extreme year in the 1992 USFWS Biological Opinion, which called for a minimum lake level in Upper Klamath Lake of 4,139 ft in at least 6 out of the 10 years covered by the document (USFWS 1992). However, lake levels could go as low as 4137 ft in 4 of the 10 years, as long as these lower levels did not occur in two consecutive years (Table 5).

Table 5. Minimum lake elevations (feet above sea level) for Upper Klamath Lake in late summer proposed for "critical dry" water years (such as the year 2001) in recent Biological Opinions and Biological Assessments. The lowest minimum monthly lake elevations for the year are in bold.

	1992 USFWS Biological Opinion	2001(b) USBR Biological Assessment	2001 USFWS Biological Opinion[1]	2002 USBR Biological Assessment
April	4141.0	4141.1	4142.5	4141.9
May	4141.0	4140.4	Month not specified	4141.4
June	4139 (**4137**)[2]	4139.5	4142.5	4140.1
July	4139 (**4137**)[2]	4138.8	4141.5	4138.9
August	4139 (**4137**)[2]	4137.5	4141.0	4137.6
September	4139 (**4137**)[2]	**4136.8**	4140.5	**4137.1**
October	4139	4136.9	**4140.0**[3]	4137.3

[1] Lake level is regardless of water year type

[2] The minimum surface elevation could not be lower than 4,137 ft above mean sea level for more than 4 years out of the 10-year period and these lower levels could not occur in any two consecutive years.

[3] The original 4140.0 level was amended to 4139.0 (as discussed in text).

In 2001, the USFWS concluded that more protective management for suckers was necessary because several major fish kills had occurred during the operation plan established by their 1992 Biological Opinion (USFWS 2001). In their 2001 Biological Opinion, USFWS noted that lake levels alone would not prevent fish kills, but that lake level is a factor contributing to conditions that lead to fish kills (USFWS 2001). Therefore, the 2001 USFWS Biological Opinion called for a minimum lake level of 4,140 ft for 2001 to reduce the chances of adverse conditions that caused previous fish kills.

By the end of the 2001 water year, actual delivery of water to the Klamath Project from Upper Klamath Lake and the Klamath River (via the A-canal, North Canal, and ADY Canal of the Klamath Reclamation Project; Figure 6) was 71,520 acre-feet (J. Rasmussen, pers. comm.). The total amount of water delivered in 2001 from Upper Klamath Lake and the Klamath River was lower than the average delivery during 1991 through 2000 (Rykbost and Todd 2002).

Water was also delivered to the project from other reservoirs in 2001. In the "Eastside Project", 65,450 acre-feet were delivered from Clear Lake and 36,590 acre-feet were delivered from Gerber Lake. The total amount withdrawn from Clear and Gerber (102,040 acre-feet) was the highest withdrawal in 40 years, partially because some geographic areas usually served by Upper

Klamath Lake received water from Clear and Gerber Lakes instead (J. Rasmussen, pers. comm.)[4].

In 2002, USBR released a new Biological Assessment that proposed minimum lake levels for Upper Klamath Lake for a 10-year time period from April 1, 2002 through March 31, 2012 (Table 5). The USFWS Biological Opinion (2002) did not propose different management criteria, but did conclude that the proposed lake levels would substantially reduce the area of habitat available for larvae, juvenile, adult spawning, and access to deep water refuge.

Klamath River

For critical dry years, such as 2001, the USBR proposed a minimum instream flow below Iron Gate Dam of 398 cfs in their 2001 Biological Assessment (USBR 2001b). In their 2001 Biological Opinion, NMFS determined that this minimum instream flow was too low. USBRs proposed minimum flow for critical dry years was also lower than the range of flows (600-900 cfs) that had occurred from 1992 to 2000. The 2001 NMFS Biological Opinion called for minimum river flows of 1,000 cfs in the Klamath River below Iron Gate Dam, based on historical and recent analyses of instream flow requirements (discussed in Science Question 4). However, USFWS and NMFS realized that under the drought conditions of 2001, lake levels could not be maintained at or above 4,140 ft while releasing 1,000 cfs from Iron Gate Dam during late summer**.** Therefore, USFWS amended the original 4140.0 level to 4139.0. Throughout the 2001 water year, actual flows in the Klamath River generally remained above 1,000 cfs (see Science Question 4 for further discussion).

The 2002 NMFS Biological Opinion calls for considerably higher minimum flows in the Klamath River than USBR identified, but recognizes that water management agencies and users could not immediately meet those flows without difficulty (Table 6). Therefore, from 2003 through 2005, NMFS will allow the minimum flows proposed in the USBR 2002 Biological Assessment (Table 6). From 2005 to 2010, NMFS calls for water managers and water users to develop multiple actions (e.g., cooperative actions between USBR, State of California, and State of Oregon; water banking and conservation; alternative water sources; more efficient irrigation practices) to meet the flows proposed by the 2002 NMFS Biological Opinion. By 2010, NMFS expects the minimum flows represented in Table 6 to be met through such multiple actions.

[4] Rasmussen, John. Personal Communication. 2003. USBR, Klamath Falls, Oregon.

Table 6. "Critical dry" water year proposed minimum summer monthly flows for Klamath River below Iron Gate Dam. The lowest minimum monthly flows are in bold.

	2001(b) USBR Biological Assessment	2001 NMFS Biological Opinion	2002 USBR Biological Assessment	2002 NMFS Biological Opinion[1]
		(cfs)		
April 1–15	569	1,700	874	1,500
April 16–30	574	1,700	773	1,500
May 1–15	525	1,700	633	1,500
May 16–31	501	1,700	608	1,500
June 1–15	476	2,100	591	1,400
June 16–30	536	1,700	619	1,400
July 1–15	429	**1,000**	**501**	**1,000**
July 16–30	427	**1,000**	**501**	**1,000**
August	**398**	**1,000**	517	**1,000**
September	538	**1,000**	722	**1,000**

[1]Proposed flows in NMFS (2002) Biological Opinion refer to a "dry" water year instead of "critical dry" water year. NMFS (2002) uses a different system to define water years, and the system does not have a "critical dry" water year type (Table 4).

Report Organization

The remainder of this report is divided into four major sections:

Science Questions and Answers. This section presents four broad questions posed by the IMST, which the Team considers to be most important to resolving the scientific debate about the science presented in the USFWS and NMFS 2001 Biological Opinions. In this report, we address the following science questions:

Part I: Upper Klamath Lake and Resource Management Issues:

Science Question 1: What is the status of sucker populations in Upper Klamath Lake? Are these populations continuing to decline?

Science Question 2: What are the major factors responsible for fish kills in Upper Klamath Lake? Are these factors influenced by lake level?

Science Question 3: Will management of lake levels have significant effects on the survival of sucker populations?

Part II: Klamath River and Resource Management Issues:

Science Question 4: Are the NMFS (2001) determinations of minimum flow requirements for coho salmon in the Klamath River below Iron Gate Dam based on the best available science?

In previous reports, the IMST has consistently advocated for a landscape approach to natural resource management (e.g., IMST 1999a, IMST 2002). Whenever possible in this report, we have attempted to describe the context of changes to the landscape of the Klamath Basin that impact the hydrology and the native fishes of the region. Nevertheless, the technical questions that we felt were important to address in this report can be grouped into questions about Upper Klamath Lake and about Klamath River below Iron Gate Dam. To help the reader locate information in this report, we have divided the four science questions into two parts, which correspond with the two regions of the basin. Findings and conclusions specific to each region can be found at the end of each part. The findings and conclusions are based on the answers to the science questions.

The answers to each science question are organized conceptually. However, the IMST tries to identify differences in conclusions among the various reviews. In particular, we directly address issues raised by an interim report produced by a National Research Council panel (NRC 2002). We chose to emphasize points raised by the NRC (2002) because of the prominence of this review panel and the potential weight the NRC review may have on management decisions. The conclusions of the OSU-UC Davis report (Braunworth et al. 2002) and University of California Peer Review (University of California 2001) also are emphasized.

Landscape-level Conclusions. This section summarizes the IMST's conclusions that are not specific to either Upper Klamath Lake or the Klamath River. The conclusions are based on the answers to the science questions.

Recommendations. These are the specific recommendations of the IMST to the State of Oregon and its agencies.

Part I. Upper Klamath Lake And Resource Management Issues

In this section, we present the answers to three science questions related to the management of Upper Klamath Lake to promote the survival of endangered Lost River and shortnose suckers. These three questions are highly interrelated. In the first question, we briefly review the status of sucker populations in Upper Klamath Lake. We discuss the evidence that populations have declined from historical levels and evidence that the populations are continuing to decline. In the second question, we describe environmental factors associated with fish kills and the relationship of these factors with the volume of water in Upper Klamath Lake, or “lake level”. In the third question, we evaluate the scientific evidence that management of “lake level” can influence survival of sucker populations. We emphasize how management of lake level can impact habitat quantity and quality, juvenile production, and the probability of fish kills.

Science Question 1. What is the status of sucker populations in Upper Klamath Lake? Have these populations declined, and are these populations continuing to decline?

Long-term Declines in Sucker Abundance in Upper Klamath Lake

Anecdotal evidence indicates that sucker populations in Upper Klamath Lake were historically large and supported a substantial local fishery. For example, Foster (2002) reported that until 1900, Modoc and Klamath Indians caught at least 50 tons of suckers per year at a single Lost River location. Concerns over population abundance of suckers in Upper Klamath Lake were raised after Bienz and Ziller (1987) conducted population estimates on the lower Williamson and Sprague Rivers in the mid-1980s.

Lost River and shortnose suckers were listed as endangered under the ESA in 1988, and under the California ESA in 1974. The decision to list both species as endangered (Bienz and Ziller 1987; USFWS 1988) and several subsequent assessments (Scoppetone and Vineyard 1991; USFWS 1992; USFWS 2001) concluded that sucker populations have declined sharply from historical population abundances. The USBR identified several major factors that were related to the declines of the sucker populations including dams, water diversions out of the lake, drainage of marshes around the lake, over harvest of suckers in the lake and its tributaries, competition with exotic fish species, and lake eutrophication (USBR 1992). As we describe below, little quantitative information on population trends is available prior to 1995 (when index sampling was initiated as a relative measure of sucker abundance; Perkins et al. 2000b).

Recent Trends in Abundance

In the 2001 Biological Opinion, USFWS evaluated the evidence that these two sucker species have declined since the agency’s 1992 Biological Opinion (USFWS 2001). They concluded that:

> “It is unclear what annual LRS [Lost River sucker] and SNS [shortnose sucker] population sizes are in UKL [Upper Klamath Lake]. However trends are apparent, although the available information should be used with extreme caution when drawing conclusions about annual changes in population size. The available data are generally not statistically robust and therefore of limited use for inter-annual comparisons” (USFWS 2001, Section III, Part 2, p. 45).

In support of the statement that “trends are apparent”, they offer the following evidence,

> “By 1995, there was an increase in the numbers of spawning adults in the Williamson and Sprague rivers due to recruitment of the strong 1991 year class (Perkins et al. 2000[b]). However, fish kills in 1995, 1996 and 1997 apparently had a substantial negative effect on sucker population sizes and age class distributions. From 1995 to 1997 there was a substantial decline in the number of adults making spawning runs in the Williamson River, that amounted to an estimated 80-90% reduction in the adult population size for both LRS and SNS (Perkins et al. 2000[b]). Markle et al. (2000) found evidence that numbers of suckers in the Williamson River spawning migration in 1999 were still apparently depressed by loss of adults in 1995-1997 fish kills. However, for the 2000 spawning run, Cunningham and Shively (2001) found slightly higher abundance index values for LRS and SNS in the lower Williamson River than for the previous 3 years and an improved size-class distribution, indicative of possible improving population status” (USFWS 2001, Section III, Part 2, p. 45).

Biologists have captured adult suckers in the Williamson and Sprague Rivers since 1984 with trammel nets and by electrofishing (Figures 10 and 11; Perkins et al. 2000b). These fish are presumed to be moving into the tributaries to spawn, and returning to the lake after spawning (Perkins et al. 2000b). Decreasing numbers of fish were observed between 1995 and 1998, concurrent with three consecutive years of major fish kills (1995-1997) in Upper Klamath Lake (Perkins et al. 2000b; Figure 11). Comparison of Figures 10 and 11 (note differences in scale) also suggests spawning may have occurred over a shorter period in the 1980s in comparison to the 1990s (Perkins et al. 2000b). During the electrofishing in 1984 and 1985, only three suckers were observed during ten days of sampling in March (Figure 10), while a peak in catch per unit effort for Lost River suckers was observed in March in 1995-1997 (Perkins et al. 2000b).

Relative abundance index information (such as catch per unit effort) for both Lost River and shortnose suckers from 1995-2003 suggests that population levels were higher in 1995 and steadily decreased in the years following the fish kills of 1995-1997 (Perkins et al. 2000b). These populations after 1997 have not shown any indications that they have recovered to levels prior to the fish kills (Rip Shively, pers. comm.[5]).

[5] Shively, Rip. Personal Communication. 2003. USGS Biological Resources Division, Klamath Falls, OR.

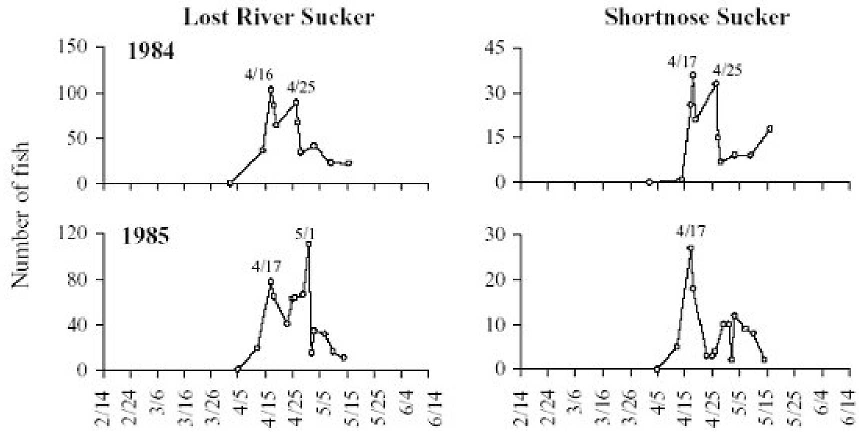

Figure 10. Abundance of adult Lost River and shortnose suckers captured by electrofishing (1984-1985). Figure reproduced from Perkins et al. (2000b). Electrofishing was conducted in a 7.3 km stretch of the Williamson-Sprague river system by C. Bienz (Klamath Tribes) and J. Ziller (ODFW). Note the differences in scale among the x-axes.

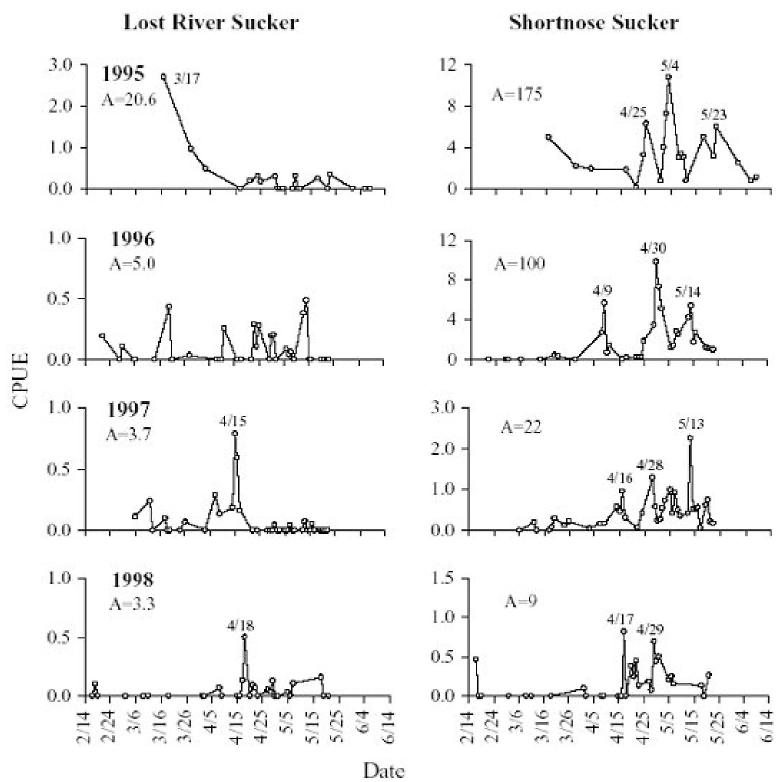

Figure 11. Catch per unit effort (CPUE) of adult Lost River and shortnose suckers captured by trammel nets (1995-1998) in the lower 1 km of the Williamson River. Figure reproduced from Perkins et al. (2000b). The abundance index (A) represents the sum of the daily mean catch per unit effort (CPUE) values. Note the differences in scale among the x-axes.

As we will discuss in the following section (page 44), the fish kills in the mid-1990s followed a period when production of juvenile suckers was high. This recruitment of young fish was likely from the 1991 and 1993 year classes. These year classes were just beginning to recruit into the adult population when major fish kills occurred in 1995, 1996, and 1997 (as indicated by the age data from fish recovered in those kills). The increase in total numbers to the adult population was likely in the low hundreds of thousands (Markle and Cooperman 2002).

While the USFWS (2001) was conservative about the conclusions they drew about trends in sucker abundance in Upper Klamath Lake over the past decade, all subsequent reviews, including Markle et al. (2001) were even more conservative. Estimations of fish populations in large lakes are extremely difficult and variation in estimates is generally high. Gear selectivity for different species, ages, habitats, and season introduce error that is difficult to quantify. Markle and Cooperman (2002) conclude that there is no clear evidence that populations have continued to decline between 1990 and 2000.

The NRC (2002) pointed out that empirical data from the mid-1990s (number of fish observed in fish kills) revealed that sucker populations were larger than the USFWS had estimated in the 1980s:

> "During the 1980s, qualitative evidence indicated that declines might have reduced the sucker populations in Upper Klamath Lake to just a few thousand old (greater than 10 years) fish (USFWS 1988). More recent estimates that were made possible incidentally by episodes of mass mortality suggest, however, that the populations are considerably larger than they appeared to be in the 1980s …" (NRC 2002, p.11-12).

This statement could easily be misinterpreted to mean that the NRC concluded that sucker populations have not declined. The NRC intended this statement to mean that recent population estimates are more accurate than early estimates, and it is possible that sucker populations have not changed over the last two decades (D. Policansky, pers. comm.[6]).

The IMST knows of no information or population estimates that would indicate that the sucker populations have remained the same since the 1980s. The loss of more fecund older fish (which produce more offspring than young fish) from Upper Klamath Lake populations (as indicated by ages of fish in fish kills) indicates that present populations are not as resilient as former populations. Hence, current populations warrant protection measures (e.g., management of lake levels, habitats for critical life stages, protection of spawning areas, migration routes).

Unfortunately, data available on sucker abundances in Upper Klamath Lake are based on a variety of indices of population size. It is extremely difficult to accurately estimate the total abundance of fish or other aquatic organisms in large ecosystems like Upper Klamath Lake. The fish are distributed unevenly throughout a large area. Their vulnerability to capture differs by fish species, fish size, habitat type, and gear type. In many cases, time, financial effort, and limitations in sampling methodology prohibit accurate estimates of total abundance. Faced with these difficulties, fisheries scientists use alternative quantitative approaches to estimate approximate numbers of fish in a population or trends in those numbers. In this case, biologists may quantify relative abundance. Thus, using a consistent sampling methodology over a number of years, one can assess a trend in relative abundance over time. In other words, it may be

[6] Policansky, David. Personal Communication. 2003. NRC Committee on Endangered and Threatened Fishes of the Klamath River Basin. Washington, D.C.

possible to determine whether a population is increasing or decreasing in size without knowing the exact total number of fish in the lake at any given time. In Upper Klamath Lake, the variety of sampling methods used over the last 30 years provides a very general measure of trends in abundance. **The IMST strongly encourages federal and state management agencies to ensure the continuation and consistency of recent fish population measurements (e.g., monitoring programs developed by Oregon State University and USGS) to provide more rigorous measures of the status of sucker populations in Upper Klamath Lake.**

Changes Age Structure of Suckers in Upper Klamath Lake

A population's age structure indicates the proportion of individuals in different age groups within a population. Both Lost River and shortnose suckers have long life spans and reproduce for the first time at late ages. Lost River suckers can live to be more than 43 years old and begin reproducing at 7-9 years of age, while shortnose suckers are known to live up to 33 years and begin reproducing at 6-7 years of age (Markle and Cooperman 2002). According to all documents reviewed by the IMST, the age structure of sucker populations in Upper Klamath Lake has changed over approximately the last decade.

Evidence that supports the change in sucker age structure in Upper Klamath Lake comes from fish collected during major fish kills. In particular, a fish kill from 1986 has been compared with several fish kills in the 1990's (1995, 1996, and 1997). A sample of 190 Lost River suckers collected during a 1986 fish kill showed most of the population to be greater than 15 years old (Figure 12; Scoppetone and Vinyard 1991).

In contrast, the majority of dead fish collected in fish kills in 1995, 1996, and 1997 were younger than 10 years old (see Figure 13 for data from 1997; USBR 2001b). The 1991 year-class was the predominant year class represented in each year of the kill, with age 4+ fish dominating the 1995 kill, age 5+ fish dominating the 1996 fish kill, and age 6+ dominating the 1997 fish kill.

The major recruitment of young suckers after the 1987 year-class likely reflects the effects of closing the sucker fishery (Figure 13). However, older fish -- which were a major portion of fish observed in the 1986 fish kill -- were poorly represented in the 1997 fish kill. This may indicate that adult fish had already died and therefore were a small fraction of the population in 1997. Assuming samples shown in Figures 12 and 13 are both representative of the population in Upper Klamath Lake, a major population shift to younger fish occurred after 1986. This is particularly troubling in light of the decreased numbers of tributary spawners observed between 1995 and 1997 (Figure 11; Perkins et al. 2000b).

A modified (truncated) version of Figure 13 also was included in the NRC report (Figure 14; NRC 2002), but it does not include all dead fish observed in the die-offs. The complete sample of the 1997 fish kill is illustrated in Figure 13 for comparison.

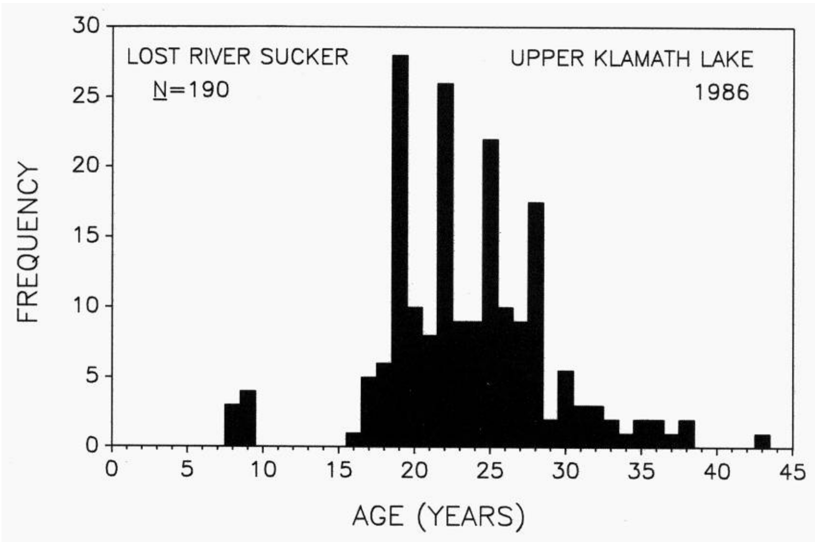

Figure 12. Ages of Lost River suckers sampled in 1986 from a fish kill. Reproduced from Scoppettone and Vinyard (1991).

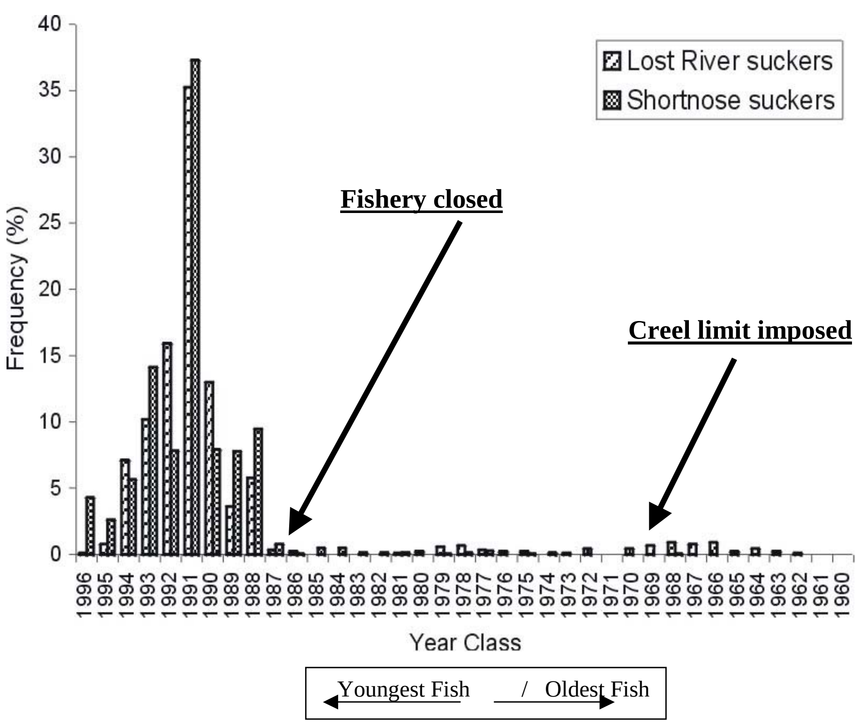

Figure 13. Estimated age distribution (abundance by year class or year of birth) of Lost River and shortnose suckers collected from the 1997 fish kill in Upper Klamath Lake. Creel limits were established in 1969 and the fishery on suckers was closed in 1987. Frequency (%) is the percentage of total carcasses collected during the fish kill. (USGS, unpubl. data, as reported in Markle and Cooperman 2002).

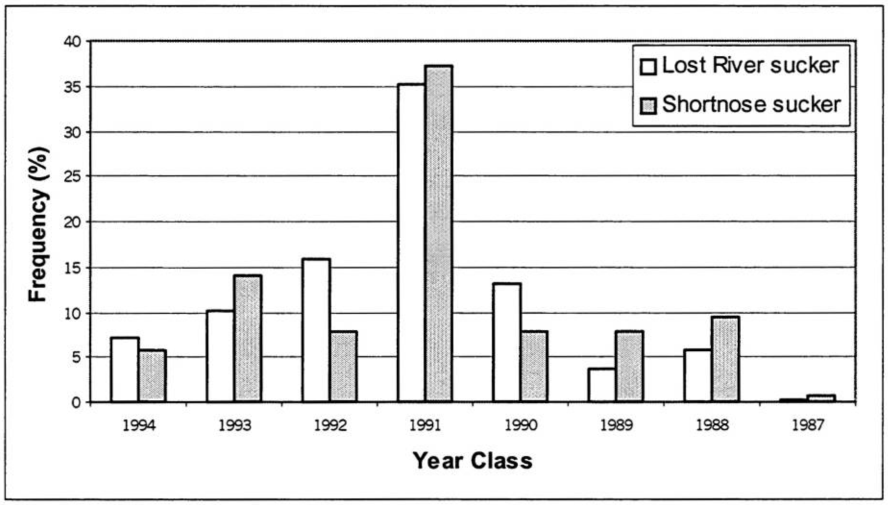

Figure 14. Partial age distribution of Lost River and shortnose suckers collected from the 1997 Upper Klamath Lake fish kill. This figure represents selected year classes (1987-1994); see Figure 13 for all fish observed in the 1997 die-off. Frequency (%) is the percentage of total carcasses collected during the fish kill. (USGS and USFWS, unpubl. data, as reported in NRC 2002).

Differential Mortality of Suckers by Age Class

As we will discuss in more detail in Question 2, the fish kills in Klamath Lake in 1995, 1996, and 1997 may be related to hypoxia [low dissolved oxygen levels] present at the time. The tolerance levels of the suckers to low dissolved oxygen (96 hr LC_{50}[7] of 1.6 mg/L for Lost River and 1.3 mg/L for shortnose sucker; Saiki et al. 1999) appear to approximate the low dissolved oxygen levels present in the lake (Perkins et al. 2000a). One caveat is that these tolerance tests were conducted with life history stages considerably younger than those accounted for in the fish kills, and the specific tolerance to low dissolved oxygen of either sucker species in the size ranges found dead in the lake is unknown. Further, Perkins et al. (2000a) suggested that the larger fish tended to be more susceptible to hypoxia-related mortality than smaller individuals. They propose that this can be explained by the fact that larger individuals are oxygen-limited because of their greater biomass relative to gill surface area. Both contentions appear to be inferences rather than conclusions.

At this time it cannot be clearly, scientifically established whether or not larger individual suckers were more susceptible to low dissolved oxygen than smaller individuals. Perkins et al. (2000a) determined the length frequencies of dead fish in the kills from a sampling scheme not designed to proportionally sample fish in the lake (R. Shively, pers. comm.[8]). The lead scientist for the fish kill inventories indicated that smaller suckers are more likely to be mixed with other fish (e.g., bluegill, minnows, younger fish of all species) that have small body sizes. Large suckers are larger than any other species in the lake and their size makes them more visible from a distance. Therefore, it is thus possible that the collection of dead fish was biased towards larger individuals. Casselman and Harvey (1975) may have encountered a similar difficulty, supporting the contention that larger individuals of a species are more likely affected by low dissolved oxygen. While it is possible that larger fish succumbed during a winter die-off [researched by Casselman and Harvey (1975)] in greater relative proportion than smaller individuals, this is based on inference and not conclusive science. However, in chapters of the USFWS Field

[7] LC_{50} refers to the concentration of a substance that is lethal to 50 percent of the individuals being tested in a laboratory setting.
[8] Shively, Rip. Personal Communication. 2003. USGS Biological Resources Division, Klamath Falls, Oregon.

Manual for the Investigation of Fish Kills (Meyer and Barclay 1990), both Hunn and Schnick (1990) and Meyer and Herman (1990) indicate that low dissolved oxygen kills the larger fish of a population to a greater extent than it kills smaller fish. While the literature certainly appears to be clouded on the relationship of size to low dissolved oxygen, the seminal review by Doudoroff and Shumway (1970) states that “young fish are believed to be less resistant to O_2 deficiency than older and larger individuals, because of their generally higher metabolic rates”.

Implications of Change in Age Structure
The presence of young fish in the population is an indication that young fish are being recruited into the population, though reproduction does not occur until 6-7 years of age in shortnose suckers and 7-9 years of age in Lost River suckers. The low abundance of large suckers in recent fish kills raises concerns about the potential contribution spawning suckers make to the populations. A relative increase in younger–and therefore smaller–fish in the population could mean that fewer fish are mature and that fecundity[9] of spawning individuals will be lower. This is because larger, older females produce more eggs and more viable eggs in many fish species. Lost River suckers produce 44,000-236,000 eggs per female, and shortnose suckers produce 18,000-72,000 (Perkins et al. 2000b). Therefore, if older individuals are lost from the population, fewer eggs (roughly one-third as many) will be produced at equal population abundances. If a population is recruitment-limited, we would expect recruitment to be lowered while these younger fish mature

No formal population viability or extinction risk studies have been conducted, but these changes in age structure likely increase the risk of extinction. For many long-lived fish species with delayed maturation (such as Lost River and shortnose suckers), juvenile survival is highly variable; therefore, protection of adults is crucial to maintain a robust population (Winemiller and Rose 1992).

Summary of Science Question 1
From our review of available reports, IMST concludes that current sucker populations in Upper Klamath Lake exhibit a higher proportion of younger fish than populations in the 1980’s, and sucker populations have declined from historical levels. Estimating sucker population size and trends in a large lake like Upper Klamath Lake is extremely difficult. Although federal, Tribal, and state agencies have increased their investigations over the last two decades, current databases require additional information. At this time, it is not possible to accurately determine the current total abundance of suckers in Upper Klamath Lake or the trend in abundance over the past 15+ years with reliability.

Science Question 2. What are the major factors responsible for fish kills in Upper Klamath Lake? Are these factors influenced by lake level?

Fish kills, or fish die-offs, in Upper Klamath Lake over the last 20 years are well documented. The long-term history of fish kills before this period is poorly documented, though fish kills are likely in shallow productive lakes. The noted ichthyologist, C.H. Gilbert then of Stanford University, first documented a fish kill of suckers in June 1894. Other fish kills were observed in 1932, 1971, and 1986 (Perkins et al. 2000b). In recent years the USFWS has attempted to

[9] Fecundity is defined as the number of offspring an individual produces.

quantify the size and timing of fish kills in Upper Klamath Lake. Major die-offs occurred in three consecutive years in the mid-1990s: 1995, 1996, and 1997 (USBR 2001b). Identifying the cause of the fish kills in Upper Klamath Lake in the last decade has been of particular interest because of concern about the status of sucker populations. Fish kills almost entirely occur during summer, although researchers have also raised the possibility that winterkill events could occur in Upper Klamath Lake (Simon and Markle 2001).

Proximate Causes of Fish Kills and Relationship of These Factors to Lake Level

The proximate cause of fish die-offs is poor water quality conditions, either toxicity of lake water or inadequate concentrations of dissolved oxygen. Complex ecological and chemical changes in Upper Klamath Lake lead to the exposure of fish to these poor water quality conditions. In this section, we describe the series of events that lead to low dissolved oxygen or toxic conditions in the lake, the processes that expose fish to these conditions, and the relationship of lake level to these processes. As we will demonstrate, Upper Klamath Lake is a highly complex system, and the processes that expose fish to low dissolved oxygen are closely related to those that expose fish to toxic conditions. In the following section, we discuss how current and historical patterns of land use have contributed to low water quality in Upper Klamath Lake.

In an idealized lake in temperate latitudes (Figure 15), the sun warms lake water, which causes differences in water density that prevent or impede complete mixing of the lake (Hutchinson 1957). Just as oil and water do not mix, cooler (below 4°C), high density water at the bottom of the lake does not mix readily with the layer of warmer, less dense water near the surface.

The major force responsible for mixing water in lakes is wind at the lake surface. During early summer, wind speeds may not be sufficient to mix warm water down to the lake bottom. This resistance to mixing can lead to distinct thermal-density strata, which are termed the epilimnion, metalimnion, and hypolimnion in a thermally stratified lake. If mixing in a lake is limited, oxygen from the atmosphere cannot diffuse effectively into the lower portion of the lake. As a result, dissolved oxygen concentrations may be far less than saturation near the lake bottom.

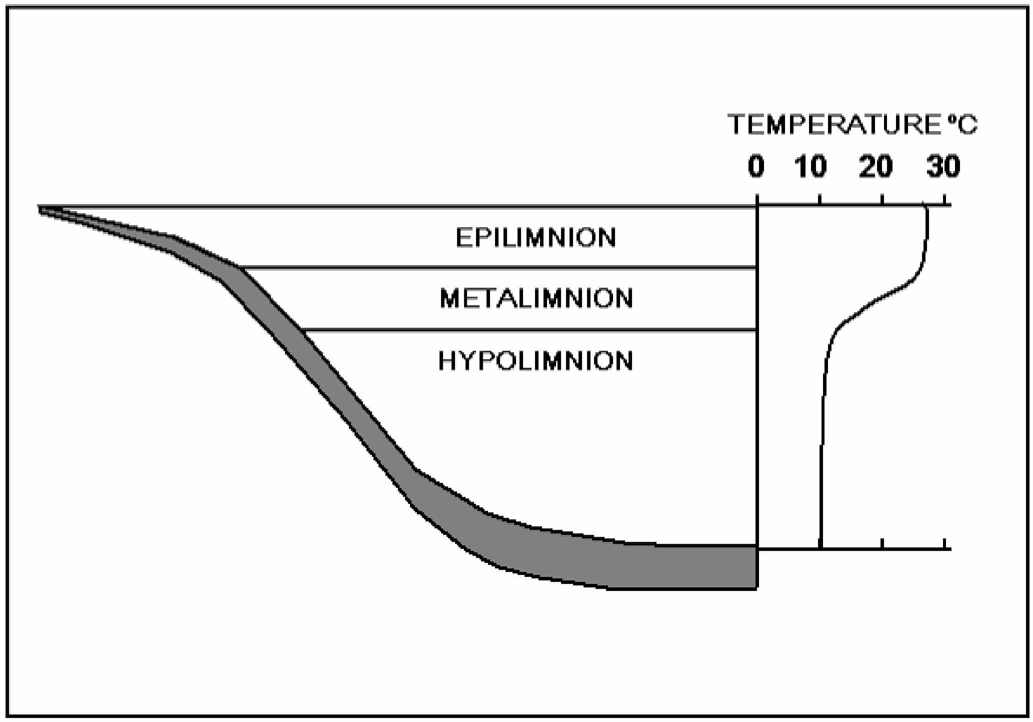

Figure 15. Diagram of thermal stratification of a lake and a typical temperature profile in a deep stratified lake. As we describe in the text, Upper Klamath Lake is a shallow lake, and does not fit this idealized portrayal. A thermal profile of Upper Klamath Lake is presented in Figure 16.

In contrast to this idealized description of a lake, Upper Klamath Lake is shallow (see Table 1, Figure 3), and wind completely mixes the lake frequently during summer. Upper Klamath Lake is a **polymictic** lake under the Hutchinson (1957) classification system. A polymictic lake experiences frequent and irregular periods of **holomixis**, or complete mixing. The closest example of this condition is illustrated in the temperature profile for August 27 in Figure 16B. Even on this date dissolved oxygen concentrations were 2°C warmer at the surface than at a depth of 1 m and dissolved oxygen concentrations were more than 2 mg/L higher at the surface. On other dates (7/2, 7/16, 8/12), the difference in temperature between the surface and water at a depth of 3 m was 3-6 °C and dissolved oxygen concentrations decreased to as low as 3 mg/L at the 3-m depth (Figures 16A and B). This illustrates the potential for the lake to exhibit resistance to mixing because of temperature differences between surface waters and deeper water. As a result, dissolved oxygen concentrations may also be 1) higher on the surface where oxygen is supplied by diffusion from the atmosphere and by photosynthesis by phytoplankton and 2) lower in deeper water where removal of oxygen by microbial activity is greatest and supply of oxygen by photosynthesis is limited because of decreased light intensity.

The pattern of wind speed through the year is an important determinant of mixing in a large shallow lake like Upper Klamath Lake. During summers with low wind speeds and/or high temperatures, Upper Klamath Lake may experience periods of reduced mixing and lower dissolved oxygen concentrations. Summers with high winds and/or cooler temperature would exhibit more frequent mixing. While Upper Klamath Lake may not develop the sharply demarcated strata of a deep, thermally stratified lake, it experiences several periods of reduced mixing during most summers (Figure 16). During these periods of reduced mixing, dissolved oxygen concentrations in the deeper water can be far less than saturation and sufficiently low enough to stress organisms that require higher oxygen concentrations, such as suckers.

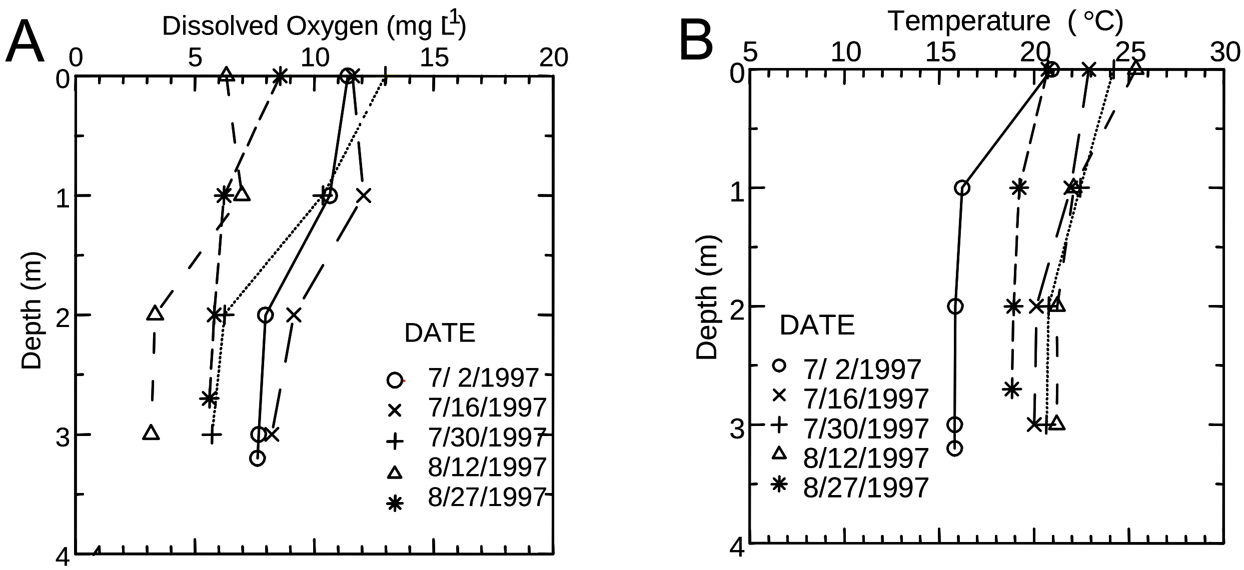

Figure 16. Vertical profile of (A) dissolved oxygen (B) temperature from Upper Klamath Lake during summer 1997, illustrating mixing on some dates and non-mixing on others. Data collected at Mid-North station site, and provided by Jake Kann, Aquatic Ecosystem Sciences.

In Upper Klamath Lake, even during periods when the lake is stable, nighttime cooling often causes a convergence of surface and off-bottom temperature and dissolved oxygen values (T. Wood, USGS, unpubl. data). Low dissolved oxygen is not caused by reduced wind mixing alone. High densities of phytoplankton in Upper Klamath Lake may reduce light at 1 m in depth to “almost complete darkness” (Welch and Burke 2001). Thus, reduced photosynthetic oxygen production and high respiratory demands for oxygen below the surface layer contributes to the low dissolved oxygen observed in Upper Klamath Lake when algal biomass is high.

In a productive lake, such as Upper Klamath Lake, oxygen is consumed through decomposition of dead organic matter (including phytoplankton) and by respiration of organisms. Organic sediments in Upper Klamath Lake have demands for oxygen, which can lead to oxygen depletion in the lake when the lake suddenly mixes or when sediments are suspended in the water column. This effect on oxygen concentrations is greatest when complete mixing has been prevented by thermal-density gradients and then high winds or cool periods lead to sudden increases in mixing. These conditions could lead to oxygen depletion and subsequent fish kills. With the high biological oxygen demand in the water column and sediment oxygen demand in Upper Klamath Lake, dissolved oxygen values can decline rapidly.

Oxygen consumption can also lead to a series of chemical changes in the lake that strongly influence water quality and effects on aquatic organisms:

- First, the addition of carbon dioxide as a result of biological respiration during decomposition leads to decreased pH [Note: In contrast, the high rate of carbon dioxide uptake through photosynthesis causes extremely high pH in the surface waters].
- Second, under low dissolved oxygen concentrations (or under concurrently low redox[10] potentials), nitrate molecules are converted to ammonium and unionized ammonia, which can be toxic. The proportion of unionized ammonia, the more toxic form, increases as pH rises, which occurs with increasing photosynthesis (Table 7; Deas and Orlob 1999).

All of these processes may create conditions that are potentially detrimental to aerobic organisms, such as fish, insects, zooplankton, and many plants (Wetzel 2001).

Table 7. Percentage of total ammonia as unionized ammonia in distilled water (APHA 1995 as reported in Deas and Orlob 1999). Note the substantially higher percentages of unionized ammonia (more toxic) at pH > 8.0 and influence of higher temperature.

Temp.	**Percentage unionized ammonia at given pH**									
ºC	(ºF)	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0
5	(41)	0.01	0.04	0.11	0.40	1.1	3.6	10	27	54
10	(50)	0.02	0.06	0.18	0.57	1.8	5.4	15	36	64
15	(59)	0.03	0.08	0.26	0.83	2.6	7.7	21	45	72
20	(68)	0.04	0.12	0.37	1.2	3.7	11	28	55	80
25	(77)	0.06	0.17	0.51	1.8	5.1	14	35	63	84
30	(86)	0.07	0.23	0.70	2.3	7.0	19	43	70	88

Processes that Expose Fish to Low Water Quality

When wind forces are great enough to cause mixing of deeper water with surface water, these low oxygen and toxic layers may come to the surface, killing fish that reside there. In a shallow, productive, polymictic lake like Upper Klamath Lake, these mixing events and subsequent exposure of fish to stressful conditions may be common (Wood et al. 1996). As an example, Welch and Burke (2001) found that the difference between the oxygen in surface water and water at the lake bottom are greatest in Upper Klamath Lake when the differences between density (temperature) in surface waters and bottom waters are greatest (Figure 17). However, these are not necessarily the times of absolute lowest dissolved oxygen concentrations. Fish kills occurred in 1995, 1996, and 1997 during periods of mixing after a period of high resistance to mixing. The periods of high resistance to mixing led to low oxygen concentration in the deeper water (Figure 17; Welch and Burke 2001).

[10] The redox potential is a measure of electronegativity, or the affinity of a substance for electrons, compared with hydrogen.

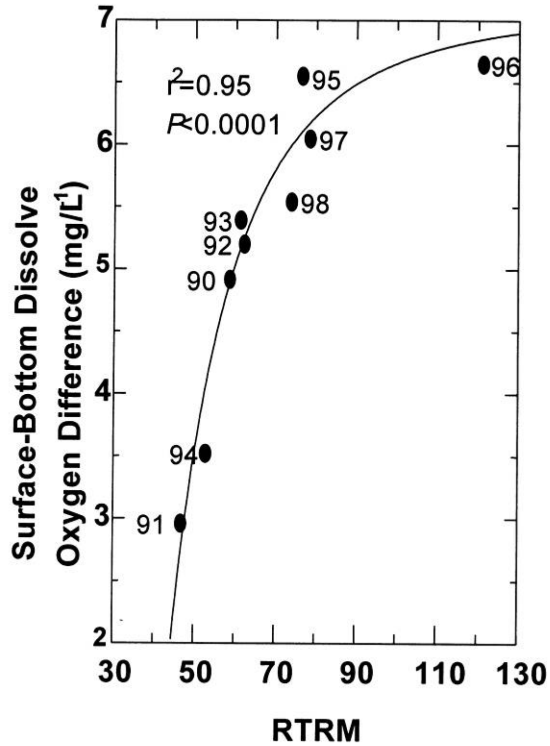

Figure 17. Mean relative thermal resistance to mixing (RTRM, a water column density index) relative to dissolved oxygen for July-August. From Welch and Burke (2001).

Fish kills and the factors linked to their occurrence are complex, and lake level can have opposite effects on factors that lead up the major fish kills. High lake elevations have been associated with both 1) greater abundances of larval and juvenile fish and 2) major fish kills. Larval and juvenile fish populations tend to be more abundant during years of higher stream flow and lake elevation (Table 8 on page 51). High densities of fish and potential crowding may contribute to adverse effects of environmental conditions. At the same time, records during the 1990s show that higher lake elevations have been associated with greater resistance to mixing and differences in dissolved oxygen between surface waters and lower depths have been greater during years (1995-1998) of high lake elevations (Figures 17 and 18). Major fish kills have occurred during years in which the lake elevations have been higher, resistance to mixing has been greater, and differences in dissolved oxygen between surface and lower waters have been greater (in particular, three years: 1995, 1996, and 1997). However, during 1993 and 1998, lake levels were also high and resistance to mixing was moderate, but no fish kills occurred.

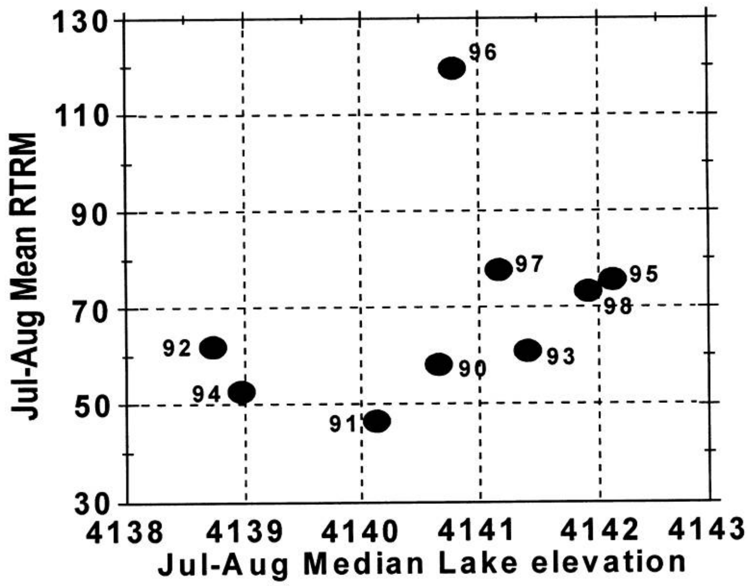

Figure 18. Relationship between lake elevation and mean relative thermal resistance to mixing (RTRM). Relative thermal resistance to mixing is a water column density index. From Welch and Burke (2001).

Phytoplankton blooms are another important ecological factor in exposing fish to stressful conditions, including high pH and low dissolved oxygen. Rapid increases in phytoplankton abundance are more likely to occur in shallow productive lakes. Recent analyses by Wood et al. (1996) demonstrated links between timing of stratification, water temperature, phytoplankton production, and dissolved oxygen concentrations. Phytoplankton blooms are associated with high pH because phytoplankton remove carbon dioxide and bicarbonate from the water, causing pH to rise. Crashes in phytoplankton communities in surface waters can cause abrupt declines in dissolved oxygen. This occurs because a large amount of organic matter is created when the phytoplankton die. The decomposition process removes oxygen and results in lower oxygen concentrations in the water. When these waters are subsequently mixed during a period of either high wind speed or low resistance to mixing, dissolved oxygen concentration drops throughout the lake.

Perkins et al. (2000a) noted the sequence of events related to phytoplankton blooms in Upper Klamath Lake and sudden crashes that can be associated with fish kills:

> “Suckers collected during the fish kills, as well as live fish captured the following spring, had a high incidence of afflictions such as parasitic and bacterial infections, cysts, and ulcers. The 1995 and 1996 fish kills were biased toward larger species (suckers), and larger individuals within species. Associated with each fish kill was an extended period of water column stability and high algal biomass (>150 µg L^{-1} chlorophyll a) before the kills, followed by a well-mixed water column and algal collapse with little residual algae. Before the kills, algal photosynthesis caused high pH (9-10) for 30-90 days, which maintained a large proportion of the total ammonia in the toxic, un-ionized form (200-2000 µg L^{-1} NH_3). Algal collapse decreased photosynthesis and increased biological oxygen demand, leading to dissolved oxygen levels less than 4.0 mg/l throughout the water column for 10-24 hours a day, for up to several days. Fish mortality coincided with

> algal bloom collapse and continued for 20-30 days after the period of low dissolved oxygen. We concluded that hypoxia, caused by the collapse of *A.* [*Aphanizomenon*] *flos-aquae* blooms was the primary mechanism that triggered the 1995-97 fish kills. The susceptibility of fish to hypoxia was probably enhanced by chronic exposure to stressful levels of pH, ammonia, and dissolved oxygen during summer months prior to and during initiation of the kills. Exposure to water quality stressors also made fish susceptible to disease, which probably caused much of the post-hypoxic mortality." (Perkins et al.2000a, p.4).

Fish kills rarely are caused by single factors. Under stress, fish exhibit decreased tolerances to multiple factors (e.g., environmental conditions, toxic substances, low food availability), making it difficult and invalid to attribute mortality to a single factor (Wedemeyer et al. 1984). Stress can weaken fish and make them more vulnerable to other sources of stress. Fish exhibit higher incidence of bacterial infections (*Flavobacterium columnare*) during die-offs, which is a common response to stress (Wedemeyer et al. 1984).

A laboratory study of Lost River suckers indicates that this species may not be as sensitive to multiple stressors as some other fish species. Lost River suckers held experimentally in Upper Klamath Lake water for 14 days exhibited mortality at dissolved oxygen concentrations of 1.4 mg/L (Meyer and Hansen 2002). In laboratory experiments, Lost River and shortnose suckers exhibited 50% mortality when held for 96 hr at dissolved oxygen concentrations of 1.3 to 2.1 mg/L (Saiki et al. 1999). Juvenile Lost River suckers did not show effects of low dissolved oxygen, high pH, or high un-ionized ammonia concentrations until they reached lethal levels of these individual measures of water quality (Meyer and Hansen 2002). In general, cumulative effects of sublethal stressors contribute to the mortality of most fish species before lethal levels are observed and often contribute to fish kills. These phenomena will be important in future studies of Klamath Lake and fish kills.

<u>Relationship with Lake Level</u>

Inorganic nutrient concentrations -- and the related occurrence of phytoplankton blooms-- in Upper Klamath Lake may be influenced by lake level, although evidence suggests that the relationship is complex. Phosphorus and nitrogen loading directly influences the potential primary production in Upper Klamath Lake. Nutrient loading can be estimated by subtracting the sum of background and atmospheric sources from observed total concentrations in the lake. In Upper Klamath Lake, 40% of the total phosphorus and 66% of the total nitrogen are estimated to come from human sources and land use practices (Kann and Walker 2001; Boyd et al. 2002). Phytoplankton increase their photosynthetic rate as phosphorus concentrations increases (Welch and Burke 2001; Walker 2001).

Phosphorus loading is greater during high water flow years because a greater mass of phosphorus-laden water enters the lake (Kann and Walker 1999). Regression analysis of data from 1992 to 1994 indicated that timing of the first bloom and maximum June of chlorophyll were not significantly correlated with lake level, but they were correlated with temperature (degree days) from April 1 – May 15, a measure of relative warmth of the spring season (Wood et al. 1996). However, this study noted that higher concentrations of chlorophyll were observed in June of the year of lowest lake level, than in the year with the highest lake level.

Wind is more effective in mixing and resuspending lake sediments when lake surface levels are low, and much of the phosphorus in the lake is associated with suspended sediments. Laenen and

LeTourneau (1996) estimated that 90% of the lake was vulnerable to sediment resuspension when lake levels were at 4,137 ft. Resuspension of sediments in a 10-mile per hour wind were estimated to load 530 tons of phosphorus into the lake water at a 4138 ft lake level. Laenen and LeTourneau (1996) concluded that the likelihood of sediment resuspension was an order of magnitude lower when lake levels were 4,140 ft instead of 4,137 ft. The pH of lake water also influences phosphorus release into the water column from sediments. At high pH (e.g., related to algal blooms), greater amounts of phosphorus would be released from sediments into the overlying waters (Welch and Burke 2001).

These processes create potentially confounding conditions because years with high river flows (more riverine input) may also be years with higher lake levels, depending on management. The 2002 USFWS Biological Opinion cited information from US Geological Survey (Wood 2002) that higher lake levels in the spring can adversely affect water quality in late summer. These effects are more likely in years in which high inflow events deliver high amounts of phosphorus-rich sediments into the lake. Such events were estimated to occur at intervals of 5 to 20 yr. However, years with higher lake levels are less susceptible to resuspension of sediments, increased sediment biological oxygen demand, and provide more dilution of sediment derived phosphorus. Greater amounts of phosphorus may be available for algal blooms in high flow years but greater lake volumes may reduce the effects of internal sources of phosphorus, particularly from lake sediments. On the other hand, lower phosphorus loading in low river flow years can be offset by increased resuspension and subsequent greater concentrations in the reduced volume of the lake.

Two major studies of the limnological conditions in Upper Klamath Lake (Burleson Consulting 2002; Welch and Burke 2001) have drawn differing conclusions about links between lake level and fish kills. The first, a study of Klamath Lake in 2001 commissioned by the USBR concluded that,

> "The most likely direct cause of fish kills seems to be rapid lowering of DO [dissolved oxygen] throughout the water column. Under these circumstances, the fish would have no refuge for escape in either a horizontal or vertical direction. They would die rapidly. Any effects of NH_3, bacterial diseases of the fish gills, or the presence of other toxicants would increase the effect of low DO. The rapid lake destratification overnight observed in this study provides a mechanism for such fish kills in the whole water column." (Burleson Consulting 2002, p.27).

Burleson Consulting (2002) related the reduced mixing and subsequent chemical changes to a period of low wind and the higher lake levels. They concluded that, "If the prevention of fish kills is of paramount importance, in future, the lake should be maintained at a shallower depth to prevent fish kills until artificial oxygenation can be installed"(Burleson Consulting 2002, p.33).

Welch and Burke (2001) were commissioned to scientifically evaluate limnological data from Upper Klamath Lake for the period from 1990-1998 by the Bureau of Indian Affairs. In contrast, Welch and Burke (2001) concluded that,

> "Ultimately, stress on fish arises from poor water quality conditions of low DO [dissolved oxygen], high ammonia, and high pH...In the summer, poor water quality arises from the growth and decay of large algal blooms...Lake level ultimately affects fish stress, morbidity, and mortality through two direct pathways, as well as indirectly through feedback mechanisms. First, increased lake level directly lowers light availability

> to algae which lowers growth rate and therefore delays and limits the actual size of the spring and even late summer algal blooms. Second, increased lake level directly dilutes TP [total phosphorus] entering the water column from the sediments...which in turn limits the maximum possible concentration of the spring and late summer algal blooms." (p. xiii).

Welch and Burke (2001) further noted the complexity of the relationship between lake level and factors that lead to fish kills:

> "The exact effect of lake levels on fish stress, morbidity, and mortality in any particular year is not predictable because of climate and weather variability. In particular, unusually strong wind-induced mixing can ameliorate the effects of a large bloom, and unusually weak wind-induced mixing can enhance the deleterious effects of a small bloom...Regardless of this uncertainty, these climatic and weather factors cannot be managed, whereas lake level can." (p. xiii).

The apparent contradiction between these two studies warrants discussion. Lake levels have numerous effects on water quality, some of which may counteract each other. The two studies agreed that rapid mixing after a period of stratification or reduced mixing could lead to poor water quality conditions that cause fish kills. Burleson Consulting (2002) recommended lower lake levels to reduce the stability of non-mixing conditions. As discussed earlier, the lower lake levels have less resistance to mixing, which maintains higher dissolved oxygen concentrations at lower depths. On the other hand, Welch and Burke (2001) recommended that the negative effects of low lake levels (e.g., higher phytoplankton concentrations, greater vulnerability to resuspension of sediments and phosphorus by wind, and higher nutrient concentrations) outweighed the influences on stability of stratification. The IMST finds that both conclusions are scientifically sound. The survival of larval, juvenile, and adult suckers likely depend on the specific sequence of weather, stream flows, nutrient delivery, phytoplankton blooms, water column stability,and lake level within a given year. Continued monitoring and analysis of relationships between lake levels and limnological conditions in Upper Klamath Lake are needed to better understand these complex interactions.

Relationship of Land Use Change to Frequency and Magnitude of Fish Kills

It is important to know the influences land use activities have on the spatial and temporal patterns of nutrients in order to understand 1) the timing and magnitude of phytoplankton blooms and 2) interactions of blooms with patterns of lake stratification. In this section, we describe how human activities in the Klamath Basin have accelerated eutrophication (i.e., increased primary production or photosynthesis) by introducing nutrients that stimulate phytoplankton growth and lower dissolved oxygen concentrations. We also discuss the implications for restoration activities in Upper Klamath Lake basin.

Studies of the sediment cores clearly document several major changes in the environmental conditions in Upper Klamath Lake since EuroAmerican settlement. First, erosion and sediment input into the lake have increased in the 20th century (Eilers et al. 2001; Colman et al. 1999). Second, nitrogen and phosphorus levels in the sediments have changed; indicating potential increases in both nitrogen and phosphorus loading (Eilers et al. 2001; Colman et al. 1999). As much as 40% of the phosphorus coming into Upper Klamath Lake is derived from agricultural sources (Kann and Walker 2001; Boyd et al. 2002). Several studies have indicated that watershed management practices could significantly reduce nutrient loading into Upper Klamath Lake (Gearhart et al. 1995; Anderson 1998; Boyd et al. 2002). Snyder and Morace (1997) conducted experimental manipulations to determine the quantities of phosphorus that were contained in wetlands around Upper Klamath Lake and concluded that 250,000 tons of phosphorus and 4,300 tons of nitrogen had been delivered to Upper Klamath Lake as a result of wetland draining. This amounts to 30% and 22% of the phosphorus and nitrogen, respectively, that are contained in these wetland soils. Third, along with changes in erosional inputs and nutrient loading, the relative abundance of major phytoplankton species has changed. *Aphanizomenon flos-aquae* was not present in the lake during the 19th century, but is now the dominant phytoplankton species (Colman et al. 1999). Overall, these studies concluded that anthropogenic effects of land use in the basin increased the potential for phytoplankton blooms, which have been linked to fish kills (see prior section).

One of the major landscape alterations affecting nutrient delivery to Upper Klamath Lake has been the draining and diking of marshes surrounding Upper Klamath and Agency Lakes. As we discussed in the Introduction, extensive wetlands historically lined the margin of Upper Klamath and Agency Lakes (Geiger et al. 2000). Two-thirds of the wetlands adjacent to Upper Klamath Lake (over 30,000 acres) were isolated or eliminated by dike construction and wetland draining, leaving between 17,000-18,000 acres of undrained wetlands today (Table 2 on page 8, Figure 19 on page 44; also see Figures 4 and 5 on pages 12-13). These historical wetlands were important filters that modify the form, amounts, and timing of nutrients delivered into the lake from the surrounding watershed. The loss of the nutrient retention function of these wetlands is likely a major reason for nutrients entering the lake, resulting in increased algal blooms and subsequent die-offs of suckers. By using computer modeling, Walker (2001) estimated that wetland and riparian restoration were the most effective approach for reducing phosphorus loading into Upper Klamath Lake. Preliminary data indicate that nutrient reductions from these wetlands being restored offers 82-100% annual reductions in nutrient loading into Upper Klamath Lake from its watershed (BLM 2002 as reported in Boyd et al. 2002; p. 19 Upper Klamath Lake TMDL – Responses to Public Comments). This nutrient retention function of wetlands was formally recognized in recent acquisition of more than 17,500 acres of agricultural land in the original marsh area to be restored back to wetland.

A major question facing management entities in Upper Klamath Lake is the time frame for response to management actions. There is ample evidence that human activities increase phosphorus loading into the lake. Several restoration measures (e.g., wetland restoration, riparian protection) are likely to reduce phosphorus loading into the lake, but the amounts of phosphorus stored in the lake and its sediments is much larger than annual loading rates. Managers and the public may question how long it will take before such management actions could substantially influence lake productivity, phytoplankton blooms, and related fish kills. Such actions have been effective in the Tualatin River in Oregon (Unified Sewerage Agency 1999; Oregon Dept. Environmental Quality 2001) and Lake Washington, a deep lake near Seattle, Washington**.** However, Upper Klamath Lake is a large, shallow eutrophic lake and may not respond like these other systems. Because of high phosphorus levels accumulated in the sediment, significantly reducing phosphorus levels may take decades. A system that includes implementing restoration measures and long-term monitoring (>10 yr) would provide specific answers for Upper Klamath Lake but the agencies and public will not obtain the answers to their questions immediately.

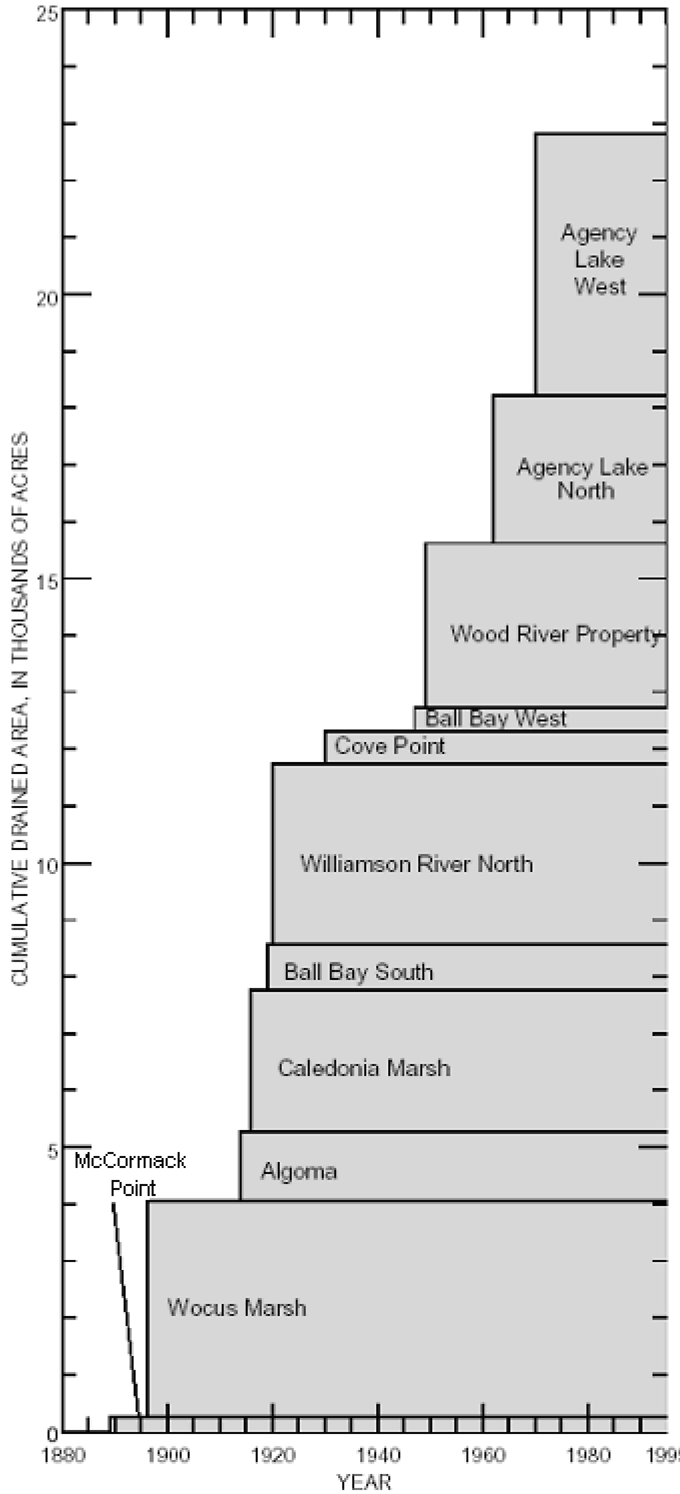

Figure 19. Cumulative area of drained wetlands adjacent to Upper Klamath Lake over time. This area excludes about 8,200 acres of drained wetlands that were not considered in the study by Snyder and Morace (1997). Each block represents an incremental addition to the cumulative area. Reproduced from Snyder and Morace 1997. See also Figures 4 and 5 on pages 12 and 13.

Summary of Science Question 2

In summary, we conclude that lake depths are related to the relative resistance of Upper Klamath Lake to mixing and the ability of wind to cause mixing. In addition, lake levels are directly related to lake volume, which influences the production and concentration of phytoplankton, sediment re-suspension, and oxygen concentrations (increasing through photosynthesis and decreasing during decomposition of dead organisms). Rapid turnover of the lake after a period of stratification will expose fish to water quality conditions that may be stressful or lethal (e.g., low dissolved oxygen concentrations, elevated pH, or ammonia). In addition, fish exhibit higher incidence of bacterial infections during die-offs, which is a common response to stress (Wedemeyer et al. 1984). Under stress, fish exhibit decreased tolerances to multiple factors, making it difficult to attribute mortality to a single factor.

Therefore, the IMST concludes that it is plausible that lake levels potentially could have an indirect effect on fish die-offs. Higher lake levels reduce the ability of the wind to mix the lake, which potentially leads to lower dissolved oxygen concentrations and associated adverse conditions (Burleson Consulting 2002). But more importantly, higher lake levels dilute the algae and nutrients in the lake, reduce the development of algal blooms, and reduce resuspension of bottom sediments (Wood et al. 1996; Welch and Burke 2001). Management of lake levels and maintenance of higher lake levels will not prevent the development of adverse conditions that lead to fish kills, but lake levels influence several variables that may reduce the likelihood of such conditions. As noted by others, it is not possibly to control the wind and weather, but it is possible to manage the lake level. Furthermore, we conclude that land use change in the basin has influenced conditions in Upper Klamath Lake (e.g., nutrient concentrations) that are related to fish kills. In the following section, we discuss the implications of these conclusions for lake level management and for sucker population viability.

Science Question 3. Will management of lake levels have significant effects on the survival of sucker populations?

The background action leading to this question was USFWS's change in recommended lake level from their 1992 Biological Opinion to their 2001 Biological Opinion. In 1992, the USFWS identified a lake level of 4137.0 ft[11] as a minimum for protecting the shallow littoral (nearshore) habitat of larval and juvenile suckers (USFWS 1992). A higher level of 4139.0 feet was used as the minimum level during years with more normal precipitation and runoff. At that time, USFWS expected that this higher level would protect larval and juvenile fish and would be adequate to allow adults to reach their spawning areas. During the 1990's, fish die-offs continued and concerns about water quality remained. Regardless of the potential multiple causes of the die-offs, management of the watershed and lake were not adequate to absolutely prevent die-offs during this period. Citing the lack of effectiveness of the levels identified in the 1992 Biological Opinion, USFWS raised the target level for lake management to 4140.0 ft in their 2001 Biological Opinion (USFWS 2001).

To answer this Science Question, we evaluate several lines of scientific evidence that USFWS used to justify managing the volume of water in Upper Klamath Lake in order to improve survival of sucker populations:

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[11] The minimum surface elevation could not be lower than 4,139 ft above mean sea level for more than 4 years out of the 10-year period covered by the 1992 Biological Opinion and these lower levels could not occur in any two consecutive years.

- Protection of habitat and access to habitat for adult and juvenile suckers,
- Relationship of lake level with juvenile production, and
- Relationship of lake level with water quality degradation and probability of fish kills.

Lake level management to protect sucker habitat and access to habitat

Adult/Spawning Habitat

Adult suckers are found at varying depths in the lake. In an analysis of daytime radio-telemetry data, 95% of suckers were found in water that was 3-15 ft deep (Peck 2000, Reiser et al. 2001). This analysis was conducted on data collected when the lake level below 4,137 ft (Peck 2000, Reiser et al. 2001). Based on these data, USFWS (2001) concluded that 3 ft is a minimum depth necessary for adult suckers in Upper Klamath Lake (USFWS 2001, Section III, Part 2, p.109).

USFWS (2001) then evaluated the amount of habitat ≥ 3 ft available at different lake levels and determined that lower lake levels decrease habitat availability for adult suckers:

> "When the lake is full at 4143.3 ft, about 10,000 hectares of "potential" sucker habitat (3-15 ft) are present in the northern portion. However, at an elevation of 4138 ft, potential habitat is reduced to 5,161 hectares, a reduction of nearly 50 % (Reiser et al. 2001). The availability of habitat in the 6- 9 ft range, that appears to be differentially utilized by the adult suckers, declines sharply at lake elevations below 4141 ft, from near 4000 hectares to only about 1,000 hectares at 4138 ft. The available data demonstrate that availability of habitat within the depth range utilized by adult suckers is severely reduced at lower lake levels." (USFWS 2001, Section III, Part 2, p.109).

Suckers spawn over gravel or cobble 1) in tributary rivers to Upper Klamath Lake and 2) in shallow areas of the lake with upwelling from subsurface flows, or springs (Markle and Cooperman 2002). Spawning along the shoreline of the lake and in tributaries occurs between February and May (Perkins et al. 2000b; Figures 10 and 11).

Lake level also is important for the availability of spawning habitat. The USFWS Biological Opinion noted that the lower extent of spawning occurred at 4138.5 ft in Sucker Springs, a historically important spawning area.

> "At elevations of 4140, 4141, 4141.5, 4142.0, and 4142.5 ft, respectively, approximately 35%, 55%, 65%, 80%, and 90% of the spawning substrate at Sucker Springs is inundated to a depth of at least 1.0 ft, which is the approximate minimum depth for sucker spawning. A 2 ft minimum water depth would better ensure sufficient depth for reproduction" (USFWS 2001).

Reiser et al. (2001) determined that 15 and 25% of the potential spawning habitat in Ouxy Springs and Sucker Springs were at least two feet deep at lake elevations of 4141.5 ft and 4142 ft, respectively. The Klamath Tribes surveyed sucker spawning at Sucker Springs in 1995 and found that the 50% cumulative frequency depth for inshore spawning was 1.8 ft (50% deeper and 50% shallower). Off shore spawning obviously occurred at deeper depths, with a 50% cumulative frequency of spawning at a depth of 2.9 ft (USFWS 2001). Spawning in the shallow margins of Upper Klamath Lake also influenced distribution of sucker larvae because more than 90% of the embryos were collected where the depth of the lake bottom ranged from 1.0 to 3.5 ft (USFWS 2001).

Habitat quantity, as well as access to habitat, can be limited by poor water quality. Surveys of suckers in Upper Klamath Lake indicate that suckers are not consistently found in habitats with dissolved oxygen concentrations less than 4.0 mg/L (Simon et al. 2000a). In summer, suckers use habitats in Upper Klamath Lake with access to tributary inputs (Peck 2000; USBR 1996; Reiser et al. 2001). These areas include Pelican Bay, Fish Banks, and the mouths of the Williamson River, Odessa Creek, Short Creek and Wood River. Suckers have access to areas with deeper water and access to inflows at lake elevations greater than 4141 ft. The deeper water zone is shifted offshore as lake level becomes lower, influencing the access of suckers to possible refuges during periods of lower water quality (USFWS 2001).

While lake level is an important management tool for spawning Lost River Suckers and shortnose suckers, appropriate management of tributary spawning habitat is also crucial. Adult shortnose and Lost River suckers from Upper Klamath Lake migrate into tributaries, mainly the Williamson and Sprague rivers, to spawn. Therefore, protection of critical spawning habitat is important for the recovery of these species. Both the Williamson and Sprague watersheds have been affected by land use practices, including grazing, forestry, and water withdrawals. In the Williamson River, unscreened irrigation diversions may entrain larval suckers and reduce recruitment into Upper Klamath Lake. Spawning habitat has been lost in Sprague River because of channelization, sedimentation, increased water temperatures, and high nutrient concentrations. Additionally, the Chiloquin Dam (upstream of the confluence of these two rivers) is at least a partial barrier to the annual spawning migration. USFWS concluded that spawning habitat below the dam was “very likely limited” (USFWS 2001, Section III, Part 2, p.139) and previously estimated that more than 95% of the potential spawning habitat for Lost River and shortnose suckers was blocked and that this was to be a major reason for their declines (USFWS 1988, 2001).

Larval and Juvenile Habitat Use

After hatching, suckers remain in a larval stage for approximately 40-50 days (Markle and Cooperman 2002). Because spawning occurs over an extended period in the spring, larval suckers are generally present in the lake between March and July (USFWS 2001). Suckers that hatch in the tributaries travel into Upper Klamath Lake while still in the larval stage (Markle and Cooperman 2002). In Upper Klamath Lake, larval suckers occupy shallow water habitats near shore. Aquatic macrophytes (submerged, floating, and emergent aquatic plants) provide hiding cover for larval suckers (Markle and Cooperman 2002).

Juvenile suckers are found in Upper Klamath Lake after April (Markle and Cooperman 2002). Later in summer and in early fall, juvenile suckers occupy open rocky substrates near shore:

> “Catches were generally low on small particle substrates such as sand and fines. Shoreline substrates near the edge of marshes are heavy, unconsolidated, organic fines, or a compact peat substrate. Our cast net data suggest age 0[12] suckers and all fish generally avoid these substrates, and thus marshes, along the shoreline, and inhabit rocky substrates as preferred habitats. Although marshes may be important for improved water quality and larval fish rearing, our data have not suggested that these are important for juveniles later in the summer/fall.”(Simon et al. 2000b, p.13-14).

[12] “Age 0” fish, also known as young-of-the-year, refers to fish in their first year of life.

Large numbers of juveniles do not occur in silty areas. Older juveniles possibly expand their distribution into open water during the fall season, but there is no direct evidence for juvenile movement into open waters (R. Shively, pers. comm.[13]).

The relationship of lake level to the quantity of certain habitat types in Upper Klamath Lake can be estimated. For example, Cooperman and Markle (2003) report that at 4142.0 ft lake level, approximately 445,000 ft^2 of aquatic vegetation is inundated with water. This is 57% less than when the lake is at 4143.0 ft, and 242% more than 4141.0 ft (Cooperman and Markle 2003). However, the relationship of the quantity of emergent vegetation to juvenile productivity is not well understood and has been a subject of controversy (Cooperman and Markle 2003; Lewis 2003 (see discussion in following section). Markle et al. (2002) found that the volume of emergent vegetation available for larval suckers decreases sharply with decreasing lake elevation (Figure 20). At a lake elevation of 4139 ft, little emergent vegetation is inundated and therefore unavailable to larval suckers.

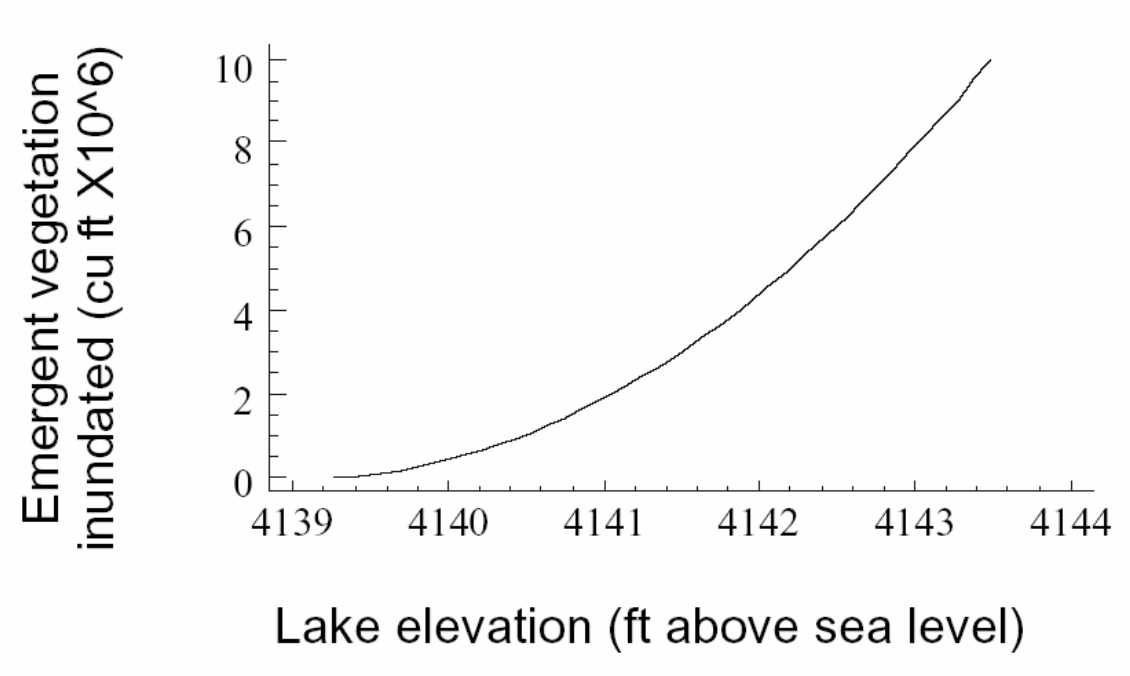

Figure 20. Relationship between total inundated emergent vegetation volume at three Upper Klamath Lake sites and lake elevation. The relationship was calculated from data in Dunsmoor et al. (2000) and reported by Markle et al. (in prep.).

The location of submerged vegetation also may be important. For example, higher lake levels are necessary to inundate vegetation along the lower Williamson River, an area the USFWS (2001) suggests could be important to emigrating larval suckers. The IMST could not find any analysis of the relationship of gravel juvenile habitat with lake level.

[13] Shively, Rip. Personal Communication. 2003. USGS Biological Resources Division, Klamath Falls, Oregon.

USFWS 2002 Biological Opinion Conclusions on Effect of Lake Level Management on Sucker Habitat Availability

The USFWS analyzed the consequences of proposed lake levels for different life history stages of suckers in their Biological Opinion (2002). Based on data on fish distribution studies described earlier in this section, the USFWS determined that the proposed lake levels were likely to totally eliminate the habitat for larval suckers in the lower Willamson River and Goose Bay in July during a critically dry year. Late summer/fall habitats for adult suckers would be reduced by more than 50% in critically dry years, and less than 46% of the baseline habitat greater than 3 ft would be accessible in late summer. These analyses demonstrate that lake levels have a direct consequences on the types of habitats that have been identified as important for different life history stages of suckers.

Lake level management and juvenile production

Elucidating the relationship between lake level and juvenile production requires careful attention to changes in climatic conditions both among and within years. At very low water levels, low numbers of juvenile suckers have been observed in Upper Klamath Lake August to October (Table 8; Markle and Cooperman 2002). For example, by the end of summer (September 15), Upper Klamath Lake was drawn down to 4,137.54 ft in 1992 and 4136.98 ft in 1994 (Table 8). Both of these years had low abundances of juvenile suckers. No juvenile suckers were caught during late season cast net sampling (335 samples) in 1992. In 1994, an average of 0.04 shortnose suckers per cast and 0.01 Lost River suckers per cast were caught (300 samples). Limnological conditions in these low water years have been examined as well. Welch and Burke (2001) noted the lowest dissolved oxygen and high pH during July and August of 1992 and 1994. These were also years of poor recruitment (Table 8).

The year 1991 was also a low water-year. The water elevation on September 15, 1991 was 4,138.49 ft, and relatively high populations of juvenile suckers were observed late in the season that year (Table 8). Cast net sampling (44 samples) in late season in 1991 caught an average of 0.43 shortnose suckers per cast and 0.39 Lost River suckers per cast, more than 10-30 times as many as in 1994 depending on species (Table 8). The September lake level in 1991 was approximately one foot deeper than in 1992, when no juvenile suckers were captured and approximately 1.5 feet deeper than 1994, when numbers of suckers captured were less than one-tenth as many as in 1991. Lake levels in 1992 and 1994 were similar to the minimum lake level proposed in the 2001 USBR Biological Assessment. Trawl estimates of larval suckers are highly variable at levels higher than 4139.15 ft, and substantially larger numbers of age 0 fish were caught in beach seines above this lake level.

The 1991 water-year[14] was examined in detail by NRC (2002) and other reviews. The NRC (2002) discounted lake level as an appropriate management tool based on the large numbers of fish from the 1991 year-class in the 1997 fish kill. They pointed out that 1991 was the third lowest lake level in the last decade and in the lower 15% since 1950 but it exhibited strong sucker recruitment. In addition, the NRC Report indicated that several non-drought years had low juvenile recruitment, citing a study from Oregon State University. “Simon et al. (2000) have reported generally declining abundance during the non-drought interval 1995-1998” ”(NRC 2002; p.19). They concluded that “Overall, the presumed causal connections between lake levels

[14] Water-year begins October 1 and ends September 30.

and recruitment of the sucker populations in Upper Klamath Lake do not have strong scientific support at present"(NRC 2002; p.18).

The IMST does not concur with this conclusion for three reasons. First, use of emergent vegetation by young-of-the-year occurs in spring and early summer. While water level in 1991 was low in September-October, the lake level in early summer was similar to higher years. Second, the NRC only considered lake level and not associated climatic and water quality conditions. The year 1991 was a cool, windy year (Wood et al. 1996). In the Biological Opinion, the USFWS noted that water quality was "relatively good" in 1991, which would favor good survival and recruitment (USFWS 2001, Section III, Part 2, p.48). Lastly, their interpretation of low abundance in 1995-1998 ignores any other influences on juvenile recruitment into the adult population such as fish kills (1995, 1996, 1997).

Table 8. Upper Klamath Lake elevation, fish kills, juvenile sucker production, and A-canal entrainment 1991-2001. Years are in order by September 15th lake elevation (highest elevation first). CPUE is catch per unit of effort. Blanks indicate no data. Larval and juvenile data from Simon and Markle (2001) updated for 2001 samples. Table modified from data presented in Markle and Cooperman (2002).

Year	Sept. 15 Elevation	Mass Sucker Mortality[1a]	Larval trawl[1] CPUE	Beach seine CPUE[2]	Beach seine % SNS[2]	Late season SNS fixed-site cast net CPUE[3]	Late season LRS fixed-site cast net CPUE[3]	SNS-October total juvenile abundance[4]	LRS-October total juvenile abundance[4]	A-Canal Juvenile entrainment[5]
1999	4140.50	No	23.25	53.40	93			68,795	108,399	
1998	4140.22	No	3.95	6.90	85			11,626	5,082	246,524
1995	4140.14	Yes	11.65	29.02	91	0.29	0.05	9,129	38,313	
1997	4140.13	Yes	15.73	19.19	85			1,483	0	46,708
1993	4139.83	No		21.66	94	0.64	0.78			
2001	4139.56	No	8.80	8.45	19			5,007	13,077	
2000	4139.47	No	5.20	54.17	82			25,698	33,323	
1996	4139.15	Yes	20.05	87.08	88			74,383	11,288	
1991	4138.49	No		4.94	95	0.43	0.39			
1992	4137.54	No				0.00	0.00			
1994	4136.98	No		0.17	88	0.04	0.01			

1a. Small localized mortalities of fish, such as sculpins, can occur in many years, but large, lake-wide mortalities of thousands of adult suckers are the “large fish kills” (Perkins et al. 2000a) or mass mortalities of concern to management.

1. Larval trawl - mean number of larvae per trawl per year based on sampling every third week, April thru July, at 10 fixed near shore locations in Upper Klamath Lake. A matched pair of larval trawls is done at each location, one in an unvegetated area and one in nearby vegetation if available.
2. Beach seine – CPUE as mean number of age 0 juvenile suckers per seine per year based on sampling every third week, late June and early August at the same 10 locations as larval trawl sampling. Two samples are collected per location. % SNS is the percent of beach seine CPUE attributable to SNS, remainder are LRS.
3. Late season fixed-site cast net CPUE – mean number of age-0 juvenile suckers collected per cast net per year, 1991-1995, based on multiple cast net samples at 10 - 17 fixed near shore locations in Upper Klamath Lake, variably sampled once per month from August – October or September - October. This was the only relatively consistent “late season” sampling prior to 1995.
4. October total juvenile abundance – End of growing season estimate of the total number of age-0 juvenile suckers, 1995 – 2001, in Upper Klamath Lake based on stratified random near shore cast net and off shore otter trawl sampling. Estimates are based on weighted density estimates of suckers on different substrates extrapolated to the total shoreline area within 10 m of shore for cast nets and for total offshore area for trawls. Extrapolations assume that densities on a substrate are uniform within 10 m of shore for cast nets and are uniform lake-wide for trawls.
5. A-canal juvenile entrainment – estimated total entrainment of juvenile and sub-adult suckers (Gutermuth et al. 2000). A-canal entrainment was estimated to equal 75% of total out-of-lake transport of suckers with other entrainment at Link River canals.

Lake level management to prevent fish kills
Several critiques of the 2001 USFWS Biological Opinion note the lack of significant correlation between lake levels and occurrence of fish kills. As we describe in Science Question 2, the premise that lake levels are related to fish die-offs has been controversial. The NRC (2002) concluded that empirical data from Upper Klamath Lake did not support the Reasonable and Prudent Alternative for management of lake level in the 2001 USFWS Biological Opinion.

> "...there is presently no sound evidence for recommending an operating regime for the Klamath Project that seeks to ensure lake levels higher on average than those occurring between 1990 and 2000. At the same time the committee concludes that there is no scientific basis for operating the lake at mean minimum levels below the recent historical ones (1990-2000), as would be allowed under the USBR proposal. Operations leading to lower lake levels would require acceptance of undocumented risks to the suckers" (NRC 2002, p.3-4).

They continue,

> "An essential premise of the lake-level recommendations is that the adverse water quality conditions known to stress or kill endangered suckers are associated with the lowest water levels within the recent historic range..."(NRC 2002, p.16).

The NRC based their finding on the lack or weakness of simple relationships between lake level and single measures of water quality and occurrence of fish kills.

The 2001 USFWS Biological Opinion clearly stated that, "Fish kills are not related to lake levels" (USFWS 2001, Section III, Part 2, p.70). The USFWS indicated that lake levels were one factor in multiple conditions that are associated with fish kills (e.g., dissolved oxygen, pH, ammonium, phytoplankton blooms, access to critical habitats, nutrient loading and concentrations). Other factors, such as wind speed, solar radiation, and air temperatures, also influence water quality conditions and may override or obscure the effects of lake level. These climatic factors are highly variable from year to year and make management complex and difficult to predict. These factors cannot be controlled by natural resource management agencies and can only be influenced indirectly by lake volume or level.

The USFWS decision to manage the lake based on lake level also has been criticized because factors other than low dissolved oxygen concentrations may cause fish kills (e.g., elevated ammonia, pH, hydrogen sulfide). It is important to note that reductions in dissolved oxygen directly influence these other chemical conditions, and thus the other conditions are related to lake level as well. Factors that lead to hypoxia and elevated ammonium would create adverse water quality conditions for fish populations and could lead to fish kills. Additional changes in pH and other water quality parameters could exacerbate these adverse conditions.

IMST Findings on Upper Klamath Lake Compared with Other Reports
We have prepared Table 9 as a comparison of the different reports to minimize the confusion that multiple reports inevitably generate. We stress that this is our best interpretation of the various reports. Selection and interpretation of quotes was verified with authors of NRC (2002) and Chapter 5 of the OSU-UC Davis report (Markle and Cooperman in Braunworth et al. 2002) to assure accurate summary of their conclusions. Where specific numbers were not provided, we have attempted to give our interpretation of the numerical value that was intended in the

respective report. The findings in the NRC report are consistent with several findings in our report, but they differ sharply on several points (Table 9).

<u>Direct vs. indirect evidence</u>

Overall, the NRC concluded that there was no clear evidence that lake levels were directly or indirectly related to the status of sucker population in Upper Klamath Lake:

> "Despite a monitoring record of substantial length, there is no clear evidence of a connection between the lake levels and the welfare of the two sucker species in Upper Klamath Lake. Lake levels cannot be reduced, however, below those observed in the past 10 years without risk of adverse occurrences that are not described in the detailed monitoring record (1990-present; analyses complete through 1998). A negative association between the welfare of the species and lake level could emerge if lake levels are reduced below those of recent historical experience. The absence of any empirical connection between the observed lake levels and the welfare of the endangered suckers cannot be taken as justification for continuous or frequent operation of the lake at the lowest possible levels, given that the effects of operating the lake at lower levels are undocumented. Thus, while the observational record contradicts important underlying assumptions of the RPA [Reasonable and Prudent Alternative], it does not provide an endorsement for the lake levels proposed in the USBR biological assessment, which, if implemented, could take interannual mean lake levels well below those of recent historical observation." (NRC 2002, p.20).

The NRC Report did conclude that lake levels lower than the mean lake levels for the period from 1990-1998 would not be prudent and may favor recruitment of suckers.

The NRC Report also concluded that lake levels lower than the mean lake levels for the period from 1990-1998 would not be prudent and may favor recruitment of suckers. "At the same time the committee concludes that there is no scientific basis for operating the lake at mean minimum levels below the recent historical ones (1990-2000), as would be allowed under the USBR proposal. Operations leading to lower lake levels would require acceptance of undocumented risk to the suckers." (NRC 2002).

The NRC Report also concluded that lake levels lower than the mean lake levels for the period from 1990-1998 would not be prudent and may favor recruitment of suckers. "At the same time the committee concludes that there is no scientific basis for operating the lake at mean minimum levels below the recent historical ones (1990-2000), as would be allowed under the USBR proposal. Operations leading to lower lake levels would require acceptance of undocumented risk to the suckers." (NRC 2002).

The NRC (2002) focused its conclusions on relationships for which there is clear evidence from measurements in Upper Klamath Lake and did not give strong weight to evidence from the larger scientific literature and broader scientific concepts in its findings (D. Policansky, pers. comm.[15]). However, the IMST considers information on habitat use, studies of other lake systems and fish communities, as well as empirical evidence from Upper Klamath Lake to be relevant scientific

[15] Policansky, David. Personal Communication. 2003. NRC Committee on Endangered and Threatened Fishes of the Klamath River Basin. Washington, D.C.

information that resource management agencies are required to use in making resource management decisions.

As we discussed in this question and the previous Science Question, links between lake levels and 1) habitat for critical life history stages of suckers and 2) conditions that could lead to fish kills are evident. Even if no strong correlation can be observed (due to noise from complexity), the IMST concludes that there is credible evidence that indicates a connection between lake level and the welfare of sucker species. This complex interaction involves lake level, habitat for larval, juvenile, and spawning adult suckers, phosphorus loading, mixing, phytoplankton blooms, and toxic conditions, as established in the answer to Science Questions 2 and 3. Therefore, lake level must be evaluated along with several other factors when devising management actions to promote sucker survival.

We recognize the increased certainty provided by basing conclusions only on direct evidence for a specific location, such as the National Research Council applied in its evaluation of management actions for Upper Klamath Lake. At first glance, the more limited and conservative perspective of the NRC committee would seem to lower the chances of being wrong. However, limiting the scientific basis for the determination of appropriate management actions increases the potential for placing a resource at risk simply because the available observations are inadequate and the larger body of valid scientific information from other systems has been ignored. If management actions for all natural resources were limited only to the specific system that was being managed, many lakes and streams would have no management because empirical evidence for those individual lakes or streams is nonexistent. The IMST considered both measurements from Upper Klamath Lake and the body of scientific literature to develop conclusions about the technical basis for resources management actions.

Table 9. Reviews of the 2001 USFWS Biological Opinion on suckers in Upper Klamath Lake. Quotes are from 2001 USFWS Biological Opinion (USFWS 2001), NRC report (NRC 2002), OSU-UC Davis report (Chapter 5 by Markle and Cooperman in Braunworth et al. 2002), and University of California Peer Review (2001). IMST interpretations of quotes are in bold.

Conclusions in 2001 USFWS Biological Opinion	IMST Report	NRC Report	OSU-UC Davis Report	University of California Peer Review
1. USFWS document is technically sound and based on best available science.	**IMST conclusions:** **USFWS Biological Opinion is technically sound. As with all ecological processes and natural resources, variation in space and time create uncertainty inherent in all management decisions.**	**IMST interpretation:** **NRC says USFWS Biological Opinion has scientific support for most recommendations except for minimum lake levels.**	**IMST interpretation:** **OSU-UC Davis report says USFWS Biological Opinion is technically sound.**	**IMST interpretation:** **UC Peer Review says USFWS Biological Opinion is technically sound.**
"The Service concludes that the pre-project minimum lake levels of 4140 ft (and similar minimum lake levels presented in the RPA [Reasonable and Prudent Alternative] are necessary to protect suckers from adverse water quality and are based on the best available science." (Section III, Part 2, p.87) "This BO [Biological Opinion] is based on: (1) information presented in Reclamation's final BA [Biological Assessment] dated February 13, 2001; (2) information presented in previous BAs and BOs addressing operation of the Project; (3) information obtained from Reclamation in meetings regarding operation of the Project, and from the results of ongoing field research activities; (4) information provided in published and unpublished reports on the biology, distribution, systematics, and status of the affected listed species and the ecosystems upon which they depend; (5)		"The NRC committee concludes that all components of the Biological Opinion issued by the USFWS on the endangered suckers have substantial scientific support except for the recommendations concerning minimum water levels for Upper Klamath Lake" (p.3)	"The data on which the management of Upper Klamath Lake elevation is based vary in completeness" (p.113) "Although there was no requirement for peer review, the 2001 BiOp [Biological Opinion] was sent to peer reviewers as a rough draft ... and as a final document ..." (p.113)	"The Biological Opinion is generally supported by sound science and hard data, and appropriate literature and research sources are cited. Because much of the data are from unpublished reports it is difficult to adequately assess some of the interpretations made in the Biological Opinion. While this is a common situation in documents of this type, it should be recognized that many of the interpretations and assumptions in the Biological Opinion are not supported with data that have been evaluated or interpreted by the general scientific community." (p.2 summary)

Conclusions in 2001 USFWS Biological Opinion	IMST Report	NRC Report	OSU-UC Davis Report	University of California Peer Review
communications with field researchers who have conducted, or are now conducting research on the biology of affected listed species or the ecosystems upon which they depend; (6) other available commercial and scientific information; and (7) comments and reports received in response to reviews of the March 13, 2001 draft BO [Biological Opinion].” (Memorandum of transmittal for USFWS 2001 Biological Opinion)				
2. Management of lake level is a technically sound approach to reduce the potential for fish kills in Upper Klamath Lake. “...both Reclamation and the Service recognize that high lake elevations can enhance the probability of year-class survival and reduce the frequency and magnitude of major sucker die-offs, and is the only short-term way to offset some of the threat to sucker populations in UKL [Upper Klamath Lake].” (Section III, Part 2, p.106)	**IMST conclusion:** **IMST agrees with USFWS that Upper Klamath Lake level is one of several appropriate management tools to reduce conditions that lead to fish kills.**	**IMST interpretation:** **NRC says that, because there is no evidence of links between sucker die-offs and lake levels, management of Upper Klamath Lake level is not an appropriate or effective management option.** “...there is presently no sound scientific basis for recommending an operating regime for the Klamath Project that seeks to ensure lake levels higher on average than those occurring between 1990 and 2000. At the same time, the committee concludes that there is no scientific basis for operating the lake at mean minimum levels below the recent historical ones (1990-2000), as would be allowed under the USBR proposal. Operations leading to lower lake levels would require acceptance of undocumented risk to the suckers” (p3-4)	**IMST interpretation:** **OSU-UC Davis report says lake level is an appropriate tool for sucker management, though the amount of benefit to suckers is not well documented.** “The amount of water in Upper Klamath Lake ... is a particularly important variable in this story because it is manageable” (p.93) “The amount of insurance provided by 1 foot of lake elevation is not described. The empirical data suggest uncertainty regarding the size of the benefit of higher lake elevations. The 2001 BiOp [Biological Opinion] recognizes that other factors, primarily algal bloom dynamics and disease, complicate this relationship.“(p.112)	**IMST interpretation:** **UC Peer Review says that lake level is an appropriate tool for sucker management...with some limitations.** “The reviewers are in general agreement that higher lake levels need to be maintained, but there is concern that maintaining higher lake levels will not significantly improve water quality because of the nutritional loading from runoff in the Klamath Basin, and that the improved water quality may still not result in increased survival of the sucker populations.” (p.1 summary)

Conclusions in 2001 USFWS Biological Opinion	IMST Report	NRC Report	OSU-UC Davis Report	University of California Peer Review
3. Managing Upper Klamath Lake levels alone will not prevent sucker die offs "The Service acknowledges that meeting prescribed lake elevations does not ensure year-class success or prevent sucker die-offs. Other factors including weather, *AFA[Aphanizomenon flos-aquae]* bloom dynamics, disease outbreaks, and poor water quality can all lead to year-class failure and sucker die-offs independent of lake level." (Section III, Part 2, p.106).	**IMST conclusion:** **IMST agrees with USFWS that Upper Klamath Lake levels alone will not prevent sucker die-offs because lake is shallow and frequently mixing (thereby, creating hyper-eutrophic conditions).**	**IMST interpretation:** **NRC agrees with USFWS Biological Opinion that managing lake levels alone will not prevent sucker die-offs.** "Impairment of water quality, primarily through eutrophication of Upper Klamath Lake, is a cause of mortality and stress for sucker populations...the present scientific evidence for this association is credible. An essential premise of the lake-level recommendations is that the adverse water-quality conditions known to stress or kill the endangered suckers are associated with the lowest water levels within the recent historical range of levels (since 1990, when consistent documentation first began). Presumption of this connection, which is essential to the arguments for specific lake levels that are proposed in the RPA [Reasonable and Prudent Alternative], is inconsistent with present information on Upper Klamath Lake." (p.16-17) "Higher water levels are potentially supported on the grounds of improved survival of fry or juveniles rather than suppression of adult mortality" (p.17) "...substantial mass mortality [of suckers] occurred in 1971, the year of highest recorded water levels since 1950 (USFWS 2001),	**IMST interpretation:** **OSU-UC Davis report agrees with USFWS Biological Opinion that managing lake levels alone will not prevent sucker die-offs.** "[Lake elevation] often is not the most important variable, but other variables often are weather related or less manageable for other reasons ... Lake elevation also is cross-correlated with other variables of interest such as temperature and other important water quality variables." (p.93) "Specific mechanisms by which lake elevation influences water quality in a positive or negative way include, but are not limited to: dilution of nutrients and algae, delayed onset of algal blooms, lower water temperatures via a greater resistance to heating, higher dissolved oxygen availability and resupply rate, reduced internal loading of nutrients. Fish kills and poor water quality are thought to be set up in late spring by conditions conducive to large algal blooms." (p.108) "The USFWS believed that lake elevation was only part of a complex of factors creating fish kills and that fish kills may have been avoided during the 2 very low water years because of climatic conditions."(p.113)	**IMST interpretation:** **UC Peer Review agrees with USFWS Biological Opinion that lake level alone will not prevent sucker die-offs.** "While lake level is important for survival of these species, there is weak evidence that lake level alone is a strong predictor of long-term survival of these two species." (p.1 summary)

Conclusions in 2001 USFWS Biological Opinion	IMST Report	NRC Report	OSU-UC Davis Report	University of California Peer Review
		and within the past 10 years, mortality of adults was highest in 1995, 1996, and 1997 none of which were years of low water level ...The USFWS itself has found no association of mass mortality with lake levels." (p. 17) "Overall the presumed causal connections between lake levels and recruitment of the sucker populations in Upper Klamath Lake do not have strong scientific support at present" (p.18)		
4. Lake levels influence biological and chemical conditions that potentially cause fish kills. "Low lake levels per se do not cause fish kills; they can however, contribute to conditions that cause fish kills. Low lake levels can contribute to conditions that promote *AFA [Aphanizomenon flos-aquae]* blooms chiefly by increasing average light intensities in the water column and aiding internal nutrient loading, and can also worsen water quality conditions through a number of mechanisms, but chiefly by reducing lake volume/surface area ratios which reduce DO [dissolved oxygen] levels and increasing pH and ammonia concentrations, as discussed in detail below." (Section III, Part 2, p.71).	**IMST conclusion: USFWS conclusion is conceptually sound and supported by data on several fundamental relationships.**	**IMST interpretation: NRC says causal mechanisms used by the USFWS related to lake level may operate but data from Klamath Lake do not support these mechanisms.** "A substantial data-collection and analytical effort by multiple agencies, tribes, and other parties has not shown a clear connection between water level in Upper Klamath Lake and conditions that are adverse to the welfare of the suckers" (p.3) "No relationship between lake levels and population densities of algae (as shown by chlorophyll)... is evident, however, in the 9-year water-quality monitoring record that has been fully analyzed...Thus, the idea of relieving eutrophication through phosphorus dilution caused by higher lake levels is not consistent with the irregular	**IMST interpretation: OSU-UC Davis report says ecological links between lake levels and sucker die-offs are plausible and supported by some data.** "Although wind is not manageable, the working hypothesis in the 2001 BiOp [Biological Opinion] is that higher lake elevations could ameliorate the negative consequences of low summer winds. The BiOp [Biological Opinion] states: 'Low lake levels per se do not cause fish kills; they can however, contribute to conditions that cause fish kills. Low lake levels can contribute to conditions that promote AFA [*Aphanizomenon flos-aquae*] blooms chiefly by increasing average light intensities in the water column and aiding internal nutrient loading, and also can worsen water quality conditions through a	(Not addressed)

Conclusions in 2001 USFWS Biological Opinion	IMST Report	NRC Report	OSU-UC Davis Report	University of California Peer Review
		relationship between chlorophyll and lake level. Also, lake level fails to show any quantifiable association with extremes of dissolved oxygen or pH." (p.17) "there is no evidence as yet, however, that the significance of undesirable mixing events is higher when lake levels are low than when they are high. As a result, mixing as a cause of water quality conditions leading to mortality cannot be interpreted at this time in terms of lake level." (p. 19) "A negative association between the welfare of the [sucker] species and lake level could emerge if lake levels are reduced below those of recent historical experience." (p. 20)	number of mechanism, but chiefly by reducing lake volume/surface area ratios which reduce DO [dissolved oxygen] levels and increasing pH and ammonia concentrations...' Among examples to illustrate this point, the BiOp describes differences between shallower Agency Lake and Upper Klamath Lake proper." (p.108)	
5. Data on sucker populations are not statistically robust. Since the 1992 USFWS Biological Opinion, sucker populations may have continued to decline. "It is unclear what annual LRS [Lost River suckers]and SNS [shortnose suckers] population sizes are in UKL [Upper Klamath Lake]. However trends are apparent, although the available	**IMST conclusion:** **Data on sucker populations consist of different methods of obtaining measures of relative abundance for selected habitats and time periods. The efficiency of capture is strongly influences by fish species, size of fish, habitat type, and gear type. Long-term monitoring using consistent techniques for fish capture and consistent sampling protocols are essential.**	**IMST interpretation:** **NRC says that sucker population data are not sufficiently robust to support conclusions about population change.** "The population sizes of endangered suckers in Upper Klamath Lake and elsewhere in the Klamath Basin are uncertain, but the abundances of these populations, which once were	**IMST interpretation:** **OSU-UC Davis report says data are incomplete for drawing conclusion.** "Increased imperilment is not well documented because it has been difficult to get rigorous estimates of the annual adult population." (p.111)	(Not addressed)

Conclusions in 2001 USFWS Biological Opinion	IMST Report	NRC Report	OSU-UC Davis Report	University of California Peer Review
information should be used with extreme caution when drawing conclusions about annual changes in population size. The available data are generally not statistically robust and therefore of limited use for inter-annual comparisons. (Section III, Part 2, p. 45).” “By 1995, there was an increase in the numbers of spawning adults in the Williamson and Sprague rivers due to recruitment of the strong 1991 year class (Perkins et al. 2000[b]). However, fish kills in 1995, 1996 and 1997 apparently had a substantial negative effect on sucker population sizes and age class distributions. From 1995 to 1997 there was a substantial decline in the number of adults making spawning runs in the Williamson River, that amounted to an estimated 80-90% reduction in the adult population size for both LRS [Lost River suckers] and SNS [shortnose suckers] (Perkins et al. 2000[b]). Markle et al. (2000) found evidence that numbers of suckers in the Williamson River spawning migration in 1999 were still apparently depressed by loss of adults in 1995-1997 fish kills. However, for the 2000 spawning run, Cunningham and Shively (2001) found slightly higher abundance index values for LRS and SNS in the lower Williamson River than for the previous 3 years and an improved size-class distribution, indicative of possible improving population status.”		large enough to support commercial fisheries, are much lower than they were when agricultural development and water management began. Unfortunately, quantitative estimates of population sizes are not available” (p.11) “During the 1980s, qualitative evidence indicated that declines might have reduced the sucker populations in Upper Klamath Lake to just a few thousand old (greater than 10 years) fish (USFWS 1988). More recent estimates that were made possible incidentally by episodes of mass mortality suggest, however, that the populations are considerably larger than they appeared to be in the 1980s...” (p.11-12)	“Figure 1. Population index trends in Williamson River shortnose sucker spawning runs, 1995-2000 (USGS 2001)” (p.97) Figure shows steep decline in spawner population size after 1995-1997 fish kills to relatively low population levels. “Populations seem to have been increasing from 1988 to 1995, but those gains were lost in the 1995-1997 fish kills.” (p.111)	

Conclusions in 2001 USFWS Biological Opinion	IMST Report	NRC Report	OSU-UC Davis Report	University of California Peer Review
(Section III, Part 2, p. 45)"				
6. Since the 1980s, age class structure of sucker populations has shifted to a dominance of younger fish. **"**In the mid-1980s large, old fish dominated spawning populations. However, over the next 13 years there was only a single strong year class produced and that was in 1991 (Perkins et al. 2000)." (Section III, Part 2, p. 45)" "Current sucker population status data indicates that populations are...primarily dominated by fish less than 10 years old (mostly 1991 year class), and supported by development of only one strong year class since 1995 (in 1999)." (Section III, Part 2, p. 107)"	**IMST conclusion:** **IMST agrees with USFWS conclusion that sucker population sizes and age-class composition of sucker populations have changed during the last century, with a decline in older fish and a shift to a greater proportion in younger age classes.**	**IMST interpretation:** **NRC did not address the change in age-class structure of sucker populations. As described above in 5, NRC concluded that population sizes of suckers are uncertain.** "During the 1980s, qualitative evidence indicated that declines might have reduced the sucker populations in Upper Klamath Lake to just a few thousand old (greater than 10 years) fish (USFWS 1988). More recent estimates that were made possible incidentally by episodes of mass mortality suggest, however, that the populations are considerably larger than they appeared to be in the 1980s..." (p.11-12) **Note the clarification of this quote on page 29 in this IMST report.**	**IMST interpretation:** **OSU-UC Davis report says sucker populations seem to have been increasing since closure of fishery, but those gains were lost in the 1995-1997 fish die-offs; however, data are sparse; sucker population structures have been changing.** "Populations seem to have been increasing from 1988 to 1995, but those gains were lost in the 1995-1997 fish kills." (p.111) "The lack of long-term adult abundance data and quantifiable fish kill data is a major data gap."(p.97) "The impact of the closure of the fishery seems to be reflected in the age-class distribution of suckers killed during the 1997 fish kill ... Those data show that most of the population susceptible to fish kills in 1997 was born after the fishery closed." (p.100) "Coupled with the apparent declining adult abundance, the shift in age structure to younger fish means that reproductive potential declined. The loss of large, old fish during the [1995-1997] fish kills means that ... the reproductive potential would have been lower in 2001." (p.97)	(Not addressed)

Conclusions in 2001 USFWS Biological Opinion	IMST Report	NRC Report	OSU-UC Davis Report	University of California Peer Review
7. Wetlands play an important role in Upper Klamath Lake ecology "Wetlands play a crucial part in the ecology of UKL today; however, in the past, prior to widespread wetland loss and degradation, they were even more significant." (Section III, Part 2, p. 38)"	**IMST conclusion:** **Historical wetland distributions provided significant nutrient uptake and storage; Important factor in reducing phytoplankton productivity in Upper Klamath Lake.**	(Not addressed)	**IMST interpretation:** **OSU-UC Davis report says loss of wetlands contributes to increased nutrients in Upper Klamath Lake; report does not explicitly make link to fish management or restoration.** "Many human activities contribute nutrients to the lake, including cattle grazing, agricultural fertilization, drainage of wetlands, and, to a lesser extent, soil erosion and domestic sewerage." (p.107) "The production and export of external nutrient loads to Upper Klamath Lake is exacerbated by the loss of the filtering effects of wetlands and streamside riparian vegetation." (p107)	(Not addressed)
8. USFWS calls for coordination between agencies "Representatives from Reclamation, FWS, and NMFS shall coordinate with representatives from USGS, OSU, ODFW, CDFG, BIA, affected Tribes, and other parties, as appropriate, to consider and discuss available options for Project operation during a low water year that maximize implementation of RPA	**IMST conclusion:** **Scientific support exists for coordination between agencies. Watershed practices, water withdrawal, non-point source pollution, and distributions of fish species throughout river networks make interstate and multi-agency coordination essential.**	**IMST interpretation:** **NRC says there is scientific support for interagency coordination.** "The committee finds reasonable scientific support ...for [interagency] coordination" (p.27)	(Not addressed)	

Conclusions in 2001 USFWS Biological Opinion	IMST Report	NRC Report	OSU-UC Davis Report	University of California Peer Review
components for FWS and NMFS listed species. FWS and NMFS shall consider the results of this discussion when the agencies coordinate to determine how to best satisfy RPA component 1 and Klamath River flows downstream for the coho salmon in order to best protect each listed species."				

IMST Conclusions on Upper Klamath Lake and Resource Management

In this section, we present our conclusions specific to Upper Klamath Lake and resource management issues. IMST conclusions specific to management of the Klamath River below Iron Gate Dam are presented at the end of Part II: Klamath River Management and Resource Issues. IMST conclusions that are not specific to either region are presented in the section on Landscape-level Conclusions following the Part II conclusions.

Conclusion 1: Sucker populations may have declined in the last decade, particularly in response to three major fish kills and several low water years, though population sizes are difficult to accurately estimate and are subject to many sources of error. Long-term declines over the last century have been substantial.

> The degree of decline since the 1992 USFWS Biological Opinion and the effectiveness of management actions have been debated. In general, data on sucker abundance do not strongly demonstrate that sucker populations have continued to decline since the early 1990s, when conservation actions were recommended in 1992 USFWS Biological Opinion. The accuracy of fish population assessments is low; therefore, detection of trends at low abundance is poor. The combination of low population estimates and weak accuracy of methods for population estimation creates substantial risks for resource management actions and warrants precautionary approaches. In addition, three major fish kills have occurred since the 1992 Biological Opinion, indicating that major threats to sucker populations still occurred under the management policies that were being implemented from 1992 to 2003. However, all technical sources conclude that sucker populations are far lower than historical levels of abundance.

Conclusion 2: Between 1991 and 2001, abundance of juvenile suckers was lowest in the years of lowest lake levels.

> Abundances of larval and juvenile suckers have been extremely low during recent years of low lake elevations and much higher during years of high lake levels. We agree with the USFWS 2001 Biological Opinion that recruitment of juvenile fish is poor in years with late summer lake levels below 4138 ft.

Conclusion 3: Availability of spawning areas and access to refuges in Upper Klamath Lake are greater during high than low water.

> Between February and May, spawning occurs along the shoreline of the lake and in tributaries. In summer, suckers use habitats in Upper Klamath Lake with access to tributary inputs. The deeper water zone is shifted offshore as lake level becomes lower, influencing the access of suckers to possible refuges during periods of low water quality.

Conclusion 4: IMST concludes that factors involved in fish kills are complex and difficult to predict. They involve lake levels, phytoplankton blooms, stratification, winds, mixing, and bottom sediments. We also agree with the NRC that there is no strong scientific data to link fish kills with lake levels between 1990 and 2000. Typically, from such a short time series it is difficult to determine scientifically whether a relationship does or does not exist.

Many factors are associated with die-offs of suckers in Upper Klamath Lake (e.g., dissolved oxygen, pH, ammonia, temperature, bacterial infections). All of these are interrelated, and it is impossible to identify a single causal factor in the die-offs. All of these factors are related to the phytoplankton blooms, subsequent decomposition, and periods of lake stratification and mixing. In addition, environmental and climatic variability (e.g., temperature, duration of warm weather, winds) make occurrence of phytoplankton blooms and fish kills even more variable and less predictable.

Continued monitoring and analysis of relationships between lake levels and limnological conditions in Upper Klamath Lake are needed to better understand these complex interactions,

The IMST agrees with the USFWS BO that prescribed lake levels will not ensure sucker survival or prevent fish die-offs. We also agree with the NRC Interim Report that there is no strong scientific data to link fish kills with lake levels between 1990 and 2000. This lack of a clear relationship, however, does not indicate that management of lake levels is unwarranted. Lake levels influence other aspects of sucker life histories and empirical evidence from Klamath Lake is scientifically stronger for these relationships. IMST also agrees with the NRC Interim Report that lake levels below those observed during these years may jeopardize sucker populations.

Conclusion 5: Regulating lake levels is one of the few options available to management agencies to protect sucker populations. IMST agrees with USFWS that lake level management is one of several appropriate management tools to reduce conditions that may lead to fish kills, but lake level management alone will not prevent sucker die-offs. The minimum lake levels required for protection of suckers are not exact.

Higher lake levels offer several potential benefits to fish populations. Lake level determines the availability of critical habitats for spawning adults and young fish (e.g., use of emergent vegetation by larval suckers, use of nearshore open gravel habitat by juvenile suckers).

Factors that contribute to phytoplankton production (e.g., resuspension of sediments and phosphorus during mixing) and development of phytoplankton blooms (e.g., lake volume) are related to lake levels. Management of lake levels cannot guarantee the prevention of future fish kills because of the complex factors related to stratification, primary production, lake turnover, and external nutrient loading. Weather is a major factor that determines the conditions that lead up to fish kills and the high winds cause rapid lake mixing that frequently coincides with the major fish kills. Obviously, weather, warming, and wind are highly variable, difficult to predict, and impossible to manage. These factors cannot be controlled by natural resource management agencies and can only be influenced indirectly by lake volume or level. Fish kills will occur at any lake level if unfavorable environmental conditions occur. The fish kills of 1995, 1996, and 1997 occurred during years of relatively high lake elevations.

Although the IMST agrees with NRC (2001) that there is no clear empirical evidence for the relationship between lake levels and fish kills , based on available data low lake levels (below 4137 ft) have reduced availability of lake spawning and rearing habitats and are associated with low abundances of juvenile suckers.

We also agree with NRC that lowering lake levels below the mean levels that occurred during the period from 1990-2000 would pose substantial risks to sucker populations and would not be prudent.

We conclude that lake levels are the only factor that can be controlled and that high lake levels, although not ensuring prevention of fish kills, is prudent and ecologically sound. Low lake levels jeopardize populations (data indicate poor sucker performance between 4137 and 4140 ft; the 2001 USFWS BO identified 4137.1 ft as a critical depth).

Conclusion 6: Wetland and riparian restoration could lower the risk of sucker die-offs and provide additional benefits to the Upper Klamath Lake and Klamath River system.

Lake levels are not the direct cause of algal blooms. Increased nutrient loading into the lake from human actions in the watershed and destruction of wetlands around the lake directly and indirectly increase the potential and extent of phytoplankton blooms. Actions to reduce nutrient loading into Upper Klamath Lake and restoration of wetlands around Upper Klamath and Agency Lakes are likely to reduce the frequency and extent of phytoplankton blooms in the future. These actions should be recognized and aggressively pursued by management agencies via current regulatory and restoration programs (Total Maximum Daily Loads, Oregon Senate Bill 1010, Riparian Wetland Reserve Programs, etc.).

Conclusion 7: Management of tributary spawning habitat, using a watershed approach, will be important to survival of sucker populations.

The spawning habitats for Lost River and shortnose suckers in the Williamson and Sprague Rivers need protection to enhance recovery of these species in Upper Klamath Lake. Assessment of the potential effectiveness of the existing fish ladder for passage of adult suckers at the Chiloquin Dam is needed, and if necessary, the ladder should modified and made more effective for passage of suckers. A watershed approach, involving multiple agencies, is the most technically sound method available to improve the water quality of the major sucker spawning tributaries.

Part II: Klamath River and Resource Management Issues

In this section, the IMST identifies relationships in the Klamath River basin that are specific to coho salmon. Because they are listed as threatened under the ESA, NMFS only addressed coho salmon in their 2001 Biological Opinion. However, natural resource management agencies recognize the dangers of single-species management (Lee 1993; NRC 1996) Two other important salmonid species, chinook salmon and steelhead occur in the mainstem Klamath River and are also affected by management decisions made for coho salmon. These two salmonid species have environmental and habitat requirements that often closely resemble those of coho salmon. Therefore, the IMST believes that environmental and habitat conditions for other aquatic species are relevant issues for federal resource managers in the Klamath Basin.

Science Question 4. Are the NMFS (2001) determinations of minimum flow requirements for coho salmon in the Klamath River below Iron Gate Dam based on the best available science?

Historically, coho salmon occurred in the Klamath River as far north as the mouth of Lower Klamath Lake in California (see Figure 1 on page 9). Currently, Klamath River coho salmon are limited to Klamath River reaches and tributaries downstream of Iron Gate Dam. Coho salmon populations in the Klamath River basin are part of the Evolutionarily Significant Unit (ESU) for the Southern Oregon/Northern California Coasts (SONCC) coho salmon, one of six regional ESUs (Weitkamp et al. 1995). The SONCC coho salmon are listed as threatened under the federal ESA. Chinook salmon and steelhead also occur in the Klamath River but are not currently listed under the federal ESA.

Under the California ESA, coho salmon in the California North Coast Region have been listed as a candidate species since 2001. The California Fish and Game Commission recently found that coho salmon warrant California ESA listing and has directed the California Department of Fish and Game (CDGF) to produce a Coho Recovery Plan for the California North Coast, including the Klamath, Scott, Shasta, and other Klamath Tributaries by the end of 2003. Production of this recovery plan in coordination with NMFS is currently underway.

California coho salmon populations are estimated to be at less than one percent of their recent historical (mid-twentieth century) abundance; almost half of the streams that historically contained coho salmon no longer support them (Brown and Moyle 1991). Coho salmon have been found in 36% of 396 California streams that once supported coho populations (Brown et al. 1994). Several of the California streams that lost coho salmon stocks were in the Klamath River basin. Reasons for decline in SONCC coho salmon populations include habitat degradation, harvest, water diversions, artificial propagation, and ocean conditions (NMFS 2001).

Habitat degradation in the Klamath River basin includes changes in channel morphology and substrates, loss and degradation of wetlands and riparian areas, declines in water quality, altered streamflows, impediments to fish passage, and loss of freshwater and estuarine habitats. NMFS (2001) identified major human activities that led to declines in coho salmon in Oregon and California including water withdrawals, unscreened diversions for irrigation, over harvest by non-tribal fisheries, logging, road building, grazing, mining, urbanization, stream channelization, dams, wetland loss, and beaver trapping (NMFS 1997).

Upper Klamath Lake is the major water source of the Klamath River (see Figures 1 and 2; pages

9 and 10). Therefore, most of the water that is discharged from Iron Gate Dam (located in California) ultimately comes from Upper Klamath Lake (although some water comes from Clear Lake and Gerber Lake via the Lost River Diversion Channel). Consequently, Upper Klamath Lake is being managed to not only provide irrigation water but to also support suckers in Upper Klamath Lake and coho salmon in the Klamath River. Water withdrawal (including withdrawals from Upper Klamath Lake) by the Klamath Reclamation Project reduces flows in the mainstem Klamath River as it flows through Oregon before entering California. These water withdrawals potentially affect the survival of coho salmon, as well as chinook salmon and steelhead.

Presence of Coho Salmon in Mainstem Klamath River

Juvenile coho salmon have been observed in the mainstem Klamath River during every month from March through September. Resource agencies have documented juvenile coho salmon migration from tributary streams into the mainstem Klamath River soon after emergence from the gravel (USFWS 1997; CDFG 1994). Coho salmon fry and smolts enter the Klamath from March through July (Figure 21; USFWS 1996). These fish need adequate mainstem rearing and outmigration flows. Coho salmon young-of-the-year occupy the mainstem Klamath River from April through late July, and coho salmon yearlings are present from mid-March through August (USFWS 1997). Young-of-the-year were found in the mainstem Klamath River during August and September (Belchik 1997 as cited by Giannico and Heider (2002). In 2001, the USFWS observed coho salmon juveniles in the mainstem Klamath River during all of their surveys, which extended through late July (USFWS data from T. Shaw, pers. comm.[16]).

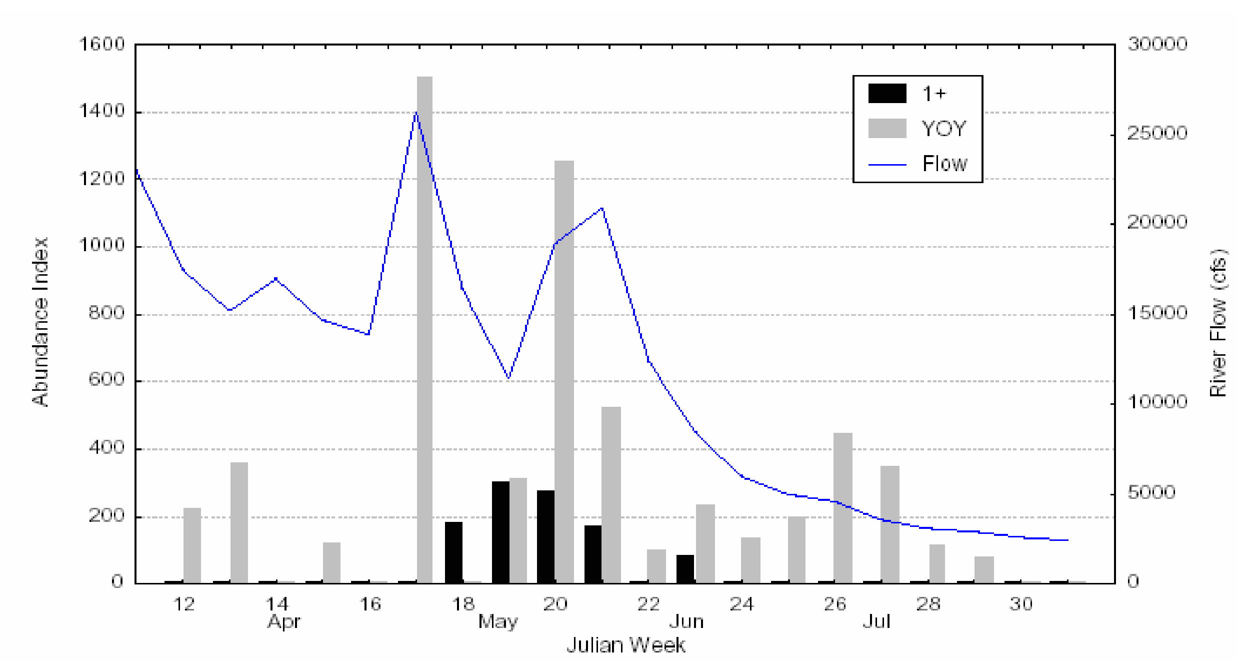

Figure 21. Juvenile coho abundance versus flow in Klamath River in 1996. Weekly abundance of juvenile coho salmon determined at Big Bar trap at river kilometer 80 of the mainstem Klamath River. Mean weekly flow of the Klamath River measured at Orleans, California (USFWS 1996). Two age classes of juvenile coho are represented: young-of-the-year (YOY) and age 1+.

[16] Shaw, T. Personal Communication. 2001. USFWS, Arcata, California.

Since 1988, the USFWS has conducted fish trapping at a site on the mainstem Klamath River at river kilometer 80 (Big Bar river access, 10 river-kilometers above the Trinity River confluence). Several juvenile salmonid species have been captured in this trap, including coho salmon, chinook salmon, and steelhead. Other fish species captured in the Big Bar Trap on the mainstem Klamath River include green sturgeon, Pacific lamprey, Klamath smallscale sucker (*Catostomas rimiculus*), and sculpins (*Cottus* spp.). Scheiff et al. (2001) show abundances of wild and hatchery juvenile coho salmon captured in this trap from April to July in every year from 1988-2000 (Figure 22). Because the USFWS Big Bar Trap was only operated April to July of each year, coho salmon juveniles present in the mainstem Klamath River after July were not counted.

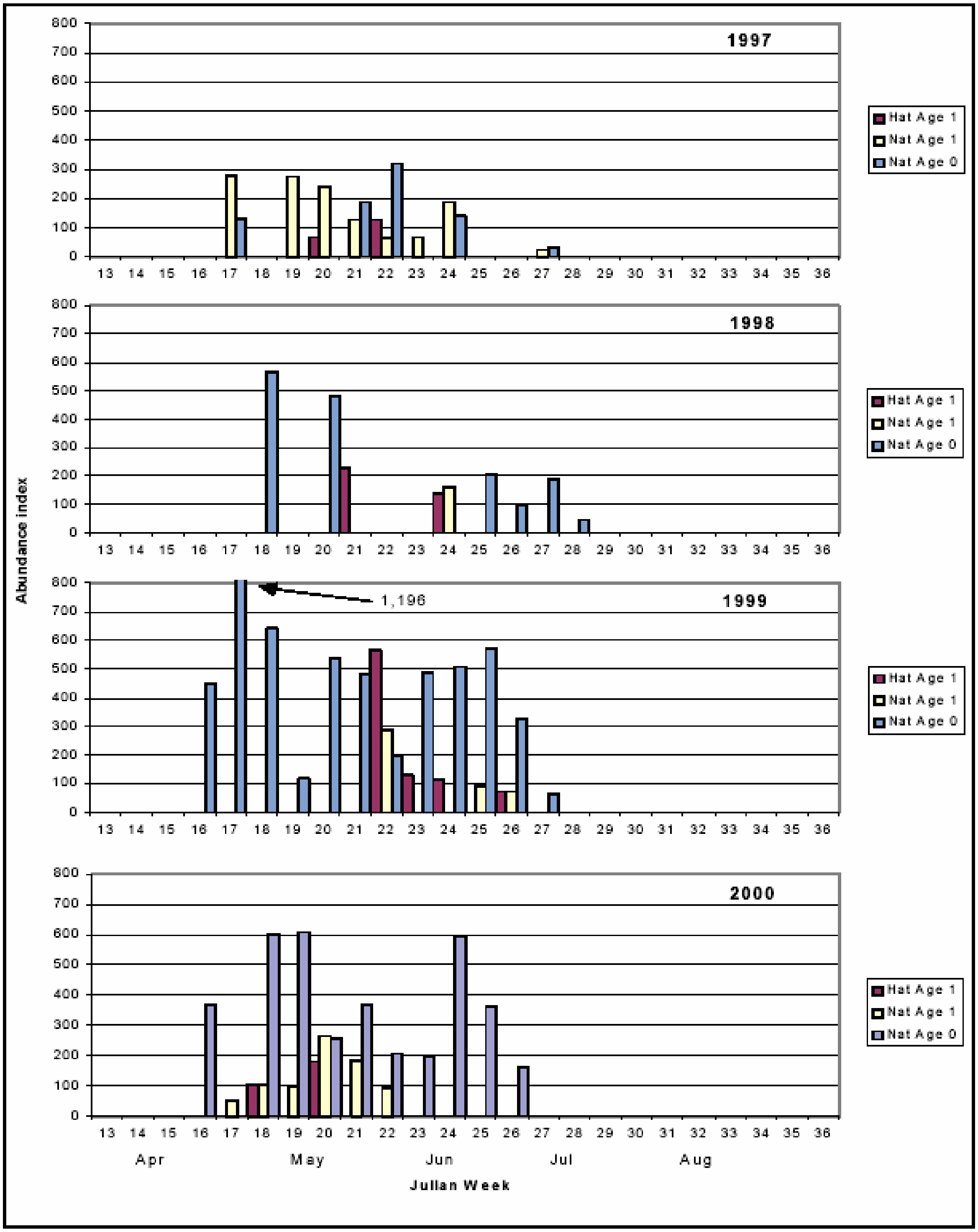

Figure 22. Juvenile coho salmon in the mainstem Klamath River, April-July (1997-2000). Weekly abundance index totals for natural (Nat) and hatchery (Hat) juvenile coho salmon at the USFWS Big Bar trap on the mainstem Klamath River. Julian week refers to week number beginning January 1. Abundance index is a measure of number of fish trapped adjusted for effort. See Scheiff et al. (2001) for methodology.

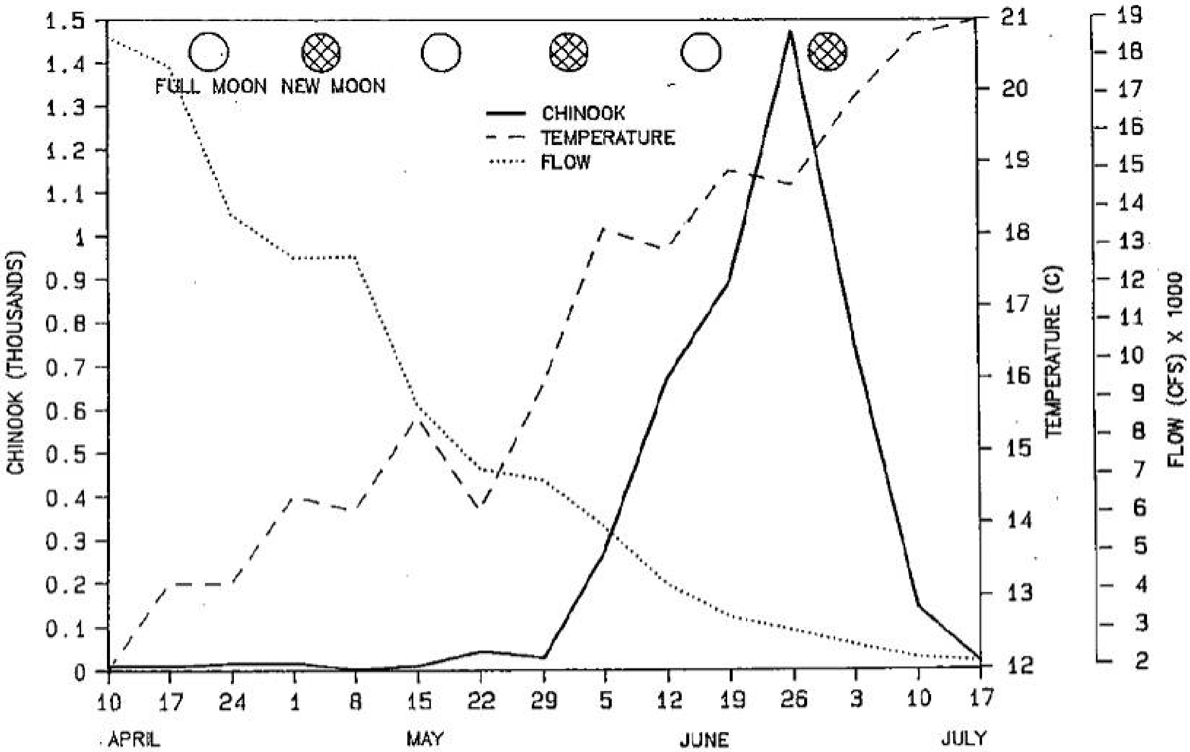

Figure 23. Juvenile chinook salmon captured in 1989 while migrating in mainstem Klamath River. Coincidental Klamath River streamflow, temperature, and lunar phase are also shown. Catches represent seven-day total of migrating chinook salmon based on weekly catch effort. Reproduced from Craig (1991).

Both juvenile coho salmon and juvenile chinook salmon are present in the mainstem Klamath River April through July. Juvenile chinook salmon migrate during a time of decreasing streamflow and increasing stream temperature in the Klamath River, as shown in Figure 23 (Craig 1991). Craig (1991) notes that although river flow, water temperature, and lunar phase can affect emigration of juvenile chinook to a degree, no apparent consistent relationship exists between these factors and catches of juvenile chinook. Figure 23 does not show causal relationships, but illustrates that the timing of outmigration of juvenile chinook salmon occurs in a season when the mainstem Klamath River has increasing water temperature and decreasing streamflow.

In summary, all studies indicate that juvenile coho salmon use the mainstem Klamath River into early to mid-summer; however, none of the studies have looked for late season abundances. The mainstem Klamath River clearly supports wild and hatchery juvenile coho salmon, as well as other important fish species (e.g., chinook salmon, steelhead, green sturgeon, Pacific lamprey) for critical periods during summer. Wild coho salmon inhabit the Klamath River as juveniles, and migrate through the Klamath River as returning adults and as smolts going to the ocean.

Importance of Tributaries to Coho Salmon

Questions about the influence major tributaries (Shasta, Scott, Salmon, and Trinity) on salmonids and the mainstem Klamath River raise serious questions about management of water in the tributaries and maintaining adequate instream flows in the Klamath River below Iron Gate Dam. The NRC (2002) suggested that these tributaries provide more available habitat for coho salmon than the mainstem and hence are more important to the populations. However, salmonid habitat in the tributaries has been adversely affected by land use activities and water withdraws. For example, from 1964 to 1994 as much as 46 – 91% (average of 75 %) of Trinity River's instream flow was diverted in inter-basin transfers to the Sacramento River (USFWS and Hoopa Valley Tribe 1999). The NRC also concluded that increasing flows in the mainstem Klamath River during critical dry water years (as defined in Table 3 on page 20) might not significantly increase coho salmon survival. The IMST agrees that the major tributaries are important habitat for coho salmon in the Klamath River basin, however, the relative contribution of these tributaries to the mainstem is poorly understood since data are limited in their spatial and temporal extents.

The fate of coho salmon in the Klamath River is uncertain, but there is no doubt that they occur in the mainstem at least through September (CDFG 1994; USFWS 1996; Belchik 1997; USFWS 1997; Scheiff et al. 2001, Giannico and Heider 2002). Therefore, minimum instream flows in the mainstem is a relevant issue, regardless of whether or not the proportion of coho salmon in the mainstem is smaller than in the tributaries. Juvenile and migrating coho salmon (as well as chinook salmon and steelhead) occupy the mainstem Klamath River below Iron Gate Dam, and adequate habitat needs to be provided.

Flow management in the mainstem Klamath River requires appropriate flow contributions from large tributaries. Determining appropriate flow contributions from these tributaries is necessary to manage flows required in the mainstem. Much of the 2001 USBR Biological Assessment and the 2001 NMFS Biological Opinion focused on providing flows to the Klamath River from Upper Klamath Lake, Clear Lake, and Gerber Lake through discharges at Iron Gate Dam. This focus on discharge from Iron Gate Dam overlooks the importance flow from of major tributaries downstream of the dam. The volume of unimpaired (unaltered by management) flow from the tributaries is substantial and these tributary junctions may provide important holding habitat for migrating smolts and adult salmon.

The Coho Recovery Plan being developed by the State of California will include some management activities of tributaries to the Klamath River (W. Bennett, pers. comm.[17]) Allocation of stored water is one management tool. However, lack of water storage on the Shasta, Scott, and Salmon Rivers will limit some instream flow options for the mainstem Klamath River. The Oregon portion of the Klamath River basin has approximately 500,000 acre feet of storage, and two major California tributaries to the Klamath River (Shasta and Scott Rivers) have 180,000 acre feet of storage. A large portion of the water flowing in Trinity River, a third major tributary, is diverted away from the Klamath River and into the Sacramento River. Authorization of water withdrawals should be considered collectively with other management options.

In summary, rigorous studies of the distributions and abundance of coho salmon and other species in the mainstem Klamath River and its tributaries throughout the year are critical for developing appropriate management actions. The IMST concludes that management of BOTH

[17] Bennett, W. Personal Communication. 2003. Department of Water Resources, Sacramento, California.

the mainstem Klamath River and its major tributaries is extremely important; therefore, the state of California has a major role in the recovery of coho salmon and management of other important species in the Klamath River system. Management of the flows, habitats, and environmental conditions of just the mainstem Klamath River in isolation (without managing its tributaries) will be incomplete and will overlook a critical part of the Klamath River basin and habitats for its aquatic resources.

Minimum Streamflow for Coho Salmon in Klamath River

Relationships between streamflow and survival and abundance of salmonids in streams have long been noted (Wickett 1954; Everest et al. 1985). Streamflow regimes directly influence the depth and velocity of water, total available habitat for salmonids and their prey organisms, access to spawning and rearing habitat, and migration pathways. High flows redistribute sediments and flush spawning gravels (Spence et al. 1996). Flows also affect water quality (e.g., dissolved oxygen) and temperatures. Commercial catches of coho salmon in Washington were correlated with streamflows during the freshwater rearing phase in 21 river basins (Smoker 1955). Numbers of coho salmon spawners in the Puget Sound were correlated with summer streamflows during the period from 1952 to 1977 (Matthews and Olson 1980).

Adult Return of Coho Salmon and Use of Chinook Salmon Data

Due to the low numbers of coho salmon in the Klamath River, data on the relationship of spring flows to adult return of coho salmon three years later inherently would be highly variable and other factors (e.g., ocean harvest, habitat degradation, sport fishing) may obscure such relationships if they existed. Chinook salmon are found in relatively higher abundance in the Klamath River and provide a closely related surrogate for understanding factors that may influence the status of coho salmon.

Because chinook salmon and coho salmon are both cold-water species, with many similar requirements, data on chinook salmon provide some information relevant to coho salmon as long as scientists and managers are cautious about differences between the species. Though minor differences in thermal responses exist between chinook salmon and coho salmon, these two species are closely related and are relatively similar, physiologically (Groot and Margolis 1991).

In general, data on fall chinook salmon in the Klamath Basin are more available than data for coho salmon (Giannico and Heider 2002). Giannico and Heider (2002; p.142) noted in their discussion of USFWS unpublished data that "chinook data do show a relationship between river flows during emergence and smolt migration and spawner abundance of that year class 3 and 4 years later." In addition, the 2001 USBR Biological Assessment also presented a dataset from Craig (1998) showing relationships between chinook salmon returns with river flows during smolt migration (USBR 2001a). The IMST notes that correlations between Klamath River flows and chinook salmon presented in the 2001 USBR Biological Assessment are weak but statistically significant.

Because scientists agree that the data on coho salmon in the Klamath River are scarce and subject to many sources of variation, scientists do not expect strong statistically significant relationships between abundance of adult coho salmon and Klamath River flow. This lack of a statistically significant relationship does not mean that streamflow does not affect the performance and survival of coho salmon. Lack of an observed correlation does not negate the probable importance of river flows in providing adequate habitat for coho salmon in the Klamath River.

Importance of Establishing a Hydrologic Context

Studies of the mainstem Klamath River and habitat requirements for coho salmon quickly encounter a difficult challenge—establishing a reference hydrograph for the unimpaired flow in the Klamath River. As noted in our discussion of the history of management, water has been withdrawn and redistributed throughout the Klamath River basin since the end of the 1800s. Except for a few small streams, no major streams or tributaries with truly natural hydrographs or patterns of streamflow now exist in the Klamath River basin. Flow in the mainstem Klamath River has been greatly altered.

Because decisions about instream flow requirements are based on seasonal patterns of *unimpaired flow* (unaltered by management), there has been extensive debate about the appropriate reference condition for the Klamath River. The US Geological Survey is well experienced in hydrological analysis and could contribute substantially to the management of Klamath River resources by leading a cooperative, basinwide assessment of unimpaired flows as a reference for all management decisions. In addition, much of the controversy and confusion surrounding minimum flows in the Klamath River are due to the many methods used to determine minimum flows. See Appendix A for a discussion of these different methods.

Modification of Klamath River Flow

The Klamath River begins at Lake Ewauna downstream from Upper Klamath Lake in Oregon (see Figures 1 and 2 on pages 9 and 10) and has several dams constructed on the mainstem (J.C. Boyle, Copco Dams No.1 and No. 2, and Iron Gate Dam). The construction and operation of these facilities associated with the Klamath Reclamation Project and downstream hydroelectric generation have significantly altered the natural hydrographs of the Klamath River (NMFS 2001).

The Iron Gate Dam (completed 1962) was constructed to regulate flow releases from the Copco dams. However, operation of Iron Gate Dam did not restore the frequency and magnitude of flows to Klamath River observed before the construction of all reservoirs and dams on the mainstem Klamath River. Comparison of the pre-dam hydrographs (Figure 24) to post-dam hydrographs (Figure 25) demonstrates that mainstem flows have been greatly reduced during the summer season (June through August) and increased in winter (October through January). Historical flows ranged from just below 1,000 cfs up to almost 4,000 cfs, and modern flows have a wider range than historical flows (ranging from approximately 750 cfs. up to almost 4,500 cfs). In addition, the stair step pattern of modern flows from June through September reflects management of flows from Iron Gate Dam. In comparing these two figures, please note that they have different scales and were measured at two different locations along the mainstem Klamath River.

Yearly water management of the Klamath Reclamation Project varies by water year type (above-average, below-average, dry, and critical dry). Water years, as defined by USBR (2001a), USFWS (2001), and NMFS (2001) are based on the net inflow into Upper Klamath Lake predicted for the period from April through September (Table 3 on page 20). During most critical dry years from 1968-1998, USBR regulated flow in the Klamath River to levels below 1,000 cfs (Figure 9 on page 21).

Early studies estimated that flow reduction in the Klamath River below 1,000 cfs would negatively impact salmon populations (Wales 1944). This analysis was reconfirmed by later analyses by CDFG in 1955 (Sletteland 1995). In 1996, Trihey and Associates (1996) and Hecht and Kamman (1996) investigated Klamath River streamflow requirements to meet Tribal Trust responsibilities for the Yurok Tribe[18]. Minimum flow requirements for a typical above-average water year for Tribal Trust Species (coho salmon, spring and fall chinook salmon, steelhead, green sturgeon, Pacific lamprey, and eulachon, *Thaleichthys pacificus*) were estimated with a modified Tennant method, which is one of the more simple and easy instream flow methods (Tennant 1976, Trihey and Associates 1996). The flows recommended by Trihey and Associates (1996) were based on a consideration of habitat available under flow regimes in the Klamath River prior to the Klamath Reclamation Project and analysis of the consequences of altering those flows through water consumption, diversion, and storage. Streamflows recommended by Trihey and Associates (1996), USBR (2001a), and INSE (1999[19]) are shown in Table 10.

[18] The US has a trust responsibility to protect Tribal Trust resources. The US protects and holds Tribal fishing, gathering, hunting, and water rights in trust for the benefit of the Tribes (USBR 2002). USBR is obligated to protect fishing rights by preventing activities under its control that would adversely affect those rights, even though activities may occur off the reservation.

[19] Recommended flows by INSE (1999) is discussed in the Phase I Report Section of this report.

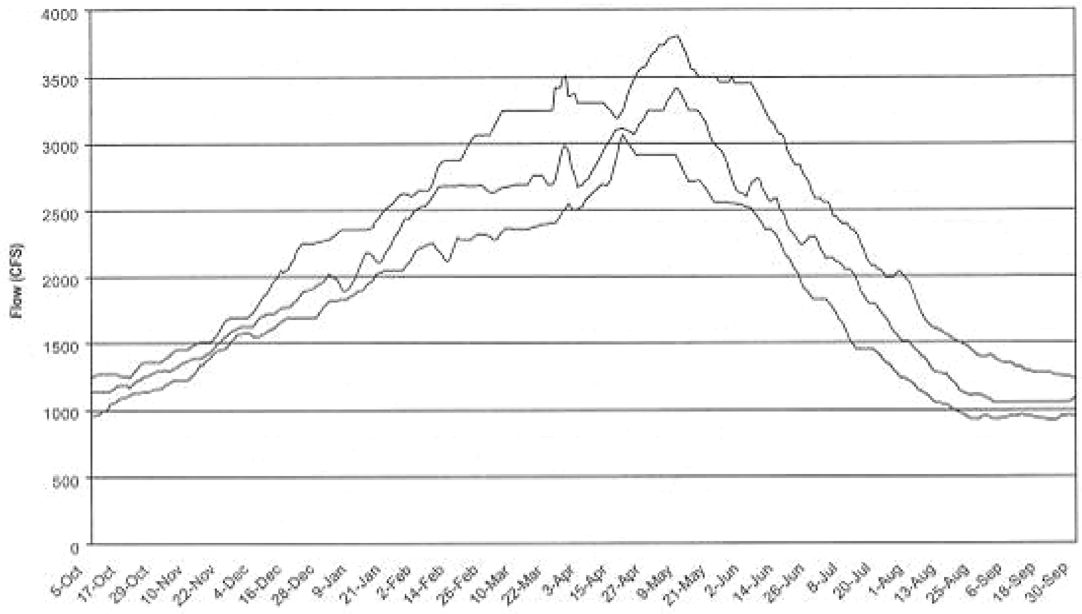

Figure 24. Klamath River flows before dams and facilities were built on the river. Average river flows from 1905 to 1913 at Keno, Oregon (near the California border, upstream from current Iron Gate Dam site). Five day moving averages: historic median, (middle line) 25th percentile (lower line) and 75th percentile (upper line). Reproduced from NMFS (2001).

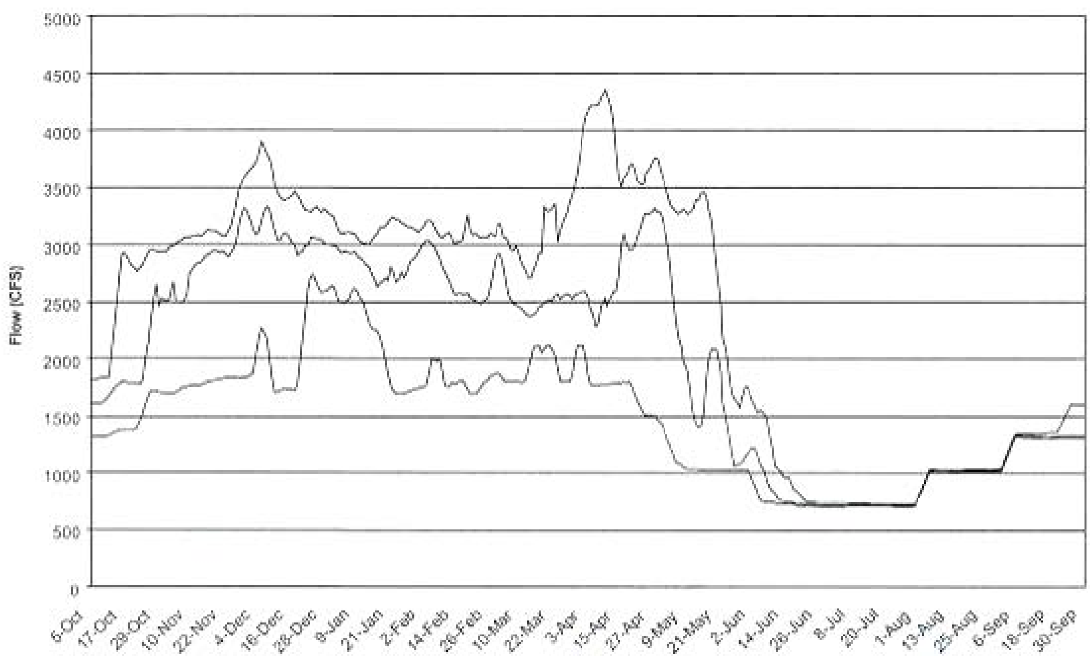

Figure 25. Klamath River flows after dams and facilities were built on the river. Flows measured at Iron Gate Dam, California (downstream from Keno, Oregon). Figure depicts average flows for the years 1963, 1966, 1969, 1970, 1973, 1985, and 1989. Five day moving average: normal water year median (middle line), 25th percentile (lower line) and 75th percentile (upper line). Reproduced from NMFS (2001). This figure has a different scale and was measured at a different location than Figure 24.

Table 10. USBR (2001a) proposed minimum flows for an above-average water year compared to Phase I Report (INSE 1999) proposed minimum flows for a normal water year, and Trihey and Associates (1996) proposed minimum flows. Data in this table is also presented in Figure 27. Note: when two values are given for a month, the first value is the minimum flow for the first two-week period of that month and the second value is the minimum flow for the last two-week period of that month.

Month	Phase I (cfs) (INSE 1999)	Trihey (cfs) (Trihey & Assoc. 1996)	USBR (cfs) (USBR 2001a)
October	1476	1200	1329
November	1688	1500	1337
December	2082	1500	1387
January	2421	1500	1127
February	3008	1500	910
March	3073	1500	1953/2101
April	3307	2000	1781/1629
May	3056	2500	1026/1730
June	2249	1700	760/742
July	1717	1000	705/680
August	1346	1000	1011
September	1395	1000	1035

Trihey and Associates (1996) recommended summer flows in the Klamath River downstream from Iron Gate Dam to be at least 1,000 cfs. For above-average water years, the USBR did not follow the Trihey and associates (1996) recommended minimum flows, proposing summer flows below 1,000 cfs, and spring flows below 2,000 cfs (USBR 2001a). NMFS, however, agreed with the analyses of Trihey and Associates (1996) for summer flows (NMFS 2001).

2001 Water Year

The 2001 water year was predicted to be a critical dry year. During consultations with USBR, NMFS found that: (1) SONCC coho salmon in the Klamath River below Iron Gate Dam were jeopardized by the low flows in the river, (2) coho salmon habitat in the mainstem Klamath River had been adversely affected by these low flows, and (3) coho salmon and their habitat would continue to be threatened by actions proposed in the 2001 USBR Biological Assessment (NMFS 2001). NMFS concluded that minimum instream flows of 1,000 cfs during the summer (July through August) were appropriate and would not jeopardize the species (NMFS 2001). The minimum flows below Iron Gate Dam proposed by NMFS were considerably higher than those recommended by USBR (Table 11).

Table 11. Proposed minimum flows at Iron Gate Dam for 2001, a critical dry water year. Note: NMFS only presented minimum instream flows for April through September. When two values are given for a month, the first value is the minimum flow for the first two-week period of that month and the second value is the minimum flow for the last two-week period of that month.

Time Period	USBR (cfs)(USBR 2001a)	NMFS (cfs)(NMFS 2001)
October	904	-
November	909	-
December	914	-
January	1011	-
February	525	-
March	501 / 521	-
April	569 / 574	1,700
May	525 / 501	1,700
June	476 / 536	2,100 / 1,700
July	429 / 427	1,000
August	398	1,000
September	538	1,000

Klamath Reclamation Project operations substantially affect flows, fish habitat, and water quality in the Klamath River below Iron Gate Dam. For both above-average and critical dry water years, NMFS concluded that the operations proposed in the 2001 USBR Biological Assessment would result in continued decline in the habitat conditions for coho salmon, and that USBRs proposed minimum flows were not based on the biological requirements of coho salmon. The alternative flows proposed by NMFS were intended to prevent further decline of the threatened coho salmon until long-term protection measures could be implemented (NMFS 2001).

As predicted, the 2001 water year was a severe drought year. Actual flows for 2001 below Iron Gate Dam are shown in Figure 26. Streamflows in the Klamath River below Iron Gate Dam met the 1,000 cfs minimum recommended by NMFS (2001) for most of the 2001 season.

Phase I Report

Prior to 2001, the Institute of Natural Systems Engineering (INSE) prepared a report for USBR known as the "Phase I" report (INSE 1999), which estimated minimum instream flows required for coho salmon below Iron Gate Dam. INSE (1999) used five established hydrologically based techniques[20] to estimate minimum flow requirements for *normal water years*. According to INSE (1999), normal water years had pre-project mean annual flows of 2,575 cfs in the Klamath River below where Iron Gate Dam was later constructed. Results from the five hydrologic techniques were averaged, and monthly minimum instream flows were recommended for the Klamath River below Iron Gate Dam. The average recommended flow was higher than 1,000 cfs (Table 10).

[20] Hoppe Method, New England Flow Recommendation Policy, Northern Great Plains Resource Program Method, Tennant Method, and Washington Base Flow Method

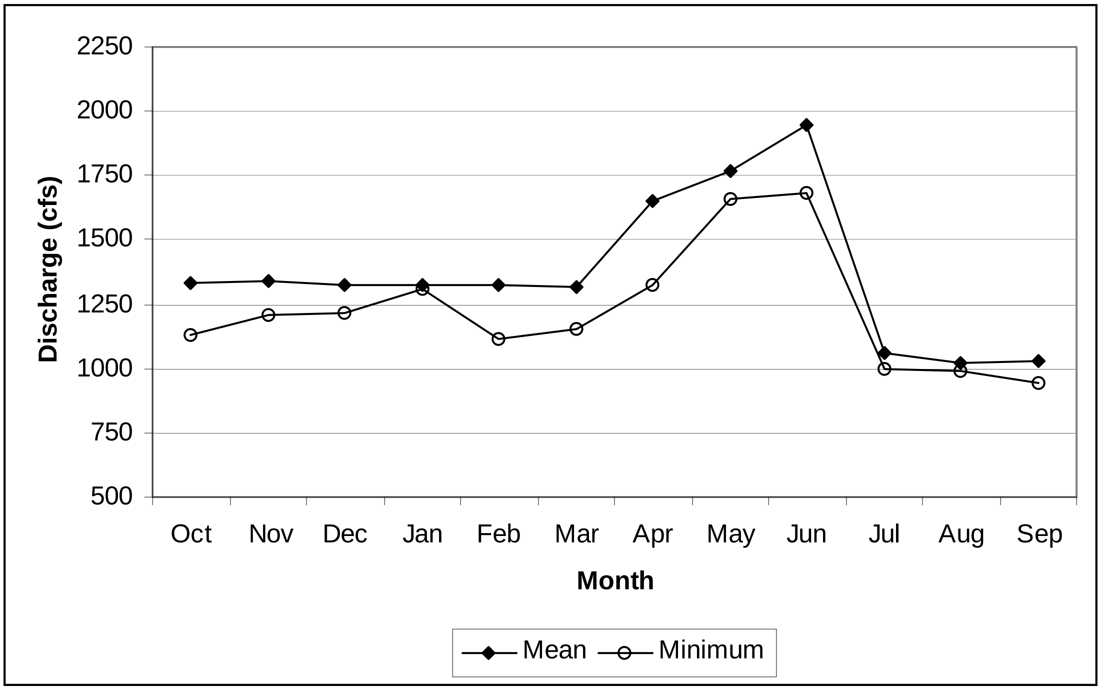

Figure 26. Actual Klamath River flows (mean and minimum) below Iron Gate Dam, California throughout 2001 water year. Values based on preliminary data provided by California Data Exchange Center (http://cdec.water.ca.gov) for Klamath River below Iron Gate Dam (Station ID: KIG) operated by USGS and Karuk Tribe of California.

Phase I minimum flows proposed for a normal water year are considerably higher than USBR (2001a) proposed minimum flows for an above-average water year, and higher than Trihey Associates (1996) proposed minimum flows (Figure 27 and Table 10). To set the context for determining instream flow requirements, INSE (1999) attempted to establish the natural shape of Klamath River's historical hydrograph pattern from before dams were operational on the river. This unimpaired flow was based on zero-demand flow, which differs from a naturalized flow that includes natural demands on river flow from marshes, etc. (Rasmussen, J. pers. comm.[21]). INSE unimpaired flow was anticipated to provide a better ecological flow regime than managed flows and would help maintain the physical and ecological linkages between the mainstem and the tributary systems (INSE 1999). Based on the Phase I report, if highest priority for Klamath River flow is based the needs of coho salmon, the USBR (2001a) proposed operations would not meet biological criteria (NMFS 2001).

[21] Rasmussen, John. Personal Communication. 2003. USBR, Klamath Falls, Oregon.

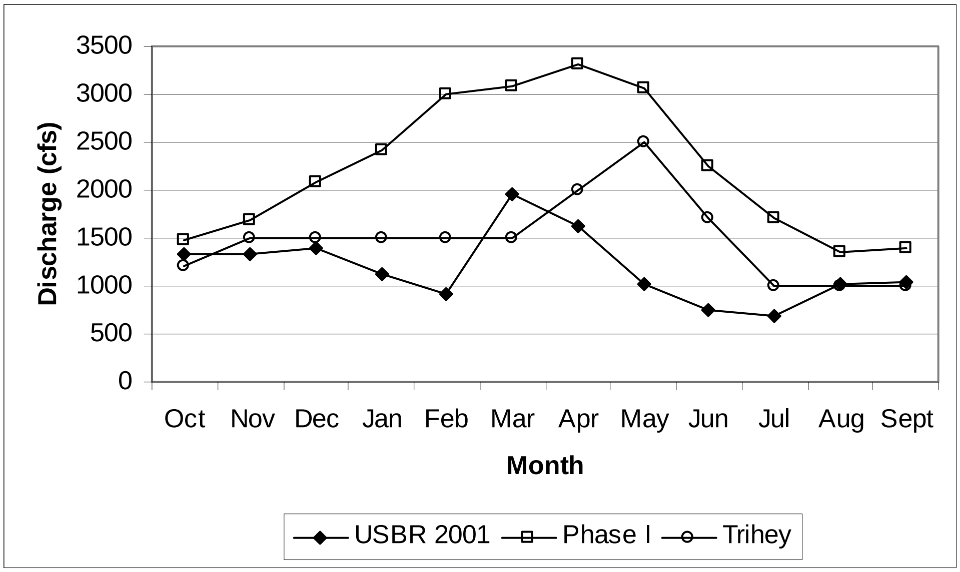

Figure 27. USBR (2001a) proposed minimum flows for an above-average water year compared with Phase I report (INSE 1999) proposed minimum flows for a normal water year and Trihey Associates (1996) proposed minimum flows. Data in this figure is also presented in Table 10.

In 2001, USBR compared the Phase I report proposed minimum monthly recommendations for a normal water year to USBR proposed minimum and mean monthly flows for an above-average water year (USBR 2001a). USBR noted that their proposed mean monthly flows exceeded those minimum monthly flows proposed by the Phase I Report from September through May 15. However, USBR failed to emphasize that the two documents were reporting different types of flow. The USBR flows were mean monthly flows but the Phase I report flows were minimum monthly flows, which would be inherently lower than mean flows. Also, the USBR flows were for an above-average water year but the Phase I Report flows were for a normal water year, which also would be inherently lower (Table 10; Figure 27).

In their 2001 Biological Opinion, NMFS rejected recommendations from the Phase I report for water management, not biological, reasons; water supply projections for the 2001 drought could not ensure adequate water in Klamath River and Upper Klamath Lake in late summer if the Phase I flows were used.

The analyses of instream flows and minimum flow recommendations in the Phase I report (INSE 1999) were criticized in a report submitted to the USBR by Miller (2001). Most of the criticism dealt with literature citations including the use of non-peer reviewed literature, and the lack of field verification or calibration estimated flows. The Phase I report used several well accepted hydrologically based approaches. These approaches were criticized because more recent methods were available. Nonetheless, the methods used by INSE (1999) incorporated analysis of flow duration curves and hydraulic determination of flow depth and velocities (using levels suitable for different life stages of salmonid species in the Klamath River), which are widely accepted in determining minimum instream flows. These analyses are also incorporated in the more recent approaches such as Instream Flow Incremental Methodology that incorporate biological and hydrological data (Appendix A). In addition, previous determinations of minimum instream flows for the Klamath River are quite similar to the Phase I minimum flows.

In a scientific review article, several noted natural resource scientists suggested that for adequate protection of fishery resources, new instream flow standards must be established and that existing standards be revised (Castleberry et al. 1996). The first step of this process is to set conservative (i.e., protective) instream flow standards. In the face of scientific uncertainty it is necessary to set conservative standards based on available information while noting deficiencies in the standards (Castleberry et al. 1996). The Phase I report set more conservative minimum flows for the interim period than other reports and noted deficiencies in the methods they used leading to their recommended flows.

<u>Phase II Report</u>

The Phase I report (INSE 1999) was followed by a draft "Phase II" report (Hardy and Addley 2001b), which estimated flow requirements based on field measurements of channel dimensions, velocities, and fish distributions. The draft Phase II Report, released in November 2001, determined minimum instream flows for the Klamath River using simulated hydrologic regimes of flow below Iron Gate Dam and field data with incremental methods. In simple terms, the draft Phase II report proceeded in four steps.

Step 1 simulated river flows estimated unimpaired (unaltered by management) river discharges, providing patterns of river discharge under different flow probabilities. These streamflows ranged from flows that would be exceeded only 10% of the years (10% exceedance; therefore, a relatively high flow) to flows that would be exceeded 90% of the years (90% exceedance; therefore, a relatively low flow)[22]. Specific instream flows for each exceedence level was determined for the Klamath River from Iron Gate Dam to the mouth of the Shasta River. These draft Phase II simulations of unimpaired flows are shown on Table 12 and Figure 28.

In Step 2, field data on fish distributions and habitat use (i.e., depth, velocity) were used to determine the amount of habitat under various unimpaired flows for coho salmon, chinook salmon, and steelhead (Table 13). In Step 3, these data for multiple species were combined to create a composite matrix of habitat availability for priority salmonid species and their life stages (Table 14).

[22] Water year types used by Hardy and Addley (2001b) would correspond to exceedence values as follows: Extremely wet – 10% exceedence; Wet – 30% exceedence; Average – 50% exceedence; and Critically Dry – 90% exceedence.

Table 12. Unimpaired monthly flows *estimated* by the draft Phase II report for the Klamath River between Iron Gate Dam and Shasta River for various exceedence flow levels. Reproduced from Hardy and Addley (2001b). Exceedance flow levels: 90 = exceeded 90 % of the time, a relatively low flow. 10 = exceeded only 10% of the time, a relatively high flow. Data is presented graphically in Figure 28.

Exceedance	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
10	5282	6439	6302	6430	5259	4163	2829	2131	2076	2169	2664	4522
20	3792	5416	5463	5391	4613	3690	2528	1935	1843	1991	2284	3541
30	3666	4245	5045	4869	4313	3473	2129	1639	1813	1885	2081	2910
40	2990	3724	4394	4541	3785	2870	1986	1490	1754	1700	2020	2460
50	2738	3072	3913	3841	3568	2689	1854	1425	1503	1589	1897	2282
60	2541	2914	3389	3078	2848	2216	1739	1300	1377	1492	1717	2100
70	2299	2559	2838	2637	2361	2033	1462	1158	1296	1450	1613	1903
80	2037	2249	2390	2342	2218	1797	1325	1141	1174	1394	1584	1762
90	1871	1922	1909	1908	1962	1533	1148	1004	1021	1163	1434	1643

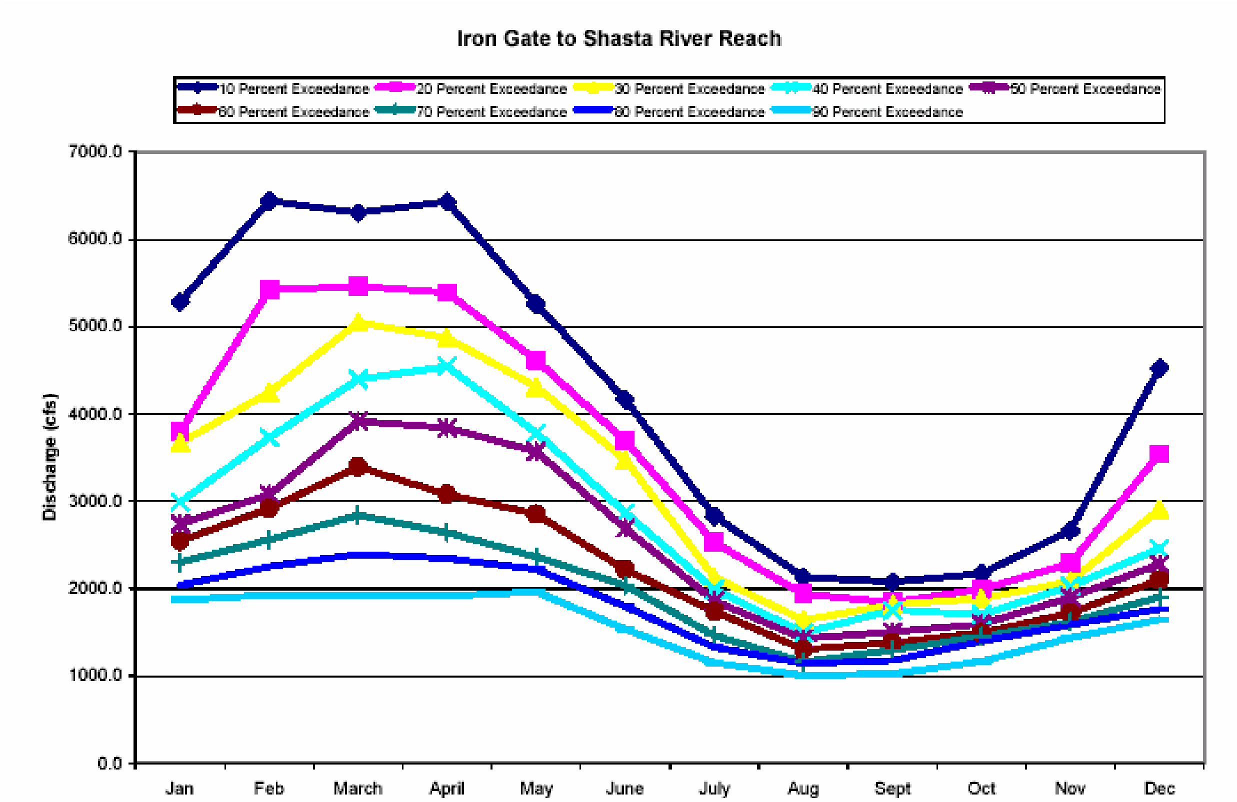

Figure 28. Unimpaired monthly flows *estimated* by the draft Phase II report for the Klamath River between Iron Gate Dam and Shasta River for various exceedence flow levels. Reproduced from Hardy and Addley (2001b). Data for figure is also presented in Table 12.

Table 13. Salmonid habitat available in the Klamath River between Iron Gate Dam and Shasta River identified by draft Phase II report. Percent of maximum habitat was estimated for each species and life stage based on estimated monthly unimpaired flows at each exceedence level. Species and life stages include spawning chinook salmon; young-of-the-year (YOY) chinook salmon, coho salmon, and steelhead; and 1+ 'summer' steelhead. Exceedance flow levels: 90 = exceeded 90 % of the time, a relatively low flow. 10 = exceeded only 10% of the time, a relatively high flow. Reproduced from Hardy and Addley (2001b).

ESTIMATED MONTHLY UNIMPAIRED FLOWS AT EACH EXCEEDENCE LEVEL (%)	**PERCENT OF MAXIMUM HABITAT AVAILABLE TO SALMONIDS**											
Chinook Salmon Spawning	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
10 (high flow)	24	15	16	15						91	77	33
20	47	23	22	23						95	88	53
30	50	37	26	28						97	93	70
40	67	48	35	32						99	94	83
50	75	65	44	45						100	97	88
60	81	69	56	65						100	99	92
70	87	80	72	78						100	100	97
80	94	89	85	86						100	100	98
90 (low flow)	97	96	96	96						97	100	100
Chinook Salmon YOY	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
10 (high flow)	97	82	84	82	97	100						
20	97	96	96	97	100	97						
30	96	100	98	99	100	95						
40	89	97	100	100	97	87						
50	85	91	98	98	95	84						
60	81	88	94	91	87	72						
70	75	81	87	83	76	67						
80	67	73	77	76	72	61						
90 (low flow)	62	63	63	63	64	58						
Coho Salmon YOY	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
10 (high flow)		89	90	89	99	92						
20		100	100	99	96	86						
30		93	98	97	93	83						
40		86	94	95	87	73						
50		76	89	88	84	69						
60		73	81	77	72	59						
70		66	72	68	62	54						
80		59	63	62	59	50						
90 (low flow)		52	51	51	53	47						
Steelhead YOY	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
10 (high flow)				83	94	100	89	74	72			
20				92	98	97	84	68	66			
30				97	99	95	74	62	65			
40				98	98	90	69	61	64			
50				98	96	87	66	60	61			
60				93	89	76	64	59	60			
70				86	80	71	61	57	59			
80				79	76	65	59	57	57			
90 (low flow)				67	69	61	57	57	57			
Steelhead 1+ Summer	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
10 (high flow)						30	39	53	55			
20						32	44	59	61			
30						33	53	68	62			
40						39	57	72	64			
50						42	61	74	72			
60						51	65	79	76			
70						56	73	84	79			
80						63	78	85	84			
90 (low flow)						71	85	90	89			

Table 14. Composite matrix portraying habitat available to priority species and life stages of salmonids in the mainstem Klamath River between Iron Gate Dam and Shasta River, as estimated in draft Phase II report. Exceedence flow levels: 90 = exceeded 90 % of the time, a relatively low flow; 10 = exceeded only 10% of the time, a relatively high flow. YOY = young-of-the-year. Reproduced from Hardy and Addley (2001b).

FLOW EXCEEDENCE	PERCENT HABITAT AVAILABLE TO SALMONIDS											
Composite Matrix	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
10 (high flow)	24	82	84	82	97	92	89	53	55	91	77	33
20	47	96	96	97	100	86	84	59	61	95	88	53
30	50	100	98	99	100	83	74	68	62	97	93	70
40	67	97	100	100	97	73	69	72	64	99	94	83
50	75	91	98	98	95	69	66	74	72	100	97	88
60	81	88	94	91	87	59	64	79	76	100	99	92
70	87	81	87	83	76	54	61	84	79	100	100	97
80	94	73	77	76	72	50	59	85	84	100	100	98
90 (low flow)	97	63	63	63	64	47	57	90	89	97	100	100
Priority species and Life stage	chinook salmon spawning	chinook salmon YOY				coho salmon YOY	steelhead YOY	steelhead 1+ summer		chinook salmon spawning		

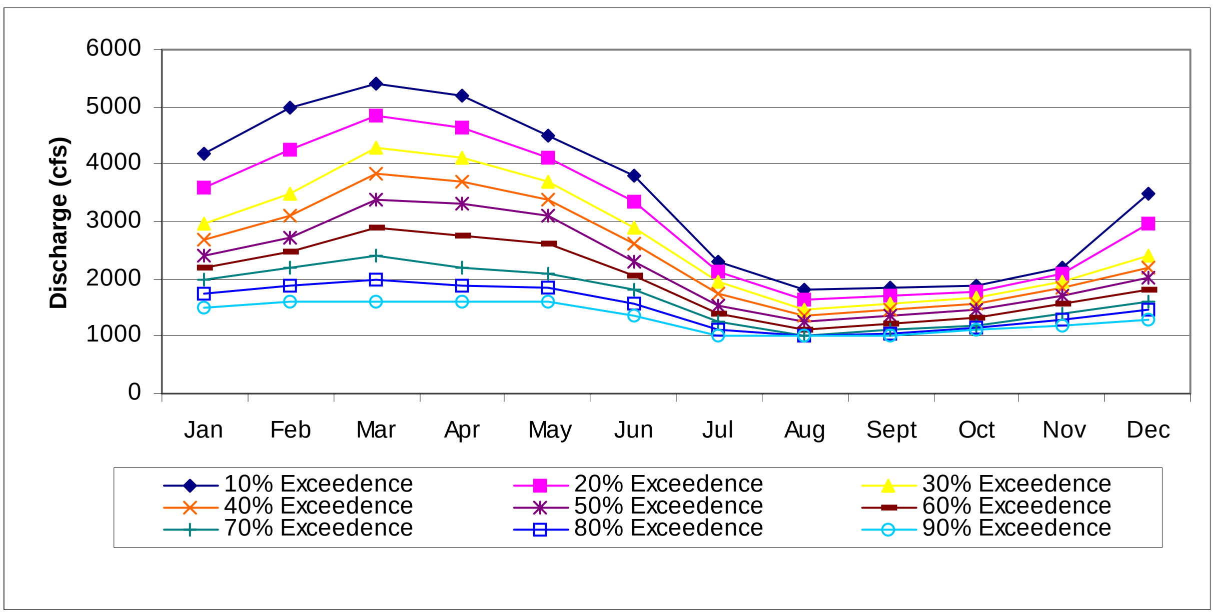

Figure 29. Monthly instream flows *recommended* for salmonids by draft Phase II report. Flows were recommended for the reach of the mainstem Klamath River between Iron Gate Dam and Shasta River at each exceedence level. Note that none of the recommended flows are lower than 1,000 cfs. Reproduced from Hardy and Addley (2001b).

The draft Phase II report (Tables 13 and 14) indicated that minimum flows required by salmonids in late summer at the 90% exceedance level (low flow) would be approximately 1000 cfs (Hardy and Addley 2001b). The habitat available for age 1+ steelhead increases with decreased flow possibly because this age class occupies riffles and rapid habitats, which are increased at low flow. This explains the higher percentage of habitat available to salmonids during July, August and September at low flows (Table 14) because other salmonids were not represented for those months (Table 13). The IMST notes that flows in the Klamath River have been reduced to 600-900 cfs within the last decade and represent potentially significant risks to the salmonids in the Klamath River.

In step 4, the minimum instream flows recommended for salmonids by the draft Phase II report shown in Figure 29 are based on available salmonid habitat (Table 14) and estimated unimpaired flows (Table 12 and Figure 28). The draft Phase II report minimum instream flows are consistent with all previous determinations of instream flows based on incremental flow methods (such as the Tennant Method, Appendix A).

The flows recommended in the draft Phase II report (Figure 29) based on field data are lower than flows estimated in the report (Figure 28). However, both the estimated unimpaired Klamath River flows and the recommended Klamath River flows are generally above 1,000 cfs.

<u>Summary of Minimum Streamflow for Coho Salmon</u>

In summary, determining minimum instream flow requirements for biota is complex because the interaction between flow and biota are complex and highly sensitive to river regulation and water withdrawal (Petts and Maddock 1994). Petts and Maddock (1994) summarized three major roles that water flows have within stream/river systems:

(1) Streamflow characteristics define the environmental domains within which each biological community develops;

(2) Streamflows of different magnitude determine the channel and floodplain morphology, and the types and age structure of the different sediment landform units that comprise river corridors;

(3) Groundwater and river regimes determine the nature of vertical interactions within the hyporheic zone.

Water allocation concerns have traditionally been directed at maintaining habitat for a target species, often a salmonid, during summer months (Petts and Maddock 1994). Traditionally, the intent of allocations was to determine the bare minimum level of water needed to allow for migration and spawning of salmonids. The maintenance of minimum flow is only one of a range of considerations necessary for the protection or rehabilitation of riverine systems and their biota. Instream flows and hydrographs affect stream channel morphology (including habitat features), movement of fine sediments and gravels, aquatic food webs, and riparian vegetation, which are all necessary for maintaining productive systems. Stalnaker (1994) suggests that by managing for minimum flows sufficient protection is not provided for stream resources during drought cycles, nor does it provide the opportunity for optimal fish production during wet years.

Water Temperature Effects on Coho Salmon in Klamath River

Salmonids require cold, well-oxygenated, unpolluted water (IMST 2002). Both Oregon and California have listed the Klamath River as water quality impaired for temperature, dissolved oxygen, and nutrients under the federal Clean Water Act. The basis for listing the Klamath River as impaired was aquatic degradation due to excessively warm temperatures, low dissolved oxygen, and algal blooms associated with high nutrient loads, water impoundments, and agricultural water diversions (NMFS 2001).

Average temperatures recorded in the mainstem Klamath River during 1999 are shown in Table 15. For an indication of the risks to salmonids, the summer water temperatures in the mainstem Klamath River after the end of June were above the State of Oregon temperature standards (ODEQ 1994/1996 Database) for rearing salmonids (64°F) and spawning salmonids (55°F).

Table 15. Klamath River water temperatures from May 1 through November 1999. Information derived from two sites, 60 miles apart, in a USBR water quality study. Reproduced from USBR (2001a).

Klamath River Below Iron Gate, California			Klamath River Near Seiad, California		
Semi-Monthly Period	**Average Tem. (°F)**	**Average Flow Data (CFS)**	**Semi-Monthly Period**	**Average Tem. (°F)**	**Average Flow Data (CFS)**
5/1-5/15	52.95	3,489	5/1-5/15	52.60	6,894
5/16-5/31	55.26	2,668	5/16-5/31	56.39	7,003
6/2-6/15	62.17	1,920	6/1-6/15	58.16	5,223
6/16-6/30	65.05	1,953	6/16-6/30	64.02	4,708
7/1-7/15	68.62	1,353	7/1-7/15	68.41	2,505
7/16-7/31	69.37	1,310	7/16-7/31	Na	1,911
8/1-8/15	70.41	1,125	8/1-8/15	70.86	1,591
8/16-8/31	69.82	1,148	8/16-8/31	71.10	1,561
9/1-9/15	67.23	1,323	9/1-9/15	67.07	1,610
9/16-9/30	65.24	1,371	9/16-9/30	65.15	1,736
10/1-10/15	61.57	1,390	10/1-10/15	60.51	1,712
10/16-10/31	56.96	1,490	10/16-10/31	54.67	1,906
11/1-11/15	52.95	1,818	11/1-11/15	53.06	2,510
11/16-11/30	50.10	1,818	11/16-11/30	49.02	2,579

Even with high water temperatures in the Klamath River, coho salmon have been observed in the mainstem from March through September (CDFG 1994; USFWS 1996; Belchik 1997; USFWS 1997; Scheiff et al. 2001; Giannico and Heider 2002). Measured water temperatures in the Klamath River upstream from where fish were observed ranged from 62.1ºF to 74.2ºF (USFWS unpublished data on spawner escapement and age composition, as reported by Giannico and Heider 2002). Because the upstream temperatures approached or exceeded the upper incipient lethal levels for coho salmon, those fish observed may have been occupying microhabitats with cooler temperatures (Brett 1952; Sandercock 1991).

At present no data are available on the presence, size, or temperatures of cold-water microhabitats (thermal refugia) in the Klamath River. Additional studies of fish distributions during summer and early fall and their ability to survive and migrate to the ocean would answer some of these questions about use of possible cool microsites in the mainstem Klamath River. There is little evidence on the effects of higher minimum flows from Iron Gate Dam on cool-water microhabitats in the Klamath River (NMFS 2001; NRC 2002). Management agencies need to develop a better understanding of the distribution of cold-water microhabitats in the Klamath River and the effects of different summer discharges on those critical habitats.

Streamflow requirements for the Klamath River are designed to provide habitat for aquatic biota, and the 2001 NMFS Biological Opinion focused on requirements for coho salmon, in particular.

However, the principal findings by NRC included concerns about how higher flows may modify the thermal environment for coho salmon:

> "However, the committee did not find clear scientific or technical support for increased minimum flows in the Klamath River main stem . . . Finally, and most importantly, water added as necessary to sustain higher flows in the main stem during dry years would need to come from reservoirs, and this water could equal or exceed the lethal temperatures for coho salmon during the warmest months. The main stem already is excessively warm. At the same time, reduction in main-stem flows, as might occur if the USBR proposal were implemented, cannot be justified. Reduction of flows in the main stem would lead to habitat conditions that are not documented, and thus present an unknown risk to the population." (NRC 2002; p. 4).

As stated above, some scientists are concerned about potential negative impacts on coho salmon due to warm water releases from Upper Klamath Lake entering the Klamath River below Iron Gate Dam. However, water from Upper Klamath Lake passes through several reservoirs (Lake Ewauna, J.C Boyle, Copco Numbers 1 and 2, and Iron Gate) before it is discharged from Iron Gate Dam into the Klamath River (Figure 1 on page 9). In the spring, water released from Iron Gate Dam comes from the relatively cool hypolimnion of Iron Gate Reservoir (Deas and Orlob 1999; NMFS 2001). In the summer, the water discharged from Iron Gate Dam is warmer than in the spring, but is still several degrees cooler than water downstream at Seiad, California (NMFS 2001). Water released from Iron Gate Dam does not cool the river water to a point that it is below the favorable temperature range for salmonids, which was referred to as "appreciable thermal benefits" to the Klamath River by NMFS (2001; p. 20).

Much of the water in the mainstem Klamath River comes from Upper Klamath Lake. In a late summer study of potential thermal patterns in the Klamath River water temperatures were decreased slightly by the addition of instream flows at 1,000 cfs from Iron Gate Dam. Bartholow (1995) concluded that these instream flow levels did not cool the water enough to provide thermal conditions required by salmonids. However, small numbers of salmonids do occur in the mainstem Klamath River throughout the summer, possibly residing in cool-water microhabitats.

<u>A Flow Management Model</u>

Deas and Orlob (1999) conducted a major study that modeled river flows, storage in reservoirs, flow management strategies, temperature, and water quality below Iron Gate Reservoir. This modeling exercise demonstrated that flow has a direct impact on river temperature:

> "At low flows, mean stream velocity is reduced and transit times through the study reach are increased . . . In general, increased transit times lead to increased opportunity for heat exchange through the air-water interface. During summer periods this translates to a greater thermal loading potential." (Deas and Orlob 1999; p. 181).

Deas and Orlob (1999) simulated the temperature effect of a range of flows (500, 1000, 2000, and 3000 cfs) one day in mid-August (Figure 30). At a flow rate of 500 cfs, on average it took water 2.5 days to travel 60 miles from Iron Gate Dam to Seiad, California. At the flow rate of 500 cfs, the river warmed 2.7°C over the 60-mile study reach (a heating rate of 0.045°C per mi).

Transit times were faster at higher flows (2 days, 1.5 days, and 1.25 days for 1,000 cfs, 2,000 cfs, and 3,000 cfs, respectively). Heating rates at the higher flows were less (0.035°C, 0.022°C, and 0.013°C per mile for 1,000 cfs, 2,000 cfs, and 3,000 cfs, respectively). Lower heating rates at higher flows were also related to greater water mass for warming and increased river depth. Increased surface area had a minor influence on warming compared to water mass and water depth (Deas and Orlob 1999).

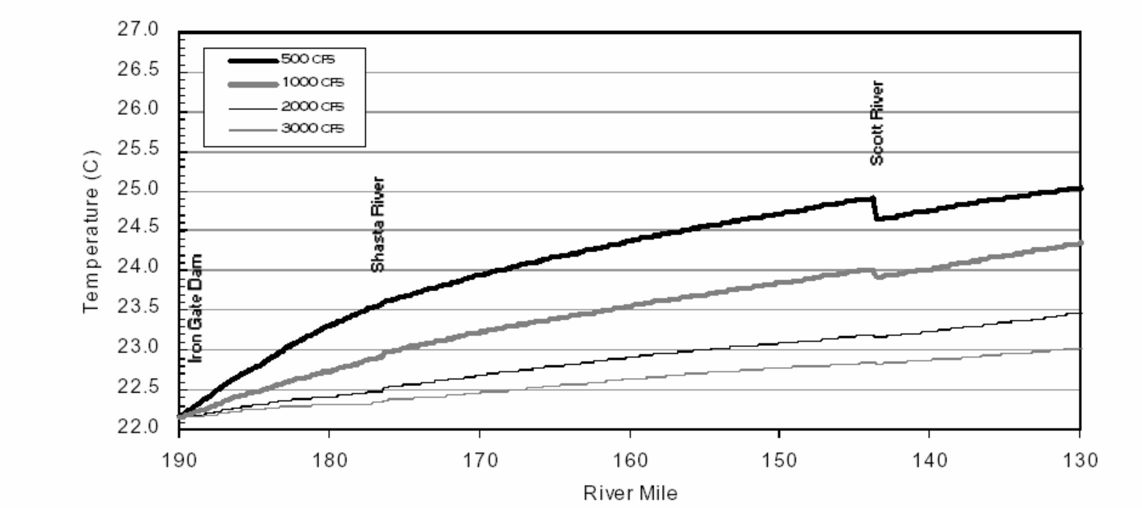

Figure 30. Simulated longitudinal daily mean water temperature profile in the Klamath River from Iron Gate Dam, California to Seiad Valley, California. Simulated Iron Gate Dam releases ranged from 500 through 3000 cfs for one day in August Reproduced from Deas and Orlob (1999).

Deas and Orlob (1999) also concluded that the Shasta River (at River Mile 177) would cause little thermal change in the mainstem Klamath River, but the Scott River (at River Mile 143) would contribute cooler water and provide a thermal benefit to the mainstem river. However, water volumes from the Shasta and Scott Rivers were determined to be insufficient to be able to have a thermal impact during high flows in the mainstem Klamath River (Deas and Orlob 1999).

Overall, the Deas and Orlob modeling study of the Klamath River indicated that increased flows would result in slightly cooler temperatures in the mainstem Klamath River (e.g., a difference of 1°C cooler from 500 cfs to 1,000 cfs) and that the increased flows would not increase river temperature (Deas and Orlob 1999). Their principal findings stated:

> "Increasing flow reduces transit time in the study reach, moderating the diurnal temperature range and providing modest temperature benefits in downstream reaches. ...Combining increased reservoir storage and selective withdrawal provided the greatest degree of water temperature control in the reach below Iron Gate Dam." (Deas and Orlob 1999; p. 3).

Water Temperature Summary

Small numbers of coho salmon inhabit the mainstem Klamath River throughout the summer, even during periods of higher thermal stress (USFWS 2001). Potential thermal reductions have not been analyzed for tributaries entering the mainstem. However, Total Maximum Daily Load analysis by Oregon Department of Environmental Quality indicated that restoration of riparian vegetation along the major rivers entering Upper Klamath Lake could significantly lower the water temperatures of these systems (Boyd et al. 2002). In several cases, the potential thermal reductions in upper Klamath River basin streams were estimated to meet the water quality standards for temperature, thereby cooling the water entering Upper Klamath Lake. Similar riparian restoration could possibly cool tributary water entering the mainstem Klamath River. The IMST concludes that riparian management along streams and rivers entering the Klamath River below Iron Gate Dam could contribute to cooler water temperatures in the river.

September 2002 Klamath River Fish Kill

At least 33,000 adult salmon and steelhead, including both naturally spawned and hatchery fish, died in the lower reaches of the Klamath River during September 2002 (CDFG 2003). The proximate causes of the fish kill were the pathogens: the ciliated protozoan *Ichthyopthirius multifilis* (ICH) and the bacterium *Flavobacter columnare* (columnaris).

Other factors produced conditions that set the stage for this massive die-off. Salmonids entering the Klamath River during mid-September encountered 1) high water temperatures (20.5 ^{o}C is typical in the lower reaches at this time of the year) and 2) low streamflows (760 cfs average September flow at Iron Gate and 2,129 cfs at Klamath, CA). In addition, the returning fall chinook salmon were at average to above-average numbers (preseason estimate, 132,600 individuals). Fish passage was also apparently restricted because of lack of storm events and subsequent lack of channel scour since 1997-98.

In previous years, streamflows had been lower at Iron Gate Dam, however, the fish runs were also lower than those seen in 2002 and high concentrations of fish were not confined to the lower river. In 2001, a year of higher flows in the Klamath River, no fish kill occurred even though chinook salmon runs were high (over 200,000 individuals). This lack of a fish kill was possibly due to the high flow released from Iron Gate Dam that year (1026 cfs), which demonstrates the efficacy of the minimum flow requirement of 1000 cfs (CDFG 2003).

CDFG (2003) concluded that the September 2002 fish kill appeared to be caused by a combination of 1) high densities of fish in the lower river due to low streamflows and restricted passage, 2) warm temperatures that were stressful for salmonids, and 3) favorable conditions for transmission and outbreak of salmonid diseases. The CDFG (2003) report also concluded that the only environmental factor of the three that can be controlled effectively by human management is Klamath River streamflows below Iron Gate Dam.

Summary of Flow Requirements for Coho Salmon

Coho salmon need cold water and sufficient access to habitat during juvenile and adult stages.

The IMST recognizes the presence of wild and hatchery coho salmon in the mainstem Klamath River as well as in the tributaries. The IMST finds that NMFS (2001) determinations of minimum flow requirements for coho salmon in the Klamath River below Iron Gate Dam are based on the best available science.

Maintaining minimum instream flows is necessary because coho salmon are present in the Klamath River mainstem during the summer and the flows are needed to maintain fish passage and habitat and cooler water temperatures. The IMST agrees with 2001 NMFS Biological Opinion that increasing instream flows in the Klamath River above those proposed in the 2001 USBR Biological Assessment recommendations for above-average water years and critically dry water years is defensible action based on cold-water fish species presence that includes coho salmon. With the exception of the 2001 Biological Assessment, all previous instream flow determinations calculated over the last 58 years by the Tribes and the State of California have called for 1,000 cfs or higher minimum instream flows for August below Iron Gate Dam during critically dry water years and above-average water years.

Although the NRC concluded that there was no relationship between flows in the Klamath River and adult return of coho salmon (NRC 2002), the IMST concludes that relationships between flows, habitat requirements and temperature support management actions to maintain minimum in-stream flows in the Klamath River basin

The IMST concludes that insufficient data are available to evaluate the relationship between Klamath River flows during coho salmon freshwater juvenile stages and returning adult coho salmon three years later. Existing data are also inherently highly variable because of multiple factors that determine the abundance of returning adult salmon. Ocean conditions and commercial/sport harvest may obscure these links in historical records. As a result, significant statistical correlations between flows during juvenile stages and adult salmon returns are unlikely. Data on chinook salmon presented in the 2001 USBR Biological Assessment show a relationship between chinook salmon spawners and Klamath River flows during their juvenile freshwater stage. Although these relationships may also apply to coho salmon, it should be noted that juvenile fall-run chinook salmon in the Klamath River migrate to the ocean during their first year of life, whereas coho salmon usually spend about 1.5 years in freshwater, including the summer and fall periods.

Since Upper Klamath Lake is the main source for Klamath River streamflows, the IMST finds that additional water from Upper Klamath Lake might provide minor temperature improvement. Since subsurface additions (from springs) to the Klamath River downstream of Iron Gate Dam are minimal, additional Upper Klamath Lake water would not negatively affect river temperatures.

The IMST finds that the tributaries of the Klamath River are important for providing coho salmon spawning habitat and providing additional streamflow to the mainstem Klamath River. Streamflow from tributaries allows fish passage during migrations, and often provides cool water microhabitats in the mainstem Klamath River.

While it is clearly important for the state, Tribal, and federal co-managers within the Klamath River basin to develop better information on all life history stages of coho salmon and other species, it should be recognized that it is extremely difficult to measure particular life history stages under adverse conditions (e.g., high flows, turbid waters, deep water, complex habitats, large river habitats, mixed species). The empirical data from the Klamath River will always exhibit high variance and will require reliance on sound scientific concepts developed from other systems and the scientific literature.

The IMST concludes that scientific support exists for coordination between agencies. Watershed practices, water withdrawal, non-point source pollution, and fish species distributions throughout river networks make interstate and multi-agency coordination essential.

IMST Findings on Klamath River Compared with Other Reports

In this section the IMST compares its findings with the findings of the NMFS 2001 Biological Opinion, the NRC report (NRC 2002) and the OSU-UC Davis report (Braunworth et al. 2002). The IMST has prepared Table 16 as a comparison of the different reports discussing coho salmon in the Klamath River. We stress that this is our best interpretation of the various reports. Selection and interpretation of quotes was verified with authors of the NRC report (2002) and the OSU-UC Davis report (Chapter 6 by Giannico and Heider in Braunworth et al. 2002) to assure accurate summary of their conclusions. Where specific numbers were not provided, we have attempted to give our interpretation of the numerical value that was intended in the respective report.

Table 16. Reviews of the 2001 NMFS Biological Opinion on coho salmon in the Klamath River basin. Quotes are from: 2001 NMFS Biological Opinion (NMFS 2001), NRC report (NRC 2002), and the OSU-UC Davis report (Chapter 6 by Giannico and Heider in Braunworth et al. 2002).

Conclusions in 2001 NMFS Biological Opinion	IMST Report	NRC Report	OSU-UC Davis Report
1. The NMFS (2001) instream flow requirements in the Klamath River below Iron Gate Dam provided by Upper Klamath Lake) are justified. These instream flows are higher than those called for by the USBR Biological Assessment (2001a).	**IMST conclusion:** **IMST agrees with NMFS that increased instream flows in Klamath River are defensible based on presence of coho salmon and other cold-water species;** **All determinations of instream flow requirements calculated by Tribes and by State of California over the last 58 years have called for >1,000 cfs minimum flow below Iron Gate Dam in August.**	**IMST interpretation:** **NRC found that neither the NMFS recommendation for increased instream flows nor the USBR recommendation for reduced instream flows were scientifically justified.**	**IMST interpretation:** **OSU-UC Davis report says increased flows in mainstem Klamath River are justified based on presence of coho salmon.**
"Based on available information, NMFS has determined that Project operation under the proposed action included in the ongoing Project BA (Reclamation 2001) is expected to result in an appreciably reduced likelihood that SONCC coho salmon will both survive and recover in the wild." (p.27) "Given the available information and analyses, it is NMFS judgment that IGD [Iron Gate Dam] releases of 1,000 CFS during the July through August 2001 period are both necessary and appropriate in this critically dry year and will not jeopardize the species." (p.32) "A basic premise for [the NMFS] reasonable and prudent alternative is that operation of the Klamath Project substantially affects flows, fish habitat, and water quality in the Klamath River below IGD." (p.29)		"...the committee...did not find clear scientific or technical support for increased minimum flows in the Klamath River main stem. Although the proposed higher flows are intended to increase the amount of habitat for coho fry in the main stem, the increase in habitat space that can occur through adjustments in water management in dry years is small and possibly insignificant." (p.4) "At the same time, reduction in main-stem flows, as might occur if the USBR proposal were implemented, cannot be justified. Reduction in flows in the main stem would result in habitat conditions that are not documented, and thus present an unknown risk to the [coho salmon] population."(p.4) "Progressive depletion of flows in the Klamath River mainstem would at some point be detrimental to coho salmon through stranding or predation losses."(p.25) "The committee does not find scientific support for the proposed minimum flows as a means of enhancing the maintenance and recovery of the coho population. The proposal of the USBR, however, as given in its biological assessment, could result in more extreme suppression of flows than has been seen in the past and cannot be justified. On the whole, there is no convincing scientific justification at present for deviating from flows derived from operational practices in place between 1990 and 2000."(p.27)	"During summer months in dry years, water releases at IGD [Iron Gate Dam] contribute significantly to in-stream flows in the Klamath River." (p.140) "The assumption behind the request for higher flows is that the higher the flow[in the spring], the shorter the duration of the trip to the estuary and, therefore, the higher the survival rate of coho smolts." (p.140) "Although habitat in tributaries is important to the long-term maintenance of wild coho salmon, mainstem habitat cannot be written off without negatively affecting the Klamath Basin populations." (p.144) "Some limited spawning also occurs in the mainstem, where USFWS biologists have recorded coho spawning in the Klamath River between Iron Gate Dam and the confluence of the Shasta River." (p.129) "...human activities have altered flows in the lower Klamath River. However, ...their effects on habitat availability and salmonid abundance remain contentious..." (p.134)

Conclusions in 2001 NMFS Biological Opinion	IMST Report	NRC Report	OSU-UC Davis Report
2. Coho salmon populations and their status are affected by discharge rates in the mainstem Klamath River. There is very little data on adult return of coho salmon in the Klamath River.	**IMST conclusions:** **Not enough data are available to evaluate the relationship between Klamath River coho salmon and discharge rates.** **Such relationships are complex and adult returns are affected by many factors *after* young coho salmon migrate from the Klamath River to the Pacific Ocean;** **Ocean conditions and harvest may obscure these links in historical records;** **USBR (2001a) cites data for chinook salmon that show weak but significant relationships between numbers of returning adult chinook salmon and Klamath River flows during rearing and migration. Factors that influence chinook salmon may also affect coho salmon because these two species are closely related.**	**IMST interpretation:** **NRC concluded that few data exist, and the available data do not show strong links exist between Klamath River flows and coho salmon abundance.**	**IMST interpretation:** **OSU-UC Davis report noted relationships between chinook salmon and Klamath River flows, and noted the incomplete data for Klamath River coho salmon.**
"...the survival of salmon fry is expected to decrease under the [USBR] proposed action." (p.24) "Under the proposed minimum flows in the Project operations BA, flows could be relatively low during some years and, in turn, survival of coho salmon smolts could be poor." (p.24) "Coho smolt...outmigrate during [April and May], and substantially higher flows (e.g. 1,700 CFS) are expected to result in increased smolt survival." (p.31) "Limited information exists regarding coho salmon abundance in the Klamath River Basin. Adult coho salmon have been counted in a few Klamath River tributaries; however, these counts are incomplete because they are typically only made incidentally to their purpose of determining fall chinook salmon escapement and they may not account for fish that spawn below the weirs...[Juvenile] counts are also focused on fall chinook and therefore incomplete with regard to sampling for coho salmon juveniles. As such, both adult and juvenile counts are valuable for documenting the presence of coho salmon in specific areas during key time periods, but less valuable for determining population status or trends. However, they do highlight the low abundance and precarious status of coho salmon populations in the Klamath River Basin."(p.6)		"...when related to specific flow conditions, year of class strength, abundance of various life history stages, or other biological indicators of success would greatly improve the utility of modeling and other n formation. The small size and scattered nature of the present native coho population makes collection of such data difficult, however." (p.25) "The proposed low-flow limits on the Klamath River might not benefit the coho population significantly. Although the provision of additional flow seems intuitively to be a prudent measure for expanding habitat, the total habitat expansion that is possible with the limited water available in dry years is not demonstrably important to maintenance of the population. In wet years, any benefits from increased flows will be realized without special limits. Year classes that have high relative strength should have emerged from the wet years of the recent past flow regime if flow is limiting. This does not appear to have been the case in the past decade, however. Thus factors other than dry-year low flows appear to be limiting to survival and maintenance of coho." (p.23)	"Historically, the Klamath River Basin was well known for its large runs of chinook salmon. Its coho salmon populations were relatively large...Over time, however, coho salmon stocks have been greatly reduced and now consist largely of hatchery fish. Only small runs of wild coho salmon remain in the Basin." (p.128) "The incomplete trapping record provides limited information on trends, but remains a useful indicator of the extremely small size of coho salmon populations in the Klamath Basin." (p.129) "...better data are available for Klamath Basin fall chinook salmon...chinook data do show a relationship between river flows during emergence and smolt migration and spawner abundance of that year class 3 and 4 years later (USFWS, unpublished data on spawner escapement and age composition)." (p.142) "The migration of adult coho salmon typically coincides with periods of high water discharge..." (p.129)

Conclusions in 2001 NMFS Biological Opinion	IMST Report	NRC Report	OSU-UC Davis Report
3. Water additions to the Klamath River from Upper Klamath Lake would maintain the area of fish habitat and would not increase water temperatures downstream. "The NMFS has...determined that the [USBR 2001a] action, as proposed, is likely to adversely modify critical habitat for the SONCC coho salmon." (p.29) "After considering thee risk of potential competing habitat requirements between coho salmon fry in the spring, and juvenile coho salmon in the summer, it is NMFS judgment that providing 40 to 50 percent of maximum fry habitat between IGD [Iron Gate Dam] and the Scott River under flows of 1,7000 CFS during April and May 2001 is appropriate to maximize coho salmon survival during this critically dry year and will not jeopardize the species." (p.31) "...Project operations can adversely affect Klamath River aquatic habitat in the summer, and exacerbate adverse temperature and water quality conditions suspected to cause coho salmon production bottleneck." (p.26) "Although additional flow releases from IGD [Iron Gate Dam] would not be expected to cool the mainstem river to the preferred range, higher flow releases from IGD than those that would occur under the proposed action during the June through September period are not expected to result in elevated water temperatures downstream." (p.25) "From about mid-June through September, water released from IGD is typically several degrees cooler than that measured at Seiad..." (p.25) "By early summer, the epilimnion of the [Iron Gate] reservoir has heated to a sufficient depth that water released to the River does not provide appreciable thermal benefits, with the exception of a moderated diurnal cycle (Deas and Orlob 1999)."(p.20) "Low stream flows compound high water temperature problems, because a smaller volume of water is more easily heated and cooled, causing larger diurnal changes in the water temperature of the Klamath River (Trihey and Associates 1996; INSE 1999)."(p.15)	**IMST conclusion:** **Additional water from Upper Klamath Lake might provide minor temperature improvement;** **Because subsurface additions to the Klamath River (from springs) downstream from Iron Gate Dam are minimal, additional Upper Klamath Lake water would not negatively affect Klamath River temperatures;** **Models of river temperature show that releases from Iron Gate Dam would not warm the river and might decrease the temperature slightly;** **There are few data on existence of cold-water microhabitats (tributary junctions, subsurface flow) or the use of coldwater refuges by coho salmon in the Klamath River. Existing data cannot refute or demonstrate the importance of such habitats for the relatively warm mainstem Klamath River.**	**IMST interpretation:** **NRC concluded that Upper Klamath Lake water could impair river water quality.** "Although the [NMFS] provision of additional flow seems intuitively to be a prudent measure for expanding habitat, the total habitat expansion that is possible with limited water available in dry years is not demonstrably important to maintenance of the [coho] population." (p.23) "...water added as necessary to sustain higher flows in the main stem during dry years would need to come from reservoirs, and this water could equal or exceed the lethal temperatures for coho salmon during the warmest months." (p.4) "Increased flows ...could have a detrimental effect on the availability of thermal refugia (mainly mouths of small tributaries). Thermal refugia may be most accessible and most extensive at low flows. Increase of flows might reduce the size of these refugia by causing more effective mixing of the small amounts of locally derived cool water with much larger amounts of warm water from points upstream." (p.24-25) "...fry that enter the main stem must find cool, well-shaded pools, or return to a suitable tributary." (p.22)	**IMST interpretation:** **OSU-UC Davis report says additional volumes of lake water into Klamath River might provide minor temperature improvement and more access to habitat.** "The RPA [Reasonable and Prudent Alternative] stated that under IGD releases of 1,700 cfs for April and May, coho salmon fry would have access to approximately 50 percent of the maximum available habitat..." (p.140) "...it was expected that the minimum in-stream flows requested in the RPA [Reasonable and Prudent Alternative] would moderate the daily fluctuations in water temperature, provide modest cooling in downstream reaches, and reduce the water-transit time between IGD [Iron Gate Dam] and the Seiad Valley. However, the effectiveness of this practice is uncertain and deserves close examination." (p.143) "Twenty-eight [cool-water areas] were associated with tributary confluences, and four with springs...Only the Shasta and the Scott [tributaries] were warmer than the mainstem Klamath during the 3 days of the [2001] survey. In fact, these tributaries were warmer than the mainstem Klamath throughout July and August." (p.126)

Conclusions in 2001 NMFS Biological Opinion	IMST Report	NRC Report	OSU-UC Davis Report
4. Tributaries to klamath river are important to coho salmon "Successful immigration...depends on adequate fish passage conditions in the mainstem river and access to tributaries." (p.32)	**IMST conclusion:** **Tributaries to the Klamath River are important to coho salmon for spawning and for providing flow to the main river allowing fish passage**	**IMST interpretation:** **NRC emphasized the importance of tributaries for coho salmon.** "... tributary conditions appear to be the critical factor for this population [coho salmon]; these conditions are not affected by operations of the Klamath Project and therefore are not addressed in the RPA [Reasonable and Prudent Alternative]." (p.4)	**IMST interpretation:** **OSU-UC Davis report noted the importance of tributaries for coho salmon.** "Spawning [of coho salmon] typically takes place in tributaries..." (p.129)
5. NMFS calls for coordination between agencies. "If...Reclamation expects they will be unable to operate the Project to provide for the [RPA} minimum flow regime...representatives form Reclamation, USFWS, and NMFS shall coordinate with representatives from the Bureau of Indian Affairs and appropriate Indian tribes and states to consider and discuss available options for Project operation and necessary levels of protection for listed species." (p.33) "Reclamation should actively participate in restoration planning activities with other entities with an active interest in addressing Klamath River fishery, habitat, and water quality restoration." (p.37)	**IMST conclusion:** **Scientific support exists for coordination between agencies;** **Watershed practices, water withdrawal, non-point source pollution, and distributions of fish species throughout river networks make interstate and multi-agency coordination essential.**	**IMST interpretation:** **NRC says there is scientific support for interagency coordination.** "The committee finds reasonable scientific support ...for [interagency] coordination" (p.27)	**IMST interpretation:** **OSU-UC Davis report says scientific support exists for interagency coordination.** "An integrated basinwide management plan that balances the needs of all stakeholders is necessary to end the systematic and gradual erosion of natural resources in the Klamath Basin and provide for the needs of all users of the Basin's water." (p.143) "...collaboration among different government agencies and interest groups is needed for the evaluation of appropriate management practices for this basin." (p.144)

IMST Conclusions Specific to Klamath River

IMST conclusions specific to Upper Klamath Lake management were presented at the end of Part I: Upper Klamath Lake Management and Resource Issues. In this section, we present our conclusion specific to Part II: Klamath River and Resource Management Issues**.** This conclusion is based on our independent review of the scientific literature and available data to determine the technical basis of the 2001 NMFS Biological Opinion.

Conclusion 8: Review of the literature indicates that the scientific basis for NMFS (2001) decision requiring minimum instream flows at Iron Gate Dam for coho salmon in the Klamath River is conceptually sound.

Some scientists have questioned the decision to provide instream flows in the mainstem Klamath River below Iron Gate Dam saying it is not warranted because the mainstem is not used by salmon during certain periods and temperatures are too high in late summer. All literature reviewed by the IMST indicates that coho use the mainstem Klamath River, and all studies of minimum instream flows have concluded that a late summer flow of 1,000 cfs is the minimum required to provide habitat for salmonids. The presence of coho salmon in the Klamath River basin make the coho salmon requirements for minimum instream flows in the mainstem Klamath River a relevant issue, regardless of whether the proportion of coho salmon in the mainstem Klamath River is smaller than in the tributaries. Coho salmon (as well as chinook salmon and steelhead) occupy the mainstem Klamath River and adequate habitat must be provided. Historical river flows have been questioned, but resolution of the hydrologic regime can be accomplished straightforwardly. Lack of simple cause-and-effect relationships has been used as an argument to forego flow management in the Klamath River, but simple cause-and-effect relationships for Pacific salmon are rare.

Studies and critiques clearly document the importance of major tributaries in the Klamath River (Shasta, Scott, Salmon, Trinity Rivers) to instream flows. This points to a productive area for development of better landscape-level alternatives through consultation of the federal government with the states of Oregon and California. Instream flow requirements at the point immediately below Iron Gate Dam could be modified based on consideration of management alternatives and water use in those four tributaries.

Conclusion 9: Data on distribution of coho salmon and habitat use in the mainstem Klamath River throughout the year are scarce and incomplete. Decisions about management actions are limited by the timeframe and spatial extent of existing data.

Landscape-Level Conclusions

IMST conclusions on a landscape-level are presented here. These conclusions are based on our independent review of the scientific literature and available data to determine the technical basis of the 2001 Biological Opinions prepared by USFWS and NMFS. These conclusions are followed by specific recommendations to the State of Oregon and its agencies.

Conclusion 10: The 2001 Biological Opinions prepared by USFWS and NMFS were based on the best available science. The types of data and information used in the Biological Opinions are appropriate and technically sound.

> The Biological Opinions used peer-reviewed literature, graduate theses, agency reports, and reports from consultants. While a large portion of this literature is not peer-reviewed, that does not mean that it is scientifically unsound. For example, graduate theses are carefully reviewed and critiqued by graduate committees of university faculty. No scientifically based information, of which we are aware, was ignored or misinterpreted in either Biological Opinion.

Conclusion 11: Upper Klamath Lake, the Klamath River and Klamath Basin watershed have been changed by many factors (e.g., land use, erosion, nutrient loading, wetland destruction, and introduction of non-native species), which have all contributed to decline of shortnose and Lost River suckers and coho salmon.

> Declines of natural resources in general, or salmon stocks in particular, rarely are caused by single factors. Several critics have expressed concern that controls on water quantity in Upper Klamath Lake and the Klamath River do not consider other causes of decline and are therefore not credible. Most of the freshwater factors identified for the declines of salmon in the Pacific Northwest (e.g., habitat degradation, dams, water diversion, commercial and sport harvest) (Nehlsen et al. 1991) occur in the Klamath River basin and contribute to resource decline.

Conclusion 12: The IMST recommends that future research and management include lake stratification and stability, weather, historical precipitation levels and streamflow, and historical fish distributions.

> Management of a large river basin, a large shallow lake, adjacent wetlands, and associated refuges is extremely complex. Several of the questions raised about historical climate and streamflow, limnological relationships in a shallow lake, nutrient retention in wetlands and riparian areas, consequences of changes in population age structure of fishes, use of lower river habitat, and specific habitat relationships for suckers and salmon could be answered through focused research and monitoring over the next 10-20 years. Longer-term records are essential for understanding such variable and complex responses.

Conclusion 13: The IMST finds that a high degree of uncertainty is related to complex phenomena and/or scarce empirical information. In the face of uncertainty, a precautionary approach to management is warranted.

In many cases, the source of uncertainty is complex behaviors of physical and biological responses to multiple drivers or causal factors. This variance or the scarcity of data does not indicate that any of the actions recommended by the USFWS or NMFS are technically unsound. IMST has recommended that the State of Oregon directly acknowledge the Precautionary Principle as a guiding principle in the Oregon Plan for Salmon and Watersheds (IMST 1999b, IMST 2000). Management of Upper Klamath Lake is another area where explicit statement of precautionary measures would provide a clear conceptual framework and increase the understanding of state and federal actions.

Conclusion 14: Interstate coordination and an active negotiation process are needed for management of Upper Klamath Lake and the Klamath River.

Current coordination on water management in the Klamath River and its major tributaries is extremely limited. Negotiation of the federal government, state, and citizens could provide some water for human consumption (though not all that is being requested by water users), protect critical habitat for juvenile suckers and Klamath River salmonids, and be technically defensible. This appears to be a productive area for developing additional information and finding management alternatives. In a large lake like Upper Klamath Lake, small differences in lake elevation (inches) amount to large volumes of water. This may provide the States of Oregon and California, Tribal co-managers, and the federal government a margin for negotiation that would still protect survival of the suckers.

Recommendations

The science questions previously answered in this report provide the basis for these recommendations. In general, our approach was to develop and answer each science question and then summarize our findings and conclusions for each question. Our specific recommendations are developed from our findings and conclusions. In some cases a specific recommendation is drawn narrowly from a specific finding and conclusion, but in many cases the recommendations resulted from a synthesis across several findings and conclusions. For this reason the order in which recommendations appear do not correlate with the order in which material was covered in the science questions. The recommendations are grouped into broad subject areas for convenience. The order is not intended to imply priority. We consider each recommendation as important to accomplishing the mission of the Oregon Plan.

IMST recommendations are based on our assessment of the best available science as it pertains to salmonid and watershed recovery and the management of natural resources. Recommendations are directed to one or more agencies or entities that have the ability to implement, or to affect changes in management or regulation that are needed for implementation. It should be noted that the IMST looks beyond an agency's *current* ability to implement the recommendations because current legal, regulatory, or funding situations may need to change. It is the belief of the IMST that if an agency agrees that a recommendation is technically sound and would aid the recovery of salmonid stocks and watersheds, the agency would then determine what impediments might exist to prevent or delay implementation and work toward eliminating those impediments. The Team also assumes that each agency has the knowledge and expertise to determine how best to identify and eliminate impediments to implementation and to determine appropriate time frames and goals needed to meet the intent of the recommendation. In addition, the IMST recognizes that an agency may already have ongoing activities that address a recommendation. Our inclusion of such an "overlapping" recommendation should be seen as reinforcement for needed actions.

Senate Bill 924, which created the IMST, specifies that agencies are to respond to the recommendations of the IMST, stating "(3) If the Independent Multidisciplinary Science Team submits suggestions to an agency responsible for implementing a portion of the Oregon Plan, the agency shall respond to the Team explaining how the agency intends to implement the suggestion or why the agency does not implement the suggestion". Once agency responses are received, the IMST reviews the scientific adequacy of each response and if further action or consideration by the agency is warranted. IMST reviews of responses are forwarded to the Governor and the State Legislature. State agencies are expected to respond to IMST recommendations within six months after a report is issued.

The format of the recommendation section is important to understand. The following will illustrate the format:

#. Each specific recommendation is numbered, shown in bold and is directed to one or more agencies or entities of state government. The agency (or agencies) or entity listed is believed to have lead responsibility, but logically would collaborate with the other agencies or entities listed in developing the response to the recommendation as required by Senate Bill 924.

> Inset under each recommendation is a brief explanation or illustration of the context for the recommendation, or what is meant by it, and sometimes suggestions on what should be incorporated into its implementation. This inset material is related to the recommendation but is not an explicit part of it. This means that the agency or entity that is taking the lead for responding to the recommendation is not required (Senate Bill 924) to incorporate the material in the inset into their response. Our goal in providing the inset is to improve understanding of our meaning and to suggest direction for implementation.

Protection of existing healthy ecosystems and salmonid strongholds is the first and most important element of the Oregon Plan. Currently, many land use practices in the Klamath Basin are not consistent with the goals of the Oregon Plan for Salmon and Watersheds. In making a case for continuing such activities, their compatibility with maintenance of healthy aquatic ecosystems needs to be demonstrated.

Protection and restoration of many ecosystems in the Klamath Basin can be accomplished by the following recommendations:

Recommendation 1: The IMST recommends that the State of Oregon work with the State of California and the federal agencies and tribal co-managers to develop an integrated long-term management program for the entire Klamath River Basin.

> The status of sucker populations in Upper Klamath Lake and status of coho salmon populations in the mainstem Klamath River are determined by basin wide habitat conditions and consequences of human actions. Other federal agencies are required to consult with USFWS and NOAA Fisheries to make certain that federal actions do not jeopardize a listed species under the Endangered Species Act. State and local agencies generally have not restricted water availability and are limited only through consultations with federal agencies. The issues in the Klamath River Basin cannot be addressed adequately by unilateral actions on the part of single agencies. A multi-state integrated long-term management program with federal and tribal co-managers that addresses the issues and actions for the entire Klamath River Basin and involves the public would be more effective in managing the natural resources and environmental conditions throughout the basin.

Recommendation 2: The IMST recommends that the State of Oregon consult with the State of California and the federal and tribal co-managers to develop a program for collecting relevant data on sucker populations and lake habitats and salmonid populations and river habitats in the Klamath River Basin.

> Management of populations of Lost River suckers, shortnose suckers, coho salmon, and other species (e.g., chinook salmon, steelhead, green sturgeon, Pacific lamprey) requires sound scientific information on the abundance, dynamics, and distributions of the species. The lakes and rivers in the Klamath River Basin are extensive and complex systems of aquatic habitats. Monitoring programs cannot possibly measure the abundance of all the critical species throughout their distributions and for all life history stages. Monitoring programs must be carefully designed to focus on critical measures that are needed for management decision. Monitoring will require coordination and communication between

all responsible state and federal agencies. Present monitoring programs are diffuse and weakly coordinated.

Recommendation 3: The IMST recommends the Department of Fish and Wildlife of the State of Oregon to collaborate with the State of California and the federal and tribal co-managers to develop monitoring data is needed on salmonid use of the mainstem Klamath River throughout the entire year, including summer and autumn.

One of the major questions and areas of disagreement about management of the mainstem Klamath River has been the use and importance of mainstem habitat for coho salmon throughout the year. IMST recommends that all relevant agencies work collectively to clearly identify the distribution and abundance of all salmonids in the mainstem Klamath River through each month of the year. These data will be critical for future management decisions and are essential for designing and guiding restoration of the major tributaries of the Klamath River.

Recommendation 4: The IMST recommends that the State of Oregon collaborate with the State of California and the federal and tribal co-managers to develop and test a model that relates the influence of management actions on Upper Klamath Lake, on the long-lived sucker species in the lake, and flows in the Klamath River.

The long lives of the Lost River suckers and shortnose suckers make population assessment and assessment of risk both difficult and important. Management agencies in the basin have not yet developed models of sucker population dynamics that incorporate the longevity, age of first reproduction, and fecundity. In addition, modeling fish population dynamics in Upper Klamath Lake would require incorporation of patterns of lake stratification and water quality. Such models would be useful for exploring the implications of future management actions, including lake level management and wetland restoration efforts. The models should also allow managers to compare the impact of variable climatic conditions (including prolonged droughts and effects of global climate change) on Upper Klamath Lake, Klamath River flows, and fish populations.

Recommendation 5: The IMST recommends that the State of Oregon work with the State of California and the federal and tribal co-managers to resolve the debate about the historical climate and streamflow in the Klamath River Basin and develop a common framework for determining appropriate instream flow in the mainstem Klamath River.

Many of the participants in the management process have questioned the historical evidence of stream flows, lake levels, and precipitation. A panel of regional experts could analyze available records, receive inputs from public and involved parties, and establish a standard framework for historical climatological and hydrological conditions in the lakes and rivers of the Klamath River Basin.

Recommendation 6: The IMST endorses efforts to restore the wetlands around Upper Klamath Lake and recommends that the State of Oregon place high priorities on opportunities to restore wetlands and riparian areas along streams and lakes within the Klamath River Basin.

None of the actions called for in the Biological Opinion or in any other federal or state documents call for the restoration of pristine conditions. Most of the actions would recover relatively minor portions of historical ecosystem conditions or functions. The State of Oregon should consider the most effective remedial or restoration actions and reduce activities that cause environmental impairment. The Total Maximum Daily Load process for the Klamath River Basin in Oregon concluded that restoration of riparian areas along the major streams and rivers and restoration of wetlands along Upper Klamath Lake would reduce nutrient loading to the lake and Klamath River, and this conclusion is also repeated in several technical assessments and publications. The IMST concurs with this conclusion and encourages the agencies within the Klamath River Basin to develop coordinated or joint programs to increase the extent of riparian restoration along streams and rivers in the basin and wetland restoration around Upper Klamath Lake.

Recommendation 7: The IMST recommends that the State of Oregon, State of California, and federal agencies increase technical assistance to land owners along streams, rivers, and lakes in the Klamath River Basin restore riparian areas, wetlands, and streamflows to the degree possible.

Based on Recommendation 5, the IMST encourages the states and federal agencies to increase the technical assistance to private landowners and to maximize the implementation of programs to restore riparian areas and wetlands.

Recommendation 8: The IMST recommends that the State of Oregon develop explicit, measurable benchmarks for environmental conditions that represent periods of high ecological risk. State policies could be refined to identify precautionary actions that would be triggered during periods of high risk and greater uncertainty.

The series of state and federal assessments of Upper Klamath Lake, Klamath River, and other lakes and rivers in the basin has resulted in a growing but loosely organized body of information on environmental conditions, ecosystems, and population trends. Synthesis of this information and continued revision through future management assessments could provide the basis for a common framework of environmental and ecosystem conditions that present threats to the natural resources of the basin. This framework would provide the basis for establishing conditions under which specific precautionary measures should be implemented. Again, coordination by the state and federal agencies involved in resource management in the Klamath River Basin would be required for such an approach to be effective over the long term.

Recommendation 9: The IMST recommends that the Oregon Water Resources Department resolve and complete the on-going adjudication process in the Klamath River basin. The previous IMST recommendations require active water resource management in the Klamath River Basin, and adjudication is essential before implementing these recommended actions.

Completed adjudications are crucial to efficient and equitable administration of water rights, and to pro-active long-term management of water as a resource. Completion of the adjudication process (sorting out undetermined water rights and distributing water according to priority date) would allow water allocation measures to be implemented in the Klamath River Basin. The following Oregon water law tools would contribute to resolution of Klamath River Basin water conflicts: temporary transfers, instream leases, split season leases, drought year options, water-banking, voluntary rotation agreements and allocations of conserved water. These tools, however, will not be available until the adjudication is complete. The entire process of adjudication is required to be completed before the state can ask landowners and water managers to enter into formal management agreements.

Recommendation 10: The IMST recommends that in tributaries and springs of Upper Klamath Lake, ODFW, in collaboration with other state agencies, assess water quality and fish passage problems that potentially limit sucker recovery. The IMST recommends that ODFW assess effectiveness of the existing fish ladder for passage of adult suckers at the Chiloquin Dam. ODFW and DEQ should assess and improve water quality in spawning areas.

Recovery of fish is potentially limited by access to spawning habitat and by effects of low water quality on spawning fish, eggs, and larval fish. We encourage the responsible management agencies to assess passage and water quality limitations to sucker recovery.

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APPENDIX A. Methods to Determine Minimum Instream Flow

Much of the controversy and confusion surrounding minimum flows in the Klamath River is due to the many methods that can be used to determine minimum flows and the resources being considered. Minimum instream flows for regulated rivers can be estimated by several instream flow methods. Numerous methods exist and their use varies by state, region, and agency. Methods can be categorized as either *standard setting methods* or *incremental methods*.

Standard setting methods identify minimum flow standards that are required to protect certain instream flow values of interest (e.g., fish, as recreation opportunities). Petts and Maddock (1994) also refer to these as *hydrological methods*. Espegren (1998) further divided the *standard setting methods* into *non-field methods* and *habitat retention methods*. *Non-field methods* (e.g., Tennant Method) derive instream flow recommendations from historical streamflow records rather than field data. *Habitat retention methods* use hydraulic field data to examine relationships between stream discharge and indices of fish habitat. A justification for methods based on hydrological data is that stream flora and fauna have evolved to survive periodic disturbances in flows without major population changes (Petts and Maddock 1994). A major criticism of *habitat retention methods* is that they exclude any explicit consideration of actual habitat requirements (Petts and Maddock 1994). The NRC Report (2002) recommended the use of additional biological data in the final determination of flows required to avoid jeopardy. Nonetheless, the simplicity of *habitat retention methods* (hydrological methods) and long record of judicial recognition of the methods make them important as 'first-cut' analytical tools.

Incremental methods evaluate habitat impacts relative to incremental changes in instream flows (Bovee et al.1998; Espegren 1998). These methods combine extensive hydraulic data with biological information on various life stages of target aquatic species (Bovee et al.1998; Espegren 1998). One method, widely used in the United States is the *Instream Flow Incremental Methodology (IFIM)*. *IFIM* is required by federal agencies for developing fish habitat-streamflow recommendations in Oregon (B. McIntosh, pers. comm.[23]). The output from *IFIM* models can then be used to evaluate the relative impacts of water resource development scenarios on downstream aquatic habitats; however, *incremental methods* do not necessarily result in species-target flow values, especially if habitat protection standards have not been defined (Espegren 1998). Petts and Maddock (1994) list one other category known as *Physical Habitat Simulation (PHABSIM).* This method integrates changing hydraulic conditions with discharge and an organism's habitat preference. *PHABSIM* requires detailed field survey data. *PHABSIM* is often used within an application of *IFIM* to generate habitat-discharge relationships.

[23] McIntosh, B. Personal communication. 2003. ODFW, Corvallis, Oregon.