Introduction

The situation

Controversy continues to rage about 2001 allocations of Upper Klamath Lake waters. An April 2001 Endangered Species Act determination required a minimum level for Upper Klamath Lake. Another determination, issued at the same time, required minimum discharge from Iron Gate Dam into the Klamath River downstream from Upper Klamath Lake.

Discharges from Upper Klamath Lake into the Klamath River to meet the Iron Gate requirement could not be used by the Klamath Reclamation Project administered by the Bureau of Reclamation. Approximately 1,200 farmers, who normally irrigate more than 200,000 acres of Klamath Reclamation Project land, did not receive water from April to July. Some surplus water was then allowed to flow into the Project's canals and ditches for about 6 weeks. These waters were too little and too late to permit most affected farmers to maintain a viable agricultural operation in 2001.

The Endangered Species Act requirements of minimum Lake levels and minimum discharge from Iron Gate Dam were based on biological opinions of the U.S. Fish and Wildlife Service and the National Marine Fisheries Service. These opinions were binding on all federal agencies with responsibility for water allocation, specifically the Bureau of Reclamation. They addressed the effects of the Klamath Reclamation Project on the endangered Lost River sucker, the endangered shortnosed sucker, the threatened bald eagle, and the threatened coho salmon. As noted, these opinions required a minimum water level in Upper Klamath Lake and minimum discharges from Iron Gate Dam on the Klamath River downstream from Upper Klamath Lake. Given these requirements, it is far from clear whether there will be sufficient water every year to maintain Upper Klamath Lake levels, meet discharge requirements from Iron Gate Dam, and provide irrigation water for Project lands.

Under the arid conditions in the Klamath Basin, the way water is used has great effect on the ecological, economic and social future of the area. Thus, it is no surprise that the 2001 Klamath Basin events generated great controversy. Sharp differences of opinion exist among people residing in the area, as well as among those living elsewhere who have an interest in the Klamath Basin.

These differences of opinion arise about many issues. Some believe that irrigated agriculture is not compatible with the type of ecological development they favor for the area. Others believe substantial irrigated acreage is consistent with ecological sustainability. Some disputes arise about historical interpretations. For example, how unique was 2001 in a long-run sense? Are similar years likely to arise 1, 2, or 3 years in 10? Other questions abound. For example, what is the relation of water quantity to water quality in fish survival? How will the future of rural communities, rural families, and low-income people be affected by decisions related to issues such as those just identified? There also are debates about water rights priorities and who should bear the costs of decisions intended to benefit the greater good. These questions do not exhaust the differences that exist among those with an interest in the Klamath Basin.

The need for reliable information

Generally speaking, the greater the controversy, the more valuable reliable information becomes. When great controversy exists, there usually is uncertainty or lack of knowledge about many factors related to that issue. Furthermore, if most people have a vested interest in an issue, they have a strong incentive to develop information favorable to their point of view, but little incentive to develop information unfavorable to their point of view. Even though information developed by those with a vested interest may be correct, it is likely to be incomplete.

Such conditions clearly are present in the Klamath Basin controversy. As this report will show, there is complexity, uncertainty, and lack of knowledge concerning many issues related to the controversy. Few individuals or organizations have an incentive to develop information that would improve the quality of the arguments being advanced.

From the outset, both Oregon and California Extension personnel in the Klamath Basin recognized the need for improved information. As events in 2001 unfolded, they held and attended numerous meetings in the communities affected by water allocation decisions. Many of the participants at these meeting also recognized the need for more complete and reliable information. They were concerned about the factual accuracy and completeness of items reported in the media and used in arguments. Extension personnel in both Oregon and California are faculty members at Oregon State University and the University of California and, as the controversy developed, they drew increasingly on the resources of their respective universities. This report is a continuation of activities to obtain reliable information that have been underway from the onset of the controversy.

The nature of this report

The intent of this report is to provide an authoritative, non-advocacy account of the ecological, economic, social, and institutional policy issues in the Klamath Basin relevant to the 2001 water allocation controversy. Reliable information is unlikely to remove all controversy, but it serves to narrow, reduce, or eliminate differences of opinion on many matters. To the extent differences of opinion remain after improved information becomes available, debate and negotiation likely will become more productive.

In July 2001, it was decided this report would be prepared. The decision was made by a group of scientists and administrators from Oregon State University and the University of California, together with local Extension personnel. The group had participated in a field trip in the area and reviewed the existing controversy. Several had previously conducted research or participated in educational activities in the Basin. All were familiar with natural resource issues in the West. The group agreed the report should be prepared promptly, with a final version to be made available early in 2002.

To the extent time and opportunity permitted, the report:

- Increases understanding of what is known, and what is not known, about natural resources, people, economics and institutions. Information is presented through data and analysis in the text, as well as sources referenced in the report.

- Provides interested parties a set of references on a wide range of subjects related to Klamath Basin water allocation.
- Identifies management alternatives and lessons that can be learned from the Klamath experience.
- Proposes future actions to address particular information needs and reduce remaining uncertainties.
- Assesses potential (and, where possible, documented) consequences of the decision to withhold irrigation water.

The report is intended to serve policy makers, citizens, administrators, journalists, and others. Many difficult water allocation decisions will need to be made in the Klamath Basin after 2001, and they will have important ecological, economic, and social consequences. The Klamath experience also may be useful to those facing similar problems elsewhere in the West.

The Klamath Basin water allocation problem is a constantly changing issue. As this report was being prepared, many individuals and groups were conducting investigations, making reports, and otherwise providing new information. One example is the National Academy of Sciences review of the biological opinions of the U. S. Fish and Wildlife Service. The authors of this report were aware of these efforts and have taken advantage of additional information as it became available.

Nonetheless, there are characteristics of this report that distinguish it from others. Thus, duplication has not been a significant problem. A distinctive feature of this report is its comprehensive nature. It examines the entire system affected by water allocation decisions—including social, institutional, biological, and economic components. Because of the breadth of expertise in the two university systems, it has been possible to assemble information about the many pieces of the system and show how they fit together. The report makes clear that changes in one part of the system often have consequences throughout the system

The geography of the Basin posed special problems in the preparation of this report. The minimum lake levels and minimum discharges from Iron Gate dam required the Bureau of Reclamation to reduce water going to the Klamath Reclamation Project that lies to the south of Upper Klamath Lake in Oregon and northern California. Yet clearly there are broader geographic implications. Each author has the responsibility to state the geographic frame of reference for his or her chapter. For example, the economic analysis did not examine the economics of the downstream Klamath River fishery, and there is only limited discussion of water quantity and quality factors above and below Upper Klamath Lake. Examples of such factors include nutrient concentrations in waters entering the Lake and downstream inflows of cool water.

Those preparing this report did not always agree about every subject included in the report. It could not have been otherwise. When the ecological, economic, and social issues of the Klamath Basin are considered, there is no single, correct answer to questions such as what constitutes relevant data, how data are to be interpreted, and the relative importance of many variables. Each author was expected to bring "state of the art" knowledge in his or her field of expertise. Accepted peer review procedures were used to provide quality control throughout the report. The name(s) of those responsible may be found on each section of the report. The differences of opinion that remain among the authors arise for many reasons. These include the lack of previous research and data about many important issues, the unsettled state of science, and differences of opinion among those doing peer reviews.

Several of the chapters are lengthy and, in places, somewhat complex. A summary of each section will be prepared as part of the final report.

The 2001 Klamath Basin water allocation decisions were unusual in the history of the West generally, and in the history of the Endangered Species Act in particular. They created uncertainty and hardship for many people. Those decisions also revealed needed adjustments in government performance at the federal, state, and local level. This report makes clear that such adjustment must be made if the ecological, economic, and social future of places in the West such as the Klamath Basin are to be served.

Draft
December 14, 2001

Klamath Water Allocation Background

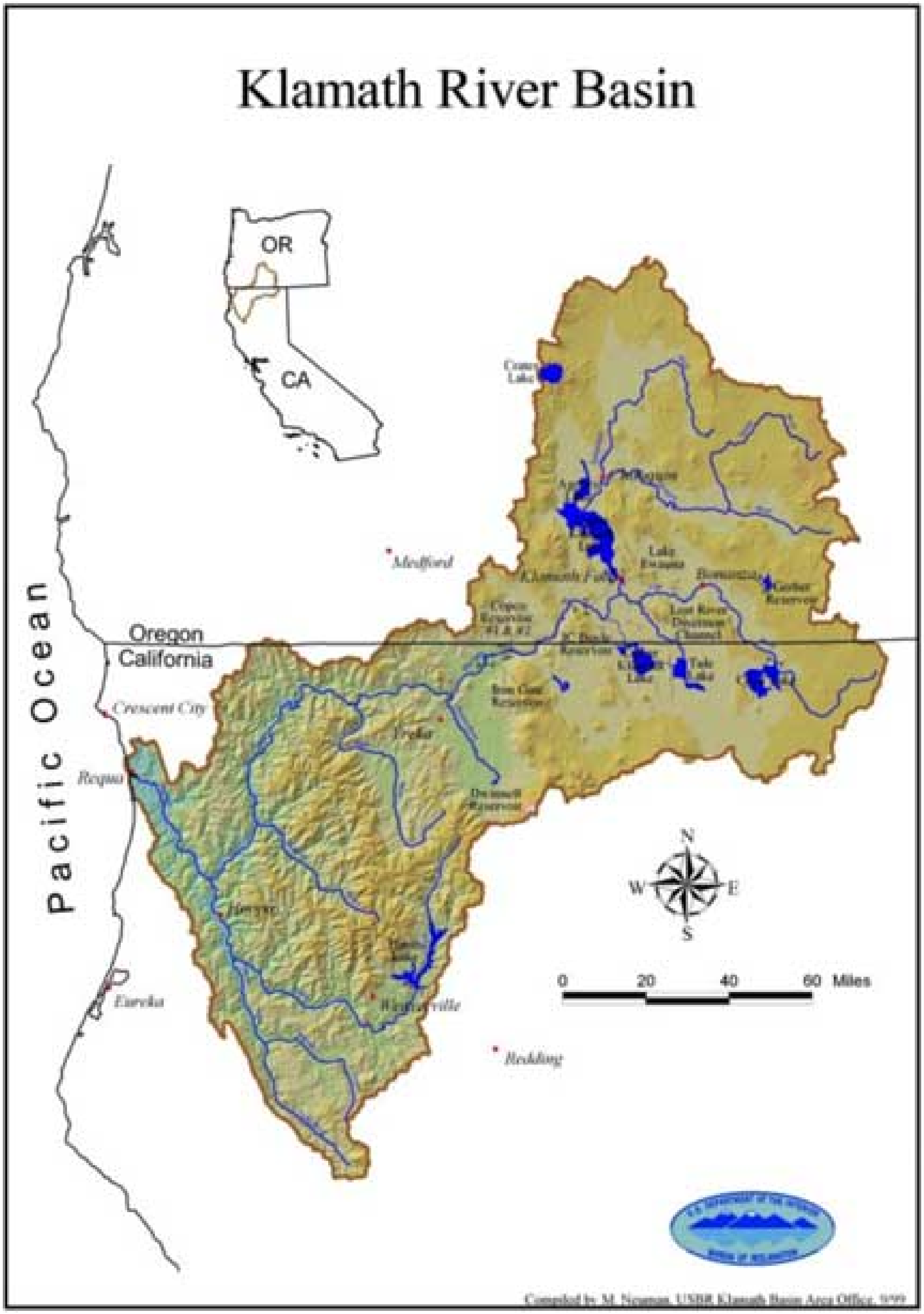
Ron Hathaway, Oregon State University Extension Service, Klamath County

The Upper Basin is a high-elevation, short-growing-season area created from volcanic and sedimentary events. Klamath Basin geology reflects repeated volcanic activity, erosion, and sedimentary rock deposition with episodes of landscape faulting and folding. It is an area where the high desert and the Cascade Mountain range meet. This provides the two dominant geophysical features that influence the climate and drainage of the basin. Elevations range from 4,000 ft. in the southern end of the Basin to 8,700 ft. at Crater Lake in the northern end. This variation in elevation causes wide temperature ranges with a possibility for frost any day of the year. The Cascade Mountain range to the west traps most of the coastal moisture, leaving the east side cooler and drier and exposing the Basin to a rain-shadow effect. The eastern and southern sides are formed by sage- and juniper-covered fault blocks and ridges.

Upper Klamath Lake is the largest lake in Oregon and the main storage reservoir for the USBR Klamath Project. It is 60,000 to 90,000 acres in size with a mean summer depth of 7 feet, as described elsewhere in this report. The lake fills a graben many thousands of meters deep, mainly with volcanic debris and sediments. This sedimentation continues today, producing a large, shallow lake. Link River is the outlet for Upper Klamath Lake, which empties into Lake Ewauna and Klamath River and reaches the Pacific Ocean through northern California. The town of Klamath Falls fans out south and east of Link River and Lake Ewauna.

The California-Oregon border approximately cuts the Basin in half. Clear Lake on the California side of the Basin is the second main source of water to the Klamath Reclamation Project, with a 25,760-acre surface area and maximum summer depth of 30 feet. It is the source of the Lost River, which flows north out of Clear Lake, turning west and south, eventually ending up in the Tule Lake sump, a closed basin system until man's manipulation in the 20th century.

Approximately 8,000 square miles of the three counties are irrigable lands serviced by the Klamath Irrigation Project, owned and operated by the U.S. Bureau of Reclamation (BOR), with 62 percent of the lands in south-central Oregon and 38percent in north-central California (U.S. Bureau of Reclamation 2001). The Project provides irrigation water to approximately 240,000 acres, including two national wildlife refuges. Upper Klamath Lake is the primary water storage feature of the Project. Other water sources are the Lost and Klamath Rivers, and Clear Lake and Gerber reservoirs. The project consists of 19 canals that total 185 miles. There are three main pumping plants. The Bureau contracts with 15 irrigation districts and has 20–25 independent contracts for water use.[1] Figure 1 details the extent of the Klamath Irrigation Project in southern Oregon and northern California.


Klamath River Basin
OR
CA
Pacific Ocean
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Crescent City
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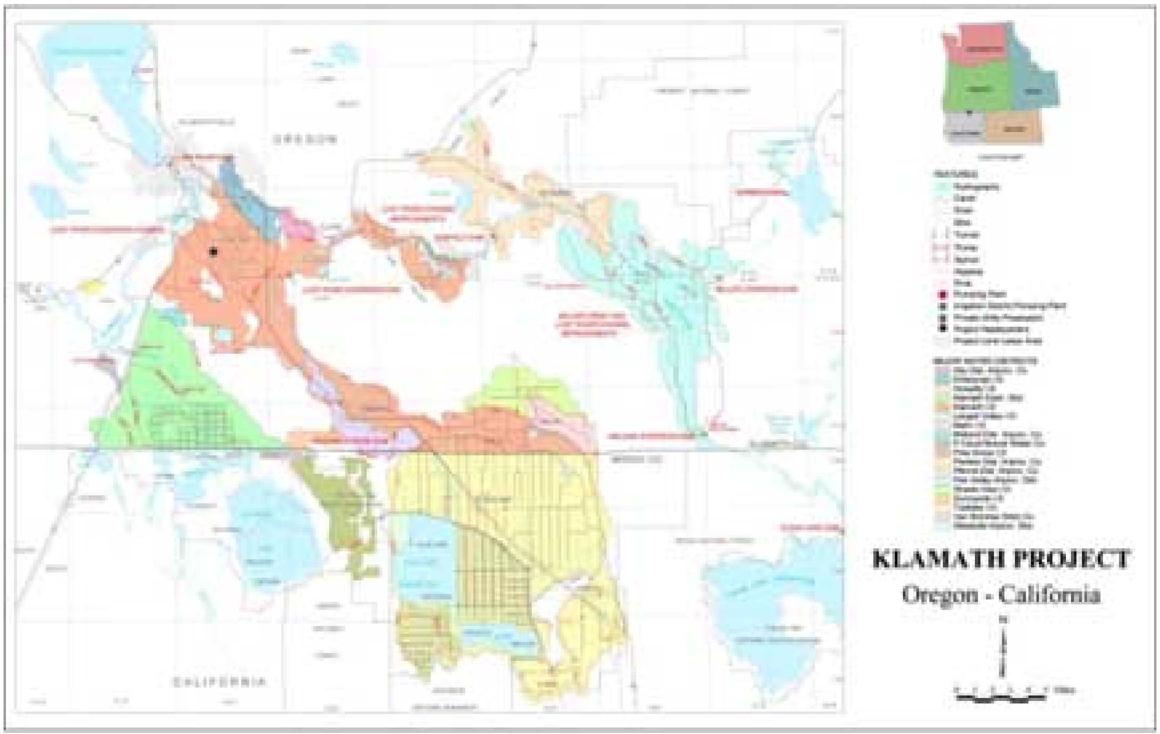


Climate and weather information are in the Water chapter.

Water allocation decision

On April 6, 2001, the Bureau of Reclamation Klamath Project Area Office mailed notice by letter to project water users below Upper Klamath Lake in the project notifying them that Project water would not be available for use until such time as the 2001 operations plan or other such written notification was completed.

> …Reclamation is currently operating the Klamath Project (Project) in accordance with the 2000 Annual Operations Plan that expires on March 31, 2001. Current conditions indicate a potential for shortage of water in the upper basin and, if precipitation does not increase significantly over the next few months, severe water shortages are likely during the upcoming 2001 irrigation season. **Therefore, you are notified that Project water is not available for use until such time as the 2001 Operations Plan or other such written notification is completed.**

> Reclamation submitted a final Biological Assessment on January 22, 2001, to NMFS with a request for formal consultation regarding the effects of ongoing Project operation on coho salmon. On February 13, 2001, a final Biological Assessment and request for formal consultation regarding bald eagles and Lost River and shortnose suckers was submitted to the Service. Draft biological assessments were reviewed by the Service, NMFS, Project water users,

PacifiCorp, and the four Tribes in the Klamath Basin. We anticipate sharing information as the consultation progresses.

Reclamation is in the process of developing the 2001 Annual Operations Plan. Biological opinions resulting from current consultations will be a critical part of the plan's formulation. While it is possible that there may be drastic reductions in Project agriculture and refuge deliveries in 2001, Reclamation is working diligently to avoid such an outcome. However, until Reclamation completes the consultation process, no diversion of Project water may occur that would result in a violation of Section 7(d) of the ESA which prohibits *"….any irreversible or irretrievable commitment of resources…"* pending completion of consultation. To date, Reclamation has not made a determination as to whether and to what extent Project water could be delivered in advance of completed consultations. Thus, until such a determination is made or the consultations are completed, no Project water may be diverted or used unless expressly authorized by Reclamation.…

Klamath Reclamation Project

The Klamath Reclamation Project construction was authorized May 15th, 1905, in accordance with the Reclamation Act (43 U>S>C> S 372 *et seq,* Act of June 17, 1902 Stat. 388). A complete history of the Klamath Project is available from the Klamath Basin Area Office "Klamath Project Historic Operation. November 2000.". In 1907 construction of the California Northeastern Railway line which served as a dike between the Klamath River and Lower Klamath Lake. Clear Lake Dam was constructed in 1910. Wilson Dam and the Lost River Diversion Canal were completed in 1912. Link River Dam was constructed in 1921. Gerber Dam was completed in 1925. Pumping Plant D, which moves water from Tule Lake Sumps to Lower Klamath Lake area, was completed in 1941.

Major features of the project are summarized. These are taken from the Water Chapter of this report, which cites the 2001 Biological Opinion (BiOp). The editorial additions are in bold, the 2001 BiOp in italic.

Klamath/Agency Lake

"*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. [The USBR area capacity table cites a surface area of 77,593 acres at 4,143.30 ft and 44,200 acres at 4,136.0 ft elevation]. Historically, the lake had a surface area of about 105,000 acres (Rosborough 1917, cited by Gearheart et al. 1995). Mean summer depth is about 7 feet. Hydraulic residence time is approximately 0.5 years. Its waters are generally well mixed because of shallowness. The major sources for UKL are the Williamson/Sprague (46% of total inflow) and Wood (15%) rivers, and various large springs (17%) which provide about 78% of the annual inflow (Miller and Tash 1967). Regulation of water levels in UKL began in 1919, with completion of the Link River Dam. By 1921 the reef at the entrance to Link River was lowered. Prior to construction of the dam, the lake level varied from about 4,139.9 to 4,143.1 ft, with a mean* *annual variation of about 2 ft (USBR data). However, the range may have been even greater, from 4,139.9 to 4145 (USBR 2000b). Since 1921, water levels have varied from 4,136.8 to 4,143.3 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 has had profound effects on the ecology of the lake, as described below"* (Biological Opinion, 2001).

A-Canal

The A-Canal (Main), 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 ft wide x 8 ft deep x 9 miles long. Maximum flow is 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 the charge-up period. Orders for water are placed by irrigators with the watermaster [an employee of KID, not the state 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. (Biological Opinion, 2001).

Clear Lake Dam and Reservoir

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 National Wildlife Refuge. The dam is an earth and rock fill structure with a crest length of 840 ft and a height of 36 ft above the streambed. The crest of the dam is at elevation 4,552.0 ft and is 20 ft wide. At the normal maximum water surface elevation of 4,543 ft, the dam will impound a total of 527,000 acre-ft in **Clear Lake Reservoir.

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 lake with shallow depths in order to reduce downstream flows to reclaimed wetlands near Tule Lake; thus it is not an efficient water storage facility. Seepage losses are also high. Annual evaporation and seepage losses account for over half of the average inflow of water, 128,120 acre-ft, at higher elevations. At maximum storage capacity of 4,543 ft above mean sea level, the reservoir has a surface area of 25,760 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 land in the Langell Valley depends on water from Clear Lake. These irrigation projects operated by Langell Valley and Horsefly irrigation districts divert approximately 36,000 acre-ft of water each year from Clear Lake (Service 1994b). Prior to construction of the dam a natural lake and marsh/meadow existed. During most years the Lost River below the present dam would run dry from June through October. Since construction, Clear Lake has been lower than the October 1992 elevation [1992 Biological Opinion minimum lake elevation—4,519.29 ft] 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 4,513.09 ft. Pre-impoundment elevation records for Clear Lake only exist for a few years, (1904–1910), but 4,522 ft is the lowest elevation recorded for the natural lake. Inflow to Clear Lake averages 128,120 acre-ft but has varied from 18,380 acre-ft in 1933–1934 to 368,550 acre-ft in 1955–1956 (Service 1994b).

The outlet at Clear Lake is opened in the spring, usually around April 15, to provide irrigation water to the Langell Valley Irrigation District (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-ft from October 1 through March 1, summer drawdown releases are occasionally necessary. (Biological Opinion, 2001).

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 3,830 acres and an active capacity of 94,270 acre-ft at the spillway crest, elevation 4,835.4 ft. In an average year, Gerber Dam, the source of water for Miller Diversion Dam, releases about 40,000 acre-ft of irrigation water.

Construction of Gerber Dam was completed in May of 1925. The reservoir is used to store seasonal runoff to meet irrigation needs (17,000 acres) of the Project, primarily for the Langell Valley Irrigation District (LVID), and to limit runoff into Tule Lake. Prior to construction of the dam, no reservoir existed and Miller Creek would run dry from June to October in most years. (Biological Opinion, 2001).

Lost River

The Lost River traverses approximately 100 miles from Clear Lake Reservoir to Tule Lake. Throughout most of its length, the river is highly channelized and managed. Two important structures include the Lost River Diversion Dam (Wilson Dam) which allows discharge of up to 3,000 cfs to the Lost River Diversion Channel, and the Anderson-Rose Dam, which facilitates diversion to the J-Canal for irrigation of land within the Tulelake Irrigation District (TID). The J-Canal has a capacity of 800 cfs and typically diverts about 135,000 acre-ft to TID. The Lost River has lost all semblance of a natural river system and is a highly managed feature of the Project with several impoundments. USBR documents refer to the Lost River as the Lost River Improved Channel. Implementation of the decision to drain and reclaim Tule Lake and the Lower Klamath Lake for agricultural production required changes in and management of the Lost River.

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 8 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 Tulelake area. During the summer months the channel is operated as if it were a forebay for the Miller Hill Pumping Plants and the Station 48 turnout. 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" (Biological Opinion, 2001).

Tule Lake Sumps

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 the 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 flows 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 ft 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 channel, the "English Channel." The two sumps have a surface area 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, Lu, and Carlson 1995). Water level elevations in Tule Lake sumps have been managed according to criteria set in the 1992 BO. From April 1 to September 30, a minimum elevation of 4,034.6 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 31, a minimum elevation of 4,034.0 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"
(Biological Opinion, 2001).

Klamath Straits Drain

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 lifted twice by pumps and is then discharged to the Klamath River. The Straits Drain is in the Lower Klamath National Wildlife refuge, which in turn receives drainage water from the Tule Lake National Wildlife Refuge. 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 flow conditions within the drain. Water quality conditions are monitored continuously near the outlet of the channel to the Klamath River" (Biological Opinion, 2001).

ADY Canal

"The [headworks] 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" (Biological Opinion, 2001).

North Canal

The North Canal diverts water from Klamath River to approximately 10,000 acres of private agricultural lands in the Klamath Drainage District of the Lower Klamath Lake area. The diversion has a capacity of approximately 300 cfs. Total annual diversions through the North Canal have ranged from a low of 28,000 acre-ft in 1992, 1994, and 1998, to a high of 49,000 acre-ft in 1995 (Table 1). In 1999 and 2000, the total April through October inflow was about 35,000 acre-ft (USBR data). Winter flooding of agricultural fields provides control of rodents (drowning and/or exposure to raptor predation), weeds, and plant diseases, and habitat for waterfowl. Surplus water is discharged to the Klamath Straits Drain. The 10-year average diversion to the North Canal has been 37,000 acre-ft. Much of this returns to the Klamath River through the Straits Drain after flood irrigation during winter months. As in the ADY Canal, gates to Klamath River are left open and the canal is holding water year-around at the elevation maintained in the Klamath River.

Other Klamath Project features

Minor laterals, which divert 95 percent of actual deliveries to farms, include 680 miles of channels. A total of 728 miles of drain ditches range in depth from a few ft to 10 ft with discharge capacities up to 600 cfs (Straits Drain) (Biological Opinion, 2001). Most drains retain water throughout the year and are important sources of recharge for shallow domestic wells, as are main canals and laterals during the irrigation season. This fact has been clearly demonstrated during the current drought by many wells becoming inoperable by mid-summer 2001. These canals and drains provide several thousand acres of habitat for birds, amphibian species, reptiles, and mammals.

Homestead Project lands

Agricultural lands in the Klamath Project were homesteaded, with the first public lands opened March 1917. The Tule Lake area of the project was open to 10 public homesteaded entries from 1922 to 1948.

Klamath River Basin Compact

The Klamath River Basin Compact was ratified by Congress September 11th, 1957. The purpose of the compact was to deal with water resources in the Klamath River Basin. Purposes of the compact were "to facilitate and promote orderly development, use, conservation and control thereof." An additional purpose of the Compact was to further intergovernmental cooperation for equitable distribution among the two states and the federal government; for preferential rights to the use of water; for prescribed relationships between beneficial uses of water. The Klamath compact established water priorities. Priorities were established as: 1) domestic use, 2) irrigation use, 3) recreational use, including use for fish and wildlife; 4) industrial use; 5) generation hydroelectric power; 6) such other uses as are recognized under laws of the state involved. The Compact created a three-member commission to administer the compact. Representation on the commission is one member from California Department of

Water Resources, one from Oregon State Water Resources Board, and one federal representative appointed by the President.

Wildlife refuges

Two national wildlife refuges are located within the Project area. The Lower Klamath National Wildlife Refuge, our nation's first waterfowl refuge, containing 46,900 acres, was established by President Theodore Roosevelt in 1908. The refuge was established as a "preserve in breeding ground for wild birds and animals." Tule Lake National Wildlife Refuge was established in 1928again as a "preserve in breeding ground for wild birds and animals." Tule Lake refuge consisted of 39,116 acres of mostly open water and croplands. The Kuchel Act of 1964 was passed to settle issues related to wildlife refuge and agricultural use of lands within the project area. The Kuchel Act was "dedicated to wildlife conservation…for the major purpose of water management, but with full consideration to the optimum agreeable use that is consistent there with."

Tule Lake and Lower Klamath National Wildlife Refuges

> "*The 2001 Habitat Management Plan for the Tule Lake NWR calls for Sump 1A to be permanently maintained and Sump 1B to be drawn down in May and flooded again in September or October or later as supply permits. Evaporation losses for Sump 1A, assuming an area of 9,500 acres, is estimated to be 36,400 acre-ft. Sump 1B is about 3,500 acres and will require an estimated 7,000 acre-ft of water to re-flood. Additionally, there will be 400 acres of flood fallow lots and 885 acres of seasonal wetlands on Tule Lake NWR outside of Sump 1A and Sump 1B. The flood fallow lots will be permanently flooded and will require approximately 1,200 acre-ft of water to meet ET losses throughout the year. The water requirement for the seasonal wetlands would be an estimated 1,800 acre-ft. Seasonally flooded areas will be drawn down in May and flooded again in September or October or later as supply permits. The seasonal areas include the Headquarters fields (85 acres), Covey Point (200 acres), and 600 acres of new seasonal lands in Sump 3. The total water requirement for Tule Lake NWR is 46,400 acre-ft. This does not include any irrigation needs for farmed areas on the lease lands. The 2001 Habitat Management Plan for Lower Klamath NWR calls for a total of 11,163 acres of permanently flooded wetlands, 11,379 acres of seasonally flooded wetlands, 4,476 acres of grain fields, and 4,561 acres of flooded upland areas. Of the total seasonal acreage, 8,161 acres will be flooded from September 1 to October 31. The remaining seasonal acreage as well as all grain and upland areas will be flooded after October 31. Water requirements were estimated using the ref_for982.xls model for Lower Klamath NWR, assuming median precipitation and the 20% exceedence ET rate for the permanent wetlands. The total water requirement for the period May 1–October 31 is 50,660 acre-ft. Of the 50,660 acre-ft, 26,110 acre-ft is for permanent wetlands and 24,540 acre-ft is for seasonal wetlands to be filled before October 31. After October 31, additional water will be needed to fill the remaining 3,236 acres of seasonal wetlands (9,090 acre-ft), the 4,476 acres of grain fields (11,190 acre-ft), and the roughly 300 acres of upland area that will be flooded with ADY water this year (about 1,000 acre-ft). In addition, the permanent wetlands will*

require freshening flows of up to 5,480 acre-ft at some point during the winter. The total demand for the period November 1–April 30 is 26,760 acre-ft. This brings the total water requirement for the refuge in 2001 to 77,420 acre-ft. This does not include any lease land irrigation needs" (USFWS- Klamath Basin NWR, 2001).

Project operation

The Klamath Project currently (2000) includes 240,000 acres plus national wildlife refuge lands. The Project generally provides water to 200,000 acres, varying annually. In an average year of operation, inflow in the Upper Klamath Lake is 1.3 million acre-feet average. Usable storage of Upper Klamath Lake is 486,830 acre-feet. The Project, including wildlife refuges, consumptively uses approximately 350,000 acre-feet of water annually. The Klamath Project is noted for high irrigation efficiencies, which are achieved project-wide through water reuse. Normal year net use is 2.0 acre-feet per acre, including water for Tule Lake and Lower Klamath national wildlife refuges.

Endangered Species Act

Protection of threatened coho salmon in the Klamath River below Iron Gate Dam, and protection of the Lost River and Shortnose suckers in UKL, under the federal Endangered Species Act (ESA), were primary influences of the 2001 water allocation for the Klamath Project. The endangered species act (ESA) was passed by Congress in 1973. Purpose of the ESA is to "provide a program for the conservation of…endangered and threatened species" (16 U.S.C. § 1531[b]). Additionally, the ESA is "to provide a means whereby the ecosystems upon which endangered species and threatened species may be conserved, to provide a program for the conservation of such endangered species and threatened species and take steps as may be appropriate to achieve that purposes." The ESA is "not merely to avoid elimination of that species, but to bring the species back from the brink sufficiently to obviate the need for protected status" (Id. § 2[b]).

Under the ESA, the Lost River and Shortnose suckers were listed as endangered July 18, 1988. 1992 was a critical dry-water year for the Klamath Reclamation Project. This was one of the driest records for the project. The Bureau of Reclamation developed a conservation plan for operation of the Klamath project during periods of critical water years. On July 22, 1992, the Bureau of Reclamation completed consultation with the U.S. Fish and Wildlife Service regarding the biological opinion on effects of long-term operations of the Klamath Project. This biological opinion provided for variance in minimum lake level in the Upper Klamath Lake. 1994 was another critical dry-water year for the Klamath Reclamation Project. It was the third-driest year on record for the Project. 1994 also marked the beginning of government meetings with tribes. This was also the year of the first attempt to initiate an annual operation plan, Klamath Project Operational Plan (KPOP). In 1995, the Bureau of Reclamation prepared an annual operation plan for the Klamath Project. Annual operation plans were subsequently prepared for the years 1996 through 2000. On April 7, 1995, the Bureau of Reclamation held the initial conferencing with the National Marine Fisheries Service (NMFS), the agency responsible for salmon. This conferencing found that the KPOP was not likely to jeopardize coho salmon. However, coho salmon were proposed for listing.

Water management

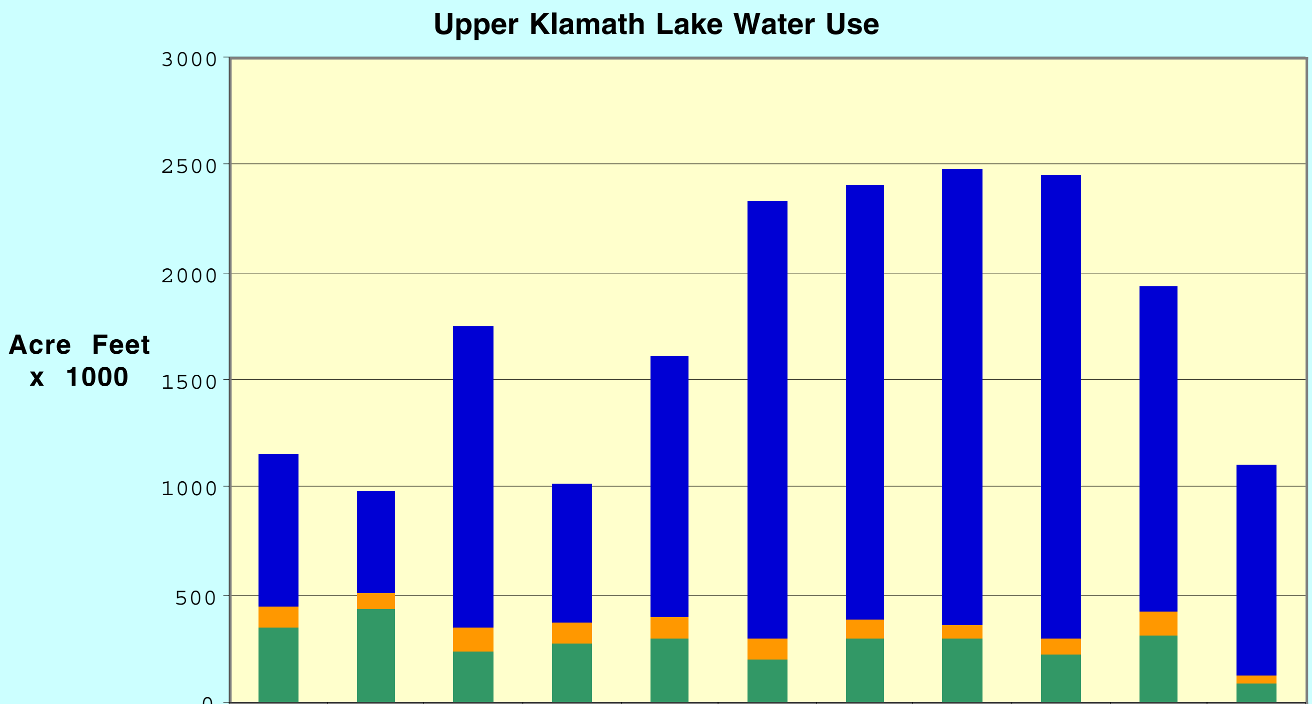
Water management, water rights, and other water uses are an issue within the Project. The BOR maintains it has authority to administer water in the Project while the State of Oregon differs in opinion. On July 25, 1995, a BOR solicitor sent a letter regarding water rights to the Klamath Project Area office. In this letter the solicitor stated that none of the rights for water are quantified—ESA, refuge, project, or tribes. However, the Klamath tribes' rights to hunting, fishing, and gathering were preserved. The solicitor further stated that reclamation is "not free to disregard these rights and its discretion to determine and to fill these rights." In response to the BOR solicitor's letter, the Oregon Water Resources Department (OWRD) responded with a letter dated March 18, 1996. OWRD stated that there are issues regarding the authority of the Interior Department to manage the project pending completion of the adjudication process. The OWRD also took issue regarding United States-claimed water rights. In response to the OWRD letter, the BOR solicitor wrote a letter (dated January 9, 1997) that said the Interior's conclusion regarding the number of issues differed from the OWRD's. The solicitor reaffirmed long-standing positions of the United States regarding management of water projects for irrigation, wildlife production, and Indian rights. The solicitor also stated that the BOR was free to develop a plan to govern operations pending completion ofn the Klamath Basin adjudication process.

ESA-Project issues

Under the ESA, listing of the southern Oregon or California coho salmon was completed May 6, 1997. Coho salmon were listed as threatened under the ESA. In 1998, the first formal consultation was held with NMSF regarding Klamath Project operations. In July 1999, NMFS issued a biological opinion stating that the project operation would not likely jeopardize coho salmon during the defined period of operation. In 2000, the BOR operated the project in accordance with the determination pursuant to section 7 (d) of the ESA in a below-average water year.

In September of 2000, the BOR and U.S. Fish and Wildlife Service (USFWS) held a consultation. As a result of this consultation, the variance for lake levels for critical (below average) water-year operation was removed. In January 2001, Reclamation forwarded to NMFS a biological assessment of Project operations on coho salmon and requested initiation of formal consultation with USFWS. On February 13, 2001, Reclamation forwarded a biological assessment of project operation on Shortnose and Lost River suckers to USFWS. The BOR requested formal consultation with the USFWS to develop reasonable and prudent alternatives (RPAs).

On March 13, 2001, the USFWS issued a draft Biological Opinion (BiOp). This draft BiOp concluded that the sucker population in Upper Klamath Lake was at risk. USFWS proposed RPAs that would include a minimum service elevation of Upper Klamath Lake of 4,140 and 4,142.5 ft. from January through October. On March 19, 2001, NMFS completed their draft BiOp. This opinion found that the Project operation would jeopardize coho salmon. NMFS proposed four RPAs of minimum water flows in Klamath River below Iron Gate Dam. The implementation of the RPAs resulted in severely limited availability of Klamath Project irrigation water. The RPAs provided that 70,000 acre-feet of water for irrigation would be made available from Clear Lake and Gerber reservoirs for the Horsefly and Langell Valley irrigation districts.



	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Iron Gate Flow	701	464	1394	652	1211	2031	2028	2115	2157	1515	988
Refuges	103	83	111	99	101	91	86	58	75	121	37
Agriculture	344	429	241	268	295	204	292	303	219	304	84

Data is for water supplied from UKL only and does not include Agriculture and Refuge water use supplied by the Lost River system or from ground water wells.

10/08/01

On April 6, 2001, USFWS released to NMFS their final biological opinions on suckers, coho, and bald eagles. The biological opinions concluded that operation of the project as proposed by the BOR would jeopardize suckers and coho salmon. Further, it would cause harm—not jeopardy—to bald eagles. The BiOp also adjusted UKL elevations and Klamath River flows to reflect reduced water availability. The Klamath Lake minimum was set at 4,139 feet (elevation above sea level), with a long-term goal of 4,140 feet elevation. The Klamath River flows from April through September were increased. Klamath River flows below Iron Gate Dam were set at: April through June, 1,300 cubic feet per second (cfs); June 1–15, at 2,100 cfs; June 15–30 at 1,700 cfs; July through September, 1,000 cfs; and in October return to 1,300 cfs.

On April 6, 2001, BOR notified project irrigators that Project water was not available for use. On April 13, 2001, a judge's order declared that the BOR was enjoined from sending irrigation water deliveries to the Klamath Project whenever Klamath River flows dropped below the minimum Hardy Phase I flows, until such time as formal consultation to a no-jeopardy finding by NMFS or the BOR's final determination that the proposed plan is unlikely to adversely affect coho salmon.

These biological opinions resulted in a significant change in water distribution.

Early economic and social results

The Oregon State University Department of Agriculture and Resource Economics conducted an economic impact study indicating $157 million would be lost in Klamath Project total gross agricultural sales, and an additional $79 million in reduced personal, employment, proprietary income, and other property value would result from the water area allocation decisions.

On July 24, 2001, Secretary of the Interior Gale Norton released 70,000 to 75,000 acre-feet of water from UKL to assist farmers in the Basin Project. Early estimates of the effect on social services: the Klamath Lake County Food Bank had increased requests from 772 families; the Klamath County Mental Health Department requests for precommitment investigations were up by 67 percent; crisis services were up 64percent; and mental health medical services were up 32 percent. Klamath County also responded by opening the Drought Crisis Resource Center in Merrill.

This assessment resulted from efforts and interest from faculty of University of California and Oregon State University.

Note: References for this chapter are listed in other chapters throughout the report.

Draft
December 14, 2001

Water Resources

Kenneth Rykbost, Klamath Experiment Station, Oregon State University

Introduction

Surface water, stored in Klamath Irrigation Project facilities, including Upper Klamath Lake (UKL), and delivered to nearly 200,000 acres of agricultural land through a complex system of canals, drains, and pumping stations, has served as the lifeblood of the region's agricultural industry for nearly a century. The effect of federal agencies' policies to protect endangered suckers in UKL and threatened coho salmon in the lower Klamath River, combined with regional drought conditions, has been the elimination of normal surface water supplies for about 170,000 acres of agricultural land and severe restrictions on supplies to two very important wildlife refuges dependent on Project facilities and irrigation return flows.

Understanding the complex hydrology of the Upper Klamath Basin requires an extensive description of historical and current conditions. Factual data on the Bureau of Reclamation (USBR) Klamath Irrigation Project (Project), including a map of the Project, is appended. The most important structures and geographical, climatic, and hydrologic aspects of the region are briefly described. While much greater detail is needed to completely and accurately define the Project and its components, the Appendix will be a useful point of reference throughout the Assessment Report.

The Biological/Conference Opinion Regarding the Effects of Operation of Reclamation's Klamath Project on the Endangered Lost River Sucker, Endangered Shortnose Sucker, Threatened Bald Eagle and Proposed Critical Habitat for the Lost River/Shortnose Suckers (Biological Opinion, 2001), prepared by the Klamath Falls Fish and Wildlife Office in April 2001, provides an exhaustive description of the Project. Rather than rewrite extensively what has already been written about the important features of the Project, much descriptive material has been taken from this report, with the written permission of Mr. Steven Lewis, U.S. Fish and Wildlife Service (USFWS). All material taken directly from this report will be presented in *italics*.

Climatic conditions and weather records

Limited Klamath Falls weather records are available dating back to 1884. The U.S. Water Bureau monitored rainfall at Klamath Falls until an official National Oceanic and Atmospheric Administration (NOAA) station for Klamath Falls was established at the Kingsley Field Air Force Base in 1949. A weather station at the Klamath Experiment Station (KES) has been maintained since 1984. The KES station, located approximately one-half mile west of Kingsley Field, became the official NOAA station for Klamath Falls in 1997, when the Kingsley Field station was formally abandoned. In *Climatological Data Oregon*, the KES station is identified as

Klamath Falls Ag Sta. A third weather station for Klamath Falls is reported as station Klamath Falls 2 SSW. This station is operated by Pacific Power and Light and is located near the Klamath River. Since 1999, the USBR has established four Agricultural Meteorological (AgriMet) stations in the region. Stations are located at KES, Agency Lake Ranch, Lower Klamath Lake area, and in the Langell Valley.

U.S. Water Bureau annual rainfall records are complete from 1884 through 1948 except for the years 1890–1901 and 1903 (Rykbost and Charlton, 2001b). More detailed weather records from 1949 to the present are available from NOAA and from KES annual research reports for 1987 through 2000. The long-term annual rainfall at Klamath Falls has been about 13 inches per year with a range of less than 8 inches to more than 20 inches. When data are averaged by decade, a fairly consistent range of about 12 to 14 inches annually is observed.

High elevation areas in the upper watershed receive much higher precipitation. Crater Lake receives an average of more than 500 inches of snowfall (a water equivalent of more than 40 inches) and has a long-term average annual precipitation of approximately 65 inches (*Climatological Data Oregon*). The eastern flank of the Cascade Mountains is a major source of recharge for Upper Klamath Lake (UKL). The majority of the region's precipitation occurs from November through March. Over the past 16 years, Klamath Falls has experienced an average of about 5.5 inches of precipitation from April through October, out of a total annual average of 13 inches (Rykbost and Charlton, 2001b).

The drought of 2000–2001 started in March 2000. Total rainfall recorded at KES from March 1, 2000 through October 2001 was 10.5 inches, about 55 percent of normal. The drought followed a 4-year period (1995–1998) of the highest rainfall recorded at Klamath Falls since records began. Unfortunately, limited water storage capacity did not allow the surplus water to be stored for later use.

The 2000–2001 drought, while serious, is not unprecedented. Multiple years of low rainfall were experienced in 1914–1921, 1928–1935, 1951–1956, 1965–1968, 1970–1978, and 1991–1994. During the period of full development of the Project (since 1960), 1992 and 1994 produced the most serious water supply deficiencies. Several areas within the Project experienced reduced water deliveries in 1992 and 1994, including Tule Lake and Lower Klamath National Wildlife Refuges.

Upper Klamath Basin groundwater resources

Current year groundwater studies and monitoring efforts being performed by several agencies should provide new information regarding local groundwater hydrological conditions. With the 2001 decision to withhold surface water from most of the Project, a flurry of well development activities was initiated. Private individuals developed several wells in the Project in late spring. Funding from California and Oregon legislatures to assist irrigation districts in well development is expected to result in up to 20 new large irrigation wells. TID has brought six new wells into production as of August, with maximum production approaching 12,000 gallons per minute (gpm) for the largest producing well. (For conversion to other measures, approximately 450 gpm = 1 cfs = 2 acre-ft over 24 hours). Pump test yields on nine TID wells have ranged from 4,000 to 12,000 gpm with six of nine wells exceeding 9,000 gpm. Depths of the nine completed wells range from 571 ft to 2,380 ft. All but two of the wells are more than 1,400 ft deep.

An optimistic projection of 150 to 175 cfs from a $5 million fund in California, and 50 to 75 cfs from the $2 million fund in Oregon, would account for about 15 to 20 percent of typical surface-water diversions for agriculture and refuge use. To date in 2001, the Oregon Water

Resources Department (OWRD) has approved 89 of 92 applications for drought/supplemental-use wells in the region, representing 20,500 acres (Ned Gates, OWRD, personal communication).

Depths to aquifers suitable for irrigation wells vary from 150 ft in southern portions of the Project in Copic Bay to more than 2,000 ft in other areas. The upper surface of water-bearing basalt bedrock ranges in depth to over 1,000 ft. Several wells developed in 2001 are more than 2,000 ft deep. An unsuccessful well in the Henley area stopped at 2,146 ft without finding a productive aquifer. Fortunately, static water level in most of these wells rises to within 50 ft or less of the surface.

The ability of groundwater aquifers to sustain season-long or long-term use has not been determined. Several of the high-producing wells developed in 2001 were pumped for only a few weeks in 2001. Extensive monitoring of wells and examination of logs from newly developed wells is underway by California Water Resources Department, OWRD, and U.S. Geological Survey hydrologists.

Failures of 17 domestic wells and 10 livestock/yard wells in the Henley and Merrill areas, and 5 domestic wells in the Tulelake area, were reported by late July. All of the failed wells in the Henley and Merrill area were shallow wells that receive recharge from canal and surface application seepage (Ned Gates, OWRD, personal communication). In some cases these may be resolved by lowering pump bowls or replacing shallow well pumps with deeper submersible pumps. Others will need to be extended deeper into the aquifer. Several irrigation wells in the southern portion of TID are reported to have lowered static water levels considerably in nearby wells. Static level in a well in Malin, Oregon, declined by more than 20 feet in 2001. Full-season pumping will be required to have any assurance of the extent to which wells can replace surface irrigation supplies on a season-long basis.

The economic consequences of replacing surface water with wells are significant. Energy requirements will vary with well depth, static water levels, capacity, and source of power, but in any case will be considerably greater than costs for pressurizing surface water. Installation costs for newly developed wells currently are ranging from $50,000 to $600,000, with several of these wells producing in the range of 5,000 to 10,000 gpm. Three attempts at well drilling in 2001 resulted in dry holes at costs of about $60,000, $70,000, and $100,000.

The latest projection for well development at TID with the $5 million in state funding indicates production of 75,000 gpm may be achieved. This equates to about 170 cfs, or 340 acre-ft/day. Assuming 100 days of pumping and 2 acre-ft crop use, this volume would serve about 17,000 acres. Based on an initial investment of $5,000,000, the cost of replacing surface water with groundwater would be about $300/acre. Pumps and pumping costs are in addition to well development costs. As an example, the pump and installation costs for one of the largest wells at TID was about $65,000, and monthly electrical costs for continuous use are estimated at $800 at current low rates. At 10,000 gpm, this well could service about 2,000 acres.

The replacement of surface water with well sources offers little savings for delivery systems and irrigation district operation and maintenance costs. Conveyance structures are required to move water to individual properties. The newly developed wells are pumping directly into existing canals.

In Oregon, permanent water rights for new wells may be difficult to acquire. Most of the wells within the Project that were developed in the early 1990s are permitted for declared droughts or supplemental use. When new wells interfere with previously permitted wells, permitted wells must be “fully developed” before the offending well is shut off. Fully developing a well involves deepening the well through the bearing aquifer (Ned Gates, OWRD, personal communication).

California has fewer regulations for development of wells, but both Modoc and Siskiyou counties have ordinances against exporting groundwater out of the county. Waivers could be obtained, provided all water needs within the county are being met.

In one respect, substitution of well water for surface supplies for agricultural and refuge use is contrary to water quality concerns. Discharge of nutrient-rich, warm water from Klamath Lake to the Lower Klamath River puts salmonids at risk below Iron Gate Dam. If Klamath Lake water were used for irrigation and the refuges and cool, high-quality groundwater were discharged to the river, benefits for fish may be realized. This issue may receive more attention in the future.

The Upper Klamath Basin watershed

Klamath/Agency Lake

"*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.* (The USBR area capacity table cites a surface area of 77,593 acres at 4,143.30 ft and 44,200 acres at 4,136.0 ft elevation). *Historically,* (before diking and drainage of properties adjacent to UKL) *the lake had a surface area of about 105,000 acres (Rosborough 1917, cited by Gearheart et al. 1995). Mean summer depth is about 7 feet. Hydraulic residence time* (mean time between inflow and discharge) *is approximately 0.5 years. Its waters are generally well mixed because of shallowness. The major sources for UKL are the Williamson/Sprague (46% of total inflow) and Wood (15%) rivers, and various large springs (17%) which provide about 78% of the annual inflow (Miller and Tash 1967). Regulation of water levels in UKL began in 1919, with completion of the Link River Dam. By 1921, the reef at the entrance to Link River was lowered.* (The reef or natural bedrock constriction at the head of Link River was cut to a lower elevation with dynamite). *Prior to construction of the dam, the lake level varied from about 4,139.9 to 4,143.1 ft, with a mean annual variation of about 2 ft (USBR data). However, the range may have been even greater, from 4,139.9 to 4,145 (USBR 2000b). Since 1921, water levels have varied from 4,136.8 to 4,143.3 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 has had profound effects on the ecology of the lake, as described below"* (Biological Opinion, 2001).

There is contradictory published and anecdotal evidence regarding pre-Project lake elevation minimums (elevation refers to height above mean sea level). John C. Boyle (1987) cites an elevation of 4,137.8 ft for the reef at Link River. A picture in the book shows fishermen standing among rocks in the Link River above Favell Museum with no water visible in the river. The picture's footnote, dated July 18, 1918, states that high south winds pushed the water level below the reef. U.S. Water Bureau rainfall records indicate an extended drought from 1914 through 1919. The U.S. Army Corps of Engineers (1982) cites a natural low-water minimum elevation of 4,137.1 ft and the elevation of the upper reef at 4,137.8 ft. Grover *et al.* (1923) cite a minimum elevation of 4,139.63 ft on September 2 and November 5, 1917 and states: "stage somewhat lower in July, 1918, recorder not working."

Artifacts were found at several sites exposed at low lake levels in 1992 and 1994, indicating these may have been semi-permanent or seasonal campsites used by indigenous inhabitants during pre-settlement times. Early settlers were reported to have harvested grass hay at McCornack Point, Caledonia Marsh, and Hank's Marsh, which are currently inundated (Donald Hagglund, personal communications).

UKL has a storage capacity of approximately 486,828 acre-ft at a full pool elevation of 4,143.3 ft. In 1994, lake elevation declined to 4,136.8 ft, with storage capacity at 39,201 acre-ft (USBR data). Storage capacities at 4,140.0 and 4,139.0 ft are approximately 241,000 and 174,000 acre-ft, respectively. Management of lake elevations at 4,140.0 or 4,139.0 ft, versus allowing the elevation to decline to dead storage at 4,136.0 ft, represents a reduction in available water for other uses of 241,000 or 174,000 acre-ft, respectively.

Modeling of the hydrology of UKL by USBR (2001) has been based on the period from 1961 through 1998. Year types have been classified based on net inflow to the lake from April through September. The average (arithmetic mean) net inflow for the 38-year period was calculated as 500,400 acre-ft. The standard deviation of the mean was 187,000. Years when inflow was above 500,400 acre-ft from April through September were classified as above average. Years with inflow between 500,400 acre-ft and less than one standard deviation below (312,000 to 500,400 acre-ft) were classified as below normal. Years with inflow between one and two standard deviations below the average (185,000 to 312,000 acre-ft) were termed dry years. In 1992 and 1994, inflows were 155,000 and 179,000 acre-ft, respectively. These years were classified as critical years.

The 1961 to 1998 era included 20 above average, 11 below average, 5 dry, and 2 critical year types. The USBR has based recommendations for Project operations plans on these hydrologic year classes and estimates of potential inflow from April 1 snowpack surveys at key locations in the upper watershed. The snowpack survey for 2001 indicated a critical year type and the lowest inflow on record. USBR data indicated net inflow to UKL from April through September 2001 was about 200,000 acre-ft, exceeding April through September inflow to UKL in 1992 and 1994.

Lake elevation records from the USBR show lower average lake elevations were maintained during the 30-year period from 1922 to 1951 than the average for the 1961–1998 period. For August through October, mean end-of-month elevations were approximately 1.0 ft lower during the first 30 years following construction of the Link River Dam. During this period, lake levels declined below 4,138.0 ft in 8 of 30 years. From 1961 to 1998, lake levels fell below 4,138.0 ft in only 4 years out of 38.

The decade of the 1990s included the extremes of water supply since the Project was established in 1905. Table 1 summarizes Project hydrology for the 10-year period from 1991 through 2000. Data are presented on a calendar-year basis. While hydrology data for the Project are usually presented on a water-year (October 1 to September 30) basis, in some respects it is easier to visualize diversions for agricultural use on a calendar-year basis. The Project includes other key points of diversion, which are more difficult to define. For example, the Lost River Diversion Channel is a major component of the system, but data sets do not indicate the direction of flows.

Tributaries and inflow sources for Upper Klamath Lake

Williamson River

The single largest source of inflow to UKL is the Williamson River, which discharges into northeast Klamath Lake. Major tributaries to the Williamson River include Sycan River and

Sprague River, with headwaters in the Gearheart Mountains to the east; and Spring Creek, which dominates late summer flows below its confluence with the Williamson River above Chiloquin, Oregon. Miller and Tash (1967) estimated the Williamson River contribution to UKL inflows at 46 percent.

Table 1. Hydrologic data for the Upper Klamath Basin for 1991 through 2000 and for January 1 through September 30, 2001. Precipitation data are from the Klamath Experiment Station and flow data are from the Bureau of Reclamation Klamath Project Office. All data are presented on a calendar-year basis.

	Total	UKL Releases[2]		Diversions		Releases		Discharge	Klamath River Flow	
Year	annual precip.	Link River	A Canal	North Canal	ADY Canal	Gerber Reserv.	Clear Lake	Straits Drain	Keno Dam	Iron Gate Dam
	inches	1,000 Acre-ft								
1991	9.29	427	264	38	108	12	34	75	340	601
1992	11.34	400	227	28	71	1	8	31	271	469
1993	14.96	1,118	223	43	91	31	28	94	1,200	1,468
1994	7.72	480	226	28	81	37	8	61	361	556
1995	19.06	893	232	49	88	30	29	87	955	1,278
1996	19.54	1,468	252	36	71	52	32	132	1,719	2,159
1997	14.29	1,366	255	40	86	60	45	100	1,521	1,884
1998	19.51	1,418	236	28	78	53	101	128	1,896	2,218
1999	11.54	1,355	282	36	91	94	118	111	1,759	2,052
2000	11.51	1,047	273	41	93	37	57	78	1,123	1,438
Mean	13.88	997	247	37	86	41	46	81	1,115	1,412
2001[1]	4.24	556	40	16	26	35	65	17	559	757

1/January through September 30

2/Releases from Upper Klamath Lake

Significant agricultural diversions out of the Williamson, Sprague, and Sycan rivers have occurred since before 1905. Diversions from the Williamson River by USFWS to the Upper Klamath Marsh and by The Nature Conservancy to the Sycan Marsh have been expanded since the late 1980s, reducing inflows to UKL (James Ottoman, Robert Sanders, Edward Bartell, personal communications). Newly developed or planned wetlands in the Williamson River Delta Preserve also are likely to require more water than agricultural production on this property operated as Tulana Farms. Kann (2001a) estimates evaporation losses from open water surfaces at 3.23 ft/year and from wetlands at 70 to 83 percent of this or 2.26 to 2.68 ft/year. Bidlake (1997) reported evapotranspiration loss from Wocus Bay and Sagebrush Point wetland sites from May through October 1996 of 26 and 27 inches, respectively. Bidlake and Payne (1998) reported evapotranspiration from wetland sites at Wocus Bay and Upper Klamath NWR for May through October 1997 at 35 and 27 inches, respectively. This exceeds water use for cereals and row crops, as will be discussed later in this report.

Wood River

The Wood River enters Agency Lake at the northeast corner and accounts for 18 percent of total inflow (Miller and Tash 1967). The Wood River, which originates as springs at Kimball Park, includes flows from streams originating within Crater Lake National Park (Anne and Sun Creeks), and Fort Creek and Crooked Creek, which are formed by springs on the east side of the Wood River Valley.

Other inflow to Upper Klamath Lake

Sevenmile Creek and Sevenmile Canal combine flows from several springs on the west side of the Wood River Valley and some return flows from irrigation diversions. The 7,200-acre Agency Lake Ranch diverted water out of the Sevenmile Canal for livestock production until the property was purchased for water storage in the late 1990s.

Miller and Tash (1967) estimated that Sevenmile Canal, Fourmile Canal, Central Canal, and several small creeks contributed approximately 9 percent of UKL inflow. Precipitation and pumped drainage from agricultural properties adjacent to the lake was estimated at 4.4 and 5.1 percent, respectively. The remaining 17.4 percent of lake inflows were estimated to be coming from springs discharging directly to the lake.

Miller and Tash (1967) estimated losses from the lake at 78 percent for discharges to the Link River and A-Canal, 20.4 percent from evapotranspiration, and 1.5 percent for pumping and diversions for agriculture. It is recognized that inflow contributions will vary with year type hydrologic conditions. For example, in drought years, springs and spring-fed streams will contribute more, while the Williamson River system will contribute a greater percentage in years with high rainfall and heavy snowpacks.

Discharges from Upper Klamath Lake

Link River/Lake Ewauna/Klamath River

Discharges through the Link River Dam traverse about 1 mile in Link River, enter Lake Ewauna, and leave the upper basin at the Keno Dam located 21 miles below the Link River. Elevations in the Klamath River above Keno can vary by up to 3.0 ft but are maintained within a range of about 6 inches most of the time. In addition to Klamath Lake discharges, the Klamath River above Keno receives inflow from the Lost River Diversion Channel, the Klamath Straits Drain, Klamath Falls and South Suburban sewage treatment plants, and Collins Products and Columbia Plywood mills.

Diversions out of the river include the Lost River Diversion Channel, ADY-Canal, North Canal, Keno Irrigation District diversion, and numerous small irrigation diversions to individual farms and ranches. Flows at Keno Dam are managed to meet required flow targets at Iron Gate Dam. Between Keno Dam and Iron Gate Dam, accretions from springs and minor tributaries add about 300,000 acre-ft annually or about 400 cfs averaged over the year (USBR data). During the April to September irrigation season, accretions below Keno are usually in the range of 250 to 350 cfs. In the drought years of 1992 and 1994, annual accretions were about 200,000 acre-ft (Table 1).

Major elements of the Klamath Irrigation Project

A-Canal

"The A-Canal (Main), 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 ft wide x 8 ft deep x 9 miles long. Maximum flow is 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 the charge-up period. Orders for water are placed by irrigators with the watermaster (an employee of KID, not the state 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"* (Biological Opinion, 2001).

Entrainment or passage of endangered suckers into the A-Canal is a major concern for future operations of the project. The USBR, the Klamath Irrigation District (KID), and other interested parties have been working since 1995 to develop a screening system to prevent fish from getting into the canal. Because the canal intake is near the lake's outlet at the Link River Dam, current patterns around the intake are complex and are influenced by lake elevation and flows to either structure. Preliminary screen designs have been evaluated but have not proven satisfactory. The bid for the final design of screens for the A-Canal was let in September 2001. A-Canal screening should be in place in 2003. For several years, USBR and USFWS have been recovering entrained fish during the draining of the canal in October and returning them to UKL.

Typical diversion through the A-Canal includes extended periods of flows on the order of 1,000 cfs. During the 1990s, total annual diversions through this structure have ranged from about 220,000 to 280,000 acre-ft. During the drought years of 1992 and 1994, the A-Canal diversions were 227,000 and 226,000 acre-ft, respectively (Table 1) (USBR data).

Clear Lake Dam and Reservoir

"*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 National Wildlife Refuge. The dam is an earth and rock fill structure with a crest length of 840 ft and a height of 36 ft above the streambed. The crest of the dam is at elevation 4,552.0 ft and is 20 ft wide. At the normal maximum water surface elevation of 4,543 ft, the dam will impound a total of 527,000 acre-ft in Clear Lake Reservoir.*

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 lake with shallow depths in order to reduce downstream flows to reclaimed wetlands near Tule Lake; thus it is not an efficient water storage facility. Seepage losses are also high. Annual evaporation and seepage losses account for over half of the average inflow of water, 128,120 acre-ft, at higher elevations. At maximum storage capacity of 4,543 ft above mean sea level, the reservoir has a surface area of 25,760 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 land in the Langell Valley depends on water from Clear Lake. These irrigation projects operated by Langell Valley and Horsefly irrigation districts divert approximately 36,000 acre-ft of water each year from Clear Lake (Service 1994b).

Prior to construction of the dam a natural lake and marsh/meadow existed. During most years the Lost River below the present dam would run dry from June through October.

Since construction, Clear Lake has been lower than the October 1992 elevation [1992 Biological Opinion minimum lake elevation—4,519.29 ft] *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 4,513.09 ft. Pre-impoundment elevation records for Clear Lake only exist for a few years, (1904–1910), but 4,522 ft is the lowest elevation recorded for the natural lake. Inflow to Clear Lake averages 128,120 acre-ft but has varied from 18,380 acre-ft in 1933–1934 to 368,550 acre-ft in 1955–1956 (Service 1994b).*

The outlet at Clear Lake is opened in the spring, usually around April 15, to provide irrigation water to the Langell Valley Irrigation District (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-ft from October 1 through March 1, summer drawdown releases are occasionally necessary" (Biological Opinion, 2001).

During the high rainfall years from 1995 through 1998, Clear Lake was allowed to fill only to approximately 400,000 acre-ft because of concern for the integrity of the earthen dam. Construction began on a new structure immediately below the existing dam in September 2001 at an estimated cost of $6,000,000 (John Cook, USBR, personal communication). Although raising the dam at Clear Lake has been suggested as an opportunity for storage augmentation, the failure to fill the reservoir in its 90-year history indicates this is not likely to increase water supply. The new structure will allow raising storage capacity to the original design capacity. The 2001 Biological Opinion requires a minimum elevation of 4,521.0 ft in Clear Lake on September 30. The storage sacrificed at this level compared to Reclamation's minimum of 4,519.29 is about 17,000 acre-ft.

Releases from Clear Lake during the period 1991–2000 averaged 46,000 acre-ft on a calendar-year basis (Table 1). The range was from 8,000 acre-ft in both 1992 and 1994 to 118,000 acre-ft in 1999. Net recharge of the reservoir (releases +/- change in storage) was –36,000, –33,000, and –60,000 acre-ft in 1991, 1992, and 1994, respectively, and +187,000 acre-ft in 1995. In 2000, the reservoir experienced a net recharge of -500 acre-ft. Long-term average inflow to Clear Lake is reported to be 117,000 acre-ft (USBR).

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 3,830 acres and an active capacity of 94,270 acre-ft at the spillway crest, elevation 4,835.4 ft. In an average year, Gerber Dam, the source of water for Miller Diversion Dam, releases about 40,000 acre-ft of irrigation water.

Construction of Gerber Dam was completed in May of 1925. The reservoir is used to store seasonal runoff to meet irrigation needs (17,000 acres) of the Project, primarily for the Langell Valley Irrigation District (LVID), and to limit runoff into Tule Lake. Prior to *construction of the dam, no reservoir existed and Miller Creek would run dry from June to October in most years"* (Biological Opinion, 2001).

Proposals have been made to raise Gerber Dam by 3 to 5 ft. This is projected to increase storage capacity by up to 20,000 acre-ft at a cost of approximately $3,000,000 (John Cook, USBR, personal communication). However, in most years Gerber Reservoir does not receive sufficient inflow to fill current capacity. USBR proposed a minimum elevation of 4,796.52 ft for Gerber Reservoir for 2001. The Biological Opinion requires a minimum elevation of 4,802.0 ft on September 30. The difference in storage at these elevations is less than 4,000 acre-ft (USBR data). The 2001 Biological Opinion allowed for diversion of a combined volume of 70,000 acre-ft from Clear Lake and Gerber Reservoir for irrigation in the LVID and HID and for a minimum lake level in Tule Lake. As of late September, the 2001 combined releases from these reservoirs were about 100,000 acre-ft (USBR data) (Table 1).

The average release from Gerber Reservoir for calendar years 1991–2000 has been 41,000 acre-ft (Table 1). Releases ranged from 1,000 acre-ft in 1992 to 94,000 acre-ft in 1999. Net recharge, as defined above, has ranged from -100 acre-ft in 1994 to +84,000 acre-ft in 1995. Average inflow is 55,000 acre-ft (USBR).

Lost River

The Lost River traverses approximately 100 miles from Clear Lake Reservoir to Tule Lake. Throughout most of its length, the river is highly channelized and managed. Two important structures include the Lost River Diversion Dam (Wilson Dam) which allows discharge of up to 3,000 cfs to the Lost River Diversion Channel, and the Anderson-Rose Dam, which facilitates diversion to the J-Canal for irrigation of land within the TuleLake Irrigation District (TID). The J-Canal has a capacity of 800 cfs and typically diverts about 135,000 acre-ft to TID. The Lost River has lost all semblance of a natural river system and is a highly managed feature of the Project with several impoundments. USBR documents refer to the Lost River as the Lost River Improved Channel. Implementation of the decision to drain and reclaim Tule Lake and the Lower Klamath Lake for agricultural production required changes in and management of the Lost River.

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 8 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 Tulelake area. During the summer months the channel is operated as if it were a forebay for the Miller Hill Pumping Plants and the Station 48 turnout. 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"* (Biological Opinion, 2001).

Tule Lake Sumps

"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 the 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 (drain and convert to productive farmland) *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 flows 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 ft 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 channel, the "English Channel." The two sumps have a surface area 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, Lu, and Carlson 1995).

Water level elevations in Tule Lake sumps have been managed according to criteria set in the 1992 BO. From April 1st to September 30, a minimum elevation of 4,034.6 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 4,034.0 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" (Biological Opinion, 2001).

The above discussion makes an important point about historical, unaltered hydrology of the region. The Lost River drainage was connected to the Klamath River not as a source, but as a sink, for excess water during years of high water supply. The flows down Klamath River during 1995-1999 were enhanced by a significant contribution from the Lost River watershed. In an unaltered state, a portion of Klamath River flows would have been diverted through the Lost River Slough to Tule Lake, where it would have evaporated.

In studies to determine flow requirements for Iron Gate Dam, historical flows have been based on flows observed in 1905–1912 (Balance Hydrologics, Inc. 1996). This was a period of above-normal precipitation. U.S. Water Bureau records indicate an average annual precipitation at Klamath Falls of 15.82 inches for the 8-year period, compared with an average of 13.22 for 1884–1949 (Rykbost *et al. 2001)*. The dike constructed in the Lost River Slough in 1890 prevented overflow from Klamath River going to its historic destination in Tule Lake during these years of above average water supply. Basing historical flows on this period inflates flows from two perspectives: use of a period when precipitation records for Klamath Falls indicate water supply was 20 percent above normal; and use of a period when natural overflow from Klamath River to Tule Lake was prevented.

Klamath Straits Drain

"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 lifted twice by pumps and is then discharged to the Klamath River. The Straits Drain is in the Lower Klamath National Wildlife refuge, which in turn receives drainage water from the Tule Lake National Wildlife Refuge. 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 flow conditions within the drain. Water quality conditions are monitored continuously near the outlet of the channel to the Klamath River" (Biological Opinion, 2001).

Average annual discharge of drainage water to the Klamath River from the Klamath Straits Drain for the period from 1991–2000 is approximately 81,000 acre-ft, with peak flows occurring in late winter. During drought years of 1992 and 1994, discharge was 31,000 and 61,000 acre-ft, respectively (Table 1). During the other years of this 10-year period, the discharge ranged from 75,000 to 128,000 acre-ft.

An analysis of water quality conditions in the Lost River sub-basin for purposes of establishing Total Maximum Daily Load (TMDL) targets, identified the Klamath Straits Drain as a potential point source pollution contributor of nutrients from agricultural activities to Klamath River. Water quality concerns include pH, dissolved oxygen (DO), temperature, nutrients, bacteria, and chlorophyll-a. Recirculation of Straits Drain water through agricultural and/or the Lower Klamath National Wildlife Refuge during at least portions of the year has been suggested as a possible solution for discharges. Construction of wetland filtering prior to discharge to the river also has been investigated.

In addition to the previously discussed Lost River Diversion Channel, the Lost River watershed has a second altered feature connecting it to the Klamath River. Drainage from the Tule Lake refuge, through Sheepy Ridge to the Lower Klamath refuge and out through the Straits Drain, contributes significant quantities of discharge that were historically lost as evaporation from Tule Lake. From 1996 through 1999, over 100,000 acre-ft annually was discharged to the Klamath River through the Straits Drain (Table 1). A portion of this originated in the Lost River watershed and would not have reached the Klamath River under natural conditions.

Prior to development of the Project, a reef at Keno, Oregon backed up Klamath River, forming Lower Klamath Lake. This lake ranged in size to about 75,000 acres depending on watershed conditions. In 1907, a dike was constructed to isolate Lower Klamath Lake from the Klamath River and serve as a bed for a railroad connecting Klamath Falls with points south. Construction of the railroad was completed in 1909. This was the beginning of efforts to drain Lower Klamath Lake and convert the region to agricultural land and a wildlife refuge. This change resulted in increasing river flows by eliminating access of Klamath River to the Lower Klamath Lake area, thus reducing evaporative losses in the upper basin.

ADY Canal

"The [headworks] *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"* (Biological Opinion, 2001).

Average annual diversion out of Klamath River to the Lower Klamath Lake area through the ADY Canal for 1991 to 2000 was 86,000 acre-ft (Table 1). A minor portion of this is used to irrigate about 500 acres of crops or pastures and the remainder is diverted to refuge lands. In 1999 and 2000, total diversions from April through October were about 60,000 and 50,000 acre-ft, respectively (USBR data). Off-season diversions are used to flood habitat in the Lower Klamath National Wildlife Refuge. Diversions to the ADY Canal have been quite consistent from year to year, ranging from 71,000 to 108,000 acre-ft from 1991 to 2000. Additional water is diverted to the Lower Klamath NWR by Pumping Plant D, through Sheepy Ridge. Water use in the refuge is discussed later.

The intake for the ADY Canal and the final pumping station for the Straits Drain are located immediately adjacent and could easily be modified to divert Straits Drain drainage water into the ADY Canal for recirculation through agricultural lands or the refuge. While this could result in a potential buildup of salts, it may be an alternative to avoid discharge of contaminants to Klamath River at critical times of the year. It is a concept worthy of investigation. An additional alternative would be to divert water from the Straits Drain to the intake for the North Canal, replacing river diversion for irrigation of agricultural land in the Klamath Drainage District.

North Canal

The North Canal diverts water from Klamath River to approximately 10,000 acres of private agricultural lands in the Klamath Drainage District of the Lower Klamath Lake area. The diversion has a capacity of approximately 300 cfs. Total annual diversions through the North Canal have ranged from a low of 28,000 acre-ft in 1992, 1994, and 1998, to a high of 49,000 acre-ft in 1995 (Table 1). In 1999 and 2000, the total April through October inflow was about 35,000 acre-ft (USBR data). Winter flooding of agricultural fields provides control of rodents (drowning and/or exposure to raptor predation), weeds, and plant diseases, and habitat for waterfowl. Surplus water is discharged to the Klamath Straits Drain. The 10-year average diversion to the North Canal has been 37,000 acre-ft. Much of this returns to the Klamath River through the Straits Drain after flood irrigation during winter months. As in the ADY Canal, gates to Klamath River are left open and the canal is holding water year-around at the elevation maintained in the Klamath River.

Other Klamath Project features

Additional features of the Project are not described in detail, but are important in the overall functioning of the project. It is beyond the scope of this report to describe all diversion dams, lateral canals, drains, pumping stations, and sumps that are used to direct flows, recover return flows, and facilitate distribution of water within the Project and discharge water to the lower Klamath River. However, it is noteworthy that minor laterals, which divert 95 percent of actual deliveries to farms, include 680 miles of channels. A total of 728 miles of drain ditches range in depth from a few ft to 10 ft, with discharge capacities up to 600 cfs (Straits Drain) (Biological Opinion, 2001). Most drains retain water throughout the year and are important sources of recharge for shallow domestic wells, as are main canals and laterals during the irrigation season. This fact has been clearly demonstrated during the current drought by many wells becoming inoperable by mid-summer 2001. Several of these wells came back on-line within days after canals were charged in late July and early August. These canals and drains provide several thousand acres of habitat for birds, amphibian species, reptiles, and mammals.

Tule Lake and Lower Klamath National Wildlife Refuges

"The 2001 Habitat Management Plan for the Tule Lake NWR calls for Sump 1A to be permanently maintained and Sump 1B to be drawn down in May and flooded again in September or October or later as supply permits. Evaporation losses for Sump 1A, assuming an area of 9,500 acres, is estimated to be 36,400 acre-ft. Sump 1B is about 3,500 acres and will require an estimated 7,000 acre-ft of water to re-flood.

Additionally, there will be 400 acres of flood fallow lots and 885 acres of seasonal wetlands on Tule Lake NWR outside of Sump 1A and Sump 1B. The flood fallow lots will be permanently flooded and will require approximately 1,200 acre-ft of water to meet ET losses throughout the year. The water requirement for the seasonal wetlands would be an estimated 1,800 acre-ft. Seasonally flooded areas will be drawn down in May and flooded again in September or October or later as supply permits. The seasonal areas include the Headquarters fields (85 acres), Covey Point (200 acres), and 600 acres of new seasonal lands in Sump 3. The total water requirement for Tule Lake NWR is 46,400 acre-ft. This does not include any irrigation needs for farmed areas on the lease lands.

The 2001 Habitat Management Plan for Lower Klamath NWR calls for a total of 11,163 acres of permanently flooded wetlands, 11,379 acres of seasonally flooded wetlands, 4,476 acres of grain fields, and 4,561 acres of flooded upland areas. Of the total seasonal acreage, 8,161 acres will be flooded from September 1 to October 31. The remaining seasonal acreage as well as all grain and upland areas will be flooded after October 31.

Water requirements were estimated using the ref_for982.xls model for Lower Klamath NWR, assuming median precipitation and the 20% exceednce ET rate for the permanent wetlands. The total water requirement for the period May 1 – October 31 is 50,660 acre-ft. Of the 50,660 acre-ft, 26,110 acre-ft is for permanent wetlands and 24,540 acre-ft is for seasonal wetlands to be filled before October 31.

After October 31, additional water will be needed to fill the remaining 3,236 acres of seasonal wetlands (9,090 acre-ft), the 4,476 acres of grain fields (11,190 acre-ft), and the roughly 300 acres of upland area that will be flooded with ADY water this year (about 1,000 acre-ft). In addition, the permanent wetlands will require freshening flows of up to 5,480 acre-ft at some point during the winter. The total demand for the period November 1–April 30 is 26,760 *acre-ft. This brings the total water requirement for the refuge in 2001 to 77,420 acre-ft. This does not include any lease land irrigation needs"* (USFWS-Klamath Basin NWR, 2001).

The Tule Lake National Wildlife Refuge receives water from the Lost River and drainage from the TID. Lost River supplies can originate from Clear Lake or Gerber Reservoirs or from UKL via the Lost River Diversion Channel. Water for the Lower Klamath Wildlife Refuge is provided by pumping drainage from Sump 1A through Sheepy Ridge or from Klamath River through the ADY Canal diversion.

Data on water use within the Lower Klamath NWR for 1998, 1999, and 2000, provided by USFWS-NWR, is presented in Table 2. Total usage was about 88,000 acre-ft in 1998 and 1999 and 80,000 acre-ft in 2000. Reduced use in 2000 occurred because of the need to meet target lake elevations and Iron Gate Dam flows required by the 2000 Operations Plan.

The estimation of water use in the refuges indicates an average consumptive use of 3.25 acre-ft/acre for the Tule Lake sumps, which are primarily permanently flooded. The Lower Klamath refuge consumptive use averages 2.45 acre-ft/acre. Over 50 percent of this refuge is devoted to seasonal flooding or grain production. In contrast, crop consumptive-use ranges from about 1.75 acre-ft/acre for grain to about 2.0 acre-ft for potatoes and onions, and 2.5 acre-ft/acre for alfalfa and pastures. Data for these crops for 1999 and 2000 are available on the USBR AgriMet Web site.

The wildlife refuges within the Project were established in 1908, 3 years after the Project was authorized. As a result, the refuges have a junior water priority in relation to the majority of lands within the Project. The 2001 Biological Opinion calls for maintenance of a minimum surface elevation of 4,034.6 ft in Sump 1A. Other than this requirement, no provisions are made in the Biological Opinion or the USBR 2001 Operations Plan for supplying water to the refuges. At mid-summer, it was expected that only 1,000 acres of permanent wetlands could be maintained in the Lower Klamath NWR (James Hainline, USFWS-NWR, personal communications). In late summer, arrangements were made by interested parties to augment this supply from several sources, including newly developed wells in California, discharges from Clear Lake and Gerber Reservoirs, and depletion of storage behind dams in the Klamath River.

Table 2. Estimated water use in Lower Klamath National Wildlife Refuge by month for permanent marsh, seasonal marsh, and grain units in 1998, 1999, and 2000.[1]

		Water Use (acre-feet)												
Units	Acres	J	F	M	A	M	J	J	A	S	O	N	D	Total
							1998							
Permanent	7,417	560	1,090	2,070	3,100	3,940	4,930	5,590	4,770	3,570	2,290	720	520	33,150
Seasonal	15,670	8,810	2,190	3,710	1,710	0	0	0	0	11,290	10,880	3,600	2,160	44,320
Grain	3,530	7,150	0	0	0	0	0	3,530	0	0	0	0	0	10,680
Total	26,617	16,520	3,280	5,780	4,810	3,940	4,930	9,120	4,770	14,860	13,170	4,320	2,680	88,150
							1999							
Permanent	9,060	690	1,340	2,530	3,790	4,810	6,020	6,820	5,830	4,360	2,790	880	630	40,490
Seasonal	12,710	8,590	1,440	2,280	480	0	0	0	0	11,290	5,550	2,760	1,950	34,340
Grain	4,460	9,020	0	0	0	0	0	4,460	0	0	0	0	0	13,480
Total	26,230	18,300	2,780	4,810	4,270	4,810	6,020	11,280	5,830	15,650	8,340	3,640	2,580	88,310
							2000							
Permanent	7,720	590	1,140	2,150	3,230	4,100	5,130	5,810	4,960	3,710	2,380	750	540	34,490
Seasonal	14,420	1,090	1,350	2,110	220	0	0	0	0	13,070	8,620	4,260	4,170	34,890
Grain	3,630	7,360	0	0	0	0	0	3,630	0	0	0	0	0	10,990
Total	25,770	9,040	2,490	4,260	3,450	4,100	5,130	9,440	4,960	16,780	11,000	5,010	4,710	80,370

[1/]Data provided by U. S. Fish and Wildlife Service, Klamath Basin National Wildlife Refuges.

Water quality concerns in the Upper Klamath Basin

Temperature

Most of the water bodies in the Upper Klamath Basin are included as water-quality limited for temperature in the Oregon 303D list. While some of the tributaries feeding UKL meet target temperatures, UKL, the refuges, Lost River, and Klamath River exceed temperature standards during summer months. Several springs in the Lost River near the Olene Gap discharge warm water directly to Lost River. Geothermal wells occur in several areas of the watershed. Wells on the east side of the Lower Klamath Lake area discharge water at >195^{0}F. Several wells within the Lower Klamath NWR produce water at 140 to 180^{0}F. Markle (this report) mapped springs near Bare Island in UKL during low lake levels in 1994, and found many with temperatures exceeding 86^{0}F. While some reduction in stream temperatures at higher elevations might be realized by improvements in riparian areas, significant temperature reductions in large reservoirs above and below Klamath Lake will be difficult to achieve.

Hypereutrophic conditions of Upper Klamath Lake

"*The hypereutrophic* (nutrient rich) *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). Extensive blooms of the cyanobacterium* Aphizomenon flos-aquae (AFA) *cause significant water quality deterioration due to photosynthetically elevated pH (Kann and Smith 1993) and to both supersaturated and hypoxic concentrations (Perkins et al. 2000b; Welch and Burke 2001; Walker 2001). AFA is the dominant primary producer in UKL, comprising >90% of the primary producer biomass during blooms. Both high pH and low DO* (dissolved oxygen) *reach levels in UKL known to be lethal to* *suckers, and as such are important parameters affecting survival and viability of native fishes. Bioassays have shown that pH values >9.55 caused a loss of equilibrium in juvenile SNS (Falter and Cech 1991), and that values >10.3 proved lethal to larval and juvenile LRS and SNS (Saiki et al. 1999). Bioassays also show that DO levels <2.4 mg/l are lethal to larval and juvenile SNS. It is important to note that sub-lethal effects are likely to occur prior to reaching the lethal levels described above (Kann and Smith 1993; Reiser et al. 2001). Meyer et al. (2000) and Lease (2000) documented structural changes in the gills of larvae exposed to un-ionized ammonia concentrations 3.5 times lower than the lowest concentration at which significant growth and mortality effects occurred. Swimming performance was reduced at pH 10.* (Saiki *et al* [1999] reported 96-hour LC-50 un-ionized ammonia concentrations of 0.5 and 0.8 ppm for LRS and 1.1 and 0.5 ppm for SNS larvae and juvenile, respectively.)

Lake volume and mean depth have a direct effect on physical, chemical, and biological processes. There is a direct reduction of habitat available for fishes as lake level is lowered, particularly the reduction in shoreline rearing habitat of larval and juvenile endangered sucker species (Dunsmoor et al. 2000; Klamath Tribes 1995; Reiser et al. 2001). In addition, lowered lake elevation and volume can exacerbate various productivity-related water quality problems" (Biological Opinion, 2001).

This discussion of water-quality effects related to lake elevation is greatly amplified in the Biological Opinion and was the basis for establishment of minimum lake-elevation targets to protect endangered sucker species, promote recruitment of additional year-classes, and improve water quality. Detailed discussions in the Biological Opinion consider phosphorous (P) loading/pH relationships, the extent of anthropogenic contributions to P loading, temperature/lake elevation relationships, wind speed/water quality relationships, and water-quality relationships to fish kills experienced in 1995–1997. It is beyond the scope of this report to repeat a description of the interrelationships between the water quality parameters of concern. However, there is not consensus on interpretation of the many studies and reports related to these and other aspects of natural resource issues in the region. Several aspects of the assumptions and interpretations used as a basis for lake elevation management are discussed below.

External and internal P loading of Upper Klamath Lake

Defining studies on nutrient loading in UKL were reported by Miller and Tash (1967) and Snyder and Morace (1997). Both studies investigated the contributions of drainage water from agricultural properties adjacent to UKL to P loading. Studies reported by Walker (1995), Kann and Walker (1999), Perkins *et al*. (2000b), and Walker (2001), building on the data and theories from these and other studies, have developed models projecting solutions to water quality problems based on reduction of P loading from agricultural activities and maintenance of high lake elevations (dilution effect).

Miller and Tash (1967) attributed 26 percent of external P loading to pumped drainage from agricultural properties discharged directly into UKL. Snyder and Morace (1997) arrived at a similar conclusion, although they devoted a full page of their report to "Limitations and Concerns Involved in Calculations of Nutrient Loads and Values." Their summary stated "these loading estimates are only an indication of the order of magnitude of nutrient contributions from these areas." Neither of these studies describes natural background P sources in any detail, although Snyder and Morace (1997) reported high P concentrations in three artesian wells on the Wood River Ranch property.

Kann and Walker (1999) report on the monitoring of UKL nutrient concentrations at nine sites from 1991 through 1998. They modeled nutrient loading of the lake and attributed 40 percent of external P loading to anthropogenic (caused by human activities) sources, as did Walker (1995). In the construction of their nutrient budget, Kann and Walker (1999) only include nutrient loads at the source (springs) as background, and assign all other external nutrients to anthropogenic influence. They estimate external sources contribute 39 percent, while internal sources (re-suspension of sediment P and discharge from springs in UKL) account for 61 percent of total P loading in UKL. As a worst case, their anthropogenic contribution accounts for only about 16 percent (0.39 X 0.40) of total P loading. An extensive data set on lake water nutrient concentrations included in an appendix in Kann and Walker (1999) was not considered in the Biological Opinion.

More recent research (Rykbost *et al.*, 1999; Rykbost and Charlton, 2000; Rykbost and Charlton 2001a) demonstrates natural background P sources are partially responsible for P loading in drainage waters from agricultural properties adjacent to UKL. Water applied to properties at the southern end of UKL to recharge soil profiles comes out of Klamath Lake with a high nutrient load. Nutrient concentrations in numerous springs and artesian wells are also reported, indicating high natural P loading in aquifers in the Wood River Valley. Major springs feeding tributaries to UKL contain sufficient P to support algal blooms in the absence of anthropogenic contributions, as evidenced by the eutrophic condition of UKL pre-dating settlement of the region. During an expedition to the region in the 1840s, John C. Fremont would not allow horses to drink from Klamath Lake at Rattlesnake Point because of the foul water quality (Fremont 1845).

Other water quality factors in Upper Klamath Lake

Numerous references to un-ionized ammonia toxicity effects on endangered species suggest the importance of this to lake management. The Biological Opinion emphasizes theoretical models of lake depth/wind speed/Relative Thermal Resistance to Mixing (RTRM)/ and P/pH relationships. An extensive empirical data set that documents ammonia concentrations in UKL over 10 years also exists. This data from Kann and Walker (1999) is summarized in Tables 3–5. Table 3 shows mean lake-wide concentrations of total P, total N, and ammonia N by month averaged over years. Small sample size for winter months suggests these data may not be useful. Extensive sampling was conducted from June through October, when water quality is most affected by algal blooms and high temperatures. Concentrations of P, N, and ammonia peaked in July and were at minimum levels in spring months. Table 4 compares lake-wide nutrient concentrations averaged over years. While differences between years were minor for total P and total N, differences in ammonia concentration were greater than an order of magnitude. High ammonia concentrations were observed in years of high lake level (1996–1998) while the lowest concentrations were observed in 1992 and 1994 when lake levels were very low. Table 5 focuses on the summer months when algal blooms and fish die-offs occur.

Table 3. Lake-wide mean concentrations of total phosphorus (TP), total nitrogen (TN) and ammonia nitrogen (NH_3 - N) by month for Upper Klamath/Agency Lake, 1991 - 1998. [1]

Month	No. of Samples	Total Phosphorus (TP)	Total Nitrogen (TN)	Ammonia Nitrogen NH_3 - N
		ppm		
January	6	0.09	1.42	0.48
February	22	0.07	0.95	0.08
March	40	0.05	0.60	0.08
April	84	0.06	0.72	0.04
May	105	0.06	0.67	0.05
June	142	0.12	1.67	0.14
July	149	0.22	2.25	0.35
August	146	0.19	2.03	0.21
September	127	0.19	1.88	0.27
October	118	0.14	1.73	0.23
November	34	0.09	1.21	0.26
December	1	0.09	2.42	0.84

1/ Data from Appendix I (Kann & Walker 1999)

Table 4. Lake-wide mean concentrations of total phosphorus (TP), total nitrogen (TN) and ammonia nitrogen (NH_3 - N) averaged for all months in Upper Klamath/Agency Lake for 1991 through 1998.[1]

Year	No. of Samples	Total Phosphorus (TP)	Total Nitrogen (TN)	Ammonia Nitrogen NH_3 - N
		ppm		
1991	126	0.18	1.76	0.09
1992	138	0.14	1.46	0.04
1993	134	0.10	1.35	0.15
1994	117	0.11	1.44	0.03
1995	159	0.15	1.81	0.07
1996	94	0.12	1.52	0.28
1997	124	0.15	1.64	0.60
1998	129	0.12	1.28	0.41
Mean	128	0.13	1.53	0.21

1/ Data from Appendix I (Kann & Walker 1999)

Table 5. Lake elevation at June 30 and October 31 and mean lakewide nutrient concentrations for July through October in Upper Klamath/ Agency Lake, 1991 - 1998.[1]

Year	Lake Elevation		Mean Nutrient Concentration		
	6/30	10/31	TP	TN	NH_3 - N
	ft		ppm		
1991	4141.5	4138.2	0.26	2.37	0.07
1992	4139.5	4137.6	0.16	1.67	0.02
1993	4142.6	4139.6	0.13	1.63	0.23
1994	4140.8	4136.9	0.13	1.63	0.02
1995	4143.1	4139.4	0.22	2.35	0.05
1996	4142.2	4139.0	0.18	2.07	0.39
1997	4142.2	4140.3	0.22	2.29	0.91
1998	4143.0	4140.2	0.16	1.65	0.42

1/ Lake elevation data from BOR and nutrient data, Appendix I (Kann & Walker 1999)

High ammonia concentrations in 1996 and 1997 coincided with severe fish die-offs. Ammonia concentrations were low during summer months from 1991 through 1995. The Biological Opinion, while not discussing ammonia data in detail, mentioned ammonia in reference to fish die-offs. "*From June through August 1996, un-ionized ammonia levels were generally higher than in any of the previous five years sampled. Mean lake-wide ammonia concentrations were 70–95 ug/l (Perkins et al. 2000b).*" Data from Kann and Walker (1999) indicate ammonia concentrations of 50—1,020 ug/l for this period with levels above 400 ug/l on four of eight sampling dates. From June through October 1997, ammonia concentrations ranged from 350 to 1,644, with an average of 779ug/l. Perkins, Kann, and Scoppettone (2001), in their Figure 1, show un-ionized ammonia concentrations peaking at about 0.30 ppm in July and again in September 1996 and at about 0.9 ppm in late July 1997. They do not present data for years prior to 1995.

Weather conditions and lake water quality

Differences in weather conditions, including water temperature and wind speed, are cited as a main reason for fish kills in the Biological Opinion. "*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. AFA populations bloomed in June were generally declining. A lack of wind mixing likely reduced 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 after the 1996 die-off were unusual. For example, the mean monthly July temperature was 73.5^{0}F, making it the second warmest in 69 years of record at the Klamath Falls airport. The

August mean monthly temperature, 70^{0}F was ranked 11th over the 69-year record. Warm weather was also associated with previous fish die-offs in 1995, 1986, and 1971.

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 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 afternoon and early evening hours" (Biological Opinion, 2001).

An alternative to comparing the 1996 and 1997 years with 69- or 27-year data sets, a period during which a significant deterioration of water quality in UKL may have occurred, is to compare conditions over the most recent 10 years of 1991–2000. Table 6 shows mean monthly air temperatures recorded at the KES station for April through October for these years. It should be noted that during years when both Kingsley Field and KES stations were in operation, daily mean air temperatures were 2 to 3^{0}F higher at the airport. This was thought to be due to the proximity of the airport station to large buildings and extensive paved areas. In this 10-year data set, July mean temperatures were the same for 1992, 1996, and 1998. Only 1993 and 1995 were several degrees cooler for both July and August. The August 1996 mean temperature was essentially the same as in 1991, 1992, 1997, and 1998; three years of no fish die-offs and one year with a die-off. At lower lake elevations, 1991 and 1992 may have experienced higher water temperatures relative to air temperatures because of reduced buffering capacity, a relationship pointed out in the Biological Opinion.

Tables 7 and 8 show mean daily wind speed and the number of days per month when mean wind speed exceeded 5 mph, measured at the KES station in June through September for 1991 through 2000. Wind speeds were lower with fewer days of speeds above 5.0 mph in July and August 1996 compared with 1991–1994. The years 1998 and 2000, which experienced no fish die-offs, were equally low in wind speeds. KES data were the same as airport data for July and August of 1996.

Table 6. Mean monthly air temperature for April through October measured at the Klamath Experiment Station, Klamath Falls, OR for 1991 - 2000.

	Year										Mean
Month	91	92	93	94	95	96	97	98	99	00	84-99
	Mean Monthly Air Temperature (^{0}F)										
April	42	48	42	45	42	44	43	43	42	47	44
May	46	59	53	54	51	49	56	47	49	51	51
June	54	62	65	58	57	58	58	58	56	61	59
July	68	64	57	69	63	69	64	69	62	63	65
August	65	67	61	62	61	66	65	67	63	64	64
September	63	57	58	60	60	55	58	62	59	64	58
October	52	50	49	45	47	48	47	45	49	45	48
Mean	56	58	55	56	54	56	56	56	54	56	56
June-Aug Mean	62	64	61	63	60	64	62	65	60	63	63

Table 7. Mean monthly wind speeds in miles/hour measured at the Klamath Experiment Station weather station for June through September in 1991 - 2000.

	Year										
Month	91	92	93	94	95	96	97	98	99	00	Mean
	miles/hour										
June	5.1	5.6	4.5	4.4	5.3	3.8	4.8	3.1	4.7	4.6	4.6
July	3.8	3.8	4.1	4.2	3.6	3.2	3.2	3.1	3.6	3.2	3.6
August	3.4	3.3	3.4	3.3	3.5	3.0	3.2	2.8	3.3	3.1	3.3
September	3.5	3.3	2.6	3.3	3.1	3.3	3.0	3.5	3.8	3.0	3.2
Mean	4.0	4.0	3.7	3.8	3.9	3.3	3.6	3.1	3.9	3.5	3.7

Table 8. Number of days/month when mean daily wind speed measured at the Klamath Experiment Station weather station exceeded 5.0 miles/hour in 1991 - 2000.

	Year										
Month	91	92	93	94	95	96	97	98	99	00	Mean
	days/month										
June	13	18	10	7	13	2	8	8	12	10	6.1
July	2	7	5	7	4	2	1	1	6	0	3.5
August	3	3	2	1	5	1	2	0	2	1	2.0
September	3	5	0	3	3	7	2	4	8	3	3.8
Mean	5.3	8.3	4.3	4.5	6.3	3.0	3.3	3.3	7.0	3.5	3.9

The Biological Opinion states *"Fish kills are not related to lake levels. 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 data 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. Therefore there is no clear relationship between lake elevation and fish kills."*

In fact, lake elevation remained higher in 1997 (4,140.0 ft at end of September) than in 1995 (4,139.7 ft at end of September). The value used for August average lake level is not indicated, but it is above 4,140.0 ft. This is higher than the long-term average for the Project since 1905. It should be noted that no fish kills have been reported in any of the 13 years since 1905, when minimum lake elevation fell below 4,138.0 ft. In 1932, when a fish kill was observed, the mid-August lake level was also above 4,140.0 ft. During the first 30 years following the construction of Link River Dam (1922–1951), lake elevation fell below 4,138.0 ft in 10 years (USBR data). The 1932 fish kill occurred at a relatively high lake elevation. In 30 years since 1971, five fish kills have occurred while minimum lake levels have been maintained 1 ft higher than during the 1922–1951 era during late summer and have fallen below 4,138.0 ft on only four occasions.

Role of pH in Upper Klamath Lake water quality

"Kann and Smith (1999) suggested that efforts to improve water quality in UKL and Agency Lake might be focused on reducing AFA productivity to a point that pH levels can be tolerated by the fish community. The results of analysis showed that a 50% reduction in Chl-a [chlorophyll-a] *levels, from 200 to 100 mg/l, would result in a 45% reduction in the probability of exceeding a pH of 9.5. Modeling by Welch and Burke (2001) found similar reductions. Such a reduction may be possible if anthropogenic nutrient inputs, especially TP (*total phosphorus)*, to the lake are reduced 30–50% (Walker 2001). Walker (2001) points out that this could be achieved since an 8% decrease in TP was observed in the past decade, likely as a result of watershed and wetland restoration"* (Biological Opinion, 2001).

The Biological Opinion makes several references to massive and early algal blooms and poor water quality in 1992 and 1994. Unpublished data from USBR compares several water quality parameters for 1990 through 1999 during summer months. The data do show high chlorophyll-a levels in June and early July of both 1992 and 1994, but low levels in August and September. In 1995, 1996, and 1997, chlorophyll-a peaks occurred later in July, when temperatures were probably higher, but also occurred in September. While the reasons are unclear, algal blooms extended much later into the season in years with high lake elevations.

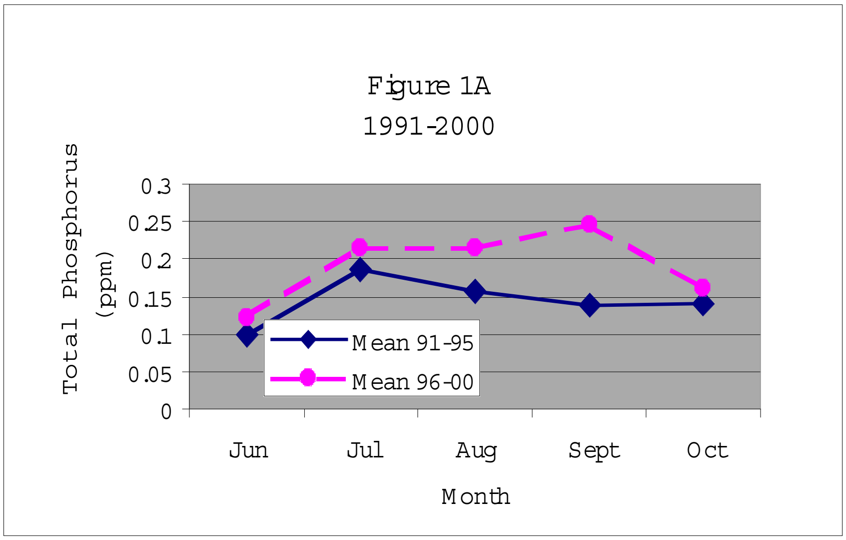
Walker (2001) indicates an 8 percent reduction in external TP loading to UKL has been achieved in March through May during the 1990s. Presumably, this is attributed to less pumping of drainage water from agricultural properties that have been taken out of production for restoration of wetlands or development of water storage (Wood River Ranch, Tulana Farms, Agency Lake Ranch). If this is the case, it is not reflected in data on TP concentration of UKL lake water at the south end of the lake.

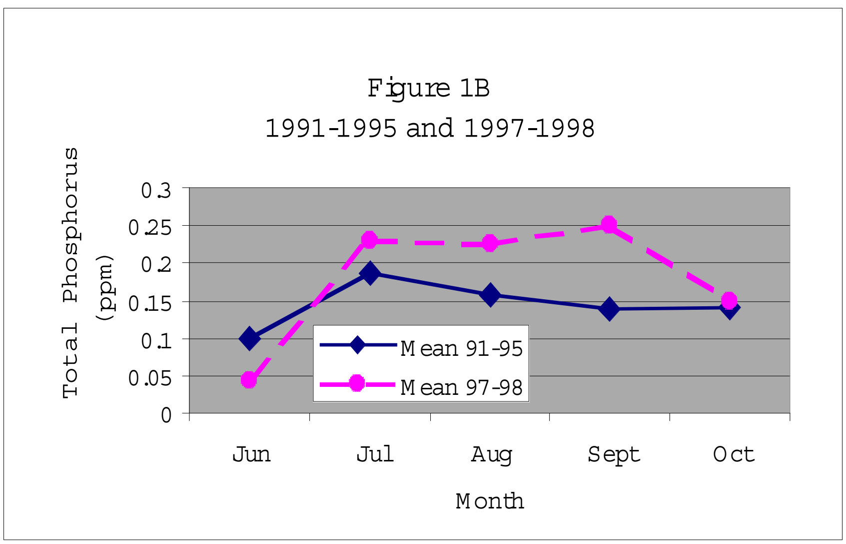
Kann and Walker (1999) present a data set on TP concentration at the Fremont Bridge over the 1991–1998 period. Rykbost and Charlton (2001a) monitored the nutrient loading at the A-Canal headworks during May through October in 1999 and 2000. These sites are within about 300 ft of each other. Comparisons of TP concentrations over the 10-year period are shown by month for June through October in Figure 1. Each comparison indicates higher TP concentrations in the latter years. In combination with greater lake volume, the trend suggests much greater TP was discharged from the lake during the past 5 years. In a recent Technical Memo, Kann (2001a) concludes "the apparent decreasing March-May lake TP trend for the years 1991–1998 reported in Walker (2001) does not hold when 1999 and 2000 data are added to the analysis."

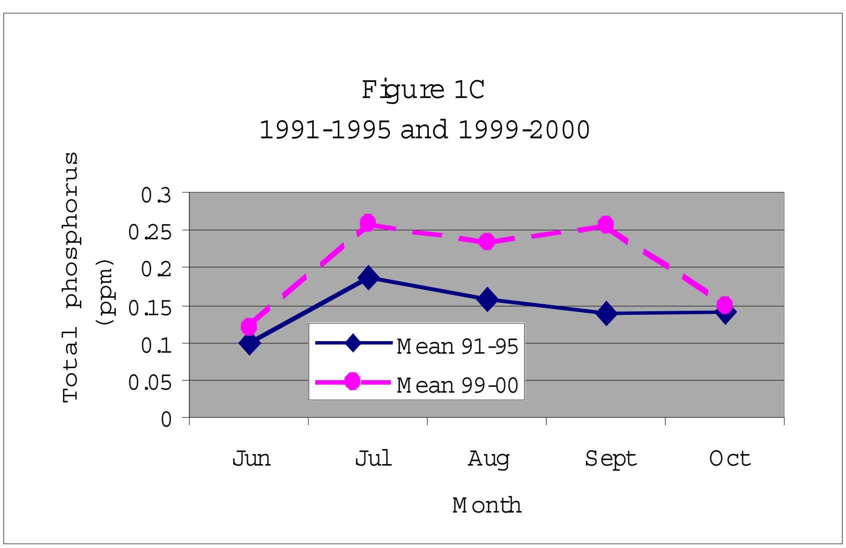
Klamath Lake water quality summary

"*The Service concludes that the pre-project minimum lake levels of 4,140 ft (and similar minimum lake levels presented in the RPA) are necessary to protect suckers from adverse water quality and are based on the best available science. In reaching this conclusion, the Service recognizes that a relationship between water quality and lake levels in UKL that is statistically significant, for example at a 95% confidence level, has not been established. However, based on our analysis of the best available science, we conclude that minimum UKL elevations approximating those experienced pre-project are supported. The dominant factors controlling water quality in UKL are weather and climate, which are not controllable, whereas lake levels can be managed. Considering the high risk that adverse water quality poses to sucker survival, managing UKL using pre-project lake levels with a minimum elevation of about 4,140 ft is considered by the* *service to be necessary to ensure sucker survival and recovery"* (Biological Opinion 2001)

Figure 1. Total Phosphorus Concentration at UKL Outlet







This statement summarizes USFWS reasons for lake level management. Other interpretations of available data can lead to a different conclusion. There is clearly evidence that fish kills have occurred at relatively high lake levels and not at very low lake levels. In low lake-level situations in 1991, 1992, and 1994, ammonia concentrations in the lake were very low, while very high concentrations were observed in 1996 and 1997 when major die-offs occurred. In 1991, a new year-class of SNS and LRS was successfully recruited even though lake level fell to 4,138.18 late in the season. This class survived the low lake levels experienced in 1992 and 1994. A 1992 year-class was "well represented" in the 1996 fish kill (Biological Opinion 2001) and recent U.S. Geological Survey data on sucker captures at spawning sites indicate the presence of both 1992 and 1994 year classes in the population (Rip Shivley, USGS, unpublished data).

As noted earlier, there is not consensus on pre-project minimum lake elevations. Boyle (1987), U.S. Army Corps of Engineers (1982), and Grover *et al* (1923) all suggest that lake elevations fell below 4,140 ft on several occasions prior to construction of Link River Dam. Available data not cited in the Biological Opinion show higher P concentration in UKL during the high lake level years of 1996–2000, than during the period of low lake levels from 1991 through 1994. Much of the water quality analysis is based on theory and models, while empirical data from 8 years in Kann and Walker (1999), one of the major studies cited throughout the BO, was not considered.

Water quality in other water bodies

Discharges to the Klamath River at the Straits Drain have been a focal point for concern over several parameters, including nutrients. Past and current studies suggest P concentrations of 0.3 to 0.4 ppm are common during portions of the year. The discharge includes drainage from agricultural fields irrigated with diversions from the North and ADY canals and drainage water from the Lost River via Tule Lake and Lower Klamath refuges. Ongoing unpublished studies by U.C. Davis and U.S. Geological Survey personnel will attempt to define the nutrient loading in greater detail.

Rykbost and Charlton (2000, and 2001a) monitored nutrient loading to the Project from diversions at the A-Canal, North Canal, and ADY Canal during 1999 and 2000. Total loading from these diversions was estimated at approximately 180,000 lb P and 2,000,000 lb N in both years. Preliminary data from the Straits Drain (Kaffka, unpublished data) indicate an annual discharge of approximately 100,000 lb P. Thus the Project, including refuges and any inputs from the Lost River system and Klamath River via the Lost River Diversion Channel, is a net sink for P diverted out of Klamath Lake and Klamath River. A comparison of P concentration at A-Canal and diversions from the river indicates an increase in P concentration between Link River Dam and North and ADY canals. This may be due to discharges from Klamath Falls and south suburban sewage treatment plants, storm drains, and lumber mills. Contributions from waterfowl in the Miller Island reach of the river and decomposition of wood debris in river sediments also may be involved.

The other major concern for water quality is related to water temperature at the Iron Gate Dam, as it affects threatened Coho salmon. Given conditions of water bodies in the upper basin, little can be done to avoid high temperature at the dam during summer months. This has been well documented in models developed by Deas and Orlob (1999) based on empirical data collected over several years and locations. Higher flows released from the upper basin may increase the temperature at Iron Gate Dam because of greater dilution of accretions below Keno Dam, which are coming into the river as cool spring water. Summer temperatures in UKL frequently exceed 70^{0}F. An unpublished data set from multiple locations in UKL identifies temperatures at specific sites as high as 82^{0}F.

Flow requirements at Iron Gate Dam

The reduction in available water for agriculture and refuge use resulting from maintaining UKL at a minimum elevation of 4,139.0 ft in a critical year type is about 174,000 acre-ft compared to available water if the elevation were allowed to go to 4,136.0 ft, at dead storage. In contrast, the high flows at Iron Gate Dam required by the National Marine Fisheries Service (NMFS) 2001 Biological Opinion for Coho salmon have far greater effect on water supply in the upper basin.

Table 9 illustrates flows past Iron Gate Dam under several scenarios. During the droughts in 1992 and 1994, total flows from April 1 through September 30 were about 150,000 acre-ft and 250,000 acre-ft, respectively. In the 2001 Biological Assessment (BA), USBR proposed a flow regime for April 1 through September 30 of about 180,000 acre-ft. The NMFS requirement for that period for 2001 was about 500,000 acre-ft. This was a compromise from the initial draft Biological Opinion submitted on January 19, 2001, which called for 790,000 acre-ft during April-September. The difference between the USBR BA proposal and the Operations Plan (320,000 acre-ft) is about equal to the 10-year average diversion for the A-Canal, North Canal, and ADY Canal less the return to Klamath River at Straits Drain.

Table 9. Iron Gate Dam monthly flows in acre-ft proposed by INSE (Institute for Natural Systems Engineering), Trihey and Associates and Reclamation.

			Bureau of Reclamation			
Month	INSE	Trihey	Above Ave.	Below Ave.	Dry	Critical
	Flow (1000 Acre-ft/month)					
January	90.8	73.8	69.3	82.0	54.6	62.2
February	100.4	89.3	50.5	85.9	41.5	29.2
March	128.0	92.2	124.8	98.3	44.6	31.4
April	148.9	92.2	101.5	82.1	44.1	34.0
May	167.1	83.3	84.1	61.9	51.9	31.5
June	189.0	92.2	44.7	42.4	39.4	30.1
July	196.8	119.0	42.6	42.7	33.5	26.4
August	187.9	153.7	62.2	43.1	39.8	24.5
September	133.8	101.2	61.6	43.1	44.6	32.0
October	105.4	61.5	81.7	80.4	52.4	55.6
November	82.8	61.5	79.6	78.8	51.9	54.1
December	83.0	59.5	85.3	88.2	54.7	56.2
Total	1,613.9	1,079.4	887.9	828.9	553.0	467.2

Table 9 presents Iron Gate Dam flows by month in acre-ft requested in the January 2001 draft Biological Opinion, suggested in the Trihey and Associates (1996) report, and proposed under four year-classes in the 2001 USBR BA. USBR proposed flows are based on the hydrology of the Project since 1961 and take use of water for irrigation and refuges into consideration. The INSE (Hardy Phase I) and Trihey models do not allow flexibility to adjust for hydrologic conditions in any given year. The INSE model calls for flows equal to the average annual inflow to UKL. With accretions below

Keno Dam accounting for about 300,000 acre-ft in an average year and inflow to UKL averaging 1,300,000 acre-ft, the INSE Iron Gate flow requires all average available UKL water.

An analysis of the hydrology of the project from 1961 through 1997 compared INSE required flows with discharges from UKL. The analysis showed that under INSE required flow regimes, in 13 years out of 37, flows could not have met INSE targets even if no water had been diverted for irrigation or the refuges. Only in 15 years of 37 was sufficient water available to meet the flow targets and historical use for irrigation and refuges. This analysis did not take minimum lake elevations into consideration. Holding lake levels at a minimum of 4,139.0 ft or higher would increase the number of years not meeting flow targets.

The flows suggested in the Trihey report would have left no water for irrigation or refuges from UKL in 1992 and 1994 and less than current use quantities in an additional 6 of 37 years. The modified plan for 2001 operations would have resulted in no water for agriculture or refuges in 1992 and less than current use in 5 additional years from 1961 to 1997. Clearly, the adoption of a long-term operations plan based on Iron Gate Dam flows within the range of values between the INSE and Trihey targets will result in significant shortfalls in surface water supply for the Project.

Economics of irrigation water in the Project

Users of Klamath Project irrigation water pay operation and maintenance (O&M) fees to the irrigation districts delivering these supplies. Fees range from $12/acre for the Van Brimmer Ditch Co. to $70/acre for the pressurized Shasta View Irrigation District. (Smith and Rykbost 2001). The fees are due irrespective of water delivery. There is no charge for the water.

In view of the supply shortfall anticipated for the 2001 season, the USBR offered Project users an opportunity to submit bids for foregoing surface water in 2001 and to Project users or others that could deliver groundwater from wells to Project delivery systems. Bids, submitted for nearly 25 percent of the Project acreage, ranged from $55 to $4,000/acre. USBR accepted bids on about 150 parcels at up to $300/acre. A total of 16,525 acres were accepted for the program at a total cost of about $2,760,000, or an average of $167/acre. The groundwater purchasing program acquired about 67,000 acre-ft of groundwater at an average price of about $33/acre-ft and a total cost of about $2,208,000. Accepted bids for well water ranged from $25 to $52/acre-ft (USBR data).

Project irrigators enjoy reduced electricity prices for irrigation pumps through a 50-year contract that expires in 2006. The rates range from $0.003 to $0.006/kw-h. The negotiations for contract renewal have begun, but it is anticipated that the very favorable rates will not be renewed. Any increase approaching standard charges will significantly affect irrigation costs, particularly for wells with lifts greater than a few feet. For a perspective on potential effects, Pumping Plant D, which pumps drainage from Tule Lake NWR Sump 1A to the Lower Klamath NWR, typically costs $50,000/year to operate at rates of $0.003/kw-h during non-peak or $0.005/kw-h during peak demand periods. At current commercial rates, about 10 times higher, the annual electrical cost for this pumping station would increase to about $500,000. This would increase O&M fees for the Tulelake Irrigation District members by about $7.00/acre, a 25 percent increase.

Effects of water management in 2001

The Project Operations Plan for 2001 provided about 70,000 acre-ft to the Horsefly and Langell Valley Irrigation Districts from Clear Lake and Gerber Reservoirs. Water from private wells and minor quantities from the Lost River, derived from purchased well water, maintained limited supplies for up to about 75,000 acres within the Project. A small release in late July from Upper Klamath Lake (75,000 acre-ft) provided significant late-season relief to pastures and hay crops. Remaining fields in the Project were not irrigated through the summer. The Klamath County Tax Assessor estimates that about 85,000 acres in Klamath County, 67 percent of project lands in the county, received no water in 2001. An additional acreage that only received the late delivery in August was considered to have received no water for tax assessment purposes. The late release from Klamath Lake was inefficiently used because of difficulty in moving it through canals clogged with weeds. Fields normally irrigated with return flows from drains were unable to be served from this release.

Failure to charge the Project canals resulted in elimination of habitat for numerous species in thousands of acres of canals and drain ditches. The lack of seepage from these sources contributed to the failure of a number of shallow wells used for domestic and livestock supplies.

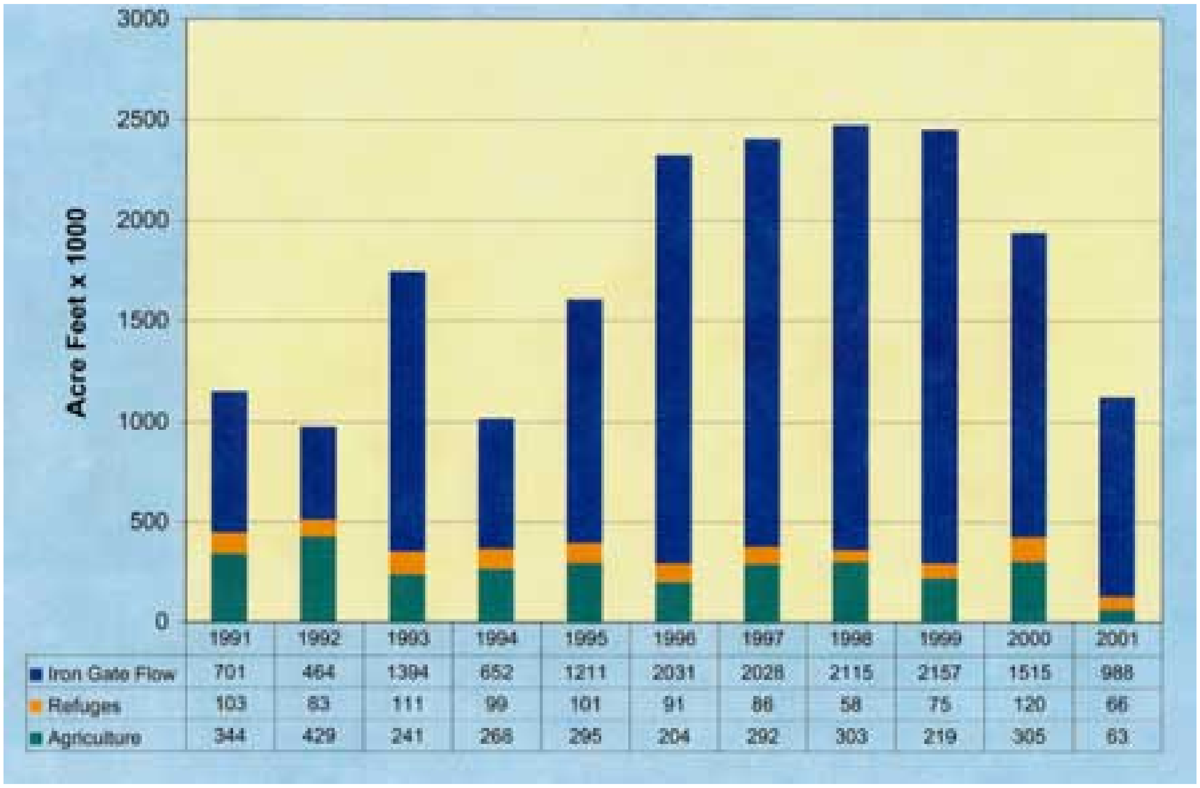
The major change in water allocation implemented in 2001 is illustrated in Figures 2 and 3. Data provided by USBR shows relative allocation of water from UKL to Iron Gate Dam flows, Tule Lake and Lower Klamath National Wildlife Refuges, and agricultural lands in the Project. Data does not include water use supplied by the Lost River system or from groundwater wells. In 2001, agriculture received 22 percent of the average diversion for 1991–2000. In contrast, Iron Gate Dam flows were 68 percent of the 1991–2000 mean and refuge use was 71 percent of the 1991–2000 mean. Figure 3 compares UKL water allocation during drought years of 1991, 1992, 1994, and 2001. Total water availability in 2001 was greater than in 1992 and 1994 and similar to the supply in 1991.

Project storage water made unavailable by minimum elevations established in the USFWS 2001 Biological Opinion included 4,000 acre-ft in Gerber Reservoir, 17,000 acre-ft in Clear Lake Reservoir, and 174,000 acre-ft in UKL. This quantity of water would have been sufficient to irrigate more than 100,000 acres of cereal or potato crops, using about 1.75 acre-ft/acre, or 85,000 acres of alfalfa or pasture using 2.25 acre-ft/acre.

The water lost to higher flows at Iron Gate Dam imposed by the NMFS 2001 Biological Opinion can be determined from pre-listing flow regimes. Prior to the listing of Coho salmon, the standard flow requirements for Iron Gate Dam were based on Federal Energy Regulatory Commission (FERC) minimum flows established at the time Iron Gate Dam was licensed. These minimums were 1,000 cfs for May, 710 cfs for June and July, 1000 cfs for August, and 1,300 cfs for September. Using the period from May through September, actual 2001 flows at Iron Gate Dam were about 408,000 acre-ft. FERC minimum flows would have been about 300,000 acre-ft. The difference would have provided adequate irrigation water for about 60,000 acres of cereals or potatoes or 48,000 acres of alfalfa or pasture.

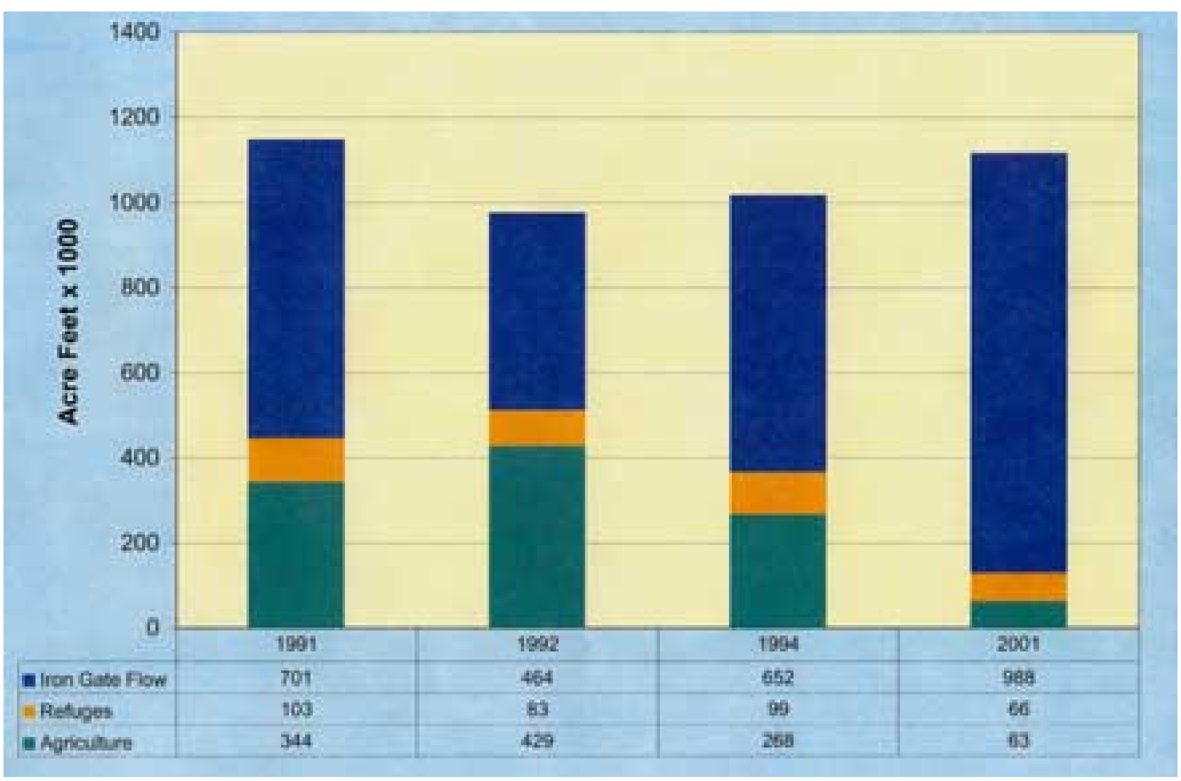
In summary, operation of the Project under the 1992 USFWS Biological Opinion and FERC minimum flow requirements would have resulted in near-normal irrigation and refuge water supply in 2001. Including 174,000 acre-ft of lost storage in UKL, 75,000 acre-ft of water released in July and August, and 108,000 acre-ft of reduced flows from May through September, UKL could have provided 357,000 acre-ft for irrigation and refuges. This represents nearly exactly the 1991–2000 average diversions to the A-Canal, North Canal, and ADY Canal.

Figure 2. Klamath Lake waters allocation for Iron Gate Dam flows, refuges, and agriculture for 1991-2001 (USBR).



	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Iron Gate Flow	701	464	1394	652	1211	2031	2028	2115	2157	1515	988
Refuges	103	83	111	99	101	91	86	58	75	120	66
Agriculture	344	429	241	268	295	204	292	303	219	305	63

Figure 3. Klamath Lake water allocation for Iron Gate Dam flows, refuges, and agriculture in drought years of 1991, 1992, 1994, and 2001 (USBR).



	1991	1992	1994	2001
Iron Gate Flow	701	464	652	988
Refuges	103	83	99	66
Agriculture	344	429	268	63

Summary

The basis for the change in water allocation from historical practice was the opinion that increased flows past Iron Gate Dam and increased lake levels in Upper Klamath Lake would improve water quality and habitat for threatened and endangered species. This report has attempted to provide additional data related to water quality issues, particularly in relation to UKL.

Empirical data from UKL suggest water-quality improvements anticipated for high lake levels required by the Biological Opinion will not be realized. Data from the 1990s indicate high lake levels during fish kills in 1995–1997 were associated with massive late-season algal blooms and high ammonia levels. Limited data collected by Burleson Consulting in August 2001 indicated ammonia concentrations near Eagle Point and Ball point ranged from 0.4 to 1.3 at a lake elevation of about 4,140 ft (Nadia Burleson, personal communications). Ammonia concentrations were very low during years of relatively low late-season lake levels from 1991 to 1994.

Empirical data also indicates that maintenance of relatively high lake levels from 1996 to 2000 was not accompanied by reduced phosphorus, the driving force for algal blooms in UKL. Phosphorus concentration in UKL during summer months has been higher in 1996–2000 than during 1991–1995. Algal blooms have persisted into late summer in each year since 1996.

Increased flows past Iron Gate Dam may have a detrimental effect on water quality by diluting cool water from accretions below Keno Dam with warm and nutrient-rich water from UKL. Summer temperatures in excess of 70^0F are common in UKL. High volumes of water at this temperature below Iron Gate Dam may result in death of resident fish. In late August 1994, flows were increased from about 500 cfs to 900 cfs in an effort to encourage salmon to move into the river. A resulting fish kill of adult salmon in the Klamath River mainstem was documented.

Through September 2001, flows at Iron Gate Dam have been maintained at a minimum of 1,000 cfs. Releases from UKL account for about 70 percent of the flow. With high nutrient loads from June through late summer, UKL water is delivering more nutrients to the lower river than would be the case with lower flows and diversion of UKL water into the Project.

Documentation of the many effects of elimination of surface water supply to most of the Klamath Irrigation Project lands in 2001 will require long-term monitoring. A very important part of that will be to document water quality in UKL and at Iron Gate Dam. Similarly, any effects of the actions taken on listed species, including bald eagles, should be documented. State water resource agencies and the U.S. Geological Survey are monitoring groundwater development. Providing detailed accounting of the knowledge gained about groundwater hydrology will assist in planning future use of this resource. Timely availability of information developed to all stakeholders will be important.

Literature cited

Abney, R.M. 1964. A comparative study of past and present conditions of Tule Lake. Bureau of Sport Fisheries and Wildlife. Tule Lake NWR, Tulelake, CA.

Balance Hydrologics, Inc. 1996. Initial assessment of pre- and post-Klamath Project Hydrology on the Klamath River and impacts of the project on in-stream flows and fisheries habitat. 39 pp. and appendix.

Bidlake, W.R. 1997. Evapotransporation from selected wetlands at Klamath Forest and Lower Klamath National Wildlife refuges, Oregon and California. U.S. Geological Survey (prepared for U.S. Fish and Wildlife Service), Tacoma, WA. 19 pp.

Bidlake, W.R., and K.L. Payne. 1998. Evapotransporation from selected wetlands at Klamath Forest and Upper Klamath National Wildlife Refuges, Oregon. U.S. Geological Survey (prepared for U.S. Fish and Wildlife Service), Tacoma, WA. 21 pp.

Boyle, J.C. 1987. Fifty Years on the Klamath. J. Shaw Historical Library 1 (2), 13–43.

Climatological Data Oregon. National Oceanic and Atmospheric Administration, National Climatic Data Center, Department of Commerce, Asheville, NC.

Deas, Michael L., and G.T. Orlob. 1999. Klamath River modeling project. Center for Environmental and Water Resources Engineering, Department of Civil and Environmental Engineering, Water Resources Modeling Group. University of California, Davis. Sponsored by the U.S. Fish and Wildlife Service, Klamath Basin Fisheries Task Force, Davis, CA.

Dunsmoor, L., L. Basdekas, B. Wood, and B. Peck. 2000. Quantity, composition, and distribution of emergent vegetation along the Lower River and Upper Klamath Lake shorelines of the Williamson River Delta, Oregon. Completion Report. Klamath Tribes, Chiloquin, Oregon and U.S. Bureau of Reclamation, Klamath Basin Area Office, Klamath Falls, OR. 27 pp.

Falter, M.A., and J.J. Cech. 1991. Maximum pH tolerance of three Klamath Basin fishes. Copeia, 4:1109–1111.

Fremont, John Charles. 1845. Report of the exploring expedition to the Rocky Mountains in the year 1842 and to Oregon and north California in the years 1843–1844. House Executive Doc. 166, 28th Cong., 2nd Sess., 583 pp.

Gearheart, R.A., J.K. Anderson, M.G. Forbes, M. Osburn, and D. Oros. 1995. Watershed strategies for improving water quality in Upper Klamath Lake, Oregon. Humboldt State University, Arcata, CA.

Grover, Nathan C., H.D. McGlashan, and F.F. Henshaw. 1923. Surface water supply of the United States, 1919 and 1920, Part XI. Pacific Slope Basins in California. Water-Supply Paper 511. Department of Interior, U.S. Geological Survey, Washington, D.C. pp. 374–375.

Kaffka, S.R., T.X. LU, and H.L. Carlson. 1995. An assessment of the effects of agriculture on water quality in the Tulelake region of California. Research progress report 108. University of California, Intermountain Research and Extension Center, Tulelake, CA. 85 pp.

Kann, J. 1993a. Agency Lake limnology, 1990-1991. Pages 103-187 *In*: C. Campbell (Ed.) Environmental research in the Klamath Basin, Oregon—1991 Annual Report. U.S. Bureau of Reclamation technical report R-93-16, Denver, CO.

Kann, J. 1993b. Agency Lake limnology, 1992. Pages 91–137 *In*: C. Campbell (Ed.) Environmental research in the Klamath Basin, Oregon – 1992 Annual Report. U.S. Bureau of Reclamation technical report R-93-16, Denver, CO.

Kann, J. 2001a. Trend in Upper Klamath Lake total phosphorus concentration during spring (March–May), 1991–2000. Technical memo prepared for the Klamath Tribes Natural Resources Dept. Chiloquin, OR. 8 pp.

Kann, J. 2001b. Comparative water loss from wetland evapotranspiration in the Upper Klamath National Wildlife Refuge vs. expected regional open-water evaporation From lakes and reservoirs. Technical memo prepared for the Klamath Tribes Natural Resources Dept, Chiloquin, OR. 4 pp.

Kann, J., and V.H. Smith. 1993. Chlorophyll as a predictor of elevated pH in a hypereutrophic lake: Estimating the probability of exceeding critical values for fish success. Klamath Tribes Natural Resources Department Research Report: KT-93-02, Chiloquin, OR. 22 pp.

Kann, J., and V.H. Smith. 1999. Estimating the probability of exceeding critical pH values critical to fish population in a hypereutrophic lake. Can. J. Fish Aquat. Sci. 56:2262–2270.

Kann, J., and W.W. Walker. 1999. Nutrient and hydrologic loading to Upper Klamath Lake, Oregon, 1991–1998. Report submitted to Klamath Tribes, Chiloquin, Oregon and the U.S. Bureau of Reclamation, Klamath Falls, OR. 48 pp.

Klamath Tribes. 1995. Upper Klamath and Agency Lakes water quality assessment and inflow nutrient budget and endangered species restoration program support. Progress report. Natural Resources Department, Chiloquin, OR.

Lease, H.M. 2000. Histopathological changes in gills of Lost River suckers (*Deltistes luxatus*) exposed to elevated ammonia and elevated pH. MS thesis, University of Wyoming, Laramie, WY.

Martin, B.A., and M.K. Saiki. 1998. Effects of ambient water quality on the endangered Lost River sucker in Upper Klamath Lake, Oregon. MS thesis. Humboldt State University, Arcata, CA. 55 pp.

Meyer, J.S., H.M. Lease, and H.L. Bergman. 2000. Chronic toxicity of low dissolved oxygen concentrations, elevated pH, and elevated ammonia concentrations to Lost River suckers (*Deltistes luxatus*) and swimming performance of Lost River suckers at various temperatures. Research report. University of Wyoming, Department of Zoology, Laramie, WY. 56 pp.

Miller, W.E., and J.C. Tash. 1967. Interim Report. Upper Klamath Lake studies, Oregon. Water Pollution Control Series, Paper WP-20-8. Federal Water Pollution Control Administration, Pacific Northwest Laboratory, Corvallis, OR. 37 pp.

Perkins, D.L., J. Kann, and G.G. Scoppettone. 2000b. The role of poor water quality and fish kills in the decline of endangered Lost River and shortnose suckers in Upper Klamath Lake. Final report. U.S. Geological Survey, Biological Resources Division, Western Fisheries Research Center, Reno Field Station, Reno, NV.

Perkins, D.L., J. Kann, and G.G. Scoppettone. 2001. (Not referenced in the BO)

Reiser, D.W., M. Loftus, D. Chapman, E. Jeanes, and K. Oliver. 2001. Effects of water quality and lake level on the biology and habitat of selected fish species in Upper Klamath Lake. Prepared for Bureau of Indian Affairs.

Rykbost, K.A., and B.A. Charlton. 2000. Nutrient loading in the Klamath Irrigation Project. Pages 11–22 *In*: Research in the Klamath Basin, 1999 annual report. Special Report 1016. Agricultural Experiment Station, Oregon State University, Corvallis, OR.

Rykbost, K.A., B.A. Charlton, and R.L. Dovel. 1999. Nutrient loading in Klamath/Agency Lakes and background sources. Pages 9–21 *In*: Research in the Klamath Basin, 1998 annual report. Special Report 1007. Agricultural Experiment Station, Oregon State University, Corvallis, OR.

Rykbost, K.A., and B.A. Charlton. 2001a. Nutrient loading of surface waters in the Upper Klamath Basin: agricultural and natural sources. Special Report 1023. Agricultural Experiment Station, Oregon State University, Corvallis, OR 14 pp.

Rykbost, K.A., and B.A. Charlton. 2001b. Weather and Crop Summary, 2000. Pages 7–17 *In:* Research in the Klamath Basin, 2000 Annual Report. Special Report 1030. Agricultural Experiment Station, Oregon State University, Corvallis, OR.

Saiki, M.K., D.P. Monda, and B.L. Bellerud. 1999. Lethal levels of selected water quality variables to larval and juvenile Lost River and shortnose suckers. Environmental Pollution 105:37–44.

Smith, J.E., and K.A. Rykbost. 2001. Klamath Basin crop trends. Pages 1–6 *In:* Research in the Klamath Basin, 2000 Annual Report. Special Report 1030. Agricultural Experiment Station, Oregon State University, Corvallis, OR.

Snyder, D.T., and J.L. Morace. 1997. Nitrogen and phosphorus loading from drained wetlands adjacent to Upper Klamath and Agency Lakes, Oregon. Water Resources Investigation Report 97-4067. U.S. Department of Interior, Geological Survey, Portland OR. 67 pp.

Trihey and Associates, Inc. 1996. Instream flow requirements for tribal trust species in the Klamath River. 43 pp.

U.S. Army Corps of Engineers. 1982. Upper Klamath Lake, Oregon water resources development project (Potential eutrophication control measures for Upper Klamath Lake, Oregon: data evaluation and experimental design). Prepared by Entranco Engineers, Bellevue, Washington for U.S. Army Corps of Engineers, San Francisco District.

U.S. Bureau of Reclamation. 1941. (Not referenced in the BO).

U.S. Bureau of Reclamation. 1953. (Not referenced in the BO).

U.S. Bureau of Reclamation. 2000b. Klamath Irrigation Project sucker salvage and Langell Valley fish survey report—1998. Unpublished report. U.S. Bureau of Reclamation, Klamath Basin Area Office, Klamath Falls, OR.

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

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, OR.

U.S. Fish and Wildlife Service—Klamath Basin National Wildlife Refuges. 2001. National Wildlife Refuges 2001 water requirements. Agency report. Tulelake, CA.

U.S. Fish and Wildlife Service—Klamath Falls Fish and Wildlife Office. 2001. Biological/conference opinion regarding the effects of operation of the Bureau of Reclamation's Klamath Project on the endangered Lost River sucker (*Deltistes loxatus*), endangered shortnose sucker (*Chasmistes brevirostris*), threatened Bald Eagle (*Haliaeetus leucoephalus*), and proposed critical habitat for the Lost River/shortnose suckers. U.S. Department of Interior, Sacramento, CA. 295 pp.

Walker, W.W. 1995. A nutrient-balance model for Agency Lake, Oregon. U.S. Department of Interior, U.S. Bureau of Reclamation, Denver, CO.

Walker, W.W. 2001. Development of a phosphorus TMDL for Upper Klamath Lake, Oregon. Prepared for Oregon Department of Environmental Quality.

Welch, E.B., and T. Burke. 2001. Interim summary report: relationship between lake elevation and water quality in Upper Klamath Lake, Oregon. Prepared for the Bureau of Indian Affairs.

Draft
December 14, 2001

Instream Flows and Coho Salmon Habitat in the Lower Klamath River

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Introduction

The Klamath River Basin, from its headwaters in south central Oregon to its estuary by Requa, California, covers an area of approximately 9,691 square miles. For practical purposes, the Klamath Basin can be described as consisting of an upper and a lower section separated by a river reach with a series of four hydroelectric dams (Figure 1). The Upper Klamath Basin, upstream from Keno Dam, includes the sub-basins of the Williamson, Wood, Sprague, and Lost rivers; the Upper Klamath Lake, Tule Lake, Clear Lake, and Gerber Reservoir. The Lower Klamath Basin, downstream from Iron Gate Dam, comprises the tributary sub-basins of the Shasta, Scott, Salmon, and Trinity rivers, in addition to the lower sections of the Klamath River. This report, which assesses the possible effects of 2001 IGD water releases on coho salmon availability, focuses primarily on the Lower Klamath Basin because the distribution of anadromous salmonids (those that spawn and rear in freshwater, but complete their growth and maturation at sea) in this basin is restricted to the lower section by hydroelectric dams.

A review of the geology and hydrology of the Klamath River Basin suggests that during dry periods and before dam constructions, the upper basin was the principal source of water for the Lower Klamath River in late summer and early fall (Hecht and Kamman 1996). The upper and lower parts of the basin have different geomorphologies. The Upper Klamath Basin is characterized by volcanic basalts with numerous fractures and cavities that give the area a high water storage capacity; whereas the Lower Klamath Basin is rich in alluvial fans and lake clay sediments and has only a minor component of thin volcanic basalts. Snowmelts recharge the groundwater reservoirs of the upper basin on an annual cycle. Historically, these aquifers, in combination with Upper Klamath Lake, Lower Klamath Lake, and a vast network of wetlands, may have maintained relatively high and constant flows in the Lower Klamath River during late summer and early fall months (Boyle 1976; Hecht and Kamman 1996).

Many studies indicate that salmonid resources in the Klamath Basin have been negatively affected by the cumulative impacts of more than a century of different human activities. The most severe and irreversible impacts, however, seem to be those associated with the development of irrigation and hydroelectric projects that have eliminated access to hundreds of miles of fish habitat and have changed the annual hydrograph (i.e., graphical representation of water discharge over time) as well as the summer temperature regime of the Lower Klamath River (KRBFTF 1991; Trihey and Associates 1996; USFWS 1997; INSE 1999).

The following species of anadromous fish are found in the Klamath Basin: coho salmon (*Oncorhynchus kisutch*), chinook salmon (*O. tshawytscha*), steelhead trout (*O. mykiss*), coastal cutthroat trout (*O. clarkii*), green sturgeon (*Acipenser medirostris*), eulachon (*Thaleichthys pacificus*), and Pacific lamprey (*Lampetra tridentata*). Historically, chinook salmon (of both fall and spring types), coho salmon, and steelhead trout entered Klamath Lake. From Upper Klamath Lake, it is likely that spring chinook salmon and steelhead trout moved farther upstream into the uppermost tributaries of the basin (KRBFTF 1991; Deas and Orlob 1999).

Although all species of anadromous fish in the Klamath River are in serious decline, two salmonid species in particular—coho salmon and steelhead trout—have undergone status review by the National Marine Fisheries Service (NMFS) under the Endangered Species Act (ESA). As a result, coho salmon have been listed as threatened. The listing of this species, as well as that of the Lost River sucker and shortnose sucker in the upper part of the basin, has prompted the implementation of unprecedented water management actions by the Bureau of Reclamation (BOR) between April 1 and September 30, 2001. In the case of coho salmon, a formal ESA Section 7 consultation process was initiated on January 22, 2001, between the BOR and the NMFS. As a result, the NMFS issued a Biological Opinion (BO) that found "jeopardy and adverse modifications" of critical salmon habitat in the Lower Klamath River and provided a "Reasonable and Prudent Alternative" (RPA) that established an interim spring-fall IGD water-release schedule aimed at preventing further decline of the listed fish and adverse modifications to its habitat.

This chapter provides a general review of key aspects of coho salmon habitat, introduces the reader to different human impacts that affect salmonids and their habitat in the Klamath Basin, describes the status of salmonid stocks in the Pacific Northwest and in the Klamath Basin in particular, and explains the relationship between instream flows and fish habitat availability. Finally, the chapter reviews the most salient aspects of the RPA and elaborates on the potential effects of this year's water releases on coho salmon habitat in the Lower Klamath Basin.

Status of wild salmonids in the Pacific Northwest

The different species of salmonids comprise local populations, referred to as stocks, which are adapted to the specific environmental conditions of their watersheds of origin (Ricker 1972). In the particular case of anadromous populations, their tendency to spawn in their natal streams maintains a high level of reproductive isolation between them. This type of isolation allows for the development of watershed-specific adaptations (e.g., thermal tolerance and migration timing) at the population level and increases the genetic variability of the species (Thorpe et al. 1981). A high level of genetic variation among the populations of a species provides the basis for future evolution, and an "insurance" of adaptation to environmental change (White and Nekola 1992).

Many wild populations of anadromous salmonids (*Oncorhynchus* spp.) in western North America are currently at risk of becoming extinct, while others have declined from 50 percent to 85 percent of their average historic abundance (Nehlsen et al. 1991; Northcote and Burwash 1991; Slaney et al. 1996). A review by Weitkamp et al. (1995) of coho salmon status in California, Oregon, and Washington identified six different population groups (i.e., Evolutionary Significant Units—ESUs) and indicated that wild populations in all ESUs are significantly below historical levels. In southern Oregon, Nehlsen et al. (1991) considered all but one coho salmon population to be at "high risk of extinction." In northern California, coho salmon populations, including hatchery fish, could be at 6 percent of the abundance they had during the 1940s. They have been eliminated in many streams, and in some watersheds, adults are observed only one year in three (CDFG 1994). In other words, two of the three spawner lines have been lost.

It is obvious that the anadromous salmonid populations of the Klamath Basin are not the only ones in the Pacific Northwest that face a bleak future. Such widespread declines cannot be attributed to one single land development project, nor even to one natural factor. However, it is worth noting that although several hypotheses have been advanced to explain these declines (e.g., overfishing, freshwater habitat loss, interactions with hatchery fish, and ocean habitat changes), freshwater habitat loss has been associated with the decline of every one of the 214 salmonid stocks that Nehlsen et al. (1991) identified as either facing high to moderate risk of extinction or being of special concern. These researchers recognized different factors that had a negative impact on wild stocks, but concluded that freshwater habitat degradation and loss were among the leading causes of their decline. Even though there may be some stocks that are primarily affected by a single factor, in light of the available evidence it is reasonable to conclude that a combination of all the above-mentioned factors, with their relative importance varying from year to year, is behind the widespread decline in salmonid abundance.

The abundance and distribution pattern of animals is determined by the availability and spatial distribution of resources (Milinski and Parker 1991). The uneven distribution of resources, in both space and time, creates patches of better or poorer "habitat" among which individual organisms distribute themselves. Habitat can be defined simply as the “place” where an organism lives and the range of environmental conditions (both physical and biological) it requires to live, grow, and reproduce (Odum 1971). The spatial scale of an organism’s habitat is not fixed; rather, it is determined by the range of action (home range) of that organism. Thus, the habitat of a large or relatively mobile organism (i.e., birds) is large and contains within its physical boundaries the smaller-scale habitats of smaller, or less mobile, organisms. This kind of organization implies a hierarchy of habitats that are nested in space. A river represents a particularly good system to further illustrate this point. The entire watershed makes up the environment of smaller-scale subsystems, such as stream sections, which in turn constitute the environment of habitat systems at even smaller scales, such as stream reaches. Each stream reach is made up of smaller components, pools, and riffles, and these habitats contain patches or microhabitats of different types (Frissell et al. 1986). Habitat components, at different spatial scales, are all interconnected by the flowing water and receive the cumulative effects of upstream human activities and natural landscape level processes. Such cumulative effects may reduce or eliminate fish habitat in large river channels, small stream reaches, marshes, and even estuaries (Henderson 1991; Turner and Meyer 1993; Williams 1993).

Habitat degradation and loss are side effects of different types of human activities. The initial changes to the aquatic components of a watershed begin with the early alterations that humans introduce to its terrestrial components. Mining and logging have historically preceded a number of other land-use activities in coastal watersheds of the Pacific Northwest. These “extraction operations” indirectly affected stream morphology and hydrology by modifying the soil and its vegetation cover. They also have directly altered stream channels and their substrates through practices such as moving heavy machinery and skidding logs across channels and building—and subsequently blasting—“splash dams” to float and transport the logs downstream. The expansion of agriculture into river valleys and the encroachment of grazing into riparian zones have altered the connectivity of stream channels with their floodplains. In California and Oregon, hydroelectric projects have been particularly common. Dams created impassible barriers to fish migration, and the regulation of flows altered the structure of channels and the hydrology of rivers. More recently, urban sprawl has begun to cover, in an irreversible manner, ever-larger portions of coastal watersheds (Gregory and Bisson 1997).

To understand how land-use activities such as agriculture, dam construction, mining, logging, or urban development may affect fish production, it is necessary to know the habitat requirements of the different species and to identify the general environmental changes brought about by human activities in each watershed. Because juveniles of different salmonid species have specific nursery habitat requirements and different lengths of freshwater residence, they are not equally susceptible to all development activities. As an example, in British Columbia, land uses have harmed some sockeye salmon (*O. nerka*) stocks at two different stages of their life cycle. During the egg incubation phase, they may be negatively affected by the silt deposition and gravel displacement that inadequate mining and timber harvest practices may cause; during the juvenile migration period, they may be prevented from entering lake nursery habitat by newly built dams (Nehlsen et al. 1991). Chum salmon (*O. keta*) have been largely affected by degraded water quality and siltation of spawning bed gravel in many watersheds (Nehlsen et al. 1991). In the case of coho salmon, their relatively long period of residence in freshwater makes this species particularly susceptible to habitat alterations caused by human activities (Hicks et al. 1991; Henderson 1991).

Coho salmon habitat requirements

Coho salmon are anadromous salmonids that typically exhibit a 3-year life cycle almost equally divided between the freshwater and the sea phase (Sandercock 1991). Although in some populations coho salmon fry inhabit lakes, where they are found in the littoral zone (i.e., near the shore) (Mason 1974), the majority prefer small coastal streams and relatively small tributaries of larger systems (such as the Shasta and Salmon rivers within the Klamath Basin). Shortly after emergence from the gravel, juvenile coho salmon establish feeding territories that they will defend from other salmonids. They tend to be more territorial in stream reaches with fast-flowing waters, whereas in slow-flowing areas it is common to find them forming loose aggregates and cruising for food (Mundie 1969).

Individuals that "take residence" normally occupy a small space with slow-moving waters, from which they make short excursions to feed or to chase intruders away. Subordinate fish, which are not able to establish a territory, tend to be less aggressive than dominant individuals and have a reduced growth rate due to their lack of access to good feeding areas (Chapman 1962). In general, the young of this species prefer zones with reduced water velocity, favor pools over other types of habitat, and use instream structures as protection from high water flows. In this manner they may minimize their energy expenditures to maintain position while feeding on drifting prey (Mundie 1969; Everest and Chapman 1972; Fausch 1993). Coho are visual predators and seldom feed from the bottom. They prefer to capture invertebrates that drift either suspended in the water column or on the surface (Nielsen 1992). In addition to providing prey items and shelter from water velocity, instream and riparian cover provides other benefits. Low-hanging overhead cover such as undercut banks and root wads may decrease the amount of light reaching the water surface, thereby making fish less visible to potential predators and minimizing stream temperature extremes (Murphy and Hall 1981). Instream cover also can provide refuge from predators and simultaneously increase visual isolation among competitors. Visual isolation may reduce aggressive interactions among competitors, and therefore could lead to an increase in the number of fish occupying a given area (Dolloff 1986; Fausch 1993).

As is the case for other salmonids, coho salmon prefer cool and well-oxygenated waters. The upper lethal temperature for juvenile coho is 25ºC (Sandercock 1991). Brett (1952) found that exposure to temperatures in excess of 25ºC or a quick rise in temperature from less than 20ºC to 25ºC resulted in a high mortality rate. Brett also observed that coho preferred a temperature range of 12ºC to 14ºC, which is close to the optimum temperature for maximum growth efficiency. In autumn, as water temperatures decline and flows increase, juvenile coho salmon redistribute either into deeper pools, smaller tributaries, or lateral channels where cover provided by fallen logs or root wads is abundant (Bustard and Narver 1975; Cederholm and Scarlett 1982; McMahon and Hartman 1989; Nickelson et al. 1992).

Fish habitat and instream flows

Nothing defines fish habitat better than water. The quality and the quantity of this indispensable fish "habitat component" determines whether fish can actually live in a particular aquatic habitat, what species of fish can use it, and how many individuals can occupy it. Salmonids can live only in water with chemical (i.e., oxygen concentration and pH) and physical (i.e., temperature) characteristics that are within their relatively narrow range of tolerance. Water quality requirements for salmon have been well established by a large number of physiological studies (Bjornn and Reiser 1991; Groot and Margolis 1991). However, water quantity requirements, particularly for stream-dwelling fish, have been more difficult to determine.

Some of the most common tests of the flow/fish relationship took the form of a series of analyses of correlations between fish abundance (e.g., density or number of fish per unit of area) and various physical and chemical characteristics of the stream flow regime (Binns and Eiserman 1979). Despite regional and watershed specific differences, several studies have identified consistently the same set of variables as very important in controlling fish abundance. These variables are water velocity, minimum water column depth, instream cover, substrate composition, water temperature, dissolved oxygen, alkalinity, and turbidity (Gosse and Helm 1981; Shirvell and Dungey 1983). The fact that almost all these variables are influenced by instream flows in a direct or indirect manner explains why water flows can have such a strong controlling effect on fish numbers.

Water velocity and water column depth affect upstream fish migration.The faster the velocity of water, the harder it is for fish to migrate upstream (although fish may take advantage of turbulent flows and eddies to be assisted in their upriver migration); and the deeper the water column, the more likely it is fish will save energy by traveling trough deep and relatively colder waters. For a series of techniques to estimate stream discharges that provide suitable depths and velocities for upstream passage of adult salmonids, see Thompson (1972). The amount of spawning habitat in a stream also is regulated by flows. D.H. Fry (cited in Bjornn and Reiser 1991, p. 89) explains that "as flow increases, more and more gravel is covered and becomes available for spawning. As flows continue to increase, velocities in some places become too high for spawning, thus canceling out the benefit of increases in usable spawning area near the edges of the stream. Eventually, as flows increase, the losses begin to outweigh the gains, and the actual spawning capacity of the stream starts to decrease. If spawning area is plotted against streamflow, the curve will usually show a rise to a relatively wide plateau followed by a gradual decline." Egg incubation is affected by the amount and velocity of the water circulating among the gravel particles and eggs. This, in turn, may increase or decrease with the depth and the quantity of the surface water (Wickett 1954).

Seeding rate (abundance of spawners) is the primary factor regulating the abundance of juvenile salmonids present in a stream. Because numbers of anadromous spawners are determined in part by their ocean survival, their numbers do not necessarily show a direct relationship with instream flows in their natal streams. That said, it is worth noting that Smoker (1955) found a correlation between the commercial catch of coho salmon and annual runoff, summer flow, and lowest monthly flow in 21 western Washington basins 2 years prior. Smoler's data were for the 1935–-54 period, but in the last decades of the 20th century, hatchery production of coho salmon smolts increased to the point that such comparisons are no longer possible in most systems. However, Mathews and Olson (1980) analyzed data from Washington for the 1952–77 period and found that summer instream flows still had an important influence on total coho salmon production in Puget Sound area streams.

Given a certain level of seeding, there are several environmental factors that control the abundance of fry. In turn, smolt production in streams and rivers also is affected by flows. Factors such as the amount of suitable habitat, quality of cover, and productivity of the stream set an upper limit (i.e., carrying capacity) on the abundance of juvenile fish, and the population is held at that level by density-dependent interactions (i.e., competition and some types of predation). Carrying capacity, and hence fish abundance, may vary yearly if controlling habitat components, such as instream flow, changes from year to year at critical periods such as late summer (Bjorn and Reiser 1991).

The amount of suitable habitat to be occupied by salmonids in streams is a function of instream flows, channel morphology, gradient, and in some cases instream or riparian cover availability. Suitable habitat for each salmonid life stage has water of sufficient depth and quality flowing at appropriate velocities. The addition of cover increases the complexity of the habitat and usually the carrying capacity of the stream reach. Diversion of water from streams and/or impoundments leads to altered instream flows and potential changes in the carrying capacity of streams for salmonids. The relationship between flow and carrying capacity varies with channel geometry and even valley form (e.g., it differs between a channel dominated by riffle habitat within a narrow canyon and a channel with many pools in a broad valley). In general, the relationship must start at the origin (no flow, no fish), increase (not necessarily in a uniform manner) with flow increases up to a point, and then level off or even decline if flows become excessive. The existence of this relationship has been empirically demonstrated (see Kraft 1972; Stalnaker 1979; White et al. 1981) and is not in dispute; what remains to be defined is the nature of the relationship (or the shape of the curve representing this relationship) between flow levels and fish abundance. Because the relationship is not a linear one and it varies with channel structure and the fish species under consideration, its theoretical formulation has been the goal of many models.

The complex dynamics of river systems, combined with the diverse repertoire of adaptive behaviors salmonids are able to display, limit the predictive capability of any model, and instream flow quantification methodologies are not an exception to this. Nevertheless, such methodologies constitute broadly applicable and useful tools to establish the minimum flows needed in a stream channel to ensure that a given proportion of habitat is available to fish during low-flow periods. However, since pre-determined instream flows are not compatible with the emerging emphasis on ecosystem-based management, these methodologies can be more effective at protecting aquatic resources if used within the context of watershed-scale adaptive management programs.

Instream flow quantification methodologies are classified into two general categories: standard setting, and incremental methodologies. Standard setting methodologies are techniques used to determine the minimum flow needed to protect certain habitat types of interest for the benefit of fish and other aquatic life. The application of these methods usually results in a minimum flow value for a specified stream reach, below which water may not be withdrawn for consumptive use. The minimum or "threshold" flow is almost always less than the historical level and, therefore, reduces the current amount of available habitat; yet these methods are used in many states. Standard-setting methods can be further divided into non-field (e.g., Tennant Method) and field (R2CROSS) types (Espegren 1998).

The Tennant Method is a non-field technique used for setting "target" percentages of mean annual discharge that are expected to "protect" specified amounts of aquatic habitat (Tennant 1976). This method was developed for fish-bearing stream sections and has become popular because it is a quick, cheap, easy, and objective approach that can be readily applied to both recorded flows and estimated mean annual discharges. The Tennant Method has been commonly used in the U.S. since 1976 (second only to the more popular Instream Flow Incremental Methodology or IFIM) and many regulatory agencies still consider it a useful, albeit coarse, tool that can be used to set instream flow appropriations over a large number of streams in a short period of time and at a relatively low cost. However, because it is a non-field method, many managers and scientists consider that it should not be used as the sole basis for developing instream flow recommendations (Castleberry et al. 1996). In fact, Tennant (1976) indicates that field verification of this method is necessary to establish what are appropriate "target" flow levels.

Incremental methodologies, such as the Instream Flow Incremental Methodology (IFIM), combine hydraulic data with biological information on selected aquatic organisms to assess habitat alteration relative to incremental changes in flow. They help evaluate a series of possible alternative development scenarios and their effect on aquatic species (Stalnaker 1993). These methods were developed from habitat versus flow functions that take into consideration life-stage-specific relations for target species (i.e., fish migration, spawning and nursery habitat availability versus flow). They are field-based techniques often used to evaluate the impacts of hydroelectric projects and to develop conditions for water licenses and permits on very controversial stream segments with high water-development potential. Incremental methodologies simulate the quantity and quality of potential habitat resulting from proposed water development, illustrated for a series of alternative flow regimes (Trihey and Stalnaker 1985). Their downside, from the perspective of the stream ecosystem, is that they do not define flow targets in terms of the natural variability of the hydrograph, paying little attention to the importance of dynamic flow changes in maintaining the river ecosystem structure and function. They focus only on the most "valued" species and the most vulnerable life stages of that species, which involves a subjective value judgment. This is a particularly important issue if we are to begin thinking of stream flow management as part of a larger program of ecosystem management.

Human activities in the Klamath Basin

The Klamath Basin has a long history of human activities that have altered its hydrology and, as a result, the availability and quality of fish habitat in the system. Commercial harvesting of timber in the Lower Klamath Basin started in the late 1800s, concurrent with the development of a commercial fishery in the river estuary and surrounding coastal waters (KRBFTF 1991). Mining, primarily for gold, was a very common activity, particularly in the middle reaches of the Klamath River. The cultivation of crops and the raising of cattle began in the 1850s. The hydrology of most of the Klamath Basin was altered drastically by the development of many water-diversion projects. Although mining was the first activity that diverted water from the river, irrigation diversions for agriculture has been, and still is, a very common practice, not only in the upper basin but also in some lower tributaries to the Klamath River like the Shasta, Scott, and Trinity rivers.

Mining

Gold mining had its own impact on the aquatic environment of the Klamath Basin. In the 1800s, it was carried out primarily by means of suction dredging and placer mining—two methods that disrupt stream substrates and negatively impact fish spawning beds, food production, and nursery habitats (Bjornn et al. 1977; Hassler et al. 1986). Other types of mining, such as tunnel mining for gold, copper, and chromite, have been intermittent in different parts of the basin during the past 100 years, and instream gravel mining has been a more sporadic activity (KRBFTF 1991).

Forestry

Gold mining used large amounts of timber, and this demand made possible the establishment of many lumber mills in the central part of the Klamath Basin (Wells 1881). Timber harvest increased with the arrival of the railroad in 1887 to Yreka (California), and experienced extraordinary growth after World War II. Because of this, log rafting, road construction, skid trail construction, earth removal, and other related practices increased to the point of presenting a threat to fish life in the Klamath River, and "corrective actions" were ordered by the California Legislature in 1957 (KBRFTF 1991).

Agricultur*e*

While forestry has been the predominant type of land use in the lower basin, agriculture and ranching have flourished in the fertile valleys and hillside grasslands of the Upper Klamath Basin as well as in the floodplains of tributaries such as the Shasta and Scott rivers. Land clearing to provide for much-sought-after farm and ranchland modified the vegetation of entire valleys, with native trees and perennial grasses being replaced by crops and junipers, brushes, and forbs (USSCS 1983; KRBFTF 1991).

As farmland became more valuable, flood control measures became increasingly common , and as a result riparian vegetation was removed from entire river reaches, stream channels were straightened, and dikes were built along stream banks. Flooding was not the only problem, however, and by the mid 1900s pressure to conserve soil and water resources prompted farmers and ranchers in various valleys to organize soil conservation districts (KRBFTF 1991).

Water diversions

The U.S. Bureau of Reclamation began the construction of the Upper Klamath Irrigation Project, near Klamath Falls, Oregon, in 1905. Marshes, Lower Klamath Lake, and most of Tule Lake were drained and a complex network of levees, dikes, pumping stations, and channels were developed to divert water from the Upper Klamath Lake and Klamath River to irrigate ~220,000 acres of agricultural land (i.e., the Project). The main water-diversion facilities that were built on the Klamath River immediately downstream from Upper Klamath Lake include the A Canal (1906–1907), the Lost River Diversion Dam (1912), the Link River Dam (1921), and Keno Dam (1967) (see Rykbost's chapter in this report for a detailed description of the water-diversion system in the Upper Klamath Basin). The network of irrigation channels was designed to re-route water from the lake through farmland and return the unused water volume back to the river. The Project's operation becomes more water-intensive during very dry years due to the requirements of agricultural crops. Hence, during dry years the quantity and quality of water returned to the Lower Klamath River becomes more dependent upon the Project's operations than in years when rainfall and snow pack are at normal or high levels. Project water requirements, in combination with the series of dams that were built in the Klamath River for the production of electricity, reduce summer flows, increase nutrient load, and alter water temperature in the river. This seems to affect the quantity and quality of fish habitat downstream from IGD during summer and early fall, especially during dry years (KRBFTF 1991; USGS 1995; Deas and Orlob 1999).

Hydroelectric projects

During the late 1800s, small, water-impounding dams supplied the water needed for mining and farming operations. However, these small projects did not represent a permanent barrier to fish migration because they were often washed out during floods. It was not until 1892 that the first large dam was built; it was part of the hydroelectric power plant project on the Shasta River. Since then, the California Oregon Power Company (COPCO) identified numerous potential dam sites in the Klamath River, but because the proposed projects were not always feasible based on hydroelectric power production alone, whenever possible the company tried to develop irrigation supply benefits as well (Boyle 1976; KRBFTF 1991).

The KRBFTF (1991) report shows that COPCO's Klamath River flow records started in May 1910, before the construction of any of the dams. These flows were measured on a daily basis at Ward's Bridge and reached a maximum level of 4,500 cfs and a minimum of 1,450 cfs. Over time, these records revealed a change in the river flow regime from a relatively uniform flow to one with lower flows in the summer and higher flows in early spring. Boyle (1976) and the USGS (1995) have attributed the relative uniformity in the river's flow to the moderating influence of the large and shallow Upper and Lower Klamath lakes in the headwaters of the basin. The Klamath Irrigation Project, located in the lower portion of the Upper Klamath Basin, has been considered the cause of the observed changes in the river's flow regime. These hydrological changes apparently became more accentuated as the Bureau of Reclamation's irrigation projects progressed (Boyle 1976) and COPCO moved ahead with its plans to build a series of hydroelectric dams (KRBFTF 1991).

The first large dam on the mainstem of the Klamath River was Copco 1, which was completed in 1917 in the Ward's Canyon area, northeast of the town of Yreka, California. Copco 1 created a reservoir with a holding capacity of 77,000 acre-feet of water. This hydroelectric project created the first impassable barrier to the migration of anadromous salmonids to the Upper Klamath Basin (Snyder 1931). In 1925, Copco 2 was completed immediately downstream from Copco 1 (Boyle 1976). Because no minimum flows were required for the operation of these dams, their water releases fluctuated from 200 cfs to 3,200 cfs in response to peak power demands and regulatory capacity. Such changes in flow made the water level in the river rise or drop several feet within a 20-minute period (Jones and Stokes 1976, KRBFTF 1991, Deas and Orlob 1999). These extreme and frequent changes in flow had very negative impacts on fish habitat and fish production in the Lower Klamath Basin (Snyder 1931; Jones and Stokes 1976). In 1947, the proposed "solution" to this problem was the construction of a re-regulating dam below Copco 2 that would eliminate the daily peaks of water discharge. It took 13 years for the construction of this dam to begin. Water users in the upper basin were concerned about the allocation of water and opposed COPCO's plans for more dams. It was not until the Federal Power Commission (FPC) approved COPCO's Big Bend hydropower project, and commanded the extension of its contract with the Bureau of Reclamation, that upper-basin water rights were dealt with in a manner that allowed plans for the construction of a flow-regulating dam to proceed (KBRFTF 1991). In 1958, the FPC granted approval for the construction of Big Bend dam and power plant (now known as J.C. Boyle) upstream of Copco 1, on the Oregon side of the interstate border. By then, COPCO had reached an agreement with the California Department of Fish and Game regarding flow-release regimes, and thus obtained the state water rights and the license from the FPC to build the recommended flow-stabilizing dam downstream from Copco 2 (Jones and Stokes 1976). The construction of IGD began in 1960 and it was completed by 1962. IGD is located 7 miles below Copco 2 and its reservoir has a capacity of 58,000 acre-feet of water. It now marks the limit to upstream fish migration in the Klamath River.

Main tributaries of the Lower Klamath River

In addition to the Lower Klamath River mainstem, salmonids are known to utilize spawning and nursery habitats in its many tributaries. The largest tributary systems, such as the Shasta, Scott, Salmon, and Trinity sub-basins, may influence the Lower Klamath River mainstem's water volume and quality and, therefore, its salmonid carrying capacity (KRBFTF 1991).

The confluence of the Shasta River with the Lower Klamath River is located approximately 14 miles downstream from IGD, at mile 176 of the river's mainstem. The Shasta River Sub-basin covers an area of approximately 340 square miles. It contains an estimated 50,000 acres of agricultural land under active irrigation, which in 1988, as an example, used 150,500 acre feet of water (KRBFTF 1991; Siskiyou County Farm Bureau 2001). Like the upper part of the Klamath Basin, the Shasta Valley receives very little rainfall (between 11 and 17 inches per year), and groundwater within this system is recharged via melting snow and stored in porous volcanic rocks. Stream flows and agricultural uses within the Shasta River sub-basin are dependent upon inputs from springs and subsurface flows.

In 1928, Dwinnell Dam was built on the upper Shasta River to hold irrigation water for the Montague Water Conservation District. Thus, Lake Shastina, with its maximum water-storage capacity of 41,300 acre-feet, was created. Dwinnell Dam not only prevents anadromous salmonids from using the upper reaches of this system but is reported to prevent the recruitment of new gravel and have negative effects on the quality of the water in the river below. Water in Lake Shastina heats up during the summer months and is enriched with nutrients derived from agricultural and urban-related activities. The release of this water into the Shasta River below the dam decreases its dissolved oxygen concentration and increases its temperature, thus further reducing the availability of good-quality salmonid habitat in this sub-basin during the summer months. (Dong et al. 1974; KRBFTF 1991).

The Scott River enters the Lower Klamath River at mile 143, or 47 miles downstream of IGD. The Scott River Resource Conservation District (RCD) is 1,176,160 acres in size, with 294,160 privately owned acres and 882,000 acres of public land (CARCD 2000). In this region, flat and fertile valleys have been used since the early 1900s for crop production, grazing, and urban development. Estimates of water use within the Scott River Valley in 1988 show that 96,400 acre-feet of water were delivered via 200 diversions along 240 miles of ditches and pipelines to 34,100 acres of crop and pasture lands. The amount of irrigated land in the valley was reported to have changed very little between 1958 and 1991 (Siskiyou County Farm Bureau 2001). Although large and permanent dams were never built on the Scott River, summer nursery habitat for salmonids has still been affected by human activities. As early as 1974, fish habitat-related problems were documented in many reaches of this river that were either totally dry or running in an intermittent manner during July, August, and part of September (CDFG 1974).

The Salmon River sub-basin, which drains into the Lower Klamath River near mile 68, is the only one of the major sub-basins within the Lower Klamath Basin that is not affected by water diversion projects. A large proportion of this catchment area is under National Wilderness designation and is covered by forests. Therefore, fire, road construction, and timber harvest have been the main types of disturbances that have affected the system during the past century (USFWS 1994). In 1977, fires burned 56,000 acres of forest in this sub-basin, and some 450 million board feet of wood were reported salvaged during the subsequent 5 years. Another 78,128 acres of forest were burnt in 1987 (KRBFTF 1991). Numerous landslides and high sediment loads have negatively affected spawning gravel and invertebrate production in the river. USFWS (1994) assessments of habitat attributes, however, indicate that the relatively low quality of the spawning habitat may have only minor negative implications for salmon production in this sub-basin. The main limiting factor is the elevated summer water temperature, which is high enough to reduce the survival of juvenile salmonids (USFWS 1994).

The Trinity River sub-basin is the largest and most complex of all sub-basins and joins the Lower Klamath River at mile 43. During the first half of past century, the Trinity River was characterized by a dynamic and meandering channel that moved back and forth across its relatively broad floodplain over time (USFWS 1999). This sub-basin sustained large chinook salmon, coho salmon, and steelhead runs until the construction of the Trinity and the Lewiston dams (a.k.a. Central Valley Project's Trinity River Division or TRD) in the early 1960s. This project not only prevented fish access to 109 miles of spawning and nursery habitat above Lewiston, California, but it diverted between 80 and 90 percent of the annual flow of the upper portion of this river into the Sacramento River Basin. This resulted in drastic changes in the flows of the Trinity River, which affected its channel morphology, its substrate composition, and the characteristics of both its flood plain and riparian areas. The original channel structure included an alternating sequence of gravel-rich riffles and deep pools that provided good salmonid habitat. In the absence of high flow events after dam construction and operation, the channel structure changed to a continuous and uniform "run" or glide type of habitat that became confined, over time, by riparian berms (KRBFTF 1991; USFWS 1999; USDI 2000). The changes in the Trinity River had a strong and negative effect on the sub-populations of salmonids that relied upon it. Despite hatchery supplementation, fish abundance in the Trinity River has been reduced between 53percent (steelhead) and 96percent (coho salmon) after the construction and operation of the TRD Project began (USFWS 1999; USDI 2000). After a lengthy review and decision-making process, the Department of Interior ordered the TRD Project to put into practice a "preferred alternative" that included the augmentation of variable annual instream flow releases from Lewiston Dam, a coarse sediment introduction plan, the construction and rehabilitation of 47 channels, and the implementation of adaptive management and watershed restoration programs (USDI 2000). It is estimated that trans-basin water exports from the Trinity into the Sacramento River will be curtailed by 52percent because of this decision (Ahern 2000).

In addition to the four sub-basins described above, smaller scale water diversion projects for land irrigation have been built in several minor direct tributaries of the Lower Klamath Basin. The affected creeks are: Grider Creek, Cottonwood Creek, Horse Creek, Bogus Creek, Little Bogus Creek, and Willow Creek (KRBFTF 1991).

Status of Klamath Basin coho salmon

According to the BO (NMFS 1991), the Southern Oregon/Northern California Coast coho salmon Evolutionary Significant Unit (SONCC ESU) "was listed as threatened under the ESA on May 6, 1997. This ESU includes coho salmon populations between Cape Blanco, Oregon, and Punta Gorda, California." The listing of these stocks was the response of NMFS to abrupt declines in their abundance, in particular during the past decade. The designation of "critical habitat" (i.e., waterways, substrate, and riparian zones below naturally impassable historical barriers) for the stocks within the above-mentioned ESU followed in May of 1999.

Historically, the Klamath River Basin was well known for its large chinook salmon runs. Its coho salmon populations were relatively large, but never as abundant as in some of the large basins north of Cape Blanco, such as the Columbia River or the Fraser River (Weitkamp et al. 1995). Over time, however, coho salmon stocks have been greatly reduced and now are formed largely by hatchery-produced fish. Small, wild runs of coho salmon still remain in the basin (CDFG 1994). Out of a total of 396 streams within this ESU that once had coho salmon runs, Brown et al. (1994) found recent survey information for 115 (30 percent) of them. Seventy-three (64 percent) of these streams still supported coho salmon, while 42 (36percent) did not. The streams identified as lacking coho salmon runs were all tributaries of the Klamath and Eel rivers (Brown et al. 1994; Weitkamp 1995).

Estimates from 1994 data for the SONCC ESU in the Klamath Basin assess the average spawning coho salmon population at 7,080 wild fish and 17,156 hatchery fish. Combined with Rogue River estimates, spawning adult coho salmon are estimated to be 10,000 wild fish and 20,000 hatchery fish (PFMC 1999).

Because fish sampling in the Klamath River has focused on economically important salmon runs (i.e., fall chinook salmon), data on wild coho spawners (i.e., escapement estimates) have not been collected on a regular basis. Unfortunately, fish-counting weirs are removed from the river after the fall chinook salmon migration is over and before flows reach high levels. The migration of adult coho salmon typically peaks during these periods of high water discharge; therefore, the spawning counts of this species based on the operation of fall chinook sampling devices capture only the earliest coho salmon that enter the system. High flows during the period that coho usually migrate upstream make the use of fish-counting weirs impractical and often dangerous. In a similar manner, juvenile trapping efforts in this basin also have focused on chinook salmon smolts and have provided relatively poor estimates of coho salmon smolt output.

Notwithstanding these technical difficulties, the California Department of Fish and Game has estimated that total coho salmon runs are less than 6percent of what they were in the 1940s (CDFG 1994); this estimate is within the range reported by other sources that already identified Klamath River coho salmon as of special concern a decade ago (Nehlsen at al. 1991).

Fish-counting weir data for the Shasta and Scott rivers show similar declines in the abundance of coho salmon spawners during the last 30 years. Shasta River fish counts, during years when trapping started and ended at equivalent times, show an average escapement (i.e., number of spawners that return to their natal stream) of 217 coho salmon in the 1970s and only 7 in the 1990s. Between 1991 and 2000, coho salmon counts ranged from 0 to 24 fish, with 1 or 0 fish counted during four of these years (CDFG unpublished data). Counting weirs in the Scott River indicated an equivalent trend with an annual average count of 25 coho salmon (range = 5 to 37) between 1982 and 1986, and an average of 4 fish (range = 0 to 24) between 1991 and 1999. Again, within the past decade, one single year accounted for most of the fish observed, whereas no coho salmon were counted during four of those years (CDFG unpublished data). These data emphasize the importance that one year's spawning success can have on the survival of these coho salmon stocks.

Smolt data also suggest that Klamath Basin coho salmon stocks are in trouble. Juvenile traps, operated on the river's mainstem, were used to estimate indices of smolt production. Based on counts from these traps between 1991 and 2000, the annual average number of wild coho salmon smolts was estimated at only 548 individuals (range = 137 to 1268 individuals) (USFWS 2000). For the same period, an average output of 2,975 wild coho salmon smolts (range = 565 to 5,084 individuals) was estimated for Willow Creek, within the Trinity River sub-basin (USFWS 2000). The incomplete trapping record provides limited information in terms of temporal trends, but it still is a useful indicator of the extremely small size of coho salmon populations in the Klamath Basin. Furthermore, the presence of young-of-the-year coho salmon in these smolt traps helps to shed some light on how the young fish are distributed within the system during their period of freshwater residence.

Although, coho salmon show a strong preference for small streams over mainstem river habitat, some fry may end up being displaced into mainstem and even estuarine habitat if fish densities are too high or stream habitat is somehow limited (Sandercock 1991). In the spring, shortly after emerging from the gravel, coho fry distribute themselves throughout their natal stream reach and establish feeding territories that are aggressively defended from any intruders. As late emerging fry try to establish their own feeding "posts," they find that most of the nearby good nursery habitat already has been claimed by the early emerging individuals, which had the opportunity to start feeding earlier and, consequently, grow bigger and become successful at defending their territories. The territorial behavior of the young coho salmon tends to force them to move in search of vacant nursery habitat (Chapman 1962). Although some fry move upstream, the vast majority move downstream. Thus, many individuals end up in the river's mainstem and even in the estuary where they are not likely to survive (Sandercock 1991).

A 1997 USFWS report and the 2001 mainstem trap data (CDFG unpublished data) show that young-of-the-year coho salmon are emigrating from the Shasta and Scott rivers, where they probably were spawned, into the mainstem of the Lower Klamath River between March and August. Considering the low numbers of coho salmon fry that have been reported for these sub-basins, it is unlikely that these fish were displaced downstream because of competitive interactions with other juveniles of their own species. Instead, the most likely explanation for their summer movement is that declining water quality and quantity in the lower-order tributaries force these young fish to seek refuge elsewhere. Thus, they end up in the river's mainstem earlier than in other river systems. This exploratory behavior and movement in search of adequate nursery habitat has been well documented, especially before the onset of winter (Sandercock 1991).

Lower Klamath River instream flows

All Klamath River Basin hydrological studies that we had access to (USGS 1995; Hecht and Kamman 1996; Trihey and Associates 1996; INSE 1999) conclude that human activities have altered flows in the Lower Klamath River. However, the nature of these changes and their precise magnitude is somewhat ambiguous and, consequently, their effects on salmonid habitat availability and fish abundance remains contentious, to say the least.

A USGS (1995) study characterized the baseline flow regime for the Klamath River Basin. Baseline flows in this case meant historical flow conditions that provide a basis for comparison of past flow conditions to contemporary and possible future alternative water management scenarios. This study did not identify any significant changes in annual water discharge at Keno Dam (on the Klamath River, upstream from hydroelectric dams) between 1914 and 1960 that could be attributed to human intervention in the flow regime. However, the analysis of monthly flows showed a discernible seasonal change in water discharge both below IGD and in the Scott River after 1960. Lower Klamath River flows below IGD have become higher in February and lower between June and September than in previous decades. Evaluations of seasonal trends in flow for the Scott River near Fort Jones also show a reduction in flow between July and August after 1960. Such changes in flow could be attributed to changes in crop patterns, irrigation techniques, and water demand due to changes in summer weather patterns, according to the USGS (1995). The analysis of daily flow fluctuations in the Lower Klamath River presented in this study confirmed that the operation of IGD created a steady flow and eliminated abrupt changes in water discharge of up to 2,000 cfs. The biggest single changed item in the USGS gage records was flow during dry years. This led the authors of the study to conclude that human water use during years of drought drastically reduces the already limited flows of the Lower Klamath River.

In 1996, Hecht and Kamman were commissioned by the Yurok Tribe to quantitatively estimate the historic flow patterns in the Klamath River for Trihey and Associates (1996) to subsequently develop recommendations regarding flow needs for salmon. Although agricultural diversions were in place in 1905 above Klamath Lake (i.e., on the Williamson and Sprague rivers), USGS gage data from 1905 though 1912 at Keno were used to estimate “natural flows” in the river. These data reflected a period of record during which water diversions were at a minimum, until the construction of the Lost River Diversion Dam in 1912 (Hecht and Kamman 1996). The years 1905 through 1912 were identified to be above average for precipitation and runoff in much of the Upper Klamath Basin. To counter this, stream flow and rainfall data were normalized to a period of average rainfall using annual precipitation indices. Hecht and Kamman (1996) divided the average flow/annual precipitation during the 1905–1912 period by the average flow/annual precipitation value over a long-term period (1905–1994). These indices suggested that conditions during the 1905–1012 period were wetter than normal in northern California at Yreka (index 1.21) than in southern Oregon al Klamath Falls (index 1.04). (Note that the higher the index above 1.0, the wetter the 1905–1912 period relative to average conditions over the longterm.). The authors explained that they chose the Klamath Falls (1905–1994) index because it is closer to the center of the Upper Basin and appears to be an accurate record. They found it preferable to the longer (1872–1994) but more distant record from Yreka, which included data of poor quality for 1911 and 1912. They did not use the index of 1.34, calculated using the BOR’s inflow records, because this index suggested conditions were wetter than indicated by either of the rainfall records. This index is likely to have been affected by the long-term decline in inflow to Upper Klamath Lake from the Sprague and Williamson river systems. This artificially reduced the long-term inflow average, which, as the denominator in the calculation of the index, leads to an inflated result (Hecht and Kamman 1996).

To estimate pre-project flows at IGD, Hecht and Kamman (1996) added historical flow accretions between Keno and IGD to the Keno flow record. These accretions were estimated in a separate study by CH2M Hill using USGS flow records, because no gage data existed for IGD until 1960. After adding the estimated accretions to the pre-Project flows at Keno, Hecht and Kamman (1996) concluded that the average annual flow in the Lower Klamath River at IGD was about 1.8 million acre-feet/year prior to the completion of the Irrigation Project. A second phase of Hecht’s and Kamman’s (1996) study comprised the analysis of changes in flow at a gauging station over time. Stations with long flow records were selected and similar pre and post-Project water-year types were identified. They chose and matched water-year types that had similar earlier short-term and long-term conditions, such as 1916/1985 and 1918/1987. For example, both 1916 and 1985 experienced above-normal runoff and precipitation, and were preceded by 4 years of high water availability. Thus, the 1916/1985 year pair represents historical vs. current flow conditions for relatively wet periods; while the 1918/1987 pair corresponds to flow conditions during relatively dry periods.

Based on their analyses, Hecht and Kamman (1996) concluded that flows in the Lower Klamath River have been reduced from historical levels by water-diversion projects in the Upper Klamath Basin and the Shasta, Scott, and Trinity sub-basins. They also indicated that the Project changed the seasonal distribution of flows, usually increasing water discharge very slightly during fall and early winter and markedly reducing spring and summer flows. This shift in flow regimes between pre-project times and the mean monthly 1961–96 flows is shown in Figure 2 (based on Hecht's and Kamman's data). A graph of annual average pre-project flows (hydrograph) indicates that higher flows were available in the river channel before all diversions and dams were built. According to Hecht and Kamman (1996), the Upper Klamath Basin in July–August of 1911–1913 (pre-Project wet period) contributed between 30 and 35percent of the river flow at its mouth; whereas during July–August of 1983–1985 (a comparably wet post-Project period) this flow contribution was reduced to 10 or 15percent of the flow at the river's mouth. Their study estimated that, during droughts, the post-Project flow contributions of the upper basin to the flow recorded at the mouth of the river becomes even lower, approximately 5percent%.

Hecht's and Kamman's (1996) "pre-project" flow estimate at IGD was subsequently used by Trihey and Associates (1996) to develop minimum instream flow recommendations. Trihey and Associates (1996) used the Tennant Method and applied it based on 60percent of the mean annual discharge estimated by Hecht and Kamman (1996). The recommended minimum instream flows are included in Table 1 along with those originally established by the Federal Energy Regulatory Commission (FERC) and those requested by the Yurok Tribe in response to the draft BO by the NMFS.

In 1999, a study was initiated by faculty from the Institute for Natural Systems Engineering (INSE) of Utah State University to quantify the minimum monthly flows for the Klamath River below IGD needed to maintain and restore the aquatic resources of the river, with special emphasis on salmonids. These researchers elaborated interim minimum instream flow recommendations using a battery of hydrology-based methods. Such recommendations were intended to be of temporary application (Phase I) until field-based methods, incorporating site-specific information, tributary flows, and water quality, are used to validate and refine the minimum recommended flows (i.e., Phase II of INSE report, draft manuscript completed but not made public yet). The minimum instream flow recommendations described by INSE (1999) were calculated on the premise that suitable salmonid habitat is directly related to flow regime and were focused on four basic flow components: fish habitat flows, channel maintenance flows, riparian flows, and valley maintenance flows. For purposes of determining interim minimum instream flows for the Klamath River, INSE (1999) used five different minimum instream flow setting methods (i.e., Hoppe, New England Flow Recommendations Policy, Northern Great Plains Resource Program, Tennant, and Washington Baseflow) and subsequently took the average monthly flow across the five estimated values to calculate the "best estimate". This study has been criticized by Miller (2001), who prepared a review for the BOR, for making the independent corroboration of its analyses and conclusions difficult by not providing supportive data, using "outdated" methods when "newer" more biologically based methods were available, modifying the methods used without clear justification, and not providing complete citations in the document and materials in the appendix.

Although the reports by USGS (1995), Hecht and Kamman (1996), and INSE (1999) differ in their characterization of the magnitude of changes that occurred in the river, their discrepancies are relatively minor and can be explained by differences in their initial objectives, analytical techniques, and underlying assumptions. However, they all describe a common scenario of water depletion in the river as well as annual and monthly flow changes that follow the patterns of water use in the upper basin and in the main sub-basins of the lower basin. The study by Hecht and Kamman (1996) estimates "pre-project" mean annual flows at IGD for a normal water year (i.e., neither too wet nor too dry) of about 2,575 cfs (equivalent to 1.8 million acre-feet of water). This is based on 1905–12 gage records, corrected for a normal year because that period was wetter than normal. The mean annual flow these studies calculated using 1961–96 gage records was 2,060 cfs (approximately 1.5 million acre-feet). This suggests a flow reduction of 515 cfs or 372,800 acre-feet, which roughly matches the estimated 245,000 to 350,000 acre-feet (depending on year type) used by the Klamath Project operations. This reduction in annual flow is controversial for some who prefer to use the historical rainfall records from Yreka to estimate pre-Project flows. These records suggest the 1905–1912 period was 20percent wetter than normal and justify the pre-Project average annual flow at IGD to be corrected accordingly to approximately 1.5 million acre-feet/year, which is not different from the post-Project estimates of Hecht and Kamman (1996). Such comparison, however, may not be appropriate since it is comparing flows that are normalized using two different precipitation gages—the Yreka gage for the pre-Project flows and the Klamath Falls one for the post-Project.

Both the USGS (1995) study and Hecht's and Kamman's (1996) report arrive, independent of each other, at the conclusion that water management practices have increased late winter and early spring flows, and reduced summer flows compared to estimated pre-Project flows (see Figure 2).

Dams and water diversions in the basin not only have changed the Lower Klamath River's seasonal pattern of flow but also have negatively affected the quality of the water. In recent years, temperatures on the mainstem of Lower Klamath River have exceeded 20ºC for periods of weeks between mid-July and late September. This trend has been particularly evident during dry years such as 1994 (Kier and Associates 1997). Although instream flows between July 1 and September 1, 2001, were higher than during previous dry years, due to regulation changes set forth by the BO (NMFS 2001), maximum daily temperatures below IGD ranged from 19.6ºC to 22.5ºC and minimum daily temperatures from 18.6ºC to 20.6ºC for the 90 days of record (USGS 2001).

The combined effects of high temperatures, high nutrient concentrations, and low dissolved oxygen levels during the summer months can create extremely stressful conditions for coho salmon and other salmonids in the Lower Klamath River. High nutrient concentrations (especially N and K) typically promote eutrophication. This condition and the associated increase in the abundance of algae and aquatic plants tend to lead to increased sedimentation and water temperatures, slower water velocities, and lower levels of dissolved oxygen at night. In June of 2000, temperatures and dissolved oxygen levels reached critical levels in the Klamath River and resulted in an estimated kill of >1,000 fish/mile for ~10 miles (CDF&G 2000).

Stream flows affect salmonid habitat in a variety of ways. Increased water flows provide a lower stream surface-to-volume ratio, which may buffer the diurnal fluctuations in stream temperatures and dissolved oxygen levels (INSE 1999). This practice also is recommended by Bartholow (1995) for selected times of the year such as June and October, because during the warmer July–September period it is important to maintain the beneficial effects that colder water from springs and some tributaries may provide to salmonids (at least during normal flow years). Larger stream volumes also accompany increased habitat availability on the margins of the channel (Bjornn and Reiser 1991). This habitat not only functions as shelter to juvenile coho salmon but also adds to the connectivity between riparian vegetation and the stream channel that is critical for maintaining food webs and energy flows through a functional riparian ecotone (Otting 1999, Dwire 2001).

Implications of 2001 Biological Opinion for coho salmon

Based on the consultation history presented in the 2001 BO (NMFS 2001), the NMFS received a request for formal consultation under section of the ESA on March 1999, when the BOR forwarded a draft Environmental Assessment of the Klamath Project Annual Operations Plan. On July 12, 1999, the NMFS issued a BO on the operation of the Klamath Project through March 2000. On April 4, 2000, NMFS informed the BOR that the 1999 BO and the associated incidental take statement had expired on March 31, 2000, and that their agency had to request ESA section 7 consultation again with regard to the operation of the Klamath Project. The BOR responded with a letter on April 26, 2000, stating that "[the BOR has] determined that the proposed flows [included in the letter]…are both sufficient and necessary to avoid possible 7 (d) foreclosures and to fulfill Reclamation's obligation to protect Tribal trust resources." On January 22, 2001, the BOR requested initiation of formal ESA section 7 consultations with regard to the ongoing operation of the Klamath Project. This letter included a Biological Assessment of the Project's operation on coho salmon from the SONCC ESU.

As part of this consultation, the NMFS reviewed the status of SONCC coho salmon, the environmental conditions in the area, the potential effects of the proposed ongoing operation of the Klamath Project, and its cumulative effects. Afterwards, it concluded that the proposed action was "likely to jeopardize the continued existence of SONCC coho salmon" and adversely alter critical coho salmon habitat. Subsequently and as part of the BO, the NMFS presented its "Reasonable and Prudent Alternative" (RPA) to the operations proposed by the BOR. The RPA was based on the premises that: a) the operation of the Klamath Project substantially affects flows, fish habitat, and water quality in the Lower Klamath River; and b) the Klamath Project is not the only human activity that has a negative effect on salmonid habitat and anadromous salmonid populations in the Klamath Basin. According to the NMFS (2001), the proposed RPA aimed to prevent further decline of the listed species that the NMFS concluded were likely to be jeopardized by the ongoing operation of the Klamath Project. The agency indicated that it was in the process of collecting additional information and conducting analyses about the relationship between IGD releases and fish habitat availability with the intent to develop a comprehensive BO addressing all water-year types to be provided to the BOR on or before June 7, 2001. In the meantime, the April 6, 2001 BO was a subset of the more comprehensive report being developed and was intended to specify only the minimum instream flows for the April–September period of 2001.

As described earlier in this section, there is ample evidence that water releases from IGD have a strong effect on the amount of salmonid spawning and, in the case of coho salmon, nursery habitat available in the Lower Klamath River mainstem. This point becomes particularly important during the spring–summer months when flows in tributaries to the Lower Klamath River are at their lowest level and, in the case of extremely dry years like 2001, contribute only a negligible amount of water to the mainstem of the river. Furthermore, because summer nursery habitat for salmonids in these "almost-dry" tributaries seems to become extremely scarce as flows go down, the mainstem of the river and some minor spring-fed brooks are likely to become the only refuge juvenile coho salmon (and steelhead) use to survive until fall.

During summer and in dry years, water releases at IGD contribute significantly to instream flows in the Klamath River. Because of the hydrology of the system, the climate of the region, and the number of tributaries present, the importance of IGD releases increases with river mile, according to a flow study conducted by the U.S. Geological Survey (1995). Therefore, the IGD to Shasta River reach is the one that relies the most upon IGD water releases. Based on USGS gage data, the BO estimates that, on average, between July and October, from 1962 to 1991, water releases at IGD contributed approximately 60 to 85percent of the river flows measured at Seiad Valley (Fig. 1), and 50 to 65percent of the river flows measured at Orleans (Fig. 1). These data also seem to indicate that the importance of IGD water releases increases during dry years; thus, late summer estimates have suggested that about 90percent of the river flow in the Seiad Valley was directly attributable to IGD water releases (NMFS 2001).

Considering both the above mentioned contributions of IGD releases to the Lower Klamath River flow and the preliminary field data provided by INSE (from its Phase II flow study, in preparation), the NMFS presented through its BO an RPA to replace the BOR's water-release plan for this critically dry year. The RPA states that under IGD releases of 1,700 cfs for April and May, coho salmon fry would have access to approximately 50percent of the maximum available habitat and chinook salmon fry would have access to close to 65percent of their nursery habitat. Through this process and aiming at maintaining between 40 and 65percent of the mainstem channel's salmonid habitat during different months, the RPA established the April–September minimum water releases at IGD. Such releases (both from the draft and final versions of the BO) are summarized in Table 2, along with FERC's minimum flows, the flows proposed by the BOR for dry and critically dry (like 2001) years. The table also includes the actual flows that were measured at IGD between April and September 2001 (obtained from the USGS Web site). Although the RPA flows recommended in the final version of the BO (NMFS 2001) stand out as relatively high when compared to those recommended by either FERC or BOR, they are much lower than the minimum instream flows recommended for the restoration and maintenance of aquatic resources by the

INSE's Phase I study (INSE 1999) (see Fig. 3). In fact, the RPA flows (NMFS 2001) are closer in magnitude to the minimum instream flows recommended by Trihey and Assoc. (1996) and by the Yurok Tribe (2001); however, the shape of the graphics (i.e., hydrographs) that these various flow regimes generate is somewhat different (Figure 3). The main difference between the instream flows recommended by FERC or BOR for a critically dry year, like 2001, and the ones requested by the BO (NMFS 2001), Trihey and Assoc. (1996), or the Yurok Tribe (2001), is during spring and early summer. Those who recommend higher flows argue that coho smolts (which have been rearing in the system for some 12 to 14 months and are ready to enter coastal waters) migrate to the ocean in the spring and are likely to benefit from relatively higher flows. The assumption behind the request for higher flows is that the higher the flow, the shorter the duration of the trip to the estuary and, therefore, the higher the survival coho smolts may enjoy. Although, there is no guarantee that the "additional" release of water will work as intended and make a difference in the final number of fish that survive their seabound migration, the assumption finds support in some studies on smolt migration and survival (see Sandercock 1991).

The BO's RPA clearly states the need to balance the needs for higher flows in the spring with the need for regulating flows in a manner that can ensure that after one of the driest winters in recent decades the limited water supply available would last until the fall. This balancing act may explain why the water release at IGD (1,700 cfs) requested in the RPA for the spring period, although higher than the one approved by FERC, is lower than the water releases asked for by Trihey and Assoc. (2,500 cfs) or the Yurok Tribe (2,100 cfs). In contrast, the instream flows requested for the first 2 weeks of June by the RPA show a slightly higher peak (2,100 cfs) than those petitioned for by other parties (except for the INSE) (Fig. 3). The rationale behind these "flushing" flows is that they could help the last coho salmon smolts move downstream and enter coastal waters before the water in the Lower Klamath River becomes too warm for salmon to survive. For the rest of the summer, July–September, the flows requested in the RPA remain constant at 1,000 cfs. Such flows are slightly more than the ones FERC established for July during critically dry years but they match the flow levels established by FERC and recommended by Trihey and Assoc. (1996) and the Yurok Tribe (2001) for the month of August. Contrary to what might be expected, the September flows requested in the RPA only match those that Trihey and Assoc. (1996) suggested but are lower than the flows established by FERC or asked for by the Yurok Tribe (2001). The slight increase in September's water discharge has been proposed to assist upstream migrating fall chinook salmon. This type of action is supported by a study on fall chinook passage in the Lower Klamath River by Vogel and Marine (1994), but only for late September and October. Based on the arguments presented in the RPA, the recommended instream flows for September seem to be another balancing act between what is needed for the maintenance of fish habitat in the short term and what can be released from IGD without risking insufficient water availability later on.

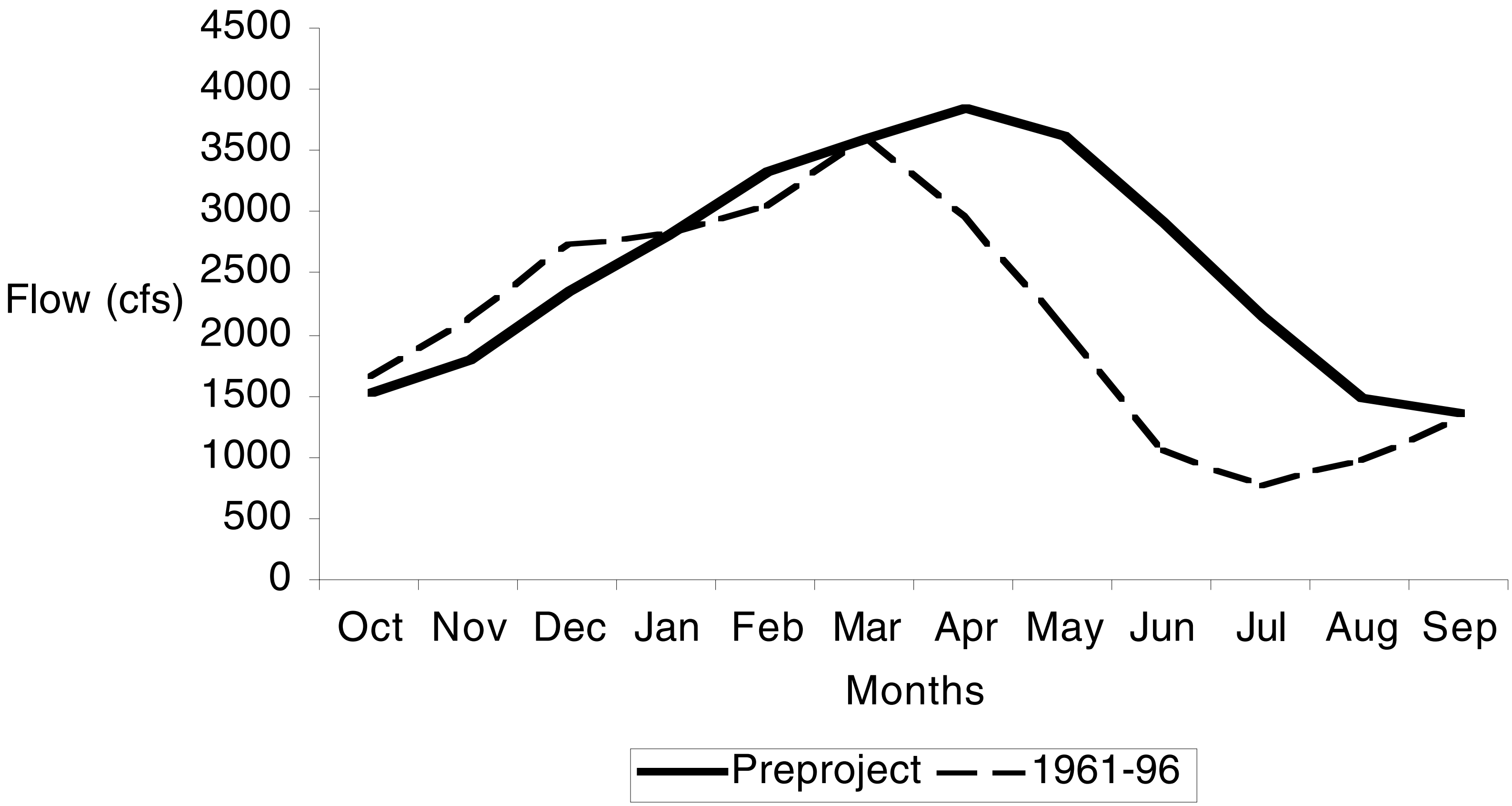
The Lower Klamath River has been listed as water-quality impaired by both Oregon and California under Section 303 (d) of the Federal Clean Water Act. Excessively high water temperatures, elevated nutrient concentrations, and the associated low dissolved oxygen levels have all been identified as important limiting factors for salmonids. The water release schedule requested in the RPA may help alleviate the effects of low in-steam flows on salmonid habitat, but it cannot solve water quality-related problems. This limitation, at least regarding water temperature, is due to the shallow characteristics of the Iron Gate Reservoir, which does not have a hypolimnion (i.e., lower and colder layer of water in a lake or reservoir) large enough to release relatively colder water into the river below. By increasing the volume of water present in the channel, it seems that the minimum instream flows requested in the RPA would help reduce the amplitude of the daily fluctuations in water temperature. This is likely to lessen the already high temperature-induced stress juvenile coho salmon may suffer in the Lower Klamath River. The effectiveness of this practice, however, is uncertain and deserves close examination.

There are important information gaps (e.g., coho salmon population structure, habitat distribution, juvenile migration patterns, water temperature regimes, water quality parameters, etc.) that need to be addressed in the Klamath River Basin before the effects of future water allocation decisions can be understood, anticipated, and minimized in an adequate and just manner. In the meantime, it is not surprising that agencies such as the NMFS, which are responsible for the management of common natural resources, may opt for a risk-averse approach when regulating instream flows during a critically dry year like 2001 in a river like the Klamath with listed coho salmon. Unfortunately, such a response is not satisfactory for many of the basin's stakeholders—either for those who contest that the recommended flows were not enough to avoid negative effects on the river's coho salmon stocks or for those who consider that instream flows do not affect fish habitat availability and fish abundance. Once additional information becomes available, it is hoped that the final decision on water allocation during years of scarcity will respond to the legitimate needs of Klamath River Basin's stakeholders through the development of an effective program of ecological and social restoration/protection that facilitates the coexistence of people and fish.

Figures And Tables

Fig. 1 will be a map of the Klamath River Basin.

Fig. 2. Mean Monthly Flows at Iron Gate Dam



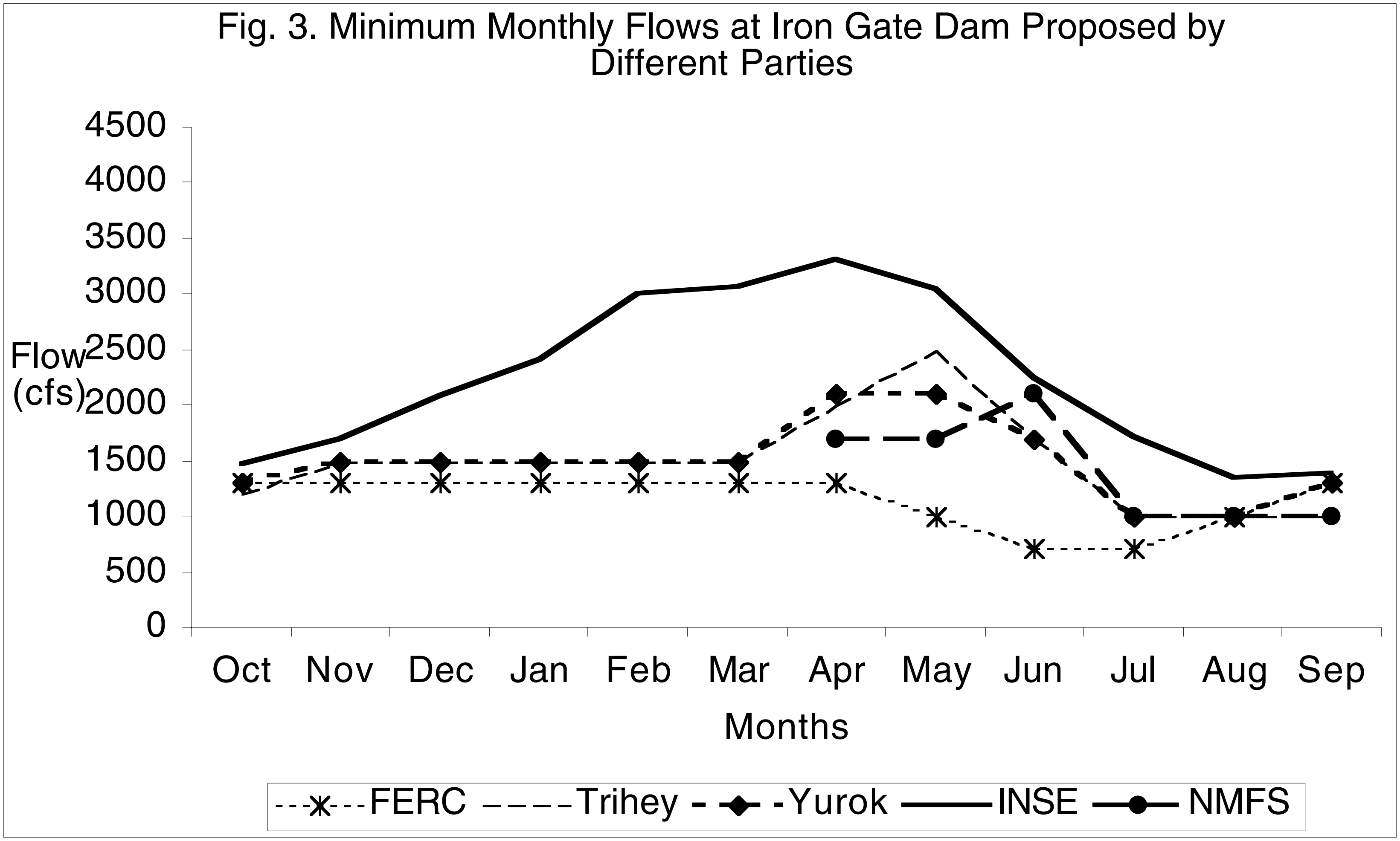


Fig. 3. Minimum Monthly Flows at Iron Gate Dam Proposed by Different Parties
4500
4000
3500
3000
2500
2000
1500
1000
500
0
Flow (cfs)
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Months
FERC
Trihey
Yurok
INSE
NMFS

Table 1. Estimated pre-project mean monthly flows, mean monthly flows between 1961 and 1996, and recommended minimum monthly flows at Iron Gate Dam (data from INSE 1999).

Month	Mean Monthly Pre-project Flows (1905–12) (cfs)	Mean Monthly Flows (1961–96) (cfs)	FERC (cfs)	Trihey & Assoc. (Tennant) (cfs)	Yurok Tribe (cfs)	INSE (Mean Various Methods) (cfs)
October	1,536	1,664	1,300	1,200	1,300	1,476
November	1,809	2,142	1,300	1,500	1,500	1,688
December	2,358	2,744	1,300	1,500	1,500	2,082
January	2,827	2,825	1,300	1,500	1,500	2,421
February	3,331	3,047	1,300	1,500	1,500	3,008
March	3,604	3,601	1,300	1,500	1,500	3,073
April	3,857	2,970	1,300	2,000	2,100	3,307
May	3,627	2,046	1,000	2,500	2,100	3,056
June	2,930	1,050	710	1,700	1,700	2,249
July	2,147	758	710	1,000	1,000	1,714
August	1,503	970	1,000	1,000	1,000	1,346
September	1,370	1,303	1,300	1,000	1,300	1,395

Table 2. Recommended minimum monthly flows at Iron Gate Dam.

Date	FERC Minimum Flows	BOR Proposed Dry Year average minimum flows	BOR proposed critically dry year minimum flows	NMFS *Draft* 2001 Biological Opinion Flows	NMFS *Final* 2001 Biological Opinion Flows	Actual Flows, 2001
April 1–15	1,300	728	569	1,700	1,700	1,528
April 16–30	1,300	754	574	2,100	1,700	1,667
May 1–15	1,000	761	525	2,100	1,700	1,749
May 16–31	1,000	924	501	2,100	1,700	1,704
June 1–15	710	712	476	1,800	2,100	2,099
June 16–30	710	612	536	1,400	1,700	1,695
July 1–15	710	547	429	1,000	1,000	1,008
July 16–31	710	542	427	1,000	1,000	1,016
August	1,000	647	398	1,000	1,000	1,026
September	1,300	749	538	1,300	1,000	1,025

Literature Cited

Ahern, T. 2000. Interior Secretary and Tribes gather at Hoopa reservation to release Trinity River Fishery Restoration Plan (Press Release)

Bartholow, J.M. 1995. Review and analysis of Klamath River Basin water temperatures as a factor in the decline of anadromous salmonids with recommendations for mitigation. *In* Compilation of Phase I Reports for the Klamath River Basin—May 1995. Prepared by River Systems Management Section, National Biological Service. Fort Collins, CO.

Binns, N.A., and F.M. Eiserman. 1979. Quantification of fluvial trout habitat in Wyoming. Trans. Amer. Fish. Soc. 108: 215–228.

Bjornn, T.C., and D.W. Reiser. 1991. Habitat requirements of salmonids in streams. Pp. 83–138. *In* Meehan, W.R. (ed.). Influences of forest and rangeland management on salmonid fishes and their habitats. American Fisheries Society, Bethesda, MD.

Bjornn, T.C., M.A. Brusven, M.P. Molnau, J.H. Mulligan, R.A. Klamt, E. Chacho, and C. Schaye. 1977. Transport of granitic sediment in streams and its effects on insects and fish. University of Idaho. Forest, Wildlife and Range Experimental Station, Bulletin No. 17. Moscow, ID.

Boyle, J.C. 1976. Fifty years on the Klamath. Klocker Printery, Medford, OR.

Brett, J.R. 1952. Temperature tolerance in young Pacific salmon, genus *Oncorhynchus*. Journal of the Fisheries Research Board of Canada 9: 265-321.

Brown, L.R., P.B. Moyle, and R.M. Yoshiyama. 1994. Historical decline and current status of coho salmon in California. N. Amer. J. Fish Manage. 14: 237–261.

Bustard, D.R., and D.W. Narver. 1975 a. Aspects of the winter ecology of juvenile coho salmon (*Oncorhynchus kisutch*) and steelhead trout (*Salmo gairdneri*). Journal of the Fisheries Research Board of Canada 32: 667–680.

Castleberry, D.T., J.J. Cech Jr., D.C. Erman, D. Hankin, M. Healey, et al. 1996. Uncertainty and instream flow standards. Fisheries 21: 20–21.

CARCD (California Association of Resource Conservation Districts). 2000. Web site: http://carcd.org. 801 K Street, Suite 1318, Sacramento, CA 95814.

CDFG (California Department of Fish and Game). 1974. Stream flow needs for anadromous salmonids in the Scott River Basin, Siskiyou County—A summarized report. Yreka, CA. 27 p.

CDFG. 1994. Petition to the California Board of Forestry to list coho salmon (*Oncorhynchus kisutch*) as a sensitive species. California Department of Fish and Game Report, available from Board of Forestry, 1416 Ninth, Sacramento, CA.

CDFG. 2000. Documentation of the Klamath River Fish Kill, June 2000. Yreka, CA. 17p plus appendices.

Cederholm, C.J., and W.J. Scarlett. 1982. Seasonal immigrations of juvenile salmonids into four small tributaries of the Clearwater River, Washington, 1977–1981. Pp.

98–110. *In* Brannon, E.L., and E.O. Salo (eds.) Proceedings of the salmon and trout migratory behaviour symposium. June 1981. University of Washington, Seattle, WA.

Chapman, D.W. 1962. Aggressive behaviour in juvenile coho salmon as a cause of emigration. J. Fish. Res. Board Can. 19: 1047–1080.

Dolloff, C.A. 1986. Effects of stream cleaning on juvenile coho salmon and Dolly Varden in southeast Alaska. Trans. Amer. Fish. Soc. 116: 829–838.

Dong, A.E., K.W. Beatty, and R.C. Averett. 1974. Limnological study of Lake Shastina, Siskiyou County, California. U.S.Geological Service, Water Resources Investigations 19-74. Menlo Park, CA. 59p.

Dwire, K.A. 2001. Relations among hydrology, soils, and vegetation in riparian meadows: influences on organic matter distribution and storage. Ph.D. dissertation. Oregon State University, Corvallis, OR. 168p.

Espegren, G.D. 1998. Evaluation of the standards and methods used for quantifying instream flows in Colorado. Colorado Water Conservation Board. Denver, CO.

Everest, F.H., and D.W. Chapman. 1972. Habitat selection and spatial interaction of juvenile chinook salmon and steelhead trout in two Idaho streams. J. Fish. Res. Board Can. 29: 91–100.

Fausch, K.D. 1993. Experimental analysis of microhabitat selection by juvenile steelhead (Oncorhynchus mykiss) and coho salmon (Oncorhynchus kisutch) in a British Columbia stream. Can. J. Fish. Aquat. Sci. 50: 1198–1207.

Frissell, C.A., W.J. Liss, C.E. Warren, and M.D. Hurley. 1986. A hierarchical framework for stream habitat classification: viewing streams in a watershed context. Environmental Management 10: 199–214.

Gosse, J.C., and W.T. Helm. 1981. A method for measuring microhabitat components for lotic fishes and its application with regard to brown trout. Pp. 138–141. *In* Armantrout, N.B. (ed.). Acquisition and utilization of aquatic habitat inventory information. American Fisheries Society, Bethesda, MD.

Gregory, S.V., and P.A. Bisson. 1997. Degradation and loss of anadromous salmonid habitat in the Pacific Northwest. Pp. 277–314 in Stroud, D.J., P.A. Bisson, and R.J. Naiman (eds.). Pacific salmon and their ecosystems: status and future options.

Groot, C., and L. Margolis. 1991. Pacific salmon life histories. UBC Press. Vancouver, British Columbia, Canada. 564p.

Hassler, T.J., W.L. Somer, and G.R. Stern. 1986. Impacts of suction dredging on anadromous fish, invertebrates and habitat in Canyon Creek, California. Final Report, California Coop. Fisheries Research Unit, Humboldt State University, Arcata, CA.

Hecht, B, and G.R. Kamman. 1996. Initial assessment of pre- and post-Klamath Project hydrology on the Klamath River and impacts of the Project on instream flows and fishery habitat. Balance Hydrologics, Inc. 1760 Solano Ave., Suite 209. Berkeley, CA.

Henderson, M.A. 1991. Sustainable development of the Pacific salmon resources in the Fraser River Basin. Pp. 133–154 in Dorcey, A.H.J. (ed.). Perspectives on sustainable development in water management: towards agreement in the Fraser River Basin. Westwater Research Centre, University of British Columbia, Vancouver, British Columbia, Canada.

Hicks, B.J., J.D. Hall, P.A. Bisson, and J.R. Sedell. 1991. Response of salmonids to habitat changes. Pp. 483–518 in Meehan, W.R. (ed.). Influences of forest and rangeland management on salmonid fishes and their habitats. Amer. Fish. Soc., Sp. Pub. 19, Bethesda, MD.

INSE (Institute for Natural Systems Engineering). 1999. Evaluation of interim instream flow needs in the Klamath River: Phase I. Final Report. Prepared for the Department of the Interior. Utah State University. Logan, UT.

Jones and Stokes Inc. 1976. Case study No. 1: Iron Gate Dam, Klamath River. *In* Assessments of Effects of Altered Stream Flow Characteristics on Fish and Wildlife. Part B: California Case Studies. Pp. 19–35. Prepared for U.S. Fish and Wildlife Service. Fort Collins, CO.

Kier, William F. and Associates. 1997. Klamath Resource Information System (KRIS). Computer database program, ver. 1.0.

Kraft, M.E. 1972. Effects of controlled flow reduction on a trout stream. J. Fish. Res. B. Canada 29: 1405–1411.

KRBFTF (Klamath River Basin Fisheries Task Force). 1991. Long range plan for the Klamath River Basin Conservation Area fishery restoration program. U.S. Fish and Wildlife Service, Klamath River Fishery Resource Office, P.O. Box 1006, Yreka, CA.

Mason, J.C. 1974. Aspects of the ecology of juvenile coho salmon (*Oncorynchus kisutch*) in Great Central Lake, B.C. Fish. Res. B. Can. Tech. Rep. 438. 37 p.

Mathews, S.B., and F.W. Olson. 1980. Factors affecting Puget Sound coho salmon (*Oncorhynchus kisutch*) runs. Can. J. Fish. Aquat. Sci. 37: 1373–1378.

McMahon, T.E., and G.F. Hartman. 1989. Influence of cover complexity and current velocity on winter habitat use by juvenile coho salmon (*Oncorhynchus kisutch*). Canadian Journal of Fisheries and Aquatic Sciences 46: 1551–1557.

Milinski, M., and G.A. Parker. 1991. Competition for resources. Pp. 137—168 in Krebs, J.R., and N.B. Davies (eds.) Behavioural ecology: an evolutionary approach. Third edition. Blakwell Scientific Publications, Oxford, England.

Miller, W.J. 2001. Review of “Evaluation of interim instream flow needs in the Klamath River. Phase 1 final report” by Institute for natural Systems Engineering, August 5, 1999. Miller Ecological Consultants, Inc. Fort Collins, CO.

Mundie, J.H. 1969. Ecological implications of the diet of juvenile coho in streams. Pp. 135–152 in Northcote, T.G. (ed.). Symposium on salmon and trout in streams. H.R. MacMillan Lectures in Fisheries, Institute of Fisheries, University of British Columbia, Vancouver, B.C.

Murphy, M.L., and J.D. Hall. 1981. Varied effects of clear-cut logging on predators and their habitat in small streams of the Cascade Mountains, Oregon. Can. J. Fish. Aquat. Sci. 38:137–145.

Nehlsen, W., J.E. Williams, and J.A. Lichatowich. 1991. Pacific salmon at the crossroads: stocks at risk from California, Oregon, Idaho, and Washington. Fisheries 16: 4–21.

Nickelson, T.E., J.D. Rodgers, S.L. Johnson, and M.F. Solazzi. 1992. Seasonal changes in habitat use by juvenile coho salmon (*Oncorhynchus kisutch*) in Oregon coastal streams. Canadian Journal of Fisheries and Aquatic Sciences 49: 783–789.

Nielsen, J.L. 1992. Microhabitat-specific foraging behavior, diet, and growth of juvenile coho salmon. Trans. Amer. Fish. Soc. 121: 617–634.

NMFS (National Marine Fisheries Service). 2001. Biological opinion. Ongoing Klamath Project Operations. April 6. Southwest Region. 58 p.

Northcote, T.G., and M.D. Burwash. 1991. Fish and fish habitat of the Fraser River Basin. Pp. 117–141 in Dorcey, A.H.J., and J.R. Griggs (eds.). Water in sustainable development: exploring our common future in the Fraser River Basin. Westwater Research Centre, University of British Columbia, Vancouver, British Columbia, Canada.

Odum, E.P. 1971. Fundamentals of ecology. W.B. Saunders Co., Philadelphia, USA.

Otting, N.J. 1999. Ecological characteristics of montane floodplain plant communities in the upper Grande Ronde Basin, Oregon. MS thesis. Oregon State University, Corvallis, OR. 71 p.

PFMC (Pacific Fishery Management Council). 1999. Review of the 1998 Ocean Salmon Fisheries. Portland, OR.

Ricker, W.E. 1972. Hereditary and environmental factors affecting certain salmonid populations. Pp. 19–160 in Simon, R.C., and P.A. Larkin (eds.). The stock concept in Pacific salmon. University of British Columbia Press, Vancouver, British Columbia, Canada.

Sandercock, F.K. 1991. Life history of coho salmon. Pp. 395–445 in Groot, C., and L. Margolis (eds.). Pacific salmon life histories. University of British Columbia Press, Vancouver, B.C.

Siskiyou County Farm Bureau. 2001. Efficiency of agricultural water application systems: water use in Scott and Shasta valleys. Web site: www.snowcrest.net/siskfarm/wateff2.html.

Shirvell, C.S., and R.J. Dungey. 1983. Microhabitat chosen by brown trout for feeding and spawning in rivers. Trans. Amer. Fish. Soc. 112: 355–367.

Slaney, T.L., K.D. Hyatt, T.G. Northcote, and R.J. Fielden. 1996. Status of anadromous salmon and trout in British Columbia and Yukon. Fisheries 21: 20–35.

Smoker, W.A. 1955. Effects of streamflow on silver salmon production in western Washington. Doctoral dissertation. University of Washington. Seattle, WA.

Snyder, J.O. 1931. Salmon of the Klamath River. California Department of Fish and Game. Fisheries Bulletin No. 34.

Stalnaker, C.B. 1979. The use of habitat structure preferenda for establishing flow regimes necessary for maintenance of fish habitat. Pp. 321–337 in Ward, J.V., and J.A. Stanford (eds.). The ecology of regulated streams. Plenum Press, New York, NY.

Stalnaker, C.B. 1993. Fish habitat models in environmental assessments. Pp. 140–162 in Hildebrand, S.G., and J.B. Cannon (eds.). Environmental Analysis: The NEPA-experience. CRC Press, Boca Raton, FL.

Tennant, D.L. 1976. Instream flow regimes for fish, wildlife, recreation, and related environmental resources. Fisheries 1(4): 6–10.

Thompson, K. 1972. Determining stream flows for fish life. Pp. 31–50 in Proceedings of Instream Flow Requirement Workshop. Pacific Northwest River Basins Commission. Vancouver, WA.

Thorpe, J.E., J.F. Koonce, D. Borgeson, B. Henderson, A. Lamsa, P.S. Maitland, M.A. Ross, R.C. Simon, and C. Walters. 1981. Assessing and managing man's impact on fish genetic resources. Canadian Journal of Fisheries and Aquatic Sciences 38: 1899–1907.

Trihey and Associates, Inc. 1996. Instream flow requirements for Tribal Trust Species in the Klamath River. Prepared on behalf of the Yurok Tribe. Eureka, CA.

Trihey, E.W., and C.B. Stalnaker. 1985. Evolution and application of instream flow methodologiesto small hydropower development: an overview of the issues. Pp. 176–183. In Olson, F.W., R.G. White, and R.H. Hamre (eds.). Proceedings of the symposium on small hydropower and fisheries. The American Fisheries Society, Denver, CO.

Turner II, B.L., and W.B. Meyer. 1993. Environmental change: the human factor. Pp. 40–50 in McDonnell, M.J., and S.T.A. Pickett (eds.). Humans as components of ecosystems: the ecology of subtle human effects and populated areas. Springer-Verlag, New York, NY.

USBR (U.S. Bureau of Reclamation). 2001. Central Valley Project—Shasta/Trinity River Diversions Engineering Data. USBR Data Web. http://dataweb.usbr.gov/html/mpshaengdata.html

USDI (U.S. Department of the Interior). 2000. Record of Decision – Trinity River Mainstem Fishery Restoration. December 19, 2000. 28p.

USFWS (U.S. Fish and Wildlife Service). 1994. Klamath River Fall Chinook Review Team Report: An assessment of the status of the Klamath River Fall Chinook Stock as required under the Salmon Fishery Management Plan. Pacific Fishery Management Council, Portland, Oregon.

USFWS. 1997. Klamath River (Iron Gate Dam to Seiad Creek) life stage periodicities for Chinook, coho, and steelhead. Coastal California Fish and Wildlife Office. Arcata, California.

USFWS. 1999. Trinity River Flow Evaluation—Final Report. Arcata, CA (available from www.ccfo.R1.fws.org/TRFlow).

USGS (U.S. Geological Survey). 1995. Klamath River Basin Characterization of Hydrology Data from USGS Records. In Compilation of Phase I Reports for the Klamath River Basin—May 1995. Prepared by River Systems Management Section, National Biological Service. Fort Collins, CO.

USGS. 2001. Water gage database, Water Resources of California. Internet access: http://water.usgs.gov/ca/nwis.

USSCS (U.S. Soil Conservation Service). 1983. Soil survey of Siskiyou County, California. Central Part, Yreka.

Vogel, D.A, and K.R. Marine. 1994. Preliminary assessment of increased Klamath River flows for salmon during the late summer and fall of 1994. Vogel Environmental Services, 21600 Wilcox Rd. Red Bluff, CA.

Walters, C. 1993. Where have all the coho gone? Pp. 1–8 in Berg, L., and P.W. Delaney (eds.). Proceedings of the coho workshop. May 26–28, 1992. Nanaimo, British Columbia, Canada.

Weitkamp, L.A., T.C. Wainwright, G.C. Bryant, G.B. Milner, D.J. Teel, R.G. Kope, and R.S. Waples. 1995. Status review of coho salmon from Washington, Oregon, and California. U.S. Department of Commerce, NOAA Tech. Memo. NMFS-NWFSC-24. Northwest Fisheries Science Center, Seattle, WA.

Wells, H.L. 1881. History of Siskiyou County, California. D.J. Steward and Co. (Reprinted in 1971). Oakland, CA.

White, P.S., and J.C. Nekola. 1992. Biological diversity in an ecological context. Pp. 10–27 in Barker, J.R., and T.D. Tingey (eds.). Air pollution effects on biodiversity. Van Norstrand Reinhold, New York, NY.

White, R.G., J.H. Milligan, A.E. Bingham, R.A. Ruediger, T.S. Vogel, and D.H. Bennett. 1981. Effects of reduced stream discharge on fish and aquatic macroinvertebrate populations. University of Idaho, Water and Energy Resources Research Institute, Research Technical Completion Report. Project B-045-IDA. Moscow, ID.

Wickett, W.P. 1954. The oxygen supply to salmon eggs in spawning beds. J. Fish. Res. B. Canada 11: 933–953.

Williams, M. 1993. An exceptionally powerful biotic factor. Pp. 24–39 in McDonnell, M.J., and S.T.A. Pickett (eds.). Humans as components of ecosystems: the ecology of subtle human effects and populated areas. Springer-Verlag, New York, NY.

Yurok Tribe. 2001. Letter to I. Lagomarsino. Preliminary Yurok Tribe comments on 2001 draft biological opinion on ongoing Klamath Project operations. March 23.

Draft
December 14, 2001

Review of Relationships between Lost River and Shortnose Sucker Biology and Management of Upper Klamath Lake

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Abstract (timeline)

Historically, Lost River (LRS) and shortnose suckers (SNS) were abundant in Upper Klamath Lake and were utilized as a subsistence fishery by the Klamath Tribe. In the 1900s, the suckers, known locally as "mullet," were subjected to a snag fishery on spawning adults. The fishery became increasingly more regulated, first by making them "game species" under Oregon statute in 1959, followed by bag limits in 1969, and closure of the fishery in 1987. Over the period from 1966 to 1986, the annual harvest of fish declined 95 percent from about 12,500 to 687 fish and several spawning groups went extinct.

In 1988, both species were listed as federally endangered and the Williamson/ Sprague runs were estimated at less than 12,000 LRS and less than 3,000 SNS. After listing, monitoring programs shifted from fishery-based to non-fishery based. By the time of the 1992 Biological Opinion (BiOp) for the Klamath Project, managers operated under assumptions that adult populations and recruitment were low but a major source of adult mortality, the fishery, had been controlled. Factors responsible for the decline of these species were thought to include "the damming of rivers, dredging and draining of marshes, instream flow diversions, over-harvest, introductions of nonnative fish, and a shift toward hypereutrophication and poor water quality in Upper Klamath Lake and waters downstream" (1992 BiOp). Because both species are long-lived and highly fecund (produce large numbers of eggs), it was thought, "Infrequent gaps in recruitment will not adversely affect healthy populations," but because of inconsistent recruitment (new young spawners) and poor age structure (large numbers of year classes with zero fish), the 1992 BiOp did not allow for more than 2 consecutive years of low water (a minimum surface elevation as low as 4,137.0 feet through September 30). Low lake elevation was thought to reduce necessary larval and juvenile shoreline habitats and was assumed to equate with low recruitment. A low lake elevation of 4,139.0 feet was thought adequate to "provide suitable habitat for the maintenance and enhancement of sucker populations and will improve the chances of reaching the spring spawning water level."

Bureau of Reclamation recovery actions in the 1990s focused on marsh and spawning site reclamation, salvage of diverted suckers from irrigation ditches, and research to better understand sucker biology, dams, and lake water quality and quantity. Two contrasting events during the 1990s were the production of several apparently good year classes (1991, 1993, 1995, and 1999) and the significant loss of adults in three consecutive fish kills (1995–1997). The size of each fish kill easily equaled the annual size of the fishery in the 1960–1980s and the 1996 and

1997 fish kills were certainly much larger. Although data from the early 1990s appeared to indicate rebounding adult populations, by the time of the 2001 BiOp, managers' assumptions about the populations were largely the same as in 1992 except that a source of adult mortality—fish kills—was clearly not under control. In response to generally low juvenile recruitment and adult fish kills of the previous decade, the decision in the 2001 BiOp was to raise the minimum lake elevation from 4,139 to 4,140 ft. The cornerstones of the 2001 Biological Opinion were: 1) a Congressional mandate to err on the side of the species of concern in the face of uncertainty; 2) a failure of the Bureau of Reclamation to implement certain requirements of prior BiOps; 3) increased imperilment of the species since 1992; and 4) an increased concern for the effects of poor water quality. The mix of relevant factors in 2001—poor water quality, adult fish kills, and adult populations perhaps at similar levels as 1992—suggested that there was uncertainty in the response of these populations to the actions taken since 1992. Managers acknowledged that lake elevation alone could not guarantee recruitment and healthy adults, but argued that elevations as low as 4,137 ft could pose significant risk and elevation targets of 4,139 ft had had uncertain benefits in the previous decade. Thus, in the face of uncertainty, the decision was made to raise the minimum elevation to 4,140 ft.

Introduction

Lost River (LRS) and shortnose (SNS) suckers became federally listed endangered species in 1988 but concern for their declining abundance had been raised by OSU Professor, Carl Bond, and others in the 1960s. In 1983, the Klamath Tribe, Oregon Department of Fish & Wildlife (ODFW), and U.S. Fish and Wildlife Service (USFWS) initiated a study of Klamath suckers (Bienz and Ziller 1987). These studies discovered populations composed of older fish (95 percent of LRS were more than 19 yrs old) and prompted the Klamath Tribe to curtail sucker fishing in 1985 and the State of Oregon to close the fishery in 1987 (Scoppettone and Vinyard 1991). An additional cause for concern was water quality, primarily high nutrient loads (phosphorus and nitrogen) and associated blooms of blue green alga (*Aphanizomenon flos-aquae*), high pH, and low dissolved oxygen (Vincent 1968). More recently, researchers have documented additional loss of spawning populations, large fish kills, fluctuating abundance, variable recruitment of juveniles, simplification of the age/size structure through loss of older fish and the success of non-native fish. The concern for water quality has expanded to include other anthropogenic (human-caused) changes in Upper Klamath Basin, including water diversions and loss of floodplain, wetland, and riparian habitats. The USFWS considers these species to be at unacceptably high risk of extinction (USFWS 1993, 2001). Because a federal agency, U.S. Bureau of Reclamation (USBR), manages the release of water from the habitat of endangered species (Upper Klamath Lake, see Policy chapter), section 7 of the Endangered Species Act requires that USFWS and USBR ensure that the Klamath Project does not jeopardize those species.

In the following we provide background information on aspects of sucker life history, demographics, and physiological tolerances in order to understand both the threats to their existence and the logic behind management and recovery efforts. We relate monthly elevations of Upper Klamath Lake to biological processes and compare the USFWS 2001 Biological Opinion (2001 BiOp) with the 1992 BiOp.

Sucker biology background

Both suckers are long-lived, up to 43 yr (LRS) and 33 yr (SNS), with a reproductive lifespan for females beginning at 7–9 yr (LRS) and 6–7 yr (SNS). Females produce 70,000–200,000+ eggs per spawning season. Beuttner and Scoppettone (1990) and Perkins et al. (1998) found evidence that larger suckers produce more gametes (eggs and sperm) but it is not known whether gametes improve in quality as adult size increases, a common pattern in other fishes (Sinclair 1988). Females may not spawn every year. They may, for example, skip years if energy reserves are low, if they have been significantly stressed, or if environmental conditions are not appropriate, but this suspicion is difficult to document. Suckers are iteroparous (an individual spawns in many years). The advantage of the long-lived, iteroparous strategy is that an individual's progeny production is spread over many years, increasing the likelihood of spawning when environmental conditions are favorable for progeny survival, thereby reducing the impact of environmental variation on lifetime reproductive success (Leaman and Beamish 1984; Goodman 1984; Schultz 1989). Such a strategy benefits from a broad distribution of spawning age classes because there is greater reproduction from older fish and because different-aged fish tend to spawn at different times during the season, thus extending the annual spawning season within a year, again spreading risk over time.

While longevity compensates for varying environmental conditions, it also makes fish more susceptible to over-exploitation. The removal of larger fish through fishing mortality can be detrimental to long-lived species, especially when the fishery targets large spawning fish. Because they are iteroparous, individuals are subjected to mortality every year they spawn and the probability of reaching old age is reduced. The result is lowered egg production and truncation of the upper end of the age distribution of spawners and their potentially higher reproductive potential (Borisov 1978; Beverton 1986; Leaman and Beamish 1984).

In Upper Klamath Lake, tagging studies suggest suckers spawn either in lakeshore springs or in the Willamson and Sprague rivers and seldom mix between these spawning sites. Perkins et al. (1998) and USGS (2001) have reported recapture of 446 suckers at lakeshore springs, and only 1 had been originally tagged in an area away from the springs. USGS (2000) reports recapture of 119 Lost River suckers at lakeshore springs; 118 had been tagged at the springs and 1 in the Williamson River. The same effort recaptured four previously tagged shortnose suckers, all of which were recaptured at the original tagging location. Fish movement among eastern lakeshore springs has been observed. USGS (2001) reports a total of 69 suckers (63 Lost River suckers and 6 shortnose suckers) were captured at least twice in 2000 at shoreline spawning areas. Of the 63 Lost River suckers, 48 percent were recaptured at springs other than where they were first captured, and 5 out of 7 shortnose suckers were captured at sites other than where they were tagged. However, it has not been documented that suckers actually spawn at multiple locations. Capture at different springs demonstrates movement and is suggestive, but does not conclusively prove lack of reproductive isolation between spawners at different lakeshore springs.

At this time, genetic and size distribution data are inconclusive as to whether in-lake and river spawning groups are reproductively isolated or broadly mixing (panmictic). For example, different sizes of spawners might indicate that spawning groups are not randomly drawn from the whole population but are reproductively isolated. Perkins et al. (1998) found larger LRS at lake springs relative to con-specifics in the river, except in 1998. USGS (2001, Table 2) suggests median size differences between river and lake spawning suckers are minimal, but more recent analyses suggest LRS at lake shore springs are larger than con-specifics at other locations (Rip Shively, USGS personal communication). Genetic data collected to date cannot discriminate between lake and river spawners (unpublished data).

It also is not known whether progeny also display fidelity to natal sites (i.e., are imprinted and have homing ability) and therefore, whether spawning groups are self-maintaining or part of a panmictic population created by intergenerational mixing (river progeny recruiting to in-lake springs or vice versa). The presence or absence of spawning site fidelity is an important question because high fidelity effectively limits natural recolonization of suitable sites. Also, multiple spawning sites may offer greater protection from chance events than a single site of comparable area. Thus, loss of high-fidelity spawning groups (if that is the life history strategy of these species) could lower total production beyond the simple loss of adult numbers and reduce the "buffer" provided by multiple sites.

The strategy of producing large numbers of small eggs means that there usually is high mortality in the early life of most fishes. Average patterns of freshwater fish mortality suggest 95 percent do not reach the juvenile stage (Houde 1994). Field work done in 1989 indicates apparent larval mortality rates within the Williamson River were 93 percent per day (Larry Dunsmoor, Klamath Tribe, personal communication). Cooperman and Markle (1999 and unpublished data) documented that larval sucker movement through the Williamson River can take as little as 1 day, and that greater than 99 percent of larvae exit the Williamson before completing flexion (caudal fin formation). This suggests that the 93 percent mortality level calculated by Dunsmoor is reached within the first days of the larval life history stage, a developmental stage that lasts approximately 40–50 days. Simon and Markle (2001) showed annual October population estimates of juveniles (1995–2000) ranged from 0 to 108,000 for LRS and about 1,500 to 74,000 for SNS. They also suggested that winter mortality (winter kill) might routinely reduce young-of-the-year abundance an additional 90 percent by the following spring. Because mortality rates are high for a relatively long time, very small changes in rates or duration can lead to dramatically different outcomes (Houde 1987). Fisheries scientists are seldom able to measure these rates with the precision needed to detect small changes and thus have difficulty determining causes of annual differences in year-class production. Despite this, it is clear from the following studies that acute environmental conditions (primarily water quantity, water quality, and other organisms) can adversely affect the numbers of young and older suckers.

Sucker distribution and habitat use change throughout the life cycle. Eggs are deposited in unconsolidated gravel/cobble bottoms in areas of ground water upwelling or in portions of rivers 2–6 ft deep with moderate current. Larval suckers are most abundant in near-shore areas of northeast UKL and the lower Williamson River. Larvae are associated with macrophytes (large non-woody plants), particularly emergent macrophytes (those partly above the water surface) such as *Scirpus acutus* (hardstem bullrush), *Sparghanium eurycarpum* (river burr reed), and *Polygonum coccineum* (water smartweed). During summer, the daytime habitat of age-0 juveniles shifts to include both emergent macrophytes and near-shore clean rocky substrates (sand, gravel, small boulders) but not fine silty bottoms (Simon et al. 2000). Also during summer, the center of abundance of age-0 juveniles moves southward in the lake, perhaps associated with the distribution of preferred gravel substrates. By fall, juveniles are no longer associated with near-shore habitats and move offshore to deeper waters where all substrates are fine silts. Older juveniles and adult suckers are found through out UKL, but are concentrated in the northern third of the lake (Reiser et al. 2001).

In Upper Klamath Lake, lake elevation is highly autocorrelated and cross-correlated with other variables of interest. For example, because of lake management and seasonal hydrological cyles, August 15 elevations are highly autocorrelated with elevations on earlier dates. Similarly, temperatures and other important water quality variables are highly correlated with dates, as are lake elevations, thus leading to complex cross-correlations. Thus, it is important to understand that simple relationships between suckers and lake elevations may not relate only to water quantity. Over the past decade, juvenile abundance has been monitored in late summer. Since 1995, the effort has used a stratified random design to calculate a September index of year-class strength (Simon et al. 2000). Despite using different methodologies in 1991–1994, a September year-class strength index can be estimated for 1991 through 1994 based on the number of individuals caught adjusted by the effort used to catch them (catch per unit effort, CPUE). When September year-class strength indices are arranged by July 15 lake elevation, it is clear that there is a relationship with water quantity (Figures 1 and 2). When lake elevation exceeds 4,141.7 on July 15, the average LRS index is about two times higher than at lower elevations, and four times higher for SNS. The result is a probability distribution—higher lake elevations are more likely to produce higher indices but are not guaranteed to do so. For example, there are low water years (1991) when year-class strength was strong and high water years (1998) when year-class strength was poor. Those unusual observations do not negate the pattern, but do suggest that factors other than lake elevation are important. This is similar to the situation when climatologists tell us we are in a wet climactic cycle and we experience a year that is drier than during dry cycles.

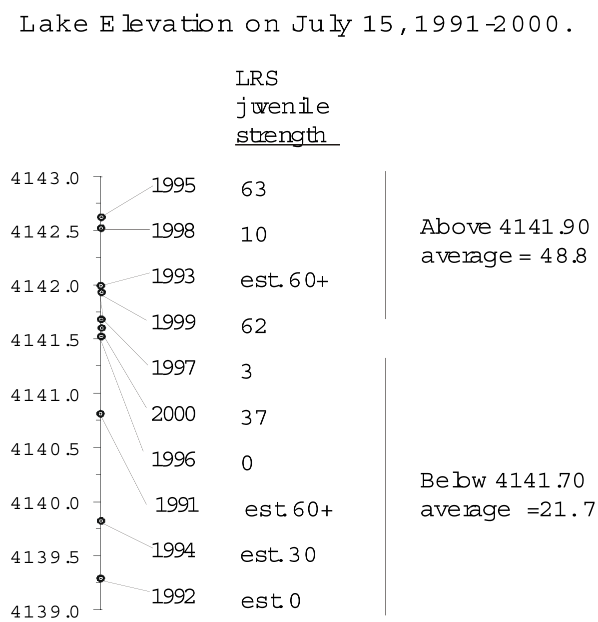


Figure 1. Relationship between Upper Klamath Lake elevation on July 15 and Lost River sucker September juvenile year class strength (Simon et al. 2000). Years 1991–1994 estimated based on fixed cast net and trawl catch per unit effort data.

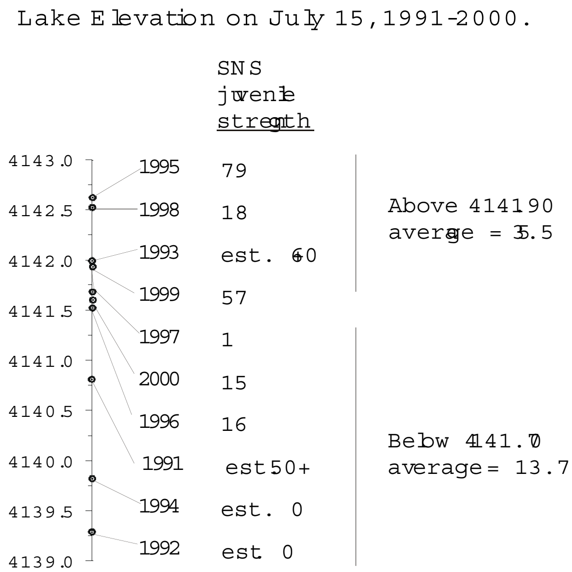


Figure 2. Relationship between Upper Klamath Lake elevation on July 15 and shortnose sucker September juvenile year class strength (Simon et al. 2000). Years 1991–1994 estimated based on fixed cast net and trawl catch per unit effort data.

Some water quality parameters (temperature, pH, dissolved oxygen, and unionized ammonia) frequently reach levels stressful to suckers (Loftus 2000). Lethal effects of water quality on Klamath suckers have been examined in multiple laboratory tolerance studies (Falter and Cech 1991; Castleberry and Cech 1992; Monda and Saiki 1993; Bellerud and Saiki 1995; Saiki et al. 1999). All studies report similar findings. Saiki et al. (1999) found concentrations required to kill at least 50 percent of larvae or juveniles in 96 hr tests were temperatures of 30.3–31.8 C, 0.5–1.1 mg/l ammonia, 10.3–10.4 pH, and 1.3–2.1 mg/l DO. Meyer et al. (2000) examined 14- and 30-day chronic effects and found mortality thresholds from 0.37–0.69 mg/l ammonia, >10 pH, and 1.5–2.0 mg/l DO. In support of the lab studies, positive daytime field collections of juveniles have seldom been associated with these lethal conditions (Simon and Markle 2001 and earlier reports). Poor water quality also may exert a significant indirect effect. Adult fish kills in 1995, 1996, and 1997 were caused by *Flavobacterium columnare*, an opportunistic bacterial infection that is always present but which causes death only when fish are stressed by low oxygen, high pH, warm temperatures, and/or high unionized ammonia. In contrast, Terwilliger et al. (MS) could find no indirect effects of poor water quality on juvenile growth, even during a year of excessively high unionized ammonia levels (1997). They suggest that surviving juveniles may have found water quality refugia.

The fish community of the Klamath Basin has changed in the past century with unknown consequences. Scoppettone (1991) reported 84.5 percent of the fish biomass in UKL is exotic species, and Logan and Markle (1993) reported that exotic fishes were 58 percent of the fish captured in trap nets in Agency Lake and the northern portion of Upper Klamath Lake and 92 percent of the beach seine fish fauna. Fathead minnows represented 59 percent of the fish in trap net samples in Agency Lake and 27 percent in Upper Klamath Lake in 1992 (Simon and Markle 1997). The latter also reported that declines in fathead minnow abundance from 1991–1995 were associated with an increase in some native fishes. Since 1995, patterns have been more complex. In 1998, the year following the 1995–1997 fish kills, beach seine catch rates dropped for age 0 native fishes (suckers, blue chub, and tui chub) but rose for exotic age 0 yellow perch and were unchanged for fathead minnows (Simon and Markle, 2001). Fathead minnows prey on larval suckers in a laboratory setting (L. Dunsmoor, Klamath Tribe, unpublished report) and young yellow perch are known to be opportunistic fish eaters (Hubbs and Lagler 1974). The impacts of exotic species on sucker larvae are unknown, but it has been suggested that management actions enhancing habitat availability or water quality for the benefit of suckers could also have positive effects for exotic species.

Status of endangered suckers

Because the species were poorly studied, the initial cause of concern was declining catches in a popular seasonal snag fishery and elimination of some of those fisheries (Andreasen 1975). Klamath suckers were game fish by Oregon statute and in 1969, Oregon Department of Fish and Wildlife (ODFW) instituted a bag limit of 10 suckers (locally referred to as “mullet”). The “mullet” fishery on Klamath suckers was extremely popular. It was of historical importance to the Klamath Tribe as well as to the rest of the community. 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 the 1960s ODFW’s Klamath Falls office maintained a mailing list of mullet fishermen from Seattle to Los Angeles who were sent a postcard informing them of the timing of the sucker runs. They harvested an estimated 100,000 lbs in 1966 (ca. 12,500 fish) according to ODFW’s Art Gerlach (*Eugene Register-Guard*, May 7, 1967). From 1966 through 1978, ODFW data files show a decline from 3.5–5.6 suckers per fisher before the 1969 bag limit, to 1.5–3.0 suckers per fisher afterwards. From 1966 to 1974, average lengths declined from 25.7 in to 21.3 in, average weight declined from 7.54 lb to 4.9 lb, and number of fish caught per hour declined from 1.19 to 0.87. The decline in catch rate continued through 1986 (Fig. 3).

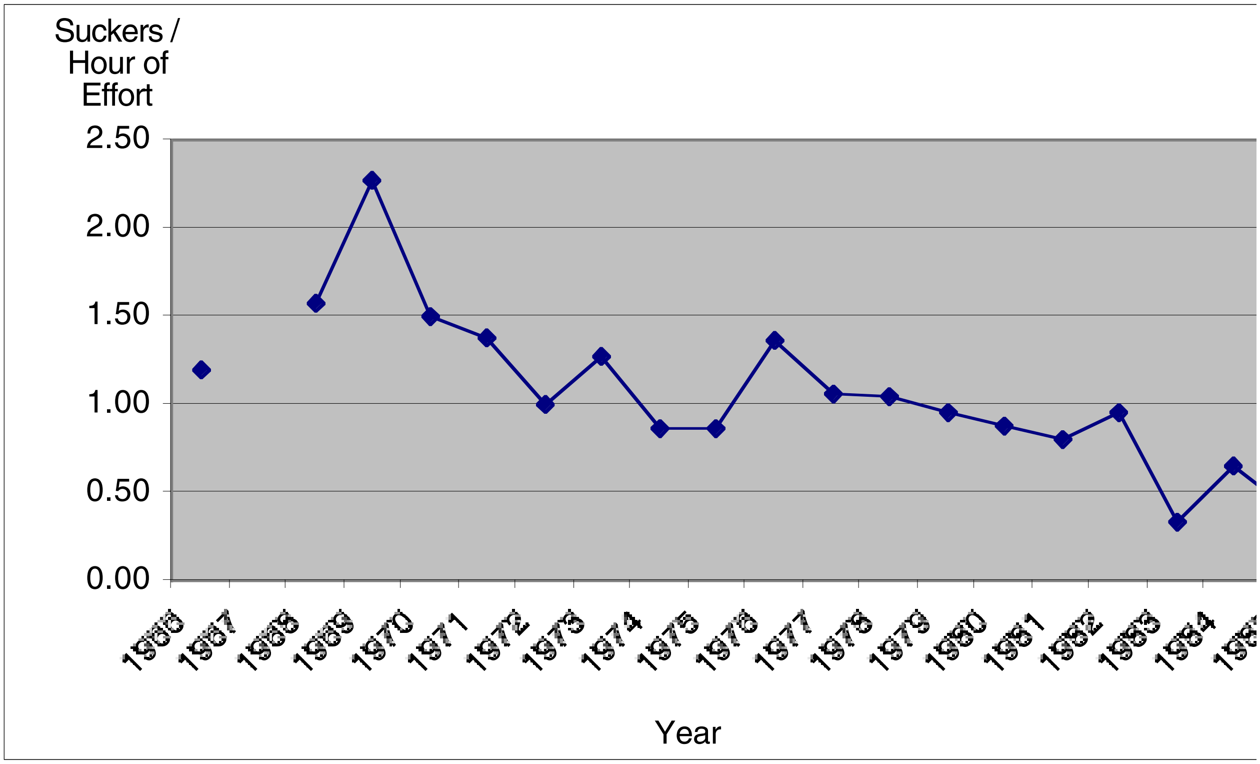


Figure 3. Relationship between sucker catch rate and year (data before 1974 also reproduced in Andreasen 1975).

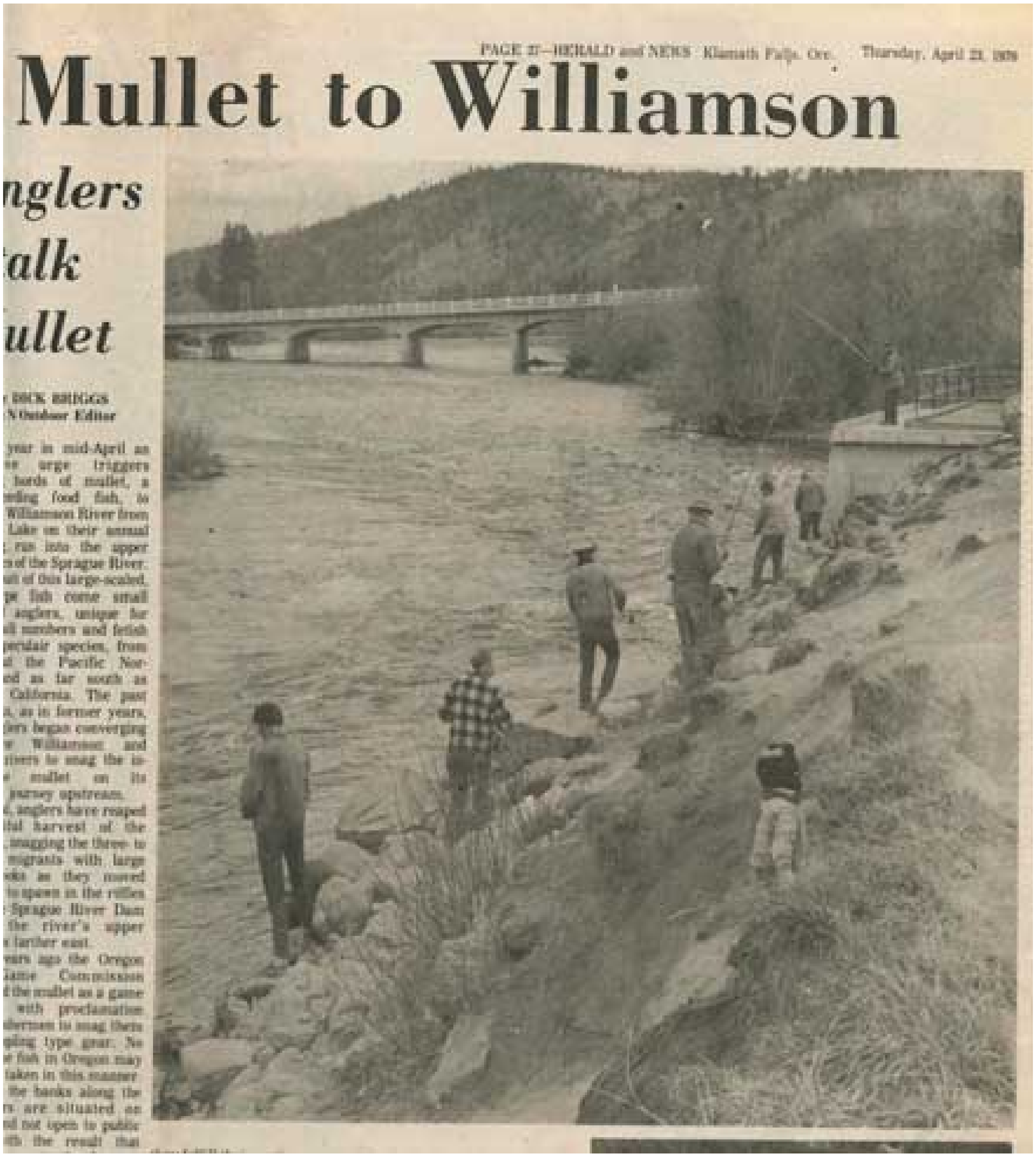
In 1984 and 1985, Bienz and Ziller (1987) estimated the harvest had dropped to 1,262 and 687 fish, respectively, and 92 percent of the 1985 catch was LRS. Thus, in 19 years the catch had dropped about 95 percent from about 12,500 fish to 687. This decline may be understated since ODFW files indicate undersized fish were often discarded and not counted in the 1960–1970s.

The "mullet" fishery was a snag fishery in which anglers used treble hooks weighted with sparkplugs to snag large spawning fish (Figures 3 & 4). There is direct and indirect evidence that the fishery may have contributed to elimination of several spawning groups. During the record-low lake elevations of 1994, Oregon State University researchers mapped shoreline substrates, including the distribution of sparkplugs and treble hooks. Many sites with sparkplugs, such as Ouxy and Sucker Springs, are known sucker spawning sites, but at least four other areas on the eastern shore between Modoc Point and Sucker Springs had treble hooks and spark plugs, as well as flowing springs, suggesting historical sucker spawning (unpublished data).

Numerous other locations are thought to have lost sucker spawning groups in the past 20–-30 years. The last spawning fish were seen at Harriman Springs on the west side of the lake in 1974 (Andreasen 1975) and no spawning has been observed at Barkley Springs on the southeast side of the lake since the late 1970s (Perkins et al. 1998), where extensive habitat modifications limiting access to the spring is thought to have caused extirpation. More than 90 springs were mapped on Bare Island in 1994, many with water too hot (>30C) for spawning, but spawning suckers were reported at a Bare Island spring in the early 1990s, an observation unconfirmed based on surveys in 1997 (Perkins et al. 1998) and 2001 (R. Shively, USGS, personal communication). In Agency Lake sub-basin, sucker spawning was last documented in

Crooked Cr. in 1987 (R. Smith, ODFW, personal observation) and in Fort Cr., Seven Mile Cr., Four Mile Cr., Crystal Cr., and Odessa Springs in the late 1980s and early 1990s. The Wood River may have the last spawning suckers in this subbasin, based on recent captures of a few adult SNS and capture of larvae in 1992 (Markle and Simon 1993; Simon and Markle 1997). In addition, annual monitoring of larval and juvenile suckers in Agency Lake has shown a long-term decline in the 1990s, with only two juveniles caught in 2000 and one juvenile caught in 2001 (Simon and Markle, 2001).

Figure 4. A 1967 "muleteer", Ken Mills showing catch with spark plug/ treble hook snagging gear (Eugene Register Guard, May 7, 1967)



PAGE 27—HERALD and NEWS Klamath Falls, Ore. Thursday, April 23, 1970

Mullet to Williamson

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y DICK BRIGGS
N Outdoor Editor

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Figure 5. Sucker fishers below Highway 97 bridge on Williamson R. (*Klamath Falls Herald and News*, Apr. 23, 1970.)

Several attempts have been made to estimate the size and age structure of sucker populations in UKL (Bienz and Ziller 1987; USFWS 2001). Confidence intervals are large, methodologies differ, and interpretation of these numbers should be cautious. At an order-of-magnitude scale, all of the estimates suggest adult populations between 1984 and 1997 are measured in the low thousands to low 100 thousands. The populations that sustained the fishery in the 1960s and earlier were almost certainly larger. Because there are no reliable long-term adult abundance data, managers have relied on indices. For example, a Williamson River spawning abundance index has been downward since 1995 (Figure 6). This decline was especially disturbing because it coincided with the time when the relatively strong 1991 and 1993 year classes would have been expected to begin spawning.

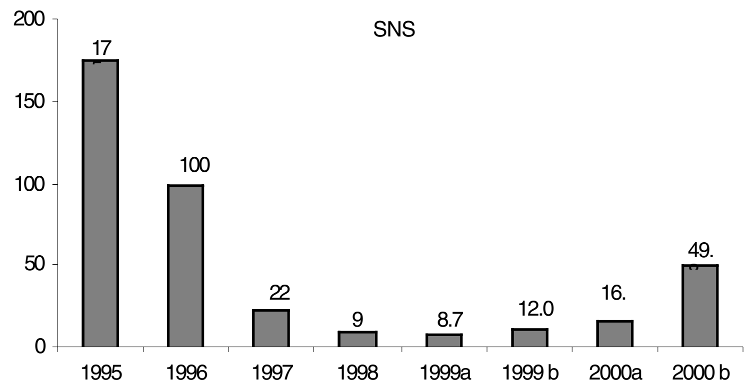

Figure 6. Population index trends in Williamson River spawning runs, 1995–2000 (USGS 2001).

The number of fish killed during the 1995–1997 fish kills is also uncertain, but the numbers collected give some idea of the magnitude of these events. The numbers of dead suckers collected during each fish kill event were 472 (1995), 4,453 (1996), and 2,335 (1997) (Perkins et al., 2000). Collections were not systematic and involved different levels of effort, making interannual comparisons difficult. If the numbers collected are considered minimum estimates, they suggest that the fish kills were at least the same order of magnitude as the snag fishery in the early 1980s and probably as large as or much larger than earlier snag fisheries. The lack of long-term adult abundance data and quantifiable fish kill data is a major data gap.

In the 1980s, the populations in UKL appeared limited by lack of juvenile recruitment and were heavily skewed to older fish, 19–28 yrs (Buettner and Scoppettone 1990; Scoppettone and Vinyard 1991). In the late1990s, successful recruitment from 1991 and 1993 year classes brought in some younger fish (Cunningham and Shively 2000; USFWS 2001), but many older fish appear to have died prematurely, probably because of the fish kills in 1995, 1996, and 1997. Based on lengths of suckers entering the Williamson River in 2000 (Cunningham and Shivley 2001) and ages estimated from a size/age relationship (Buettner and Scoppettone 1990), LRS spawners were 5–35 yrs. and SNS spawners 4–27 yrs with median ages of about 12 yrs (LRS) and 9 yrs (SNS). The ranges and median ages suggest that most of the fish were produced after closure of the fishery. Coupled with the apparent declining adult abundance, the shift in age structure to younger fish means that reproductive potential declined. For example, the loss of large old fish during the fish kills means that even if the adult populations in 1992 and 2001 were the same size, the reproductive potential would have been lower in 2001.

Criteria date-specific monthly elevations of Upper Klamath Lake

The 2001 BiOp (Section III, Part 2, pages 143–145) provides date-specific minimum elevations for UKL and justification (Table 2). Five criteria are presented for minimum lake elevation guidelines; winter-kill, shore-line spawning, young-of-year habitat, water quality, and access to refugia. Each criterion is discussed below.

Table 2. Mandated date-specific minimum levels for UKL and justifications.

Date	Minimum level	Justification criteria
Jan 1	4,141.0	• Reduce potential of winter-kill • Water depth for shore-line spawning
Feb 15	4,141.5	• Water depth for shore-line spawning • Reduce potential of winter-kill
Mar 15	4,142.0	• Water depth for shore-line spawning • Reduce potential of winter-kill
Apr 15	4,142.5	• Water depth for shore-line spawning • Inundated emergent vegetation for y-o-y habitat
June 1	4,142.5	• Inundated emergent vegetation for y-o-y habitat • Moderate water quality
Jul 15	4,141.5	• Inundated emergent vegetation for y-o-y habitat • Moderate water quality • Access to refugia
Aug 15	4,141.0	• Inundated emergent vegetation for y-o-y habitat • Moderate water quality • Access to refugia
Sep 15	4,140.5	• Moderate water quality • Access to refugia
Oct 15	4,140.0	• Moderate water quality • Access to refugia • Reduce potential of winter-kill

Winter kill

"Winter kill" is mass mortality of fishes during winter, usually associated with low dissolved oxygen levels caused by ice cover, which prevents wind-generated re-oxygenation of water. Following ice cover, additional oxygen comes only from photosynthesis, which is also low in winter. Snow on top of ice may exacerbate conditions by further reducing light penetration and photosynthesis. At any given initial concentration, the total amount of dissolved oxygen is a function of volume, thus higher lake elevations equate to more available oxygen.

The rate at which oxygen is removed from water is a function of the biological oxygen demand (BOD, resulting from respiration of living organisms such as bacteria, plants, and fish) and chemical oxygen demand (COD, the reaction of chemicals with oxygen). In UKL, BOD is thought to be notably greater than COD and bacterial decomposition is typically the greatest BOD component.

A fish's vulnerability to winter kill is dependent on many factors, including species and life stage, physiological condition, and severity of the winter. Documenting winter-kill is difficult and has not been documented in Upper Klamath Lake suckers. Simon and Markle (2001) hypothesized that winter kill may occur in Upper Klamath Lake since several species, including juvenile suckers decline by about 90 percent in abundance between late fall and early spring. The 2001 BiOp (page 192) addresses the potential interaction between lake level and winter kill, "there is a higher probability of low DO at lower elevations.…Welch and Burke (2001) estimated…that DO levels would be adverse to suckers after 60 days of ice cover or less. To reduce the risk of catastrophic winter fish kills, they recommended that UKL end of season levels should not go below 4,140 ft and be brought up quickly."

Shore-line spawning

Because there is evidence of loss of in-lake spawning groups, maintaining viable lake-shore spawning is a primary management concern. Lake-shore spawning typically extends from February to May with most in March and April (USGS 2001). Both the number of sites and total surface area for lake-shore spawning is directly related to lake elevation. Surveys of Sucker Springs found >60 percent of spawning was in water greater than 2 ft deep, leading Reiser et al. (2000) to suggest minimum acceptable water depth during spawning season should be 2 ft above lake shore springs. The relationship between lake elevation and percent of spawning habitat at two important eastern shore springs shows 13–45 percent of the spawning substrates will be > 2 ft deep during March and April if the 2001 BiOp elevations are met (Table 3). These elevations equal the pre –Link River dam (1921) elevations for February and March but are 0.44 ft higher than pre-1921 April elevation of 4,142.06 ft (Figs. 7 & 8). The 2001 BA requested lower levels (Fig. 8).

Table 3. Relationship between 2001 BiOp minimum lake elevation (ft above mean sea level (MSL)) and percent of spawning habitat at two important eastern shore springs (from Reiser et al. 2001).

Date	Lake elevation	Potential habitat, % > 2 ft deep	
		Sucker Springs	Ouxy Springs
Feb 15	4,141.5	5	0
Mar 15	4,142.0	27	13
Apr 15	4,142.5	45	33

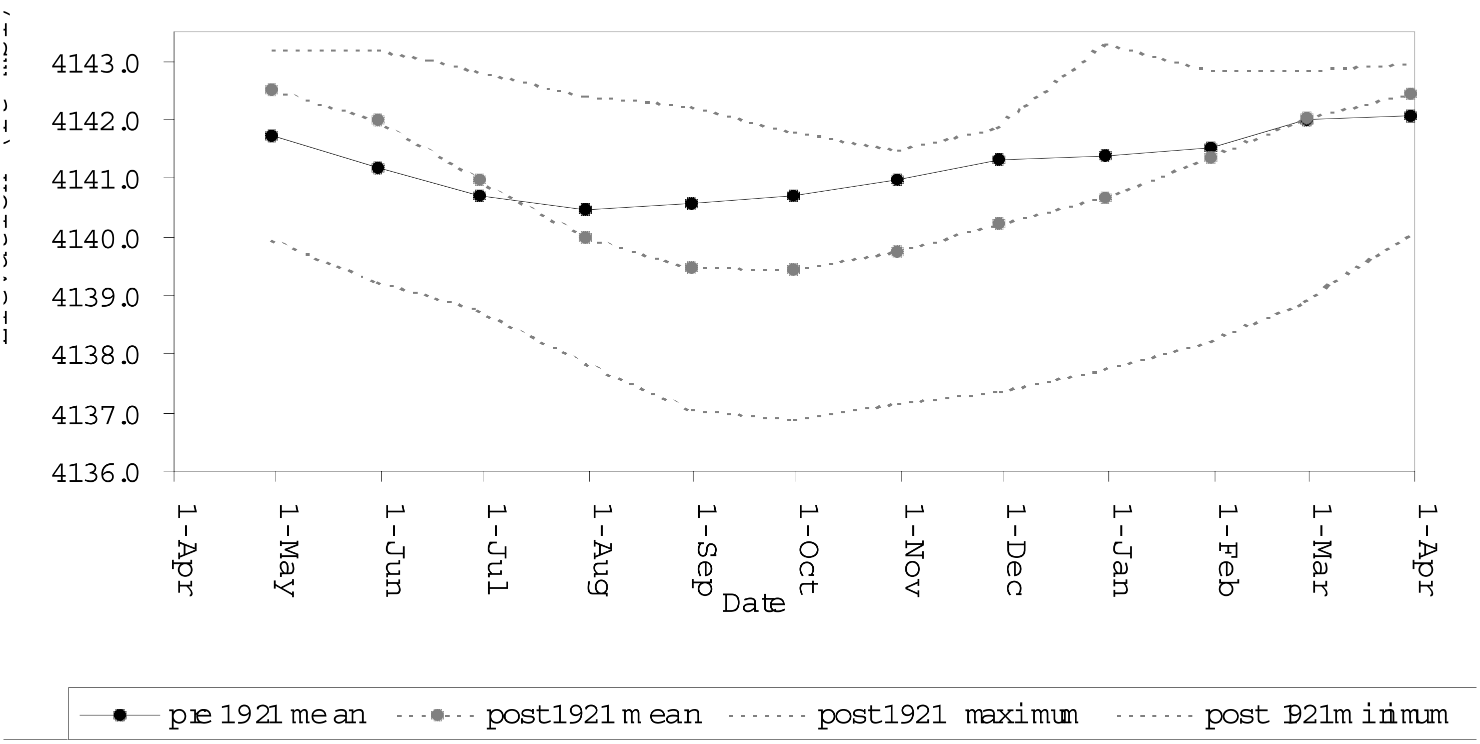

Figure 7. Relationships between lake elevation and month before 1921 and after 1921. Outer dotted lines show total range of variation since 1921.

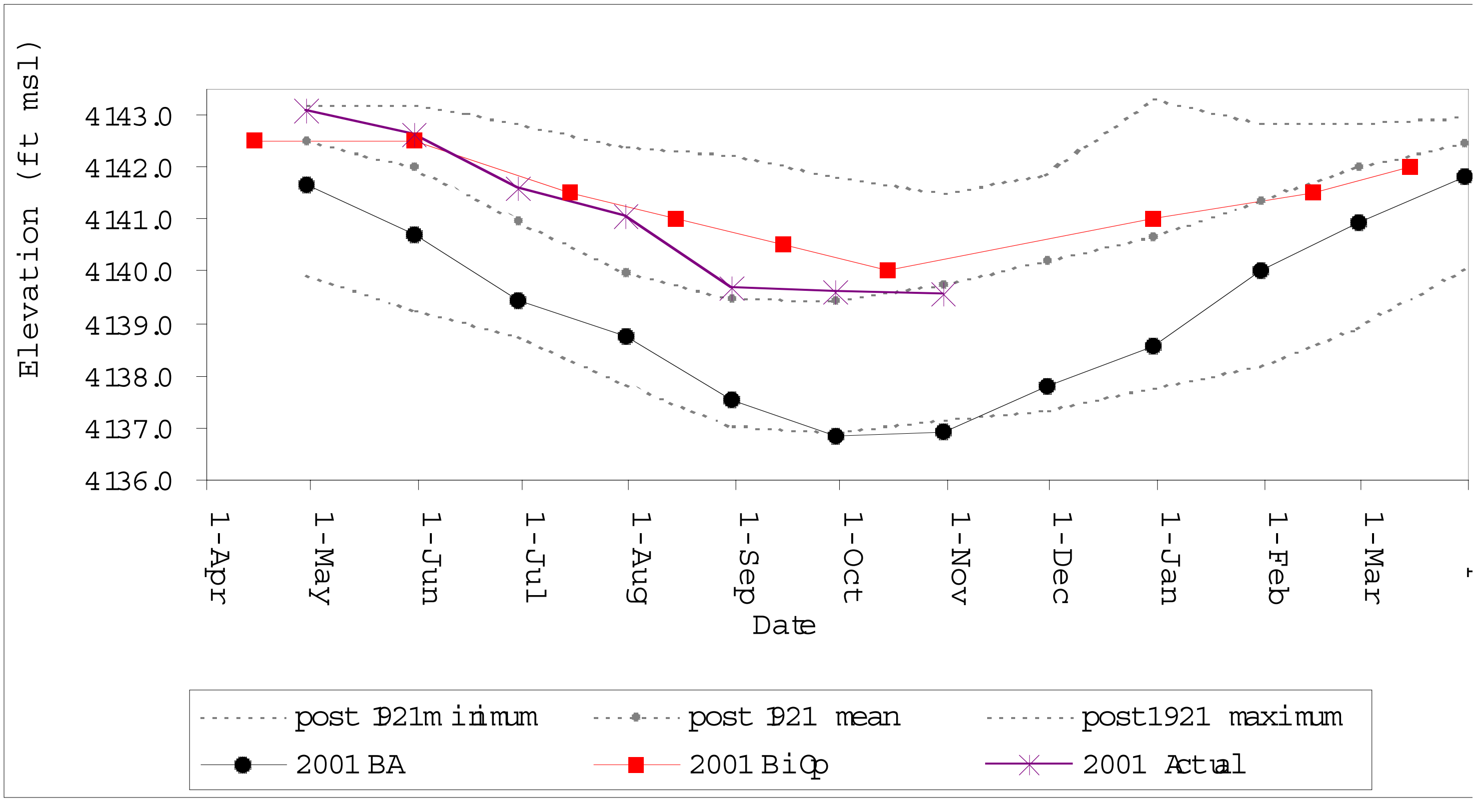

Figure 8. Lake elevations as suggested by the 2001 BiOp, 2001 BA, and actual 2001elevations as permitted with the coho amendment. Dashed lines show mean, minimum, and maximum monthly values since 1921 as in Fig. 7.

Young-of-the-Year habitat

"Young-of-the-Year" (YOY) or "age-0" refers to fish after hatching and before completion of their first winter. YOY suckers typically range from 10 to 75 mm, though LRS may reach 100 mm in years with good growth rates. YOY suckers are subdivided into larval and juvenile stages. Larval suckers typically are in the Williamson River-UKL system from March thru June and juveniles after April. The mouth of the Williamson River and Goose Bay are two areas known to have high concentrations of larval and juvenile suckers and are considered critical rearing grounds. Larval suckers are associated with emergent macrophytes around the periphery of the lake and the edges of the Williamson River. The volume of emergent macrophyte habitat potentially available to young suckers is a function of lake elevation, such that less than 10 percent of emergent macrophytes around the lake periphery are are under 1 foot of water at 4,140 ft, 10–25 percent at 4,141.0, 40–60 percent at 4,142.0 and 85–100 percent at 4,143.0 ft (Reiser et al. 2001). During the time frame YOY suckers are present, the lake levels required by the 2001 BiOp results in availability of about 70 percent of the emergent macrophytes near the mouth of the Williamson River to a minimum of about 5 percent in the Williamson River and Goose Bay.

The relationship between lake elevation and YOY production does not appear to be simple or linear. The minimum elevation set for July 15, 2001 (target—4,141.5 ft, actual 4,141.43 ft) was the fourth-lowest since 1991. Of the 3 years when elevations were lower, a juvenile strength index was zero in 1992 and 1994, when July 15 lake elevations were 4,139.29

ft and 4,139.87 ft, respectively (Figs. 1 & 2). However, in the other low water year, 1991, very good year-classes were produced with a July 15 elevation of 4,140.81 ft. Years with higher lake elevations produce better year classes on average (Figs 1 & 2). These patterns suggest that the 2001 elevation would be expected to produce a poor year-class and preliminary calculations confirm year-class strength for SNS and LRS will be low (Simon and Markle, Oregon State University, unpublished data).

Water quality

Poor water quality has been implicated as a cause of fish kills in 1995, 1996, and 1997 (Perkins et al. 2001). The ultimate cause of the UKL water quality problem is excessive nutrients, especially nitrogen and phosphorous, due to natural inputs, external sources, and internal loading (see Water chapter). UKL was historically eutrophic and the bitter, foul water was described in early accounts (Williamson and Abbot 1857). However, sediment cores of the lake bottom show the nutrient budget of UKL has changed dramatically in the past 50–100 years (Eilers et al. 2001). Sediment cores show increases in the sediment accumulation rate, nitrogen and phosphorus concentrations, and a shift toward the nuisance alga responsible for existing poor water quality (Eilers et al 2001).

"Natural input" is synonymous with "background" concentrations that existed in the absence of "recent," post-1900 human activity. Upper Klamath Basin has extensive upwelling of groundwater containing nitrogen and phosphorous (Water chapter). External sources of nutrients are those that originate "upstream" from UKL and enter the lake via surface water run-off or groundwater upwelling. Multiple anthropogenic activities contribute nutrients to UKL, including cattle grazing, agricultural fertilizer, and drainage of wetland (Bortleson and Fretwell 1993; Snyder and Morace 1997; Risley and Laenen 1999). Soil erosion and domestic sewerage practices are lesser. Wetland soils of the Klamath Basin have a high percentage of organic matter, normally maintained in the soil as refractory material (undecomposed remains of plants), and not biologically available. Drainage of wetlands dries the soil, allows oxygenation that promotes aerobic bacteria which decompose refractory material and produce bio-available nutrients, which can enter UKL either via groundwater discharge or during seasonal pumping of drainage water. The production and export of external nutrient loads to UKL is exacerbated by loss of the filtering effects of wetlands and streamside riparian vegetation. These habitats filter and immobilize nutrients by capturing particulate matter suspended in surface run-off and by uptake of nutrients transported in groundwater (Gregory et al. 1991; Kauffman et al. 1997; Naiman and Décamps 1997).

"Internal loading" is the liberation of nutrients from the lakebed into the water column. Nutrients bound to sediment are not biologically available until liberated into the water column. It is estimated that up to 61 percent of the annual phosphorous budget of UKL comes from internal loading (Kann and Walker 1999). Internal loading is particularly troublesome in UKL because it happens in summer when water quality already may be stressful to fish. The high pH, which can cause stress to fish, also initiates internal loading, triggering or maintaining algal blooms and further exacerbating the situation. A primary contributor to the annual budget of internally loaded nutrients is the decayed remains of previous years' algae.

Although the relationships between nutrient load, water quality, and lake elevation are complex and non-linear, it is thought that higher lake levels promote better water quality (Kann 1995; Loftus 2000; Reiser et al. 2001). Specific mechanisms by which lake elevation influence water quality include, but are not limited to, dilution of nutrients and algae, delaying onset of algae blooms, lower water temperatures via a greater resistance to heating, higher dissolved oxygen availability and re-supply rate, and reduced internal loading. Poor water quality results from large algal blooms interacting with climatic conditions such as speed, direction, and duration of wind. Wind speed has been suggested as a significant influence on oxygen levels in UKL during late summer, and therefore, an important factor in fish kills (USFWS 2001). Wind mixes atmospheric oxygen into the water column but also may re-suspend bottom sediments and liberate nutrients (Laenen and Le Tourneau 1996; Wood 1999). Although wind is not manageable, the 2001 BiOp suggested that higher lake elevations could ameliorate the negative consequences of low summer winds. Therefore, an important management goal must be the reduction in magnitude and intensity of algal blooms so that climatic conditions need not be factored into future decision-making.

Access to refugia

In UKL, water quality refugia are most important when low dissolved oxygen and high temperature, pH, and unionized ammonia create stressful conditions for suckers in late summer and early fall. These conditions are typically created when blue-green algae concentrations are highest or when the algae have begun to die-off. Groundwater springs and the mouths of inflowing tributary streams are sites of better water quality (Buettner and Scoppettone 1990) and may serve as refugia from the stressful conditions of the main lake body (Vincent. 1968). Use of water quality refugia by adults appears to be limited by water depth. Radio-tracked daytime depth of adult suckers indicate a preference for depths of 6–9 ft and avoidance of water 0–3 ft deep (Buettner 2000; Reiser et al. 2001). It is unclear whether suckers will choose poor, deep water over good, shallow water since both behaviors have been observed. Bienz and Ziller (1987) report finding between 100 and 200 adult suckers in Pelican Bay on August 27, 1986, a period when the main body of UKL had poor water quality, and Reiser et al. (2001) report limited evidence that suckers utilize Pelican Bay during episodes of poor water quality. However, these authors and others suggest that the observed suckers were "lethargic" and potentially in poor health. Large numbers of dead suckers were collected from Pelican Bay and other "clear water" areas of the lake during the fish kills of the mid-1990s. Conversely, at lake levels below 4,137.0 ft, suckers have been found to relocate away from the northeast shore of UKL, to the west where deeper water is available but quality is more stressful (Reiser et al. 2001).

The 2001 minimum elevation for UKL on July 15 was 4,141.5 ft and on September 15, 4,140.5 ft. These levels were specified, in part, to ensure adequate water depths in areas of groundwater and tributary inflows so that adult suckers could gain the benefits of high quality water without the presumed stress of shallow water. At levels above 4,141.0, 38–40 percent of the lake has a depth of 6–9 ft, the preferred depth of suckers. At 4,140.0 ft, 27 percent of the lake is in the 6–9 ft depth range, and at 4,139.0 about 18 percent of the lake is in this range (Reiser et al. 2001). Because refugia tend to exist around the periphery of the lake, it is likely that the rate of loss of refugia at preferred depths is greater than for the lake-wide values given above.

The Biological Opinions

Although closure of the snag fishery occurred before federal listing, it was a critical management decision that allowed the remaining old fish the opportunity to reproduce and the populations to begin recovery. All subsequent actions have helped promote recruitment or ensure that some proportion of females live long lives, 20–30+ years. The 1992 BiOp recognized that successful annual recruitment was not expected in long-lived species and allowed 4 in 10 years of compromised (lowered) lake elevation. More recently, a series of fish kills from 1995to 1997 added an adult mortality rate similar to or greater than the annual historical snag fishery. This led to increased uncertainty about previous assumptions, and more recent actions have attempted to increase the probability of recruitment and reduce the probability of fish kills.

Prior to the April 2001 BiOp, The Klamath Project had operated under a 1992 BiOp and subsequent amendments (except in 1997 when the Project operated without a BiOp—R. Larson, personal communication).. The 2001 BiOp is notably more "conservative" in protecting the aquatic system, requiring higher water levels to be maintained in UKL. The movement of the Service to a more conservative stance appears to be linked to four factors—a benefit of the doubt instruction, failure to implement requirements and recommendations specified in the 1992 Biological Opinion, a perception of greater imperilment of the sucker species since 1992, and a greater emphasis on water quality issues since 1992.

The most influential factor appears to be that "Congress instructed the Service to provide the 'benefit of the doubt' to the species of concern when formulating its biological opinion" (H.R. Conf. Rep. No. 697, supra, at 12; p. 124 of 2001 BiOp, page numbers are those for Section III, part 2). When there is uncertainty, as exists in any complex ecosystem such as Upper Klamath Lake, this instruction suggests that the Service always must select upper confidence bands. The difference between 1992 and 2001 decisions appears to be a more optimistic view in 1992 that managing lake elevations near the post-1921 average, stopping the fishery, salvaging suckers from irrigation ditches, and enhancing spawning sites would lead to recovery. The large fish kills observed during this management regime suggest doubt about this optimistic view.

Failure to implement specific recommendations and requirements delineated in the 1992 BiOp was also identified as a factor in the more conservative approach of the 2001 BiOp. Specific issues included installation of a fish screening device to limit entrainment of suckers to the A-Canal, rehabilitation of Barkley Springs, assessing methods of improving sucker passage over Sprague River Dam in Chiloquin, and identifying ways to reduce the projects demand for water and augment supply.

In the Reasonable and Prudent Alternative section of the 1992 BiOp, USFWS wrote, "Reclamation shall implement a method to reduce entrainment of larval, juvenile, and adult Lost River and shortnose suckers into the A-Canal within five years of issuance of this biological opinion." On page126 of the 2001 BiOp, USFWS wrote, "Reclamation has not complied with installation of a screen facility requirement on the A-Canal, as directed by an amendment to an RPA in the 1992 BiOp, and has at this time committed to no additional screening at any of its facilities. 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." Entrainment of suckers to the A-Canal is significant (Gutermuth, 2000). Salvage operations aim to rescue suckers that are stranded in the A-Canal at the end of irrigation season, but the efficiency of salvage is unclear because the percentage of fish entrained and returned in a viable condition to UKL is unknown and salvage does not rescue larval or smaller juvenile suckers. It is unclear how failure to screen the A-Canal influenced the Service's decision process for 2001. Because low water elevations allowed for in the 1992 BiOp are now considered to jeopardize suckers, it seems reasonable to conclude that water elevation requirements would not have been more "relaxed" had the A-Canal been screened in compliance with the 1992 BiOp.

Three additional recommendations developed in the 1992 BiOp but not resolved by 2001 are the restoration of Barkley Springs, improving fish passage around the Sprague River Dam, and reducing the demand for water by the irrigation community. Point 8 of "possible mitigation measures" of the 1992 BiOp states, "Historically Barkley Springs was the site of prolific spawning activity. Thirty years ago Hagelstein Park was developed by Klamath County in the immediate vicinity of the springs. Construction of the park included diking, ponding, and the rerouting of water. This caused spawning to essentially cease, although it has been reported that as late as 1973 great numbers of suckers attempted to reach this traditional spawning ground. This work would be completed in time for the sucker spawning runs in March of 1993." In 1993, Reclamation added spawning substrate at two locations at the spring and in 1995 installed a water control device to attempt to ensure the spawning areas were kept at adequate depth throughout the spawning season. Despite these efforts, no sucker spawning has been observed at Barkley Springs in the past decade (M. Buettner, Bureau of Reclamation, personal communication).

Point 9 of the 1992 BiOp states, "Assess Methods to Improve Passage in the Sprague River. If a feasible plan is determined before March 1993, Reclamation will attempt to implement it before spawning in 1993." Between 1992 and 2001, no changes were made to the Sprague River Dam. The Sprague Basin above the dam has been extensively modified from its pre-dam condition, including loss of riparian zones and establishment of exotic fish species. It is unclear whether suckers hatched in the Sprague River would survive in sufficient numbers due to water quality and exotic fishes. It is also unclear whether there would be significant downstream impacts from the release of sediments accumulating behind the dam, although a Reclamation study done in 1997 documented little sediment deposition behind the dam (Mark Buettner, Bureau of Reclamation, personal communication). Both of these issues appear to have contributed uncertainty about the wisdom of removing or modifying Sprague River Dam.

It is not clear whether implementation of the actions called for in the 1992 BiOp would have changed the decision in the 2001 BiOp. Presumably, if screening had been done and suckers re-established at Barkley Springs and the Sprague River, and these actions could be linked to increased recruitment of juveniles, Service might have concluded that a lower lake elevation was reasonable and prudent. However, the third and fourth caveats, below, suggest in the short term at least, that this is not true.

The third factor influencing Service's shift to a more conservative approach was their position that UKL suckers are more imperiled now than they were in 1992. Page 156 of the 2001 BiOp states, "However, the RPAs have not been fully implemented and evidence now indicates that the two endangered sucker species are more imperiled than when previous opinions were issued." Increased imperilment is not well documented because it has been difficult to get rigorous estimates of the annual adult population size. Instead, the Service noted declines in spawning run indices (Fig. 6) and estimated losses from fish kills in 1995, 1996, and 1997. However, the responses of the populations from 1988 to 1995 are not clear. Essentially, the populations appear to have been increasing from 1988–1995, but those gains were lost in the 1995–1997 fish kills. Because of uncertainty in the adult abundance information it is possible that the authors of both decisions presumed population estimates of about the same order of magnitude.

Even if the Service agreed that population abundances were similar in 1992 and 2001, there are differences in reproductive potential. The older fish present in 1992 would have had much greater reproductive potential than the younger fish in 2001. In addition, the 2001 BiOp uses new information to show that two aspects of the 1992 opinion (Table I-2) required revision. The first was that the 4-in-10-year compromised (lower) elevation of 4,137 ft would jeopardize suckers based on lake elevation—water quality interactions and sucker recruitment and survival. The empirical data from the 2 lowest years (1992 and 1994) show no recruitment (Figs. 1 & 2) and no fish kills, but the latter may have been avoided because of climactic conditions (2001 BiOp). The higher lake elevations required in the 2001 BiOp do not relate solely to water quality and also include access to preferred habitats, and possible delayed effects. Left unanswered is whether compromised elevations of any elevation or frequency create jeopardy. The second is that the uncompromised minimum elevation of 4,139 ft would jeopardize suckers. The BiOp does not show that this elevation is a threat, but given certain climate outcomes, it says it might be a threat. On page 106 of the 2001 BiOp, "The Service acknowledges that meeting prescribed lake elevations does not ensure year-class success or prevent sucker die-offs. Other factors including weather, *AFA* bloom dynamics, disease outbreaks, and poor water quality can all lead to year-class failure and sucker die-offs independent of lake level. However, both Reclamation and the Service recognize that high lake elevations can enhance the probability of year-class survival and reduce the frequency and magnitude of major sucker die-offs, and is the only short-term way to offset some of the threat to sucker populations in UKL." In other words, "Since winds cannot be managed, summer and early fall lake levels in UKL need to be managed near the higher pre-project levels to reduce risk of catastrophic fish kills" (p. 86).

The empirical data suggest uncertainty regarding the size of the benefit of higher lake elevations. Even in "expected" wind-speed ranges with July–August lake elevations greater than 4,141 ft, the data show that a fish kill happened in 2 of 6 years (1995 and 1997). As expected in the worse case "weak wind scenario," a July–August elevation of 4,140.8 ft also was associated with a fish kill (1996). The 2001 BiOp recognizes other factors, primarily AFA bloom dynamics and disease, as confounding this relationship, but as cited above (p. 195), considers higher lake levels as a means to reduce the negative consequences of these unmanageable factors. Because each year provides a different set of circumstances, it is important that long-term data sets be maintained and that modeling and empirical analyses continue.

In summary, the 2001 BiOp makes a case for revising the conditions of the 1992 BiOp. The 2001 BiOp suggests that lowered lake levels are no longer reasonable because of concerns for water quality, population size, age structure, and recruitment. Essentially, the experience since the 1992 BiOp demonstrated uncertainty about the previous choice of a minimum lake elevation. The population size and age structure necessary for lower or compromised lake levels to again be considered reasonable or prudent is not described. Further support for the more restrictive water management program is the congressional instruction to provide "benefit of the doubt," supplemented by a belief in greater imperilment of the species, failure to implement prior requirements, and an increased concern for water quality. The 2001 BiOp makes a case that the 4-in-10-year compromised elevation of 4,137 ft might create jeopardy, but it does not address whether compromised elevations or their frequency can be considered reasonable and prudent in the future. The BiOp also presents an argument for raising the uncompromised elevation 1 foot to 4,140 ft. The argument is primarily based on a potential indirect benefit to ensure against low wind speeds, but the amount of insurance provided by 1 foot of lake elevation is not described.

The decision process

Although there was no requirement for peer review, the 2001 BiOp was sent to peer reviewers as a rough draft (dated February 5, 2001) and as a final document (dated April 5, 2001). The rough draft was reviewed by researchers actively working in the Basin and the final draft reviewed by additional groups (University of California Davis, the Governor's Independent Multidisciplinary Science Team, and the National Research Council). Widespread misunderstanding of the peer review process was evident in the local community. Ideally, peer review is constructively critical, but our negative critical review of the rough draft received wide circulation while more positive critical reviews of the final draft by us, and others, did not. To some extent it appeared that peer criticisms of the BiOp were equated with the idea that there were no problems for suckers—an incorrect interpretation. The intellectual process of science is iterative, as it applies to both single documents and to long-term management. In the case of Upper Klamath Lake management, the 2001 BiOp was a new iteration of the 1992 BiOp. For example, changes from the 1992 BiOp might have been due to changes in the abundance, and therefore the perceived threat to suckers, or to changes in the nature of the threats. The 2001 BiOp made both claims and the function of peer review was to critically challenge them. Some claims, such as changes in adult abundance since 1992, were not well documented. Challenges to those claims did not mean that the populations were healthy. The primary evidence was declines since 1995, but there were apparently increases in the late 1980s to early 1990s, such that abundances in 2001 may not have been substantially different than 1992 even though age structure probably was different. Other claims, such as fish kills, were well documented and substantially altered the nature of threats.

The public is not served when it misunderstands or is misled by the critical nature of peer review. It is a process that seeks to refine and improve data collection, analysis, and interpretation. The use of critical peer reviews to claim that the decision or the process behind the 2001 BiOp were based on "junk science" is wrong, confounds a difficult situation, and deflects energies away from solving real problems.

Acknowledgments

Reviews of a draft of this manuscript were provided by M. Buettner, L. Dunsmoor, J. Kann, R. Larson, K. Rykbost, R. Shively and T. Welch. Their critical comments improved the chapter and we are grateful for their help.

Literature cited

Andreasen, J.K. 1975. Systematics and status of the family Catostomidae in southern Oregon. Doctoral dissertation. Oregon State University, Dept. fisheries and wildlife. Corvallis, OR.

Bellerud, B. and M.K. Saiki. 1995. Tolerance of larval and juvenile Lost River and Shortnose suckers to high pH, ammonia concentration, and temperature, and to low dissolved oxygen concentration. National Biological Service, California Pacific Science Center.

Beverton, R.J.H. 1986. Longevity in fish: some ecological considerations. Basic Life Sci. 42:161-185.

Bienz, C. and J. S. Ziller, 1987. Status of three lacustrine sucker species (Catostomidae). Report to U. S. Fish and Wildlife Service, Sacramento, CA., 39 pp.

Borisov, V.M. 1978. The selective effect of fishing on the population structure of species with a long life cycle. J. Ichthyol. 18:896-904.

Bortleson, G.C. and M.O. Fretwell. 1993. A review of possible causes of nutrient enrichment and decline of endangered sucker populations in Upper Klamath Lake, Oregon. Portland, OR, United States Geological Survey. Water Resources Investigation Report 93-4087

Buettner, M. 2000. Analysis of Tule Lake water quality and sucker telemetry, 1992-1995. U.S. Bureau of Reclamation, Klamath Basin Area Office, Klamath Falls, OR. March.

Buettner, M. and G. Scoppettone. 1990. Life history and status of Catostomids in Upper Klamath Lake, Oregon. A cooperative study by National Fisheries Research Center, Reno, Nevada, and the Klamath Indian Tribe, Chiloquin, Oregon, and Oregon Deptartment of Fish and Wildlife, Corvallis, Oregon.

Castleberry, D.T. and J.J.J. Cech. 1992. Critical thermal maxima and oxygen minima of five fishes from the Upper Klamath Basin. California Fish and Game 78: 145-152.

Cooperman, M.S. and D.F. Markle. 1999. Ecology of Upper Klamath Lake shortnose and Lost River suckers 2. Larval ecology of shortnose and Lost River suckers in the lower Williamson River and Upper Klamath Lake. 1999 annual report. Oregon State University, Dpeartment Fisheries and Wildlife, Corvallis, OR. Submitted to US Bureau of Reclamation, Klamath Falls Office, Klamath Falls, OR.

Cunningham, M.E. and R.S. Shively. 2001. Monitoring of Lost River and shortnose suckers in the lower Williamson River, 2000. In Monitoring of Lost River and shortnose suckers in the Upper Klamath Basin, 2000. Annual report of research to the U.S. Bureau of Reclamation. 29 pp. Contract # 00AA200049.

Eilers, J., J. Kann, J. Cornett, K. Moser, A.S. Amand and C. Gubala. 2001. Recent paleolimnology of Upper Klamath Lake, Oregon. Report to US Bureau of Reclamation, Klamath Falls Office, Klamath Falls, OR. by JC Headwaters, Inc., Roseburg, OR.

Falter, M.A. and J.J.J. Cech. 1991. Maximum pH tolerance of three Klamath basin fishes. Copeia 1991: 1109-1111.

Gregory, S.V., F.J. Swanson, W.A. McKee and K.W. Cummins. 1991. An ecosystem perspective of riparian zones: Focus on the links between land and water. Bioscience 41: 540-550.

Goodman D. 1984. Risk spreading as an adaptive strategy in iteroparous life histories. Theoret. Popul. Biol. 25:1-20.

Gutermuth, B., E. Pinkston, and D. Vogel. 2000. A-canal fish entrainment during 1997 and 1998 with emphasis on endangered suckers. New Earth/Cell Tech: Research and Development Dept., Klamath Falls, OR. In collaboration with Natural Resource Scientists, Inc., Red Bluff, CA. Report to the Bureau of Reclamation under grant 8-FG-20-16580. 51 pp.

Houde, E. D. 1987. Fish early life dynamics and recruitment variability. American Fisheries Society Symposium 2:17-29.

Houde, E.D. 1994. Differences between marine and freshwater fish larvae: implications for recruitment. ICES Journal of Marine Sciences 51: 91-97.

Hubbs, C.L. and K.F. Lagler. 1974. Fishes of the Great Lakes Region. The University of Michigan Press.

Kann, J. 1995. Effect of lake level management on water quality and native fish species in Upper Klamath Lake, Oregon. Klamath Tribes Natural Resources Department. Chiloquin, OR.

Kann, J. and W.W. Walker. 1999. Nutrient and hydrologic loading to Upper Klamath Lake, Oregon, 1991-1998. Report prepared for Klamath Tribes Natural Resource Department and US Bureau of Reclamation: 48 pgs.

Kauffman, J.B., R.L. Beschta, N. Otting and D. Lytjen. 1997. An ecological perspective of riparian and stream restoration in the western United States. Fisheries 22: 12-24.

Laenen, A. and A.P. Le Tourneau. 1996. Upper Klamath basin nutrient loading study - Estimate of wind-induced resuspension of bed sediment during periods of low lake elevation. USGS Open File Report 95-414. Portland, OR.

Leaman, B.M and R.J. Beamish. 1984. Ecological and management implications of longevity in some northeast Pacific groundfishes. Int. North Pac. Fish. Comm. Bull. 42:85-97.

Loftus, M.E. 2000. Assessment of potential water quality stress to fish. Prepared by R2 Resource Consultants, Redmond, WA.

Logan, D. and D.F. Markle. 1993. Fish faunal survey of Agency Lake and northern Upper Klamath Lake, Oregon. Pages 251-278 *in* S.G. Campbell, ed. Environmental research in the Klamath Basin, Oregon: 1992 annual report. Technical report R-93-16. US Bureau of Reclamation, Denver office, Colorado.

Markle, D.F. and Simon, D.C. 1993. Preliminary studies of systematics and juvenile ecology of Upper Klamath Lake suckers — Final report. Oregon State University, Dept. Fisheries and Wildlife, Corvallis, OR. 129 pgs.

Meyer, J.S., H.M. Lease and H.L. Bergman. 2000. Chronic toxicity of low dissolved oxtgen concentrations, elevated pH, and elevated ammonia concentrations to Lost River suckers (*Deltistes luxatus*) and swimming performance of Lost River suckers at various temperatures. Research report. Univ. of Wyoming, Laramie, WY.

Monda, D. and M.K. Saiki. 1993. Tolerance of juvenile Lost River and shortnose suckers to high pH, ammonia concentration, and temperature, and to low dissolved oxygen concentration. Final technical report. U.S. Fish and Wildlife Service, National fisheries contaminant research center, Dixon, CA. 68pgs.

Naiman, R.J. and H. D camps. 1997. The ecology of interfaces: Riparian Zones. Annual Review of Ecological Systems 28: 621-58.

Perkins, D., G.G. Scoppettone, and M. Buettner. 2000a. Reproductive biology and demographics of endangered Lost River and shortnose suckers in Upper Klamath Lake, Oregon. Unpublished manuscript. USGS-BRD, Reno, NV.

Perkins, D.L., J. Kann and G.G. Scoppettone. 2000b. The role of poor water quality and fish kills in the decline of endangered Lost River and shortnose suckers in Upper Klamath Lake, USGS-Biological Resource Division report, submitted to US Bureau of Reclamation, Klamath Falls project office, Klamath Falls, OR. Contract 4-AA-29-12160.

Reiser, D.W., M. Loftus, D. Chapin, E. Jeanes and K. Oliver. 2001. Effects of water quality and lake level on the biology and habitat of selected fish species in Upper Klamath Lake. R2 Resource Consultants, Inc. Redmond, WA.

Risley, J.C. and A. Laenen. 1999. Upper Klamath Lake basin nutrient loading study - Assessment of historic flows in the Williamson and Sprague Rivers. USGS Water Resource Investigation Report 98-4198. Portland, Or. 28 pgs.

Saiki, M.K., D.P. Monda and B.L. Bellerud. 1999. Lethal levels of selected water quality variables to larval and juvenile Lost River and shortnose suckers. Environmental Pollution 105: 37-44**.**

Scoppettone, G. G. and G. Vinyard, 1991. Life history and management of four endangered lacustrine suckers, pp. 359-377, in W. L. Minckley and J. E. Deacon (eds). Battle against extinction, native fish management in the American West. Univ. Arizona Oress, Tuscon, AZ, 517 p.

Schultz, D.L 1989. The evolution of phenotypic variance with iteroparity. Evolution 43: 473-475.

Simon, D. and D. F. Markle, 1997. Interannual abundance of nonnative fathead minnows (*Pimephales* promelas) in Upper Klamath Lake, Oregon. Great Basin Naturalist, 57:142-148.

Simon, D.C., M.R. Terwilliger, P. Murtaugh, and D.F. Markle. 2000. Larval and juvenile ecology of Upper Klamath Lake suckers: 1995-1998. Report submitted to US Bureau of Reclamation, Klamath Falls office, Klamath Falls, OR. April.

Simon, D. and D. F. Markle, 2001. Annual survey of abundance and distribution of age 0 shortnose and Lost River suckers in Upper Klamath Lake. Annual report to US Bureau of Reclamation, Klamath Falls, OR, 59 pp.

Simclair, M., 1988. Marine populations, an essay on population regulation and speciation. Univ. Washington Press, Seattle, 252 p.

Snyder, D.T. and J.L. Morace. 1997. Nitrogen and Phosphorous loading from drained wetlands adjacent to Upper Klamath and Agency Lakes, Oregon. USGS with cooperation from the Bureau of Reclamation. Water Resources Investigation Report 97-4059. Portland, OR.

Terwilliger, M. R., P. A. Murtaugh , J. Kann, and D. F. Markle. MS. In review. Associations between water quality and daily growth of juvenile shortnose and Lost River suckers in Upper Klamath Lake, Oregon. Trans. Am. Fish. Soc.

USGS. 2001. Monitoring of adult Lost River and shortnose suckers in the Upper Klamath Basin, 2000. Annual report of research to the U.S. Bureau of Reclamation, Mid-Pacific Region, Klamath Area Office. 114 pgs.

USFWS. 1993. Lost River (*Deltistes luxatus*) and Shortnose (*Chasmistes brevirostris*) Sucker Recovery Plan. Portland, OR.

USFWS. 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 brevirostri*s), threatened bald eagle *(Haliaeetus leucocephalu*s) and proposed critical habitat for the lost river/shortnose suckers. Klamath Falls, OR., Dept. of the Interior**:** 295 pgs.

Vincent. 1968. The influence of some environmental factors on the distribution of fishes in Upper Klamath Lake. Oregon State University, Dept. Fisheries and Wildlife, Corvallis, OR.

Welch, E.B. and T. Burke. 2001. Interim Summary Report: Relationship between lake elevation and water quality in Upper Klamath Lake, Oregon. Prepared by R2 Resource Consultants, Inc. Redmond, WA. Prepared for US Bureau of Indian Affairs. March.

Williamson, L.R.S. and L.H.L. Abbot. 1857. Reports of explorations and surveys to ascertain the most practicable and economical route for a railroad from the Mississippi River to the Pacific Ocean. Washington, D.C., Department of Defense.

Wood, T.M. 1999. Sediment oxygen demand in Upper Klamath and Agency Lakes, Oregon.
USGS Water Resources Investigation Report 01-4080**;** 13 pgs. Portland, OR.

Draft
December 14, 2001

Review of the relationships between bald eagle biology and federal environmental decisions on the Klamath Project

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Introduction

The bald eagle (*Haliaeetus leucocephalus*) historically ranged throughout North America except in extreme northern Alaska and Canada and central and southern Mexico (Stalmaster 1987). One-quarter to one-half million bald eagles were present on the North American continent when Europeans first arrived (Gerrard and Bortolotti 1988). Populations exhibited a slow but widespread decline due to habitat loss, decline of wintering foods (e.g., bison carrion, anadromous fishes, waterfowl, shorebirds), and persecution from the time of European settlement. The first major decline in the bald eagle population probably began in the mid- to late 1800's (Gerrard and Bortolotti 1988). Nesting sites were lost to shore development, and eagles were shot, trapped, and poisoned as livestock predators (Dale 1939). Alaska paid a bounty for killing eagles between 1917 and 1952. Eagles were believed to prey on domestic lambs and so were shot by many sheep ranchers, and beginning in the 1930's, shot from aircraft (Dale 1939). These, and other factors, reduced bald eagle numbers through the 1930's.

During the 1940's, dichloro-diphenyl-trichloroethane (DDT) was used to control mosquitoes in coastal and wetland areas. As a result of foraging on contaminated prey, the bald eagle decline accelerated. In the late 1960's and early 1970's, it was determined that DDE, the principal breakdown product of DDT, had built up in the fatty tissues of adult female bald eagles and prevented the calcium release necessary to produce strong egg shells. This consequently caused reproductive failure throughout the range of the bald eagle. In response to the decline, on March 11, 1967, the Secretary of the Interior listed those populations of the bald eagle south of the 40th parallel as endangered under the Endangered Species Preservation Act of 1966. However, the decline continued until DDT was banned from use in the United States on December 31, 1972. In 1978, the eagle was listed as endangered throughout the lower 48 states except Michigan, Minnesota, Wisconsin, Washington, and Oregon, where it was designated as threatened (USDI 1978).

In the 1970's, the U.S. Fish and Wildlife Service (USFWS) developed a recovery program for the bald eagle that divided the lower 48 states into five geographically separate recovery regions. Because the bald eagle had met most numerical population goals established in the Recovery Plan, it was reclassified as threatened in all of the lower 48 states in 1995 (USDI 1995). It has recovered across most of its range, with the population essentially doubling every 7 to 8 years (USFWS 1999). In 1998, the total population in the lower 48 states exceeded 5,748 nesting pairs, thereby providing support for the proposal to remove the bald eagle from the

Federal endangered species list in 1999 (USFWS 1999). The proposal to delist the species is still pending.

Because of its location, high prey abundance, and relatively mild winter weather conditions, the Klamath Basin of Oregon and California supports the largest wintering population of bald eagles in the United States (over 1,000 individuals have been counted during a single winter day) outside of Alaska. The Oregon portion of the Klamath Basin Management Zone (KBMZ), as defined in the Bald Eagle Pacific Recovery Region (PRR) Recovery Plan (USFWS 1986), supports 117 breeding pairs of eagles (31percent of the population in Oregon; Isaacs and Anthony 2000). Bald eagles in the Klamath Basin feed primarily on waterfowl and fish (Frenzel 1985), among other prey species. According to the 2001 biological assessment for the Klamath Project (page 60), "the manipulation of the timing and amount of water available across the landscape of the Upper Klamath Basin (which is largely controlled by the Klamath Project) directly and indirectly affects the survival of bald eagle populations." The following sections provide information on the legal status of bald eagles, aspects of their biology in the PRR and KBMZ, and current federal environmental documentation and decisions.

Legal status

Bald eagles in the Klamath Basin receive protection under two state and four federal environmental acts. The type and initiation of protection provided by each act is described below:

1. California Endangered Species Act: the bald eagle was listed as endangered in 1971, with a revision in 1980. The eagle is currently considered endangered at nesting and wintering sites.
2. Oregon Endangered Species Act: listed as threatened.
3. Migratory Bird Treaty Act (16 U.S.C. 703): passed in 1918, affords protection to bald eagle adults, nests, and nest contents.
4. Bald Eagle Protection Act (16 U.S.C. 668): passed in 1940, made it illegal to kill, harm, harass, or possess bald eagles, alive or dead, including eggs, feathers and nests.
5. Lacey Act (SS 42): passed in 1981, prohibits bald eagle importation into the United States or any territory of the United States.
6. U.S. Endangered Species Act of 1973 (ESA): in 1978, listed as endangered throughout the lower 48 states except Michigan, Minnesota, Wisconsin, Washington, and Oregon, where it was designated as threatened (43 FR 6233, February 14, 1978). Because the main goal of the Federal Endangered Species Act is to restore endangered and threatened species to the point where they are again viable, self-sustaining members of their ecosystems, the ESA contains provisions for recovering a species after it is listed.

In the 1970's, the USFWS developed a recovery program for the bald eagle that divided the lower 48 states into five geographically separate recovery regions. The Pacific Recovery Region consists of California, Nevada, Oregon, Washington, Idaho, Montana, and Wyoming. A recovery plan was prepared for each recovery region, and the plan for the PRR was completed in 1986 (USFWS 1986). The plan states that "the primary objective … is to outline steps that will provide secure habitat for bald eagles in the 7-state Pacific Recovery Region and increase populations in specific geographic areas to levels where it is possible to delist the species." Each state is further divided into management zones; Oregon encompasses 10 zones, in part or whole, one of which is the KBMZ. The Pacific Recovery Plan specified that delisting should occur on a region-wide basis, and should be based on 4 criteria:

a. a minimum of 800 pairs nesting in the 7-state PRR;
b. nesting pairs should produce an annual average of at least 1.0 fledged young per year per pair, with an average success rate per occupied site of not less than 65 percent over a 5-year period;
c. population recovery goals must be met in at least 80 percent of the management zones; and
d. a persistent, long-term decline in any wintering populations greater than 100 eagles would provide evidence for not delisting the species.

Because it has met most numerical population goals in the United States, the bald eagle was reclassified as threatened in all of the lower 48 states in 1995 (USDI 1995), and in 1999 was proposed for removal from the Federal endangered species list (USFWS 1999).

The bald eagle is also afforded additional consideration and/or protection by the Convention on International Trade in Endangered Species, Clean Water Act, Federal Land Policy and Management Act, Fish and Wildlife Coordination Act, and National Environmental Policy Act.

Management activities

Consideration of bald eagles in land use management has increased tremendously since the federal listing of the species in 1978. In Oregon and California, the special needs of bald eagles are incorporated in land management plans developed by all of the major federal landowners, including the National Park Service, U.S. Forest Service, Bureau of Land Management, Department of Energy, Department of Defense, U.S. Army Corps of Engineers, Bureau of Reclamation (BOR), and the USFWS Refuge System. Native American Tribes are also committed to monitoring and managing bald eagles under their jurisdiction.

The ESA extends additional consideration of bald eagle needs to every project that receives federal funds or requires a federal permit. This requirement produces benefits to bald eagles through required project modifications, such as avoidance, minimization, and mitigation measures associated with a wide variety of activities including land and water development projects, transportation projects, hydroelectric dam licensing, irrigation systems operation, airport operations, and any work carried out with federal grant monies.

Nesting surveys

The Oregon Cooperative Fish and Wildlife Research Unit, located at Oregon State University, has monitored occupied bald eagle territories throughout Oregon and the Washington portion of the Columbia River Recovery Zone since 1971 (Isaacs and Anthony 2001). The Research Unit monitors previously active territories and searches for new ones each year (Isaacs, personal communication). In their 2001 report, Isaacs and Anthony (2001) provided a list of previously unknown sites and nests, a summary of activity and productivity for Oregon and the Columbia River Recovery Zone, landowners with bald eagle nest trees in Oregon, activity and productivity for the last 5 years by recovery zone, highlights of the survey, and population and productivity graphs. Contributors to this extensive effort include numerous Federal and state agencies, local families, and foundations.

Midwinter bald eagle surveys

Midwinter surveys of bald eagles have been conducted across the nation for four decades. In 1979, the National Wildlife Federation assumed the task of coordinating a nation-wide combined agency and private volunteer winter count (Knight et al. 1981, Steenof et al. 2001). According to Steenof et al. (2001) and Stinson et al. (2001), the National Wildlife Federation's 1984 guidelines standardized midwinter survey routes and surveys, and recommended that the same experienced observers conduct them. These midwinter counts can be an effective way to monitor long-term changes in bald eagle populations (Steenof et al. 2001). She further explained that this method allows for monitoring modifications or threats to habitat or important wintering areas. Standardized routes across Oregon and California have been surveyed since 1984, and one route runs through the Klamath Basin.

The Klamath Basin National Wildlife Refuge has conducted routine annual counts of waterfowl and bald eagles in the Lower Klamath National Wildlife Refuge (Thomson, personal communication) since 1982. Although these surveys are not part of the nation-wide midwinter bald eagle survey, they appear to follow the standardized guidelines recommended by the National Wildlife Federation. One distinction is that the National Wildlife Refuge (NWR) surveys often were conducted more than once each January. The Klamath Basin midwinter survey data are available on the internet (http://www.klamathnwr.org/cenfindex.html).

Bald eagle biology

Breeding population size, rate of recruitment, and productivity

Increasing breeding population size is a strong indicator that bald eagle recruitment and productivity has risen. Since 1970, the breeding population has essentially doubled every 7 to 8 years, exceeding 5,748 nesting pairs in 1998 in the lower 48 states (Figure 1)(USFWS 1999). In the PRR, the number of nesting pairs rose to 1,480 in 1998 (USFWS 1999), of which 321 (30 percent) were in Oregon, and 107 (8 percent) were in the KBMZ (Isaacs and Anthony 2000). The number of occupied territories (breeding pairs) continues to rise in Oregon, with 372 in 2000 and 393 in 2001 (Isaacs and Anthony 2001).

The steady increase in size of the breeding bald eagle population is a clear indication that recruitment and productivity has been good. The number of occupied breeding areas in the PRR has steadily increased from 861 in 1990 to 1,480 in 1998, representing a 72 percent increase (Figure 1)(Steenof, unpublished data). Concomitantly, the number of young raised per year increased. Productivity in the PRR has remained relatively stable throughout that same period, ranging from 0.95 to 1.17 with an average of 1.04 (Steenof, unpublished data).

There are numerous influences on bald eagle recruitment and productivity. For instance, Anthony and Isaacs (1989) found that productivity was higher at nests farther from human disturbance compared to nests that were closer. Hansen et al. (1986:119) tested three alternative explanations for the regulation of breeding by bald eagles in southeast Alaska, and reported that "(1) food abundance in spring strongly influences where or if … eagles lay eggs and when they lay eggs; (2) habitat quality is important when breeding eagles select a breeding area …, and (3) food supplies during incubation and rearing regulate offspring survival." They concluded that food supplies influence egg and chick survival.

Nests

Bald eagles nest in large trees that are close to open bodies of water, which function as aquatic foraging areas (Anthony and Isaacs 1989). In Oregon, all nests have been found within 7.2 km of permanent bodies of water, and most nests (85 percent) are within 1.6 km of water (Anthony and Isaacs 1989).

Nest trees are usually the tallest in the forest stand. In the Pacific Northwest, nest trees are from 30-96 percent taller than adjacent stands (Stalmaster 1987). In Oregon, Ponderosa pine (*Pinus ponderosa*) and Douglas-fir (*Psuedotsuga menziesii*) were the most frequently used species for nest construction (Anthony and Isaacs 1989). Most of these nest trees are located on the top quarter of slopes, and nests are positioned from 0 to 45 percent below the tops of nest trees (Anthony and Isaacs 1989).

Life span and age of sexual maturity

Bald eagles in the wild have a life span of at least 28 years (Schempf 1997). Captive birds have lived more than 47 years, and they are believed to be capable of reproducing for 20-30 years (Stalmaster 1987). Harmata et al. (1999) estimated a maximum life span of 15.4 years for bald eagles produced in the Greater Yellowstone Ecosystem, where most of the known fatalities were human related.

Breeding generally begins at age 6, but sometimes they defer breeding until age 7 or 8 in populations at carrying capacity (Bowman et al. 1995, Harmata et al. 1999, Buehler 2000). However, when food is particularly abundant, or when a population decline has left many territories vacant, raptors breed at a younger age than usual (Newton 1979). Consequently, bald eagles may attempt to breed at age 4 where there is less competition for food and limited potential for mates (Gerrard et al. 1992, Buehler 2000). In the Klamath Basin, territorial eagles lay eggs as early as mid-February, and pairs are known to repair nests throughout the year (Isaacs, personal communication).

Ecologists consider species such as the bald eagle to be K-strategists (MacArthur and Wilson 1967) because they are relatively long lived and large bodied and they exhibit slow development, delayed reproduction, long-term parental care of young, and they produce few young. Life-history traits combine to limit their ability to respond to increased mortality. Consequently, bald eagles exist in populations that, when compared with shorter-lived organisms, require both high adult and juvenile survivorship (Congdon and Dunham 1997). These life history traits provide bald eagles with limited ability to respond to chronic increases in juvenile mortality and even less ability to respond to increased mortality of adults (Congdon et al. 1993).

Sources of mortality

The bald eagle is subject to many sources of mortality. Recovery Plan task 2.221 is to “determine the main causes of eagle mortality” (USFWS 1986). Based on 1,429 eagle carcasses examined between 1963 and 1984, gunshot (23 percent), trauma (21.1 percent), poisoning (11.1 percent), and electrocution (9.1 percent) were the most prevalent causes of death (National Wildlife Health Laboratory 1985). Red-tailed hawks (*Buteo jamaicensus*), ravens (*Corvus corax*), crows (*C. brachyrhynchos*), magpies (*Pica* spp.), gulls (*Larus* spp.), wolverines (*Gulo luscus*), raccoons (*Procyon lotor*), and black bears (*Ursus americanus*) may eat eggs and hatchlings (McKelvey and Smith 1979, Nash et al. 1980, Doyle 1995, Perkins et al. 1996).

Nestlings are sometimes killed by their nestmates (Brown 1977). Juvenile bald eagles are prone to accidents, predation, or starvation during their first year (Stalmaster 1987). Adults have few natural enemies, and the most frequently reported causes of adult mortality are human-related (Stalmaster 1987, Franson et al. 1995, Harmata et al. 1999). Adult bald eagles occasionally die in aggressive encounters with other bald eagles, golden eagles (*Aquila chrysaetos*), or peregrine falcons (*Falco peregrinus*)(Jenkins and Jackman 1993, Driscoll et al. 1999).

Although many causes of direct mortality are known, Grier (1980) emphasized that while survival rate is perhaps the most important component of population regulation, it is the least-studied population parameter in bald eagles. Because bald eagles are K-strategists, their survival is believed to be the most critical element in maintaining or increasing their populations, with production of young as secondary (Grier 1980, Stalmaster 1987). Grier (1980) suggested that a population with moderate nest success and productivity, such as that found in the PRR, must have high survival of juveniles (70 percent) and adults (90 percent) for the population to grow. However, Driscoll et al. (1999) and Harmata et al. (1999) suggested that higher juvenile survival and adult immigration from adjacent regional populations may account for increasing populations in some localized areas of Washington despite higher than expected adult mortality. This view exemplifies the importance of regional bald eagle populations, such as the wintering population in the Klamath Basin.

Migration

Bald eagles generally follow migration corridors when on route between spring/summer and wintering areas in the Pacific Northwest (Figure 2). Eagles leave northern breeding grounds during fall to seek milder climates where prey are concentrated during the winter months. Fall migration may be a response of dwindling food supplies on breeding areas, or a lack of feeding opportunities when lakes and rivers freeze over in the interior. The relatively mild winter climate, abundant winter waterfowl, and small mammal populations in the Klamath Basin (Keister et al. 1987, Frenzel and Anthony 1989) attract bald eagles from as far away as Glacier National Park, Montana (McClelland et al. 1994, Young 1983), Skagit River, Washington (Watson and Pierce 2001), and southern California (Isaacs, personal communication).

Watson and Pierce (2001) provided evidence that bald eagles wintering in the Klamath Basin travel vast distances across the Pacific Northwest and from as far as Alaska (Figure 2). Some eagles that winter in the KBMZ also exhibit a rare behavior of reverse migration because they travel from southern California in the fall northward to winter in the Klamath Basin (Frenzel 1985, Detrich 1986). Although winter climate is considerably colder in the Klamath Basin, this reverse migration from California is thought to be due to the relatively higher quantity and availability of prey in the Klamath Basin compared to that in the arid southern California region.

Winter congregations

The midwinter bald eagle surveys represent a unique source of baseline data that provides an opportunity to monitor the general status of wintering congregations. Between 1986 and 2000, midwinter counts in the lower 48 states increased an estimated 2 percent per year (Steenhof et al. 2001). Sixty-three percent of the survey routes showed increasing trends; however, the Northwest region was essentially unchanged. The number of wintering bald eagles fluctuated in the Klamath Basin during that time (Mauser and Thomson 2001).

Bald eagles generally winter in areas with a relatively mild climate that support a combination of communal roosts and abundant available food. Characteristics of communal roosts are specific and influence their use, the size of food resource patches often influence the size of the eagle concentration, and the juxtaposition of these two habitat features across the landscape is essential.

Communal roosts

Bald eagle communal night roosts are recognized as important components of wintering habitats (Anthony et al. 1982). The Pacific States Bald Eagle Recovery Team recommended communal roosts be identified and protected (USFWS 1986). Communal roosts have been determined as sites where more than 1 eagle roosts for more than 1 night (Buehler et al. 1991) and at least 3 eagles for at least 2 nights (Anderson et al. 1985).

Characteristics of forest stands, roost trees, and size of roosts used by bald eagles vary considerably among regions of the 48 contiguous states (see Keister and Anthony 1983). In general, bald eagles prefer to roost in trees that are taller and more open in structure than those in the surrounding forest stand. Eagles especially prefer defoliated trees, such as snags, spike-topped conifers, and large deciduous trees. In northwest Washington (Hansen et al. 1980), bald eagles prefer to communally roost in Douglas-fir, but they will roost in Ponderosa pine where this species is dominant. In the Klamath Basin, five primary bald eagle communal roosts have been identified (Keister and Anthony 1983). They are referred to as Bear Valley, Caldwell, Cougar, Three Sisters, and Mount Dome communal roosts (Figure 3), and are described as being in old, open-structured trees closer to feeding areas (Keister and Anthony 1983). The forest stands in which these communal roost trees occur have a mean density of 53.1 trees/ha, diameter at breast height of 54.3 cm, height of 26.4 m, and 7.3 percent spikes and snags (Keister and Anthony 1983). Four of the five roosts are Ponderosa pine stands.

The adaptive significance of communal roosts is based on the proximity of communal roosts to foraging areas. Edwards (1969) showed that bald eagles used roosts nearest those hunting territories having high prey densities and shifted hunting areas when they were disturbed or when prey became scarce. Additionally, Hansen et al. (1986) found that the density of bald eagles in habitats adjacent to foraging areas was about 10 times higher than in areas far from foraging areas. However, Keister et al. (1985) used a model of energy consumption in bald eagles while considering distances between roost and forage areas, and reported that energy demand did not influence the use of different communal roosts during winter in the Klamath Basin. They proposed that this was due to: (1) high food availability and relatively mild winter weather conditions during their study, or (2) an increase in energy output required to fly a greater distance to a roost that had a microclimate affording only a slight increase (4-7 percent) in nightly energy savings. Keister et al. (1985) also showed that distances greater than 5 km between foraging areas and roosts created an energy disadvantage to communally roosting bald eagles that wintered in the Klamath Basin. More than one factor, such as flight distance, influence how bald eagles select communal roosts, but greater distances between foraging areas and communal roost sites undoubtedly result in increased energy expenditure. Distances from roost sites and foraging areas are highly variable in Oregon, with maximum straight-line distances being up to 21 km in the Crooked River, Oregon (Isaacs et al. 1993), 5.6 km in Upper John Day River, Oregon (Isaacs et al. 1996), and ranges of 6-20 km in the Klamath Basin, Oregon (Keister et al. 1985).

Food resources

"Winter raptor populations are often food-limited" (Newton 1979:80). Consequently, it is not surprising that this view extends to bald eagles (Sherrod et al. 1976, Stalmaster 1981). Hansen et al. (1982:57) emphasized the importance of food for bald eagles by stating "the thread that interconnects virtually all aspects of bald eagle ecology is the bird's relentless pursuit of food." During fall and spring, bald eagles migrate to areas such as the Klamath Basin where weather conditions are generally milder and food patches support a large abundance of available prey compared to other areas in the PRR.

Two ecologically important patterns of how bald eagle food resources are distributed across a region are: (1) small but regularly dispersed, predictable units; and (2) large resources (Hansen et al. 1986). Small but predictable food resources include individual fish in a lake, large mammal carrion, and gut piles during a hunting season. Large resources include salmon spawning grounds (Servheen 1975, Stalmaster et al. 1979, McClelland et al. 1982), lakes and waterfowl refuges with high concentrations of wintering waterfowl (Keister 1981, Isaacs and Anthony 1987, Mauser and Thomson 2001), dam sites where fish kills are common (Southern 1963, Steenhof 1976), and areas with abundant large mammal carrion (DellaSala et al. 1989, Isaacs et al. 1993) and small mammals (Platt 1976, Keister et al. 1987, Isaacs et al. 1993). It seems that the Klamath Basin supports the largest predictable food resource for wintering bald eagles in the PRR, comprised primarily of waterfowl.

Relationship between winter eagle numbers and quality, size, availability, and predictability of food resources

The abundance of bald eagles at wintering areas is related to the quality, size, availability, and predictability of food resources. The correlation between numbers of wintering bald eagles and their prey has been reported by other studies (Servheen 1975, Griffin et al. 1982, Stalmaster and Gessaman 1984, Restani et al. 2000). In the Upper Skagit River, Washington, the number of eagles varied consistently with abundance of chum salmon (*Oncorhynchus keta*) carcasses, where years with more carcasses had more eagles (Mills 2000). Hansen et al. (1982) reported that the eagle population in the Chilkat Valley, Alaska was most closely correlated with salmon abundance; the number of eagles increased with fish abundance until about 1,400 fish carcasses were available. Hansen et al. (1982) suggested that when food abundance was greater than the threshold level, it no longer limited the size of the eagle population in their study area. They also postulated that the downward turn in the relationship at higher levels of fish abundance may be a function of date because the higher fish counts occurred in mid-January when most eagles had already migrated out of their study area.

There are numerous other examples of bald eagle abundance being related to the availability of food resources across the PRR. Keister et al. (1987) studied the use of communal roosts and foraging areas by bald eagles in the Klamath Basin, Oregon and concluded that eagle and waterfowl numbers were related, but that the highest numbers of eagles were not associated with the highest numbers of waterfowl in a particular year. They further suggested that numbers of waterfowl in the basin, even during mid-winter lows, provided sufficient food for more than 500 eagles. Additional evidence comes from the Pacific Northwest Coast (Hansen et al. 1986), Upper John Day River, Oregon (Isaacs et al. 1996), Crooked River, Oregon (Isaacs et al. 1993), and Harney Basin, Oregon (Isaacs and Anthony 1987). The common theme among these studies is that eagle abundance varied through time due to the effects of weather on the availability of prey. Specifically, periods with deep snow and/or ice reduced availability of prey. The relationship between food abundance and the size of fall and winter eagle concentrations in Washington state was used to develop an energetics model that accurately predicted population size as a function of food levels and weather conditions (Stalmaster 1983).

Because winter weather conditions affect the availability of prey, it is not surprising that Hansen et al. (1982) emphasized food availability rather than abundance for defining food resources used by bald eagles. Regardless of the abundance of a food resource, its accessibility influences an eagle's ability to successfully forage on it (e.g., an abundance of fish carcasses imbedded in ice along the shoreline of a river is not accessible), therefore determining its functional value to a wintering population. Hansen et al. (1982), McClelland et al. (1982) and DellaSala et al. (1989) described important winter food resources as being predictable from one year to the next.

There is also evidence that bald eagles exhibit behavioral adaptations that enable them to switch from one food resource to another within the same wintering area. Bald eagles wintering in the Klamath Basin are adapted to switching from one type of prey to another and eat at least 25 species of birds, 2 species of mammals, and one species of reptile (Frenzel and Anthony 1989). Prey switching depends on the timing and availability of the alternative prey species. For example, Keister et al. (1987:419) reported "several factors determined use of feeding areas by bald eagles (in the Klamath Basin). Season … was the important factor influencing use of the Oregon feeding area as flooding of agricultural fields with use of montane voles (*Microtus montanus*) as prey occurred only during last winter. Waterfowl populations at Lower Klamath Refuge … were most important in predicting eagle use at that location, and ice cover was … most important at Tule Lake."

In its biological opinion, the USFWS used results from Mauser and Thomson's (2001) examination of midwinter counts of bald eagles and waterfowl in the Lower Klamath NWR to identify a predator-prey relationship between these species (Figure 4). The USFWS interpreted the pattern of increasing variance in eagle numbers at high waterfowl numbers as likely evidence of prey swamping, a phenomenon where prey abundance surpasses predator need, so that food availability is no longer a factor in determining predator numbers (Craighead and Craighead 1956, Ricklefs 1983). In the biological opinion, (Section III, Part 1, page 23), the USFWS concluded that 125,000 waterfowl were needed to support a wintering population of bald eagles, and developed a strategy to provide a mix of permanent and seasonal wetland habitats and winter-irrigated small grains sufficient to "provide for the number of eagle that are likely (given historical data) to winter in the Lower Klamath NWR in most years." The USFWS further stated "However, years of unusually high numbers of eagles above the documented range would increase the bald eagle's need above the threshold." Young (1983) observed movements of radio-tagged bald eagles at American Falls Reservoir, Idaho, and estimated that as many as five times the maximum daily count of bald eagles may have used the area for periods ranging from one day to all winter. If this pattern of use exists in the Lower Klamath NWR, many more bald eagles may use the area during a given winter than the estimated 958.

Human activities

Responses by eagles to human disturbance have been reported in several studies. DellaSala et al. (1989) found that most bald eagles foraged more than 50 m from roads in the Willamette Valley where domestic sheep carrion was the primary food. Marr et al. (1995) postulated that the significant increase in persistence of sheep carcasses located less than 200 m from a road or house in the Willamette Valley was because they were unlikely to be used by eagles. Isaacs et al. (1993) reported that use of large mammal carcasses by bald eagles was affected by distance from human activity and that carcass condition and flushing responses caused by human activity along roads decreased with distance from roads. Stalmaster (1980) and Skagen (1980) reported similar responses by wintering bald eagles to boating activities along rivers in northwest Washington where salmon carcasses were the primary food.

Human activities also influence the selection of alternative nests within breeding territories (Anthony and Isaacs 1989). Present guidelines by the USFWS (1981) for managing eagle nesting habitat suggest distances of approximately 100 m (primary zone) and 200 m (secondary zone) from the nest tree, which correspond to areas of 3.2 and 12.7 ha, respectively. According to Anthony and Isaacs (1989), these areas are too small, and the guidelines do not provide flexibility for site-specific management. Based on breeding phenology (Isaacs et al. 1983), Anthony and Isaacs (1989) recommended that human activities within 800 m of nests be restricted from January 1 to August 31 of each year.

Human-related changes are not always negative for bald eagles. A variety of freshwater fish have been introduced to Oregon and California waters and reservoirs and have created habitat for fish and concentration areas for wintering waterfowl. Dam-caused fish fatalities may have made some fish species more available to eagles. Eagles can scavenge the afterbirth and carcasses of livestock (Isaacs et al. 1993). Hunter-crippled waterfowl and other game are probably more available to eagles, and road-killed deer are a significant new food source (Isaacs et al. 1996).

Recent Federal environmental documentation and decisions

The ESA attempts to bring populations of listed species, such as the bald eagle, to healthy and sustainable levels so that they no longer need special protection. To reach this goal, in addition to prohibiting activities that may harm listed species, the ESA requires federal agencies to use their authority to conserve threatened and endangered species (see 16 U.S.C. §§ 1531(c), 1526(a)(1)). Section 7 of the ESA applies exclusively to Federal agencies, such as the BOR, and requires that the USFWS prepares the biological opinion for listed species that may be affected by the federal action. The most recent Section 7 consultation process for the Klamath Project began on December 18, 1999, when the BOR requested reinitiating consultation with the USFWS regarding the 1992 biological opinion. During this procedure the USFWS considered in detail the effects of the project on the bald eagle. The following information addresses some of the documentation and decisions relating to bald eagles that were developed by the BOR and USFWS through the Section 7 consultation process, and emphasizes the legal imperative for the USFWS to make decisions despite large uncertainties (National Research Council 1995).

The Society of Conservation Biology's statement on "Independent Scientific Review in Natural Resource Management" (Meffe et al. 1998) provides several insightful recommendations for improving the application of independent scientific review to complex environmental policy decisions. Specifically, the USFWS must seek peer review during public comment periods, document reviewer's opinions, and maintain a record of all materials received on listings and recovery plans prepared under the ESA (USFWS-NMFS 1994). However, because the ESA does not require the USFWS to seek peer review of biological opinions (USFWS-NMFS 1994), this review of the recent federal environmental documentation and decisions is not required, and was not requested by the USFWS.

Biological assessment

Procedural aspects of interagency consultation under Section 7 required that the BOR prepare a biological assessment to identify protected species likely to be affected by the proposed action and that outlines the nature and extent of the project's impacts on the species (see 16 U.S.C. § 1536(c)). Thus, the "Biological/Conference opinion regarding the effects of operation of Reclamation's Klamath Project on the endangered Lost River sucker, endangered shortnose sucker, threatened bald eagle, and proposed critical habitat for the Lost River/shortnose suckers" (Biological Opinion 2001) was prepared by the Klamath Falls Fish and Wildlife Office in April 2001. To determine the full effects of the project on the bald eagle, the BOR and USFWS must evaluate, as well as determine the magnitude of direct, indirect, and cumulative effects on the species (50 C.F.R. § 402.14(g)(3)). According to these regulations, direct effects are project activities that essentially result in the immediate effect on bald eagles. Indirect effects are caused by the proposed action and are later in time, as in reduced acreage of wetland and irrigated crops available for maintaining waterfowl (bald eagle prey) as a result of the reduction in allocated water. In the 2001 biological assessment, the BOR provided a section on the effects of the Klamath Project on bald eagles and described the effects at the scale of nesting, wintering, and nonbreeding immature, subadult, and adult bald eagles in the vicinity of the project (Biological Opinion 2001).

In the 2001 biological assessment (Biological Opinion 2001:60), the BOR stated "the manipulation of the timing and amount of water available across the landscape of the Upper Klamath Basin (which is largely controlled by the Klamath Project) directly and indirectly affects the survival and recovery of bald eagle populations." It further reported on the status of breeding eagles in the area, and on page 61, stated that "Because they are dependent on water bodies for food supply most of these nesting pairs could be affected by the proposed action." It continued with "forage availability is expected to be lower for some time following periods of large draw-downs, and this may in turn result in lower reproductive rates among the resident bald eagles." The assessment concluded, "impacts to the wintering birds are not just a local impact but a significant regional one."

Cumulative effects refer to the additive impacts of state, local, or private actions, unrelated to the Klamath Project, on bald eagles (50 C.F.R. § 402.02, 51 Federal Register 19,932 (1986)). An ESA cumulative effects analysis begins by determining the total impacts of the project and its connected activities on a hypothesized resource "cushion." The solicitor defined this resource cushion as "that amount of a particular natural resource like water, air, vegetation or habitat (upon which a given listed species is dependent), that could be utilized or consumed, without jeopardy to the continued existence of the species" (USDI 1982). The 2001 biological assessment (Biological Opinion 2001, Section 9.0, pages 84-89) provided a detailed description of cumulative effects, including activities such as grazing, forestry, and private water diversions on suckers. It stated, "transportation of hazardous materials by truck and train along the eastern and southern margin of Upper Klamath Lake and over tributaries could result in spills and negative impacts to the listed and unlisted species in the basin's waters. Algae and Daphnia harvesting in Upper Klamath Lake may result … use of chemicals such as pesticides, herbicides, mosquito or midge control chemicals could result in negative impacts to listed species throughout the basin. The diversion of water directly from Upper Klamath Lake by private (non-Project) water users may result in the taking of suckers and reduction of habitat." However, the BOR did not identify cumulative effects relating specifically to the bald eagle.

Biological opinion

According to the "consultation history" (Section 1.1) in the 2001 biological opinion, the USFWS has completed nine separate Section 7 consultations with the BOR that required a decision on the effects of the Klamath Project on bald eagles. Five of these were formal consultations, four were reinitiating previous formal consultations, and all resulted in a determination of "no jeopardy to the bald eagle." One was completed in 1991, four in 1992, and one each in 1994, 1995, 1996, and 2001. Prior to the 2001 biological opinion, discussions regarding impacts on bald eagles were virtually absent. The current biological opinion (Biological Opinion 2001) provides detailed information on the historical and current natural history, status, distribution, and recruitment of bald eagles in the Klamath Basin, and extends its assessment of impacts to the PRR. All of these earlier biological opinions were superceded by the 2001 biological opinion (Biological Opinion 2001).

The USFWS's recent, detailed information in the 2001 biological opinion (Biological Opinion 2001) on the effects of the Klamath Project on the bald eagle appears for three reasons. First, the BOR's incomplete description in the 2001 biological assessment of specific project operations, and how such operations may effect the bald eagle, established footing for the USFWS to examine, as well as determine the magnitude of the full effects of the project on this species (50 C.F.R. § 402.14(g)(3)). Second, new information was available on the number, distribution, and productivity of nesting bald eagles in Klamath Basin and across the PRR, which indicated an increase in the breeding and wintering populations. There are 117 nesting pairs of bald eagles in the Klamath Basin, and many of them have territories overlapping the Klamath Project. The USFWS concluded that the type and intensity of impairment and injury of nesting bald eagles likely to result from implementation of the project would be broad. Further conclusions were that "Likely effects range from temporary periods of hunger and increased energy expenditure for less concentrated or lower quality food, increased exposure to injury risks at food sources, increased exposure to inclement weather and lowered fat reserves, to the more extreme forms of reduced fitness during breeding initiation, and death through starvation or injury" (Biological Opinion 2001, Section III, Part 1, page 31).

The 117 nesting pairs in the Klamath Basin represent a relatively small number compared to the total number (1,480) in the PRR. This is emphasized in the 2001 biological opinion, (Biological Opinion 2001, Section III, Part 1, page 29), which stated that "The effects of the proposed action would likely reduce nesting success of some or all 117 pairs that currently use the Klamath Basin … Given the large number of nests as compared to the estimate of 800 needed to recover the species, the reduction in nesting success of bald eagles is not likely significant." Thus, even if all nests in the Klamath Basin were impacted by the proposed action, more than enough nests still occur outside the Klamath Basin to meet the recovery goal of 800 nests.

The third reason for the USFWS's detailed information and biological opinion on the bald eagle stems from considering the effects of the project on the proposed delisting (USFWS 1999). This is primarily due to the Recovery Plan specifying that before delisting, "Wintering populations greater than 100 individuals should be stable or increasing" (USDI 1986). The Klamath Basin supports the largest population of wintering bald eagles outside of Alaska, ranging from 200 to 1,100 eagles during a single survey day. Eagles are known to travel from Alaska, Montana, Washington, and Southern California to take advantage of winter forage, communal roosts, and relatively mild climate found in the Klamath Basin. In the biological opinion (Section III, Part 1, page 8), the USFWS states “The combination of abundant food and roosting habitat is so unusual and important that its protection was cited as the reason the Bear Valley National Wildlife Refuge was established in 1978. Bear Valley NWR is one of the few refuges or sanctuaries of its kind in the United States.”

In the 2001 biological opinion, the USFWS based its affects analysis on two analyses: (1) a waterfowl threshold based on the relationship between bald eagle and waterfowl numbers (Mauser and Thomson 2001), and (2) a derived minimum water delivery (DMWD) to provide waterfowl habitat necessary to sustain the waterfowl threshold (Biological Opinion 2001). These two analyses contain uncertainties, but satisfy the ESA directive to the USFWS, BOR, and Secretary of the Interior to use the “best scientific and commercial information data available” (16 U.S.C. § 1536(a)(2)). Decision making in this context not only requires careful evaluation of existing data, it also entails consideration of major scientific uncertainties (National Research Council 1995). In the following paragraphs, we evaluate the major scientific uncertainties faced by the USFWS during the Section 7 consultation process, and consider the type of data and analysis used by Mauser and Thomson (2001). We further provide additional analyses and an alternative interpretation of Mauser and Thomson’s (2001) data.

We recognize three concerns with the eagle count data used by Mauser and Thomson (2001) that may result in underestimates of the wintering population size. Mauser and Thomson (2001) used midwinter aerial survey data that were collected in a similar manner to those following the 1984 guidelines established by the National Wildlife Federation (Knight et al. 1981, Steenof et al. 2001), with the exception that their data included multiple counts within each January. Their data represent a sample of midwinter counts collected using a single method (aerial flights) and were intended to provide an index to winter eagle numbers in the basin. While these methods aid in reducing variability in the data due to differences in observers and methods, Anthony et al. (1999) and Isaacs et al. (1993) reported that single counts resulted in variable and negative bias (underestimates) compared to the double-survey method (simultaneous aerial and ground surveys). Double surveys always include bald eagles that were seen from the ground that were not observed from the air and vice versa. Eagles that were subadults, flying, or perching at locations other than on the ground or on fence posts were often missed during aerial surveys (Isaacs et al. 1983).

A corollary concern is that Mauser and Thomson’s (2001) surveys were generally conducted in the early part of January, and consequently may not reflect the time when eagle numbers are at their peak in the Klamath Basin. The “highest estimates of the population … [occurred] during the second week in January and the first week of February” in Klamath Basin (Keister et al. 1987:416). Furthermore, many of Mauser and Thomson’s (2001) counts were from a single survey conducted during January, resulting in an inability to determine the number of unique individuals in the survey area. For instance, counts of unmarked eagles during a single winter day, as used by Mauser and Thomson (2001) preclude obtaining an estimate of the number of individual bald eagles present through the winter. Furthermore, the survey data used by Mauser and Thomson (2001) seem to have been considered in the 2001 biological assessment and the 2001 biological opinion as total numbers of individual eagles wintering in Lower Klamath NWR. For reasons given above, they actually represent minimum numbers.

The final concern with Mauser and Thomson’s (2001) data set is that it consists of single counts during some years, which prevent measuring the repeatability (precision) and bias in the data. To calculate an estimate of mean bald eagle abundance and a measure of precision for each estimate (e.g., standard error or confidence limits), at least three counts should be conducted within each period of interest, in this case, midwinter. Without a measure of precision, it is unclear whether or not the counts actually differed from one year to the next.

We suggest that there are problems with the data analysis employed by Mauser and Thomson (2001). The data analysis does not take into account the effects of time, weather, increasing bald eagle population levels, and prevalence of waterfowl disease, which may explain some of the variation they detected at waterfowl numbers greater than 125,000. We provide two alternative interpretations for the pattern of increasing variation in the data. First, the number of occupied territories in the PRR has consistently increased since 1986, exceeded 800 beginning in 1990, and has continued to do so over the last decade (USFWS 1999). In 1998, there were 1,480 pairs in the PRR (USFWS 1999). Because the U.S. bald eagle population essentially doubles every 7 to 8 years (USFWS 1999), the high counts used by Mauser and Thomson (2001) may not be related to waterfowl numbers, but rather increased numbers associated with a growing population across the Northwest. Secondly, the increased variation (trapezoidal shape) in bald eagle numbers with increasing numbers of waterfowl is inherent in many biological data sets (Neter et al. 1989), and may represent naturally increasing variation in eagle numbers corresponding to greater numbers of waterfowl.

We reanalyzed Mauser and Thomson's (2001) data to determine if factors, such as variation among years (time) and population levels could further explain variation in the data (Burnham and Anderson 1998). We fitted nine separate simple linear regression models to the data, each of which represented an alternative hypothesis relating winter eagle numbers to waterfowl numbers (Table 1), and used the information theoretic approach (Akaike's Information Criterion (AIC)) to select the model that "best" fit the data (Burnham and Anderson 1998). The best fitting model(s) balance model bias with the amount of variation that is explained by the model. This analysis approach is considered superior to traditional statistical analyses using p-values, and is widely used in the field of wildlife ecology (Burnham and Anderson 1998). The piecewise regression model chosen by Mauser and Thomson (2001) with an asymptote at 125,000 waterfowl was included as one of the nine models. To prevent problems in interpretation, the response variable (eagles) was not transformed to correct the lack of constant variance because we transformed the explanatory variable (waterfowl) using the natural log transformation to test for a pseudo-threshold.

This analysis resulted in two models fitting the data best (competing AIC-values), which hypothesized that eagle numbers varied as a linear and natural log function of waterfowl numbers (Table 1). Because both models have the same number of parameters and fit the data equally, there is no basis for selecting one over the other. Nonetheless, this analysis provides evidence that the original linear regression model used by Mauser and Thomson (2001; Figure 4) fits the data better compared to their piecewise regression model used in the 2001 biological opinion. The point of this analysis is to provide additional insight into the influence of time, as well as the type of relationship between numbers of eagles and waterfowl. It appears that the increase in eagle population levels over time do not contribute greatly to variation in the data. A straight line relationship, based on all 31 observations is "best" for representing the data, which suggests that while variation in eagle numbers increases with increasing waterfowl numbers, it is not at a magnitude that warrants a change in the slope at 125,000 waterfowl. The straight-line model appears to be more appropriate for representing a relationship between bald eagle and waterfowl numbers in the Lower Klamath NWR. However, this relationship is not strong and only provides a qualitative tool for suggesting how bald eagle numbers may change as a result of changes in waterfowl numbers. Actual bald eagle and waterfowl counts for January 2002 will be available in February and may provide some evidence for the impact of the water distribution plan on bald eagles.

If the relationship between eagle and waterfowl numbers is a straight line, then there is no basis for selecting a minimum number of waterfowl to support a wintering population of bald eagles in the Lower Klamath NWR. This represents a major scientific uncertainty in the data and leads to an equally challenging question of where, along the y-axis in Figure 4, to select the number of bald eagles representing the current wintering population size. We propose three alternatives for identifying the current wintering bald eagle population size, which can then be used for determining the minimum waterfowl threshold and associated water requirements.

The first alternative stems from Congress' instruction to the USFWS to provide the "benefit of the doubt" to the listed species when formulating its biological opinion (Connor v. Burford, 848 F.2d 1441-1454 (Ninth Cir. 1988)). When there is uncertainty, as exists in any complex ecosystem such as Klamath Basin, in making a biological opinion, this instruction suggests that the USFWS might select upper confidence limits, which in this case would lead to an upper-level estimate of the number of bald eagles wintering on Lower Klamath NWR. Using this approach, the size of the wintering population during an average year can be estimated by adding the mean number (195) of eagles from Mauser and Thomson's (2001) data to the standard error of the mean (SE)(36) = 231 bald eagles.

The second method is more subjective, and is based on the Recovery Plan. According to the Recovery Plan, before delisting, "Wintering populations greater than 100 individuals should be stable or increasing" (USDI 1986). This suggests that to avoid the influence of the Klamath Project on the delisting of bald eagles, the project should not result in impacts to eagles that may lead to destabilizing or reducing the eagle population currently wintering in the Lower Klamath NWR. Because the eagle population has continued to increase over the years, and as many as 958 eagles wintered in the area in 1992, it is reasonable to suspect that the current population can exceed 958 when environmental conditions and prey abundance are optimal. Therefore, a current wintering population size of at least 958 is plausible. The peak 1992 count followed the 1991 drought, during which winter habitat for waterfowl was likely reduced throughout much of the Pacific Flyway. The result was relatively high waterfowl numbers concentrated on the Lower Klamath NWR, and have may have simplified bald eagle counts.

The third alternative to identifying the size of the wintering bald eagle population requires a differentiation between daily and overall winter population sizes. Mauser and Thomson's (2001) count data were daily counts in early January, representing the daily population size in the Lower Klamath NWR. However, individual eagles migrating to the Klamath Basin arrive while others depart throughout the winter. In a study of marked individuals, maximum daily counts only represented 20 percent of the daily and wintering estimates because of asynchronous arrivals of individuals (Young 1983), suggesting that many more eagles may use the Lower Klamath NWR than the maximum observed in any one day. Additional evidence of a larger overall winter population size than the peak number counted in a single day is provided by Driscoll et al. (1999) and Harmata et al. (1999), who suggested that migration from adjacent regional populations may account for increasing populations in some local areas. Furthermore, Keister (1981) reported increasing numbers of eagles in the Klamath Basin during his study, and proposed that it was due to: "(1) the loss of wintering habitat elsewhere, with major shifts in use to the Klamath Basin, and (2) the increase of western bald eagle populations." If the pattern reported by Young (1983) was used for identifying the average size of the wintering population in the Lower Klamath NWR, the number would be 975 eagles (5 x 195 (daily average reported by Mauser and Thomson (2001)). This may represent the average size of the wintering population during the period when the data were collected, but the current size of the wintering population in the Lower Klamath NWR is likely to be larger.

These three alternatives reveal the uncertainty in estimating the size of the wintering bald eagle population in the Lower Klamath NWR, thereby giving rise to the USFWS's challenge in anticipating incidental take given the implementation of the Klamath Project. In the 2001 biological opinion (Section III, Part 1, page 32), the USFWS stated "Given the historical range of numbers of eagles that winter on Lower Klamath NWR, the Service anticipates up to 950 eagles could be incidentally taken, mainly through reduced access to food, per year as a result of the proposed action when water delivery from all sources to the Lower Klamath NWR is below 32,255 acre-feet." Our three alternatives and the analysis used in the 2001 biological opinion examined Mauser and Thomson's (2001) data, which are only for the Lower Klamath NWR. These analyses did not take into account the combined number of bald eagles throughout the total area that may be affected by the Klamath Project. Nonetheless, the USFWS does provide a detailed perspective of effects of the Klamath Project on bald eagles in the PRR, and compares these effects to the four recovery criteria identified in the Pacific States Bald Eagle Recovery Plan (USFWS 1986)(Section 111, Part 1, page 29). However, the amount of incidental take at the scale of the entire project was not quantified. The USFWS considered take throughout the Klamath Basin by stating "The maximum amount of take would be equal to the peak number of eagles using the Klamath Basin and winter roosts during that year" (Section III, Part 1, page 32). Therefore, the USFWS's anticipated amount of take (950 eagles) given the implementation of the Klamath Project (Section 6.1 in Section III, Part 1, page 32) appears to fall short of the total number of bald eagles that may be affected by the Klamath Project.

Although our three alternatives focus on identifying the population size in the Lower Klamath NWR, the ecology of bald eagles in the Klamath Basin is more complex because they use a large area (approximately 1,600 km^2) with variable use of three foraging areas and five communal roosts on a weekly basis (Keister et al. 1987). "Therefore, management will have to focus on the entire basin, regardless of state or federal boundaries …" (Keister et al. 1987).

Data gaps

Obviously there are numerous gaps in our knowledge of bald eagles across the PRR and in the Klamath Basin. We found a gap in knowledge regarding the:

1. Current breeding population size across the PRR;
2. Current wintering population size across the PRR;
3. Number of individuals that use the Klamath Basin (KB) or Lower Klamath NWR during winter;
4. Importance of the KB to bald eagles across the PRR;
5. Changes in the spatial distribution of all age classes across the KB, southern Oregon, northern California, and the entire PRR that occur when winter prey is unavailable at traditional foraging areas;
6. Importance of Lower Klamath NWR winter habitat to juvenile, subadult, non-breeding adults, and breeding adults in the KB, southern Oregon, northern California, and the entire PRR;
7. Importance of winter habitat and prey conditions in the Lower Klamath NWR to productivity of eagles that winter in KB, but nest elsewhere;
8. Survival of all age classes under all water management and regional water conditions.

Future needs

We prepared the following list of future needs to help direct current monitoring efforts and future research towards answering questions asked by endangered species biologists now making regulatory and management decisions for bald eagles.

1. Continue nesting surveys to document size and distribution of the nesting population under all conditions, including the California portion of Recovery Zone 22.
2. Conduct satellite telemetry to determine movements of eagles nesting and wintering in the KB, including following residents from nestling to maturity.
3. Continue monitoring population size and distribution in the KB in winter.
4. Initiate studies of food habits of wintering eagles during years of high and low winter waterfowl abundance on refuges.
5. Investigate the relationship of water level to bald eagle nesting success at Upper Klamath Lake.
6. Analyze the complete bald eagle and waterfowl count data set recorded from December through February by the Klamath NWR.

Acknowledgments

Drafts of this chapter were reviewed by R. Anthony and F. Isaacs of the Oregon Cooperative Fish and Wildlife Research Unit, Department of Fisheries and Wildlife, Oregon State University; W. Braunworth, Associate Program Leader, Extension Agriculture Program, Oregon State University; R. Hathaway, Oregon State University, Extension Service, Klamath Falls; and D. Mauser and D. Thompson of the U.S. Fish and Wildlife Service; their comments vastly improved the quality of the document.

Literature cited

Anderson, D. P., R. G. Anthony, and M. V. Ichisaka. 1985. Wintering ecology of bald eagles on the Lewis River, Washington, 1984-1985. Report prepared for Pacific Power and Light Co., Portland, Oregon. 69 pages.

Anthony, R. G., and F. B. Isaacs. 1989. Characteristics of bald eagle nest sites in Oregon. Journal of Wildlife Management 53:148-159.

Anthony, R. G., R. L. Knight, G. T. Allen, B. R. McClelland, and J. I. Hodges. 1982. Habitat use by nesting and roosting bald eagles in the Pacific Northwest. Transactions of the 47th North American Wildlife and Natural Resources Conference 48:332-42.

Anthony, R. G., M. G. Garrett, and F. B. Isaacs. 1999. Double-survey estimates of bald eagle populations in Oregon. Journal of Wildlife Management 63:794-802.

Bowman, T. D., P. F. Schempf, and J. A. Bernatowicz. 1995. Bald eagle survival and population dynamics in Alaska after Exxon Valdez oil spill. Journal of Wildlife Management 59:317-324.

Boyd, R. 1985. Strategies of Indian burning in the Willamette Valley. Canadian Journal of Anthropology 5:65-86.

Brown, L. 1977. Eagles of the World. Universe Books, New York.

Buehler, D. A. 2000. Bald eagle (*Haliaeetus leucocephalus*). Birds of North America No. 506. The Birds of North America, Inc., Philadelphia, Penn. 40 pages.

Buehler, D. A., T. J. Mersmann, J. D. Fraser, and J .K. D. Seeger. 1991. Effects of human activity on bald eagle distribution on the northern Chesapeake Bay. Journal of Wildlife Management 55:282-290.

Burnham, K. P., and D. R. Anderson. 1998. Model selection and inference: a practical information-theoretic approach. Springer-Verlag, Inc. New York. 352 pages.

Congdon, J. D., and A. E. Dunham. 1997. Contributions of long-term life history studies to conservation biology. Pages 205-206 *in* G. K. Meffe and C. R. Carroll. 1997. Principles of Conservation Biology, Second edition. Sinauer Associates, Inc. Sunderland, Mass.

Congdon, J. D., A. E. Dunham, and R. C. van Loben Sels. 1993. Delayed sexual maturity and demographics of Blanding's turtles (*Emydoidea blandingi*): implications for conservation and management of long-lived organisms. Conservation Biology 7:826-833.

Craighead, J. J., and F. C. Craighead Jr. 1956. Hawks, owls, and wildlife. Dover Publications, Inc. New York. 443 pages.

Dale, F. H. 1936. Eagle "control" in northern California. Condor 38:208-210.

DellaSala, D. A., C. L. Thomas, and R. G. Anthony. 1989. Use of domestic sheep carrion by bald eagles wintering in the Willamette Valley, Oregon. Northwest Science 63:104-108.

Detrich, P. J. 1986. The status and distribution of the bald eagle in California. M.S. Thesis, California State University, Chico.

Doyle, F. I. 1995. Bald eagle, *Haliaeetus leucocephalus*, and northern goshawk, *Accipiter gentilis*, nests apparently preyed upon by wolverine(s), *Gulo gulo*, in the southwestern Yukon Territory. Canadian Field-Naturalist 109:115-116.

Driscoll, E. E., R. E. Jackman, W. G. Hunt, G. L. Beatty, J. T. Driscoll, R. L. Glinski, T. A. Gatz, and R. I. Mesta. 1999. Status of nesting bald eagles in Arizona. Journal of Raptor Research 33:218-226.

Edwards, C. C. 1969. Winter behavior and population dynamics of American eagles in Utah. Ph.D Dissertation, Brigham Young University, Provo, Utah.

Franson, J. C., L. Sileo, and N. J. Thomas. 1995. Causes of eagle deaths. Page 68 *in* E. T. LaRoe, G. S. Farris, C. E. Puckett, P. D. Doran, and M. J. Mac (editors). Our living resources: a report to the nation on the distribution, abundance, and health of U.S. plants, animals, and ecosystems. U.S. Department of Interior, National Biological Service, Washington, D.C. 530 pages.

Frenzel, R. W. 1985. Environmental contaminants and ecology of bald eagles in Southcentral Oregon. Ph.D. Thesis. Oregon State University, Corvallis.

Frenzel, R. W., and R. G. Anthony. 1989. Relationship of diets and environmental contaminants in wintering bald eagles. Journal of Wildlife Management 53:792-802.

Gerrard, J. M., and G. R. Bortolotti. 1988. The bald eagle: haunts and habits of a wilderness monarch. Smithsonian Institution Press, Washington and London. 177 pages.

Gerrard, J. M., P. N. Gerrard, P. N. Gerrard, G. R. Bortolotti, and E. H. Dzus. 1992. A 24-hour study of bald eagles on Besnard Lake, Saskatchewan. Journal of Raptor Research 26:159-166.

Grier, J. W. 1980. Modeling approaches to bald eagle population dynamics. Wildlife Society Bulletin 8:316-322.

Griffin, C. R., T. S. Baskett, and R. D. Sparrowe. 1982. Ecology of bald eagles wintering near a waterfowl concentration. U.S. Department of Interior, Fish and Wildlife Service Special Wildlife Report, Wildlife No. 247. Washington, D.C.

Hansen, A. J., M. V. Stalmaster, and J. R. Newman. 1980. Habitat characteristics, function, and destruction of bald eagle communal roosts in western Washington. Pages 221-229 *in* R. L. Knight, G. T. Allen, M. V. Stalmaster, and C. W. Servheen (editors). Proceedings of the Washington bald eagle symposium, Seattle. The Nature Conservancy.

Hansen, A. J., M. V. Stalmaster, and J. R. Newman. 1982. Habitat characteristics, function, and destruction of bald eagle communal roosts in western Washington. Pages 221-230 *in* R. L. Knight, G. T. Allen, M. V. Stalmaster, and C. W. Servheen (editors). Proceedings of the Washington State Bald Eagle Symposium, Seattle. The Nature Conservancy.

Hansen, A. J., M. I. Dyer, H. H. Shugart, and E. L. Boeker. 1986. Behavioral ecology of bald eagles along the northwest coast: a landscape perspective. Oak Ridge National Laboratory, Environmental Sciences Division, Publication No. 2548. 166 pages.

Harmata, A. R., G. J. Montopoli, B. Oakleaf, P. J. Harmata, and M. Restani. 1999. Movements and survival of bald eagles banded in the Greater Yellowstone Ecosystem. Journal of Wildlife Management 63:781-793.

Isaacs, F., and R. G. Anthony. 1987. Abundance, foraging, and roosting of bald eagles in the Harney Basin, Oregon. Northwest Science 61:114-121.

Isaacs, F., and R. G. Anthony. 2000. Results of the 2000 bald eagle nest survey. Oregon Cooperative Wildlife Research Unit. Oregon State University, Corvallis. 35 pages.

Isaacs, F., and R. G. Anthony. 2001. Results of the 2000 bald eagle nest survey. Oregon Cooperative Wildlife Research Unit. Oregon State University, Corvallis.

Isaacs, F. B., R. Goggans, and R. G. Anthony. 1993. Habits of bald eagles wintering along the Crooked River, Oregon. Northwest Science 67:55-62.

Isaacs, F. B., R. G. Anthony, M. V. Hayden, C. D. Miller, and W. Weatherford. 1996. Habits of bald eagles wintering along the John Day River, Oregon. Northwest Science 70:1-9.

Jenkins, J. M., and R. E. Jackman. 1993. Mate and nest site fidelity in a resident population of bald eagles. Condor 95:1053-1056.

Keister, G. P., and R. G. Anthony. 1983. Characteristics of bald eagle communal roosts in the Klamath Basin, Oregon and California. Journal of Wildlife Management 47:1072-1079.

Keister, G. P. 1981. Characteristics of winter roosts and populations of bald eagles in the Klamath Basin. M.S. Thesis, Oregon State University, Corvallis. 82 pages.

Keister, G. P., and R. G. Anthony. 1983. Characteristics of bald eagle communal roosts in the Klamath Basin, Oregon and California. Journal of Wildlife Management 47:1072-1079.

Keister, G. P., Jr., R. G. Anthony, and H. R. Holbo. 1985. A model of energy consumption in bald eagles: an evaluation of night communal roosting. Wilson Bulletin 97:148-160.

Keister, G. P., Jr., R. G. Anthony, and E. J. O'Neill. 1987. Use of communal roosts and foraging areas by bald eagles in the Klamath Basin. Journal of Wildlife Management 51:415-420.

Knight, R. L., R. C. Friesz, G. T. Allen, and P. J. Randolph. 1981. A summary of the mid-winter bald eagle survey in Washington. Washington Department of Game, Olympia. 74 pages.

MacArthur, R. H., and E. O. Wilson. 1967. The theory of island biogeography. Princeton University Press, Princeton, N.J.

Marr, N. V., W. D. Edge, R. G. Anthony, and R. Valburg. 1995. Sheep carcass availability and use by bald eagles. Wilson Bulletin 107:251-257.

Mauser, D. M., and D. Thomson. 2001. Minimum habitat needs for wintering bald eagles on Lower Klamath NWR. Draft report, U.S. Fish and Wildlife Service, Klamath Basin National Wildlife Refuge, Tulelake, California. 17 pages.

McClelland, B. R., L. S. Young, D. S. Shea, P. T. McClelland, H. L. Allen, and E. B. Spettigue. 1982. The bald eagle concentration in Glacier National Park, Montana: Origin, growth, and variation in numbers. The Living Bird 21:133-155.

McClelland, B. R., L. S. Young, P. T. McClelland, J. G. Crenshaw, H. L. Allen, and D. S. Shea. 1994. Migration ecology of bald eagles from autumn concentrations in Glacier National Park, Montana. Wildlife Monograph No. 125:1-61.

McKelvey, R. W., and D. W. Smith. 1979. A black bear in a bald eagle nest. Murrelet 60:106-107.

Meffe, G. K., P. D. Boersma, D. D. Murphy, B. R. Noon, H. R. Pulliam, M. E. Soulé, and D. M. Waller. 1998. Independent scientific review in natural resource management. Conservation Biology 12:268-270.

Mills, L. 2000. Skagit River Bald Eagle Natural Area annual report winter 1999-2000. Report to The Nature Conservancy and SRBENA Committee. Mount Vernon, Washington.

Nash, C., M. Pruett-Jones, and G. T. Allen. 1980. The San Juan Islands bald eagle nesting survey. Pages 105-115 *in* R. L. Knight, G. T. Allen, M. V. Stalmaster, and C. W. Servheen (editors). Proceedings of the Washington Bald Eagle Symposium, 14-15 June, 1980, Seattle, Washington. 254 pages.

National Wildlife Health Laboratory. 1985. Bald eagle mortality from lead poisoning and other causes, 1963-1984. Unpubl. Report. 48 pages.

National Research Council. 1995. Science and the Endangered Species Act. National Academy Press, Washington, D.C.

Neter, J., W. Wasserman, and M.H. Kutner. 1989. Applied linear regression models. Richard D. Irwin, Inc., USA.

Newton, I. 1979. Population ecology of raptors. Buteo Books, Vermillion, S.D. 399 pages.

Perkins, D. W., D. M. Phillips, and D. K. Garcelon. 1996. Predation on a bald eagle nestling by a red-tailed hawk. Journal of Raptor Research 30:249.

Platt, J. B. 1976. Bald eagles wintering in a Utah desert. American Birds 30:783-788.

Restani, M., A. R. Harmata, and E. M. Madden. 2000. Numerical and functional responses of migrant bald eagles exploiting a seasonally concentrated food source. Condor 102:561-568.

Ricklefs, R. E. 1983. The economy of nature. Chiron Press, Inc. New York, New York. 510 pages.

Rohlf, D. J. 1989. The endangered species act: a guide to its protections and implementation. Stanford Environmental Law Society, Stanford Law School, Stanford, California, 207 pages.

Schempf, P. 1997. Bald eagle longevity record from southeastern Alaska. Journal of Field Ornithology 68:150-151.

Servheen, C. 1975. Ecology of the wintering bald eagles on the Skagit River, Washington. M.S. Thesis, University of Washington, Seattle.

Sherrod, S. K., C. M. White, and F. S. L. Williamson. 1976. Biology of the bald eagle on Amchitka Island, Alaska. Living Bird 15:143-182.

Skagen, S. K. 1980. Behavioral responses of wintering bald eagles to human activity. Pages 231-241 *in* R. L. Knight, G. T. Allen, M. V. Stalmaster, and C. W. Servheen (editors). Proceedings of the Washington State Bald Eagle Symposium, Seattle. The Nature Conservancy.

Sorenson, K. 1995. Ventana Wilderness Sanctuary bald eagle restoration program. Ventana Wilderness Sanctuary, Research and Education Center, Monterey, Calif.

Southern, W. E. 1963. Winter populations, behavior, and seasonal dispersal of bald eagles in northwestern Illinois. Wilson Bulletin 75:42-55.

Stalmaster, M. V. 1980. Management strategies for wintering bald eagles in the Pacific Northwest. Pages 49-67 *in* R. L. Knight, G. T. Allen, M. V. Stalmaster, and C. W. Servheen (editors). Proceedings of the Washington State Bald Eagle Symposium, Seattle. The Nature Conservancy.

Stalmaster, M. V. 1981. Ecological energetics and foraging behavior of wintering bald eagles. Ph.D Dissertation, Utah State University, Logan. 157 pages.

Stalmaster, M. V. 1983. An energetics simulation model for managing wintering bald eagles. Journal of Wildlife Management 47:349-359.

Stalmaster, M. V. 1987. The bald eagle. Universe Books, New York. 227 pages.

Stalmaster, M. V., and J. A. Gessaman. 1984. Ecological energetics and foraging behavior of overwintering bald eagles. Ecological Monographs 54:407-428.

Stalmaster, M. V., J. R. Newman, and A. J. Hansen. 1979. Population dynamics of wintering bald eagles on the Nooksack River, Washington. Northwest Science 53:126-131.

Stalmaster, M. V., R. L. Knight, B. L. Holder, and R. J. Anderson. 1985. Bald eagles. Pages 269-90 *in* Management of Wildlife and Fish habitats in Forests of Western Oregon and Washington. Publication No. R6-F&WL-192-1985. U.S. Department of Agriculture, Forest Service. Washington, D.C.

Steenhof, K. 1976. The ecology of wintering bald eagles in southeastern South Dakota. M.S. Thesis, University of Missouri, Columbia. 148 pages.

Steenhof, K., L. Bond, L. Leppert, and K.K. Bates. 2001. The midwinter survey: an approach to monitoring bald eagle (*Haliaeetus leucocephalus*) populations. USGS Forest and Rangeland Ecosystems Science Center, Boise, Id. Unpublished report. 4 pages.

Steenof, K. unpublished data. Bald eagle winter counts. USGS Forest and Rangeland Ecosystems Science Center, Boise, Id.

Stinson, D. W., J. W. Watson, and K. R. McAllister. 2001. Draft Washington State Status Report for the Bald Eagle. Washington Department of Fish and Wildlife, Olympia. 90 pages.

Towle, J. C. 1979. Settlement and subsistence in the Willamette Valley: some additional considerations. Northwest Anthropology Reserve Notes 13:12-31.

U.S. Department of the Interior. 1978. Endangered and threatened wildlife and plants; determination of threatened for the bald eagle, final rule. U.S. Fish and Wildlife Service. 50 C.F.R., Part 17, Federal Register, February 14, 1978. 43:6233.

U.S. Department of the Interior. 1982. Memorandum to Regional Solicitor, Rocky Mountain Region from Associate Solicitor, Conservation and Wildlife, U. S. Department of the Interior, July 6, 1982.

U.S. Department of the Interior. 1995. Endangered and threatened wildlife and plants; reclassification of the bald eagle from endangered to threatened in all of the lower 48 States. U.S. Fish and Wildlife Service. 50 C.F.R. Part 17, Federal Register, July 12, 1995. Pages 35999-36010.

U.S. Department of the Interior. 1999. Endangered and threatened wildlife and plants; proposed rule to remove the bald eagle in the lower 48 states from the list of endangered and threatened wildlife. Proposed rule. 50 C.F.R. Part 17, Federal Register, July 6, 1999. Pages 36453-36464.

U.S. Fish and Wildlife Service. 1986. Recovery plan for the Pacific bald eagle. U.S. Fish and Wildlife Service. 163 pages.

U.S. Fish and Wildlife Service. 1981. Bald eagle management guidelines, Oregon-Washington. U.S. Fish and Wildlife Service Pamphlet, Portland, Oregon. 8 pages.

U. S. Fish and Wildlife Service and National Marine Fisheries Service. 1994. Interagency policy for peer review in Endangered Species Act activities. Federal Register 59:34270.

Watson, J. W., and D. J. Pierce. 2001. Skagit River bald eagles: movements, origins, and breeding population status. Final Report. Washington Department of Fish and Wildlife, Olympia, Wash. 80 pages.

Young, L. S. 1983. Movements of bald eagles associated with autumn concentrations in Glacier National Park. M.S. Thesis, University of Montana, Missoula. 102 pages.

Personal communications

Isaacs, Frank. 2001. Oregon Cooperative Wildlife Research Unit. Oregon State University, Corvallis, Oregon.

Thomson, Danielle. 2001. U.S. Fish and Wildlife Service, Klamath Basin National Wildlife Refuge, Tulelake, California.

Table 1. Nine models, associated hypotheses, and fit statistics from simple linear regression analyses[1] carried out on Mauser and Thomson's (2001) bald eagle and waterfowl count data used in the 2001 biological opinion.

Model	Hypothesis	No. of parameters	AICc[2]	ΔAICc[3]
lwaterfowl	Eagle numbers vary as a loge function of waterfowl numbers (threshold)	3	415.2	0.0000
waterfowl	Eagle numbers vary as a linear function of waterfowl numbers	3	415.3	0.0773
ldate lwaterfowl	Eagle numbers vary as a loge function of waterfowl numbers through a loge time trend (threshold with additive effects of waterfowl and year)	4	417.6	2.3480
date lwaterfowl	Eagle numbers vary as a loge function of waterfowl numbers through a linear time trend (threshold with waterfowl with linear year effects)	4	417.8	2.5508
date waterfowl	Eagle numbers vary as a linear function of waterfowl numbers through a linear time trend (threshold with effects of waterfowl and linear year effects)	4	417.9	2.6492
ldate	Eagle numbers vary as a loge function time (threshold)	3	420.1	4.8233
Piecewise[4]	Eagle numbers vary as a piecewise function with waterfowl numbers, having two linear slopes changing at a known number of waterfowl (Piecewise regression chosen by Mauser and Thomson (2001), which assumes eagle numbers change linearly at 125,000 waterfowl)	3	420.6	5.3711
date	Eagle numbers related linearly to time trend (time trend)	3	420.8	5.5902
date2	Eagle numbers vary through time (time effects)	19	499.2	83.9759

[1] Regression analysis carried out using SAS version 8 (1999).
[2] Akaike's Information Criterion. Lower values indicate better models (Burnham and Anderson 1998).
[3] Change in AIC. A change ≥2 represents strong support that the preceding model is a better fit of the data (Burnham and Anderson 1998).
[4] Regression model consisting of two pieces (Neter et al. 1989) with the slope changing at 125,000 waterfowl.

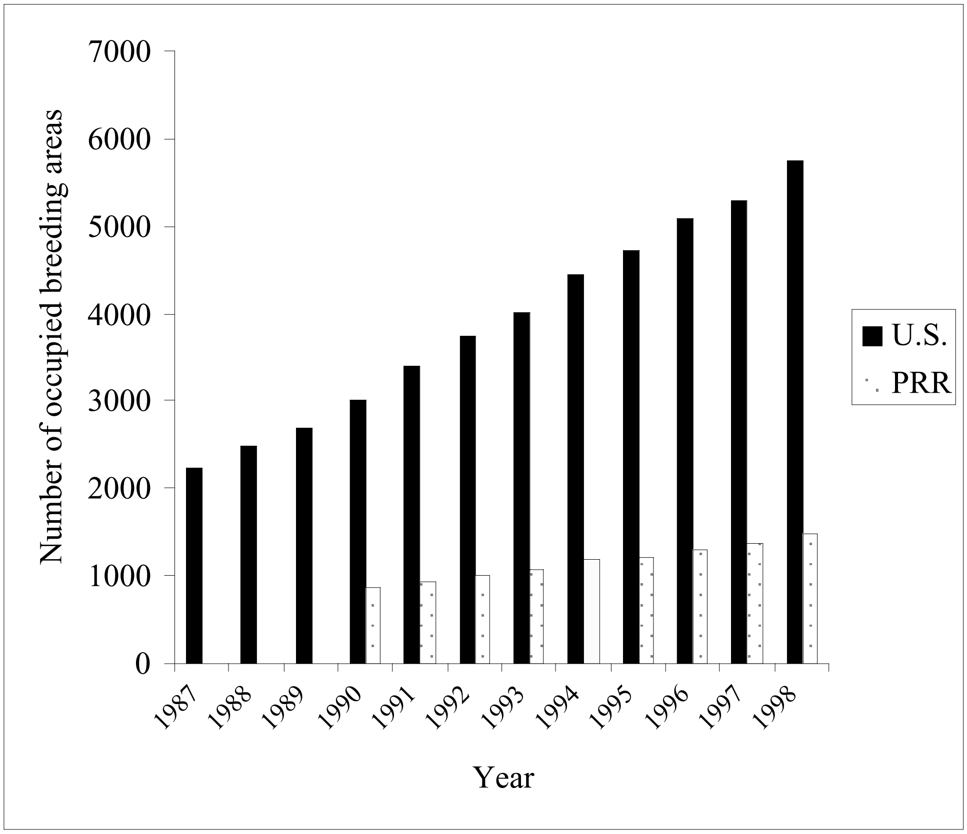

Figure 1. Total number of bald eagle breeding pairs in the conterminous United States and Pacific Recovery Region (PRR) 1987-1998 (U.S. data (1987-1998) from U.S. Fish and Wildlife Service website: http://midwest.fws.gov/RockIsland/activity/endangrd/eagle.htm and PRR data (1990-1998) from Steenof, unpubl. data).

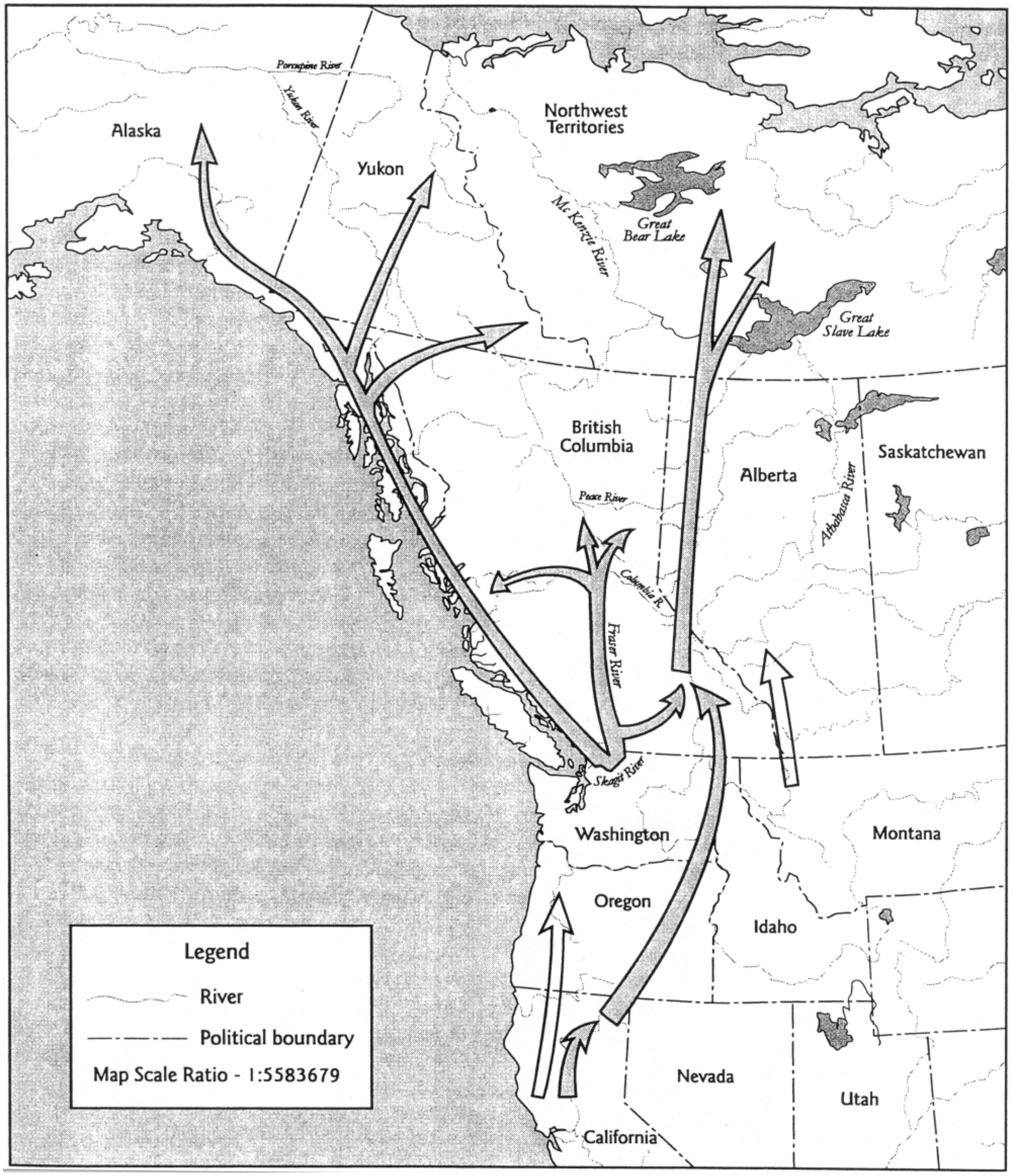

Figure 2. Bald eagle migration corridors in the Pacific Northwest (shaded arrows based on Watson and Pierce 2001; clear arrows based on McClelland et al. 1994 and Sorenson 1995; duplicated from Stinson et al. 2001).

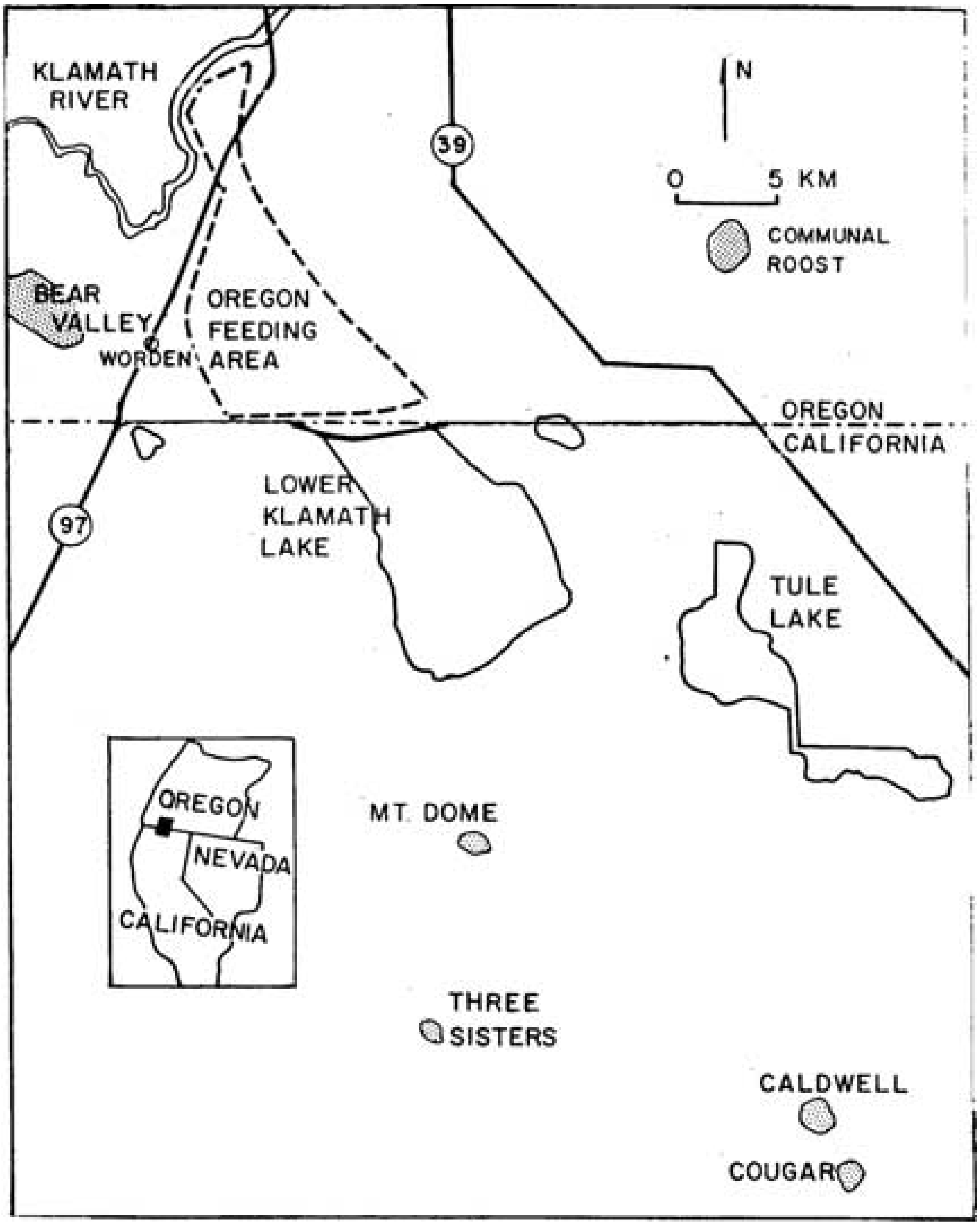

Figure 3. Major bald eagle wintering areas in the Klamath Basin of southern Oregon and northern California; duplicated from Keister and Anthony (1983). (*** OSU NEEDS TO GET PERMISSION TO USE THIS FIGURE. It’s from page 5 of Stinson, D. W., J. W. Watson, and K. R. McAllister. 2001. Draft Washington State Status Report for the Bald Eagle. Washington Department of Fish and Wildlife, Olympia. 90 pages. [WDF&W, Wildlife Program, 600 Capitol Way N, Olympia, WA 98501-1091.)

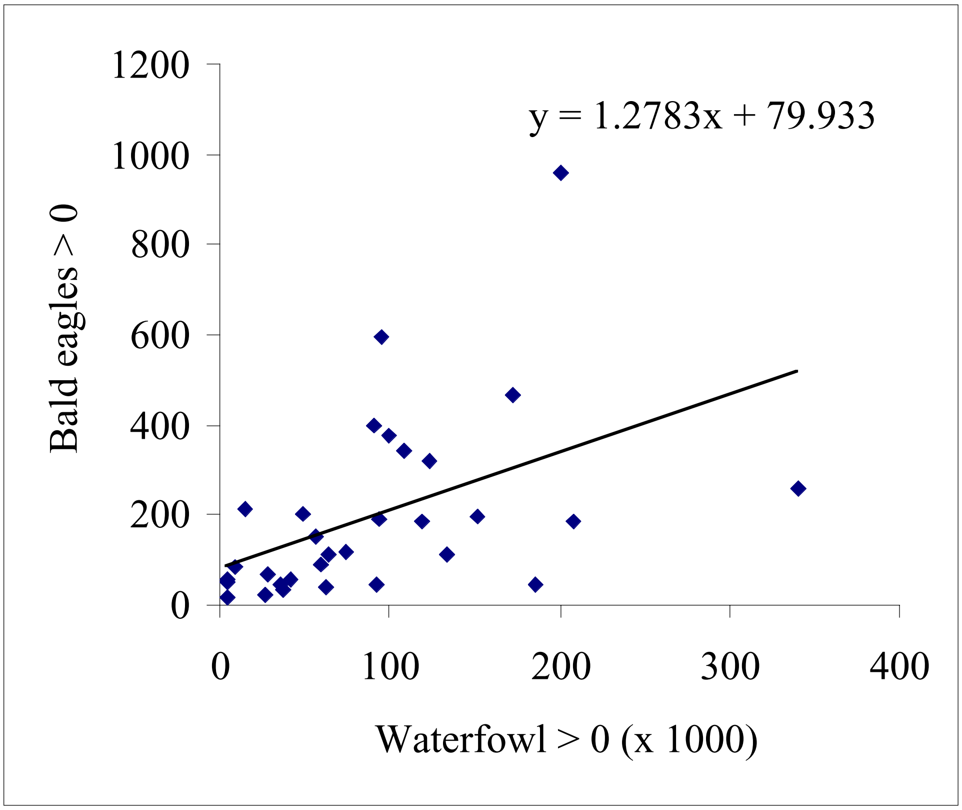

Figure 4. Scatterplot and correlation between numbers of bald eagle and waterfowl in the Lower Klamath NWR in the Klamath Basin (source: Mauser and Thomson 2001).

Draft
December 14, 2001

Relationships between mule deer biology and federal environmental decisions on the Klamath Project

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Introduction

Trade-offs between wildlife and the values of reservoirs, timber management, agriculture, and other land and water development activities commonly result from environmental regulatory and policy decisions. Confrontations also may arise between the conservation needs of threatened and endangered species and non-listed species that are managed, such as big game. The impacts on big game of the federal environmental decisions to restrict the allocation of water to farmers in the Klamath Basin have not been considered.

Because current federal decisions associated with the Klamath Project derive from procedural aspects of interagency consultation under Section 7 of the Endangered Species Act between the Bureau of Reclamation (BR) and the U.S. Fish and Wildlife Service (USFWS), state agencies provided comments regarding the effects of the decisions on big game. Here, we summarize the status and wildlife value of mule deer (*Odocoileus hemionus*) in the Klamath Basin and discuss how current federal environmental decisions for managing water in that area may influence this species.

Status of mule deer

Mule deer are the most sought big-game species in Oregon, with annual harvests since 1952 ranging from 16,000 to nearly 98,000 (Verts and Carraway 1998). They are one of five species of big game in the Klamath Basin. The other four are elk (*Cervus elaphus*), pronghorn (*Antilocapra americana*), cougar (*Felis concolor*), and black bear (*Ursus americanus*).

Estimated populations in North America increased from about a half million to 4.7 million between the 1920s and 1960s (Julander and Low 1976; Rue 1978). Between 1926 and 1933, estimates for National Forests in Oregon ranged from 28,654 to 55,570, suggesting that mule deer were abundant (Bailey 1936). They also were believed to be abundant in nonfederal areas during that time (Cliff 1939). McKean and Luman (1964) concluded that the mule deer population in Oregon had declined since that period. In 1990, the population in Oregon was estimated to be 256,000 (ODF&W 1990).

To manage game species, such as mule deer, the Oregon Department of Fish and Wildlife (ODFW) divided the state into 77 Wildlife Management Units (WMU). Seven WMUs lie within the Klamath Basin of Oregon. However, the majority of the Klamath Project lies within the Klamath Falls and Keno WMUs. Present management strategies differ by WMU based on buck:doe (male:female) ratios (ODFW 1990). Mule deer are present in all seven WMUs in the

Oregon portion of the Klamath Basin (ODFW 2001). Deer population trend estimates for the Klamath Falls WMU were 3.0 mule deer per survey mile in 1999 and 3.1 in 2000 (ODFW 2001).

Wildlife value

Mule deer evolved in North America before the presence of humans. Their prevalence throughout western North America makes them important in human subsistence, recreation, and nonconsumptive aesthetics. A total of 1,162 hunters purchased hunting tags for the Klamath Falls WMU, and 37 percent successfully harvested deer in 2000. No Oregon-specific data are available on the economic value of mule deer hunting. The average value of a deer-hunting trip to a hunter in California was estimated at $191, or $115 per recreation-visitor day (Loomis et al. 1989). Additionally, the general public in California derived an average value of $11 per trip on outdoor trips where they saw deer and $15 per trip on trips taken primarily to view deer (Loomis et al. 1989). In 1987, California deer hunters spent $184 million (Loomis et al. 1989).

Mule deer also contribute significantly to the structure and functions of ecosystems and are considered ecological indicators (Hanley 1996). They have large home ranges, often exhibit seasonal migrations, and require spatially diverse habitat elements such as food and cover. Mule deer are prey for various mammalian predators and birds of prey and substantially affect vegetation composition and basic ecosystem processes such as nutrient cycling, thereby functioning as a keystone species (Hanley 1996; Hobbs 1996).

Potential influences of current federal environmental decisions

ODFW and U.S. Department of Agriculture's Animal Plant Health Inspection Service, Wildlife Services (USDA, APHIS, WS) are primary sources of data on big game in the Oregon portion of the Klamath Basin. The Portland Office of the ODFW maintains a comprehensive database on damage by ungulate game species, from which we received information on deer, elk, and pronghorn. For each Wildlife Management Unit, ODFW maintains an annual tally of the number of kill and hazing permits issued, fence contracts completed, tree cages used, hay stacks protected, repellents and noise makers used, hazing efforts completed, trapping efforts completed, and times advice was given. ODFW also publishes "Big Game Statistics" each year, which contains population data and harvest survey information of big game harvested in Oregon. ODFW uses transects as an index to estimate trends in mule deer populations rather than attempting to estimate the population size per se. Trend counts also include herd composition data.

Problems inherent in this type of data limit their use in making assessments of individual- and population-level responses by these species to the current federal environmental decisions. These data are based on broad geographic areas that encompass a variety of natural and human-modified habitats, weather conditions, and water sources. Within any one area, natural habitats may be converted to agriculture or houses, thereby encroaching into previously available habitats. Weather conditions are highly variable, and availability to natural and man-made water sources may vary depending on season, climate, and agricultural and domestic use by people. Additionally, increased complaints may be due to an increase in the human population rather than the status of big game populations. Furthermore, we suspect that big game damage would increase on farms that did receive water because the availability of green vegetation was limited. However, damage complaints actually declined in 2001 because so few farms produced a cover crop that attracted deer. Consequently, it is not possible to determine whether changes identified in the data are based on habitat conditions, loss of existing habitat, weather conditions, availability of water, or size of the wildlife population. Furthermore, precision of the available data both from the standpoint of variation among annual counts and the landscape scale at which it is collected makes it unlikely that changes in deer population can be contributed to changes in water distribution in the Klamath Basin.

The changes to the Klamath Project described in the 1992 and 2001Bureau of Reclamation's Biological Assessments have modified the timing and amount of water available across the landscape in the Upper Klamath Basin. Such changes, coupled with the current drought conditions, will likely increase distances among available water sources and reduce nutritionally rich irrigated forage crops, and may have direct and indirect influences on big game, such as mule deer. Direct influences include physiological stress on mule deer bucks after the rut, pregnant females during the winter, and young fawns during the spring and summer, and decreased survival and reproduction. Indirect influences may be shifts in local and regional distributions, increased risk of automobile collisions while travelling long distances, and crowding at remaining forage and water sources. Additionally, animal damage complaints from individual producers may rise due to increased foraging on ornamental plantings and irrigated crops by mule deer.

Weather

Given that recent drought conditions led to the Reclamation's modification to the Klamath Project, it is important to discuss the theoretical influences of the current federal environmental decisions on mule deer in light of weather conditions. Weather can directly affect wildlife by harming and killing individual animals, such as young that are often especially susceptible to severe weather. Weather can also indirectly affect wildlife populations by restricting movements; destroying, preventing access to, or reducing the production of food and cover resources; and it can influence the abundance of competitors, predators, and disease organisms (Bailey 1984).

Quantity and quality of forage production vary substantially among years depending on the amount and seasonal distribution of precipitation. Reproductive success in mule deer has been correlated with seasonal precipitation patterns (Shaw 1965), and improved forage conditions during years with extra moisture are one factor related to higher reproduction (Wallmo 1973; Anthony 1976). During drought periods, limited forage supplies may reduce small mammal populations, resulting in a shift of coyote (*Canis latrans*) predation to deer (Bailey 1984). Current federal environmental decisions, coupled with summer drought conditions, may result in decreased fawn and yearling nutrition, which in turn may cause poor physical condition leading to decreased winter survival.

Weather is a variable factor capable of large effects on wildlife and habitats. Because it is unpredictable, weather adds uncertainty to the predictions of wildlife managers and requires frequent review of management decisions. Extreme climatic conditions may override the effects of management on wildlife populations, perhaps requiring a reversal of management strategies (for example, see Severinghaus 1972).

Forage

Forage is necessary to animals as a source of energy and for growth and maintenance. Mule deer diets vary by location, season, sex, and other factors (Kufeld et al. 1973; Wallmo 1978; Main and Coblentz 1990). When given access to seasonally abundant, nutritious, herbaceous plants of high digestibility, deer will select those species over browse species of lower digestibility (Demarais and Krausman 2000). In the Klamath Basin, mule deer forage heavily on irrigated crops such as grains, alfalfa, and beets (Hainline, USFWS, pers. comm.). When natural vegetation is reduced during drought years, irrigated crops provide improved nutritional value for mule deer during autumn and winter. The reductions of water in the Klamath Basin will likely result in a reduction in the quantity and quality of irrigated crops available as forage to mule deer. Changes in the availability of natural and irrigated crops also will result in changes in the local distribution of mule deer as individuals move to forage in areas where irrigated crops are available.

Interactions between forage and other aspects of mule deer biology also may influence deer survival. For instance, Bailey (1984) suggested that habitat condition, including forage quality, availability of water, and weather should not be considered as a population regulating factor without simultaneously considering predation. McNamara and Houston (1987) and Sinclair and Arcese (1995) reported an interaction between foraging and predation, and emphasized that it is meaningless to consider these factors in isolation. For example, better forage conditions enable deer to spend less time feeding, thereby lowering chances of predation (Kie et al. 1991; Kie 1999).

Physiology

Mule deer physiology can be broken down into growth, fat deposition and mobilization, water requirements, and thermal relationships (Demarais and Krausman 2000). All of these physiological factors inevitably influence survival. However, we suggest that fat deposition and mobilization and water requirements may be best for considering the influence of the Klamath Project on mule deer.

Fat deposition and mobilization. Generally, mule deer store fat in spring and summer and deplete it in fall and winter (Anderson et al. 1972, Wallmo 1981). Males reach their lowest point of fat storage following rut and into winter and early spring (Anderson et al. 1972). Females undergo a less pronounced annual cycle of fat deposition and loss compared to males, and reach a low point in their fat storage cycle during lactation because of high energetic demands for feeding fawns (Anderson et al. 1972). Adult females maintain greater fat reserves during critical winter periods than males, and have higher survival rates during these seasons. Reduced quantity and quality of irrigated crops available as forage to mule deer in the Klamath Basin may result in mule deer having poorer nutritional condition, decreased fat reserves, and subsequently may decrease survival rates. Increased winter-kill would be an indicator of such conditions. Poor nutritional condition also may result in low birth weights in fawns and subsequent higher mortality.

Water requirements. Mule deer that live in arid and semiarid environments are adapted to scarcity of freestanding water. Hazam and Krausman (1988) and Hervert and Krausman

(1986) reported that desert mule deer in Arizona visited sources of water on average once a day and consumed 5 to 6 liters of water per visit during the hot summer months, while visitation rates and amount of water consumed per visit declined during cooler seasons of the year. They also found that female mule deer drink more water than males during late summer. Females often are found closer to sources of water than males, presumably because of the demands of lactation, and may remain close to water sources year-round (Bowyer 1984, Fox and Krausman 1994, Boroski and Mossman 1996, Main and Coblentz 1996).

Mule deer are capable of obtaining water from a variety of sources. They can obtain water by consuming succulent plants, dew on the surface of plants, and through metabolic processes (Anderson 1981). Whether mule deer actually require freestanding water has been debated (Severson and Medina 1983). For instance, Lauteir et al. (1988) suggested that while mule deer may exist for periods of time without access to freestanding water, survival may be marginal during these periods. The current decision to reduce the amount of water allocated to farmers and national wildlife refuges in the Klamath Basin has reduced the availability of irrigated crops where mule deer may obtain dew from the surface of plants, and it may increase travel distances between freestanding surface water.

The abundance and spacing of water sources also can influence the distribution of mule deer in a local area. In northern California, mule deer averaged 1.19 to 1.55 kilometers (km) away from water sources, with a mean maximum distance of 2.46 km (Boroski and Mossman 1996). Female and male deer distribute themselves at different distances from water sources (Bowyer 1984; Fox and Krausman 1994; Boroski and Mossman 1996; Main and Coblentz 1996). This differential proximity to water led to recommendations for managing artificial water developments for mule deer in northern California, which included spacing the water developments less than 3.2 km apart with a maximum of 4.6 km (Wood et al. 1970; Boroski and Mossman 1996). The reduction of water provided to farmers and national wildlife refuges in the Klamath Basin may reduce surface levels, but likely will not eliminate water sources. Only in areas where irrigated crops are not receiving water or where secondary or tertiary canals are dry are mule deer likely to change distribution patterns. However, the presence of water in the major lakes, rivers, and canals of Klamath Basin will likely meet water requirements for mule deer.

Reproduction

A change in the spacing and availability of freestanding water and reduction in quantity and quality of forage in the Klamath Basin may increase physiological stress and reduce reproduction in mule deer. The reproductive potential of mule deer is lower in habitats having poor-quality forage compared to those in habitats with high-quality browse (Taber and Dasmann 1957). Well-nourished females might breed at 17 months of age, whereas those in poor condition breed first as late as 41 months of age (Mackie et al. 1982; Anderson and Wallmo 1984). Timing and synchrony of reproduction are adaptations to long-term climatic patterns that help ensure that females have adequate nutrition during late gestation and parturition and that fawns are born at an optimal time of year (Robinette et al. 1977; Wallmo 1978; Bowyer 1991).

The ability to vary reproductive performance in response to environmental conditions may be of considerable adaptive importance for mule deer in the Klamath Basin, but abrupt depletion of water within the Klamath Basin may alter sex ratios in the mule deer population. Mule deer are polygynous and breed during the autumn (Thomas and Cowan 1975). Females usually breed for the first time at 17–18 months of age, and usually give birth to one young at 24–25 months; older females give birth to twins 64 percent of the time (Hines 1975). In most populations, adult females outnumber adult males by more than 2:1 (Robinette et al. 1957). Significantly more females can occur in heavily hunted populations (Mackie et al. 1982), and this appears to be the case in the Klamath Falls Management Unit (237 females : 27 males; ODFW 2001). Though it is not clear whether the reduction of water sources and associated irrigated crops used as forage by mule deer in the Klamath Basin will affect males more than females, increased losses to adult males could affect the existing sex ratios.

Adult female mule deer commonly give birth to two fawns in areas having adequate nutritional levels, while females breeding for the first time often will conceive only a single fawn (Anderson and Wallmo 1984). Adult females also are in poor condition following late gestation and lactation. Conversely, adult males are in poorest condition following rut, and consequently suffer greater mortality during winter (Flook 1970; White 1973; Kie and White 1985). Current decisions for managing water in the Klamath Basin, coupled with existing drought conditions, may decrease the numbers of fawns, the physical condition and survival of adult females after late gestation and lactation, and the physical condition and survival of adult males following rut.

Conclusions

The Klamath Project and current federal environmental decisions may potentially influence mule deer in several ways. First, the current weather conditions (drought) in the Klamath Basin, in combination with these decisions to reduce water, may alter habitat conditions to a level that causes a reduction in water sources and forage. Wild animals are well adapted to variable weather conditions within their environment (Kelsall and Telfer 1971). Nevertheless, weather extremes do cause mortality, and human-induced habitat losses and changes, such as managing water across the Klamath Basin, may cause population crowding, reduced reproduction, and physiological stress in mule deer in the Klamath Basin. However, the most likely effect of reduced availability of water in the Basin is a change in the distribution of mule deer, leading to increased use of irrigated crops.

Monitoring of mule deer in upper Klamath Basin should be conducted during and for several years following the period related to the current federal environmental decisions in the Klamath Basin to determine the extent of the influence on the mule deer population. This information, coupled with water allocations imposed by federal environmental decisions, would prove valuable in making harvest recommendations for mule deer that adjust harvest limits to current weather, habitat, water allocations, and herd conditions. The late winter herd counts will be the first opportunity to determine whether water withdrawals in the Klamath Basin have impacted deer populations. However, given the variability in those counts, it is unlikely that changes in population levels will be detected.

Acknowledgments

Comments on this chapter were provided by B. Coblentz of Oregon State University, Department of Fisheries and Wildlife; R. Hathaway, Oregon State University, Extension Service, Klamath Falls; and J. Mortenson from the Oregon Department of Fish and Wildlife.

Literature cited

Anderson, A.E. 1981. Morphological and physiological characteristics. Pages 27-97 in O.C. Wallmo, ed., Mule and black-tailed deer of North America. University of Nebraska Press, Lincoln.

Anderson, A.E., D.E. Medin, and D.C. Bowden. 1972. Indices of carcass fat in a Colorado mule deer herd. Journal of Wildlife Management 36:579–594.

Anderson, A.E., and O.C. Wallmo. 1984. *Odocoileus hemionus*. Mammalian Species 219:1–9.

Anthony, R.G. 1976. Influence of drought on diets and numbers of desert deer. Journal of Wildlife Management 40:140–144.

Bailey, V. 1936. The mammals and life zones of Oregon. North American Fauna 55:1–416.

Bakeless, J. 1947. Lewis and Clark: partners in discovery. William Morrow and Company, New York, 498pp.

Birgressen, B. 1998. Adaptive adjustment of the sex ratio: More data and considerations from a fallow deer population. Behavioral Ecology 9:404–408.

Boroski, B.B., and A.S. Mossman. 1996. Distribution of mule deer in relation to water sources in northern California. Journal of Wildlife Management 60:770–776.

Bowyer, R.T. 1984. Sexual segregation in southern mule deer. Journal of Mammalogy 65:410–417.

Bowyer, R.T. 1991. Timing of parturition and lactation in southern mule deer. Journal of Mammalogy 72:138–145.

Crouch, G.L. 1966. Preferences of black-tailed deer for native forage and Douglas-fir seedlings. Journal of Wildlife Management 30:471–475.

Crouch, G.L. 1981. Coniferous forest habitats: Part 1, Food habits and nutrition, Pages 423-433 in O.C. Wallmo, ed., Mule and black-tailed deer of North America. University of Nebraska Press, Lincoln.

Demarais, S., and P.R. Krausman. 2000. Ecology and management of large mammals in North America. Prentice-Hall, Inc. Upper Saddle River, New Jersey, 778pp.

Flook, D.R. 1970. Causes and implications of an observed sex differential in the survival of wapiti. Report Series Number 11, Canadian Wildlife Service, Ottawa.

Fox, K.B., and P.R. Krausman. 1994. Fawning habitat of desert mule deer. Southwestern Naturalist 39:269–275.

Hanley, T.A. 1996. Potential role of deer (Cervidae) as ecological indicators of forest management. Forest Ecology and Management 88:199–204.

Hazam, J.E. and P.R. Krausman. 1988. Measuring water consumption of desert mule deer. Journal of Wildlife Management 52:528–534.

Hervert, J.J., and P.R. Krausman. 1986. Desert mule deer use of water developments in Arizona. Journal of Wildlife Management 50:670–676.

Hoefs, M., and U. Nowlan. 1994. Distorted sex ratios in young ungulates: the role of nutrition. Journal of Mammalogy 75:631–636.

Hobbs, N.T. 1996. Modification of ecosystems by ungulates. Journal of Wildlife Management 60:695–713.

Julander, O., and J.B. Low. 1976. A historical account and present status of the mule deer in the West. Pages 3–19 in G.W. Workman and J.B. Low, eds., Mule deer decline in the West: A symposium. Utah State University, Logan.

Kie, J.G. 1999. Optimal foraging and risk of predation: Effects on behavior and social structure inungulates. Journal of Mammalogy 80:

Kie, J.G., C.J. Evans, E.R. Loft, and J.W. Menke. 1991. Foraging behavior by mule deer: the influence of cattle grazing. Journal of Wildlife Management 55:665–674.

Kie, J.G., and M White. 1985. Population dynamics of white-tailed deer (*Odocoileus verginianus*) on the Welder Wildlife Refuge, Texas. Southwestern Naturalist 30:105–118.

Kelsall, J.P., and E.S. Telfer. 1971. Studies of the physical adaptation of big game for snow. Pages 134–146 in A.O. Haugen ed., Snow and ice in relation to wildlife and recreation symposium. Iowa State University, Ames. 280 pp.

Kufeld, R.C., O.C. Wallmo, and C Feddema. 1973. Foods of the Rocky Mountain mule deer. USDA Forest Service Research Paper RM-111. U.S. Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO.

Loomis, J., M. Creel,and J. Cooper. 1989. Economic benefits of deer in California: hunting and viewing status. Institute of Ecology Report 32, University of California, Davis.

Mackie, R.J., K.L. Hamlin, and D.F. Pac. 1982. Mule deer. Pages 862–877 in J.A. Chapman and G.A. Feldhamer, eds., Wild Mammals of North America—Biology, management, economics. Johns Hopkins University Press, Baltimore, MD.

Main, M.B. and B.R. Coblenz. 1990. Sexual segregation in ungulates: A critique. Wildlife Society Bulletin 18:204–210.

Main, M.B. and B.R. Coblenz. 1996. Sexual segregation in Rocky Mountain mule deer. Journal of Wildlife Management 60:497–507.

McCullough, D.R., D.S. Pine, D.L. Whitmore, T.M. Mansfield, and R.H. Decker. 1990. Linked sex harvest strategy for big game management with a test case on black-tailed deer. Wildlife Monographs 112:1–41.

McNamara, J.M., and A.I. Houston. 1987. Starvation and predation as factors limiting population size. Ecology 68:1515–1519.

ODF&W. 1990. Mule deer management plan. Oregon Department of Fish and Wildlife. Unpublished document.

ODF&W. 2001. Big Game Statistics. Oregon Department of Fish and Wildlife. Unpublished document.

Pond, C.M. 1978. Morphological aspects and the ecological and mechanical consequences of fat deposition in wild vertebrates. Annual Review of Ecology and Systematics 9:519–570.

Robinette, W.L., N.V. Hancock, and D.A. Jones. 1977. The Oak Creek mule deer herd in Utah. Publication 15:1–48. Utah State Division of Wildlife Resources, Salt Lake City.

Robinette, W.L., J.S. Gashwiler, J.B. Low, and D.A. Jones. 1957. Differential mortality by sex and age among mule deer. Journal of Wildlife Management 21:1–16.

Rue, L.L. III. 1978. The deer of North America. Outdoor Life Books. Crown, New York.

Shaw,H. 1965. Investigation of factors influencing deer populations. Pages 125–143 in Wildlife Research in Arizona, 1964. Arizona Game and Fish Department, Phoenix. 251 pp.

Severinghaus, C.W. 1972. Deer weights as an index of range conditions in two wilderness areas of the Adirondack region. New York Fish and Game Journal 2:154–160.

Severson, K.E., and A.L. Medina. 1983. Deer and elk habitat management in the Southwest. Journal of Range Management, Monograph No. 2.

Short, H.L., D.R. Dietz, and E.E. Remmenga. 1966. Selected nutrients in mule deer plants. Ecology 47:222.

Sinclair, A.R.E., and P. Arcese. 1995. Population consequences of predation-sensitive foraging: The Serengeti wildebeest. Ecology 76:882–891.

Smith, B.L., R.L. Robbins, and S.A. Anderson. 1996. Adaptive sex ratios: Another example? Journal of Mammalogy 77:818–825.

Thomas, D.C., and I. McT. Cowan. 1975. The pattern of reproduction in female Columbian black-tailed deer, *Odocoileus hemionus columbianus*. Journal of Reproduction and Fertility 44:261–272.

Urness, P.J. 1981. Desert and chaparral habitats: Part 1, food habits and nutrition. Pages 347–365 in O.C. Wallmo, ed., Mule and black-tailed deer of North America. University of Nebraska Press, Lincoln.
U.S. Bureau of Reclamation. 1992. Biological Assessment of Klamath Project's continuing operations on the endangered lost river sucker and shortnose sucker. Final Biological Assessment of the Mid-Pacific Region's Klamath Basin Area Office, Klamath Falls, Oregon.
U.S. Bureau of Reclamation. 2001. Biological Assessment of Klamath Project's continuing operations on the endangered lost river sucker and shortnose sucker. Final Biological Assessment of the Mid-Pacific Region's Klamath Basin Area Office, Klamath Falls, Oregon. February 13, 2001.
Verts, B.J., and L.N. Carraway. 1998. Land mammals of Oregon. University of California Press, Berkeley.
Wallmo, O.C. 1978. Mule and black-tailed deer. Pages 31–41 in J.L. Schmidt and D.L. Gilbert, eds., Big Game of North America: Ecology and Management. Stackpole Books, Harrisburg, PA.
Wallmo, O.C. Important game animals and related recreation in arid shrublands of the United States. Pages 98–107 in Arid Shrublands, Proceedings of the 3rd Workshop U.S./Australia Rangelands Panel, Tucson, AZ.
Wallmo, O.C. 1981. Mule and black-tailed deer distribution and habitats. Pages 1–15 *in* O.C. Wallmo, ed., Mule and black-tailed deer of North America. University of Nebraska Press, Lincoln.
Wallmo, O.C., and W.L. Regelin. 1981. Rocky Mountain and Intermountain habitats: Part 1, food habits and nutrition. Pages 387–398 in O.C. Wallmo, ed., Mule and black-tailed deer of North America. University of Nebraska Press, Lincoln.
White, M. 1973. The whitetail deer of the Arkansas National Wildlife Refuge. Texas Journal of Mammalogy 15:72.
Wood, J.E., T.S. Bickle, W. Evans, J.C. Germany, and V.W. Howard, Jr. 1970. The Fort Stanton mule deer herd. Agricultural Experiment Station Bulletin Number 567. New Mexico State University, Albuquerque.

Draft
December 14, 2001

Upper Klamath Basin Soil Resources

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Background

A brief general introduction to the geography and geologic development of the Upper Klamath Basin provides some perspective to the following discussions on Upper Klamath Basin soils as they influence productivity and land values. The Upper Klamath Basin is a high-elevation, short-growing-season area created from volcanic and sedimentary events. Klamath Basin geology reflects repeated volcanic activity, erosion, and sedimentary rock deposition with episodes of landscape faulting and folding.

It is an area where the high desert and the Cascade Mountain range meet. This provides the two dominant geophysical features that influence the climate and drainage of the Basin. Elevations range from 4,000 ft. in the southern end of the Basin to 8,700 ft. at Crater Lake in the northern end. This variation in elevation causes wide temperature ranges with a possibility for frost any day of the year. The CascadeMountain range to the west traps most of the coastal moisture, leaving the east side cooler and drier and exposing the Basin to a rain-shadow effect. Sage- and juniper-covered fault blocks and ridges form the eastern and southern sides (Powers, et. al.).

Upper Klamath Lake is the largest lake in Oregon and the main storage reservoir for the USBR Klamath Project. It is 60,000 to 90,000 acres in size with a mean summer depth of 7 feet, as described elsewhere in this report. The lake fills a graben (sunken area of earth's crust bound by faults) many thousands of meters deep, mainly with volcanic debris and sediments. This sedimentation continues today, producing a large shallow lake. The outlet for Upper Klamath Lake is the mile-long Link River that empties into Lake Ewauna, which then becomes the Klamath River, eventually reaching the Pacific Ocean through northern California. The town of Klamath Falls fans out south and east of Link River and Lake Ewauna.

The California-Oregon border approximately cuts the Basin in half. Clear Lake on the California side of the Basin is the second main source of water to the Klamath Reclamation Project with a 25,760-acre surface area and maximum summer depth of 30 feet. It is the source of the Lost River, which flows north out of Clear Lake, turning west and south and eventually ending up in the Tule Lake sump, a closed Basin system until man's manipulation in the 20th century (United States Department of the Interior Bureau of Reclamation, Klamath Project Map).

Soil formation

Soils, as used in this discussion, are dimensioned segments of landscape capable of supporting such higher plants as trees, shrubs, grasses, and agricultural crops. Soils are formed through the interaction of five major factors: climate, parent material, relief (topography), plant and animal life, and time. Most of the precipitation in the Upper Basin area occurs from October to March and is sufficient to moisten the soil to a depth of up to 5 feet. Evaporation greatly exceeds precipitation during the growing season.

Parent material is the unconsolidated mineral or organic matter in which soils form. Many distinctive kinds of parent material have influenced the formation and properties of soils in the survey area. The influence of parent material in soil formation can be profound where materials are contrasting and other soil-forming factors are weak. The soil properties most affected by differences in parent material in the survey area are bulk density (weight per unit volume), available water holding capacity, fertility, and availability of nutrients.

Soils generally are described from organic to mineral depending on their origin, and vary from peat to sandy loam and clay loam soils throughout the irrigable areas of fertile farmland. Soils in Klamath, Siskiyou, and Modoc counties in general can be divided into two broad categories. Highly organic muck soils are found in drained lakebeds, and mineral soils, ranging from sands to loams, are found in upland areas. The muck soils are characterized by having high fertility and water-holding capacities. The mineral soils tend to vary more and are more dependent on textural differences in regard to water and fertility status. Parent material and relief cause most of the differences in soils of the area.

Most of the agriculturally significant soils in the Upper Basin formed in lacustrine (lakebed) or alluvial (water borne) sediment weathered mainly from diatomite, tuff, and basalt. Soils on lake terraces in the Basins commonly are underlain by diatomite, or diatomite stratified with lacustrine sandstone. Some soils formed partly in sediment that washed off the lake terraces and partly in alluvium from outside the Basins. Soils that formed in lacustrine and alluvial sediment in the survey area have somewhat lower bulk density and somewhat higher available water-holding capacity compared to soils of similar texture and other mineral origin.

Fibrous organic material covers the floor of much of Upper Klamath Lake and large areas and bays around the lake, which have been diked and drained for irrigated cropland. The organic soils formed in this material have low bulk density, high available water-holding capacity, critical plant and animal nutrient deficiencies including copper and selenium, and low thermal conductivity. When farmed, this soil is subject to continuing subsidence (lowered soil surface elevation) due to oxidation of organic material.

Relief and landforms have been important factors both in soil formation and in determining the distribution of soils in the survey area. Relief also determines the location of lakes, streams, marshes, and soils that have a water table, soils that have alkali, and soils that are subject to flooding.

Man also has influenced differences in soils. He has diked and drained large areas of marsh, and cut and filled the land in leveling for irrigation. Man has also had an extensive, though recent, influence in modifying soil properties, by removing parts of soils from the landscape, and creating new areas of soils. It is estimated that more than 100,000 acres in the survey area has been leveled and smoothed for irrigation. Deep ripping to break up the hardpans, intensive fertilization, and irrigation have changed the reaction of the upper part of some soils from alkaline or neutral to slightly acid to strongly acid. Irrigation and drainage also have redistributed carbonates in the soils, decreased their salt and sodium contents, and lowered the depth of water tables. Tile drainage systems have been installed in many of the fields in the region to facilitate the lowering of perched water tables.

The Klamath Reclamation Project

The focus of this report is on soils of the Upper Klamath Basin and in particular within the United States Department of the Interior, Bureau of Reclamation's Klamath Reclamation Project, which encompasses 233,625 acres of irrigable lands in Klamath County, Oregon, and Modoc and Siskiyou counties in California. Man's activities during the early part of the 20th century started the change from a natural shallow lake-marsh system to an agricultural and waterfowl refuge system. Project development was begun in 1906 with construction of the main A-Canal out of Upper Klamath Lake. In 1908, the Keno Reef in the Klamath River below Keno was lowered, which began turning Lower Klamath Lake into agricultural land and a wildlife refuge. Tule Lake also was reclaimed for agriculture and a wildlife refuge with the diversion of part of the Lost River drainage area to the Klamath River and establishment of an evaporation Basin by expansion of Clear Lake.

Other major elements of the modern-day Klamath Project include the Lost River Diversion Channel that can control flooding in the Tulelake area by diverting water from the Lost River to the Klamath River, and the Tule Lake Tunnel that conveys drainage water from the Tule Lake sumps to the Lower Klamath National Wildlife Refuge and back to the Klamath River via the Klamath Straits Drain. The Diversion Channel also can augment irrigation supplies to the Klamath Project from the Klamath River.

Soil capability classes and crop yield potential

U.S. Department of Agriculture (now USDA Natural Resources Conservation Service, formerly USDA Soil Conservation Service) soil capability classes show, in a general way, the suitability of soils for most kinds of field crops. Soils are classified according to their limitations for field crops, the risks of damage from cultivation, and their response to treatment. The grouping does not consider major and generally expensive land forming that would change slope, depth, or other characteristics of the soils, possible but unlikely major reclamation, and does not apply to horticultural or other crops that require special management.

Soils are placed in Capability Classes represented by Roman numerals I to VIII. The numerals indicate progressively greater limitations and narrower choices for practical use. These classes are defined as follows (Soil Conservation Service, 1985):

- Class I soils have few limitations that restrict their use.
- Class II soils have moderate limitations that reduce the choice of plants or that require moderate conservation practices.
- Class III soils have severe limitations that reduce the choice of plants or that require special conservation practices, or both.
- Class IV soils have very severe limitations that reduce the choice of plants or that require very careful management, or both.
- Class V soils are not likely to erode but have other limitations, impractical to remove, that limit their use.
- Class VI soils have severe limitations that make them generally unsuitable for cultivation.
- Class VII soils have very severe limitations that make them unsuitable for cultivation.
- Class VIII soils and miscellaneous areas have limitations that nearly preclude their use for commercial crop production.

Limitations for soils in the Upper Klamath Basin include the following (Soil Conservation Service, 1985):

- Erosion: soils susceptible to erosion.
- Water: poor soil drainage, wetness, high water table or overflow.
- Soil limitations: shallow or stony rooting zone, low water holding capability, low fertility, salinity, and sodium.
- Climatic limitations: frost risk or lack of moisture.

Because of the high-altitude-induced short growing season and nearly constant possibility of frost, there are no designated capability Class I soils in the Upper Klamath Basin. Soils have essentially been down rated one class as a result.

However, for frost-tolerant crops normally grown in the area, the tables of estimated crop yields in the referenced USDA soil surveys generally underestimate current crop production potential. Irrigation and drainage within the Klamath Reclamation Project and advances in crop varieties, crop-protection strategies and agronomic systems developed in recent decades in cooperation with local producers by Oregon State University and University of California agricultural experiment stations have contributed to production capabilities beyond the basic soil survey ratings. Higher crop yields in test plot experiments and on-farm field trials are documented in annual reports of the two university stations. Yields in excess of those estimated in the original soil surveys also are documented in annual crop reports prepared by Modoc and Siskiyou County Agricultural Commissioners, Tulelake Irrigation District, Klamath County Cooperative Extension, and the U.S. Bureau of Reclamation.

An example of this is shown with a Poe fine sandy loam soil found at the Klamath Experiment Station (KES). The Klamath County Soil Survey states that alfalfa yields expected would be 5 tons/acre. However, in a variety trial conducted from 1997 to 2000 with 28 varieties, the average yield was 6.5 tons/acre. In the soil survey it also shows that expected yields of wheat would be 5,100 lb/acre. In the 2000 Western Regional Spring Wheat Nursery at KES across 39 varieties, average wheat yield was 6,150 lb/acre. For barley, soil survey yield estimates are 4,560 lb/acre. In the 2000 Western Regional Spring Barley Nursery at KES across 36 varieties, average barley yield was 5,730 lb/acre. Soil survey potato yields were estimated to be 330 cwt/acre. In the 2000 Western Regional Potato Trial across 16 varieties, average yield was 550 cwt/acre (Klamath Experiment Station).

Prime farmland

Soils falling in soil Capability Class I through Class III usually are designated Prime Farmland. When irrigated, or irrigated and drained, most of the agricultural soils in the Klamath Project can be considered Prime Farmland as defined and recognized by the United States Department of Agriculture. Prime Farmland is of strategic importance in meeting the nation’s short- and long-range needs for food and fiber. State and local land-use planning laws are designed to protect and preserve Prime Farmland. The cutoff of irrigation water to Klamath Project lands during the 2001 crop season, in effect, resulted in a temporary loss of many thousands of acres of Prime Farmland by preventing the production of economic crop yields.

Specific soil series data

An analysis was completed investigating specific soil series properties within the southern Klamath County and California portions of the Klamath Project. Data for Oregon was obtained from the "Soil Survey of Klamath County Oregon, Southern Part," issued April 1985. For the Oregon portion of this analysis, a very diverse set of soils are encountered. Seventy-five series, complexes, and associations of soils are considered fit for irrigated crops or pastures. Of these 75 series, 22 are considered Prime Farmland. These 22 series are found on more than 133,000 acres in Klamath County.

Data for the California portion of the analysis were obtained from the "Soil Survey of Butte Valley—Tule Lake Area, California, Parts of Siskiyou and Modoc Counties," issued February 1994. For the area of California considered, less diversity of the soils was apparent with most of the soils being found on the drained lakebeds of Lower Klamath Lake and Tule Lake. The soils analyzed in California included those found in the Klamath Irrigation Project and in the Tule Lake and Lower Klamath Lake National Wildlife Refuges. Ten soil series were analyzed, which accounted for more than 148,000 acres. The data for both the Oregon and the California Prime Farmland soils are included in Table 1.

Table 1. Textural class, slope, area, depth to hardpan, depth to water table, and available water for the Prime Farmland soils of southern Klamath County, Oregon, and the Klamath Project portion of Modoc and Siskiyou counties in California.

State	Soil series name	Soil textural class	Slope	Acres	Percent of total	Depth of hardpan	Depth of water table	Avail. water	Avail. Water
						inches	inches	in/depth	in/ft
OR	Calimus	fine sandy loam	0-2	3,022	1.1%	>60	>60	9.5	1.9
OR	Calimus	loam	0-2	10,543	3.7%	>60	>60	9.9	2.0
OR	Calimus	fine sandy loam	2-5	5,653	2.0%	>60	>60	9.5	1.9
OR	Calimus	loam	2-5	9,427	3.4%	>60	>60	9.9	2.0
CA	Capjac	silt loam	0-1	43,700	15.5%	>60	>60	28.2	5.6
CA	Capjac	silt loam ponded	0-1	4,240	1.5%	>60	>60	28.2	5.6
OR	Capona	loam	0-2	843	0.3%	20-40	>60	4.4	2.1
OR	Capona	loam	2-5	2,550	0.9%	20-40	>60	4.4	2.1
CA	Dehill	fine sandy loam	0-5	6,350	2.3%	>60	>60	7.2	1.4
OR	Deter	clay loam	0-2	3,503	1.2%	>60	30-72	9.9	2.0
OR	Deter	clay loam	2-7	915	0.3%	>60	>60	9.9	2.0
OR	Dodes	loam	2-15	4,693	1.7%	20-40	>60	3.9	2.1
CA	Dotta	sandy loam	0-5	4,630	1.6%	>60	>60	7.0	1.4
CA	Eastable	loam	0-5	6,250	2.2%	>60	>60	9.8	1.9
OR	Fordney	loamy fine sand	0-2	29,592	10.5%	>60	24-72	6.9	1.4
CA	Fordney	loamy fine sand	0-2	7,760	2.8%	>60	>60	6.9	1.4
OR	Fordney	loamy fine sand terrace	0-3	1,006	0.4%	>60	>60	6.9	1.4
OR	Fordney	loamy fine sand	2-20	8,964	3.2%	>60	>60	6.9	1.4
OR	Harriman	loamy fine sand	0-2	1,930	0.7%	40-60	30-72	6.9	2.0
OR	Harriman	loam	0-2	4,210	1.5%	40-60	30-72	9.0	2.3
OR	Harriman	loam	2-5	2,990	1.1%	40-60	>60	8.8	2.2
OR	Lakeview	silty clay loam	0	2,957	1.1%	>60	30-60	10.7	2.1
CA	Laki	fine sandy loam	0-2	9,570	3.4%	>60	>60	14.2	2.8
CA	Klamath	silt loam	0-1	11,720	4.2%	>60	>60	12.8	2.6
OR	Modoc	fine sandy loam	0-2	7,645	2.7%	20-40	>60	4.4	1.7
OR	Modoc	fine sandy loam	2-5	2,438	0.9%	20-40	>60	4.4	1.7
OR	Poe	loamy fine sand	0	6,100	2.2%	20-40	24-48	3.5	1.4
OR	Poe	fine sandy loam	0	1,526	0.5%	20-40	24-48	3.5	1.4
CA	Truax	fine sandy loam	0-5	4,520	1.6%	>60	>60	7.5	1.5
OR	Tulana	silt loam	0	16,671	5.9%	>60	24-60	38.2	5.0
OR	Tulana	silt loam sandy substratum	0	5,904	2.1%	>60	24-60	25.6	5.1
CA	Tulana	silt loam	0-1	7,930	2.8%	>60	>60	25.4	5.1
CA	TuleBasin	mucky silty clay loam	0-1	41,560	14.8%	>60	>60	24.0	4.8
		Total Acres		281,312					

(Soil Conservation Service 1985; and Soil Conservation Service 1994.)

For these Prime Farmland soils, depth to hardpan, depth to the water table, and available water holding capacity were determined. Hardpans, some which could be ripped by deep chisels, and bedrock at depths of less than 60 inches were indicated for 12.4 percent of the soils. These layers, if not mechanically altered, will limit water-holding capacities and rooting depth. During some portion of the year, 25.7 percent of the soils would be affected by shallow water tables found less than 60 inches below the soil surface. Drainage tiles would help these soils and extensive systems have been employed in the Klamath Basin.

The diversity of the soils is apparent when water-holding capacities were analyzed. Water-holding capacity is both a function of the inherent ability of a soil to hold water and the depth of the soil. Water-holding capacity is a key parameter in irrigation scheduling, being a principal determinant of the maximum allowable time between irrigations. Categorizing the soils in Table 1 by their relative water-holding capacities reveals the following:

- 57.3 percent of the area has soils that hold less than 3 inches of water per foot of soil.
- 14.8 percent of the area has soils that hold less than 5 inches, but more than 3 inches of water per foot of soil.
- 27.9 percent of the area has soils that hold less than 6 inches, but more than 5 inches of water per foot of soil.

When the soil depth of the different series was combined with the water-holding capacities, the amount of the water held in the total depth of the soil (down to 60 inches) was:

- 48.8 percent of the area has soils that hold less than 10 inches of water for the depth of the soil.
- 8.6 percent of the area has soils that hold less than 20 inches, but more than 10 inches of water for the depth of the soil.
- 36.8 percent of the area has soils that hold less than 30 inches, but more than 20 inches of water for the depth of the soil.
- 5.9 percent of the area has soils that hold less than 40 inches, but more than 30 inches of water for the depth of the soil.

Klamath County Tax Assessor data

In Klamath County, recent map-digitizing efforts have allowed NRCS Soil Capability Classes to be assigned to soils for tax assessing purposes. The Klamath County Tax Assessor divides the Klamath Project into six irrigated areas; Midland/Henley/Olene, Poe Valley, Merrill/Malin, Lower Klamath Lake, Shasta View/Malin, and Malin Irrigation District. Table 2 includes the soils in these areas divided into their Capability Classes.

Table 2. Capability Classes of privately owned land in six irrigated areas of Klamath County and the percentage that did not receive full irrigation in the 2001 growing season.

Area	Total acres	Crop and pasture land: Class II	Class III	Class IV	total	Non-crop total	Grand total
		Percent of Land in Each Class					
1	50,700	15.0	36.6	23.5	75.1	24.9	100.0
2	36,260	13.6	18.1	20.2	52.0	48.0	100.0
3	25,362	8.0	55.1	24.5	87.5	12.5	100.0
4	20,630	1.4	90.3	6.1	97.7	2.3	100.0
5	5,345	18.7	58.0	20.6	97.3	2.7	100.0
6	3,525	8.5	82.4	3.4	94.3	5.7	100.0
Total	141,822	11.4	44.9	19.7	76.0	24.0	100.0
		Percent of each class that did not receive full water					
1	50,700	84.4	88.1	91.3	88.4	100.0	91.3
2	36,260	59.1	68.5	59.9	62.7	100.0	80.6
3	25,362	78.0	81.8	83.3	81.9	100.0	84.1
4	20,630	89.6	70.8	76.9	71.4	100.0	72.1
5	5,345	61.0	76.0	88.4	75.7	100.0	76.4
6	3,525	28.7	82.0	96.7	77.7	100.0	79.0
Total	141,822	73.5	78.8	80.5	78.4	100.0	83.6

Klamath County Tax Assessor irrigated areas:

1 - Midland/Henley/Olene
2 - Poe Valley
3 - Merrill/Malin
4 - Lower Klamath Lake
5 - Shasta View/Malin
6 - Malin Irrigation District

For the six areas considered, no Class I (due to climatic limitations) and very limited amounts of Class V soils are present. Overall, more than 140,000 acres of land are found in the six areas. Of this land, 76 percent is classed suitable for crops. The 24 percent found in classes V to VIII are found mainly on hills and mountains that limit their use for crops.

Klamath County has decided to alter the tax liability for property for the 2001 growing season depending on whether the land received full irrigation or not. Full irrigation was defined by Klamath County Assessor Reg LeQuieu as irrigation that was available for cropland throughout the growing season (LeQuieu). A land-based survey was completed on August 3 to verify the land area that did not receive full irrigation. The special assessed value for these lands not receiving full irrigation will be $28.41 per acre. Also included in Table 2 are the percentages of each of the soil Capability Classes that did not receive full irrigation.

For the Midland/Henley/Olene area, mainly serviced by the Klamath Irrigation District, more than 88 percent of the land did not receive full season irrigation. This was the highest percent of any of the Tax Assessor's areas to not receive full irrigation. In contrast only about 63 percent of the Poe Valley area did not receive full season irrigation. This reflects more irrigation wells operating in this area and land serviced by the Horsefly Irrigation District that did receive irrigation water during the 2001 growing season from Gerber Reservoir and Clear Lake. Overall, about 108,000 acres are considered cropland in Klamath County, and of this area more than 78 percent did not receive full irrigation.

For the California portion of the Klamath Basin, the soils are in general more homogeneous than those found in the Oregon portion. The bulk of the soils are mucky silt loams, which, due to climatic, high water table, and sodicity factors, fall into the Capability Class III. . Nonetheless, high organic-matter soils common in this region produce some of the highest-yielding crops in the Project. The installation of tile drainage systems and the use of overhead irrigation systems for frost protection have mitigated most of the innate limitations of these soils. Some of the sandier, alkali-affected area near the Oregon-California border south of Malin would fall into the Class IV capability soils.

Land values

Another aspect of the loss of irrigation water in the Klamath Project that must be considered is the effect on land values. Data provided by Reg LeQuieu, Klamath County Tax Assessor, for the years 1998 to 2000 indicate the magnitude of this effect. More than 6,000 irrigated acres were sold in Klamath County during this period at an average price of $1,687 per acre. For the same time period, close to 1,300 dryland acres were sold at an average price of $783 per acre. This resulted in the dryland acres returning more than $900 less per acre as compared with the irrigated land (LeQuieu). This land value analysis is not complete, but at the time of the communication was the best available data.

Soil erosion

The wearing away of land by water, wind, ice, or other geologic processes continues to occur naturally or can be accelerated by man or catastrophes such as fires and floods. Since the Klamath Project is essentially a closed-Basin system, deposition from running water occurs at the Tule Lake Sump and in drainage ditches and canals. This loss in topsoil results in reduced farm productivity and additional expense to the irrigation districts for maintenance of the irrigation system. Adoption of efficient sprinkler irrigation systems limits soil erosion caused by water transport of soil particles. Most of the farmland in the Klamath Project is under sprinkler irrigation (80 percent) with minor acreages (20 percent) of cereal crops and pastures being surface irrigated (U.S. Department of the Interior, Bureau of Reclamation, annual Crop Reports).

Wind erosion is the major cause of soil loss, especially in the spring during field preparation. Several thousand acres of Klamath Project soils are rated as Highly Erodable Lands (HEL) by NRCS. Several thousand additional acres of deep, organic soils escape the HEL designation due to their great depth and high tolerance for incremental soil loss under the Universal Soil Loss Equation (USLE) used by the agency to determine soil loss tolerance. Nonetheless, these light, organic soils are highly subject to wind erosion when dry, and present air quality and public safety hazards beyond their modest erodability ratings.

The recent decision to deny Klamath Project water deliveries to farmers threatened to transform the productive Basin into a major dust bowl (Woodley, R.). With 30,000 acres of bare soil exposed to the Basin’s historically windy springs, serious soil erosion was a certainty. In response, the Klamath Soil and Water Conservation District (KSWCD) implemented the largest single soil-conservation effort in the Northwest (Woodley, personal communications). The KSWCD, with resources from the USDA Natural Resource Conservation Service, was able to institute a cover crop program for farmers to cover bare soil on their farms. Growers were offered cost sharing to plant a small cereal grain crop to protect exposed soil.

This effort resulted in the planting of cover crops on more than 37,500 acres in the Klamath Project, which includes portions of Klamath, Modoc and Siskiyou counties. The cost of the program for these planted acres was $1,725,000. The growers participated on a cost-share basis, providing a 25 percent match and receiving a 75 percent cost-share payment. The amount paid to participants of the cover crop program was nearly $1,293,750. Growers were reimbursed after they were determined to be eligible and their cover crop planting was certified to be complete. Some growers who reacted quickly to the situation and planted a cover crop before the program started were not eligible for the cost-share payment.

With some limitations, the program was able to conserve topsoil in the Basin. It is estimated that 95 percent of the cover crops seeded did emerge with a significant reduction in Upper Klamath Basin soil erosion. (Woodley, R.)

The Oregon Department of Environmental Quality monitors Upper Klamath Basin air quality for particulates during the firewood-burning season for health and safety reasons. There is no such air quality data available for the early 2001 spring time period, but residents greatly appreciated the cover crop program for reducing dust in the air, and farmers benefited by saving tons of soil from loss to wind erosion.

Crop rotations

Crop rotations are essential for sustainable, long-term farming operations. In general, productive rotations for the Klamath Basin include alfalfa with grain crops between no more than two row crops in an 8- or 9-year cycle. Most of the Basin’s mineral soils are low in soil organic matter. The alternating use of alfalfa and grain crops and residue management can help build organic matter while reducing insect and disease buildup in the soil. Rotations in which potatoes are grown 3 or more years apart increase yields and reduce quality losses due to soil-borne pests.

Organic soils, while naturally high in organic matter, also benefit from crop rotations in reducing insect and disease problems while improving soil tilth. There is interest in including green manure crops of sudangrass, white mustard, and rape for their beneficial effects on nematode population reductions and general soil improvement.

Economics and physical management considerations often override long-term goals, but short-term strategies are not sustainable from a soil-building perspective and can cause long-term problems. Appropriate rotations that include a diversity of both row and field crops improve soil tilth (structural integrity and organic matter) while avoiding or reducing pest problems. The loss of a dependable water source for agriculture has disrupted normal cropping rotations while adding another difficult consideration for choice of crop. Without a dependable water source, high value, input-intensive row-crop farming is not possible. This will restrict crop rotations to a less-diverse mix of crops that can survive if water is restricted and that are generally of lower value than row crops. These crops would include alfalfa, cereal grains, and pastures.

References

LeQuieu, Reg, Tax Assessor, Klamath County. 2001. Personal communication, August.

Martin, Leonard, and Stamp. Principles of Field Crop Production, Third Edition.

Oregon State University, Agricultural Experiment Station. 2001. Research in the Klamath Basin, 2000 Annual Report. Special Report 1030, July.

Powers, Lawrence W., ed.. 1999. Water Resources of the Klamath Basin. The Journal of the Shaw Historical Library, Volume 13.

United States Department of Agriculture, Soil Conservation Service. 1985. Soil Survey of Klamath County, Oregon, Southern Part.

United States Department of Agriculture, Soil Conservation Service. 1994. Soil Survey of Butte Valley-Tule Lake Area, California, Parts of Siskiyou and Modoc Counties.

United States Department of the Interior, Bureau of Reclamation. 2001. Klamath Project Map.

Woodley, Rick. District Manager, Klamath Soil and Water Conservation District. 2001. Personal communication, August.

Draft
December 14, 2001

Effect of 2001 water allocations on the agricultural landscape and crop production

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Introduction

Agriculture is the predominant land use within the boundaries of the Klamath Project. The project was fully developed by the 1960s, and since that time project irrigation water has been applied to approximately 210,000 acres of cropland annually. The principal crops in terms of acreage are alfalfa, pasture, and barley, followed by other hay, potatoes, and wheat. Other crops of importance include oats, sugarbeets, onions, and horseradish. The acreage, average yields, and crop values of each of these crops for crop years 1998-2000 are presented in Table 1.

The largest single effect of the change in water allocations in 2001 was the tremendous reduction in irrigation water available to agriculture and the resulting changes in crop vegetation in the Klamath Basin. With the prospect of no irrigation water, much of the annual crop ground went unplanted, at least initially. There was immediate concern over the likelihood of severe wind erosion of soil from fields, particularly in fields that were left bare following last year's harvest and were tilled last fall in preparation for spring planting. Many of these fields were eventually seeded in the spring with cover crops—generally barley—to help hold the soil, with little grower anticipation of harvesting a crop.

Immediately after the decision was announced by the U.S. Bureau of Reclamation (BOR) to severely limit irrigation water, growers scrambled to secure water from all available sources, including transfers of water from the Lost River system, development of private wells, and the purchase of ground water from neighbors. Much of this limited, procured water was apportioned to onion or potato production in an attempt by growers to protect existing markets and future contracts. All these activities resulted in a very untypical array of field plantings and vegetative growth in the agricultural landscape.

Major changes in 2001

1. Acreage of spring-seeded, high-value row crops such as potatoes and onions was greatly reduced.

2. Yields of potatoes and onions were near normal because of full season irrigation.

3. Acreage of sugarbeets was reduced to zero. (This was not because of a water shortage but because the closure of two northern California sugar refineries.)

4. The number of idle acres was greatly increased.

5. Barley acreage was greatly increased due to cover crop planting.

6. Much of the barley was harvested for hay because of poor grain yield concerns.

7. The yields of cereals harvested for grain were greatly reduced because of the high percentage of dryland grain.

8. Few or no new plantings were made in alfalfa or peppermint.

9. Grain fields harvested in 2000 were left as stubble fields in 2001 (except for fields that were tilled in the fall of 2000 in preparation for planting in 2001).

10. Weed control was generally not practiced in fallow fields or in dryland fields planted to grain, alfalfa, or peppermint.

11. Major increases in weed seed soil banks are certain.

12. The farm gate value of agricultural production in the project was greatly diminished.

The best available information to track changes in cropping patterns within the Klamath Project is the Annual Crops Report prepared by the BOR. Table 1 summarizes the crop acreage figures compiled by the BOR for the years 1998, 1999, and 2000, along with crop yields and average production values. Unfortunately, figures for the 2001 season were unavailable from BOR at the time of this writing.

Without figures for the entire Project, data from the Tulelake Irrigation District (TID) were evaluated to gain a sense of the magnitude of the vegetation changes that occurred during the 2001 season.

Crop production figures for 3 years, 1998, 1999, and 2000, within the TID are presented on Table 2. Based on a 3-year average, barley was produced on the greatest acreage in the district followed by alfalfa, wheat, and potatoes, respectively. Other important crops in terms of acreage included sugarbeets, onions, pasture, oats, mint, horseradish, and hay other than alfalfa (mostly grass hay). Minor plantings were made of rye and peas. The production value of these crops (farm gate sales) averaged $38,678,000 per year. On average, approximately 1,700 acres of farm ground was idled (fallowed) each year.

Similar figures for the 2001 season for TID are presented on Table 3. There were several notable shifts in the acreage. The number of idled acres jumped dramatically from less than 2,000 acres on average to 23,000 acres in 2001. Onion acreage was reduced to 30 percent of normal. Potato acreage was greatly reduced to less than 14 percent of the previous 3-year average. Wheat acreage was 12 percent of normal. Sugarbeet acreage was reduced to zero, reflecting the closure of two northern California sugar refineries. While the sugarbeet change was in no way related to the water situation, the logical effect of the loss of sugarbeets would have been an increase in the acreage of other row crops, in a normal water year.

Barley, grown for grain, was reduced from the previous years' acreage, but represented a similar percentage of the total planted acreage in 2001 as previously (about 30 percent). However, the reported barley acreage does not include the acreage of barley that was cut for hay because of insufficient soil moisture to make a grain crop. For this reason, the "other hay" crop category jumped to 5,700 acres in 2001 from an average of just over 1,000 acres previously. Peppermint, a relatively new crop to the district, had been expanding in acreage over the past 3 years. In 2001, several mint fields were abandoned and no new fields were established. In addition, a few acres of horseradish were abandoned.

Water management and yield

Following the decision to cut off irrigation in the district, there was general concern about the prospect of serious soil erosion on unplanted ground. Growers made a dedicated effort to seed the fields with a cover crop. Barley was generally selected as the cover crop of choice, given its potential to rapidly cover the ground under cool temperatures and limited moisture conditions. Most of these fields went unirrigated. Many fields produced sufficient top growth to harvest as grass hay. Other fields did mature and produced grain for harvest, but at yield levels well below the typical yield of irrigated fields. Many barley fields did not produce harvestable yield of hay or grain.

Several factors combined to determine the relative yield of individual barley fields. Better yields were attained in barley fields that followed irrigated row crops, primarily due to the presence of residual soil moisture from the previous crop. Yields were also improved by early planting and in some cases by favorable receipt of well-timed, locally heavy rainfall. The mid-season allocation of water by BOR did not help grain crops as the crops had fully matured by that time.

Production of potatoes and onions, although limited, was due to the ability of growers to locate dependable sources of water, sufficient to produce full-season crops. This water was available from existing and newly developed wells, purchases from other landowners, and transfers from other irrigation districts. Potato and onion growers went to great lengths and expense to secure at least some land with water to protect their potato markets and future onion contracts. As water was available full season, water management did not generally affect yields. However, some yield loss in potatoes and onions was attributed to production in less than desirable fields, which were selected only because they had a source of irrigation. Problems in some of these fields were attributed to poor soil tillage, lesser soil types, or less than desirable crop rotations.

Alfalfa is a deep-rooted crop. Most fields in the TID have high soil moisture holding abilities and relatively high-perched water tables. For those reasons, first cutting yields of alfalfa were near normal. However, second cutting was generally poor or non-existent. Many alfalfa growers were able to take advantage of the Department of Interior's mid-season release of 70,000 acre-ft of Upper Klamath Lake water to irrigators in the Project. The resulting mid-season irrigation on alfalfa significantly improved third-cutting yields and reduced the risk of stand losses.

Other perennial crops were also favorably affected by the mid-season allocation of irrigation water. Irrigated pastures responded to the added water, but, for the most part, livestock had been removed from the pastures by that time, so no significant increase in revenue occurred. Nonetheless, the mid-season irrigation did stimulate pasture growth and improved pasture condition, hopefully preventing stand losses this winter. Some peppermint stands may also have been saved by the mid-season water application. But, as with pasture, the mid-season application of water, the only application to peppermint, did not generally result in increased crop harvest.

The mid-season allocation of water also provided some economic relief to growers who were purchasing ground water or relying on other water transfers.

A direct consequence of the reduced water allocation was the tremendous increase in weedy fields. Weed control was generally not practiced on fallow fields. The resulting weed growth in fallow fields ranged from moderate to severe. The large difference in weed growth from field to field were due to (1) differences in weed seed populations in the soil, (2) distinct differences in the ability of individual weed species to germinate and grow under dry soil conditions, (3) tillage practices the previous fall, and (4) soil moisture retention from the previous crop.

Solid, shoulder-high weed growth was observed in many fields. Predominate weeds included those common in local agricultural production (e.g., mustards and kochia) as well as species rarely seen in production fields (principally, prickly lettuce).

Most of the fields that were in grain in 2000 were left as stubble fields in 2001, except for those fields that were tilled in the fall of 2000 in preparation for planting in 2001. The untilled stubble was generally effective in reducing soil erosion. Weed growth on grain stubble fields ranged from very slight to heavy depending mostly on weed populations in the field and the effectiveness of limited rainfall in stimulating weed seed germination.

A major concern for the 2002 crop year, and beyond, is the increase in soil weed seed populations that will certainly result from the weed growth on fallow or stubble fields. The accumulation of tremendous weed seed banks in the soil cause major difficulties in controlling weeds in the next crop cycles. Extensive weed growth in de-watered canals and drain ditches will also serve as a long-term source of weed seed.

Herbicide use was also generally curtailed in dryland grain and alfalfa because of the reduced prospect for offsetting yield increases in the absence of irrigation water. Uncontrolled weeds undoubtedly contributed to reduced yields and quality in these crops.

As a result of all the factors discussed above, the estimated value of crop production in the TID fell from a 3-year average of $38,678,000 to $16,867,000 in 2001. The loss in farm gate value was moderated to some extent by the mid-season allocation of water to alfalfa and horseradish producers and by improved prices for potatoes and alfalfa.

At present, the TID numbers are the best available estimates of the water allocation impact on agricultural production. Extrapolating the numbers from TID to the whole project should be done with caution. More land in TID may have been serviced by wells than was the case in the larger Klamath Irrigation District and other districts. Tulelake soils generally have a much higher water holding capacity than most of the soils in the rest of the Klamath Project. Also, TID has a significantly greater proportion of high-value row crops compared to the project as a whole. For these and other reasons, it is likely that the yield losses in dryland alfalfa and grain were more severe in the balance of the project. In addition, significant stand losses in alfalfa and pastures are more likely on the lighter soils in Oregon irrigation districts. Counter balancing those differences are the relatively normal water allocations in the Langell and Poe valleys and access to Oregon state water rights in some Oregon irrigation districts. A project-wide assessment of the impact on crops will have to await completion of the BOR annual crop report or initiation of an additional data collection effort. Crop production values and the affect of this production on the local and regional economies are covered in detail in other sections of this report.

Table1. CROP PRODUCTION WITHIN THE KLAMATH PROJECT (Data Source: Klamath Project Annual Crop Reports)

CROP	ACREAGE				YIELD(Unit/A)					Value($/A)				Value of Crops			
CALIFORNIA	1998	1999	2000	Average	1998	1999	2000	Average	Units	1998	1999	2000	Average	1998	1999	2000	Average
Barley	25,560	21,591	22,375	23,175	89	89	104	94	bu	169.5	169.5	218.0	185.7	$4,333,000	$3,660,000	$4,878,000	$4,290,000
Oats	1,348	1,689	1,677	1,571	131	131	158	140	bu	170.5	170.5	212.5	184.5	230,000	288,000	356,000	291,000
Wheat	7,299	13,974	10,067	10,447	106	106	86	99	bu	311.6	311.6	253.5	292.2	2,274,000	4,354,000	2,552,000	3,060,000
Other Cereals	313	63	139	172	36	36	86	53	bu	72.0	72.0	171.5	105.2	23,000	5,000	24,000	17,000
Alfalfa	10,452	11,530	12,202	11,395	6	6	6	6	tons	575.0	575.0	575.0	575.0	6,010,000	6,630,000	7,016,000	6,552,000
Other Hay	1,189	851	1,021	1,020	4	4	3	4	tons	300.0	300.0	225.0	275.0	357,000	255,000	230,000	281,000
Irrigated Pasture	2,811	2,766	2,734	2,770	5	5	4	5	aum	150.0	150.0	120.0	140.0	422,000	415,000	328,000	388,000
Peppermint	299	956	1,880	1,045	60	60	65	62	lbs	840.0	840.0	910.0	863.3	251,000	803,000	1,711,000	922,000
Sugarbeets	4,336	4,486	2,393	3,738	21	21	21	21	tons	777.0	777.0	724.5	759.5	3,369,000	3,486,000	1,734,000	2,863,000
Misc Crops	779	806	975	853	4	4	4	4		4,500.0	4,500.0	1,500.0	3,500.0	3,506,000	3,627,000	1,463,000	2,865,000
Onions	2,339	3,175	2,834	2,783	423	423	520	455	cwt	1,903.5	1,903.5	2,600.0	2,135.7	4,452,000	6,044,000	7,368,000	5,955,000
Potatoes	9,556	7,797	7,427	8,260	400	400	500	433	cwt	2,320.0	2,320.0	2,062.5	2,234.2	22,170,000	18,089,000	15,317,000	18,525,000
Pea Seed			168	168			14	14				140.0	140.0			24,000	24,000
Idle Acres	5,747	5,182	1,965	12,894													
Total	72,028	74,866	67,857	80,292										$47,396,000	$47,655,000	$43,000,000	$46,033,000
OREGON	1998	1999	2000	Average	1998	1999	2000	Average	Units	1998	1999	2000	Average	1998	1999	2000	Average
Barley	16,692	16,507	15,497	16,232	88	92	118	100	bu	178.5	175.4	229.3	194.4	$2,980,000	$2,893,000	$3,553,000	$3,142,000
Oats	5,306	3,705	3,416	4,142	145	151	158	151	bu	195.5	196.5	212.5	201.5	1,037,000	728,000	726,000	830,000
Wheat	1,954	3,741	3,421	3,039	96	99	86	94	bu	325.8	291.0	253.5	290.1	637,000	1,089,000	867,000	864,000
Other Cereals	660	547	264	490	40	54	86	60	bu	79.2	108.0	171.5	119.6	52,000	59,000	45,000	52,000
Alfalfa	35,416	36,556	39,110	37,027	5	5	6	5	tons	450.0	450.0	522.5	474.2	15,937,000	16,450,000	20,435,000	17,608,000
Other Hay	15,087	13,324	14,997	14,469	3	4	3	3	tons	225.0	262.5	225.0	237.5	3,395,000	3,498,000	3,374,000	3,422,000
Irrigated Pasture	40,827	40,345	38,987	40,053	4	4	4	4	aum	120.0	120.0	120.0	120.0	4,899,000	4,841,000	4,678,000	4,806,000
Silage/ensilage	305	390	1,123	606	7	7	7	7	tons	420.0	420.0	420.0	420.0	128,000	164,000	471,000	254,000
Other Forage			60	60			3	3	tons			180.0	180.0			11,000	11,000
Peppermint	24	545	505	358	70	60	65	65	lbs	980.0	840.0	910.0	910.0	24,000	458,000	459,000	314,000
Sugarbeets	2,731	3,067	1,479	2,426	21	22	19	21	tons	924.0	814.0	655.5	797.8	2,523,000	2,497,000	969,000	1,996,000
Horseradish		20	21	21			2	2				330.0	330.0			6,000	6,000
Onions	1,082	744	422	749	400	400	500	433	cwt	1,800.0	1,800.0	2,500.0	2,033.3	1,948,000	1,339,000	1,055,000	1,447,000
Potatoes	7,141	7,029	5,339	6,503	385	400	500	428	cwt	2,233.0	2,320.0	2,062.5	2,205.2	15,946,000	16,307,000	11,011,000	14,421,000
Pea Seed			60	60			14	14				140.0	140.0			8,000	8,000
Potato Seed			50	50			200	200	cwt			400.0	400.0			20,000	20,000
Misc	260	595	227	361										468,000	6,030,000	1,434,000	7,932,000
Idle Acres	2,918	3,617	3,699	3,411													
Total	130,403	130,732	128,676	130,057										$114,000	$114,000	$113,000	$114,000
Project Total	202,431	205,598	196,533	210,349										$47,510,000	$47,769,000	$43,113,000	$46,146,000

Table 2. CROP PRODUCTION WITHIN THE TULELAKE IRRIGATION DISTRICT (Data Source: TID Annual Reports)

	ACREAGE				YIELD (UNITS/A)					UNIT VALUE ($/UNIT)				TOTAL CROP VALUE ($)			
	1998	1999	2000	3 Year Average	1998	1999	2000	3 Year Average	Units	1998	1999	2000	3 Year Average	1998	1999	2000	3 Year Average
Barley	21,219	16,468	18,798	18,828	43.0	62.0	56.5	53.8	cwt	4.07	4.05	4.23	4.12	$3,714,000	$4,135,000	$4,493,000	$4,114,000
Wheat	7,157	13,478	10,215	10,283	62.3	66.4	60.8	63.2	cwt	5.42	5.27	4.65	5.11	2,416,000	4,716,000	2,885,000	3,339,000
Oats	1,475	965	1,067	1,169	42.0	50.0	55.0	49.0	cwt	4.50	4.00	4.25	4.25	279,000	193,000	249,000	240,000
Peas	37	280	158	158	25.0	25.0	25.0	25.0	cwt	12.00	12.00	12.00	12.00	11,000	84,000	47,000	47,000
Sugarbeets	4,038	4,203	2,379	3,540	23.0	20.0	21.0	21.3	tons	45.00	43.00	41.00	43.00	4,179,000	3,615,000	2,048,000	3,281,000
Alfalfa Hay	9,723	10,862	11,659	10,748	5.8	5.8	5.7	5.8	tons	90.00	90.00	95.00	91.67	5,075,000	5,621,000	6,369,000	5,688,000
Other Hay	1,092	253	869	738	4.0	3.8	4.0	3.9	tons	65.00	65.00	70.00	66.67	284,000	62,000	243,000	196,000
Pasture	1,752	1,707	1,700	1,720	4.0	4.0	4.0	4.0	aum	10.00	10.00	10.00	10.00	70,000	68,000	68,000	69,000
Potatoes	9,527	7,912	7,572	8,337	400.0	450.0	500.0	450.0	cwt	4.04	4.44	2.78	3.75	15,396,000	15,808,000	10,525,000	13,910,000
Onions	2,292	2,963	2,703	2,653	423.0	423.0	470.0	438.7	cwt	5.00	5.00	5.00	5.00	4,848,000	6,267,000	6,352,000	5,822,000
Mint	299	940	1,775	1,005	70.0	40.0	90.0	66.7	lbs	14.00	14.00	12.00	13.33	293,000	526,000	1,917,000	912,000
Rye	28	28	139	65	20.0	30.0	30.0	26.7	cwt	3.50	3.50	3.25	3.42	2,000	3,000	14,000	6,000
Horseradish	766	781	979	842	2.5	2.5	2.5	2.5	tons	500.00	500.00	500.00	500.00	958,000	977,000	1,224,000	1,053,000
Idle Acres	2,500	998	1,652	1,717													
TOTALS	59,405	60,840	60,013	61,803										$37,525,000	$42,075,000	$36,434,000	$38,678,000

Table 3. 2001 CROP PRODUCTION WITHIN THE TULELAKE IRRIGATION DISTRICT (Data Source: TID Annual Report)

	ACREAGE	YIELD (UNIT/A)	UNITS	UNIT VALUE($)	PRODUCTION VALUES($)
Barley	12,916	35.0	cwt	$4.23	$1,912,000
Wheat	825	47.5	cwt	4.07	160,000
Oats	525	38.0	cwt	6.50	91,000
Peas	605	12.5	cwt	14.00	106,000
Sugarbeets	0	0.0	tons	0.00	0
Alfalfa Hay	12,416	4.5	tons	110.00	6,146,000
Other Hay	5,761	2.3	tons	85.00	1,102,000
Pasture	1,288	0.0	aum	10.00	0
Potatoes	1,162	430.0	cwt	5.56	3,975,000
Onions	779	420.0	cwt	4.75	1,554,000
Mint	1,151	65.6	lbs	12.00	906,000
Rye	31	20.0	cwt	3.50	2,000
Horeseradish	830	2.2	tons	500.00	913,000
Idle Acres	23,140				
TOTAL	61,429				$16,867,000

Draft
December 14, 2001

The Upper Klamath Basin economy

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This chapter provides an overview of the Upper Klamath Basin economy and an analysis of the economic role of agriculture and food processing in the Upper Klamath Basin economy.

Overview of the Upper Klamath Basin economy

The Upper Klamath Basin covers parts of five counties in Oregon and California. Almost all of the Oregon portion of Basinthe Basin lies in Klamath County, and Basinthe Basin covers most of the county, including the county seat Klamath Falls (population about 21,000), which is the major population center in the Basin. The Basin covers the northwest corner of Modoc County (not including the county seat of Alturas, population about 3,000) and the northeast corner of Siskiyou County in California, including the county seat Yreka (population about 7,500).

Given that most economic and demographic data needed to describe and analyze the regional economy is at the county level, we consider the Upper Klamath Basin economy to be the three counties of Klamath in Oregon and Modoc and Siskiyou in California. Even though such a definition includes economic activity outside the Basin in rural areas and some small towns in these counties (such as Alturas, California), and excludes economic activity in the Basin in some small and very rural parts of Jackson and Lake counties in Oregon, nevertheless it comes closer to capturing the size and character of the economy of the region than any alternative. This regional definition also captures most of the economic impacts of activity in the Basin, since it includes the economic centers in the Basin where most of the economic effects from business and household respending of money brought into the region (particularly that associated with irrigated agriculture) occur.

Our model of the Upper Klamath Basin economy was developed using the most recent data (1998) from IMPLAN (*IM*pact Analysis for *PLAN*ing), a software and database created to assist the Forest Service and other agencies in estimating the community impacts of policy decisions. The Minnesota IMPLAN Group, Inc., currently produces, refines, and annually updates the model and data for IMPLAN. IMPLAN can generate input-output models ("I-O models") for any county or group of counties in the United States. We cross-checked and revised key components of the model with data from the U.S. Bureau of Economic Analysis, the U.S. Department of Agriculture, and Oregon State University Extension Service.

The Upper Klamath Basin is home to about 120,000 people. The Upper Klamath Basin (UKB) economy produced $4.0 billion worth of output in 1998, added $2.3 billion in value to purchased inputs, and provided almost 60,000 jobs. Table 1 presents estimates of some basic economic indicators for the UKB economy and shows how these are distributed among sectors organized according to the North American Industrial Classification System (NAICS). Appendix A indicates the types of economic activity included in each of the NAICS sectors.

Table 1. Output, value added, and employment in the Upper Klamath Basin

Industry	Industry output		Value added		Employment	
	$ Million	Shares (%)	$ Million	Shares (%)	Jobs	Shares (%)
Agriculture, fishing & related	320	7.9%	169	7.3%	5,964	10.0%
Forestry & logging	30	0.7%	16	0.7%	248	0.4%
Mining	4	0.1%	2	0.1%	33	0.1%
Construction	327	8.1%	119	5.1%	3,357	5.7%
Manufacturing—food, beverages, textiles & related	128	3.2%	20	0.9%	407	0.7%
Manufacturing—wood products, paper, furniture & related	598	14.8%	241	10.3%	4,328	7.3%
Manufacturing—high tech. & related	17	0.4%	3	0.1%	94	0.2%
Manufacturing—other (e.g., sheet metal products)	113	2.8%	35	1.5%	844	1.4%
Transportation & warehousing	263	6.5%	139	6.0%	2,257	3.8%
Utilities	128	3.2%	80	3.4%	429	0.7%
Wholesale trade	142	3.5%	97	4.2%	2,036	3.4%
Retail trade	235	5.8%	205	8.8%	6,568	11.1%
Accommodation & food services	163	4.0%	92	4.0%	4,785	8.1%
Finance & insurance	197	4.9%	138	5.9%	2,179	3.7%
Real estate & rental & leasing	279	6.9%	202	8.7%	1,535	2.6%
Other services	186	4.6%	84	3.6%	3,733	6.3%
Information	100	2.5%	55	2.3%	1,241	2.1%
Administrative and support services, etc.	28	0.7%	16	0.7%	936	1.6%
Arts, entertainment, & recreation	31	0.8%	19	0.8%	1,133	1.9%
Health care and social assistance	316	7.8%	194	8.3%	5,859	9.9%
Professional, scientific, and technical services	38	0.9%	26	1.1%	865	1.5%
Educational services	182	4.5%	170	7.3%	6,010	10.1%
Public administration	200	5.0%	200	8.6%	4,551	7.7%
Inventory valuation adjustment	7	0.2%	7	0.3%	0	0.0%
	4,032	100.0%	2,327	100.0%	59,390	100.0%

Source: IMPLAN as adjusted with Bureau of Economic Analysis and local data.

The usual way of characterizing a regional economy is to describe the shares of output, value added (or income), or employment in each of the region's major sectors. *Output* is a measure of the dollar value of total production, including the dollar value of purchased inputs used in the production process. *Value added* is a measure of the value that is added to purchased inputs in the local production process by local labor and capital. (Value added equals the dollar value of output minus the value of purchased inputs used in the production process.) Value added is *income plus indirect business taxes* such as property taxes. Income—employee compensation, proprietor income, and other property—equals 93 percent of value added in the UKB economy.[1] *Employment* is a measure of the number of full- and part-time jobs in each sector. Sectors in which the share of value added is high relative to the share of employment tend to have relatively high earnings. Table 1 presents information about the shares of each of these indicators in each of the UKB region's sectors.

The four sectors with the largest shares of output in 1998 were wood products[2] (15.5 percent), agriculture [3](11.1 percent), construction (8.1 percent), and health care/social assistance (7.8 percent). The four sectors with the largest shares of value added were wood products (11.0 percent) , retail trade (8.8 percent), real estate (8.7 percent), and public administration (8.6 percent). The four sectors with the largest employment shares were retail trade (11.1 percent), agriculture (10.7 percent), educational services (10.1 percent), and health care/social assistance (9.9 percent). Each of these measures provides a perspective on how economic activity is distributed among sectors in the regional economy. But none of them identifies how much the regional economy depends on each sector.

One way of identifying the sectors on which the region's jobs and income depend and how much each sector contributes to the regional economy is to examine a region's *economic base*. According to economic base theory, the level of overall economic activity in a region is determined by the region's "economic base," defined as its "exports to markets outside the region." (Maki and Lichty 2000; 15)[4] In an economic base model, different types of sectors play different roles. Those sectors that "export" a large share of their production or bring large inflows of money into the community are said to be *basic sectors*, or to be "responsible for" the jobs and income in the other sectors (*service sectors)* that sell a large share of their output in the local economy. In this economic-base framework, the activity of the service sectors depends on the respending of money brought in by the export sectors. In this sense, the employment and income in both basic and service sectors is dependent on the economic base and on the sectors that bring money into the region from outside.

The preferred method of estimating the economic base of a region is to use an input-output model, which directly estimates exports from each industry and, using the multipliers for each sector, generates estimates of the dependence of a regional economy on exports from each sector. A sector's contribution to a regional economy is determined by the dollars brought into the economy by that sector and the subsequent respending associated with these dollars. The contribution of an industry to the region's *employment* is the number of employees in all industries whose jobs are dependent, directly or indirectly (through interindustry linkages), on the exports of that industry (Cornelius et al. 2000; 14).

Table 2 summarizes the contribution of each sector to total regional employment, based on an analysis using the Upper Klamath Basin I-O Model. The procedure used to derive the estimates in Table 2 is described in Waters et al. (1998). The table compares the employment *in* a sector (as shown in Table 1) with employment *dependent* on a sector's production that is exported outside the region. The jobs under the Sectoral Employment columns are jobs in the given sector. The jobs in the Export-Dependent columns are jobs from *all* sectors that are dependent on the exports from the given sector.

As an example, there are 4,328 jobs *in* the Manufacturing—woods products sector in the UKB region. However, there are 6,992 jobs in the UKB region *dependent* on wood products exports. Of these, 3,087 jobs are *directly dependent* on the exports of wood products from the county. These jobs are related to the direct purchases made by wood products firms as they

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1 In the UKB economy, employee compensation is 56 percent, proprietor income is 10 percent, and other property income is 27 percent of value added.

2 "Wood products" is defined here to include both forestry & logging, and manufacturing—wood products, paper, & furniture.

3 "Agriculture" is defined here to include agriculture, fishing & related, and manufacturing—food, beverages, textiles, and related.

4 The term "exports," as used here, includes any activities that bring dollars into the regional economy, including federal transfer payments and income to households from outside the region.

produce the products for export. In addition, there are 2,121 jobs *indirectly dependent* on wood products exports: these are the jobs created by the spending of the firms whose inputs were purchased by wood products to produce the exports. Yet another 1,784 jobs are *induced* by wood products exports: these are the jobs in retail trade, real estate, and health care that are created by the household respending of income earned in all the jobs generated directly and indirectly by wood products exports. The money that is brought into the UKB region by wood products exports is spent and respent in ways that generate these 6,922 jobs.

Table 2 indicates the dependence of Upper Klamath Basin regional employment on two natural resource sectors. *Agriculture* (agriculture, fishing & related, and food products manufacturing) supports 13.7 percent of the region's jobs, and *wood products (*forestry & logging and wood products manufacturing) supports 12.6 percent. Table 2 also identifies the dependence of the regional economy on two other sectors that are commonly the focus of local economic development efforts. Although the *Tourism* sector (Accommodation & Food Services and Arts, Entertainment & Recreation) has 10 percent of the total jobs in the region, it contributes only 3.4 percent of the export employment base. *Retail trade*, the sector with the largest employment share (11.1 percent), provides only 1 percent of the export employment base.

Table 2. Export base employment, Upper Klamath Basin Region, 1998.

Sector	Sectoral employment		Export-dependent employment				
	Number of jobs	Share (%)	Direct	Indirect	Induced	Total	Dependency index (%)
Agriculture, fishing & related	5,964	10.0	4,530.5	1,051.5	1,004.0	6,586.0	11.1
Forestry & logging	248	0.4	242.5	144.0	52.1	438.6	0.7
Mining	33	0.1	27.0	4.5	8.6	40.1	0.1
Construction	3,357	5.7	2,809.2	1,127.5	1,139.2	5,075.9	8.6
Manufacturing—food, beverages, & related	407	0.7	374.1	865.0	288.2	1,527.3	2.6
Manufacturing—wood products, paper, furniture & related	4,328	7.3	3,088.6	2,126.0	1,803.2	7,017.8	11.8
Manufacturing—high tech. & related	93	0.2	29.7	24.2	11.2	65.1	0.1
Manufacturing—other (e.g., sheet metal products)	844	1.4	727.7	319.9	271.9	1,319.5	2.2
Transportation & warehousing	2,257	3.8	1,102.5	517.8	618.9	2,239.2	3.8
Utilities	429	0.7	35.7	26.1	27.4	89.2	0.2
Wholesale trade	2,035	3.4	351.9	75.6	104.4	531.9	0.9
Retail trade	6,568	11.1	423.2	21.6	82.2	527.0	0.9
Accommodation & food services	4,785	8.1	1,541.0	188.5	226.8	1,956.3	3.3
Finance & insurance	2,179	3.7	138.8	34.5	43.1	216.4	0.7
Real estate & rental & leasing	1,535	2.6	95.3	49.8	26.4	171.5	0.3
Other services	3,733	6.3	1,110.2	237.5	235.3	1,583.0	2.7
Information	1,241	2.1	143.4	48.6	47.5	239.5	0.4
Administrative and support services, etc.	936	1.6	48.0	6.1	7.4	61.5	0.1
Arts, entertainment, & recreation	1,133	1.9	26.7	5.3	3.4	35.4	0.1
Health care and social assistance	5,859	9.9	370.8	64.5	122.3	557.6	0.9
Professional, scientific, and technical services	865	1.5	77.0	10.2	23.0	110.2	0.20
Educational services	6,010	10.1	4,545.9	86.0	1,207.6	5,839.5	9.8
Public administration	4,551	7.7	4,551.2	33.5	1,492.2	6,076.9	10.2
Households (e.g. Social Security)			11,952.4	1,946.6	3,185.4	17,084.4	28.8
Total	59,390	100.0	38,343.3	9,014.8	12,031.7	59,389.8	100.0

Source: UKB Modified IMPLAN Model

Table 2 also shows that UKB regional employment is even more dependent on *income to households from outside the region* than on any single industrial sector. Household income from government transfer payments (e.g., Social Security), dividends, commuters' income, rental payments, and other sources of income originating outside the region is an important part of the export base: 17,084 jobs (or 28.8 percent of the jobs) in 1998 were dependent on those payments to households from outside the UKB region.

The dependence of the UKB economy on *federal and state government and educational institutions* is also evident from Table 2. Almost one-fifth of the jobs in the region depend on federal and state funding for services such as education and for government personnel. “Public administration” —federal and state payments to governments (federal payments in lieu of taxes, for example, or federal forest payments, or state-shared cigarette and highway revenues) and to government personnel (USFS, USDA, USFWS, for example)—supports 10.1 percent of all UKB region jobs. State and federal funding for “Educational services” (K–12 schools, the community college in California, and the Oregon Institute of Technology) plus OIT tuition payments by nonresidents supports 9.7 percent of the region’s jobs.

Table 3 provides estimates of the shares of regional income and value added dependent on each sector’s exports. The table also includes the comparable employment shares from Table 2. The major sectors on which regional employment depends also drive regional income and value added: “household income from outside the region,” wood products (manufacturing and forestry/logging), agriculture (agriculture and food manufacturing), and public administration. Because earnings in wood products sectors are higher than in the agricultural sectors, the regional *income* share that is dependent on wood products is higher than the *employment* share; and the regional *income* share dependent on agriculture is less than the *employment* share.

Table 3. Upper Klamath Basin Region export-base-dependent employment, income and value added 1998.

Sector	Jobs dependency index (%)	Income dependency index (%)	Value added dependency index (%)
Agriculture, fishing & related	11.09	9.14	9.24
Forestry & logging	0.74	0.93	0.99
Mining	0.07	0.09	0.10
Construction	8.55	8.43	8.33
Manufacturing—food, beverages, & related	2.57	2.60	2.64
Manufacturing—wood products, paper, furniture & related	11.82	14.68	14.50
Manufacturing—high tech. & related	0.11	0.10	0.10
Manufacturing—other (e.g., sheet metal products)	2.22	2.37	2.35
Transportation & warehousing	3.77	5.01	4.97
Utilities	0.15	0.37	0.39
Wholesale trade	0.90	0.90	1.02
Retail trade	0.89	0.65	0.73
Accommodation & food services	3.29	1.93	2.02
Finance & insurance	0.36	0.59	0.58
Real estate & rental & leasing	0.29	0.64	0.70
Other services	2.67	1.96	1.97
Information	0.40	0.44	0.44
Administrative and support services, etc.	0.10	0.06	0.06
Arts, entertainment & recreation	0.06	0.03	0.03
Health care and social assistance	0.94	0.88	0.86
Professional, scientific, and technical services	0.19	0.17	0.16
Educational services	9.83	8.17	7.84
Public administration	10.23	11.57	11.04
Households (e.g. Social Security)	28.77	28.28	28.94
Total	100.00	100.00	100.00

Source: UKB Modified IMPLAN model

Farming in the Upper Klamath Basin economy

Farms and Farm Characteristics. There were 2,239 farms in the Upper Klamath Basin in 1997 (Table 4). Farms averaged 896 acres in size. Most of the farms (78 percent) had some irrigation, and 27 percent of the region's farmland is irrigated. About one-third of the farms (38 percent) hire farm workers. Most (82 percent) farms are sole proprietorships and 78 percent are operated by the person living on the farm. Only 29 percent of the operators work full-time off the farm (more than 200 days). This is about three-quarters of the national average: 37 percent of all U.S. farm operators work more than 200 days off the farm.

Table 4. Characteristics of Upper Klamath Basin farms and farm operators, 1997

Farm characteristics	Klamath, OR	Siskiyou, CA	Modoc, CA	Klamath Basin total
Number of farms	1,066	733	440	2,239
Land in farms (acres)	713,534	628,745	662,927	2,005,206
Average size of farm (acres)	669	858	1,507	896
Number of farms with irrigation (farms)	851	556	337	1,744
Irrigated land (acres)	243,205	139,534	159,219	541,958
Market value of agricultural products sold ($000)	100,622	74,244	63,797	238,663
Net cash return from agricultural sales for the farm unit ($000)	20,104	16,389	11,249	47,742
Farms with hired labor (farms)	380	259	206	845
Number of hired farm workers (workers)	1,779	2,795	1,664	6,238
Hired farm labor payroll ($000)	9,745	11,309	6,169	27,223
Number of sole proprietor farms	882	603	359	1,844
% Sole proprietor farms	83%	82%	82%	82%
Number of farm operators living on farm operated	871	569	317	1,757
% of farm operators living on farm operated	82%	78%	72%	78%
Number of farm operators working more than 200 days off-farm	347	201	101	649
% of Farm operators working more than 200 days off-farm	33%	27%	23%	29%

Source: 1997 Census of Agriculture

Production and Sales. Table 5 reports the value of production for each commodity for each county and for the region. The value of total agricultural production for the region for 1998 is estimated to be $283 million. (The Census estimate of the value of sales for 1997 was $239 million. All production in a region is not sold, since some production, such as hay or pasture, is used as input in the dairy or cattle operation. This year's sales also may involve previous year's production, if it includes sales out of inventory, or this year's production may be held in inventory for sales in future years. The value of production therefore generally will differ from the value of sales.) It is clear that raising livestock is the principal agricultural activity in the region: cattle, hay, and pasture account for 65 percent of the value of production.

Table 5. Value of agricultural production in the Upper Klamath Basin, 1998 ($1,000).

Commodity	Klamath, OR	Siskiyou, CA	Modoc, CA	Klamath Basin total	% of Total value of production
Alfalfa hay	30,726	25,203	12,825	68,754	24.3%
Cattle	32,850	23,635	9,000	65,485	23.2%
Potatoes	14,217	19,323	7,866	41,406	14.6%
Pasture and range	n/a	13,005	7,560	20,565	7.3%
Other hay	4,856	3,713	3,588	12,157	4.3%
Barley	5,225	3,280	2,187	10,692	3.8%
Onions	n/a	2,862	2,464	5,326	1.9%
Wheat	1,660	2,805	859	5,324	1.9%
Dairy	13,112	2,442	n/a	15,554	5.5%
Horseradish	n/a	n/a	896	896	0.3%
Sugar beets	3,832	n/a	3,284	7,116	2.5%
Nursery products	n/a	17,271	n/a	17,271	6.1%
Other	1,000	5,319	5,973	12,292	4.3%
Total	107,478	118,858	56,502	282,838	100%

Source: Oregon State University Extension Service, California Agricultural Statistics Service

Income. Different sources of county-level information on the economics of agriculture in the Upper Klamath Basin provide somewhat different estimates of income and employment. Usually this is due to different definitions of what appear to be similar indicators. The Agriculture Census 1997 provides an estimate of "net cash return from agricultural sales." This income measure does not include government payments, other farm-related income, or imputed rent, and it does not include deductions for depreciation. The 1997 Census estimate of "net cash returns from agricultural sales" for the UKB region is $48 million. (Table 6). The U.S. Bureau of Economic Analysis (BEA) provides estimates of "farm proprietors' income" that include government payments, farm-related income such as custom work and rent, and imputed rent for farm dwellings, and that deduct a capital consumption adjustment for depreciation. Farm proprietors' income for 1998 is estimated by BEA to be about $12 million, 0.5 percent of total personal income in the Upper Klamath Basin.

The Census and BEA also provide estimates of farm labor income. The 1997 Agriculture Census estimates "hired farm worker payroll" at $27 million. The BEA estimates farm worker earnings at $26 million for 1998.

BEA estimates that farm labor and proprietor income totaled about $38 million or about 1.6 percent of total personal income in 1998.

Employment. The Census of Agriculture reports that there were 2,239 farm operators and 6,238 hired farm workers in 1997 (Table 4). The BEA estimate of farm proprietors for 1998 (Table 6) is 2,702, which is larger than the Census estimate for 1997. The BEA full- and part-time farm wage and salary employment estimate for 1998, however, of 1,812 is less than one-third of the Census estimate for 1997.[5] Total farm proprietor and farm wage and salary employment represents 7.6 percent of total full- and part-time employment in the BEA estimates.[6]

5 The Oregon Employment Department estimate of total agricultural (worker) employment in 1997 is 1,490, twice the BEA estimate of 746, suggesting that BEA substantially undercounts farm workers.

6 The UKB IMPLAN model estimate of employment in Agriculture, fishing & related (which includes proprietors and hired farm workers) for 1998 is 5,964, accounting for 10 percent of total employment.

Table 6. Farm income, employment and personal income in the Upper Klamath Basin, 1987.

	Klamath, OR	Siskiyou, CA	Modoc, CA	UKB Region
Farm labor and proprietors' income (LPI) ($000)	9,681	16,169	12,368	38,218
Farm proprietors' income ($000)	-2,627	7,686	6,788	11,847
Farm wages, perquisites, and other labor income of hired farm workers	12,308	8,483	5,580	26,371
Personal income ($000)	1,265,488	897,055	184,730	2,347,273
Population	63,160	44,024	9,338	116,522
Per capita personal income	20,036	20,376	19,783	20,144
Farm LPI as share of total PI	0.8%	1.8%	6.7%	1.6%
Farm proprietors' income as share of total PI	-0.2%	0.9%	3.7%	0.5%
Farm employment	2,059	1,587	868	4,514
Farm proprietors' employment	1,313	893	496	2,702
Farm wage and salary employment	746	694	372	1812
Total full- and part-time employment	32,427	22,251	4,561	59,239
Farm employment as share of full- and part-time employment	6.4%	7.1%	19.0%	7.6%

Source: US Bureau of Economic Analysis, Regional Economic Information System

Klamath Reclamation Project in Upper Klamath Basin agriculture

The Klamath Reclamation Project provides water to two-thirds (63 percent) of the 2,239 farms—and to four-fifths (80 percent) of the irrigated farms —in the Upper Klamath Basin. (Table 7). The Project contains about one-third (36 percent) of the region's irrigated acreage. Project farms produce almost half (45 percent) of the value of agricultural sales in the region.

Table 7. Klamath Reclamation Project (KRP) in Upper Klamath Basin (UKB).

Irrigated Farms 1997		Irrigated Acres 1997 (1000s)		Value of Sales 1997 ($1000s)	
UKB	KIP	UKB	KIP	UKB	KIP
1744	1400	542	195	$ 238,663	$ 108,539

Source:1997 Census of Agriculture; Tables 1 and 2 of Burke (2001) [next chapter in this report]

The next two chapters in this report analyze the impact of the changes in water allocation in the Klamath Reclamation Project that resulted from the issue of a new set of biological opinions about water needed to protect endangered and threatened species in Upper Klamath Lake and the Klamath River. The next chapter looks at the impacts of the 2001 Biological Opinions on on-farm crop production in the Klamath Reclamation Project. The subsequent chapter examines the economic effects of these changes in KRP agricultural production on the overall economy of the Upper Klamath Basin region.

References

Cornelius, Jim, David Holland, Edward Waters, and Bruce Weber. 2000. Agriculture & the Oregon Economy. OSU Extension Service , Corvallis, OR.

Maki, Wilbur R., and Richard W. Lichty. 2000. Urban Regional Economics. Iowa State University

7 Personal income is estimated by place of residence (for farms this is the same as place of work); employment is estimated by place of work.

Press , Ames, IA.

Waters, Edward C., Bruce A. Weber, and David W. Holland. 1999. The Role of Agriculture in Oregon's Economic Base: Findings from a Social Accounting Matrix. Journal of Agricultural and Resource Economics 24(1):266–280.

Appendix A. North American Industry Classification Sector descriptions

Agriculture, fishing & related: Growing crops, raising animals, harvesting fish and other animals, and services that support natural resource-based production.

Forestry & logging: Farm production of stumpage, pulpwood, fuel wood, Christmas trees, and fence posts. Operation of timber tracts, tree farms, and forest nurseries plus reforestation.

Mining: Establishments that extract naturally occurring mineral solids, such as coal and ores; liquid minerals, such as crude petroleum; and gases, such as natural gas. The term *mining* is used in the broad sense to include quarrying, well operations, beneficiating (e.g., crushing, screening, washing, and flotation), and other preparation customarily performed at the mine site, or as a part of mining activity.

Construction: Construction of buildings and other structures, heavy construction (except buildings), additions, alterations, reconstruction, installation, and maintenance and repairs. Establishments engaged in demolition or wrecking of buildings and other structures, clearing of building sites, and sale of materials from demolished structures are also included. This sector also includes those establishments engaged in blasting, test drilling, landfill, leveling, earthmoving, excavating, land drainage, and other land preparation.

Manufacturing—(food, wood products, high tech–, other): the mechanical, physical, or chemical transformation of materials, substances, or components into new products. The assembling of component parts of manufactured products is considered manufacturing, except in cases where the activity is appropriately classified in Construction.

Transportation & warehousing: Providing transportation of passengers and cargo, warehousing and storing goods, scenic and sightseeing transportation, and supporting these activities.

Utilities: Provision of the following utility services: electric power, natural gas, steam supply, water supply, and sewage removal. Within this sector, the specific activities associated with the utility services provided vary by utility: electric power includes generation, transmission, and distribution; natural gas includes distribution; steam supply includes provision and/or distribution; water supply includes treatment and distribution; and sewage removal includes collection, treatment, and disposal of waste through sewer systems and sewage treatment facilities.

Wholesale trade: Establishments engaged in wholesaling merchandise, generally without transformation, and rendering services incidental to the sale of merchandise.

Retail trade: Establishments engaged in retailing merchandise, generally without transformation, and rendering services incidental to the sale of merchandise.

Accommodation & food services: Lodging and/or prepared meals, snacks, and beverages for immediate consumption.

Finance & insurance: Firms with payroll primarily engaged in financial transactions (transactions involving the creation, liquidation, or change in ownership of financial assets) and/or in facilitating financial transactions, pooling risk, or under writing insurance and annuities.

Real estate & rental & leasing: Renting, leasing, or otherwise allowing the use of tangible assets (e.g., real estate and equipment), intangible assets (e.g., patents and trademarks), and establishments providing related services (e.g., establishments primarily engaged in managing real estate for others, selling, renting, and/or buying real estate for others, and appraising real estate).

Other services: Services not specifically provided for elsewhere in the North American Industry Classification System (NAICS). Establishments in this sector are primarily engaged in activities such as repair and maintenance of equipment and machinery, personal and laundry services, and religious, grant making, civic, professional, and similar organizations. Establishments providing death care services, pet care services, photo finishing services, temporary parking services, and dating services also are included. Private households that employ workers on or about the premises in activities primarily concerned with the operation of the household are included in this sector.

Information: Establishments engaged in the following processes: (a) producing and distributing information and cultural products, (b) providing the means to transmit or distribute these products as well as data or communications, and (c) processing data. The main components of this sector are the publishing industries, including software publishing, the motion picture and sound recording industries, the broadcasting and telecommunications industries, and the information services and data processing services industries.

Administrative and support services, etc.: Routine support activities for the day-to-day operations of other organizations. These essential activities are often undertaken in-house by establishments in many sectors of the economy. The establishments in this sector specialize in one or more of these support activities and provide these services to clients in a variety of industries and, in some cases, to households. Activities performed include: office administration, hiring and placing of personnel, document preparation and similar clerical services, solicitation, collection, security and surveillance services, cleaning, and waste disposal services.

Arts, eEntertainment, & recreation: Establishments that operate facilities or provide services to meet varied cultural, entertainment, and recreational interests of their patrons. This sector comprises (1) establishments that are involved in producing, promoting, or participating in live performances, events, or exhibits intended for public viewing; (2) establishments that preserve and exhibit objects and sites of historical, cultural, or educational interest; and (3) establishments that operate facilities or provide services that enable patrons to participate in recreational activities or pursue amusement, hobby, and leisure-time interests.

Health care and social assistance: Providing health care and social assistance for individuals. The services are delivered by trained professionals. All industries in the sector share this commonality of process, namely, labor inputs of health practitioners or social workers with the requisite expertise. Many of the industries in the sector are defined based on the educational degree held by the practitioners included in the industry.

Professional, scientific, and technical services: Establishments that specialize in performing professional, scientific, and technical activities for others. These activities require a high degree of expertise and training. The establishments in this sector specialize according to expertise and provide services to clients in a variety of industries and, in some cases, to households. Activities performed include: legal advice and representation; accounting, bookkeeping, and payroll services; architectural, engineering, and specialized design services; computer services; consulting services; research services; advertising services; photographic services; translation and interpretation services; veterinary services; and other professional, scientific, and technical services.

Educational services: Instruction and training in a wide variety of subjects. This instruction and training is provided by specialized establishments, such as schools, colleges, universities, and training centers. These establishments may be privately owned and operated for profit or not for profit, or they may be publicly owned and operated. They also may offer food and accommodation services to their students. Educational services usually are delivered by teachers or instructors that explain, tell, demonstrate, supervise, and direct learning. Instruction is imparted in diverse settings, such as educational institutions, the workplace, or the home through correspondence, television, or other means. It can be adapted to the particular needs of the students; for example, sign language can replace verbal language for teaching students with hearing impairments. All industries in the sector share this commonality of process; namely, labor inputs of instructors with the requisite subject matter expertise and teaching ability.

Public administration: Administration, management, and oversight of public programs by federal, state, and local governments.

Source: U.S. Executive Office of the President/Office of Management and Budget(OMB). 1999. North American Industry Classification System. Jist Works, Inc., Indianapolis, IN.

Draft
December 14, 2001

On-farm economic analysis

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Objectives of the on-farm economic analysis

The objectives of this chapter are two-fold:

1. To present an estimate of the impact the 2001 biological opinion had to on-farm crop revenue.
2. To suggest alternative water allocation mechanisms that could increase on-farm crop revenue without increasing the water allocated to irrigation.

This analysis focuses on the irrigated land within in the United States Bureau of Reclamation Klamath Basin Project (the Project).

Background of the Project

Authorized by the United States Bureau of Reclamation in 1905, the Project encompasses over 200,000 acres on approximately 1,400 farms. The farms receiving irrigation water from the Project annually generate on-farm crop revenue of approximately $100 million. The primary crops irrigated within the Project are alfalfa hay, pasture, small grains (barley), potatoes, and wheat.

Construction of the Project joined two separate watersheds, namely:

1. The Klamath River watershed, which originates at Upper Klamath Lake in Oregon and supplies water to Lower Klamath Lake as well as the Klamath River.
2. The Lost River watershed, formerly a closed system, comprised of Gerber Reservoir in Oregon and Clear Lake and Lower Tule Lake, both in California.

The two watersheds are joined by two physical structures. The Lost River Diversion Canal joins the Lost River to the Klamath River. The second structure joining the two watersheds is a pipe, through which irrigation runoff is pumped from Tule Lake to Lower Klamath Lake.

Because the Project lands receive water from two watersheds, farmers within the Project may receive different restrictions on their diversions. The reason for receiving different restrictions on diversions is simply because the hydrology of the two watersheds may be different in any one year. The importance of this fact will become clear later on in this chapter when estimates of on-farm crop revenue are made under varying quantities of irrigation water deliveries.

Section overview

In addition to this introduction this chapter contains five other sections. The first section presents agricultural economic and statistical data about the Project. The second section describes the model used to estimate the response of on-farm crop revenue to various levels of irrigation diversions. The results of the model are presented in the third section. The structure of the results section aligns with the objectives of this chapter. The first subsection in the results section presents a discussion of the impact of the 2001 biological opinion to on-farm crop revenue. The second subsection in results describes how changes in policies could make the existing water "go farther," measured in terms of increases in on-farm net revenue. The fourth section quantifies the impacts of various combinations of biological opinions and hydrologic year types on irrigation diversions. The fifth and final section summarizes the findings and discusses possible improvements on the analysis.

Klamath project agricultural economic statistics

Crop mix and acreage

The acres planted in the Project by crop and watershed for the years 1987 through 1998 are shown in Table 1. Total acres and the mix of crops planted have changed little over this 12-year period. The Klamath River watershed comprises most of the land in the Project, approximately 170,000 acres or 87 percent of the total Project acres. Alfalfa hay, irrigated pasture, and feed grains make up approximately 75 percent of the Klamath River watershed crops. Potatoes (categorized as vegetables) make up most of the remaining 25 percent of the crops grown in the Klamath River watershed. Hay and pasture are the primary crops grown in the Lost River watershed.

Sugarbeets, which came into production in 1990 in the Project, will likely not be grown any longer due to the closing of a processing plant. The number of acres in production over this period of time is relatively unchanged because irrigation insulated farm managers from natural droughts. The years 1992 and 1994 were dry; however only 1992 shows a reduction in total acres in production and the greatest reduction in acreage in 1992 occurred in the Lost River watershed. The data for 1988 is incomplete, which is why the total acres in production in that year are noticeably low.

On-farm crop revenue

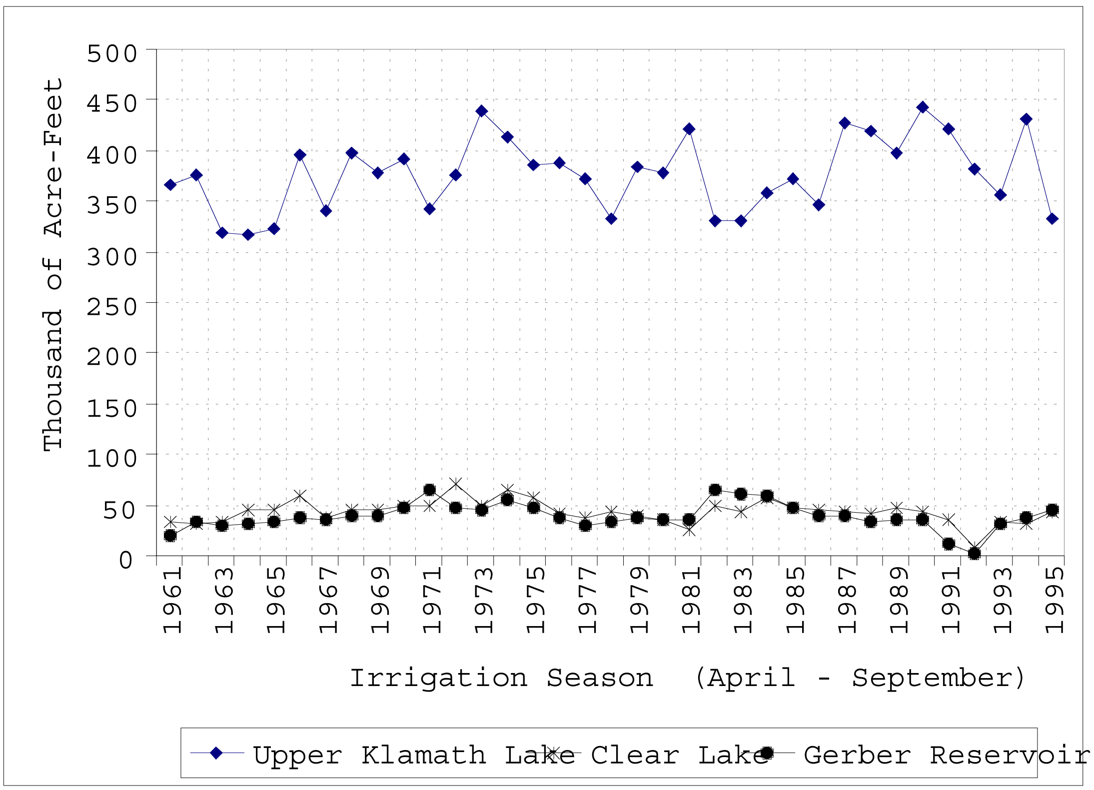
The nominal on-farm crop revenue generated on Project lands from 1987 through 1998 is shown in Table 2. Generally, the total on-farm crop revenue is near $100 million per year. Farms in the Klamath River watershed generate approximately 90 percent of the total on-farm Project revenue. Potatoes generate 30 percent of the total on-farm crop revenue on roughly 16 percent of the total land in the Project. Volatility in revenue is due to fluctuations in crop prices and yields rather than a change in the quantity of land in production. Table 3 shows the historical prices by crop. Notice that the price of potatoes (categorized as vegetables) ranged between $46 per ton to $133 per ton. It is not a coincidence that the year with the highest revenue, 1995, is the same year that the price of potatoes was higher than any other year in the time series. The prices for 2001 are estimates, used in the analysis of this chapter.

Irrigation diversions

Figure 1 shows the releases of water into the Project by source for the years 1961 through 1995. Recall that Gerber Reservoir and Clear Lake provide water to the Project's lands that are within the Lost River watershed. Releases from these sources make up a significantly smaller portion of the total water released into the Project. Most Project water comes from releases from Upper Klamath Lake, between just over 300,000 acre-ft in 1964 to nearly 450,000 acre-ft in 1990.

Historically, the quantity of water released in any irrigation season does not necessarily reflect whether that hydrologic year was dry. Particularly, prior to the listing of the sucker fish, farmers in the Project were not competing with the environment for water and, therefore, received enough water to irrigate all their lands. This can be seen by examining the two driest years on record for this time period—1992 and 1994. Notice that releases into the lands of the Upper Klamath Lake watershed were also not noticeably low in 1992 and 1994. And releases into the lands of the Lost River watershed (from Gerber Reservoir and Clear Lake) were close to normal in 1994. The only indication that 1992 was a critically dry year is the fact that little water was released into the Lost River watershed—simply because there was little water to release.

Figure 1. Irrigation diversions into the Project by source.



Source: U.S. Bureau of Reclamation reservoir operations model entitled Klamath Project Operations Model (KPOP-SIM).

Water rights and allocations within the Project

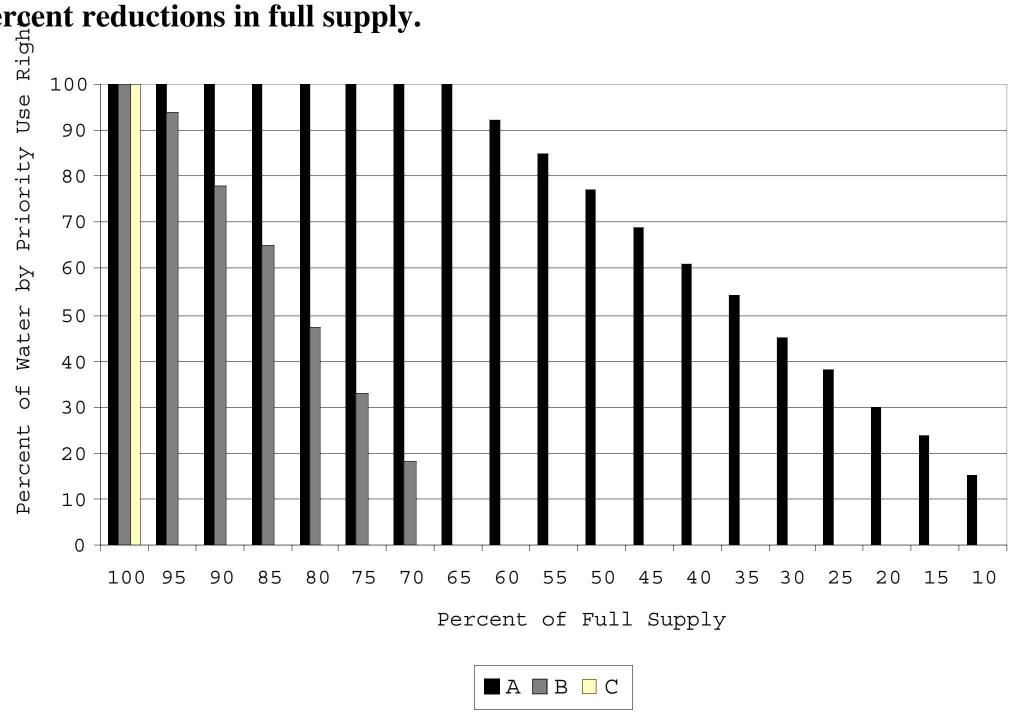
The water rights attached to Project lands fall into one of three categories, called a priority use right. The three categories are referred to as "A," "B," and "C." Legally, the priority use right dictates how water is allocated throughout the Project. The A priority rights holders, or users as they are sometimes referred to, have the most senior rights to water, followed by B users and finally C users. Seniority of right in this case means that, when water is allocated among the users, the A users receive all the water they can beneficially use before either the B or

C users receive any water. Once the A users receive all the water they can beneficially use, deliveries begin to the B users until the B users receive all the water they can put to beneficial use. Lastly, the C users receive their allocation.

The drought of 2001 combined with the new biological opinions—calling for higher water levels in Upper Klamath Lake and greater in-stream flow in the Klamath River—created a situation where the Bureau of Reclamation had to forgo irrigation deliveries to all three of the priority use right categories. In the future the priority use right system may be used to allocate irrigation diversions. Specifically, the Bureau may have to determine how to allocate water to Project lands when irrigation diversion are less than a full supply and greater than zero. "Full supply" is defined as the amount of water required to irrigate all of the Project lands.

Figure 2 details how a percent reduction in full irrigation diversions would translate into a percent reduction in irrigation diversions by priority use right. Figure 2 shows that the C users lose all their diversions almost immediately. At 95 percent of full diversions the C users receive zero diversion. The B users receive less and less of their diversion until full diversions are down to 65 percent, at which time the B users receive no water. The first reduction in delivery to the A users occurs when diversions are 65 percent below full.

Figure 2. Percent of full irrigation diversions allocated by priority use right for various percent reductions in full supply.



The percent of land categorized by priority use right and state is given in Table 4. Land that holds an A priority use right comprises 67 percent of the total land in the project. The lands that hold B and C priority use rights comprise 30 percent and 3 percent of the land, respectively. Nearly all of the B land is in Oregon and nearly all of the C land is in California. The result of this distribution of priority use rights means that if the Project lands suffer a reduction in irrigation diversions of between 95 percent and 65 percent, most of the reduction will be felt in Oregon (ignoring the small percentage of C lands that are in California).

The model

This section of the chapter describes the model that was used to estimate the change in on-farm crop revenue resulting from a change in irrigation diversions. This section begins with background detailing how the model came to be built, followed by a description of the use of economic theory in the model. A description the model's uses and shortcomings conclude this section.

Historical background of model development

The model was developed from 1996 through 1998 at Oregon State University (OSU) and the University of California, Davis (UCD) with a grant from the U.S. Department of Agriculture (USDA). The purpose of the grant was to study the economic and hydrologic impacts occurring in the Project resulting from changes to irrigation diversions and water allocations (see Burke 1999).
Model development required coordination with staff members at the U.S. Bureau of Reclamation (USBR) office in Klamath Falls, Oregon. At the time of the model development, the USBR was preparing to write an Environmental Impact Statement (EIS) for the Klamath Basin. It became apparent that the model being developed by OSU and UCD would have usefulness in the EIS process. Therefore, the USBR contracted to continue the effort. Furthermore, in September 2000, the USBR funded an effort to incorporate the model into the existing reservoir operations model (KPOP-SIM) currently in use in the Klamath Falls USBR office.

The model

The model is a combined hydrologic and economic model. The economic model is a short-run model that assumes farm managers maximize their net on-farm crop revenue through cropping decisions and irrigation technology improvements that are constrained—in part—by available water, fixed capital, and cultural practices. The input to the economic model includes, historical crop patterns, per acre average yield of crops grown in the Project, variable costs of crop production, available water, and crop prices. The output of the model includes estimates of cropping patterns within an irrigation district given a set of inputs. Of primary interest for this analysis is the input that quantifies the amount and allocation of available irrigation diversions to farm manager and/or irrigation districts.

Irrigation diversions enter into the model in two ways: first, how much total irrigation diversions are available to the Project, and second, how will the available diversions be allocated? The answer to the first question comes from the analysis that translates the available diversions into a percentage of full water supply available to the Project. This analysis depends on the time-series of diversion data presented in Figure 1. The second way diversions enter into the model is by allocating the available irrigation diversions among the water districts as shown in Figure 2.

The model assumes that the farm managers and/or irrigation districts will be informed about how much water is available to them as a percentage of full supply. The model also assumes the farm manager receives this information in a timely manner so that business decisions can be made with full information about resource availability. Once the percentage of full supply of water is known, the model is run with various assumptions about how the available water is allocated among irrigation districts and/or farms.

An allocation method can take many forms. Two examples of how to constrain limited irrigation diversions are (1) directly, by constraining the water deliveries to farms and irrigation districts, or (2) indirectly, by constraining the amount of land that is in production. For example, if the irrigation diversion were determined to be 50 percent of full supply, either the water deliveries could be measured to assure only 50 percent of full supply was delivered, or the quantity of land in production could be reduced by 50 percent. The first allocation method—directly measuring water deliveries—has the advantage of increasing the flexibility of the farm manager (to allocate water as he or she sees fit). The disadvantage of directly measuring water deliveries is that the measurement devices needed to manage deliveries to the A, B, and C users are not currently in place in the Project.

The indirect method of assuring the appropriate quantity of water is delivered—by constraining the number of acres of land in production—has the advantage of being a "manageable" method in the Project today, but reduces the farm manager's flexibility regarding the use of their resources and results in lower overall on-farm crop revenue within the Project. A comparison of the impact these two allocation methods have on on-farm crop revenue will be presented in the Results section of this chapter.

Model uses and shortcomings

Uses and shortcomings of the model are discussed in this section. Two model shortcomings are (1) the model assumes the availability of a timely and accurate estimate of the percent of full irrigation diversion available in the coming growing season, and (2) the model is a short-run model.

In the above description of the percent of full irrigation diversions available to irrigation districts and/or farms, the assumption was that the percent of full supply information would be available when farm managers are making production plans for the upcoming year. There is a significant amount of controversy around this assumption.

The controversy takes two forms. First, many of the Project farm managers feel they receive little information regarding the availability of irrigation supplies, and the information that is available is too late to be of help in making production decisions, i.e., planting decisions and securing operating lines of credit. Some farm managers in the Project feel this information is needed as early as November or December of the year preceding the growing season. Some farm managers feel that the information could come later, in the spring of the planting season, and still be used in planting decisions. The advantage to announcing the available supplies earlier rather than later is that the farm manager has more time to make decisions. The drawback of making the estimate earlier—about how much water will be available during the coming growing season—is that less data about the hydrology of the coming year are available simply as a consequence of time. Therefore, the estimate of water availability may be far below the amount of water that will ultimately be available. Regardless of the timing of the announcement, or the information content, what is important to point out in this analysis is that the model assumes something that is not currently occurring—that is, the farm manager gets full information in a timely manner. Therefore, the model suggests a best-case correspondence between water availability and on-farm crop revenue.

The second form of controversy surrounding the assumption of timely information about water availability is that the estimate of available irrigation diversions is correct. The hydrology of the Project is complex. Many factors contribute to the available supplies including, but not limited to summer precipitation, average temperature during the growing season, and timing of the run-off from the winter snow pack. An above-average snow pack year may result in a below-average water year if above-average temperatures in the spring lead to early snow melt. Conversely, impacts of a relatively dry winter could be offset by above-average summer rains. These events have happened in the Project, making forecasting available irrigation diversions a difficult task. In order to quantify the value of accurate forecasts, one of the scenarios, discussed below, addresses the impact of an incorrect estimate of irrigation diversions on crop yield, and therefore on on-farm crop revenue.

Lastly, implications of the short-run nature of the model will be described. The model assumes that farm managers are operating to cover their variable costs of production. Fixed costs are not a factor in the results generated by the model. The benefit of this type of model is that it estimates the on-farm response to short-run, i.e., seasonal, changes in inputs. The model was developed this way because, at the time, a paradigm shift was not what was being modeled in the Project. Rather the model was developed to estimate the impacts to occasional annual shortages in available irrigation diversions. The disadvantage of not including fixed cost in the model is that the "break-even point"—the point past which it is no longer economically feasible to remain in farming for the long-term—is not determined.

Finding this break-even point is a difficult task. The information necessary to determine the break-even point of a farm operation varies by farm. Primarily, such an analysis involves the level of long-term debt being carried by the farm manager (not to be confused with annual operations debt). For the purposes of this analysis, the short-run analysis is used to understand the link between on-farm crop revenue in the short run; the analysis is not used to predict how many farms, or how many acres, could remain in production in the long run under a paradigm shift involving available irrigation diversions at perpetually reduced levels, compared to historical levels, based on new biological opinions.

The results

The results are separated into two subsections, which describe:

- The estimated impact of the 2001 biological opinions to on-farm crop revenue in 2001.
- Policy changes that could mitigate the impact of reduced irrigation deliveries to on-farm crop revenue, e.g., ways to make the available water "go farther."

The impacts are measured on the on-farm crop revenue in the Project.

Impact of the 2001 biological opinions on 2001 on-farm crop revenue

Two events significantly impacted the level of on-farm crop revenue generated in the Klamath Project in 2001. First, a record drought reduced the supply of water available to all water users in the basin. Secondly, a revised biological opinion for the level of Upper Klamath Lake, combined with a new biological opinion about Klamath River flows led the Bureau of Reclamation to announce in April 2001 that there would be no irrigation diversions for the year.[1]

The results presented below disaggregate the estimated effects to on-farm crop revenue of these two events namely, the drought and the 2001 biological opinions for the lake and river. To

[1] Subsequent to the announcement that irrigation deliveries would be zero in 2001, the Bureau released 70,000 acre-ft of water in mid-season.

disaggregate the effects the model was run three times using three different assumption sets. The in-stream flow requirement, lake-level minimum, and hydrologic year (representing inflows) used in the model are seen in Table 5. The assumption set labeled "*Baseline*" estimates on-farm crop revenue in a year with *near normal water supplies* (1986 was used as a proxy) and the *biological opinion in effect for 2000 on the lake levels.* Although there was no biological opinion on the river flow minimums in 2000, there were *minimum FERC flows, which the Bureau has managed to in the past; therefore those FERC minimums are used as the river constraint.*

The second assumption set shown in Table 5, labeled "Drought-Only (revised FERC minimum flow)," estimates the on-farm crop revenue using the biological opinion for the lake that was used last year (2000), the revised minimum FERC flows, and a hydrologic year that is classified as "critically dry" (1992 was used as a proxy). The only difference between the baseline assumption set and this Drought-Only (revised FERC minimum flows) assumption set is the hydrologic year that was used as a proxy, 1992, versus the near-normal year of 1986.

The third and final assumption set shown in Table 5, "Drought and 2001 Biological Opinions," estimates the on-farm crop revenue using this year's biological opinions and the hydrology from 1992. The lake level minimums used in this assumption set are colloquially referred to as "4140" due to the level requirement in the July through September timeframe that is highest, namely, the August requirement of 4,140.79 ft above sea level. The flow requirements are much greater than the 1992 operations. The 2000 actual flows are used here because they are close to the flow requirements under the 2001 river flow biological opinion.

Table 6 presents the estimates of on-farm crop revenue under all three assumption sets and disaggregates the results in order to gain visibility into the impact to on-farm crop revenue from (1) the drought and (2) the new biological opinions.

If the river were operated according to the revised FERC minimums, then the estimate of full irrigation diversions available to the Upper Klamath River users is 55 percent while the Lost River users would have had 35 percent of their full suppl —generating 70 percent of on-farm crop revenue using full-supply revenue as a basis. Model results for the combined effect of the drought and the 2001 biological opinions suggest that, while the Upper Klamath Lake users would have received no water, the Lost River users could have received 25 percent of their supply, generating 25 percent of total on-farm crop revenue.

On-farm crop revenue is not zero when irrigation diversions are zero because of the availability of groundwater within the Project lands. For the purposes of this analysis, the level of groundwater pumping is based on historical levels (45,000 acre-ft) and therefore does not include new sources made available this year with emergency funds from the state of California groundwater pumping at historical levels (see text box entitled Tulelake Well Program below). Additionally, the USBR delivery of 70,000 acre-ft of surface water in mid-season in 2001 is ignored, assuming farm managers did not plan on the late delivery and therefore did not plant. The comparative analysis shown in Table 6 estimates the impact of the 2001 biological opinions to on-farm crop revenue. The difference in on-farm crop revenue due to the drought alone is estimated to be a $29.7 million loss. The difference in on-farm crop revenue due to both the drought and the new biological opinions is a loss of $74.2 million. Taking the difference of these differences produces an estimate of the cost of the 2001 biological opinions to on-farm crop revenue in the Klamath Project in 2001: *the effect of the 2001 biological opinion to on-farm crop revenue is $44.5 million.*

It should be noted that in 1992, a critically dry year, the shortage in irrigation diversion was mitigated by allowing the Klamath River flows to fall significantly below the FERC minimums. The flows ranged between 400 and 900 ft^3/s compared to the FERC minimum flows that range between 900 and 1,900 ft^3/s. If the 2001 river flows had been managed as in 1992, the irrigation diversion shortage could have been eliminated.

Policy options that can increase on-farm crop revenue without increasing irrigation diversions

This subsection will cover three topics:

- The general relationship between irrigation diversions and on-farm crop revenue.
- How greater flexibility in the method by which water is allocated could increase on-farm crop revenue using the same quantity of water.
- How greater flexibility in the timing of the measurements of lake levels could potentially save on-farm crop revenue.

The first of the above points—the general relationship between irrigation diversions and on-farm crop revenue—acts as a background to the subsequent discussion regarding water allocation methods and flexibility in the timing of lake levels.

General relationship between irrigation diversions and on-farm crop revenue

The general relationship between irrigation diversions and on-farm crop revenue on Project lands is illustrated in Figure 3. The horizontal axis displays the percent of full supply of irrigation diversions. The left-hand vertical axis displays on-farm crop revenue. The right-hand vertical axis displays percent of on-farm crop revenue, based on water allocations at 100 percent of full supply.

Tulelake Well Program

The California Department of Water Resources, the Governor's Office of Emergency Services, and Tulelake Irrigation District are currently developing supplemental groundwater resources in the California portion of the Upper Klamath River Basin. At this time a total of 10 wells have been drilled in Siskiyou and Modoc counties for the purpose of providing supplemental water for irrigating 20,000 acres of cover crops in an effort to preserve valuable agricultural topsoil and to augment surface water supplies for future water shortages (see table below). Groundwater development was initiated May 4, 2001, when Governor Davis allocated $5 million to the program in his Klamath Basin Drought Emergency Proclamation.

TULELAKE IRRIGATION DISTRICT

WELL SUMMARY TABLE

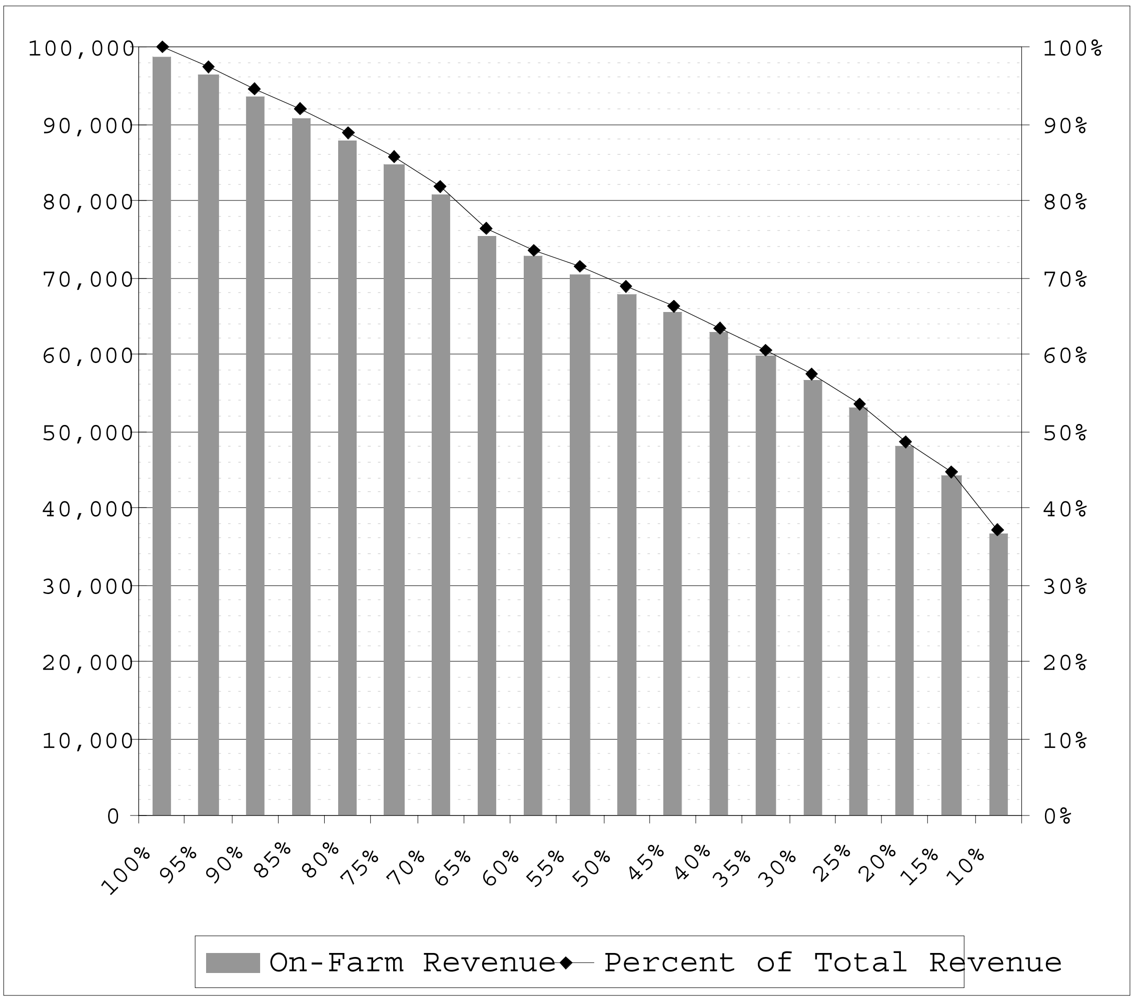
October 12, 2001

TID	DATE STARTED	DATE COMPLETED	COMPLETED DEPTH	PRODUCTION ZONE	PUMP TEST YIELD	START DELIVERIES	STATUS
#1	5/26/2001	6/8/2001	740 ft	245' - 685'	9,300 gpm	6/27/2001	pumping
#2	7/27/2001	8/3/2001	1,545 ft	1,260' - 1,540'	12,000 gpm	8/25/2001	pumping
#3	6/9/2001	6/28/2001	1,680 ft	1,153' - 1,680'	9,000 gpm	7/24/2001	pumping
#4	6/28/2001	7/8/2001	1,4432 ft	1,211 - 1,433	10,000 gpm	8/15/2001	pumping
#5	7/14/2001	7/20/2001	1,566 ft	935' -1,556'	9,500 gpm	°	pumping
#6	6/6/2001	6/29/2001	2,380 ft	822' - 2,358'	6,000 gpm	7/13/2001	waiting for pump
#7	6/29/2001	7/8/2001	2,030 ft	814' - 1,687'	4,000 gpm	9/21/2001	pumping
#8	8/16/2001	8/29/2001	1,810 ft	1,240' - 1,800'	°	°	waiting for pump

When irrigation diversions are 100 percent of full supply, on-farm crop revenue is near $99 million, and by construction, the percent of revenue is 100 percent. When irrigation diversions are 95 percent of full supply, on-farm crop revenue is $98 million and the percent of revenue is just under 99 percent. Therefore, the first 5 percent reduction in irrigation diversions causes a 1 percent reduction in on-farm crop revenue. The next 5 percent reduction in irrigation diversions, to 90 percent of full supply, causes a 2 percent decrease in on-farm crop revenue.

The rate of decrease in on-farm crop revenue increases slightly with each 5 percent decrease in irrigation diversions until the total decrease in irrigation diversions is 65 percent, at which point the percent decrease in on-farm crop revenue from 70 percent to 65 percent of full irrigation diversion is 3 percent. After 65 percent of full irrigation diversions, the percent decrease in on-farm crop revenue for each 5 percent decrease in irrigation diversions is close to 2 percent, until irrigation diversions are 20 percent of full supply, at which time the percent decrease in on-farm crop revenue for each 5 percent decrease in irrigation diversions is between 3 and 4 percent.

Figure 3. Relationship between irrigation diversions and on-farm crop revenue.



The reason the rate of change in on-farm crop revenue increases at 65 percent of full irrigation diversions and then decreases after 65 percent of full irrigation diversions is due to the A, B, C priority-use right water-allocation method. Near the 65 percent point in irrigation diversion, the allocation of water to the B users is completely suspended while the A users are still receiving a full supply (refer back to Figure 2). Assuming some heterogeneity of land quality, this allocation method forces the highest-quality B land completely out of production, while the lowest-quality A lands are all still in production.

Caution should be exercised in interpreting the information shown in Figure 3. Recall that the model generating this data is a short-run model. The implication of a short-run model is that the fixed debt costs of the on-farm operation are being covered. This may not be the case if year after year the percent of irrigation diversions to farmer managers is below historical levels. The data presented in Figure 3 is helpful in understanding the 1-year impact of a reduction in irrigation diversions, assuming operations will return to near-normal conditions in the following years.

Increasing on-farm crop revenue with policy changes that reallocate existing irrigation diversions

The current water allocation method in the Project follows the A, B, C priority-use right method already described in this chapter. The results that will be presented in this subsection of the chapter answer the question *"What if there were greater flexibility in the method of allocating water?"* Estimates of on-farm crop revenue under two different allocation methods will be presented. Those methods assume:

1. Water measurement devices (meters) are installed so that the water-allocation methods constrain water deliveries directly, instead of constraining the number of acres in production. For example, if the amount of water available to a B user is 50 percent of their full supply then they will receive 50 percent of their full water supply rather than only being permitted to plant 50 percent of their acres.
2. Prorating equally any reduction in irrigation diversions across all users, regardless of the A, B, and C priority-use right distinction.

The percent of on-farm crop revenue generated under the above two allocation methods when irrigation diversions range from 100 to 10 percent of full supply is shown in Figure 4. For reference, the baseline percent of on-farm crop revenue, originally shown in Figure 3**,** is included in Figure 4. The percent of on-farm crop revenue is higher under either of the alternative water allocation methods than under the baseline method for any level of irrigation diversion. When meters are used so that reductions in water deliveries can be managed by measuring water rather than fallowing land, the percent of total on-farm crop revenue is between just slightly higher than baseline to 2 percent above baseline. Since meters generate higher on-farm crop revenue, an analysis could be developed to determine how long a meter-installation program would take to pay back. Since a 1 percent change in revenue is roughly equal to $1 million in the Project, if the meter-installation project cost less than $2 million, the payback could be between 1 and approximately 5 years, depending on the percentage of irrigation diversions.

In this example, the smallest decrease in on-farm crop revenue occurs when shortages in irrigation diversions are proportionally allocated across the Project, without regard to A, B, C priority-use right designation. For example, when irrigation diversions are 70 percent of full supply, on-farm crop revenue is 90 percent of total under the proportional water allocation method, versus 80 percent under the baseline water allocation method.[2] Specifically, under the baseline water allocation method, the B user's water allocation is near zero and yet the A users are receiving 100 percent of their water supplies when irrigation diversions are near 70 percent of normal. Presuming the lowest value land is removed from production first, this allocation

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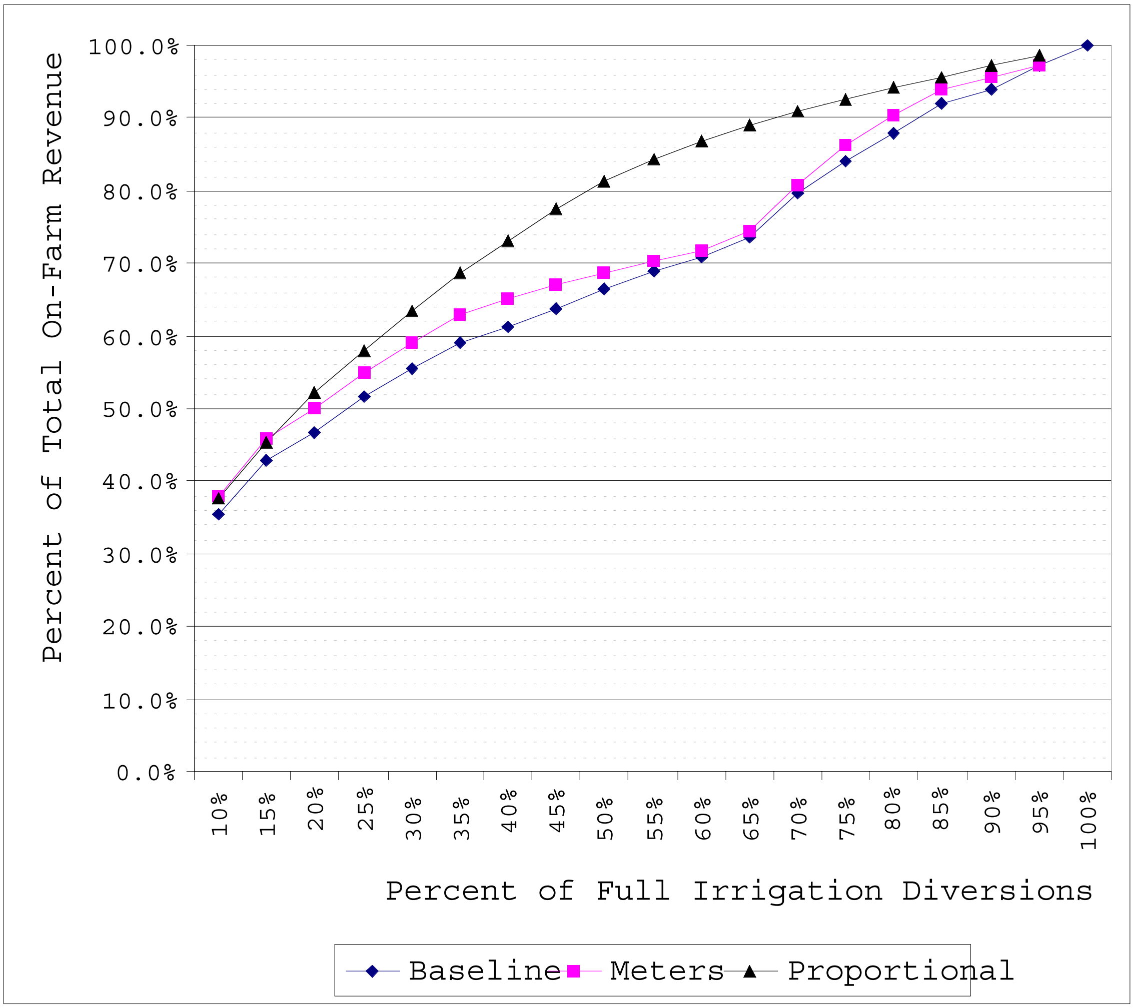
[2] The overall impact of such a water allocation approach is to reduce the return flow out of the Project (through the Klamath Straits drain). Increasing overall Project efficiency may have a detrimental effect on both the Lower Klamath Lake and Tule Lake national wildlife refuges. Both refuges are dependent on the return flows of the Project to maintain wildlife habitat.

method forces the highest value B land from production before the lowest value A lands are removed from production. For an intuitive numerical example of this result see the text box below entitled "How water allocations can affect total on-farm crop revenue."

Figure 4. Percent of on-farm crop revenue under various water allocation methods and a range of irrigation diversions.



How water allocations can affect total on-farm crop revenue

Assume the relationship between irrigation diversions and on-farm crop revenue follows the pattern:

Percent of Irrigation Diversion	Percent of On-farm crop revenue
100%	100%
50%	70%
0%	20%

Now assume there are three farms, farm A, farm B, and farm C. Farm A holds an A priority-use right to water. Farm B holds a B priority-use right to water. Farm C holds a C priority-use right to water. Assume the quantity of water used on each farm is the same and each farm produces $100 of on-farm crop revenue when irrigation diversions are 100 percent. Therefore, total revenue from all the farms is $300. A comparison of the revenue generated under the A, B, C priority-use right water-allocation method and the proportional method is presented in Table 1 assuming irrigation diversions must be cut to 50 percent of full. Total on-farm crop revenue under the A, B, C priority use right method is $190, or 63 percent of total. Total on-farm crop revenue under the proportional method is $210, or 70 percent of full. Simply because the "pain is shared" in the reduction of irrigation diversions, the decrease in on-farm crop revenue can be lessened by 7 percent.

Table 1. On-farm crop revenue under two water allocation methods.

Farm	Full irrigation deliveries	A, B, C priority-use right	Proportional
A	$100	$100	$70
B	$100	$70	$70
C	$100	$20	$70
Total	$300	$190	$210
% of Full	100%	63%	70%

The results suggest another method of water allocation that could mitigate the effects of decreases in irrigation diversions even more than the proportional allocation, namely, a water market. The proportional allocation method mitigates for some of the loss to total on-farm crop revenue by more closely equating the value of the land in production than the A, B, C allocation method. A water market moves even further in that direction by equating the value of the water in production. Allowing willing sellers to offer water to potential buyers, both parties could be made better off. Increasing the flexibility of water allocation methods, to better equate the value of water on the margin, increases the output of the Project.

Increasing on-farm crop revenue with policy changes that increase the flexibility of when lake levels are measured

The level of Upper Klamath Lake is measured on the dates listed in Table 5. For example, under all four of the assumptions sets shown in Table 5, the lake level must be 4,139 ft above sea level at the end of September. If, as the end of September nears, there is a concern that the lake level will not be met, irrigation diversion may be stopped until the lake measurement is taken. The nervousness about meeting the lake level requirements during the height of the growing season has been captured in a colloquialism: local stakeholders refer to this period as the "nervous narrows." The need to stop irrigation deliveries for a time to meet lake levels may arise for whatever reason—hotter than normal summer temperatures, lower than average summer precipitation, etc.—the question is, how will on-farm crop revenue be impacted?

The results presented in Table 7 assume a mid-season cessation of irrigation diversions beginning on August 15 and resuming August 31. The reduction of on-farm crop revenue as a result of the cessation is approximately $12.5 million. The reduction in on-farm crop revenue is based on the impact the cessation has on crop yield. The data on the change in crop yield was obtained from field trials performed at the University of California, Davis, Intermountain Research and Extension Center.

The reduction in on-farm crop revenue from potatoes (classified as vegetables) accounts for most ($9.8 million) of the total reduction. Potatoes, as a row crop, are relatively more sensitive to cessations in watering earlier in the season rather than later because they must become established. Once established, a reduction in irrigation water has less of an impact on the crop yield. If the 2-week cessation occurred from September 1 through 15 instead of August 15 through 31, the impact on on-farm crop revenue could be decreased**.** Table 8 shows the difference in on-farm crop revenue under irrigation cessations beginning August 15 and September 1. More than $8.2 million of on-farm crop revenue could have been saved in potatoes (nearly $8.9 million in total) if the 2-week cessation was moved back 2 weeks.

To the extent there is flexibility in the determination of the date when the lake levels must be taken, there is potential to save on-farm crop revenue. Each year, the impact a cessation in irrigation would have on crop yield may be different, however if the agencies involved can increase their operational flexibility without serious injury, a marginal gain may be available.

Effects of various combinations of biological opinions to irrigation diversions

In order to gain more insight into the impact the lake levels and in-stream flow regimes may have on irrigation diversion in the Project, Figure 5 and Figure 6 show the percent of full supply for five historical hydrologic traces under four different combinations of lake level and in-stream flow regimes for Upper Klamath Lake and Lost River, respectively. Two lake levels are examined, namely:

- 4,139 ft above sea level.
- 4,140 ft above sea level.

The three in-stream flow regimes examined are:

- The 1992 operations (a critically dry year when FERC minimums were violated).
- The 2000 operations (hydrologically, an above-average year that closely approximates the 2001 biological opinion).
- The flows recommended by Dr. Hardy in the Phase I analysis of in-stream flow required for habitat restoration.[3]

[3] Dr. Hardy is an associate professor at Utah State University. He is under contract with the Bureau of Indian Affairs to assess the river flow required to improve habitat in the Klamath River.

The lake levels and flow regimes are combined into four sets of data (although six sets are possible, only four are presented here) of the lake levels and in-stream flow regimes. These four data sets are then combined with five different hydrologic year traces. There is one of each hydrologic year trace classified as critically dry, dry, and below average and two hydrologic year traces classified as above average shown in these figures.

The USBR defines the hydrologic year types in its annual Environmental Assessments. Above-average years are any years where snow pack and spring in-flows are greater than the average. A below-average year type is any year where the snow pack and spring in-flows are one standard deviation below average. A dry year is defined where the snow pack and spring in-flow are two standard deviations below average. Critically dry years are any years the snow pack and spring in-flows are more than two standard deviations below normal.

Figure 5 shows the percent of full irrigation diversions that may be available to the Upper Klamath Lake users under four various combinations of river and lake biological opinions and hydrologic year types. Under the lake level requirement of 4,139 ft above sea level, three different river flow requirements were tested. The results are (1) under no flow requirement irrigation diversions are 100 percent regardless of year type; (2) under the 2001 biological opinion the above and below average year types have 100 percent of irrigation diversions; however in dry and critically dry years irrigation diversions are 65 percent and 10 percent, respectively; (3) when river flow requirements follow Dr. Hardy's report only one above-average year, 1982, has full irrigation deliveries and one above-average year, 1986, has 40 percent deliveries, the below-average year has 10 percent, and there are no irrigation diversions in dry and critically dry years.[4]

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[4]The reason 2 above-average years can result in different estimates for the percent of irrigation diversion occurs as a result of the methods of classifying year types. Recall that the estimate of how much water is available is made based on the inflows into Upper Klamath Lake (and Gerber and Clear lake reservoirs) in the spring, before the summer precipitation and temperature are known. After the spring announcement two factors can and have influenced the amount of agricultural demand for irrigation (or the supply of water). Namely, (1) summer precipitation can make up for below-average spring inflows into the Project reservoirs, and (2) cooler summer temperatures may decrease the demand for irrigation water. Combined, these factors can change a hydrologic year that appears below average in the spring (based on inflow data) into a hydrologic year when all demands are met. Conversely, a hydrologic year that appears to be above average in the spring may emerge into a hydrologic year when all demands are **not met**. An example of this situation can be seen by examining the results when the

Under the lake level requirement of 4,140 ft above sea level, one river flow requirement was tested: 2001 biological opinion, which shows 100 percent deliveries in above- and below-average years but no irrigation diversions in dry or critically dry years.

Figure 6 presents the same analysis as in Figure 5 for the Lost River watershed. In all cases when the hydrologic year type is critically dry, the percentage of full supply is between 25 and 30 percent. In the Lost River watershed, a relatively larger portion of full supply is met with groundwater. The model assumes groundwater is static over year types, therefore the result seen in Figure 6, that even in critically dry years at least 25 percent of full supply is available, is driven by the availability of groundwater.

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hydrologic year is 1986, an above-average year. This result shows the complexity of the hydrology in the Project lands and illustrates the difficulty of predicting available irrigation diversions.

Figure 5. Percent of full water supply under various biological opinions, Upper Klamath Lake.

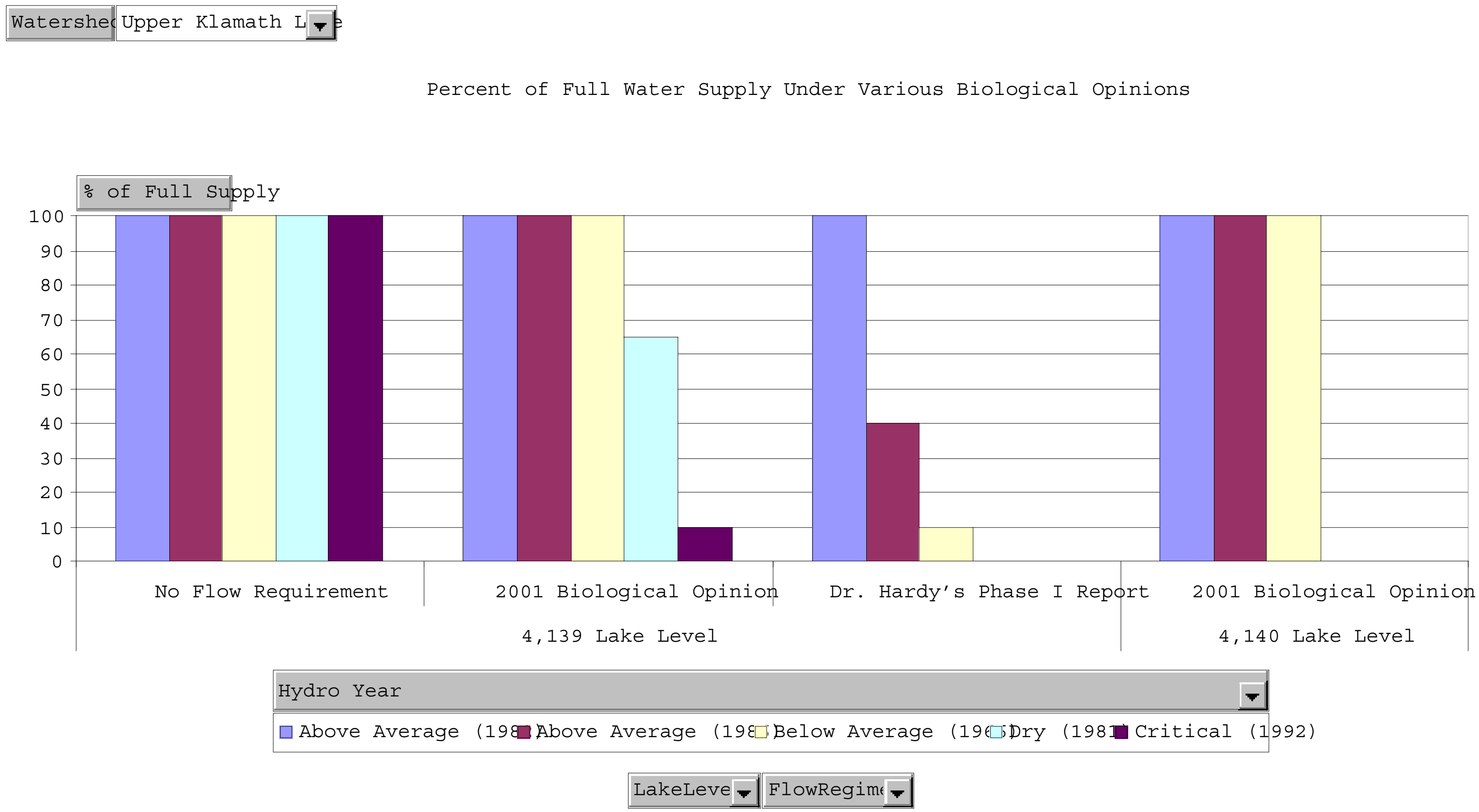
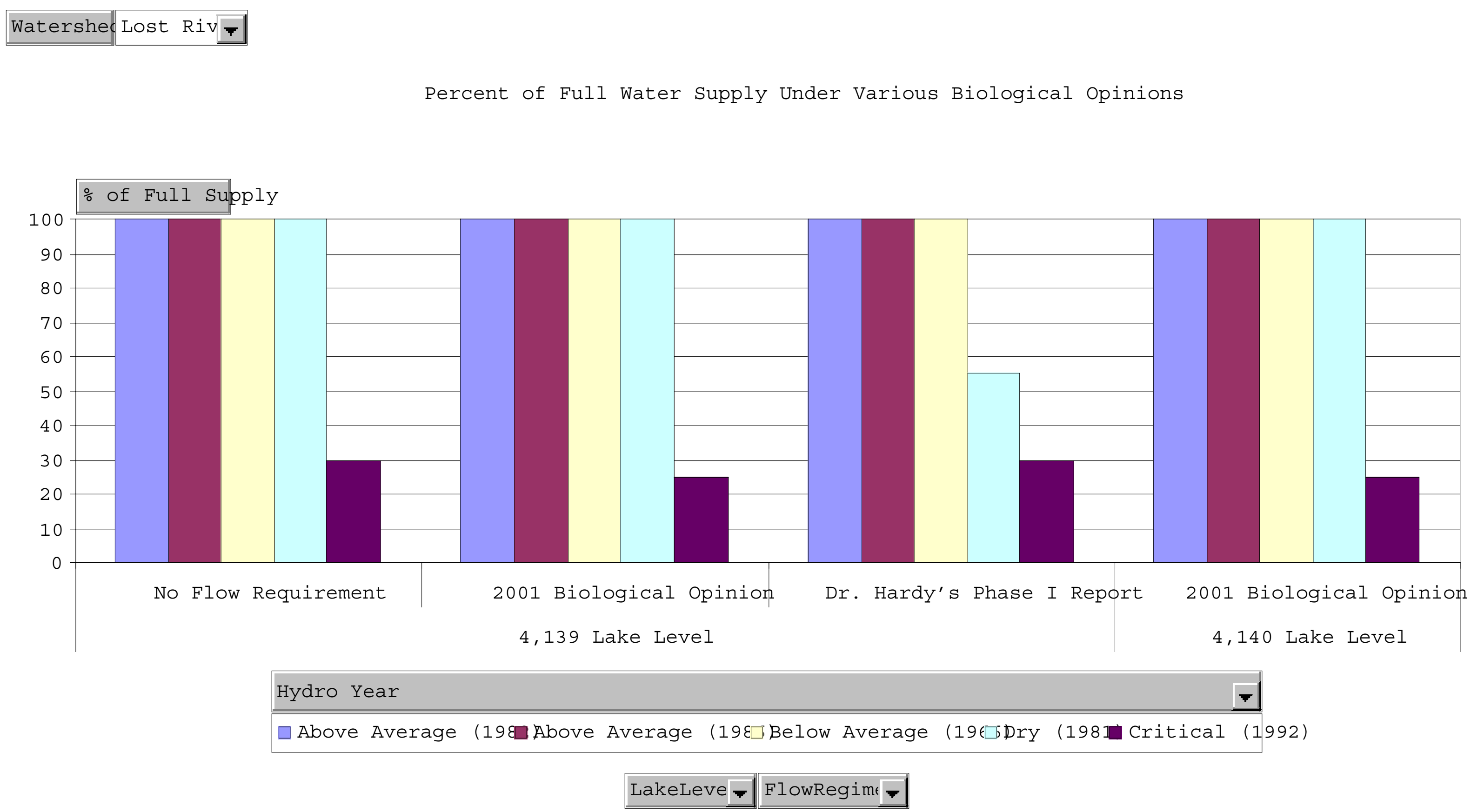


Figure 6. Percent of full water supply under various biological opinions, Lost River.



Summary and conclusions

This section of the analysis presents an estimate of the impact of the 2001 biological opinion to on-farm crop revenue in the Project. The impact is estimated to be between $44.5 million and $74.2 million. In addition, this section presents the estimate of impacts to on-farm crop revenue in the Project from policy changes regarding water allocation methods and flexibility in the timing of lake level measurements. Changing water allocation methods through the installation of measurement devices had a 1-year increase in on-farm crop revenue of between 0.3 and 2.4 percent. Using a proportional method to allocate water instead of the existing A, B, C priority-use right method could save as much as 10 percent of total on-farm crop revenue, depending on the percent of full irrigation diversions. Increasing the flexibility of when lake level measurements are taken could potentially save $8.9 million, or roughly 9 percent of total on-farm crop revenue.

The irrigation diversion available to the Project under various hydrologic year-types and biological opinions was estimated. Under both below- and above-average year hydrologic conditions, at the 2001 biological opinions for Upper Klamath Lake and Klamath River, the estimated full supply of water available to the Project would be 90 to 100 percent for the Klamath River watershed and approximately 100 percent for the Lost River watershed. If the year type is dry or critical—under the same biological opinions—the Klamath River users receive 5 percent and no water, respectively.

If the Hardy flows replace the 2001 biological opinion for in-stream flows in Klamath River, the percentage of full supply water available in the Klamath River watershed in above-average years would be between 100 and 40 percent. In a below-average year the percentage of full supply would be 5 percent. In dry and critical years there would be no water available for irrigation diversions.

The model used to estimate the change in on-farm crop revenue is a short-run model. The results cannot be used to extrapolate the number of farms that may be forced out of business in the long run if the water allocation paradigm in the Project changes significantly from historical delivery patterns. Further extension of this work would include incorporating a long-run analysis in order to fully understand the impacts of changing water allocations in the long-run.

References

Burke, S. M. 1999. Measuring the on-farm response to changing water allocation supply and methods: the case of the Klamath Basin. Ph.D. Dissertation, Oregon State University, Corvallis.

United States Department of Interior. 1999. Draft Klamath Project 1999 Annual Operations Plan Environmental Assessment.

Draft
December 14, 2001

The Impact of the 2001 Klamath Irrigation Project Operations Plan on the Economy of the Upper Klamath Basin

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Introduction

On April 6, 2001, the Bureau of Reclamation released the 2001 Klamath Project Operations Plan (KPOP) that severely limited irrigation water deliveries to project irrigators. This operations plan was based on new biological opinions that raised the required lake levels on Upper Klamath Lake and increased the required stream flows into the main stem of the Klamath River at Iron Gate Dam. In meeting these requirements in a critically dry year, the KPOP indicated that the Bureau would release no water to Klamath Irrigation Project irrigators in 2001.

This chapter provides an estimate of the short-run impact of the 2001 KPOP on the Upper Klamath Basin (UKB) regional economy. The analysis focuses on the short-run (i.e., first year) economic impacts. It is not a benefit/cost assessment of the Bureau's decision. We recognize that there may be economic impacts that extend beyond the first year. These potential impacts are discussed in this report, but are not formally assessed.

Estimating regional economic impacts with an input-output model

The input-output (IO) model described in a previous chapter contains information about economic transactions in an economy, and allows analysts to estimate the impact of a change in policy or an economic shock on output, personal income, and employment. The impacts include *direct impacts* (changes in spending by the sector(s) directly affected by the policy), *indirect impacts* (changes that occur in all sectors because the directly affected sectors have more or less money to respend to buy inputs from other businesses in the county), and *induced impacts* (changes in all sectors due to changes in household respending of income from directly and indirectly affected sectors).

Impacts can be estimated for gross *output* (sales), personal income, or employment. The output (sales) measure in an IO model does not net out input purchases from other businesses in the region and thus "double counts" sales in most cases. If a feed mill buys barley from a grain farmer and then produces and sells processed feed, both the processed feed and the barley from which the feed is made are counted in output. The output impact estimate for the feed mill thus "double counts" by including both the value of the final sales and the value of the feed input used to make the final product. The gross output measure of the IO model is thus inconsistent with the usual "output" measures used in national income accounts (such as the Gross National Product), which count only "final sales" or value added.

Because those concerned about the well-being of county residents often care more about income and jobs than gross sales, and to avoid the "double counting" problem, economists prefer to estimate *income* impacts, which measure value added by economic activity in a region, or *employment* impacts, which measure jobs. When estimating income impacts, the IO model counts the income paid to feed-mill workers, for example, who produce exported feed, and the additional income in the region (including the wages to the farm worker and income of the land owner—both of which add value to the production process) generated by the export of feed. All of this income is reflected in the income impact estimate of the feed-mill sector exports.

Assumptions in an IO model affect the interpretation of the results. The most important assumptions are that:

- Prices of goods and services used as inputs in the production process are assumed not to change.
- Firms are assumed not to adjust their production processes—technology is assumed not to change.
- There are no economies of scale. If a firm cuts its production in half, it will halve its purchase of all inputs.
- There are no supply constraints. Firms can purchase all they want of any input at the initial price.

This implies that the model is most appropriate for short-run analysis of changes of modest size. Very large scale changes may involve supply constraints and price changes and substitution of one input for another. Prices and technology and production processes do change over the longer run.

Baseline and impact scenarios

Impact analysis requires the construction of an impact scenario identifying what is expected to happen under specified assumptions about a policy or other change. This impact scenario is compared with a baseline scenario based on assumptions about what is expected to happen *without* the specified policy or other changes. As in the previous chapter, the baseline scenario assumes a "normal" water year with pre-2001 biological opinion lake level and stream flow requirements. The impact scenario models the 2001 KPOP, which was designed to meet the stream flow and lake level water requirements of the 2001 biological opinions in a critically dry year. In meeting these stream flow and lake level requirements, the Bureau indicated in the 2001 KPOP that it would release no water for Klamath Irrigation Project (KIP) irrigators. The impact of the 2001 KPOP is the difference in estimated output, income, and employment between the baseline and an impact scenario incorporating the 2001 KPOP requirements. Since we estimate the impact of the 2001 KPOP, our estimates do not take into account the effects on production of unanticipated irrigation releases authorized in the summer of 2001 by Secretary Norton.

Constructing an impact scenario for the 2001 KPOP involves estimating the changes in KIP-related agricultural exports from implementation of the 2001 KPOP compared to agricultural exports in the baseline scenario. The changes in agricultural exports are entered into the UKB input-output model to estimate the changes in regional output, employment, and income in the UKB economy due to the 2001 KPOP in which the stream flow and lake-level requirements of the 2001 biological opinions are met in a critically dry year.

Estimating agricultural exports under the impact scenario

We start with the estimates of *on-farm crop production* in the *Klamath Irrigation Project* under the two scenarios from the previous chapter. Estimating the changes in KIP-related agricultural exports from the region under the 2001 KPOP scenario required four sets of adjustments to the KIP on-farm crop production impacts.

The first adjustment accounted for the fact that some crop production is used as inputs to other sectors. The pasture consumed by ranch-fed cattle, the potatoes used as inputs to the dehydrated food products plant, and the barley used in the production of prepared feeds were valued at $2.9 million. Thus the crop production impact of $74.2 million estimated in the previous chapter was reduced by $2.9 million so that this production loss would not be counted twice. The $2.9 million shows up as estimated losses in the cattle, dehydrated food products, and prepared feed, as described below

The second adjustment was to estimate livestock losses, which involved estimating the value of pasture fed to livestock. Livestock in the KIP rely on irrigated pasture primarily as a source of grazing forage during the spring, summer, and fall months of the year. Reduction in available forage translates into a loss of feed inputs to the livestock sector. The economic losses in the livestock sector were estimated as the reduced value of forage measured in terms of animal grazing units produced on the affected project acreage. Grazing rates applicable to irrigated pasture in the district were estimated as the 3-year (1998-2000) average private grazing rates reported for Oregon by the USDA National Agricultural Statistics Service.

In addition to the foregone value of grazing, livestock producers may have experienced additional losses associated with forced early sales of feeder cattle from these pastures. Without alternative grazing lands in the region, producers sell beef cattle at lower weights and/or prices than anticipated. The estimated losses from these forced sales were based on producer estimates of current returns from forced spring/summer liquidation, relative to expected returns with normal fall marketing. The extent of forced marketing was projected based on the size and composition of the herd displaced by the loss of grazing forage, as well as the projected liquidation rates. An adjustment was made to account for the grazing expenses that are not incurred as a result of early marketing. The forced sale losses are applied to feeder cattle only, and not the breeding herd. Losses to the breeding herd are discussed in a later section.

The third adjustment involved estimating changes in prepared feeds. Prepared feed mills purchase barley from local irrigators. The UKB input-output model estimates how much feed grain (barley) the feed mill purchased in the base year. The reduced export of the prepared feed sector is the value of the prepared feed that would be produced with this much less local barley. (The value of this barley is included in the reduced export of prepared feeds, not in reduced feed grain exports, as described above.)

The final change involved estimating losses to dehydrated foods manufacturing sector. Our estimates assumed that reduction in local potato production would very nearly eliminate the dehydrated foods products sector: the operations would cease to operate rather than attempt to import potatoes to supply their needs. The UKB IO model provides an estimate of total dehydrated food exports, the value of purchases of potatoes from local farmers, and the production technology of the dehydrated food products sector. This information was used to estimate the change in local potato exports that would result from almost eliminating the dehydrated food products sector. (The impact of the reduced potato production is included in the estimated reduction in dehydrated food products sector exports, as noted above.)

This direct impact of implementation of the 2001 KPOP on *gross export sales* of the agricultural producers and processors is shown in Table 1.

Implementation of the 2001 KPOP was estimated to directly reduce gross agricultural sector output in the three-county Upper Klamath Basin region by $95 million, as compared with a baseline scenario in which water for irrigation was unconstrained. This represents a 30 percent reduction in agricultural sector output.

Table 1. Klamath Project 2001 Operations Plan direct agricultural sector impacts.

IMPLAN sectors\scenarios		On-farm crops production: Baseline	On-farm crops production: Critically dry year & 2001 B.O.	Agricultural sector export impact
1	Dairy farm products			-1,098
3	Ranch fed cattle			-7,594
5	Cattle feedlots (increase)			421
6	Sheep, lambs, and goats			-527
8	Other meat animal products			-24
9	Miscellaneous livestock			-655
11	Food grains	2,581	2	-2,579
12	Feed grains	16,366	9	-15,539
13	Hay and pasture	40,721	12,773	-26,437
18	Vegetables	31,824	6,492	-24,776
20	Miscellaneous crops	7,313	5,317	-1,996
68	Dehydrated food products			-6,619
78	Prepared feeds, N.E.C			-7,254
	Total	98,805	24,592	-94,677

Impact of 2001 KPOP on Upper Klamath Basin regional economy

Table 2 identifies the direct, indirect, and induced impacts of the implementation of the 2001 KPOP on gross output, income, and employment in the Upper Klamath Basin.

The 2001 KPOP is estimated to reduce gross output by about $134 million, a reduction of 3.2 percent of total regional output.[1] The *direct* impact of the reduction in KIP agriculture and associated processing, derived in Table 1, is $95 million. This reduction generates an additional *indirect* $22 million output reduction (in industries that supply the directly affected sectors). And these direct and indirect impacts *induce* another $17 million reduction in local spending by local households employed in the directly and indirectly affected sectors.

[1] Our gross output and income estimates are in 2001 dollars. As noted above, gross output is a measure of total local sales, which includes the full value of each local transaction before netting out costs.

Personal income is a measure of local employee compensation, net proprietor income,[2] and other property income. Implementation of the 2001 KPOP is estimated to reduce total personal income by $68 million, about 3.1 percent of baseline income. Total regional employment is reduced by an estimated 2077 jobs, or 3.5 percent.

Table 2. Klamath Project 2001 operations plan regional impacts.

		Critically Dry Year, 2001 B.O.				Total %
Upper Klamath Basin Economy	Baseline	Direct	Indirect	Induced	Total	Change
Output ($million)	4,032	-95	-22	-17	-134	-3.2%
Income ($million)	2,167	-46	-12	-10	-68	-3.1%
Employment (jobs)	59,390	-1,356	-430	-270	-2,077	-3.5%

Longer-term economic impacts

The input-output analysis focuses on the short-run economic impacts. There are a number of potential longer-term economic impacts (e.g., those that occur in future water years, crop years, or calendar years). This section is intended to provide (1) an inventory of these potential impacts, and (2) a brief discussion of the economic rationale underlying the potential impacts. Given the current uncertainties underlying these effects and the fact that these impacts occur in future years, we do not attempt to quantify these potential impacts.

Land values

As a capital asset, the agricultural use value of land reflects the discounted present value of the stream of all future expected net cash flows arising from farming the land. Thus, factors that affect the expected future net cash flows from farming will in turn affect the agricultural use value of land. If the 2001 drought situation is merely an extreme weather event that reoccurs infrequently (e.g., 2 years out of 100) then the impact on land values would be minimal (particularly if land owners receive disaster payments or other assistance that helps offset the temporary decline in revenue). However, if the current operations plan reflects a fundamental change in the water allocation criteria that in turn reduces the expected quantity of irrigation water available in any given weather year, then this change in water regime would have a significant impact on agricultural use values.

The discussion of options in the Bureau of Reclamation's Environmental Assessment indicates that there may in fact be a change in the underlying allocation criteria that will likely reduce expected quantities of irrigation water available under any given weather year. If so, then a careful study of how the change in allocation criteria will affect expected future irrigation deliveries would be needed to assess the potential impact on agricultural use values of land. Such a study should also investigate the relationship between agricultural use values of land and

[2] Proprietor income is gross proprietor receipts less fixed and variable costs.

market values of land in the area. In agricultural areas these two values are generally quite close. In areas with significant development or other uses (e.g., recreational), market values often exceed agricultural use values. In these cases, market values are generally not significantly affected by changes in the profitability of agriculture.

Costs of reestablishing perennial crops

Stands of perennial crops (e.g., mint, alfalfa, grass hay) may also suffer from prolonged drought conditions resulting from the lack of irrigation. These losses are likely to be most acute for recently established forage stands, or shallow-rooted crops such as peppermint. Economic impacts arise to the extent that these reestablishment or renovation expenses exceed normal establishment expenses. Under normal conditions perennial crops are reestablished on intervals typically varying from 2 to 5 years, such that some stands are likely to be reestablished, regardless.

Establishment costs per acre for impacted perennial crops in the Klamath District are reported below as a reference to gauge loss potential. These are the variable costs of establishing a crop as estimated in crop enterprise budget prepared by the Oregon State University Extension Service, and do not include fixed machinery and land expenses.

Crop	Variable cost per acre
Alfalfa	$305
Pasture	$262
Peppermint	$1,341

Stand survival could be monitored over the 2001-2002 year and a determination made as to the extent of increased costs incurred due to unanticipated reestablishment.

Loss of market contracts

Several important cash crops in the Klamath Irrigation District are produced under contract with processors or under long-standing marketing agreements with buyers. As a result of the disruption in supply, it is possible that these contracts or markets may have been lost and may not be regained in future years. Alternatively, growers may have arranged for crop sourcing outside the Klamath District in order to meet commitments, even though at a higher procurement cost. Again, the status of future contracts or marketing arrangements could be monitored as a basis for determining whether this impact warrants additional consideration.

Long-term costs of forced liquidation of the cattle-breeding herd

A critical aspect of the reduction in irrigation water releases is assessing how the decline in irrigated forage production affects livestock production in both the short and long run. As discussed earlier, the near-term impacts of reduced irrigated grazing for livestock are estimated as the foregone value of forage lost on irrigated pastures, as well as the decrease in sales value attributable to forced early sale of market animals.

Depending on the duration of the suspended irrigation, and the coincidental grazing conditions on other pastures and range in the region, beef cattle herds in the affected region could experience additional losses arising from adjustments to reductions in irrigated pasture. Beef producers must locate replacement feed sources to offset the loss of irrigated pasture in the Klamath Project. Grazing rates on nearby pastures or ranges would be expected to increase, subject to even more limited availability in the event of a widespread, sustained drought. In this situation, resident beef producers reliant on Klamath Project irrigated pasture might face significant increases in grazing costs, either through higher local rates, higher purchased feed costs, provision of supplemental drinking water, or greater transportation costs incurred in moving cattle to other areas.

As an alternative to finding or paying higher feed costs, beef producers might be forced to reduce their cattle breeding herds (liquidation). This breeding herd (cows, bulls, and replacements) can be considered an asset, valued at the present value of the future stream of benefits (sales of the offspring in subsequent years). Herd liquidation provides a one-time increase in cash receipts, but erodes the longer-term economic viability of livestock operations by reducing or eliminating this asset. Forced sale of the breeding herd at prices below the asset value would generate additional losses.

Reduced property tax revenues and local government services

The Klamath County Assessor estimated that, as currently irrigated farmland was reassessed as dryland for property tax purposes this year, local government revenue from property taxes would decline by about $480,000. The long-run impact of this reduction depends on whether the reduction is permanent (whether irrigation water deliveries are curtailed in future years), and on what program cuts are made in response to the reduction in property taxes of the county, school district, and other local governments. Here again, an ongoing assessment of local government revenues and service would provide a basis for understanding the long-term impacts of reduced water allocations.

Longer-term impacts on labor supply

When there are economic disruptions in a community and people lose their jobs, some who lose jobs move to other places where jobs are more plentiful. This applies to both the farm labor and the workers in nonfarm businesses that are affected by the reductions in farming activity. If additional people become unemployed due to the irrigation water reductions, it is not unreasonable to expect that some of them will move, particularly after unemployment benefits terminate, given the relatively unfavorable local unemployment situation. (Klamath County's unemployment rate is consistently 3 percentage points higher than the state average.) Some would return if the irrigation restrictions are lifted in future years, but others would not and employers would bear costs of finding and retraining workers.

Conclusion

Reduced water deliveries to agricultural operations in the Klamath Project are expected to have significant economic impact on UKB agriculture and a modest impact on the UKB regional economy. Based on our assumptions, a three-county IMPLAN model, and on estimates of crop production impacts from the previous chapter, we estimate that the 2001 Klamath Irrigation Project Operations Plan can be expected to reduce agricultural output in the UKB by 30 percent in the short run. This impact will be felt in other sectors of the UKB economy because of the economic interrelationships between sectors. The 2001 KPOP can be expected to reduce personal income by 3.1 percent (almost $70 million) in the three-county UKB region. As noted above, this impact measure estimates the change in employment compensation, proprietor income (net of costs), and other property income for those directly and indirectly affected by the reduced water allocation. The plan is expected to also reduce total gross sales (output) by 3.2 percent ($134 million) in the three-county UKB region during the first year. Two-thirds of this impact is expected to be in the agricultural sector. The 2001 Klamath Irrigation Project Operations Plan will also affect jobs. Our estimate is that the plan would reduce employment by 3.5 percent (over 2,000 jobs) in the three-county region.

These estimates are for the first year, and do not take into account any long-run impacts. The effect of a prolonged reduction in irrigation water on the agricultural economy could involve some adjustments in the input supply and processing sectors as well as the long-term impacts described above. Changes in these sectors would have an impact on the viability of the agricultural production sectors. Possible longer-run impacts that ought to be monitored include these sectoral adjustments, as well as effects on land values, costs associated with reestablishing perennial crops, cattle herd liquidation and restocking, loss of market contracts, reduced property tax revenues and government services, and impacts on local labor supply.

References

Department of Agricultural and Resource Economics, "Economic Impacts of 2001 Klamath Project Water Allocation," Oregon State University, May 22, 2001.

Draft
December 14, 2001

Consequences for the Community

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Summary

In this chapter, we review the consequences of the decision to curtail Klamath Reclamation Project water on communities and individual community members. In addition to looking at available data from local, county, state, and national sources, we conducted focus groups and individual interviews with residents of the affected communities.

We found that, in general, the population of the three counties within the Project area—Klamath County, Oregon, and Modoc and Siskyiou Counties, California—has decreased over the past decade. In addition, these counties routinely experience a higher-than-average rate of unemployment and have a slightly lower-than-average per capita income. We also found an aging population in all three counties: over one-third of the residents in these counties is more than 45 years old.

There is emerging evidence that needs for social services such as food banks, physical and mental health care, and job training have increased over the past year. However, much of this data is impressionistic and data collection has been inconsistent over the years, so it is difficult to determine any changes that can be attributed directly to the water situation. Social service providers, however, are very anxious for their clients and their own organizations.

We found that many new groups have emerged throughout the basin to help individuals and communities deal with any losses due to the decision to curtail water. These groups have been able to raise impressive amounts of money for local social assistance such as supplementing food bank supplies and funding legal challenges.

We organized the stories we heard in the focus groups and interviews into five different topics. This information provides a snapshot of what was happing in the Basin from September through November 2001.

- **Community support and community polarization.** Almost all of our participants described how the water situation had drawn the community together in many ways. Getting 6,000 people to a rally in Klamath Falls, raising money to help community members throughout the Basin, and organizing multiple approaches to getting the story across to people outside the area were all offered as examples of how the community had coalesced around the concerns of the farmers and ranchers. Yet almost all of our participants also described incidents of polarization in the community around issues related to the water situation. These ranged from tension in long-term relationships to highly confrontational incidents between farmers and environmentalists, between farmers

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and state and federal agencies, between farmers and tribal members, and/or between farmers and farm workers.

- **Uncertainty about the future and long-term planning**. All our participants described the situation similarly: intolerably uncertain and increasingly frustrating. The farmers talked about how not knowing whether there will be Project irrigation water next year only exacerbates the uncertainty inherent in agriculture. And for those not directly involved in farming, the uncertainty has rippled through social service agencies, schools, state and federal agencies, and local businesses. And yet we also heard from farmers and others that this "crisis" was unexpected *only* in its appearance in 2001. Many have been planning and working to shift reliance from irrigated fields and the agricultural economy to alternative crops and new business sectors.
- **The role of information.** While all participants we talked with agreed that information was needed, there was little agreement about just what constituted "good" information that could help move conversations and decisions forward. There was almost unanimous disapproval of the way the media had handled the situation, although some claimed that the media was too biased toward the farmers and others claimed that the farmers weren't getting a fair shake. Others were highly critical of the media for sensationalizing the situation and actually leading to more polarization. Farmers and others believed that the basic science exists to develop reasonable recovery plans, although there is great concern about whether or not that information is being used appropriately and legitimately.
- **Getting help.** All the participants expressed concern about helping the farming community and others affected by the situation. Everyone recognizes that without assistance of many different kinds, the farmers, farm workers, and others in the community will continue to be negatively affected. Participants generally rely most strongly on their personal networks, and support primarily comes from family and friends. Very few told us that they had asked for assistance beyond the family. Some farmers are knowledgeable about various assistance programs and have begun using them. Assistance for other members of the community is limited and social service providers are concerned that increased needs precipitated by the water situation will limit services for the neediest members of the community.
- **Needed: visionary leadership**. It is clear to many of our participants that the visionary leadership needed to craft workable solutions in the Klamath Basin is not there. However, it is not clear from our interviews what participants would like from leadership beyond bringing people together. Farmers would like leaders to "make sure that agriculture stays whole to protect our society," while others look for someone to get a broad-scope discussion going, provide concise national policy from the top, promote education about the situation, and see the big picture and bring people together.

The communities affected by the curtailment of Klamath Irrigation water during the growing season of 2001 took a social hit, the impact of which is likely only to be fully realized in the months and years ahead. To date, they have worked together as a community to help members who have been most affected, have polarized around already existing stress lines, and have learned quickly how to operate in a highly visible political arena—contradictory and complex responses to a dynamic and ambiguous situation. It appears that most members of these communities are committed to finding solutions that are acceptable to all. Residents of the Basin, however, are likely to craft workable solutions only if they can apply the lessons they're learning this year as they move forward into the uncertain future.

Background

As described above, more than 1,000 farmers in the Klamath Project lost all access to Project water from April to July 2001, at which point Secretary of the Interior Gail Norton allowed surplus water to flow through the Project for about 6 weeks. During the season, farmers and community members expressed great concern about the fate of their planted fields as well as fears for the coming year. Stories about the farm supporters were seen frequently in the *New York Times*, the *Wall Street Journal*, and the *Oregonian* during this period. The reports were not only of farmers challenging the decision through civil disobedience but of the increased need for community services, the ideological divisions emerging throughout the community, a sense of loss of a way of life, and betrayal by elected officials. This section reviews these and other consequences for the communities of Klamath, Modoc, and Siskyiou counties that were affected by the water shut off to the Klamath Project.

We begin this chapter with a brief discussion of our research methodology, providing details about the sources of interview data and community statistics. Next, we describe the demographic characteristics of the counties in which the Klamath Basin lies. This demographic portrait is followed by information about the availability and use of social services and social support organizations in the area. Finally, we present the findings from our interviews with 69 members of the Klamath Basin community. Using the words of local farmers, social service providers, businesspeople, tribal representatives, federal and state employees, and conservationists, we paint a portrait of a community under stress. While the details of stories shared with us may not be entirely accurate, belief in the stories certainly shapes the behavior of Basin residents.

What we did

Consequences of the decision for the affected communities can be seen at least partially in the economic data provided above and through publicly available data that describe changes in community services. We looked at data from the U.S. Census, county and state agencies, and non-profit organizations including churches and other community social service providers. In order to get some sense of whether the past year has been unique in any way, we wanted to collect data for 3 years: 1992 (drought year), 1997 (normal precipitation), and 2001. Unfortunately, data collection and reporting methods for the information we wanted were inconsistent, making a quick assessment impossible. Instead, we are typically limited to a few indicators for the years 1997, 2000, and 2001 (to date). In the summaries below, we report any available 1992 data.

Calculation of changes in the economy and social services can help us understand some aspects of consequences for the communities when we collect data over the years, average it, and compare it with other years to see whether the situation has changed. This information will be essential for understanding impacts to the community over the long term; however, it does not give voice to the people who are living through the current events as individuals, families, and community members. Numbers and graphs cannot fully capture the complexity of the community's concerns and responses. For that, we turned to a qualitative research approach and asked individuals to describe their own experiences and perceptions.

Qualitative research can be seen as a companion to quantitative research as well as an independent research method following certain processes for thinking about, collecting, examining, and interpreting data. Qualitative research is a way to provide first-hand accounts of the life experiences and perceptions of individuals from their unique perspective regarding moments, events, and situations, and to elicit and make sense of the meaning of this phenomenon in the lives of individuals. Proponents of quantitative investigation might question the validity of this analysis because there is no hypothesis testing included within the design; rather, it is a method that builds theory and attempts to bring out both the subjective and objective meaning of an event—in this case the water situation in the Klamath Basin—in the lives of those affected (Denzin and Lincoln 1994; Gilgun, Daly, and Handel 1992).

Who we talked with

For this study, we conducted 11 focus groups and 15 one-on-one semi-structured interviews (total: 69 people) to explore impacts on individuals, families, and communities. The questions we asked are attached as Appendix A. Focus groups were chosen as a data collection method for several reasons. First, focus groups allowed us to talk in depth with many people over a relatively short period of time. We also believed that talking and listening with neighbors and colleagues about common experiences would provide participants with an opportunity to describe their own experiences and learn from others. Although Stewart and Shamdasani (1998) note the advantages of using focus groups to collect data, it is important to remember that the groups are not random samples of the entire population; therefore the results are not generalizable to all people living in the Klamath Basin.

Instead, the samples are "purposive" in that we intentionally selected respondents who have been involved in various ways in the current events and activities. Purposive samples are used when we want to explore a complex situation in great detail with exactly the people who are involved—those who have the most experience or knowledge about a situation. Purposive samples do not necessarily represent the general public, but they can provide insight about the situation from multiple perspectives. For these reasons, the information reported from the focus groups should be considered a snapshot of the experiences and understanding of several community members from September to November 2001. Experiences and emotions change over time, and our results might have been different if we had conducted the research prior to September 11, 2001, for example, or after the drought ends and farmers are ensured that they will have irrigation water.

We convened two groups of farmers (trying to separate those who relied most heavily on Project water from those who didn't), using a random selection of names from a list of farmers kept by the Klamath County Extension Service and the Tulelake Research and Experimental Station. We did this to make sure that we heard from respondents in both Oregon and California to capture any differences due to state-related variables (e.g., regulations, tax laws, state relief programs).

One group of farm workers was convened with the assistance of a local translator. He invited participation through announcement of the focus group at a local resource center for farm workers. This focus group was conducted in Spanish with the assistance of the translator in both the interview and translation of the transcript.

A purposive sample of social service providers was selected from Tulelake, California, using a "snowball" sampling technique in which we asked a key informant who had been active in the area for a long time to provide the names of others who might be willing to participate in a focus group. We then asked each of those people, whether or not they agreed to participate, to suggest the names of other people who might be interested and willing to participate. A matching focus group of service providers from Klamath Falls was then convened (e.g., a food bank director was in both groups). We included individuals who worked in existing organizations that provided a variety of social services including food banks, health care, mental health, education, and emergency shelter. Again, we conducted a group in Oregon and another in California to capture any differences based on state variables, and also, in this case, to talk with social service providers working in both a larger community like Klamath Falls as well as those working in smaller rural communities.

Purposive samples of federal and state agency staff who are on the "front lines"—they meet regularly with community members—were selected with assistance from a key informant at one of the agencies. A single focus group was convened with both state and federal agency participants.

We also used a "snowball" sampling technique to identify individuals who were self-identified as conservationists. While all of these participants claimed membership in local, state, and and/or national environmental groups, their level of personal activism ranged from quite passive to very active.

Two focus groups were convened with a purposive sample—one with business owners from Klamath Falls and the second matched with similar types of businesses in smaller towns (e.g., grocery store, restaurant).

A member of the Klamath Tribe helped to organize a conversation with tribal members. This conversation was held at the reservation offices.

In addition, we conducted 15 in-depth semi-structured interviews with individuals who were unable or unwilling to participate in a focus group. These interviews were conducted using the same questions used in the focus groups. Table 1 describes the categories of participants in the focus groups and interviews.

Table 1: Categories of participants in focus groups and interviews.

Focus groups (11)	**Interviews (15)**
Klamath Tribe	Manager of grocery store
Bonanza farmers	State/federal agency staff (2)
Klamath business owners	Conservationist
Tulelake business owners	Farmers –(5)
Tulelake service providers	Urban business owner (not taped)
Klamath Falls service providers	Urban business owner
Tulelake farm workers	Rural service provider
State/federal agency staff	Klamath Falls service provider
Conservationists	
Merrill farmers (2)	

How the focus groups worked

For focus groups to be successful, participants need to be comfortable sharing information in a semi-public setting. While it is the facilitators' primary responsibility to ensure that people are able to participate, other strategies also are used to create effective focus groups. Every effort is made to keep participation confidential, especially for reporting purposes, by using first names only in the discussion and on the transcript, and by deleting any information that can easily identify an individual. Because participants may know each other through other community contacts and confidentiality is difficult to maintain, other techniques are used to create an environment where people feel safe to respond to questions and to interact with each other. One way to do this is to create groups of relatively homogenous people to ensure that existing animosity or enmity is not exacerbated, conversations move beyond arguments, and participants hear from others in similar situations.

Each focus group had 2 to 14 participants and most were conducted with two facilitators. One facilitator directed the conversation, asking questions and probing in more depth as issues were raised. The second facilitator took notes and watched to ensure that all participants were heard. The group with farm workers was conducted in Spanish with a translator.

All focus groups and all but one interview was tape recorded (with participants' permission) and professionally transcribed for analysis. Extensive notes were taken for the interview that was not recorded. We examined the transcripts to identify and characterize the major issues raised by participants as they described their experiences of the consequences of the decision to stop water delivery to Project farmers. Once the issues had been characterized, a draft was developed using participant's own words when appropriate. Brackets are used to indicate where we modified participants' words to enhance readability or protect confidentiality.

The affected communities

Klamath County is located in the eastern foothills of the Cascade Mountains, bordering northern California. It covers 6,151 square miles, making it the fourth-largest county in Oregon. Klamath Falls, the county seat and largest town, rests on the southern shore of Upper Klamath Lake, one of the largest bodies of fresh water in the Pacific Northwest. Oregon towns in Klamath County and in the Klamath Project area include Merrill, Malin, and Klamath Falls.

Two California counties are served by the Klamath Project. Siskiyou County is directly south of the Oregon border and Modoc County is located in the northeast corner of California. Yreka is the county seat and the largest town in the county. The only Siskiyou county town within the Klamath Project is Tulelake, just south of the Oregon border. Alturas is the county seat and largest town in Modoc County. Newell, a small, unincorporated town, is the only community within the Klamath Project in Modoc County. While all three of the counties can be described as "rural," Klamath Falls (population 19,462) provides major services for most of the basin communities. Table 2 describes the three counties in more detail.

All three counties have significant populations of Native Americans and Hispanics. As described below in Table 3, American Indians constitute about 4 percent of the population of each county, although the national population is only about 1percent. While there are about twice as many Hispanics as Native Americans in the three counties, this population concentration is quite low for California, where almost one-third of the population identifies themselves as Hispanic. The Hispanic population in Klamath County is about average for the state of Oregon. The 2000 Census also shows that the small communities affected by the decision to curtail water have a high percentage of Hispanic residents: 45 percent of Tulelake is Hispanic, 54 percent of Malin, and 33percent of Merrill.

Due to the seasonal, temporary, and ephemeral nature of their jobs, determining the number of migrant workers is difficult. As shown in Table 3, migrant workers in the basin are most likely to reside in California rather than Oregon.

Although these three counties and several towns were most directly impacted by the water situation, the impact of the decision rippled throughout the Klamath Basin to other farmers and non-farming community members outside of the Klamath Project area.

Table 2: Description of counties in Klamath Project: 2000.

County	Area: sq miles	County: population	City/towns: population (2000)	Major industrial sectors
Klamath	6,135	63,755	Klamath Falls: 19,462 Merrill: 897 Malin: 638	Service Forestry Manufacturing[5]
Modoc	3,944	9,449	Tulelake: 1,029	Government (44%) Agriculture (14%) Retail (14%)
Siskyiou	6,281	44,301	Newell (unincorporated)	Government (26.5%) Services (22.5%) Retail (20.6%)

Source: U.S. Census 2000

Table 3: American Indian and Hispanic populations in Klamath Project counties: 2000.

	American Indian County	American Indian State	Hispanic County	Hispanic State	Migrant workers (estimated) [6]
Klamath County	4.2%	1.3%	7.8%	8%	~200
Modoc County	4.2%	1%	11.5%	32%	662
Siskyiou County	4%	1%	7.6%	32%	2658

Source: U.S. Census 2000

Demographics

In the following section, we review information about social trends in the Project Counties including population, age, employment rates, and income, using demographic data available from the U.S. Census at the national, state, and county levels. As displayed below in the first row of Table 4, the population of Klamath, Siskiyou, and Modoc counties had all

[5] The largest employers in Klamath County include Merle West Medical Center, Jeld-Wen, Sykes Enterprise (High Tech Support), Collins Products (particleboard, plywood, siding), and Columbia Plywood.

[6] Migrant & Seasonal Farm workers Enumeration Profits Study, 9/2000; includes seasonal and migrant, excludes those working with livestock, poultry, fisheries.

declined more than 5 percent in 2000, after generally growing during the period from 1992–1997 (although Modoc County posted a small loss of population in 1997).

Table 4: Demographic data for Klamath Project counties.

	1992	**1997**	**2000**
Population:		**Pop/ (% change)**	**Pop/(% change)**
Klamath	62,074	67,491 (+9%)	63,775 (-6%)
Modoc	10,536	10,496 (-.5%)	9,449 (-10%)
Siskiyou	45,568	47,648 (+5%)	44,301 (-7%)
Population 45+	**% of total pop**	**% of total pop**	**% of total pop**
Klamath	21,199 (34%)	24,530 (36%)	16,041 (25%)
Modoc	3,933 (36%)	3,961 (38%)	2,771 (29%)
Siskyiou	17,157 (38%)	18,192 (38%)	20,643 (47%)
Per capita income			
Klamath	$15,968	$19,485	$20,886
Modoc	$15,913	$19,054	$21,427
Siskyiou	$16,658	$19,898	$21,092

Source: U.S. Census 2000. Bureau of Economic Analysis

An aging population: As described in the second row of Table 4, one-third or more of the people in the three Project counties are more than 45 years old. The general age of a population is a reflection of the distribution of experience, knowledge, skill, and (usually) wealth accumulation across the generations. This imbalance of age in the Klamath Project counties suggests, among other things, that farmers and ranchers who lose their ability to make a living on their land may be (or feel they are) too old to find other occupational opportunities. Another fear is that families with children are leaving the area because parents are unable to find jobs. With the loss of students comes loss of funding for public education. We found that this demographic is of concern to community members. Apprehension was expressed regarding the ability of aging farmers and other affected community members to retrain for new jobs or even to find alternative employment opportunities if farms or ranches were lost. One 50-year-old farmer told us:

> It's very, very frustrating when you read career-oriented materials. Bachelor's degree, Master's degree. For god's sake, I've got to go to school three more years to get there. And, who's going to hire somebody who's in their mid-fifties? I guess realistically the only chance you've got in most cases would be somewhere in the public sector. There's very few private enterprises that are going to hire someone that old, because how long are they going to get to use you?

Older farmers were also discouraging their children from going into farming. One farmer told us:

> I have a son that was kind of wanting to go into farming a few years ago. And he's 22 now and I love farming and it's a fantastic life and I wouldn't want to change unless I absolutely had to. But he was wanting to go into farming and I sort of discouraged it. Because the situation, the way things were going around here.

Another concern of the aging population has been the reliance on the farm and land to provide for retirement funds, either through a leasing arrangement or outright sale. Without water for irrigation, the property values of farms have declined and there are few willing to take on a farm or ranch without water. One of our participants told us about an elderly family in the neighborhood. The husband has farmed all his life, on a small farm of less than 200 acres:

> They are at a position where their acreage is too small to warrant drilling a well. They don't have any extra finances; they're living off their savings. All they have is their home and their property. And that's what their retirement is. That's what they've worked their whole lives for, for the land.

Income and employment: As shown in the second row of Table 4, the per capita income continues to grow in the three counties of the Klamath Project, although in 2000 all three lag behind the average per capita incomes of the country as a whole ($21,684) as do the California counties lag behind the average per capita income of that state ($22,770). Klamath County per capita income is slightly higher than the average for Oregon ($20,718) (U.S. Census Bureau 2001).

As described in Table 5 below, average unemployment rates are typically quite high in the Klamath Project counties compared to unemployment rates at either the national or state level. The unemployment pattern for all three counties is similar in that unemployment rates are highest during the months of December, January, February, and March, at which point rates start to decline through summer (June, July, and August) and then start to rise again. This cyclical pattern, common to most areas dominated by the farming economy, has held over the past decade, even during those years (such as 1992) when average unemployment rates were very high. Interestingly, unemployment rates in the three Klamath Project counties started out high this year as usual, but have continued to decline over the year with no upturn at the end of the growing season (U.S. Bureau of Labor Statistics).

Table 5: Unemployment rates for Klamath Project counties.

	1992	**1997**	**2000**	**1/01–10/01 (avg)**
Klamath County	10.2%	9.8%	8.1%	8.7%
Oregon	7.5%	5.6%	4.9%	5.7%
Modoc County	11.1%	11.5%	8.3%	6.4%
Siskiyou County	15.0%	12.0%	9.5%	8.3%
California	9.1%	6.3%	4.9%	5.0%
United States	7.5%	4.9%	4.0%	4.6%

Source: U.S. Department of Labor, Bureau of Labor Statistics

Social service use and provider impressions

We wanted to determine whether there have been changes in the types or amounts of social services that have been requested and/or provided to community members over the past year as a result of the water cut-off. We started out to collect information that could be used to document changes over the past decade (1992–2001), which saw drought years as well as years with normal amounts of precipitation. Unfortunately, we found that little data had been consistently collected by the social service providers' organizations. For those groups and organizations that did collect data, it was common to find that collection methods had changed sometime during the decade and it was difficult to compare data from 1992, for example, to more recent information. More information about social service delivery may be available for analysis with more resources than were available for this review.

Instead, we decided to use the available data and interviews with service providers to present a snapshot of the impressions and concerns about social service needs in the Klamath Basin. This information should be used cautiously because, as mentioned, the figures cited below are mostly provider impressions of the current situation and no rigorous methods were used that would allow us to indicate the water curtailment was indeed responsible for increased problems and/or social service usage. The past year has been stressful for all of us with the contentious and prolonged Presidential election, the economic downturn, and the September 11, 2001 terrorist attacks, all of which are likely to contribute to the social impacts observed by our respondents and which cannot be disentangled from the results reported below. The information, however, can be valuable in helping to get a sense of how residents of the Klamath Basin understand what's happening.

Difficulties in finding service provision information are exemplified by the data provided by the Klamath County Health Department. The current system for data collection began in 1997, although those data are problematic for our purposes because they cover only the period from February through December and include only information about Adult Outpatient Services without any sub-provider information included. The 2000 and 2001 data include all services provided by the Klamath County Mental Health Department along with those of the sub-providers (to whom patients are referred or who contract to provide specific services at the Mental Health department). Therefore, it is impossible to compare changes in service provision with the 1997 data.

Due to the difficulties in collecting robust information in the three counties, we present for interest only an example of changes in the amount of mental health services provided in Klamath County. Information about some of the services provided by the Mental Health Department during 2000 and 2001 are described in Table 6 below. Because the data for 2001 were for January 1, 2001 to October 1, 2001 only, we extrapolated the data to the end of the year, assuming that service levels would stay the same; we recognize that this assumption may be flawed.

Table 6: Changes in a sample of services provided by the Klamath County Mental Health Service.

	2000 service count	2001 service count[7]	% Change in service
Assessment: Determination of need, concluding with diagnosis	1,177	1,069	-9%
Referral screening: Assessment for referral to non-mental health services	193	212	+10%
Crisis screening: Assessment of immediate need and provision of intervention treatment	694	1,067	+54%
Precommitment investigation: Services for determining commitment to Mental Health Division	441	610	+38%
Family therapy: Planned treatment for a consumer that includes family participation	831	761	-8%
Individual therapy: Planned treatment for a consumer	3507	2419	-31%

Source: Klamath County Mental Health Department

While this data must be considered cautiously, it appears that there has been an increase since last year in the services provided for crisis screening and precommittment investigations. Yet other services, including family and individual therapy, have actually declined this year. In addition to providing the data, staff at Klamath County Mental Health talked with us about what they were seeing in their day-to-day practice. They told us that one of the big differences this year is the amount of support Mental Health is providing to the primary care physicians in the community. They have consulted with physicians so that affected families could be served by the physicians they are familiar and comfortable with. One staff told us, the "most affected by the water crisis were those not eligible for the Oregon Health Plan due to land and equipment holdings. They were experiencing increased stress and anxiety, needing an [anti-anxiety] drug or sleep medication, not a referral or treatment by the mental health department." Mental Health Department staff recommended that we talk directly with the primary care physicians working with families and individuals in the area.

Following that suggestion, we talked with a family practitioner and asked him to describe what he saw happening with his patients. He reported a 70 percent increase in the number of patients he saw this summer. One predominant complaint, he reports, is depression. He estimates that prior to this summer, depression in his clients was about 1:15; now it is 1:3. In addition to

[7] Using the information available through 10/01/01, we extrapolated the data through the end of 2001 by assuming an equal level of service each month.

depression, he reports a long list of ailments that he attributes to stress in the community including heart attacks, kidney infections in adult men (uncommon and stress related), approximately three times more hypertension than a year ago, five cases of bleeding ulcers that led to surgery, and elevated triglyceride and cholesterol levels in people directly working on the water issue. He also told us that he knows of 14 or 15 divorces since last June, two suicides that occurred late winter and early spring, and three heart attacks he feels he can attribute to events related to the water curtailment.

We also talked with another health provider in a small town clinic who reported that overall client numbers are down at her clinic. She told us that she knows of at least 50 families, mostly Hispanic, who have left the area. She has not experienced the same increase in stress-related services as reported by above.

The Klamath Crisis Center/Harbor House provides shelter for women and children who are the victims of domestic violence. Because this is their first year in operation, they are unable to compare service delivery with previous years. Wanda Powless of the Center reported a general increase in depression and anxiety-related after-hours crisis calls over the summer and into fall. The shelter (Harbor House) was full during June, July, and August, with 32 women and children in residence. September and October occupancies, however, were down again.

Stan Gilbert, Executive Director of the Klamath Youth Development Center, was able to give us information about service provided during March, April, and May in both 2000 and 2001. As displayed in Table 7, all categories of service increased in 2001 compared with 2000 services. Emergency response calls, for example, increased over 100% in both March and May 2001. Gilbert said he believes that "these increases are a result of the water crisis, although I have no real proof to support the claim."

Table 7: Services provided by Klamath Youth Development Center in selected months of 2000 and 2001.

	Total appointments		**Emergency response calls**		**New referrals**	
	2000	**2001**	**2000**	**2001**	**2000**	**2001**
March	1,441	1,782	12	29	65	79
April	1,460	2,350	17	23	67	104
May	1,513	2,348	13	29	79	127

Source: Klamath Youth Development Center

Niki Sampson, Director of the Klamath-Lake Counties Food Bank, told us that during the 1997–1998 fiscal year (July 1–June 30), 1,300 households received food assistance one to seven times. During the 2000–2001 fiscal year, 2,250 households received food assistance 1 to 10 times. Between July 1 and September 30, 2001, she reports that 3,200 households received food assistance one to three times. However, approximately 1,025 have received food *one to four times per month.* Sampson speculates that the increase is due directly to the irrigation shut-off and people losing their jobs in agriculture, or a cut back in work hours. She anticipates continued increases as winter heating bills begin taking a larger portion of the family income.

Debi Worch at the Migrant Education Service for Modoc and Siskiyou counties told us that there were 290 participants in Migrant Head Start and 178 during 2001 to date. All families in her Head Start program have been in the area for less than 3 years.

As shown in Tables 8 and 9, crime rates in Klamath County and the towns of Merrill and Malin were not significantly higher than they have been in the past decade. If we assume that we can double the rates for 2001 since we have data for only the first 6 months, crime rates will still be mostly lower than the rates for 1997. This is supported by staff at Tulelake City Police and Klamath County Sheriff offices, who commented that they thought crime rates were down.

Table 8: Total offenses in Klamath County (not specially arrested or cleared).

	1992	1997	YTD[8]
Crime against person	763	969	424
Crime against property	2,251	3,353	1,210
Behavioral crime	1,476	2,260	918

Source: Oregon Uniform Code Reporting, and includes Klamath County Sheriff, Oregon State Police-Klamath Falls, and Klamath Falls Police

Table 9: Total reported crimes and incidents for Merrill and Malin, Oregon.

	1992	**1997**	**YTD**[5]
Merrill PD	49	140	73
Malin PD	NA	21	15

Source: City Recorder for Malin and Merrill Police Clerk

As described above, some of this data is anecdotal, and that which is not is difficult to compare with other periods due to the lack of information in both current and past years. Some of the impacts that people attribute to the “crisis,” for example, occurred before April 6, 2001. In the focus groups and interviews, our respondents told us how they were experiencing this year’s events; they may be able to go back sometime in the future with more data and/or time to reflect and re-attribute consequences and impacts of the decision to curtail water in 2001. But for the time being, almost all of the service providers we talked with and collected information from reported increased need for their services. “Real” or perceived, the needs are felt as real in the present moment and that is what they use to understand the current situation and make decisions for themselves and their organizations.

[8] YTD is for 6 months Jan–June, 2001. Source: Report # DRI NO-ORO180000

These social service providers were anxious not only for their clients, but for their organizations and groups as well. They were concerned about continuing to provide services to everyone who needed them and about staff "burn-out" from the increased workloads and/or anxiety associated with community response to the water situation. One exception to this trend is that we heard concern from some educational services about how reduced numbers and subsequent reduced funding will impact their ability to provide services.

Social capital

For many reasons, life is easier in communities that are connected through multiple social organizations that create networks and trust as people work and play together. Civic and religious organizations, bowling leagues and reading groups, little league and soccer teams—these and other types of involvement with others in the community can create a dense web of relationships that cross political, economic, and ideological boundaries. It is believed that these informal relationships are critical in helping community members develop strong and vital communities. By analogy to physical and human capital, some people call this notion of networking "social capital" (Putnam 1995). All three forms of capital are believed to enhance individual and community productivity and effectiveness in solving problems.

A brief assessment of the traditional forms of social capital revealed a large number of churches, most with energetic congregations, in all communities affected by the water situation. There are 7 churches, for example, in the Tulelake and Newell area, 3 in Malin, 4 in Merrill, and 58 functioning churches in Klamath Falls. Traditional networking opportunities for farmers also appeared to be working in the area. One example is the grange in Tulelake and the three granges in Klamath County—fraternal organizations that provide benefits such as insurance programs, credit cards, and support for legislative action. The Klamath County Farm Bureau, an advocacy group for farmers that is connected to the larger Oregon and American Farm Bureaus, also provides multiple services and programs as described in Table 10 below. As you can see from the lists, professional services are provided by the Farm Bureau. These services are especially helpful to many farmers who are self-employed and have little or no access through other mechanisms. Other types of social services are also included, such as education activities for farmers and future farmers, community service programs, and even opportunities for members to express themselves artistically through a photo contest.

Table 10: Benefits and programs of the Klamath County Farm Bureau.

Member benefits	Programs
• Insurance programs • Credit card • Telephone discount • Prescriptions/eye care • Travel and entertainment • Vehicle discounts • Labor/employer services • Ag trading online • Accuweather • Industrial supplies • Citizens network for foreign affairs	• Young Farmers and Ranchers • Leadership Farm Bureau • Rural Health and Safety • Ag Crime—R.I.P. • Ag in the Classroom • FELS Labor Service • Scholarship Foundation • Photo Contest • Food Check-out Day • Water Quality Program

Source: Klamath County Farm Bureau

In addition to the Farm Bureau, other professional associations are available for farmers and ranchers in the Klamath Basin, including the Klamath Water Users Association, the Klamath Cattlemen's Association, the Klamath County Cattlewomen, the Klamath Potato Grower's Association, the Tulelake Grower's Association, and the Tulelake Horseradish Grower's Association. State Extension offices also are available in all three counties, providing research and education specific to the community's needs.

If a community has a robust stock of social capital, they should be able to respond effectively to challenges as they arise. We found that farmers, ranchers, and other community members were able to organize several responses to the drought and subsequent water curtailment. Community members created a Web site that became a clearinghouse for information about what was happening, a place for on-line discussions and sharing of information, and where notices about meetings and other gatherings were posted (see klamathbasincrisis.org). Almost 300,000 people have visited since April 26, 2001 when the site went up. The Klamath County Chamber of Commerce established the "Klamath Ag Relief Fund" in April of 2001. As of September 25, 2001, they had collected $17,000 from businesses and individuals. To date, about $5,000 has been disbursed (meat bought for the County Food Bank), with the remaining $12,000 to be distributed through programs such as Operation School Belle to purchase winter clothing.

In August of 2001, the "Klamath Bucket Brigade" was formed and then registered as a Nevada for-profit corporation doing business in Oregon. Fund organizers say they have plans to convert to nonprofit status. They have collected $157,000 to date through auctions, relief convoys, and a $15-per-plate benefit dinner. About $1,000 has been spent fixing a pump and the rest is in accounts for distribution to farmers.

The Klamath Water Foundation was also formed in August 2001 and hopes to unite the agricultural, retail, and other community entities. The Foundation is comprised of various specialized departments, such as communications, education, political awareness, and the environment, each chaired by a Klamath County resident. The departments offer opportunities for community members to participate in various activities. The Foundation is seeking formal certification as a non-profit organization and a second certification as a political action committee. This organization has raised about $25,000 and expects to use the funds for legal cases involving water issues, supporting a bill for amending the ESA, and assisting County Commission efforts to privatize the water delivery system. The stated mission of the Klamath Water Foundation is to "enhance productive co-existence among Klamath Basin water users, to sustain traditional livelihoods, and to protect the local communities, economy, and environment."

Another group, the Farmers Against Regulatory Madness (FARM), has collected $11,500 primarily through collections at the head gates and through direct solicitation of area businesses. It is obvious from the amount of money raised by these various groups that the communities of the Klamath Basin want to support the farmers and ranchers as they live through this drought year. The rapid response of group organization and fund raising suggests that the farmers have a tight social network of relationships developed through other social efforts that enabled them to quickly organize responses as the situation changed throughout the spring and summer of 2001.

Personal, family, and community impacts

As described above, we talked with nearly 70 people living and working in the Klamath Project counties to find out how the decision to halt water deliveries to Project irrigators was affecting them, their families, and their communities. As you always find when talking in-depth with people, our participants' experiences are complex and complicated, and they are only beginning to learn what the long-term impacts might be for themselves and their community. We found that an individual's descriptions of experiences and perceptions were contradictory from moment to moment, inconsistent in the retelling, but always painfully raw. In addition, as Klamath Basin residents began to adapt to new circumstances, the tragedy of September 11, 2001, took the Klamath Basin off the front page of the country's newspapers and turned the attention of many of the people we talked with to other concerns. It is in this context that the discussion of our findings from the interviews is presented below.

After reviewing the transcripts of the interviews and focus groups, several themes emerged that help organize the reporting of participants' experiences and perceptions. In order to tell the story of the participants' experiences, we use their own words when appropriate (always concealing their identity), or develop a summary with information from multiple people. The extent and strength of the responses is described only qualitatively. Unless noted otherwise, we use the word "community" to refer to the entire area supported by the Klamath Project because this is how our participants used the term.

We want to reiterate that participants' responses were complex and complicated and this summary cannot do justice to their experiences. We hope, however, to capture the wide range of experiences and perceptions they described during the interviews through a method that juxtaposes the contradictions and conflicts in their stories, letting the reader sense the difficulties that our participants have in talking about, explaining, and understanding what was happening. Our report represents the perceptions of participants and does not assess the accuracy of those perceptions.

Community support and community polarization

In addition to the traditional social impacts caused by a sudden change in economic and/or environmental conditions such as changes in employment, population, and income, we found that many participants in our groups talked about the farmers' response to the decision to halt delivery of water. Their highly visible strategies for publicizing the irrigators' situation rippled throughout the community, creating strong emotions that are entwined with concerns for the farmers themselves.

A sense of support: When first asked how the water situation affected the community, many participants told us that it has brought the community together. A service provider described the unity she saw in the community during a public rally: "You saw, if you were at that rally, 6,000 of us were at the fair grounds. Where and when have 6,000 of us ever gathered for anything? Short of giving away money, you aren't going to get that many people anywhere." The highly visible and publicized actions such as the "bucket brigade" and turning the water back on at the head gates suggested to this woman and others we talked with that there was a strong sense of community and unity among the residents of the Klamath Basin in their support of the farmers who did not receive irrigation water. This theme was illustrated in other ways as well. For instance, a farmer told us that

> the one positive thing, if there is something, is that it has pulled the whole community together. There's been a lot of support from Klamath businesses…. I think it has always been there, but [I] just wasn't aware of it. When they started shutting off the water people came together; I mean the letters to the editor were 99% pro ag. A lot of them were not from farmers in the Project area. If it's someone local you recognize the name, there were people we didn't even know that were supporting us.

Another farmer noted that he was surprised by the support "we got from Eugene, the liberal capital of the world, up there with Berkeley." He cited the positive press in the *Eugene Register-Guard* along with articles in the *New York Times* and the *Sacramento Bee* as evidence that "it's finally waking some people up to what's going on in this country."

Another respondent described the 4-H livestock sale this past summer as an example of public support. People thought that the annual sale would be really low because of the water situation; instead there was a record year with a high number of sales and high price per pound for the heifers raised by members. A Klamath Falls business owner told us that this was "because people want to show support for that community and make sure it continues." This support is also shown by directly helping one another. A small-town business owner told us about how this year "where I live there's been more help when you're working cows, there's more help there [if needed] like driving a truck in the spud field or jump[ing] on a hay rake or something." He believes this is indicative of the strong support between families, friends, and other businesses that came together through the "tragedy" to help each other.

Another Klamath Falls business owner described how the water issue was considered "just a farmer problem" in the spring. Then with the public-relations activities such as the newspaper articles, the bucket brigade, and other community wide programs, it "very much became a community problem. And it kind of pulled everybody back together." While a federal/state agency worker who has lived in the basin for 6 years did not describe the events as pulling community members together, she did believe that the "incredibly small community—people that lived here all their lives in a very intertwined network, saved us from escalation."

A sense of division: Yet only slightly below the surface of these descriptions of a community coming together to support the farmers were dissensions that continued to erupt throughout the interviews. These ranged from tension in long-term relationships to highly polarized and confrontational incidents between farmers and environmentalists, farmers and state and federal agencies, farmers and tribal members, and/or farmers and farm workers. There is friction among farmers themselves over who received water this year, who received drought assistance, and who was willing to sell their land. For some basin residents, the perception of a farming community under siege is strong enough to provide evidence of a conspiracy to rid the West of all farmers. And, for others, the racism that mostly lies below the surface of social life in the basin emerged as some framed the issue as "Indians vs. farmers." While each of these will be discussed in more detail below, a service provider's joking comment about his family is a description of the tensions in the community:

> My family is all over the board and isn't very tolerant of each other. My [kids] go out on the bucket brigade. My wife is [an ethnic minority] and a liberal Democrat. She says, 'Why are the farmers doing all this griping, what about the laborers? They are the ones that were slave labor in the first place. The farmers got property money. What about those immigrants?' And I'm a maniac. I think that we [should] organize and take over the state and feds [agencies].

While farmers can describe and appreciate support for the farmers from the larger community, they were finding that the relationships among their professional colleagues—farmers and nonfarmers—were becoming weaker, leaving them isolated from other people, news, and events. It was common for farmer participants to note a loss of sense of community. For example, one farmer from the Merrill area described the situation this way:

> People just don't go out and socialize in any venue. They have just disappeared. And when you talk to them they look down a lot. They don't have a lot to say. And these were formerly talkative people, people you might see in the coffee shop every morning, . . .and they're not conserving 75 or 80 cents of a cup of coffee. It's just, it's a little bit of shame, anger, I don't know.

Two other farmers echoed these concerns:

> People are just not as friendly. You know this is a small town, everyone knows each other. Everyone talks to everyone else; now people just don't talk, they don't go out and socialize, don't go to festivals like the Potato Festival. It's been an annual event for 60+ years. I didn't even go this year.

> Every other weekend someone would be having a party or barbecue. You'd go over and have a few beers and cook a steak. I don't know that I went to one barbecue all this summer. Nobody wants to socialize, there's nothing to celebrate.

While most farmers told us that this retreat from socialization was to be expected as people dealt with their problems individually, we were also told of differences with potential for polarization emerging in the farming community itself. One farmer was concerned that "people will get upset because I've got a job … will they start looking at people who are maybe a little more insulated maybe as much by dumb luck as anything?" He described this feeling as "a big cloud hanging over the community." Another farmer told us that the "willing seller, willing buyer issue" has divided some people. He and others described the tension felt by individuals who would like to sell their farms and leave, yet feel they are betraying the community somehow. He said that he doesn't "even want to talk about that with anybody unless I know what their way of thinking [is]. Because there's been a lot of bad situations in the basin because of that." Another farmer provides more detail about these concerns:

> So if you do sell your ranch out to the "willing seller," you wouldn't have the community to keep business open. If we lose two or three of these businesses, where do we go for parts? You can't blame the farmers for wanting to sell out, you know, if the money is there and [there is] someway of getting out of this thing. But what does the rest of the community do? It's just a domino effect. Even if they get out, they're not going to spend their money here. They're going to go somewhere else and spend it.

Another farmer said she "didn't know the whole story behind every single person that wants the buy out. But I resent the government wanting to spend money for a buy out."

Participants also talked about the tension emerging as they continue participating in civil disobedience and planning meetings while maintaining their farms and ranches and living their lives. One participant told us that "all of a sudden you have to go bail hay, and I took a lot of criticism for leaving, they wanted me to stay at the head gates and help them." Another described his life:

> You're on all these committees you make a commitment to. Then they turn on the water and you have to get out to the farm to take care of things, equipment and stuff for 3 weeks, trying to generate a few dollars. For a while, all I did was meetings, that was my job. Got all these commitments and plus this other job, there only so many hours in a day.…How do I balance this out and then, oh yeah, I forgot I had a family, where do they come in?

Another farmer also reported that he's starting to see how the pressures on the farmers involved in the planning and organizing are becoming less appreciated by some who have

> less tolerance with some of the organizations because they're not getting anything done. We want to see them doing everything they can. And the people in the organizations are just starting to get really burnt; they're just burnt out. They meet two, three, four times a day, every day….And there are a few that are moving away and just not going to the meetings and just complaining like most other farmers do most of the time.

Us against them. In addition to the conflicts within the farming community described by our participants, other sources of conflict have emerged within the larger community. One of the major issues described by our respondents was their concern that framing the issue as "farmers vs. fish," "farmers vs. Indians," or "farmers vs. feds" has oversimplified the situation and created a sense that others are "out to get the farmers." Environmentalists, Native American Tribes, and federal and state agencies have all been blamed for the current situation, which has created a tense environment for many residents of the basin who may support the farmers as members of the community but hold other perspectives as well. Members of these groups told us that those individuals who have become especially vocal and vociferous in their support of the farmers and ranchers have silenced their own voices and concerns.

Farmers and conservationists. Community members who described themselves as conservationists had concerns as well. All but one of the participants in this group had resided in the Klamath Basin for 20+ years. The concerns shared by the group about the media bias regarding the situation can be summed up in the words of one participant: "There is an assumption that everyone in Klamath Falls feels this way and that it is fine to put down a big bucket in front of the court house and that it represents all of our feelings." A common response of these participants is a sense of embarrassment about these actions, illustrated by the following quote:

> I guess I knew that this was a small community and a very conservative community. At the same time there are a lot of people here who are more broad-minded. So when I see the signs on the highway [criticizing the decision] and I know a lot of people coming into Klamath Falls are seeing that, I am embarrassed.[9] I know there are a lot of people here who don't feel that way.

This embarrassment also extended to the local media who were described as presenting biased and one-sided information about what was happening. One participant told us

> I resent the image the media created and you had to go outside of the basin to get balanced representation of the real problem and what the impacts were. Personally this was the first time in my 30-plus years of living in the basin that I considered moving away…the local media feeding the idiocy, the poor law enforcement. It makes us look ridiculous and I really resent that.

Several members of this group also talked about their fear that violence could erupt during public rallies or during heated conversations with farmers. One told us that she "felt a real sense of being afraid in my own community. I [need to] go by the head gates every day as I ride to work. [I'm afraid that they might think that] 'someone on a bike must be against what I have to say.' Watching the sheriff not enforcing laws…city policy not enforcing laws. So I feel unprotected and that has not happened since I lived here." Another told us that she would never go near the head gates, worried that someone "might be firing a gun around there."

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[9] During our trips to the area, we observed roadside signs expressing concerns including: "New Addition to the ESA: Tulelake Farmers," "Stop Playing God – You Don't Qualify," "An Opinion is Killing our Communities," "No Water, No Barley, No Beer," and "Federally Created Disaster Area." We also saw many signs that were more restrained, including: "73 Years of Water Until Now," "Where Water Flows, Your Food Grows," and many creative versions of "Support Our Farmers."

Another member of this group went to the head gates for the first bucket brigade and was surprised at the talk of violence. He heard people name specific environmentalists who they claimed would be hung if they came down the street. He had the sense that his farming community friends, whom he describes as “wonderful; you can’t find bigger heart[s],” would participate in a lynching if prominent and active environmentalists ever showed up at a rally.

A conservationist we talked with during a one-on-one interview described how the polarization with the farming community led to, in his words, a “completely ridiculous” outcome:

> [An employee at a state agency] was [head of the sailing club] this year. It got so far out this year that they were accusing him of holding back water in Upper Klamath Lake so he’d have enough water to sail his boat. You know, it is completely ridiculous, but you know it makes good press: self-serving agenda as [head of the sailing] club. And, not only that, the farmers say, ‘Oh well, you guys aren’t supporting us, all you care about is sailing your boats.

None of the conservationists we talked with was happy about the situation in which farmers found themselves. Almost all described themselves as having many friends who had farms and ranches and knew of the trouble they were having. Furthermore, some are at least as disappointed in the agencies responsible for managing natural resources as the farmers are. One told us that he was

> ashamed of our agencies. Like I mentioned earlier, I was involved in some of the same agencies which helped created this problem. We were talking about how not to let this happen and here we are 20 years later and haven’t done that. So I have little empathy for these agencies being in the hot seat right now.

Yet, to a person, the conservationists who participated in focus groups and interviews believed that any solution for the Basin would have to involve the consideration of multiple perspectives, including those of the farmers. They were discouraged, however, that years of friendship and working together on community projects were being destroyed by the short-term actions taken to resolve what they believe is a problem that has been a long time coming. As one told us, “Even before the water crisis, there’s been a long and steady decline in the ag economy for reasons way beyond the water issues. You know, the consolidation of multi-national corporations, the grain cartels, NAFTA. The ag economy isn’t what it used to be.” He was concerned that after years of work with community members trying to find solutions for allocation of water rights, the farmers’ desperate response this year would create irreparable splits with others interested in resolving the problems of the Klamath Basin.

Farmers and Indians. Another framing of the issue as “farmers vs. Indians” revealed a strain of racism that usually ran “quietly beneath the surface,” as one farmer participant said. Members of all groups noted incidents where Tribal members were shunned or treated badly, and all disassociated themselves from this behavior. A service provider described an incident about an annual fundraiser held every year for a local treatment facility. The pow-wow was designed to

> honor people in recovery, who have gotten jobs, gotten families back, who aren’t doing crimes anymore. And its 90 percent non-Indian. We go around to

> corporations and places in town and they donate money—$200–$500—because a pow-wow is expensive. This year 90 percent of them said no because you're associated with the Klamath tribe. Most of our clients aren't tribal members, so what's that about?

The social service providers, many of them working with the non-white population of the basin, described multiple incidents where their clientele were treated rudely or even violently.

Tribal members we talked with described how an intentional decision was made for the tribes and individuals to stay as far from confrontational situations as possible. Tribal members were advised in the tribal newspaper and through word of mouth to "walk away" from arguments or other tense situations. This may have been what this Klamath Falls business owner was seeing when she described the following:

> We have a lot of Native Americans that come in to use [this service]. And before they were very vocal when they were standing in line, somewhat loud when they were talking with their friends and around everybody else. …. But after this happened they would come and they would walk with their head down, they walked slowly, they stood in line quietly, they didn't talk with other people in line, they looked straight ahead, they were very courteous.

Instructions to remain nonconfrontational were hard on the tribal members, according to one of our participants, "because we had guns pulled on us, were run off the road, there was one beating where a guy ended up in the hospital pretty bad." This participant also described an incident in an elementary school where each student was asked to take a position on the water issue:

> [When] they finally get to an Indian child in this classroom, because of our prompting and parents telling him 'just stay out of it,' the student said, 'I want to stay out of it, I don't want to have a response.' The teacher told him it was a class project and he had to have a response. And, he said, 'Well, I really don't want to say anything.' The kid was sent down to the principal's office and they actually expelled the kid from school.

The tribal government intervened, sending a letter to the school asking that the child be immediately reinstated and that this type of teaching be discouraged. The student went right back to school, but tribal members were left feeling betrayed by the portrayal of the problem in the public school.

Tribal members believe that they have supported the farmers from the beginning; they have gone back to Washington, D.C. "several times and seen congressman, senators, and other legislative people. We've asked for funding and are trying to come up with a solution. Because we didn't want to see anybody lose their livelihood because we know, we've been there." They also have maintained a low visibility throughout much of the spring and summer, trying to remain out of confrontational situations as illustrated by the following quote:

> Imagine, if you will, what would have happened if there would have been a confrontation? We've had offers from other organizations throughout the country,

> just as agriculture has, to come in the area. This could have become a full-blown civil war in the area and that's not good for anyone.

The tribal members we talked with were convinced that the relationships built with the irrigators through the Alternative Dispute Resolution (ADR) process can be salvaged and solutions can be found. One described how through the ADR, great strides were being made for the adjudication of irrigation water, even traveling to Washington D.C. to describe to others how well they were doing. He continued:

> Then all of a sudden the drought of 2001 comes along and that's put everything to a screeching halt. But right now we're trying to pick it back up again. We've had meetings with the irrigators where one of them actually said that 'everything that was built up to this point was gone. We're going to have to start at the beginning again.' I told them, 'well, I don't know about that. You know, we think we can just kind of pick up where we left off.' It took a little encouraging, but finally they said, 'We can go ahead and things that we've already built we'll just keep adding to that.' We're still trying to work with them as much as we can.

Just as the conservationists are willing to keep working with the irrigators to find solutions that work for everyone, according to our participants, so are the tribes. It is important to note that all of the people we talked with are local—they live and work with farmers and their families and they seem to see the farmers' problems as their problems as well. As one person put it, "We're never going to have a sustainable community if one component of the community is … in the dumper."

Farmers and state/federal agencies. Finally, we talked with representatives of state and federal natural resource agencies who work in the Basin, most of them for many years. Many in the farming community hold the agencies responsible for their problems because of the decision to halt water delivery in the Basin during the drought of 2000–2001. Agency folks we talked with are frustrated by the anger from the farming community because they believe staff have been supportive in many ways over the years. In addition, they are frustrated because

> to a large degree we have lost what little authority we had. Now it is virtually impossible to do anything without regional offices and/or Washington offices involved. I think that it is frustrating that those of us at the local level have a clearer idea of what the problems are and what the possible solutions are, but have no authority to do anything. It is really out of our hands.

Despite their own frustrations with the agencies involved, local employees of the agencies still describe themselves as treated as "outsiders," with hostility, and uncomfortable in many public situations. One participant said:

> You know, you are really reluctant to go out into the community and freely associate with people. You try to avoid situations where the water crisis might come out. I feel reluctant to tell people who I am employed by, what my job is."

Another person described herself as "shrinking" because she was unable to express her own views.

Agency staff members also believe that most of the community remains unheard and the voices that *are* heard represent the "more extreme views and certainly [don't] represent the range of views that the community has." Instead, there is intimidation to only express the single view that the farming community "must be made whole." Many agency staff report feeling "threatened" as they performed their duties, wore their uniforms, or interacted with the public. They believe that people pretty much recognize that individuals in the local offices aren't making the decisions, but "collectively, like at the head gates, you run into problems. Because of mob mentality."

These agency staff perceive their relationships with the public to have changed as a result of the drought and subsequent water decisions. People are asked for identification and are frisked as they enter federal buildings, setting up an adversarial relationship right away. One person described how the trust with the agriculture community has been harmed, remembering "the times I used to be able to go out on a guy's ranch" and following up with, "there is more reservation there now." Another claimed that the strategy of keeping farmers at the head gates is

> just to keep up the image without physically taking over…we have to provide guards and I imagine we've spent well over a million dollars on protecting the head gates. You stop and think about it—there might be something better to do with that money.

Uncertainty about the future and long-term planning

While all of our participants described a complex and dynamic situation, with many contradictory personal and community experiences, they all shared one way of describing the circumstances: intolerably uncertain and increasingly frustrating. The farmers talked about how not knowing whether there will be Project irrigation water next year only exacerbates the uncertainty inherent in agriculture from other sources such as weather, prices, and disease. And for those not directly involved in farming, the uncertainty has rippled through social service agencies, schools, state and federal agencies, and local businesses. And yet, we also heard from farmers and others that this "crisis" was unexpected *only* in its appearance in 2001. Many have been planning and working to shift reliance from irrigated fields and the ag economy to alternative crops and new business sectors.

Living in limbo. Farmers routinely told us that their greatest need is water and some kind of assurance that they would consistently receive water. Without that, they couldn't plan, as this farmer indicated: "Usually you have a plan, you know what you're going to do with your operation. You're going to do this and do this and at the end of the year you hope it works out and you've made a little money." A younger farmer said that "[I am] young enough, I have [a business degree]. I've had some offers at banks and different places. They say if I ever want to change careers, come see me. If they would come out and say you're never going to have water again, you're done, then I could move." He went on to say:

> Where am I going to be 10 years from now? I don't even know where I'm going to be next year. You can't make any long-term plans right now. When I got out of college I had a plan with goals, knew what I was going to do. This is where I wanted to make my career.

We were told by farmers that without a definite decision one way or the other about the availability of water, they wouldn't be able to make it economically. A Merrill farmer told us that couldn't mean

> waiting until April 6th for a decision, saying, 'oh yeah, you get some water.' I mean, planning and planting takes a lot of time. You don't decide to do this tomorrow. It's a 6, 8, 10-month lead time for an individual crop.

Some business owners, especially those in farm-related businesses, have seen a decline in their business this year. They, too, are unsure how to plan for the future, how much inventory they should stock, how long they can hang on to employees. One Klamath Falls business owner mentioned, "I think people are pretty nervous about how to spend, how to plan for their business futures, and then I think personally people are really nervous too because there's a lot of people out of work." An outdoor sport-related business owner that has been affected by the water decision wonders whether to make [other arrangements] for other parts of the state. Finally, a business owner wonders, "How easy will it be to attract new industry here if you don't know if you can keep an educated work force?"

The business owners in the small towns of the southern basin were more unsettled about the future than were the Klamath Falls owners. As the small towns have relied heavily on the ag industry for years, any downturn in that sector will affect them quickly. And they were concerned that the true impact of the season without water will only be seen this coming winter. One business owner pointed out:

> There's a lot of people right now that aren't doing too badly because they still have the income coming from last year's potato crop. So they have income and they don't have the outgo of cash that they would have had to plant this year's crop. But when they run out of that money, then this community is really going to feel it. They've all cut back trying to conserve this money and stretch it as far as they can, which has hurt the business community. But when that money's gone, then we're looking at real big problems.

A farmer explained further how many effects will be delayed until next winter:

> In this business you grow crops in one calendar year and 75 percent of that is sold in the next calendar year. So your income comes a year later. All our income from last year, 75percent comes in this year. We didn't operate our farm [this season] so we don't have the fertilizer bills, the rent payments, the this and that, all the ongoing expenses to offset the income so we're looking at bankruptcy and possibly a $200,000 tax liability. And no way to generate any money to pay any of it. And there was no way to do any tax preparation or planning because you didn't know it was coming.

The social service providers in the basin are also seeing how the uncertainty has affected those parts of the community that have had little voice in the conflict to date: the farm workers, the unemployed, and other traditional clients of the social service agencies (e.g., Head Start, County Health, Mental Health, etc.) One service provider from a small community reported:

> Suicide calls have increased, they want to end life. They feel like they have no choice—'I can't do this anymore.' We bring it around to what they can't do anymore and it is the fear of living in the unknown. Not knowing what to expect. What's going to happen? What's going to happen to my family? What's going to happen to my kids? I can't take care of myself anymore and no one understands.

Other service provider participants described a "feeling of powerlessness" and uncertainty, a "constant up-in-the-air feeling" for both staff and clients. This was echoed by a Klamath Falls service provider who said:

> one of the things that I think we are all affected by personally is what the future has in store for us as far as what we all do if this place is going to become a dustbowl. Do you buy a home? Do you buy a car? Do you do anything if you're not sure what the future has in store? …you just don't know what is going to happen year to year.

Another described how some of her clients were hoarding food just out of fear. "They are not using it, they are hoarding it. They want to make sure that they can get through next year."

Alternative arrangements. Yet farmers also told us that they have plans underway for alternative crops, other jobs, and other ways of organizing their farms. Almost every farmer we talked with had alternative sources of income—either another family member worked off the farm, they held another job themselves, or they were experimenting with "value-added crops." One said that "We're not sitting around twiddling our thumbs either, we're probably trying to be as busy and as inventive as we ever have been to find other venues." A Merrill farmer was somewhat typical in his arrangements:

> I've got a wife who teaches and so I do have some security. None of my children are involved in agriculture. …I'm looking at transportation, trucking, more and more outside seed sources. And, I'm trying to grow higher value crops that we can sell elsewhere.

While most farmers were modest about their planning for the future, they were all involved in making choices that left them alternatives to their irrigated farms. One farmer we interviewed talked about diversifying through different crops. He's been looking the last couple of years to find some different ways of making money. According to him, "that's a given."

Some business owners told us that their businesses have not been affected by the water situation, that they too have been planning for an economy that is not primarily ag-related. One shop owner told us how she had been buying carefully but was surprised to find that her business remained strong. She worked with other local business owners to promote a "buy locally" campaign that she believes has been successful. She found that her sales stayed up and she was

> almost embarrassed. I was afraid to tell anyone I was doing well here. …You know how people are suffering and things are happening. So I began to talk slowly to other friends and businesses…[and found that] the other businesses…were doing well.…We have people shopping now that I haven't seen before. So there are new customers, not only old customers.…[I'm] making sure that we have items that are like in the $20 and under range…making sure that we can capture the feel-good dollars.

This business owner identified businesses that weren't doing as well, including ag-related businesses, many restaurants, and hair salons. Ice cream, espresso, and gift shops didn't seem to be affected, in her view. She reported that the Small Business Development Center at Oregon Institute of Technology told her that most local businesses were up except for a "select few that were down."

One group of people who have not been able to develop alternative sources of income have been the farm workers, some of them undocumented, who work the fields and harvest the crops of the Klamath Basin. All of the workers we talked with had lived in the Basin for at least 3 years, many for up to 20. They and their families consider this area their home. Some have incomes that are non-ag related, but most rely on at least two family members working in the fields. They told us, however, that there was little work this summer and most workers were unemployed and waiting for a change in the situation, or they had left the area to find work.

One farm worker described how the foreman of the packing shed where her husband worked said, "They were [told by the farmer that he was] gonna pay them as if they were still working. That'd be about 20 hours a week, that they were gonna pay them that…but there's never been a check that they've gotten." Another in the group joined in to continue the story:

> As an owner I think he would feel terrible [for not being able to pay his workers]. So you might say something stupid like 'I'm going to pay you.' [But when the workers didn't get paid] it felt like they were playing a joke on them. It's a terrible thing because then you plan. Whew, I'll have some work.

Another participant finished the story, "This farmer got money, they gave him money for not planting because there was no water. But the workers got nothing."

Some of the farm workers qualify for unemployment, although assistance ran out early in the season. Workers with children born in the U.S. were eligible to receive about $80–100 a month in food stamps for a family of four. Undocumented workers did not receive any assistance beyond that provided by nonprofit service agencies such as the local food banks. When asked what they needed, one farm worker said, "What we need most of all is work. Because when you're not working, you feel sick."

The role of information

While all participants we talked with agreed that information was needed, there was little agreement about just what constituted "good" information that could help move conversations and decisions forward. There was almost unanimous disapproval of the way the media had handled the situation, although some claimed that the media was too biased toward the farmers and others claimed that the farmers weren't getting a fair shake. One farmer learned through personal experience not to believe everything he reads in the paper or hears on the news. He told us about attending a hearing with Congressional representatives, listening carefully and taking notes: “And then you see an article in the paper by an individual that you know is pro the other side and it was as if he had been at a completely different meeting.”

Others were highly critical of the media for sensationalizing the situation and actually leading to more polarization. One agency staff told us that she thought “the level of attention has not been equivalent to the amount of adverse effects; that it has been a lot of hype.” She believes that the media language prevented people from coming together to find a resolution. Many respondents report getting calls from family and friends outside the area concerned about their safety after reading or hearing reports in the media about what’s been happening in the Basin. A farmer told us that when his brother-in-law flew in over Klamath Lake he couldn’t believe it: “From everything I’ve read in the paper, I thought the lake was dry.”

The decline of the suckerfish was serious enough that the Klamath Tribe stopped harvest on the lake in 1986, 2 years before the Endangered Species Act was invoked to protect the fish. When asked, a tribal leader described the type of information that is needed to restore the system:

> We need some tremendous studies on the system itself and to start doing some restoration work from the headwaters to the ocean. It’s a massive task. We used to have salmon runs before the dams came in and we lost those you know…We need studies done on the full aquifer system, from the head waters to the ocean. We need studies on the terrestrial system, what effect logging and everything has had on the watershed and how to do some restoration work for wildlife. …We need to get the studies first for comparison and begin on how to do some restoration work.

We heard that the farmers in the Basin believe that much of the science has been done and now needs to be applied, and they echo this call for good information. They express concern that decision makers who only listen to science that supports their agendas have ignored data. This farmer told us that he believes that the federal agencies

> are not looking at all the facts that are available. There are a lot of noted scientists out there, some of them work right up here at Klamath Falls, world-renowned even we’ve got. I mean they know their business. They’ve presented it to the Fish and Wildlife at some of those meetings we had last winter on those suckerfish. And they just disregarded it. They picked out what they wanted; they just disregarded some very pertinent information on studies that have been done on suckerfish up here for years.

Another farmer told us that he believes that “most everyone in the county is capable of making an intelligent decision on something if they have all the facts.” There appears to be great frustration that science has been unable to provide “facts” that would allow water allocation issues to be resolved. Challenges to the science used to make the decision are commonplace, and challenges to scientists’ credibility are frequent. Farmers would like their own local knowledge and experience to count for more in the decision process “because we live this and we know that some of this stuff is just outright boldfaced lies.” Environmentalists have challenged the data provided by both the agencies and the farmers, while the tribes have been collecting their own data all along. The National Academy of Science met in November 2001 to review the science behind the latest biological opinion, but farmers we talked with were convinced that it would be the "same old, same old" and no academic scientists would be challenged on their findings.

> You get people all pumped up about that [the NAS review] until you find out who is on the review committee. Same old people, same old science, same old answers. They say, 'oh no, you'll get a fair review.' Bullshit.

When the media is suspect for sensationalizing the news and science is suspect for not being able to solve the problems of the community, people end up with no shared understanding of the world. Their disagreements are amplified by any lack of common explanations of what's happening. One result has been farmers and business owners who interpret actions and information they receive about the agencies' decisions as additional evidence of a conspiracy to "save the West from being developed and growing food out here and turn this into huge wetlands."

A general distrust of government was expressed by many of the participating farmers, business owners, and social service providers. Whether the current situation created or enhanced existing feelings is difficult to determine. One farmer told us that the "general feeling in the Basin is betrayal. And our government is doing nothing. Rural America elected the Bush administration and they're not helping us hardly at all." He went on to explain:

> We got the $20 million, but how long did it take them to get that done? Overnight we can find billions of dollars to go to New York. How many flags do you see in Merrill? There are people in Merrill that won't give the Pledge of Allegiance and I'm one of them.

Getting help

All the participants we interviewed expressed concern about helping the farming community and others who were not used to receiving assistance. As one social service provider noted, "Food stamps and public assistance really isn't in the vocabulary especially in the ag community. There is no way." Yet everyone recognizes that without assistance of many different kinds, the farmers, farm workers, and others in the community will continue to be negatively affected.

Personal support networks. When asked, most participants told us that their personal networks were strong and support primarily came from family and friends. Very few told us that they had asked for assistance beyond the family. One farmer described how he and his brother have begun to take on more responsibility with their mother because she lost the rental payment from her farm:

> Social security is not there to support her, pay for insurance, the things on her land, taxes. If the farm is not operating and generating money she is down to her flat social security check. How does she keep her insurance or the house or car? Right now we're all here, but if we all leave to find work she'll be left out here by herself.

Another woman described how she was pitching in to help her son's family by babysitting so that her daughter-in-law could work outside the home.

Agency staff told us that, in general, their offices were close-knit and supportive of each other. One reported, "We have been trying to keep everyone aware of what's happening. That way nobody gets blindsided by some activity." Another person told us that the staff had had a "lot of counseling…I have lost several employees and am losing another one now. And, quite frankly, it is tough to get people to come here." One agency has tried to keep individuals out of the media as much as possible. Agency staff also reported that they have received support and encouragement from agency and professional colleagues from around the country. Another woman told how her children tried to protect her from the unfolding events. They hid the newspaper one day and she "never found it. There was a bunch of bad news in it, so they rented a comedy at Blockbuster….So they put up with me being crabby."

Resistance to change. Underneath the stories of solid support, we also heard stories of increased drinking, isolation, and separation and divorce. One farmer talked about how his wife has left, saying that she just couldn't take how the uncertainty and resulting depression affected their marriage. The stress of the situation undoubtedly exacerbated existing problems in the marriage.

Conservationists and agency staff expressed frustration with the farmers and their supporters who insisted on claiming the right to continue current practices even though others were starting to recognize that multiple concerns will need to be considered for any permanent solution. One agency participant remembers how difficult shifting to considering multiple perspectives has been for him and others:

> Well my God, a paradigm shift for me. …After the 1994 drought we found people knocking at our door. 'Hey what about us? We are the Indians upstream.' 'What about us, we are the Indians down stream.' 'What about us, we are the ORNC' (Oregon Natural Resources Council). 'What about us, we are the fishermen.' Open the door and you have to let them all in and start listening to all of them…that shift—we are a multi-faceted agency and we're listening to everybody.… It is easy to have a guidebook that says once you get to this point you lean this way to the farming community or maybe you…And it isn't that way anymore. Now you come to a decision point and you don't have a book anymore. How do you do it and make everyone happy? Our guidelines are so fuzzy anymore….

We heard from a conservationist who notices that

> people in the agricultural community every year just expect to get their water and now all of a sudden things have changed. How are they responding? Are they being proactive and saying, 'I have to do something differently? Or find water somewhere else? Dig a well? Find a different crop?' Or, are they just saying, 'The government is doing this to me and I am going to lash out and wait for my water to come back.'

Other participants reinforced this perception that the farmers feel a sense of entitlement to a stable world that others have been asked to move past long ago. A farmer declared, "So I guess somehow someone has to decide is this community worth having? And to do that as it stands today, that involves irrigation water. …If these people are going to be allowed to live and pursue their happiness and their occupations as they've been pursuing them, there has to be a tolerance of the use of the land as we've been using it."

A business owner in Klamath Falls described how a

> lady comes in and starts crying because they didn't know how they were gonna make it because the rent that they received from someone farming their property was their way of life.…And, they're not going to go to Wal-Mart and become greeters. They're just not. Their pride's too thick, it's just too strong to do that.

And tribal members want to remind the farming community that they have been asked to give up their traditional ways of life many times.

Yet farmers, business owners, conservationists, agency staff, and tribal members all described assistance programs that farmers had access to. One woman described her husband as very successful "with a lot of the assistance programs and the water buyout programs, the set-aside acreage program." She thinks that older farmers might not know how to access these programs or maybe don't use them because of pride and unwillingness to ask. One farmer told us

> we've never played government games before. And just in the last couple of years that we've been getting some at all. So now this year is really full bore in trying to get everything you can out of everything…if it wouldn't have been for the government programs this year, we'd be in big trouble.

Needed: visionary leadership

As the farmers became more politically active and experienced over the summer, it became clear to many of our participants that the visionary leadership needed to craft workable solutions in the Klamath Basin is not there. A social service provider from a small town found the most frustrating thing was the "complete void in leadership." She explained:

> [That is] is not to say that our local politicians and community leaders aren't doing a good job in managing the situation, but in a year from now we are going to be in the same place. Five years from now we're going to be in the same place. And, 5 years ago we were in the same place but just didn't know it because the water was flowing.

Tribal members and agency staff shared their concerns about the leadership void in almost identical terms. It is not clear from our interviews what participants would like from leadership beyond bringing people together. Farmers would like leaders to "make sure that agriculture stays whole to protect our society," while others look for someone to get a broad-scope discussion going (conservationist), provide concise national policy from the top (agency staff member), promote education about the situation (business owner), and see the big picture and bring people together (service provider).

Concerns about the lack of leadership were supplemented by concerns about slow responses by the agencies and the courts to problems that were experienced in the here and now by most of our participants. One of the farmers who is supportive of the new administration said

> we're learning a lot about how slow the process is. Once you appoint the Secretary of the Interior, then the under secretaries, and there's a whole level under that. And until the new people are appointed, all the old ones are still there. I think we're finding out how powerful bureaucrats are.

Another farmer, however, recognized any solution was going to take time, regardless of changes in the national bureaucracy. Yet, he reminds us all

> you just can't put a career or a life on hold for 10 years while you truly take the time you need to take. The lives and occupations and the farms that are at stake—it's instant.

Conclusions

The Klamath Basin area is facing a number of challenges in the coming years. Although the water restrictions in 2001 had a dramatic effect on approximately 1,000 farm families, the effects of the water limitations rippled out far beyond those farms. Furthermore, the families directly affected by lack of Klamath Reclamation Project water were not facing difficulties only in 2001, but rather have faced many years of restricted incomes due to high costs and low prices for their crops and are likely to face an extended period of recovery.

It is clear from our conversations with farmers, business owners, government employees, representatives from the Hispanic and Native American communities, conservationists, and social service providers, that the impact of water restrictions is both deep and wide. While many participants talked about the ways in which the community had come together to support the farmers, many also talked about the ways in which the community had become polarized. Farmers who were thinking of selling their farms feared being scorned by those who wished to continue farming. Environmentalists and government workers were particularly scorned, although participants were quick to point out that it was not the local environmentalists or government workers who were at fault. Some farmers were quick to blame tribal members, and farm workers reported that farmers were not doing enough to help them out. The polarization had resulted in community members pulling back and avoiding social situations they perceived to be risky.

In addition to polarization, uncertainty about the future and the inability to make long-range plans troubled our participants. This was particularly true for farmers who were older and faced the prospect of finding a new occupation. Although the unpredictability of water access has encouraged many affected individuals to begin thinking about alternative sources of income and farming strategies, most people we talked with who rely on farming income are still hoping that with some rain and/or a court decision they will be able to continue their current practices.

The uncertainty was exacerbated by a perceived lack of information. Many community members felt that information was being withheld; others noted that the media was presenting a very biased view of the situation. The work of scientists was viewed as the "same old science" when answers to the communities' problems were not forthcoming.

Farmers in particular questioned the lack of forthcoming assistance on a large scale, although accepting direct and immediate aid already available through social and financial assistance programs was rare (except possibly food bank usage). Community members, however, were willing and did seek and receive social support from family members and friends. This support appeared to be mutual only within one's particular group at this point.

Finally, frustration was expressed frequently about the resistance to changing how both the water and the land are managed. There was an acknowledgment, most likely precipitated by frustration with current natural-resource management policies, that the community is desperate for active and unified leadership that considers the voices of all those concerned.

The communities affected by the curtailment of Klamath Irrigation water during the growing season of 2001 took a social hit, the impact of which is likely only to be fully realized in the months and years ahead. To date, they have worked together as a community to help members who have been most affected, have polarized around already existing stress lines, and have learned quickly how to operate in a highly visible political arena – contradictory and complex responses to a dynamic and ambiguous situation. It appears that most members of these communities are committed to finding solutions that are acceptable to all. Residents of the Basin, however, are likely to craft workable solutions only if they can apply the lessons they're learning this year as they move forward into the uncertain future.

References cited

Denzin, Norman K., and Yvonna S.Lincoln (eds.). 1994. Handbook of Qualitative Research. Sage Publishing, Thousand Oaks, CA.

Gilgun, Jane F., Kerry Daly, and Gerald Handel. 1992. Qualitative Methods in Family Research. Sage Publishing, Newbury Park, CA.

Milstein, Michael. 2001. Klamath Basin Farmers Still Wait for Relief from Weather, Congress. The Oregonian: November 19, 2001: A5.

Putnam, Robert. 1995. Bowling Along: America's Declining Social Capital. Journal of Democracy 6(1): 65–78.

Stewart, David, and Prem Shandasani. 1998. Focus Group Research. Pp 505–526 in Bickman and Rog, Ed., Handbook of Applied Social Research Methods.Sage Publishing, Thousand Oaks, CA.

United States Census Bureau. 2001. http://www.census.gov.

Appendix X
Klamath Basin—social impact assessment

Focus group and interview protocol

1. Introduction: Name and pertinent background information (e.g., where they work, what they do, how long they've lived in the area…general, get-to-know-each-other details)

2. How has the current water shortage/situation affected your community, friends, and neighbors, and any other social group that is important to you (e.g., church groups, membership organizations)?
   How has the current water shortage/situation affected your family?
   How has the current water shortage/situation affected you personally?

   Probe for details about *changes* in physical/mental health, relationships with others, job opportunities, general sense of the world.

   Additional questions for farmers/ranchers, business owners, and others as appropriate:

   - Did you look for alternative income earning opportunities to compensate for lost income from irrigated agriculture? How successful were you in finding alternative income?
   - Can you estimate the percentage of the losses due to water restrictions that was offset with supplemental earning?
   - Including government payments, what percentage of the losses due to water restrictions was offset by all supplemental sources of income?

3. How has the current water shortage/situation changed the way you do your job(s)?

   Probe for details about *changes* in the way they work, the types of people they interact with, how they approach their job.

4. What types of support or help do you receive from others such as family, friends, neighbors, church groups, public service providers, etc. in dealing with the impact of the current water shortage? Is this different—in type or amount—from the assistance you've received in the past?

5. What other kinds of support or help do you need to get along over the next 6 months? What about in the longer term (1–2 years)?

Focus group and interview participants' demographic information

In order to compare the results across the several focus groups we are doing, we would appreciate some general information about you. Your answers to this questionnaire and the things you said during the focus group will be held in strict confidence. All of our reports will summarize statements within and among the focus groups without direct reference by name or details to individuals.

Thank you for your time in the focus group. If you are interested in seeing a copy of our report, please provide your name and address on the sign-up list.

1. How long have you lived in the area?
2. What is your occupation?
3. How long have you been in this occupation?
4. What is your age?
   18–25
   26–35
   36–45
   46–55
   56–65
   65+
5. What is your gender? Male _____ Female _____
6. What is your race/ethnicity?
   White
   Hispanic
   Native American
   African American
7. What is your level of education?
   ____ less than HS
   ____ HS degree
   ____ some college
   ____ college degree
   ____ some graduate school
   ____ graduate degree

Draft
December 14, 2001

Policy impacts of the Klamath decision

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Overview

In 2001, the Bureau of Reclamation's Operation Plan for the Klamath Project initially provided no irrigation water for its agricultural contractors. This unprecedented action had long been expected by a number of water interests, but the Bureau's water contractors within the Klamath Basin were unprepared when they learned in early April that they could no longer rely on the Bureau to find a way to deliver water. The abruptness and magnitude of the rupture in the traditional relationship between the Reclamation Project operators and contractors signified a reordering of priorities within the basin. Rather than providing water first and without fail to farmers, the interaction of biophysical, historical, and institutional circumstances aligned to place greater emphasis on instream water values. The Bureau had insulated its contractors from climatic variability, institutional fragmentation, historical commitments, and the impacts of the water diversions that irrigated contractors' fields. But long before the 2001 irrigation curtailment, Native Americans experienced a similarly painful deprivation as they watched Upper Klamath Lake transform into a highly eutrophic reservoir, and once-abundant fish populations dwindle as seemingly external pressures crept into the Klamath Basin.

The 2001 curtailment also fueled an ongoing national debate surrounding the application of the Endangered Species Act (ESA). The Interior Department had developed elaborate alternatives[1] to strict ESA compliance in order to mitigate the impacts on economic expectations and avert an expected political backlash. However, the long simmering tensions surrounding the allocation of the basin's water were left unattended as interests on all sides sought injunctive and declarative relief in the courts, culminating in the 2001 cutoff of irrigation water to project contractors.

Does the Klamath decision change the framework of public policy? Specifically, does it stretch the institutional and legal envelope of acceptable events, or is it consistent with the normal patterns of resolution for such issues? We sought to answer these questions in several ways that reflect dynamics internal and external to the Klamath Basin. We evaluated the Klamath decision in light of related judicial interpretations regarding the Endangered Species Act, Tribal powers and water rights, takings, and the specific qualities of those in the Klamath Basin. We compared the institutional basis for conflict resolution in the Klamath with those of other river basins in California. Although the human impact of the Klamath decision is unprecedented in its totality, abruptness, and measurable costs of water reallocation, we conclude that the Klamath decision is consistent with the record of legal interpretation; it is a consequence of historical processes in an arena of exceedingly weak institutional opportunity for resolution. Administrative options existed that were not taken, specifically the Administration's choice not to act preemptively, or to appeal the judicial decision that triggered immediate and total water

[1] We refer to the habitat conservation planning programs outlined in Section 1539 of the ESA.

reallocation. The Klamath decision illuminates particular weaknesses of the current structure that offer opportunities for avoiding similar collisions in the future, in the Klamath and elsewhere.

Social organization of the Klamath River Basin

The impacts of general policy and law depend on the specific character of the social system in which they are applied. Although river basins are hydrologically interdependent systems, their social systems rarely, if ever, display equivalent complimentary or consistent integration. They are divided among groups, interests, and jurisdictions that are influenced by forces unrelated to the basin in which they co-exist. The tension between disparate interests and shared resources is central to understanding the institutional impacts and opportunities in the application of policy and law. Thus, the Central Valley system of California has been building capacities for coordinated action since the establishment of the Flood Commission in the 1880's.[2] A century of growth and diversification of coordinated relations has created the basis for CALFED, the consensus-oriented current stage of coordination. The TVA and Columbia River Basin programs emerged through huge (New Deal) infusions of Federal finance, capacity, and authority. The Eel-Russian Basin Commission evolved through a gradual federation of local, state, and national interests, then spawned two different systems of relationships that could increase the effectiveness of financial and political mobilization. The Klamath displays the diffusion of the Eel a decade ago while facing the additional forces of strong irrigation districts and rising tribal strengths. The issue throughout these basin systems is the balance between capacities for coordination and dispersion of interests and organizations.

The Klamath Basin displays institutional characteristics that are unique for its size. Because of its unique qualities the Klamath has responded to more general trends in extreme ways. By this, we mean that the people and agencies of the basin were forced into an either/or corner that other basins have been able to avoid through negotiation, exchange, and coordination.

The Klamath is extreme in three ways. First, it is socially dispersed and hydrologically divided. Its main tributary, the Trinity, has been substantially diverted to the Central Valley, where it is governed by the macro forces of California water. The separations between the tribes and European-American settlers, between upstream and downstream populations, and between utilitarian and protectionist interests, are both sharp and without much past provocation to overcome them. The distinction between agricultural and nonagricultural populations contains all of these sources of separation.

Second, the density of its population, financial stakes, and intra-basin relations has been extremely low when compared with any other basin of equivalent size on the Pacific western slope.

Third, despite jurisdictional divides between the tribes and the states, among tribes and among states, a compensatory Federal commitment to coordination has been virtually absent, and certainly weaker than in any other comparable basin on the Pacific slope. Instead, Federal commitments until recently have been territorialized in ways that created other fragmenting area jurisdictions rather than compensatory opportunities for negotiation, exchange and coordination.

Into the mix have come more general forces that take on particular strength in this context.

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[2] Robert Kelly's book, *Battling the Inland Sea: American political culture, public policy, and the Sacramento Valley, 1850-1986*, provides a vivid account of the emergence of this process.

First is the shift of relative Federal strength from the older comprehensive territorial agencies—the U.S. Forest Service, Bureau of Land Management, Bureau of Reclamation—toward the newer specialized functional agencies—National Marine Fisheries Service, Environmental Protection Agency, U.S. Fish and Wildlife Service, i.e., toward agencies that focus on specific connective relationships and qualities. There is as yet little basis within the Federal government to coordinate the interactions between its territorial and functional agencies.

Second is the long-term shift from Federal to state jurisdiction of water use rights, but relative shift of public trust rights in the opposite direction. Thus, once broad Federal reserved rights have moved substantially to within state water rights systems, while species-habitat protection has enabled the expansion of public trust reserves under Federal authority.

Third is the growing momentum toward recognition and fulfillment of tribal sovereignty. This includes the gradual reduction of tribal dependence on, and control by, the Federal government, as well as the rise of unresolved issues between tribal and state governments.

Although these trends are nationwide, their convergence in the Klamath met little basin capacity to resolve the conflicts they bear with them. Indeed, they provoked basinwide relationships and identities for the first time. These relationships and identities focused, as would be expected, on differences rather than common interests. In combination with law, this helped to create a situation in which the primary issue was not how to overcome conflict through cooperation but which party would end up being forced into a corner. The challenge ahead is to move toward the next phase of institutional development, the growth of compensatory capacities that give strength to common interests in a shared resource.

The institutional fragmentation of a common river

The essential institutional quality of the Klamath River system is the fragmentation of interests and authorities without compensating relationships for the resolution of conflicts. The Klamath is an extreme case in this regard. Although the third largest California river,[3] it displays little of the institutional fabric that has developed for the Sacramento-San Joaquin or Eel-Russian systems. Its major tributary, the Trinity[4], has been managed primarily as an extension of the Central Valley system, subjected to a wholly different and external set of institutional and political dynamics that effectively isolate these hydrologically connected river systems. Although holding senior water rights, the tribes have been isolated from decision processes about the river. The divisions of jurisdiction among Federal, Oregon, California, and tribal sovereignties are largely unresolved, or are perceived as resolved but in highly ambiguous and thus far unimplementable ways. In particular, the extent of Federal deference to state water law, and the extent to which tribal rights depend on the relative balance of Federal to state power, are historical issues that do not, and perhaps may never, display clear resolution.

The April 6 decision focused on a small piece of this fragmented system. Although irrigated agriculture operates in a system including Gerber and Clear lakes, the Lost River, and the Link Canal, as well as a hardrock groundwater basin and upstream watersheds, the decision focused solely on water releases from Upper Klamath Lake. Although these water releases affect threatened and endangered species in wildlife refuges downstream from the irrigation districts, the decision focused on effects on species in the Upper Klamath Lake and the Klamath mainstem. Although tributary flows affect habitat conditions and population dynamics in the

[3] California Water Atlas
[4]

mainstem, these were not included in the focus of the decision. Even the small piece of the system covered by the decision involves the Klamath Tribe and Bureau of Indian Affairs, the Bureau of Reclamation, U.S. Fish and Wildlife Service, National Marine Fisheries Service, at least four irrigation districts, the Bureau of Land Management, the Federal Energy Regulatory Commission, and the National Resource Conservation Service, as well as PacifiCorp, the private operator of the public dam. This fragmentation is a fractal microcosm of the larger system.

The April 6 decision was consistent with law. The Bureau of Reclamation had no option but to comply with the court's judgment. The court's judgment was consistent with the mainstream record of precedent. Although we would argue that preemptive administrative actions were available, what seems clear is that the institutional fragmentation of the basin would not have supported, might have blocked, and indeed may have prevented, effective preemptive efforts. Moreover, it prevented effective articulation of a judicial issue that would have offered the court a broader array of appropriate decisions.

Issues the Klamath decision generates

Our conclusions suggest that an unusually weak and undeveloped institutional context, largely insulated from developments in Western basins of equivalent scale and significance, made the April 6 clash almost inevitable unless, as it had in analogous situations in prior years, the Administration had acted preemptively or chosen to appeal. Nevertheless, the dire drama of the event raises issues that have meaning beyond the Klamath.

To what extent should one group bear the cost of satisfying a public purpose?

This question is common to the literature and judicial record on "takings." Virtually all takings cases have involved the loss of potential future values as a consequence of public actions. What is distinctive about the Klamath case is that the costs were real and measurable rather than potential or speculative. Klamath farmers absorbed the full brunt in immediate terms.

Is the EIS approach sufficient for decisions that must be rendered on the basis of timebound hydrologic information?

While it is possible to criticize the Bureau of Reclamation for not taking required steps of biological review in a timely fashion, or for not developing a viable long-term strategy in the forewarning decade, it is also clear that the procedural path it had to follow did not mesh either with the narrow temporal window for essential hydrologic information, with the time requirements of biological science, or with the absence of an institutional basis for resolution of conflicts among interests. The procedural path is a source of rigidity and brittleness amidst natural and social processes that are largely beyond administrative control.

How do we weigh scientific uncertainty against disproportionate burden with regard to the satisfaction of a public purpose?

Contrary to the prospective, therefore uncertain, losses associated with the judicial record on "takings," the losses to Klamath irrigators were immediate, real, and certain. The certainty of irrigators' losses can be compared with the certainty of the scientific predictions upon which the April 6 decision was based. While this is not a matter of simple balance, it points out the possible need for a more articulated range of legitimate criteria and conclusions that can respond to the character of this balance in different situations. One could imagine, for example, that observable costs would have some higher degree of standing than prospective losses, or that the safeguards on judgments of scientific certainty would be somewhat stronger or more timely in such circumstances.

What is a legitimate durable basis for the adjudication of Klamath River water distributions?

The current basis for water allocation in the Klamath remains poorly articulated. The most recent and controlling court decision (*U.S. v. Adair* U.S. District Court 478 F. Supp. 336, and on appeal 723 F.2d 1394) allowed the Federal government to set priorities of allocation while deferring to state water law for the actual quantification and allocation of water rights. Unresolved is the extent to which Federal deference places tribal water rights under state law. Oregon adjudication of Klamath waters seems destined for permanent delay. This may be because the state's authorities are too confined for the broader array of sovereign jurisdictions involved. Perhaps the state's capacities lack the support necessary to bring adjudication to a sound conclusion. Tribal rights, although senior, have only begun to be asserted, but tribal claims are gaining momentum through investments in science, law, and the growth of alliances with complementary interests. Public trust rights are expanding through specialized agencies like the National Marine Fisheries Service, the U.S. Fish and Wildlife Service, and the Environmental Protection Agency, while property-based Federal reserved rights and related claims—through agencies like the Bureau of Land Management, the Bureau of Reclamation and the Forest Service— are weakening relative to new Federal and existing state powers. In this context, the current adjudication process seems incapable of comprehending the power of the complex interests involved.

Why has the Klamath Compact been ineffectual?

The Klamath Compact was created in 1957 as an initial basis for institutional coordination in the basin. Why has it failed? Based on comparative assessments, we suggest that a compact is as effective as the shared purposes and resources of its constituent institutions. The institutional fragmentation of the Klamath has been too severe to support or respond to a basin-wide framework, and governmental support has been too weak to compensate for the disparity between intent and reality. Although a harsh lesson, the April 6 decision should make their interdependence clear to all interests in the basin. If that leads to an effective strategy of institutional development, there should be increasing ability to avoid similar shocks in the future.

Institutional strategy

What are requirements of an effective strategy for an institutional basis that diminishes the chance of future shocks like the Klamath decision?

We suggest several fundamentals.

Sufficient Federal commitment of authority and resources to the basin to overcome the disparate directions of its agencies and to mediate among the interests of Oregon, California and the tribes.

The clashing missions and motives of Federal agencies in the Klamath dissipated the Federal capacity for a constructive role. Such a role would include the capacity for inter-agency coordination, for oversight and finance of a program of scientific and technical studies sufficient for equitable mediation of water allocation among diverse public interests. Some of the problems are legal and procedural: the Klamath is outside the range of conditions for which general approaches have been developed. Some problems arise from the fragmentation and weakness of political constituencies and the absence of a Klamath voice and claim. Some arise in Federal reluctance to engage state and tribal water interests in a basin with several states and tribes, except in regard to highly specialized and forceful driving assertions of public trust responsibility. The Federal commitment is very unbalanced for the nature of the basin.

State acknowledgement, respect and support for tribal rights.

Although senior rights holders in the Klamath, the tribes continue to be treated as residuals in Oregon and California water allocation processes. This is a permanent call for trouble because it denies normal access to process and encourages extra-process strategies. Although coded in environmental currency for use of the Endangered Species Act, tribal claims have formed the subliminal bass beat in the Klamath situation. The claims are strong and strengthening, so continuing denial perpetuates conflicts that will be argued ever more explicitly in jurisdictional terms.

A governing correlative principle of adaptive water allocation in times of scarcity.

The absoluteness of agricultural water expectations expressed a social dominance for agriculture, a sense of special entitlement, that no longer exists in the Klamath Basin. Other basins have faced this situation at earlier stages, recognizing the need for correlative allocations, institutional processes that form and legitimize them, that accommodate all interests as best possible in times of stress. All or nothing is not a viable stance in a context of interdependence and growing equality among interests.

A harsh lesson

Although the Klamath decision has been argued in terms of environment v. agriculture, the currency is an artifact of the deeper social and political issues that have determined and eroded possibilities for adaptive conciliation. Fragmentation has been indulged for too long to avoid havoc for one or another interest. The costs are huge. The causes are not those interests who are in dispute, but a broader institutional incapacity to create relationships that achieve equitable allocations in scarce times. Despite its scale, the Klamath Basin has been kept at the margins of state and Federal institutions and has remained insulated from adaptations to similar stresses occurring in other basins. One consequence is that it has not informed the broader discussions of public policy and has become an extreme case in policy application. While it has provided lessons about policy flaws, particularly the risks of absolutes of any kind, it has largely demonstrated the need for development of a Klamath institutional fabric that is consistent with the intensity and range of interdependent interests in the basin.

Contextual factors preceding the 2001 Operation Plan for the Klamath Project

The Klamath Project

The Klamath Project is among the oldest projects built and operated by the Bureau of Reclamation. The Secretary of the Interior authorized development of the project on May 15, 1905, under provisions of the Reclamation Act of 1902 (32 Stat. 388). Construction began on the project in 1906 with the building of the main "A" Canal. Project water was first made available

May 22, 1907, to the lands now known as the Main Division. This initial construction was followed by the completion of Clear Lake Dam, the Lost River Diversion Dam and many of the distribution structures, and the Lower Lost River Diversion Dam. Link River Dam, at the outlet of Upper Klamath Lake (UKL), was completed in 1921 and regulates the flows of this once natural lake. Upper Klamath Lake provides the majority of irrigation supplies for project lands. The Malone Diversion Dam on Lost River was built in 1923 to divert water to Langell Valley. The Gerber Dam on Miller Creek was completed in 1925; the Miller Diversion Dam was built in 1924 to divert water released from Gerber Dam. Clear Lake and Gerber Dams provide flood protection and irrigation benefits to Lost River-dependent lands. Irrigation water is delivered through this system to about 220,000 acres in Klamath County in southern Oregon and Modoc and Siskyou counties in northern California (USBR 2001). The project is operated so that flows of the Lost River and Klamath River are completely controlled except in some flood periods.

The focus of the 2001 curtailment is the water in UKL. The lake is fed by the Williamson, Sprague, and Wood rivers. The area of the contributing watershed is about 3,800 mi^2. Average annual inflow is 1.3 million acre-ft (MAF). When the lake is full, the average lake depth is about 8 ft. In a drought average lake depth may be reduced to 3 ft. Storage capacity is 486 thousand acre-ft (TAF), making for 3:1 ratio of average inflow to storage. This limited storage capacity is insufficient to simultaneously provide water for Reclamation project irrigation, other non-project irrigation, and instream needs through a drought year, especially if allocations are based on a normal water year.[5] Average annual diversions to project contractors and the wildlife refuges at the southern end of the project range between 300 and 475 TAF. Within the project, water use efficiency rates are high compared to other arid regions and California at about 2.2 acre-ft per acre. This is in large part due to the configuration of the project. Return flows are reused successively by "downstream" farms, the wildlife refuges, and finally return into the Klamath River.

The three worst droughts on record have occurred in the last 10 years: in 1992 inflows were about 570 TAF, in 1994 about 640 TAF, and in 2001 about 750 TAF (Ryan 2001). In the 1992 and 1994 droughts, competing instream demands for water had not yet attained legally enforceable priority, so farmers were allocated water until supply was exhausted.

Upper Klamath Lake is hypereutrophic and experiences high rates of phosphorous loading from upstream runoff. Logging and ranching activities that accelerate erosion and nutrient leaching in the volcanic soils upstream have been cited as factors contributing to higher nutrient runoff levels. Approximately 40 percent of the phosphorous load is thought to derive from these sources (Kaan 2001). These nutrients become embedded in lake sediments of at least 1 m and become resuspended through wind action. Estimates of the embedded phosphorous range from 60 to 90 percent (Kaan 2001, Todd 2001). Approximately 35,000 acres of former marshland at the upstream end of the lake were converted to farmland in the last century, thereby reducing the capacity of the wetland to filter nutrients as they enter the lake. In recent years about 15,000 acres of these farmlands have been restored to wetlands.

Two fish species that inhabit UKL, the Lost River and shortnose sucker, have been listed as endangered by the U.S. Fish and Wildlife Service (USFWS), and lake conditions have been cited as prime contributing factors in the decline of these populations.

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[5] With 50-55 percent of normal water availability there is not sufficient water to meet total demand for ESA species, as determined by USFWS and NMFS. This is evident from a comparison of the Bureau's actual 2001 flow regime with the flows recommended in the NMFS biological Sprague opinion.

The Link River dam withholds UKL's water and marks the hydrologic division between Upper and Lower Klamath basin. Below Link River Dam, the Klamath runs about 260 miles to the Pacific Ocean. The major tributaries along this course are the Shasta, Scott, Salmon, and Trinity rivers. The Klamath ranks third in flow among California rivers. Historically, the Klamath River is known for large runs of coho and chinook salmon. The development of water resources on the tributaries and mainstem have contributed to the loss of spawning habitat and have been implicated as jeopardizing the survival of the coho salmon by the National Marine Fisheries Service (NMFS).

A general adjudication of the Upper Klamath basin was initiated in 1976 under state law. The state action follows the United States' 1975 Federal suit, *U.S. v. Adair* (U.S. District Court 478 F. Supp. 336, and on appeal 723 F.2d 1394), in which the United States sought a declaration of water rights within the Williamson drainage. In large measure the Federal and tribal plaintiffs ultimately prevailed in *Adair* inasmuch as the priority dates of their water rights are superior to the Klamath project and all of its contractors, and that they were allowed to proceed concurrently in a Federal court. But the state adjudication is the venue where the actual quantification of those rights will occur, and that process is ongoing.

The ascendance of Endangered Species Act issues in the Klamath Basin is a parallel process that has also worked through Federal courts. Here also, Federal interests have, for the moment, prevailed. Outside of the basin, the legal issue of takings integrates ESA issues with water allocation decisions. We discuss these themes in greater detail below.

Tribal issues

The Klamath Indian Tribes have treaty-based rights. The exercise of some of these rights is affected by project operations. When the Klamath Project was initiated there were thousands of Native Americans and early settlers actively using the basin's resources. The Modoc and Klamath tribes had hunted, fished, and foraged "since time immemorial" in the upper basin. Most directly pertinent to the 2001 curtailment is the Oregon Klamath tribe's longstanding reliance on indigenous Lost River and shortnose suckers and the Hupa and Yurok tribes' reliance on coho salmon. Both were traditional food sources for the tribes.

In 1864 the Oregon Klamath and Modoc tribes entered into a treaty with the United States. The Klamath tribe relinquished aboriginal claim to about 12 million acres of land in exchange for a reservation of approximately 768,000 acres in the Upper Klamath Basin, above UKL. The treaty specifically protected the Indians' right to pursue their traditional culture and means of livelihood while encouraging them to develop an agricultural mode. This was not a grant of rights to the Indians, or just an implied right deriving from the congressional purpose for the land reservation of 1864, but a reservation of rights already possessed.

In 1887 Congress passed the General Allotment Act that changed the nature of land ownership within the reservation from allowing only communal ownership to allowing individual ownership. The tribal reservation was terminated in 1954 under the Klamath Termination Act. Much of the former reservation was purchased by the United States and the balance of the reservation was placed in a private trust for the remaining tribe members. To complete the Klamath Termination Act the United States condemned most of the tribal land held in trust in 1973. This eliminated tribal title, but many individual tribe members continued to own individual parcels. In addition, the United States held title to much of the former reservation, portions of which became national forest lands and national wildlife refuges. Some lands also fell into non-tribal individual ownership.

In *U.S. v. Adair*, the Federal government sought a declaration of water rights in one of the upstream tributaries to UKL, the Williamson River. They were joined by the Klamath Tribe. (Subsequent to this case the Klamath Tribes were restored as a Federally recognized tribe under the Klamath Restoration Act of 1986. Pub. L. No. 99-398, 100 Stat. 849.) In the district court proceedings, the court chose not to decide any question concerning the actual quantification of water rights. Rather, it declared that "actual quantification of the rights to the use of waters of the Williamson River and its tributaries within the litigation area will be left for judicial determination, consistent with the decree in this action, by the State of Oregon under the provisions of 43 U.S.C. § 666 [the McCarran Amendment]." The McCarran Amendment waives the United States' sovereign immunity for the limited purpose of allowing the Government to be joined as a defendant in a state adjudication of water rights. The district court found that the tribe's water rights dated from "time immemorial."

Both sides appealed. The State of Oregon and individual defendants argued, first, that the district court should have dismissed the Federal suit, and second, that the district court erroneously awarded water rights to the tribe and the United States as the tribe's successor. The United States and the tribe argued that the district court erroneously awarded water rights to non-Indian successors of Indian landowners. The questions raised in the initial case fell within three basic categories: (1) whether water rights had been reserved for the use of Klamath reservation lands in the 1864 treaty, (2) whether such rights passed to the government and to private persons who subsequently took fee title to reservation lands, and (3) what priorities should be accorded the water rights of each of the present owners and users of former reservation lands. Although the district court declined to quantify the rights, it agreed to specify the proper method for measuring the reserved water rights originally attached to the reservation.

The question of whether a Federal or state court is the appropriate forum for adjudicating Federal or tribal water rights is significant because the interests of the nation and the state may, and often do, differ. State courts are alleged to favor state interests over Federal and tribal claims because such claims represent competition for scarce water resources in the arid West.[6] The argument could be posed the other way, that Federal courts favor national interests. Nonetheless, no state possesses treaty responsibilities to the tribes comparable to those borne by the Federal government. The issue was addressed by the Supreme Court in *Colorado River Water Conservation District v. United States*, [424 U.S. 800, 96 S. Ct. 1236] in 1976. There, the court found that that the McCarran Amendment allows concurrent state and Federal jurisdiction over water rights disputes, and that the state's jurisdiction extends to Federal reserved water rights, including Indian water rights. The court cited the McCarran amendment and the use of "wise judicial administration, [and] regard to conservation of judicial resources and comprehensive disposition of litigation." The most important factor in favor of Federal dismissal and state oversight was the McCarran Amendment itself, in which the court found expressed a "clear Federal policy" to avoid "piecemeal adjudication of water rights in a river system" where a comprehensive state system for adjudication of water rights was available.[7]

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[6] For a more detailed discussion see "The Supreme Court's New Sovereign Immunity Doctrine and the McMarran Amendment: Toward Ending State Adjudication of Indian Water Rights." Stephen M. Feldman. The Harvard Environmental Law Review. Summer, 1994.

[7] In full the Amendment states that:
(a) Consent is given to join the United States as a defendant in any suit (1) for the adjudication of rights to the use of water of a river system or other source, or (2) for the administration of such rights, where it appears that the United States is the owner of or is in the process of acquiring water rights by appropriation under State law, by purchase, by

These standards allowed the court in *Adair* to determine whether concurrent proceedings in Federal and state courts or only in the state court were most appropriate. The *Adair* court found that concurrent proceedings were appropriate according to the standards in *Colorado*. This interpretation also allowed the Federal court to determine the priorities among water rights within the upper basin. Had the Oregon Department of Water Resources progressed beyond an administrative investigation (in the 7 years between the adjudication filing and the *Adair* decision) and demonstrated the intent and capacity to adjudicate the basin in a timely manner the Federal role in the basin might have been determined solely at the state level.

Citing *Winters* 207 U.S. 564, (1908), *Cappaert* 426 U.S. 128, 138 (1976), *U.S. v. New Mexico* 438 U.S. 696 (1978), and a host of supporting case law, the *Adair* court established the basis for prioritizing the U.S. and tribal water rights. Since *Winters*, the Supreme Court has consistently held that the Federal government has the power to exempt reserved water for Indian reservations from contrary state prior appropriation law. *United States v. New Mexico*; *Cappaert*; *United States v. District Court for Eagle Country*, 401 U.S. 520, 522-23 (1971); *Arizona v. California*, 373 U.S. 546, 597-600 (1963), decree entered, 376 U.S. 340 (1964).

The *Adair* court also explicated the purposes of those rights and their linkage to reservations and treaties, mindfully not specifying the actual quantity and avoiding any duplication of the judicial effort that is slated to occur in Oregon's eventual adjudication of the upper Klamath. The scope of purposes included the sustenance of game and fish with the flows necessary for their survival. The court articulated how this kind of right differs from the standard requirements of the prior appropriation doctrine. Because the diversion of water is not required to support fish and game, the water right reserved to further the tribe's hunting and fishing purposes is "unusual in that it is basically non-consumptive … Rather, the entitlement consists of *the right to prevent other appropriators from depleting the streams waters below a protected level in any area where the non-consumptive right applies*" (emphasis added). These reserved rights are not unlimited. Although the Indians once had exclusive access to the resources, the constraint the court applied is the amount of water necessary to "provide the Indians with a livelihood—that is to say, a moderate living." *Washington v. Fishing Vessel Ass'n*, 443 U.S. 658, 99 S. Ct. 3055 citing *Arizona v. U.S.* 373 U.S. 546, 83 S. Ct.1468. The court was also careful to distinguish that treaty rights only apply to members of the tribe and cannot, therefore, be transferred to the non-tribal successors. Specifically, the United States has not acquired water rights of the same type that tribal members enjoy through its reacquisition of reservation lands. Rather it has acquired water rights consistent for the purposes of the reservation to which those lands are attached. In this case forest and refuge purposes.

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exchange, or otherwise, and the United States is a necessary party to such suit. The United States, when a party to any such suit, shall (1) be deemed to have waived any right to plead that the State laws are inapplicable or that the United States is not amenable thereto by reason of its sovereignty, and (2) shall be subject to the judgments, orders, and decrees of the court having jurisdiction, and may obtain review thereof, in the same manner and to the same extent as a private individual under like circumstances: Provided, That no judgment for costs shall be entered against the United States in any such suit.
(b) Summons or other process in any such suit shall be served upon the Attorney General or his designated representative.
(c) Nothing in this section shall be construed as authorizing the joinder of the United States in any suit or controversy in the Supreme Court of the United States involving the right of States to the use of the water of any interstate stream.
43 U.S.C. § 666 (1976).

Downstream, the Yurok and Hupa Valley tribes have Federal Indian reserved fishing rights to take anadromous fish[8] within their reservations in California (Solicitor Opinion 1993). These rights were secured to the Yurok and Hupa Indians by a series of 19th century executive orders and confirmed to the Yurok and Hupa Tribes by the 1988 Hoopa [sic]-Yurok Settlement Act (HYSA), 25 U.S.C. §13OOi et - seq. The Hupa Valley Reservation is situated on a reach of a major Klamath River tributary, the Trinity River, above the confluence of these two rivers. The Yurok Reservation is situated on the mainstem of the Klamath as it feeds into the Pacific Ocean. In 1855, the President, by Executive Proclamation, established the Klamath Reservation in California. The Hupa Valley Reservation was formally set aside for Indian purposes by executive order in 1876. The HYSA partitioned the reservation into the present Hupa Valley and Yurok Reservations and declared the assets of each reservation held in trust by the United States for the benefit of the respective tribes. 25 U.S.C. 5 1300i-l(b). The Yurok and Hupa Valley Tribes' fishing rights entitle them to take fish for ceremonial, subsistence, and commercial purposes. *United States v. Eberhardt*, 789 F.2d 1353, 1359 (Ninth Cir. 1986). Like the Klamath Tribe, their fishing rights include the right to harvest quantities of fish on their reservations "sufficient to support a moderate standard of living."

The executive orders setting aside what are now the Yurok and Hupa Valley Reservations also reserved rights to an instream flow of water sufficient to protect the Tribes' rights to take fish within their reservations. *Colville Confederated Tribes v. Walton*, 647 F.2d 42, 48 (Ninth Cir.), cert. denied, 454 U.S. 1092 (1981). As with the Klamath Tribes, the Yurok and Hupa Tribes' water rights include the right to prevent other appropriators from depleting the streams' waters below a protected level.

Reserved rights are an established but pliable standard. The priority of a reserved right dates from when initial use of the resource began or from the date of the reservation and is of a quantity sufficient to fulfill the primary purposes of the reservation. Treaty rights that require water may apply even after the termination of a reservation, but may not be transferred to non-treaty interests. Klamath Basin tribes surrounding the reclamation project undoubtedly possess superior rights to those of the project and its contractors. Unanswered at the time of this writing is the exact quantification of the rights of these parties.

Implications of the Klamath decision on the Tribe-Federal-State-local relations

"Fish is code for tribes among the basin's farm community," we were told by a social worker who had spent 3 weeks retraining farmers in the agricultural communities that rely on Klamath Project waters. Although basis of the tribal claim is broader than fish or the Endangered Species Act, tribally commissioned scientific studies of basin fish populations and use of the ESA support this view. They indicate that tribal interests have been, and are, actively constructing the legal and scientific basis to support the reallocation of water within the Klamath Basin system. The Klamath Basin tribes and tribes around the nation are effectively the most senior appropriators. The assertion of their claims jeopardizes subsequent appropriators and clients of Federal projects in particular.

Judicial opinions fortify the Klamath Basin tribe's legal claim to water, and push the contest into the arena of science. Significantly, Federal courts were allowed to determine

[8] The endangered species listing and underlying science of the coho salmon is discussed in greater detail in a later section on the ESA.

priorities. How much water and what flow regimes are required to support game and fish will be the subject of agency-managed inquiry. Already there are signs that this process will be every bit as contentious as the preceding litigation. Affected project agricultural interests have sought review of Federal agency decision-making and the underlying science. Future agency actions involving science that are unfavorable to one or another interest will likely receive similar attention. In circumstances where states evince capacity and willingness to settle tribal claims, challenges to Federal adjudication may succeed.

The ESA and the issue of takings

Protection of endangered coho salmon in the Klamath River below UKL, and protection of the Lost River and shortnose sucker in UKL, under the Federal Endangered Species Act, were in the forefront of the year 2001 Operations Plan for the Klamath Project. In 1973, Congress enacted the ESA "to provide a program for the conservation of ... endangered and threatened species." 16 U.S.C. § 1531(b). The purposes of the ESA are "to provide a means whereby the ecosystems upon which endangered species and threatened species depend may be conserved, to provide a program for the conservation of such endangered species and threatened species, and to take such steps as may be appropriate to achieve [these] purposes . . ." Id. § 2(b). The Endangered Species Act requires the "Secretary of the Interior to promulgate regulations listing species of animals that are "threatened" or "endangered" under certain criteria and to designate their "critical habitat." 16 U.S.C. § 1533. The ESA further requires each Federal agency to ensure that any [Federal] agency action "is not likely to jeopardize the continued existence of any endangered species or threatened species or result in the destruction or adverse modification of [critical] habitat." Id. § 1536(a)(2). If an agency determines that a proposed action could adversely affect a listed species, it must engage in formal consultation with the appropriate expert agency, i.e., the U.S. Fish and Wildlife Service or the National Marine Fisheries Service. The consulting agency must then provide the action agency (Reclamation in this case) with a "Biological Opinion" explaining how the proposed action will affect the species or its habitat, specifically whether the proposed action will result in "jeopardy" or "no jeopardy." The ESA has had wide-ranging and often controversial impact on natural resource activities, especially so where Federal actions are involved.

In the Klamath Basin the fundamental conflict concerns the allocation of project water for irrigation and ESA requirements that water be left instream. 16 U.S.C.A. § 1536 (2) states that "[each] Federal agency shall, in consultation with and with the assistance of the Secretary, insure that any action authorized, funded, or carried out by such agency (hereinafter in this section referred to as an "agency action") is not likely to jeopardize the continued existence of any endangered species or threatened species or result in the destruction or adverse modification of habitat of such species which is determined by the Secretary, after consultation as appropriate with affected States, to be critical, unless such agency has been granted an exemption for such action by the Committee pursuant to subsection (h) of this section. In fulfilling the requirements of this paragraph each agency shall use the best scientific and commercial data available."

This passage severely restricts an agency's options. Although the Klamath Project accounts, on average, for only one-third of the available flow into UKL and a far smaller portion of the Klamath's total discharge, it must respond to a basin-scale problem that is only partially of its own creation. Many factors outside the project have contributed to the decline in fish populations, including land use practices upstream that elevate nutrient runoff and stimulate eutrophication in UKL, and development and diversion of water resources in downstream tributaries that decrease spawning habitat and degrade water quality. While the instigators of those actions have largely not been required to comply with the ESA, Reclamation is forbidden from inflicting any further jeopardy once a species threshold is been reached.

The question of Federal agency culpability and duty has worked its way through the courts in precedent-setting cases outside the basin, notably *TVA v. Hill*, and in several cases within the basin that led to and followed the 2001 Operation Plan, notably *Klamath Water Users Association v. Patterson*, *Pacific Coast Federation of Fishermen's Associations v. U.S. Bureau of Reclamation*, and *Kandra et al. v. U.S.* Often the critical issue will be procedural rather than substantive, and since Reclamation projects provide water through contractual arrangements, contract law is also intertwined in the legal wrangling over species conservation (see for example *O'Neill v. U.S.* 1995). Here again we see that the questions could be framed quite differently, for example with an emphasis on contractual relationships and secondary or tertiary concern with Federal conservation law. We now examine these cases to understand the ample warning and deliberation that preceded the 2001 plan, to understand how seemingly external factors came to shape the decision, and to infer how the plan may influence the policy framework.

In *TVA v. Hill* (Decided June 15, 1978) the Supreme Court of the United States examined in great detail the legislative background of the ESA and established Congress' clear and unambiguous intent that species preservation is among the "highest priorities." The ESA requires Federal agencies to avoid jeopardy "whatever the cost."

The case involved the nearly complete Tellico Dam in Tennessee and an endangered species, the snail darter. The snail darter's habitat would suffer total destruction if the newly constructed dam was permitted to be filled. The Secretary of Interior declared that reach of the Little Tennessee River "critical habitat" and environmental groups sued to halt dam construction. The Supreme Court affirmed the Court of Appeals injunction to halt all activities that would destroy or modify critical habitat, even though Congress had expended about $100 million on construction of the dam. Although there were undoubtedly local consequences to the decision, the principal impact was absorbed at the national level. Investment-backed expectations may have been anticipated, but the flow of benefits had not yet begun. These characteristics distinguish the *TVA* case from the Klamath cases, and a recent takings case in California, *Tulare v. U.S.*

Klamath Water Users Association v. Patterson, (U.S. District Court for the District of Oregon, Decided April 24, 1998), is another case that is driven by ESA compliance and impacts from water operations on endangered species. Reclamation proposed water flows of 1,000 cubic feet per second (ft^3/s) from the Link River Dam, the flow-controlling structure on UKL, that addressed sucker and coho needs. However, this level of flow would have violated Pacificorp's FERC license that specified 1,300 ft^3/s in September. The discrepancy in flow standards was resolved by making the Reclamation recommended flow contingent on FERC concurrence. The Klamath Water Users Association (KWUA) sought a temporary restraining order based on their alleged third party beneficiary status. The court denied this as inconsistent with the record, citing *Norse v. Henry Holt & Co.*

Judge Michael R. Hogan explicated the legal relationship between the Bureau of Reclamation, Pacificorp (a hydropower interest), and the KWUA. Judge Hogan also stated that KWUA's contract rights are subservient to senior tribal rights and subsequent legislation such as the ESA. Both Pacificorp and KWUA have a contractual arrangement with Reclamation. KWUA is not, as it had argued, a third party beneficiary under Pacificorp's contract with Reclamation, and therefore cannot legally influence the relationship between Reclamation and Pacificorp, and specifically, may not veto proposed modifications to the contractual relationship between those parties.

In the appeal of *Klamath Water Users Protective Assoc. v. Patterson* in September of 1999, Judge A. Wallace Tashima found that Federal law controls the interpretation of the contracts. The appelate court looked to *Kennewick I.D. v. U.S.* for guidance and general principles in interpreting these contracts. *A contract must be read as a whole. Contract terms are to be given their ordinary meaning.* The distinction between intended and incidental beneficiaries is explicated. The appeals court affirmed the district court finding (above).

In *Pacific Coast Federation of Fishermen's Ass'n v. Bureau of Reclamation,* N.D. Cal. April 3, 2001, Judge Sandra Brown Armstrong analyzed the procedures mandated under the ESA. In May of 2000, various conservation and fishing interests, including several defendants-interveners in this case, filed a lawsuit challenging Reclamation's 2000 Plan. Plaintiffs alleged that the Bureau of Reclamation violated the ESA by releasing water for irrigation and water flows in the Klamath River prior to consultation with NMFS (in 2000) regarding the Project's effects on threatened coho salmon. Judge Armstrong agreed and issued an injunction. The Bureau of Reclamation was enjoined from sending irrigation deliveries to the Klamath Project area whenever Klamath River flows at Iron Gate Dam drop below the minimum flows recommended in the Hardy Phase I report, until such time as the Bureau completed a plan to guide operations in the new water year [2001], and consultation concerning that plan was completed, either by (1) formal consultation to a "no jeopardy" finding by the NMFS, or (2) the Bureau's final determination, with the written concurrence of the NMFS, that the proposed plan was unlikely to adversely affect the threatened coho salmon. [This compelled the Bureau of Reclamation to act as it did in 2001.]

Pacific Coast Federation of Fishermen's Ass'n grows out of the 1999 and 2000 water operations plans for the Klamath Project. Judge Armstrong writes that "[T]he Secretary of the Interior, through the Bureau of Reclamation, must manage and operate the Klamath Project pursuant to various legal responsibilities. Pursuant to the Reclamation Act of 1902 the Bureau of Reclamation has entered into contracts with various water districts and individual water users to supply water, subject to availability, for irrigation purposes. Two national wildlife refuges, the Lower Klamath and Tule Lake national wildlife refuges, also are dependent on the operations of Klamath Project and have Federal reserved water rights to the amount of water, unreserved at the time of creation of the refuges, necessary to fulfill the primary purpose of the refuges. In addition, the Secretary of the Interior has recognized that a number of Oregon tribes, including the Klamath, Yurok and H[u]pa valley tribes, hold fishing and water treaty rights in the [Klamath] basin." *Klamath Water Users Protective Assoc. v. Patterson*, The Bureau of Reclamation has an obligation to protect tribal trust resources, including the Klamath River coho salmon. It also has an obligation under the ESA not to engage in any action that is likely to jeopardize the continued existence of an endangered or threatened species or result in the destruction or adverse modification of the critical habitat of such a species." [citations ommitted]

As noted above, under the ESA, any Federal agency must consult with the appropriate agency if its actions may impact an endangered species or its habitat. In this instance the Bureau of Reclamation failed to consult. It was ordered to do so and enjoined from releasing more water than allowed by a NMFS commissioned study (the Hardy report) until the Bureau completed a concrete plan. This set the stage for the 2001 water operations plan. Basin water users filed a procedural challenge to the 2001 Operation Plan in *Kandra et al. v. U.S.* [145 F. Supp. 2d 1192; 2001] in the U.S. District Court for the District of Oregon. On April 30, 2001, Judge Ann Aiken wrote that, as in *TVA v. Hill*, “the ESA requires an agency to avoid jeopardy [to an endangered] species, ‘whatever the cost.’”

Stephen Kandra, David Catka, Klamath Irrigation District, Tulelake Irrigation District, Klamath Water Users et al. had sought injunctive relief from implementation of the Bureau of Reclamation’s 2001 Ops Plan. Plaintiffs claimed the 2001 plan breached their contracts and was “arbitrary and capricious” under the Administrative Procedures Act (APA) in regards to the National Environmental Policy Act and the ESA.

The opinion identifies the listed endangered (shortnose and Lost River suckerfish) and threatened (coho salmon and bald eagle) species that rely on the waters in the UKL and for which the Bureau of Reclamation is accountable. The opinion also identifies the Bureau of Reclamation’s tribal (Klamath and Yurok) responsibilities. Although the tribal issues may be as strong or stronger than the ESA issues, this case is based on ESA considerations, and the tribal responsibility issues are not in the forefront.

Under the National Environmental Policy Act of 1960 [42 U.S.C.A. §§ 4321-61], Federal agencies must issue an Environmental Impact Statement (EIS) if they undertake a “major Federal action.” *Kandra* asserted that the operational changes in the 2001 Operation Plan constituted such an action. The court disagreed, noting that if it were to find otherwise, Federal agencies would be preparing EISs perpetually. Even if an EIS were required, the flow of required information (streamflow forecasts from the Natural Resources Conservation Service, Biological opinions from NMFS and USFWS) did not allow the Bureau of Reclamation adequate time to prepare an EIS before management operations began. The court also recognized the need for a long-term operating plan and chastised the Bureau of Reclamation for not issuing one.

After the Bureau of Reclamation initiated formal consultation, both the USFWS and NMFS found that Reclamation’s operations jeopardized the species under their purview, suckers and coho, respectively. Both agencies proposed “reasonable and prudent alternatives” (RPAs). Eagles would be harmed, but not jeopardized.

Upon review of the draft biological opinions, Reclamation informed the USFWS and NMFS that the forecasted water supplies for 2001 were not adequate to meet the needs of both RPAs. On April 6, 2001, USFWS and NMFS released their final biological opinions on the effects of the project on the suckers, coho salmon, and bald eagles.

The USFWS and NMFS adjusted the minimum UKL elevations and Klamath River flows to reflect the reduced water available for the 2001 water year. The minimum elevation “reasonable and prudent alternative” (RPA) was intended to increase water quality and the physical habitat for juvenile and adult suckers, and provide for access to spawning areas.

The NMFS proposed a range of minimum instream flows in the Klamath River below Iron Gate Dam from April through September. The river flows were recommended in order to increase riparian habitat for coho salmon. The RPAs in the NMFS biological opinion are limited in duration, because NMFS expects additional information regarding flow and salmon habitat will become available in the near future.

Also on April 6, 2001, Reclamation issued its 2001 Operations Plan, which incorporated the conclusions contained in the biological opinions and implements the RPAs proposed by the USFWS and NMFS. After implementation of the RPAs, the availability of irrigation water was severely limited, and most project lands received no water deliveries.

While Judge Aiken acknowledged that undisputed economic hardship would occur as a result of the plan, she stated “Threats to the continued existence of endangered and threatened species constitute ultimate harm. “*Congress has spoken in the plainest of words, making it* *abundantly clear that the balance has been struck in favor of affording endangered species the highest of priorities, thereby adopting a policy which it described as 'institutionalized caution.' Tennessee Valley Authority v. Hill*." As recognized by the District Court and the Ninth Circuit, plaintiffs' contract rights to irrigation water are *subservient to ESA* and tribal trust requirements (see *Patterson)*. Therefore, plaintiffs cannot assert breach of contract based on Reclamation's allocation of water to protect the suckers and salmon.

Plaintiffs also suggested that the Bureau of Reclamation protect the project water users against junior water users outside of the project. Under Reclamation law, the Secretary is bound to state law provided such state laws are consistent with Congressional directives (see *California v. U.S.*). The State of Oregon is adjudicating the Klamath Basin and it appeared to the Bureau of Reclamation that until the adjudication was complete, no action against juniors by seniors would be allowed by the State of Oregon.

Under the Administrative Procedures Act, an agency decision must be upheld unless it is "arbitrary, capricious, an abuse of discretion, or otherwise not in accordance with law." 5 U.S.C. § 706. The court is not empowered to substitute its judgment for that of the agency. *Citizens to Preserve Overton Park, Inc. v. Volpe*, 401 U.S. 402, 416, 28 L. Ed. 2d 136, 91 S. Ct. 814 (1971). "When specialists express conflicting views, an agency must have discretion to rely on the reasonable opinions of its own qualified experts even if, as an original matter, a court might find contrary views more persuasive." *Marsh v. Oregon Natural Resources Council,* 490 U.S. at 378. In other words, a court "may reverse the agency's decision as arbitrary or capricious only if the agency relied on factors Congress did not intend it to consider, entirely failed to consider an important aspect of the problem, offered an explanation that ran counter to the evidence before the agency, or offered one that is so implausible that it could not be ascribed to a difference in view or the product of agency expertise." *Western Radio Service Co. v. Espy,* 79 F.3d 896, 900 (Ninth Cir. 1996) (citing *Dioxin/Organochlorine Center v. Clarke*, 57 F.3d 1517, 1521 (Ninth Cir. 1995)).

Aiken writes "As an initial matter, plaintiffs' characterization of Reclamation's duty to protect ESA species and tribal resources as a "change in operations" implemented in response to various "demands" is inaccurate. Reclamation "has responsibilities under the ESA as a Federal agency. These responsibilities include taking control of the [Project] when necessary to meet the requirements of the ESA, requirements that override the water rights of the Irrigators." *Patterson*, 204 F.3d at 1213.

Similarly, the United States, as a trustee for the tribes, is obligated to protect the tribes' rights and resources. Water rights for the Klamath Basin Tribes "carry a priority date of time immemorial." *Adair*, 723 F.2d at 1414. These rights "take precedence over any alleged rights of the Irrigators." *Patterson*, 204 F.3d at 1214. Reclamation, therefore, has a responsibility to divert the water and resources needed to fulfill the tribes' rights.

As such, Reclamation's "change in operation" is mandated by law, and the requirements of NEPA do not apply. *National Wildlife Federation v. Espy*, 45 F.3d 1337, 1343 (Ninth Cir. 1995). The ESA requires an agency to avoid jeopardy to species, "whatever the cost" *TVA v. Hill*, in this case that means reallocating irrigation water to provide fish habitat.

Plaintiffs allege that the NMFS and USFWS selectively reported information in the biological opinions and ignored relevant scientific evidence. Plaintiffs would have the court substitute plaintiffs' analysis of the relevant science for that of the expert agencies. However, the court cannot force Reclamation to choose one alternative over another. See *Southwest Center for Biological Diversity v. United States Bureau of Reclamation*, (Ninth Cir. 1998) (the Secretary is *not required* to choose the best alternative or to explain why one alternative was chosen over another). Absent a showing that NMFS or USFWS failed to consider relevant, available, scientific data, plaintiffs are unlikely to prevail on this claim. Even if plaintiffs could show a likelihood of success on the merits of their ESA claims, the ESA explicitly prohibits the relief they seek.

[**Note:** Kandra relied on *T.V.A.* and was consistent in its balancing of interests in favor of protection of endangered species over other interests. However, TVA did not involve existing beneficiaries that were accustomed to and expectant of a flow of benefits. In Kandra, we are dealing with just that kind of interest. In this way, Kandra may be understood to expand the scope of the ESA.]

Takings

We now turn to the issue of regulatory takings by examining the defining takings case, *Lucas*, and a recent case that shares characteristics with the situation in the Klamath Basin, the *Tulare* case. The major point of this section is that when regulations deny an owner the use of his or her property a disproportionate burden for a public purpose is placed on the owner. This is a compensable action.

Lucas v. South Carolina Coastal Commission
Decided June 29, 1992
Supreme Court of the United States

"The Fifth Amendment is violated when land-use regulation 'does not substantially advance legitimate state interests or denies an owner economically viable use of his land.' Agins, supra, at 260."

This is a (if not *the*) leading "takings" case that involves a beachfront property owner with "investment-backed expectations" who is prohibited from developing his property by subsequent state legislation. The principal question posed is whether the owner has been deprived of all economically beneficial use of the land (bundle of rights) as a consequence of regulation. Even where that is the case, it is argued that if "background principles" were in existence that precluded nuisance or other undesirable uses of property, the state may prohibit them without compensation. That is, those uses were never part of the title to begin with.

In defining the boundaries of the Beachfront Management Act, South Carolina imposed the burden of preventing dune erosion on a subset of property owners of which Lucas was a member. The principle of disproportionate burden is implied in the court's verdict, although it is not the focus. In the Klamath instance, this is a key argument. The jurisdiction of the Bureau of Reclamation is a subset of burdened *property* users within a larger context of multiple users and cumulative effect problems. We emphasize property because the water users obtain water through contracts that specifically exclude interruptions in deliveries for a variety of reasons. This fact makes their "taking" claim more difficult, though evidently not beyond reach.

A takings claim has been filed in the Klamath. We have not seen it, but suspect it will follow the formula that prevailed in *Tulare*. There, water contractors went around the water contract, with its specific exclusions, to make the claim against regulatory agencies that issued biological opinions requiring the contracting agency, the California State Water Project, to leave water that would have been diverted to the contractors in the watercourse for reasons of species and habitat protection.

Tulare v. U.S.
United States Court of Federal Claims, Judge John P. Wiese
Filed April 30, 2001

"This case concerns the delta smelt and the winter-run chinook salmon—two species of fish determined by the U.S. Fish and Wildlife Service and the National Marine Fisheries Service to be in jeopardy of extinction. The efforts by those agencies to protect the fish—specifically by restricting water out-flows in California's primary water distribution system—bring together, and arguably into conflict, the Endangered Species Act and Californias century-old regime of private water rights. The intersection of those concerns, and the proper balance between them, lie at the heart of this litigation."

"The Fifth Amendment to the United States Constitution concludes with the phrase: "nor shall private property be taken for public use, without just compensation." The purpose of that clause—as the oft-quoted language from *Armstrong v. United States*, (1960) explains—is "to bar Government from forcing some people alone to bear public burdens which, in all fairness and justice, should be borne by the public as a whole." At issue, then, is not whether the Federal government has the authority to protect the winter-run chinook salmon and delta smelt under the Endangered Species Act, but whether it may impose the costs of their protection solely on plaintiffs."

This case explains the difference between physical and regulatory takings, and finds that the Federal government's actions, through the USFWS and NMFS, comprise a physical taking. By overlooking all state-Federal agreements subsequent to the State Water Resources Control Board's Decision 1485, and focusing solely on that document, Judge Wiese found that "The Federal government is certainly free to preserve the fish; it must simply pay for the water it takes to do so." Judge Wiese ignored the extensive background principles that Amici Curiae compiled in two briefs. This decision was unusual inasmuch as courts generally defer to the State in in-state water matters and acknowledge the state's expertise. Because there are actual costs, however, other branches of the Federal government (Department of Justice, or the Government Accounting Office, for example) may take a pragmatic and dim view of the judgments against the United States and appeal the ruling on non-ideological grounds.

Filing suit against the USFWS and NMFS is a charted course that the Klamath Water Users Association can readily adopt, with the same legal representation that succeeded in *Tulare*, Marzulla & Marzulla.

A less blunt form of administrative influence lies in whether, and how vigorously, Federal agencies are directed to appeal unfavorable judicial decisions. In *State of Idaho v. United States Forest Service* (Case No. CV01-11-N-EJL, District Court for the District of Idaho, April of 2001) the Justice department conceded that the Forest Service's roadless rule would cause plaintiffs (logging and snow-mobiling interests) irreparable harm, which significantly undermines any defense of the rule. This action was simultaneous with public announcement of administrative support for the roadless rule. This nuanced tactical approach illustrates some of the more subtle forms of influencing resource policy. No direct monetary damage has been alleged against the United States in the *Idaho* case, which should reduce interagency friction over a weak Federal defense. In *Tulare* there are monetary damages. Although the penalty phase has not yet taken place, newspaper reports estimate up to $15 million in compensation is due to the plaintiff irrigators. By refusing to appeal or by offering a weak appeal, the case that the costs of the ESA are disproportionate to the benefits it provides, or at least inequitably allocated, is advanced. This claim is magnified as attacks on the underlying science, like the National Academy of Science review of the Klamath biological opinions, uncover the inherent uncertainties of conservation science.

Summary

The financial stakes in the Klamath are modest when compared with other basins, like the Columbia and Sacramento-San Joaquin, that also confront ESA issues. Those basins have integrated systems of hydroelectric plants, water storage and conveyance structures for agricultural and municipal use, and navigation enhancements that directly serve tens of millions of people. Those basins have avoided rigid ESA compliance thus far through a variety of alternative arrangements. The costs of rigid ESA compliance in those basins would surely be many times more than those incurred in the Klamath. The fact that similar sets of Federal and state agencies confronting similar conflicts in basins of vastly different political and economic scale implies that the form of ESA implementation varies in accordance with these dimensions. Yet the message of the Klamath decision, that the ESA can inflict extreme cost on traditional resource users, is readily transferable to any ESA-resource use conflict irrespective of scale. Differential enforcement of a national regulation understandably creates a sense of injustice among those affected. However, the source of the injustice appears to lie in the relationship between political-economic integration and the degree of regulatory enforcement, rather than with the regulation itself. When viewed in combination with the *Tulare* court decision, the Klamath water allocation of 2001 may influence "stakeholders," legislators, agencies, and courts confronting claims in the Columbia, Sacramento-San Joaquin, and other river basins to weaken the ESA. Alternatively, these circumstances could motivate fragmented interests to coalesce and build the social fabric that shapes how the ESA is implemented.

The Bureau of Reclamation's Klamath Project, and its dependent contracting irrigators, inherit asymmetric responsibility for the effect of cumulative, basin-scale activities. The Bureau lacks the jurisdictional authority to address many of the sources of the basin's biophysical problems. As suggested in the history and preceding analysis, the pattern of response, both within the basin and outside of it, has often been to relocate stresses to the institutionally weaker parties. This short-run "solution" perpetuates and exacerbates the problem in the longer run.

Conclusion

Our legal and institutional assessment leads to the conclusion that the Klamath decision is consistent with existing law but raises issues in the law to potentially precedent-setting levels. In particular these are issues of (1) the extent of private burden for a public purpose, (2) the relative certainties in weighing the satisfaction of and burden for the public purposes and (3) the reasonable stress between administrative procedures and the natural and social processes in which they are used.

These issues arose in an outcome that was more extreme that any before it. In other words, although the policy was consistent with prevailing law, its application created an outcome that may well be inconsistent with legal intent.

The Federal government is one source of the difficulty: it has yet to seek means to reconcile the divergent directions among its territorial and functional jurisdictions, to seek compensatory coordination in the Klamath, or to use its capacities to avoid the dire outcomes of the April 6th decision.

A second source of difficulty is the states' continuing tendencies to treat the tribes, the senior rights holders, as residual claimants.

Finally, we note the obvious need to achieve social relations in the basin that will develop and support a governing principle of water allocation that recognizes the legitimacy of everyone's needs.

Citations

Note: Additional citations to be added.

Kaan, J. 2001. Testimony before the National Research Council, November 6, 2001. Sacramento, California. (Mr. Kaan is a consulting aquatic ecologist with Aquatic Ecosystems Sciences, LLC.)

Kelley, R. L. 1989. *Battling the inland sea : American political culture, public policy, and the Sacramento Valley*, *1850-1986*. University of California Press, Berkeley.

Ryan, M. 2001. Presentation of the Klamath Project for the National Research Council review of the 2001 Biological Opinions in Sacramento, California. November 6, 2001. Acting Area Manager, Klamath Project Region

Solicitor Opinion. 1993. *Memorandum from the Solicitor to the Secretary of Interior: Fishing Rights of the Yurok and Hupa Valley Tribes*, M-36979 (October 4, 1993) in *Klamath Project Historic Operation*. U.S. Department of the Interior, November, 2000.

Todd, R. 2001. Oregon State University Extension. Personal communication.

U.S. Bureau of Reclamation. 2001. *Klamath Project, California and Oregon*. Available at http://dataweb.usbr.gov/html/klamath.html#development

Draft
December 14, 2001

Water Law and the Klamath Basin

Reed Marbut, Oregon Water Resources Department

Introduction

The Klamath River begins in the mountains of Oregon and California east of the Cascade Range, flows generally southwesterly, and enters the Pacific Ocean near Crescent City, California. The Basin covers more than 16,000 mi^2. (For perspective, the states of New Jersey and Delaware combined cover approximately 10,000 mi^2.) Crater Lake, the only national park in Oregon, sits at the top of the Klamath River headwaters. The Klamath Marsh, Agency Lake Marsh, Lower Klamath Lake, Tule Lake Sump, and Clear Lake Reservoir are all designated as National Wildlife Refuges. Klamath Lake, at the confluence of the Williamson and Sprague rivers, is the largest lake in Oregon.

The lower Klamath River is home to a number of anadromous fish species, including the coho salmon. The Klamath Basin provides wintering habitat for the largest gathering of bald eagles in the lower 48 states. Over 80 percent of the seasonal habitat for Pacific Flyway waterfowl is found in the Klamath Basin. Hydroelectric power production has been an important resource in the Klamath since the late 19th century. Oregon has designated its lower segment of the Klamath River as a state scenic water way.

Oregon water law

As is the case in most western states, Oregon statutory law provides that all water within the state from all sources belongs to the public.[1] All such water is subject to appropriation for beneficial use. Once appropriated under the provisions of the state's water code, the right to use the water continues in the owner so long as the water is applied to a beneficial use under and in accordance with the terms of the certificate of water right, subject only to loss by non-use.[2] Except for certain defined exempt uses and uses that vested prior to enactment of the state's water code, any person intending to acquire a water right must apply to the Oregon Water Resources Department.[3]

In addition to the various state water right systems, certain authority to use and control water arises under Federal law. This authority includes the power of the Federal government to set aside (reserve) land from public domain for particular purposes (e.g., national forests, national parks, Indian reservations, military bases, etc.); to develop Federal irrigation, flood control, and hydroelectric projects; to manage rivers and lakes for protection of threatened or endangered aquatic species; and to protect navigation.

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[1] ORS 537.110.

[2] ORS 537.250(3).

[3] ORS 537.130(1).

Water law statutes

Notwithstanding the modest rule concerning use of water from a spring under ORS 537.800, Oregon water law is governed by the doctrine of prior appropriation. Oregon's appropriation procedure is set out in Oregon Revised Statutes (ORS) Chapters 536 through 541. Other ORS chapters address matters related to water resource surveys, river basin project development and interstate compacts,[4] hydroelectric power projects,[5] water use organizations,[6] and weather modification.[7] The basic statutory provisions of Oregon's appropriation doctrine are:

1. Water resource administration—ORS 536;
2. Appropriation—ORS 537;
3. Withdrawal of waters from appropriation—ORS 538;
4. Determination of pre-1909 vested and federal reserved water rights—ORS 539;
5. Distribution and transfer of rights—ORS 540; and
6. Miscellaneous provisions—ORS 541.

Water-use policy is set by the legislature and is implemented by a seven-member Water Resources Commission appointed by the Governor. Certain administrative responsibilities are delegated both by statute and by regulation to the director of the Water Resources Department (WRD). The Oregon legislature has articulated several policy standards concerning beneficial uses of water and public interest criteria associated with water use. In addition, the legislature has created programs for statewide coordination of water development and use, identification of minimum stream flows, stream basin planning, drought management, and enforcement of water use. Pursuant to its stream basin planning authority, the Commission may restrict or prohibit certain uses of water within a basin, or in cases of extreme over-appropriation, completely withdraw a stream or river from further appropriation.

Water right appropriation under Oregon's water code

Pursuant to ORS 537.130(1), an individual must submit an application for a permit before initiating a water use development. The application must describe all elements of the proposed water use. A map prepared by an Oregon certified water right examiner (CWRE) must accompany the application. (Any Oregon professional engineer or land surveyor may become certified as a CWRE upon completion of the certifying examination.) A fee must be submitted with the water right application and map.[8]

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[4]ORS 542.

[5]ORS 543.

[6]ORS 545 through 555.

[7]ORS 558.

[8]ORS 536.050(1).

The United States, the state, or any person has the power to secure a right-of-way across any public or private land as necessary for construction, maintenance, repair, and use of such right-of-way for the purpose of conveying water for all beneficial purposes. Such right-of-way may be acquired by condemnation in the manner provided by law for the taking of private property for public use.[9] In addition, any person may enter upon any land for the purpose of locating a point of diversion or a proposed canal, ditch, or other conveyance.[10]

Groundwater appropriation in Oregon

Groundwater is declared to be part of the public waters of the state, and except in limited circumstances, must be appropriated through the application/permit/certificate process.[11] Uses of groundwater for (1) stock watering, (2) watering any lawn or noncommercial garden not exceeding one-half acre in size, (3) certain school grounds and fields, (4) single or group domestic uses not exceeding 15,000 gallons per day, (5) down-hole head exchanges, and (6) single industrial or commercial uses not exceeding 5,000 gallons per day are exempt, and as such, do not need to secure a water-use permit.[12] The Commission is authorized to designate limited and/or critical groundwater areas where evidence of declining water levels or patterns of substantial interference between wells is found.[13] Well construction is regulated by the WRD.[14]

The Oregon Groundwater Code (ORS 537.505 to 537.793 and 537.992) preempts all local ordinances relating to well location, well construction, groundwater water allocation, and flow testing of wells.[15]

Pre-code water rights and adjudication

Since February 24, 1909, the right to appropriate water in Oregon has been governed by the provisions of ORS 537.110 through 270. Any use of water that began prior to February 24, 1909 is deemed to be a vested water right subject to quantification in an adjudication proceeding.[16]

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[9]ORS 772.305.

[10]ORS 537.320.

[11]ORS 537.505-537.720.

[12]ORS 537.545.

[13]ORS 537.730.

[14]ORS 537.747-537.780.

[15]See *Ashland Drilling, Inc. v. Jackson County*, 4 P.3d 748 (Or. App. 2000).

[16]Pre-1909, vested water rights are verified and documented in the adjudication proceeding described below. During the adjudication process, the right holder has the opportunity to prove the quantity of water that he/she has vested by beneficial use. Once quantified by the court, the right holder receives a decreed right for that amount.

Pre-1909 and Federal reserved water rights[17] are verified, quantified, and documented through such adjudication proceedings in the circuit court of the county in which the water use is located. This adjudication procedure is set out in ORS 539.010 through 539.240. Pre-1909 vested water rights in approximately two-thirds of the river basins in Oregon have been adjudicated.

In order to expedite collection of pre-1909 claims in the remaining river basins, the 1987 Oregon Legislature amended ORS Chapter 539 to require all property owners claiming a pre-1909 vested right to file a registration statement on or before December 31, 1994.[18] Federal reserved water right claimants, including federally recognized Indian tribes, are not required to file surface water registration statements; however, federal and Indian claimants can be required to participate in all general stream adjudications in Oregon in accordance with the McCarran Amendment.[19]

Each river basin adjudication is initiated by notice of the WRD director. Persons claiming a vested, unadjudicated right must file a "proof of claim" with the WRD. The director reviews the claims, examines each water use development, provides opportunities for affected parties to submit contests of claims and schedules appropriate hearings, and finally, prepares a “finding of fact and order of determination” to be filed in the circuit court in the county where the adjudication stream or river is located. Any person claiming an interest in the stream subject to the determination is made a party and is bound by the adjudication. The court will then review the director's determination and any exceptions that are filed, affirm or modify the order, and enter a final judgment in the form of a stream decree.

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[17]Federal reserved water rights, sometimes referred to as “Winters” rights, are rights to water created under Federal law. (See *Winters v. United States*, 28 S. Ct. 207 (1908).) These water rights are created, usually by implication, when the Federal government sets aside land from the public domain. The clearest articulation of the federal reserved water right concept is set out in the United States Supreme Court’s opinion in *Cappaert v. United States*, 96 S. Ct. 2062 (1976). “When the Federal government withdraws land from the public domain and reserves it for a federal purpose, the Government, by implication, reserves appurtenant water then unappropriated to the extent needed to accomplish the purpose of the reservation.” *Cappaert*, at 2069. “The implied-reservation-of-water-rights doctrine, however, reserves only that amount of water necessary to fulfill the purpose of the reservation, no more.” *Cappaert*, at 2071. The priority date of a water right associated with a federal reservation is the date the reservation was created. In the case of an Indian reservation, the date is generally the date of the treaty or executive order creating the reservation.

[18]ORS 539.230-539.240.

[19]43 U.S.C.⁄666. See description of the McCarran Amendment below in the discussion of the *United States v. Oregon* case.

Outline of the Oregon adjudication process

1. Director initiates adjudication with notice to basic property owners and the United States Attorney General.

2. Individuals who believe they have a pre-1909 water rights and the United States (federal reserved water right) may file a “notice of intent” to claim a right.

3. Before the 1987 amendments to ORS 539, the WRD prepared maps of water use that locate all irrigation uses by quarter-quarter section (Klamath). Under the1987 amendments, individuals must supply a map with each statement and proof of claim.

4. Notice to individuals who filed “notice of intent” to file a “statement and proof of claim” during a specified claiming period.

5. Claimants file statements and proofs of claim. Claimants who agree that the WRD maps correctly delineate their water use may check box accepting the WRD map. Claimants who disagree with the WRD map must submit a map prepared by a certified water right examiner (CWRE).

6. Claims are reviewed by the director (adjudicator) for completeness. Supplemental information/documentation may be requested.

7. Preliminary evaluation of each claim is prepared.

8. Open inspection is held. Notice of the open inspection must be at least 10 days before the beginning of open inspection period.

9. The contest period begins immediately following the open inspection period. Any person owning any irrigation works or claiming any interest in the stream involved in the adjudication may file a contest(s) opposing any claim or the director’s preliminary evaluation of a claim(s). The contest period must run at least 15 days and may be extended up to an additional 20 days at the discretion of the director.

10. Contests are referred to hearing. Contests may be settled by negotiation (stipulation).

11. The hearing officers submit preliminary orders and/or stipulations to the director (adjudicator).

12. The director (adjudicator) submits findings of fact and order of determination to the circuit court in the county where the adjudication basin is located.

13. The director provides notice to all parties that the findings and order have been submitted to the court. Any party may file exceptions to the finding and order. If no exceptions are filed, the court must enter a judgment affirming the director’s findings and order. If exceptions are filed, the court may hear the case or remand to the director or a referee for further findings.

14. Appeal of the court s final judgment is to the Oregon Court of Appeals and the Oregon Supreme Court if necessary. If there is a federal question in the adjudication, a petition for certiorari (asking for review of the Oregon Supreme Court holding) may be filed with the United States Supreme Court.

Klamath adjudication[20]

The Klamath Basin Adjudication (KBA) is the seventh subbasin adjudication in the Klamath Basin.[21] All persons claiming a right to water, the use of which began before February 24, 1909, were required to file proofs of claim with the WRD during the 1990-1991 private right claiming period. The United States and Klamath Tribes were required to file claims during the 1996-1997 federal water right claiming period. Approximately 700 claims were filed in the KBA, including approximately 400 claims filled by various agencies of the United States Government and the Klamath Tribes. The KBA is the first Oregon general stream adjudication in which large, complex federal claims have been filed.

Department staff conducted a preliminary evaluation of each claim. The claims and the WRD's preliminary evaluation were made available for inspection. Following the open inspection period, approximately 5,600 contests were filed during the contest period. All of the contests have been referred to the state Central Hearing Panel, and proceedings on several groups of contests are ongoing.

Alternative dispute resolution

Given the magnitude of the claims and the complex adjudication of these claims, the WRD believes that some form of alternative dispute resolution (ADR) could be used to resolve many of the issues surrounding the adjudication. In addition, resolution of the adjudication issues will likely involve a number of collateral matters such as the balance between water supply and demand, conjunctive surface water/ground water administration, water quality, endangered species, interstate water administration, and state/federal coordination in water management. Therefore, the WRD has initiated a voluntary ADR process to provide a forum to address adjudication claim issues and the collateral matters related to allocation and management of water in the basin.

The ADR process is intended to provide a voluntary process for resolution of KBA contests as well as a forum for evaluation of the full range of water allocation and management issues in the basin. The ADR process is a forum for claimants, other water right holders, and interested parties to meet and discuss opportunities for resolution of the basin's water issues. The director of the WRD is the ADR process leader. The department has held regular ADR monthly meetings since September 1997.

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[20]The State Engineer (director) initiated the current Klamath Basin Adjudication in 1975 with notice to almost 30,000 property owners that if they intended to file a claim in the adjudication, they must file a "Notice of Intent." Approximately 1,200 notices of intent were submitted to the WRD, including filings by a number of irrigation districts on behalf of their district members. Upon receipt of the notices of intent the WRD conducted water use surveys of the adjudication area. Individual water uses on 108 townships were mapped. On September 7, 1991, the director mailed notice to all individuals who had filed notices of intent to file statements and proofs of claim. The claiming period for federal and tribal claims was delayed by the *U.S. v. Oregon* case. Upon final resolution of the *U.S. v. Oregon* case, in August 1996, the director provided notice to the United States, the Klamath Tribes and the Klamath Project irrigation districts to file statements and proofs of claim.

[21]The Lost River, Cherry, Sevenmile, and Annie creeks, portions of the Wood River, and the North and South Forks of the Sprague River have been adjudicated. All of these adjudications were conducted before adoption of the McCarran Amendment.

Klamath Project (U.S. Bureau of Reclamation)

Pursuant to the Reclamation Act of 1902, on May 19, 1905, the U.S Reclamation Service filed a notice in the office of the State Engineer stating that the United States intended to utilize "all of the waters of the Klamath Basin in Oregon, constituting the entire drainage basins of the Klamath River and Lost River, and all of the lakes, streams and rivers supplying water thereto or receiving water therefrom ..." to furnish water to the Klamath Irrigation Project in Oregon and California. Following the filing of its notice in 1905, the Bureau of Reclamation filed plans and authorized necessary construction in compliance with the Reclamation Act.[22]

The Act of February 9, 1905, authorized the Secretary "... to dispose of any lands ... under the terms and conditions of the Reclamation Act of 1902." Since much of the area to be served by the project consisted of, in 1905, submersed lands, Congress authorized the Secretary of the Interior to raise or lower the level of Lower Klamath Lake and Tule Lake.[23] However, since the title to these submersed lands had passed to the states of Oregon and California at the time of admission to the Union, it was necessary for each state to cede title back to the United States. In 1905, Oregon "... ceded to the United States all right, title, and interest ... to any land uncovered by the lowering of water levels or by drainage of any or all of said lakes."[24] Likewise, California ceded its "... right, title, interest, or claim ..." to the lands uncovered by lowering said water levels.[25]

The project was approved by the President on January 5, 1911 in accordance with the act of June 25, 1910.[26] The total irrigable area of the project was estimated at approximately 240,000 acres, of which approximately 210,000 acres were public land and 130,000 acres were in private ownership. About 90,000 acres of the project were to be located in California and 150,000 acres in Oregon. The cost of the project was estimated at approximately $4,500,000. Major project facilities include Link River Dam (completed in 1921), Clear Lake Dam (completed in 1910), and Gerber Dam (completed in 1925).

It should be noted that there was significant irrigation development in the vicinity of Klamath Falls before initiation of the Reclamation Service Project in 1905. The Klamath Canal Company, Van Bimmer Ditch Company, the Little Klamath Water Ditch Company, and the Big Water Ditch Company were in operation for many years before initiation of the federal project. The irrigation companies, along with a number of other private water users, were incorporated into the project and ultimately served by the project facilities.

The Klamath Project currently delivers irrigation water to approximately 130,000 acres in Oregon and 70,000 acres in California. During a normal year, the net use of water on the project is approximately 2.0 acre-ft per acre including water used by the U.S. Fish and Wildlife Service in the Tule Lake and Lower Klamath Wildlife Refuges.[27]

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[22]The Project was authorized by the Secretary of the Interior on May 1,1905, in accordance with the Reclamation Act of June 17,1902 (43 U.S.C. §372 et seq., 32 stat. 388).

[23]Act of February 9, 1905, ch. 567, 33 Stat. 714. The lands formerly inundated by Tule and Lower Klamath lakes were dewatered and were homesteaded by farmers as late as 1949.

[24]General Laws of Oregon, 1905, p. 63, January 20, 1905.

[25]Cal. Stats. 1905, p. 4, February 3, 1905.

[26]36 Stat. 835.

[27]The Lower Klamath Lake Wildlife Refuge was established in 1908, and the Upper Klamath Lake and Tule Lake wildlife

The Reclamation Act of 1905 and authorizing legislation for the Klamath Project authorized the U.S. Reclamation Service (later the U.S. Bureau of Reclamation) to enter contracts with individuals and duly formed irrigation districts for the delivery of water within the project. These contracts included repayment contracts–commonly referred to as "A" contracts,[28] Warren Act contracts–commonly referred to as "B" contracts,[29] and annual surplus water contracts–commonly referred to as "C" contracts. Historically, only about 4,000 acres in the Project received water under these temporary annual surplus water contracts.

Klamath Project operations plans and the Endangered Species Act

Since 1995, the U.S. Bureau of Reclamation (Reclamation) has operated the Klamath Project according to annual operations plans. The annual operations plans have been developed to assist Reclamation in operating the project consistent with its federal statutory obligations and responsibilities, including obligations under the Reclamation Act, the Endangered Species Act (ESA), and in accordance with the U.S. Department of the Interior's tribal trust responsibilities. In addition, to Reclamations contractual obligations to deliver water to project irrigators and responsibilities under the ESA, each operations plan must be able to address annual varying hydrological conditions, changes in agricultural cropping patterns, and changes in national wildlife refuge operations.

Prior to 1994, operation of the project was primarily dictated by Reclamation's contractual obligations for delivery of irrigation water and for downstream river flows made in coordination with PacifiCorp. Deference was given to PacifiCorp's Klamath River Federal Power Act license (FERC License). However, in 1988, with the listing of the Lost River and shortnose suckers as endangered under the ESA, Reclamations operational considerations began to change. In 1989, Reclamation began consultation with the U.S. Fish and Wildlife Service (USFWS) under Section 7 of the ESA.

The USFWS issued is first biological opinion (BiOp) for recovery of the suckers in 1992. This BiOp set minimum lake elevations for Upper Klamath Lake at 4,141 ft above sea level by May 31, and 4,139 ft from June 1 through the end of February. In addition, the 1992 BiOp allowed the lake elevation to drop to 4,137 ft from June 1 through September 30 in no more than 2 consecutive years and in no more than 4 years in a 10-year period. Since there were adequate supplies of water for most of the years between 1992 and 2001, the minimum lake elevations in these years did not deprive the project of regular supplies.

However, in 1997, the water budget picture was further complicated by the listing of southern Oregon/northern California coho salmon as threatened under the ESA. In 1998, Reclamation initiated consultation with the National Marine Fisheries Service (NMFS) under Section 7 of the ESA.[30] The first BiOp on the coho was issued in 1999. Again, adequate water years in 1999 and 2000 allowed for regular deliveries to project irrigators during those seasons.

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refuges were established in 1928.

[28]Repayment contracts are entered into by the U.S. Bureau of Reclamation pursuant to Article 9(d) of the Reclamation Act of 1939 to provide for repayment of Project costs. The contracts specify an acreage to be covered. In most cases these contracts do not specify an amount of water, relying on beneficial use as the limit of water used. Klamath project repayment contracts are all written in perpetuity.

[29]Act of February 21, 1911, ch. 141, 36 Stat. 925. These contracts provide for a water supply at a certain point, with responsibility of the contractor to construct, operate, and maintain all necessary conveyance facilities.

[30]Section 7 of the ESA requires Federal agencies that intend to take an action, which would be likely to jeopardize the existence of a listed species, to consult with the Federal agency responsible for the listing and the recovery of a threatened or endangered species. Since operation of the project is deemed to be an "action" under the ESA, Reclamation must consult on each of its annual operation plans with both USFWS and NMFS.

However, in 2001, the water needs of the listed species (suckers in Upper Klamath Lake and coho in the lower Klamath River[31]), along with the reduced water supplies caused by the record drought of 2001, resulted in an April announcement that there would be no irrigation deliveries during the 2001 season from Upper Klamath Lake.[32]

Klamath Indian Reservation

The Klamath Indians have hunted, fished, and foraged in the Upper Klamath River Basin for many generations. In 1864, the Klamath and Modoc tribes entered into a treaty with the United States whereby they relinquished aboriginal claim to some 12 million acres in exchange for a reservation of approximately 800,000 acres in the Upper Basin. The tribes held the land in communal ownership until Congress passed the General Allotment Act of 1887. Pursuant to the Allotment Act, parcels of tribal land were granted to individual Indians in fee. Approximately 25 percent of the original reservation passed from tribal ownership to individual Indians. Over time, many of these allotments passed into non-Indian ownership.

In 1954, Congress enacted the Klamath Termination Act,[33] under which tribal members could give up their interest in tribal property for cash. A large majority of the tribal members chose to sell. In 1958, the Federal government purchased 15,000 acres of the Klamath Marsh to create the Klamath Forest Wildlife Refuge. In 1961, and again in 1975, the United States purchased large forested portions of the former reservation to become part of the Winema National Forest. In 1973, the United States condemned most of the rest of the tribal land and essentially extinguished the original Klamath Reservation. The United States now holds title to approximately 70 percent of the former reservation land.

United States v. Adair[34]

In September of 1975, the United States filed suit in Federal district court in Portland for a declaration of water rights within an area whose boundaries roughly coincide with the former Klamath Indian Reservation. The suit named as defendants some 600 individual owners of land within the former reservation. The Klamath Tribe and State of Oregon intervened in the case.[35]

The United States and tribe argued that the tribe and individual Indians retained an implied reserved water right for agricultural purposes and to protect their traditional hunting and fishing

[31]New BiOps on both the suckers and the coho were issued in early 2001. In the case of the suckers, the minimum lake elevations were set no lower than 4,140 ft. In the case of the coho, revised downriver releases were increased from those set in the 1999 BiOp.

[32]Klamath Project irrigation supplies were curtailed in 2001 only for deliveries from Upper Klamath Lake. Deliveries in the Lost River portion of the project from Clear Lake and Gerber Reservoir were made on a regular schedule for the 2001 season. In addition, on July 24, 2001, the Department of the Interior was able to release approximately 75,000 acre-ft of water from Upper Klamath Lake for irrigation deliveries

[33]25 U.S.C. §§ 564.

[34]723 F.2d 1394 (Ninth Cir. 1983).

[35]The United States filed suit in the Federal district court in Portland for a declaration of water rights within an area whose boundaries roughly coincide with the former Klamath Indian Reservation. The suit named as defendants some 600 individual owners of land within the former Reservation. The Klamath Tribe, arguing that they and their members had interests in the water within the former reservation, and thus in the potential outcome of the case, intervened as a plaintiff. The State of Oregon, arguing that since landowners hold their water rights through the state, intervened as a defendant.

lifestyles, notwithstanding the Klamath Termination Act. The state moved for dismissal of the Federal court action under the Colorado River Conservation District "abstention doctrine," arguing that the rights of the claimants should be decided in a state adjudication proceeding, not in a Federal court action.[36]

The Federal district court (Judge Solomon) denied the motion for dismissal, under the Colorado River abstention doctrine, and issued a pretrial order setting out the issues to be decided: (1) whether water rights had been reserved for the use of the Klamath Reservation by the 1864 treaty with Klamath and Modoc Tribes, (2) whether such rights passed to the government and to private persons who took title to such lands, (3) what priority dates should be accorded to each of the present owners, and (4) whether actual quantification of the rights should be left to the state court proceeding under the provisions of the McCarran Amendment.

Judge Solomon held:

> (1) The 1864 Treaty with the Klamath and Modoc Indians granted the Indians an implied reserved water right to as much water on the reservation as was necessary to preserve their hunting and fishing rights;
>
> (2) The Klamath Termination Act did not abrogate such water rights;
>
> (3) Individual Indians who were allotted lands within the former reservation are entitled to water essential to their agricultural needs with a priority date of 1864;
>
> (4) Non-Indian successors to Indian allottees have an 1864 water right for actual acreage under irrigation when the non-Indian obtained title from the Indian and to additional acreage developed with reasonable diligence; and
>
> (5) The U.S. Forest Service acquired reserved water rights for timber production and conservation of water flows.

The United States, tribes, and Oregon all appealed the district court decision to the Ninth Circuit Court of Appeals. The Ninth Circuit Court generally affirmed Judge Solomon, while providing more specific detail as to the various reserved water rights within the former reservation.

The priority date of the tribes' reserved water right to support its hunting and fishing lifestyle is time immemorial. This right is a non-consumptive, instream water right not based on the doctrine of prior appropriation—it is a right to prevent depletion below a protected level; however, it is not a wilderness servitude.[37] The water is protected to support hunting and fishing as currently exercised to maintain the livelihood of tribe members, not as these rights once were exercised by the tribe in 1864.

The priority date of the individual Indians holding allotted lands is 1864. This right is to be determined by the "practicably irrigable acreage" (PIA) standard as set out in *Arizona v. California*,[38]

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[36]See, *Colorado River Water Conservation District v. United States*, 424 U.S. 800 (1976.). The United States Supreme Court in the *Colorado River Conservation District* case indicated that where a state adjudication proceeding was in progress, the policy evinced in the McCarran Amendment to avoid piecemeal adjudication of water rights counseled abstention.

[37]The Court, in describing the nature of the tribe's water right to support its treaty hunting and fishing rights, stated that the right "... retains a priority date of first or immemorial use. This does not mean, however ... that the former Klamath Reservation will be subject to a 'wilderness servitude' in favor of the Tribe."

[38]83 S. Ct. 1468, 1497-98 (1963). When the United States Government sets aside land for an Indian reservation, the courts

and is not forfeitable. Non-Indian Successors (Walton Rights) have a priority date of 1864 for acreage under irrigation on the date title passes from his/her Indian predecessor, with additional acreage developed with reasonable diligence. This right can be forfeited for non-use under state law.

Lastly, the Ninth Circuit Court held that the Federal agencies that took over control of the land within the former reservation did not receive an "Indian" reserved water right with a time immemorial or 1864 priority date. However, these agencies, the U.S. Forest Service and U.S. Fish and Wildlife Service, will be able to claim reserved water rights for forest and wildlife purposes in the state adjudication.

Adair III CV No. 75-914

The United States and the Klamath Tribe filed a "Motion for Exercise of This Court's Continuing Jurisdiction" in Federal district court in Portland on January 16, 2001. The United States' motion asks the court "... to construe certain legal issues regarding the priority date and scope of the Klamath Tribes' water rights that were previously decided in this action and thereby provide the necessary direction to certain parties to this case who are also parties to the State of Oregon's Klamath Basin Adjudication."

The United States has posed two questions to the court: First, "[D]o the Klamath Tribes have water rights to support plants from which the Tribes gather food and other items under Art. 1 of the 1864 Treaty?" Second, "[W]hat is the proper measure of the tribal water rights to support their treaty, hunting, fishing, trapping and gathering rights?"

The second question subsumes the following three related issues:

1. What is the role of the "moderate living" doctrine in quantifying the tribes' water rights?

2. What is the role of the phrase "as currently exercised" in quantifying the tribes' water rights?

3. Is the measurement of the tribes' water rights the "*minimum* amount of water" necessary to meet the needs of the Klamath Tribes' treaty resources?

The State of Oregon moved for dismissal under the Colorado River abstention doctrine. Judge Panner denied the state's motion and has reopened the *Adair* case and has agreed to accept briefing on legal issues to be in conflict with prior orders in the case.

United States v. Oregon[39]

On December 20, 1990, the United States filed suit in Federal district court in Portland seeking a temporary restraining order (TRO) and a permanent injunction to prohibit Oregon from requiring the Federal government to file claims in the Klamath adjudication. (Oregon law states that if a party to

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have held that there is created an implied reserved water right for enough water to satisfy the purpose of the (Indian) reservation. (See discussion of federal reserved water rights above at n., 17.) In *Arizona v. California*, at 1498, the United States Supreme Court stated that "... water was intended to satisfy the future as well as the present needs of the Indian Reservations ... that enough water was reserved to irrigate all practically irrigable acreage on the Reservations." The determination of "practicable irrigable acreage" (PIA) in the adjudication of a reservation is fact specific as to each parcel on the reservation. Factors such as soil conditions, topography, and access to water are considered in the determination of whether any particular acre is irrigable.

[39] 44 F.3d 758 (Ninth Cir. 1996).

adjudication fails to file a statement and proof of claim within the time specified in the notice, all rights are forfeited and such party may not later claim a water right.) This suit was filed on behalf of various Federal agencies that manage Federal land in the Basin, including the Bureau of Reclamation, as operator of the Klamath Project. The Klamath Tribes and the individual Klamath Indian allottees filed for intervention in the suit.[40]

The Federal district court granted the TRO and injunction to allow the case to be argued on the merits. The United States and Oregon entered a stipulated agreement to not require the Federal government to file claims until 60 days after the suit was concluded.

The underlying issue of the case is whether the United States is immune from suit in state court. In general, the United Sates is immune unless Congress has expressly waived its immunity. However, in 1952, the McCarran Amendment was enacted waiving Federal sovereign immunity in state general stream adjudications.[41] The United States argued that, notwithstanding the McCarran Amendment, it had not waived its sovereign immunity in the Klamath adjudication, and therefore, it need not file claims. In addition, the tribes argued that they would be deprived of due process because the state had a history of hostility to the tribes' treaty rights, including the claims to water rights.

The United States' argument that sovereign immunity had not been waived was based upon a strict reading of the language in the McCarran Amendment. Their point was that Oregon's adjudication system was not a "suit" for the determination of water rights. In addition, the United States argued that the department's adjudication procedure was administrative, not judicial, and that the adjudication was not comprehensive in that it did not include all water users and did not include groundwater uses.

The Federal district court (Portland) held that the United States must file claims in the Klamath adjudication and must pay the state adjudication fees. In addition, the tribe must file claims, but is not required to pay fees. The allottees' motion to intervene was denied. The United States and tribes filed an appeal to the Ninth Circuit Court of Appeals. The Ninth Circuit Court affirmed the district court except for the fees, holding that the United States cannot be required to pay state fees under the McCarran Amendment. The Klamath Tribes petitioned the United States Supreme Court for certiorari. The United States opposed this petition. The Supreme Court denied the tribes' petition and did not take the case. The allottees eventually settled with the state and filed claims in the adjudication.

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[40]The Klamath Tribe, and members of the tribe holding allotments within the former reservation, argued to be allowed to intervene in the case to protect their rights to the water of the reservation as determined in the *Adair* case. (See discussion of *United States v. Adair* above.)

[41]43 U.S.C.⁄666(a). Consent is hereby given to join the United States as a defendant in any suit ... for the adjudication of rights to the use of water of a river system or other source ... The United States, when a party to such suit, shall (1) be deemed to have waived any right to plead that the state laws are inapplicable or that the United States is not amenable thereto by reason of sovereignty ...

Klamath Basin fact sheet

Irrigation demand (does not include Lost River Valley irrigation)

Project (includes irrigation and refuge uses)

Acreage		
	BOR	202,000 acres
	Districts	187,000 acres
Water		±500,000 acre-feet

Upper basin (above Upper Klamath Lake)

Acreage	88,000 acres
Water	±184,000 acre-feet

Storage capacity

Upper Klamath Lake	486,830 acre-feet
Clear Lake	481,300 acre-feet
Gerber Reservoir	92,300 acre-feet

Adjudication claims (approximate)

Total claims	700
Private	300
Federal agencies and Klamath Tribes	400

Permitted, certificated and decreed water rights

Water rights		
	Surface	966
	Groundwater	664
	Reservoir	467
Dams		54
Total diversion rate		5,400 ft^3/s

Summary tabulation of the Federal agency claims

U.S. Forest Service—214 claim forms claiming 416 water rights

17	Claims for consumptive uses
117	Claims for instream flows for timber production, channel maintenance (favorable conditions of stream flow), fish, wildlife and recreation
13	Claims for instream rights for lakes
62	Claims for instream rights for springs
5	Claims for wilderness water rights

U.S. Bureau of Land Management—52 claims for water on BLM land

51	Claims for waterholes (Public Reserve No. 107)
1	Claim for the Klamath Wild and Scenic River

National Park Service—21 claims for Crater Lake National Park

10	Claims for instream water rights
11	Claims for 44 consumptive uses

U.S. Fish and Wildlife Service—22 claims for water rights in four wildlife refuges

9	Claims for irrigation of approximately 63,000 acres
12	Claims for approximately 200,000 acre-ft of water/year for wildlife refuge uses
1	Claim for approximately 80 ft^3/s for stockwater

U.S. Bureau of Indian Affairs—393 claims on behalf of the Klamath Tribes

5	Claims for consumptive uses
52	Claims for instream flows in, above and below the former reservation
1	Claim for minimum water level in Upper Klamath Lake
1	Claim for minimum water level in the Klamath Marsh
334	Claims for wildlife seeps and springs within the former reservation

Klamath Tribes—five claim forms incorporating all of the claims filed by the Bureau of Indian Affairs. In effect duplicate claims to the BIA filing

U.S. Bureau of Reclamation—seven consolidated claims for the Klamath Project

Diversion of 3,505 ft^3/s for irrigation of 218,654 acres of irrigation
486,830 acre-ft of storage in Upper Klamath Lake
92,300 acre-ft of storage in Gerber Reservoir
481,300 acre-ft of storage in Clear Lake

Klamath Basin cases

Kimball v. Callahan, 493 F.2d 564 (Ninth Cir. 1974) (Kimball I)
The 1864 treaty with the Klamath Tribes gave the tribes the exclusive right to hunt, fish and gather on their reservation.

Kimball v. Callahan, 590 F.2d 768 (Ninth Cir. 1979) (Kimball II)
The treaty rights survived the Klamath Termination Act.

U.S. v. Adair, 723 F.2d 1394 (Ninth Cir. 1983)
See discussion above.

Adair III CV No. 75-914 (Filed January 16, 2001)
See discussion above.

Parravano v. Babbitt, 70 F.3d. 539 (Ninth Cir. 1995)
Hoopa Valley and Yurok tribes have federally reserved fishing rights.

U.S. v. Oregon, 44 F.3d 758 (Ninth Cir. 1996)
See discussion above.

Bennett v. Spear, 117 S. Ct. 1154 (1997)
Lost River irrigators have standing to bring judicial challenge to the USFWS biological opinion, which made a jeopardy finding on the Lost River and shortnose sucker and identified maintenance of minimum water levels in Clear Lake and Gerber Lake as reasonable and prudent alternatives. Irrigators had standing to challenge the biological opinion under the ESA based on injury in fact from reduced water delivery, which was traceable to biological opinion.

Bennett v. Spear, 5 F. Supp. 882 (D. Or 1998)
On remand, district court held that the record did not support the USFWS determination that retaining minimum levels in Clear and Gerber lakes would help avoid jeopardy.

Klamath Water User's Association v. Patterson, 204 F.3d 1206 (Ninth Cir. 1999)
Klamath Water Users Association brought contract action against the Bureau of Reclamation and PacifiCorp, challenging the operation of Link River Dam (which controls level of Upper Klamath Lake). Court held that the irrigators are not third party beneficiaries of the contract for the operation of the dam. The court went on to observe, in dictum, that the Bureau can operate the dam to meet ESA and tribal trust obligations.

Langell Valley Irrigation District v. Babbitt, Case No. 00-6265-HO (D. Or. 2000)
LVID challenges Bureau releases from Clear Lake, on the east side of the Klamath Basin, for delivery to various uses on the west side. Same result as in *KWUA v. Patterson*.

Water for Life v. State of Oregon, Case No. 00-1260CV, (Klamath County Circuit Court, August, 2000)
Water for Life sought to enjoin the Klamath Basin Adjudication on procedural grounds. Circuit court dismissed the action on the ground that plaintiffs can raise procedural arguments when the adjudicator's findings and order of determination reach circuit court.

In the Matter of Lost River, Case No. 1918-001 (2000) (Klamath County Circuit Court, May 12, 2000)

Lost River irrigators sought modification of the 1918 Oregon decree adjudicating the waters of the Lost River. The decree "recognized," without determining, the United States water rights for the Klamath Project. The Bureau moved to dismiss the modification request on the ground that (1) the 1918 decree was not valid as to the United States because the decree pre-dates the McCarran Amendment; and (2) the decree cannot be modified without the participation of the Bureau, which is an indispensable party. The court agreed and dismissed the action.

Dept. of the Interior v. Klamath Water Users Protective Assoc., 121 S. Ct. 1060 (2001)

Documents relating to claims filed in the adjudication by the Bureau of Indian Affairs on behalf of the Klamath Tribes are not exempt from disclosure under the Freedom of Information Act as interagency or intra-agency memoranda or letters.

Pacific Coast Federation of Fishermen's Assoc. v. U.S. Bureau of Reclamation, 138 F. Supp. 1228 (D. N. Cal., April 3, 2001)

Bureau was enjoined from sending irrigation deliveries to the Klamath Project at any time when required downstream flows are not met, until the Bureau completes a plan to guide operations during the new water year, and consultation on that plan is completed.

Kandra v. U.S., 2001 WL 668940 (D. Oregon, April 30, 2001)

Irrigators in Klamath Project sought preliminary injunction against Bureau's 2001 Operating Plan, under which no irrigation water deliveries would be made to the majority of land within the Klamath Project because of extreme low water conditions, ESA obligations, and tribal trust obligations. Preliminary injunction denied.

U.S. v. Adair, CV No. 75-914-PA (D. Oregon, August 9, 2001)

See discussion above.

Tulare Lake Basin Water Storage District v. United States, U.S. Cl. Ct., No. 98-101 L (April 30, 2001)

Water Storage District claimed that their contractually conferred right to use water was taken from them when the Federal government imposed water use restrictions under the Endangered Species Act. Plaintiffs seek compensation under the Fifth Amendment of the United States Constitution. Court held that by limiting plaintiffs' ability to use an amount of water, the government essentially substituted itself as the beneficiary of the contracted rights, totally displacing the contract holder. By preventing plaintiffs from using water to which they would otherwise have been entitled, they have rendered the right valueless; they have thus effected a physical taking.

Alsea Valley Alliance v. Evans and MMFS, U.S. D. Ct. Or. Case No. 99-6265 (Sept. 10, 2001)

Plaintiffs challenge the 1998 listing of the Oregon Coast coho salmon evolutionary significant unit (ESU). In its final rule listing the coho ESU as threatened, NMFS only listed the "naturally spawned" coho. Plaintiffs sought to invalidate the 1998 listing decision because the distinction between "naturally spawned" and "hatchery spawned" coho salmon is arbitrary and capricious and thus unlawful under the Federal Administrative Procedures Act. The Court agreed and held that the 1998 NMFS listing decision is unlawful and should be set aside as arbitrary and capricious.

Methow Valley Situation.

A number of private irrigation ditches divert water from tributaries of the Methow River in north central Washington. Several species of fish found in the Methow River and its tributaries have been listed as either threatened or endangered under the ESA (some by the NMFS and some by the USFWS). Some of the points of diversion of the irrigation ditches, along with portions of the ditches themselves, are located within the U.S. Forest Service's (USFS) Okanogan National Forest. The owners of these ditches were issued Special Use Permits (SUP) by the USFS to allow use of the national forest lands for diversion and conveyance of water. As a result of the ESA listings, the USFS was required to enter §7 consultation with the NMFS and the USFWS to ensure that diversion of water within the forest was not "likely to affect" the listed species. The consultation resulted in reduced irrigation deliveries. Those ditches diverting water from the tributaries of the Methow not located within the forest are subject to provisions of §9 of the ESA which prohibit "take" of a listed species. To date no §9 actions have been initiated.

Draft
December 14, 2001

Alternative Approaches to Water Management in the Klamath Basin

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Introduction

Alternative approaches to managing the competing demands on resources in the Klamath Basin are varied and numerous. Components for a long-run strategy to protect fish and other species along with agricultural interests in the basin are likely to include restoration of riparian vegetation, screening irrigation canals, reductions of nutrient flows, reforestation, dam removal, reduced fish harvest pressure, etc. Indeed, many of these actions have been recommended as components in the recent and prior Endangered Species Act (ESA) biological opinions.

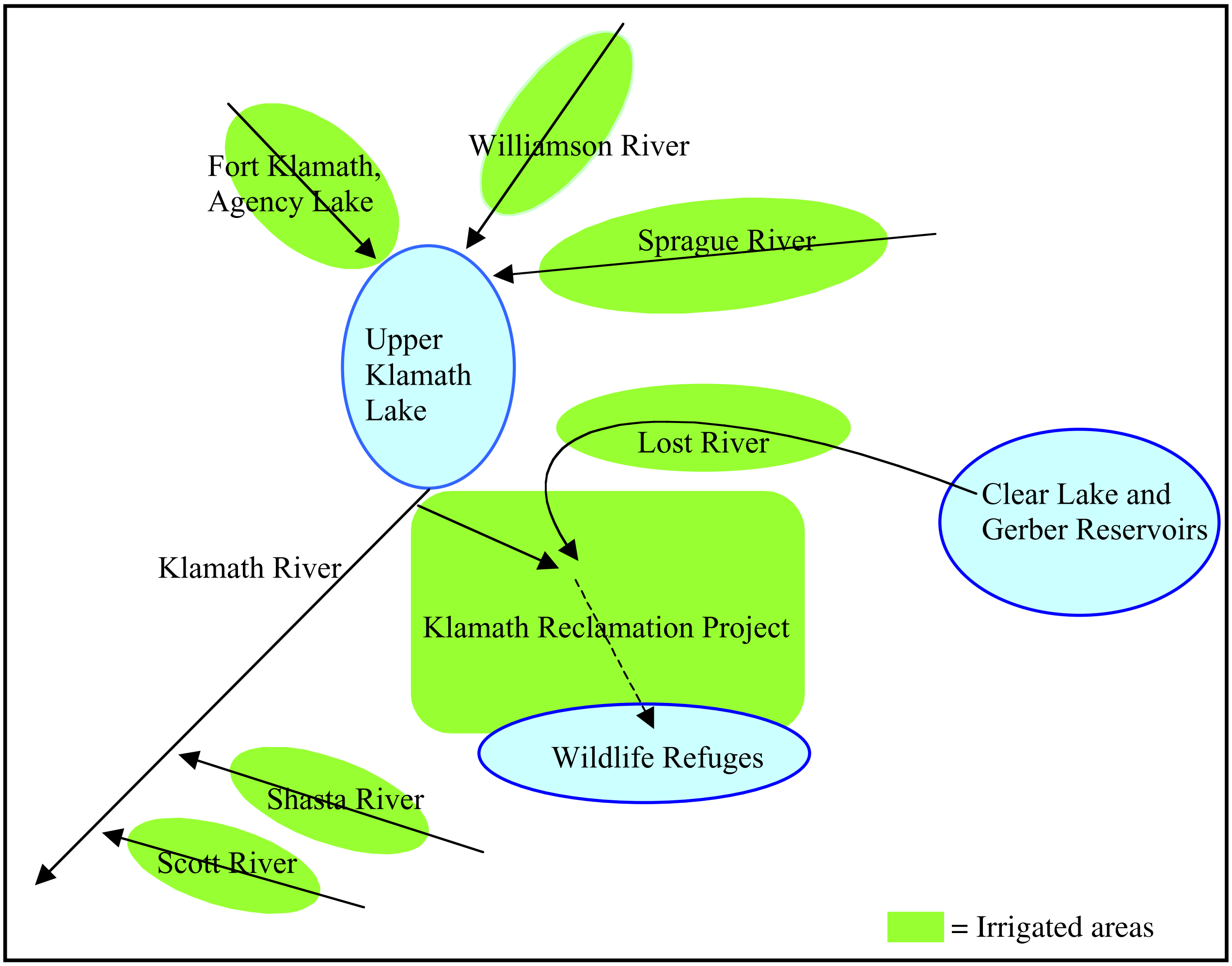
In addition to these broad actions, however, alternatives for the management and allocation of irrigation diversions in the basin may have advantages over current approaches. The aim of this chapter is to evaluate several of these alternatives compared to the actions taken in 2001. Alternatives will be evaluated based on their direct cost to the agricultural sector. To the extent that more cost-effective approaches can be identified, these may shed light on ways that future shortages can be managed to minimize the costs—provided that there is public support and the institutional capacity to carry them out.

The focus of attention here is on alternatives that deal directly with the *quantity* of irrigation water available, and the allocation of that water among competing uses. In addressing these issues, economic data and estimations of net gains and losses from allocating water on different soils in different locations must be estimated. In particular, the cost of short-run curtailment of irrigation supplies form the basis of comparisons of alternative responses to shortages like the one experienced in 2001. Importantly, the analysis is framed not within the boundaries of the Klamath Reclamation Project (KRP or "project"), but includes all irrigated areas within the basin which could reasonably be considered interconnected for purposes of satisfying the mix of competing ecological and agricultural demands.

Armed with data and estimates of short- and long-run marginal values for water, two additional mitigation options are evaluated below: supplemental groundwater pumping and adoption of efficient irrigation technology.

Two key characteristics of irrigated agriculture in the Klamath Basin are central to our investigation of alternative, cost-effective responses to water shortages. First, the acreage that was cut off from water in 2001 represents the large majority of the KRP but amounts to only 35 percent of the total irrigated area in the basin. This fact raises the possibility that other distributions of water curtailment may have been more cost-effective than one concentrated on the KRP. Cutting off water to other, less productive land is one possibility. In principle, given the infrastructure necessary to gauge and meter water deliveries, partial reductions of irrigation deliveries, or "deficit irrigation" represents another alternative.

Figure 1. Key features and irrigated areas in the upper Klamath Basin and River system.



The second characteristic of irrigated land in the basin is its highly variable productivity across different soil classes and locations. The productivity of those lands when irrigated—as reflected in their market values—varies by a factor of 10. The shares of irrigated land by soil classes II, III, IV, and V are 12, 40, 42, and 6 percent respectively.

Given this high variation in productivity, and the wide range of ways to comply with a 35 percent reduction in irrigation, first principles of economics tell us that a decentralized response to water shortage, one that accounts for the highly differentiated marginal losses and gains across different plots, will achieve the desired reduction in irrigation withdrawals at a much lower cost. If water is withheld from its highest value uses, while irrigation continues in locations where the net benefits are minimal, this inefficient arrangement will produce a high overall cost compared to an efficient (cost minimizing) allocation.

Alternative scenarios or policies of this kind will necessarily produce different economic and social effects in which some individuals may be more or less affected by these changes. Whether those alternatives are viewed positively or negatively will depend on many factors including the magnitude of the overall effects of any given scenario. The aim of the current analysis is first of all to identify ways in which the overall cost of irrigation restrictions could be reduced by promoting efficiency in water allocation. To the extent that an alternative response to a water shortage may also generate different consequences for individuals, or other undesirable social or environmental side-effects, we will want to take note of those differences as part of an overall assessment of the quantitative and qualitative differences between alternative courses of action. Still, our primary focus will be on comparisons of the cost-effectiveness of alternatives. In principle, if an alternative approach substantially lowers the overall cost of a water shortage, other ancillary effects may be mitigated with complementary actions.

An economic description of irrigated agriculture in the Klamath Basin

In this section economic data on irrigated agriculture, the value of applied water, and the cost of withholding water are compiled and presented. I begin by describing the data, how water values and losses were estimated, and including corroboration of the estimates based on comparisons with estimates using other methodologies. With these data, an economic portrait of irrigated agriculture in the basin is generated, one that will enable us to evaluate a range of alternative management and mitigation options.

To evaluate alternative management actions, two different measures of the value of water in irrigation are needed. The first of these is a measure of the "long-run" efficient use of water in irrigated agriculture. This measure reflects the net revenue or income generated when irrigation water is applied regularly to an acre of land of a given soil class. This measure of value will be reflected in, and relevant to, market sales and prices of land or water rights, or in making investments in irrigation infrastructure or other capital assets. It reflects the efficient, planned use of water in combination with capital equipment and other inputs. Given efficient capital and land markets, we expect that the sale price of agricultural land reflects the present value of the income that can be generated annually by farming it. The relationship between the annual income (Y) made possible by farming the land and its purchase price (P) is based on the interest rate (r) such that P = rY, which is the capitalization relationship for a permanent annuity. Using this relationship we can infer the value of irrigation water by comparing the sales prices of irrigated and nonirrigated lands. For example, if the right to irrigate an acre of land is expected to increase income by $60 per year, the purchase of that right, or the difference between the purchase price of irrigated versus nonirrigated land can be expected to reflect the capitalized value of these annual benefits, or raising the price by $1,000 ($60/0.06). Detailed data on land values for irrigated and nonirrigated lands at different locations and for different soil classes are presented below.

The second important measure of the value of irrigation water reflects short-run losses from unanticipated reductions in available water. This measure of value is a function of the "fixed costs" associated with production. In the short run, some fixed costs will have been incurred by irrigators who expect to apply water whether water is eventually made available to them or not. Given these committed expenses (equipment, contracts, maintenance, etc.), the cost of having water withheld will differ from (be higher than) the long-run values discussed above:

short-run changes or "surprise" adjustments in the amount of water available will generate per acre losses that exceed those reflected in the long-run marginal value of water defined above.

To illustrate, assume that 2 acre-ft of water will enable a farmer to earn income or net revenue (NR) equal to total revenues (TR) minus variable cost (VC) minus fixed cost (FC); the sudden loss of that water will cause the farmer to incur a loss of TR - VC. Under normal circumstances the irrigator expects to earn NR = TR - VC - FC. Thus, the difference between the net revenue when water is delivered, and the net loss NL = TR - VC, is accounted for by the fixed costs. If, in some circumstance, production involved zero fixed costs, then the two measures of the value of irrigation water outlined above would be equal. Since fixed costs are an integral part of agriculture in the Klamath Basin, and because the kinds of water shortage that occurred in 2001 were short-run and unanticipated, it is the short-run measure of loss that will be relevant to many considerations of mitigation and future management.

Economic value of water in the Klamath Basin

Both measures of the value of water introduced above are estimated for each location and soil class in the Klamath Basin, based on disaggregated agricultural and market data. These estimates are also compared to alternative estimation techniques and sources for validation purposes. The primary data source comes from the Klamath County Assessor's office (Klamath County Assessor 2001) where data on irrigated land areas by soil class, cropping pattern, and market value (as distinct from the assessed values used for tax purposes) are available. These data were supplemented with additional data from the county assessors in Modoc and Siskiyou counties in California, from the Bureau of Reclamation office in Klamath Falls, and from the Oregon State University (OSU) Extension Service for crop budget data.

Crops and crop rotations vary by location and soil type. For the basin overall, 54 percent of irrigated land is pasture, 22 percent alfalfa, and 5 percent other hay. These are followed by 15 percent cereal grains, 3 percent potatoes, and 0.5 percent peppermint. Other crops such as sugarbeets, peppermint, onions, and strawberries account for only fractions of 1 percent each. Alfalfa, cereals, potatoes, and peppermint are grown on type II and III soils; pasture is grown on virtually all type IV and V soils.

The long-run value of irrigation water

The long-run value of irrigation water on a per-acre basis can be estimated based on comparisons of the market value of irrigated land with the market value of similar nonirrigated land. The difference between average values of irrigated land of a given soil class and the average value of similar nonirrigated lands (typically considered class VI due to the lack of irrigation) will generally reflect the value of applied water. The difference in purchase price between irrigated and nonirrigated lands will reflect the present discounted value of the expected annual net returns from irrigation in current and all subsequent years. On an annual basis, the value of irrigation water can be estimated as this difference between the purchase price on irrigated versus nonirrigated land, multiplied by the market interest rate.

Data on irrigated land areas for the Klamath Basin are presented in Table 1. These data indicate that irrigated acreages range from class II to V, with most irrigated lands being class III and IV soils. Importantly, we see that most of the areas within the KRP that did not receive water in 2001 were high productivity class II and III soils. By contrast, many of the areas outside the KRP that received water in 2001 are class IV and V soils (e.g., in areas above Upper Klamath Lake and in the Scott and Shasta valleys).

In Table 2, average land values by soil class indicate the extreme variability in productivity of irrigated land across locations. These vary from class II irrigated areas in the KRP that sell for $2,600 per acre to class V lands that sell for between $300 and $600 per acre. These estimates of average market values reflect transactions and market information prior to the events of 2001.

By combining the data in Tables 1 and 2 we can estimate the total value of irrigated land in the basin. This figure is $654 million. We expect these market prices for land to reflect the capitalized value of the annual income generated from current use. Using an interest rate of 6 percent, this asset value suggests annual income from irrigated agriculture in the region of $39 million, which is remarkably close to the $38 million figure from the U.S. Bureau of Economic Analysis for farm income in the region is reported in the On-farm Economic Analysis chapter.

As explained above, an estimate of the long-run value of irrigation water can be computed based on the difference between the value of irrigated and the value of similar nonirrigated lands. From Table 2 we see that the difference between the market value of class II and class VI nonirrigated lands is $2,300. For class III and IV soils the computed values are between $1,000-1,500 and $700, respectively. Notice that for some areas, especially class V soils outside the KRP, the data on average market value suggest very low values to irrigation; for example, the difference between class V irrigated and class VI nonirrigated land ranges from $0 to $200 per acre. In the case of these class V soils, average values that suggest a zero marginal value for irrigation water may reflect shortcomings in the data for these particular regions. However, the preponderance of the evidence indicates that applying water to class V soils in these regions generate low net returns as irrigated pasture. Even ignoring the extreme low estimates of 0 and $50 per acre, these data indicate that the value of applied water varies by a factor of 23 between the most productive lands ($2,300 per acre) and least productive lands ($100 per acre). On average, the data suggest that irrigation water will add about $1,000 per acre to the value of land.

In general these data and estimates of long-run value are corroborated and validated by other sources and from estimations made using alternative methodologies. A local farm appraiser with many years of experience in the region estimates differences between irrigated and nonirrigated lands to be between $900 and $1,000 (Hank Caldwell, personal communication). When these estimates, based on land sales, are used to estimate the annual value of applied water (multiplying by the market interest rate), we arrive at the marginal values for water per acre per year presented in Table 3 (using a 6 percent interest rate). When compared to estimates for similar soil classes in Malheur County, Oregon, based on a more detailed statistical approach (Faux and Perry 1999), the values found in that location are nearly identical to the soil class averages in Table 3 with the exception of the class V soils in the Klamath area, which are significantly lower than those in Malheur County. Some difference between the two locations is expected due to the higher elevation and shorter growing season in the Klamath area.

Two other data sources provide estimates that are generally consistent with those presented here. The Oregon Water Trust purchases water from irrigators in Oregon to augment instream flows and protect fish habitat. Data on these actual transactions over the past several years, presented in Table 4, are of two types: one for permanent purchases of water rights, the other for 1-year leases. These data are also presented on a per acre-foot per year basis, also using a 6 percent interest rate for the permanent purchases. Given the organization's desire to minimize their costs, we should assume that these transactions most often involve irrigators of class IV and V soils. Detailed data on soil class are not available for these transactions. However, for a consumptive use of 2 acre-ft per acre in the Klamath Basin, the average annual value per acre foot for class IV and class V soils is $11.50, which is close to the $9.16 average paid by the Oregon Water Trust. Additional information on transactions by the Oregon Water Trust (reported in Niemi et al. 2001), is remarkably consistent with Faux and Perry (1999). They report that for pasture and irrigated hay they bought water rights at prices reflecting $6 to $17 per acre-ft per year, and for wheat (likely to be grown on class II or III soil) a value of $22 per acre-ft per year.

Short-run losses from unanticipated irrigation curtailment

The short-run measure of loss from having irrigation water withheld unexpectedly will reflect the financial changes faced by farmers. If a farmer is expecting to earn net revenues NR = TR - VC - FC, the complete loss of irrigation water will mean a loss of revenue (TR) and the avoidance of variable costs (VC) such as seed, fertilizer, fuel, and pumping costs. Losses, therefore, can be measured as TR - VC.

For each area and soil type in the basin, data on the observed cropping patterns are used in conjunction with OSU crop enterprise budgets to estimate the losses when water is unexpectedly withheld from a planned crop activity (OSU Oregon Agricultural Enterprise Budgets, http://osu.orst.edu/Dept/EconInfo/ent_budget/). These losses range from $509 and $464 for peppermint and potatoes, respectively, to $32 and $33 for hay and pasture. Given the crops and rotations in each zone, these numbers translate into the losses per acre presented in Table 5, which, like the long-run marginal values estimated above, vary by a factor of 10 across location and soil type, from $325 per acre on class II soils in the KRP to $33 per acre on all class V soils.

These values are consistent with the notion that farmers' losses from being denied water will exceed the income normally generated when water is received. This fact implies that farmers will be made worse off in terms of their net wealth when irrigation is withheld.

Some kinds of losses in the Klamath Basin will not be captured by these estimates, for example, the loss of an established perennial crop, dissolution of experienced and trained crews, and loss of contracts with crop processors and purchasers. To validate the estimates presented in Table 5, one source of evidence from the Klamath Basin provides possible corroboration. In the spring of 2001, the Bureau of Reclamation asked farmers to submit bids of the price at which they would willingly leave their land dry. This "demand reduction program" eventually spent $3 million on accepted bids. We would expect these bids to equal or exceed the expected losses from going without water. The average accepted bid in 2001 was $167 per acre; the average loss from Table 5 for those lands in the KRP that were denied water in 2001 (from the right-hand column in Table 5) is a remarkably close $166.

Three striking features emerge from these data. First, the value of irrigation water varies widely between location and soil type. Second, in relative terms the variation across soil class and location are similar for both measures of value: there is a factor of 10 difference across soil classes for both long-run and short-run measures of value.

Third, we observe that the limitation on irrigation water imposed in 2001 represented only about 35 percent of the water normally applied throughout the basin, yet the reductions were made by imposing 100 percent reductions on a subset of irrigators—those within (most of) the Klamath Reclamation Project (KRP). This observation raises questions about the cost-effectiveness of the way in which irrigation curtailment was implemented in 2001, and about the potential reductions in losses from more cost-effective responses.

An economic model of irrigation water allocation

The data presented above form the basis of a mathematical model that represents irrigated agriculture in the region. The model is intended to reflect the revenues and costs of irrigated agriculture in the region. It is not intended to measure or represent all aspects or consequences of irrigation curtailment that have affected many other individuals in the region. Some of those other consequences or impacts are addressed elsewhere in this report. To the extent that alternative scenarios described here have different direct consequences for farm proprietors, these differences may also carry over and alter indirect and induced effects elsewhere in the economy in similar directions.

Our model of irrigated agriculture is a system of equations representing the land areas, soil types, costs, and revenues discussed above and described in the tables. The model characterizes 16 areas in Oregon and California. Ten of these are portions of the KRP; others include irrigated areas around and above Upper Klamath Lake, and in the Shasta and Scott valleys of California. The model assumes that all areas will either be irrigated or not irrigated at all (the model does not provide for reduced or deficit irrigation on a given acre). Those portions of the KIP that were denied water in 2001 amount to approximately 178,000 acres, or about 35 percent of the 509,000 total acres irrigated in the upper basin overall.

For the analysis of short-run losses, we start from a base case where all areas in the basin (508,833 acres) are irrigated. A cut-off of irrigation for an area A, in zone, i, of soil type j, (A_{ij}) will produce a loss, L_{ij}. These loss estimates are those reported in Table 5 and as explained above. In the scenario replicating the 2001 situation, all the areas that were cut off from irrigation are required to receive zero water. Areas receive full water suffer zero losses; areas receiving zero water suffer losses as indicated. By replicating the actual allocation of water in the basin in 2001, the model produces an estimate of losses for 2001 of $28 million.

This $28 million should be interpreted as a rough approximation of the direct losses to irrigators based on changes in their revenues and costs as a result of receiving no water.[1] As mentioned above, this figure is likely to understate the losses associated with actual events in 2001 for several reasons. First, some additional costs were incurred that are not represented in these estimations, such as those associated with cover crops, canal clearing and maintenance, variable costs that were unavoidable, proprietors and workers that were under- or unemployed, or the loss of established perennial crops such as peppermint (although these represent a very small share of the area under consideration). Thus the $28 million estimate should be seen as a lower bound on direct costs to agriculture; a figure of $35 million or even higher may be a more accurate estimate of the financial losses in agriculture. If the reductions in irrigation from 2001 reflect a permanent shift to very frequent shortages, then the resulting reductions in irrigated land values should also be included as part of these losses. Still, for purposes of comparison with other scenarios, these estimates are useful to the extent that other unmeasured costs will also vary roughly in proportion to the direct costs estimated for each scenario.

[1] These loss estimates should not be confused with the "impact" estimates in other chapters that attempt to measure the repercussions on the scale of economic activity throughout the local economy. The current analysis focuses on direct measures that can be the basis for benefit-cost analysis. Net returns, income, and value-added are terms that reflect differences between benefits (revenues) and costs. The measure of local impact that is influenced by export dependency (as discussed elsewhere) should not be used to address questions of cost-effectiveness, or translated into "per acre" economic indicators.

Cost-effective allocation of irrigation restrictions

We are particularly interested in evaluating how the losses of the 2001 curtailment would have differed had more flexibility been possible in the way that water was allocated. We expect that the losses could have been significantly lower had a cost-effective, loss-minimizing approach been possible—one that cut off water from those lands that would suffer the least.

To estimate these differences we introduce an optimization algorithm that chooses the most cost-effective way to reduce the irrigated area by the same number of acres. The total losses (TL) are minimized subject to the constraint that the acres irrigated not exceed the actual irrigated area in 2001. Algebraically we can write this procedure as

Minimize: $TL = \sum L_{ij} A_{ij}$

subject to $\sum A_{ij} = A^*$ where A^* is the required acreage to be denied water.

An analogous optimization model was also used to estimate values and changes in values based on the long-run values for irrigation corresponding to Table 3.

Solving this algorithm for the cost-minimizing way to reduce the irrigated acreage by the same amount as in 2001 produces a total loss of only $6.7 million, or a three-fourths reduction in losses as compared to the estimate for the simulation of what actually occurred in 2001. Rather than curtail irrigation in the KRP, the model identifies class V and IV lands throughout the basin as the ones that will minimize losses. In particular, the cost-minimizing solution curtails irrigation on substantial areas along the Sprague and Williamson rivers, Fort Klamath, in the Lost River area (Langell Valley), and in the Shasta and Scott River valleys.

This cost-minimizing scenario involves choosing which acres to irrigate, but not how much water to apply to each. If gauges and volume meters were available throughout the Basin, one could fine tune the allocation of water to include partial reductions in the applied water for some fields. Such deficit irrigation may lower the cost of irrigation reduction even further than the acre-to-acre reallocation reflected in the optimization model above. The costs of installing gauges and metering devices must also be considered. For flood irrigation diversions, the installation of flumes and meters to record volumes can cost $2,500 at each diversion point. Piped diversions may cost $1,000. An inventory of diversion points in the area counts 300, but there are about 850 irrigated farms. If one such device is required for each of the 850 irrigated farms in the Basin, and with about half of the diversions being piped, the average cost of installation would be about $3 per acre. This is a one-time cost, not an annual cost. Therefore, given these estimates, these costs do not appear to significantly alter the net returns to irrigated agriculture in the Basin.

An analysis of irrigation management involving deficit irrigation and fine tuning of water deliveries was undertaken for the Klamath Reclamation Project by Adams and Cho (1999). They only included the project in their model, but their results provide some evidence of the additional potential for cost reductions. First, if one were to impose a uniform reduction in available water of 35 percent to all irrigated land in the basin, the estimates from Adams and Cho suggest that this would cost $32 million, which would be similar to our estimate for the 100 percent curtailment of the KRP from 2001. If, however, it were possible to cost effectively withhold water from 20 percent of irrigated acreage in the basin, and also to introduce an 18 percent reduction in water deliveries to the remaining irrigated acreage, the same total reduction would be achieved as was imposed in 2001. Based on the model above and extrapolating from Adams and Cho, the total cost would be approximately $4.6 million, or an 83 percent reduction in cost.

Comparisons of the cost of these alternative reallocation scenarios are summarized in Table 6. It is important to recognize, however, that any change in the allocation of scarce water will produce a set of consequences for many individuals that differ from the circumstances of 2001. Some would see these changes as improvements; others would not. For example, reductions in output or acres irrigated within irrigation districts would mean that their operating costs would be shouldered by a smaller revenue base.

Implementing cost-effective water management is, of course, more difficult than estimating the cost-savings that might result. How the legal, administrative, and political institutions might be realigned to facilitate cost-effective responses to scarcity is the critical question facing the region. The on-going process of adjudicating water rights, and the prospect of high-priority water rights being sold to those users with relatively high risk of large losses represent promising future opportunities. Before looking specifically at the implications of markets for water rights, we evaluate several other management and mitigation options below.

Alternative management and mitigation options

The sections below evaluate the economics of several alternative management and mitigation approaches that have been mentioned as ways to ameliorate or avoid future conflicts involving irrigation water. These options represent only a subset of the possible steps that could, and perhaps should, be taken to improve the situation in the Klamath Basin. Analyses of some other options are beyond the scope and resources of the current study. For example, we do not attempt here to evaluate the benefits and costs of actions to improve water quality in lakes and streams, such as restoration of riparian habitats, or modification of land use in sensitive areas. We also do not look at augmenting water storage with new reservoirs.

Supplementing irrigation with groundwater

In drought years might it be feasible to supplement the restricted irrigation diversions by pumping groundwater, or by using this groundwater to augment instream flow so that additional irrigation diversions could be permitted? There are important hydrological concerns about doing this on a large scale due to the possibility (and evidence) that such pumping would have adverse effects on local aquifers, private wells, and public drinking water supplies and subsurface irrigation in nearby areas. For these reasons there may be legal obstacles as well.

Our goal here, however, is to provide an approximate picture of the costs and benefits of such an approach. The question is, can the installation of high-volume groundwater pumps be an economically viable way to respond to drought conditions in the Klamath Basin? We are not asking if such pumps can be economically justified to permanently augment irrigation supplies, but rather to be used only as a source of supplemental irrigation water in times of extreme need.

Recently the Tulelake Irrigation District projected that with $5 million, a well producing 170 ft^3/s could be developed. Assuming 100 days of pumping and 2 acre-ft per acre in crop use, this volume would serve about 17,000 acres. A key question is how often would this contingent supplementation be required? The drought conditions observed in 2001 and in 1992 represent extreme conditions that occur only 5 percent of the time based on data from the past 41 years. Changes in forests, climate, and biological requirements may ensure that irrigation water scarcity will occur much more frequently in the future. If we assume that supplemental water is needed once every 4 years, can the kind of costs estimated by the Tulelake Irrigation District be economically justified? It depends on how the available water is otherwise allocated.

Based on the $5 million investment cost and a 5 percent annual cost for maintenance and depreciation (given usage only 1 year in 4), the cost per acre when supplementation is offered would be $74 per acre for the investment and depreciation. Assuming pumping requires 100 feet (total dynamic head), and with a commercial rate (or opportunity cost) for energy of 3.5 cents per KWH, the cost per acre would be $9, for a total cost of $83 per acre of supplemental pumping.

If a groundwater pumping activity would permit 17,000 additional acres to be irrigated, which acres would these be? In the absence of groundwater pumping, the efficient allocation would involve irrigating the high-value lands and leaving the lower value lands dry. If we assume that, in the absence of groundwater pumping, irrigation water will be allocated efficiently (for example, as the result of water rights markets as discussed below), then the incremental areas irrigated as a result of groundwater pumping would be lower value lands. Since one-half of the acreage normally irrigated is class IV and V soils where losses generally are about $33 per acre, supplemental irrigation with groundwater pumping cannot be justified if it costs $83 per acre, even under the generous assumption that it is needed 1 year out of 4. If an efficient allocation of water in future drought years is not possible, and the most productive lands are, in fact, required to be left dry 1 year out of 4, then the $83 per-acre cost would be justified to avoid losses ranging from $174 to $325 per acre.

Improving irrigation efficiency

Irrigation efficiency is defined as the ratio of the amount of water actually consumed by the crop to the total amount of water diverted (from surface or groundwater) for irrigation. Depending on the irrigation technology being used, a farmer may need to apply twice the water required by the plants being grown. The quantity of water that is not consumed by the plant will flow back to the stream, percolate down into the ground, or evaporate. It is generally assumed that water which percolates into the subsoil will eventually find its way back into the stream, but this may take hours, days, or years, depending on the soils, geology, and the distance to the stream. The benefits to fish of changes in irrigation diversions vary greatly depending on what is assumed about the amount and timing of changes in these return flows. Evaporation will vary as well depending on temperatures and humidity, but is often assumed to account for no more than 10 or 15 percent of the water applied.

In the Klamath Basin surface or flood irrigation is most common, especially on the less productive lands. For most high-productivity lands, sprinkler irrigation is already being used. Flood irrigation efficiency may be less than 50 percent; sprinklers may be higher than 70 percent. Conveyance efficiencies (typically canals for transporting water) of 70 to 80 percent are common in the Northwest; some are as low as 20 percent for unlined canals. Overall efficiencies including conveyance and irrigation average less than 50 percent, and in some cases as low as 20 percent (Butcher et al. 1988).

While irrigation efficiency may be an important factor affecting the potential for satisfying agricultural and ecological demands, it should not be assumed that promoting improved irrigation efficiency in agriculture will result in less water being diverted from the stream, and hence more water left for fish or other instream uses. Consistent with this perception, several western states have passed legislation encouraging farmers to invest in improved on-farm irrigation technology (Huffaker and Whittlesey 2000). The reality is more complicated, however, since improved irrigation efficiency will also reduce return flows.

Assume a farmer diverts 400 acre-ft with an irrigation efficiency of 40 percent. This means that his consumptive use is 160 acre-ft, and assuming 10 percent is irretrievably lost to evaporation or deep percolation, we can expect that 200 acre-ft end up as return flow into the river. What happens if this farmer adopts improved irrigation technology that raises irrigation efficiency to 70 percent, if the stream diversion is lowered from 400 to 350 acre-ft? On the face of it, this would appear to be good for fish because it leaves an additional 50 acre-ft in streams or lakes. With higher irrigation efficiency, however, the consumptive use is now 245 acre-ft, and with 10 percent (35 acre-ft) still irretrievably lost, the return flow is only 70 acre-ft. Adding 70 acre-ft to the 50 that are no longer diverted implies a lower stream flow of 120 instead of the 200 that occurred before the adoption of the new technology. In general it is quite possible that investment in irrigation efficiency can substantially *reduce* water left for streams or lakes, depending on what changes the farmer may make in his farming practices and on how other irrigators downstream may respond to changes in the availability of stream flows at different times—especially in settings where surface water is already over-appropriated via existing senior and junior right holders.

This issue is especially relevant to the Klamath Basin where water that is "wasted" in irrigation due to inefficient irrigation technology frequently provides an ecological benefit elsewhere. In areas above Upper Klamath Lake, return flows from irrigation return to streams, Upper Klamath Lake, and either the KRP or instream flows below Link River Dam. Return flows in the Lost River watershed and the project are believed to be reused by other irrigators as these waters seep into canals, wells, and subsurface irrigation. In addition, the return flows within the project serve to supply water to the wildlife refuges at Tule Lake and Lower Klamath Lake. Return flows in the Shasta and Scott River areas supplement streamflows and augment habitat for coho salmon. Overall, it is hard to make the case that improved irrigation efficiency will make more water available for fish and wildlife habitat. If, however, return flows are very slow so that "wasted" irrigation water does not return to lakes and rivers during the critical months, then there may be potential gains from improved irrigation efficiencies—but not without a cost. Ultimately the cost of making more water available for fish by encouraging adoption of improved irrigation efficiency must be compared to the cost of the alternatives.

Indeed, improved irrigation efficiency does not necessarily mean more economic efficiency or higher net revenues. Even in cases where improved irrigation efficiency makes more water available for fish, this may not benefit the farmer. For some crops, especially low-value crops, the cost of improved irrigation technology may be higher than the net revenues from production. For high-value crops, there may be some gains to farmers for using sprinkler irrigation due increased yields, lower labor and pumping costs, or the possibility of switching to a higher value crop. The costs of improved irrigation efficiency will be primarily the capital costs of the new irrigation technology and their associated maintenance costs. Sprinkler systems can cost $400-1,200 per acre to install. The annualized cost for these investments would then amount to $24-72 per acre per year. Given the net revenues for class IV and V soils reported in Table 3, the costs of these investments would be prohibitive unless they also make possible additional cost savings or added revenues.

One cannot, however, assume that farmers will divert less water when irrigation efficiency improves; they may change the crops they grow or other practices so that the amount of water applied stays the same, but the consumptive use increases. Indeed, low irrigation efficiency may be good for fish since return flow is wasted water for the farmer, but it mostly represents water that ends up back in the stream either on the surface or through aquifers, delayed, however, by hours, months, or perhaps years depending on the soils and geology. If return flows occur over a period of months, much of the water returns to the stream in seasons when maintaining instream flow is not critical. In this situation, reducing irrigation diversions when instream flows are critical to fish will have a positive impact because the concurrent reduction in return flows will be slight, making the net effect on instream flow larger.

Even under the generous assumptions that improved irrigation efficiency makes additional water available for fish, we will want to ask, at what cost? Hoffman and Willett (1999) compared grated pipe irrigation with wheel-line, center pivot, and linear move techniques for irrigation systems in the Kittitas Valley, Washington. When the costs of these alternative technologies were compared to the amount of "saved water", the cost per acre-foot of water ranged from $40 for center pivot to $61 for linear move. These estimates do not offer encouragement that technology adoption in irrigation can represent a cost-effective way to resolve water conflicts in the Klamath basin, at least not on a large scale.

Land retirement

The 2001 events in the Klamath Basin and the conflicts between ecological and agricultural uses of water has led some to question whether agriculture is compatible with competing ecological goals. This is a complex question that does not have a simple "yes" or "no" answer, certainly not one based solely on the existing methods for valuing and comparing benefits and costs. Moreover, the eventual outcomes for water allocation in the basin are likely to be determined by evolving interpretations of tribal rights, interpretations of the Endangered Species Act, and competitive forces in national and international agricultural markets.

Nevertheless, some of the economic data assembled here may provide some perspective and insight relevant to this question.

Although the relative magnitude of benefits versus costs cannot be assumed to be the sole factor in determining outcomes, such comparisons can be instructive and illuminating. In the current context, one may wish to ask whether the value of water used in agriculture is higher or lower than water used for the protection of species or for other instream uses such as recreation. Several studies in the West have estimated the value of increasing instream flow to enhance salmon populations in northern California from $33 to $53 per acre-foot (Colby 1989). In addition, the actions of the Oregon Water Trust, discussed above and described in Table 4, indicate a willingness by environmental interests to pay between $9 and $23 per acre-foot for water to protect instream habitat for fish.

In the case of permanent retirement of agricultural lands, it is the long-run value of water that is relevant, and this is presented in Table 3. What is most noteworthy from these economic data (presented on a per-acre basis rather than per-acre-foot basis, but where 2 acre-feet per acre is typical in the region) is that the value of water in agriculture can be shown to be both higher and lower than the range of ecological values summarized above depending on the location and soil class in question. The value of water applied to pastures on class V soils in the basin are in the range where land retirement to augment instream flows may appear reasonable based on estimates of value. Organizations like the Oregon Water Trust have purchased water rights in this price range to augment instream flows. These low values are not surprising given the high altitude and relatively low-value crop activities on some of these lands.

More striking, however, is the other end of the productivity spectrum. Those areas in the basin characterized by class II and III soils generate values from the application of water in the range of $60 to $144 per acre, or $30 to $72 per acre-foot. This range is 3 to 15 times higher than that reported above for ecological values. Admittedly these are imprecise measures intended only to provide an order-of-magnitude comparison, but on this basis we find that more than half of the agricultural land in the basin generates net revenues from the application of water that exceed the range currently in evidence for instream, ecological uses.

An incremental approach to retirement of some irrigated lands in order to augment stream flows, say by environmental organizations or government programs, would presumably involve purchases of class V lands in the upper reaches of the river system. From Table 2 we expect that the purchases of these irrigated lands would cost $300-600 per acre, or $150-300 per acre-foot of water. For arrangements involving the purchase of water rights for instream uses, but leaving the land available for nonirrigated purposes (nonirrigated land in these areas is valued at $200-400 per acre), the cost of permanent augmentation of instream flows would be lower, in the range of $50-100 per acre-foot. These one-time purchase costs correspond to an annualized cost of $3-6 per acre-foot per year.

Once the adjudication of water rights in the area is complete, voluntary sales of water rights by irrigators to environmental groups or the government will be possible. Consequences of these changes may affect others in the basin by concentrating the burden of maintenance and overhead costs on the remaining irrigators.

Markets for water rights

In the face of continued uncertainty about the total amount of water available for irrigation in the Klamath Basin, efficiency suggests that the highest priority water rights will have the highest financial value when held by those irrigators with the highest risk of loss. Our analysis of short-run water values above indicates that most of these water users are within the KRP, where losses from water curtailment exceed $300 per acre. By contrast, many irrigators in other areas face losses of perhaps $33 per acre. The possibility that the most vulnerable irrigators (those facing losses of more than $300) could buy or swap water rights of different priority dates would bring about a reduction in uncertainty and vulnerability in those areas where it is the most costly.

With differences in losses of, say, $250, the willingness to pay for a swap of priority dates would depend on the expected frequency with which the junior right holder would not receive water. If the senior right holder expects always to receive water, and the junior right holder expects to be denied water 1 year out of 3, then the higher priority right would be worth up to $83 per year more to the high-loss producer than the low-loss producer. The permanent swap characterized here would be worth up to $1,389 ($83/0.06) to the high-loss producer.

In general, there can be serious obstacles to the sale or exchange of water right across locations in a given water system due to potential "third-party effects," legal prohibitions, or other institutional constraints. In the case of the Klamath Basin, there appears to be reason for optimism. Temporary sales or transfers of water among irrigators appear to be prohibited under state law for most circumstances. However, the permanent sale of a water right, or the exchange of water rights carrying different priority dates, seems to be permissible under Oregon law. Given the distribution of water values within the basin, most efficiency-augmenting transfers would generally move senior water rights from upstream to downstream. This would reduce the likelihood of the kind of "third-party effect" whereby an intermediate priority date water right holder located in between the other two right holders might find him- or herself unable to obtain water. If the ownership of water rights evolved so that most senior water rights were in the KRP area, basin-wide management of water allocation would involve restricting water diversions among the junior right holders in the upper reaches of the basin to ensure adequate supplies for the senior right holders below.

Were such a reallocation of priority rights to occur, it would appear to produce the unintended but desirable side effect of leaving more water instream in the upper portions of the basin and in Upper Klamath Lake. Additionally, in years when water supplies were inadequate to provide water to junior right holders, the curtailment of water deliveries in these upper reaches would also have an ameliorating effect on stream and lake contamination from agricultural chemicals and animal waste.

The exception to the idea that more senior water rights would move downstream and avoid most third-party complications involves the Scott and Shasta rivers. The analysis above suggests that perhaps 3,500 acres in those valleys would be a less efficient allocation of high-priority water rights, but there is no physical way to move water from those tributaries upstream to the KRP and they are also rights within the jurisdiction of California. Alternative institutional arrangements may be possible, however, to achieve the desired outcome. This might include government or nongovernmental organization purchases of these water rights to augment instream flow in the Scott and Shasta rivers. To the extent that these actions have ameliorating effects on fish habitat, subsequent requirements for instream flows at Link River dam may be able to be relaxed somewhat to fulfill ESA or future tribal requirements.

A scenario where adjudicated water rights were shuffled via market transactions within the basin in such a way to minimize financial risks to the agricultural sector overall is unlikely to emerge without conducive and supportive institutions to encourage these mutually beneficial transactions. External funding may serve a catalytic role to purchase, and then resell, high priority water rights. Some purchases may be considered as a way of retiring ecologically sensitive areas, to augment and protect instream flow.

In addition to the possibility of these efficiency-increasing transactions, the adjudication of water rights might reduce the losses from water shortages in a secondary way. Junior right holders can be expected to alter their production decisions based on the recognition that they face a relatively high risk of being denied water. Given this fact, they are likely to take precautionary measures that reduce their vulnerability. This may include the purchase of insurance against water loss. But it may also involve actions or contingency plans that will enable these irrigators to reduce their losses, for example by lowering their fixed costs.

There is some evidence to suggest that when a temporary loss of water is anticipated and planned for, the losses faced by the irrigators can be significantly reduced. Recall that in the data from the Klamath Basin, the ratio between the short-run losses from being denied water and the long-run annual value of water was 5:1. But data from the Oregon Water Trust, where contracts for both permanent purchases and 1-year leases were made, suggest a difference of only 2.5:1 ($23 versus $9 per acre-foot). These market transactions may reflect the short-run value of water in situations where irrigators anticipate, plan for, and are in a unique position that allows them to avoid significant fixed costs. We should not assume, however, that these values would be similar to the losses resulting from *unanticipated, nonvoluntary* curtailment of irrigation deliveries. If these data are indicative of how losses can be reduced when water curtailment is anticipated, the adjudication of water rights and “early warnings” to junior right holders may further reduce the costs associated with uncertain water supplies in the basin.

Biological flexibility with contingent arrangements

The adjustments and mitigation measures discussed above involve finding ways for irrigated agriculture to respond to drought conditions in a more flexible, cost-effective way. In face of the two biological opinions in 2001, scarce water in the basin must be allocated among Upper Klamath Lake suckers, Klamath River coho salmon, and farmers. The question raised in this section is, under drought conditions must it be that the farmers always take the hit?

To a significant degree this is a question for biologists and the federal courts. But given the requirement that response to ESA listings be "reasonable and prudent," one might consider more flexible rules for species protection that allow exceptions to a general rule (for lake level or stream flow) under certain circumstances. Indeed, prior responses have in some cases made similar allowances. The idea here is that for a given lake level or stream flow requirement, exceptions might be allowed. The requirement might be relaxed by a specified amount, with the provision that if an exception is granted, it cannot be granted for X years.

To illustrate, consider the possibility that the required lake level in Upper Klamath lake were allowed to be lowered by 1 foot below the desired minimum, say, once every 5 years, and that the instream flow requirement below Link River Dam were allowed to be relaxed by 25 percent, say, once every 5 years. This would represent a set of rules in which water shortages would sometimes impose costs on farmers, but sometimes on fish. Based on the distribution of high and low hydrological years, how often, and to what extent, would severe irrigation restrictions be necessary? Depending on the biological requirements and temporal distribution of low-water years, a flexible allocation mechanism of this kind might make it possible to avoid severe reductions like the one experienced in 2001. Instead, there might be only infrequent, modest restrictions.

Once again, however, the possibility of implementing a proposal of this kind would depend on the judgment of biologists and court interpretations of the ESA as to whether such an approach could be considered reasonable and prudent.

Concluding comments

The legal and political institutions and infrastructure that currently exist in the Klamath Basin were developed over the past 100 years to fit the circumstances of that period, in which per capita income was low and the abundance of natural resources was relatively high. For these historical reasons, some institutions and infrastructures have not kept pace with change. In particular, the current lack of adjudicated water rights and water metering devices are two key obstacles to the introduction of alternative management approaches to allocate water in the basin in a way that would promote efficiency, reduce uncertainty, and avoid calamities like the one experienced in 2001.

Of the alternatives evaluated here, cost-effectiveness and future flexibility are promoted most directly by a mechanism that would allow scarce water for irrigation to find its way to the highest value use. Centralized control or management by government agencies has a poor track record in this regard, although there may be ways that substantial improvements in cost-effectiveness can be achieved administratively. Even privately owned and metered water can face impediments to contractual transfers of water that raise efficiency, given the legal restrictions on such transfers, potential third-party effects, or physical obstacles such as distance, timing, or moving water uphill. The cost of installing control and metering devices on some flood-irrigated land may reduce net returns to zero, and make these lands prime candidates for land retirement.

In the current context, the completion of the adjudication process promises to create a new opportunity for the reallocation of water rights among groups and users with different interests and risks. Whatever the outcome of tribal water right claims or future ESA rulings and biological opinions, if water rights can be bought and sold across different locations within the basin, this will make it possible for water available to irrigators to be allocated with the greatest certainty to those users with the most to lose from not getting their water. Users with junior water rights may find themselves developing contingency arrangements to reduce their fixed costs, planting crops more tolerant to deficit irrigation, or diversifying their farm activities. Insurance policies for curtailment of water deliveries may become available. Other mechanisms not evaluated here that also reduce uncertainty, promote flexibility, and encourage cost-effective responses, may also contribute to improved water management in the Klamath Basin.

References

Adams, R. M., and S. H. Cho. 1998. Agriculture and endangered species: an analysis of trade-offs in the Klamath Basin, Oregon. Water Resources Research 34:10, 2741-2749.

Colby, B. G. 1989. Estimating the value of water in alternative uses. Natural Resources Journal 29:511-527.

Faux, J., and G. M. Perry. 1999. Estimating irrigation water value using hedonic price analysis: a case study in Malheur County, Oregon. Land Economics 75:440-452.

Hoffman, T. R., and G. S. Willett. 1999. The economics of alternative irrigation systems in the Kittitas Valley of Washington State. Extension Bulletin No. 1875, State of Washington.

Huffaker, R., and N. Whittlesey. 2000. The allocative efficiency and conservation potential of water laws encouraging investments in on-farm irrigation technologies. Agricultural Economics 24:47-60.

Niemi, E., A. Fifield, and E. Whitelaw. 2001. Coping with competition for water: irrigation, economic growth, and the ecosystem in Upper Klamath Basin. ECONorthwest, Eugene, Oregon.

Jaeger, W. K., and R. Mikesell. Increasing streamflow to sustain salmon and other native fish in the Pacific Northwest. Contemporary Economic Policy. (In press, 2002 expected publication date.)

Klamath County Assessor. 2001. Klamath County Assessor's Certified Farm Use Study, 2001-2002. Klamath Falls, Oregon.

OSU Agricultural Enterprise Budgets**, http://osu.orst.edu/Dept/EconInfo/ent_budget/.**

Table 1. Irrigated acreage in the Klamath Basin.

Name	Soil Class:	II	III	IV	V	Totals
Areas above Upper Klamath Lake:						
Fort Klamath Valley		0	1,800	8,025	26,055	35,880
Modoc Point to Chiloquin		2,710	6,475	7,215	335	16,735
Sprague River Valley		0	640	54,120	910	55,670
North Country		0	5,410	16,865	1,530	23,805
Areas east and south of Upper Klamath Lake						
Swan Lake Valley		2,620	8,310	14,930	0	25,860
Bonanza (nonproject)		4,541	6,425	6,354	0	17,320
Langell Valley (nonproject)		3,145	6,611	5,209	535	15,500
Poe Valley (nonproject)		525	697	778	0	2,000
West of 97 to Keno (nonproject)		2,388	9,048	11,367	198	23,000
Lower Klamath Lake (non-project)		69	4,614	309	7	5,000
Klamath Irrigation Project Areas						
Merril-Malin area		2,030	13,965	6,205	0	22,200
Poe Valley		4,424	5,873	6,562	0	16,859
Midland-Henley-Olene		7,625	18,555	11,890	0	38,070
Bonanza-Dairy-Hildebrand[1]		*2,569*	*3,635*	*3,596*	*0*	*9,800*
Langell Valley		*3,315*	*6,969*	*5,491*	*565*	*16,340*
Lower Klamath Lake		211	14,021	941	23	15,195
Malin Irrigation District		300	2,905	120	0	3,325
Shasta View District		1,000	3,100	1,100	0	5,200
West of 97 to Keno		387	1,467	1,843	32	3,730
Tule Lake / California portion		13,244	40,000	20,000	0	73,244
Shasta & Scott Valleys		8,000	41,100	35,000	0	84,100
Totals:		59,103	201,620	217,920	30,190	508,833

[1]Italics indicate portions of the KIP that received water in 2001.

Table 2. Average market values for irrigated land by location and soil class (per acre).

Soil Class:	II	III	IV	V	Nonirrigated (class VI)
Areas above Upper Klamath Lake:					
Fort Klamath Valley[1]	--	1,100	850	600	400
Modoc Point to Chiloquin	1,700	1,100	850	600	400
Spraque River Valley	--	1,000	750	300	200
North Country	--	750	750	250	200
Areas east and south of Upper Klamath Lake					
Swan Lake Valley	2,100	1,450	750	370	200
Bonanza (nonproject)	2,100	1,450	750	370	200
Langell Valley (nonproject)	2,100	1,450	750	370	200
Poe Valley (nonproject)	2,600	1,400	1,000	500	300
West of 97 to Keno (nonproject)	1,700	1,100	850	600	400
Lower Klamath Lake (non-project)	2,600	1,900	1,000	301	300
Klamath Irrigation Project Areas					
Merril-Malin area	2,600	1,350	1,000	500	300
Poe Valley	2,600	1,400	1,000	500	300
Midland-Henley-Olene	2,600	1,400	1,000	500	300
Bonanza-Dairy-Hildebrand	*2,100*	*1,450*	*750*	*370*	*200*
Langell Valley	*2,100*	*1,450*	*750*	*370*	*200*
Lower Klamath Lake	2,600	1,900	1,000	300	300
Malin Irrigation District	2,600	1,900	1,000	300	200
Shasta View District	2,600	1,350	1,000	300	200
West of 97 to Keno	1,700	1,100	850	600	400
Tule Lake / California portion	2,600	1,800	1,100	--	300
Shasta & Scott Valleys	2,000	1,650	1,050	--	300

[1] Values based on agricultural use. Recreational demand has increased land values in this area.

Table 3. Marginal value of applied water in irrigated agriculture (per acre per year).

Soil Class:	II	III	IV	V	Average (weighted)
Areas above Upper Klamath Lake:					
Fort Klamath Valley[1]	--	42	27	12	17
Modoc Point to Chiloquin	78	42	27	12	41
Sprague River Valley	--	48	33	6	33
North Country	--	33	33	3	31
Areas east and south of Upper Klamath Lake					
Swan Lake Valley	114	75	33	10	55
Bonanza (nonproject)	114	75	33	10	70
Langell Valley (nonproject)	114	75	33	10	67
Poe Valley (nonproject)	138	66	42	12	76
West of 97 to Keno (nonproject)	78	42	27	12	38
Lower Klamath Lake (non-project)	138	96	42	0	93
Klamath Irrigation Project Areas					
Merril-Malin area	138	63	42	12	64
Poe Valley	138	66	42	12	76
Midland-Henley-Olene	138	66	42	12	73
Bonanza-Dairy-Hildebrand	*114*	*75*	*33*	*10*	*70*
Langell Valley	*114*	*75*	*33*	*10*	*67*
Lower Klamath Lake	138	96	42		
Malin Irrigation District	144	102	48	6	104
Shasta View District	144	69	48	6	79
West of 97 to Keno	78	42	27	12	38
Tule Lake / California portion	138	90	48	--	
Shasta & Scott Valleys	102	81	45	--	68
Weighted average:					60
Unweighted average:	103	68	37	9	
Comparison with estimates for Malheur County, Oregon[2]	105	67	35	32	

Based on comparison of market price data for irrigated versus nonirrigated land.
[1]These values reflect agricultural use. Recreational demand has increased land values in this area.
[2]Based on hedonic price analysis from Faux and Perry (1999).

Table 4. Recent water rights transactions to augment streamflows.

Oregon locations	Current use	Contract type	Consumptive use (af/year)	Price paid	Cost/af [1]
Rogue River, Sucker Creek	Fallow	purchase	67.80	$ 8,800	$ 7.79
Rogue River, Sucker Creek	Fallow	purchase	107.62	$ 13,627	$ 7.60
Rogue River, Sucker Creek	Fallow	purchase	57.47	$ 8,138	$ 8.50
Deschutes River, Squaw Creek	Pasture	purchase	417.19	$ 42,900	$ 6.17
Deschutes River, Squaw Creek	Pasture	purchase	308.08	$ 44,352	$ 8.64
Deschutes River, Squaw Creek	Pasture	purchase	48.14	$ 7,425	$ 9.25
Deschutes River, Squaw Creek	Pasture	purchase	8.46	$ 870	$ 6.17
Deschutes River, Squaw Creek	Pasture	purchase	96.27	$ 13,860	$ 8.64
Rogue River Little Butte Creek	Hay	purchase	173.95	$ 20,000	$ 6.90
Hood River, Fifteenmile Creek	Wheat	purchase	71.76	$ 26,307	$ 22.00
				Average:	**$ 9.16**
Deschutes River, Buck Hollow Creek	Hay	one-year lease	196.80	$ 6,630	$33.69
Deschutes River, Buck Hollow Creek	Hay	one-year lease	196.80	$ 6,630	$33.69
Deschutes River, Buck Hollow Creek	Hay	one-year lease	196.80	$ 6,630	$33.69
Grande Ronde River, Crow Creek	Hay	one-year lease	194.00	$ 1,600	$8.25
Umatilla River, E. Birch Creek	Hay	one-year lease	238.50	$ 2,500	$10.48
Deschutes River, Trout Creek	Hay	one-year lease	1135.50	$ 23,843	$21.00
Deschutes River, Trout Creek	Hay	one-year lease	270.00	$ 4,680	$17.33
John Day River, Hay Creek	Hay	one-year lease	248.80	$ 14,500	$58.28
Rogue River, S.F. Little Butte Creek	NA	one-year lease	83.34	$ 1,438	$17.25
Deschutes River, Buck Hollow Creek	Hay	one-year lease	196.80	$ 6,630	$33.69
Grande Ronde River, Crow Creek	Hay	one-year lease	197.70	$ 5,272	$26.67
Deschutes River, Tygh Creek	Pasture	one-year lease	94.50	$ 945	$10.00
Rogue River, S.F. Little Butte Creek	NA	one-year lease	83.34	$ 1,438	$17.25
Grande Ronde River, Crow Creek	Hay	one-year lease	197.70	$ 5,136	$25.98
Deschutes River, Tygh Creek	Pasture	one-year lease	94.50	$ 945	$10.00
Rogue River, S.F. Little Butte Creek	NA	one-year lease	83.34	$ 1,438	$17.25
Umatilla River, Couse Creek	Wheat/Pea	one-year lease	1065.9	$ 23,800	$22.33
Deschutes River, Buck Hollow Creek	Hay	one-year lease	196.80	$ 5,000	$25.41
Grande Ronde River, Crow Creek	Hay	one-year lease	197.70	$ 5,136	$25.98
Rogue River, S.F. Little Butte Creek	NA	one-year lease	83.34	$ 1,438	$17.25
Umatilla River, Couse Creek	Wheat/Pea	one-year lease	1065.9	$ 23,800	$22.33
Umatilla River, Couse Creek	Wheat/Pea	one-year lease	1065.9	$ 23,800	$22.33
				Average:	**$23.19**

[1] Assumes a 6% discount rate to compute annualized cost of permanent acquisitions.
Source: Oregon data from Oregon Water Trust; Washington data from Washington Water Trust.

Table 5. Losses per acre from irrigation curtailment.

Soil Class:	II	III	IV	V	Average (weighted)
Areas above Upper Klamath Lake:					
Fort Klamath Valley	--	33	33	33	33
Modoc Point to Chiloquin	250	203	33	33	134
Sprague River Valley	--	219	33	33	35
North Country	--	33	33	33	33
Areas east and south of Upper Klamath Lake					
Swan Lake Valley	175	122	33	33	76
Bonanza (nonproject)	307	275	33	33	195
Langell Valley (nonproject)	179	36	33	33	64
Poe Valley (nonproject)	236	132	33	33	121
West of 97 to Keno (nonproject)	178	123	33	33	83
Lower Klamath Lake (non-project)	325	61	33	33	63
Klamath Irrigation Project Areas					
Merril-Malin area	318	284	33	33	217
Poe Valley	236	132	33	33	121
Midland-Henley-Olene	292	279	33	33	205
Bonanza-Dairy-Hildebrand	*307*	*275*	*33*	*33*	*195*
Langell Valley	*179*	*36*	*33*	*33*	*64*
Lower Klamath Lake	325	61	33	33	63
Malin Irrigation District	308	227	33	33	227
Shasta View District	324	284	232	33	281
West of 97 to Keno	178	123	33	33	83
Tule Lake / California portion	174	174	33	33	136
Shasta & Scott Valleys	238	188	33	--	128

Table 6. Cost estimates for reduced irrigation diversions in the Upper Klamath Basin under alternative approaches.

Estimated losses from actual 2001 cut-off in KRP	$28-35 million
Losses with cost-minimizing acre-acre transfers	$6.7-9.0 million
Losses with basin-wide uniform 35% reductions in applied water	$32 million
Losses with acre-acre transfers and deficit irrigation	$4.8 million

Draft
December 14, 2001

A synthesis: institutional and public policy analysis

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This synthesis draws mainly on chapters prepared by Woodward, Romm, and Langridge; Jaeger; and an appendix paper by Marbut. In addition, those chapters dealing with natural resources, as well as those concerned with economic and social matters, provide the reality with which institutions and policies must deal.

Institutions and policies reflect the formal and informal arrangements made by individuals for dealing with one another in groups. Formal institutional arrangements are the means by which obligations, responsibilities, rights, and entitlements are stated in the law and take form in policies, programs, and organizations. This synthesis is concerned mostly with formal institutional arrangements. Particular institutions, policies, and programs usually come into existence at a particular time to serve a specific purpose or purposes. Under our system of government, all three branches—legislative, judicial, executive—typically are involved in public policies. Additional complexity arises from divisions of power among Federal, state and local governments.

An institution may be effective in serving the purpose for which it was created at the time it was created, but social needs always change with the passage of time. New programs often come into existence to serve needs that were not apparent when an earlier policy was established. Conflicts, inconsistencies, unclear responsibilities, and fragmented authority may then develop. Such a result does not necessarily mean individual programs have failed, or are dysfunctional. Rather, it may indicate government activity, taken as a whole, is not performing effectively. In 2001 in the Klamath Basin, biological opinions, made under the Endangered Species Act, required that the Bureau of Reclamation not honor its contractual obligation to supply irrigation water to the Klamath Reclamation Project. No institutional provision existed or was made to provide for the payment of compensation for the failure of the Bureau to honor its contractual obligation, or to consider the needs of a wildlife refuge that held a water right for irrigation return flows. Few would argue such events provide evidence that government institutions were functioning properly from the standpoint of the total community.

Corrections or improvements in institutional performance to address difficulties may take one of two avenues. One avenue is to address the difficulty by treating it as an **exception.** This means the difficulty is considered sufficiently unique that institutional rules or guidelines can be suspended and a solution sought by other means. The other avenue is to **modify** one or more institutions. When this avenue is chosen, it means conditions either are different than they were when the institution was established, or something important was neglected at that time.

How should the 2001 water allocation problem in the Klamath be viewed? Woodward et al. consider the Klamath situation to be sufficiently unique that it should not serve as a legal precedent. This judgment is based largely on a comparison of institutions in the Klamath with other California rivers. Uniqueness may also stem from the event that triggered the problem, in this case the 2001 drought conditions in the Klamath Basin. In addition, uniqueness may be judged as to whether a particular situation, such as the Klamath Basin in 2001, may occur elsewhere, or has elements that may be duplicated elsewhere. In other words, is it possible the Klamath Basin 2001 issues will arise elsewhere in the West?

Three alternative, highly preliminary, views are sketched here of how institutional change in the Klamath Basin might result from events in 2001. Alternative I considers the 2001 situation to be an anomaly, or highly unusual event, and treats it as an **exception** to events that established institutions were designed to address. Alternative II is labeled here as a **moderate modification** and will be described more fully subsequently. Alternative III pertains to a **major modification.** It will be discussed more fully later as well.

Alternative I proposes minimal institutional change, but delineates fundamental improvements in operating procedures that may be undertaken. Two suggestions made by Woodward et al. with respect to the Klamath are consistent with the exception avenue. One is for the Bureau of Reclamation to take leadership with water users in formulating plans consistent with objectives of the Endangered Species Act when water is in short supply. For example, the Jaeger chapter provides examples of biological flexibility that will permit practices to be followed under the Act that have not previously been used. Plans can be made to take advantage of such opportunities. They provide evidence progress is being made toward the accomplishment of, for example, Endangered Species Act objectives.

Additionally, Woodward et al. suggest that the court decision in *Tulare vs. United States* be tested to determine if compensation must be paid when the cost of a taking falls heavily on a particular group. This case involved water contractors, as plaintiffs, to claim against regulatory agencies that left water, normally diverted, in the water course for the protection species of fish in jeopardy. The issue was not whether the federal government has authority to protect endangered species, but whether it could impose the costs of doing so solely on the plaintiffs. As quoted in Woodward et al., Judge Wiese wrote in his decision "The federal government is certainly free to preserve the fish; it must simply pay for the water it takes to do so." If the verdict is upheld, institutions would largely remain intact, but the way they are applied would be determined on a case-by-case basis. Presumably, the court would clarify the contractual obligation of the Bureau of Reclamation to supply irrigation water, should the verdict in *Tulare vs. United States* not be upheld. Again, the particular circumstances arising in the Klamath Basin would be considered within existing institutions, and would not require institutional modification.

The drought of 2001 may be considered by some as an event unlikely to be duplicated. In such a circumstance it would not be sensible to modify institutions to provide for an event unlikely to be repeated. There is considerable evidence presented in the report to assist judgments as to the uniqueness of the 2001 drought. Yet, the difference of opinion that remains on the subject suggests there are inadequate data to permit a definitive judgment on this matter. Regardless of what one believes the probability of another 2001 drought to be, it is clear that probability is important in deciding if it should be considered an exception under the law.

A third reason for considering whether the Klamath experience is an exception is whether such a situation may arise elsewhere. This was not discussed to any significant extent elsewhere in this report. Yet it needs to be considered if the lessons to be learned from the Klamath experience are to be developed thoroughly. It is unlikely the conflicting needs of endangered species, economic systems, communities, and government agencies will come together elsewhere precisely as they did, and do, in the Klamath Basin. Yet such conflicting interests are present elsewhere, and the lessons of the Klamath may apply.

Consider next Alternative II, moderate institutional modification. The key assumption here is that certain institutions are considered more basic than others and are not changed in a fundamental way. Less basic institutions may be modified to make the more basic institutions perform better, or to remove inconsistencies between or among them. The Endangered Species Act, Reclamation legislation, and California and Oregon state water laws are considered to be more basic institutions. The relative legal standings of endangered species, Native American water rights, and out-of-stream water uses are not questioned. Possible changes in other institutions are the essence of this alternative. The strategy here is to create a more adaptable, flexible system for managing water in the Klamath Basin while leaving the basic institutional framework intact. Adaptability and flexibility are time-honored techniques for addressing uncertainty. One way of providing for adaptability and flexibility in water management in the Klamath Basin is to require, or permit, resource interdependencies in the basin to be incorporated in the institutional framework. By way of example, two such interdependences are described next:

- Land in the Klamath Reclamation Project is not the only land use in the basin that affects Upper Klamath Lake levels, water quality, or the amount of water that flows from the basin into the Klamath River. This interdependency among basin water uses and users is a source of adaptability and flexibility in decision-making as noted in the chapter by Jaeger. Institutions will need to be modified if this is to occur.

- Biological information presented in this report makes it clear that water quality, as well as quantity, is important for many in-stream water uses. Further, water quality varies geographically within the basin. So long as water requirements do not recognize qualitative considerations, the waters of the basin will not be put to their highest social use.

The chapter written by Bill Jaeger provides evidence that water could be used more effectively if a basin-wide perspective were employed in decision-making. It is not necessary to accept all of the numbers presented by Jaeger to conclude that the incremental value of water varies within the basin. This fact alone indicates that water could be used more effectively if it could be moved between and among locations within the basin. An elementary principle of economics states that if an economic system is to achieve its potential, the incremental value of a useful scarce resource must be equal in all alternative uses. It is clear this condition is not met in the Klamath Basin. In a similar vein, the fact that many public and private decisions are made with reference only to water quantity provides evidence that social gains would result from a consideration of water quality. For certain purposes, an entire acre-foot of water from one source may be needed to be as useful as only 0.8 acre-foot from another source that has (say) two degrees lower temperature.

Jaeger discusses institutional modifications that would be necessary to accommodate such interdependencies. In some cases the needed institutional modifications would be minor, but other modifications may be difficult to make. Water markets are one means for moving water rights among uses, users, and locations. Jaeger notes that Oregon water law probably can accommodate permanent transfers of water rights, but short-run, or temporary, transfers may be another matter.

Water markets require that rights in water be specific with respect to place, quantity, and ownership. Such conditions do not exist in the Klamath Basin. Part of the reason lies in Oregon law, but part reflects conditions in the Klamath. Do water rights for the Klamath Reclamation Project reside with the Bureau of Reclamation, the reclamation district, or with individual farmers? Until such questions can be answered unambiguously it will be difficult for water markets to function well. Yet the fact that Basin-wide institutions and water markets exist elsewhere indicates moderate modifications of water institutions is a viable alternative for the Klamath Basin.

Alternative III, a major institutional modification, would involve consideration of significant change in basic water institutions. For example, some may believe significant acreages of irrigated agriculture are not compatible with ecological integrity in the Klamath Basin. Others maintain the Endangered Species Act does not provide the flexibility needed to reconcile conflicting interests in the Nation's natural resources. Significant institutional change may be required to accommodate these or other opinions about the direction that should be taken in the Klamath Basin. This report did not investigate changes of this nature to any great extent. The emphasis in this report was on the consequences of the 2001 water allocation decisions that took certain institutions as given. Even so, some of the findings have direct implications for institutional design. For example, the Jaeger chapter presents data that show the economic product of the basin likely would be the greatest from some combination of irrigated agriculture and recreational resource activity. This finding suggests the desirability of the co-existence of environmental preservation and natural resource use.

In the preparation of this synthesis, each of the three alternative approaches to institutional modification were examined from a local, state, and federal perspective. The examination made clear that improvement in performance, as well as institutional modification, should be considered at every level of government. A great deal can be said about the benefit that would come from the Klamath community achieving success with a few common undertakings. To that end two observations are made:

- The Klamath Basin Compact Commission is one of the few institutions that can assemble all, or most, of the major interests in the basin. While the commission, as such, may have limited powers to address some problems, it may have unrealized potential as a forum and as an incubator for ideas. Perhaps consideration should be given toward keeping the Commission robust and viable.

- Each of the alternatives considered directs attention to the fundamental importance of the adjudication process for water rights in the Klamath Basin. Clarity with respect to where water rights reside is necessary for the proper functioning of water institutions under all of the alternatives considered. All, or most, of the significant water interests in the basin could unite in an effort to bring this process to a prompt and reliable conclusion. Both Federal and local government might well emphasize the importance of this process and offer their assistance to that end. Such assistance might take various forms, including monetary assistance.

This report has emphasized, in one way or another, the allocation of water among competing uses. Much less attention has been given to the distribution of income that would result from different water allocations, or that might stem from an institutional imperative such as a judicial decree. Yet even if such matters were considered sufficiently, it would not be a simple matter to know how compensation should be paid for failure to deliver water when there is a contract to do so. In such matters the way water rights are defined and in whom they reside is of great importance. This demonstrates, once again, the fundamental importance of the adjudication process.

This synthesis was written under the assumption that institutions and public policies are our servants, rather than our masters. This assumption not only requires recognition of the importance of institutions, but also to the continuing importance of improvements in, and modifications of, those institutions.