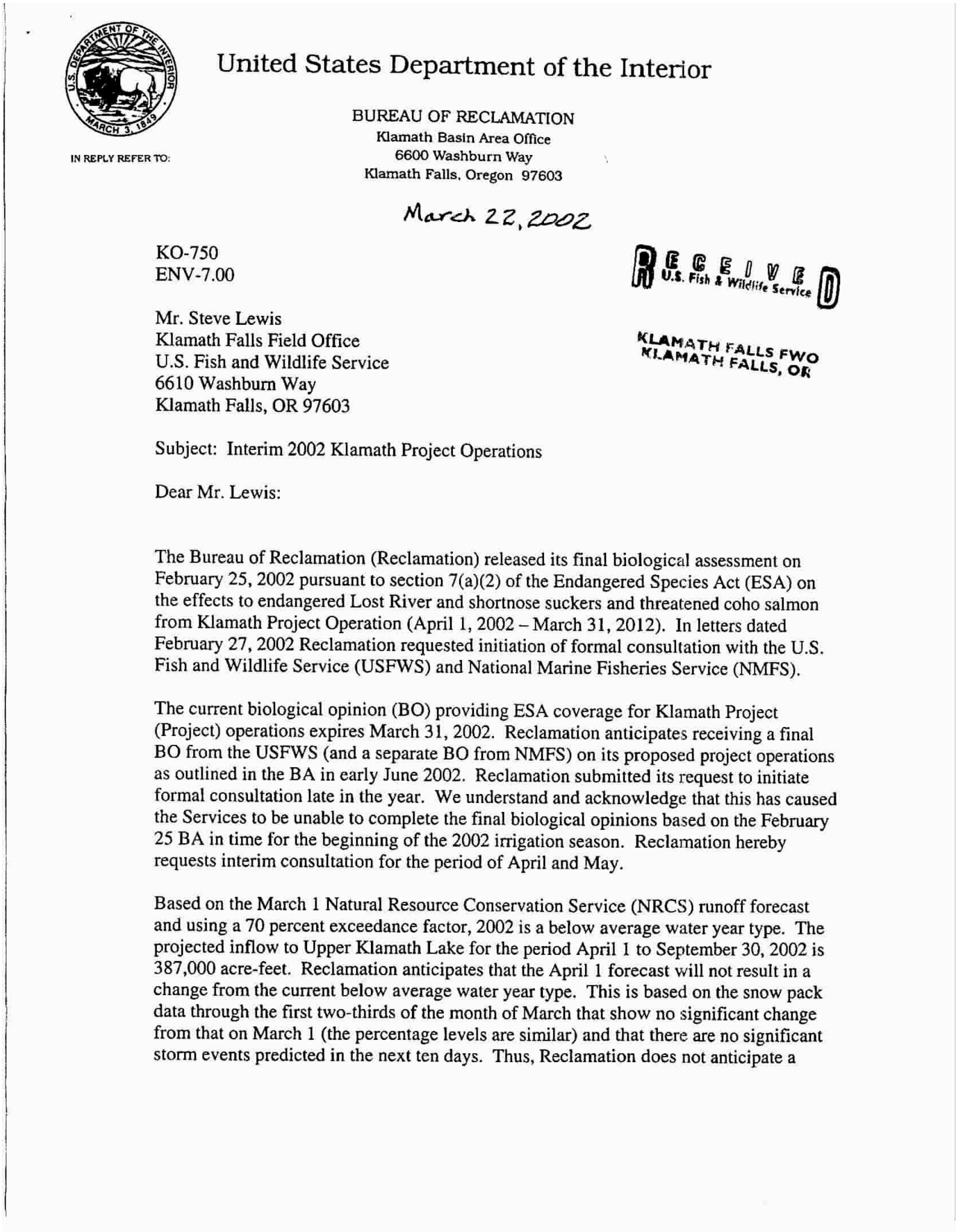


MARCH 3, 1849

United States Department of the Interior

BUREAU OF RECLAMATION
Klamath Basin Area Office
6600 Washburn Way
Klamath Falls, Oregon 97603

IN REPLY REFER TO:

March 22, 2002

KO-750
ENV-7.00

RECEIVED
U.S. Fish & Wildlife Service

KLAMATH FALLS FWO
KLAMATH FALLS, OR

Mr. Steve Lewis
Klamath Falls Field Office
U.S. Fish and Wildlife Service
6610 Washburn Way
Klamath Falls, OR 97603

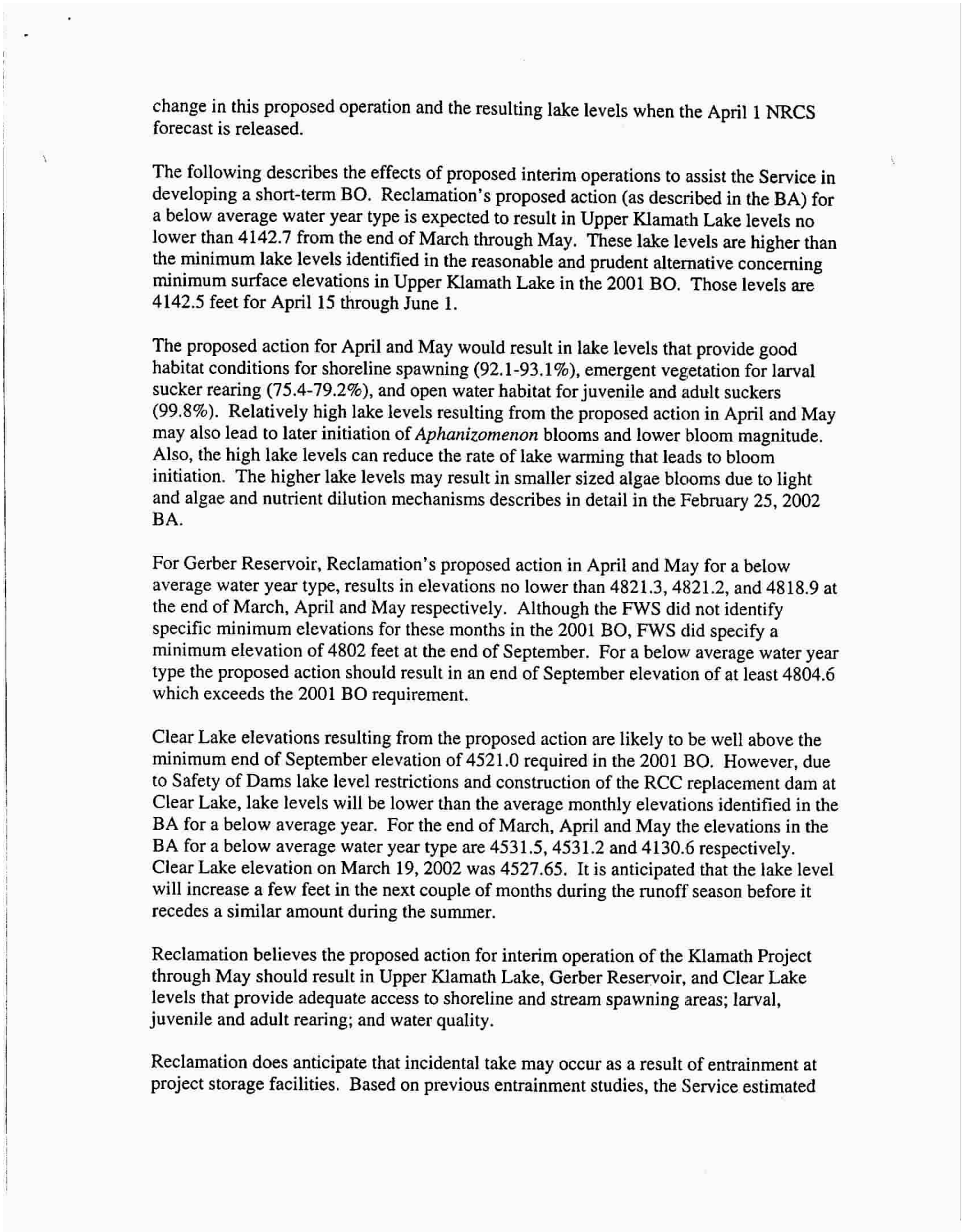
Subject: Interim 2002 Klamath Project Operations

Dear Mr. Lewis:

The Bureau of Reclamation (Reclamation) released its final biological assessment on February 25, 2002 pursuant to section 7(a)(2) of the Endangered Species Act (ESA) on the effects to endangered Lost River and shortnose suckers and threatened coho salmon from Klamath Project Operation (April 1, 2002 – March 31, 2012). In letters dated February 27, 2002 Reclamation requested initiation of formal consultation with the U.S. Fish and Wildlife Service (USFWS) and National Marine Fisheries Service (NMFS).

The current biological opinion (BO) providing ESA coverage for Klamath Project (Project) operations expires March 31, 2002. Reclamation anticipates receiving a final BO from the USFWS (and a separate BO from NMFS) on its proposed project operations as outlined in the BA in early June 2002. Reclamation submitted its request to initiate formal consultation late in the year. We understand and acknowledge that this has caused the Services to be unable to complete the final biological opinions based on the February 25 BA in time for the beginning of the 2002 irrigation season. Reclamation hereby requests interim consultation for the period of April and May.

Based on the March 1 Natural Resource Conservation Service (NRCS) runoff forecast and using a 70 percent exceedance factor, 2002 is a below average water year type. The projected inflow to Upper Klamath Lake for the period April 1 to September 30, 2002 is 387,000 acre-feet. Reclamation anticipates that the April 1 forecast will not result in a change from the current below average water year type. This is based on the snow pack data through the first two-thirds of the month of March that show no significant change from that on March 1 (the percentage levels are similar) and that there are no significant storm events predicted in the next ten days. Thus, Reclamation does not anticipate a



change in this proposed operation and the resulting lake levels when the April 1 NRCS forecast is released.

The following describes the effects of proposed interim operations to assist the Service in developing a short-term BO. Reclamation's proposed action (as described in the BA) for a below average water year type is expected to result in Upper Klamath Lake levels no lower than 4142.7 from the end of March through May. These lake levels are higher than the minimum lake levels identified in the reasonable and prudent alternative concerning minimum surface elevations in Upper Klamath Lake in the 2001 BO. Those levels are 4142.5 feet for April 15 through June 1.

The proposed action for April and May would result in lake levels that provide good habitat conditions for shoreline spawning (92.1-93.1%), emergent vegetation for larval sucker rearing (75.4-79.2%), and open water habitat for juvenile and adult suckers (99.8%). Relatively high lake levels resulting from the proposed action in April and May may also lead to later initiation of *Aphanizomenon* blooms and lower bloom magnitude. Also, the high lake levels can reduce the rate of lake warming that leads to bloom initiation. The higher lake levels may result in smaller sized algae blooms due to light and algae and nutrient dilution mechanisms describes in detail in the February 25, 2002 BA.

For Gerber Reservoir, Reclamation's proposed action in April and May for a below average water year type, results in elevations no lower than 4821.3, 4821.2, and 4818.9 at the end of March, April and May respectively. Although the FWS did not identify specific minimum elevations for these months in the 2001 BO, FWS did specify a minimum elevation of 4802 feet at the end of September. For a below average water year type the proposed action should result in an end of September elevation of at least 4804.6 which exceeds the 2001 BO requirement.

Clear Lake elevations resulting from the proposed action are likely to be well above the minimum end of September elevation of 4521.0 required in the 2001 BO. However, due to Safety of Dams lake level restrictions and construction of the RCC replacement dam at Clear Lake, lake levels will be lower than the average monthly elevations identified in the BA for a below average year. For the end of March, April and May the elevations in the BA for a below average water year type are 4531.5, 4531.2 and 4130.6 respectively. Clear Lake elevation on March 19, 2002 was 4527.65. It is anticipated that the lake level will increase a few feet in the next couple of months during the runoff season before it recedes a similar amount during the summer.

Reclamation believes the proposed action for interim operation of the Klamath Project through May should result in Upper Klamath Lake, Gerber Reservoir, and Clear Lake levels that provide adequate access to shoreline and stream spawning areas; larval, juvenile and adult rearing; and water quality.

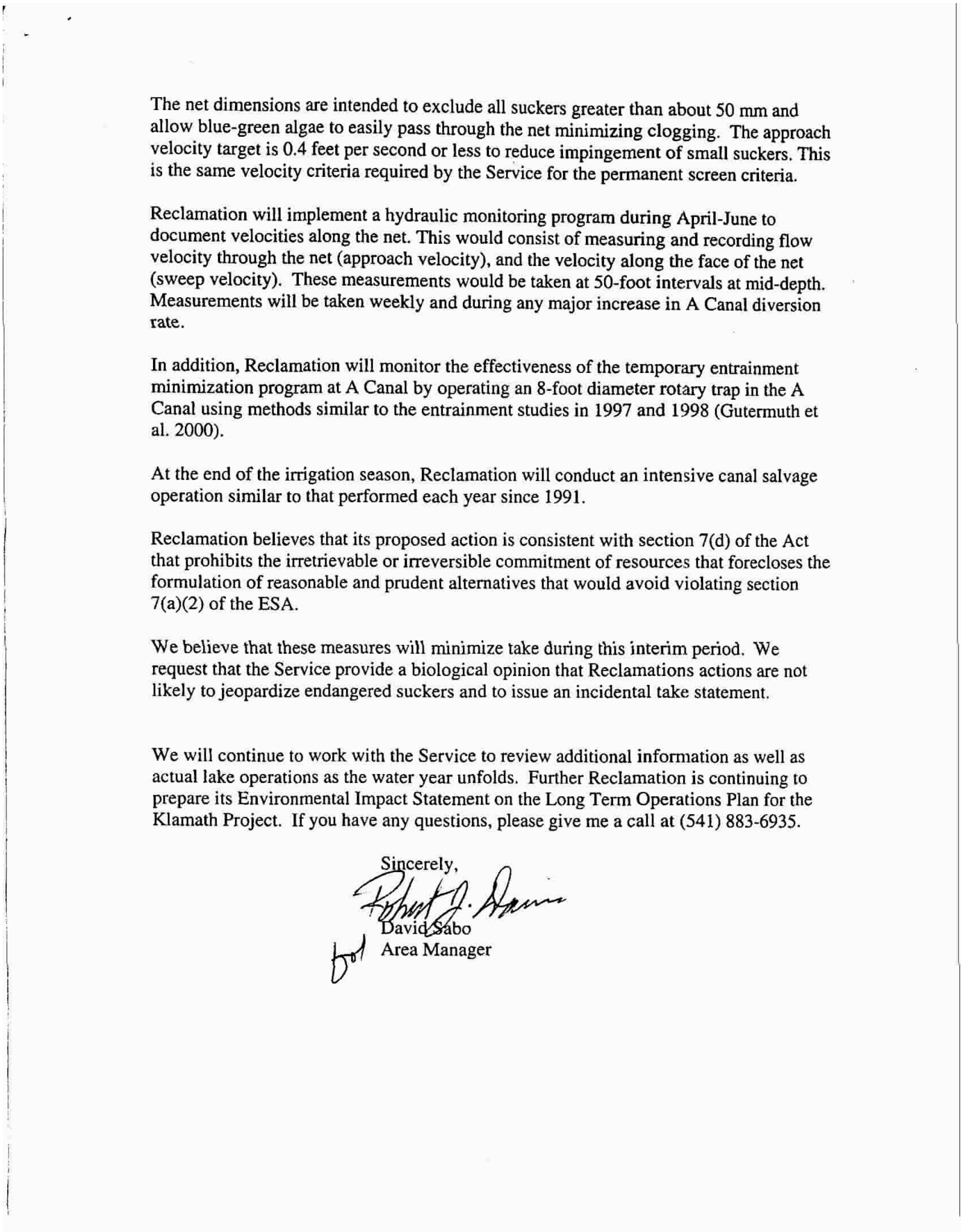
Reclamation does anticipate that incidental take may occur as a result of entrainment at project storage facilities. Based on previous entrainment studies, the Service estimated that up to 6 million total individuals of Lost River and shortnose suckers may be taken by Project operations for the entire irrigation season (mostly larvae and age 0 juvenile suckers) at all project facilities (2001 BO). However, to minimize incidental take during April and May, Reclamation proposes several actions. Reclamation will install and operate permanent (Service-approved) fish screens at Agency Lake Ranch and Clear Lake in 2002. Reclamation also proposes to employ temporary entrainment reduction measures at the A Canal in 2002 and install a permanent screen facility by April 1, 2003. In addition, Reclamation proposes to conduct fish salvage operations in the Project canals at the end of the irrigation season according to a Service approved plan.

Reclamation believes that sucker entrainment associated with the proposed action period of April and May may be relatively low due in part to sucker life stage timing. For example, larval suckers in UKL are most abundant in May and June (Reclamation 2001). Therefore, they are not present to be entrained in during April diversions. Also, most sucker larvae in UKL are produced and generally inhabit shoreline areas near the Williamson River over 15 miles away from the A-Canal (Simon et al. 2001). Thus, larval sucker densities are generally lower near the A Canal and the time required for the poor swimming larvae to move to the A Canal is most likely several weeks. The earliest date larval suckers were collected in the A Canal was May 21(Gutermuth et al. 2000). Peak larval entrainment occurred during June.

Previous entrainment studies at the A Canal and Link River Dam documented over 90% of the annual entrainment consisted of age 0 suckers during August and September (Gutermuth et al. 2000). Juvenile sucker entrainment during April – June was very low (<2%). Adult Lost River and shortnose suckers sampled from the A Canal and Link River Dam diversions were rare particularly during April-May. Adult sucker radio telemetry studies documented that most adult suckers occupy the upper portion of UKL and therefore are not very vulnerable to entrainment (Peck 2000). Canal salvage operations in the A Canal from 1991-2001 also documented few adult Lost River and shortnose suckers.

Reclamation proposes to reduce entrainment at the A Canal by installing a deflection curtain adjacent to the A Canal and parallel to the current to guide weak swimming surface oriented larval suckers (Markle and Simon 1993) away from and downstream of the canal entrance. The polypropylene curtain will be approximately 600 feet long and 3 feet deep. It will be maintained in position by a float line at the top secured at both ends with anchors. The curtain will hang down in the water by use of a weighted line along the bottom and frequent anchor lines.

Reclamation also proposes to install and maintain a barrier net in front of the A Canal from April–June to minimize entrainment of juvenile and adult suckers. The barrier net will be approximately 600 feet long and 8 feet deep and ¼ inch delta style mesh. The top line has large floats every 12 inches wrapped with the netting and the bottom line with ¼ inch coil steel chain attached for weight. Reclamation will monitor the net regularly to ensure the net has a good seal to the lake bottom along its entire length.



The net dimensions are intended to exclude all suckers greater than about 50 mm and allow blue-green algae to easily pass through the net minimizing clogging. The approach velocity target is 0.4 feet per second or less to reduce impingement of small suckers. This is the same velocity criteria required by the Service for the permanent screen criteria.

Reclamation will implement a hydraulic monitoring program during April-June to document velocities along the net. This would consist of measuring and recording flow velocity through the net (approach velocity), and the velocity along the face of the net (sweep velocity). These measurements would be taken at 50-foot intervals at mid-depth. Measurements will be taken weekly and during any major increase in A Canal diversion rate.

In addition, Reclamation will monitor the effectiveness of the temporary entrainment minimization program at A Canal by operating an 8-foot diameter rotary trap in the A Canal using methods similar to the entrainment studies in 1997 and 1998 (Gutermuth et al. 2000).

At the end of the irrigation season, Reclamation will conduct an intensive canal salvage operation similar to that performed each year since 1991.

Reclamation believes that its proposed action is consistent with section 7(d) of the Act that prohibits the irretrievable or irreversible commitment of resources that forecloses the formulation of reasonable and prudent alternatives that would avoid violating section 7(a)(2) of the ESA.

We believe that these measures will minimize take during this interim period. We request that the Service provide a biological opinion that Reclamations actions are not likely to jeopardize endangered suckers and to issue an incidental take statement.

We will continue to work with the Service to review additional information as well as actual lake operations as the water year unfolds. Further Reclamation is continuing to prepare its Environmental Impact Statement on the Long Term Operations Plan for the Klamath Project. If you have any questions, please give me a call at (541) 883-6935.

Sincerely,

Robert J. Davis

for David Sabo
Area Manager

# Biological/conference Opinion
# Regarding the Effects of Operation of the
# Bureau of Reclamation's Klamath Project
# During the Period April 1, 2002, Through May 31, 2002
# 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/shortnose Suckers

Prepared
by
United States Fish and Wildlife Service
Klamath Falls Fish and Wildlife Office
March 28, 2002

United States Department of the Interior

FISH AND WILDLIFE SERVICE

Klamath Falls Fish & Wildlife Office
6610 Washburn Way
Klamath Falls, OR 97603
(541)885-8481 FAX: (541)885-7837

March 28, 2002

In Reply Refer To: 1-10-02-F-107

Memorandum

To: David Sabo
Area Manager, Bureau of Reclamation, Klamath Falls, OR

From: Steven A. Lewis
Project Leader, Klamath Falls Fish and Wildlife Office

Subject: Bureau of Reclamation's Proposed Operation of the Klamath Project for the Period April 1 through May 31, 2002.

This document represents the Fish and Wildlife Service's (Service or FWS) biological opinion and conference report (BO), based on our review of the subject action in accordance with section 7 of the Endangered species Act of 1973, as amended (Act; 16 U.S.C. 1531 *et seq*.). At issue are the effects of the proposed operation of the Klamath Project (Project) by the Bureau of Reclamation (Reclamation) for an interim period, April 1 through May 31, 2002, 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 (collectively referred to as "suckers").

This BO was prepared with the knowledge that the Natural Resource Conservation Service's predicted inflows for 2002 into Project reservoirs are likely to result in a below average inflow year, as defined by Reclamation's February 25, 2002, biological assessment (BA) on proposed operation of the Project for a 10-year period from April 1, 2002 to March 31, 2012.

Reclamation, in consultation and with the assistance of the Service, is charged with ensuring that operation of the Klamath Project is not likely to jeopardize the continued existence of endangered and threatened species or adversely modify their critical habitat. Incorporated in this BO are conservation recommendations intended to encourage long-term survival of the species.

This BO was prepared in response to Reclamation's letter of March 22, 2002, requesting formal consultation on their operation of the Project during April and May 2002. This BO covers the period from April 1, 2002, through May 31, 2002. We also are consulting with Reclamation on their proposed operation of the Project over a 10-year period (April 1, 2002 through March 31, 2012). The BO addressing that action will be issued by June 1, 2002, and will supercede this BO.

This BO is based on: (1) information contained in Reclamation's letter of March 22, 2002; (2) information presented in Reclamation's final BA dated February 25, 2002 addressing operation of the Project over a 10-year period; (3) information in the Services' April 5, 2001, BO addressing operation of the Project from April 2001 to April 2002; (4) information in Reclamation's February 13, 2001, BA; and (5) new information developed since completion of the 2001 BO. A complete administrative record of this consultation is on file at the Service's Klamath Falls Fish and Wildlife Office.

This interim opinion recognizes the ongoing and required studies, monitoring, reporting, restoration activities, and other efforts to reduce entrainment, enhance fish passage, and minimize incidental take within the Project. The status of these activities is being reviewed as we analyze the proposed action for the 10-year period beginning in 2002.

## Introduction

The action as proposed by Reclamation would operate Project reservoirs (Upper Klamath Lake, Gerber Reservoir, and Clear Lake) at elevations during April and May 2002, that would equal or exceed the hydrologic baseline (i.e., lake elevations that would occur without project operations).

In February 2002, the National Research Council issued an Interim Report entitled, "Scientific Evaluation of Biological Opinions on Endangered and Threatened Fishes in the Klamath River Basin." That report is considered in this interim BO and will be fully integrated into the Service's BO for the 10-year plan of operations, to be issued no later than June1, 2002.

## 1. CONSULTATION HISTORY

On April 5, 2001, the Service issued a jeopardy BO with a Reasonable and Prudent Alternative on the operation of the Klamath Project.

On February 27, 2002, Reclamation formally requested consultation on the proposed operation of the Project from April 1, 2002 through March 31, 2012; their BA dated February 25, 2002, was provided with that request. On March 22, 2002, Reclamation provided the Service with a memorandum requesting formal consultation on Project operations for April and May 2002, based on the February 25, 2002, BA. A list of previous consultations on the Klamath Project was provided in our April 5, 2001, BO.

The February 13, 2001, BA describes Reclamation's compliance with reasonable and prudent alternatives, and terms and conditions associated with the Services' 1992, 1994, and 1996 BOs (USBR 2001, USFWS 1992, 1994b, 1996). Reclamation's February 25, 2002, BA, also includes a proposal to provide screening at A-canal and to develop fish passage at the Link River Dam. These actions would fulfill two of the most significant requirements from previous BOs.

According to the BA, Reclamation has initiated or completed most of the Priority 1 and 2 action items identified in the *Lost River and Shortnose Sucker Recovery Plan* (USFWS 1993).

Reclamation has funded over $10.5 million in ecosystem restoration projects benefitting the recovery of these species and has purchased the 7,200-acre Agency Lake Ranch.

## 2. DESCRIPTION OF PROPOSED ACTION

### Definition of the Action Area

The “action area” is defined as “all areas to be affected directly or indirectly by the Federal action and not merely the immediate area involved in the action” (50 CFR 402.02). Based on information contained in the description of the proposed action, the status of the species, and the effects of the action, we have determined that the action area for this consultation extends from Iron Gate Dam upstream in the Klamath River to Link River Dam, including Lake Ewauna and Link River; Upper Klamath Lake to its highwater line, and tributaries as far upstream as are affected by Project operations; Clear Lake and Gerber Reservoir to their high water lines, and tributaries as far upstream as are affected by Project operations; the entire Lost River from Clear Lake Dam to the Tule Lake sumps, including all of Miller Creek, and any tributaries of the Lost River that are affected by Project actions. Also included in the action area are dams, canals, drains, and facilities owned or operated, or related by contract or agreement to Reclamation’s Klamath Project, and the approximately 220,000 acres of irrigated land serviced by the Project. Service actions on Refuge lands serviced by the Project are not included in this consultation because they are subject to separate section 7 consultations.

### Reclamation's Proposed Action

Reclamation requested consultation for the period April 1 to May 31, 2002, for a below average year type, as described in the February 25, 2002, BA, concurrent with a consultation on the 10-year plan of operations for the Project, as described in the February 25, 2002, BA.

Reclamation’s proposed action (as described in the February 25, 2002, and March 22, 2002, BAs) for a below average water year type is expected to result in Upper Klamath Lake levels no lower than 4142.7 feet from the end of March through May, which represent levels higher than the natural hydrologic baseline for this time of the year.

The proposed Upper Klamath Lake water levels are based on Reclamation's predicted inflows, at the 70% exceedence level, and a "hydrologic baseline" for the lake developed by Philip Williams & Associates (2001). The hydrologic baseline assumes: 1) inflows are impaired by up-basin withdrawals; 2) there are no Project diversions from the lake; and 3) a gate opening at Link River Dam that mimics the former reef, which acted as a water level control.

For Gerber Reservoir, Reclamation’s proposed action in April and May for a below average water year results in elevations no lower than 4821.3, 4821.2, and 4818.9 feet at the end of March, April and May, respectively. Although the Service did not identify specific minimum elevations for these months in the 2001 BO, we did specify a minimum elevation of 4802 feet at the end of September.

Clear Lake elevations resulting from the proposed action are likely to be well above the minimum end of September elevation of 4521.0 feet required in the 2001, BO. However, due to Safety of Dams lake level restrictions and construction of the roller compacted concrete replacement dam at

Clear Lake, lake levels will be lower than the average monthly elevations identified in the BA for a below average year. For the end of March, April and May, elevations in the BA for a below average water year type are 4531.5, 4531.2 and 4530.6 feet, respectively. Clear lake elevation on March 19, 2002, was 4527.65 feet. It is anticipated that the lake level will increase a few feet in the next couple of months because of the runoff before it recedes during the summer.

Reclamation proposes to reduce entrainment at the A-canal by installing a deflection curtain adjacent to the A-canal and parallel to the current to guide larval suckers away from and downstream of the canal entrance. The polypropylene curtain will be approximately 600 feet long and 3 feet deep. It will be maintained in position by a float line at the top and secured at both ends with anchors. The curtain will hang down in the water by use of a weighted line along the bottom and frequent anchor lines.

Reclamation also proposes to install and maintain a barrier net in front of the A-canal from April to June, 2002, to minimize entrainment of juvenile and adult suckers. The barrier net will be approximately 600 feet long and 8 feet deep with a small opening, delta-style mesh. The top line has large floats every 12 inches and the bottom line has a 1/4-inch coil steel chain attached for weight. Reclamation will monitor the net regularly to ensure the net has a good seal to the lake bottom along its entire length. A temporary barrier net is already installed and will be replaced as soon as the new net is available (personal communication, M. Buettner, USBR).

The net dimensions are intended to exclude all suckers greater than about 50 mm in length and allow blue-green algae to easily pass through the net, to minimize clogging. The approach velocity target is 0.4

feet per second or less to reduce impingement of small suckers. This is the same velocity criterion required by the Service for the permanent screen criteria.

Reclamation will implement a hydraulic monitoring program from April to June, 2002, to document velocities along the net. This would consist of measuring and recording flow velocity through the net (approach velocity) and the velocity along the face of the net (sweep velocity). These measurements would be taken at 50-foot intervals at mid-depth. Measurements will be taken weekly and during any major increase in the A-canal diversion rate.

In addition, Reclamation will monitor the effectiveness of the temporary entrainment minimization program at A-canal by operating an 8-foot diameter rotary trap in the A-canal using methods similar to the entrainment studies in 1997 and 1998 (Gutermuth et al. 2000). At the end of the irrigation season, Reclamation will conduct intensive canal salvage to remove entrained suckers, similar to that performed annually since 1991.

All other Project features will be operated as described in the February 25, 2002, BA (personal communication, D. Sabo, USBR).

## 3. STATUS OF SPECIES/ENVIRONMENTAL BASELINE

The status and environmental baseline as they relate to the bald eagle and two endangered suckers were updated in the 2001 BO (USFWS 2001), and is included here by reference (USFWS 2001). We do not have any new information to conclude that the status and baseline for the bald eagle either range-wide or within the action area has changed. New information on the suckers developed since the 2001 BO will be fully summarized in the BO addressing the proposed 10-year operation of the Project now being prepared by the Service.

Pertinent new information includes: (1) USGS studies on the Williamson River and lake populations completed in 2001, indicates that Upper Klamath Lake spawning populations increased in 2002 and 2001; (2) USGS sucker age data compiled in 2002, indicate some survival of 1988-1996 year classes; (3) USGS analysis of water quality and fish die-off information suggests that Winter/Spring storm events, which flush nutrients into Upper Klamath Lake, may lead to adverse water quality later in Summer that create lethal conditions for fish; (4) small fish kills occurred in 2001, but no large die-offs were observed; and (5) Oregon State University studies indicate that 2001 was poor in terms of age 0 sucker recruitment.

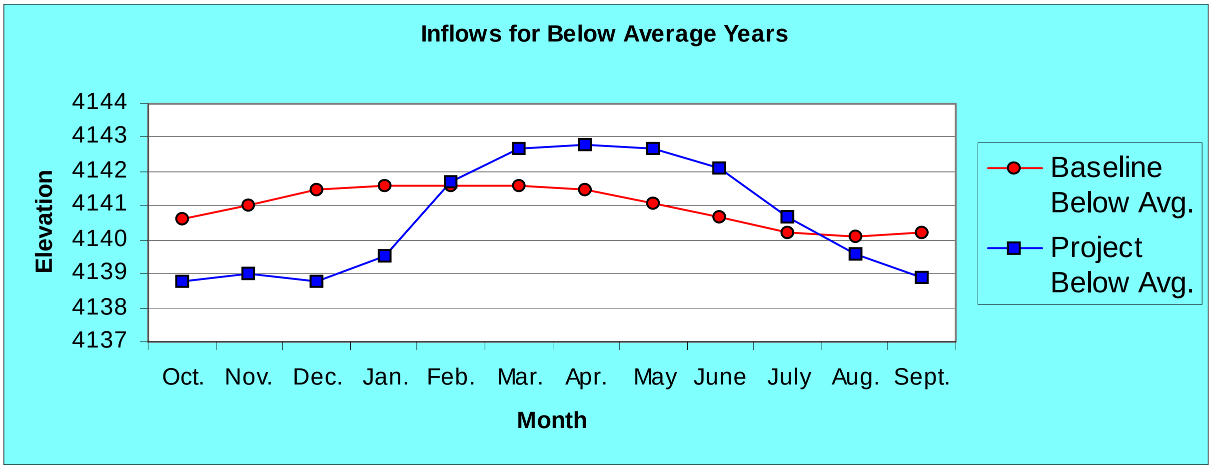
Overall, these studies mentioned above indicate an adult sucker population in Upper Klamath Lake whose status appears to be slowly improving from catastrophic losses that occurred in the mid-1990s. No new data are available for other sucker populations.

New information provided by USGS (Wood 2002) indicates that operation of the lake in spring above the baseline could have adverse effects on water quality later in summer. These adverse effects are most likely to occur in a year with a high inflow event when nutrient-rich sediments are flushed into the lake. This apparently happens at intervals of 5 to 20 years, therefore these adverse water quality effects are unlikely to occur this year.

## 4. EFFECTS OF THE ACTION

Under the proposed action, minimum Upper Klamath Lake elevations in April and May would be at least 4142.7 feet. Baseline hydrologic elevations (i.e., estimated lake elevations during the two-month period under consultation), as modeled by Philip Williams & Associates, during this same period would range from 4141.1 to 4141.6 feet (Figure 1). Thus, elevations under the proposed action are approximately 1 foot higher than baseline. The higher lake levels should be beneficial by providing improved water quality, greater access to spawning habitat, and more habitat for larval suckers, compared to the hydrologic baseline levels.

**Figure 1. End-of-month elevations for Upper Klamath Lake, based on Reclamation's 10-year BA.**



Lake levels in Upper Klamath Lake, Gerber Reservoir, and Clear Lake during April and May, 2002, are anticipated to exceed elevations that would occur without Reclamation's operation of the Klamath Project and the impacts of lake levels on factors that affect suckers and bald eagle are not anticipated to exceed those identified previously.

Operation at these levels will not preclude development of operational criteria for end of irrigation season lake levels which will be considered as part of the ongoing 10-year consultation. Therefore, the effects analysis for this consultation is centered on effects of the operation of the Project during the 2- month period.

Entrainment of suckers in Project facilities during these 2 months will primarily consist of larval suckers. Proposed conservation actions (i.e., deflection curtain, barrier net, hydraulic monitoring, effectiveness monitoring and salvage) will minimize entrainment.

Reclamation believes that sucker entrainment associated with the proposed action period of April and May, 2002, would be relatively low due, in part, to the timing of the proposed action relative to sucker life stages. Larval suckers in Upper Klamath Lake are most abundant in May and June (USBR 2001), thus few larvae will likely be entrained in April diversions. The earliest date larval suckers were collected in the A-canal was April 21 (Gutermuth et al. 2000), but peak larval entrainment occurred during June.

Previous entrainment studies at the A-canal and Link River Dam documented over 90% of the annual post-larval entrainment consisted of age 0 suckers during August and September (Gutermuth et al. 2000). Age 0 sucker entrainment from April to June was low (<2%). Adult Lost River and shortnose suckers sampled from the A-canal and Link River Dam diversions were rare, particularly from April through May. Adult sucker radio telemetry studies documented that most adult suckers occupy the upper portion of UKL and therefore are not very vulnerable to entrainment (Peck 2000). Canal salvage operations in the A-canal from 1991 to 2001 also documented entrainment of few adult Lost River and shortnose suckers.

Entrainment will occur at the Link River Dam associated with both the operation of the Dam and the associated penstocks that provide water for the PacifiCorp's power generation facility.

Entrainment of suckers will occur at Clear Lake and Gerber dams. No data are available to estimate levels, but it is likely to be relatively much smaller in comparison to Upper Klamath Lake, owing to larger populations of suckers in Upper Klamath Lake, and larger numbers of larvae produced by Upper Klamath Lake sucker populations.

Overall, we anticipate that the proposed action will result in entrainment of up to 100,000 larvae and 5,000 juvenile, sub-adult, and adult Lost River and shortnose sucker from April 1 to May 31, 2002. We don't believe this adverse effect is highly significant because: (1) this represents a small fraction of the larval, juvenile, sub-adult, and adult sucker populations; (2) larvae experience high levels of natural mortality owing to starvation and predation; and (3) the proposed deflection curtain, barrier net, salvage, hydraulic monitoring, and effectiveness monitoring, should minimize the adverse effects of entrainment.

The Service concludes that the proposed action may affect, but is not likely to adversely affect the bald eagle. We base this conclusion on the presumption that the proposed action is for April and May 2002, and that even though the manipulation of water levels in the Klamath Project will affect waterfowl, the prey-base of nesting bald eagles, those impacts to eagles will be discountable or insignificant..

## 5. CUMULATIVE EFFECTS

Cumulative effects in the action area were addressed in the April 5, 2001, BO, and are included here by reference. The Service is not aware of any new information indicating that those effects have significantly changed in a way that would affect our analysis of project operation during April and May, 2002.

## 6. CONCLUSION

After reviewing the current status of the species, the effects of the proposed action, and the cumulative effects, it is the Services' biological opinion that the action, as proposed from April 1, 2002 to May 31, 2002, is not likely to jeopardize the continued existence of the suckers or bald eagle.

The Service reached this conclusion for the following reasons:

1. The proposed action provides for higher elevations in Upper Klamath Lake in April and May 2002, compared to the baseline hydrologic levels, providing improved water quality, greater access to spawning habitat, and more habitat for larval suckers.

2. The levels of entrainment caused by the proposed action do not affect a significant proportion of the larval, juvenile, sub-adult, and adult populations, and these levels will be minimized by proposed actions involving a deflection curtain, barrier net, hydraulic and effectiveness monitoring, and canal salvage.

3. The proposed action provides for adequate elevations in Clear Lake and Gerber Reservoir in April and May 2002. Water quality, access to spawning habitat, and habitat for larval suckers should be adequate.

Consultation on the remainder of the irrigation season is underway and is anticipated to be completed before this BO expires.

The Service finds that the proposed action will lead to incidental take of endangered suckers, as described in the section on incidental take. This level of take is not likely to jeopardize the continued existence of the shortnose and Lost River suckers because, during April and May, 2002, take of adults and sub-adults is small relative to the likely population sizes, and take will consist primarily of larvae, which are produced in large numbers and most of which will not contribute to the future population owing to natural mortality.

## 7. INCIDENTAL TAKE STATEMENT

This incidental take statement applies to incidental take of Lost River and shortnose suckers resulting from the operation of the Project. This interim opinion recognizes the ongoing studies, monitoring, reporting, restoration activities, and efforts to reduce entrainment, enhance fish passage, and minimize incidental take within the Project as described in the February 25, 2002, BA.

Sections 4(d) and 9 of the Act, as amended, prohibit taking (harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or to attempt to engage in any such conduct) of listed species of fish or wildlife without a special exemption. Harm is further defined to include significant habitat modification or degradation that results in death or injury to listed species by significantly impairing behavioral patterns such as breeding, feeding, or sheltering. Harassment is defined as actions that create the likelihood of injury to listed species to such an extent as to significantly disrupt normal behavior patterns which include, but are not limited to, breeding, feeding or sheltering. Incidental take is any take of listed animal species that results from, but is not the purpose of, carrying out an otherwise lawful activity conducted by the Federal agency or the applicant. Under the terms of section 7(b)(4) and section 7(o)(2), taking that is incidental to and not intended as part of the agency action is not considered a prohibited taking provided that such taking is in compliance with the terms and conditions of this incidental take statement.

The measures described below are non-discretionary, and must be implemented by Reclamation so they become binding conditions of project authorization for the exemption under 7(o)(2) to apply. Reclamation has a continuing duty to regulate the activity that is covered by this incidental take statement. If Reclamation (1) fails to adhere to the terms and conditions of the incidental take statement through enforceable terms, and/or (2) fails to retain oversight to ensure compliance with these terms and conditions, the protective coverage of section 7(o)(2) may lapse. In order to monitor the impact of incidental take, Reclamation must report the progress of the action and its impact on the species to the Service as specified in the incidental take statement 50 CFR §402.14(i)(3).

Reclamation anticipates that incidental take may occur as a result of entrainment at Project reservoirs. Based on previous entrainment studies, the Service estimated that up to 6 million total individuals of Lost River and shortnose suckers may be taken by Project operations for the entire irrigation season (mostly larvae and age 0 juvenile suckers) at all project facilities (2001

BO). Based on the analysis in the Effects section, the Service anticipates that approximately 100,000 suckers will be taken by Project operations during the period April 1 to May 31, 2002. Approximately 95% would be age 0 suckers. Total entrainment over the 2-month period represents 2% of the annual estimated entrainment of 6 million suckers. Adult mortalities are anticipated to be small and will effect a small component of the population. The barrier net and salvage will reduce incidental take.

### Amount or Extent of Anticipated Take

Based on the above analysis in the Effect section, the Service anticipates that approximately up to 100,000 larvae and 5,000 juvenile, sub-adult, and adult Lost River and shortnose sucker will be taken by Project operations during April and May 2002.

### Effect of the Take

In the accompanying biological opinion, the Service determined that this level of anticipated take is not likely to result in jeopardy to the species or destruction or adverse modification of proposed critical habitat.

The Service establishes the following reasonable and prudent measures to minimize anticipated incidental take of listed suckers.

### Reasonable and Prudent Measure and Term and Condition

The Service believes that Reclamation is implementing most measures needed to reduce incidental take over the two-month period of the proposed action. The Service believes the following reasonable and prudent measure (RPM) with the following term and condition is necessary to minimize impacts of incidental take of the suckers.

- Monitor effectiveness of fish curtain and barrier net and repair if necessary.

### Term and Condition

The following term and condition is provided to implement RPM #1:

- The effectiveness of the curtain and net at A-canal shall be monitored every 2 days. Holes shall be repaired to maintain effectiveness.

This incidental take statement applies to Project operations from April 1 through May 31, 2002, and will be superceded by a new statement when the consultation on the 10-year plan of operations is completed. Therefore, section 9 exemptions provided herein will expire at the end of the day on May 31, 2002.

### Monitoring Requirements Under the Term and Condition

When incidental take is anticipated, the term and condition must include provisions for monitoring to report the progress of the action and its impact on the species [50 CFR, 402.14(i)(3)]. Reclamation proposes to operate a rotary trap in A-canal to monitor entrainment and should report the results of any entrainment to the Service in the 2002, annual salvage report.

Reclamation needs to provide the Service with a brief report on monitoring of nets by June 15, 2002.

## Reporting Requirements

Upon locating a dead, injured, or sick endangered or threatened species specimen, initial notification must be made to the nearest Service Law Enforcement Office. In Oregon, contact the U.S. Fish and Wildlife Service, Division of Law Enforcement, 301 Post Office Bldg., Klamath Falls, Oregon 97601 (phone: 541/883-6900). In California, contact the U.S. Fish and Wildlife Service, Division of Law Enforcement, District 1, 2800 Cottage Way, Room W-2928, Sacramento, California 95825 (phone: 916/414-6660). Care should be taken in handling sick or injured specimens to ensure effective treatment and care and in handling dead specimens to preserve biological material in the best possible state for later analysis of cause of death. In conjunction with the care of sick or injured endangered species or preservation of biological materials from a dead animal, the finder has the responsibility to ensure that evidence intrinsic to the specimen is not unnecessarily disturbed.

The Service is to be notified within three (3) working days of the finding of any endangered or threatened species found dead or injured in the Klamath Project service area. Notification must include the date, time, and precise location of the injured animal or carcass, and any other pertinent information. In California and Oregon, the Service contact person for this information is Mr. Steven A. Lewis (541/885-8481).

If, during the course of the action, the amount or extent of the incidental take limit is exceeded, the Federal agency must immediately reinitiate consultation with the Service.

## 8.0 CONFERENCE REPORT

Critical habitat for the suckers was proposed in 1994, but has not been finalized. The primary constituent elements identified in the proposal are as follows: (1) water of sufficient quantity and suitable quality; (2) sufficient physical habitat, including water quality refuge areas, and habitat for spawning, feeding, rearing, and travel corridors; and (3) a sufficient biological environment, including: adequate food levels, and natural patterns of predation, parasitism, and competition.

The proposed action will likely affect the primary constituent elements of the proposed critical habitat in Project reservoirs by: increasing water levels; improving water quality; and increasing access to water quality refuge areas, spawning, and larval and juvenile rearing habitats. The Service's preliminary determination is that these effects will be beneficial and therefore will not likely lead to adverse modification of proposed critical habitat.

## 9.0 CONSERVATION RECOMMENDATIONS

Section 7(a)(1) of the Act directs Federal agencies to utilize their authorities to further the purposes of the Act by carrying out conservation programs for the benefit of endangered and threatened species. The term "conservation recommendations" is defined as suggestions from the Service regarding discretionary measures to: (1) minimize or avoid adverse effects of a proposed action on listed species or critical habitat; (2) conduct studies and develop information; and (3) promote the recovery of listed species. The recommendations provided here relate only to the proposed action and do not necessarily represent complete fulfillment of the agency's 7(a)(1) responsibilities under the Act.

1. The Service recommends that Reclamation begin an analysis of potential factors that might lead to catastrophic fish kills and determine what actions can be taken to reduce the threat of these events.

2. Closely monitor nutrient concentrations in Upper Klamath Lake if a storm event occurs resulting in a 5- to 20-year runoff event in the Williamson River (as determined by USGS gage data), in coordination with the Service, implement actions that minimize amounts of nutrients that enter Upper Klamath Lake.

3. Reclamation should implement measures such as barrier nets, fish screens, or angled trash racks at the Link River hydroelectric diversions to minimize entrainment of juvenile, sub-adult, and adult suckers. At this time, the Service recognizes Reclamation's position that they lack the authority to require the operator of the hydroelectric project (PacifiCorp) to implement such measures but we encourage the Bureau to pursue all available avenues to address this issue.

In order to be kept informed of actions that either minimize or avoid adverse effects or that benefit listed species or their habitats, the Service requests notification of the implementation of any conservation recommendations.

This concludes the consultation and conference for the Klamath Project for the April to May, 2002, time period. You may ask the Service to confirm the conference opinion as a biological opinion issued through formal consultation if the critical habitat is designated. The request must be in writing. If the Service reviews the proposed action and finds that there have been no significant changes in the action as planned or in the information used during the conference, the Service will confirm the conference opinion as the biological opinion on the Project and no further section 7 consultation will be necessary.

## 10. REINITIATION NOTICE

Reclamation shall request reinitiation of consultation if: (1) the amount or extent of incidental take is exceeded; (2) new information reveals effects of the agency action that may affect the species or critical habitat in a manner or to an extent not considered in this opinion; (3) the agency action is subsequently modified in a manner that causes an effect to the species or critical habitat that was not considered in this opinion; or (4) a new species is listed or critical habitat designated that may be affected by the action.

If you have any questions regarding this opinion, please contact the Klamath Falls Fish and Wildlife Office Project Leader at (541) 885-8481.

## 11. LITERATURE CITED

Gutermuth, B., E. Pinkston, and D. Vogel. 2000. A-canal fish entrainment during 1997 and 1998 with emphasis on endangered suckers. Completion report. New Earth/Cell Tech, Klamath Falls, Oregon and Natural Resource Scientists, Inc., Red Bluff, California.

Peck, B. 2000. Radio telemetry studies of adult Shortnose and Lost River suckers in Upper Klamath Lake and tributaries, Oregon. Unpublished report. U.S. Bureau of Reclamation, Klamath Basin Area Office, Klamath Falls, Oregon.

U.S. Bureau of Reclamation. 2001. Biological assessment of Klamath Project's continued operations on endangered Lost River and shortnose sucker. U.S. Bureau of Reclamation, Mid-Pacific Region, Klamath Basin Area Office, February 13, 2001.

U.S. Bureau of Reclamation. 2002. Final biological assessment. The effects of the proposed actions related to Klamath Project operation (April 1, 2002 - March 31, 2012) on federally-listed threatened and endangered species. U.S. Bureau of Reclamation, Mid-Pacific Region, Klamath Basin Area Office, February 25, 2002.

U.S. Fish and Wildlife Service. 1992. Biological opinion on effects of long-term operation of the Klamath project. Klamath Falls, Oregon.

U.S. Fish and Wildlife Service. 1993. Lost River and Shortnose Sucker Recovery Plan. Portland, Oregon.

U.S. Fish and Wildlife Service. 1994a. Proposed determination of critical habitat for Lost River and shortnose sucker. 59(230): 61744-61759.

U.S. Fish and Wildlife Service. 1994b. Biological opinion on effects of Long-Term Operation of the Klamath Project, with special emphasis on Clear Lake Operations. Portland, Oregon.

U.S. Fish and Wildlife Service. 1996. Biological opinion on effects of PacifiCorp and The New Earth Corporation Operations, as Permitted by U.S. Bureau of Reclamation, for the Lost River and Shortnose Sucker. Klamath Falls, Oregon.

U.S. Fish and Wildlife Service. 2001. Biological/Conference Opinion Regarding the effects of operation of the Bureau of Reclamation's Klamath Project 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/Shortnose Suckers, April 2001. Klamath Falls, Oregon. .

Williams, Philip and Associates. 2001. Hydrodynamic modeling of Upper Klamath Lake. PWA, Portland, Oregon. Prepared for U.S. Bureau of Reclamation.

Wood, T.M. 2002. Water quality sections of the 2001 biological opinion for the Klamath Project. Memorandum to Ron Larson, USFWS, March 2002.

## Personal Communications:

David Sabo, Bureau of Reclamation, Klamath Project, Klamath Falls, Oregon.

Mark Buettner, Bureau of Reclamation, Klamath Project, Klamath Falls, Oregon.

# APPENDIX B - HISTORIC OPERATION AND PROJECT FEATURES

Reclamation has incorporated by reference information from it 1992 BA, 2001 BA and a report titled "Klamath Project Historic Operation, November 2000. These documents contain descriptions of Project features and operations that are not included in its 2002 BA. The following information from these documents is included for the convenience of readers.

## 1.0 HISTORIC PROJECT OPERATION

### 1.1 General

The Klamath Project stores water in Upper Klamath Lake (Klamath River System) and in Gerber and Clear Lake Reservoirs (Lost River system). The distribution system delivers water via a system of canals to lands in the Langell Valley, Poe Valley, Klamath Irrigation District, Tule Lake area, and Lower Klamath Lake area. The primary diversion points include Malone and Miller Creek Diversion Dams in the Langell Valley, diverting Lost River (Clear Lake releases) and Miller Creek (Gerber Reservoir releases) respectively; the Lost River Diversion Dam and Channel, controlling diversions into and out of the Klamath River; the A-Canal diversion works on Upper Klamath Lake, controlling water to the Klamath Irrigation District as well as the Poe Valley and the Tule Lake area; the Anderson-Rose Diversion Dam on the Lost River, which also diverts water to the Tule Lake area; and the Ady Canal, which diverts water from the Klamath River into the Lower Klamath Lake area. In addition, Project irrigators divert directly from both the river systems and Upper Klamath Lake (USBR 2000). None of these facilities have fish screens or provide fish passage, except for the fish ladder at Link River Dam which was designed to pass trout.

Typical water delivery operations under the Project begin in late fall, when the Ady and North Canals are used to deliver water from the Klamath River to lands throughout the Lower Klamath Lake area. This water is used to flood irrigate private, federal lease, and Lower Klamath National Wildlife Refuge lands. The drain water is returned to the river via the Straits Drain. Winter flooding is the primary irrigation pattern. Irrigation and refuge water deliveries however, continue throughout the year. Diversions in the Ady and North Canals range from a low during the summer months of 100 cubic feet per second (cfs) to a high of 500 cfs during the late fall and winter.

In March or early April, the A-Canal diversions from Upper Klamath Lake begin. Flows generally begin at about 500 cfs to charge the canal system, with a gradual increase to a peak of near 1000 cfs in May or June. (USBR 1992a) The amount diverted is typically about 20 to 30 percent of the annual outflow from the lake and 50 percent of the summer outflow (PacifiCorp 2000). This diversion serves the largest area and delivers the most water of any Project feature. Water deliveries typically continue into October. Drainage water from this part of the system can go in one of two different directions. Some returns to the Klamath River with the remainder flowing into the Lost River for reuse by other districts and the Tule Lake National Wildlife Refuge (USBR 1992a). New Earth also operates its algae harvest facility at the C drop of A canal (USBR 1996). Agriculture returns from this diversion, approximately 400 cfs in the summer, enter the Klamath River through the Ady/Straits Drain canal just upstream of Keno dam. In the fall and winter, excess and irrigation drain water from the Lost River Basin and Lower Klamath Lake (a closed system) are added to the total flow of the Klamath River upstream of Keno dam from the Lost River Canal. Such inflow may be as high as 3,000 cfs per month, but is usually from 200 to 1,5000 cfs (PacifiCorp 2000).

Diversions at Miller and Malone Diversion Dams generally begin in April with flows of about 200 cfs. Flows reach a peak of about 400 cfs and are stopped in about October. These diversions serve about 30,000 acres in the Langell Valley. Drainage water from this system returns to the Lost River.

Diversions at Anderson-Rose generally begin in mid-March with flows of 200 cfs. Flows reach a peak of about 450 cfs and are stopped during October. Anderson-Rose diversions serve the Tule Lake area. All the drainage flows enter the Tule Lake Sump.

The Tule Lake NWR receives water from the Tule Lake area and from the Lost River. Since the Lost River Basin was a naturally closed basin, Reclamation constructed a pump and tunnel system (pump "D") from Tule Lake to Lower Klamath NWR. Return flows accrue to Tule Lake and are reused for irrigation before the water is ultimately passed through the pump system and to Lower Klamath Lake where it is used for irrigation and refuge operations. Finally, the water is returned to the Klamath River via the Straits Drain.

In an average year, Gerber Dam, the source of water for the Miller Diversion Dam, releases about 40,000 acre-feet of irrigation water. Clear Lake releases during an average year will be about 36,000 acre-feet. In an average year, UKL is operated to stay within a set of operational guidelines that provide for irrigation storage, flood protection, ESA requirements, and Tribal trust responsibilities. All water that is not needed to regulate within these guidelines is released to the Klamath River. During an average year the Klamath River release is over 900,000 acre-feet. In addition, 350,000 to 450,000 acre-feet is used by the Klamath Project for irrigation and refuge operations.

The Project also modifies flows in the Lost River and the Klamath River. Lost River flows are significantly reduced below the Lost River Diversion Dam and Anderson-Rose Diversion Dam (USBR 1992). PacifiCorp, under the direction of Reclamation, operates its Klamath River Hydropower Facilities to meet upper Klamath Lake levels and downstream flows in the Klamath River below Iron Gate Dam (PacifiCorp 2000). Original flows follow the typical western pattern of very high flows in the spring followed by very low flows in the late summer and fall. The Project now tends, in most years, to temper the magnitude of these extremes and change the timing of flow patterns (USBR 2000a).

The following discussion is based on a Reclamation report entitled *Klamath Project Historic Operation*, dated November 2000. This report contains the best available information on how Reclamation proposes to operate the Project. However, the report describes Project operations relative to three water year types (wet, average, and drought) rather than four (above average, below average, dry and critical dry) as discussed in Reclamation's 2001 and 2002 BA. Reclamation's 2002 BA did not indicate whether these general operational sequences would be altered by its current proposal or whether the Drought Plan referenced will still be in effect.

### Wet Year Operations

During wet year operations, full supplies would be available for Klamath River releases below Iron Gate Dam and Project irrigation needs would also be fully met along with the needs of the refuges. During these periods Gerber would be typically spilling water and Clear Lake would be storing all inflow or controlled releases are made to the Lost River. During a high run-off year Upper Klamath Lake may produce as much as 2.4 million acre-feet of net inflow, most of which could not be stored and would have to be bypassed to the Klamath River.

The primary concern during these operations would be for the protection of lives and property. Facilities would be operated to provide for a controlled release of water from the basin. The Lost River is prone to flooding during high runoff periods. A system of dikes in Langell Valley channelizes the flow during these high flow periods.

Water may be bypassed into the lower Lost River (below Wilson Dam) to the sump area in the Tule Lake Refuge when the capacity of the Lost River Diversion to send the water to the Klamath River is exceeded.

It has been necessary to flood the federal lease land in the Tule Lake area, thus delaying the farming operations. This was the case during the 1964-65 flood. In addition, the Lower Klamath area would experience difficulty in the removal of water in time for the planting of crops.

Average Year Operations

In most average years the Project water users, including the wildlife refuges, would receive average irrigation. No restrictions would be in place that would effect timing or quantity of deliveries. The average year inflow to UKL is 1.3 million acre-feet. The Project consumptively uses approximately 350,000 acre-feet including the wildlife refuges. Supplies of irrigation water in the Lost River system depend upon the carryover storage from the previous year. Average inflow to Lost River reservoirs is insufficient to meet irrigation demand without sufficient carryover storage.

Drought Year Operations

These operations are described in a Reclamation report entitled “Drought Plan”(USBR 1992a). The following text is excerpted from that report.

In previous drought years, in order to conserve as much water in UKL as possible, the Project initiated a variance (i.e., reduce flow to below those set forth by the Federal Energy Regulatory Commission) in the Klamath River below Iron Gate. The variance is issued as soon as irrigation supplies are threatened. The variance not only conserves water for irrigation, but also allows for later releases of water for downstream needs in the lower Klamath River.

The primary source of information concerning inflow to the Project reservoirs is from the Natural Resource Conservation Service (NRCS), formerly Soil Conservation Service (SCS). Should the NRCS forecast indicate that insufficient water will be available, the Project's **"Drought Plan"** becomes the operational tool for the distribution of limited water supplies. This plan is explained later in detail (USBR 1992a).

### 1.2 Project Operations Since 1995

Since 1995, Reclamation has operated the Klamath Project according to an annual operations plan. Each of these years through 2000 was an above average water year condition. The annual operations plans have been developed to assist Reclamation in operating the Klamath Project consistent with its obligations and responsibilities, given varying hydrological conditions. Project operation has been influenced during this period by events and actions such as: (1) varying hydrological conditions in the watershed from year to year; (2) changes in the Klamath River watershed and lands adjacent to Upper Klamath Lake; (3) changes in agricultural cropping patterns; (4) changes in national wildlife refuge operations; (5) previous consultations under section 7(a)(2) of the ESA; (6) recognition of trust responsibilities for Klamath Basin Indian Tribes, both upstream and downstream of the Project; and (7) obligations and responsibilities described in July 25, 1995, and January 9, 1997, Regional Solicitor's memoranda.

The 37 years of historic April through September net inflow data to UKL (using 1996 bathymetric data) were used in a statistical analysis to determine the hydrologic year type indicators for the KPOPSIM water model. The first step was to determine if the data fit a normal distribution. Once this determination was made the arithmetic mean (average) was calculated (500,400 af). Next, the standard deviation (based on the sample) was calculated (187,600 acre-feet). Approximately 68% of the inflow years fall within the range of 500,400 +/ 187,600 af. The average minus one standard deviation equaled approximately 312,000 af. The water years between 500,000 af and 312,000 af are defined as below average inflow. Because there are significant operational spills for inflows above 500,000 af, the upper end of the area defined by the mean plus one standard deviation was not used and 500,000 af was used as the above average indicator. For the boundary between critical and dry, the mean minus 2 standard deviations was calculated and found to be lower than the lowest inflow on record. Since this couldn't be used, percentile rankings were developed for the full 37 years of inflow data and the third percentile was found to be 185,000 af and was used for the dry indicator. Anything below the dry indicator would be classified as a critical dry year. In summary, the net inflows for the four water year types (April through September) are: above average >500,000 af; below average 312,000-500,000 af; dry 185,000-312,000; and critical dry <185,000 af.

## 1.3 Historic Water Surface Elevations 1961 - 1998

The following tables and figures are included in their entirety from Reclamation's 2001 BA.

### 1.3.1 <u>Upper Klamath Lake</u>

Table 4 presents historical water surface elevation data for water years 1961- 1998 (October 1960-September 1998) based on PacifiCorp's daily records for the period. This table summarizes the historical end of month minimum, maximum and average elevations for each water year type (above average, below average, dry and critical dry). All values are in feet above mean sea level (USBR datum). Figures 1-4 provide a graphical presentation of the historic data. The graphs have boxes with upper and lower bounds representing the average +1 standard deviation and the average –1 standard deviation respectively, and lines running up and down from the boxes representing the magnitude of the maximum and minimum values.

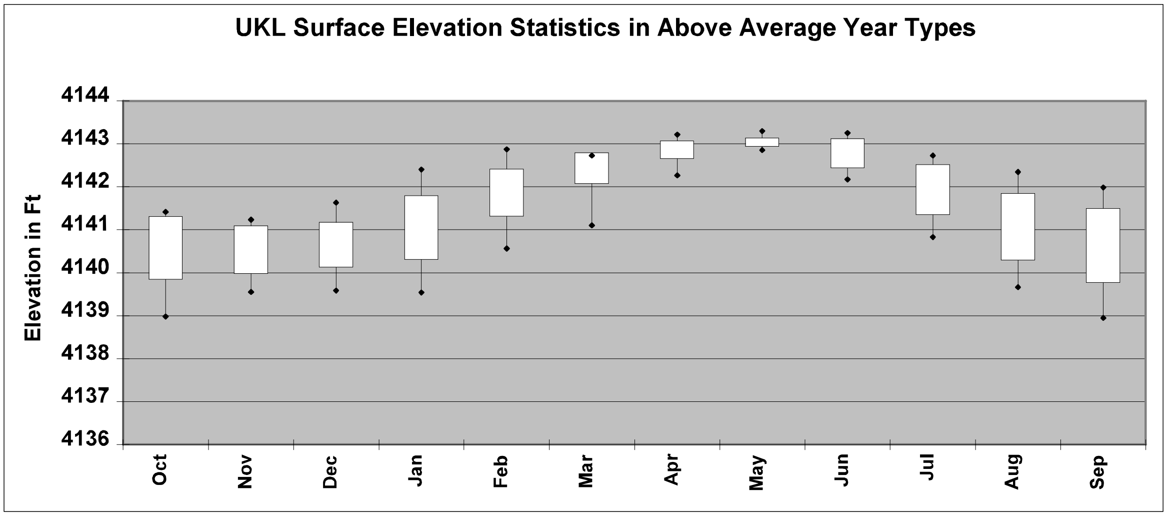
**Table 4. End of the month Upper Klamath Lake elevations by water year type (1960-1998).**

| | 20 Above Average Years | | | | 11 Below Average Years | | | |
|---|---|---|---|---|---|---|---|---|
| | Maximum | Minimum | Average | St. Dev. | Maximum | Minimum | Average | St. Dev. |
| Oct | 4141.41 | 4138.98 | 4140.57 | 0.73 | 4141.35 | 4138.36 | 4139.51 | 0.82 |
| Nov | 4141.23 | 4139.55 | 4140.53 | 0.56 | 4141.21 | 4138.99 | 4140.00 | 0.72 |
| Dec | 4141.63 | 4139.58 | 4140.64 | 0.52 | 4143.50 | 4138.80 | 4140.60 | 1.09 |
| Jan | 4142.40 | 4139.54 | 4141.05 | 0.75 | 4143.02 | 4139.41 | 4140.96 | 1.00 |
| Feb | 4142.87 | 4140.56 | 4141.86 | 0.55 | 4142.20 | 4140.15 | 4141.41 | 0.68 |
| Mar | 4142.73 | 4141.10 | 4142.43 | 0.36 | 4142.73 | 4141.35 | 4142.25 | 0.37 |
| Apr | 4143.21 | 4142.26 | 4142.86 | 0.21 | 4143.06 | 4142.15 | 4142.68 | 0.25 |
| May | 4143.29 | 4142.85 | 4143.03 | 0.10 | 4143.16 | 4142.22 | 4142.64 | 0.30 |
| Jun | 4143.25 | 4142.17 | 4142.78 | 0.34 | 4142.79 | 4141.30 | 4142.05 | 0.47 |
| Jul | 4142.73 | 4140.83 | 4141.93 | 0.59 | 4141.91 | 4140.00 | 4140.97 | 0.61 |
| Aug | 4142.34 | 4139.66 | 4141.07 | 0.78 | 4141.80 | 4138.85 | 4140.07 | 0.81 |
| Sep | 4141.98 | 4138.95 | 4140.63 | 0.86 | 4141.46 | 4138.18 | 4139.53 | 0.84 |

| | 5 Dry Years | | | | 2 Critical Years | | | |
|---|---|---|---|---|---|---|---|---|
| | Maximum | Minimum | Average | St. Dev. | Maximum | Minimum | Average | St. Dev. |
| Oct | 4139.60 | 4138.18 | 4138.66 | 0.50 | 4137.59 | 4136.93 | 4137.26 | 0.33 |
| Nov | 4140.50 | 4138.96 | 4139.78 | 0.51 | 4138.32 | 4137.80 | 4138.06 | 0.26 |
| Dec | 4141.81 | 4139.66 | 4140.70 | 0.72 | 4139.27 | 4138.58 | 4138.93 | 0.34 |
| Jan | 4141.54 | 4140.26 | 4141.12 | 0.46 | 4140.27 | 4140.01 | 4140.14 | 0.13 |
| Feb | 4142.38 | 4140.41 | 4141.62 | 0.67 | 4141.35 | 4140.94 | 4141.15 | 0.20 |
| Mar | 4142.84 | 4141.70 | 4142.42 | 0.43 | 4142.19 | 4141.80 | 4142.00 | 0.20 |
| Apr | 4142.95 | 4141.68 | 4142.44 | 0.49 | 4142.12 | 4141.68 | 4141.90 | 0.22 |
| May | 4142.85 | 4141.40 | 4142.43 | 0.54 | 4142.00 | 4140.70 | 4141.35 | 0.65 |
| Jun | 4142.45 | 4140.39 | 4141.63 | 0.71 | 4140.81 | 4139.45 | 4140.13 | 0.68 |
| Jul | 4140.86 | 4139.10 | 4140.21 | 0.63 | 4139.04 | 4138.77 | 4138.91 | 0.13 |
| Aug | 4139.78 | 4138.38 | 4139.11 | 0.50 | 4137.72 | 4137.52 | 4137.62 | 0.10 |
| Sep | 4139.45 | 4137.55 | 4138.49 | 0.62 | 4137.43 | 4136.84 | 4137.14 | 0.30 |

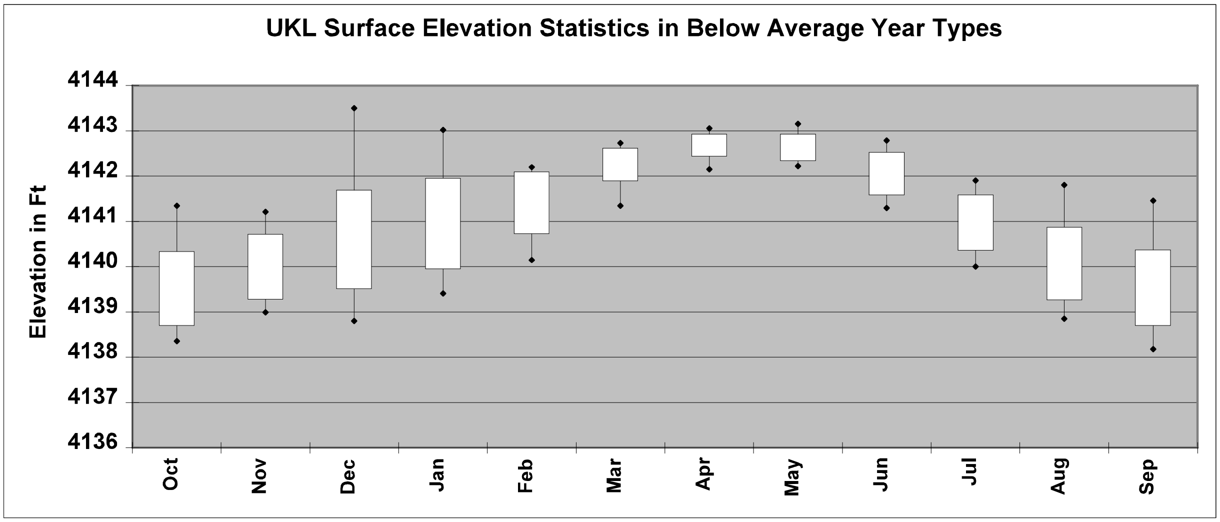
*Above Average Year* - Above average years occurred in 20 of the 38 hydrologic years utilized for this assessment (52.6%). The minimum elevation ranged from 4138.95 at the end of September to 4142.85 at the end of May. The average ranged from 4140.53 at the end of November to 4143.03 at the end of May (Table 4, Figure 1).

**Figure 1. Upper Klamath Lake end of month elevations (1960-1998) for above average water years.**



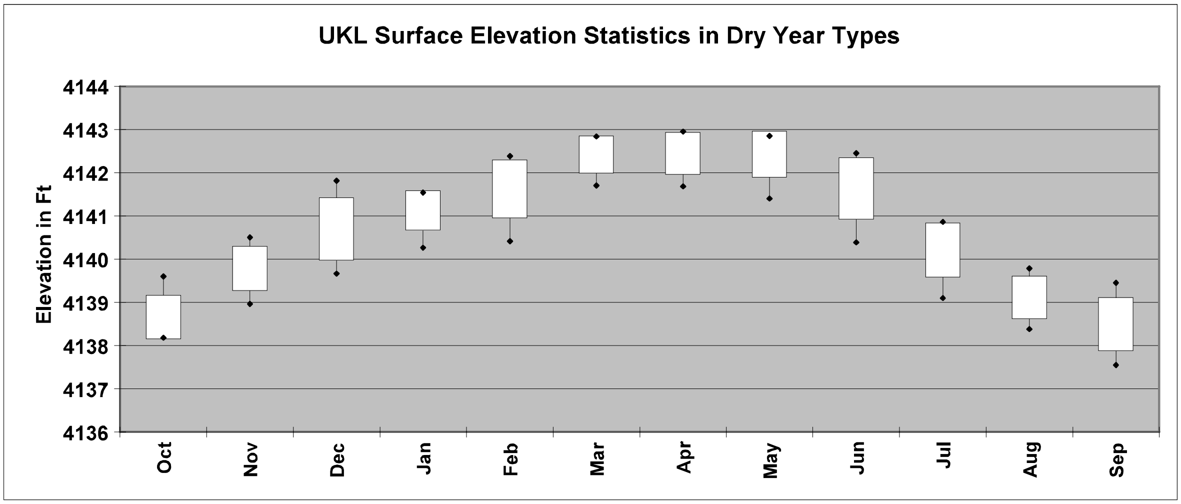
*Below Average Year* - Below average years occurred 11 of the 38 hydrologic years utilized for this assessment (28.9%). The minimum end of the month elevation ranged from 4138.18 in September to 4142.22 in May (Table 4, Figure 2). The average end of the month elevation ranged from 4139.51 in October to 4142.68 in April.

**Figure 2. UKL end of month elevations (1960-1998) for below average years.**



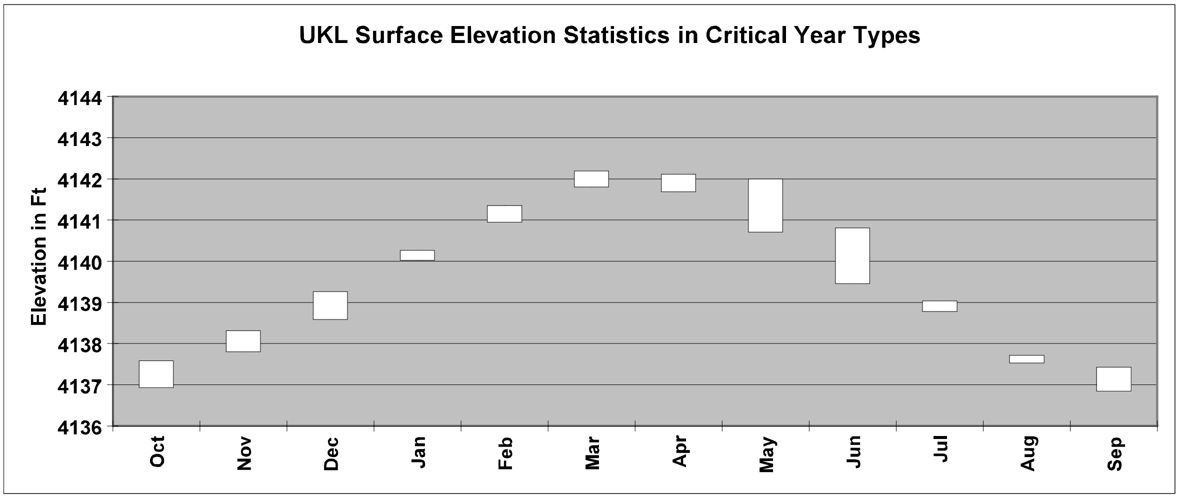
*Dry Year* - Dry water years occurred 5 out of 38 hydrologic years utilized for this assessment (13.2%). The minimum end of the month elevation ranged from 4137.55 in September to 4141.70 in March (Table 4, Figure 3). The average end of the month elevation ranged from 4138.49 in September to 4142.44 in April.

**Figure 3. Upper Klamath Lake end of month elevations (1960-1998) for dry water years.**



*Critical Dry Year* - Critical dry years occurred in 2 of the 38 hydrologic years utilized for this assessment (5.3%). The minimum end of month elevation ranged from 4136.84 in September to 4141.80 March (Table 4, Figure 4). The average end of the month elevation ranged from 4137.14 for September to 4142.00 for March.

**Figure 4. Upper Klamath Lake end of month elevations (1960-1998) for critical years.**



1.3.2 Clear Lake Reservoir

Statistics on historical water surface elevation data for water years 1961-1998 (October 1960-September 1998) are summarized by water year type in Table 5. Figures 5-8 from Reclamation's 2001 BA provide a graphical presentation of these data.

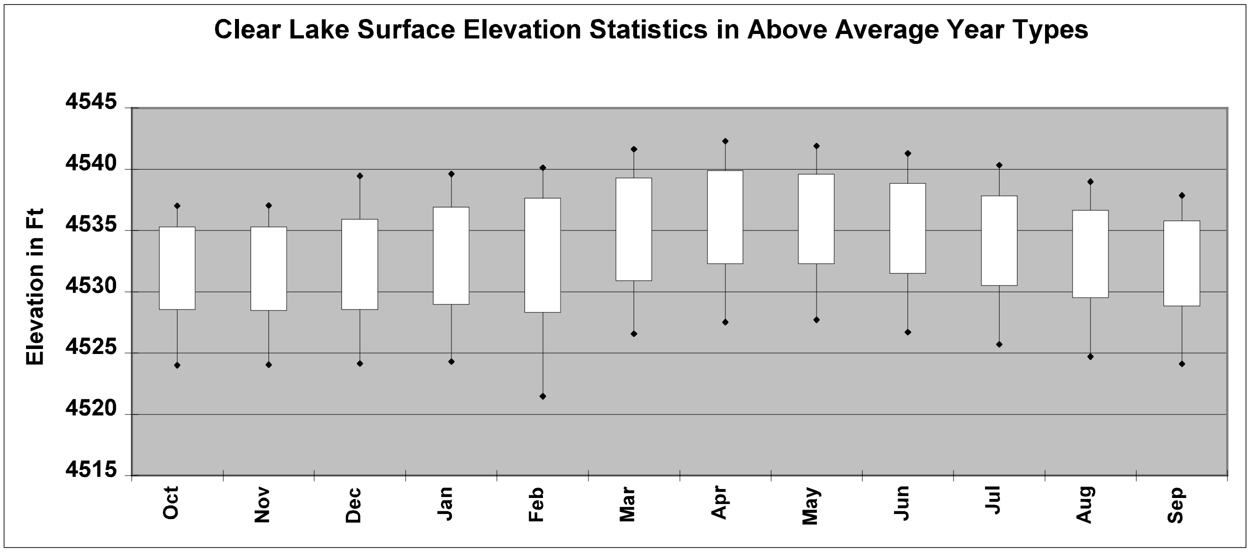
**Table 5. End of the month Clear Lake Reservoir elevations by water year type (1960-1998).**

| | 20 Above Average Years | | | | 11 Below Average Years | | | |
|---|---|---|---|---|---|---|---|---|
| | Maximum | Minimum | Average | St. Dev. | Maximum | Minimum | Average | St. Dev. |
| Oct | 4537.02 | 4524.00 | 4531.90 | 3.37 | 4532.60 | 4521.33 | 4527.05 | 3.33 |
| Nov | 4537.05 | 4524.05 | 4531.87 | 3.41 | 4532.96 | 4521.47 | 4527.17 | 3.36 |
| Dec | 4539.43 | 4524.15 | 4532.21 | 3.70 | 4533.78 | 4521.70 | 4527.86 | 3.37 |
| Jan | 4539.60 | 4524.30 | 4532.93 | 3.98 | 4535.44 | 4521.87 | 4528.70 | 3.75 |
| Feb | 4540.11 | 4521.46 | 4532.97 | 4.68 | 4536.50 | 4523.37 | 4530.18 | 4.37 |
| Mar | 4541.63 | 4526.57 | 4535.07 | 4.21 | 4537.45 | 4524.25 | 4530.91 | 4.35 |
| Apr | 4542.28 | 4527.52 | 4536.08 | 3.80 | 4537.15 | 4525.50 | 4531.25 | 3.81 |
| May | 4541.89 | 4527.70 | 4535.91 | 3.67 | 4536.50 | 4525.10 | 4530.66 | 3.69 |
| Jun | 4541.27 | 4526.70 | 4535.16 | 3.68 | 4535.84 | 4524.08 | 4529.96 | 3.69 |
| Jul | 4540.33 | 4525.70 | 4534.14 | 3.66 | 4534.70 | 4522.88 | 4528.81 | 3.77 |
| Aug | 4538.97 | 4524.70 | 4533.08 | 3.57 | 4533.65 | 4521.90 | 4527.86 | 3.80 |
| Sep | 4537.86 | 4524.12 | 4532.29 | 3.49 | 4532.86 | 4521.28 | 4527.17 | 3.78 |

| | 5 Dry Years | | | | 2 Critical Years | | | |
|---|---|---|---|---|---|---|---|---|
| | Maximum | Minimum | Average | St. Dev. | Maximum | Minimum | Average | St. Dev. |
| Oct | 4528.30 | 4522.50 | 4525.38 | 1.91 | 4521.54 | 4519.30 | 4520.42 | 1.12 |
| Nov | 4528.30 | 4522.51 | 4525.71 | 1.85 | 4521.65 | 4519.29 | 4520.47 | 1.18 |
| Dec | 4528.48 | 4522.80 | 4526.60 | 2.05 | 4521.96 | 4519.35 | 4520.66 | 1.30 |
| Jan | 4529.02 | 4522.85 | 4527.45 | 2.32 | 4525.89 | 4519.40 | 4522.65 | 3.24 |
| Feb | 4532.00 | 4527.00 | 4529.45 | 1.83 | 4526.20 | 4523.00 | 4524.60 | 1.60 |
| Mar | 4532.68 | 4527.10 | 4529.85 | 1.87 | 4526.30 | 4522.84 | 4524.57 | 1.73 |
| Apr | 4532.54 | 4526.90 | 4529.59 | 1.83 | 4525.84 | 4522.75 | 4524.30 | 1.54 |
| May | 4532.18 | 4526.42 | 4529.14 | 1.87 | 4525.39 | 4521.77 | 4523.58 | 1.81 |
| Jun | 4531.20 | 4525.65 | 4528.28 | 1.81 | 4524.49 | 4521.18 | 4522.84 | 1.66 |
| Jul | 4530.20 | 4524.45 | 4527.11 | 1.87 | 4523.16 | 4520.44 | 4521.80 | 1.36 |
| Aug | 4529.13 | 4523.52 | 4526.18 | 1.86 | 4521.43 | 4519.82 | 4520.63 | 0.80 |
| Sep | 4528.30 | 4522.75 | 4525.52 | 1.88 | 4521.70 | 4519.42 | 4520.56 | 1.14 |

*Above Average Year* - The minimum end of the month elevation ranged from 4524.00 in October to 4527.70 in May (Table 5, Figure 5). The average end of the month elevation ranged from 4531.87 in November to 4536.08 in April.

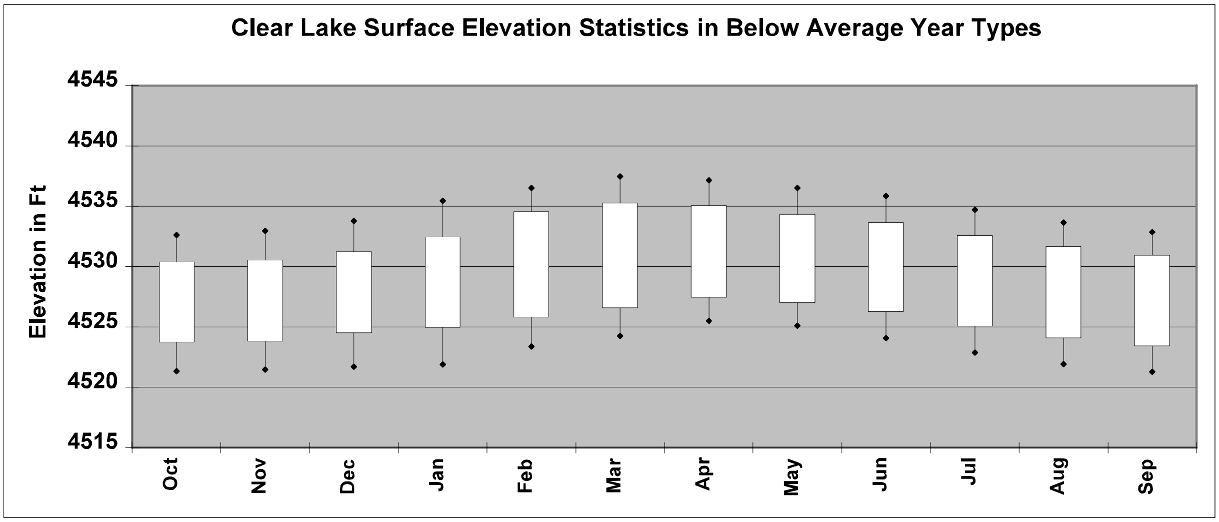
**Figure 5. Clear Lake Reservoir end of month elevations (1960-1998) for above average years.**



*Below Average Year* - The minimum end of the month elevation ranged from 4521.28 in

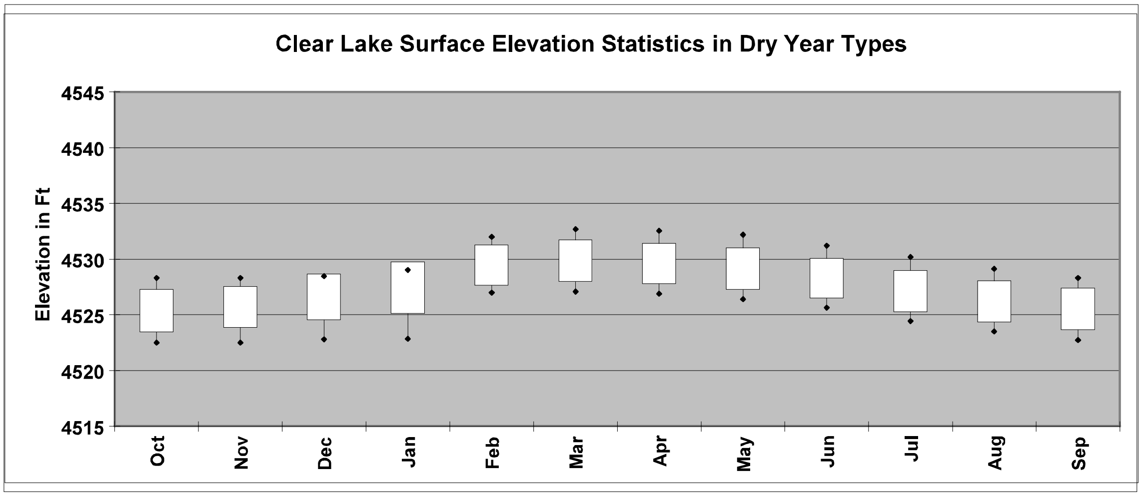
September to 4525.50 in April (Table 5, Figure 6). The average end of the month elevation ranged from 4527.05 in October to 4531.25 in April.

**Figure 6. Clear Lake Reservoir end of month elevations (1960-1998) for below average years.**



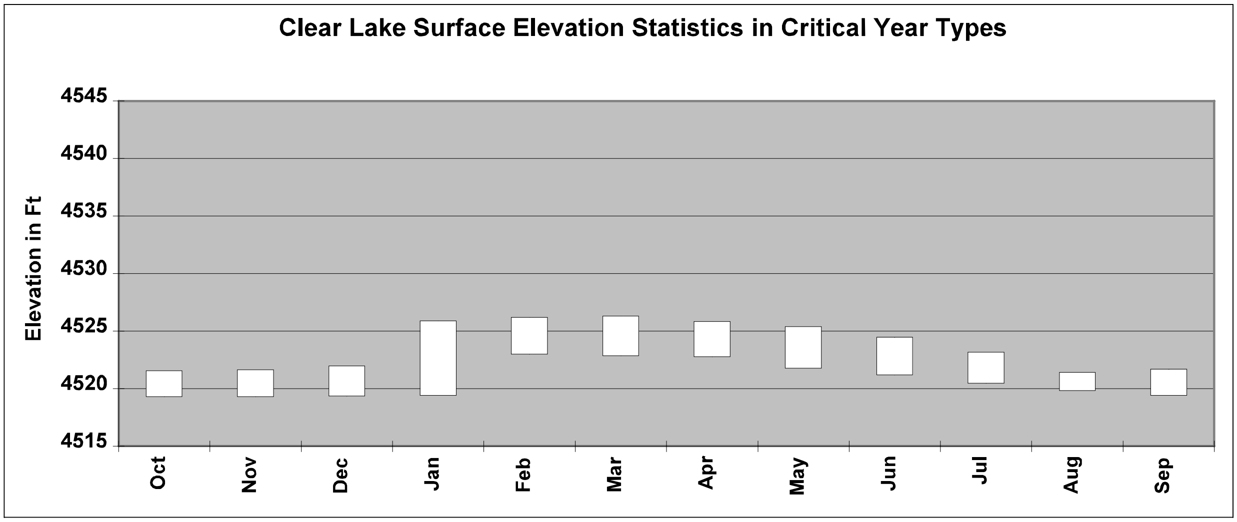
*Dry Year* - The minimum end of the month elevation ranged from 4522.50 in October to 4527.10 in March (Table 5, Figure 7). The average end of the month elevation ranged from 4525.38 in October to 4529.85 in March.

**Figure 7. Clear Lake Reservoir end of month elevations (1960-1998) for dry years.**



*Critical Dry Year* - The minimum end of the month elevation ranged from 4519.29 in November to 4523.00 in February (Table 5, Figure 8). The average end of the month elevation ranged from 4520.42 in October to 4524.60 in February.

**Figure 8. Clear Lake Reservoir elevations (1960-1998) by month for critical dry years.**



1.3.3 <u>Gerber Reservoir</u>

Statistics on Gerber Reservoir historical water surface elevation data for water years 1961-1998 (October 1960-September 30, 1998) are summarized by water year type in Table 6 from Reclamation's 2001 BA.

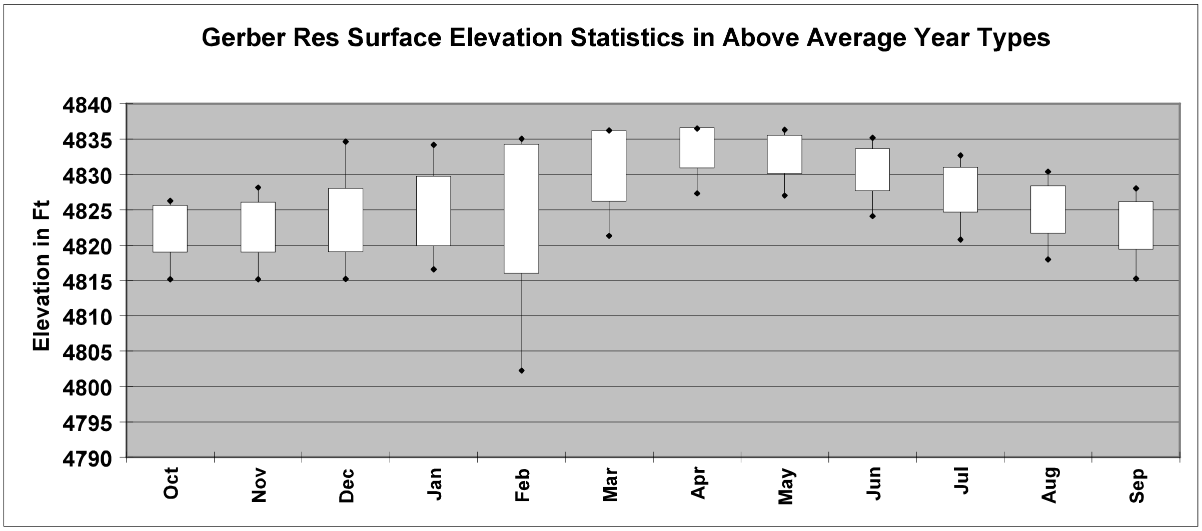
**Table 6. End of the month Gerber Reservoir elevations by water year type (1960-1998).**

| | 20 Above Average Years | | | | 11 Below Average Years | | | |
|---|---|---|---|---|---|---|---|---|
| | Maximum | Minimum | Average | St. Dev. | Maximum | Minimum | Average | St. Dev. |
| Oct | 4826.26 | 4815.18 | 4822.30 | 3.32 | 4821.49 | 4794.27 | 4810.09 | 8.00 |
| Nov | 4828.12 | 4815.16 | 4822.54 | 3.55 | 4823.04 | 4795.93 | 4810.89 | 7.91 |
| Dec | 4834.60 | 4815.20 | 4823.50 | 4.49 | 4831.40 | 4798.80 | 4814.01 | 9.16 |
| Jan | 4834.18 | 4816.58 | 4824.79 | 4.94 | 4829.70 | 4799.14 | 4815.54 | 9.37 |
| Feb | 4835.04 | 4802.24 | 4825.11 | 9.14 | 4832.03 | 4803.80 | 4819.94 | 7.85 |
| Mar | 4836.19 | 4821.30 | 4831.21 | 5.00 | 4835.00 | 4809.00 | 4823.32 | 7.49 |
| Apr | 4836.48 | 4827.30 | 4833.75 | 2.85 | 4834.59 | 4812.37 | 4825.40 | 5.94 |
| May | 4836.29 | 4827.00 | 4832.83 | 2.71 | 4832.57 | 4810.35 | 4823.20 | 5.75 |
| Jun | 4835.16 | 4824.10 | 4830.66 | 2.99 | 4830.03 | 4807.88 | 4820.67 | 6.04 |
| Jul | 4832.68 | 4820.81 | 4827.80 | 3.19 | 4826.78 | 4804.13 | 4817.16 | 6.33 |
| Aug | 4830.39 | 4817.98 | 4825.00 | 3.34 | 4823.64 | 4801.24 | 4814.01 | 6.61 |
| Sep | 4828.00 | 4815.26 | 4822.76 | 3.39 | 4821.63 | 4794.47 | 4810.77 | 7.86 |

| | 5 Dry Years | | | | 2 Critical Years | | | |
|---|---|---|---|---|---|---|---|---|
| | Maximum | Minimum | Average | St. Dev. | Maximum | Minimum | Average | St. Dev. |
| Oct | 4809.20 | 4797.98 | 4803.25 | 3.64 | 4806.59 | 4796.62 | 4801.61 | 4.99 |
| Nov | 4811.50 | 4797.96 | 4805.52 | 4.78 | 4806.74 | 4796.62 | 4801.68 | 5.06 |
| Dec | 4821.60 | 4798.04 | 4808.91 | 7.84 | 4807.08 | 4797.06 | 4802.07 | 5.01 |
| Jan | 4822.20 | 4798.18 | 4811.02 | 8.61 | 4816.63 | 4798.79 | 4807.71 | 8.92 |
| Feb | 4825.65 | 4804.82 | 4816.35 | 6.69 | 4822.94 | 4800.74 | 4811.84 | 11.10 |
| Mar | 4825.91 | 4804.18 | 4817.55 | 7.24 | 4823.30 | 4801.28 | 4812.29 | 11.01 |
| Apr | 4824.71 | 4808.26 | 4818.08 | 5.58 | 4822.48 | 4801.14 | 4811.81 | 10.67 |
| May | 4822.84 | 4808.10 | 4816.55 | 4.91 | 4820.80 | 4798.86 | 4809.83 | 10.97 |
| Jun | 4819.52 | 4803.60 | 4813.29 | 5.39 | 4817.81 | 4798.36 | 4808.09 | 9.73 |
| Jul | 4815.48 | 4799.22 | 4809.19 | 5.55 | 4814.08 | 4797.73 | 4805.91 | 8.18 |
| Aug | 4812.90 | 4798.60 | 4806.10 | 4.70 | 4810.16 | 4797.01 | 4803.59 | 6.57 |
| Sep | 4809.64 | 4798.08 | 4803.37 | 3.74 | 4806.78 | 4796.52 | 4801.65 | 5.13 |

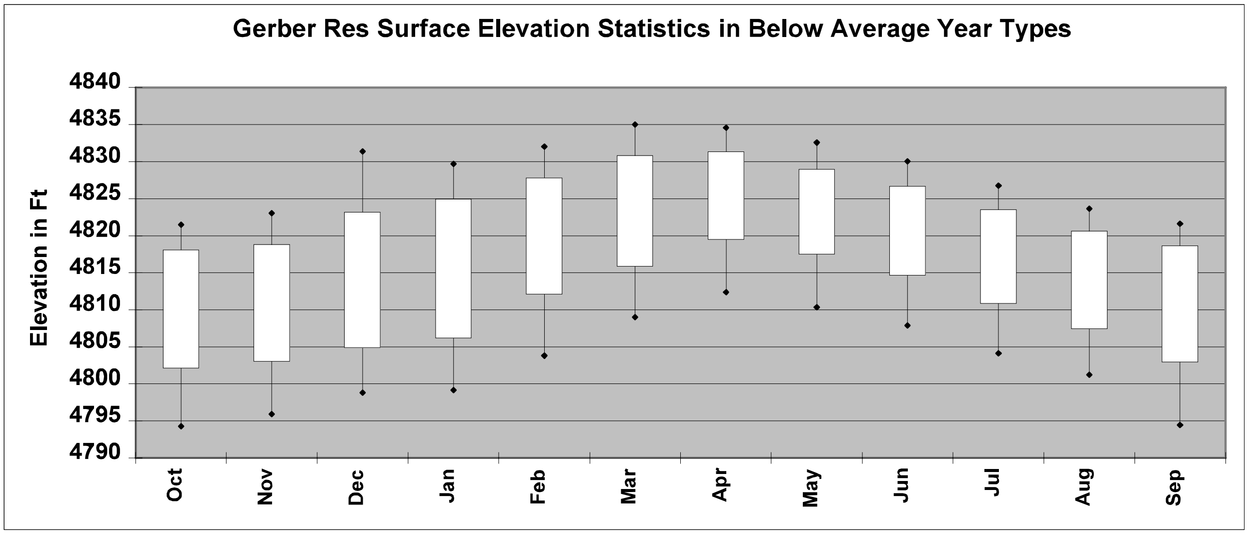
*Above Average Year* - The minimum end of the month elevation ranged from 4802.24 in February to 4827.30 in April (Table 6, Figure 9). The average end of the month elevation ranged from 4826.26 in October to 4836.48 in April.

**Figure 9. Gerber Reservoir end of month elevations (1960-1998) for above average years.**



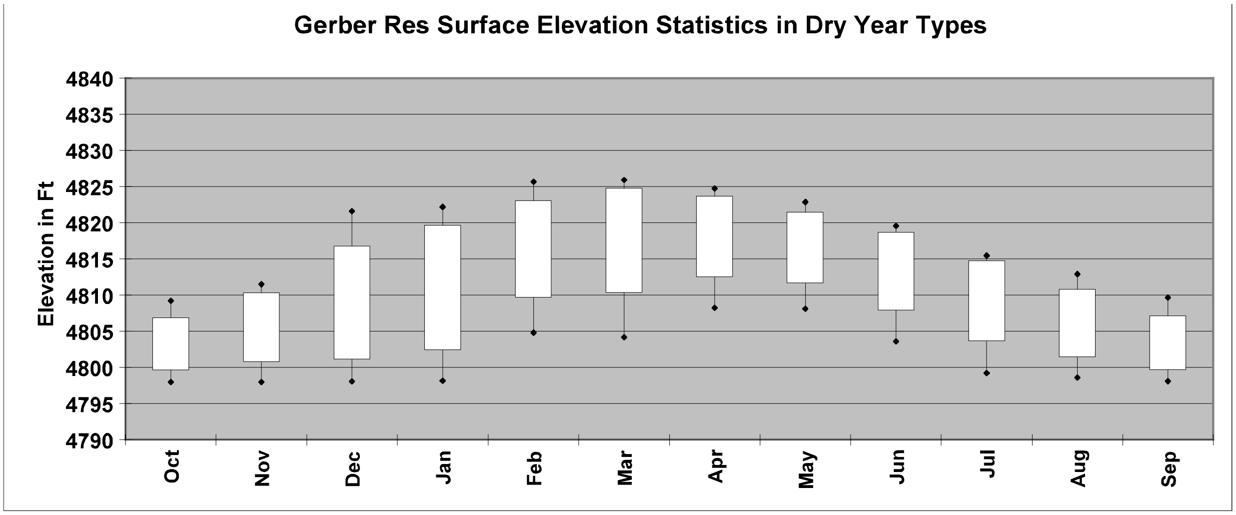
*Below Average Year* - The minimum end of the month elevation ranged from 4794.27 in October to 4812.37 in April (Table 6, Figure 10). The average end of the month elevation ranged from 4810.09 in October to 4825.40 in April.

**Figure 10. Gerber Reservoir end of month elevations (1960-1998) for below average years.**



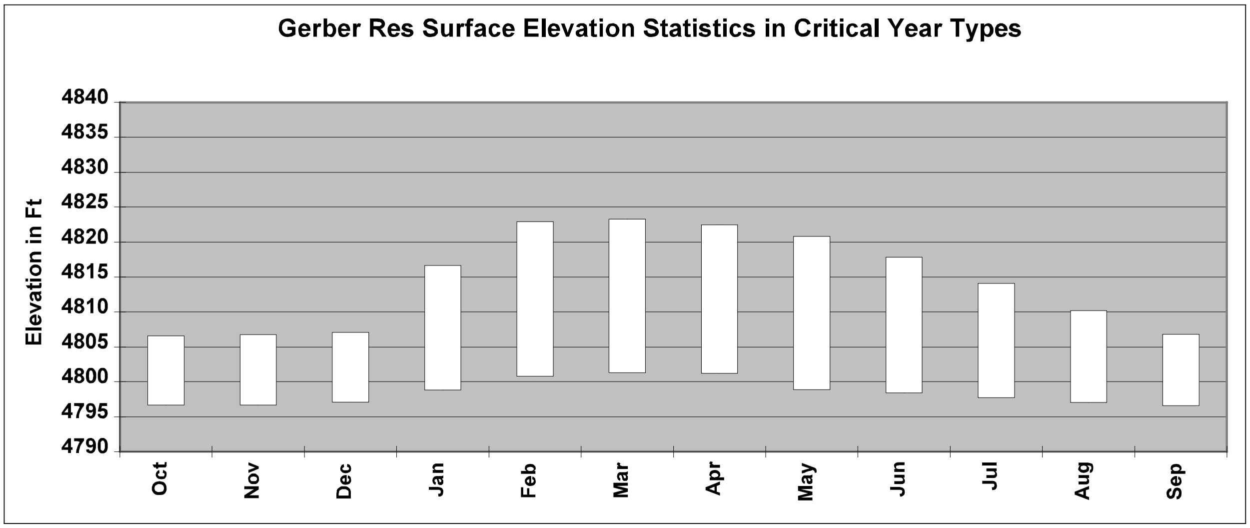
*Dry Year* - The minimum end of the month elevation ranged from 4797.98 in October to 4808.26 April (Table 6, Figure 11). The average end of the month elevation ranged from 4803.25 in October to 4818.08 in April.

**Figure 11. Gerber Reservoir end of month elevations (1960-1998) for dry years.**



*Critical Dry Year* - The minimum end of the month elevation ranged from 4796.52 in September to 4801.28 in March (Table 6, Figure 12). The average end of the month elevation ranged from 4801.61 in October to 4812.29 in March.

**Figure 12. Gerber Reservoir end of month elevations (1960-1998) for critical dry years.**



### 1.3.4 Agricultural and Refuge Water Use

Water is diverted from Project storage facilities to provide for crop production and needs on National Wildlife Refuges located within the Project service area (Table 7). (USBR 2001)

**Table 7. Crop and refuge water use from UKL (1961 through 1999–values in 1,000s of acre-feet).**

| | 19 Above Average Years | | | 11 Below Average Years | | |
|---|---|---|---|---|---|---|
| Time Step | Maximum | Minimum | Average | Maximum | Minimum | Average |
| October | 28.9 | 6.58 | 17.78 | 27.77 | 12.34 | 18.53 |
| November | 15.86 | .49 | 6.78 | 14.25 | 2.28 | 6.81 |
| December | 17.28 | .39 | 8.68 | 16.43 | 1.52 | 8.5 |
| January | 22.74 | 5.43 | 12.43 | 23.57 | 6.24 | 13.79 |
| February | 17.64 | 2.33 | 7.28 | 11.10 | 2.94 | 8.03 |
| March | 12.87 | .3 | 4.69 | 10.68 | 1 | 6.07 |
| April | 52.85 | 5.49 | 21.14 | 52.85 | 21.92 | 36.17 |
| May | 76.70 | 28.95 | 55.15 | 81.83 | 50.55 | 65.49 |
| June | 103.54 | 45.33 | 81.72 | 102.05 | 73.11 | 86.17 |
| July | 105.38 | 75.33 | 91.35 | 104.55 | 75.37 | 93.25 |
| August | 87.20 | 47.71 | 74.63 | 88.58 | 36.08 | 71.50 |
| September | 61.45 | 34.63 | 48.09 | 60.95 | 40.15 | 48.76 |

| | 5 Dry Years | | | 2 Critical Years | | |
|---|---|---|---|---|---|---|
| Time Step | Maximum | Minimum | Average | Maximum | Minimum | Average |
| October | 29.13 | 8.83 | 20.50 | 31.17 | 14.62 | 22.90 |
| November | 16.52 | 1.5 | 6.15 | 9.51 | 5.57 | 7.54 |
| December | 17.09 | 6.15 | 11.99 | 20.33 | 15.26 | 17.80 |
| January | 20.67 | 9.33 | 13.72 | 19.70 | 11.14 | 15.42 |
| February | 12.12 | 2.23 | 7.27 | 12.60 | 7.35 | 9.98 |
| March | 17.99 | 1.75 | 10.15 | 16.30 | 11.07 | 13.69 |
| April | 67.32 | 27.11 | 41.53 | 63.63 | 57.64 | 60.64 |
| May | 58.73 | 37.60 | 50.47 | 90.12 | 51.50 | 70.81 |
| June | 91.75 | 70.99 | 81.70 | 87.66 | 78.67 | 83.17 |
| July | 99.81 | 87.40 | 95.28 | 103.77 | 58.25 | 81.01 |
| August | 83.48 | 76.26 | 79.37 | 90.84 | 64.91 | 77.88 |
| September | 66.07 | 49.63 | 58.56 | 33.46 | 32.15 | 32.81 |

## 2.0 PROJECT FACILITIES

### 2.1 Gerber Dam and Reservoir

Gerber Dam is located on Miller Creek about 14 miles east of Bonanza, Oregon. Gerber Reservoir has a surface area of 3830 acres and an active capacity of 94,270 acre feet at the spillway crest, elevation 4835.4 feet. The dam is a variable radius, thin arch concrete dam, with a structural height of 88.0 feet and a crest length of 485 feet. The elevation of the top of the dam is 4841.9 feet, and the elevation of the top of the 3.5-foot parapet wall is 4845.4 feet. The arch thickness at the crest is 5 feet and at the base 17.85 feet.

Construction of Gerber Dam was completed in May of 1925. The reservoir is used to store seasonal runoff to meet irrigation needs of the Project, primarily for the Langell Valley Irrigation District (LVID), and to limit runoff into Tule Lake.

The spillway is located in the center of the dam and consists of an uncontrolled overflow crest with a length of 150 feet and a crest elevation of 4835.4 feet. The spillway has a capacity of 17,500 cfs at elevation 4845.4 feet (top of the parapets). The spillway discharge falls into a plunge pool in which the water surface is maintained by a riprap weir.

The outlet works consists of three, 36-inch-diameter, cast iron conduits about 15 feet long installed through the base of the dam. The conduits have trash-racked bellmouth intakes with a downstream transition into the rectangular gate section. Releases are controlled at the downstream end of the outlet works by three, 2-foot 6-inch by 2-foot 6-inch, cast iron, manually operated high-pressure gates. The high-pressure gates are enclosed in a concrete control house which was built as an integral part of the downstream face of the dam. The centerline elevation of the control gates is 4775.0 feet. The outlet gates are normally submerged and discharge directly into the spillway plunge pool. The maximum combined design capacity of the three outlet conduits is about 900 cfs when the reservoir level is near the dam crest (USBR Web).

Prior to the construction of the dam, no reservoir existed and Miller Creek would run dry from June to October in most years.

The outlet at Gerber is opened in the spring (approximately April 15) to provide irrigation water to the LVID lands. The outlets would normally be shut off on October 1. To prevent freezing of the outlet valves during the winter approximately one cubic foot per second is bypassed and released into the Miller Creek channel. The bypass usually begins in November and continues to the beginning of the irrigation season.

During the irrigation season the outlets are operated on demand of LVID. Maximum flows recently experienced are in the 170 cfs range. LVID operates the dam during the irrigation season under a purchase order type agreement for Reclamation. During the fall and winter Reclamation operates the dam. During the spring the dam is operated to provide the maximum amount of storage possible and still provide flood protection to the Tule Lake lands. There is no attendant at the dam during the year, although past experience shows that the dam is visited by the district at least twice a week to make gate changes and record readings. Studies completed by Reclamation[1] indicate that with a recurrence of the 1924-34 drought, deficiencies approaching 80 to 95 percent would occur. During the 1991 irrigation season the reservoir release was stopped in early July due to the lack of inflow that spring.

The entire Gerber watershed was surveyed by Reclamation in 1970 to summarize available data on the use of water above the Dam (USBR 2000).

### 2.2 North Canal (Langell Valley Irrigation District)

Constructed in 1918, a small earth channel structure 20 ft wide x 4 ft deep x 6 miles long with a stop log diversion structure is located on Miller Creek approximately six miles below Gerber Dam. The North Canal, operated by Langell Valley Irrigation District, carries all irrigation water released from Gerber Dam to lands within Langell Valley Irrigation District. Maximum outflow is approximately 200 cfs.

No water is released to Miller Creek below the structure, although return flows from irrigation of adjacent lands provide some inflow.

The canal is operated in response to crop demand, generally beginning in April. At the end of the irrigation season (October), the canal is drained and the water returned to the Lost River. The entire supply of water for this canal comes from Gerber Reservoir. During 1991, the district maintained a minimum pool for fish and eagles in Gerber, thereby necessitating the cessation of irrigation flows during mid-July.

During the non-irrigation season the stoplogs in the structure are removed allowing free passage of flow down Miller Creek (USBR 1992a).

### 2.3 Clear Lake Dam and Reservoir

---

[1] Upper Lost River Diversion, Concluding report on possibilities for water resource development and a supplemental water supply for Langell Valley, Bureau of Reclamation, June 1972.

Clear Lake Dam is located in California on the Lost River about 39 miles southeast of Klamath Falls, Oregon, and provides storage for irrigation and reduced flow into the reclaimed portion of Tule Lake and the restricted Tule Lake Sumps in Tulelake NWR. The dam is an earth and rockfill structure with a crest length of 840 feet and a height of 36 feet above the streambed. The crest of the dam is at elevation 4,552.0 feet and is 20 feet wide. At the normal maximum water surface elevation of 4,543.0 feet, the dam will impound a total of 527,000 acre-feet in Clear Lake Reservoir. Clear Lake has earthen Dikes which are located at the south end of Clear Lake and provide protection to the Tulelake homesteaded lands. There are two dikes that are interconnected and are both earth core and rip-rap protected. The Main dike runs east and west and was constructed when the stop logs were placed in the spillway in the late 1930's. The South Dike runs southeast and was constructed in 1974 when the spillway was raised permanently. The dikes do not become operative until surcharge on the reservoir is reached.

The spillway structure consists of a concrete overflow weir and side channel located at the left abutment of the dam. With a crest elevation of 4,543.0 feet, the overflow weir is 357 feet in length and has a rated capacity of 5,650 cfs at 2.7 foot depth of flow (Water Surface Elevation 4,545.7 ft). The spillway was reconstructed in 1974.

The Outlet works consist of an Outlet Tunnel comprised of two 53" high x 4'0" wide outlet tubes which extend from the base of the outlet control structure at the upstream face of the dam, to a point approximately 31 feet downstream where they merge into one 7 ft x 7 ft arched outlet tunnel. Two screw-lift outlet gates are located in the outlet control structure, each 4 ft wide by 4'9" high. Each gate is raised and lowered by a hand-cranked screw-lift assembly. A portable power unit is available to power the gate mechanism (USBR Web).

Prior to the construction of the dam a natural lake and marsh/meadow existed. The meadow was seasonally farmed by the Carr Livestock Company. During most years the Lost River below the present dam would run dry from June through October. Historic elevations are included in the appendix.

The outlet at Clear Lake is opened in the spring, usually around April 15, to provide irrigation water to LVID, Horsefly Irrigation District (HID) and private "Warren Act" contract lands. In most years the outlets are shut off around October 1. No other releases are made from the dam unless an emergency condition dictates otherwise. Since the reservoir has a storage limitation of 350,000 acre-feet from October 1 through March 1, summer drawdown releases are occasionally necessary.

A purchase order is issued each year that permits LVID to operate the dam on a reimbursable basis. LVID operates the gates and reports the changes to Reclamation on a daily basis. Flow changes are dictated by the needs of HID and LVID and the private users along the Lost River. During the non-irrigation season Reclamation operates the dam and reservoir. The reservoir is managed to store as much water as possible without encroaching on the operational guidelines. The target elevation after March 1 is 4537.4. Should inflow cause this elevation to be exceeded the water must be released in a timely manner until that elevation is reached. During the irrigation season the dam is visited approximately twice a week and, during the winter, once a month.

During 1970 a careful review and survey of all the water impoundments above the dam was made. This report[2] summarized pertinent facts about private and Federal storage dams and water spreading operations in the watershed (USBR 1992a).

During the history of the reservoir the level has been below elevation 4,522.0 ten years during the fall and winter months. Fall elevations and years in which they occurred are as follows:

| Date | Elevation | Date | Elevation |
|---|---|---|---|
| 1930 | 4,521.84 | 1935 | 4,518.60 |
| 1931 | 4,517.20 | 1936 | 4,521.15 |
| 1932 | 4,519.84 | 1937 | 4,521.60 |
| 1933 | 4,517.70 | 1961 | 4,521.28 |
| 1934 | 4,514.50 | 1962 | 4,521.44 |

### 2.4 Malone Diversion Dam

Constructed in 1923, the Malone Diversion Dam is located approximately eleven miles below Clear Lake Dam on the Lost River. The purpose of the dam, operated by LVID pursuant to Bureau supervision, is to divert water released from Clear Lake into the West Canal and the East Malone Lateral for irrigation in the LVID.

The dam, an earth embankment wing with a concrete gate structure, has a spillway elevation crest of 4,158 and total usable capacity of approximately 500 acre-feet. Normal irrigation releases into the west canal are 130 cfs, and 30 cfs into the east Malone Lateral.

When LVID begins receiving orders for irrigation deliveries from areas served by the West Canal and the East Malone Lateral, the radial gates are lowered to fill the reservoir. The reservoir water surface is maintained at or near 10.0 feet above the gate sill. The West and East Malone Canals are regulated at the dam. At the end of the irrigation season, the radial gates are raised to allow for passage of flood waters during the winter and spring.

### 2.5 West Canal (Langell Valley Irrigation District)

The West Canal headworks are located at Malone Dam on the Lost River approximately ten miles below Clear Lake. Water is released at Clear Lake and then diverted by Malone Dam into the West Canal. The West Canal, operated by LVID, supplies irrigation water to over 17,000 acres of land located in two irrigation districts (Horsefly ID and Langell Valley ID).

The West Canal is an earthen channel 20 ft wide x 4 ft deep x 10 miles long that was constructed in 1918. Maximum outflow is 200± cfs.

The canal is operated in response to crop demand. At the end of the irrigation season, the canal is drained into the Lost River. The entire supply of water for this canal comes from Clear Lake Reservoir (USBR 1992a).

### 2.6 Wilson Diversion Dam & Reservoir (Lost River Diversion Dam)

Wilson Diversion Dam, a concrete multiple arch with earth enbankment wings, was constructed

---

[2] Klamath Project, Clear Lake Watershed Report, Water Rights Engineering Branch-Sacramento, June 1970.

in 1912, approximately eight miles southeast of Klamath Falls on the Lost River. It is operated by Reclamation for the purpose of diverting water from the Lost River into the Klamath River for irrigation and flood control.

The dam with a spillway crest elevation of 4094.5 creates an impoundment with a surface area of 340 acres and 2,300 acre feet of storage. Inflows are dependant on Lost River Flows. Maximum Release to the Diversion Channel is 3,000 cfs.

The dam is operated primarily as a diversion dam, diverting Lost River flows into the Diversion Channel and thence to the Klamath River. During the irrigation season the water surface behind the dam is raised slightly to facilitate irrigation pumping from the reservoir. During the winter and spring the reservoir is lowered to provide a cushion for high flow conditions. The dam is able to divert a maximum of 3,000 cfs of Lost River flows into the Diversion Channel and must spill any flows above that amount into the Lost River below the dam.

### 2.7 Lost River Diversion Channel

The Diversion Channel, operated by Reclamation begins at Wilson Diversion Dam and travels in a westerly direction, terminating at the Klamath River. It was constructed originally in 1912 and enlarged in 1948. It is an earthen channel eight miles long. The channel is capable of carrying 3,000 cfs to the Klamath River from the Lost River system during periods of high flow. The channel is designed so that water can flow in either direction depending on operational requirements. During the irrigation season the predominant direction of flow is from the Klamath River. Miller Hill Pumping Plant is located on the channel along with the Station 48 drop to the Lost River system.

During the fall, winter, and spring, the channel is operated so that all of the water that enters from the Lost River is bypassed to the Klamath River. During periods that the flow is in excess of 3,000 cfs water is bypassed into the Lost River. During the spring of most years it is necessary to import water from the Klamath River to the Lost River for early irrigation in the Tule Lake area. During the summer months the channel is operated as if it were a forebay for the Miller Hill Pumping Plants (see below) and the Station 48 turnout (see below). Depending on the needs of these two irrigation diversions, water that is not able to come from the Lost River must come from the Klamath River.

If necessary Reclamation can isolate the diversion channel from both the Lost River and the Klamath River for emergency and maintenance activities. During normal operations, water levels in the channel are maintained at or near the levels in the Klamath River.

### 2.8 Miller Hill Pumping Plant (Lost River Diversion Channel)

Miller Hill pumping plant constructed in 1941 has three 35 cfs concrete base interior design pumps units (105 cfs maximum flow) that lift water from the Diversion Channel into the C-4-e lateral (see the Lost River Diversion Channel) for irrigation use. The pumping plant is operated by Klamath Irrigation District pursuant to a Joint Liability type contract with Reclamation.

Operation. The pumps are operated on demand of the irrigators that take water from the C-4-e system. The pumps are not used during the non-irrigation season.

### 2.9 Station 48 Turnout (Lost River Diversion Channel)

Station 48, a concrete box culvert with slide gates was constructed in 1948, is a turnout located on the south bank of the Lost River Diversion Channel. Maximum flows are 550 cfs. The discharge from the turnout enters a short channel and then enters the Lost River. The turnout is operated, pursuant to a Purchase Order, by radio telemetry from the Tulelake Irrigation District (TID) Headquarters.

Tulelake Irrigation District operates the Station 48 gates to provide the required flow into the J-Canal located at Anderson-Rose Diversion Dam (see Anderson-Rose details). TID must estimate the amount of return flows to the Lost River between Station 48 and the headworks of the J-Canal and then adjust Station 48 to provide for the J-Canal needs. If the amount of water released is too high, the excess is spilled into the Lower Lost River below the Anderson-Rose dam.

Gates are normally opened from the first of March until mid-November. From 12 to 36 hours are normally required for water from Station 48 to reach Anderson-Rose Dam. It is difficult to determine the amount of water required at the dam due to unknown quantities of return flow between Station 48 and Anderson Rose Dam, and also the time lag between diversions at Station 48 and the dam. (USBR 1992a)

## 2.10 Anderson-Rose Diversion Dam (J-Canal Headworks*)*

Anderson-Rose Dam was constructed in 1921 by the Reclamation to provide the necessary forebay for the J-Canal headworks located on the left abutment of the dam. The J-Canal is the main distribution canal for the Tulelake Irrigation District (TID).

The Anderson-Rose Dam is a reinforced concrete slab and buttress with a concrete overflow spillway and gate structure. It has a spillway height of 12 feet and length of 204 ft and two outlet gates into the Lost River. In addition, the headworks for the J-Canal are located on the left abutment of the dam. The dam, operated by Tule Lake Irrigation District (TID) pursuant to Joint Liability type contract, is located on the Lost River in Oregon. In flows are dependent on releases from Station 48 and irrigation return flows. Maximum Diversion is 800 cfs with approximately 135,000 acre feet per year diverted to the J-Canal.

During the irrigation season the elevation of the Lost River is maintained at or very near the spillway crest. This provides for a maximum head for the J-Canal intake structure. Releases are carefully controlled from Station 48, located approximately ten miles above the dam, via telemetry to coincide with return flows accruing to the Lost River and irrigation demands of TID (J-Canal) to minimize potential spills below the dam. Occasionally operational spills do occur because of the time lag between Station 48 and the dam and the fact that returns to the river are not pre-measured.

Anderson-Rose Dam is the main source of water diversions for Tulelake Irrigation District, with the average of 135,000 acre feet per year diverted to the J-Canal. Other sources of water inflow to TID include return flows from the Klamath Irrigation District. Water in the system is eventually diverted onto individual farm units, either privately owned land or leased land within the Tule Lake National Wildlife Refuge (16,925 acres of irrigated land lie within the refuge).

There are currently 37 pumping plants with a total of 69 pumps within TID. Capacity of these pumps range from a low of 2 cfs to a high of 300 cfs. Irrigation in the district normally starts around March 1 and continues through mid-November. Return flow from fields eventually flow to the Tulelake Sumps. Average operations of TID are as follows: Station 48 to the Lost River = 60,000 AF; diverted at Anderson Rose Dam = 135,000 AF; diversions within the system = 250,000 AF; Pumping Plant D volume = 100,000 AF (USBR 1992a).

## 2.11 Pumping Plant D (Tule Lake Sumps*)*

Pumping Plant D, constructed in 1941 and enlarged in 1949, removes excess water from the Tule Lake Sumps and discharges it into the P-Canal System. It is operated by the by Tulelake Irrigation District pursuant to a Joint Liability type contract with Reclamation. This is the only outlet point from the sump area. The low speed interior design turbine pumps, five pumps with a combined total of 3,650 horsepower turbine are housed in a concrete building within the Tule Lake National Wildlife Refuge. Maximum flow is 300 ft/sec with total annual pumpage ranges from a low of 50,000 AF to a high of 143,000 AF, averaging 91,000 AF.

The sumps act as a natural collection area for drainage return flows from Project lands. A portion of water is then removed from the sumps and used to irrigate the reserved sump lease lands and wildlife lands within the Refuge and then returned to the sumps by pumping. A considerable area within the sumps has become a decadent marsh due to low water depths caused by siltation.

## 2.12 Tule Lake Sump Area

The Tule Lake Sumps are operated by Tulelake Irrigation District pursuant to a Joint Liability type contract with Reclamation. Earthen dikes surround the 12,500 acre sumps, approximately 4 feet deep, which stores approximately 54,000 AF. The primary purpose of the sump area was originally for flood control.

The pump(s) are operated to maintain certain objective levels on the Tule Lake Sumps. These objective level were set by the U.S. Fish and Wildlife Service to facilitate hunting and waterfowl production and by Reclamation to protect the Tule Lake area from flooding and the reserved sumps that are leased by Reclamation. Occasionally the pumps are operated to provide irrigation water to the lands that are dependent on the P-Canal system (see above), including both Federal and private lands. Water from D Plant is the only source of irrigation water for some private lands and part of the Lower Klamath NWR.

Considerable maintenance of the pumping plant is required during the time of the year that it is operated. Of particular concern is the need to remove great quantities of weeds that collect on the trashracks in front of the pumps.

## 2.13 P-Canal System

Constructed in 1942, the P-Canal system, consisting of the Tule Lake Tunnel Outlet Canal, and the P, P-1, and P-1-a Canals, conveys the water discharged from the Tule Lake Tunnel to wetlands located within the Lower Klamath NWR. In addition, water is conveyed to Federal leased lands in the lower Klamath area and to private land owners under surplus water rental agreements (see water rentals). The canal system is operated by Reclamation.

The 15 miles of unlined earth canals are up to 25 feet in width and vary in depth up to 5 feet. Maximum flow in P-1 is 250 cfs; P is 150 cfs; and P-1-a is 50 cfs.

The system is operated to transport water to and through the Lower Klamath Refuge that is considered excess to the Tule Lake Sumps. Pumping Plant D removes water from the Tule Lake Sump and discharges into the P-Canal Outlet Tunnel. The water is then used by individuals, the Refuge, or discharged to the Klamath Straits Drain and thence the Klamath River. On occasion, Pumping Plant D is not pumping to meet objective levels in the sump. During these periods "Special Pumping" is allowed so that water users in Lower Klamath Lake can get water.

Pursuant to a purchase order from Reclamation, the canals in this system are periodically chained to remove aquatic growth (a heavy chain is dragged along the bottom of the canal to dislodge the weeds rooted in the bottom).

During some times of the year the canal system is allowed to drain out. This depends upon water requests, D plant pumping, and refuge water needs.

### 2.14 Klamath Straits Drain (Pumping Plants E, EE, F & FF)

The Klamath Straits Drain, constructed in 1941 and operated by Reclamation, begins at the Oregon-California border and proceeds north to the Klamath River. It is a 60 ft wide x 4-6 ft deep x 8.5 mile earth channel with relift pumping stations. The water is relifted twice by pumps and is then discharged to the Klamath River. The Straits Drain is in the Lower Klamath NWR which in turn receives drainage water from the Tule Lake NWR. The Straits Drain was enlarged in 1976 to provide additional capacity to drain problem areas within the Refuge. Maximum flow is 600 cfs.

The Klamath Straits Drain is operated at levels that will provide adequate drainage to both private lands and refuge lands. The pumps are operated to meet the flow conditions within the drain. Water quality conditions are monitored continuously near the outlet of the channel to the Klamath River.

### 2.15 Ady Canal Headworks (Southern Pacific Railroad Crossing at Ady)

The structure, a concrete box culvert with slide gates and stoplogs, was constructed in 1912 by the Southern Pacific Railroad in cooperation with Reclamation to control the water flow into the lower Klamath Lake area through the Klamath Straits Channel. It is operated by Reclamation. At the present time these gates are left open to allow irrigation water into the lower Klamath area in a controlled manner. Water flow is controlled by the Klamath Drainage District using automatic gates located downstream from this facility. Irrigation flow is 250 cfs.

Gates at the railroad are left in the open position all the time. Flow through the structure is controlled by the district's automatic gates located downstream.

### 2.16 Minor Laterals

Numerous small laterals were constructed by Reclamation beginning in 1905. The 680 miles of earth channels (some are concrete lined) provide irrigation service to agricultural lands. Very little water is diverted directly from the main canal systems on the Project. Approximately 95% of the deliveries to farms occur from the small laterals. The laterals range in depth from one foot to over five feet and in width from two foot to over twenty feet. Maximum flow ranges from 0 to 250 cfs.

The laterals are operated by the various irrigation districts to provide field deliveries of irrigation water to farmers. Flows are dictated by the requirements of the farmers and the capacities of the laterals. As a rule, the laterals are drained during the non-irrigation season and refilled at the beginning of the season. During the drain down of the laterals in the fall water is released to drains and directly to the river systems depending on location.

Laterals are periodically cleaned of sediment during the non-irrigation portion of the year. During the irrigation season, the laterals and canals are treated with herbicides to suppress the growth of aquatic weeds within the canal prism.

## 2.17 Minor Drains

Hundreds of small earth channel drains, a total of 728 miles in length, were constructed by Reclamation beginning in 1905. They provide drainage to agricultural lands which receive irrigation water from Project facilities. The drains range in depth from a few feet below the land surface to over ten feet in depth. In most cases water remains in the drains year round. The terminus of most drains is either in the Lost River or the Klamath River. Maximum flows are 0 to 300 cfs.

The drains are operated to provide for agricultural drainage. Maintenance activities include periodic cleaning of the drains to maintain flows. Some relift pumping plants are located on the drainage system.

## 2.18 Project Diversions

From 1997 - 2000, Reclamation inventoried water diversions throughout the Klamath Project service areas and has prepared a preliminary draft report, identifying 193 diversions owned by federal, state, irrigation districts, or private entities. Private diversions represent the largest number, 122. Of these 132 were documented in the Lost River area and 61 are on the Klamath River from Link River Dam to Keno. Diversions are both gravity fed and pumped with a wide variance in capacities and duration of operation. Most of the large diversions are gravity fed. Only three of these diversions have fish screens. ODFW has placed screens on their Miller Island Wildlife Area diversions. Reclamation’s Agency Lake Ranch diversion is scheduled to be screened in 2001 and A-channel in 2003.

Outside of the Klamath Project Service area, Reclamation estimated Klamath Lake diversions by assigning one diversion to each property. Twenty four large diversions were estimated.

## 2.19 Pumping Plants (General)

There are numerous small pumping plants on the Klamath Project that relift irrigation water and drainage flows. These plants are generally less than 10 cfs (1 cfs to 100 cfs) and are located throughout the Project. They are all electrically operated and in some cases are automatic. They range from low head slow revolution to high speed turbine pumps. Most if not all have trashracks associated with them that must be cleaned periodically but are not screened to minimize fish entrainment. Some of the pumps are operated by districts and far more are operated by individuals for their farming operations.

The pumps are operated on crop demand to remove drainage water or provide irrigation. Some of the pumps are used all year long and others only during the irrigation season.

## 2.20 Direct Farm Deliveries (Water User-operated Facilities)

Water users receive their irrigation supplies, for the most part, through turnouts or pumps constructed on canals and laterals. The farmer then applies the water to fields for the irrigation of crops. In some cases farms are supplied by drains and relift pumps. Drains collect water from previously irrigated fields and move the water to the next point of diversion.

Water use is controlled by the respective irrigation districts. Scheduling of water deliveries allows the irrigation of all lands in rotation. The farmer orders a specific amount of water in advance of need.

## 2.21 Refuge Operations (Project Lease Lands)

The Lower Klamath, Tule Lake, Upper Klamath Lake, and Clear Lake NWRs are integral with the operations of the Klamath Project. Decisions by the Service are made during the year as to management of marshlands and farmlands. These decisions have an impact upon the operations of the Bureau of Reclamation.

## 2.22 Klamath Project Lease Areas

The Klamath Project is responsible for leasing over 23,000 acres of farmland to individuals residing mostly in the Klamath Basin. These leases generated 1.5 to 2.6 million dollars in annual revenue in recent years.

The Kuchel Act (PL 88-567) governs the leasing of these lands. The Act states in part:

> ***Sec. 4.*** *The Secretary shall, consistent with proper water fowl management, continue the present pattern of leasing the reserved lands of the Klamath Straits unit, the Southwest Sump, the League of Nations unit, the Henzel lease, and the Frog Pond unit, all within the executive order boundaries of the lower Klamath and Tule Lake National Wildlife Refuges.... Leases for these lands shall be at a price or prices designed to obtain the maximum lease revenues. These leases shall provide for the growing of grain forage, and soil building crops...(78 Stat. 851; 16 U.S.C. § 695n)*

Leases are renewed during December and any leases not renewed or coming up for re-bidding are offered in February to area farmers. All leasing arrangements are approved by the U.S. Fish and Wildlife Service prior to being offered.

## 2.23 Agency Lake Ranch

Reclamation entered into a lease of approximately 7,123 acres of land that is adjacent to Agency Lake in Klamath County. The purpose in leasing this ranch is to enhance the storage capability of Upper Klamath Lake .

Approximately 7,000 acre-feet of water is diverted over approximately 7-14 days during the time that inflow to Upper Klamath Lake is in excess of the lake’s current ability to store the runoff in the reservoir. Water delivery to the ranch occur during April from Sevenmile Canal at the terminus of Sevenmile Creek. Maximum diversion rate will be 300 cfs.

Water is pumped back into the lake when surface elevation of the lake is decreasing during May. Approximately three weeks is required. Enough water is left on the ranch to maintain soil moisture and limit the release of nutrients from the organic peat soils.

Monitoring for juvenile and adult fish populations in Sevenmile Canal is done prior to beginning water diversions. The Service is notified if juvenile and/or adult suckers are found in the vicinity of the diversion to develop a method to ensure that entrainment of these fish does not occur. Reclamation has used a block net (one-inch square mesh) in the Sevenmile Canal to limit possible entrainment fo fish during diversions and will install a fish screen in 2001.

Any suckers that become trapped in the impoundment during dewatering are rescued. Water quality in the impoundment and water entering and leaving the ranch is monitored.

## 2.24 A-Canal - The A-Canal (Main)

A-Canal, constructed in 1905, was the first irrigation facility completed on the Klamath Project. The canal supplies irrigation water, either directly or indirectly through return flows, to the majority of the Project. The headworks for the canal are located on Upper Klamath Lake west of the City of Klamath Falls and are operated by the Klamath Irrigation District (KID). The earth channel with lined sections is 60 feet wide x 8 feet deep x 9 miles long. Maximum Flow are 1,150 cfs.

The canal is operated on a demand basis. Generally, the canal is charged with water in March or April. Flows average 500 cfs for this charge-up period. Orders for water are placed by irrigators with the watermaster who then schedules the flow in the canal. At the end of the irrigation season, generally during October, the canal is drained into the Lost River and the Lost River Diversion Channel.

## 2.25 The New Earth Company Algae Harvesting Facilities

### 2.25.1. C Canal Algae Harvest Facility

New Earth is permitted by Reclamation to operate and maintains an algae harvesting and processing facility at the head end of the C Canal. All of the water that flows down the C canal (average flow 535 cfs) will pass through 630 sq. ft. of debris reduction devices (DRDs) to remove coarse debris (3/8 inch mesh). Operation of the DRDs will be ensured by manual removal and cleaning several times a day. Water is then routed through a series of distributary pipes to the screening infrastructure. At that structure, water is passed by gravity flow over a series of fine mesh algae harvest screens that are elevated above the C Canal. The algae and any entrained larval fish are removed and the water returned to the C Canal downstream of the harvest facility. Algae concentrated on the screens is washed into collection channels adjacent to the screens and pumped in a slurry to the processing building adjacent to the canal.

In all described harvest scenarios, the described harvest period will vary slightly depending on growing conditions in the lake. In general, algae harvest takes place during the summer when the algae is most concentrated, approximately June 1 to October 15. During harvest the fine mesh screens from which the algae is harvested are operated 24 hours a day. During 1995, approximately 20% of the flow from the C Canal during the harvest season was passed through the facility screens. In 1996, additional screens were being added to allow for processing of 100% of the C Canal flow. DRDs may be operated 24 hours per day, during all algae harvest activities or between June 1 and October 15, whichever is greater. Operations of the DRDs is ensured by manual removal and cleaning several times a day (USBR 1996).

### 2.25.2 B Canal Algae Harvest Facility

New Earth received approval from Reclamation to expand their facilities at the C Canal to harvest algae from the adjacent B Canal. A total of six pumps may deliver water from behind 450 ft. sq. of DRDs located within the walls near the head of the B Canal to a series of fine mesh algae harvest screens suspended above the B Canal. There, algae and any entrained larval stage fish will be removed. This process allows New Earth to harvest virtually all algae from water that flows through the A canal without blocking fish from passing down the B Canal and possibly into the Lost River. DRDs will be operated 24 hours a day, during all algae harvest activities or between June 1 and October 15, whichever is greater. Operation of the DRDs will be ensured by manual removal and cleaning several times a day (USBR 1996).

### 2.26 Link River Diversion Dam and Upper Klamath Lake

Link River Dam, also known as Link River Diversion Dam, is a feature of the Klamath Project, and is located on the Link River just west of the city of Klamath Falls, Oregon. The dam was completed in 1921 and is operated by PacifiCorp under contract to Reclamation to provide hydroelectric power production, flood control, and diversion of irrigation water.

The reservoir, Upper Klamath Lake, is for the most part a natural lake that covers an area of 85,000 acres at reservoir water surface elevation 4143.3. It has an active storage capacity of 523,700 acre-feet between elevations 4143.3 and 4136 and an inactive storage capacity of 211,300 acre-feet between elevations 4136 and 4126. The dead storage volume below elevation 4126 has not been determined.

An unusual condition exists at Link River Dam in that hydraulic control of large outflows from Upper Klamath Lake is established at a reef located at the south end of the lake, approximately 0.4 miles upstream from the dam. A 100-foot-wide channel was cut through the reef to an invert elevation of 4131 feet when the dam was constructed; the remaining portion of the reef is at approximate invert elevation 4138. Because of the controlling influence of this reef, it is possible during large flood events to have reservoir water surface elevations in Upper Klamath Lake higher than the top of dam elevation of 4145.0, while water surface elevations between the dam and the reef are below the top of dam, provided that the dam gates are opened sufficiently to pass the water that flows over the reef. At maximum reservoir water surface elevation of 4143.3 feet, the maximum reef discharge is 8,500 cfs (USBR Web). Prior to construction of the Link River Dam, upper Klamath Lake levels fluctuated between 4140 and 4143 feet (USBR 2001).

Link River Dam is a reinforced concrete buttress and slab diversion structure consisting of multiple slide gate and stoplog bays with a common operating deck at elevation 4145.0. It has a structural height of 22.0 feet, a hydraulic height of 8.0 feet, and a crest length of 435.0 feet.

There is a total of 44 flow-through outlet or spillway bays (one spillway bay has a fish ladder constructed on its downstream side). At the east (left) end of the dam are seven canal-outlet bays through which water flows into the East (or Ankeny) Canal. The fish-laddered spillway bay is the next bay to the right of the Ankeny Canal outlets. Continuing west from the fish-laddered bay toward the right side of the dam, there are 24 stoplogged spillway bays. Immediately to the west of the spillway section are six river-outlet bays. To the right of the river-outlet section at the west (right) end of the dam are six canal outlet bays through which water discharges into the West (or Keno) Canal.

The Ankeny canal-outlet section at the left end of the dam is composed of seven bays, each with a 5.0-foot wide by 7.0-foot high slide gate; each of the slide gates has its own electric-motor driven hoist. This gate section is the headworks structure for the Ankeny Canal which supplies water to a 12-foot diameter wood stave pipe that leads to the East Powerplant. The sill elevation of each gate bay is 4130 feet. The capacity of the pipe limits the discharge from the gate structure to 1,000 cfs.

Twenty-four of the 25 spillway bays are equipped with 8-foot wide timber or concrete stoplogs. The 10 right-most spillway bays are equipped with steel-framed concrete panel stoplogs; the remaining spillway stoplogs are made of wood. The fish-laddered bay is not stoplogged. Stoplogs are removed and installed with an overhead monorail electric hoist and trolley. The crest elevation of each of the spillway bays is 4135 feet. The combined design discharge capacity of the spillway section is 13,000 cfs.

The river-outlet gate section consists of six bays, each with a 5.0-foot-wide by 7.0-foot high slide gate. The sill elevation of each gate is 4130 feet. The four gates on the right side of the river-outlet section are identical to the gates within the adjacent west canal outlet section, and are operated with the same gantry-mounted chain-and-sprocket assembly. The two left-most river-outlet gates have their own individual electric motor drive hoists. A stilling basin was constructed for the river-outlet section in 1952. The design discharge capacity of the river-outlet section is 3,000 cfs.

The Keno canal-outlet section at the right end of the dam forms the headworks for the Keno Canal. This canal-outlet section consists of six gate bays, each bay with a 5.0-foot wide by 7.0-foot high slide gate. The sill elevation of each gate bay is 4129 feet. The slide gates are operated by screw-lift hoists that are driven by an electric-motor driven chain-and-sprocket assembly, that is mounted on a gantry. The Keno Canal delivers water to the West Powerplant; the discharge from the west canal-outlet structure is limited to 2950 cfs by the capacity of the Keno Canal. Only two of the Keno Canal slide gates (the second and fourth gates from the right end of the dam) are routinely used to make releases into the canal (USBR Web).

Link River Dam provides regulation of UKL and is operated pursuant to a Reclamation contract with Pacific Power (formerly Copco).

## 2.27 PacifiCorp Project Facilities

The physical description of the Link River Dam facility is discussed above. Reclamation has management control of UKL elevations and Iron Gate dam releases. PacifiCorp operates Link River Dam and Iron Gate Dam releases under the direction of Reclamation. Reclamation’s control of operational conditions, coupled with relatively small active storage in the Klamath Hydroelectric Project reservoirs means that PacifiCorp’s operations have little or no control over the river’s flow regime, except on a short-term (hourly, daily) basis and at certain locations (PacifiCorp 2000).

Link River Dam and the associated Eastside (3.2 megawatt [MW]) and Westside (0.6 MW) powerhouses are the most upstream facilities, located near RM 254 within the city limits of Klamath Falls, Oregon. Reclamation owns the Link River dam and PacifiCorp operates it under Reclamation’s directive. The dam was built to supply water to both the Project and PacifiCorp’s Klamath Hydroelectric Project. The Eastside and Westside powerhouses and associated waterways are part of a FERC project. Keno Dam, a re-regulating facility with no generation capability, is the next facility, 20 miles downstream at RM 233. Keno reservoir buffers inflow and outflow of USBR’s Irrigation Project. The next facility is J.C. Boyle (80 MW). The dam is at RM 224.7 and the powerhouse is several miles downstream at RM 220.4. As the river continues into California, it enters Copco reservoir, which supplies Copco No. 1 (20 MW) and No. 2 (27 MW) hydroelectric facilities, at RM 198.6 and RM 196.8, respectively. The Iron Gate facility (18 MW) is farthest downstream at RM 190. Fall Creek, a tributary, flows through a small powerhouse (2.2 MW) and then into the upper end of Iron Gate reservoir (PacifiCorp 2000).

### PacifiCorps' Eastside and Westside Facilities

Link River Dam, located at RM 254 in Klamath Falls, Oregon, is the Project-related facility furthest upstream and the point of diversion for the Eastside and Westside powerhouses. Construction of Link River Dam was completed in 1921. The dam is a reinforced concrete slab about 16 feet high. The spillway section consists of six spill gates and numerous removable stop log spill gates. The Eastside facilities consist of 1,729 feet of wood-stave flowline, 1,362 feet of steel flowline, a surge tank, and a powerhouse on the east bank of Link River. The Westside facilities consist of a 5,575-foot-long earthen canal, 140 feet of steel penstock, and a powerhouse on the west bank of the Klamath River. Maximum diversion capacity for the Eastside powerhouse is 1,200 cfs; for Westside it is 250 cfs. The Eastside powerhouse consists of a single Vertical Francis 3.2-MW unit. The Westside powerhouse consists of a Horizontal Pit-type Francis 0.6-MW unit.

There are no fish screens at the Eastside and Westside canal intakes from the Link River Dam. A pool and weir type fish ladder was constructed at the dam in 1926 and modified with a vertical slot entrance pool in 1988. Reclamation owns the ladder and PacifiCorp operates it. The ladder consists of 11 pools, is approximately 105 feet long, and provides for approximately 13 feet in elevation gain. Flow through the ladder is dependent upon UKL water surface elevation and is adjusted manually by PacifiCorp operators. The affected reach between the Link River Dam and the Eastside powerhouse tailrace is approximately 2,600 feet long.

The Link River Dam provides regulation of UKL, diverts water from the lake to the Eastside and Westside powerhouses, and releases a minimum flow in the Link River reach between the dam and the Eastside powerhouse. Upper Klamath Lake is not part of PacifiCorp’s Klamath Hydroelectric Project. PacifiCorp operates the Link River Dam and maintains lake levels and releases flow at Reclamation’s direction by following an operating range dictated by spring runoff conditions. Reclamation directs operations according to a contract with PacifiCorp. Operations must balance the requirements for (1) ESA species found in UKL and downstream, (2) irrigation, and (3) power, while maintaining sufficient carryover storage. Should operations threaten irrigation supplies, Reclamation reserves the right to take over facility operation.

The total storage capacity of UKL is 523,700 acre-feet, which represents most of the storage capacity in the entire basin (PacifiCorp 2000). Prior to construction of the Link River Dam, UKL fluctuated 3 feet, from 4140 to 4143 ft (USBR 2001). Following dam construction, normal operating conditions at Link River Dam historically provided for a 6.3-foot lake fluctuation, although current lake elevations are dictated by the 1996 BO. Such operations result in an annual fluctuation of 4.3 feet. Over the last several years, lake elevations have been increased to full pool elevation (4,143.3 ft msl) just before onset of the irrigation season in May, followed by a gradual drawdown until the end of the season in mid-October.

Diversions to the Eastside powerhouse are somewhat variable, as flow through the powerhouse is operated to regulate UKL and Keno reservoir water surface elevations and to ensure instream flows downstream of Iron Gate Dam. Diversions to the Westside powerhouse are either 0 or 230 cfs. Flows through the facility cannot be varied as at the Eastside powerhouse, thus the Westside powerhouse is either at 230 cfs flow and generating or at 0 cfs and shut down. Changes in flows into Keno reservoir can include altering flows through the Eastside powerhouse or adjusting spill at the Link River dam. The minimum affected reach instream flow is 90 cfs, based on an agreement between ODFW and PacifiCorp. An allowable rate of change in flow released at the dam (hereafter referred to as the ramp rate) became a standard operating procedure in the 1980s, based on discussions with ODFW. The ramp rate is now part of the 1996 BO issued by the Service that PacifiCorp follows in operating the dam.

The ramp rate for the reach between Link River Dam and the Eastside powerhouse requires that flows change by no more than (1) 100 cfs in 30 minutes when release flows are between 500 and 1,500 cfs, (2) 50 cfs in 30 minutes when release flows are between 300 and 500 cfs, and (3) 20 cfs in 5 minutes when release flows are between 0 and 300 cfs. A fish salvage must be conducted in side channels if flows drop below 350 cfs. As per PacifiCorp's operations and maintenance plan written for the 1996 BO, the minimum flow downstream of the Eastside powerhouse is 450 cfs. At flows less than this, a fish salvage must be conducted.

Turbine maintenance typically is on an annual basis and occurs at both powerhouses during the spring. Outages usually occur for approximately 5 days. Dewatering of the waterways is not always necessary. Instream flow in the bypass reach and downstream of the Eastside powerhouse is maintained by spill at Link River Dam.

### Keno Facilities

Keno Dam is a re-regulating facility located at about RM 233, approximately 21 miles downstream of Link River Dam. There is no power generating capability at this facility. Construction of Keno Dam was completed in 1967. The concrete dam has a height of 25 feet and a spillway width of 40 feet through each of the six spill gates. The impoundment upstream of the dam has a surface area of 2,475 acres and a total storage capacity of 18,500 acre-feet. There is a 24-pool weir and orifice type fish ladder at the dam. This fish ladder gains 19 feet in elevation in approximately 350 feet. The Klamath River reach from Keno Dam downstream to the J.C. Boyle reservoir is about 5 miles long.

Keno Dam operates as an agricultural diversion dam to control elevations of Keno reservoir for the Project. PacifiCorp built the facility intending to produce hydroelectric power, but the facilities were never developed. The constant reservoir level allows irrigators to withdraw water during the growing season and the dam regulates river level fluctuation from variable agricultural return flows. As per a FERC license, PacifiCorp has an agreement with ODFW to release a minimum stream flow of 200 cfs at the dam. Flows through Keno Dam generally mimic instream flows downstream from Iron Gate dam and approach the minimum flow only during critically dry water years. Reservoir levels rarely fluctuate more than 6 inches seasonally, although the reservoir may be drawn down about 2 feet annually for 1-2 days to provide an opportunity for irrigators to conduct maintenance on their pumps and canals. There is no ramp rate requirement for flow released from the dam. Controlling releases in this way would be very difficult, since agricultural return flows are not regulated. Furthermore, controlling flows according to a ramp rate would cause reservoir levels to fluctuate, thereby compromising the irrigators' ability to obtain water via the pumps.

As there is no generating facility at Keno Dam, turbine maintenance is not an issue. However, spill gate testing is conducted annually and at 5-year intervals. Each spill gate is partially opened during annual maintenance testing and fully opened during 5-year testing to ensure that the operator motors are functioning correctly. This testing is usually conducted in the spring during periods of high river flow.

### J.C. Boyle Facilities

The J.C. Boyle development consists of a reservoir, dam, diversion canal, and powerhouse on the Klamath River between about RM 228 and 220. Construction was completed in 1958. J.C. Boyle facilities consist of an earth-filled dam 68 feet tall impounding a narrow reservoir of 420 surface acres (J.C. Boyle reservoir). The impoundment formed upstream of the dam contains about 3,495 acre-feet of total storage capacity and 1,724 acre-feet of active storage capacity, according to facility drawings.

The dam has three spill gates and can divert up to roughly 3,000 cfs, which is the hydraulic capacity of the powerhouse. The intake from the dam to the power canal is screened with four vertical traveling screens (0.25-inch mesh) with high-pressure spray cleaners. A weir with cleaning orifice fish ladder approximately 569 feet long with 57 pools is located at the dam for fish passage. The change in elevation between pool 1 and pool 57 is about 67 feet. The concrete-walled canal extends just over two miles along a cliff face before entering a tunnel and steel penstocks. The powerhouse is located about 4.3 RM downstream of the dam. Each penstock serves a separate 40-MW unit. The next downstream facility is Copco No. 1 reservoir, approximately 17 miles away.

The J.C. Boyle development generally operates as a load-factoring facility when flow is not adequate to allow continuous and efficient operations. This type of operation results in flows from the powerhouses that vary according to power demand. Normal operation at the J.C. Boyle facility is to generate electricity at efficient loadings with available water. Generation occurs when there is sufficient water available for efficient use of one or both turbines. As a result, flows downstream from the powerhouse may fluctuate on a daily basis, based on the amount of water available to the plant. High river flows in excess of powerhouse hydraulic capacity or efficient loadings of the units can allow continuous operation of the powerhouse. During cold weather conditions, the plant generates power around the clock, not necessarily at peak efficiencies, to prevent freeze damage to the canal or equipment.

The load-factoring operation allows commercial and recreational rafting opportunities from the powerhouse to Copco reservoir from May to mid-October. During that period, timing of flow release may be in part determined by rafting use in the downstream reach.

The minimum flow requirement, as established in the FERC license (FPC 1956), from the dam into the roughly 4-mile-long affected reach is 100 cfs (the reach of the Klamath River channel between the dam and the powerhouse). However, large springs within the affected reach supply an estimated additional 350 cfs of accretion flow, such that actual minimum flows in the reach are approximately 450 cfs or greater. River fluctuation downstream of the dam and the powerhouse are limited to a 9-inch-per-hour ramp rate, as measured at the USGS gauge 0.25 mile downstream of the J.C. Boyle powerhouse, as established in the FERC license (FPC 1956). Operating conditions can result in a fluctuation of about 3.5 feet between minimum and full pool elevations in the J.C. Boyle reservoir, but the average daily fluctuation is about 2 feet. There are no specific requirements established for reservoir fluctuations.

Facility maintenance is usually scheduled on an annual basis in the fall, following the whitewater recreation season. Unit outages usually last two weeks or less and are offset to allow generation at the other unit to continue. Canal maintenance typically is a one-day event that results in dewatering the canal, removing rocks that have fallen into the canal, and inspecting the canal wall. To prevent the loss of fish that might be in the canal, a fish salvage occurs as the canal is dewatered. As at Keno Dam, partial spill gate testing is conducted annually and a full spill gate test is conducted every five years.

### Copco No. 1 Facilities

The Copco No. 1 development consists of a reservoir, dam, and powerhouse located on the Klamath River between about RM 204 and RM 199 near the Oregon-California border (Figures 2-1 and 2-2). Generation at unit 1 began in 1918. Copco No. 1 Dam is a concrete arch dam 126 feet high, with 13 spill gates across the top. The impoundment formed upstream of the dam is approximately 1,000 surface acres containing about 45,500 acre-feet of total storage capacity and 6,235 acre-feet of active storage capacity. The Copco No. 1 powerhouse is located at Copco dam and has two Double Runner Horizontal Francis turbines, each 10 MW. Combined hydraulic capacity of the turbines is roughly 3,200 cfs. Water diverted through the Copco No. 1

powerhouse is directed to the Copco No. 2 powerhouse intake (described below) through the approximately one mile-long reservoir.

Copco No. 1 Dam operates for power generation, flood control, and control of water surface elevations of Copco and Iron Gate reservoirs. Like the J.C. Boyle development, Copco No. 1 generally operates as a load-factoring facility, usually from spring to high flows in early winter. Typical operation is to generate during the day, when energy demands are highest, and store water during the non-peak times (weeknights and weekends). When river flows are near or in excess of turbine hydraulic capacity, the powerhouse generates continuously and excess water is spilled through the spill gates. There are no minimum instream flow or ramp rate requirements for the short downstream reach between Copco No.1 and Copco No. 2 developments. Copco reservoir can fluctuate 5.0 feet between normal minimum and full pool elevations, but the average daily fluctuation is about 0.5 foot. There are no specific requirements established for reservoir fluctuations.

Maintenance at Copco No.1 is an annual event and typically occurs in the spring. Maintenance on each turbine unit requires a shutdown of approximately 2 weeks. Depending on time of year and river flow, water might be spilled over the dam. Annual and 5-year spill gate testing is also conducted.

### Copco No. 2 Facilities

The Copco No. 2 development consists of a diversion dam, small impoundment, and powerhouse located just downstream of Copco No.1 dam between about RM 198.3 and RM 196.8 (Figures 2-1 and 2-2). The reservoir created by the dam has minimal storage capacity (73 acre-feet). As a result, Copco No.2 is entirely dependent upon Copco No.1 for water to generate with and functions as a slave to the Copco No.1 powerhouse.

Completed in 1925, the Copco No. 2 Dam is small compared to Copco No. 1 Dam, being only 33 feet high. The conduit to the powerhouse consists of portions of wood-stave, rock tunnel, and steel penstock. Two Vertical Francis (13.5 MW each) units with a combined hydraulic capacity of 3,200 cfs reside in the powerhouse.

Copco No. 2 operation follows that of Copco No. 1. Water spills over the spillway crest when flows from Copco No. 1 exceed the hydraulic capacity and limited storage capacity of this facility. There are no minimum instream flow or ramp rate requirements for the short (about 1.5 miles) downstream reach between Copco No. 2 dam and Iron Gate reservoir, but PacifiCorp releases a minimum flow of 5-10 cfs as standard operating practice. Water surface elevations of the reservoir rarely fluctuate more than several inches. No specific requirements have been established for reservoir fluctuations.

Maintenance at Copco No. 2 is an annual event, typically occurring in the spring. Maintenance on each turbine unit requires a shutdown of approximately two weeks. Depending on time of year and river flow, water might be spilled over the Copco No. 2 dam. Annual and five-year spill gate testing is also conducted.

### Iron Gate Facilities

The Iron Gate development consists of a reservoir, dam, and powerhouse located on the Klamath River between about RM 196.8 and RM 190 about 20 miles northeast of Yreka, California. Iron Gate is the part of the Klamath Hydroelectric Project farthest downstream. The rock-fill Iron Gate Dam was completed in 1962 and is 173 feet high. The impoundment formed upstream of the dam is approximately 944 surface acres and contains about 58,794 acre-feet of total storage capacity and 3,790 acre-feet of active storage capacity. An ungated spillway 730 feet long leads to a large canal, allowing the transport of high flows past the structure. The powerhouse is located at the base of the dam and consists of a single Vertical Francis unit (18 MW) with a hydraulic capacity of 1,735-cfs.

The Iron Gate facility is operated for base load generation and for providing stable flows in the Klamath River downstream of the dam. It also provides the required minimum flows downstream of the facility. During periods of high flow, when storage is not possible, water in excess of generating capacity passes through the spillway.

FERC stipulated minimum instream flow requirements to protect downstream aquatic resources as a condition of PacifiCorp’s current Project license. FERC minimum flows are 1,300 cfs from September through April, 1,000 cfs in May and August, and 710 cfs in June and July. Since 1996, however, Reclamation’s annual Project Operation Plans have dictated instream flow releases. During that time, instream flow releases from Iron Gate Dam, as required by the annual Project operation plans have generally exceeded the required FERC instream flows.

Downstream river fluctuation caused by releases at Iron Gate Dam are limited to the lesser of a 3-inch-per-hour or 250-cfs-per-hour ramp rate as established in the FERC license (FPC 1956). Iron Gate reservoir can fluctuate a maximum of about eight feet between normal minimum and full pool elevations. Average daily fluctuation is roughly 0.5 foot. There are no specific requirements established for reservoir fluctuations.

With no spill gates at the dam and just a single unit, maintenance at the Iron Gate powerhouse involves a single annual outage typically lasting two weeks. Due to the need for river levels less that 2,000 cfs (to allow the crew safe access to the turbine), maintenance typically occurs in late spring. To maintain downstream Klamath River flows, water is spilled over the dam.

Fall Creek Facilities

The Fall Creek development is located on Fall Creek, a tributary of the Klamath River, approximately 0.4 miles south of the Oregon-California border. The Fall Creek development consists of two small diversion dams, an earthen ditch, a penstock, and a powerhouse. The upstream-most diversion is located on Spring Creek; when in use it diverts water over to Fall Creek. The diversion on Fall Creek then diverts water into the waterway that supplies the powerhouse. Since both streams are predominantly spring fed, there is no storage reservoir and the powerhouse operates as a run-of-the-river facility. A 69-kV transmission line of approximately 1.7 miles extends from the powerhouse to the Copco No. 1 development. Built in 1903, the Fall Creek hydroelectric facility is one of PacifiCorp’s oldest. The dam on Fall Creek is a log crib, earth filled diversion dam. Waterway length from dam to penstock intake is approximately 4,560 feet. The penstock drops over the hillside, providing a 730-foot head to the three Pelton turbines in the powerhouse. Generation capacity is 0.5 MW for Unit No. 1, 0.45 MW for Unit No. 2, and 1.25 MW for Unit No. 3. Hydraulic capacity of the three turbines totals 50 cfs.

The Fall Creek facility is operated for base load generation. It also provides the required minimum flow of 15 cfs downstream of the facility. During periods of higher flow, water in excess of diversion capacity (50 cfs) passes over the diversion dam. FERC minimum flow requirements are 0.5 cfs at all times from the Fall Creek diversion dam into Fall Creek, and a 15-cfs continuous flow in Fall Creek (or a quantity equal to the natural flow of the stream, whichever is less) at the outlet of the powerhouse tailrace.

Maintenance at the Fall Creek facility is scheduled annually and usually occurs in the summer. With three generating units, one unit can be shut down for maintenance while the others continue to operate. A typical shutdown lasts one to three days per unit. If there is a need to completely shut off water to the powerhouse, downstream flows can be met by removing diversion boards at the dam or by spilling canal water at the penstock intake back into the bypass reach.

Transmission Lines

The eight transmission line segments associated with the Project are dedicated solely to Project facilities. From the Eastside facility, line 11-8 (69 kV) crosses the bypass reach and connects the powerhouse to a tap point on line 11. The Westside plant has no associated transmission lines, since all adjacent lines would still exist, apart from the facility.

One short transmission line is associated with the J.C. Boyle powerhouse. Line 98 (69 kV), also referred to as line 18-4 on the FERC drawing, connects the powerhouse to a tap point on line 18. This line is currently idle.

Two line segments are associated with the Fall Creek powerhouse. Line 3 (69 kV) connects the Fall Creek powerhouse to Copco No. 1 switch yard, approximately one mile to the east. Another very short segment of line 3 connects the powerhouse to a tap point on line 18, which runs nearly overhead.

Three lines are associated with Copco No. 1 powerhouse. Line 15 (69 kV) connects Copco No. 1 switch yard to Copco No. 2, approximately one mile to the west. Lines 26-1 (69 kV) and 26-2 (69 kV) connect Copco No. 1 switch yard to Copco No. 1 powerhouse. No transmission lines are associated with Copco No. 2 powerhouse.

One line is associated with Iron Gate powerhouse. Line 62 (69 kV) runs along the north side of the reservoir, from the powerhouse to Copco No. 2.

## 3.0 CONTRACTUAL RELATIONSHIPS

### 3.1 Repayment Contracts

The Project water users obtain their irrigation water supply from Project facilities pursuant to various contracts with Reclamation. Reclamation obtained water rights for the Project in accordance with California and Oregon State law, pursuant to the Reclamation Act of 1902. The priority date for Project water rights is generally 1905, and some rights may date from 1878.

Reclamation entered into numerous contracts pursuant to Article 9(d) of the Reclamation Act of 1904 with various irrigation districts to provide for the repayment of Project costs and the granting of water rights. The contracts specify an acreage to be covered by the water right granted and in most cases do not specify an amount of water relying on beneficial use for the amount of water used. The contracts are all written in perpetuity.

In all, over 250 contracts for water service are administered either directly or through irrigation districts on the Klamath Project. Contracts also cover the operation of the system that was transferred to the water users for operational responsibility. Irrigation Districts that fall into this category are Klamath Irrigation District, Tule Lake Irrigation District, and the Langell Valley Irrigation District.

In addition to the above, the Bureau of Reclamation entered into numerous contracts that were written pursuant to the Warren Act of 1911. These contracts provided for a water supply at a certain point, with the responsibility of the contractor to construct all the necessary conveyance facilities (i.e. pumps, laterals, and turnouts) and be responsible for operation and maintenance.

Some of the districts and their respective contracts that own all or a portion of their systems are (Only the most recent contract is listed):

| District Name | Contract Date | Acreage |
|---|---|---|
| Van Brimmer Ditch Company | November 6, 1909 | 3,315 |
| Klamath Basin Improvement District | April 25, 1932 | 10,403 |
| Enterprise Irrigation District | March 18, 1935 | 2,981 |
| Malin Irrigation District | May 5, 1936 | 3,507 |
| Pine Grove Irrigation District | June 19, 1936 | 927 |
| Sunnyside Irrigation District | June 25, 1936 | 595 |
| Westside Improvement District | October 20, 1936 | 1,190 |
| Shasta View Irrigation District | August 20, 1938 | 4,141 |
| Klamath Drainage District | April 28, 1943 | 19,229 |
| Emmitt District Improvement Company | December 1, 1947 | 424 |
| Midland District Improvement Company | February 2, 1952 | 581 |
| Poe Valley Improvement District | July 20, 1953 | 2,636 |
| Ady District Improvement Company | August 5, 1954 | 435 |
| Plevna District Improvement Company | February 7, 1958 | 523 |
| Horsefly Irrigation District | August 24, 1976 | 9,843 |
| Upper Klamath Lake Contractors | Various contract dates | 7,918 |
| Individual Contracts | Various contract dates | 9,960 |

Nearly all contracts written during the past 85 years on the Klamath Project obligate the United States to the delivery of irrigation water. Clauses in most contracts include language similar to the following example:

> *"The United States shall deliver in the Klamath River at the outlet of Upper Klamath Lake..in all a total of 522.7 irrigable acres, a sufficient quantity of water as may be beneficially used upon said lands...the quantity of water sufficient for the irrigation of said 522.7 acres shall be as determined by the Secretary of the Interior...."*

The contracts additionally provide that the United States shall be held harmless in the event of a shortage.

### 3.2 Temporary Water Contracts

Each year Reclamation makes a determination if surplus water is available for sale to irrigators (See forecasting). In many cases irrigators have been receiving surplus irrigation water from Reclamation for over 50 years. For numerous reasons these irrigators were never given permanent water rights status by virtue of a long term contract with the United States. Concurrently, the districts also make a determination whether or not to sell surplus water. The irrigable acreages covered by surplus water contracts in 1990 was 3,797.

The acreage represented by these temporary contracts represent less than 2% of the total acreage irrigated on the Project. Water is delivered to these lands through the existing irrigation systems. In many cases the water is delivered and controlled by the irrigation districts.

### 3.3 National Wildlife Refuges

Four national wildlife refuges lie adjacent to or within Klamath Project boundaries: Lower Klamath; Tule Lake; Clear Lake; and Upper Klamath. These refuges were established by Executive Orders dating as early as 1908. The refuges are managed by the Service under the Migratory Bird Treaty Act, the Refuge Administration Act, the National Refuge System Improvement Act, and other laws pertaining to the suitable habitat and resources for migratory birds of the Pacific Flyway. Portions of the refuges are also used for agricultural purposes. The refuges either receive water from or are associated with Project facilities. Reclamation has an obligation to ensure that the refuges receive adequate water to fulfill their federal reserved water rights (i.e., the amount of water necessary to fulfill the primary purposes of the refuges) when in priority and when water is available. In addition, Reclamation can continue to provide available Project water for beneficial reuse by the refuges to the extent of past and current usage and consistent with Project purposes (DOI, 1995). The refuges have federally reserved water rights for the water necessary to satisfy the refuges' primary purposes. In addition, the Lower Klamath and Tule Lake refuges have water rights based on a portion of the Klamath Project water right.

### 3.4 COPCO Power Contract

In 1917, the United States entered into a contract with California Oregon Power Company (COPCO) under which the power company was given the right to construct the Link River Dam at the outlet of Upper Klamath Lake, and the right to use certain amounts of water after the requirements of the Klamath Project were satisfied. The contract was to cease, and title of the dam was to vest in the United States, 50 years from the date of execution. The contract was renewed early as a result of FERC Project 2082 concerning the construction and operation of downstream Klamath dams operated by Pacific Power (formerly COPCO).

The present contract, which will expire in 2006, allows the power company to operate the dam within certain guidelines (see above) unless it is determined by Reclamation that irrigation supplies are threatened. In 1997, the contract was modified and the modification must be renewed annually.

## 4.0 WATER RIGHTS INFORMATION

### 4.1 Acquired Water Rights

In addition to initiating the appropriative rights procedure in the State of Oregon, the United States acquired some early pre-project rights to use of water by purchase from landowners with prior rights entitlement. The fact that a considerable number of these rights were purchased by the United States indicates that early private development of the basin was well under way at the advent of Reclamation. It was necessary to purchase these rights from the entities involved so that Reclamation had full control of all of the rights to the use of water in the basin. The federal project would not be possible without the elimination of conflicting uses.

### 4.2 Appropriation by the United States

The basic water rights required for the operation of the Klamath Project are derived from certain legislation of the State of Oregon enacted in 1905 (Chap. 228, Ore. Gen. Laws, 1905); later Sec. 116.438 (Ore. Comp. Laws Annotated).

Similar legislation was enacted by the Legislature of California on February 3, 1905, relative to the Klamath Project areas in California.

On May 19, 1905, a "Notice of Intention to Utilize All Waters of the Klamath Basin" was filed by the Reclamation Service, Predecessor to the Bureau of Reclamation, in the office of the State Engineer of Oregon. It is recorded in "Water Filings" at Page 1. This notice was also published in the *Klamath Falls Express* of Klamath Falls, Oregon on June 15, 22, 29, and July 6, 1905.

The Reclamation Service of the United States filed detailed plans and specifications covering the construction of the Klamath Irrigation Project with the State Engineer, of Oregon, on May 6, 1908, and on May 8, 1909, filed with the State Engineer proof of authorization of the construction of the works therein set forth.

Prior to December 19, 1914, appropriative water rights could be acquired in California by posting and recording a notice stating the nature and quantity of the proposed appropriation and by thereafter exercising due diligence in putting the water to beneficial use. The required postings were made on behalf of the United States.

### 4.3 Adjudication Proceedings

A formal adjudication of a river system sets down in a competent court the relative rights to the use of water within the area that is being adjudicated. Testimony is received from all persons claiming a right and the State makes determinations based on the testimony of the relative priority dates. The Klamath River Basin adjudication is in such a process.

In 1918 the State of Oregon began the adjudication of the Lost River system. Certificates were issued to individuals that had rights that pre-dated the Klamath Projects filings. Since Reclamation was not a party to the adjudication, certificates were not issued to Reclamation or its contractors. The State did, however, set aside 60,000 acres for Reclamation to later claim certificates on. This was a far greater amount of land than could possibly be served from the Lost River. A considerable amount of mapping of the irrigated lands was completed by the State under contract to Reclamation during the late 1980's. The intent was to finally receive certificates on the lands, however, due to several problems the certificates have not been issued.

A number of irrigators above Gerber Dam claimed to have not been notified of the 1918 adjudication. As a result the State reopened the process and completed it in 1989. This portion of the adjudication set forth the relative priorities of water use above Gerber Dam.

The Klamath River Basin Adjudication covers all Project lands served by the Klamath River. Other federal entities involved include the National Park Service, U.S. Department of Agriculture, Bureau of Land Management, the U.S. Fish and Wildlife Service, and Bureau of Indian Affairs on behalf of the Klamath Tribes. In 1975, the State of Oregon, through its Water Resources Department (OWRD), initiated the Klamath River Basin adjudication to determine all claims to surface water in the Basin. By 1986, the State of Oregon had completed a considerable amount of work in mapping the places of use within the Project.

In 1990, the OWRD reissued notices of intent to adjudicate the Klamath River Basin, and during 1991, required all persons claiming a right to the use of water from the River to file. The United States did not file, claiming that the adjudication violated the McCarran Amendment which requires that any adjudication involving the United States must be complete and include ground water. In subsequent legal proceedings, the United States lost, and as a result, all claims were to be filed with the State in April 1997 for both use and storage. Open inspection of claims was extended through March 2000. In May 2000, several thousand contests were filed on individual claimants and the State’s Preliminary Evaluations of Claims.

Concurrent with the Klamath adjudication, the State of Oregon has begun an Alternative Dispute Resolution (ADR) process in an attempt to resolve as many water rights issues in the adjudication as possible to avoid litigation by various claimants. The U.S. has participated in the ADR process from its beginning, along with the Klamath Tribes, various individuals, and the Klamath Project water users. Meetings are held monthly. The ADR process may help solve disputes; however, difficult issues remain to be resolved.

The State of Oregon has proposed a broad settlement framework that is being considered by the Administrative Subcommittee of the ADR Group. In addition, the Klamath Tribes and project irrigators have negotiated a framework settlement agreement which is under review by various parties to the ADR. The Klamath Tribes have also presented a settlement proposal on the tributary area above Upper Klamath Lake. Several technical teams have been formed to deal with specific ADR issues. Reclamation actively participates on the Hydrology Technical Committee (USBR 2000a).

## 4.0 WATER SUPPLY FORECASTING

Each year the Klamath Project forecasts available water supplies beginning in January. Information such as watershed conditions, carryover storage, Soil Conservation Service forecasts, projected water use for both irrigation and wildlife use, and other available data for varied sources are used by Klamath Project personnel to forecast the condition of Project systems during the ensuing year. The forecast and water supply declaration have been presented in annual operations plans since 1995.

This information is presented to the water user community as soon as practicable, usually in early May. Along with the information, the Project provides a **water supply declaration** that delineates how much water is available to meet the demands that may be placed upon it.

Should the forecast indicate that a short water supply may prevail, meetings with all affected resource agencies are held to attempt to moderate the shortages and provide a fair and equitable allocation procedure for the available supply. Full consideration is given to irrigation uses, wildlife and fishery needs, recreational uses, power needs and domestic needs. However, in cases of extreme shortage, the priorities listed in Article III of the Klamath River Basin Compact dictate the allocation. The Bureau has developed a *Drought Plan*, dated February 12, 1992, for the Project that will be followed in the event of a severe shortage. This Plan is reproduced below.

## 5.0 TRIBAL TRUST RESPONSIBILITIES

In its BA, Reclamation did not assess whether the proposed operation of the Klamath Project is consistent with its trust responsibility to the Klamath Tribes, including what lake levels comprise the water necessary for the tribal trust resources in Upper Klamath Lake. This BO does not make that assessment either, as it only concerns whether the contemplated action by Reclamation will jeopardize the listed sucker species. This trust responsibility issue will be addressed in Reclamation’s annual operations plan and during the long-term planning process for the Klamath Project.

## 6.0 DROUGHT PLAN

A copy of the entire text of the Klamath Project Drought Plan is included and begins on the following page.

February 12, 1992

DROUGHT PLAN

Upper Klamath Lake Watershed

Priority and Execution Plan for Administration
of Water Rights and Water Delivery on the
Klamath Project in the Event of a Drought

## General

It should be emphasized that before any actions are taken to limit the amount of water available to Project water users, efforts will be made to minimize, or possibly avert, the shortages that are forecasted. Water users will be represented in these efforts to attempt to work out a plan that will be fair and equitable to those involved.

It should also be noted that return flows generated by Project water users are an important factor in determining the total amount of water use figures. These return flows are reused many times in the agricultural use cycle and may ultimately affect several downstream users.

An emphasis would be placed on conserving water, growing crops that use less water, farming practices that will save water, possible fallowing of land that is less productive, and most important, cooperation among the water users. Only after avenues of conservation and cooperation are explored would the water be allocated on a priority basis within the Project.

One of the key themes in any prioritization of water rights on the Project is that the Bureau claims a 1905 right for all Project lands regardless of the type of contract that the water users may have. However, within the Project the Bureau can prioritize use by date of contract and type of contract. All other diverters of water not in the Project would be considered junior to Project needs if their priority date was after 1905.

There are two basic types of contracts on the Project, a 9(d) Repayment contract and a Warren Act type contract. The 9(d) type contract was used for Main and Tulelake Divisions of the Project. These Divisions were, for the most part, homesteaded by Reclamation. The Warren Act was used to grant a secondary right of use to users above the gravity system and/or not in the above mentioned Divisions of the Project.

## First Priority of Use Within the Project (Class A)

The Van Brimmer Irrigation District's contract with the United States recognizes that district's right to the use of 50 $ft^3$/s. The United States eliminated the district's supply of water by reclaiming Lower Klamath Lake, and was then obligated to provide another source of supply. The result of that obligation is that the Van Brimmer Irrigation District has a priority that predates 1905.

The Klamath Irrigation District, also known as the Main Division, was the first land developed for irrigation and, as such, would have the first right to the use of irrigation water after Van Brimmer. The district was the successor to the Klamath Water Users Association who contracted with the United States on November 6, 1905. The first contract between the United States and the district was dated July 6, 1918 and was written pursuant to the 1902 Federal Reclamation Act.

Tulelake Irrigation District's contract is dated September 9, 1956, and is also a 9(d) type contract. The contract specifically states that the district has the same contractual right and priority date as ther contracts written pursuant to the 1902 Act on the Project.

Federally owned areas leased by the United States are considered to have the same priority date as other Class A users. During extreme drought circumstances Reclamation may voluntarily limit deliveries to federal lease lands, thus preserving a supply to the other Class A water users.

There are several individual contracts within Klamath Irrigation District that were written pursuant to the 1902 Act in the 1970's. These are for minor acreages, somewhere in the neighborhood of 400 acres.

### Second Priority of Use Within the Project (Class B)

All of the following contracts were written pursuant to the Warren Act of February 21, 1911. These contracts include a clause which states that the water right is subject to the main division land's first right. The Warren Act was cited in the contracts so that a secondary right could be issued to the contractor. The Warren Act contains a clause in Article 1 which states in part "..., preserving a first right to lands and entrymen under the project.". In addition, most of the contracts contain the very same wording. Given that understanding, the following order of precedence by contract date will be followed:

<u>Enterprise Irrigation District</u>. Receives water out of the A-Canal through the Klamath Irrigation District system. The date of the contract is October 5, 1920.

<u>Klamath Drainage District</u>. Receives water out of the Klamath River below the Link River Dam. The date of the contract is August 24, 1921.

<u>Malin Irrigation District</u>. Receives water out of the D-Canal through the Klamath Irrigation District system. The date of the contract is September 9, 1922

<u>Shasta View Irrigation District</u>. Receives water out of the D-Canal through the Klamath Irrigation District system. The date of the contract is October 6, 1922.

<u>Sunnyside Irrigation District</u>. Receives water out of the Van Brimmer Canal system. The Van Brimmer Canal gets its supply of water from Upper Klamath Lake through the Klamath Irrigation District system. The date of the contract is October 24, 1922.

<u>Pine Grove Irrigation District</u>. Receives water out of the A-Canal (Klamath Irrigation District system). The date of the contract is June 19, 1936.

<u>Colonial Realty Company-Westside Improvement District</u>. Receives water out of the Tulelake Sump and at the end of the J-1 lateral. The District was incorporated into Tulelake Irrigation District as an improvement district. The date of the contract is October 20, 1936.

<u>Plevna District Improvement Company</u>. Receives water out of the Klamath River below the Link River Dam. The date of the contract is April 1, 1940.

<u>Emmitt District Improvement Company</u>. Receives water out of the Klamath River below the Link River Dam. The date of the contract is December 1, 1947.

<u>Midland District Improvement Company</u>. Receives water out of the Klamath River below the

Link River Dam. The date of the contract is February 2, 1952.

<u>Poe Valley Improvement District</u>. Receives water out of the Lost River below Harpold Dam. The District is highly dependent on return flows from the Klamath Irrigation District system in Poe Valley. The contract does not mention where the water is to come from, only that it will be made available in the Lost River. The date of the contract is July 20, 1953.

<u>Ady District Improvement Company</u>. Receives water out of the Klamath River below the Link River Dam. The date of the contract is August 5, 1954.

<u>Klamath Basin Improvement District</u>. Receives water through the Klamath Irrigation District system. The date of the contract is April 25, 1962.

<u>Miscellaneous Warren Act Contracts</u>. This group of contracts are scattered throughout the Project and get their water supply from the Lost River and Upper Klamath Lake/Klamath River. Some of the contracts have been turned over to Klamath Irrigation District to administer. Contract dates range from 1915± to 1960±.

### Third Priority of Use Within the Project (Class C)

The first group of water users that would need to be shut off in the event of water shortages would be the temporary water rental contracts. Rental water is sold to individual farmers on an "if and when available" status. The Klamath Irrigation District and Tulelake Irrigation District both have clauses that allow them to sell rental water. In addition, Reclamation has rental contracts with users in the P-Canal and the Lost River areas.

### Execution Plan

In the event that there was insufficient projected supplies of water available within the system from the Klamath River, the following actions would be taken:

<u>March 10</u>. If necessary, on this date or before, letters will be sent to all water users advising them that Reclamation can expect a deficiency in supplies of irrigation water and that sales of rental water may not be allowed pending the outcome of the April 10 meeting and April forecasts. Also, at this time, separate letters will be sent to the Class B users advising them of our intent to limit their use of water should supplies fall below Reclamation’s projections. The letter would also request that the appropriate portion of Exhibit 1 be completed by the respective districts and returned to Reclamation no later than March 26.

<u>April 10</u>. On or before this date an allocation projection meeting would be hosted by Reclamation in which the district manager and the board chairman from each district would attend. Reclamation would have the information from Exhibit 1 compiled and a proposed allocation available. This would become the basis for discussions, potential revisions and efforts to arrive at an equitable reallocation of available supplies. Factors such as reduced acreages, crops that use less water, farming practices that reduce water use, and other water saving measures would be taken into consideration. The final projected allocation would be determined from this meeting.

<u>May 10</u>. Reclamation would revise the allocation using percentages based on changes in storage and run-off that occur between April 1 and May 1 and send the data to the districts via certified mail.

In the event that the cooperative effort discussed in the April 10 meeting reaches an impasse, the following plan would be followed:

The sufficiency of the water supply would re-evaluated by the Project and, if found insufficient to meet secondary demands, Klamath Irrigation District, Tulelake Irrigation District and Klamath Drainage District, would be notified to stop or limit deliveries to the specified Class B users under their delivery control points. In addition, the Project would notify other specified Class B users to stop or limit delivery of irrigation water.

Letters would be sent to the Class A Users assigning them an acre-foot allocation and flow schedule for the balance of the irrigation season.

The above described measures would remain in effect until the Bureau declared a water supply status capable of meeting all contractual commitments.

# APPENDIX C - STATUS OF LOST RIVER AND SHORTNOSE SUCKERS

This section provides information the current status of the Lost River and shortnose suckers that is relevant to formulating this BO. The information presented here is the basis against which the effects of the proposed action are measured over the life of the action.

This section of the BO was prepared using the best scientific and commercial information available from the following sources: 1) Reclamation's February 25, 2002, BA for this consultation (USBR 2002b); 2) April 2001 BO on operations of the Klamath Project (USFWS 2001) 3) Reclamation's February 13, 2001, BA (USBR 2001); 4) July 15, 1996, BO for PacifiCorp and The New Earth Company operations, and Reclamation's BA for this consultation (USBR 1996a; Service 1996); 5) December 1, 1994, proposed rule for sucker critical habitat (Service 1994a); 6) August 11, 1994, BO for operation of Clear Lake (Service 1994b); 7) April 1993 final recovery plan for the suckers (Service 1993a); 8) July 22, 1992, BO on long-term operations of the Klamath Project, and Reclamation's February 28, 1992 BA (USBR 1992a; Service 1992a); 9) July 18, 1988, final rule listing the suckers as endangered (Service 1988); 10) recovery plans for Lost River and shortnose suckers (Service 1993); 11) communications with field researchers who have conducted, or are currently conducting, research on the listed suckers; 12) communications with Reclamation personnel and applicants; 13) peer review comments on the March 13, 2001 draft BO; 14) peer review comments on the April 5, 2001 final BO; 15) National Research Council, draft interim report from the committee on endangered and threatened fishes in the Klamath River basin (NRC 2002a); and 16) available scientific reports and publications pertinent to this consultation.

This section of the BO will cover the following two Klamath Basin species which are federally listed as endangered and are known to occur in the action area and may be affected: 1) shortnose sucker (*Chasmistes brevirostris*) (SNS), and 2) Lost River sucker (*Deltistes luxatus*) (LRS).

## 1.0 STATUS OF SPECIES: LOST RIVER AND SHORTNOSE SUCKERS

The Lost River sucker (*Deltistes luxatus*) and shortnose sucker *(Chasmistes brevirostris*) were federally listed as endangered on July 18, 1988 (USFWS 1988). At the time of listing, perceived threats to the species included: 1) loss of historical populations and range; 2) habitat loss, degradation and fragmentation; 3) drastically reduced adult populations; 4) overharvesting by sport and commercial fishing; 5) large summer fish die-offs caused by declines in water quality. 6) lack of significant recruitment; 7) hybridization with the other two sucker species native to the Klamath Basin; 8) potential competition with and introduced exotic fishes 9) lack of regulatory protection from Federal actions that might adversely affect or jeopardize the species;

These two fish were once very abundant and were critical seasonal foods of Native Americans and white settlers in the upper Klamath River basin (Cope 1879; Gilbert 1898; Howe 1968). Sucker spawning migrations occurred in the spring at a critical time when winter food stores had been exhausted. The Klamath and Modoc Indians dried suckers for later use. It was estimated that the aboriginal harvest at one site on the Lost River may have been 50 tons annually (Stern 1966). Settlers built a cannery on the Lost River and suckers were also processed into oil and salted for shipment. In 1900, the Klamath Republican newspaper reported that "mullet," as suckers were referred to, were so thick in the Lost River that a man with a pitch fork could throw out a wagon load in an hour. The first reference to sport fishing of "mullet" appears to be a 1909 reference to sportsmen snagging "mullet" in the Link River at Klamath Falls (Klamath Republican, Oct. 14, 1909). In 1959, suckers were made a game species under Oregon State law and snagging suckers in the Williamson and Sprague River was popular with locals and out-of-town sportsmen (Bragg 2001). By 1985, Bienz and Ziller (1987) estimated the harvest had dropped by about 95%. Based on this information, the game fishery was terminated in 1987, just prior to federal listing.

Lake suckers, similar to the Klamath species, were once more widespread and much more numerous before the end of the Pleistocene, when the western Great Basin became more arid and the vast pluvial lakes largely dried up. The present distribution of lake suckers is confined to remnants of those pluvial lakes. *Chasmistes* is known as fossils from the Miocene and was widely distributed in the West, including California, Oregon, Utah, and Wyoming, with considerable fossil material coming from Fossil Lake, Oregon, in the Fort Rock basin (Miller and Smith 1981). A number of extinct *Chasmistes* spp. are known only from fossils (Miller and Smith 1981). Today, only two lake suckers are found in remnant lakes of the Basin and Range province. The cui-ui, *Chasmistes cujus*, is confined to Pyramid Lake, but historically also occurred in Winnemucca Lake, both in the Lahontan Basin in northwestern Nevada. The June sucker, *Chasmistes liorus*, is found only in Utah Lake, Bonneville Basin (Sigler and Sigler 1987). A third species, the Snake River sucker, *Chasmistes muriei*, collected below Jackson Dam in Wyoming, likely became extinct in the 20th Century (Miller and Smith 1981). All extant lake suckers, including *Chasmistes* species and the LRS, are currently listed as endangered under the ESA, largely due to the adverse effects of water diversions, poor water quality attributable to land management practices and habitat losses.

Historically, both LRS and SNS occurred throughout the Upper Klamath Basin (above Keno), with the exception of the higher, cooler tributaries dominated by resident trout and the upper Williamson, which is isolated by the Williamson Canyon (see Historic and Current Sucker Distributions above). At the time of listing, shortnose and Lost River suckers were reported from UKL, its tributaries, Lost River, Clear Lake Reservoir, the Klamath River, and the three Klamath River reservoirs (Copco, Iron Gate, and J.C. Boyle). The general range of both suckers had been substantially reduced from its historic extent by the total loss of major populations in Lower Klamath Lake, including Sheepy Lake, and Tule Lake (USFWS 1988). Although a very small population of suckers has since been found in Tule Lake (see below). The Klamath River reservoir populations receive individuals carried downstream, but they are isolated from the upper Basin by dams and show no evidence of self-sustaining reproduction (Desjardins and Markle 2000). The current geographic ranges of the two suckers have not changed substantially since listing. Only two additional shortnose sucker and one Lost River sucker populations have been recognized. They all occur in isolated sections of the Lost River drainage, within the historical ranges of the species, and include a small population of each species in Tule Lake (including the lower Lost River below Anderson Rose Dam), limited to several hundred adults for each species, and an isolated population of SNS in Gerber Reservoir.

## 1.1 Sucker Status: Upper Klamath Lake

### 1.1.1 <u>Upper Klamath Lake: Population Estimates</u>

Monitoring the population status of SNS and LRS in UKL and its tributaries has received considerable attention. Although the available population estimates provide perspective on population size and trends, the high variability of the UKL system, sampling constraints, and unmet statistical assumptions have made it extremely difficult to obtain accurate population estimates. Accordingly, they should be used with extreme caution.

The first attempt to assess the status of sucker populations in UKL was done by Bond et al. (cited in Andreasen 1975). They found that suckers represented only 1% of the fish caught.

In 1959, suckers were made a game species under Oregon State law and snagging suckers in the

Williamson and Sprague River was popular with locals and out-of-town sportsmen (Bragg 2001, Cooperman and Markle 2001). In the 1960's ODFW estimated 100,000 lbs. per year (ca. 12,500 fish) were harvested (Eugene Register-Guard, May 7, 1967). ODFW data indicated from 1966 through 1978, an approximate 50% decline in catches (from 3.5-5.6 suckers per angler before the 1969 bag limit, to 1.5-3.0 afterwards). More than 3,000 suckers were taken in the snag fishery in 1968 (Golden 1969). Numbers of harvested suckers from spawning runs in the Sprague and lower Williamson rivers increased from 1.2 fish per hour in 1966 to 4.7 fish/h in 1969 and then, from 1969 on, there was a steady decline to 0.8 fish/h in 1974 (Andreasen 1975). Average weight of suckers caught in the fishery declined about 40% from 1966 to 1974, a (from 7.5 lbs to 4.9 lbs), and declines continued to the time of listing. By 1985, Bienz and Ziller (1987) estimated the harvest had dropped by about 95%. Based on this information, the game fishery was terminated in 1987, just prior to federal listing (USFWS 1988).

In the mid-1980's the Tribes and ODFW attempted to estimate population numbers and trends through tag-recapture, creel surveys and electrofishing during the Williamson-Sprague River spawning run (Bienz and Ziller 1987). The tag-recapture study estimated a population of 23,123 (95% confidence interval = 11,858-86,712) LRS in 1984, which declined to 11,861 (95% CI = 8,478-19,763) in 1985. The SNS population estimate was 1,026-10,461 (95% CI) in 1984, and no estimate was made in 1985 due to a lack of recaptured tags. These estimates apply only to the Williamson-Sprague River spawning population. During this period the catch of suckers per electrofishing river trip declined from 56.5 to 23.9 LRS and 17.6-3.3 SNS from 1984-1986. These populations all predate a major fish die-off which occurred in UKL in August 1986 (Bienz and Ziller 1987, Scoppettone 1986, Scoppettone and Vinyard 1991).

Reclamation funded efforts by USGS/BRD to provide population estimates based on fish tagging efforts in the Williamson/Sprague spawning runs and recovery of tags from the fish kills in 1995-97 (Perkins 1996, Perkins et al. 1997, Shively 2002a, USGS unpub. data). Additional funding has supported continued monitoring efforts by USGS/BRD and OSU (Markle et al. 2000b; Perkins 1996; Perkins et al. 1997; Perkins et al. unpub. data; USGS 2002).

The population estimate data derived from fish kills should be used with considerable caution for a number of reasons, including: (1) very low number of tags were actually recovered and included in calculations, resulting in extremely broad confidence intervals; (2) many of the suckers collected from the die-offs were in a highly decomposed state; some may have lost their tags, and sampling was difficult; (3) the die-off fish may represent a biased group of fish that are not randomly drawn from the tagged population; (4) the die-off may have been selective for age/size classes not well represented in the Williamson River where most of the tagging occurred; (5) the estimates are based on an assumption of no recruitment into the adult population during the intervening time; (6) the estimates are based on an assumption that all adults participated in the spawning run each year, even after the stressful environmental conditions of the study period; 7) the estimates used statistical methods that are not robust when basic assumptions are violated, which almost certainly occurred (see below); and 8) the estimates are for the populations prior to the fish kills and do not reflect the impacts of the die-off.

The USGS population estimates utilized the Lincoln-Petersen method to estimate abundance, which is not statistically robust under violations of its assumptions (Shively 2002). Two primary assumptions of this method are that (1) all fish had an equal chance of being marked, and (2) marked fish have mixed randomly in the population. A violation of at least one of these assumptions likely occurred with the 1997 estimate. Fifty percent of tagged fish recaptured from the 1997 fish kill were collected on one date, indicating that fish were highly unlikely to have mixed randomly into the Summer UKL population. The second assumption, that all fish in the fish kill sample had an equal opportunity to be marked, was also not met, since the UKL sucker populations contain spawning groups that utilize various sites besides the Williamson/Sprague rivers (where most of the tagging was done) and it appears that not all individuals make a spawning run each year (USGS 2002). The USGS estimates are also sensitive to size biases in the sampling and possibly fish kill mortality patterns. Perkins et al. (1996) provided estimates for shortnose suckers computed two different ways, with and without adjustment for size selectivity of fish recovered during the fish kill. The resulting estimates for SNS show the considerable difference in methods: N = 229,588 (+/- 158,207 95% CI) with no adjustment vs. N = 107,653 (+/- 73,795 95% CI) with adjustments. For this comparison, Perkins used a different method (Chapman 1951, cited in Perkins et al. 1996) rather than Lincoln-Petersen.

In the 1995 die-off approximately 300 LRS and 100 SNS were checked for tags, but no tags were detected, and it was not possible to estimate population size. In 1996, the LRS population prior to the fish kill was estimated at 94,000 (+/- 82,000; 95% confidence interval) and the SNS population was estimated at 250,000 (+/-175,000 95% CI), respectively (USGS, unpub. data). In 1997, the LRS population prior to the fish kill was estimated at 46,000 (+/-45,000 95% CI) and the SNS population was estimated at 146,000 (+/-90,000, 95% CI).

The broad confidence intervals and uncertainties associated with the available data make absolute population estimates and interannual comparisons inappropriate.

### 1.1.2 Upper Klamath Lake: Fish Die-offs

Water quality in UKL consistently reaches levels known to be stressful or lethal to suckers and other fish in late summer and early fall (see Environmental Baseline). This is supported by observations showing that major fish die-offs have historically occurred in UKL and have increased in frequency. When ichthyologist, C.H. Gilbert visited the lake in June 1894, a fish kill was apparently underway, because many dead and dying fish were observed (Gilbert 1898). Major fish kills have been documented in 1932, 1971, 1986, 1995, 1996 and 1997 (Buettner 1997). Other small, localized fish die-offs have been observed annually on UKL since 1992 when extensive research and monitoring activities began. Small, localized, short-lived, fish kills now occur annually in UKL, in addition to the larger catastrophic fish kills (see below).

In 1971, a series of articles appeared in the Herald and News regarding a large fish kill in UKL that affected an estimated 30 million fish, mostly chubs (Briggs 1971). The die-off first became noticeable in the third week of July 1971 and extended from Bare Island to the south end of the lake. By mid-August dead fish were reported in the mouth of the Williamson River and near Rocky Point. There were so may dead fish around the lake that a widespread cleanup was undertaken. The die-off was attributed to higher than normal temperatures, an intense bloom of the blue-green alga *Gloeotrichia*, low levels of DO, a parasitic copepod (*Learnea sp.*), and Columnaris disease. It is very likely that other fish kills occurred in the lake in the 19th and 20th centuries but were not reported. However based on available records, these events were infrequent or involved few fish and thus were not sufficiently noticeable to be reported.

In July/August 1986 a major fish die-off occurred in UKL (Bienz and Ziller 1987; Scoppettone 1986; Scoppettone and Vinyard 1991). Bienz and Ziller (1987) observed 100 to 200 adults suckers in the area of Pelican Bay influenced by input of spring water. Water quality in UKL at the time was poor and they postulated that the suckers were there to avoid the poor conditions. During late July and August there were several reported fish kills involving suckers.

In 1995, the die-off occurred during September and October with 378 LRS and 124 SNS collected. A detailed discussion of the 1995 die-off was provided in Reclamation (1996a), in Perkins et al (2000b), and Loftus (2001).

During July 1996, dead suckers began appearing in UKL, presumably because of stressful conditions associated with poor water quality, e.g., low DO, and a bacterial disease outbreak. Between August 8 and October 3, 1996, some 6,049 dead suckers were collected (Perkins 1996). The numbers peaked in Pelican Bay and Odessa Creek, the most frequently monitored areas, during the weeks of August 26 and September 2. Lake-wide, the greatest numbers of suckers were collected the week of September 2. The weekly number of LRS and SNS captured was similar among the two species.

Initial collections occurred from August 8 to August 20 in the clear water areas of Pelican Bay, and Odessa Creek. By August 23, it was apparent that the fish kill was becoming more widespread throughout the lake. Lake-wide surveys were attempted on August 26 and August 29; however, the quantity of dead suckers encountered precluded complete coverage of the lake on both occasions. Subsequent collections were made at various areas in the lake and along the shoreline. Fish kill monitoring in the clear water areas of Pelican Bay and nearby creeks (Harriman, Odessa, Short) was more rigorous and systematic than for the rest of the lake. These areas were thoroughly collected at two to four day intervals throughout the fish kill. Most fish were dip-netted off the bottom, with some found floating or along the shoreline.

It is difficult to assess the spatial distribution of the fish kill in 1996. Suckers were found dead throughout UKL excluding Agency Lake. Highest densities of fish were also collected along the south shoreline (Perkins 1996). The fish found in this area appeared more highly decomposed than those from other areas of the lake. We suspect that most of these fish died in the northern areas of the lake and were carried by wind-induced currents to the south end of the lake. Higher numbers of suckers were also collected from the eastern shoreline. Prevailing winds during this period were from the northwest. Hundreds of dead suckers were seen floating on the surface and hidden in dense beds of submerged aquatic vegetation in Pelican Bay. Most of these suckers were not collected.

The approximately 6,000+ suckers ( 2,213 LRS, 1,912 SNS, and 1,875 KLS and unidentified suckers) and collected during the 1996 fish kill undoubtedly represent only a small fraction of the number that died. Due to the poor water clarity in most lake areas, only fish floating or littered along the shoreline could be collected. Most likely, large numbers of dead fish sank to the bottom like those observed in the clear water areas. It is suspected that many dead fish initially sank to the bottom and then floated up after a period of days after bacterial decomposition occurred and the body cavity filled with gases. Attempts were made to evaluate dead sucker floating/sinking mechanisms to determine if estimates could be made of the percentage of dead fish floating (D. Perkins, USFWS, pers. comm.). Experiments were highly variable and inconclusive.

At the south end of the lake, most fish were collected while walking along the shoreline. In this effort, many fish were found hidden in bulrush stands and others were partially or completely buried in the ground at the water/shoreline interface. Collections along the shoreline in other areas of the lake were less thorough with only fish readily observed by boat being collected. Based on the observation of field biologists, it was speculated that the number of fish collected may have represented only 2.5 to 10% of the suckers that were floating, which does not include dead fish that sank to the bottom and were never observed (Perkins 1996).

Fish less than 30 cm FL were conspicuously absent from the fish kill. Also, smaller fish were not obvious among the sick fish in the clear water areas. On one occasion, large numbers of small chubs were seen floating on the lake; however hundreds of birds had eaten all the fish by the next day. Large concentrations of fish-eating birds have been seen on many occasions during the late summer months feeding on small fish. Thus, the thousands of birds in the vicinity of UKL during the fish die-off may have effectively consumed most small fish that died in the fish kill. OSU biologists noted a substantial drop in age 0 sucker cast net catches in September and October suggesting these fish were perhaps affected by the die-off (Simon and Markle 1997); although, such declines have been seen in other years as well.

The length frequency distribution of LRS captured in the 1996 fish kill was generally similar to distribution of fish captured in the 1996 (March -May) spawning assessment from the Williamson River. Fish from 40 to 50 cm were the most numerous size range for both the fish kill and the spawning run. The length frequency distribution of SNS greater than 30 cm FL that were captured in the 1996 fish kill were shifted about 3 cm larger than the distribution of fish captured in the spawning assessments of the same year. In the spawning assessment, SNS ranging from 32 to 40 cm were the most common sizes, while in the fish kill most were 35 to 44 cm. The difference in length distribution appears to be related to a non-random sample of the population for either the spawning group or the fish kill. When die-off frequencies are plotted for fish collected at springs and lake locations, it is apparent that the springs fish were larger (Perkins et al. 2000b). Several potential hypotheses to explain this are discussed in USGS (1996).

Another major UKL fish die-off occurred in late summer 1997. The first signs of an impending fish kill were seen in mid-July when USGS biologists noted a substantial increase in trammel net mortalities. Also, during the week of August 4, Cell Tech's fyke net collection of suckers exiting the lake via the Link River Dam increased sharply from tens of suckers in previous weeks to over 400 suckers. This exodus peaked the week of August 11 with >1000 fish (Gutermuth et al. 1998b). During the week of August 11, chubs and suckers were first found dead throughout UKL. Suckers were also observed congregating and dying at freshwater inflow areas at Pelican Bay, Williamson River, and Odessa Creek. Dying suckers were observed to have numerous external parasites, primarily anchor worms, and to be lethargic in nature.

Over 2,300 large juvenile and adult suckers were collected in 1997, including 1,251 SNS and 885 LRS. The largest numbers of fish were collected from Pelican Bay (USGS, unpub. data). Substantial numbers were also gathered from the lower Williamson River, Ball Point and the mouth of Shoalwater Bay in the northern portion of the lake. Dead suckers were collected from July 23 to September 22, with a peak in late August. Adult blue chubs and tui chubs were the most frequently encountered fish littering the shoreline of UKL and lower Williamson River, and accounted for approximately 64% and 27% of the dead fish respectively. Dead redband trout, sculpins, and yellow perch were also collected. Approximately 90 trout were collected from the Pelican Bay/Harriman Creek area and lower Williamson River.

Dead and dying fish were provided to the ODFW Pathology Lab, and the Service Fish Health Center for examination (Foott 1997; Holt 1997). Columnaris was recovered from 80% of the fish submitted and *Learnea* copepod (anchor worms) infestation was observed on 73% of the fish. No viruses were isolated. Foott (1997) also noted a high prevalence of kidney abnormalities.

Sucker tolerance to adverse water quality conditions, environmental variables and causal factors related to fish die-offs in UKL are discussed under Environmental Baseline. Although sucker die-offs have received the most attention, adverse, yet non-lethal, water quality conditions stress fish and significantly degrade their fitness and resilience. Loftus (2001) has evaluated the Klamath Tribes and USBR long-term water quality data set for UKL to assess when water quality would likely cause stress. Such stress, although not acutely lethal could have significant adverse short-term and long-term effects (e.g., reduced growth and reproduction; increased susceptibility to disease, parasitism, physical abnormalities, and predation) and could be a factor leading to mortality and reducing overall fitness. During the period from 1990 to 1998, Loftus found that total stress days in summer ranged from 24 to 104. Low DO and high pH were the primary factors that would cause stress, with un-ionized ammonia likely being less significant before 1996. Beginning in the spring of 1996, un-ionized ammonia concentrations became substantially and consistently higher in UKL. They often reached sublethal levels at times when DO and pH would also be stressful (Reiser et al. 2001; Loftus 2001). One or more of the stressors occurred over several weeks at high levels prior to and during the die-offs in 1995-1997. Cumulative stress-day values were highest during July and August 1995 and 1997 when fish kills occurred. Stress was also likely to be high during July and August 1992 and 1994 when very low DO values were present. These data indicate that even though large fish kills may not occur annually in UKL, suckers are likely routinely stressed.

In the 1986 sucker die-off, most suckers collected were large, old LRS. However, two years after the die-off substantial numbers of younger LRS were documented in the spawning run that were not noted in the1986 spawning assessment. In 1995, 378 Lost River and 124 SNS were collected in a die-off. This compares to 2,213 and 1,912 LRS and SNS, respectively in 1996. The ratio of LRS to SNS was 3 to 1 in 1995 and 1.2 to 1 in 1996. This data suggests differential vulnerability to mortality each year. Also, the small number of suckers less than 30 cm FL may be related to differential mortality with larger fish affected more than small fish.

### 1.1.3 Upper Klamath Lake : Production of Larvae and Juveniles

Cooperman and Markle (2001) suggested that the sport fishery may have contributed to elimination of several spawning groups. The last spawning suckers were seen at Harriman Springs in 1974 (Andreasen 1975); no spawning has been observed at Barkley Springs since the late 1970’s (Perkins et al. 1998). In Crooked Creek the last documented sucker spawning sighting was in 1987, and in Fort Cr., Seven Mile, Four Mile, and Crystal Creeks, and Odessa Springs it was in the late 1980’s and early 1990’s (Cooperman and Markle 2001). The Wood River may have the last spawning suckers in that sub-basin; with larvae being last seen in 1992 and adult SNS in 1996 (Markle and Simon 1993; Simon and Markle 1997). Monitoring of larval and juvenile suckers in Agency Lake by OSU biologists has shown a long-term decline, with the 2000 juvenile abundance index at zero (Simon and Markle 2001).

Oregon State University (Simon et al. 2000a,b; Simon and Markle 2001) has monitored the status of larval suckers in UKL since 1995. Since 1995, larval trawl catch rates have been substantial every year except 1998 (Simon and Markle 2001). Mean larval trawl catch rates in 1999 were higher than any year since 1995. The proportion of positive catches (catches >0) was 51, 53, 44, 36, 43 and 49% for 1995-2000 respectively. The proportion of large catches (>100 fish) ranged from 0.0-7.1%, with the two highest percentages in 1996 and 1999, and the two lowest in 1998 and 2000. Although one larval survey effort resulted in high catch rates in 1997, it did not persist as catches dropped by the next survey and combined catches with all gears were low throughout the year. High levels of un-ionized ammonia that year may have inflicted high mortality on larvae (Simon et al. 1998). There was no correlation among adult spawning run indices and larval indices from 1995-1999 (Markle et al. 2000b; Simon et al. 2000a).

Simon et al. have monitored the status of juvenile suckers in UKL since 1991 and reported that annual abundance (based on CPUE of beach seines) for age 0+ suckers at the end of summer were relatively high in 1991, 1993, 1995, 1996, 1999 and 2000, but were very low in the drought years of 1992 and 1994, and in 1997 and 1998 during and following the fish kills (Simon et al. 2000b; Simon and Markle 2001). The relatively low abundance of age 0 suckers in UKL in 1998 has been questioned by Gutermuth et al. (1999) who found large numbers of juvenile suckers in entrainment studies at the Link River canals. This discrepancy has not been resolved. Gutermuth et al. (1999) also found more sucker larvae entrained in the canals in 1998 than in

1997. Simon et al (2000b) found that age 0 sucker numbers were up in 1999, with mean catches from beach seines, cast nets, and otter trawls, being the highest of any year from 1995-1998. There was little

correlation ® = 0.22) among adult spawning run indices and beach seine indices from 1995-1999, but there was a much stronger correlation ® = 0.77) between larval trawl and beach seine indices.

Simon et al. (2000a) found that age 0 LRS peaked in 1995 with an estimated late summer/early fall abundance index of 35,000; however, this value was exceeded in 1999 with an estimate of >80,000 (Simon et al. 2000b). Simon et al. (2000a) considered that age 0 SNS had peaked in 1996 at 16,000, but 1999 data showed an even larger estimate of >80,000 (Simon et al. 2000b). As in previous years, there was almost an order of magnitude decrease in age 0 sucker abundance during summer and fall. The exact cause of this decline is unknown but dispersal, predation, water quality, and especially entrainment losses are potential factors (Simon and Markle 2001).

Based on shoreline cast net surveys, the mean shoreline abundance index for LRS was about four times higher in 1998-1999 than 1995-1997 and was intermediate in 2000 (Simon and Markle 2001). The mean shoreline abundance index for SNS was highest in 1999 but similar to 1995, 1996, and 1998, with lowest catches in 1997 and intermediate catches in 2000. Other indices suggest near-shore abundance was highest in 1999 compared to all other years. The proportion of positive catches (>0), and the proportion of large catches (>5 and >10) were all highest in 1999.

Otter trawl catches in late summer/fall were much higher in 1999 than any other year. The total number of age 0 suckers captured during this survey (186) exceeded the total of 60 age 0 suckers captured in all random trawl surveys from 1995-1998. Of these 60, 37 were caught in 1995 and only 23 from 1996-1998. Of the186 age 0 suckers caught otter trawling 156 (84%) were LRS and 30 (16%) were SNS.

The mean whole-lake abundance index for both Age 0 LRS and SNS in 1999 were the highest in the period 1995-2000, while 1997 was the lowest for both species. These estimates, along with larval trawl, and beach seine data, suggest that 1999 was a good year for juvenile sucker recruitment. The 1998 cast net data as these numbers are probably inflated from a single sample in which an inordinately large number (1168) of suckers were caught. Without this sample, cast net abundance data are similar to 1997. Larval trawl and beach seine data from 1998 are also similar to that of 1997, and suggest that these two years probably represent poor recruitment.

During the period 1995-1998, larval and juvenile sucker abundance generally declined (Simon et al. 2000b). During this same period, adult spawning run indices of both LRS and SNS also declined (Markle et al. 2000b). Adult spawning run indices continued to decline in 1999 (Markle et al. 2000b), but larval and juvenile numbers reversed their declining trends and were abundant in 1999. The poor stock-recruitment relationship, expressed by a poor correlation between adult spawning population and young fish produced, indicates that environmental factors may be controlling recruitment.

In all years, age 0 Lost River and SNS abundance indices in September and October were less than August (Simon and Markle 2001). This consistent annual trend of sharply decreasing age 0 sucker numbers in late summer and fall remains a concern. While this may be partially explained by a shift in habitat from shoreline to offshore areas (Simon et al. 1996), it also may be due to downstream movement of young suckers out of the lake, entrainment, high mortality rates, or a combination of these factors (Simon and Markle 2001).

Spring catch rates of age 1+ suckers in UKL for all years were relatively low (Simon et al. 2000a,b; Simon and Markle 2001). For example in the spring of 1999, no age 1+ suckers were collected in otter trawls. This trend is disturbing and may suggest that late Fall and Winter mortality is high, resulting in little or no recruitment even though larval and juvenile numbers appear substantial in summer and fall samples (Simon and Markle 2001). However, the otter trawl is not effective at catching larger fish, and thus this trend could be explained by sampling bias. Recruitment is perhaps better determined by a regular examination of age-class frequency.

### 1.1.4 Upper Klamath Lake : Recruitment to the Adult Spawning Population

In the 1980's, LRS spawning runs in the Williamson and Sprague Rivers were dominated by large and presumably older fish (Buettner and Scoppettone 1990). Aging data collected from a lake die-off in 1986, indicated that most fish were 19-28 years old. Twenty-six year classes were documented with fish ranging from 8 to 43 years old. In 1988, 33 LRS were aged from spawning runs up the Sprague and Williamson rivers. These fish ranged from 9-30 years old with the majority between10 and 11 years.

SNS spawning runs in the 1980's in the Williamson and Sprague Rivers were numerically small (Buettner and Scoppettone 1990). Length frequency and ageing data was not nearly as extensive as for LRS. Only 18 SNS were aged from 1986 to 1988. They ranged from 4 to 25 years and represented 12 year-classes. SNS size distributions from 1989 to 1994 were similar to those from the 1980's with most fish ranging from 37-50 cm FL (Perkins 1996). Size distribution of the 1995 and 1996 SNS runs in the Sprague and Williamson Rivers were mostly 30-40 cm FL.

The Klamath Tribes captured small numbers of suckers from the Sprague and Williamson Rivers from 1989 through 1996 for hatchery propagation and other research purposes. Size distribution of these captures were presented by USGS (1996). Although the sample sizes were small, LRS distributions were similar from 1989 to 1994 with mostly larger fish (50-75 cm FL). Size distribution of the 1995 and 1996 LRS spawning runs in the Williamson and Sprague Rivers were shifted downward; most fish were 40-50 cm FL.

The shift in size distribution appeared to be related to recent recruitment to the adult population combined with a disappearance of older year classes. Age distribution information is based mostly on fish die-off events during 1995 (USBR 1996c), 1996 (Perkins 1996) and 1997 (USGS, unpub. data). Ninety-five percent of the suckers were age 7 years or younger with most age 4 (1991 year-class) and 5 (1990 year-class). Only age 14 and 9 year-classes were documented for LRS and SNS respectively.

Examination of about 860 suckers from the 1996 fish kill documented LRS and SNS that were mostly 2-8 years old (USGS, unpub. data). Eighteen year-classes of LRS and 11 year-classes of SNS were identified. The most abundant year-class of both species was 1991; the 1988, 1989, 1990, 1992 and 1993 year classes were also fairly well represented. In 1997, older LRS and SNS were dominant in the die-off, with 28 and 20 year-classes represented respectively.

Bienz and Ziller (1987) aged 10 adult SNS that were found dead in UKL in August 1986. Six fish were 19 years old, the remaining fish were 12, seven, seven and four years old respectively. Scoppettone and Coleman (unpub.) aged 190 LRS found dead in UKL in August 1986. Ninety percent of the fish were greater than19 years of age; no fish were less than 8 years of age.

## 1.2 Sucker Status: Clear Lake

No studies were done on the fish fauna of Clear Lake prior to construction of the dam in 1910. Because there is no fish passage over Clear Lake Dam, it is obvious that suckers were present in the lake prior to completion of the dam. The earliest studies on suckers in Clear Lake were done in 1973 and 1974 by Andreasen (1975); only 59 sucker specimens were reported being collected. By that time the “mullet” snag fishery on the Lost River had ended. Collections made of LRS and SNS in Clear Lake between 1989 and 1993 showed a wide range of size classes, potentially indicating fairly consistent recruitment (Buettner and Scoppettone 1990; Buettner and Scoppettone 1991; CDFG 1993; USBR 1994c).

Drought conditions in the Clear Lake watershed in the early 1990s temporarily reduced the habitat available for all fish. Clear Lake reached a minimum elevation of 4,519.2 ft (28,380 acre-ft) in October 1992, the lowest elevation for this reservoir since 1935 and only 5% of the reservoir's total capacity (Service 1994b). Populations of suckers in small reservoirs above Clear Lake may have been eliminated due to total or near complete desiccation during the summer of 1992, but probably were reestablished via spawning runs from Clear Lake in the spring of 1993 (M. Buettner, USBR, pers. comm.). There were strong spawning runs in 1993, but the low discharge of Willow Creek probably precluded any significant upstream migration in 1991 and 1992 (G. Scoppettone, USGS, pers. comm.). Large numbers of larval and juvenile suckers were observed in Willow Creek and tributaries during sampling in the spring and summer of 1993 (G. Scoppettone, USGS, pers. comm.). Researchers were unable to get a reliable population estimate of adult suckers in the 1993 spawning run due to sampling difficulties associated with ice conditions and high flows. Several LRS captured in Clear Lake in 1992 and 1993 exhibited signs of stress such as a noticeably thin appearance with sunken eyes, possibly the result of low lake levels and severe winter conditions (M. Buettner, USBR, pers. comm.). LRS and SNS captured in Clear Lake during late summer of 1993 appeared to be in relatively good condition (M. Buettner, USBR, pers. comm.), but condition factors for both species tended to be lower than those in Tule Lake (CDFG 1993).

The most recent status information on suckers in Clear Lake was done in 2000 by USGS (R. Shively, pers. comm.). They collected 155 LRS, ranging from 8-70 cm FL, and 339 SNS, ranging up to 49 cm FL. Although no aging has been done on these fish, the broad range of sizes potentially suggests a diverse age structure.

Preliminary analyses suggest that suckers in Clear Lake are relatively young. LRS in the Clear Lake drainage ranged up to only 27 years of age (CDFG 1993), but sample sizes were limited and it is likely that the maximum age for LRS in Clear Lake is greater than this (G. Scoppettone, pers. comm.). Maturity of Clear Lake LRS occurs at approximately age nine (G. Scoppettone, pers. comm.), and growth characteristics are currently being analyzed for Clear Lake suckers. Growth of LRS in Clear Lake has been assumed to be similar to those in UKL, although growth rates can vary and could be slower in less productive waters like Clear Lake (G. Scoppettone, USGS, pers. comm.).

In Clear Lake, most SNS mature at age five (CDFG 1993). Ages of SNS from the Clear Lake watershed ranged from one to 23 years of age (Buettner and Scoppettone 1991), but sample sizes were limited, and it is possible that the maximum age for SNS in Clear Lake is greater than 23 years (Scoppettone, pers. comm.). Sixteen year-classes were represented in Clear Lake in 1989 and 1990, with the largest group being five years of age (Buettner and Scoppettone 1993). This suggests good recruitment but low adult survivorship.

### 1.3 Sucker Status: Gerber Reservoir

In May 1992, during the drought, over 200 SNS were salvaged from Gerber Reservoir. They ranged in size from about 8 to 46 cm FL. Monitoring since 1992 within the Gerber watershed has documented a substantial SNS population exhibiting a wide range of size classes. The presence of smaller suckers indicates the population in Gerber Reservoir has successfully recruited recently. While the population of SNS in Gerber Reservoir appears to have more frequent recruitment than some other populations, there is still the problem of restricted distribution and lack of genetic connectivity with other populations. This is, however, not likely to be a problem unless the population declines to a small size.

Some suckers are entrained at the outlet of Gerber Dam. Sucker salvage operations were conducted below Gerber Dam in 1992, 1993, and 1997. In 1992, 229 suckers were captured and relocated to Gerber Reservoir. They ranged from 8 to 46 cm FL with considerable representation at sizes from 12.5 to 40 cm FL. In 1993, 34 suckers were collected below the dam including about 20 age 0 suckers. Salvage operations in October 1997, as part of a Safety of Dams evaluation, captured 152 suckers ranging from 8-47 cm FL. Most fish were 15-26 cm FL. Because of the risk of injury to personnel, salvage operations have been discontinued.

Reclamation monitored fish populations in Gerber Reservoir from April 1992 to June 1996. A total of 597 suckers > 28 cm FL were captured during these five years (USBR, unpub. data). Sucker catches (fish > 28 cm FL) by year from 1992-1996 were ranged from 12 to 288. All larger suckers were tagged with either a floy anchor tag or PIT tag and released. Only one fish was recaptured (1995). Total sucker catches for 1992-1996 ranged from 14 to 615. Most suckers collected ranged from 30-53 cm FL. However, the majority of the sampling effort was based on large mesh (2 inch stretch) trap nets and trammel nets. On several occasions, small-meshed (1 inch stretch) trap nets were used and many smaller-sized fish were captured (7-28 cm FL). Ages of 44 suckers, 30 of which were adults collected for genetic studies and the remainder mortalities from salvage operations below Gerber Dam documented 10 different year-classes. Fish ranged from 2-14 years old, indicating a young population in the reservoir.

Sucker condition factors have varied considerably in the Gerber population. SNS captured in 1992 and spring 1993 were very thin compared to those from Clear Lake, Tule Lake and UKL, while SNS captured in 1994-1996 were substantially more robust. For example, based on a linear regression analysis, a 40 cm FL fish collected in 1992 would weigh about 0.6 kg compared to about 0.8 kg in 1994 (USBR unpub. data). Extremely low water levels, high turbidity, and low DO concentrations in 1992 may have contributed to their poor condition; however, the environmental conditions associated with the variability in condition factors have not been analyzed for the Gerber populations.

### 1.4 Sucker Status: Lost River

The Lost River currently supports an apparently small population of SNS and very few LRS. Suckers, primarily SNS, have been reported from throughout the drainage (Koch and Contreras 1973; Buettner and Scoppettone 1991; Shively et al. 2000b). However, the majority of both adults and juveniles are caught above Harpold Dam and to a lesser extent from Wilson Reservoir (Shively et al. 2000b). Based on length frequency distributions it appears that several year classes are represented within the Lost River.

Sucker spawning habitat in the Lost River is very limited. Sucker spawning has been documented below Anderson-Rose Dam, in Big Springs, and at the terminal end of the West Canal as it spills into the Lost River. According to residents, sucker spawning at Big Springs is now rare but historically it was an important spawning site and was used as a major fishing site during the spawning migration by Modoc Indians (Klamath Echos). Suspected spawning areas that have suitable habitat (rocky riffle areas) include the spillway area below Malone Reservoir, just upstream of Keller Bridge, just below Big Springs, just below Harpold Dam, and adjacent to Station 48. Spawning has also been documented in Miller Creek, and is suspected in Buck Creek and Rocky Canyon Creeks (Shively et al. 2000b).

### 1.4.1 Lost River - above Malone Dam

Reclamation has collected a few LRS and SNS each year during salvage operations immediately below Clear Lake Dam. These fish were released in the Lost River either near Olene or in Malone Reservoir. Few suckers are believed to occupy the 8-mile reach between Clear Lake Dam and Malone Reservoir owing to the high gradient and lack of pool habitat. Additionally flows in this reach are highly variable, being high in summer during irrigation releases and being low the remainder of the year when halted at the end of irrigation season. Malone Reservoir is not believed to support a viable sucker population, but instead probably contains waifs entrained into the Lost River from Clear Lake (Buettner and Scoppettone 1991). In July 1992, four trap nets were set overnight in Malone Reservoir on the Lost River, at the upper end of the Langell Valley; only two adult SNS were captured. Later in 1992, 350 SNS and 4 LRS were salvaged at Clear Lake by Reclamation and placed in Malone Reservoir. Shively et al. (2000b) caught two adult SNS, one KLS, three adults with morphologies intermediate to SNS and KLS, and only one juvenile above Malone Dam. Further upstream in East Fork of the Lost River all 12 adults were either KLS or intermediates.

### 1.4.2 Lost River - Malone to Harpold Dam

In April 1992, four trap nets (1-inch stretch) were set overnight in the Lost River between Malone Dam and Keller Bridge in the Langell Valley area. No suckers were captured in this shallow, low gradient channelized river section that averaged about 2 ft deep. There was very little flow and no water was being released from Malone Reservoir.

Approximately 100 SNS were observed by Reclamation staff at Big Springs near Bonanza in April 1992 (M. Buettner, USBR, pers. comm.). Thirteen adult SNS were captured. Four spawning sites were identified in the springs. Water depths at spawning sites ranged from 1.2 to 2.4 ft and bottom substrate consisted mostly of gravel and small cobble. Sucker eggs were observed in the substrates and about 4 weeks later hundreds of sucker larvae were observed in the springs. According to residents, sucker spawning at Big Springs is now rare but historically it was an important spawning site and was used as a major fishing site during the spawning migration by Modoc Indians (Klamath Echos). Additional, but unconfirmed spawning areas may exist in Buck or Rocky Canyon Creeks (Shively et al. 2000b). Several adult suckers were captured near the mouth of Buck Creek in June and juvenile suckers were captured in Buck Creek (Shively et al. 2000b).

Later in April 1992 a survey was conducted from Keller Bridge to Bonanza using a boat electrofisher. Ten adult suckers were captured and another 10 were seen but not collected. Most suckers were sampled from deeper pools about 2-4 miles below Keller Bridge. In September three adult SNS were captured 0.2 miles above Big Springs.

In April 1995, seven juvenile suckers were captured in the Lost River adjacent and downstream of Big Springs using a backpack electrofisher. One adult SNS 48 cm FL was captured and radio-tagged. On May 23, 1995, trammel nets were fished for 2-5 hours in at Harpold Road below Big Springs; one adult SNS , 38 cm FL was captured. In October 1998, Reclamation staff collected SNS in North Canal, operated by Langell Valley Irrigation District (Peck 1999).

In 1999, Reclamation and USGS biologists conducted a more detailed fish sampling effort on the Lost River and selected tributaries from June 11 to October 5 (Shively et al. 2000b). While adult suckers were captured throughout the river system, the majority were captured above Harpold Dam. The 66 adult suckers caught in the Harpold reach were all SNS. The majority of juvenile suckers were also captured in the Harpold Reach and near the confluence with Miller Creek.

Downstream flows in Miller Creek are shut off at the end of the irrigation season, usually on October 1. A 1-2 cfs bypass is released into Miller Creek in winter to prevent the outlet valve from freezing. Before Miller Creek empties into the Lost River, flows are diverted into North Canal during the irrigation season, thus little flow reaches the Lost River at any time of year. Some suckers are annually salvaged from North Canal. In 1999, substantial numbers of adult suckers were observed in the lower portion of Miller Creek, below East Langell Valley Road (B. Peck, pers. comm.). Twenty-one SNS were captured using a backpack electrofisher and about 20 additional suckers were observed but not captured on April 28. Suckers ranged from 34-47 cm FL and included 18 males and three females; all suckers were ripe. On April 29, another 15 adult SNS were sampled and/or observed from Miller Creek above the Wooden Bridge approximately 1mile upstream of the confluence of the Lost River. On May 4, 12 suckers were collected from several sites sampled between East Langell Valley Road and the mouth of Miller Creek. Small numbers (<10) of adults were observed through May 26. In 1998, SNS were observed spawning in the middle canyon area on April 26th (A. Hamilton, pers. comm.).

Sucker eggs were documented at several riffle areas in Miller Creek from East Langell Valley Road to the mouth on May 4, 1999 (B. Peck, pers. comm.). On May 20, sucker eggs were found at two riffle sites below the Wooden Bridge. Seven groups of larval suckers containing about a dozen fish each were observed in the backwater areas. Three locations with suitable spawning gravel above the Wooden Bridge were checked for sucker eggs and none were found. No larvae were observed in this section. However, sucker larvae were common throughout the reach from East Langell Valley Road to the mouth on May 25.

Few observations were made above East Langell Valley Road and none above Miller Creek Dam during the 1999 sucker spawning run (B. Peck, USBR, pers. comm.). A rock and cobble check dam on private property downstream of the diversion dam may restrict or block upstream passage. On May 25 visual observations in backwater areas in North Canal failed to document any sucker larvae. But, larvae were found just below East Langell Valley Road on this date. Young-of-the-year juvenile suckers were observed throughout the year in lower Miller Creek. On May 17, 2000, dozens of juvenile suckers, 4-8 cm FL were sampled from the Willow Hole about 0.5 miles upstream from the mouth.

The 1999 sucker spawning run in Miller Creek was apparently stimulated by the controlled release of water (470-490 cfs) from Gerber Reservoir between February 17 and April 23 to minimize the risk of flooding (USBR unpub.). In 2000, no water was released from Gerber Reservoir prior to irrigation season and suckers were not observed spawning in Miller Creek. Flows in lower Miller Creek ranged from approximately 5-10 cfs during the spawning season (March – May). At these lower flows, passage may be restricted by the shallow water depths (2-3 inches) at the mouth of Miller Creek. During late spring and summer, passage improves as water levels in the Lost River increase due to agriculture return flows. Spawning access and habitat may be improved through constriction of the stream channel at the mouth.

These observations indicate that a small, resident population of SNS is likely present in Miller Creek. Whether or not this is a self-reproducing population is unknown since suckers are likely entrained at Gerber Dam and move downstream.

### 1.4.3 Lost River - Harpold Dam to Lost River Diversion Dam

On May 23 and 26, 1995, trammel nets were used in Wilson Reservoir; nine SNS were collected.

In 1999 surveys Shively et al. (2000b) caught a single LRS and 22 SNS, along with 52 juvenile suckers in the reach below Harpold Dam. Twenty-two adult SNS suckers were captured and pit tagged from Wilson Reservoir. These fish ranged in size from 30 to 49 cm FL (B. Peck, USBR, pers. comm.). During a June (6/24/99) overnight trap net set in Wilson Reservoir, over 600 fish, mostly brown bullhead (*Ameiurus nebulosus*) and pumpkinseed sunfish (*Lepomis gibbosus*) were collected (B. Peck, USBR, pers. comm.). In this trap netting effort, a method usually employed in efforts to catch small fish (<15 cm FL), no suckers were captured. On September 24, 1999, brown bullheads were the only fish collected during five Wilson reservoir trammel net sets (B. Peck, pers. comm.).

On March 22, 2000, five trammel nets were set in Wilson Reservoir. From these nets, a total of 12 suckers ranging in size between 36 and 52 cm FL were collected (B. Peck, USBR, pers. comm.). These suckers included SNS, KLS, and many that exhibited morphology intermediate between these two species. All were pit tagged and four were radio tagged for telemetry studies. No evidence was obtained showing that adult suckers move downstream of Wilson Reservoir (B. Peck, USBR, pers. comm. 2000). Two suckers were captured below Horseshoe Dam in April 2000 and two KLS were collected in one day of spring trammel netting at the Olene gap on the Lost River, upstream of Wilson reservoir (B. Peck, pers. comm.).

During late January and early February of 1997, a relatively small fish kill occurred in the southern end of Wilson Reservoir near the LRDC head gates. A minimum of 55 juvenile suckers (86-188 mm FL), of unidentified species, were apparently killed when DO concentrations dropped to lethal levels (<1 mg/l measured by Reclamation biologists on 2/5/97) below an ice cover. In late August and early September of 1999, a summer fish kill occurred in the LRDC below the Wilson Reservoir headgates. It is presumed that low oxygen conditions caused this kill when anoxic waters from the bottom of the thermally stratified Wilson reservoir were mixed upward and delivered to the LRDC. Collections of dead fish from that period included only tui chubs (*Gila bicolor*), however abundant fish eating birds (e.g., Caspian and Forster's terns, great egrets, etc.) were present and may have consumed any juvenile suckers present.

### 1.4.4 Lost River - Lost River Diversion to Anderson Rose Dam

Shively et al. (2000b) caught only relatively low numbers of juvenile suckers in the Lost River below Lost River Diversion Dam.

The Lost River Diversion Channel (LRDC) presently can flow either east or west, depending on Lost River flows and water demands within the Project. While the LRDC does not provide the lacustrine habitat that is preferred by lake suckers, water quality conditions in the Lost River's near Wilson Reservoir may seasonally be very poor and may cause migration out of the reservoir and into the LRDC (B. Peck, USBR, pers. comm.). The overall connectedness of Klamath Project water bodies suggests that endangered fish could easily gain access to the LRDC, but there is very little information on the use of the canal by suckers.

Limited sampling in the LRDC was done by Contreras in 1973 and also by USBR in 2001, as part of salvage activities to allow extension of the airport runway (USBR 2002a). Contreras (1973) reported sighting several sucker specimens and dip netting two S.S. from the LDC pool below Wilson reservoir. He also gill netted one SNS from the LRDC at a site approximately ¼ mile west of the Wilson Reservoir gates at the C-G foot bridge. His surveys were not comprehensive and his gill netting was limited in duration because heavy algae blooms clogged his sampling gear. The salvage sampling by USBR in October 2001 encountered no suckers in the LRDC between the airport and Station 48; however, water quality was poor before and during sampling, so some mortality of suckers may have already occurred (USBR 2002a). Several fish kills and collection efforts in Wilson Reservoir, directly upstream of the LRDC, have also recovered both juvenile and adult suckers (USBR unpub. data).

### 1.4.5 Lost River - Anderson Rose Dam to Tule Lake

Populations of suckers in historical Tule Lake migrated up the Lost River to spawn at Big Springs (River Mile 42), near Bonanza, Oregon and probably other shallow riffle areas with appropriate spawning substrate (Coots 1965 and Klamath County 1976). The construction of Lost River Diversion Dam in 1912 by Reclamation restricted sucker migrations out of Tule Lake to the lower 23 miles of the Lost River. In 1921, construction of the Anderson-Rose Diversion Dam further restricted migrations to the lower 7 miles of the river.

Reclamation has monitored endangered sucker spawning runs from Tule Lake into the Lost River annually since 1991 (USBR 1998c). Although dozens of suckers were observed spawning during May each year and some eggs were found in the substrate, substantial numbers of larval suckers were only observed in 1995. Although no intensive larval emigration sampling was conducted, Reclamation believes that enough visual observations were made during most years to detect good larval sucker survival had it occurred. The apparent lack of spawning success in most years appeared to be related to the lack of adequate spawning habitat. Reclamation monitored water quality during both years and found that temperature, DO, pH, and specific conductance were adequate for sucker spawning and incubation. However, relatively high concentrations of ammonia have been measured in this area that may contribute to low survival of larvae (USBR, unpub. data). In 1995, Reclamation constructed a spawning channel below Anderson Rose Dam and added gravel to a known spawning riffle. Spawning did not appear to occur in the channel. In 1996, the channel washed out under high winter flows and was not rebuilt.

Beginning in 1999, Reclamation changed operations in the Lost River below Anderson Rose Dam. Specifically, releases of 30 cfs were started on April 15 and continued until spawning and incubation were complete in early June. Previously, releases of 50 cfs were required beginning April 1 and continuing for at least four weeks (1992 BO). Observations in 1995, 1999, and 2000 by Reclamation biologists show that releases of 30 cfs may be adequate for sucker passage up to and spawning below Anderson Rose Dam. In 1999, suckers began migrating to the dam as early as two days after releases were started. In 2000, the first suckers were observed April 21, 6 days after the April 15 start date.

### 1.5 Sucker Status: Tule Lake

Historically the Lost River had very significant runs of suckers, apparently originating from Tule Lake. The Modoc Indians and white settlers ate suckers or used them for livestock food (Cope 1879; Coots 1965; Howe 1968). Sucker runs up the Lost River were once so large that several canneries were set up to can and process suckers into dried fish, oil, and other products (Howe 1968; Andreasen 1975).

The vast sucker populations that migrated out of Tule Lake are severely reduced today. The lake was sampled for suckers in 1973, but none were collected (Koch and Contreras 1973). However, in 1991 both species were observed spawning below Anderson-Rose Dam, and in 1992-93 about 20 specimens of each species were captured in Tule Lake (Service 1993a). Further sampling has confirmed a small population of both species in the Tule Lake sumps (Scoppettone, Shea, and Buettner 1995). The negative results of Koch and Contreras are likely explained by limited collecting effort in areas where suckers aggregate and low sucker population levels. It seems unlikely that suckers have only recently re-invaded the sumps via entrainment of fish into irrigation canals. Suckers inhabiting Tule Lake, while low in number, were found to have a high condition factor (ratio of weight to length) relative to that of other Klamath Basin sucker populations. Adult suckers captured in the sumps had fewer external parasites and were larger and heavier than suckers from Clear Lake and Gerber Reservoir.

Scoppettone, Shea, and Buettner (1995) sampled fish in Tule Lake sumps from 1992 to 1994. Tui and blue chubs predominated the catch, with relatively few suckers; in nearly 3,000 trap hours only 67 suckers were collected. All fish were tagged and released, but only one recapture was made for each species. Based on this very limited capture and recapture data, they estimated 159 adult SNS (95% CI: 48-289) and 105 LRS (95% CI: 25-175). Suckers collected in this study were represented by few size classes with those of about 46 cm FL predominating for SNS, and those 46-60 cm FL for LRS (Scoppettone, Shea, and Buettner 1995).

In 1999, the Service (Klamath Basin NWR) set trammel nets in Tule Lake on two occasions in April. Nine Lost River and five SNS were captured from twelve net sets of 1-2 hours. One SNS originally tagged in 1993 was recaptured. In April 2000 the Service set five nets for 2-3 hours. Eleven LRS and fifteen SNS were captured. Two of the LRS were fish marked in previous years.

From 1993-2000, spawning runs were observed in the lower Lost River at Anderson Rose Dam, where Reclamation tagged and released 91 LRS and 14 SNS below the dam. In 1995, two of 9 LRS that were tagged in 1993 were recaptured. In 1999, one out of 17 LRS captured was a recapture from 1993 and in 2000 seven LRS were previously tagged fish (40 captured).

While an accurate estimate of the population size is not possible, the available information suggests that sucker population sizes in what remains of the lowest reach of the Lost River and Tule Lake are limited to a few hundred individuals of each species.

Sucker habitat in Tule Lake sumps for juveniles and adults is limited because of shallow depths because the sumps have been filling with sediment. Approximately 8,000 and 5,000 acre-ft of storage were lost from sumps 1A and 1B, respectively, between 1958 and 1986 (USBR unpub. data). Wind- and water-borne silt is coming primarily from agriculture in the Lost River watershed (Service 1998c). Since the Tule Lake sumps are shallow, with an average depth of less than 4 ft, this loss of habitat is significant. Reduction of water depth in Tule Lake is a threat to the suckers because it increases the risk of winter freeze, reduces the amount of deepwater habitat for adult suckers, increases avian predation, and may contribute to poor water quality by allowing the water to heat more rapidly and allowing sediments and nutrients to be more readily mixed by wind shear. Adoption of better soil management practices in the Lost River watershed would likely reduce the rate of sedimentation. The Refuges are developing a plan of sump rotation that may help alleviate the problem of siltation in Tule Lake, however, sediment transported by the Lost River will continue to be a problem until erosion in the Lost River watershed is reduced.

Rearing habitat in the Lost River downstream of Anderson-Rose Dam is limited both by water quality and structural features of the channelized river. The lower Lost River is, at high lake levels, made up almost entirely of backed-up sump water, and water quality conditions reflect those in the sump. A few small irrigation return drains empty into the river in this reach and may contribute to water quality degradation.

The above studies suggest that sucker populations residing in what remains of Tule Lake are likely limited by a lack of recruitment, inadequate water depth, and seasonally poor water quality. At first examination, the small size of the sucker population in Tule Lake would suggest that they are of little significance. However, if significant sucker die-offs in UKL continue, sucker populations elsewhere, including Tule Lake, will become crucial to the long-term survival of these species (Perkins et al. 2000a). Other than Clear Lake and UKL, Tule Lake is the only other site that contains a significant population of both LRS and SNS; Gerber Reservoir does not contain LRS. The small Tule Lake populations appear to be healthy, relatively free of parasites and skin infections, and to have a higher condition factor than suckers found elsewhere in the Basin. If water quality, depth, and spawning requirements of suckers can be met, the Tule Lake populations could make an important contribution toward the recovery of the LRS and SNS.

## 1.6 Sucker Status: Lower Klamath Lake

Prior to 1917, Lower Klamath Lake was seasonally connected to the Klamath River either when it flooded in Spring or later in the summer when the river level was down and water flowed from the lake to the river (Weddell 2000). Steamboats were even able to navigate the Klamath Straits, a slough that connected the lake and river. The railroad completely severed that connection by 1917, and by 1924, the majority of the Lower Klamath wetlands had been drained (Weddell et al. 1998; Weddell 2000). Connectivity between Lower Klamath Lake and the rest of the Klamath Basin is now limited to water pumped through the ridge from Tule Lake and various irrigation channels that connect into the Keno impoundment, primarily the Klamath Straits Drain and Ady Canal.

Prior to about 1924, suckers migrated up Sheepy Creek (a spring-fed tributary to Lower Klamath Lake) in sufficient numbers that they were taken for food or to feed hogs (Coots 1965). In 1960, small numbers of adult suckers were observed moving up Sheepy Creek in the springtime (Coots 1965). Available survey information from Lower Klamath Lake or its tributaries since 1960 is scanty. California Department of Fish and Game records show no recent surveys for Sheepy Creek (D. Maria CDFG, pers. comm. 2001). Koch and Contreras (1973) sampled two sites on Sheepy Creek and three on the Klamath Straits Drain and caught no suckers. However, sampling conditions were difficult on Sheepy Creek.

Although irrigation diversions near the mouth of Sheepy Creek apparently block passage upstream and the creek is substantially reduced by irrigation demands during the summer, most of the creek lies on private land and has not been sampled (Buettner and Scoppettone 1991). Buettner and Scoppettone (1991) did limited single night gill net sets in the Lower Klamath Lake system (June 28-29, 1990), including Lower Klamath Lake - Unit 1 and 2 (2 sites), Sheepy Lake (3), Klamath Straits Drain (1), and Ady Canal (1). They caught no suckers, although Buettner (pers. comm. 1999) suggested that suckers might occasionally reach the Lower Klamath Lake sub-basin from the Klamath River via the Ady Canal. An adult sucker was caught near the mouth of Ady canal during sampling for a pelican contaminant study around 1980 (J. Hainline, pers. comm.). Available information suggests that occasional suckers may disperse into the Lower Klamath Lake sub-basin, including Ady canal, but that they are probably prevented from returning to the Keno impoundment and Lake Ewauna by the pumps in the Straits Drain and flow characteristics of the Ady canal. There are at present no known resident populations of suckers in the Lower Klamath Lake sub-basin.

## 1.7 Sucker Status: Link River

Prior to construction of the Link River Dam, there were apparently large spawning runs of suckers migrating up the Link River in March, which were described as “immense congregations” of fish weighing two to six pounds (Klamath Republican 1901). The origin of these runs is not recorded; presumably, they came up out of Lower Klamath Lake or the Lake Ewauna/Keno reach, as lentic habitat was not available below Keno prior to construction of J.C. Boyle dam. Suckers apparently occupied the Link River even in summer, as evidenced by accounts of stranded ‘mullet’, when flow to the Link River was cutoff by southerly winds producing a seiche (oscillation of the upper surface) in Upper Klamath Lake that lowered the level at the outlet to below the sill (Spindor 1996).

There has been no concerted effort to survey the Link River itself for fish distribution and seasonal use patterns. However, the limited information available demonstrates that adult suckers still make an attempt to migrate upstream in the Link River during the Spring, and at least juveniles apparently reside in the river below the dam throughout most of the year. Primarily juvenile suckers are consistently caught during salvage operations conducted at the base of the

Link River Dam during maintenance operations and spill termination, which occurs in most seasons except the January-March time period (USBR 2000). In 1995, 12 suckers (17-51 cm FL) were salvaged in April, 138 juveniles (12-23 cm) in May, and a single juvenile in December. In 1996, 132 suckers (10-36 cm FL) were salvaged in May, 19 (11-29 cm) in June, and a single juvenile in July. In 1997, 10 suckers (9-13 cm FL) were salvaged in June, and 68 suckers (9-25 cm) were salvaged in May. After a spill termination in October 1998, no suckers were observed. In 1999, 12 suckers (about 80 mm FL) were salvaged after a spill termination in September, and in October 1999, 18-19 salvage operations were carried out that caught 44 suckers (7-18 cm FL). In 2000, 12 suckers (5-16 cm FL) were salvaged after a spill termination in September.

From 1988 to 1991, a cooperative study was conducted by PacifiCorp and ODFW to evaluate the status and effectiveness of fish passage at the Link River and other Klamath River fish ladders (Hemmingsen et al. 1992; PacificCorp 1997). Sucker data from this study are available from two sources, original data sheets apparently from J. Fortune (ODFW unpub.) and the PacifiCorp (1997) report which summarizes the data; the two sources provide slightly different numbers, but the data sheets provide more specific information.

At Link River (Fortune data), a total of 19 suckers were caught during the study period, including 4 LRS (525-585 mm FL), 3 SNS (410-465 mm), 2 large-scale (600-625 mm), 7 Klamath small-scale (395-475 mm) and 3 unidentified juveniles (187-212 mm). Suckers were present in the ladder only in 1989, a high-flow year with releases from Link River Dam reaching 3,900 cfs, and only in the Spring (April 5 to June 7). PacifiCorp (1997) reported a total of 18 suckers, including 4 LRS, 3 SNS, 6 large-scale, 3 Klamath small-scale and 2 unidentified juveniles. Adult suckers were also sighted incidentally by PacificCorp at the mouth of the fish ladder in 1996 (Frank Schrier, Pacific Corps, pers. com. cited in USBR 2001), and Reclamation captured two adult suckers from the ladder in June 1998 (USBR 2001).

While suckers appear to still occupy habitat throughout the Link River in low numbers, the lower Link River is probably crucial to suckers and other fish, since it may be the best habitat now available in the reach upstream of Keno. The lower Link River probably serves as a critical refuge for fish during periods of low DO. Water quality in Lake Ewauna is frequently very poor and the higher quality of water in the Link River may allow fish from the lake to survive. Link River, because of its high gradient and numerous cascades, has a significant potential for oxygenation of water prior to entry into Lake Ewauna where there is a high biochemical oxygen demand. Furthermore, a number of small springs along and in the channel add fresh, high-quality water to the river. In summer, when most of the flow is diverted into the hydroproject, water quality in the Link River itself and the reach’s potential to oxygenate water entering Lake Ewauna is greatly compromised by the reduced flow caused by the diversions.

At this time, suckers attempting to move up into UKL, including those that have been entrained from UKL and delivered downstream by diversion channels, are effectively prevented by the Link River Dam. Mature suckers trapped below the Link River Dam are prevented from reaching spawning grounds in UKL or its tributaries.

### 1.8 Sucker Status: Keno Impoundment (Lake Ewauna to Keno Dam)

Historically, Lake Ewauna and the upper Klamath River were connected to both the Lost River, at least in years of high water, and to Lower Klamath Lake. In 1890, the paddle-wheeler “Mayflower” was able to navigate up the Lost River Slough and moved down the Lost River to near Merrill. The Lost River Slough was located near the current location of the Lost River Diversion Canal. Steamboats also moved through the Klamath Straits (now Klamath Straits Drain) between the river and Lower Klamath Lake. The Lake Ewauna/upper Klamath River reach may have formed a critical connectivity corridor for suckers moving between the Upper and Lower Klamath Lakes and the Lost River.

Currently, Lake Ewauna and the upper reach of the Klamath River above the Keno Dam form an impoundment 20 miles-long by 300 to 2600 ft-wide, with depths of 9 to 20 ft (the Keno Impoundment, see Environmental Baseline). Water quality in this reach of the Klamath River is seasonally poor and it is 303(d)-listed by ODRD for DO, pH, Chl-a, and ammonia (CH2M Hill 1995; ODEQ 1998).

Very little is known about the present use of the Keno to Link River reach by suckers or other fishes, and apparently no systematic sampling has been done to date. Hummel (1993) ran 42 trap net sets at various locations throughout the Keno/Lake Ewauna reach in June-July 1993, catching six SNS (21-32 cm FL) at sites dispersed from the Keno bridge to Lake Ewauna. Hummel also reported three suckers (unspecified size or species) trap netted at the Klamath Wildlife Area in an earlier day of trap netting. In 1996, ODFW carried out two days of sampling (May 15 and August 29) in the Lake Ewauna/Keno reach during which they apparently caught a single Lost River sucker of unspecified size (ODFW 1996).

There is evidence that suckers migrate upstream past the Keno Dam. From 1988 to 1991, a cooperative study was conducted by PacifiCorp and ODFW to evaluate the status and effectiveness of fish passage at this and other fish ladders (Hemmingsen et al. 1992; PacifiCorp 1997). Sucker data from this study are available from two sources, original data sheets apparently from J. Fortune (ODFW undated) and the PacifiCorp (1997) report which summarizes the data; the two sources provide slightly different numbers, but the data sheets provide more specific information. At Keno (Fortune data), a total of 141 suckers were caught during the study period, including 8 adult LRS (48-61 cm FL), 4 SNS (22-42 cm FL), 103 KLS (29-51 cm FL), 5 unidentified suckers (19-42 cm FL), 21 unidentified juveniles (no lengths), and apparently no KLS were identified. The LRS were all caught in May-June 1988-89. The SNS were caught in April, July and September of 1990-91. Klamath small-scale sucker (KSS), *Catostomus rimiculus,* were caught August-October 1988 (13: 29-51 cm FL), April-June 1989 (71: 31-51 cm FL) with just two on October 12, April 1990 (6: 37-44 cm FL) or August-October 1990 (9: 40-48 cm), and September 1991 (2: 41 cm FL). Unidentified suckers were caught in April 1990 and September 1991 (5: 19-42 cm FL). Unidentified suckers recorded as juveniles with no lengths were caught in August - September 1989 (6), August 1990 (5), and late July-September 1991 (10). PacifiCorp (1997) reports a total of “130 suckers”, including 6 adult LRS, 3 SNS, 6 KLS, 99 KSS, and 22 unidentified juveniles (note incorrect addition).

The capture of adult suckers in the lentic Keno/Lake Ewauna reach, the presence of suckers both in the Link River itself and at both the Link River and Keno fish ladders, and the apparent outmigration of tens of thousands of juveniles from UKL in the late summer and fall (see Larval and Juvenile Abundance above, and Effects of Action: Entrainment ) suggests that the improvement of habitat quality in the Keno Impoundment, coupled with adequate fish passage at the Link River and Keno Dams, would be a key component to recovery of the suckers.

## 1.9 Sucker Status: Klamath River Reservoirs

Downstream of Keno Dam the Klamath River consists of three primary reservoirs (J.C. Boyle, Copco and Iron Gate) and three riverine reaches. A detailed description of the reservoirs is presented in Desjardins and Markle (2000) and Fishpro (2000). The riverine reaches are: (1) Keno Dam to J.C. Boyle Reservoir (3 miles), (2) J.C. Boyle Dam to Copco #1 Reservoir (22 miles; the distance between the two Copco dams is so short, <1 mile, and the size of the reservoir at Copco #2 so small (<40 acres), that this reach is considered fish habitat), and (3) Copco Dam #2 to Iron Gate Reservoir (1 mile). Four species of suckers are known from the Klamath River and its reservoirs: LRS, SNS, KLS, and the KSS. However, the KSS, a principally riverine and stream-dwelling species which is rare in the upper Basin, will not be included in the following discussion. Due to the high-energy character of the river reaches, the primarily lacustrine LRS and SNS are not expected to occupy them, except potentially for spawning and during movements or migrations between the various reservoirs and ultimately into the upper Basin, providing passage were available. Of the five dams, only Keno and J.C. Boyle have fish passage facilities. While both the Keno and J.C. Boyle ladders are apparently passable by suckers to some degree, neither is designed for optimum sucker passage.

The most intensive study of suckers in the upper Klamath River reservoirs is that of Desjardins and Markle (2000) done in 1998-1999. Additional surveys were made by Coots (1965), Beak Consultants (1987), Buettner and Scoppetone (1991) and ODFW (1995); trapping in the J.C. Boyle and Keno ladders in 1988-91, provides additional information about the presence and movement of suckers in the Klamath River (ODFW undated, PacifiCorp 1997).

SNS is the only lake sucker that occurs in abundance in the Klamath drainage below Keno, and adults have been consistently collected in all three reservoirs (J.C. Boyle, Copco, and Iron Gate). Copco apparently contains the largest population of adults. However, the two lower reservoirs contain primarily larger adults (> 30 cm FL), while subadults (10-30 cm FL) are present only in J.C. Boyle. Although larval suckers have been caught in all three reservoirs, the identity of the specimens under 5cm FL is uncertain. SNS spawning behaviors have only been recorded from Copco, but there is no evidence that SNS consistently survive past 5-10 cm FL in the reservoir (Beak Consultants 1987, Buettner and Scoppettone 1991, Desjardins and Markle 2000).

LRS and KLS are apparently rare in the two upper reservoirs and have not been recorded from Iron Gate. In 1956, Coots did catch three LRS in Copco, however it is unclear whether they were abundant at the time (Coots 1965); more recent surveys have caught only a few individuals. ODFW and PacifiCorp caught only 8 LRS and no KLS passing the Keno Dam from 1988-1991 (ODFW unpub. data; PacifiCorp 1997).

### 1.9.1 J.C. Boyle Reservoir

J.C. Boyle Reservoir is 1.7 miles downstream from the Keno Dam (from upper end of reservoir). The J.C. Boyle Dam was built in 1958 at river mile 224.7. The reservoir is about 3.6 miles long, has a surface area of about 420 acres, a mean depth of about 15 ft, a maximum depth of about 50 ft, and about 7.5 miles of shoreline. Due to its shallowness the reservoir has proportionately more littoral habitat, suitable to suckers, than the other two downstream reservoirs. The daily fluctuation is about 1.5 ft, due to irregular water releases for power generation. Spencer Creek is the major tributary.

During the Desjardins and Markle (2000) study, trap netting in 1999 (April-July, 197 hrs) caught 30 identifiable subadult SNS (14-27 cm FL), a size class that corresponds to roughly 1-2 years old. Trap netting in 1998 (Sept.-Oct.,118 hrs total soak time) caught no SNS or LRS. Trammel netting in 1998-99 combined caught 18 larger subadult and adult SNS (26-40 cm FL). Only two identifiable LRS were caught in J.C. Boyle during the study. In 1993, Reclamation sampled J.C. Boyle Reservoir eight times, collecting 20 SNS, 1 LRS, 6 KLS and 30 KSS. ODFW conducted an electrofishing survey at J.C. Boyle Reservoir on June 14, 1995. They captured 32 unidentified juvenile suckers.

Desjardins and Markle (2000) considered J.C. Boyle to be a possible sink for UKL larvae and juvenile suckers entrained into the Klamath River. J.C. Boyle was the only reservoir where juveniles (<5 cm) were plentiful. It is important to note that Desjardins and Markle used an arbitrary length of 3 cm to separate juveniles from larvae, and that they did not identify either to species. Therefore these samples could represent locally produced (Spencer Creek) Klamath small-scale suckers. No SNS, LRS or KLS have been recorded spawning in Spencer Creek. The larvae and juveniles in their analysis were all <5 cm and "juveniles" averaged 3.3-3.5 cm (Desjardins and Markle 2000, Figure 9). This size class is considerably smaller than the age-0 suckers entrained at the outlet of UKL during the peak of the catch pulse, which were generally 5-17 cm in August and September (Gutermuth et al. 2000). In the reservoir study, beach seining was the only sampling method that would have captured this size class (5-17 cm FL) were they to arrive from upstream in the fall (August-October). Only 13 seine pulls were made in August 1998 and none were done in 1999; apparently, no juveniles greater than 5 cm were caught in the seines (see trap netting results above).

### 1.9.2 Copco Reservoir

Copco Reservoir is 26 miles downstream from the Keno Dam and 22 miles downstream from J.C. Boyle Dam. Copco #1 Dam was built in 1918 at river mile 198.6. The reservoir is about 4.5 miles long, has a surface area of about 1000 acres, a maximum depth of about 108 ft, and about 13.2 miles of shoreline. The daily fluctuation is about 1 foot. Shovel Creek is the only perennial tributary.

Coots (1965) caught both LRS and SNS in Copco Reservoir. However, by the 1980's few LRS were captured in sampling by CDFG (CDFG 1980, cited in Desjardins and Markle 2000). Beak Consultants (1987) conducted the first intensive study of sucker populations in Copco Reservoir in order to provide information on suckers in relation to the proposed Salt Caves Hydroproject upstream of Copco. They located a SNS spawning site in the Klamath River between Copco Reservoir and the confluence of Shovel Creek. SNS gathered at a presumed staging area in the upper reservoir during the first two weeks of April when temperatures were about 11 C. Fish then moved upstream to a presumed spawning site. Spawning activities peaked the last week of April, when temperatures were 13-15 C, and were over by mid-May. Larval suckers were first collected on May 5,th peaked mid-May, and were no longer present by 10 June. Buettner and Scoppettone (1991) sampled fish in Copco and Iron Gate reservoirs. In Copco Reservoir some very large SNS were found, some were >50 cm fork length, and up to 33 years old. No juvenile SNS were caught. Beak Consultants caught a single LRS, and Buettner and Scoppettone caught none. In 1993 Reclamation sampled Copco Reservoir and captured 10 adult shortnose suckers ranging from 43-50 cm FL. Buettner and Scoppettone (1991) suggested that poor water quality entering from upstream, scouring and dewatering of spawning areas by variable flow released from J.C. Boyle and the presence of exotic reservoir-adapted predators all had negative effects on the suckers in Copco Reservoir.

During the Desjardins and Markle (2000) study, trap netting in 1998 (October, 35 hrs) and 1999 (March-October, 219 hrs) apparently caught no more than four SNS >10 cm FL, and all would have been caught in 1999 (based on discrepancy between Table 2, total identified SNS caught and Fig. 7, size distribution of adult SNS caught in trammel nets). Trammel netting caught 6 adult SNS in 1997, 91 adult SNS (31-55 cm FL) in 1998 and 64 adult SNS (41-57 cm FL) in 1999. Only one identifiable LRS and two Klamath large-scale were caught in Copco during the study. Desjardins and Markle (2000) caught only larval suckers (10-17 mm) in their combined drift net, larval trawl dip net and beach seine sampling in Copco. Essentially absent was the "juvenile" size class that was present in J.C. Boyle (3 individuals, 3-5 cm FL).

### 1.9.3 Iron Gate Reservoir

Iron Gate Reservoir is 33 miles downstream from the Keno Dam and 1.4 miles downstream from Copco #2 Dam. The dam was built in 1962 at river mile 190.1. The reservoir is about 6.8 miles long, has a surface area of about 944 acres, a mean depth of over 35 ft, a maximum depth of about 167 ft, and about 19 miles of shoreline. Due to its average depth and steep banks, the reservoir has relatively little littoral habitat, suitable to suckers. The daily fluctuation is about one foot. Fall and Jenny creeks are the two perennial tributaries.

During the Desjardins and Markle (2000) study, trap netting in 1998 (October, 56 hrs) and 1999 (March-September, 206 hrs) caught no SNS. Trammel netting caught 9 adult SNS in 1997, 2 adult SNS (about 49 cm FL) in 1998 and 11 adult SNS (41-54 cm FL) in 1999. No identifiable LRS or KLS were caught in Iron Gate during this or earlier sampling.

Desjardins and Markle (2000) caught only larval suckers (< 23 mm) in their combined drift net, larval trawl dip net and beach seine sampling in Iron Gate (1998-99). Notably absent were the 3-5 cm size class that was present in J.C. Boyle.

## 2.0 CURRENT THREATS AND CONSERVATION NEEDS

The threats to the species are discussed below with the conservation needs that address each threat and the general status of the species relative to that threat (detailed discussions are presented in Appendix D Status). The specific status of the various populations are then discussed below by area (eg. Status: Upper Klamath Lake). Conservation needs, as understood in this context, are those actions or conditions necessary to bring an endangered or threatened species to the point at which protection under the Endangered Species Act is no longer necessary. The discussion below addresses the primary threats recognized at the time of listing and two additional threats recognized since listing, lack of passage and entrainment.

### 2.1 Loss of historical populations and reduction in range

> Conservation Need: Establish sufficient viable, self-sustaining populations in as much of the historical range as possible to provide resiliency for the species against localized extirpations (eg. prolonged drought, contaminant spills, disease and catastrophic water quality declines). Multiple populations also help ensure the diversity of the species and improve its ability to adapt to changing environmental conditions.

The Lost River and shortnose suckers were once very abundant and were critical food resources for Native Americans and white settlers in the upper Klamath River basin (Cope 1879; Gilbert 1898; Howe 1968). It was estimated that the aboriginal harvest at one site on the Lost River may have been 50 tons annually (Stern 1966). Settlers built a cannery on the Lost River and suckers were also processed into oil and salted for shipment. In 1900, the Klamath Republican newspaper reported that “mullet,” as suckers were referred to, were so thick in the Lost River that a man with a pitch fork could throw out a wagon load in an hour. In 1959, suckers were made a game species under Oregon State law, and snagging suckers in the Williamson and Sprague River was popular with locals and out-of-town sportsmen (Bragg 2001). By 1985, Bienz and Ziller (1987) estimated the harvest had dropped by about 95%. Based on this information, the game fishery was terminated in 1987, just prior to federal listing.

Historically, both LRS and SNS occurred throughout the Upper Klamath Basin, with the exception of the higher, cooler tributaries dominated by resident trout and the upper Williamson, which is isolated by the Williamson Canyon. At the time of listing, Lost River and shortnose suckers were reported from UKL, its tributaries, Lost River, Clear Lake Reservoir, the Klamath River, and the three Klamath River reservoirs (Copco, Iron Gate, and J.C. Boyle). The general range of both suckers had been substantially reduced from its historic extent by the total loss of major populations in Lower Klamath Lake, including Sheepy Lake, and Tule Lake (USFWS 1988). The Klamath River reservoir populations receive individuals carried downstream, but they are isolated from the upper Basin by dams and show no evidence of self-sustaining reproduction (Desjardins and Markle 2000). The current geographic ranges of the two suckers have not changed substantially since listing. Only two additional shortnose sucker and one Lost River sucker populations have been recognized. They all occur in isolated sections of the Lost River drainage, within the historical ranges of the species, and include an isolated population of SNS in Gerber Reservoir and a small population of each species in Tule Lake, limited to several hundred adults.

### 2.2 Habitat loss, degradation and fragmentation

> Conservation Need: Provide adequate habitat availability to meet the needs of all life-history stages in sufficient quantity to ensure recruitment and support viable self-maintaining populations.

The Klamath Basin has lost huge areas of emergent marshes and open lake environments that were previously used by suckers. Lower Klamath Lake no longer supports suckers, and available habitat in Tule Lake is now limited to a few hundred acres or less. Conditions in the Lost River have limited suckers to a few primary reaches of the river. In UKL emergent vegetation, crucial to larval and juvenile suckers, is greatly reduced in extent and often fragmented into isolated patches along the shoreline or left dry as lake levels drop. Current habitat availability and conditions in the Klamath Basin are greatly dependent on water management. In UKL availability of larval and juvenile habitat is constrained by lake level, with much of the available habitat lost by mid-late summer as water levels fall. Adult habitat is also limited by low summer/fall lake levels.

### 2.3 Small or isolated adult populations [reproduction]

> Conservation Need: Increase and maintain populations sizes to ensure genetic viability.

Populations in Tule Lake and the Lost River (Lost River sucker in particular) appear to have fallen to less than a thousand adult individuals. The primary limitation to these populations are habitat limitation by adverse water quality, sedimentation, impoundment, isolation from spawning areas and lack of significant recruitment.

The Clear Lake and Gerber Reservoir populations are each currently isolated by dams from the rest of the Klamath Basin. Although these populations appear to be maintaining themselves, each is subject to significant reduction during prolonged drought with no ability to replenish the gene pool through immigration of individuals from neighboring areas.

### 2.4 Isolation of existing populations by dams [passage]

> Conservation Need: Provide fish passage suitable to suckers.

There are nine primary dams within the natural range of the Lost River and shortnose suckers, none of which currently provides suitable passage for suckers. The dams physically isolate sucker populations, prevent genetic exchange, block access to essential habitat, cut off escape from adverse conditions downstream, and prevent the return of entrained suckers to upstream habitat and spawning areas. The proposed fish ladder at the Link River Dam is intended to allow spawning adults to pass the dam, but the smaller juvenile and sub-adult suckers will remain isolated downstream. Completion of the Link River fish ladder is not expected until at least January 2006.

### 2.5 Poor water quality leading to large fish die-offs and reduced fitness

> Conservation Need: Improve water quality to a level where adverse effects are not sufficient

to threaten the continued persistence of the species.

Water quality in UKL consistently reaches levels known to be stressful to suckers and periodically reaches lethal levels in August - September, resulting in catastrophic die-off events. Major fish die-offs have been recorded since the late 1800's but have increased in frequency in the last few decades. Small, localized fish die-offs have been observed annually on UKL since 1992 when extensive research and monitoring activities began. In the 1995, 1996 and 1997 a series of major fish kills reduced the adult population by 80-90%.

Water quality in Clear Lake and Gerber Reservoirs is primarily determined by shallow reservoir depths, which reduce available habitat and cause declines in dissolve oxygen, resulting in stress to the fish and reducing their general fitness. Available habitat in Tule Lake is severely limited by shallow depths and further limited by seasonal declines in water quality. All three areas are subject to potential winter fish-kills when shallow depths are associated with prolonged ice-cover.

### 2.6 Lack of significant recruitment

> Conservation Need: Increase frequency and magnitude of recruitment to a level sufficient to offset adult mortality and allow populations to reach sustainable levels.

Successful recruitment of substantial new cohorts into the UKL spawning populations has only occurred 2-3 times in the last seventeen years (1984-2001). During this time there have been four catastrophic, and many minor fish die-offs, caused by adverse water quality (see Status: Upper Klamath Lake). Recruitment in Clear Lake and Gerber Reservoirs appears to be maintaining viable populations. There is no evidence of successful recruitment in the small Tule Lake population or in the lower Klamath River reservoirs.

### 2.7 Entrainment into irrigation and power diversion channels

> Conservation Need: Substantially reduce entrainment of larvae, juveniles and adults to increase recruitment to the adult spawning population and reduce mortality of adults, both of which are necessary for the establishment of a viable, self-sustaining natural population.

Entrainment of suckers into Klamath Basin irrigation and power diversions is documented to account for the loss of millions of larvae, tens of thousands of juveniles, and hundreds to thousands of adult suckers each year. There are currently no fish screens at principal diversion sites that meet State or Federal screening criteria. Reclamation is currently in the final design phase for construction of a fish screen at the A-Canal, which should be operational by July 22, 2003. However, the proposed facility will not screen larval fish under about 30 mm, and so larval entrainment of suckers can be expected to continue. Suckers screened from entering A-Canal will still have to contend with entrainment just downstream at the Link River Diversions. The fact that adequate screening has not been provided anywhere within the Klamath Project after nearly a century of operation is considered by the Service to be a major factor imperiling and retarding the recovery of the two endangered suckers.

### 2.8 Hybridization with other Klamath sucker species

> Conservation Need: Maintain rates of hybridization appropriate to the evolutionary framework in which the suckers are evolving.

Hybridization was believed to be widely occurring in Klamath basin suckers and was considered a threat by the Service at time of listing. From 1997-2001 several different laboratories (OSU, UCD, and ASU) have utilized independent strategies to find morphological and genetic characters for resolving questions regarding reproductive isolation, classification, systematic relationships, and the extent of hybridization among Klamath Basin suckers. The preliminary evidence suggests that some hybridization may be natural within the Klamath sucker fauna, and hybridization may not represent as great a threat as was thought at the time of listing. However, the biological and conservation implications of hybridization, as well as the degree to which recent man-made changes to the Klamath Basin have altered the natural rate of hybridization, are still not resolved.

Hybridization was believed to be widely occurring in Klamath basin suckers and was considered a threat by the Service at time of listing (USFWS 1988). It was suspected that hybridization was indicative of a limitation of spawning habitat and resultant cross-fertilization of eggs (Williams et al. 1985). Koch and Contreras (1973) noted that suckers in the Lost River system were never morphologically distinct except for those in Clear Lake. Andreasen (1975) believed that some hybridization had occurred between LRS and KLS, and SNS and KLS, and had occurred to such an extent in the Lost River that the SNS was no longer present there as a distinct species. SNS in the Lost River system are atypical and resemble KLS, and have adapted to conditions in streams and small reservoirs there. Miller and Smith (1981) also suggested that the SNS from Clear Lake were introgressed with KLS; however, meristic data indicates these fish are SNS (M. Buettner, USBR, pers. comm. 1999). Ziller (1985), during studies on the sucker population status in the Sprague River reported that 8% of those suckers collected were “hybrids.” Bienz and Ziller (1987) later determined that 35% of suckers from the Williamson/Sprague River identified with some SNS characteristics were classified as “hybrids.” Miller and Smith (1981) considered that the SNS specimens they examined from UKL did not fit any of the recognized taxa, and could be SNS x KLS “hybrids.” Markle et al. (2000a) reported that 6% of the adult suckers collected in the lower Williamson River in 1999 were possible “hybrids.” Cunningham and Shively (2001) reported that 17% of suckers collected in the lower Williamson River in 2000 exhibited intermediate morphological states and were characterized as potential “hybrids”. An even greater percentage (31%, considered to be LRS x KLS “hybrids”) was collected in the fish ladder at the Chiloquin Dam (Shively et al. 2001). These values are considerably higher than the 1% “hybrids” found at shoreline spawning sites along UKL, which are dominated by LRS.

It is uncertain if the observed morphological intermediacy observed in some individual suckers is due to a natural tendency within the Klamath basin suckers for extreme phenotypic plasticity, close genetic relationships, hybridization, or a combination of these factors. Early allozyme studies failed to identify hybrids (Moyle and Berg 1991; Buth and Haglund 1994).

From 1997-2001 several different laboratories have utilized independent strategies to find morphological and genetic characters for resolving questions regarding reproductive isolation, classification, systematic relationships, and the extent of hybridization among Klamath Basin suckers. OSU has been studying sucker meristic and morphometric parameters and single copy nuclear DNA techniques. ASU geneticists are using mitochondrial DNA sequence variation methods and University of California, Davis researchers have evaluated allozyme, amplified fragment length polymorphisms (AFLP) and nuclear micro satellite methods.

Wagman and Markle (2000a) examined 28 randomly chosen loci, sequenced 10,421 base pairs, and found no fixed differences in four Klamath Basin sucker species. Some of the loci were much better markers for outgroup species, like the Klamath smallscale suckers from the Rogue River, than for the Klamath Basin suckers and suggested that the technique is useful. The authors concluded that, based on their investigation, the Klamath Basin sucker species are genetically similar. Similarity might be a result of hybridization and that hybridization could be a natural and necessary source of genetic variation which could provide survival benefits.

Tranah and May (1998, 1999) screened 66 allozyme loci and determined that there was a lack of sufficiently diagnostic variation to continue to use this method. The authors also tested AFLP techniques, which proved to be more diagnostic. A number of taxon specific markers were found for LRS and small-scale suckers including several population specific markers. One marker specific to an SNS was detected while no bands specific to large-scale suckers were found. Interspecific comparisons demonstrated that SNS and KLS, although distinct, are genetically very similar. The close genetic relationship of these taxa suggests either "recent" introgressive hybridization or recent speciation between these groups. Here "recent," refers to evolutionary history and could be tens of thousands of years or more. LRS from Clear Lake and UKL are very similar and form a distinct group that is more closely related to the SNS-KLS taxonomic cluster than to the small-scale sucker group. The Rogue River and Klamath populations of small-scale sucker form the most distinct group.

Mitochondrial DNA studies by ASU produced similar preliminary results, suggesting that all Klamath Basin suckers were similar genetically (Dowling 1999, 2000). Dowling surmised that all species have been influenced by hybridization in the past, with recent isolation obtained by KSS and LRS. SNS and KLS were similar and gene exchange among these forms apparently still occurs. LRS have retained substantial genetic distinctiveness, suggesting continued reproductive isolation.

OSU and ASU combined meristic and morphometric and mitochondrial DNA analyses of Klamath Basin suckers (Markle et al. 2000a). Based on these efforts, four species can be recognized, each with two or more recognizable geographic forms. Rogue and Klamath basin small-scale suckers differ in morphological characters associated with dorsal fin placement and in mtDNA. LRS and SNS from Lost River and Upper Klamath subbasins differed in meristic features. KLS had morphological and meristic differences between the Upper Williamson, Sprague and Lost River sub-basins and some individuals from the Upper Williamson had a unique mt-DNA haplotype. Hybridization rates may approach 10% for some populations.

Markle et al. (2000a) stated that all of the evidence supports the hypothesis that Klamath Basin suckers are part of a species complex or "syngameon." "Syngameons" are groups of interbreeding species that maintain their ecological, morphological, genetic, and evolutionary integrity, through natural selection, in spite of hybridization. Botanists have identified many examples of syngameons, which have been ecologically and evolutionary distinct for millions of years and hybridizing throughout (Templeton as cited by Markle et al. 2000a). The preliminary evidence suggests that some hybridization may be natural within the Klamath sucker fauna. However, the biological and conservation implications of this hybridization, as well as the degree to which recent man-made changes to the Klamath Basin have altered the natural rate of hybridization, are still not resolved.

### 2.9 Potential competition with and predation by non-native fishes

> Conservation Need: Ensure that the sucker populations can withstand the adverse effects of competition and predation from introduced fishes.

The Upper Klamath Basin presently contains 17 taxa of native fishes (Logan and Markle 1993b; Moyle 1976; Shively et al. 2000; S. Reid pers. comm. 2002). Of these, at least 13 are endemic taxa and found only in the Basin. At least 18 species of exotic fishes have been introduced and have established populations in the upper Basin. Little is known about the ecological and competitive interactions of the introduced fishes with the native suckers and this a major gap in our ability to assess their impact. Many of the fishes are predators which could prey on larval and juvenile suckers. One species of particular concern is the fathead minnow, *Pimephales promelas*. This small minnow first appeared in UKL in 1974 and has increased in abundance to where it is frequently the most abundant fish captured in both UKL and the Lost River (Simon and Markle 1997b, 2001; Shively et al. 2000b). Fatheads generally occupy the same near-shore habitat as larval and juvenile suckers and may be significant predators on larvae (Dunsmoor 1993; Klamath Tribes 1995). It is not practical to attempt removal of non-native fishes once they have become established. However, habitat management to the benefit of native suckers, especially larvae and juveniles, and recovery of the adult population to a point where reproduction offsets the adverse effects of competition will allow the suckers to sustain viable populations in the face of increased competition and predation.

### 2.10 Over harvesting by sport and commercial fishing

> Conservation Need: Reduce harvest to levels that allow for viable natural populations to maintain themselves.

The Lost River and shortnose suckers were once very abundant and were critical seasonal foods of Native Americans and white settlers in the upper Klamath River basin (Cope 1879, Gilbert 1898, Howe 1968). Sucker spawning migrations occurred in the spring at a critical time when winter food stores had been exhausted. The Klamath and Modoc Indians dried suckers for later use. It was estimated that the aboriginal harvest at one site on the Lost River may have been 50 tons annually (Stern 1966). Settlers built a cannery on the Lost River and suckers were also processed into oil and salted for shipment. In 1900, the Klamath Republican newspaper reported that “mullet,” as suckers were referred to, were so thick in the Lost River that a man with a pitch fork could throw out a wagon load in an hour. The first reference to sport fishing of “mullet” appears to be a 1909 reference to sportsmen snagging “mullet” in the Link River at Klamath Falls (Klamath Republican, Oct. 14, 1909). In 1959, suckers were made a game species under Oregon State law and snagging suckers in the Williamson and Sprague River was popular with locals and out-of-town sportsmen (Bragg 2001). By 1985, Bienz and Ziller (1987) estimated the harvest had dropped by about 95%. Based on this information, the fishery was terminated in 1987, just prior to federal listing. As a result of the regulatory termination of sport and commercial fishing, over harvest is no longer considered a current threat to the species.

## APPENDIX D - LIFE HISTORY OF LOST RIVER AND SHORTNOSE SUCKERS

This section provides biological/ecological information on the life history of the listed species relevant to formulating this BO. The information presented here is the basis against which the effects of the proposed action are measured over the life of the action.

This section of the BO was prepared using the best scientific and commercial information available from the following sources: 1) Reclamation's February 25, 2002, BA for this consultation (USBR 2002b); 2) April 2001 BO on operations of the Klamath Project (USFWS 2001); 3) Reclamation's February 13, 2001, BA (USBR 2001); 4) July 15, 1996, BO for PacifiCorp and New Earth operations, and Reclamation's BA for this consultation (USBR 1996a, Service 1996); 5) December 1, 1994, proposed rule for sucker critical habitat (Service 1994a); 6) August 11, 1994, BO for operation of Clear Lake (Service 1994b); 7) April 1993 final recovery plan for the suckers (Service 1993a); 8) July 22, 1992, BO on long-term operations of the Klamath Project, and Reclamation's February 28, 1992 BA (USBR 1992a, Service 1992a); 9) July 18, 1988, final rule listing the suckers as endangered (Service 1988); 10) recovery plans for Lost River and shortnose suckers (Service 1993); 11) communications with field researchers who have conducted, or are currently conducting, research on the listed suckers; 12) communications with Reclamation personnel and applicants; 13) peer review comments on the March 13, 2001 draft BO; 14) peer review comments on the April 5, 2001 final BO; 15) National Research Council, draft interim report from the committee on endangered and threatened fishes in the Klamath River basin (NRC 2002a); and 16) available scientific reports and publications pertinent to this consultation.

This section of the BO will cover the following two Klamath Basin species which are federally listed as endangered and are known to occur in the action area and may be affected: 1) shortnose sucker (*Chasmistes brevirostris*) (SNS), and 2) Lost River sucker (*Deltistes luxatus*) (LRS).

### 1.0 TAXONOMY AND DESCRIPTIONS

The LRS was described as *Chasmistes luxatus* by Cope in 1879, from specimens collected in UKL. Shortly afterward, Eigenmann (1891) described *Catostomus rex,* from the Lost River and Tule Lake. This species has been regarded as a synonym of *D. luxatus*. Seale (1896) created the monotypic genus *Deltistes* based on its unique gill raker morphology. Various authors have placed this taxon in either *Deltistes* or *Catostomus,* but currently *Deltistes* is the name most widely in use by fish biologists, including the American Fisheries Society and the Service (Andreasen 1975; Miller and Smith 1981).

The SNS was described as *Chasmistes brevirostris* by Cope in 1879, based on specimens from UKL. Fowler (1913) suggested that *C. brevirostris* should be transferred to the genus *Lipomyzon*, but this has not been accepted by later workers. Two additional nominal species, *C. stomias* and *C. copei*, were later described by Gilbert (1898) and Evermann and Meek (1898), respectively from UKL and vicinity. Andreasen (1975) believed that the Lake of the Woods sucker was a distinct species, *Chasmistes stomias,* it became extinct in 1952 owing to fish control operations. Both species were synonomized with *C. brevirostris* by Miller and Smith (1981).

Adult LRS can reach 39 inches in length (with females being slightly larger than males). Adult SNS are smaller, and are generally less than 20 inches in length. The various Klamath sucker species are best distinguished by multivariate discrimination utilizing lip morphology, vertebral counts, gillraker counts, and head shape (Markle and Simon1993). Cavalluzzi and Markle (OSU) have produced a key based on a suite of characters, including:

position of lip relative to maxilla, presence or absence of gap between lower lip lobes, lip fleshiness, lip position, and head and body shape. Nevertheless, field identification is often problematic due to the high degree of morphological variability expressed by the various species and an accurate identification is frequently dependent on the experience of the observer. Due to the similarity of the SNS and KLS (*Catostomus snyderi*), it is very difficult to make accurate field identifications.

## 2.0 HISTORIC AND CURRENT SUCKER DISTRIBUTIONS

SNS and LRS were undoubtedly present in Lake Modoc, the Pleistocene lake that inundated all of the upper Klamath Basin from Wood River to Tule Lake below 4240 ft elevation (Dicken 1980; Dicken and Dicken 1985). The lake outlet near Keno was at a much higher elevation than the current river, as flow was blocked below the 4240 ft. elevation. Lake Modoc had several interconnecting arms and was approximately 1,000 square miles in area and 75 miles in length. The lake began to dry up at the end of the Pleistocene about 10,000 to 12,000 years ago. UKL, Agency Lake, Tule Lake sumps, and Lower Klamath Lake are the major remnants of Lake Modoc. The absence of suitable lake habitat in the Klamath River, prior to the construction of dams, suggests that neither LRS nor SNS had substantial populations downstream of Keno.

During historic times, SNS and LRS were apparently very abundant and widespread in the Upper Klamath Basin including UKL and its lower tributaries; and the Lost River system, including Clear Lake, Tule Lake and Lower Klamath Lake (Andreasen 1975; Buettner and Scoppettone 1991; Cope 1879; Gilbert 1898; Miller and Smith 1981; Moyle 1976; Perkins and Scoppettone 1996; Scoppettone and Vinyard 1991; Scoppettone and Buettner 1995; Sonnevil 1972; Stine 1982; USFWS 1993a; Williams et al. 1985). KLS was also probably widespread in the Upper Klamath basin, and probably occurred in the Lost River system as well (Andreasen 1975; Buettner and Scoppettone 1990). LRS is recorded from UKL, its tributaries, including the Williamson, Sprague, and Wood rivers; Crooked, Crystal, Sevenmile, and Odessa creeks, and Fourmile Creek and Slough; the Lost River system, including Miller Creek and Tule Lake; and Lower Klamath Lake, including Sheepy Lake. The specific historical distribution of the SNS is less well understood because of its similarity to the KLS. However, SNS certainly occurred in UKL, its tributaries, and the Lost River system. The presence of the SNS in the Lost River drainage prior to construction of the Lost River Diversion Canal by Reclamation in 1912 has been questioned (Williams et al. 1985; Moyle 197; Scoppettone and Vinyard 1991; Service 1993a). However, the presence of SNS in both Clear Lake and Gerber Reservoir indicates they were native to the Lost River system prior to the dams, built in 1910 and 1925, which lack fish passage. While not recorded from Tule and Lower Klamath Lake specifically, the suitability of habitat and the open connectivity of these lakes with both UKL and the Lost River make it reasonable to assume that SNS was present throughout the Upper Klamath Basin as well.

At the time of listing, SNS and LRS were reported from UKL, its tributaries, Lost River, Clear Lake Reservoir, the Klamath River, and the three Klamath River reservoirs (Copco, Iron Gate, and J.C. Boyle). The general range of both suckers had been substantially reduced from its historic extent by the total loss of major populations in Lower Klamath Lake, including Sheepy Lake, and Tule Lake (USFWS 1988). Although a very small population of suckers has since been found in Tule Lake (see below). The current geographic ranges of the two suckers have not changed substantially since listing. Only two additional shortnose sucker and one Lost River sucker populations have been recognized. They all occur in isolated sections of the Lost River drainage, within the historical ranges of the species, and include a small population of each species in Tule Lake ( including the lower Lost River below Anderson Rose Dam), limited to several hundred adults for each species, and an isolated population of shortnose suckers in Gerber Reservoir.

The Lost River sub-basin contains major sucker populations physically and genetically isolated in two reservoirs, Clear Lake and Gerber. The Clear lake dam was built in 1910 and increased the size of an existing shallow lake. Both LRS and SNS, as well as KLS, are present in the Clear Lake reservoir and apparently occurred in the drainage prior to closure of the dam, which provides no fish passage. Gerber Reservoir was built by damming Miller Creek in 1925. Prior to construction of the dam, sucker populations in the inundated portion of Miller Creek were likely relatively small. LRS is not known from Gerber Reservoir and apparently was not present in upper Miller Creek when it was closed by the dam.

The majority of adult suckers in the Clear Lake basin probably reside in the reservoir itself and use the tributary streams primarily for spawning. However, the tributaries and smaller upstream impoundments provide essential rearing habitat and contain little-understood resident populations of suckers. In the Clear Lake watershed there are more than 30 small reservoirs, many being <100 acre-ft in size, that serve as stock ponds (USBR 1970a). Most of these reservoirs are shallow and become choked with macrophytes in summer (Buettner and Scoppettone 1991). Water depth is likely to be highly variable in these ponds and most become dry in mid- to late-summer during droughts. Koch et al. (1975) found SNS in a number of these upstream reservoirs, including Wild Horse, Avanzino, Boles Meadow, Telephone Flat, and Bayley; the largest population was in Wildhorse Reservoir. Buettner and Scoppettone (1991) reported SNS distribution in Clear Lake tributaries to include Boles, Willow, and Fletcher creeks, and in reservoirs upstream of Clear Lake which contain water in most years, including: East, West, Lower, and Middle Fourmile Valley, Boles, Weed Valley, Wildhorse, and Avanzino, with most SNS coming from Avanzino Reservoir and upper Willow Creek. Most of the SNS found upstream of Clear Lake during the non-spawning season are likely age 0 fish; however, during wet climatic periods, SNS may mature in tributary streams and reservoirs. These SNS likely mature at a smaller size than they do in Clear Lake where food is more plentiful. Reoccurring droughts probably eliminate fish from most of these reservoirs but they are later reestablished from Clear Lake and any other refugial areas. Distribution survey data revealed LRS in the California reach of lower Willow Creek and Boles Creek upstream to Avanzino Reservoir (Buettner and Scoppettone 1991), and in Fletcher Creek approximately 8 miles above Avanzino Reservoir (Perkins and Scoppettone 1996). In a distributional survey of the Clear Lake watershed conducted in the summers of 1989 and 1990, LRS were collected in lower Willow Creek and Boles Creek upstream to Avanzino Reservoir (Buettner and Scoppettone 1991). In late spring of 1993, sucker larvae were found in the north fork of Willow Creek where it crosses from Oregon into California, and in the headwaters of Fletcher Creek, approximately 8 miles above Avanzino Reservoir, near private land known as Mulkey Place (M. Yamagiwa, pers. comm.).

In the Gerber watershed, adult and juvenile suckers do not generally remain in the tributary spawning areas, since streams are often reduced to isolated pools or very low flows by the end of May. However, some apparently resident juvenile suckers (10-18 cm FL ), either SNS or KLS, have been documented in several Gerber Reservoir tributaries including Ben Hall, Barnes Valley, Long Branch and Lapham creeks, and adults appear to be frequently stranded by receding flows in pools, where a few may survive through the summer (A. Hamilton, pers. comm.).

## 3.0 DIET

LRS and SNS feed primarily on zooplankton and aquatic insect larvae (Buettner and Scoppettone 1990; Scoppettone et al.1995; Parker et al. 2000). LRS eat benthic chironomids (larval midges), while SNS feeds mostly on planktonic zooplankton, primarily cladocerans (*Daphnia* and *Chydorus* spp.). Both suckers appear to feed on the larger size classes of available invertebrate prey and also consume some detritus (Parker et al. 2000). Sucker larvae also appear to be omnivorous. It is not known what SNS feed on in rivers, but since zooplankton are less abundant, they may be more dependent on aquatic insect larvae.

## 4.0 LONGEVITY AND GROWTH RATES

Both LRS and SNS can be long lived, with LRS from UKL documented to reach at least 43 years of age, and SNS from Copco Reservoir reaching 33 years of age (Scoppettone 1988). Adult LRS can reach 39 inches in length (with females being slightly larger than males). Adult SNS are smaller, and are generally less than 20 inches in length. In their first year Klamath suckers have growth rates >0.5 mm/day, with LRS rates being somewhat higher than SNS, and rates positively correlated with ambient temperature (Simon et al. 2000). Larvae reach about 25-30 mm in July and are generally considered as young-of-the-year (YOY) juveniles above that size (Buettner and Scoppettone 1990, Simon and Markle 2001). By October of their first year LRS are about 70-100mm SL and SNS are slightly smaller at 50-80mm.

## 5.0 REPRODUCTION AND SPAWNING

### 5.1 Size at Maturity

Sexual maturity for LRS begins at about age 4+ and a minimum size of about 380 mm (size mode 465 cm FL) for males and age 7+ with a modal size of about 535 mm FL for females, when they begin to enter the spawning population (Buettner and Scoppettone 1990; Perkins et al. 2000a). Male and female SNS reach sexual maturity at 4+ years at a minimum size of about 270mm for males and 320mm for females ( modes 325 mm and 340 mm, respectively). Environmental conditions and growth rates vary and modal sizes of each year class may vary on the order of 50mm (Perkins et al. 2000a). Both species are highly fecund with 18,000-72,000 and 44,000-236,000 eggs being produced in one spawning season by female SNS and LRS, respectively (Perkins et al 2000a). Larger females produce substantially more eggs and therefore contribute relatively more to recruitment.

### 5.2 Spawning Areas

Klamath basin suckers can be grouped into three groups based on where they spawn. Adult SNS and LRS primarily occupy lake habitats, of these some migrate into tributaries to spawn (adfluvial spawners) while others spawn in suitable nearshore habitats, primarily springs, within UKL and perhaps in some reservoirs (lake spawners). There are also apparently some SNS and KLS that both live and spawn in streams, at least during years of adequate flow (stream resident). Adfluvial and lake spawning populations appear to rarely exchange individuals and may be reproductively isolated (Perkins et al. 2000a; Shively et al. 2000a; Hayes and Shively 2001).

Currently most of the LRS and SNS in Upper Klamath Lake spawn in the Williamson and Sprague River below Chiloquin Dam or in spawning sites upstream of the in the Sprague River including: Kirk Springs (also called Sucker Springs); Kamkaun and Lalo springs; S'Ocholis Canyon; and Beatty Springs (Larry Dunsmoor, Klamath Tribes, pers. comm. 2000). Small spawning populations of LRS and SNS may utilize the Wood River, based on adults caught in the river during the spring spawning season and larvae caught outmigrating (Markle and Simon 1993; Simon and Markle 1997; R. Shively, USGS, pers. comm.). Historically, sucker spawning also occurred in other UKL tributaries including Crooked Creek, Fort Creek, Sevenmile Creek, Fourmile Creek, Odessa Creek, and Crystal Creek (Stine 1982). Mike Dickenson (ODFW fish hatchery) apparently observed spawning runs of suckers several times in Crooked Creek, as late as 1987 (Roger Smith, ODFW, pers. comm. 2001). Over the last decade, exploratory surveys in the tributaries have been conducted in the spring (including visual, electrofishing, trap and trammel net surveys by Reclamation, USGS, Klamath Tribes, ODFW, Cell Tech and OSU), and no evidence has been found for current use of the tributaries for spawning.

Both LRS and SNS spawn at multiple shoreline sites of UKL especially near springs and in areas, mostly along the eastern shore with a gravel substrate (Buettner and Scoppettone 1990). Along the eastern shore of UKL spawning likely occurs at Sucker, Silver Building, Ouxy, and Boulder springs, and Cinder Flats (Shively et al.2000; Hayes and Shively 2001). Historically, suckers spawned at several locations along the western shore of UKL, e.g., Odessa and Harriman springs. Andreasen (1975) reported observing a few suckers spawning in Harriman Spring in 1974. These were apparently among the last suckers to use the spring since there are no later records. On the eastern shore, large numbers of suckers historically spawned at Barkley Spring in Hagelstein Park, but there has not been documented spawning there in the past few decades.

In the Lost River sucker spawning habitat is very limited. Spawning has been documented below Anderson-Rose Dam, in Big Springs, and at the terminal end of the West Canal as it spills into the Lost River. According to residents, sucker spawning at Big Springs is now rare but historically it was an important spawning site and was used as a major fishing site during the spawning migration by Modoc Indians (Klamath Echos). Suspected spawning areas that have suitable habitat (rocky riffle areas) include the spillway area below Malone Reservoir, just upstream of Keller Bridge, just below Big Springs, just below Harpold Dam, and adjacent to Station 48. Spawning has also been documented in Miller Creek, and is suspected in Buck Creek and Rocky Canyon Creeks (Shively et al. 2000b).

In the Clear Lake drainage, the only confirmed spawning habitat for LRS and SNS is Willow Creek and its tributaries (Buettner and Scoppettone 1991). In Willow Creek LRS spawned 3.7 to 5.5 km upstream from the lake while SNS traveled further upstream, 4.4 to 47 km (Buettner and Scoppettone 1991; Perkins and Scoppettone 1996). SNS migrate prior to spawning as far as Fletcher Creek and its tributary Bayley Creek, 47 km upstream from the lake (Perkins and Scoppettone 1996). These fish were not from Avanzino Reservoir which was dry the previous summer. In late spring of 1993, sucker larvae were found in the north fork of Willow Creek where it crosses from Oregon into California, and in the headwaters of Fletcher Creek, approximately 8 miles above Avanzino Reservoir (M. Yamagiwa, Modoc National Forest, pers. comm.). Some SNS have been tracked to near the mouth of Mowitz Creek, but spawning there could not be confirmed (Perkins and Scoppettone 1996). Mammoth Springs on the southeast side of Clear Lake may be an additional spawning site, but is as yet unverified (Koch and Contreras 1973). East Fork Willow Creek and Wildhorse Creek also may be used by suckers for spawning but this has not been confirmed.

In the Gerber Reservoir drainage, Barnes Valley Creek is the primary spawning tributary for the Gerber SNS population and is the only available spawning tributary during low precipitation or low runoff years. Spawning activity has been monitored by BLM at the CCC Road crossing annually since 1992 (USBLM 2000). Spawning migrations were documented in Barnes Valley Creek for all years. Spawning activity itself has been documented at or near the CCC Road crossing in the spring of all survey years except 1994, which was a year when stream flows were very low and of short duration. A concrete road crossing located in the lower portion of Barnes Valley Creek appears to have restricted passage under low flow conditions. BLM replaced the crossing in September 2000. Additional visual observations have been made at specific locations in the Gerber watershed over the course of a few dates each spring. The streams surveyed included Ben Hall, Long Branch, Pitch Log and Wildhorse Creeks. Sucker larvae were found in Ben Hall Creek in 1993, 1995, 1996, 1998, and 1999. Dry Prairie Dam located on Ben Hall Creek blocks passage to upstream spawning habitat depending on the flows and the timing of the placement of dam boards. Intermittent streams are suspected of providing additional spawning habitat, based on past observations of suckers in the headwaters of Ben Hall Creek. Long Branch and Pitch Log Creeks, tributaries to Barnes Valley Creek had evidence of sucker spawning in only 2-3 years. No spawning or documentation of larvae was observed in Wildhorse Creek, where a waterfall near the inlet to Gerber Reservoir appears to be impassable. Another Gerber tributary, Barnes Creek, is a small tributary that does not support known sucker spawning. This stream is seasonally dammed for irrigation and stock water purposes.

### 5.3 Timing of Spawning Activity

The timing of spawning migration is somewhat variable form year to year, and is apparently dependent on age, species, sex, and environmental conditions. Larger suckers and males appear to migrate earlier than smaller ones and females. LRS tend to spawn earlier than SNS (Andreason 1975; Ziller 1985; Perkins et al. 2000a). LRS may aggregate at spawning sites on the eastern shore of UKL as early as February. Temperatures at spring outlets where spawning occurs can be 10° C or more above ambient lake temperatures at that time (Andreasen 1975). Within the Sprague and Williamson River watershed, suckers begin their spawning migration as early as February (Markle 1993), with spawning activity often continuing well into May (Andreasen 1975; Buettner and Scoppettone 1990) or June, depending on flow regimes and temperatures. Spawning migration peaks between mid-April and early May (Andreasen 1975; Markle 1993; Perkins et al. 1997; Markle et al. 2000b; Perkins et al. 2000a). LRS and SNS numbers in the fish ladder at Chiloquin Dam in 1996 peaked in the first half of May (Klamath Tribes 1996); downstream movement peaked in late-May and early-June. In the lower Williamson River, spawning migration begins when temperatures reach about 5° C (Andreasen 1975), but peak migration is associated with water temperatures of 10-15° C (Perkins et al. 1997). LRS spawning in the upper Sprague River may be earlier than those in the lower Sprague or Williamson rivers (Perkins et al. 1997). Golden (1969) suggested that spawning in the Williamson River above the confluence with the Sprague River may be limited by temperature, which remains relatively cool year-round owing to a large spring influence.

Along the eastern shore of UKL likely spawning occurs at Sucker, Silver Building, Ouxy, and Boulder springs, and Cinder Flats, and in 2000-2001 extended from late-February to early June (Shively et al.2000; Hayes and Shively 2001).

Spawning runs of adult LRS and SNS up Willow Creek, a tributary of Clear Lake, primarily occurred in February and March, depending on ice and flow conditions, but extended to April and June, respectively (Perkins and Scoppettone 1996). LRS spawning migration begins when water temperatures are 4-8° C, while SNS migration starts when temperatures reach 7-10° C.

In Gerber Reservoir tributaries peak adult migration occurs near May 15 in most years (USBLM 2000). The duration of adult migration is estimated to be between three and four weeks, depending on flow conditions. The timing and duration of flow events are highly variable, and successful reproduction appears to be dependent upon coincidence of runoff events and spawning readiness (A. Hamilton, pers. comm.). Spawning usually occurs during periods of rapidly dropping hydrographs. Larval out-migration generally occurs between May 15 and June 5.

### 5.4 Spawning Habitat Characteristics

LRS and SNS typically spawn in areas with gravel substrate where eggs are broadcast or slightly buried (Perkins et al. 2000a). In gravel substrates, eggs are deposited in the top several centimeters, and between the spaces in larger cobble. However, eggs may be carried downstream where fine sediments have filled inter-cobble spaces. Observed velocities over stream spawning gravels have ranged from 0.01-0.85 m/s (LRS) and 0.7-1.2 m/s (SNS) (Buettner and Scoppettone 1990, 1991; Perkins and Scoppettone 1996). In the lower Williamson/Sprague rivers, SNS were found mainly spawning in the downstream areas of pools and riffles in gravel substrates (Bienz and Ziller 1987). Egg predation by flatworms, fish, and other predators may be significant (Klamath Tribes 1995), but its impact has not been assessed.

Water depth for most stream spawning sites ranges from about 0.4-4.0 ft (Buettner and Scoppettone 1990, Perkins and Scoppettone 1996). In the Williamson/Sprague spawning sites spawning depths ranged from 11-70 cm for both species, with over 90% occurring in 11-50 cm for LRS and about 95% in 20-60 cm for SNS (Buettner and Scoppettone 1990). Stream spawning sites surveyed in Willow Creek (Clear Lake) ranged from 30-130 cm (Perkins and Scoppettone 1996).

Water depth for most lakeshore spring spawning sites ranges from about 1.0-4.0 ft. In 1995, the Klamath Tribes conducted an intensive sucker spawning survey at Sucker Springs (Klamath Tribes unpub. data, cited in Reiser et al. 2001). This survey documented sucker spawning in water depths of 0.5-3.7 ft. However, over 95% of successful spawning, as indicated by embryos and emerging larvae, occurred at depths greater than1.0 ft, with about 35% at 1.0-2.0 ft. Nighttime visual observations made at the springs on numerous occasions over the last decade using night vision equipment (M. Buettner, USBR, pers. comm.) support the above spawning depth preference observations.

## 6.0 LARVAL BIOLOGY

The early life-history of LRS, SNS and KLS were described by Buettner and Scoppettone (1990). LRS and SNS eggs vary from about 2.5 to 3.2 mm in diameter. Upon hatching sucker larvae are 7-9 mm total length (TL), mostly transparent, and have large eyes and a terminal mouth. A yolk sac is present up to a length of about 12 mm. Up to this size the larva is referred to as a “protolarva.” The next stage of development is the “flexion mesolarvae” stage which is characterized by absorption of the yolk sac; development caudal fin rays; upward flexion of the notochord; and more extensive dorsal pigmentation. The mesolarva continues to develop fins. By the “metalarva” stage at 18-28 mm TL, a full complement of median fins rays are present as well as the preanal finfold. By about 30 mm, when the preanal finfold is absorbed and all fins rays are developed, the larva transforms into the juvenile stage.

Data from studies done at the Klamath Tribe’s Braymill Hatchery on the Sprague River indicate that LRS incubated at a mean temperature of 14.4° C require an average of 136 thermal units (TU), or nine days to hatch. A “TU” is equal to temperature x days. Swim-up required 278 TU, or 19 days. SNS incubated at 15.3° C required 89 TU or six days for hatching and 250 TU or 16 days for swim-up (Dunsmoor, cited in Perkins and Scoppettone 1996). Therefore, after an approximate 2-3 week incubation and hatching period, larval suckers move out of spawning substrates and enter the water column.

Larval fish need to begin feeding before they exhaust their yolk or they starve. It has been shown for other fish that larval survival, and subsequent year class strength, can be determined by the availability of suitable food during this critical period (e.g., Crecco et al. 1983 as cited by Klamath Tribes 1996). Yolk reserves are gone or nearly so by the time the LRS and SNS become flexion mesolarvae. Gut fullness was evaluated on sucker larvae to determine whether they were finding adequate food in the lower Williamson River before entering the lake. In 1989, frequency of full guts was substantially higher in mid-June than mid-May at river kilometer (rkm) 0.1 (Klamath Tribes 1996). Twenty-five percent had empty guts in May while almost none were empty in mid-June. However, in 1995, 76% and 88% of larval suckers collected at rkm 0.7 had empty guts on June 8 and June 15-16 respectively (Klamath Tribes unpub. data).

In 1998, larvae from drift samples in the river seldom had food in the gut, particularly larvae from Modoc Point bridge (Cooperman and Markle 2000). At the lower Williamson River station only 3% had food during May 25-29 compared to 16% during June 15-19, and gut fullness was mostly rated low for larvae with food. Most of the larvae captured from daytime pop netting in the Williamson River had empty or low gut fullness indices compared to mostly medium to high gut fullness in lake-captured fish (Cooperman and Markle 2000). Flexion larvae across river and lake zones show a dramatic difference in gut fullness, with the lake-caught larvae much more likely to have food in the gut.

It is suspected that larval suckers subsist mainly on zooplankton, and that larval survival is likely greatly influenced by the degree of coincidence between zooplankton bloom formation and larval entry into nursery areas (Klamath Tribes 1996). High densities of larval suckers may not be able to rear in the lower Williamson River until food production increases, which may explain why postflexion mesolarvae were virtually absent at rkm 0.1 in May, but were present in June of 1989. In 1995, post-flexion mesolarvae and metalarvae were absent from June samples but present in July (Klamath Tribes, unpub. data). Littoral macrophytes may support a more diverse assemblage of small-bodied zooplankters, those that would be useable as food for larval suckers, than open water areas (e.g., Wetzel 1983 as cited by Klamath Tribes 1996). This may be one reason for the disproportionate use of the emergent vegetation zone by sucker larvae.

The Klamath Tribes conducted a study in 1999 to assess the effects of starvation on larval sucker growth and survival (Klamath Tribes, unpub. data). The preliminary results show that a 3-day delay in the onset of feeding results in a statistically significant decrease in both burst swimming speed and in body depth. After six days without feeding, burst speed was almost half of that of fed larvae, and by nine days, a broad array of starvation effects were evident including: reduction in body depth and length; smaller eye diameter; fewer developing fin rays; and reduced burst speed. Thus, it is clear that sucker larvae deprived of food begin showing adverse effects after 3-6 days. Weakened larvae would likely be less able to feed and avoid predators and, as a result, survivorship of starved larvae may be reduced.

Researchers have consistently observed sucker larvae with empty guts in the lower Williamson River (Cooperman and Markle 2000; L. Dunsmoor, pers. comm.). If early feeding minimizes starvation and reduces vulnerability to predation, larval sucker survivorship would be improved by facilitating transport of larvae through the Williamson River and into UKL. Restoration of the emergent wetland/riparian habitat in the lower Williamson River area may also support greater food resources for sucker larvae. Efforts are currently underway by TNC and other partners to restore the historic form and function of the lower Williamson River Delta. It is hoped that this restoration will benefit larvae.

Numbers of emigrating sucker larvae at Clear Lake were estimated by Perkins and Scoppettone (1996) for 1993 -1994. Numbers of LRS larvae ranged from about 0.5 to 1 million, while SNS larvae ranged from 0.01 to 12 million. In 1995 total emigrating sucker larvae numbered about 2.5 million. Estimated survival from egg to larvae ranged from 1 to 10% for both SNS and LRS.

### 6.1 Larval Out Migration

Larvae of adfluvial sucker stocks that spawn in tributaries may spend relatively little time upriver before drifting downstream to the lakes (Buettner and Scoppettone 1990; Cooperman and Markle 2000). In the Williamson River, larval sucker out-migration from spawning sites can begin in May and is generally completed by the end of July.

Intensive larval sucker emigration studies were conducted during 1987, 1988, and 1989 in the lower Williamson River (Buettner and Scoppettone 1990; Klamath Tribes 1996). Estimated total numbers of emigrating sucker larvae at rkm 9.8 were 14, 35, and 73 million for 1987, 1988, and 1989, respectively. In 1989, an additional estimate of the number of emigrating larvae entering UKL was made. Only 4.9 million larvae were estimated at rkm 0.1 from May 1-June 28, 1989.

Timing of larval emigration was assessed during four years using drift nets (1987 and 1988 - Buettner and Scoppettone 1990; 1989 - Klamath Tribes 1996, 1998; Markle et al. 2000b). Date of first sucker larvae capture for all years was during the first week of May. However, during 1989 substantial numbers of suckers were captured on the first sample day. Peak emigration in the lower Williamson River was as early as mid-May (1987) to as late as mid-June (1998). Substantial numbers of larvae were captured from mid-May to mid-June during all four years. Larval drift was very low by the sampling ending dates (that ranged from June 28 to July 15).

In 1998, OSU monitored larval emigration at the Modoc Point Road bridge on the lower Williamson River (rkm 8). Larval drift sampling began on May 5 and larval suckers were first captured on May 17. However, sucker larvae were first observed in the lower Williamson on May 5, 1998 (Cooperman and Markle 2000). The last larval sucker captured in the drift net was July 15. Two peaks in larval abundance were documented, at the end of May and middle of June (Markle et al. 2000b). This compares to peak emigration in 1987-1989 ranging from early May to mid-June (Buettner and Scoppettone 1990; Klamath Tribes 1996).

In 1998, larval sucker movement through the lower Williamson River, as measured by density of larval suckers in drift samples, was largely restricted to 2100-0500 hr with a peak about 0300 hr (Cooperman and Markle 2000). This corresponds closely with diel sampling by Buettner and Scoppettone (1990). Perkins and Scoppettone (1996) found in Willow Creek (Clear Lake) that larvae emigrated in some numbers throughout the night but peaked near midnight. Larvae appear to move to the river margins, perhaps to seek cover, during the day (Klamath Tribes 1996).

All three developmental stages of sucker larvae (protolarvae, mesolarvae, and metalarvae; Snyder and Muth 1988 as cited by the Klamath Tribes 1996) were observed in the Williamson River in 1989 (Klamath Tribes 1996). Each developmental stage lasts about 2-4 weeks. Sucker larvae from mid-May at rkm 9.8 were about 63% protolarvae and 37% flexion mesolarvae while in mid-June protolarvae and flexion mesolarvae were 25% and 75% respectively. Most of the larvae entering the lake in 1989 were flexion mesolarvae (early development stage of mesolarvae), while a small proportion of the emigrating larvae had taken up residence near the river mouth and had developed into postflexion mesolarvae (late development stage of mesolarvae) by mid-June. On June 8 and June 15-16 1995, mostly flexion mesolarvae (11-13mm TL) were collected from pop net samples at rkm 0.7 on the Williamson River. On July 21, approximately 20%, 50%, and 30% were flexion mesolarvae, postflexion mesolarvae, and metalarvae, respectively.

In 1998, 83% of the larvae captured in drift net samples at Modoc Point Road bridge were protolarvae and 17% flexion mesolarvae (Cooperman and Markle 2000). In the lower Williamson River near the mouth 49% were protolarvae and 51% flexion mesolarvae. No post-flexion mesolarvae or metalarvae were collected in drift net samples at the Modoc Point Bridge. Very few larvae were captured in pop net sampling near the mouth.

The Klamath Tribes monitored wind direction and strength in 1989, and found that wind influenced the cross sectional distribution of larvae at the water's surface near the mouth of the Williamson River (Klamath Tribes 1996). On nights when the wind was blowing parallel to the channel, larvae were symmetrically distributed across the channel with the most in the middle and the fewest on the edges. However, when the wind was strong and blowing to the east, perpendicular to the channel, larval distributions were strongly skewed to the eastern channel and shoreline. It is likely, therefore, that wind influences larvae movements and distribution in UKL. Since larvae are relatively weak swimmers, this seems reasonable.

Larvae caught in the Williamson River were primarily preflexion (>93%), those in the lake were primarily postflexion (>94%), and flexion stage larvae were about equally abundant. This suggests that larvae quickly leave the river at or near flexion, possibly in as little as a day or two (Cooperman and Markle 2000). Lake larvae had fuller guts than those from the river indicting that food may be more abundant in the lake than in the river. During the daytime, 90% of the larvae were collected in emergent vegetation. There is some evidence that larval drift may vary with lunar phases (Markle and Simon 1993, Guthermuth 1998).

In 1998 and 1999, OSU biologists studied larval sucker biology in the area of the lower Williamson River and adjacent UKL (Cooperman 1999; Cooperman and Markle 2000; Markle et al. 2000b). Larvae first appeared in the lower river when water temperatures reached 11° C. There were two peaks in abundance, one in late-May and another in mid-June; low but steady production levels extended into early July. Simon et al. (2000) found that median egg hatch dates for juvenile suckers collected in September was early June, meaning that about 50% of the juveniles came from the relatively small fraction of larvae detected after June 15th.

Bienz and Ziller (1987) reported that sucker larvae in the lower Williamson River were not seen until mid-May in 1983 and 1984. They found no larvae upstream on the Williamson above the confluence with the Sprague River. Peak larval emigration was the first week of July.

OSU biologists also found that sucker larvae were present in drift net samples in the lower Williamson River only between 2100 and 0500 hrs and peaked at 0300 hrs, suggesting that drift is confined to a brief 4-hr period at night; however, alternate dispersal mechanisms are possible (Cooperman and Markle 2000).

OSU systematically monitored larval sucker distribution and relative abundance in UKL from 1995-1999 using larval trawl methods (Simon et al. 2000a). Larval suckers were first captured in late April during most years, peak catches occurred in June, and densities dropped to very low levels by late July.

Sucker larvae have been observed in UKL at Sucker Springs as early as April 1 (M. Buettner, USBR, pers. comm.). Simon et al. (1996) observed substantial numbers of larvae on April 4, 1995, during shoreline searches. Essentially all sucker larvae have transformed to juveniles by the end of July (Simon et al. 2000a).

Larval suckers were distributed throughout Upper Klamath and Agency lakes from 1995-1999 (Simon et al. 2000a). Catch rates were usually highest at the mouth of the Williamson River or Goose Bay. They were also relatively high near Hagelstein Park in most years. Other sites that occasionally had high numbers include Howard Bay (1996), Ball Bay (1999) and Stone House (1999). Very low catch rates were experienced in Agency Lake from 1995-1999.

Cooperman and Markle (2000) documented substantial numbers of sucker larvae in the area west of the Williamson River mouth. It was previously assumed that few larvae occurred in this area because the Williamson River typically flows east towards Goose Bay. Pop net catches were several times higher for this site than Goose Bay in June 1998. However, later in the season the Goose Bay area had larger numbers of advanced larvae and juveniles.

At the Link River, larval suckers have been collected as early as April 28th and as late as July 18th (Gutermuth et al. 1999). Collection of some early-stage larvae at the Link River suggests that some spawning occurs nearby at undetected sites or that wind-driven currents rapidly transport larvae down the lake and into the Link River.

In Willow Creek (Clear Lake Basin), emigration of LRS larvae begins around April 1 and lasts until about mid-May (Perkins and Scoppettone 1996). Some SNS stay in the streams and emigrate to Clear Lake as juveniles. Very little is known about the early life history of stream-resident suckers but it appears that it is completed in natal streams.

## 6.2 Larval Rearing Habitat in Upper Klamath Lake

Larval fish produced at lake shoreline and tributary stream spawning areas may be present from March through July (Simon et al. 1996; Simon et al. 2000b). Larval habitat in UKL is generally nearshore in water less than 50 cm deep and generally associated with emergent aquatic vegetation or some form of structure such as logs or large rocks (Buettner and Scoppettone 1990, Markle and Simon 1994; Klamath Tribes 1995, 1996; Cooperman and Markle 2000; Reiser et al. 2001). Buettner and Scoppettone (1990) found that about 85% of larval suckers were found in water depths between 0.3 and 1.6 ft. Emergent vegetation provides cover from predation by fathead minnows, sculpins, and other fish, protection from currents and turbulence caused by wind and wave action, and complex structure for prey including zooplankton, macroinvertebrates, and periphyton (Klamath Tribes 1996). In UKL, larvae appear to be concentrated near the mouth of the Williamson River, in Goose Bay, and may also be common in the lower Wood River. These sites are near known spawning areas. Dunsmoor found larval densities as high as 16 larvae/square meter in Goose Bay emergent vegetation (Klamath Tribes 1995).

In 1998, OSU documented that sucker larvae in pop net samples were much more abundant in emergent macrophytes than in woody vegetation such as willows, and unvegetated areas (Cooperman and Markle 2000; Cooperman 2002). Woody vegetation and unvegetated sites had similar densities. Also, there was no significant difference in numbers of suckers caught in *Sparganium* (bur-reed) and *Scirpus* (bulrush) vegetation types.

Habitat utilization studies on sucker larvae have indicated that high densities occur in the shallow littoral areas (Buettner and Scoppettone 1990; Klamath Tribes 1991, 1996; Markle and Simon 1993; Simon et al. 1995, 1996). Microhabitat studies by the Klamath Tribes and OSU determined that sucker larvae generally occurred at higher densities in and adjacent to emergent vegetation than areas devoid of vegetation (Klamath Tribes 1996; Cooperman and Markle 2000).

Larvae do not appear to use submerged vegetation as an alternative to emergents (Cooperman 2002).

Dunsmoor et al. (2000) quantified potential larval habitat adjacent to the Williamson River mouth. It is believed that larvae emigrating from the Williamson River move east and then south along the shoreline. Because of the large numbers of spawning adult suckers in the Williamson River, the area around the river mouth is believed to be crucial nursery habitat for sucker larvae. As discussed above, aquatic emergent macrophytes may provide an important refuge and feeding area for larvae. The structural complexity provided by the vegetation may provide protection from predators, waves, and currents, and may have an increased diversity of zooplankton prey (Dunsmoor 1993; Klamath Tribes 1995).

Channelization and diking in the lower Williamson River straightened the channel, eliminating natural meanders and associated wetlands that would be more productive of larval sucker food available while in transit to the lake. Combined with channel deepening and reduced flow velocities, first-feeding larvae may be deprived of a critical food supply as evidenced by the frequency of empty guts that has been observed (Cooperman and Markle 2000).

Sucker predation by fathead minnows (*Pimephales promelas*) in the laboratory was greatest at shallow water depths (1 ft) when larvae lacked cover (Dunsmoor 1993, Klamath Tribes 1995). Diurnal predation by a variety of visual predators likely explains why larvae drift in the river at night and are found in aquatic vegetation in UKL during the day. Historically the margins of

UKL were much more extensively vegetated but alterations resulting from diking and water level management have reduced vegetated acreage by about 40,000 ac. Based on larval needs for emergent vegetation for cover, Klamath Tribes (1995) recommended that water level elevations at Goose Bay, east of the Williamson River mouth, reach 4142.6 ft on June 1 and 4141.6 ft on July 15, inundating 70% and 28% of emergent habitat, respectively. A similar conclusion was reached in data analyses by Reiser et al. (2001).

Dunsmoor et al. (2000) found that three emergent plant species dominated near the Williamson River mouth: hardstem bulrush or tule (*Scirpus acutus*), knotweed (*Polygonum coccineum*), and river burr-reed (*Sparganium eurycarpum*). A strong positive relationship was found between the width of the vegetation zone and the shore cross-sectional area; thus more vegetation was present in areas where more suitable cross-sectional habitat was present. The vegetation was limited by steep slopes and greater depths. Also, the amount of wave energy reaching the shoreline was determined to limit emergent vegetation, especially affecting the distribution of the river burr-reed. Of special concern was the observation that extensive areas of shoreline were devoid of emergent vegetation. One critical shoreline is the area east of the Williamson River mouth. Here vegetation was sparse and consisted mostly of knotweed. The study concluded that essential "stepping stones" of existing emergent vegetation be maintained to link the Williamson River mouth with more extensive vegetated shorelines east of Goose Bay.

The importance of bottom substrate for sucker larvae is unknown. Most sites where sucker larvae are found have sand or gravel/cobble substrates. However, substrate along the Tulana shoreline west of the Williamson River where high densities of larvae have been found is mostly peat. Since larval suckers are mostly distributed in the upper part of the water column (Buettner and Scoppettone 1990) substrate may not be a critical habitat parameter, except as it affects rooted vegetation.

Water quality associated with larval sucker distributions was monitored in 1996 by OSU during larval fish trawling. Similar to 1995, larval suckers were found in pH ranging from 7 to 10.3 (OSU, unpub. data). Larval suckers were captured at DO concentrations ranging from 4.5-12.5 mg/l, with most occurring at sites with DOs from 5.5-10.5 mg/l (OSU, unpub. data). These results are similar to those documented in 1995 (USBR 1996a). No sucker larvae were sampled at the few sample sites where DOs were 3.5 mg/l. With this exception, the distribution of DO values where larval suckers were found paralleled the DO values at all sampling sites.

Studies on larval entrainment at A-canal showed that large numbers of larvae are also present at the lower end of the lake, as mentioned above (Gutermuth et al. 1998, 1999). It seems likely that these larvae are the result of water movement from known spawning sites, e.g., in the Williamson River or in springs along the UKL eastern shore.

Larval sucker ecology and habitat use in Clear Lake and Gerber Reservoirs is unstudied at present. Permanent emergent vegetation is generally scarce or absent along the reservoir shorelines. However, some vegetative cover may be provided by flooded annual grasses and herbs remaining from the previous growth season prior to lake level rising in the spring. Additional cover may be provided by high turbidity, and larvae may utilize shallow shoreline areas to avoid predators. The lower reaches of the primary spawning tributaries do provide emergent shoreline vegetation and extensive submerged during the spring and early summer when larvae would be present. Desjardins and Markle (2000) found that larvae in Copco Reservoir did not show preference for vegetated versus non-vegetated sites; however the presence of abundant exotic fish predators may have dominated distributions, and there was little, if any, survival of larvae past June.

## 7.0 JUVENILE HABITAT

Juvenile sucker (suckers of 2.5-10 cm total length) habitat is generally in nearshore areas less than 1.3 m in depth, mostly less than 50 cm deep (Markle and Simon 1993; Reiser et al. 2001, Simon et al. 2000b; Simon and Markle 2001; VanderKooi 2002; Vincent 1968). Juveniles in unvegetated habitats appear to avoid pure sand and softer mud or organic substrates and occur primarily over rocky substrates including rock, gravel, and over gravel and sand mix. From 1995-2001, age 0 sampling by OSU was based on random monitoring of specific habitat types to provide habitat-specific densities. Highest age 0 sucker densities were found over small mix and gravels and lowest densities were found over fines, sand, and boulders (Simon et al. 2000a, Simon unpub. data 2002). The low catches over boulder substrates may be associated with poor sampling efficiency using cast nets. Diverse substrate types are found mostly in the shoreline areas (<10 m from high-water mark). Fine particle substrates ("muck") occupy the vast majority of the offshore areas.

The use of difficult-to-sample vegetated habitats is not well understood; however, recent evidence suggests that emergent vegetation may provide important habitat for juvenile suckers. The juvenile monitoring by OSU focused on mostly unvegetated locations due to sampling difficulties associated with vegetated areas. However, the Klamath Tribes have observed age 0 juvenile suckers in emergent vegetation along the lower Williamson River and Goose Bay (L. Dunsmoor, Klamath Tribes, pers. comm.), and limited sampling by Reiser et al. (2001) also found juvenile LRS in vegetated areas, with about 75% (31 fish) of the juvenile suckers they caught coming from a single site at the outlet of Short Creek and 20% (8) from the east side of Agency Straits. In a more extensive study, USGS conducted trap net surveys in emergent vegetation (predominately *Scirpus*) and adjacent unvegetated areas during summer 2000 and 2001 (VanderKooi 2002). Catch rates varied considerably by location and date, but generally showed substantial use of both vegetated and unvegetated shoreline habitats by juvenile suckers. In the Goose Bay and Modoc Point sampling areas, about 50-80% of the juvenile suckers were caught in the emergent *Scirpus* habitat versus open water habitats. In contrast, along the shoreline east of the mouth of the Williamson 80% of the suckers were caught in open water habitat just offshore of emergent vegetation banks. Very little information is available on distribution of juvenile suckers in extensive stands of emergent vegetation at Hanks Marsh and Upper Klamath Marsh. During four seasonal sampling periods in Thomason Creek, which flows through Upper Klamath Marsh, Hayes and Shively caught only six unidentified juvenile suckers in the channel, out of a total of 3,117 fish (Hayes and Shively 2002a). OSU also captured very few juvenile suckers adjacent to shoreline marsh habitats on the northern margin of UKL, and along the marsh at Squaw Point, Shoalwater Bay, and Hanks Marsh; however they were not sampling within the vegetation itself (Simon et al. 2000b).

Water quality associated with age 0 suckers has been monitored annually since 1994 (Simon et al. 1995, 1996; OSU, unpub. data). Distribution of dissolved oxygen (DO) and pH for all samples and those samples containing suckers from beach seine, cast net and otter trawls have been generally similar, indicating no obvious preference or avoidance of certain water quality conditions. In sampling vegetated and nearby openwater habitat VanderKooi (2002) found preliminary indications that DO concentrations and catches of juvenile suckers by area were positively related.

Spatial and temporal distribution of juvenile suckers in UKL has been studied through an intensive systematic monitoring program during the summer and fall from 1995-2001 (Simon et al. 2000b; Simon and Markle 2001, Simon, unpub. data 2002). Juvenile suckers were collected from throughout UKL at fixed sites using beach seines and from stratified randomly selected sites using cast nets and otter trawls. Consistently high beach seine catch rates of juveniles were documented for the mouth of the Williamson River, Goose Bay, and Modoc Point for most years; high densities also occurred at Howard Bay (1996), Hagelstein Park (1999) and Stone House

(1999). Agency Lake and most stations on the west side of UKL are generally low, and from 1995 - 2001 beach seining CPUE of Age 0 suckers in Agency Lake declined from about 5 to zero. Most Age 0 suckers caught in the beach seine are SNS. Cast net sampling show that age 0 suckers are concentrated primarily in the south end of UKL in the late summer and fall as well as along the eastern shoreline from Modoc Point to Hagelstein Park and in the Shoalwater Bay/Ball Bay region.

Within UKL, there has been a strong decline in catches of Age 0 suckers from August to September/October in OSU's sampling every year from 1995-2001 (Simon and Markle 2001; Simon, unpub. data 2002). Catches of juveniles in emergent vegetation also declined significantly near the end of August in both 2000 and 2001, coinciding with lake level dropping below 4140 ft (VanderKooi 2002). Near 4140 ft vegetated *Scirpus* habitat becomes increasingly unavailable as water level drops and at 4140 ft is essentially unavailable (Reiser et al. 2001). The late summer declines in juvenile abundance are associated with substantially increased entrainment of Age 0 juveniles into the A-canal and Link River diversion channels during the same period. Gutermuth et al. (1999, 2000) has found relatively large numbers of juvenile suckers in Link River diversion canals, and Reclamation biologists have also salvaged considerable numbers of suckers in canals leading from the A-Canal at the Link River (USBR 1997, 1998a, 1999, 2000b, 2002a). Gutermuth et al. (2000) suggested that large numbers of juvenile suckers moving into, or entrained into, the diversion canals at the lower end of UKL might be the result of a downstream dispersal behavior in late summer. However, it is currently uncertain as to whether the increased entrainment is due to a juvenile outmigration or to increased entrainment caused by increased concentration of juvenile in habitat provided by the south end of UKL.

Markle and Simon (1994) did some juvenile sucker sampling in Gerber Reservoir. Large numbers of juveniles were collected in June, suggesting spawning may occur earlier there than in UKL. Markle and Simon suggested that owing to better transparency of Gerber Reservoir water, juvenile suckers may move into deeper water before those in UKL.

## 8.0 ADULT HABITAT USE

LRS are generally limited to lake habitats when not spawning, and no large populations currently occupy riverine habitats. S.S., on the other hand, appears to be a lacustrine/reverie facultative species, with resident populations in some reverie habitats, including: Lost River, Miller Creek, Willow Creek, and other tributaries of Clear Lake and Gerber Reservoir.

Cover is a primary habitat feature required by most fish. For fish like lake suckers that primarily occupy open water, depth and turbidity provide needed cover. In streams, while deeper pools provide some cover, additional cover is provided by instream and overhanging structure. In tributaries to Clear Lake, LRS were found only in pools greater than one meter deep (Buettner and Scoppettone 1991). Perkins and Scoppettone (1996) found adult SNS in Willow Creek resting in the bottom of pools and used undercut banks, overhanging shrubs, and algae as cover. Habitat use by suckers in the reservoirs is poorly understood. Buettner and Scoppettone (1991) noted that suckers were caught at depths of 1.0-2.5 m in Clear Lake and were most abundant in the northeast section and sparse elsewhere.

Adults, and probably subadults, of both species are bottom-oriented. Depth sensors built into radio-tags (5 LRS and 3 SNS; 96 locations) showed that adult suckers consistently swam less than 1 ft above the bottom (USBR 2000d; Reiser et al. 2001). If suckers occupy only the near-bottom water column, then deeper waters of UKL (>15 ft) may not be available to suckers in summer months due to frequent occurrence of low bottom DO concentrations. The depth/habitat patterns of smaller subadult suckers (age 1+) are not known. However, it is reasonable to assume that they too are generally bottom associated as are similar-sized suckers of other species.

## 8.1 Water Depth

Whereas larvae and juvenile sucker primarily use shallow shoreline habitats, adult suckers are mainly found at deeper depths. For fish like lake suckers that primarily occupy open water, depth and turbidity provide the only available cover. Radio-telemetry data has provided data on the depth distribution of adults in UKL. In spring and summer months 95% of individual locations were in areas where bottom depths varied from 3 to 15 ft during daylight hours (no nighttime data is available). Only 1% of the observations were in water shallower than 3 ft, and only about 4% of observations were in water deeper than 15 ft. Depths shallower than 3 ft apparently do not provide large suckers with suitable cover or at depths much under 1 ft, even enough room to swim. A re-analysis of available data (see below) suggests that a minimum depth of 4-5 ft is utilized by the suckers when not constrained by the shrinking of available habitat. Preferred water depth likely increases with increasing fish size. Suckers do spawn in relatively shallow depths; however shallow spawning occurs primarily during the night, when cover is provided by darkness.

Differential use of various bottom depths by adult suckers relative to habitat availability was assessed by studying the distribution of radio-tagged sucker locations in September and October 1994, when UKL levels dropped below 4137 ft (USBR 2000d; Reiser et al. 2001). This period of minimal lake elevations provided an excellent opportunity to observe depth utilization without the confounding influence on fish distributions caused by poor water quality, since water quality conditions had improved in Fall 1994. Also, the areas of deeper water are at a minimum relative to the more extensive areas of shallow waters, challenging adult suckers to find and remain in deeper waters, if that is their preference. The 90 observations were associated with near bottom pH ranging from 7.3-9.0, water temperatures of 9.1-20.8° C, and DO from 3.8-11.2 mg/l. Only 1% of the fish were found in water shallower than 3 ft, which represented 42% of the bottom area available (lake elevation of 4137 ft). Adult suckers generally demonstrated differential use of the depth range of 6-9 ft relative to availability of those depths in the northern section of the lake (Reiser et al. 2001). Use of 3-6 and 9-15 ft depths was similar to the relative availability of these depths, but depths shallower than 3 ft appeared to be strongly underutilized in the entire telemetry study. At this time the reason for the differential use of habitat in the 6-9 ft range by adult suckers is not clear but probably relates to the need for cover.

Both Reclamation’s and Reiser et al.’s analysis of sucker depth use were based on relatively broad 3 foot depth bins (eg. 3-6 ft), and they concluded that suckers used depths of 3 ft or greater, with no discrimination of patterns within each broader bin interval (USBR 2000d; Reiser et al. 2001). However, Table B-1 presents a reanalysis of the USBR data showing utilization of habitat by one foot depth bins and compares the entire data set with the records from years of higher water levels and greater habitat choice (excluding low lake level year of 1994). In this analysis, 93% of 1051 records were in water 4 ft or deeper, and 60% of the shallower records ( < 4 ft) were from 1994, the year of lowest lake levels. Suckers also appeared to show preference for depth ranges from 5 - 11 ft, even though the greatest relative habitat availability is at depths of under five feet (Reiser et al. 2001).

**Table B - 1. Habitat use relative to water depth by adult suckers radio-tracked in UKL 1993-1998 (analysis of USBR data used in USBR 2000d). Results are presented for all years and excluding the dry year of 1994, when lake levels were particularly low and habitat selection may have been constrained by lack of availability of deeper habitat.**

| Bottom Depth (ft) | All Records (n=1051) | Percent of Total | Excluding 1994 (n=857) | Percent of Total |
|---|---|---|---|---|
| < 3 | 13 | 1% | 3 | 0% |
| 3-4 | 68 | 6% | 29 | 3% |
| 4-5 | 80 | 8% | 48 | 6% |
| 5-6 | 123 | 12% | 89 | 10% |
| 6-7 | 132 | 13% | 110 | 13% |
| 7-8 | 141 | 13% | 123 | 14% |
| 8-9 | 112 | 11% | 100 | 12% |
| 9-10 | 127 | 12% | 116 | 14% |
| 10-11 | 82 | 8% | 78 | 9% |
| 11-12 | 45 | 4% | 43 | 5% |
| 12-13 | 29 | 3% | 29 | 3% |
| 13-14 | 37 | 4% | 31 | 4% |
| 14-15 | 13 | 1% | 12 | 1% |
| > 15 | 49 | 5% | 46 | 5% |

Suckers apparently avoid shallow, clear water in UKL except when showing ill effects of poor water quality (M. Buettner, USBR, pers. comm.). Avoidance of shallow depths by adult suckers may be related to increased vulnerability to predators, including pelicans, osprey, bald eagles and man. The need to seek adequate depth in UKL may make suckers more vulnerable to the adverse effects of poor water quality because they appear to avoid inflow areas where the water quality is high, but there is a lack of cover owing to shallow depths and relatively high water clarity, and appear to remain in deeper where water quality is frequently worse.

## 8.2 Use of Water Quality Refuge Areas in UKL

The high Cascades that form the western boundary of the UKL watershed can have substantial snow pack in winter. The porous volcanic soils on the eastern slopes ensure that a large portion of the runoff will enter the regional ground water system when it melts, and consequently there are numerous springs and ground-water fed creeks in the Upper Klamath Basin along the eastern Cascade Front. The eastern base of Pelican Butte has an especially high number of springs and creeks, including Fourmile and Rock creeks, and Harriman and Malone springs (Geiger et al. 2000). Additional inflow comes from springs and creeks a few miles farther north that flow south, including: Cherry and Sevenmile creeks, and Crystal, Blue, Mares Eggs, Fourmile, Jacks, and Tiger Lily springs. All of these inflows enter UKL near Pelican Bay. Other sources of higher quality water include the Wood River and Odessa Creek, both spring fed, as well as the east-side springs. Flows in the Williamson and Sprague Rivers provide relatively better environmental conditions when water quality is poor in the rest of UKL, although the lake suckers do not typically utilize riverine habitat in the summer. All of these inflows improve water quality (higher DO, and lower temperature, pH and ammonia) in localized areas of the lake, especially in summer. While areas in UKL where high quality inflows occur generally have better water quality than the rest of the lake, this is not always the case. Mats of algae can be blown by winds and carried by surface current anywhere in the lake and adversely affect local water quality.

In summer, adult suckers frequently use areas of UKL influenced by better water quality inflows (USBR 2000d; USBR 1996a; Reiser et al. 2001). Reclamation's radio-telemetry studies showed suckers typically are located within a few miles of the Pelican Bay or the Fish Banks area, and were also found near the mouth of the Williamson River, Odessa Creek, Short Creek and Wood River. Generally, adult suckers are concentrated in the northern end of the lake, where most inflows enter, during the summer. During 1994, many of the radio-tagged suckers concentrated near the entrance to Pelican Bay during July when water depths were 3-4 ft. In August and September when lake levels dropped below 4138 ft, radio-tagged suckers moved further offshore to areas of lower water quality. Bottom elevations off Pelican Bay vary from about 4133 to 4136 ft. This information suggests that low lake levels later in summer and in early Fall may reduce available depth cover in areas with better water quality. Low lake levels apparently force suckers away from refuge areas and expose them to adverse water quality conditions.

In August 1986, Bienz and Ziller (1987) observed adult suckers in the area of Pelican Bay at the time UKL was experiencing poor water quality. Since 1986, other researchers have noted suckers using Pelican Bay, Wood River and Odessa Creek when water quality is poor in the rest of UKL (Buettner and Scoppettone 1990; USBR 1996a). Suckers are rarely observed in these areas except possibly during the spawning season. Sick and dying fish have been documented in these areas from various fish die-off events (1971, 1986, 1995). Suckers collected from the clear water areas were generally larger specimens, while those in other areas around the lake included a wider size-range (Perkins 1996; Perkins et al. 2000b). Suckers may also use the mouth of the Williamson River when water quality is poor in the rest of UKL, and there is evidence from the 1960's, when substantial numbers of suckers were seen in the Williamson and Sprague rivers during August, that they will move into the mainstem rivers in late summer, when they would typically be in the lake (Golden 1969). There have been no reported sucker die-offs in the rivers associated with these observations. During the 1996 and 1997 die-offs sick and dying adult suckers were observed in Pelican Bay, Odessa Creek, Williamson River, and Short Creek. Two and four radio-tagged SNS remained in close proximity to the Wood River in Agency Lake throughout the summers of 1996 and 1999, respectively (USBR, unpub. data). In 1996, the Klamath Tribes tagged sick suckers in Odessa Creek in an attempt to determine if they would recover. Almost all tagged fish were found dead in Odessa Creek within a couple of days. Suckers may only enter the clear-water of inflow areas when they are extremely weak, disoriented and have lost the natural urge to seek cover.

### 8.3 Spatial Distribution in UKL

Adult sucker distribution in UKL during the Summer and Fall has been assessed primarily by radio-telemetry studies from 1993-1998 (USBR 2000d; Reiser et al. 2001). Radio-tagged adult suckers did not use available habitat evenly, but instead were mostly found in the northern portion of the lake, west of a line between Eagle Point and Fish Bank, south of the mouth of Thomason Creek. There is some information from limited trawling data that some adults suckers occur throughout the lake in summer, but generally they appear to be concentrate in the northern area (Simon 2000a). Fall catches of LRS were in the northern two thirds of the lake, as were five of the six SNS caught. Adult suckers predominately use the area outside of Pelican Bay in summer where depths are adequate and the water is more turbid. This area is where in cold, clear water with high DO levels from springs mixes with warmer, turbid water with variable DO levels from the lake.

## 9.0 LOST RIVER - SUCKER MOVEMENTS AND HABITAT USE

From March 1999 to August 2000 suckers were captured and radio-tracked in the Lost River (USBR 2000e, 2001). Adult suckers were captured throughout the Lost River with the majority captured in the Harpold reach and Wilson Reservoir, as was noted in 1999 by Shively et al.

(2000b). Few fish were captured between Wilson Reservoir and Anderson-Rose Dam. Twenty-four adult suckers (372-508mm FL) were implanted with radio-tags between April 28, 1999, and May 6, 2000 at six locations on the mainstem Lost River and in Miller Creek. Only two were tagged below Wilson Reservoir. The tagged individuals included nineteen morphologically intermediate SNS/KLS, 4 KLS and 2 SNS. An adult SNS (48 cm FL) was also tagged near Big Springs in April 1995 and tracked until August.

All of the radio-tagged suckers remained within the general reaches where they were captured and either attempted no long distance movements or were constrained by dams and water quality barriers. The two individuals tagged in the Lost River well below Wilson Reservoir, between Anderson Rose and Horseshoe Dams, both remained in the vicinity of capture into the summer (June-July). Of the suckers tagged in the Lost River above the Lost River Diversion Dam or in Miller Creek, all that survived into summer had moved into the mainstem Lost River reach above Wilson Reservoir and below Big Springs. Big Springs provided consistent flow and good water quality in 1999-2000, while Wilson Reservoir has had near-anoxic water quality events every summer since 1993 (USBR 2001).

## 10.0 TULE LAKE - SUCKER MOVEMENTS AND HABITAT USE

Two radio-telemetry studies have monitored sucker movement patterns in the Tule Lake (Hicks et al. 2000; USBR 2000c). These studies indicate that adult suckers use relatively little of the total available habitat in Tule Lake, especially Sump 1B which is apparently avoided by suckers owing possibly to shallow depths and poor water quality. Adult suckers were generally located in water depths greater than 0.8 m, representing a small area of available habitat in Sump 1A. Nothing is known about habitat usage by other sucker life history stages in Tule Lake and the lower Lost River.

Reclamation conducted radio telemetry studies of adult shortnose and LRS from 1993-1995 at Tule Lake (USBR 2000c). Five adult LRS and five adult SNS were captured in Sump 1A, radio-tagged, and released in April 1993. LRS and SNS movements were similar throughout the study period with both species intermixed. LRS and SNS resided in the English Channel during March and April, then moved along the southwest dike of Sump 1A to an area at the southern end of Sump 1A. This area, called the” Donut Hole,” is located approximately one mile northeast of Pump 9 and is about 250 acres in size with a mean depth of about 3 ft. Suckers remained in the Donut Hole until late October when they began moved to the northwest corner of Sump 1A and remained there through the winter. In April 1994, they again moved to the English Channel; movement patterns in 1994 were similar to1993.

In 1999, the Refuge began a study of sucker habitat use and water quality in Tule Lake sumps as part of a proposed wetland enhancement project (Hicks et al. 2000). This was an extension of earlier radio tracking studies done by Reclamation from 1992-1995, described above. Eleven adult LRS and four adult SNS were radio-tagged during April and May. Results of the Refuge study largely agreed with those done previously by Reclamation. In April-May, when sucker are most active, they are primarily concentrated in the English Channel, between the sumps, with a scattering of fish located elsewhere in 1A. From June-September, suckers are in the Donut Hole, and in September - February, suckers are in the northwest corner of Sump 1-A.

Very few of the radio-tagged suckers migrated up the Lost River during the spawning season. None of the 10 suckers tagged in 1993 migrated upstream in 1994. In 1999, one of eight LRS tagged in Tule Lake migrated upstream to Anderson Rose Dam, and in 2000, two of 14 suckers migrated upstream.

Radio-tagged LRS and SNS generally remained in Sump 1A throughout both studies (Hicks et al.

2000; USBR 2000c). Sucker use of Sump 1A may be related to better water quality conditions that generally occurred there compared to Sump 1B. The most important water quality parameters seemed to be pH and DO. Potentially stressful and lethal levels of high pH (>10.0) were much more common in Sump 1B, and Sump 1B had more potentially stressful DO conditions. Both species of suckers concentrated in the Donut Hole in summer where DO and pH values were less variable than at other water quality sampling sites in 1A and 1B. Water quality conditions where radio tagged suckers occurred included temperatures up to 22.5° C, a pH as high as 9.9, and DO as low as 4.7 mg/l (above stressful levels of about 4.0 mg/l or lethal levels of <2.0 mg/l). The “Donut Hole” was unique in that rooted aquatic plant growth was minimal and the water was frequently quite turbid compared to other sites during the summer. The bottom substrate was firmer and composed of clay and other inorganic sediment particles compared to the softer organic peat substrates found elsewhere.

# APPENDIX E - ENVIRONMENTAL BASELINE

This section is an analysis of the effects of past and present human and natural factors that have led to the current the status of the species within the action area, including habitat/ecosystem conditions. It is a "snapshot" of the species' current status within the action area and does not include effects of the proposed action which are described later in this opinion.

## 1.0 FACTORS AFFECTING LISTED SPECIES AND ENVIRONMENT WITHIN THE ACTION AREA

This baseline analysis describes factors affecting the species environment/critical habitat in the action area. The baseline includes State, tribal, local government, and private actions currently affecting the species/critical habitat, or will be contemporaneous with the proposed action. The baseline also includes unrelated Federal actions, that have been consulted on, affecting these species/critical habitat, as well as all beneficial actions.

### 1.1 Sucker Deformities and Parasitic Infections

A number of studies have been done to better understand how sucker health affects their survival. Larval and juvenile SNS and LRS from UKL were examined to determine anomaly rates for fins, eyes, spinal column, vertebrae, and osteocranium, and their possible associations with water quality and pesticides (Plunkett and Snyder-Conn 2000). Approximately 1,400 fish collected in 1993 were ranked on the severity of anomalies. One or more anomalies were observed in about 16% of SNS and 8% of LRS. Anomaly rates >1%, greater than rates expected from systems unaffected by industrial pollution, were observed for abnormalities of the spine, opercles, and pectoral and pelvic fins in SNS and abnormalities of opercles and vertebrae in LRS. SNS exhibited higher rates than LRS for almost all anomalies. There were substantially more anomalies found in larvae and small juveniles than in larger juveniles. The anomalies described likely impair swimming, and could adversely affect feeding rates or avoidance of predators and adverse water quality conditions. Based on the high anomaly rates observed in this study, it is possible that age 0 suckers in UKL are more vulnerable to mortality, but no studies have been done to confirm this.

Numerous causes of high deformity rates in fishes have been identified, including genetics, pollutants, water quality, nutritional deficiencies, infectious agents, and physical and electrical shocks. Although no known studies have addressed natural anomaly rates in larval and juvenile fish, the anomaly rates in UKL suckers are much higher than expected for a lake lacking industrial pollutants. Although vertebral and opercular anomalies could be genetic in origin, based on their highest occurrences in small suckers, other types of anomalies do not fit the genetic hypothesis. Poor water quality and/or contaminants are also likely to contribute to the frequent high proportions of abnormal suckers in UKL.

Adult SNS and LRS from UKL exhibited a wide range of physical afflictions that included eroded, deformed and missing fins; lordosis (forward curvature of the spine); pugheads; multiple types of water mold infections; redding of the fins and body caused by hemorrhage; cloudiness of the skin caused by decreased mucous production; pigmentation loss; parasitic infections of the body and gills; lamprey wounds; ulcers; cysts; gas emboli in the eyes; exophthalmos (protruding eyes); and cataracts (USGS 1997). The frequency of many afflictions were significantly greater in 1997 and 1998 than 1995 and 1996. Of the adult suckers captured from the Williamson River in April and May, 65-92% of the fish had some type of affliction in 1997-1998, whereas only 19-21% had afflictions in 1996. In 1999, cysts were found in 35% of adult SNS and 41% of all LRS in the lower Williamson River, compared to 2 and 3% in 1997 (Perkins 1997; Markle et al. 2000b). The occurrence of the parasitic copepod, *Lernaea* (anchor worm), declined in 1999 to a rate of 39% for SNS and 26% for LRS from 84% and 56%, respectively, in 1997. Lamprey wounds were found in 17% of SNS and 30% of LRS, up from 16% and 19%, respectively. Various eye afflictions, fin damages, and other deformities were recorded for fish as well, but occurred in only a small percentage of fish captured.

Parasitic infestation rates on juvenile suckers by *Lernaea* and the digenean trematode, *Neascus* (black grub), were recently examined by Carlson et al. (2002). They found that the percent of age 0 suckers parasitized by *Lernaea* ranged from 0-7% in the period 1994-1996 but increased by nearly an order of magnitude to 9-40% in 1997-2000, with both species showning similar patterns. Although *Neascus* infestations also exhibited considerable interannual variability, they did not show a discernible pattern of infestation and were not correlated between the two sucker species. Infestations of *Neascus* were significantly higher on SNS (13-40%) than on LRS (0-10%) in all years.

### 1.2 Sucker Water Quality Tolerance

Periodic fish kills in UKL and elsewhere in the Klamath Basin indicate that water quality frequently declines to lethal levels, as are discussed below. Lethal effects of water quality on LRS and SNS have been verified by laboratory-performed tolerance studies (e.g., Saiki et al. 1999; Meyer et al. 2000).

Laboratory studies on effects of water quality on suckers can be divided into two exposure categories, acute and chronic. Acute studies are designed to determine short-term tolerance, for example over 96 hours, whereas chronic studies focus on longer term effects. Toxicity data are usually presented as the median lethal concentration necessary to kill 50% of the test organisms (LC-50). LC-50 values for LRS and SNS larvae and juveniles from Saiki et al. (1999) are summarized below in Table 1.

**Appendix C, Table 1. 96-hour LC-50 (mean and 95% confidence limits)**

| | **NH3-N (mg/l)** | **pH** | **DO (mg/l)** | **Temp. (° C)** |
|---|---|---|---|---|
| LRS larvae | 0.5 (0.44-0.52) | 10.3 (10.26-10.45) | 2.1 (2.07-2.13) | 31.7 (31.5-31.9) |
| juveniles | 0.8 (0.70-0.86) | 10.3 (9.94-10.67) | 1.6 (1.41–1.86) | 30.5 (30.0-31.0) |
| SNS larvae | 1.1 (0.73-1.53) | 10.4 (10.31-10.46) | 2.1 (1.90-2.29) | 31.8 (31.7-31.9) |
| juveniles | 0.5 (0.34-0.82) | 10.4 (10.22-10.56) | 1.3 (1.15-1.55) | 30.3 (29.4-31.3) |

The most comprehensive laboratory study on sucker acute water quality tolerance was done by Saiki et al. (1999). Comparison of 95% confidence limits indicated that, on average, the 96 hour LC-50s were not significantly different from those computed for shorter exposure times (i.e., 24 hour, 48 hour, and 72 hour) (Saiki et al. 1999). LC-50s for the four water quality parameters did not vary significantly between species. Also, there was little difference between larvae and juveniles except that larvae were significantly more sensitive than juveniles to low DO concentrations (referred to as "hypoxia"). No attempt was made to examine the effects of combined parameters.

When exposed to the highest pH treatments, LRS and SNS larvae and juveniles experienced convulsions, erratic swimming, and production of excessive mucus (Saiki et al. 1999). Dead and dying suckers showed hemorrhaging from eyes and gills, and ruptured eyes. High levels of un-ionized ammonia also caused gill bleeding; juveniles were hyperactive but larvae comatose. Lethal temperatures resulted in bloating and floating on the surface. Hypoxia resulted in swimming difficulties and gasping behavior.

The situation regarding ammonia toxicity is complex and not well studied for suckers. The form of ammonia that is toxic to fish is the un-ionized form, which is 100 times more toxic than the ammonium ion. The fraction that is in the un-ionized form increases as pH and temperature increases (EPA 1999). The freshwater aquatic life chronic criterion for fish at pH 7.5 is 8 mg/l at 0° C but goes down to 1 mg/l at 25° C. Although Loftus (2001) has suggested that ammonia toxicity may be a serious concern in UKL in winter under an ice cover, it is unclear why this could be the case since ammonia toxicity is primarily a function of temperature and pH, which are lowest in winter.

One study has addressed chronic effects of water quality on suckers. Meyer et al. (2000) examined 14- and 30-day chronic effects of low DO, and elevated pH and ammonia on larval and juvenile LRS. Mortality thresholds were found to range from 1.5-2.0 mg/l DO, >10 pH, and 0.37-0.69 mg/l ammonia. These levels correspond well with those obtained in previous studies by Saiki and others. Contrary to expectation for fish chronically exposed to toxicants, LRS generally did not display sub-lethal responses to low DO concentrations, elevated pH, or elevated ammonia concentrations based on the three traditional chronic-toxicity endpoints used (growth, whole-body ion content, and swimming performance). In the 14-day sub-lethal ammonia/sub-lethal DO test, mortality did not decrease significantly and no sub-lethal effects were observed and there was a slight but significant decrease in sodium content at pH 10 levels held for 30 days.

In the above-mentioned experiment, gill histopathology was sometimes more sensitive than the three traditional chronic endpoints, i.e., growth, whole-body ion content, and swimming performance (Lease 2000). In the ammonia test, statistically significant structural changes occurred in gills of LRS larvae exposed continuously to un-ionized ammonia concentrations 3.5 times lower than the lowest concentration at which significant mortality and growth effects occurred. Changes in gill structure that were quantified included significantly increased oxygen diffusion distance and increased thickness of secondary lamellae—the primary site for respiratory and ion regulation. Additionally, qualitative structural changes were observed, including increased number of chloride and mucous cells, the appearance of mitotic figures, and infiltration of white blood cells into the lymphatic space (Lease 2000). However, no statistically significant structural changes were detected in gills of fish exposed to the highest pH of 10.0.

Lease (2000) postulated that the interaction between ammonia and low DO might be synergistic, because exposure to ammonia caused gill structural changes, specifically increased diffusion distances, which would exacerbate respiratory stress during periods of low DO. Lease also pointed out that high pH would be synergistic as well, because at a pH >9, ammonia excretion can be inhibited and it would thus concentrate in tissues. Therefore, during periods of high pH and high ammonia, suckers may experience greater stress. Periods of low DO and high ammonia and pH in UKL occur throughout the summer, suggesting a potentially long period of stress (Loftus 2001).

Another toxicity test was performed to determine the effects of the pathogenic bacterium, *Flavobacterium columnare* ("Columnaris disease"), on LRS juveniles following 30-day sub-lethal ammonia exposures (Morris et al. abstract; Snyder-Conn et al. in prep.). Sucker die-offs that occurred during late summer of 1995-1997 were usually associated with *F. columnare*. This ubiquitous pathogen appears to be only a problem when fish are stressed by poor water quality conditions and warm temperatures. Test fish were subjected to one of four sub-lethal ammonia concentrations ranging from 0.006 to 0.43 mg $NH_3$-N/l, at a pH of 9.5 for 30 days. After the 30 days, test fish were challenged with the bacterium and continued exposure to ammonia. Results showed survival of sucker exposed to *F. columnare* decreased relative to control fish, but contrary to expectations, survival increased with increasing ammonia concentrations. Results of this study suggest that there may be a decrease in *F. columnare* virulence at high ammonia concentrations, and/or the fish may exhibit a compensatory response that increases immunity to the bacterium. In nature, the situation is vastly more complex, since increased ammonia is only one of many stressors affecting suckers during the summer and concentrations are rarely constant for more than a few days (Loftus 2001; Welch and Burke 2001).

Histopathology of the juvenile LRS used in the above ammonia and *F. columnare* challenge experiments, was also studied (Foott et al. 2000). They found three abnormalities: gill epithelium separation and swelling, and clear droplets in kidney tubular cells. Gill separation was most prevalent at the lowest ammonia concentrations, 6 ug NH3-N/l, and was believed to be a reversible condition resulting from localized edema.

There is only a single study where laboratory lethal levels of water quality on suckers can be compared with those measured *in situ*. Martin placed a series of cages containing juvenile LRS at various sites in UKL (Martin 1997; Martin and Saiki 1999). A datasonde recorded water quality parameters at each site over each 4-day test interval. Results showed that mortality occurred at all sites but there was a significant difference among sites. When mortality rates were compared to water quality parameters, rates were significantly correlated with increased pH and un-ionized ammonia, and low DO concentrations; however, low DO showed the highest correlation with mortality. Where mortality was >90%, DO levels had gone below 1.4 mg/l. This corresponds with the lower lethal DO concentrations cited above. In Martin's study, caged fish were found to be slightly less susceptible to high pH than those under laboratory conditions. Martin found no mortality in caged fish when pH averaged 10.3 and reached nearly 10.8; whereas 9.9 to 10.7 were average lethal pH levels measured in the laboratory studies cited above. Temperatures reached 28.0° C and ammonia 0.65 mg/l in Martin's experiments and were below lethal levels. Martin's in situ-measured lethal levels for the four water quality parameters showed that laboratory- and field-measured results are similar enough to be useful for predicting what levels are likely to cause in situ mortality.

Terwilliger et al. (2000) examined age 0 sucker growth rates in 1997 to find if they were correlated with various water quality parameters. They found that growth was highest at warmest temperatures but once pH and un-ionized ammonia concentrations became high, growth was reduced. The authors considered this to mean that high un-ionized ammonia produced a sub-lethal negative effect on juveniles sucker growth. This is supported by data showing un-ionized ammonia concentrations in 1997 at month-long levels considered stressful for juvenile suckers. Water quality in 1997 reached lethal levels since fish kills did occur.

### 1.2.1 Summary: Sucker Water Quality Tolerance

Laboratory and in situ studies show that suckers, although relatively tolerant of adverse water quality, are nonetheless killed when conditions reach critical levels. Mortality could occur if suckers were exposed to DO concentrations < 2.3 mg/l, pH> 9.8, temperature >29.4° C, and un-ionized ammonia >0.34 mg/l (Monda and Saiki 1993, 1994; Bellerud and Saiki 1995). However, in situ experiments strongly suggest that hypoxic conditions in UKL are most likely to produce high mortality of larval and juvenile suckers. Although both pH and un-ionized ammonia can reach in situ levels above those shown to be lethal in the laboratory, these parameters may be transient and thus the exposure time is too brief to be lethal. Although low DO levels might be transient as well, even brief exposure to very low DO can be lethal.

Results from laboratory water quality mortality studies should be viewed cautiously. Such experiments may under- or over-estimate mortality that might occur in situ, and they tell us almost nothing about sub-lethal effects. However, emphasize that laboratory-measured LC-50 values are perhaps best viewed as red flags that should alert us to potential problems. Such studies, even done under the most exacting conditions cannot, nor are they meant to, mimic real-life conditions where there are complex spatial and temporal variations in water quality parameters as well as even more complex behavioral, predator/ prey, parasitic and pathogenic, and competitive interactions. In situ studies like that of Martin (1997) done over short time periods where multiple parameters are measured simultaneously, are perhaps the best available way to examine the relationship between water quality parameters and mortality; however, such experiments still fail to capture the long-term effects or the myriad ecological factors involved. We posit that laboratory and in situ studies provide ample reason to be concerned about the threat water quality poses to LRS and SNS and on the ecosystem on which they depend.

## 2.0 UPPER KLAMATH LAKE

### 2.1 Upper Klamath Lake: Historical Conditions

UKL (including Agency Lake), with a surface area ranging from 60,000 to 90,000 acres depending on lake levels, is currently the largest water body in the Klamath basin. Historically the lake had a surface area of about 111,500 acres, if the 34,140 acres of diked and drained wetlands are added to the present surface area (Geiger 2001). Loss of in-lake wetlands reduced the area of UKL by about 30%. Mean summer depth is now about 8 feet (at 4141.3 ft). Hydraulic residence time is approximately 0.35 to 0.5 years (lake volume (546 TAF/1,540 TAF mean lake inflow) (Risley and Laenen 1999). Its waters are generally well mixed because of shallowness. The major water sources for UKL are the Williamson/Sprague (49% of total inflow) and Wood (16%) rivers, and various large springs (14%) which provide about 78% of the annual inflow; other various inflow sources and direct precipitation comprise the remaining 22% (Miller and Tash 1967; Risley and Laenen 1999).

Regulation of water levels in UKL began in 1919, with completion of the Link River Dam (Boyle 1987). By 1921, the reef at the entrance to Link River was lowered. Prior to construction of the dam, measured lake levels varied from about 4140 to 4143 ft., with a mean annual variation of about two ft (Boyle 1987, USBR data). According to Boyle (1976, 1987) the pre-dam minimum elevation of UKL was 4140.0 ft in September 1908, and the high was 4143.3 ft on April 1907; average annual variation was about 2 feet. It should be noted that during the historic period of record precipitation levels were above average and thus lake levels may have been higher than normal. Since 1921, water levels have varied from 4136.8 to 4143.3 ft., a range of about 6.5 ft (USBR data). Water level regulation has also changed the seasonal timing of high and low elevation by making the highest and lowest elevations occur earlier in the season as well as prolonging the period of low water. This likely has had profound effects on the ecology of the lake, as described below.

### 2.2 Upper Klamath Lake: Wetland 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. The total area of wetlands affecting UKL is unknown but may have totaled over 150,000 acres when upstream wetlands (i.e., Sycan Marsh with about 24,000 acres and Klamath Marsh with about 35,000 acres), those along the Sprague and Wood rivers, and in-lake wetlands, and seasonally wet meadows) areas are included (Akins 1970). Geiger (2001) estimates that 34,140 acres of marsh were isolated from the lake owing to diking and draining. This amounts to about 66% loss of in-lake wetlands. The largest existing in-lake marsh, about 14,000 acres in size, is Upper Klamath Marsh, a National Wildlife Refuge.

Geiger (2001) stressed that UKL wetlands likely played a significant water quality role in UKL before settlement. Prior to extensive diking and draining, in-lake wetlands comprised about 46% of the lake area, a relatively high figure relative to other lakes in the region (although probably not too different from Lower Klamath Lake prior to alteration). These wetlands likely played a critical role in macro- and micro-nutrient dynamics, especially phosphorous and iron, and in cycling of particulate and dissolved organics. Geiger (2001) estimates that prior to settlement, in-lake wetlands may have annually removed about 16,000 metric tons of nitrogen and 230 tons phosphorus from the lake. Additionally, Geiger (2001) and a number of other authors (e.g., Phinney et al. 1959; Gearheart et al. 1995) have pointed out the important role collodial humic substances, originating from wetlands, may have had played by regulating primary production in open water. Although not fully understood, it appears that humics in association with low pH, can reduce *AFA* blooms, and might have been one factor responsible for the absence or near absence of *AFA* until the last century as found by Eilers et al. (2001). Geiger (2001) suggests a number of possible factors are potentially involved in this inhibition, including: absorption of light; interactions with iron; interactions with nitrogen; and interactions with toxic metals.

The largest remaining in-lake wetland in southern UKL is the 1,200 acre Hanks Marsh, also a National Wildlife Refuge. An investigation of the physical, chemical and biological characteristics of Hanks Marsh was conducted by the National Biological Service from 1992 to 1994 (Forbes et al. 1998). This study provides the most detailed information of water quality in littoral wetlands in UKL to date and allows for comparison with water quality conditions in offshore areas.

Results of this study are for the most part consistent with what is known about physical and chemical conditions in inshore areas. Several parameters formed a horizontal gradient as distance from the shore zone increased. These differences are related to the dominance by emergent vegetation and resulting sheltered conditions that lead to hydrologic isolation. Conductivity, dissolved solids, pH, phosphate, and nitrate ions, and total phosphorus formed a horizontal gradient of increasing concentrations.

*AFA* blooms that are so prevalent in open water areas were not observed in the marsh. Although the exact mechanisms are not well understood, the relationship between humate content and inhibition of many planktonic algae species has been established on both a local and national level (Phinney et al. 1959; Perdue et al. 1981; Wetzel 1983). Other contributing factors include light limitation and low pH.

Most parameters exhibited substantial seasonal variations. On a study-wide basis, however, phosphorus, inorganic nitrogen, and Chl-a levels were more similar to lake water than to levels found in selected tributaries. The results of this study do not address the flux of material between the inshore and offshore zones. Some of the data suggest, however, that offshore conditions influence the outer areas of Hanks Marsh. Conversely, processes within the marsh may form water quality gradients that extend offshore. Hazel (1969) documented a hydrogen ion gradient extending into the lake from Hanks Marsh.

The benefits wetlands might provide to lake water quality (as well as sucker habitat) are lost when water levels recede and they are exposed to the air. Exposing submerged wetlands and shoreline sediments to air during late summer and fall, may increase the oxidation of these soils and could result in the release of nitrogen and phosphorus into the lake when water levels inundate these areas. These nutrients are subsequently available for *AFA* growth the following season. ODEQ has identified excess phosphorous as contributing to water quality problems in UKL.

Although about 17,500 acres of the original 35,000 acres that were diked are in the process of being restored (Wood River Ranch = 2, 900 ac; Agency Lake Ranch = 7,160 ac; Lower Williamson River Delta Preserve = 7,000 ac; and New Caledonia Marsh = 550 ac.), their soils have subsided to such an extent that they would now be deep water habitat, rather than marsh, if reconnected to the lake. However, unless these wetlands are reconnecting to the lake, the full water quality function of these wetlands will not be realized.

## 2.3 Upper Klamath Lake: Aquatic Biota

UKL has been highly productive for some time owing to its shallow depths and the abundance of nutrients that allow for development of large blooms of micro-algae and cyanobacteria. Eilers et al. (2001) studied the paleolimnology of UKL and found evidence that it has likely been highly productive for at least the last 1000 years. The species composition of algae and cyanobacteria found in sediment cores suggest a system characteristic of high nutrient conditions for the 1000 year period of record, but that a major change occurred in the last century. *AFA* resting stages (akinetes) first appeared in sediment cores at depths (about 20 cm) determined to represent sedimentation in the 20th Century, and akinete numbers increased steadily (Bradbury and Coleman, USGS 1991, unpub. data; Eilers et al.2001). *AFA* is now the dominant primary producer in UKL. The authors concluded that the appearance of *AFA* and switch in dominance was likely associated with a relative increase in phosphorus loading which benefitted *AFA* to an extent that it became dominant.

*AFA* predominance is indicative of a change in trophic status of UKL from eutrophic to hypereutrophic. Under current conditions, *AFA* bloom conditions reach concentrations of 30,000 filaments per liter (Johnson et al. 1985). *AFA* is able to fix atmospheric nitrogen, thus it is not fully dependent on available nitrogen concentrations like algae and most other cyanobacteria (Reynolds 1986). Also important, as will be discussed, *AFA* is able to increase phosphorous internal loading by producing conditions that cause release of phosphorus from lake sediments, and thereby promoting its own growth.

The Upper Klamath Basin presently contains 17 taxa of native fishes (Logan and Markle 1993b; Moyle 1976; Shively et al. 2000; S. Reid, USFWS, pers. comm. 2002). Of these, at least 13 are endemic taxa and found only in the Basin. At least 18 species of exotic fishes have been introduced and have established populations in the upper Basin. Little is known about the ecological and competitive interactions of the introduced fishes with the native suckers and this a major gap in our ability to assess their impact. Chubs, especially the endemic blue chub, and exotic fathead minnows are numerically dominant (Simon et al. 2000b). Four species of suckers are present. The LRS, SNS, and Klamath largescale sucker (*Catostomous snyderi*) are the principal suckers in the upper Basin. However, a single Klamath smallscale sucker (*Catostomous rimiculus*) has been identified from UKL during recent genetic studies (Tranah and May 1998, 1999; Wagman and Markle 2000).

Hazel (1969) found that the UKL benthos was dominated by oligochaete worms, leeches, and chironomids; maximum mean densities of chironimids reached about 2,000/square meter. Kann (1997) found that the cladocerns dominate the zooplankon biomass in UKL and can exceed densities of 100/l, although mean densities are much lower. Kann believed that cladocerns selectively grazed on smaller phytoplankon species in summer promoting the growth of *AFA*. The abundance of cladocerans in the lake has stimulated recent interest in their harvest as a food source for mariculture (Gutermuth, pers. comm.). Parker et al. (2000) speculated that hypereutrophic conditions in UKL might reduce the availability of cladoceran and chironomid prey for suckers; however, available data seems to suggest that densities of chironomids and cladocerns are high and are not likely to be limiting. More discussion on UKL ecology with emphasis on water quality is provided below.

## 2.4 Upper Klamath Lake Water Quality

The hypereutrophic status and resultant seasonally adverse water quality in UKL is well documented (USACE 1982; Kann and Smith 1993; Kann 1993a,b; Martin and Saiki 1999; Perkins et al. 2000b; Welch and Burke 2001; Walker 2001; ODEQ 2001). Extensive blooms of the cyanobacterium AFA cause significant water quality deterioration due to photosynthetically elevated pH (Kann and Smith 1993), and to both supersaturated and hypoxic DO concentrations, as well as elevated un-ionized ammonia (Perkins et al. 2000b;Welch and Burke 2001; Walker 2001). *AFA* blooms reach extreme levels of 200,000 cells/ml and Chl-a levels of >0.2 mg/l. As a result, acutely toxic, chronic, and stressful conditions for suckers and other fishes likely occur at some scale on an annual basis in the lake.

The Klamath Tribes and Reclamation have been intensively monitoring spring-fall, limnological conditions in UKL since 1990 using biweekly samples of key parameters to document temporal and spatial variability in water quality, nutrients, and *AFA* biomass. Several reports have been completed analyzing this information (e.g., Kann 1993a, 1993b; Kann and Smith 1993; Klamath Tribes 1995; Jassby and Goldman 1995; Wood et al. 1996; Kann and Smith 1999; Kann 1998; Welch and Burke 2001; Loftus 2001; Walker 2001; ODEQ 2001).

The following section attempts to summarize pertinent lake water quality information as it affects suckers and how lake elevation regulation might affect water quality.

### 2.4.1 Effects of *Aphanizomenon flos-aquae* on UKL Water Quality

The relationship of *AFA*-induced water quality changes to fish growth and survival in hypereutrophic lakes and how that relationship could be affected by lake elevation (water depth) is important in UKL because water quality has such a profound effect on the suckers and the entire lake ecosystem (Perkins et al. 2000b; Reiser et al. 2001; Welch and Burke 2001).

High nutrient loading promotes correspondingly high production of algae and *AFA*, which, in turn, modifies water quality characteristics that can directly diminish the survival and production of fish populations. The following chain of causal relationships and mechanisms, which is supported by the scientific literature, is characteristic of hypereutrophic lake systems and is likely occurring in UKL.

*AFA* + Nutrients and Light →*AFA* Growth→Water Quality→Fish Survival

Under conditions of high nutrient input and adequate light, *AFA* biomass increases until some factor, either light, temperature, nutrients, grazers, or other factors limits further growth. As biomass increases, the available soluble forms of nitrogen (N) and phosphorus (P) decrease, because the nutrients are accumulated in the *AFA* biomass, and are therefore unavailable for further biomass increase. The nutrient in shortest supply, relative to growth requirements, at a given time is the limiting nutrient. Because *AFA* can fix atmospheric nitrogen, its growth is not considered limited by nitrogen concentrations (Reynolds 1986); however, this does not necessarily mean that if additional nitrogen were available it would not lead to an increase in *AFA* biomass. A TMDL was recently developed for UKL that considered the role of nitrogen in the lake, but focused on limiting P input to improve water quality because N is more difficult to control and because *AFA* growth is not limited by nitrogen (Walker 2001; ODEQ 2001).

*AFA* blooms usually occur during June-September. Blooms have started as early as mid-May and as late as early July (Wood et al. 1996; Kann 1998). Initiation of *AFA* blooms has been linked to inoculation of the water column by migrating vegetative cells from the sediment (Barbiero and Welch 1992). Migration of *AFA* "akinete", which are resting, vegetative stages, from the sediment contributed as much as eight percent of the observed water column increase in biomass of that species in Agency Lake in 1992 (Barbiero and Kann 1994). Although the trigger that causes migration is not well understood, these authors suggested that a threshold for light reaching the sediment may be more important than temperature.

During *AFA* and other phytoplankton blooms, particularly when coupled with high rates of nighttime respiration, DO can vary considerably over a 24h period, but more importantly levels can get sufficiently low to affect fish survival. Also during blooms, available carbon dioxide in the water is used and pH rises to levels >10, in UKL's poorly buffered waters, which can be stressful to fish. Such pH and DO events probably occur at some scale annually in UKL where *AFA* growth conditions are near optimal. Following these blooms, when high levels of *AFA* and other phytoplankton biomass begin to senesce and die-off, the respiration of phytoplankton and the microbial degradation of this biomass and additional DO demand by organic-rich sediment can deplete DO and increase ammonia concentrations to levels that likely reduce growth of and are stressful or are lethal to fish.

### 2.4.2 Upper Klamath Lake: External Phosphorus Loading

Phosphorus is of particular concern in UKL due to its likely role in controlling *AFA* productivity, which in turn influences water quality conditions affecting fishes, particularly severe DO declines. Cyanobacterial blooms are associated with shallow lakes where phosphorous concentrations exceed 50-100 ug/l (Sas 1989 cited by Walker 2001); values of >100 ug/l are common in UKL. Parameters that determine phosphorus concentrations in UKL include: inflow concentrations; inflow water volume; internally regenerated phosphorus from sediments (termed internal loading); and lake volume (Welch and Burke 2001; Walker 2001).

Despite high background phosphorus levels in upper Klamath River Basin tributaries and springs (Kann and Walker 1999; Rykbost 1999; Walker 2001; ODEQ 2001), data exists from several studies indicating that phosphorous loading and concentrations are elevated substantially above these background levels (Miller and Tash 1967; USACE 1982; USBR 1993a; 1993b; USGS 2000; USGS Water Resources Data 1992-1997; Kann and Walker 1999; Welch and Burke 2001; Walker 2001; ODEQ 2001).

Much of the phosphorus entering UKL appears to originate from anthropogenic activities such as agriculture and forestry. Gearheart et al. (1995) estimated that total phosphorus (TP) loading in the UKL watershed is about equally divided between agriculture and forest land uses, being 38% and 36%, respectively. Agriculture has been identified as a major TP source in the upper Klamath Basin, especially from drained wetlands (Snyder and Morace 1997). Miller and Tash (1967) indicated that, despite accounting for only 12% of the water inflow, direct agricultural input of phosphorus from pumps and canals accounts for 31% of the annual external total phosphorus budget. Walker (1995) estimated that an increase in Agency Lake inflow phosphorus concentration from 81 to 144 ug/l (40%) is an estimate of the anthropogenic impact. Other studies show that drained and diked wetlands consistently pump effluent containing 2-10X the phosphorus concentration of tributary inflows (USBR 1993a, 1993b), and that nitrogen and phosphorus are liberated from drained wetland areas, leach into adjacent ditches, and are subsequently pumped to the lake or its tributaries (Snyder and Morace 1997). Coupled with the considerable but diffuse non-point contribution stemming from pumping from drained wetland, flood-plain grazing, flood irrigation, erosion of uplands, and channel degradation, TP input from anthropogenic sources likely accounts for a far greater percentage than that indicated by the 31%

contributed due to direct pumping alone.

TP concentrations in UKL tributaries are correlated to runoff, suggesting that erosion is the primary causative agent (Gearheart et al. 1995; Williams 1998). TP levels are often correlated with turbidity or total suspended solids because phosphorous is often bound to small-sized particles. The USGS did a study of nutrient loading in the Williamson and Sprague River basins in 1992 and 1993 to identify land-use-specific nutrient loading (Williams 1999). The study found that turbidity in the upper Sprague River was highest in the North Fork and possibly in the area downstream from Beatty. The area upstream from Beatty was a significant source of nitrogen. Results of nutrient loading by different land uses was inconclusive because of the complex land-use mosaic; however, results did suggest that TP and nitrogen from forest lands are not insignificant (Williams 1999).

The Williamson River and Wood River together accounted for 67% (48% and 19%, respectively) of the 1992-1998 TP; springs and ungauged tributaries contributed another 10%. Precipitation, Sevenmile Canal and agricultural pumping accounted for the remaining 23% (Kann and Walker 1999). Unlike flow contribution, where Wood River, Sevenmile Canal, and Pumps contribute 25% of the inflow, these same sources contributed 39% of the average annual TP load. In contrast, springs contributed 16% of the water input, but contributed only 10% of the TP load. This appears to be partially due to the consistently higher volume weighted TP concentration occurring in the pump effluent, and Wood River and Sevenmile Canal systems. The estimate of anthropogenic contribution of TP loading for all seven water years is 40% with a range of 36 to 45% for individual years. These values are very similar to the 40% anthropogenic TP contribution estimated by Walker (1995) for Agency Lake.

TP loads during the 1992 and 1994 drought years were 62% of the 1992-1998 average. The 1993 water year is of note because while flow was 108% of the 7-year average, TP load was 114% of the average. Other years (with the exception of 1996) tended to have percentage of average TP loads lower than their respective percent of average water inputs. It may be that during several low water years (e.g., 1991 and 1992), watershed sources of TP accumulate, and are then flushed into the lake during the next high flow year. Moreover, the volume weighted TP concentration of the Sprague River in 1993 is higher than any other year, indicating additional watershed contributions of TP. Because the Sprague River watershed is impacted by wetland and riparian loss, flood-plain grazing, agricultural and forestry practices, and channel degradation, it would be prone to TP export, especially during major runoff events.

An estimate of the particulate phosphorus (PP) load was taken as the TP load minus the “SRP” (soluble reactive phosphorus) load. These data clearly show an increase in the loading of PP during high runoff events for the Williamson and Sprague Rivers. During these high flow events, which typically occur from January-May, PP can increase to 60% of the TP load, compared to less than 5% during summer low flow periods. There are also noticeable spikes of PP load occurring in the Wood River and Sevenmile Canal systems, but they are not limited to high runoff periods. This pattern could be consistent with flood irrigation practices that would tend to be pulsed in nature, and where overland runoff could increase the proportion of particulates. The increase in PP loading is indicative of degraded watershed conditions. In a healthier watershed (e.g., intact riparian areas and flood plains) the concentration should tend to decrease at high flows through dilution, and particulate loading should only increase slightly (Kann and Walker 1999). Further support for role of erosion being the source of phosphorus in UKL is presented in the paleolimnological studies of Eilers et al. (2001).

There is a possible connection between elevated levels of TP, as a result of high spring flows, as discussed above, and *AFA* biomass and fish kills. Based on 5 years of data, Wood et al. (1996) concluded there was an apparent relation between TP concentration and lake level, other than the highest concentrations bein measured in 1992, the lowest lake level year. An update of that analysis in 2000, based on 10 years of data, did not alter that conclusion. Further, TP concentration was correlated with Chl-a concentration in June, suggesting that the strength of the first bloom is influenced by phosphorus concentration. External phosphorus loading from spring runoff could be an important factor in determining the phosphorus concentration in the lake at that time and may also create conditions leading to a large *AFA* biomass that is needed to create adverse water quality conditions later in the summer.

Wood (2002) noted that 5 of the 6 recorded fish kills in UKL have been in years with "extreme" spring runoff. Fish kills in 1971, 1986, 1995, 1996, and 1997, were all in years where the spring runoff recurrence intervals ranged from 7 to 20 years (Table 2 below). Sediment loading, with its associated TP, as discussed above, could play a role in *AFA* bloom dynamics in late spring that are key to adverse water quality later in summer that cause fish die-offs. Although this hypothesis seems reasonable, Wood (2002) cautions that there were fish kills in years of low flows (i.e., 1932) and years of high flows with no fish kills (i.e., 1993); however, the author states that "...this is an idea that probably deserves further thought and scrutiny."

Although this runoff-nutrient mobilization hypothesis was developed to explain the higher than normal ammonia concentrations in UKL in the late 1990s, the process is perhaps the same for phosphorus. However, Wood (USGS pers. comm.) noted that the year-to-year relationship between ammonia concentrations and inflows may not be as strong for the phosphorus data.

**Table 2. Fish die-off years and estimated spring runoff recurrence interval for Upper Klamath Lake (Wood 2002).**

| **Year of Reported Fish Die-off** | **Estimated Spring Runoff Recurrence Interval into UKL** |
|---|---|
| 1932 | "Extremely low inflow" |
| 1971 | 7 year |
| 1986 | 15 year |
| 1995 | 7 year |
| 1996 | 15 year |
| 1997 | 20 year |

A reduction in external phosphorus loading is the only practicable means of improving water quality in UKL. Walker (2001) showed a relationship between increased in TP in UKL and external anthropogenic inputs. Walker determined that a 30-50% load reduction was necessary to meet water quality criteria established by ODEQ. This 30-50% TP load reduction "target" has been adopted by ODEQ in their draft TMDL. Walker (2001) points out that this could be achieved since some data show an 8% decrease in TP possibly occurred in the past decade, likely as a result of watershed and wetland restoration efforts. However, there is some debate if this is a real trend and more data are need for corroboration (Kann 2001; Wiltsey 2001). Gearheart et al. (1995) estimated that over 50% of the annual TP load from the watershed could be reduced with appropriate management practices, and Anderson (1998) likewise estimated that in-lake TP concentration could be reduced by utilizing watershed management strategies, especially tributary wetland restoration and riparian fencing. Such activities are the focus of many restoration projects as discussed later in this chapter.

### 2.4.3 Upper Klamath Lake: Internal Phosphorus Loading

Of the phosphorus entering UKL some is transported downstream and some remains in the lake and becomes what is termed "internal phosphorus." Nutrient loading studies showed that the largest flux of phosphorus available for *AFA* growth in UKL during the summer comes from internal sources (Barbiero and Kann 1994; Laenen and LeTourneau 1996; Kann 1998; Kann and Walker 1999; Welch and Burke 2001; Walker 2001). On average, external loading was 39% of the total loading to the lake, while internal loading was 61%.

Lake outflow TP load tends to increase during high runoff events in the winter and spring, as well as during the summer period when inflow load is low. It is clear from this trend, and the increase in lake TP storage at a time when lake water storage is decreasing, that TP is being internally loaded from the sediments. These large net internal loading events are generally followed by a substantial decline, indicating a large sedimentation event. Such events coincide with *AFA* bloom crashes (Kann 1998). On an annual basis there tends to be a net retention of TP in the lake due to the significant sedimentation events from *AFA* bloom crashes and the likely settling of particulate phosphorus following high runoff events, e.g., annual average retention is 25 metric tons. However, it is evident from the negative retention, positive internal loading, during the May through September period that internal loading is a significant source of phosphorus to the lake.

A possible mechanism for internal loading of phosphorus in UKL is photosynthetically-elevated pH (Welch 1992; Sondergaard 1988; Jacoby et al. 1982; Welch and Burke 2001; Walker 2001). Although this hypothesis is not universally accepted for UKL (e.g., Wood 2002), it has both theoretical and empirical support. Welch et al. (2002) state that the feed-back-loop "...may be the strongest pH-internal P loading relationship observed in situ from any shallow lake."

The suggested mechanism is that elevated pH increases phosphorus flux to the water column by solublizing iron-bound phosphorus in both bottom and re-suspended sediments as high pH causes increased competition between hydroxyl ions and phosphate ions, decreasing the sorption of iron-bound phosphate. Evidence for this exists in UKL where it was shown that the phosphorus associated with hydrated iron oxides in the sediment was the principal source of phosphorus to the overlying water, and that iron-phosphorus fractions decreased from May to June and July (Wildung et al. 1977). Moreover, Kann (1998) showed a direct empirical relationship between pH and net internal loading in UKL. A similar mechanism could occur with phosphorus adsorbed by aluminum oxides (Jassby and Goldman 1995).

### 2.4.4 Role of pH in Upper Klamath Lake Water Quality

Hydrogen ion concentration (pH) is an important water quality parameter in UKL because it can affect aquatic organisms, including suckers, and is thought to be responsible for internal loading of phosphorus. As discussed above in "Sucker Water Quality Tolerance," pH values >9.55 caused a loss of equilibrium in juvenile SNS; swimming performance of larval LRS was reduced at pH of 10.0, and values >10.3 proved lethal to larval and juvenile SNS and LRS (Falter and Cech 1991; Saiki et al. 1999; Meyer et al. 2000).

During rapid growth, *AFA* can reach "bloom" proportions, and if the bloom is large enough, and mixing/reaeration are minimal, such as occurs when there is no or little wind, pH will increase because the rate of carbon-dioxide fixation through photosynthesis exceeds the rate of input from the atmosphere, shifting the equilibrium between free carbon-dioxide and carbonate ions in the water. This is especially a problem in UKL because of low buffering capabilities of its low-ionic strength waters. Thus, pH levels are related to the rate of photosynthesis and biomass of *AFA*.

Kann and Smith (1999) found that Chl-a and pH in UKL were highly correlated, and they developed two statistical models relating Chl-a and pH. The regression model developed between lake-wide mean values of Chl-a and pH in UKL for the June-September period yielded an r-squared value of 0.72. This value increased to 0.95 when the model was developed from UKL June Chl-a and pH. The year with the highest June Chl-a (1992) also had the highest June median pH (about 9.9) and the lowest lake level (Kann and Smith 1999).

Kann and Smith (1999) suggested that efforts to improve water quality in UKL and Agency Lake might focus on reducing *AFA* productivity to a point where pH levels can be tolerated by the fish community. The results of their analyses predicted that a 50% reduction in Chl-a levels, from 200 to 100 ug/l, could result in a 45% reduction in the probability of exceeding a pH of 9.5. Modeling by Welch and Burke (2001) predicted similar reductions. Such a reduction may be possible if anthropogenic nutrient inputs, especially TP, to the lake are reduced, as described above.

### 2.4.5 Role of Dissolved Oxygen in Upper Klamath Lake Water Quality

DO levels are a primary factor affecting suckers and other aquatic species in UKL. ODEQ (2001) in the draft TMDL for UKL sub-basin, has identified DO as exceeding State water quality criteria in 13% of samples on annual basis and 35% for August samples; consequently UKL is listed as being water quality limited for DO. In any body of water, DO levels are influenced by a variety of mechanisms, e.g., photosynthesis, organismal respiration, sediment oxygen demand (SOD), carbonaceous biological oxygen demand and nitrification, and atmospheric reaeration (Wood 2001). Of these variables, photosynthesis, SOD, and reaeration have the most effect.

SOD is critically important in a shallow and productive lake like UKL, because in the absence of DO production by photosynthesis and reaeration, SOD has the potential to lower DO to levels that adversely affect fish. The range of SOD values obtained by Wood (2001) (corrected to 20° C) in her study of UKL were relatively small, ranging from about 1 to 3 g DO/m$^2$/day (although much higher values were found in Ball Bay). These values were similar to those reported in other lakes where sediments had a moderate organic content and similar abundance of silty-sized sediment particles. Seasonal differences in SOD were primarily accounted for by differences in temperature, thus indicating that sufficient organics are present throughout the year to cause a significant SOD. Wood (2001) estimated that potential water column reductions in DO, resulting from SOD, would range from 0.4 to >3.7 mg DO/l/day in late summer. At these rates, and an absence of photosynthesis and wind-driven reaeration, DO could be reduced to low levels in less than a day.

As part of the oxygenation pilot project proposal prepared for Reclamation by Burleson Consultants (2002), a simple oxygen mass balance model was developed to assess likely DO demands in Shoalwater Bay, a potential site for oxygenation. DO demand was calculated as the sum of sediment and water column demands. Based on typical declines in Chl-a during the 1995-1997 period, water column demand was estimated to be about 0.9 mg DO/l/day. An SOD value of 1.7 g DO/m$^2$/day was used [based on Wood (2001) data, described above], which corresponds to 0.8 mg DO/l/day, based on a 7-ft water-column depth. Thus in this example, total DO demand would be 1.8 mg DO/l/day. Surface reaeration at low winds was estimated to provide about 2.8 mg DO/l/day to the entire 7 ft water column. Thus, even during low wind periods and a relatively high SOD and water column demand, there would be adequate DO available to meet water column and sediment demands (any primary production would also elevate the DO). However, if wind mixing stopped surface reaeration, DO in this example would decline at a rate of 1.7 mg/l/day and in as little as one day could take DO levels that are adequate for suckers (>4 mg/l) to lethal (<2.5 mg/l). Thus, based on this simple mass-balance model, wind mixing, even at low wind speeds, is shown to play a crucial role in maintaining DO levels.

### 2.4.6 Water Quality in Upper Klamath Lake In Winter

During winter months, *AFA* growth is minimal, most fish and other organisms are relatively inactive, and water quality conditions are generally good. However, ice-cover conditions might pose a risk to suckers because it eliminates wind-induced mixing which is responsible for oxygenation and release of potentially toxic un-ionized ammonia. If ice cover is sufficiently long and/or a snow-cover reduces light penetration, harmfully-low DO levels can occur (Klamath Tribes, unpub. data).

During most years, Upper Klamath and Agency lakes are covered with ice for a period of several weeks to several months between December and March. Refuge staff that have regularly used aircraft to count waterfowl on UKL since 1982, report that it is rare for the lake to be totally frozen over for more than a month (Hainline, USFWS, pers. comm.). However, relatively protected bays, such as, Ball Bay, Shoalwater Bay, Wocus Bay, and near the UKL outlet around the dam and marina, will stay ice covered for longer periods. For example, in the winter of 2001-2002 much of the lake was frozen from mid-January to mid-February; although isolated bays were frozen over much longer. Ice-cover conditions lasting from one to two months probably pose little or no risk to suckers.

UKL data during ice-cover conditions from 1988, 1989 and 1993 indicated DO depletion might be occurring at or near bottom depths (Klamath Tribes unpub. data). This depletion will migrate up into the water column as the season progresses if the surface is ice-covered. DO values <5 mg/l were commonly observed at depths >2 ft and concentrations of <1 mg/l were documented at several sites during 1988, 1989, and 1993 (Klamath Tribes unpub. data).

The most complete winter DO data are from Reclamation, which operates a continuously-recording datasonde at the south end of UKL, upstream of Link River Dam. Data are available for DO levels during the January - March period, from 1992 to 2001 (although there were gaps of 5 months total). These data showed the lowest recorded minimum DO was 4.3 mg/l in 1992 in 5.1 mg/l in 1993; average minimums for the period were much higher. Assuming this station is representative of the lake (which may not be the case), there is no evidence in the existing dataset of serious DO depletion during the period of the winter when it would most likely be detected. Winter DO levels in isolated, shallow bays, however are much more likely to be lower than for the lake as a whole because ice-cover is likely to be longest in such situations, circulation is weak, and SOD could strip DO from the water column most rapidly.

Another potentially important consideration regarding winter water quality as it affects suckers is un-ionized ammonia. The toxic effects of un-ionized ammonia were discussed above. Un-ionized ammonia becomes more toxic at lower temperatures and lower pH conditions (Loftus, R2 Resource Consultants. pers. comm). The concern will be what happens when pH and temperature decline in UKL in the fall when total ammonia is still high (as in 1996 –1998) (Loftus, R2, pers. comm). Currently no data are available on un-ionized ammonia levels in UKL or other Project lakes and reservoirs in winter. However, un-ionized ammonia may be a risk to suckers, especially if winter lake levels are not sufficiently high to dilute ammonia to non-toxic levels.

Although there is no reported winter kill from UKL, age 0 sucker abundance data obtained by OSU through the first year indicates that winter kill might be significant factor in accounting for much smaller numbers of suckers collected the following spring. There are no data to directly link age 0 sucker declines to adverse water quality.

### 2.4.7 Potential Effects of UKL Water Depths on Water Quality

How changes of UKL depths, as a result of water level management, might affect water quality has been a subject of considerable debate. UKL levels may affect water quality in a variety of mechanisms discussed below. Currently, support for these mechanisms is mixed. Some mechanisms are based on theory, some on results from studies on other lakes, but some do have good support from data taken in UKL.

Disagreements among limnologists about how well such mechanisms operate in UKL is to be expected since UKL limnology is complex and available data were not collected specifically to answer the question about how lake depths affects water quality. To say that the physical, chemical, and biological nature of UKL is complex, is perhaps a gross over simplification. UKL is large (77,000 acres) making it difficult to sample. It is shallow (averaging only about 8 ft), and thus is easily affected by air-water-sediment interactions. Such interactions can be rapid, such as waves that develop in a few hours owing to gusty winds. Spatial and temporal complexity makes it difficult to interpret samples spaced miles apart and taken at biweekly intervals. Furthermore, UKL consists of shallow and relatively isolated bays and deeper “trenches,” thus conditions measured at a few stations do not show the true extend of lake-wide variability, and this variability may be a crucial factor in controlling water quality conditions. Also, UKL complexity is increased by a significant North vs. South and East vs. West climate gradient which is colder and wetter towards the Northwest where the lake sits at the base of the Cascade Mts. Additionally, inflows at different points in the lake vary considerably in their physical-chemical parameters. Water entering the lake through a marsh could be chemically much different than from a river or spring. A further complexity is non-random distribution of biological processes. *AFA* blooms, which have a great effect on water quality in summer, are highly patchy and are greatly affected by wind-driven surface currents. Thus, although UKL is relatively well studied, our knowledge of how it operates is still improving.

There are at least eight potential mechanisms that relate water quality to UKL water level management (Welch and Burke 2001, Wood 2002). Each of these hypotheses is discussed below.

*Hypothesis 1: Higher lake levels reduce AFA biomass by light attenuation.*

This hypothesis is based on the fact that light intensity is attenuated exponentially when absorbed/scattered by phytoplankton as it passes through a water column (Reynolds 1986), and therefore lake level could affect *AFA* growth. The Klamath Tribes measured light extinction on several occasions throughout the summer in 1994 and correlated it with Secchi disk depths (Kann 1998). They documented that in summer, light intensities are often below levels needed for plant growth at a depth of about 3 ft. This pattern was very consistent for all sites and years during the June-September growing season. As a result, *AFA* productivity should be light limited at depths >3 ft.

In a mixed situation, which frequently occurs in UKL owing to shallow depths and exposure to wind, *AFA* cells might spend a proportion of time at depths >3 ft where light limitation causes respiration to eventually exceed photosynthesis. As the ratio of photosynthesis/ respiration declines until it becomes <1, growth slows and eventually ceases. The deeper the water column the greater the proportion of time *AFA* growth would be light limited, thereby reducing growth and photosynthetically-elevated pH (Kann and Smith 1999), and affecting the timing and magnitude of blooms in a positive way with respect to water quality (Welch and Burke 2001; Walker 2001). Welch and Burke (2001) developed a light-based *AFA* production model that predicts an approximate 30% decrease in biomass could be expected with a 3-foot increase in lake levels. Wood (2002) pointed out potential weaknesses in the model and noted that such a decrease, were it realistic, should be discernable in the 11-year monitoring dataset. In a response to Wood's analysis, Welch et al (2002) reply that "given the various influences that these factors may have on algal growth, and the sparsity of data (11 data points from 11 years of data), it is not at all surprising that this trend is not directly observable in the data."

Support for this hypothesis comes from an analysis by Scheffer (1998) of the relationship between depth and Chl-a in 142 Dutch lakes ranging in mean depth from 0.5 to 6 m, which overlaps much of the depth range in UKL which averages 2-3 m. Scheffer found good empirical support indicating that when phosphorus is not limiting, light becomes the factor controlling algae biomass, such that mean summer Chl-a levels decline linearly with increasing lake depth. Although, no data are available in Scheffer's study to indicate what species of phytoplankton dominate the Dutch lakes, judging from the high phosphorus levels (up to 1mg/l) and high Chl-a values (up to 0.5 mg/l) in these lakes it would suggest that cyanobacteria like *AFA* are present (Welch et al. 2002).

Several potential weaknesses are apparent with this hypothesis as it relates to UKL (Wood 2002). First *AFA* can regulate their buoyancy (Reynolds 1986), and therefore may not be mixed deeply into the water column for long. In fact, *AFA* is often seen as floating mats. Nevertheless, Kann (Aquatic Ecosystem Sciences, pers. comm.), who has worked extensively in UKL, suggests that wind speeds typical of UKL during the summer, commonly mix the cells into the water column. Wood (2002) agreed that *AFA* is periodically mixed through the water column, but suggested that the amount of time that *AFA* is well mixed versus when in a mat determines the effectiveness attempting to reduce *AFA* biomass through reductions in light by increasing depth. The observation that *AFA* can be dispersed into the water column is also consistent with those of cyanobacteria in other lakes (Reynolds 1986; Welch and Burke 2001). Secondly, Wood suggests that cyanobacteria can adapt to different light conditions, within limits. However, Reynolds (1986, quoting work by Harris 1978) states in general that regulation of photosynthetic efficiency by algae is not rapid, "being spread over one or more generation times."

Another factor that potentially weakens this hypothesis is a theory proposed by Scheffer (1998) to explain the dominance of green algae in some systems and cyanobacteria in other. Scheffer suggests that when nutrients are abundant and light is not limiting that green algae dominate. However, when light is limiting, owing to turbidity or a deeper water column, cyanobacteria might dominate because of their ability to move into the upper part of the water column where there is more light.

Wood (2002) suggested that ability of *AFA* to adjust their buoyancy may explain why an empirical relationship between lake levels and *AFA* biomass has not yet been found. Additional confounding effects are weather, as suggested by Welch and Burke (2001), and perhaps the interaction of spatial changes in depth and movement of *AFA* blooms by surface currents. Wood (2002) concluded that "...while it would be reasonable to assume some increase in light limitation, and consequent decrease in biomass and pH, occurs with increased elevation in UKL, this dependence on lake elevation is small compared to the larger inherent variability in these quantities due to climatic and other factors." Welch et al. (2002), in response to Wood's comments, provide a variety of reasons why they continue to support this hypothesis.

Although this light-limitation with increased depth hypothesis appears plausible because it is both simple and uses a mechanism that is well-documented elsewhere, the above discussion suggests

that *AFA's* response to the light environment is potentially complex, and further studies are needed to clarify the processes involved.

*Hypothesis 2: Higher lake levels retard AFA bloom initiation in spring*

This hypothesis is based on two possible mechanisms that could delay the initiation of the *AFA* bloom in spring through a deeper water column (greater volume) owing to: a) reductions in light intensity at the bottom owing to increased depth (Welch and Burke 2001; Walker 2001), and b) delay of increased water temperature since a larger water mass is slower to warm.

Part (a) of this hypothesis is tied to hypothesis 1 above. Part (b) is related to observations that *AFA* bloom initiation is often linked to temperature increases in the spring when temperatures reach 15-17° C, and thus lake volume has the potential to affect the timing of late-spring early-summer blooms. At low lake volume, warm late-spring and early-summer air temperatures can translate more directly to warmer water temperatures which in turn could cause early bloom development and faster *AFA* growth rates. Because maximum UKL elevations also occur during cooler (and presumably wetter) late winter and spring conditions, it is not possible to determine statistically the relative effects of volume and degree-days.

Wood et al. (1996) suggested that the time from April 1 to the start of blooms in the spring was determined more by water temperature, specifically by degree-days since April 1, than by lake level. Nevertheless, the year with the earliest large bloom was 1992 (June), which was the year with the lowest spring-time lake level throughout the 1990-1999 monitoring program. The bloom also began early in 1994, but was slower to reach a lower maximum. The latest documented *AFA* bloom of significant magnitude in UKL occurred in September 1991, but Chl-a still reached 280 ug/l.

Wood et al. (1996) showed that June Chl-a values in UKL were directly related to degree-days after April 1, implying that a longer exposure to higher temperature would produce more biomass. Kann (1998) further investigated the hypothesis of temperature control of bloom timing with a longer data set (1990-1996) and found that the relationship between time when the *AFA* reached a given biomass and degree-days since April 1 was relatively strong. The delayed bloom of 1991 coincided with the fewest degree-days during April 1-May 15 and the 1992 bloom experienced the most degree-days. Also, Kann (1988) showed a positive relationship between the time for a given biomass and the time when the first 7 consecutive day air temperatures reached 15° C.

The first part of this hypothesis is reasonable but is currently not supported by empirical data. Wood (2002) suggests that part b has a "sound theoretical basis," but is not likely to be significant since fluctuations in the average water temperature of UKL tracks fluctuations in air temperature, with only a short 1- to 3-day lag (Wood et al. 1996). Welch et al. (2002) state they used a heat transfer model that predicted depth had a greater influence on equilibrium temperature than did daily air temperature.

Another factor affecting spring bloom initiation is diel temperature fluctuations, depending on whether the daily maximum or daily average temperature is more critical in determining the timing of bloom initiation. Kann (Aquatic Ecosystem Sciences, pers. comm.) has also suggested that there may be a greater diel temperature fluctuation at a lower lake elevation.

*Hypothesis 3: Higher lake levels reduce internal phosphorus loading*

This hypothesis is based on several potential mechanisms that could relate internal phosphorus loading to UKL water-level management. Empirical evidence from UKL along with supportive

evidence from other lakes suggests that as an *AFA* bloom progresses and pH increases, this might cause sediment to water column phosphorus flux to also increase. If water-column phosphorus increased it could result in a greater *AFA* biomass which leads to increased pH, setting up a positive feedback loop (Kann 1998) (Welch and Burke 2001 Figure ES-1, p. xiii).

Low lake volume might accelerate this theoretical pH-induced feedback mechanism through two potential mechanisms. First, at low lake levels the smaller water volume would dilute the phosphorus influx to a lesser extent than a higher volume would. Secondly, as water depth decreases, phosphorus release from bottom sediments mixed into the water column by wind action could occur more frequently and the quantity of sediments resuspended could be greater.

Resuspension of sediment and release of phosphorus in UKL might be significant because while high pH could solubilize phosphorus making it available for *AFA* growth, wind resuspension could increase sediment contact with the water column thus possibly optimizing the release of iron-bond phosphorus (Sondergaard 1988). As such, higher lake volume would be expected to decrease the phosphorus available for *AFA* growth by dilution and decreased frequency and magnitude of resuspension.

Leanen and LeTourneau (1996) suggested that lake level could affect sediment resuspension in UKL by increasing wind-induced, bottom shear stress. Theoretical estimates based on UKL bathymetry indicated that the bottom shear stress created by a 10 mph wind at lake elevations as low as 4137ft could be very effective at resuspending sediment (Laenen and LeTourneau 1996). The same analysis indicated that the areally-weighted, bottom shear stress of 4140 ft elevation would be about one-half that at 4137ft, but could still be at a value that could effectively resuspend sediment. Subsequent analysis indicated that bottom shear stress decreases rapidly for lake elevations above 4140 ft. Similar results were obtained in modeling by Philip Williams & Associates (2001).

Wood et al. (1996) stated that a critical set of circumstances is required to initiate internal phosphorus loading; lake level is only one of those circumstances, and its relative importance is unknown. Wood et al. concluded that the phosphorus dataset analyzed was insufficient to quantify the contributions of wind speed and duration, fetch, high pH, and lake level (four of the most easily identified relevant variables) to the internal phosphorus loading. Modeling by Welch and Burke (2001) that assessed the effects lake levels would have on pH, indicated that by keeping the lake above a critical maximum could reduce the number of days pH levels would exceed pH 10. They found that by setting the minimum elevation at 4142 ft would reduce days with pH >10 by 64%, at 4141 ft by 51%, and at 4140 ft a pH >9.5 by 27%; all relative to historic conditions.

While the above hypothesis is largely unsupported by empirical data from UKL, it is based on several mechanisms that have broad support by limnologists working in UKL and other lakes. Further studies are however, needed to verify that it occurs and to what degree it affects *AFA* biomass.

*Hypothesis 4: Higher lake levels reduce pH and AFA biomass*

This hypothesis is related to the internal loading of phosphorus described in 3 above. Probability-based models of photosynthetically-elevated pH as a function of *AFA* biomass (as measured by Chl-a) were developed for both Agency Lake and UKL (Kann and Smith 1999). A linear relationship between Chl-a and pH was demonstrated for both Agency and UKL (June-

September). However for Agency Lake, lower Chl-a levels were associated with higher pH values than in UKL. Probability plots for regression-based probability models of exceeding

critical pH levels as a function of Chl-a concentration were also illustrative of the relationship between Chl-a and pH. At a Chl-a value of 100 ug/l there is an 18% probability of exceeding pH 9.5 for the UKL-wide mean model, while for the Agency Lake model there is a 40% probability of exceeding pH 9.5 at this same chlorophyll level. Given that Agency Lake has a mean depth of about 1.6 ft shallower (about 30%), than UKL, the light limitation mechanism can contribute to the greater than 2X difference in probability of exceeding pH 9.5 in Agency Lake (Kann and Smith 1999). In effect, the deeper water column in UKL could be limiting pH reductions by lowering photosynthesis, since productivity is limited to the upper 3 ft of the water column, and also reducing pH by dilution. Conversely, a shallower lake can be expected to increase pH by concentrating photosynthesis into a shallower water column with greater availability of light (Welch and Burke 2001). Walker (2001) noted that the light reduction effect on *AFA* by lake levels in UKL was a significant factor related to pH and TP levels. These benefits are in addition to any dilution of wind-induced internal phosphorous loading that would occur with greater lake volume/depth, and a reduction in pH-induced internal phosphorus loading.

Wood et al. (1996), applying univariant analyses, concluded that there was no evidence for a relation between Chl-a and lake level, on the basis of seasonal distribution of data or a summary seasonal statistic. USGS updated the data analyses from their earlier report (1990-1999); however, inclusion of five more years of data did not demonstrate a discernable relationship. New analyses by Welch and Burke (2001) have predicted, using three different models (Oskam, Michaelis-Menton, and Steele), that maximum Chl-a values at a mean depth of 1.5 m (5 ft) could be more than twice as great as it would be at 2.7 m (9 ft).

Wood (2002) remarked that if lake elevation affected *AFA* blooms, then it follows that a lower pH would result, but the author also noted that a quantitative link between the two remains “elusive,” and that “whether one accepts the theoretical arguments linking bloom size and lake level..., remains, unfortunately, a matter of belief and opinion, about which knowledgeable experts can legitimately disagree.” Unpublished laboratory studies by USGS using UKL sediments indicates that pH alone can only account for a small fraction of the phosphorus needed to support measured *AFA* blooms (Wood 2002).

Welch et al. (2002) point out that it is a complex task to predict the response of algal growth to the various influencing factors, especially in a lake like UKL. They also point out that although, this hypothesis is based on both theory and on data, and that most of the proposed mechanisms involved are supported by actual data from UKL.

### *Hypothesis 5: Higher lake levels mitigate low DO values*

Welch and Burke (2001) state that DO levels in UKL are primarily dependent on four factors: (1) magnitude of senescing *AFA* and algae bloom (demanding more DO than is produced by photosynthesis); (2) ratio of bottom sediment (source of SOD) to lake volume, which can be approximated by surface area: volume ratio (which increases from 0.1 at 4143 ft to 0.25 at 4137 ft); (3) extent of wind-driven reaeration; and (4) temperature (which determines rates of bio-chemical DO utilization). They cite modeling by Livingstone and Imboden that indicate the increase in DO depletion near the bottom of lakes suffering from eutrophication is largely due to increases in sediment area per unit volume, since water column demand is rather constant among different lakes.

Wood et al. (1996) analyzed the 1990-1994 UKL DO data using univariate analyses (single parameter) and concluded that the data are not sufficient to distinguish the relative importance of the various processes and the possible artifacts of data collection. Because very different DO concentrations occurred at similar lake levels, it is most likely that temporal trends were

determined primarily by seasonal factors, such as the *AFA* bloom/decay cycle, water column stability, and wind speeds; July -August water temperature control of DO saturation is not as important as these factors since it is rather constant from year to year. Addition of five more years of data (1995-1999) to the analysis did not result in a discernable DO and lake-level relationship (Wood, unpub. data).

It should not be surprising that univariate analyses did not find a relationship between lake levels and DO levels since a complex set of physical, chemical, and biological factors are likely involved, with lake levels being only one of these. DO levels should be related to rates of reaeration with in turn are dependent on wind speed which mixes the water column bringing DO from the surface into deeper depths. Welch and Burke (2001) showed that water column stability and wind speed are inversely correlated, such that stability decreases at higher wind speed. This likely explains why 1992 and 1994, both windy years (as measured at Klamath Falls), had no fish kills even though DO levels were relatively low (Welch and Burke 2001). Further, modeling indicated that in UKL, stability is more dependent on wind speed than depth, thus finding a significant relationship between lake levels and DO is confounded by the dominant effects of wind (Welch and Burke 2001).

In the oxygen mass balance model developed by Burleson Consultants (2002) for Shoalwater Bay, described above, it was predicted that in if wind mixing stopped surface reaeration, DO would decline at a rate of 1.7 mg/l/day and in as little as one day could take DO levels from adequate (>4 mg/l) to lethal (<2.5 mg/l). If the same assumptions used above were used for a water column of 3.5 ft instead of 7 ft, DO consumption rates would increase by 32% and therefore would decline more rapidly during a wind-less period. Thus, based on this simple mass-balance model, an increase in water depth is predicted to ameliorate declines in DO that occur when wind-driven reaeration is inoperative.

Wood (2002) in a critique of lake level effects on water quality, states that this hypothesis is “conceptually straightforward and theoretically sound,” and its potential significance in UKL has probably been underestimated. The author continues by saying that the temporal component of this hypothesis could be particularly important because of the sharp decline in DO that occurs at night when photosynthesis ceases, and that the effect of lake level dilution on DO depletion would be most critical in the shallower areas (<2 m) of the lake where a minor change in depth can have a proportionally large effect on nocturnal DO depletion. Welch et al. (2002) provide further support for this theory and state that DO demand of the water column during severe *AFA* crashes of nearly 250 ug Ch-a/l in a few weeks could be greater than SOD and therefore would exacerbate low-DO conditions. They point out a specific example of such a crash in August 1998 where DO went from as high as 14 mg/l to a low of >1 mg/l where a bloom crash and high RTRM values coincided.

Wood (2002) cites a study by Miranda et al. (2001) showing that in a shallow lake, the risk of reaching very low DO levels increased rapidly when depths were less than about 2 m, and the total area of shallow water changed with lake elevation. Miranda et. al (2001) developed a simple model to manage risk of low DO to a fish population in a shallow, eutrophic lake. The fish were experiencing annual die-offs associated with low DO. The researchers used a probability risk assessment to estimate the likelihood that the lake would be affected by critically low DO levels. A depth specific probability curve of low DO levels was developed using a “Monte Carlo” simulation of a DO model involving: SOD, water-column demand, air-water DO diffusion, and hours of darkness. To predict the probability that a certain area of the lake would be affected by low DO levels, the probability curve was combined with a bathymetric model of the lake, and the area affected was evaluated as a function of lake elevation. The results indicated the importance of shallow depths (<1 m) in determining the area of critically low DO. It was also evident that

water level management could be used to reduce the area of low DO concentrations, as well as reducing the area of infrequent events affecting large areas of the lake. The infrequent but large events were considered to be the greatest threat to the fish population because fish would be less likely to find refuge areas of higher DO.

The results of Miranda et. al (2001) are highly relevant to the situation in UKL because of the similar conditions; i.e., recurrent fish kills owing to high primary production and low DO levels, and shallow water depths affected by lake level management. The hypothesis that infrequent, large-scale water quality declines affect the ability of fish to avoid lethal conditions also appears applicable to UKL.

Since low DO is very likely to be a continuing problem in UKL until *AFA* biomass is reduced, it is crucial that available measures are used to mitigate its effect.

*Hypothesis 6: Higher lake levels improve under-ice and winter water quality*

Lake volume (elevation) under-ice conditions could influence the rate of DO depletion in UKL. A change in UKL elevation from 4140 to 4137 ft results in a 30% reduction in mean water column depth. With a larger sediment to volume ratio at lower lake elevations, DO depletion will occur faster than at higher lake elevations. Therefore, there could be a greater probability of low DO at lower elevations. Under-ice DO concentrations <5 mg/l were measured at elevations 4139.5 (1993), 4140.9 (1988), 4141.1 (1989) and 4141.7 ft (1988) by the Klamath Tribes. Because low DO occurred at a wide range of elevations, fish may be even more vulnerable to poor water quality during the winter when ice-cover conditions prevent air-water diffusion.

Welch and Burke (2001) estimated what DO levels in UKL could be under ice-cover condition using SOD values (1.5-3.0 gm DO/m2/day at 20° C, from Wood (2001) data), and assuming $Q_{10} = 2$, and predicted that DO levels could reach values known to be adverse to suckers after <60 days of ice cover.

Un-ionized ammonia is also considered to be a potential risk to suckers during the winter and under an ice cover (Loftus 2001), as discussed above, but, if there is any risk it would be highest in shallow bays where the sediment area to volume ratio is highest. Higher lake levels could reduce this risk by dilution.

Although, there is good theoretical justification for a connection between UKL levels and potential risk to suckers by under-ice conditions, especially for low DO, there are no empirical data to corroborate this relationship and therefore further studies are needed to determine if there is a risk.

*Hypothesis 7: Lower Lake levels improve DO levels*

Vogel et al. (2001) and Horne (2001) proposed that “lower” UKL lake levels would bring water quality benefits, especially higher DO levels. The central point of the Vogel et al. argument is that UKL suffers from low DO levels in summer because it is stratified. Burleson (2002) found evidence of thermal stratification (owing to a 1-3° C temperature differential) during sampling done in 2001 in deeper areas of the lake at Ball Point and Eagle Ridge where depths range from 27 to 36 feet. Nevertheless, most data indicate that UKL is usually well mixed and, rather than becoming stratified in summer, undergoes periods of fluctuating stability (Welch and Burke

2001; R2 Resource Consultants 2001). This distinction is not trivial since in truly stratified lakes reaeration of bottom waters by wind mixing is much reduced by water layers developed by distinct density differences. Welch and Burke (2001) conclude that a temporary lack of wind is

the primary factor responsible for summer periods of increased water column stability (and resultant lack of mixing and reaeration) in UKL, which are responsible for periodic hypoxic conditions in the water column that lead to sucker stress and die-offs.

Welch and Burke (2001, figure 4-10) show that wind speed is inversely correlated with RTRM ("Relative Thermal Resistance to Mixing," a water column stability index that is based on density differences) such that high RTRM occurs when winds speeds are low. During the recent fish kill years (1995, 1996, and 1997), RTRM was high and July-August maximum wind speeds (as measured at Klamath Falls, the nearest meteorological station with wind measurements) were relatively low. In 1992 and 1994, when median August UKL levels were lowest, wind speeds were high and, consequently, RTRM was low. Had the reverse been the case, Welch and Burke (2001) argue that DO conditions in 1992 and 1994, which were adverse, could have been even worse.

Wood (2002) points out that attempts to relate RTRM relationships to lake levels, must use water column depth as the independent variable, not lake levels, since depth varies over the lake at any one time. Wood points out that water column stability has not been investigated as a depth-dependent variable in UKL, and it is this relationship that is key to our understanding of the process. The author also suggests that the transient nature of water column stability cannot be fully appreciated when biweekly samples are the basis of the analysis, since RTRM values could change in a few hours owing to diel temperature fluctuations.

During the comment period following the release of the draft 2001 BO, the Service received a number of comments regarding the Vogel et al. (2001) report, including those from USGS (2001), Klamath Tribes (2001), R2 Resource Consultants (2001) and Welch (2001). None of these comments supported the assertion made by Vogel et al.(2001) and Horne (2001) regarding potential water quality benefits of reducing water levels in UKL.

*Hypothesis 8: Higher lake levels reduce un-ionized ammonia concentrations*

This hypothesis is similar to several others in that an increase in lake levels increases water volume and would dilute ammonia produced by microbial breakdown of *AFA* biomass. Some ammonia is taken up by phytoplankton including *AFA* as a nitrogen source. Un-ionized ammonia has been suggested as being a factor in fish kills and in contributing to chronic stress both in summer and winter (Perkins et al 2000b; Loftus 2001). This hypothesis is simple and plausible, and although not shown by empirical relationships from lake data, should nonetheless be operating in the lake. Wood (2002) states that "...if ammonia in excess of what the bloom incorporates continues to be liberated by temperature-dependent decay processes in the sediments that take-off in spring, it would make sense that more lake volume should provide some dilution."

Wood (2002) points out that ammonia levels in UKL have increased significantly since 1996 and perhaps this change was involved in the 1996 and 1997 fish kills. The explanation for the increase in ammonia during the last 5 years is being debated. Welch and Burke (2001) think it is related to low summer wind speeds which create water column conditions favoring ammonia production. Wood (2002) suggests that it might be related to the pulse of nutrients that entered the lake during high-flow events in the 1990s.

Wood (2002) suggests two potential processes might be related to ammonia production, one in which low DO in the lower part of the water column shuts off nitrification, thus allowing ammonia to increase, and one in which reducing conditions at the sediment/water interface cause nitrogen to be converted to ammonia. Wood (2002) also points out that there are features in the data that don't fit either scenario, pointing to the need for further study.

Although this hypothesis is likely to be operating in UKL there are still many unanswered questions about how the conditions that lead to ammonia production. It appears to be connected to seasonally low DO conditions in the water column and sediment, and thus is related to *AFA* bloom declines. Consequently, efforts to reduce AFA biomass and ensure adequate DO levels are present in the lake will help adverse effects of ammonia.

2.4.8 Upper Klamath Lake Water Quality: Summary

- By the late 1800s, UKL was apparently highly productive and likely experienced occasional fish kills.

- Although there are significant background levels of phosphorus, human-induced changes in the watershed as a result of forestry, agriculture, and grazing, have greatly increased nutrient input to the lake and leading to its current hypereutrophic state.

- Wetlands, which comprised about 46% of the lake area, likely played an important role in phosphorus cycling and by producing humics that may have affected algae growth. Significant wetland losses (66%), through diking and draining, likely was a major contributing factor affecting nutrient enrichment and *AFA* productivity.

- By the mid-1900s, UKL had reached a hypereutrophic status as a result of establishment of dense blooms of the cyanobacterium *AFA*.

- *AFA* blooms reach extreme levels of 200,000 cells/ml and Chl-a levels of >0.2 mg/l. As a result, acutely toxic, chronic, and stressful conditions for suckers and other fishes likely occur at some scale on an annual basis in the lake owing to high pH and un-ionized ammonia, and low DO.

- Internal loading of phosphorus contributes about 60% of total phosphorus and is likely affected by a number of factors, including shallow depths that promote wind-shear stress and resuspension of sediments, and a possible *AFA*-pH-phosphorous-*AFA* feedback loop that could increase internal loading of phosphorus and ensuring that *AFA* growth is not nutrient limited.

- Low DO levels are primarily the result of high SOD, but water column respiration may be nearly as high. Based on measured SOD values, potential water-column reductions in DO would range from 0.4 to >3.7 mg/l/day in late summer, and in the absence of photosynthesis and wind-driven reaeration, DO could be reduced to lethal levels in as little as one day.

- Low DO levels are likely to be most severe at shallow depths (<3 ft) because of the greater sediment area to water-volume ratio at these depths.

- The dominant factors controlling water quality in UKL are weather and climate.

- Greater water depths may improve water quality by a variety of hypothetical mechanisms: (1) reducing wind resuspension of bottom sediments thus reducing internal nutrient loading, and thus reducing *AFA* productivity; (2) reducing mean water-column light intensities thus reducing *AFA* productivity; (3) diluting pH, thus reducing the effect of the theoretical *AFA*-

pH-phosphorous feedback loop; (4) diluting phosphorus and ammonia, and other nutrients, thus reducing *AFA* productivity; (5) increasing the lake volume to sediment area, thus decreasing the effect of sediment DO demand on water-column DO, both during the summer when metabolic processes are high, and in winter, under ice-cover conditions when aeration ceases.

- Reduced water depths have been suggested as potentially improving DO levels in UKL because a shallow water column would be more readily mixed by wind. However, existing data indicate that water column stability (resistant to mixing) is primarily a function of wind speed rather then lake level. Also, any improvement owing to reduced depth could be offset during calm periods because of an increase in sediment-area to volume, increasing DO depletion by SOD.

- Although simple empirical relationships between lake levels and water quality are largely lacking for UKL, there is a substantial body of theoretical information and study results from UKL and other lakes indicating that greater water depths would most likely improve water quality. The degree to which water quality could be improved has not been determined and validated with empirical data from UKL.

- Finding a simple empirical relationship between UKL levels and water quality is problematic owing to: 1) previous sampling was not designed to answer this question; 2) UKL limnology is highly complicated and dynamic owing to its large size, shallow but diverse bathymetry and shoreline morphology; high susceptibility to air/water/sediment interactions; patchiness of biological and other processes, and other factors.

Based on the above discussion of the best available scientific information, the Service concludes that water quality poses a high risk to the long term survival of the endangered suckers. A number of theoretical mechanisms have been propos Hypothesis ed relating lake levels to water quality; however, empirical relationships between lake levels and those water quality parameters affecting sucker survival has not been found and there are reasons to doubt the validity of some proposed mechanisms. Nevertheless, one or more hypotheses are supported by a variety of information including data from UKL, published reports in peer-reviewed journals, as well as professional opinion of limnologists who have worked extensively on the lake. The best support is for improved water quality resulting from higher lake levels, especially as it affects nocturnal sags of DO in shallow water. Therefore, until new information is presented to the contrary, the Service concludes, based on an analysis of the best available scientific data, that there is credible reason to conclude that minimum UKL elevations could reduce the risk adverse water quality leading to fish kills. How much that risk is reduced is uncertain; however, even a small reduction in risk might improve the probability of long-term survival for these endangered species.

### 2.4.9 <u>Environmental conditions and their causal relationships to UKL fish die-offs</u>

The laboratory and in situ studies discussed above indicate that water quality in UKL reaches levels known to be stressful or lethal to suckers and other fish. This is supported by other observations showing that fish kills may not be unusual in UKL. When ichthyologist, C.H.Gilbert visited the lake in June 1894, a fish kill was apparently underway, because many dead and dying fish were observed (Gilbert 1898). Fish kills were also reported in 1932, 1971, and 1986 (Buettner 1997). In 1971, a series of articles appeared in the Herald and News regarding a large fish kill in UKL that affected an estimated 30 million fish, mostly chubs (Briggs 1971). The die-off first became noticeable in the third week of July 1971 and extended from Bare Island to the south end of the lake. By mid-August dead fish were reported in the mouth of the Williamson River and near Rocky Point. There were so may dead fish around the lake that a widespread cleanup was undertaken. The die-off was attributed to higher than normal temperatures, an intense bloom of the blue-green alga Gloeotrichia, low levels of DO, a parasitic copepod (Learnea sp.), and Columnaris disease. It is very likely that other fish kills occurred in the lake in the 19th and 20th centuries but were not reported.

It appears that a bacterial disease "Columnaris,"caused by *Flavobacterium columnare*, was the main infectious disease involved in the sucker die-offs but there may be other factors along with elevated water temperatures that predisposed fish to infection (Holt 1996; Foott 1996). In 1996, pathological examinations were conducted on 26 sick and dying suckers at the ODFW Pathology Lab at OSU. Columnaris bacteria were isolated from 24 of 26 specimens. Columnaris gill lesions were found in 78% of the LRS (9 total) and 77% of the SNS (17 total). No viruses were detected from these fish. Fungi were found in 58% and bacteria in 80% of the fish. Up to 23 leeches were attached in the mouth cavity producing ulcers and hemorrhaging. Some anchor worms were also attached to the base of the fins. Internally, the fish appeared normal except for presence of white trematode cysts on the heart.

Holt (2001) did some follow-up work on Columnaris obtained from suckers killed in the 1996 fish kill. In challenge tests done with juvenile LRS he found that isolated strains were of low virulence. This suggests that Columnaris may have had only a minor role in the 1996 fish kill and that water quality was the primary causal factor.

Histological examination of 12 moribund and 3 normal suckers were conducted by the U.S. Fish and Wildlife Service Fish Health Center, Anderson, California (Foott 1996). Lesions characteristic of bacterial infections were seen in 14 of 15 fish. All of the fish showed kidney abnormalities, specifically, degeneration of a specific region of the renal tubule. The degenerated tissue observed in the kidney is indicative of toxic tubular necrosis which can be caused by heavy metals, pesticides and other toxins (Foott 1996).

Data indicate that the 1996 die-off was linked to a combination of meteorological and biological conditions (Perkins et al. 2000b). Specifically, warm weather and relatively calm conditions during July and August led to warm water temperatures, stratification of the water column, and increased biological activity. Warm temperatures increased respiration rates and sediment and water column DO demand, as well as lowering the capacity of the water to hold DO. *AFA* populations that bloomed in June were generally declining. A lack of wind mixing likely reduced surface aeration and consequently fish were exposed to stressful levels of low DO leading to disease outbreaks and mortality.

In reviewing the Klamath Falls meteorological data records, weather conditions before and during the 1996 die-off were unusual. For example, the mean monthly July temperature was 73.5° F, making it the second warmest in 69 years of record at the Klamath Falls airport. The August mean monthly temperature, 70° F, was ranked 11th over the 69-year record. Warm weather was also associated with previous fish die-offs in 1995, 1986, and 1971.

Water temperature in UKL has been shown to be closely associated to air temperatures (Wood et al. 1996). Because UKL is so shallow and generally well mixed, water temperatures quickly respond to changes in air temperature. Lag time between changes in air and temperature appear to be only a few days during the summer.

Klamath Falls wind data indicate that July 1996 was ranked 4th out of the last 27 years for lowest mean monthly wind speed (3.2 mph). August was also a relatively calm month with an average monthly wind speed of 3.0 mph (5th out of 27 years). Wind records from the Klamath Falls airport generally indicate that winds are mostly light during the summer. However on a daily basis, winds vary, but typically are highest during the afternoon and early evening hours.

Cloud cover was also examined as it related to fish die-offs. In 1996, July and August were ranked 7th and 8th respectively as the sunniest months from the last 27 years. Sunny days can also be generally correlated to warm air temperatures during the summer. Sunny days generally dominate during summer months in all years.

Extensive water quality monitoring was conducted on UKL during 1996 to evaluate lake conditions during the die-off. Beginning about mid-July and extending through August, AFA populations were generally declining, with a large biomass of dead and dying AFA being present. Associated with the AFA decline were low DO concentrations. With calm conditions, stratification was evident, and near bottom DO was frequently <5 mg/l (Perkins et al. 2000b).

From June through August 1996, un-ionized ammonia levels were generally higher than any of the previous five years sampled. Mean lake-wide ammonia concentrations were 70-95 ug/l (Perkins et al. 2000b). Although these concentrations are well below the acute lethal levels for suckers of >0.5 mg/l, they may have contributed to stressful conditions prior to the sucker die-off (Loftus 2001).

After the 1997 die-off, dead and dying fish were provided to the ODFW Pathology Lab, and the Service Fish Health Center for examination (Foott 1997; Holt 1997). Columnaris was recovered from 80% of the fish submitted and Learnea copepod (anchor worms) infestation was observed on 73% of the fish. No viruses were isolated. Foott (1997) also noted a high prevalence of kidney abnormalities.

Perkins et al. (2000b) discussed the water quality conditions associated with the 1995-1997 fish die-offs. They concluded that the main cause of the die-offs was hypoxia caused by collapse of AFA blooms which triggered hypoxic conditions that became mixed throughout the water column. Susceptibility to hypoxia was probably enhanced by prior or simultaneous stress due to exposure to high pH and high un-ionized ammonia concentrations and low DO levels during the prior summer months. The summers of 1995-1997 experienced periods of low lake mixing and very low DO levels, due largely to the DO demand of rapidly declining and dying AFA blooms and usually higher ammonia levels. Temporary, high water-column stability created by low winds resulted in a lack of mixing and aeration.

Perkins et al. (2000b) attributed the direct cause of the fish die-offs to be low DO, because pH and hence, un-ionized ammonia (the ratio of un-ionized to ionized ammonia increases exponentially with pH) had declined to relatively low levels by the time the kills peaked due to large declines in AFA biomass. Other studies, e.g., Martin and Saiki 1999 and Saiki et al. (1999), have also considered that the primary water quality factor responsible for UKL fish kills is hypoxia. The kills occurred with mixing and very low DO concentrations due largely to the DO demand of the dying AFA blooms. The principal cause for the low DO values in July-August 1995, 1996, and 1997 that triggered the fish die-offs, in addition to bloom collapse, was high water column stability. Prior to the kills, there were low off-bottom DO levels, which were subsequently transmitted throughout the water column during mixing, thus there may have been no depths at which adequate DO levels occurred; therefore suckers and other fish may not have been able to avoid the lethal conditions.

Documented fish kills appear not to be directly related to lake levels in any simple way. They occurred in years of average, above-average-and below average, median August elevations (Welch and Burke 2001). Median August elevations are the most appropriate date for comparing lake levels and fish kills because August was the month when most kills occurred. Lake elevations in 1971 and 1995 were above average; 1986 was average, and 1997 and 1996 were below average. In 1992 and 1994, when two of the lowest elevations occurred, significant fish kills were not detected, but DO levels were low (Welch and Burke 2001), and had weather conditions been different, such as low winds speeds and higher temperatures, there is a high likelihood that there would have been significant die-offs. Data show that 1992 and 1994 were windy (Welch and Burke 2001) and under these conditions ammonia and DO levels are moderated by mixing (Welch and Burke 2001).

Although Fish kills can occur from July to October, August appears to be the month when fish kills are most likely to occur. Water quality was adverse in September and October 1996, 1997, and 1998, owing to a late summer bloom decline (Loftus 2001; Welch and Burke 2001).

Although sucker die-offs have received the most attention, adverse water quality will stress fish prior to causing mortality. Loftus (2001) has evaluated the Klamath Tribes and USBR long-term water quality data set for UKL to assess when water quality would likely cause stress. Such stress, although not acutely lethal could have significant adverse short-term and long-term effects (e.g., reduced growth and reproduction; increased susceptibility to disease, parasitism, physical abnormalities, and predation) and could be a factor leading to mortality and reducing overall fitness. During the period from 1990 to 1998, Loftus found that total stress days in summer ranged from 24 to 104. Low DO and high pH were the primary factors that would cause stress, with un-ionized ammonia likely being less significant before 1996. Beginning in the spring of 1996, un-ionized ammonia concentrations became substantially and consistently higher in UKL. They often reached sublethal levels at times when DO and pH would also be stressful (Reiser et al. 2001; Loftus 2001). One or more of the stressors occurred over several weeks at high levels prior to and during the die-offs in 1995-1997. Cumulative stress-day values were highest during July and August 1995 and 1997 when fish kills occurred. Stress was also likely to be high during July and August 1992 and 1994 when very low DO values were present. These data indicate that even though large fish kills may not occur annually in UKL, suckers are likely routinely stressed.

The National Research Council (NRC) in their interim report (NRC 2002) recently stated that no “clear connection” exists between UKL elevations and fish die-off events. In making their decision, the NRC stated that: “A substantial data collection and analytical effort by multiple agencies, tribes, and other parties has not shown a clear connection between water levels in Upper Klamath Lake and conditions that are adverse to the welfare of the suckers.” Although existing analyses have not found an empirical relationship between lake levels and fish die-offs this does not necessarily mean that they do not exist.

There appears to be three potential ways in which lake levels and fish die-offs might be related: 1) higher levels might promote die-offs; lower lake levels might promote die-offs; and 3) lake levels and die-offs are unrelated. Previously in this chapter we presented an analysis of the hypotheses that relate water quality and lake levels. Our conclusion is that, although, an empirical relationship between water levels and water quality is lacking, there is a substantial amount of scientific information to suggest that such a relationship exists, and that risk to suckers is likely reduced at higher lake levels. There are legitimate reasons why it would be difficult to find a relationship between lake levels and fish die-offs or between lake levels and the major processes that affect fish kills. Some of these difficulties have already been discussed above. Fish kills are the culmination of multiple factors that could be interrelated in a complex, non-linear, and multivariate fashion, thus making it very difficult to detect a relationship. A further complication is that fish kill data do not allow for typical correlation analysis since the data are discrete rather than continuous (i.e., there are no accurate estimates of total numbers of affected fish). Thus there is no way to know if the fish kills in the 1990s were smaller or larger in relationship to lake levels.

The Service believes, based on the best available science, that lake levels per se do not cause fish kills; they likely can; however, contribute to or mitigate conditions that cause fish kills and also

likely affect the number of fish that die. Proof that such relationships exist is most likely to come from directed studies which are specifically designed to answer this question. Accepting that lake levels may reduce risk to suckers, what lake elevations are needed to reduce the risk of adverse effects of water quality to an acceptable level is not currently known. Wood (2002) suggests that fish kills may be related to higher than average inflows which increase phosphorus levels leading to *AFA* blooms. If this is the case, then perhaps it would be best to manage the lake by mimicking pre-project lake levels and timing. This would also address water quality concerns through the summer as lake levels would not go as low as they have under previous Reclamation management.

2.4.10 <u>Availability of Water Quality Refuge Sources in Upper Klamath Lake</u>

The high Cascades that form the western boundary of the UKL watershed can have substantial snow pack in winter. The porous volcanic soils on the eastern slopes ensure that a large portion of the runoff will enter the regional ground water system when it melts, and consequently there are numerous springs and ground-water fed creeks in the Upper Klamath Basin along the eastern Cascade Front. The eastern base of Pelican Butte has an especially high number of springs and creeks, including Fourmile and Rock Creek, and Harriman and Malone springs (Geiger et al. 2000). Additional inflow comes from springs and creeks a few miles farther north that flow south, including: Cherry and Sevenmile creeks, and Crystal, Blue, Mares Eggs, Fourmile, Jacks, and Tiger Lily springs. All of these inflows enter UKL near Pelican Bay. Additional sources of higher quality water include the Wood River and Odessa Creek, both spring fed. Suckers may also use the mouth of the Williamson River when water quality is poor in the rest of UKL, and there is evidence that they will move into the mainstem Williamson and Sprague Rivers in late summer, when they would typically be in the lake, if water quality in the lake is poor (Golden 1969). These inflows improve water quality (higher DO, and lower temperature, pH and ammonia) in that portion of the lake, especially in summer. Radio-telemetry shows that adult suckers predominately use the area outside of Pelican Bay in summer where depths are adequate and the water is more turbid, as described below. This area appears to be where in summer, cold, clear water with high DO levels from springs mixes with warmer, turbid water with variable DO levels from the lake. A summary of information related to sucker use of freshwater inflow areas in UKL was presented in the BA of PacifiCorp and The New Earth Company operations associated with the Klamath Project (USBR 1996a). Additional information is provided under Adult Habitat Use.

## 3.0 CLEAR LAKE

### 3.1 Clear Lake: Reservoir History

Clear Lake Dam was constructed in 1910 to increase the storage capacity of the pre-existing lake, and to control releases of water for irrigation and flood control. It was also designed to increase evaporation rates by creating a large surface area with shallow depths in order to reduce downstream flows to reclaimed wetlands at Tule Lake, thus it is not an efficient water storage reservoir. Seepage losses are also high owing to underlying volcanic geology. Annual evaporation and seepage losses account for over half of the average inflow of water which is approximately, 128,000 ac-ft, at higher elevations. At maximum storage capacity of 4,543 ft above mean sea level, the reservoir has a surface area of about 26,000 acres and a maximum depth of about 30 ft. However, Clear Lake elevations have only surpassed 4,540 ft in four years since 1910 and have never reached maximum storage (Service 1992a); recently, Reclamation has had to control lake levels because of dam safety issues. Approximately 8,000 acres of irrigated lands in Langell Valley depend on water from Clear Lake. These irrigation canals, operated by Langell Valley and Horsefly irrigation districts, annually divert approximately 36,000 ac-ft of water from Clear Lake (Service 1994b). Most of the Clear Lake watershed is within the Modoc National Forest and very little irrigation occurs in the watershed above the lake; however, the watershed is modified by numerous stock ponds designed to hold water into the summer. Clear Lake and the land immediately around its perimeter comprise Clear Lake NWR.

Since construction of the dam, Clear Lake has been lower than the October 1992 elevation in only 4 years, all during the prolonged drought of the 1930s. In 1934, the water surface elevation was the lowest on record, reaching 4,514.0 ft. Contour maps provided by Reclamation indicate the lowest lake bed elevation is 4513.0 ft. Pre-impoundment elevation records for Clear Lake only exist for a few years (1904-1910), but 4,522.0 ft is the lowest elevation recorded for the natural lake. Inflow to Clear Lake averages 128,000 acre-ft but has varied from 18,380 acre-ft in 1933-1934 to 368,550 acre-ft in 1955-56 (Service 1994b).

Prolonged droughts have frequently affected the Clear Lake watershed. The most extended drought occurred in the 1922-1937 period, when only one year of above-average inflow occurred in 15 years. In the drought of 1987-1992, inflow was above average in only one of six years. Estimated inflows were only 51,310 acre-ft during the 1990-1991 water year and 23,350 acre-ft in the-1991-1992 water year (Service 1994b). Up to 1993, the water surface elevation in Clear Lake at the end of October had steadily declined from 4,531.8 ft in 1989 to 4,526.8 ft in 1990, 4,522.5 ft in 1991, and 4,519.2 ft in October 1992, as a result of a drought and irrigation water deliveries (USBR, unpub. data). The east lobe of Clear Lake is dry at 4,520 ft, except for a small pool of water near the dam. The 1992 water year inflow to Clear Lake was the third lowest on record (Service 1994b). If the 1993 inflow was similar to that of 1992, Reclamation had predicted that the west lobe of Clear Lake also would be dry, regardless of whether or not water was released for irrigation. Fortunately, the winter of 1992-1993 brought near record precipitation, instead of continued drought and Clear Lake elevations rebounded dramatically with a maximum of 4,529.5 ft reached in May 1993.

### 3.2 Clear Lake: Ecology

Because of shallow depths, mostly <2 m, and muddy sediments, Clear Lake is turbid owing to wind mixing; phytoplankton populations are low owing to high turbidity. Widely varying lake levels likely prevent growth of emergent vegetation. Macroinvertebrate diversity in the lake is low but densities are relatively high with oligocheats, chironomids, and nematodes dominating. Densities of chironomids reached approx. 4,500 individuals/square meter in October (Parker et al. 2000). Zooplankton is dominated by rotifers, cladocerns, and copepods. Cladocern concentrations were found to peak in August with a density of approx.120 ind./l (Parker et al. 2000). Clear Lake provides habitat for blue and tui chubs, marbled sculpin, lamprey, and large populations of both LRS and SNS (Buettner and Scoppettone 1991). The only plentiful exotic fish is the Sacramento perch (*Archoplites interruptus*).

## 4.0 GERBER DAM AND RESERVOIR

Gerber Reservoir was built by the BOR in 1925, by damming Miller Creek to provide flood protection and irrigation deliveries to about 17,000 acres in Langell Valley. It has a surface area of 3,800 acres at maximum capacity and about 150 acres at minimum elevation. Capacity varies from about 93,000 to 50,000 ac-ft. The reservoir is relatively deep, with a mean depth of >20 ft and a maximum depth of >60 ft, allowing the reservoir to stratify and undergo oxygen depletion below the thermocline. In the drought years of 1992 and 1994, DO concentrations near the bottom were <4 mg/l. The reservoir is considered eutrophic and thus is highly productive, but not to the degree of UKL . Each October most flows to Miller Creek are cut off; however; a 1-2 cfs

flow is maintained through the winter. By January or February accretion flows may be sufficient to support suckers without additional releases from Gerber Dam; however, this needs to be investigated. The larger Gerber Reservoir tributaries are: Barnes Valley, Ben Hall, and Wildhorse creeks.

Under previous BOR management, the reservoir was often drawn down very low, significantly reducing available habitat and putting the SNS there at risk from water quality and other problems. In October 1992, following a 6 year drought, Gerber Reservoir reached a minimum elevation of 4796.4 ft, which is <1% of its maximum capacity. Aeration was used to maintain water quality during the preceding summer as reservoir levels dropped. Reclamation biologists found that SNS in the reservoir at that time showed signs of stress including low body weight, poor gonadal development, and reduced juvenile growth rates (Buettner, pers. comm.).

Reclamation conducted water quality monitoring at Gerber Reservoir from October 1991 to December 1994 (USBR, unpub. data). Temperature, DO, pH, and conductivity were monitored using a datasonde. Continuous data was collected near the dam at 1 meter below the surface. Instantaneous profile data was collected at up to 8 sites around the reservoir. In 1992, an extremely low lake level year, low DO conditions were documented during the summer months. Most values ranged from 4-6 mg/l throughout the water column. In June 1992, DO reached a low of 1.1 mg/l at the bottom or the reservoir near the dam, and readings < 4 mg/l were recorded from May through mid September. In the fall, DO concentrations increased continuously as water temperatures decreased.

In 1993, a wet year with relatively high lake levels, water quality conditions were much better than 1992 (USBR unpub. data). DO concentrations were low during January and February associated with ice-cover conditions. Readings ranged from 3-6 mg/l in the top several meters and as low as 1.5 mg/l near the bottom. During the thaw and major runoff period in mid to late March, DO increased to 9-10 mg/l. DO concentrations during the summer were relatively high and variable in the surface waters associated with *AFA* bloom activity. Bottom DO dropped throughout the summer and early fall. In June readings were 7-8 mg/l, dropping to less than 2 mg/l in August-October. This change was associated with stratification of the lake. A DO level of approximately 2 mg/l is considered a high potential risk for suckers. Water temperatures were 3-5° C cooler at the bottom than the surface.

Water quality conditions in 1994, which was a low reservoir level year when the reservoir reached only 12% of capacity, were similar to 1993. In January and February, during ice-cover conditions, DO concentrations were relatively high in the upper 5-8 m (6-11 mg/l) and decreased to less than 1 mg/l at the bottom. *AFA* blooms occurred in July and August influencing pH and DO conditions. DO levels remained above 4 mg/l in the top 3-5 m. Lower DO concentrations were recorded at deeper depths during July and August.

Following the droughts of 1992 and 1994, inflows to Gerber Reservoir were relatively high owing to above average precipitation. As a result, physical and chemical habitat conditions in Gerber Reservoir apparently remained good with no adverse effects noted.

Sucker condition factors have varied considerably in the Gerber population. SNS captured in 1992 and spring 1993 were very thin compared to those from Clear Lake, Tule Lake and UKL, while SNS captured in 1994-1996 were substantially more robust (USBR unpub. data). Extremely low water levels, high turbidity, and low DO concentrations may have contributed to their poor condition; however, the environmental conditions associated with variability in condition factor have not been analyzed for the Gerber populations.

Suckers are entrained at the outlet of Gerber Dam. Salvage efforts in the plunge pool below the outlet yielded juvenile and age 0+ suckers in 1992 and 1993. Because of the risk of injury to personnel, salvage operations have not been continued. Downstream flows in Miller Creek are shut off at the end of the irrigation season, usually in October, as described above. The 1-2 cfs bypass is released into Miller Creek in winter to prevent the outlet valve from freezing. The Service is concerned that minimum winter flows in Miller Creek are inadequate and could likely result in mortality. Higher minimum winter flows would ensure Miller Creek remains physically connected with the Lost River, allowing out-migration of age-0 suckers and upstream spawning migrations of adult suckers in the spring. Before Miller Creek empties into the Lost River, flows are diverted into North Canal during the irrigation season. Thus, little flow currently reaches the Lost River at any time of year.

Historic reservoir operations have likely resulted in widely ranging amounts of available habitat and water quality that has often reached stressful or lethal levels. Continuation of such operations is likely to result in incidental take of SNS. For above average inflow years when elevations are mostly above 4815 ft, the surface area of the reservoir is about 2500 acres, of which perhaps approximately 2000 acres have adequate depth and water quality to support adult suckers. During below average and dry inflow years, when minimum elevations go down to 4800 ft, the surface area shrinks to about 750 acres, reducing sucker habitat to less than a third of the that available in above average years, and thereafter decreases very rapidly, reaching only a few acres at lowest elevations. When available habitat shrinks to a few hundred acres, adult suckers are likely stressed by water quality (in summer when DO may decline from high temperatures and high BOD, and in winter below an ice cover), increased competition for reduced prey availability, and increased incidence of disease, parasites, and predators. Effects of low lake levels on larvae and juvenile suckers is likely to be even greater than adults since they have lower food reserves, higher metabolism, lower mobility, and are more vulnerable to predators.

## 5.0 LOST RIVER

### 5.1 Lost River: Historic and Current Sucker Habitat Conditions

Aquatic habitats throughout the upper Klamath Basin are highly modified, but the Lost River and Tule Lake has perhaps been the most severely affected. As mentioned above, the Lost River was once a major spawning site for suckers that resided in Tule Lake. Modoc and Klamath Indians gathered along the Lost River during the spring spawning runs to harvest suckers. Later it was the site for several canneries. However, today the Lost River supports few suckers, and furthermore, can perhaps be best characterized as an irrigation water conveyance, rather than a river. For nearly its entire 75 mile length, from Clear Lake Reservoir to Tule Lake Sump, the Lost River is highly modified to meet agricultural demands. Flows are completely regulated, it has been channelized in one 6 mile reach; its riparian habitats and adjacent wetlands are highly modified; its flows are reduced by diversions part of the year and are high at other times when water is released from the two dam for flood control; and it receives significant discharges from agricultural drains and sewage effluent. The active floodplain is no longer functioning except in very high water conditions. This has likely affected wetlands and wet meadows and may have resulted in lowered water tables, further increasing the need for irrigation. The net result of these changes is that the Lost River aquatic ecosystem is highly degraded.

Numerous water-diversion structures are located on the Lost River including Malone, Big Springs, Harpold, Lost River Ranch, Lost River Diversion, Lower Lost River Diversion (Wilson Dam), and Anderson Rose dams. There are also numerous unscreened pumping plants that remove water, and drains that receive irrigation return flows. Unscreened UKL water can be diverted into the Lost River at several points and as far upstream as the Poe Valley, and Lost River water can be diverted to the Klamath River via the Lost River Diversion Canal.

Consequently flows are highly modified both in timing, quantity, and quality (Orlob and Woods 1964). It is possible that flows may even reverse when water is being pumped from river. The Lost River was historically connected to the Klamath River during high flows via the Lost River Slough, as discussed below (Gilbert 1898). The Lost River Diversion Canal was constructed at the location of that slough.

Owing to irregular and unplanned irrigation withdraws from the Lost River, water levels in the river may rapidly fluctuate leading to bank instability and slumping, fish are likely stranded, and fish habitat quality is much reduced. Flows in the upper reach of the Lost River, from the Clear Lake Dam to the confluence with Rock Creek, are cut off from October to April during the non-irrigation season, with the only flows coming from accretion primarily by small springs and Rock Creek. During this time, any fish found in remaining pools are likely subjected to high predation, a lack of food, and poor water quality (Contreras 1973; Koch and Contreras 1973). DO levels in the Lost River measured in September 1999 after flows were cutoff at Clear Lake Dam were <4 ppm in pools and contained numerous dying aquatic insects and mussels (USBR, unpub. data). Downstream reaches, such as below Malone Dam, can have much reduced flows in summer as water is diverted from the river into West Canal, and Miller Creek flows diverted to North Canal. A number of small pumping plants are also withdrawing water from the Lost River. How many of these diversions are screened is unknown but it is likely that few have adequate screens or even any modifications to reduce or minimize fish entrainment except for the largest fish.

Several large springs (e.g., Big, Bonanza, and Crystal springs) contribute significantly to baseflows. Big Springs, east of Bonanza, contributes about 70 cfs of artesian flow to the Lost River (Orlob and Wood 1964). There are anecdotal reports of the Lost River not flowing in late summer prior to construction of Clear Lake and Gerber dams. This appears unlikely owing to the large number of springs and wetlands and meadows that likely contributed to baseflows prior to extensive modifications of the river and its floodplain.

The highly modified nature of the Lost River is expressed in its aquatic fauna, which include many exotic, warm-water species and is dominated by highly tolerant chubs (Contreras 1973; Koch and Contreras 1973). Of the 16 fish species known from the river, 9 are non-native, warm-water fish. Koch and Contreras (1973) identified four distinct river segments, based on fish distribution and abundance: 1) upper Lost River, upstream of Bonanza, which is largely devoid of fish because of channelization and shallow depths owing to water diversions; 2) Big Springs to Harpold Dam which contains the best fish habitat owing to significant input of spring water and suitable habitat; 3) Crystal Springs Reservoir above Lost River Diversion Dam (also called Wilson Dam), which also has a relatively high diversity of fish; and 4) lower Lost River, characterized by a lack of fish habitat and poor water quality and consequent low fish diversity. A fifth reach might be added between Malone Dam and Clear Lake. This reach is relatively high gradient and rocky. It has been dewatered each winter when flows are cutoff at Clear lake Dam. Likely few fish in this dewatered reach survive through the winter. Reaches of the Lost River with relatively high fish diversity can be described as having adequate flows, better than average water quality, and better habitat or greater habitat diversity.

During the irrigation season, Miller Creek flow is diverted into North Canal. Annual salvage of large numbers of redband trout from North Canal by Reclamation fish biologists (USBR 2000d) suggests that high quality water is being released upstream at Gerber Dam. Ironically North Canal in the irrigation season now has some of the better stream habitat for fish in the Lost River system; the best habitat is in the Miller Creek canyon managed by BLM.

### 5.2 Lost River: Water Quality

High temperatures, low DO, elevated nutrients, and high levels of suspended sediments are considered to be problems in the Lost River. The Lost River is on the State of Oregon’s 303(d) list for several water quality parameters that fail to meet minimum state limits including: DO, pH, temperature, bacteria, and chlorophyll-a (Chl-a). Koch and Contreras (1973) noted that temperatures in April were highest in the upper Lost River below Clear Lake Dam and Langell Valley where flows were low owing to a lack of dam releases. Koch and Contreras (1973) noted that in Langell Valley, where the river is channelized and flows reduced by diversions, habitat is lacking.

Reclamation has conducted water quality monitoring at up to 17 locations in the Lost River between Malone Dam and Tule Lake from 1992 to the present (USBR unpub. data). Between 1992-1998, biweekly to monthly profile data were collected using datasonde water quality instrumentation that continuously monitored temperature, DO, pH, and conductivity. Reclamation has also collected more detailed water quality information quarterly at Anderson Rose Dam and Wilson Reservoir since 1980 and twice a year (May and August) at Malone Reservoir and Miller Creek Dam. Water quality constituents included: air temperature, water temperature, DO, pH, conductivity, ammonia, nitrate + nitrite N, orthophosphate, total phosphorus, Kjeldahl nitrogen, total dissolved solids, alkalinity, boron, mercury, turbidity and arsenic. Although it would be very useful to have the results of these studies, the Service is not aware of any reports resulting from these studies.

Beginning in May 1999 and extending to May 2001, Reclamation expanded its’ water quality monitoring program in the Lost River sub-basin to provide more detailed baseline information on selected water quality parameters on both a seasonal and spatial scale (Shively et al. 2000b). Sampling occurred every two weeks at 13 sites along the course of the Lost River. A detailed analysis of this data has not been completed, but it was found that DO levels were below State of Oregon standards of 5.5 mg/l at all stations except North Canal, which gets its water from Miller Creek. DO levels were lowest in Wilson Reservoir, where they were near 1 mg/l, but were also low at other stations downstream from Wilson, including #5 Drain, Anderson Rose, and East/West Bridge. It can be concluded that water quality in the Lost River limits habitat for all fish, including LRS and SNS, and can be seasonally lethal.

## 6.0 TULE LAKE SUMPS

### 6.1 Tule Lake Sumps: Historical Account

Historically, Tule Lake covered a maximum area of about 95,000 acres (Abney 1964), making it about the same size as UKL, before diking and draining reduced its surface area. Tule Lake is the terminus of Lost River, but historically, flood flows from the Klamath River would also enter Tule Lake by way of Lost River Slough. Lost River got its name from the fact that it did not directly connect to the sea.

In the 1880s, white settlers built a dike across the Lost River Slough in a first attempt to reclaim Lower Klamath and Tule lakes. Reclamation began actively reclaiming historic Tule Lake with the construction of Clear Lake Dam in 1910 and the Lost River Diversion Dam in 1912 (USBR 1953). In 1932, a dike system was constructed to confine the drainage waters entering Tule Lake to a central sump of about 10,600 acres. In 1937, maintaining the dike system became difficult as heavy inflows required an additional 3,400 acres of surrounding lands to be flooded. In 1938, the sump was increased to 21,000 acres. During the winter of 1939-40, heavy inflows entered the sump again and dikes broke, flooding an additional 2,400 acres and damaging crops. Thus, it

became necessary to control the level of Tule Lake by installing a pumping station.

In 1942, a 6,600 foot-long tunnel through Sheepy Ridge and Pumping Plant D were completed, allowing water to be pumped from Tule Lake into Lower Klamath Lake (USBR 1941). This pumping station provides flood control for Tule Lake and is now the primary source of water for Lower Klamath NWR.

The present Tule Lake is highly modified and consists of two shallow sumps, 1A and 1B, connected by a broad canal, the “English Channel.” The two sumps have a combined surface area of 13,000 acres and a maximum depth of 3.6 ft. Water entering Tule Lake comes from three sources: (1) direct rainfall, (2) agricultural return water, and (3) the Lost River. In winter, most of the Lost River flows are diverted at the Lost River Diversion Dam to the Klamath River via the Lost River Diversion Channel. In the irrigation season, this channel is also used to supply water from the Klamath River by reverse flow for lands in the Tule Lake area. Therefore, most of the water entering Tule Lake during the irrigation season originates from UKL, via the Klamath River in the Lake Ewauna area. The total mean annual inflow into Tule Lake is about 90,000 acre/ft (Kaffka et al. 995).

Critical habitat for the suckers has been proposed for Tule Lake sumps 1A and B and upstream on the Lost River to the Anderson-Rose Dam (Service 1994). In designating this area as proposed critical habitat the Service considered that Tule Lake could support viable, self-reproducing populations of LRS and SNS. If habitat in Tule Lake sump is not improved and access to upstream spawning habitats, the ability of a sucker population in the sump to be self-reproducing is doubtful.

Water level elevations in Tule Lake sumps has been managed according to criteria set in the July 22, 1992 BO and continued in the April 5, 2001 BO. From April 1st to Sept. 30, a minimum elevation of 4034.6 ft was set to provide access to spawning sites below Anderson Rose Dam for dispersal of larvae and to provide rearing habitat. For the rest of the year, October 1 to March 31st, a minimum elevation of 4034.0 ft is set to provide adequate winter depths for cover and to reduce the likelihood of fish kills owing to low DO levels below ice cover.

## 6.2 Tule Lake Sumps: Ecology

Although no recent comprehensive biological surveys exist for Tule Lake sump 1A, general field observations by refuge biologists indicate that the plant community is composed of *Scirpus acutus, Scirpus fluviatilis, Typha latifolia, Sago pectinatus, Ceratophyllum demersum, Zannichellia palustris, Myriophyllum* sp. and *Lemna* spp. (Dave Mauser, Service, pers. comm.). Abney (1964) reported that the marsh consisted of 80% bulrush, 14% cattail, 5% river bulrush with smaller amounts of giant bur-reed, sedges and rushes.

Phytoplankton surveys from UKL (Bond et al. 1968; Gahler 1969; Hazel 1969 and Johnson 1985), a primary water source for Tule Lake NWR, provide indications of phytoplankton species that exist in Tule Lake. Invertebrate surveys in Tule Lake sump 1A report the presence of coelenterata; nematodes; annelids including oligochaeta and hirudinea; mollusca including gastrapoda; arthropods including crustacea (copepoda, conchostraca and amphipoda) and chelicerata; and insecta including ephemeroptera, odonata, trichoptera and diptera (chironomids and tipulidae). General field observations by refuge biologists indicate the presence of other species including hemiptera (Dave Mauser, pers. comm.).

Sump 1A is currently being operated as a seasonal deepwater wetland. It is thought that this management will improve water quality as well as provide waterfowl habitats. No data are available on effects on water quality.

### 6.3 Tule Lake: Water Quality

Tule Lake is classified as highly eutrophic because of high concentrations of nutrients and resultant elevated aquatic plant productivity (Winchester et al. 1994; Dileanis et al. 1996). Because Tule Lake is shallow and the nutrient content is high, aquatic plant and phytoplankton activity cause large fluxes in levels of DO and pH.

During the irrigation season, water reaching the sumps has been used an average of three times by being applied to agricultural lands (Orlob and Woods 1964). Tule Lake water quality is affected by its various sources of inflow. During the irrigation season, the primary source is UKL, via the Lost River Diversion Canal and A-canal. UKL is highly eutrophic as discussed previously, with large, near-monoculture blooms of the cyanobacterium (formerly termed, blue-green alga), *Aphanizomenon flos-aquae* (*AFA*) occurring almost continuously from spring through fall (Kann 1998). Associated with the blooms are extreme water quality conditions such as high pH and low DO levels (Dileanis, 1996). Water from Clear Lake and Gerber reservoirs also flows into Tule Lake sump 1A through the Lost River after receiving agricultural return water from the Langell Valley, Horsefly, Poe Valley, Klamath and Tule Lake Irrigation Districts. Agricultural return flows contain higher concentrations of dissolved salts including sulfates and nitrates, as well as ammonia and pesticides, than the source waters.

Water quality can vary greatly both seasonally and diurnally, especially in summer. Due to the lake's shallowness and high biomass of aquatic macrophytes and filamentous green algae during summer, DO and pH levels fluctuate widely. During the winter, most inflow to Tule Lake is from localized runoff. Water quality conditions during this time of year are relatively good, except during prolonged periods of ice-cover when DO levels decline. Reclamation has documented surface temperatures up to 26° C, and DO levels from super-saturation, >15.0 mg/l, to near zero; pH occasionally exceeded 10.0 (USBR, unpub. data).

Specific conductance in Tule Lake is high, up to about 1,000 umhos/cm, compared to UKL (120 umhos/cm). This increase is due to salts leached from soils in agricultural return flows and from bottom sediments of Tule Lake. High rates of evaporation (over 3 ft per year) in the shallow and warm sumps also increases salt concentrations. Salt concentration, however, does not appear to be an immediate threat to LRS and SNS. In Pyramid Lake, where specific conductance is nearly 6.5 times higher than Tule Lake, another lake sucker, the cui-ui, *Chasmistes cujus*, thrives. The cui-ui and other lake suckers similar to the LRS and SNS have apparently evolved in habitats with high conductivities and appear to be tolerant of such conditions (Miller and Smith 1981). The high salt content of Tule Lake waters also may explain the low incidence of fish parasites (E.Snyder-Conn, USFWS, pers. comm.).

Bioassays have shown that agricultural drain water and water within Tule Lake sumps is seasonally toxic, owing to low DO and high pH and ammonia levels, to some test aquatic organisms including *Daphnia* sp. and the fathead minnow, *Pimephales promelas* (Littleton 1993, Dileanis et al. 1996). In 1991 and 1992, Dileanis et al. (1996) found that un-ionized ammonia concentrations were at potentially toxic levels in water sources, drains and receiving waters around the Tule Lake sumps, but the sumps produced the highest percentage of values above the EPA criteria 0.02 mg/l (depending on pH and temperature). Although unionized ammonia is of concern, over the short term, the frequent low DO levels in Tule Lake sumps may pose the number one threat to aquatic life, including fish (Snyder-Conn, USFWS, pers. comm.).

If suckers are somehow able to survive water quality conditions in the sump, it is likely that decreases in water depth in Tule Lake sumps may ultimately make the sumps too shallow for suckers. Between 1958 and 1986, approximately 30%, or 14 inches, of depth was lost in the sumps owing to sedimentation. The shallow depths also exacerbate low DO conditions owing to the high sediment area/volume ratio.

A variety of pesticides have been detected in waters and sediments around Tule Lake; however, the levels are below those known to be acutely toxic to aquatic life (Dileanis et al. 1996).

## 7.0 LINK RIVER

### 7.1 Link River: Environmental Baseline

The Link River historically carried the entire surface outflow from Upper Klamath Lake. The head of the river was formed by a basalt sill, near the entrance to A-canal and about one-third of a mile upstream from the present dam. Water flowed over this sill into a low-energy lacustrine reach and then over a second sill at the present dam site. From this sill the water flowed down relatively high-gradient rapids for about 1.7 miles with a drop of approximately 55 feet to Lake Ewauna. The only natural "falls" in the Link River that potentially blocked fish passage are two small drops of 3-4 ft on either side of a bedrock island about 600 ft downstream of the present dam site (USBR 2000). At flows of 2,500 cfs, or greater, the "falls" are completely inundated. Dynamite apparently was used to clear log jams in the Link River at least once in 1911 (Spindor 1996); however, the exact location and effect on the channel morphology is not known.

Water withdrawals from the upper Link River began in 1868, and in 1878 the Ankeny-Henley canal drew water from near the site of the lower bedrock sill. The A-canal was first opened in 1907, and the westside Keno Canal was completed in 1908. Regulation of water levels in UKL began in 1921, with completion of the Link River Dam and the lowering of the reef at the entrance to Link River. The reef had a elevation of 4173.8 ft (Boyle 1964). A 100-ft-wide cut was blasted through the reef down to elevation 4131 to allow lake levels to be drawn to 4136 ft (Boyle 1964). Prior to construction of the dam, the lake level varied from about 4139.9 to 4143.1 ft (USBR data), with a mean annual variation of about 2 ft (USBR data). Since 1921, water levels have varied from 4136.8 to 4143.3 ft., a range of about 6 ft (USBR data). Water level regulation has also changed the seasonal timing of high and low elevation by making the highest and lowest elevations occur earlier in the season as well as prolonging the period of low water.

At present, much of the reduced flow that reaches the Link River after diversions into A-canal is diverted around the upper 2/3 of the river by two hydropower diversions operated by PacifiCorp. The diversions, one on each side of the river, originate at the Link River Dam. The westside diversion has a maximum capacity of 300 cfs; the eastside 1200 cfs. Minimum releases to the river is 100 cfs. The power houses are located about 1/4 mile above Lake Ewauna.

Link River Dam is equipped with an old and apparently ineffective fish ladder on the east side intended to provide upstream passage for salmonids through the Link River to UKL (Ott 1990, PacifiCorp 1997). The ladder is a pool and weir type which was retrofitted to the dam in 1926. In 1952, a spillway apron and training walls were installed downstream of six stoplog bays, and the stoplogs were replaced by gates. In 1975, the stoplogs in the other bays were joined together to form wooden gates, and a lifting mechanism was installed. A vertical slot entrance pool was added in 1988. It is currently about 105 ft long, gaining 13 ft in elevation, with 11 pools. Flow through the ladder is approximately 15 cfs. The weir exits into Upper Klamath Lake at elevation 4,138.5 ft, and when lake elevations are below 4,138.5 ft, the ladder is impassable.

PacifiCorp conducted a study in 1990 to identify actions that could be implemented to improve fish passage at Link River Dam (Ott Engineers 1990). Deficiencies of the fish ladder were identified by Ott as: an approach through a long channel with little attraction flow, a poor entrance requiring fish to cross a shallow cascade, small pool volume and shallow water in the lower pools, lack of self-regulating flow adjustment, and general disrepair of the weir baffles. Very low numbers of suckers have been recorded from the Link River fish ladder, which appears to be related to operational procedures, inadequate passage facilities, and a low-flow fish barrier located downstream of the dam (Ott Engineers 1990; PacifiCorp 1997).

## 8.0 OTHER MISCELLANEOUS ONGOING EFFECTS TO ENDANGERED SUCKERS

### 8.1 Effects of Ongoing Watershed and Stream Alterations on Water Quality and Quantity

Watershed and stream alterations can affect sucker habitat and water quantity and quality. Hydrologic alterations can directly affect spawning habitat. The preferred sucker spawning substrate is gravel, and since eggs are broadcast, they will settle among the stones. Hydrologic changes that alter normal bedload movement and scour and fill patterns can excavate or bury eggs, exposing them to stream flow, and trapping or crushing eggs or fry. Increasing levels of fine sediments affects developing embryos by filling interstitial spaces within stream substrate, reducing or eliminating water flow through the substrate, cutting off the supply of oxygen, causing waste products to build up, and may be sufficient to reduce or eliminate the ability of larvae to emerge from the substrate. Hydrologic and sediment regimes can be altered by vegetation removal, site disturbance, and soil compaction associated with timber harvest and grazing, channelization, road construction, riparian clearing. and etc.

Degraded stream channels are often a result of higher peak flows and increased sediment loads resulting from watershed alterations. Streams may become incised, no longer allow over-bank flooding, and thus all energy must be dissipated with the channel resulting in increased channel erosion. Also, less water is stored in the floodplain resulting in decreased baseflows.

One of the most damaging watershed alterations is compaction of soils, causing faster runoff of surface water such as along road ditches. Roads, because they consist of compacted and impervious soils, act as extensions of the drainage system by redirecting subsurface water to the surface and routing it into stream channels more quickly. This results in increased storm flows, as discussed below, and reduced base flows in streams. Baseflows may also be reduced when fire suppression leads to higher densities of trees. Reduction of baseflows would contribute to reduced water quality in sucker habitat. Risley and Laenen (1999) noted changes in flows in the Williamson and Sprague rivers when pre-1950 flow data were compared to more recent data. These data were insufficient to allow determination of what land-use was responsible for the change, but agriculture, forestry, and grazing are the major land-disturbing actions in the watershed.

Although temperatures in the Klamath Basin rarely if ever get sufficiently high to be lethal to suckers, they do affect suckers in a variety of ways, such as *AFA* blooms and associated changes in water quality, as discussed above. Locally, suckers may seek out areas of better water quality, where lower temperatures and higher DO concentrations occur during summer (Bond et al. 1968; Hazel 1969; Bienz and Ziller 1987; Buettner and Scoppettone 1990). High temperatures may be involved with heavy parasite loads on suckers and other fish such as occur in Clear Lake (Snyder-Conn, pers. comm. 1999).

Although high temperatures can contribute to seasonally stressful water quality conditions, they may also contribute to high sucker growth rates. Terwilliger et al. (2000) found that within the 15 to 24° C range of summer temperatures that juvenile suckers in UKL experienced in 1997, growth was fastest at the highest temperatures. This suggests that higher temperatures, and associated increased growth and available food, may benefit suckers as long as water quality conditions do not become overly stressful or lethal.

ODEQ has identified nearly 25 stream segments flowing into UKL as being temperature limited (ODEQ 1998). Groundwater entering streams, especially small streams, may be an important determinant of stream temperatures (Spence et al. 1996), or may provide localized thermal refuges. Where groundwater flows originate above the neutral zone, approximately 50-60 ft below the surface, groundwater temperatures will vary seasonally, as influenced by air temperature patterns (Spence et al. 1996). Groundwater recharge is reduced when soil interstitial spaces are lost or soil “pipes” fill owing to soil compaction.

## 8.2 Effects of Ongoing Forest Practices on Water Quality and Watershed Function as they Affect Suckers

The Service assumes that forestry practices using accepted best management practices (BMPs) have minimal impacts to listed species, including suckers. However, it remains to be determined whether acceptable BMPs are being fully implemented in areas where they could affect suckers.

Timber management affects listed suckers through a variety of impacts or alterations to watershed structural conditions and functional capacity. The primary pathways for negative impacts are through alterations of stream temperature patterns, hydrologic and sediment regimes, and reduction of channel complexity as well as the structural features that maintain channel complexity. Potential adverse effects also include introduction of pollutants, e.g., fuels, fertilizers, pesticides, and herbicides, into watercourses while conducting harvest, site preparation, stand maintenance activities, and wildfire suppression.

Forests in the Klamath basin have been managed for timber production, with substantial activity in the 1925-1940 period, peaking at 800 million board feet. The current harvest is much less than this. Extensive harvesting, including partial cutting with overstory removal, clearcutting, and selective logging for old-growth pine occurred on private lands, and low intensity harvest occurs on some of the U.S. Forest Service lands.

Past forest management activities in the Klamath River basin have temporarily reduced riparian vegetative cover and increased water temperature in some streams (Light et al. 1996; USFS 1994; 1995a,b, 1996, 1998). Sediment from existing gravel logging roads continues to degrade stream habitat (Light et al. 1996). There was also a decrease in the numbers of pools in streams in the Basin (Lee et al. 1997). The watershed analysis reports, produced by Winema NF and Fremont NF, provide the most complete analyses of present conditions of watersheds and streams within the action area (USFS 1994, 1995a,b, 1996, 1997, 1998).

Private industrial forest lands in the UKL watershed comprise about 0.4 million acres. The

Oregon Department of Forestry has implemented land management plans for State and private forest lands. Water protection rules have been adopted and apply to all public and private commercial timber lands. Under these rules, operators submit a harvest plan and must obtain written approval from the State Forester before tree harvest can occur within buffers that are delineated as the "Riparian Management Zone." The Service is unaware of any data on compliance with protection rules. However, ODEQ has recently reviewed the water protection rules and found problems with compliancy with state water quality regulations. With full compliance it is assumed that aquatic ecosystems will be adequately protected and will improve.

Timber harvest has the potential to affect stream temperatures primarily through reducing streamside canopy levels. The potential for riparian vegetation to mediate stream temperatures is greatest for small to intermediate size streams and diminishes as streams increase in size, lower in the floodplain (Spence et al. 1996). Generally, small and intermediate streams represent the majority of total aggregate stream length within a watershed (Chamberlin et al. 1991). Given these relationships, maintaining adequate canopy conditions on small and medium sized streams (including intermittent streams) is necessary to avoid altering natural temperature regimes. A reduction of stream shading is considered to be the major cause of increased stream temperatures in the upper Klamath Basin (S. Kirk, pers. comm.).

Timber harvest from upland areas exposes the soil surface to greater amounts of solar radiation than under forested conditions (Carlson and Groot 1997), elevating daytime temperatures of both air and soil (Fleming et al. 1998; Buckley et al. 1998; Morecroft et al. 1998), and increasing diurnal temperature fluctuations (Carlson and Groot 1997). Relationships between shallow source groundwater flows and air and soil temperatures indicate that harvest activities in upland areas may increase stream temperatures via increasing temperature of shallow groundwater inflows. Other pathways for harvest actions to influence stream temperature include changing the volume and timing of peak flows, elevating suspended sediment levels, and altering channel characteristics (Chamberlin et al. 1991; Spence et al. 1996; USDA and USDI 1998). Channel characteristics affect stream temperatures if the stream channel width /depth ratio is increased since more water surface is exposed to heating by air and sunlight. Also, reduced summer baseflows can lead to higher temperatures, since a smaller volume of water is more readily heated than a larger volume.

Forestry practices, especially road construction, are known to be major contributors to water quality impairment. Roads also affect stream flows by increasing storm runoff. Also, some railroad logging used stream channels as grades. Lee et al. (1997) found there was strong evidence that forestry has adversely impacted streams in this region. They found correlations showing that streams were adversely modified as a result of forestry practices. Additionally they noted an inverse relationship between the intensity of forestry practices, as evidenced by road density, and the occurrence of native salmonids. Based on the analyses of Lee et al. (1997), road densities as low as 1 mile of road per square mile of watershed appear to have an adverse affect on some aquatic ecosystems. USFS watershed/ecosystem analysis reports also discuss the impacts of roads and other watershed modifications on watershed and stream function (USFS 1994, 1995a,b, 1998).

Fire suppression is also a component of the baseline affecting native fishes. In forested areas, departures from natural disturbance and successional processes due to human-related activities could result in substantive changes to vegetation structure and seral stage composition. These broad-scale changes in vegetative conditions likely will increase the probability that catastrophic wildfires and large-scale insect and disease events will occur and could likely result in sedimentation and nutrification in streams and lakes, as well as geomorphic changes and increased heating; all being adverse to aquatic ecosystems.

In summary, forestry activities that adversely affect native fish populations and their habitats are primarily timber extraction and road construction, especially where these activities affect riparian areas. These activities, when conducted without adequate protective measures, alter stream habitat by increasing sedimentation, reducing habitat complexity, increasing water temperature, and promoting channel instability. Although certain forestry practices have been prohibited or altered in recent years to improve protection of aquatic habitats, the consequences of past activities continue to adversely affect native fishes and their habitat.

## 8.3 Effects of Ongoing Agriculture Practices on Water Quality and Watershed Function as They Affect Suckers

Agriculture consumes > 90% of water used in the Upper Klamath Basin. Agriculture, directly or indirectly, has been the most significant factor affecting aquatic species in the basin. Tillage, irrigation, and water return, riparian vegetation removal, channelization, wetland fill, and pesticide use when not done according to accepted BMPs, can entrain fish and block passage, dewater and directly alter aquatic habitats, and release sediment, nutrients, and organics, and pesticides into streams. Also agriculture can result in a loss of riparian vegetation and alter stream morphology and hydrologic regimes, and increase water temperature. There is a substantial literature discussing impacts of agriculture on aquatic ecosystems in the Upper Klamath Basin (e.g., Miller and Tash 1967; Atkins 1970; Gearheart et al. 1995; Klamath County 1995; ODEQ 1994; Snyder and Morace 1997; Kann and Walker 1999), rather than review all these papers they are included here by reference and a brief summary is presented below.

Agriculture, including livestock grazing, is the major anthropogenic factor affecting UKL water quality (above-listed references and citations therein). Likewise the contribution of sediment into UKL and its tributaries owing to agriculture (and forestry) is likely to be very high as well as is indicated by sediment analyses in UKL (Eilers et al 2001). The combined effect of wetland conversion and agricultural use of former wetlands has had a major adverse effect on water quality in the lake (Snyder and Morace 1997) and has reduced habitat quantity and quality, reduced lake volume, and reduced buffering capacity of wetlands. Loss of riparian vegetation on tributary streams, as a result of farming practices and grazing, has likely led to increased stream temperatures, reduced base flow, and modification of stream channels. Flow diversions reduce base flows decreasing fish habitat and resulting in increased stream temperatures. Unscreened diversions also entrain fish, including suckers. Every major tributary flowing into UKL has been modified directly or indirectly by agriculture and grazing.

Irrigation diversions affect listed suckers by altering stream flow and through entrainment and are discussed in more detail above. Listed suckers may enter unscreened irrigation diversions and become stranded in ditches and agricultural fields. Basin streams are also channelized in some agricultural areas, especially in the Lost River drainage, reducing stream length and area of aquatic habitat, altering stream channel morphology, and diminishing aquatic habitat complexity. Additionally instream flows are reduced in the Lost River after irrigation ends each fall because flows from Clear lake and Gerber Dams are terminated.

ODA, through Oregon State Senate Bill 1010, is working with the agricultural community to help them meet TMDL requirements set by ODEQ. All of the sub-basins in the upper Klamath Basin of Oregon are developing TMDLs which will need to be approved by EPA. The Service is fully supportive of these efforts since they have a potential to significantly improve water quality and will therefore reduce threats and aid in the recovery of listed suckers.

## 8.4 Effects of Ongoing Livestock Grazing Practices on Water Quality and Watershed Function as They Affect Suckers

Livestock grazing which does not following accepted BMPs, can degrade aquatic habitat by removing riparian vegetation, destabilizing streambanks, widening stream channels, promoting incised channels and lowering water tables, reducing pool frequency, increasing soil compaction and erosion, and directly altering water quality through nutrient and sediment input (Platts 1991; Henjum et al. 1994). Grazing has also led to replacement of perennial bunch grasses with annual grasses that are less effective in soil stabilization. These effects increase summer water temperatures, reduce cover, promote formation of anchor ice in winter, and increase sediment into spawning and rearing habitats.

Livestock grazing impacts on listed sucker habitat can be minimal if grazing is managed appropriately for conditions at a specific site. Practices generally compatible with the preservation and restoration of native fish habitat may include fences to manage the timing and intensity of riparian grazing, rotation schemes to avoid overuse of areas, using riders to quickly move stock through sensitive or key riparian areas, and stock tanks so that livestock concentrate outside of riparian areas. One of the major problems associated with grazing in the upper Klamath Basin is winter grazing on water soaked soils. This problem is confounded when cattle are confined or loaf or feed in one area for sufficiently long that turf is destroyed and bare soil is exposed to surface flow.

Impacts of livestock grazing on stream habitat and fish populations can be separated into immediate and longer-term or chronic effects. Immediate effects are those which contribute to the short term loss of specific habitat features (e.g., undercut banks, spawning sites, etc.) or localized reductions in habitat quality (e.g., sedimentation, loss of riparian vegetation, trampled and compacted riparian soils, etc.). Longer-term effects are those which, over a period of time, result in widespread changes in habitat quality that can occur far downstream. Geomorphic changes in streams as a result of poor grazing management can propagate up as “head cuts” and downstream as sediments accumulate, affecting areas remote from the impact source. Increased nutrification and higher temperatures are other habitat parameters that can occur at a considerable distance from the impact source.

Short-term effects to habitat include compacting stream substrates, collapse of undercut banks, destabilized stream banks and localized reduction or removal of herbaceous and woody vegetation along stream banks and within riparian areas (Platts 1991). Increased levels of sediment can result through the resuspension of material within existing stream channels as well as increased contributions of sediment from adjacent stream banks and riparian areas. Impacts to stream and riparian areas resulting from grazing are dependent on the intensity, duration, and timing of grazing activities as well as the capacity of a given watershed to assimilate imposed activities, and the pre-activity condition of the watershed. Nutrients, including nitrogen, phosphorous, and ammonia from cattle urine and excrement are an issue that has been little studied but could be significant where cattle are concentrated near streams and where densities are high in a given watershed (Nader et al. 1998).

Significant amounts of nitrogen enter UKL from groundwater and agricultural runoff. Of the agricultural input, oxidation of drained wetlands makes large amounts of nitrogen available (Snyder and Morace 1997). Cattle can be another source since they are numerous (>75,000 head) in the Upper Klamath basin (Klamath Tribes 1994). Data from the U.S. Department of Commerce on beef production since 1920 show that numbers increased to 1960, peaking at about 140,000 head, and decreasing to about 120,000 head today.

Beef cattle produce 30 to 50 lbs of urine and 30 to 70 lbs of feces per animal per day (Nader et al. 1998). For every ton of live animal mass about 1 lb of nitrogen and 0.2 lb of TP are excreted per day. Of the nitrogen contained in feces and urine, most is lost to the atmosphere, taken up by plants, or adsorbed to soil particles; only a small fraction enters surface or ground water under typical conditions (Nader et al. 1998). The amount of nutrients originating from cattle and reaching nearby water bodies is dependent on many variables, e.g., number of cattle, time spent

near water, amount of runoff, presence of drainage ditches, and extent of nutrient uptake by grasses and forbes (Nader et al. 1998). Although a direct connection between cattle excrement, and nutrification of UKL has not been found (Hathaway and Todd 1993), it seems likely that cattle excrement is an important contributing factor, given the large number of cattle in the basin.

Long-term or chronic effects of grazing result when upland and riparian areas are exposed to activity and disturbance levels that exceed assimilative abilities of a given watershed. Increases in stream temperature and reduced allochthonous inputs following removal of riparian vegetation, increased sedimentation from in-stream, riparian and upland sources, and decreased in-stream, riparian and upland water storage capacity, work in concert to reduce the health and vigor of stream biotic communities (Platts 1991). Persistent degraded conditions adversely influence resident fish populations.

Intensive livestock grazing historically occurred throughout most of the Klamath River basin, and continues to be widespread (Light et al. 1996). Livestock grazing is a major land use within the Sprague River drainage, mostly in the lowland meadows and to a lesser extent in some forested areas. Confined animal feeding operations (CAFO), such as dairies, where relatively large numbers of cattle are confined in a small area can lead to severe water quality effects when runoff goes directly into a waterway. Increased biological oxygen demand, *E. coli*, and nutrients are the primary factors involved. Such operations do occur in the Lost River watershed and have been identified as contributing to water quality problems. Several dairies in the Lost River area have been recently fined by EPA for water quality violations.

The Service is convinced that adoption of grazing BMPs such as riparian fencing, off-site watering, pasture rotation and resting, as well as attention to areas where cattle use is concentrated in winter, can do much to improve watershed and stream function, and water quality in the Basin.

### 8.5 Effects of Ongoing Irrigation Diversion Dam Practices on Suckers

Dams have played a major part in the decline of LRS and SNS. Dams block migration corridors, isolate population segments, may result in stream channel changes, and alter water quality and provide habitat for exotic fishes that prey on suckers or compete for food and habitat with them. Most of the dams affecting the listed suckers are part of the Klamath Project or are owned by PacifiCorp, and are part of the proposed action, and therefore are discussed under the effects of the proposed action section. Chiloquin Dam is the only major dam affecting suckers that is not part of the proposed action.

Suckers are known to have migrated some distance up the Sprague River to spawn (Andreasen 1975). Chiloquin Dam on the Sprague River is thought to restrict upstream spawning migrations of LRS and SNS. The Chiloquin dam was constructed in 1928 near Chiloquin. Andreason (1975) reported that passage was poor for all species in the late 1940s. A new fish ladder was built in 1965 but in the 1970s it was not passable for fish at all river stages. Consequently most LRS and SNS spawning is concentrated into a short reach on the lower Sprague River, making it easier for predators to locate the eggs and for spawning activity to expose eggs from previous spawners. More information about the dam is found in the section on baseline conditions.

Additional discussion of the effects of irrigation diversion dams will be presented in the 4.0, “Effects of the Action.”

### 8.6 Effects of Ongoing Urban Area Activities on Suckers

Human population densities in most of the UKL watershed are relatively low. Small towns like

Chiloquin, Bly, and Merrill are unable to afford state-of-the-art wastewater treatment facilities, and thus they may contribute to water quality problems. Leaking septic systems located near water bodies has been identified as a problem (Klamath County 1995). Klamath County has prepared an assessment of water resources that provides many recommendations for water quality improvements. The Service is unaware of the current status of these recommendations. The county does have minimum set-back regulations for placement of septic systems and for development. These restrictions should help reduce adverse impacts to aquatic ecosystems.

Residential development in the Klamath Falls area and Merrill has likely had some negative effects on LRS and SNS through reductions in water quality. However, since the largest concentrations of listed suckers is upstream from urban areas, impacts are limited to Lake Ewauna and adjacent upper reaches of the Klamath River, and the Lost River below Merrill. Improvements to the city of Klamath Falls’ wastewater treatment facility are expected to help improve water quality in Lake Ewauna. However the lake is also adversely affected by nearly a half-century of log storage. Bark deposited on the bottom has a significant biological oxygen demand as it decomposes. Logs are still being stored in rafts downstream from Lake Ewauna and are believed to be contributing to poor water quality in that area (E. Snyder-Conn, Service, pers. comm.).

### 8.7 Ongoing Effects of Exotic Fishes on Suckers

One species of particular concern is the fathead minnow, *Pimephales promelas*. This small minnow first appeared in Spencer Creek in. has increased in abundance to where it is frequently the most abundant fish captured in both UKL and the Lost River (Simon and Markle 1997b, 2001; Shively et al. 2000b). Fatheads generally occupy the same near-shore habitat as larval and juvenile suckers and may be significant predators on larvae (Dunsmoor 1993; Klamath Tribes 1995).

In the final rule to list the suckers, the Service identified exotic fishes as a threat through predation and competition (Service 1988). The Upper Klamath Basin presently contains 17 taxa of native fishes (Logan and Markle 1993b; Moyle 1976; Shively et al. 2000; S. Reid pers. comm. 2002). Of these, at least 13 are endemic taxa and found only in the Basin. At least 18 species of exotic fishes have been introduced and have established populations in the upper Basin. Little is known about the ecological and competitive interactions of the introduced fishes with the native suckers and this a major gap in our ability to assess their impact. Many of the fishes are predators which could prey on larval and juvenile suckers. Some exotic fishes have become sufficiently numerous and, because of their feeding habits, could be potential threats to suckers (e.g. fathead minnow, *Pimephales promelas* and yellow perch, *Perca flavescens*).

Exotic fathead minnows (*Pimephales promelas)* were first reported from Spencer Creek in 1974 and in UKL in 1979. By the mid-1980s the population had exploded (Bienz and Ziller 1987) and has since increased in abundance to where it is now frequently the most abundant fish captured in both UKL and the Lost River (Simon and Markle 1997b, 2001; Shively et al. 2000b). Fathead minnows generally occupy the same near-shore habitat as larval and juvenile suckers and may be significant predators on larvae. Concern about the potential impacts of the fathead minnow on sucker larvae prompted The Klamath Tribes to assess their predatory capabilities (Dunsmoor

1993; Klamath Tribes 1995). Dunsmoor examined predation of larval suckers by fathead minnows in the lab (Dunsmoor 1993; Klamath Tribes 1995). He found that larvae were most susceptible to predation when water depth was shallow, there was an absence of cover, and larvae were young. Increased water depth, increased cover, and increased age all reduced predation rates. Adequate vegetative cover was an important variable in these experiments and suggests that emergent vegetation may play a critical role in reducing larval predation.

The Klamath Tribes submits that as water depth increases to about 0.6 m, the surface orientation of the sucker larvae and the bottom orientation of the fathead minnows results in enough separation to almost eliminate predation, even when the fathead minnows are hungry. As sucker larvae grew they became less vulnerable to predation by fathead minnows. The pattern of decreasing vulnerability differs by species, depth, and structure. When considering the potential outcome of predatory interactions between larval suckers and other predators like largemouth bass or pumpkinseed, there is no assurance that a similar depth effect will be operative. However, decreased predatory efficiency in structurally complex habitats has been documented in the literature for these and closely related species (Savino and Stein 1982, and Heck and Crowder 1991, as cited by Klamath Tribes 1996).

A variety of exotic warm-water fishes, especially sunfishes (centrarchids) and bull heads (*Ameiurus* spp.) are also found in the Lost River. Their abundance there is likely a result of widespread habitat modification and water management activities that have created conditions favorable to exotics, warm-water fishes.

Currently the effect of exotic fishes on listed suckers is not well understood. They are most likely a concern in areas where the habitat is highly altered and suckers are not doing well for a number of reasons. For example, in UKL, exotic fishes may play a synergistic role with other factors, e.g., effects of entrainment and adverse water quality in larval mortality, especially when lake levels are too low for larvae to find cover in emergent vegetation. However, many native fishes such as sculpins and chubs, are also likely important predators on larval fish. The critical factor is to restore ecological balance to the system and recover sucker populations to levels that can persist under the effects of predation and other threats.

## 9.0 SUMMARY OF FACTORS AFFECTING LOST RIVER AND SHORTNOSE SUCKERS IN THE ENVIRONMENTAL BASELINE

LRS and SNS populations have been and continue to be adversely affected by many factors, as described in detail above. Historically, the major adverse impact was direct habitat loss as aquatic habitat was reclaimed for agriculture. This resulted in the near complete or total loss of the Tule Lake and Lower Klamath Lake sucker populations, which were perhaps as large or even larger than those in UKL. Construction of the railroad and additional land reclamation resulted in eventual loss of suckers in Lower Klamath Lake and perhaps eliminated significant areas of rearing habitat for juvenile suckers originating in the UKL sub-basin. These losses were somewhat mitigated for by construction of Gerber and Clear Lake dams, increasing sucker habitat in the upper Lost River sub-basin. Fish eradication measures in Lake of the Woods eliminated the distinct and isolated sucker population there.

Sucker populations in UKL sub-basin have been affected differently than those in the Lost River and Lower Klamath sub-basins. UKL populations were not affected by single large actions but rather by a series of smaller, incremental actions that continue to have adverse effects today. Unlike the Lost River and Lower Klamath sub-basins, where there were large-scale habitat losses, habitat loss in UKL sub-basin has been primarily through degradation and loss of wetlands and riparian habitats, as well as water diversions and entrainment and blockage of passage. This is not to say that the other sub-basins are not experiencing habitat degradation, but rather habitat loss was so complete in the Lost River and Lower Klamath Lake systems that little original habitat remains. An example is the Tule Lake sumps, which provide habitat for a few hundred suckers and is filling in with sediment to the point where relatively little of the available habitat is used and access to spawning sites is blocked. Existing fish in Tule Lake may even be from those that were entrained into A-canal and thus might be from UKL.

Early in the 20th Century, UKL sucker populations suffered progressive degradation of spawning habitat owing to water development, land reclamation, and poor land management. Historical spawning areas in the UKL tributaries, including: Crooked, Crystal, Sevenmile, and Odessa creeks, and Fourmile Creek and Slough; and Barkley, Odessa and Harriman Springs, and at least four other springs in UKL have disappeared or significantly declined in the past 50 -75 years. Construction of the Chiloquin Dam likely reduced upstream spawning migrations and degradation of upstream habitat likely further reduced upstream spawning. Sport fishing likely had a major effect on UKL suckers, by harvesting adult suckers and reducing their reproductive potential, until it was closed just prior to listing in 1988.

Currently, the major factors adversely affecting suckers in UKL are water quality, habitat loss and degradation, and entrainment. Water quality degradation in the UKL watershed, as discussed above, was likely progressive. Although water quality in UKL was seasonally poor near the end of the 19th Century, as evidenced by early reports, *AFA* was likely not a significant factor until about the middle part of the 20th Century, as indicated by micropaleontology. It is likely that *AFA* became more significant as nutrients, especially phosphorus, from anthropogenic sources supplemented already abundant nutrients from natural sources. As a result, UKL went from a eutrophic state of high productivity to hypereutrophic, where primary production reaches a maximum where it is only limited by the availability of light.

As a result of a higher trophic state, water quality in UKL experiences severe declines on an annual basis. Dissolved oxygen, pH, and un-ionized ammonia all reach levels known to be stressful to suckers, and at times are lethal, and have been tied to recurring fish kills. UKL has undergone three significant fish kills in the past decade, owing to *AFA* bloom/decay cycles. Also fish diseases, such as Columnaris disease, may be increasing in frequency as fish become stressed by poor water quality conditions. High rates of parasitism and abnormalities have been noted as well, and may be an indirect result of water quality degradation and stress.