Assessment of the Klamath Project Pilot Water Bank: A Review from a Hydrologic Perspective

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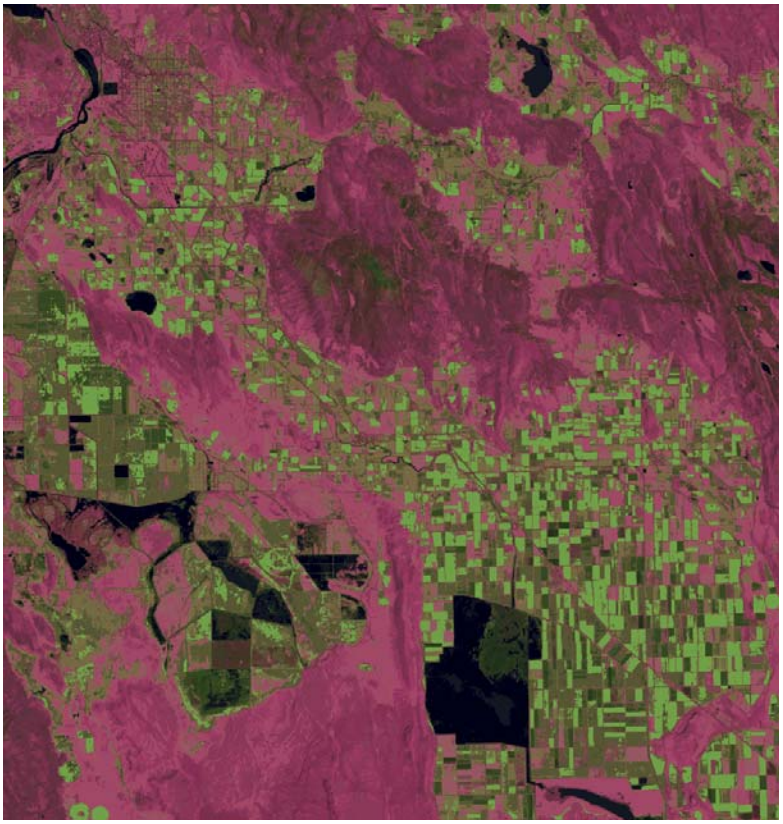

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Executive Summary

During 2003 and 2004, the Bureau of Reclamation (Reclamation) Klamath Basin Area Office operated a pilot water bank to provide additional water supplies to benefit fish and to enhance tribal trust resources. Implementation of the water bank was one of the components of the "reasonable and prudent alternative" in the 2002 Biological Opinion (BO) by National Oceanic and Atmospheric Administration (NOAA) Fisheries (formerly National Marine Fisheries Service). A primary purpose of the pilot water bank was to provide enhanced springtime in-stream flows for migration of threatened Coho salmon. The BO specified that 30,000 acre feet of water would be available from the water bank in 2002, 50,000 acre feet in 2003, 75,000 acre feet in 2004, and 100,000 acre feet from 2005 through 2011. The BO also specified flow requirements for the Klamath River at Iron Gate Dam based on five water-year types, ranging from "wet" to "dry" Similarly, a 2002 U.S. Fish and Wildlife Service (USFWS) BO specified lake-level requirements for Upper Klamath Lake in order to protect two endangered sucker species; these lake-level requirements are based on four water-year types, ranging from "above average" to "critically dry".

Reclamation requested that the U.S. Geological Survey (USGS) review the water bank concept within the framework of the overall basin hydrology, and assess the ability of the water bank to simultaneously meet the NOAA Klamath River streamflow and USFWS lake-level requirements with their current strategy or other potential strategies. USGS has a number of investigations underway in the Klamath Basin above Iron Gate Dam (upper Klamath Basin) and is developing a detailed understanding of the hydrology of the region. In 2004, the USGS provided an in-depth review of one portion of the off Project water bank program, the Klamath Basin Rangeland Trust (KBRT).

Although the water bank in the upper Klamath Basin could be reviewed from an economical, agricultural, biological or societal viewpoint, this review by the USGS was limited to the technical aspects related to the hydrology. This in-depth review required a complete understanding of the requirements of the water bank and the hydrologic constraints on the water bank. In addition, because the intent of the water bank was to enhance or augment flow in the Klamath River, the BO flow requirements were evaluated relative to the 1961-1999 measured USGS flow record.

The general hydrologic analysis in the context of the BO flow requirements resulted in a number of conclusions:

- The use of flow statistics from the 10-year period (1990s) to set flow requirements results in flows that are not consistent with, and not a reasonable representation of, the period of record from 1961-1999.
- Significant data inconsistencies were found between USGS, Reclamation, and PacifiCorp streamflow records. All agencies should use the same hydrologic data. Also, improved data collection is needed for diversions and return flows.

- Three different analyses of flow records show that for certain river year types, or for combinations of river and lake year types, required BO flows are often not attainable and that there are significant deficits in water availability based on 1961-1999 operational histories.
- Benefits from decreased consumptive use and the use of ground-water storage have likely resulted in increased Klamath River flows for threatened Coho salmon and/or higher lake levels for endangered suckers. The precise amount of the increase is not measurable in the Klamath River because the benefits are likely within the streamflow measurement error. Climate variability has a strong influence on flow and therefore masks possible changes caused by water bank activities.
- Although diversion and return data have error, these data provide the best method to directly measure the benefits of the pilot water bank. In 2003 and 2004, significant reductions in diversions of water to Reclamation's Klamath Project were apparent due to the water bank program.
- Preliminary pumpage estimates indicate that water bank activities have resulted in an approximately eight-fold increase in ground-water pumping in the vicinity of the Klamath Valley and Tule Lake subbasins. This increased pumping has resulted in acute well interference at some locations, seasonal declines of 10 to 20 feet near pumping centers, and year to year declines of 2 to 8 feet over broad areas surrounding large pumping centers.
- Climate variability imposes the greatest influence on the hydrologic system in the Klamath Basin above Iron Gate Dam. This should be taken into consideration when requirements for in-stream flow volumes and water bank volumes are being set.

Several management options including ground-water pumping/substitution, land idling, on-Project surface-water storage, new reservoirs, wetland restoration, use of properties adjacent to Upper Klamath Lake for storage, among others, are discussed in the review, and pros and cons listed. Some of these management options can provide water for increased spring time flows (e.g. new storage or ground-water pumping), whereas other management options (e.g. land idling) will only provide additional water when consumptive use is reduced primarily in the late spring and summer months. It is evident that multiple management options must be used to attain the most effective water-bank configuration. In general, most of the options discussed have been considered in the current water bank program although some have not yet been implemented.

The use of a water bank could be a viable management tool based on this assessment. However, some alternative directions for the water bank program in the upper Klamath Basin, both on and off Project, should be considered. These directions could include implementation of a planning effort to establish both long-term and short-term strategies as part of the goal to meet a variety of water needs in the basin. Flow requirements should be hydrologically attainable and based on historic streamflow data. And finally, management scenarios could be developed to adjust management schemes based on climate variability so that all water users (environmental, agricultural, and power generation) in the community are aware of hydrologic limitations and the impact on their individual needs. An adaptive management approach could be used to modify management strategies as more is learned from year to year experiences.

The present pilot water bank strategy places the burden of supplying water on Reclamation’s Klamath Project. Spreading that burden to the entire basin above Iron Gate Dam could provide more flexibility in procuring water and ensure a larger supply of water in dryer years. It must also be recognized that a water bank may not be able to meet BO requirements in extremely dry years or after several consecutive dry years.

USGS Contributors

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Introduction

During 2003 and 2004, Reclamation’s Klamath Basin Area Office operated a pilot water bank to provide additional water supplies to benefit fish, to enhance tribal trust resources, and to assure water deliveries for agriculture. Implementation of the pilot water bank was one of the components of the “reasonable and prudent alternative” in the 2002 Biological Opinion (BO) by National Oceanic and Atmospheric Administration (NOAA) Fisheries (formerly National Marine Fisheries Service). A primary purpose of the water bank was to provide enhanced springtime in-stream flows for migration of threatened Coho salmon. The BO specified that 30,000 acre feet of water would be available from the water bank in 2002, 50,000 acre feet in 2003, 75,000 acre feet in 2004, and 100,000 acre feet from 2005 through 2011. The BO also specified flow requirements for the Klamath River at Iron Gate Dam based on five water-year types, ranging from “wet” to “dry” Similarly, a 2002 U.S. Fish and Wildlife Service (USFWS) BO specified lake-level requirements for Upper Klamath Lake in order to protect two endangered sucker species; these lake-level requirements are based on four water-year types, ranging from “above average” to “critically dry”. Reclamation administers and provides federal funding for operation of the water bank in Reclamation’s Klamath Project (Project) and elsewhere in the Klamath Basin above Iron Gate Dam (upper Klamath Basin).

The pilot water bank has used several different management options to reduce consumptive use of surface water or to substitute ground water for surface water. Although the general concept of administering a water bank in the Klamath Basin above Iron Gate Dam is reasonable, it is uncertain how much the currently configured water bank program improves in-stream flows in the Klamath River during critical times of the year. In addition, the consequences of using certain management options, for example, long-term heavy pumping of ground-water resources, are not well understood. Another aspect of the present water bank strategy that is unknown is the degree to which the program could be improved by changing the geographic distribution of water bank activities in the upper Klamath Basin. Lastly, the degree to which the water bank can be made more workable by adjusting the annual requirements to reflect variations in hydrologic (or climatic) conditions should be evaluated.

On May 6, 2004, Reclamation requested that USGS review the pilot water bank concept within the context of the overall basin hydrology, and assess the ability of the water bank to simultaneously meet the NOAA Klamath River streamflow and USFWS lake-level requirements with their current strategy or other potential strategies. Dr. Charles Burt and others of the California Polytechnic State University provided a preliminary analysis of the 2003 water bank (Burt and others, 2003). However, Reclamation requested that USGS provide a technical review of the program including the design and implementation of the 2004 water bank. USGS has a number of investigations underway in the upper Klamath Basin and is developing a detailed understanding of the hydrology of the region. In 2004, the USGS provided an in-depth review of one portion of the off Project water bank program, the Klamath Basin Rangeland Trust (KBRT). In addition, the Government Accountability Office (GAO) also conducted a review of the Klamath Project Pilot Water Bank (GAO, 2005).

Purpose and Scope of Review

Although the pilot water bank in the Klamath Basin above Iron Gate Dam could be reviewed from an economical, agricultural, biological or societal viewpoint (Burke, 2004; Jaeger, 2004), this review by USGS was limited to the technical aspects related to the hydrology. This in-depth review required a complete understanding of the requirements of the water bank and the hydrologic constraints on the water bank. A number of documents provided this background including the National Research Council (NRC) Interim Review (2002), Reclamation's Biological Assessment (2002), the NOAA Fisheries 2002 BO (2002), and the U.S. Fish and Wildlife BO for Upper Klamath Lake (2002).

The review also required an understanding of the 2003 and 2004 water bank operations. Information regarding operation of the water bank was provided by Reclamation and a summary of those operations is included in this review. Data and information provided included the geographic distribution of water bank applicants and participants, the manner in which they participated, and the distribution and rates of ground-water pumping. Reclamation historic data were also provided to USGS for Klamath Project diversions, return flows, Upper Klamath Lake elevations, and Klamath River flows. An understanding of the needs of the water bank, the operation of the water bank during the past two Spring-Summer seasons, and an understanding of the hydrology of the upper Klamath Basin, provided the basis for the USGS review of the pilot water bank relative to the intended hydrologic goals of the program. One specific goal of this review was to evaluate the historic flow record for the Klamath River (1961-1999), which represents a period when Project operation was relatively consistent, to determine if water bank requirements are hydrologically feasible.

Reclamation also requested that as part of the review USGS provide a list of management options that could improve the effectiveness of the water bank program from a hydrologic standpoint. At the end of the review, management options are outlined with pros and cons listed. Many of the options listed have been considered by Reclamation or are actually part of the water bank program; however, additional considerations are posed in this review.

This review focuses on the water bank in the context of the hydrology of the Klamath Basin above Iron Gate Dam, termed the upper Klamath Basin throughout the review. The area of the upper Klamath Basin is approximately 8,000 square miles. Irrigated lands in the Project are about 400 square miles or about 5 percent of the upper basin area. The terminology “on Project” and “off Project” is used to distinguish the area within and outside the Project boundaries. In this document, the water bank is sometimes referred to as the “Klamath Project Pilot Water Bank” reflecting Reclamation’s role to administer the water bank, but as mentioned earlier water bank activities take place both on and off Project. The scope of this review included all activities of the water bank on and off Project.

Water Bank Concepts

In many areas of the western states, water banks have been established for a variety of reasons (MacDonnell and others, 1994). These reasons include the goal of moving water to where it is needed most, to create a reliable water supply during dry years, and ensuring future water supplies for people, farms, and fish (Washington DOE and WestWater Research, 2004). Through water banking, water can be exchanged between various uses.

A recent study by the Washington DOE and WestWater Research (2004) analyzed water banking legislation, policies, and programs in 12 western states. In their analysis, they define a water bank as “an institutional mechanism that facilitates the legal transfer and market exchange of various types of surface, groundwater, and storage entitlements.” Water banks can include a variety of water management strategies. Water banks generally involve multiple buyers and sellers, where deposits and withdrawals are made into and out of the “bank”

One type of water bank, an acquisition bank, is one in which water is purchased usually by a single buyer from multiple sellers for a specific use. Acquisition banks are widely used to obtain water for environmental uses. The Klamath Project Pilot Water Bank does not provide an institutional setting for water to be traded from multiple sellers to multiple buyers. Rather, it is an acquisition bank approach where Reclamation purchases water to meet environmental Endangered Species Act (ESA) needs in the Klamath River.

Programs similar to the Klamath Project Pilot Water Bank are being developed in California, as part of the CALFED Program, to provide water for environmental purposes. The CALFED Environmental Water Program (EWP) is designed to acquire water to enhance in-stream flows that are biologically and ecologically significant, improve the state of scientific knowledge related to the effects of in-stream flows, and gain knowledge regarding the institutional and social constraints facing environmental water acquisitions. Implementation of the EWP program is expected to take 30 years and the Stage 1 goal in the first 7 years is to acquire up to 100,000 acre feet per year of environmental water (http://calwater.ca.gov/Programs/EcosystemRestoration/EWP/index.asp) (Jones and Stokes, 2001a, b, c).

Klamath Project Pilot Water Bank

Biological Assessment and Biological Opinion Background

The competition for water in the Klamath Basin has escalated during the past 5 years. The situation worsened in 2001 when very dry conditions occurred in the basin causing a crisis-level water shortage. In response to this shortage, the Department of the Interior (DOI) decided that nearly all the available water would be used to maintain water levels in Upper Klamath Lake and flows in the Klamath River in order to protect the listed species in the USFWS and NOAA Fisheries BOs. These species include the Southern Oregon/Northern California Evolutionarily Significant Unit of Coho salmon (listed as "threatened" in 1997), and the Lost River and shortnose suckers (listed as "endangered" in 1988). As a result of this water crisis, many farmers in the Klamath Project were not provided irrigation water. Due to the 2001 water crisis in the basin, DOI requested that the National Research Council (NRC), which is part of the National Academy of Sciences (NAS), provide an independent review of the scientific and technical basis of the BOs.

Of the many conclusions in the NRC report (NRC, 2002), the committee concluded that "While information of a sporadic and anecdotal nature is available over as much as 100 years, routinely-collected data on environmental characteristics and fish are available only since 1990 or later. Thus, while the long-term lake level record seems to invite statistical analysis of the welfare of fish in relation to lake level, the information at hand is actually limited to a period of ten years or less." The committee concluded that for both Upper Klamath Lake levels and Klamath River flows, that there was no scientific justification to deviate from the Project operational principles/practices in effect between 1990 and 2000. While it may be true that habitat and fish behavioral data related to the listed species may have been routinely collected only since 1990, hydrologic data have been routinely collected in key parts of the basin for nearly 100 years.

In 2002, the Klamath Project Pilot Water Bank was proposed in response to the BO requirements to ensure that the operation of the Klamath Project did not jeopardize survival of listed species in the basin. The ESA requires that Reclamation consult with NOAA Fisheries and USFWS on the effects of Project operations on listed species; this consultation was summarized in Reclamation's February 25, 2002, Biological Assessment (BA) (Reclamation, 2002). The BA described planned Project operations for the period April 1, 2002 through March 31, 2012.

In the 2002 BA, Reclamation proposed "to continue operation of the features and facilities of the Klamath Project consistent with the historic operation of the Project from water year 1990 through water year 1999 ("10-year period")". Reclamation supported the use of the 10-year period by stating that "The NAS report finds no substantial scientific data to support changing the Project operations regime of the 1990's." (NRC, 2002, p.11). The BA then proposed to develop operating criteria based solely on flow statistics for the 1990s. This adoption of flow statistics from the 1990s, as a result of the philosophical statement in the NAS-NRC report, is problematic with respect to establishment of Klamath River flow requirements.

Four “water-year types” were proposed in Reclamation’s BA for the Klamath River: above average, below average, dry, and critical dry. During the 10-year period specified by the BA, the “below average” and “dry” water-year types were represented by one year each. The remainder of the years in the 10-year period included six “above average” years and two “critical dry” years.” In Table 5.9 of the BA (Reclamation, 2002, p. 72), recommended flows for the Klamath River at Iron Gate Dam were proposed for these four “water-year types” based on the flow statistics from the 10-year period. These water-year types for the Klamath River are based on April through September net inflows to Upper Klamath Lake using a 70 percent exceedance factor and the Natural Resources Conservation Service’s (NRCS) April 1 forecast. Recommended flows are not specified for individual days throughout the year, but are specified for periods ranging from approximately two weeks to one month in length. These periods are referred to herein as *time steps* (see Glossary of Terms). As described below, the proposed four water-year type classification was later modified to five water-year types.

In the 2002 BA, Reclamation proposed to initiate a water bank “through which willing buyers and sellers will provide additional water supplies for fish and wildlife purposes and to enhance the tribal trust resources. Presently, the size of the water bank is expected to be up to 100,000 acre feet with “deposits” coming from a variety of sources including off-stream storage, irrigation demand reduction, and groundwater.” (Reclamation, 2002, p.11). In the BA, Reclamation proposed the size of the water bank be calculated based on year type and data from the 10-year period.

The NOAA Fisheries (2002) BO discussed the purpose of the water bank as a component of the Reasonable and Prudent Alternative (RPA). The intent of the RPA is to outline an alternative action to be implemented by Reclamation that is economically and technically feasible, within the agency’s authority, consistent with the original intent and purpose of the Project, and that would avoid jeopardy of the listed species or adverse modification of critical habitat. In the RPA, NOAA stated that, rather than using the water bank to meet flows described in Table 5.9 of Reclamation’s BA, the water bank should be used to exceed flows in Table 5.9 of the BA and contribute to improved spring time and, if appropriate, summer habitat conditions (NOAA, 2002, p. 53). The RPA (NOAA, 2002, p.58) also proposed adopting the five “water-year types” in the Hardy and Addley (2001) Draft Phase 2 study, stating that Reclamation’s original classification strategy partitioned 80 percent of the years in the 10-year period of record into the above average and below average year types. A five-year classification strategy for required flows (Figure 1) was adopted by Reclamation and included as Table 4 in their 2004 Operations Plan (Appendix); this five-year classification is referred to as the *modified* Table 5.9 flows.

Long-term flow requirements were also established in the RPA (NOAA, 2002, Table 9, p. 70) that are based on the unimpaired flow estimates provided in Hardy and Addley

(2001). In the RPA, the flow requirements at Iron Gate Dam, beginning in water year 2006, are considered to be these long-term flows or modified Table 5.9 flows, whichever is greater for any given time step (Figure 2).

The RPA established that Reclamation would be responsible for a proportion of the required flows in the Klamath River below Iron Gate Dam. Reclamation proposed using a calculation of the percent of irrigable lands in the upper Klamath Basin to establish its share of the flows. In the 2002 RPA, this percentage was roughly estimated as 57 percent of the releases at Link River Dam needed to result in the Iron Gate Dam flows described in the RPA or the flows identified in BA Table 5.9, whichever are greater. Since Reclamation would need time to develop resources to meet the 57 percent obligation, the agency agreed to a phased approach and schedule that would build the water bank to 100,000 acre-feet in increasing annual increments by 2006. The remaining 43 percent of the flows was to be developed with Reclamation taking the lead to establish a multi-stakeholder working group (Conservation Implementation Program). The water to achieve this 43 percent of the flows would come from outside the boundaries of the Klamath Project (NOAA, 2002, p. 55). (It is our understanding that these estimated percentages of on Project and off Project irrigable lands are being questioned as a result of a recent study by the NRCS (2004); however, an analysis of these percentages was outside the scope of this review.)

The RPA also described a three-phased water bank approach for water years 2002 – 2011 (NOAA, 2002, Table 8, p.57) where the water bank requirements were as follows: 2002 = 30,000 acre feet, 2003 = 50,000 acre feet, 2004 = 75,000 acre feet, and 2005-2011 = 100,000 acre feet. The BA and BO described the general need for a water bank and the importance to meet or exceed flows; however, they did not define the source of water that would develop the volumes required. General discussion of off-stream storage, irrigation demand reduction, and ground-water pumping were listed as possible options.

Chronology of Implementation

2002

As a result of the final BO being released late in the year on May 31, 2002, a pilot water bank was not established in the 2002 water year. However, alternate sources of water were being explored in both California and Oregon. The ground-water resource was being studied by the Oregon Water Resources Department (OWRD), California Department of Water Resources (CDWR), and USGS. Starting in 2001, increased ground-water pumping was used to help meet agricultural needs and to decrease use of surface water. Also in 2001, Reclamation operated a Ground-Water Acquisition Program and began exploring options to increase reservoir storage and utilize lands adjacent to Upper Klamath Lake for water storage (e.g. Agency Lake Ranch). Although there was no pilot water bank in operation in 2002, about 19,000 acre feet of ground water were pumped from the Tule Lake Irrigation District (TID) wells that year.

KBRT, which utilizes forbearance as a water saving measure, was active in the Wood River Valley north of Upper Klamath Lake in 2002 and 2003; however, KBRT water savings were not included in Reclamation's pilot water bank until 2004.

2003

Water bank activities in the upper Klamath Basin were primarily "on Project" in water year 2003. Two management options were used. The first involved land idling where farmers were compensated to idle land; crops were not planted and irrigation did not take place on those parcels. The second management option used was ground-water substitution whereby pumped ground water was used in lieu of Project surface water. Pumped ground water was used to irrigate crops that normally would have been irrigated with Project surface water.

An estimated 59,000 acre feet of water was acquired by Reclamation from land idling and ground-water substitution (Figure 3). Land idling accounted for approximately 35,000 acre feet of the water acquired (Table 1). Ground-water substitution accounted for approximately 23,000 acre feet. As mentioned above, the 2003 pilot water bank requirement in the BO was 50,000 acre feet.

The land idling program had 335 applications submitted from which 223 contracts were finalized. Acreage included in the program totaled more than 14,000 acres and about 9,000 acres were not accepted into the program. Reclamation estimated an average water savings of 2.45 acre feet per acre included in the program, based on expected reductions in crop consumptive use. Eighty-five percent of the land in the land idling program was in Oregon; 15 percent was in California.

The request for ground-water substitution participants resulted in 187 applications, of which 92 were accepted. Approximately 11,000 acres were included in the program and 13,000 acres were not accepted. Reclamation estimated an average savings of 2.17 acre feet per acre included in the program, based on crop type and estimated consumptive use values. Sixty percent of the ground-water production occurred in Oregon; the remaining 40 percent occurred in California.

As early as 1998, Reclamation has been proactively exploring the possibility of using the ground-water system to produce stored water on a short-term basis in the Project area. Reclamation worked with the OWRD to conduct a demonstration project where ground-water production rates and impacts were evaluated. A production well was drilled and tested in the Shasta View Irrigation District. Starting in 2003, Reclamation reviewed water bank ground-water pumping applications with the OWRD to minimize adverse effects to the aquifer system and ground-water users. This consultation also took place for the 2004 pilot water bank program.

2004

In 2004, both "off-Project" and "on-Project" activities were included in the pilot water bank program. Three management options were used. The first was a land idling strategy termed "Dryland Operations". With this option, landowners were compensated for not irrigating their land; this option was implemented for both farmland and rangeland. However, farmers were still able to plant crops that could be grown with available water from precipitation, and ranchers were allowed to graze the land without irrigation. The primary off-Project activity of the 2004 water bank was dryland ranching by KBRT. The second management option used was ground-water substitution as described for 2003. With this option, ground water was pumped and used to irrigate land that was normally irrigated with Project surface-water diversions. The third option also utilized the ground-water resource, but involved "ground-water pumping" directly into irrigation canals. This water was then taken out of the canals at other locations to irrigate land.

An estimated 79,000 acre feet of water was acquired by Reclamation from the three management options (Figures 4 and 5). Dryland operations on farmland contributed more than 11,000 acre feet, of which about 9,600 acre feet were on-Project; approximately 11,600 acre feet were provided by KBRT (shown as off-Project use in Table 2). Reclamation had 277 applications for farm participation in the dryland operations program, and 52 were accepted. About 4,300 acres were accepted into the program and approximately 29,400 acres were not accepted. The average on-Project water volume compensated per acre for dryland farming operations was 2.52 acre feet. KBRT water volume per acre was estimated at 1.04 acre feet. Eighty-four percent of the dryland farming operations acreage was in Oregon.

Ground-water substitution totaled approximately 16,000 acre feet. Reclamation had 172 applicants to participate in the ground-water substitution program and 41 contracts were finalized. Nearly 7,000 acres were approved for substitution, and about 26,800 acres were not included in the program (Table 2). Reclamation estimated an average per acre volume for ground-water substitution of 2.32 acre feet. Forty-eight percent of the ground-water substitution water volume was in Oregon and the remaining 52 percent was in California.

Ground-water pumping contributed about 42,000 acre feet toward the 2004 water bank (Table 2), which included 76 contracts with three major groups of irrigators: The Mid-Basin Group in Oregon; and the Copic Bay Group and TID in California. The Mid-Basin Group was comprised of a number of irrigators in the Project that were granted permission to pump ground water through a drought permit issued by OWRD. The drought permit allowed pumping by various irrigators on a flexible schedule as determined by Reclamation. This arrangement allowed Reclamation to have an "optional contract" to purchase as much water as needed to meet water bank requirements. The first 10,000 acre feet provided by the Mid-Basin Group, was on a "fixed" or guaranteed contract. The overarching permit and optional contract allowed Reclamation to require that wells be turned on or off depending on Project operational needs and/or the impact of the pumping stress on third parties. The Copic Bay Group and TID worked under somewhat similar premises with optional contracts. Compensation to these groups was based on reported pumping volumes.

Additional ground water was pumped beyond the volumes for which irrigators were compensated. Discussion of total amounts of ground water used from 2001 through 2004, and the drawdown effects are discussed later in this review.

Flow Requirements

Purpose of analysis

Early in this review of the Klamath Project Pilot Water Bank, it became evident that a complete understanding of the required flows (modified table 5.9 and table 9) in relation to the hydrology of the basin was critical to evaluating the pilot water bank program. Water bank flows are intended to assist with meeting or exceeding the required flows.

The 2004 April through September period provides an excellent example of the challenges associated with flow and water bank requirements in a year that began as “below average” and was changed to “dry” in early May (figure 6). The BO required flows often have large, abrupt shifts between time steps. The shift in year type superimposed another large, abrupt shift in the flow requirements. Water bank flows were added to the modified Table 5.9 flows. Figure 7 compares the required flows at Iron Gate Dam (including the water bank requirements) versus actual flows measured at the USGS gage. It can be seen in figures 6 and 7 that the water bank flows are used to augment the BO flows in a manner to smooth out the abrupt changes in flow that occur from one time step to another and at the change in water-year types. This example highlights the need to evaluate the flow requirements and time steps, and their relation to the hydrology of the basin above Iron Gate Dam.

The Klamath River flow requirements are the result of a number of assessments, opinions, documents, discussions, and rulings. The final NOAA Fisheries BO flow requirements attempt to integrate the biological requirements in the upper Klamath Basin hydrologic system. However, the flow requirements as they now stand are the cumulative result of the past several years of discourse, and they were primarily formulated to provide a specific flow regime for protection of the listed species without a rigorous analysis of hydrologic considerations or water bank strategies.

A specific goal of this review was to evaluate the historic flow record for the Klamath River (1961-1999) to determine if water bank requirements were hydrologically feasible. The 1961-1999 period represents a time when no new Project facilities were constructed and the Project irrigated acreage was relatively consistent. Although this period of record does not represent “pre-development” in the basin, it does provide a reasonable representation of the hydrology of the basin through various climatic situations and demands for water. It provides a better context for evaluating hydrology than only considering the 1990s. Klamath River median daily flow at Iron Gate Dam (IGD) for the period 1961-1999, broken down by the five water-year types, is shown in figure 8. The number of years representing each water-year type is as follows: 4 years were wet, 11 years above average, 9 years average, 11 years below average, and 4 years dry. The period from 2000 through 2004 was purposely excluded from the analysis to avoid changes in the flow record as a result of recent changes in management of water in the upper Klamath Basin.

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Four different analyses of the BO flow requirements, in comparison to the 1961-1999 measured flow record, are included in the following sections. The analyses described do not include water bank volumes. Water bank volumes (up to 100,000 acre feet) would represent a flow requirement in addition to those used in these analyses. Through this series of analyses, questions arose regarding data quality. For this reason, a section was added to the review specifically addressing some of the data issues.

10-year Reference Period

The purpose of the first part of the flow requirement analysis was to review the use of the “10-year period” to set flow requirements. As mentioned earlier in this review, the NRC (2002) indicated that there was no reason to operate the Project any differently than it had been operated between 1990 and 2000. From that conclusion, the 2002 BA categorized the 1990s into year types and utilized flow statistics from those year types to determine Iron Gate Dam flows. When modified from 4-year types to 5-year types, as specified in the 2002 NOAA BO, only 1, 2, or 3 actual water years are represented in each of the five year types (see table below). The limited number of years in each category does not provide a meaningful statistical basis for setting monthly flow values. The flow value for any month in any year type can be dominated by a single storm or runoff event. The goal of this analysis was to understand the potential problems with this approach and the resulting implications for water bank requirements. For example, only one water year in the “10-year period” was used to characterize the flows in a “below average” year whereas if the period 1961 to 1999 was used, 11 water years could have been used to characterize flows for this year type providing a more statistically meaningful representation (figure 9d). Similarly, an “average” year type is characterized by only two water years from the 1990s whereas nine water years could have been included if the longer reference period was used(figure 9c).

It is important to remember that water years with similar annual flows often have very different seasonal, monthly, and daily distributions of flow depending on when or if precipitation events occur. Consequently, relying on just a few years (or only one year) to characterize an annual average hydrograph for a year type is extremely unreliable and will usually produce hydrologically unreasonable expectations for future runoff. For example, during many “average” water years, it will be very difficult (and unreasonable) to discharge 5,400 cubic feet per second (cfs) at Iron Gate Dam in January if the storm events needed to generate those flows have not occurred (figure 9c).

Water-year types for the “10-year” period

Water-year type	**1990-1999**	**1961-1999**
Wet	**1999**	1971, 1983, 1885, **1999**
Above Average	**1993, 1996, 1998**	1963, 1967, 1969, 1972, 1974, 1975, 1982, 1989, **1993, 1996,1998**
Average	**1995, 1997**	1962, 1964, 1965, 1976, 1978,1985, 1986, **1995, 1997**
Below Average	**1990**	1961, 1966, 1968, 1970, 1973, 1977, 1979, 1980, 1987, 1988, **1990**
Dry	**1991, 1992, 1994**	1981, **1991, 1992, 1994**

The BO specifies minimum flows on the Klamath River below Iron Gate Dam (USGS station 11516530) for 17 time steps from October 1 to September 30. The required flow curves for different water-year types (figure 1) contain abrupt shifts and also cross one another at different times of the year. These abrupt shifts are very apparent for the winter and spring months for all of the water-year type distributions except for the dry water-year type. These abrupt shifts in flow requirements in year types, and the “crossing” of flow requirements among year types, are artifacts of using only the 10-year period (1990-99) for developing typical or average hydrographs. The full period of record (1961-1999) of flow below Iron Gate Dam would provide a more consistent and reasonable representation of historic flow conditions for the various year types.

Table 3 compares the water years used for both the NOAA and USFWS water year classification schemes (Klamath River and Upper Klamath Lake, respectively) from two different reference periods (1990 to 1999 and 1961 to 1999). The medians of the mean-monthly flows from both reference periods, grouped by year type, are shown in figures 9a-e. It is interesting to note the longer reference period generally provides smoother monthly hydrographs. For example, during average water-year types (figure 9c) the abrupt changes in monthly winter flows that occur using the 10-year reference period are much smaller when the 39-year reference period is used. To better understand the differences between the two time periods, they were compared using graphical techniques for daily, mean monthly, and mean annual time increments.

Descriptive statistics of daily mean flow for two periods are shown in table 4. The two records are highly skewed, which is typical of daily flow records. The median flow of the longer period (1961-99) was 1,410 cfs, which is slightly higher than the median flow of 1,350 cfs for the shorter reference period (1990-99). Because of the enormous number of data counts from the two periods (14,244 and 3,652, respectively), the use of parametric or non-parametric statistical tests to determine if the two periods were from the same population was not recommended. Null hypotheses stating that the two groups are similar would have always been rejected. However, it was possible to graphically display the two data sets. Figures 10 and 11 include box plots and stream flow exceedance curves for the daily data, respectively. The figures show that many of the daily flows are higher during the longer reference period (1961-1999) than during the 10-year period For example, 47 percent of the daily flows at Iron Gate Dam were greater than 1,600 cfs from 1961 to 1999 (Figure 11). In contrast, only 30 percent of the daily flows were greater than 1,600 cfs in the 1990s. In short, the 1990s had a larger number of days with low flows (figure 10). This is not a surprising result considering that the 1990s contained three of the four “dry” water years between 1961 and 1999.

Figure 12 shows a comparison of mean monthly flows for the two reference periods. Although the differences between the two box plots are not striking, the two populations are not identical. And again, the 1990s contained a larger proportion of drier months than the longer reference period.

Figure 13 shows a comparison of mean annual flows between the two reference periods. This plot shows that the 1990s contained a larger proportion of dry years than the longer reference period, largely because of a cluster of relatively dry years in the early 1990s (1990, 1991, 1992, and 1994).

In summary, using a 10-year reference period gives too few water-year examples upon which to estimate an average monthly hydrograph for the five different year types. This short period produces unrealistic targets for future flow requirements that are metered out on monthly or finer time scales. This problem becomes particularly acute when a year type is characterized by only one or two years. Specifically using the 10-year period from the 1990s could tend to bias flow requirements because this period contains a disproportionate number of “dry” years. The degree of bias, however, depends on how these flow requirements are calculated.

Comparison of Flow Requirements and Historic Flows at Iron Gate Dam

The second part of the flow requirement analysis in this review involved comparing the historic flows at Iron Gate Dam with the flow requirements. This comparison provided a basis of understanding for potential deficits and surpluses of water under historical operational conditions.

In this section, two sets of flow requirements are considered: the flows from Table 5.9 of the 2002 BA (as modified by the May 2002 NOAA Fisheries BO), and the long-term target flows set out in Table 9 of the BO. A hybrid set of flow requirements that specify the higher of the operational criteria flows or the BO flows is also considered. This hybrid set of requirements is specified in section 11.4.5 of the NOAA BO. Flow requirements in each of these sets differ according to the water-year type (see Hardy and Addley, Draft Phase II Report, 2001).

To make the necessary comparisons, USGS streamflow records at Iron Gate Dam from 1961 to 1999 were grouped according to water-year types as defined by Hardy and Addley (2001). Again, this time period was used because it does not include any influence from the 2001 water shutoff to the Project or water-bank activities in 2003 and 2004. In addition, this period represents a time when no new Project facilities were constructed and the Project irrigated acreage was relatively consistent. Median monthly flows were calculated for each month in each water-year type (table 5). These were then compared with the three sets of flow requirements as described in the preceding paragraph. A graph of the median monthly flows and flow requirements for each year type (figure 14a-e) shows that the modified BA Table 5.9 flows and the BO Table 9 flows are often very different, and that neither resembles the historic median monthly flows from 1961 to 1999.

There are months in each water-year type when the median observed flows (1961 to 1999) exceed BO flows. These conditions usually occur in the fall and winter months. Such occurrences represent periods where there is potentially surplus water that could be used for storage. This potential is, of course, subject to other aquatic habitat and water rights considerations. In figure 14a-e the timing of these surpluses are readily apparent for each water-year type.

There are also months in each year type when the median observed flows are below the BO flows. This condition is common in spring and summer months, but occurs over much of the year during “dry” water-year types (table 6 and figure 14e). These months with deficit flows represent periods during which it could be desirable to use water from a water bank to augment stream flow in the Klamath River.

The differences between the monthly flow requirements and median monthly observed flows are shown in table 6. Negative values indicate months during which flow requirements exceed median historic flows. Summing the monthly values across the table for each year type gives an indication of the amount of surface water potentially available for water banking (again, subject to other biological and legal considerations). It is important to note that in “dry” water-year types the annual total is negative, indicating that there is no surplus water under historic consumptive use rates on and off the Project. For a water bank to be effective in dry years there must be carryover from wetter years or a source of water other than surface water. As shown in table 6, most of the potential water savings from land idling (or dryland operations) occurs from May through August. Therefore, land idling must be combined with a strategy of early season releases and later season reductions in diversion because of the large deficits that show up in January through April for most year types.

Comparison of Flow Requirements to Historic Iron Gate Dam and Keno Flows

The third part of the analysis, described in this section, was similar to the analysis in the previous section; however, an additional goal was to evaluate the proportions of water discharging at Iron Gate Dam (IGD) that are derived above and below the Keno gage. Such an analysis was needed to understand the geographic distribution and sources of water available to meet flow requirements at Iron Gate Dam.

A large portion of Klamath River flow at the gage below Iron Gate Dam enters the river in the reach between Keno and Iron Gate Dam. This flow is due to accretion from ground water and tributaries. From 1961 to 2004 the mean annual flow from accretions has ranged from 300 to 898 cubic feet per second, for water years 1994 and 1965, respectively. Mean-monthly flow accretions range from 332 to 764 cubic feet per second, for August and March, respectively (figures 15 and 16).

Irrigation diversions and return flows are insignificant in this reach. It can be assumed that these additional flows to the Klamath River below Keno are unaffected by the Klamath Project. Year to year variations in these flows generally follow the regional climatic patterns.

Historical flow records on the Klamath River, in conjunction with Iron Gate Dam minimum flow requirements, were analyzed to quantify surplus or deficit volumes of water that would occur at IGD based on given water-year types. Typically (as was apparent in the last section), flows are generally greater than minimum flow requirements during the fall and winter months. Conversely, water to meet flow requirements is not always available during the spring and summer months. Once again, these requirements do not include the additional water bank requirement of 100,000 acre feet.

In this analysis, only one flow requirement scenario was used, which was the greater of the minimum flow requirements from the NOAA Fisheries BO (NOAA, 2002, Table 9) or the modified Table 5.9 flows originating from Reclamation’s Coho Salmon Biological Assessment (Reclamation, 2002). These requirements were compared to historic median monthly flows at Keno (USGS gage 11509500) and IGD (USGS gage 11516530) for each of the five UKL based water-year types. These comparisons are shown in figures 17a-e. The difference between Keno and IGD flows can be attributed to ground-water and tributary inflows between these two gages. A surplus water volume, from a strictly hydrologic standpoint occurs when either Keno or IGD flows are above the greater of the NOAA (Table 9) and Reclamation (modified Table 5.9) flow requirements. Likewise, a deficit water volume occurs when IGD flows are below the greater of the NOAA or Reclamation flow requirements.

Monthly computed surplus and deficit water volumes are shown on figures 18a-e for the five water-year types. Surplus water volume at both Keno and IGD gages is shown. If a hypothetical storage reservoir were located near the Lower Klamath National Wildlife Refuge near Keno, water could be withdrawn from the river during the surplus months for the amounts shown in figure 18a-e and then returned to the river during the deficit months. The surplus at Keno volume is an amount that could be safely taken from the river without significantly reducing flows between Keno and IGD, while still meeting IGD flow requirements. If the larger surplus at IGD volume were withdrawn from the river at Keno, minimum flow requirements at IGD could still be met because additional flows from ground-water accretion and tributaries would enter the river below Keno. However, withdrawing a volume of water of that amount might detrimentally reduce flows in the river between Keno and IGD especially in the upper part of the reach before significant accretions or tributaries would contribute to flow.

A matrix summarizing annual water surpluses and deficits is shown in table 7 for each of the five water-year types. The annual surplus at IGD appears to exceed the annual deficit for all water-year types except “dry”. However, the annual surplus at Keno appears to exceed the annual deficit for only above average water-year types. This analysis indicates that based on historic data, the current flow requirements would be difficult to meet at IGD solely with water available above Keno. In addition, this analysis suggests that it may be difficult to meet water bank requirements without utilizing ground-water storage, increasing reservoir storage of some kind, or markedly reducing consumptive use.

Comparison of Flow Requirements and Calculated Potential Flows

This last part of the flow requirement analysis was intended to help evaluate the effects of simultaneously meeting Upper Klamath Lake elevations and Klamath River flows during various climatic conditions represented by a longer period of record (1961 to 1999). Lake level requirements, net inflow volumes, and flow accretions between Keno and Iron Gate Dam were used to understand the relation between flow requirements and potentially available water. This analysis was similar to the comparison with historic IGD flows, but has the added benefit of taking present USFWS BO limits on lake stage into consideration. This analysis also allows evaluation of different combinations of lake year types and river year types, which at present do not coincide.

Potential flows were calculated for each month of each lake year type. Water to or from lake storage was calculated for each water-year type assuming that lake stage varies according to the lake operational criteria in the 2004 Operations Plan (table 8). Other components of flow are based on median measured values for each water-year type. The other flow components include net inflow to the lake; total diversions; return flows from the Lost River diversion channel and the Klamath Strait Drain; and accretions between Keno and Iron Gate Dam. The calculated potential flows (including the various components) are shown in table 8, along with the observed median monthly flows at IGD. As expected, the calculated flows and measured flows differ. The differences are due in part to the fact that the constraints on lake stage were not in place during the historic period of record. There is also measurement error associated with the diversion and return data (discussed later). This analysis assumes no changes in historic diversions for irrigation and refuge use. In addition, this analysis does not include the potential increased water available from lake storage if the year type is changed to a dryer classification.

Comparing the calculated flows with the flow requirements is complicated by the fact that there are two systems for calculating year types. There are 4 year types for the lake and 5 year types for the river (table 3). The two classification systems overlap such that there are eight possible combinations of year types. For example, a year classified as an above average year according to the lake criteria may be classified as a wet, above average, or average year according to the river criteria. The streamflow requirements can be subtracted from the calculated potential flows to determine if there is surplus water possibly available for water banking or if there is a water deficit. This can be done for each month for each combination of year types (table 9). The figures vary markedly depending on which set of flow requirements are used and on the particular combination of year types.

Summing the monthly values for each combination of year types shows which year-type combinations potentially have water available for water banking under historic operational conditions (positive values), and which year-type combinations potentially have deficits (negative values). These are shown graphically in table 10. Surface water for water banking is unlikely to be available during year-type combinations showing negative values. For example, a deficit of about 524,000 acre feet of water would be expected for a year type classified as “critical” for the lake and “dry” for the river. This deficit exceeds the total diversion volume for agricultural and refuge uses. In contrast to simply comparing the modified BA Table 5.9 and BO Table 9 flow requirements with historic flows, comparing the flow requirements with calculated potential flows results in deficit water during even more year types. This is to be expected because the historic flows were generally not restricted by present constraints on lake stage management. This latter analysis is likely to be a better guide to the potential for water availability for water banking.

Discussion of Data Issues

Klamath River

During the course of this review of the pilot water bank program, some differences between the USGS, PacifiCorp, and Reclamation flow and stage records become apparent. At some locations all three agencies shared the same gage, but used different techniques to compute discharge values from the stage data. At other locations the agencies collected data from separate gages that were located close to each other. The following sections describe the differences in streamflow data sets observed in this review.

Link River at Klamath Falls (11507500)

The USGS has collected flow at the Link River gage since 1904. Published records for the gage from 1904-83 include Keno Canal flows. However, USGS records from 1983 to the present do not include the canal flows. For many years, PacifiCorp flow records at this location have been based on stage readings from USGS equipment at the gage. However, PacifiCorp used their own rating curve to compute flows for their records rather than using variable shift adjustments and updated rating curves developed by the

USGS. This is the likely reason there are differences between USGS and PacifiCorp values (table 11). PacifiCorp also includes Keno Canal flow in their record. It is not known to the authors how the Keno Canal flows are determined by PacifiCorp. In table 11, values from 1984 to present are not included because USGS published flows do not include the Keno Canal flows. (Note: As of September 2004, PacifiCorp is using USGS Link River flow calculations.)

Klamath River at Keno (11509500)

The USGS flow record at Keno has been continuous since 1929. The USGS and PacifiCorp use separate gages for their stage and flow measurements. The gages are located approximately 1/4 mile from each other. Differences between the two records are shown in table 12. Prior to 1977, PacifiCorp must have relied on USGS records. Since 1977, differences between the two gages can be quite large. For example, there were annual inconsistencies of over 100,000 acre feet in both 1996 and 1999.

Klamath River below J.C. Boyle Powerplant, near Keno (11510700)

USGS flow records at this station began in 1959. PacifiCorp does not have their own gage nearby nor do they have any telemetry equipment coupled to the USGS gage.

Klamath River below Iron Gate Dam (11516530)

The USGS has collected flow at the Iron Gate Dam station since October 1960. PacifiCorp flow records at this location are based on stage readings from USGS equipment in the gage. However, PacifiCorp uses their own stage-discharge rating curve to compute flows for their records, which could explain inconsistencies between the two records as shown in table 13.

The largest flow inconsistencies appear in the Link River (for the period from 1961-83) and Klamath River at Keno tables (table 11). However, the Klamath River at Iron Gate Dam table also shows some significant differences in more recent years. Because of the importance and necessity for accurate flow measurements on the Klamath River, all of the entities involved with Klamath River issues (Reclamation, NOAA, NRCS, NWS, USFS, OWRD, USGS, and Tribes) should be using a single common dataset. The flow data used by these agencies should undergo extensive reviews and checks before they are officially published. Publication of the data would be recommended so that the data are easily available to all interested parties. The method of data collection and quality of the flow data should be to USGS-type standards and generally consistent with the historic records. If deemed necessary by agencies involved, the data collection network in the Klamath River Basin could be expanded to additional sites. The data must be made available to Reclamation and PacifiCorp in an immediate real-time mode as necessary for operations.

Upper Klamath Lake

The USGS published lake stage record for Upper Klamath Lake (11507001) is computed from a weighted mean of stage data collected at three locations on the lake. These include

Rocky Point (11505800), Rattlesnake Point (11505900), and Klamath Falls (11507000). The weighted mean equation is:

$$11507001 = [0.5\ (\text{Klamath Falls}) + (\text{Rocky Point}) + (\text{Rattlesnake Pt.})]/2.5$$

PacifiCorp uses a different algorithm to calculate mean lake stage from the USGS stage record. This averaging process should also be consistent between agencies because lake stage is used in calculation of storage changes which are then used to calculate net inflow to Upper Klamath Lake. Additional lake-level gages around the lake should be considered so that lake storage can be more accurately estimated regardless of wind-driven seiches.

Diversions and Return Flows

Significant inconsistencies in the Project flow records of diversions and returns were found during this review. The inconsistencies were discovered by constructing a water balance of river flow based on the sum of diversion and return flows. Klamath River flow at Keno can be approximated by the subtraction of Lost River diversions, North Canal diversions, and Ady Canal diversions from the Link River flow record with the addition of Lost River returns and Klamath Straits Drain returns. We are aware that there are additional diversions and returns out of the Keno reach that are not part of the Klamath Project datasets (no data are available); however, those volumes are assumed to be relatively small compared to the Project and we felt that this analysis was still useful. When computed flow at Keno is compared with measured flow at Keno, inconsistencies are evident, as shown in table 14. The accuracy of discharge measurements at the USGS gage at Keno is considered “good”, meaning that 95 percent of the daily discharge values are within 10 percent of the true value. Some inconsistency between the flows at Keno measured at the USGS gage and the flows at Keno calculated from measurements of flow of the Link River, diversions, and returns is, therefore, to be expected. What is problematic with the comparison is the magnitude of the inconsistency, which for certain months is more than 25,000 acre feet, and the fact that the difference is systematic and not random. Even more problematic is the shift in the systematic differences from predominantly positive in the 1960s and 1970s (indicating that flows calculated using Link River and other measurements overestimate flows at Keno), to predominately negative in the 1980s and 1990s (indicating the flows calculated using Link River and other measurements underestimate flows at the Keno gage). Determining the cause of this inconsistency, and the apparent shift in errors, was beyond the scope of this review; however, it would be worthwhile to pursue. Measurements of flow into and out of this reach of the river are important in evaluating the effects of the water bank as well as understanding the ground-water hydrology of the area.

Ground-Water Data

A prudent ground-water management strategy requires sufficient monitoring to enable continuous evaluation of the state of the ground-water system and how it is affected by pumping, climate, and other stresses. Basic elements of a monitoring program include periodic measurement of water levels in wells in and near pumping centers and in areas away from pumping centers. The latter provide information on the response to non-pumping stresses such as climate fluctuations. Water-level data provide information on impacts to wells, the state of ground-water storage, and potential overdraft. Water-level monitoring over the past several years has been very good, largely due to funding provided by Reclamation. Data are maintained by multiple agencies, however, slowing access and hindering rapid assessment.

To properly interpret water-level trends, pumpage data should also be collected. Ideally, total pumpage figures should be collected for all irrigation wells in the basin, not just wells involved in water acquisition arrangements. This would allow better interpretation of water-level data. Efforts by Reclamation to collect pumpage data for wells involved in the water bank or the ground-water acquisition program have provided considerable useful data. Improvements could be made in tying pumpage figures to specific wells with documented locations and well logs. Collecting pumpage data from wells not involved in the water bank is out of the purview of Reclamation and would require action by state water management agencies.

Lastly, consideration should be given to monitoring ground-water discharge to streams and springs. There are certain river reaches and spring complexes that are key areas of ground-water discharge. Monitoring ground-water discharge will enable better understanding of climate-driven fluctuations as well as potential changes due to ground-water pumping. Certain discharge areas are being monitored as part of ongoing projects; however, there is considerable room for improvement and there is no long-term plan for continued monitoring.

Long-Term and Recent Trends in Klamath River Flows

The pilot water bank and KBRT programs have been in operation on the ground for the last 3 years. As more lands are removed from irrigation it is assumed that evapotranspiration losses will decrease and river flows will increase. However, trying to ascertain and quantify the impact of these programs on 2002, 2003, and 2004 river flows has been difficult for two reasons. First, the eventual target savings of the water bank program (100,000 acre-feet) is relatively small in relation to the magnitude of mean annual flow (1,557,841 acre-feet for 1961-99) of the Klamath River below Iron Gate Dam. This should not be surprising considering the size of the drainage basin upstream of Iron Gate Dam (4,630 square miles not including the Lost River, Butte Creek, or Lower Klamath Lake Subbasins). However, the pilot water bank will tend to be more significant and a larger proportion of the mean IGD flow during spring and summer months in times of drought. Second, there is significant variability in Klamath River annual flows below Iron Gate Dam over the period of record. Although the river is regulated at this location, year to year variations in climate still have a major impact on flows as shown in figure 19. The standard deviation of the 1961-99 Iron Gate Dam annual flow record is 560,035 acre-feet. Since the 100,000-acre-foot water bank requirement is 20 percent of the standard deviation, the effect of the water bank is relatively small compared to the observed climatic variations in flow.

One approach to evaluating the effects of human caused alterations in a flow record is to remove the climate component from the record. Figure 20 shows a comparison of cumulative mean annual Klamath River flows below Iron Gate Dam (11516530) with cumulative annual total precipitation records from four locations within the region for water years 1961 to 2004. Straight lines in the plot are an indication of a precipitation runoff relationship that has remained constant over time. Significant breaks, or a change in direction in the line, would suggest that there has been a major alteration in flow patterns in the watershed. These breaks can be obvious in a record when they are the result of large-scale logging or the installation of a new dam in a watershed. However, figure 20 does not show an observable break in the early 2000s on any of the four lines. The lack of any visible break does not mean that the water bank and KBRT programs have not increased surface-water flows in the basin. The lack of a break could once again point out that the magnitude of the target savings of these programs is small relative to the magnitude of flows at the Iron Gate Dam gage. The lack of break may also relate to the fact that water banking has only been in place for a few years making it difficult to detect a trend.

Trends in Klamath Project Diversions

Although both Burt and Freeman (2003) and this review have indicated some concern with regard to the quality of diversion and return data historically collected for the Project, the data are still useful to provide some sense of changes from year to year. The volume of water added by the water bank may be within the measurement error for annual Klamath River flows and may also be masked by climate variations as mentioned in the previous section, but actual diversion and return flow data could show some changes in surface-water demands and changes in the operation of the Project. For this reason, data were reviewed to assess whether a relationship was apparent between changes in diversion and return flows and water bank activities from 2000 to 2004. Caution should be exercised when evaluating the comparisons and the conclusions should be considered in the context of the data uncertainty.

It is clear that by pumping ground water and by reducing consumptive uses on agricultural lands and rangelands, that there should be true reductions in net surface-water diversions in the Project area. The goal of this analysis of Project diversions and returns is to test this hypothesis with the existing data sets, recognizing potential problems with data accuracy. This analysis points out the importance of collecting high-quality data in the future so that the hydrologic effects of changes in Project activities can be quantified and documented. High-quality data are needed on all major diversions, returns, stream gages, major pump stations, and large pumping wells.

The 2000 - 2004 diversion and return data were evaluated first by reviewing Reclamation’s annual total diversion and return data for the period of record from 1961-2004 (figure 21a). During the period of record (1961-1999), annual gross diversions for the Project (includes water delivered to wildlife refuges) have had considerable variability, most of which can be attributed to climate, ranging from a low of 320,000 acre feet during the very wet year of 1965 to a high of 490,000 acre feet in the very dry years of 1992 and 1994. This excludes 2001 because diversions through the A-Canal were severely curtailed to meet BO lake-level and flow requirements. In contrast, figure 21b shows total Klamath Project net annual water year diversions where total returns are subtracted from gross Project water diversions. Net annual water year diversions also show the impact of climate and in some wet years net annual diversions are negative due to large volumes of spill.

The additional water required in dry years appears to be derived to some extent from all points of diversion (figure 21a). However, in the 1980s and 1990s diversions to the Ady Canal and the Lost River Diversion Channel show an apparent increase, while diversions to the A-Canal and North canal remained relatively stable. From the discussion in the previous section on diversion and return data quality, there was some concern that this apparent trend could be a reflection of changes in data collection. Although 2003 and 2004 were relatively dry years, it appears that diversions were considerably less than those seen in the 1990s for similar climatic situations. This trend in 2003 and 2004 may reflect savings due to water-bank operations. Diversions in 2000 and 2002 were at a level comparable to historic volumes, and 2001 was clearly abnormal because diversions through the A-Canal were severely curtailed.

The historic record of return flows from 1961-2004 (figure 22) also indicates that return flows from 2002 – 2004 were about the same or slightly less than in climatically similar years. In wetter years, a greater proportion of the return flows come from the Lost River Diversion Channel.

We reviewed the diversion and return data by water-year type classifications. For example, water year 2004 diversions and returns were compared to the statistical averages for dry year types. This provided a method of comparison, but use of the water-year types did not allow a meaningful comparison to the historic trend of the entire data set.

As an alternate method to review the data, we developed plots of the April through September diversion and return data, versus April through September net inflow to Upper Klamath Lake. The diversion and return flow data for October through March of each water year were avoided because in wet years, large winter and spring runoff events can dominate the record and mask Project return flows. Water bank activities and water savings should be most evident during the irrigation season (April though September). We realize that Upper Klamath Lake net inflows are calculated using data from the A-Canal, which could explain some correlation between net inflow and diversion data, but felt that this analysis was still useful. This analysis focuses on recent on Project changes to diversions and returns, to and from the Klamath River Basin. Project water from Gerber Reservoir and Clear Lake are not considered; however, April through September spill from the Lost River Diversion Channel to the Klamath River is included in the analysis.

The 1961-1999 data were plotted with best-fit regression lines derived from the data. The regression lines provide a general trend of the central tendency of the historic data. As mentioned earlier, the 1961-1999 timeframe was selected because it reflects a time of relatively consistent Project operation without including the recent changes in the 2000s. Comparisons were made between the April through September net inflows to Upper Klamath Lake and the following data: (1) April through September total Klamath Project gross diversions, (2) April through September total returns, and (3) April through September net diversions. Net diversions were calculated by subtracting total returns from total diversions. Then for comparison of recent years to the historic data, individual data points for 2000 – 2004 were plotted on the same graphs. Scatter in the data about the regression line is likely a function of the diversion and return data error and climatic differences between and within years.

Total gross diversions include the A, North, and Ady canals, as well as diversions from the Klamath River to the Lost River Diversion Channel. Returns include discharges through the Lost River Diversion Channel and the Klamath Straits Drain to the Klamath River.

The plot of total gross diversions (figure 23) provides a general understanding that as net inflow to Upper Klamath Lake increases gross diversions decrease. This seems reasonable considering that wet years would correspond to increased antecedent soil moisture and increased precipitation during the growing season, which would result in decreased on-farm demand for water. Between the wettest and driest years on record, a difference in demand of about 75,000 – 125,000 acre feet has been observed. Total diversions historically range from more than 400,000 acre feet in dry years to less than 300,000 acre feet in wetter years.

April through September total gross diversions for 2003 and 2004 were notably less than years with similar inflow volumes. The 2003 and 2004 total diversions averaged about 65,000 acre feet less than during years with similar year types (as depicted by the distance from the regression line in figure 23). This reduction in diversions is consistent with on-Project water-bank activities that theoretically should have reduced demand for Project surface water by about 59,000 acre feet in 2003 (table 1) and 65,000 acre feet in 2004 (table 2).

Total gross diversions in 2000 and 2002 were the highest or among the highest relative to other years of similar net inflow to Upper Klamath Lake. In these years, the Project operated very similar to the 1961-1999 period and additional ground-water pumping was limited to about 19,000 acre feet pumped in 2002. Diversions in 2002 needed to compensate somewhat for the lack of Project operation in 2001. According to Reclamation staff, canal beds were dry and cracked. In addition, there was a large storage deficit in the shallow ground-water system that had to be refilled in 2002 for the Project infrastructure to function properly. April through September 2001 total diversions clearly fell outside the pattern of historic Project operations as a result of limited diversions. Approximately 69,000 acre feet of additional ground water was used on Project in 2001.

Return flows were evaluated in a similar manner and are shown in figure 24. In general, as net inflow to Upper Klamath Lake increases, irrigation return flow increases. From the driest years to the wettest years, irrigation returns generally increase by about 100,000 acre feet, as depicted by the regression line, with the smallest returns of about 25,000 acre feet occurring in drier years to 125,000 acre feet occurring in wetter years. For 2000, returns were slightly higher than all years with similar net inflows. Return flows for 2002 – 2004 were all similar to years with like net inflows to Upper Klamath Lake, and 2001 return flows were close to the lowest on record.

Net diversions are the sum of total diversions minus total return flows and are shown in figure 25. Net diversions probably provide the best measure of changing Project operations and the impact to Klamath River flows. As expected, April through September net diversions to the Project decrease with increased net inflow to Upper Klamath Lake; again reflecting the decreased on-farm and refuge needs for water in wet years. From the drier years to the wetter years net diversions drop about 210,000 acre feet, as depicted by the negative slope of the regression line in figure 25.

Both 2000 and 2002 had net diversions that were similar to years of like inflow to Upper Klamath Lake. However, net diversions to the Project during 2003 and 2004 averaged about 70,000 acre feet less than expected when compared to years with similar net inflows to Upper Klamath Lake (as depicted by the regression line in figure 25).This is an expected result considering that on-Project water bank activities should have reduced the need for surface-water diversions by about 59,000 and 65,000 acre feet for 2003 and 2004, respectively. Figure 25 shows where we would have expected the 2003 and 2004 water years to plot if water bank activities had not occurred and increased surface-water diversions were needed to meet typical on-Project demands. The fact that both 2003 and 2004 water years plot closer to the regression line when the effects of the water bank are removed shows that there have been decreases in diversions consistent with water bank activities. Reduced net diversions to the Project results in more water available to meet the flow and lake-level BO requirements. It is worth noting that the benefits of the water bank on Project might be even more discernible with improvements in water accounting on the Project. As expected, net diversions for 2001 were about equal to the lowest on record.

One additional check on the data presented in figure 25 was performed to evaluate the trend in total diversions mentioned in the discussion of figure 21a where it appeared that the Ady Canal and Lost River Diversion Channel diversions had increased beginning in the early 1980s. To evaluate this apparent anomaly, residuals from the regression line in figure 25 were plotted against time and are shown in figure 26. This predicted minus observed plot for April through September net diversions shows a distinct shift around the early 1980s. If the residuals were randomly distributed about the regression line in figure 25, it would be expected that the residuals in figure 26 would be randomly distributed around 0. This apparent downward trend in the residuals over time can be explained in two ways: (1) approximately 50,000 to 100,000 acre feet greater net diversions have been used by the Project since the early 1980s, reflecting an operational change; or (2) data collection for net diversions has changed significantly in the early 1980s, creating an apparent shift in the data that may be an artifact of the manner or accuracy of surface-water accounting on the Project. It is not clear why this trend occurs, but this plot again illustrates why caution should be exercised when evaluating the diversion and return data.

Due to concerns about data quality described earlier, an alternative method of evaluating net diversions was sought using Klamath River gage data at Keno and Link River. This method involved using stream gage data wherever possible to reduce error and then compute net diversions similar to the approach used in the data issue section of this review. April through September Upper Klamath Lake net inflow data were plotted against April through September Link River (Keno canal added to recent years to provide consistent record), plus the A-Canal which has one of the better flow records, minus the Klamath River at Keno (figure 27). Although this comparison is somewhat tenuous because the calculation of net inflow to Upper Klamath Lake uses Link River flows and A-Canal flows, the relationship provides results similar to the relationship between Reclamation diversion and return data, and Upper Klamath Lake net inflow.

The computed net diversions from the driest to the wettest years decrease by about 200,000 – 250,000 acre feet. In general, net Project diversions range from about 400,000 acre feet in dry years to about 150,000 acre feet in wet years (including water delivered to wildlife refuges).

Also from the computed net diversions the recent years show 2001, 2003, and 2004 fall below what might be expected from historic data. For 2003 and 2004, net diversions were again an average of about 70,000 acre feet less than similar years. 2000 and 2002 were relatively typical compared to historic records, and again computed net diversions to the Project were very small in 2001 due to the water shut off.

In summary, it is apparent that reductions in diversions have resulted from operation of the water bank in 2003 and 2004. However, caution must be exercised when evaluating the diversion and return data historically collected, because the volumes of water involved in the water bank are similar in magnitude to the uncertainty in the diversion and return flow data.

Net diversion data were evaluated in two different manners and the results were consistent; however, the two approaches were not totally independent because A-Canal data were used in both cases. Some concern is warranted due to as yet unexplained shifts in the Ady Canal and Lost River Diversion Channel flow data that occurred around the early 1980s.

The analysis described in this section focused on April through September diversions and returns; however, temporal variability within years is also important because the intent of the water bank is to assist with improving spring time flows for Coho salmon. Although we did look for the monthly effects of the water bank in 2003 and 2004, as compared to the historic record, we found it difficult to draw any defensible conclusions. We believe the uncertainty in the currently available surface-water data (diversions, returns, and river gages) is too large to see the effects on a monthly time scale. Moreover, diversions and returns are affected by many variables that confound our ability to do an accurate monthly mass balance of water. For example, the spatial distribution of on-Project storage of water (e.g. in soil, on fields, in canals and drains, and in refuges and sumps) can vary significantly from month to month. As accurate diversion and return data become available for additional years of water bank operation it may be possible to better understand the temporal distribution of reduced diversions and how these changes might impact Klamath River flows on a monthly or weekly basis.

Ground Water

Ground water has been used for irrigation in the upper Klamath Basin for more than half a century. Until recently, the amount of ground water pumped for irrigation has remained relatively stable. Therefore, the ground-water system has been in a state of dynamic equilibrium under which water levels have risen and fallen in response to climate cycles and seasonal pumping, but without chronic year-to-year declines. Historically there have been year to year declines for periods of several years during droughts, but, with rare local exceptions, water levels eventually rose to pre-drought levels during subsequent multi-year wet periods. Wells and pumps have been, for the most part, set up to accommodate these historic water-level fluctuations.

Since the mid 1990s there has been increasing interest in using ground water to reduce demands on surface-water sources. The potential for the regional ground-water system to support a substantial increase in pumping, however, is not precisely known. A cooperative project between the USGS and OWRD was launched in the late 1990s to quantify the regional ground-water system and thereby better understand its long term potential and the possible consequences of increased development. Prior to completion of the cooperative study, circumstances resulted in a substantial increase in ground-water pumping in the basin. Some of the pumping is by private parties, but a large proportion is associated with water banking efforts or similar programs (such as Reclamation’s ground-water acquisition effort in 2001).

Thanks to the efforts of many agencies, and the cooperation of water users, there has been broad monitoring of the response of the ground-water system to this increased stress. There are active monitoring efforts by the USGS, OWRD, and CDWR. Much of this work is funded by Reclamation. Data from these combined monitoring efforts has provided a picture of how the ground-water system has responded to the increased pumping, and provides considerable insight into the potential of the regional ground-water system to support increased use.

Ground-water pumping in the upper Klamath Basin during the 2000 water year is conservatively estimated to be about 137,000 acre feet. This is considered to be a reasonable estimate of annual pumping prior to 2001. The 2000 pumping is broken down by sub area in table 15. Some irrigators have used supplemental ground-water rights for many years to help offset the effects of surface-water shortages. The amounts of historic supplemental ground-water pumping are not known, but are generally considered to be a fraction of the total amount pumped.

Beginning in 2001, the use of ground water to supplement surface-water supplies increased markedly. The increase is due to both private initiative and specific government programs such as Reclamation's ground-water acquisition program in 2001, and water banking efforts in 2003 and 2004. The amounts of pumping related to government programs are shown in table 16.

The total amounts of ground-water pumped for the pilot water bank in 2003 and 2004 were 55,667 and 75,716 acre feet, respectively. The program paid for less water than was actually pumped because many well owners pumped and reported volumes in excess of the amount for which they were contracted. When compared to the ground-water pumpage in the entire upper Klamath Basin during the 2000 water year (table 15), the reported 2003 water-bank pumpage represents a 41 percent increase and the 2004 pumpage represents a 55 percent increase. Most of the 2003 and 2004 water-bank pumping occurred, however, in the Klamath Valley and Tule Lake areas which are both in the lower Lost River subbasin (figures 28a-b). When just those areas are considered, the 75,716 acre-feet of water-bank pumping during 2004 combined with the 10,700 acre feet of regular irrigation pumping (based on 2000 use figures) represents an approximately 8 fold increase in ground-water pumpage in the lower Lost River subbasin. The ground-water system has responded to the increased pumping in this area in a variety of ways as expected, including acute, seasonal, and long-term effects.

Acute effects occur close to pumping wells, generally within hundreds to thousands of feet. These effects are typically the result of the cone of depression of the pumping well spreading to neighboring wells, resulting in a drop in the static water levels. This is sometimes referred to as *well interference*. These effects typically have rapid onset and dissipate relatively rapidly after pumping ends. Many of the complaints received by OWRD in 2004 were likely due to acute effects.

Seasonal declines are the general lowering of the water table over a broad area (several square miles to tens of square miles) in response to the combined pumping of multiple wells. These effects build up over the irrigation season and largely recover over the following winter.

Seasonal declines can be evaluated by looking at water-level changes between the spring and fall of 2004 (figure 29). Although there was a general drop in water levels during this period, some wells that are hydraulically connected to the shallow aquifer system in the basin-fill sediments exhibited a rise in water levels ranging from a fraction of a foot to as much as 3 feet. This is entirely due to artificial recharge to the shallow part of the ground-water system by canal leakage and deep percolation of irrigation water during the irrigation season. Most wells distant from pumping centers showed seasonal water-level declines of 1 to 3 feet. These widespread declines are due to the natural seasonal fluctuation, possibly amplified by dispersed pumping and ongoing drought. Near the centers of pumping, however, there are broad areas covering tens of square miles where water levels in many wells dropped 10 to 20 feet during the 2004 irrigation season. Declines of 10 to 20 feet are observed in the Klamath Valley northeast of the Klamath Hills, in the area around Midland and Falcon Heights, around Pine Grove and Nuss Lake, in the area of the TID wells along the state line and extending down to the town of Tulelake, and around Copic Bay. There are smaller areas in the Klamath Valley and around Copic Bay where water level declines exceeded 20 feet in some wells.

The seasonal decline observed during the 2004 irrigation season is likely greater than that which occurred due to pumping prior to 2001. Many wells in the area may not be constructed to accommodate such large drops in water levels, particularly when added to the long-term effects.

Long-term effects are the year-to-year lowering of the water table due to pumping and climate stresses. Long-term water level declines typically occur over broad regions, such as an entire subbasin. Long-term decline is generally measured by comparing the spring high water levels each year in order to factor out seasonal declines. Such lowering of the water table has been observed over most of the upper Klamath Basin since about 2000 as a result of ongoing drought. The only exception is in shallow aquifers in the Klamath Project area, where water levels are moderated by recharge from canal leakage and deep percolation of irrigation water. Long-term declines due to pumping are in addition to this drought-related decline. Discriminating pumping related declines from drought related declines is difficult at present. The difficulty is due, in part, to the fact that many of the wells in the area are hydraulically connected to both the deep and shallow aquifer systems and are influenced by recharge from the Klamath Project. In the area of the town of Tulelake, where long-term water-level data exist, the rate of the year-to-year decline observed in the present drought cycle appears to be about twice that observed in the most recent previous drought.

The year-to-year decline can be evaluated by looking at the changes in water levels between spring 2001 and spring 2004 (figure 30). Although data are sparse in the northern part of the area, measurements show that water levels declined more than 10 feet over most of the Klamath Valley. A broad area over which declines exceed 15 feet occurs around the state line in the Tule Lake sub-basin and extends south to the town of Tulelake and north to Malin. Declines of 10 to 15 feet during this period are common north of Malin. Declines of 5 to 10 feet are common in the Copic Bay area. Three wells on the Modoc Plateau south of the Tule Lake subbasin showed declines of 5 to 10 feet.

Year-to-year declines can also be evaluated by comparing water-level measurements taken in spring 2003 and spring 2004 (figure 31). During this period, wells over the region away from pumping centers declined 0.5 to 1 foot. Declines were larger, however, near pumping centers. Water-level declines of more 4 to 8 feet were common in a broad area northeast of the Klamath Hills extending north to Miller Hill. Water levels declined 2 to 4 feet over this one-year period in the Tule Lake subbasin along State Line Road and extending south to the town of Tulelake. Declines of 2 to 4 feet were common in the Sand Hollow area northeast of Malin, and between 2 and 4 feet in the Copic Bay area.

If the pumping rates of the last two years are continued in the future, it is possible that the regional ground-water system will eventually achieve a new state of dynamic equilibrium. This will occur when the depression in the water table is large enough to redirect sufficient regional ground-water flow into the area to offset the increased pumping. At equilibrium, the increased discharge in the area of pumping must be offset by decreased discharge elsewhere. This would likely manifest itself as decreased discharge to adjacent basins, or decreased discharge to streams and lakes. At present, there is no way to reliably predict the levels at which the water table would stabilize, or the spatial and temporal distribution of the effects to adjacent areas and streams.

One component of the USGS/OWRD ground-water study is the development of a regional-scale numerical flow model that will have the capability to simulate the response of the regional ground-water system to various pumping scenarios. This will provide considerable insight to resource managers and water users. Until that tool is available, water managers must rely on inferences that can be made from the data collected over the past several years along with basic hydrologic principles.

Certain things are readily apparent from the recently collected data and our existing knowledge of the area. Ground-water pumping is accompanied by declines in water levels that occur at a variety of scales. The amount of ground water that can be pumped in a period of time will be determined in part by how much drawdown water users can tolerate, and in part by how much interference with streams and lakes can be considered acceptable. The drawdown can be easily measured. The consequences to water users of increased drawdown can be mitigated by deepening wells and pumps. The impacts of pumping on streams and lakes can be calculated or modeled, but they are in many cases virtually impossible to measure directly. Where there are acute effects to individual springs or smaller streams, the effects may be easy to measure. However, where the effects are to larger streams or lakes, and represent a small part of the overall flow, they are usually impossible to discriminate from other fluctuations and measurement error.

A substantial volume of water is stored in the regional ground-water system. The rise and fall of the water table represents changes in the volume of stored water. This storage can be actively managed. An aquifer system can be pumped intensively to provide water in times of shortage as long as there are also periods of reduced pumping during which the water levels can recover. Recovery can even be enhanced by minimizing the pumping stresses during wet periods, for example by supplying surface water to traditional ground-water users.

Efforts to date to use ground water to help offset water shortages in the upper Klamath Basin have been reasonable, particularly in light of the nascent understanding of the regional ground-water hydrology. The substantial monitoring, the selection of pumping sites to avoid interference with streams and springs, and the rotation of pumping to minimize acute well interference are all noteworthy. If the ground-water resource is to be used as part of the overall solution to water issues in the basin, however, a specific ground-water management strategy should be developed and criteria should be developed that set acceptable limits for ground-water drawdown and interception of ground-water discharge to streams, springs, and lakes. The regional numerical flow model presently under construction will be helpful to managers for developing that strategy and setting limits for ground-water use. The degree to which ground water can be utilized will ultimately depend on how much drawdown water users are willing to tolerate, and what degree of interference with streams and lakes will be considered acceptable.

Conclusions of Hydrologic Analysis

Several conclusions can be made as a result of the hydrologic analysis presented in this review. It must be emphasized, however, that the work done here was simply for review purposes and additional analysis of the hydrologic data for the basin is warranted.

- 10-year reference period:
    - Development of BO required flows based on the 39 years of record would provide more hydrologically realistic and reasonable requirements.
        - Use of the 10-year reference period (1990s) to determine flow requirements results in abrupt monthly shifts in the required flows as a result of the small number of years in each year type (figure 1).
        - For some water-year types, 10-year period derived flow requirements do not reflect a reasonable approximation of the historic record from 1961-1999.
        - Statistics for daily, monthly, and annual data from the 1990s are dissimilar to the longer time period (1961-1999) available for this type of analysis.
- Data issues:
    - Significant differences between USGS, PacifiCorp, and Reclamation streamflow data were found.
        - PacifiCorp and Reclamation use USGS stage data, but in some cases they use outdated and unshifted rating curves to calculate operational streamflow data.
        - At the Klamath River at Keno, PacifiCorp operates a gage ¼ mile from a USGS gage, which can create data inconsistencies.
    - All agencies should use the same streamflow data, and standardize field methods, quality assurance, and publication.
    - Improved measurement of diversions and returns around and within the Project is critical to quantifying the effects of water bank activities and overall Project operation.
        - A comparison of USGS streamflow records at Link River and Keno showed inconsistencies with Reclamation diversion and return flow data.
    - Monitoring ground-water levels, pumpage, and discharge are important for developing and evaluating ground-water management strategies.
- Comparison of flow requirements to historic record:
    - Three different analyses show that for certain river year types or combinations of river and lake year types, required flows are often not attainable and that there are large deficits in water availability under 1961-1999 water management schemes.

        - Water bank requirements of 100,000 acre feet per year are in addition to the required flows and were not accounted for in the analysis.
    - However, during fall and winter months of certain year types, surplus water may be hydrologically available for storage and later use within a given year or during the following year.
    - Although water may be hydrologically available during certain times of the year, biological, physical, and legal constraints may not allow use of the water.
- Long-term and recent trends in Klamath River flows:
    - Benefits of the pilot water bank and KBRT operations are difficult to measure in an analysis of Klamath River flows.
        - Increases in flow from the water bank are small relative to Klamath River flow.
        - Climate variability is large and therefore masks possible changes due to water bank activities.
    - Benefits from decreased consumptive use and the use of ground-water storage have likely resulted in increased Klamath River flows for threatened Coho salmon and/or higher lake levels for endangered suckers. The precise amount of the increase is not measurable due to reasons listed above.
- Trends in Klamath Project Diversions:
    - Although Reclamation diversion and return data have large uncertainty, these data provide the best method to directly measure the benefits from the water bank.
    - The water bank activities in 2003 and 2004 resulted in significant reductions in both gross and net diversions (April – September) in comparison to historic data (1961-1999).
        - Gross diversions averaged about 65,000 acre feet less than other years with similar inflows to Upper Klamath Lake.
        - Net diversions averaged about 70,000 acre feet less than years with similar inflows to Upper Klamath
    - This reduction in diversions is consistent with on-Project water-bank activities that theoretically should have reduced demand for Project surface water by about 59,000 and 65,000 acre feet in 2003 and 2004, respectively.
        - An alternate approach of evaluating April through September net diversions using Link and Keno USGS gage data, and A-Canal records, provided similar results and helped to confirm the prior conclusion.
- Ground Water
    - Water-bank activities have resulted in an approximately eight-fold increase in ground-water pumping in the vicinity of the Klamath Valley and Tule Lake subbasin in 2003 and 2004.
    - The increased ground-water pumping due to the water bank has resulted in acute well interference at some locations, seasonal water-level declines of

  - 10 to 20 ft near pumping centers, and year-to-year declines of 2 to 8 feet over broad areas surrounding pumping centers.
  - The seasonal and year-to-year declines are larger than historically observed.
  - The eventual consequences of continued ground-water pumping at the 2003 and 2004 rates, with respect to ground-water levels and spring discharge, cannot yet be predicted.
  - A prudent long-term water-bank strategy would be to rely on ground water only during dry years and to allow the ground-water system to recover during years when there is ample snow pack and precipitation (perhaps reducing the need for a water bank) or when other sources of water might be available. Methods to augment recovery during wet years could be explored.
  - Present and proposed USGS ground-water studies should help with ground-water management by providing the ability to estimate the declines in ground-water levels and losses of ground-water discharge to streams, springs, and lakes given various amounts and schedules of ground-water pumping.
  - Ground-water modeling results should help managers set acceptable limits for ground-water drawdown and interception of ground-water discharge to streams, springs, and lakes.
- General conclusions
  - In this analysis of flow requirements it became evident that the required flows can change abruptly from time step to time step and from year type to year type. A more temporally continuous approach using the 1961-1999 period of record would result in a “smoothing” of the flow requirements over time and as hydrologic conditions change within a year and between years.
  - Designation of just a few year types seems unnecessary and difficult to manage. If year types are used, then many more year types could be designated so that abrupt shifts are avoided.
  - If a continuous approach is not used, and water-year types continue to be used, the number and definition of year types should be identical for Upper Klamath Lake and the Klamath River. Currently, one lake year type spans three river year types.
  - Although there are some inherent limitations to streamflow forecasting and the use of forecasts to define management requirements, more frequent NRCS streamflow forecasts (every two weeks) would help “smooth” the requirements to changing estimates of water availability resulting in better informed water management schemes.
  - There seems to be no good rationale for using last year’s water-year designation to dictate flow requirements and lake levels through the following winter season. This procedure can create severe water management problems, particularly when hydrologic conditions change from wet to dry.

    - Between growing seasons (e.g. October through March), it would be better to set flow and lake-level requirements based on current hydrologic conditions, such as recent streamflows, snowpack, recent precipitation, and ground-water levels.
    - Strong consideration should be given to changing the requirement for a 100,000 acre-foot water bank every year. For example, if ground water becomes an important part of a water-bank strategy, then ground-water levels should be allowed to recover during wet cycles so that ground water can be pumped during droughts. Water banks need to have periodic deposits.

Overall, a more continuous approach for setting flow and lake level requirements would likely be more favorable from biologic, hydrologic, and water management perspectives. The exact method to accomplish this would require extended technical discussions with many agencies and stakeholders.

Management Options

In multiple brainstorming sessions we explored potential options for operation of the pilot water bank in the upper Klamath Basin. Some, if not all of these options, have probably been thought of previously by Reclamation staff. However, we hope to provide additional perspective on how options could be implemented and the potential pros and cons of each option. None of these options are simple fixes and each one presents challenges.

Ground-Water Pumping/Substitution

- Ground water is used in place of surface water for irrigation. The water is either applied to fields that were normally irrigated with Project water or the water is pumped directly into the Project canal system. This use of ground water results in reduced diversions from Upper Klamath Lake and the Klamath River.
    - **Pros:** The use of ground water allows for flexible timing of withdrawals (year round), adjustable discharges, adjustable pumping locations, and requires very little lead time to implement (in contrast to the dryland farming option) if permits are in place.
    - **Cons:** Ground-water use can result in interference problems, storage depletion, subsidence, and loss of stream baseflow. Ground-water use requires a water right in Oregon. It is costly to Reclamation to pay for and pump ground water.

- Additional considerations:
    - Conjunctive use – Ground water could be a viable source of water during dry periods. During periods of pumping, ground water would be removed from storage and water levels would decline, as has been seen in response to pumping from 2001 to 2004. Beyond periods of a few years, ground-water pumping may not be sustainable at high rates. With the return of wet conditions, the ground-water system should be allowed to recover and surface-water sources used for irrigation. In some areas, where only ground water is used for irrigation, it might be appropriate to extend

    canals or pressurized pipelines to provide surface water to those areas in wet years to augment recovery of aquifer storage, thereby making more ground water available during dry years.

  - Distribute pumping - Increased ground-water pumping generally has been limited to areas in and around the Klamath Project. Use of wells in other areas of the basin, as opposed to using surface-water sources, may provide for a greater distribution of pumping that could reduce acute well interference problems.
  - Augmented ground-water recovery – Injection of water into wells during times of peak wintertime flow may be a viable option to augment recovery of ground-water levels. Water of acceptable quality would be required. The Oregon Department of Environmental Quality (ODEQ) has authority to issue permits for such purposes. Augmentation of ground water would allow ground-water levels to be maintained in aquifers, which would assure that base flows in streams, springs, and lakes are not eventually impacted.
  - Avoid ground-water pumping adjacent to important surface- and ground-water resources such as Upper Klamath Lake, the Klamath River, and large spring complexes.

Land Idling

- With one approach of this management option, land that is normally farmed remains idle during the irrigation/growing season. Consumptive use is reduced because crops are not irrigated. An accurate estimate of the amount of water actually saved with idling would require the analysis of evapotranspiration rates in both idled and irrigated fields if this option is a large part of the water bank strategy (i.e. 2.45 feet/year is approximate due to the issue of sub-irrigation where shallow ground water provides some water for consumptive use). The method of analysis of evapotranspiration rates would be similar to that done for KBRT (USGS Review of KBRT, 2003).
- An alternative option that has been used with land idling is to refrain from irrigating land; however, crops are grown on tilled land or a reduced number of cattle graze on pasture land (forbearance). This option has been termed “dryland operations”. Crops and pastures must rely on moisture provided by natural precipitation or shallow ground water. KBRT in the Wood River Valley is an example of forbearance.
  - **<u>Pros</u>**: The processes for land idling are already established by Reclamation, the amount of land idled can be large and thereby provide large savings, and the amount of land idled can be varied from year to year as needed. With dryland operations, land remains somewhat productive and the agricultural output from the basin is less affected as compared to fully idled land. The amount of water savings is quantifiable, and where forbearance is utilized above Upper Klamath Lake there may be water-quality benefits to the lake.

    - **Cons**: It may be difficult to distinguish land that would have been idled for other reasons. The timing of water savings is not optimal for improving Klamath River flows during the spring months. Land idling alone can not provide sufficient water to meet springtime flows in certain combinations of dry lake and river water year types as shown in Table 6. Land idling is labor intensive to administer and contracts have to be made long in advance, reducing flexibility to adjust the size and configuration of the water-bank. The payments for land idling are costly and with complete idling of the land there is a loss of agricultural output (and associated commerce) from the basin. This strategy requires participation of many property owners.

- Additional considerations:
    - Reducing sub-irrigation – To receive the greatest savings from this approach, preference should be given to land idling operations not adjacent to irrigated land because of the smaller potential for sub-irrigation from shallow ground water. If idling operations occur in areas surrounded by irrigated land, reduced compensation should be considered because of the potential for sub-irrigation. Evapotranspiration rate analyses should be conducted to verify water savings.
    - Increase forbearance acreage – The KBRT forbearance concept allows the continued use of grazing land, but at the same time eliminates the irrigation of those lands which reduces consumptive use. Increasing the number of acres upon which forbearance is practiced in the Wood River Basin, and possibly other areas of irrigated pasture in the upper Klamath Basin, could provide some additional water savings and still allow the land to be productive at a reduced level. In 2004, 11,000 acres were included in the KBRT. By tripling the acreage, more than 30,000 acre-feet of water could be included in the water bank that would be available during the months of June through September.

On-Project Surface-Water Storage – Lower Klamath Lake

- This option would allow storage of water on lands that are natural or formerly natural water bodies, such as the Lower Klamath National Wildlife Refuge and the historical extent of Lower Klamath Lake.
    - **Pros**: This option may allow capture of large amounts of “excess” winter flows when they occur, reducing the need to “acquire” water. The amount of water stored could be adjustable based on hydrologic considerations and needs, and stored water could be released or pumped to Klamath River during critical months in the spring. If inundated agricultural land was used, it may be available for farming or grazing by June.
    - **Cons**: Excess surface water would be required from within a given water year, and there would be some evaporation of stored water. The quality of water stored on Project or refuge land would need to be evaluated before it could be discharged to the Klamath River. There would be water rights

considerations, and agreements would have to be made with landowners. There would likely be costs associated with leasing land for inundation, and the strategy may require expensive changes to the Project's infrastructure to convey and store water (e.g. canal modifications and building or modifying pump stations).

- Additional considerations:
    - During peak flow periods on the Klamath River, water could be conveyed through the Ady canal and Lost River Diversion Channel toward the Lower Klamath National Wildlife Refuge and the historical extent of Lower Klamath Lake, and possibly other suitable low-lying areas. Such a scenario would likely require re-engineering of the Klamath Straits Drain connection to the Klamath River to allow water to flow in the reverse direction. These diversions could be made in the December through February timeframe and the water stored until as late as May so that the water could be used as water bank water to augment spring flows. Storage of water in the winter and spring would minimize evaporation losses from the water body. In addition, these activities could help recharge the ground-water system in winter months through leaking canals and the stored water body.
    - The water-quality implications of this strategy should be carefully explored.

New Storage

- New storage would provide the ability to provide water at needed times; however, large quantities of water during winter/spring runoff events would be required to fill them. Reclamation is considering several options in this respect.
    - **Pros**: Large volumes could be stored, and reservoirs could be a long-term solution to flow requirements. If reservoirs are deep enough, water temperature could be adjusted as the water was being used.
    - **Cons**: The surplus surface water needed to fill reservoirs may not always be available. There would be substantial engineering and construction costs. Peak winter flows may be reduced as water is taken for storage. There would likely be environmental considerations, and water rights would be needed.

Wetland Restoration – Upper Klamath Lake

- Key features of Upper Klamath Lake's hydrologic system and ecosystem could be returned to more natural conditions. If sufficient wetlands were restored around Upper Klamath Lake they could provide substantial storage.
    - **Pros:** There would be increased effective storage in Upper Klamath Lake, improved habitat, and potential benefits to water quality. There would be a reduced need for building new storage.

  - **Cons:** There would be increased evapotranspiration and potentially large costs to purchase land. In dry years, when Upper Klamath Lake does not totally fill, these reconnected wetlands adjacent to the lake will not provide additional water storage and may actually increase evapotranspiration because of the expanded surface area of the lake.

Use of Properties Adjacent to Upper Klamath Lake for Storage

- This option would involve using drained wetlands adjacent to the lake for storage. This differs from restoring the wetlands in that the land would remain isolated from the lake and would be actively managed for storage. These lands could be flooded if sufficient runoff occurred in the winter time to fill the current configuration of the lake. Full lake elevation would be achieved first, then, water would be gravity fed into adjacent wetlands rather than spilled over Link River Dam. This stored or banked water would then be pumped (or gravity fed) back into the lake during times when additional flows were needed in the Klamath River from April through September. If wetland areas were kept hydrologically disconnected from the lake, water could be used without impacting the lake water level. Shallow water could be kept on properties after pumping to provide wildlife habitat, to keep peat soils saturated, and to minimize water-quality problems.
  - **Pros:** New storage reservoirs would not be needed. The timing of spring releases could be controlled for maximum benefit. The operation of the sites could be controlled by Reclamation (i.e. if properties were purchased) and water could be stored between years.
  - **Cons**: Pumping stations may need modification, and control structures between the lake or streams might need to be constructed (for gravity drainage), properties would need to be purchased or leased, and fish screens would need to be installed.

New Storage on Tributaries Between Keno and Iron Gate Dam

- There are multiple tributaries to the Klamath River below Keno and above Iron Gate Dam. There may be the potential to develop storage in these drainages to capture peak flows that could be released in the spring to augment downstream flows.
  - **Pros:** Storage could provide high quality water at appropriate times.
  - **Cons:** Construction of new storage would be required. Environmental concerns include disruption of tributary habitat for Coho salmon if fish passage above IGD is opened.

Reduce Evapotranspiration and Seepage Along Project Infrastructure

- In many areas of the Project, canals and drains often have abundant vegetative growth adjacent to them resulting from seepage of water into the shallow

subsurface. It may be possible to save water lost to phreatophytes by lining canals in selected areas where water is primarily being conveyed from one place to another. This strategy would only "charge" the Project where irrigation was actually taking place.
  - **Pros:** Leakage from canals in some areas would be reduced.
  - **Cons:** The cost would be significant, and the water bank savings would be hard to quantify. This option could affect local wetlands and wells fed by the seepage.

Operational Spills during Springtime

- Operational spills occurring in March and April may be reasonable components of the pilot water bank program. During some years, these spills occur when BO required flows are specified and spill provides needed Klamath River flow for many biological reasons such as improving spawning habitat, facilitating outmigration of smolts to the ocean, and diluting or scouring out fish pathogens or their hosts below IGD. It seems reasonable to include spill as part of the water bank.
  - **Pros:** During some years, climatic conditions may provide water needed to meet BO requirements and therefore water bank needs.
  - **Cons:** By providing credit to the water bank program for operational spills less water bank volumes would be available during the following summer months.

Future Directions for Water Bank Management in the Upper Klamath Basin

Implement Planning Effort

Development of short-term and long-term strategies is an important part of meeting the water needs in the upper Klamath Basin. Reclamation has operated the pilot water bank in the upper Klamath Basin in the past two years in reaction to the BO requirements to protect threatened and endangered species. The operation of the water bank has allowed the Project to function in a manner similar to the past. However, the goals and potential benefits of the pilot water bank program have not been fully defined or planned.

For example, the primary water-use strategy of the water bank in 2004 relied on pumping ground water, which is a viable strategy in the short term. However, long-term planning is required to determine acceptable consequences and also strategies to allow the aquifer system to recover. Monitoring of the resource must be a key component of the strategy to be successful. In the long term, the rate of ground-water pumping in 2004 may be difficult to maintain indefinitely. This management strategy requires considerable pre-planning.

A Klamath Project Pilot Water Bank concept may be a viable approach for augmenting flows in the Klamath River, particularly during dry years. Benefits of the water bank are apparent in reductions of net surface-water diversions by the Project and other water users in the upper Klamath Basin. However, it is difficult to determine if the timing of this augmentation is appropriate.. Improved measurement of diversions and returns from the Project will be required to understand the quantity and timing of the reduced net diversions from on Project activities; and, other data collection, monitoring, and analysis will be required to quantify water savings and timing by off Project management strategies in the upper Klamath Basin.

As mentioned earlier, some management options can provide water for increased spring time flows (e.g. new storage, ground-water pumping), whereas other management options (e.g. land idling) will only provide additional water when the consumptive use is reduced in primarily the summer months. But it is clear that a water bank that primarily depends on dryland farming, land idling, and/or ground-water substitution will have a limited ability to maintain required spring flows. The greatest potential benefit from these management options occurs during the peak of the irrigation season (June, July, and August).

As the water bank is now configured, ground-water pumping is a key component with dryland operations to a lesser extent. In 2004, the water bank was expanded to areas outside the Project. In the future, a wider variety of management options could be utilized with conjunctive use of ground water and surface water whenever possible. In addition, water bank activities should be further expanded outside the area of the Project. A basin-wide commitment to the water bank is needed to assure that required lake levels and flows are met.

Ground-water resources have provided needed stored water in the past few years and can continue to provide water during dry periods in the future. However, artificial/enhanced recharge of ground water may be needed when excess water is available in the upper Klamath Basin. In the short term, impacts of ground-water pumping may be limited to well interference problems. Consideration should be given to distributing ground-water pumping across a wider area of the basin. Distribution of the pumping stress will distribute impacts on the ground-water system. Over the long-term, large amounts of ground-water pumping could have negative impacts on base flow to streams. As the Klamath Basin Ground-Water Study progresses, we will have an improved ability to forecast where and when such impacts might take place. A reasonable strategy to assist with ground-water recharge could be as simple as eliminating most pumping during wet periods to allow the aquifer system to “rest” and recover.

Both ground- and surface-water storage must be a significant part of a long-term solution to store water for use within a year so the timing of flows can be adjusted, and between years, particularly when wet years precede dry years. As has been the case in the recent dry years, ground water can help reduce diversions for agriculture which provides increased streamflow at specific times. When excess surface water is once again available, ground-water storage should be replenished as soon as practical. This augmentation of recharge may occur to some extent from natural infiltration, infiltration from canals, or flooding larger areas. Recharge through well bore injection may also be an option to consider, however, appropriate permits would be required from ODEQ and

OWRD. Shifting traditional ground-water users to Project surface-water supplies during wet years could indirectly use excess surface water to accelerate recovery of the ground-water system. Planning should begin as soon as possible with the OWRD and the CDWR to develop strategies for future years when excess water is available to recharge aquifers. In wet years, excess water used to replenish aquifers would truly provide an opportunity to store water for upcoming dry years.

Limits to the storage changes in the aquifer system must be established by management agencies. The criteria for this could be setting limits for ground-water drawdown, the actual volume of ground water used, or criteria for the amount of ground water intercepted from streams, springs, and lakes as determined by a model. Once the criteria are met, ground-water pumping would cease and other management options would be initiated, such as land idling.

Surface-water storage facilities could be developed and expanded in the basin to capture surplus runoff within biological and legal constraints. Ideally, water could be stored in areas where natural water bodies occur or where they were previously reclaimed for other uses. Areas adjacent to Upper Klamath Lake, like Agency Lake Ranch, are just one example where water could be stored. By pumping the water off of adjacent properties that are isolated from the lake, flows in the Klamath River could be augmented during the critical spring months. Isolation from the lake allows use of the water while not impacting required BO lake-level requirements. Stored water could be easily quantified. Newly engineered off-stream storage facilities could also provide a similar function.

Land idling management options are likely important components of a successful water bank. However, these approaches will not provide water in early spring as needed unless large parts of the Project are not “charged” thus reducing spring-time diversions. Once again, an evapotranspiration analysis is needed for these management options to determine the amount of decreased consumptive use. In prolonged dry situations, as we have experienced in recent years and the early 1990s, land idling may have wide application. When these activities are utilized they should be distributed throughout the upper Klamath Basin. Ideally, large groups of contiguous land should be arranged in order to minimize sub-irrigation from irrigated land to non-irrigated land.

Conservation efforts throughout the basin should be considered part of the pilot water bank program. As farmers and ranchers become more efficient with irrigation practices they could get credit for water savings. This is one area where everyone involved in agriculture in the basin could become involved if increased conservation measures can be quantified; however, quantification could be difficult. Crop adjustments from higher consumptive use crops to lower consumptive use crops may provide an excellent means to conserve water while assuring land productivity. At the same time, the Klamath Project should review areas where losses may occur in the system and actively eliminate any identified problem areas.

Efforts outside the Klamath Project can be effective in meeting water bank requirements and provide a viable basin-wide, long-term strategy for the water bank. Just as conservation efforts should be considered throughout the upper Klamath Basin, contributions or deposits into the water bank should also be from the general water-use community (environmental, agricultural, and power generation) and not primarily focused on Reclamation's Klamath Project. Expanding the water bank to the entire upper Klamath Basin could provide more flexibility for obtaining water from more potential sources.

Allow Adjustments for Climate Variations

Climate variability imposes the greatest stress to the hydrologic system in the upper Klamath Basin. Expectations of in-stream flow volumes and water bank volume requirements should take this variability into account. Both should be adjusted according to comparisons with historic climate and streamflow data. This concept is problematic during prolonged dry periods in that ESA requirements call for increasing in-stream flows while agricultural activities in the basin require greater amounts of water.

Management options could be varied based on climatic conditions. For example, it may not be beneficial to set the water bank requirement at 100,000 acre feet/year in a wet year when excess water is available and extra water may not be needed. In this situation, the wet year conditions could be used to passively or actively recover water levels in the aquifer system for use during dry years rather than pumping ground water that may not be needed.

Currently, the water-year type is initially set in April and, unless changed, this designation and associated requirements continue through March of the following year. To allow appropriate planning and implementation of strategies, consideration should be made (providing water-year types continue to be used) to adjusting the water-year type for the October through March period based on current hydrologic conditions, such as the NRCS "Water-Supply Outlook" reports. For example, continuing high-flow requirements for a wet year type carried through a fall and winter with very little precipitation could prevent the filling of Upper Klamath Lake and create serious water shortages in the following irrigation season that undermine any water-bank strategies.

During periods of protracted drought, when there are several consecutive dry years, finding sufficient water for a water bank may not be practical or even possible. A management strategy should recognize and accommodate this fact.

Set Hydrologically Attainable Target Flows

A critical step in assuring success of the Klamath Project Pilot Water Bank is a restructuring of the process for determining flow requirements for the Klamath River. The required flows should be as hydrologically reasonable as the existing historic data allow. The present flow requirements are based on a classification system with 4 or 5 "year types". A more continuous approach using a relationship between April through September inflows to Upper Klamath Lake and April through September discharge at Iron Gate Dam, similar to the analysis of diversion data in this review, could provide a continuous function for adjusting flow requirements. Once flow requirements are set based on the 1961-1999 historic record, attainable water bank requirements can be established.

Develop Multi-Year Management Strategies

The type of strategic planning that could take place in the upper Klamath Basin can be described by presenting an example scenario. Presented below is a simple hypothetical situation with a sequence of climatic year types with possible management options outlined. In the actual planning process, more detailed and complete action items would need to be outlined and communicated in advance to all involved. To achieve success in adjusting water management in the basin to climatic variability, the Klamath Basin community at large will need to be aware of the strategies and when they may be asked to participate. The scenario described in the following paragraphs assumes that a 100,000 acre foot water bank would not be required in all years.

With each year that passes an improved scientific understanding of the hydrologic system and the role and capabilities of the water bank can be developed. Strategies will require modifications and adjustments as varying water year types and series of water year types are experienced. Management schemes will require adaptation to continually improve the water bank activities in the basin by learning from each year’s operational plans. Implementation of a viable water bank program will require a long-term commitment to adaptive management.

During periods of wet years, surface reservoirs would be filled and ground-water pumping would be minimal to allow aquifers to recover. Artificial ground-water recharge might occur as well. Ideally, little or no water-bank flows would be required, and water-bank activity would be largely limited to planning for future dry years. Monitoring of ground-water levels would continue in wet periods.

When a single dry year occurs after a wet period, ground water and surface storage could be used to meet water-bank needs. In the short term, there may be little need for land idling. Dryland operations may be an appropriate option. Because baseflows should still be strong, a water bank of 25,000 to 75,000 acre feet may be sufficient. There should be continued monitoring of ground water.

When a second dry year occurs, ground water and remaining surface storage could be utilized for the water bank. Land idling could be used to supply some of the water bank needs. There would be continued monitoring of ground water to determine if acceptable limits of water-level decline are being approached. As baseflows will be decreasing, a water bank of 100,000 acre feet may be needed.

When additional dry years occur it can be expected that ground-water declines may approach some unacceptable limit and pumping for water-bank purposes would have to be reduced or curtailed. In addition, surface storage may be limited or exhausted. Water bank needs may have to come largely or entirely from land idling or dryland operations.

Discussions with NOAA Fisheries and USFWS regarding current conditions and modification of monthly or seasonal flow requirements may be warranted.

When wet conditions recur, the basin would be back in the mode of ground-water recovery and reservoir filling. Water bank requirements would again be minimal, and activities limited largely to monitoring and planning.

General Summary and Conclusions

Although the pilot water bank in the upper Klamath Basin could be reviewed from an economical, agricultural, biological or societal viewpoint, this review by the USGS was limited to the technical aspects related to the hydrology. This in-depth review required a complete understanding of the requirements of the water bank and the hydrologic constraints on the water bank. Because the intent of the pilot water bank is to enhance or augment flow in the Klamath River, the BO flow requirements were evaluated relative to the 1961-1999 measured USGS flow record.

The general hydrologic analysis in the context of the BO flow requirements resulted in a number of conclusions:

- The use of flow statistics from the 10-year period (1990s) to set flow requirements results in flows that are not consistent with, and not a reasonable representation of, the longer-term period of record from 1961-1999.
- Significant data differences were found between USGS, Reclamation, and PacifiCorp streamflow records. All agencies should use the same hydrologic data. Also, improved data collection is needed for diversions and return flows.
- Three different analyses of flow records show that for certain river year types, or for combinations of river and lake year types, required BO flows will often not be attainable without substantial reductions in diversions for agriculture and refuge use and there are significant deficits in water availability based on 1961-1999 operational histories.
- Benefits from decreased consumptive use and the use of ground-water storage have likely resulted in increased Klamath River flows for threatened Coho salmon and/or higher lake levels for endangered suckers. The precise amount of the increase is not measurable in the Klamath River because the benefits are likely within the streamflow measurement error. Climate variability has a strong influence on flow and therefore masks possible changes caused by water bank activities.
- Although diversion and return data have error, these data provide the best method to directly measure the benefits of the water bank. These data indicate that in 2003 and 2004 there were reductions in diversions of water to the Klamath Project consistent with the volumes of water used to augment streamflow under the water bank program.
- Preliminary pumpage estimates indicate that water bank activities have resulted in an approximate eight-fold increase in ground-water pumping in the vicinity of the Klamath Valley and Tule Lake subbasins. This increased pumping has resulted in acute well interference at some locations, seasonal declines of 10 to 20 feet near

pumping centers, and year to year declines of 2 to 8 feet over broad areas surrounding large pumping centers.

- Observations of the response of the ground-water system to water-bank pumping indicate that the developed aquifers can sustain heavy pumping for a limited number of dry years, but that adverse effects may become untenable with continuous pumping. This suggests that a strategy whereby aquifers are allowed to periodically recover by reducing or eliminating water-bank pumping during wet periods should be considered.
- A strategy in which the water bank flow requirements vary according to water-year type, with reduced or eliminated requirements during wet periods, may make more water available during dry periods.

Several management options including ground-water pumping/substitution, land idling, on-Project surface-water storage, new storage, wetland restoration, use of properties adjacent to Upper Klamath Lake for storage, among others are discussed in the review, and pros and cons listed. Some of these management options can provide water for increased spring time flows (e.g. ground-water pumping, new storage), whereas other management options (e.g. land idling) will only provide additional water when consumptive use is reduced primarily in the late spring and summer months. It is evident that multiple management options must be used to attain the most effective water-bank configuration. In general, most of the options discussed have been considered in the current water bank program although some have not yet been implemented.

The use of a water bank could be a viable management tool based on this assessment. However, some alternative directions for the water bank program in the upper Klamath Basin should be considered. These directions could include implementation of a planning effort to establish both long-term and short-term strategies as part of the goal to meet a variety of water needs in the basin. An adaptive management approach could be used to modify strategies as more is learned from year to year experiences.

Climate variability imposes the greatest influence on the hydrologic system in the upper Klamath Basin and, therefore, expectations of in-stream flow volumes and water bank volumes should take into account this variability. Both could be adjusted according to comparisons with historic climate and streamflow data. Flow requirements should be hydrologically attainable. Management scenarios could be developed to adjust management schemes based on climate variability so that all water users are aware of hydrologic limitations and the impact on their individual needs. Although the science of understanding climate variability and streamflow forecasting is advancing, the ability to predict future water availability (months to years) in the upper Klamath Basin will continue to be challenging and some level of uncertainty will always be inherent in the process.

The present water bank strategy places the burden of supplying water on the Klamath Project. Spreading that burden to the entire basin above Iron Gate Dam could provide more flexibility in procuring water and ensure a larger supply of water in dry years. It must also be recognized that any water bank may not be able to meet the BO requirements in extremely dry years or after several consecutive dry years.

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Glossary of Terms

10-year reference period – 1990-1999

Forbearance
In the Klamath Basin this term is used to describe refraining from using irrigation water.

Pilot water bank
As specified in the 2002 BO by NOAA Fisheries (NOAA, 2002), a Klamath Project Pilot Water Bank was one of the components of the reasonable and prudent alternative. The pilot water bank was to provide up to 100,000 acre feet of water to augment Klamath River flows. The term "pilot" indicates that water bank feasibility is being tested in the initial years to evaluate the reasonableness of this water-management option. Reconsultation between Reclamation and NOAA will take place in 2006, following 3 years of water bank operation, and one point of discussion will the framework and effectiveness of the pilot water bank.

Required flows and lake elevations
These flows and elevations are specified in the NOAA (2002) and USFWS (2002) BO's – one for the Klamath River and the other for Upper Klamath Lake, respectively. The requirements are also termed BO required flows by Reclamation in their operations plans. River flow requirements are specified for the USGS stream gage at Iron Gate Dam and lake elevation requirements are as determined by the weighted mean of the three USGS-operated stage gages on Upper Klamath Lake.

- Klamath River flow requirements
    - Iron Gate Dam from Table 5.9 of the 2002 BA with RPA modifications from the 2002 BO (5.9 modified).
    - Reclamation (2004 Operations Plan Table 4 (Appendix))
    - Long-Term Flow (NOAA, 2002) – Flow recommendations from Table 9 of the 2002 BO.
- Upper Klamath Lake elevation requirements
    - U.S. Fish and Wildlife Service (2002) BO
    - Reclamation (2004 Operations Plan (Appendix))

Time steps
For Reclamation operational purposes, the year is divided into 17 time steps; most months comprise a single time step, however the months of March, April, May, June, and July are each divided into two time steps.

Upper Klamath Lake net inflow
Net inflow to the lake is calculated by adding change-in-lake-storage to measured lake outflows at Link River Dam and the A-Canal.

Water year
The term “water year” is used to describe a hydrologic year from October 1 through September 30. For example, water year 2004 was from October 1, 2003 through September 30, 2004.

Water-year type
In the Klamath Basin, each year is classified as a particular water-year type according to hydrologic conditions. The water-year type is determined for the year starting in April. Planning by Federal agencies begins with the NRCS January forecast that projects April through September Upper Klamath Lake net inflow estimates. Thereafter, these forecasts are revised as more information is collected regarding snow pack, precipitation, temperatures, runoff, etc. The April 1 forecast by NRCS is used to finalize Reclamation’s operations plan each year by setting the initial year type. The year type is specified for Upper Klamath Lake and for the Klamath River in the two BOs using different classifications.

- Lake (USFWS 2002 BO)
    - 4 categories
    - Above average, Below average, Dry, Critical Dry
- River (NOAA 2002 BO)
    - 5 categories
    - Wet, Above Average, Average, Below Average, Dry

As hydrologic conditions change, revisions to the water-year type occur generally in April through June, and the year type is finally fixed on September 30 of each year; however, water-year type then remains in place through March 31 of the following year, regardless of intervening climatic conditions.

Figure 1. -- Flow requirements for the Klamath River below Iron Gate Dam from the Biological Assessment Table 5.9 (as modified according to the 2002 BO).

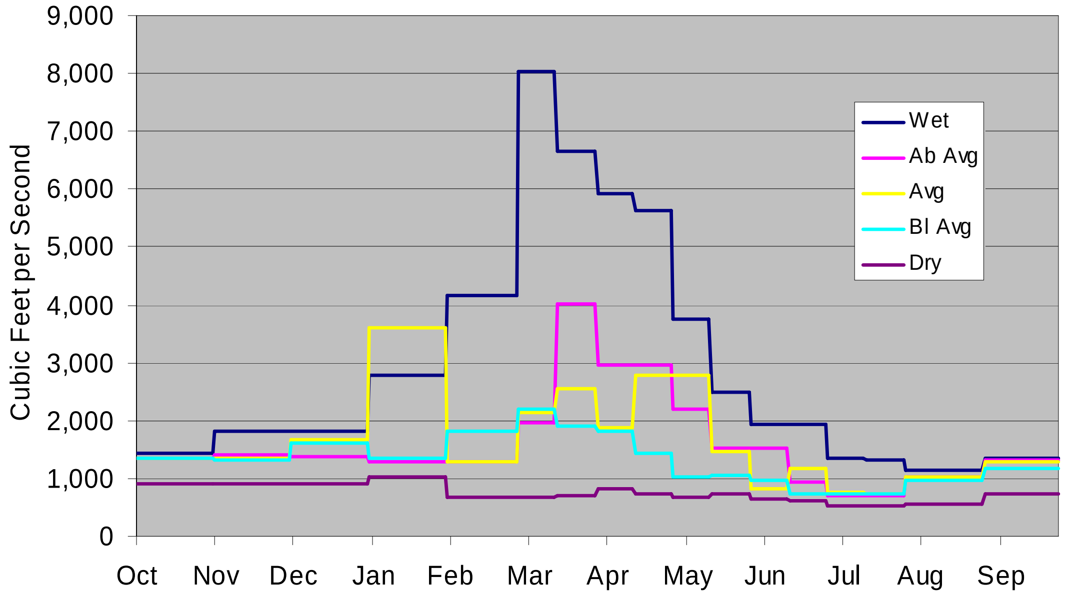
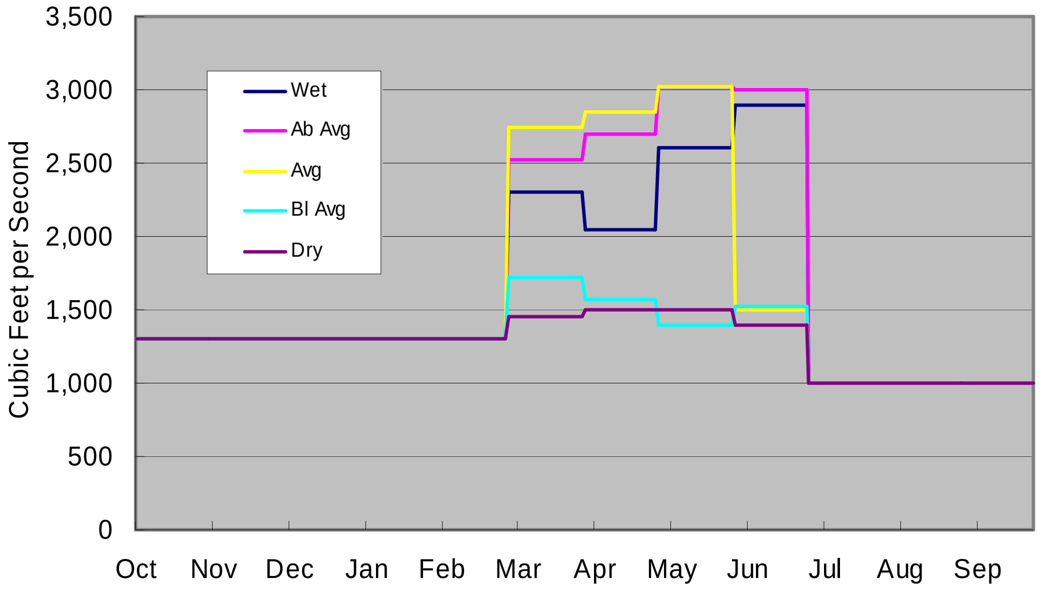


Figure 2. -- NOAA Recommended Long-Term Flow Requirements for the Klamath River at Iron Gate Dam by Water Year Type (NOAA, 2002, Table 9)



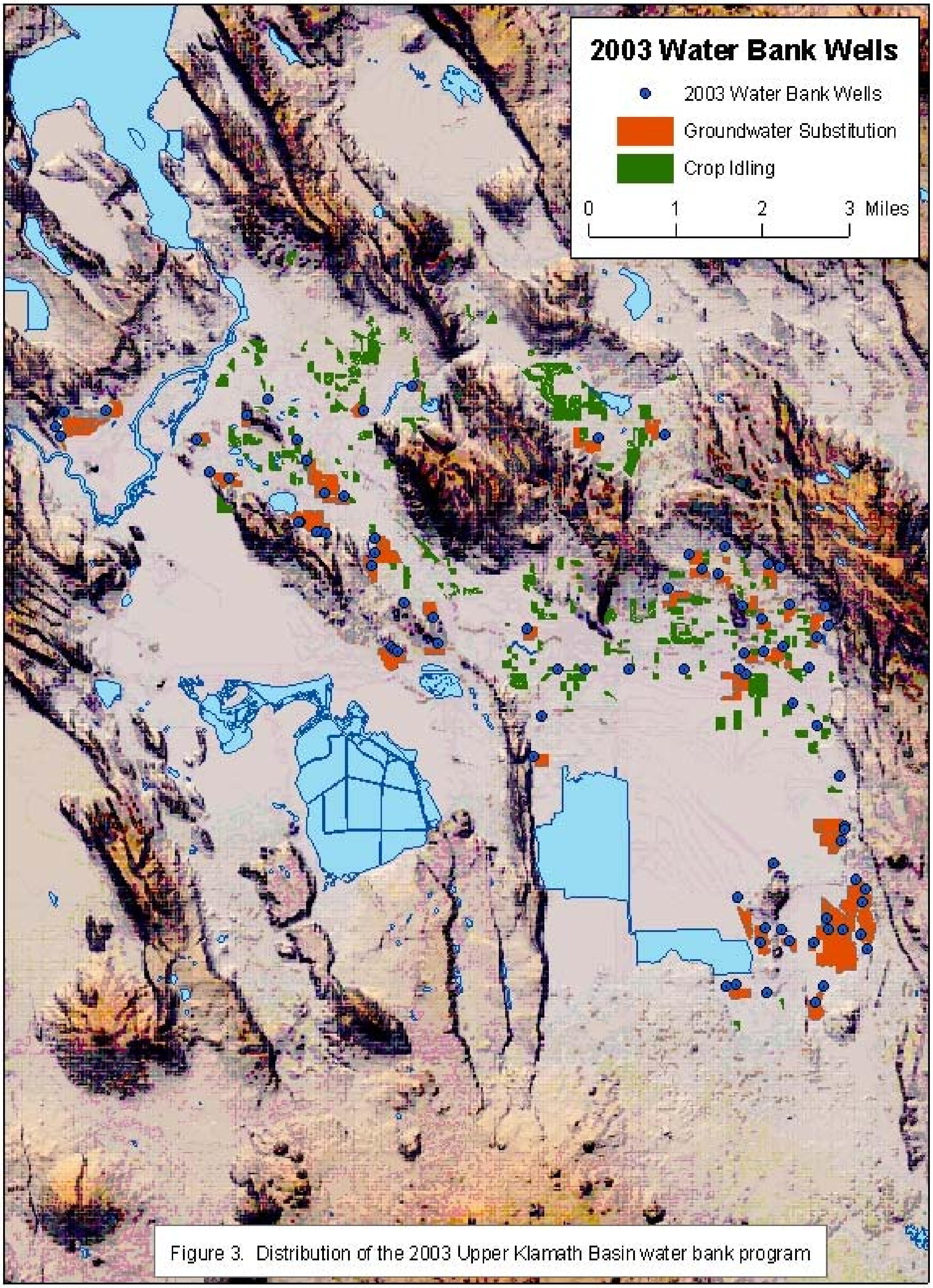


Figure 3. Distribution of the 2003 Upper Klamath Basin water bank program

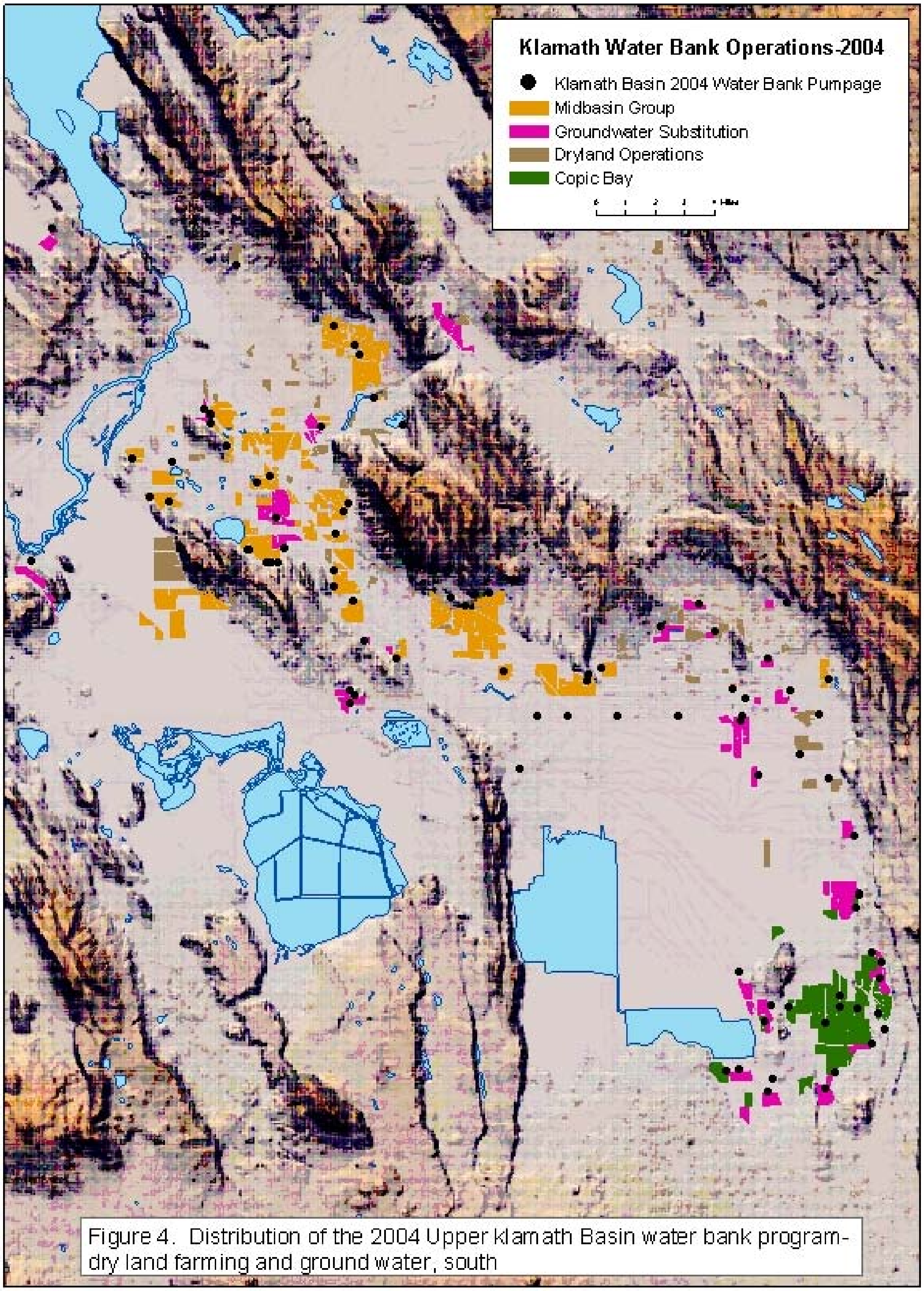


Figure 4. Distribution of the 2004 Upper klamath Basin water bank program-dry land farming and ground water, south

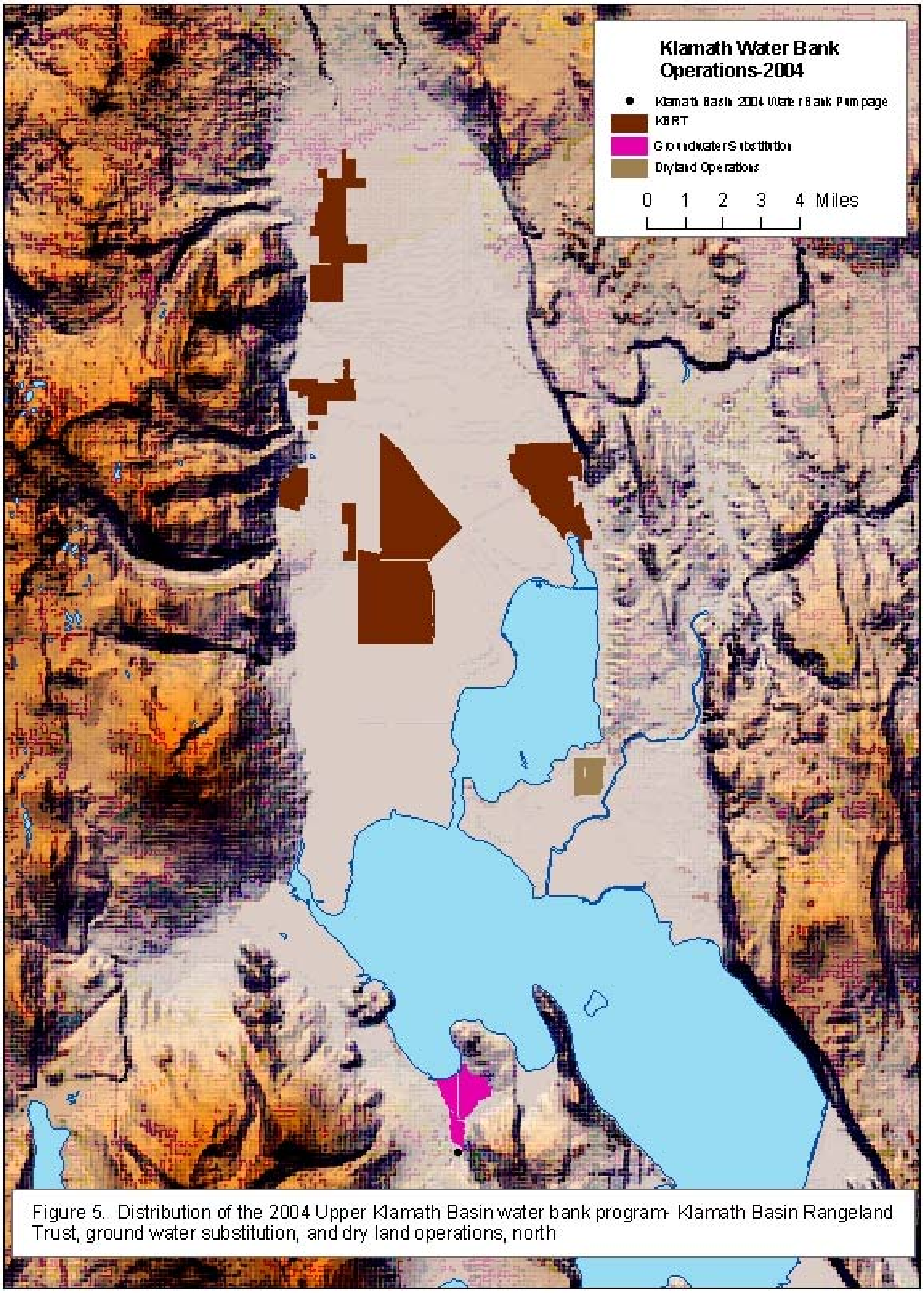


Figure 5. Distribution of the 2004 Upper Klamath Basin water bank program- Klamath Basin Rangeland Trust, ground water substitution, and dry land operations, north

Figure 6. -- Water Bank Requirements from 2004 "Actual" Operations

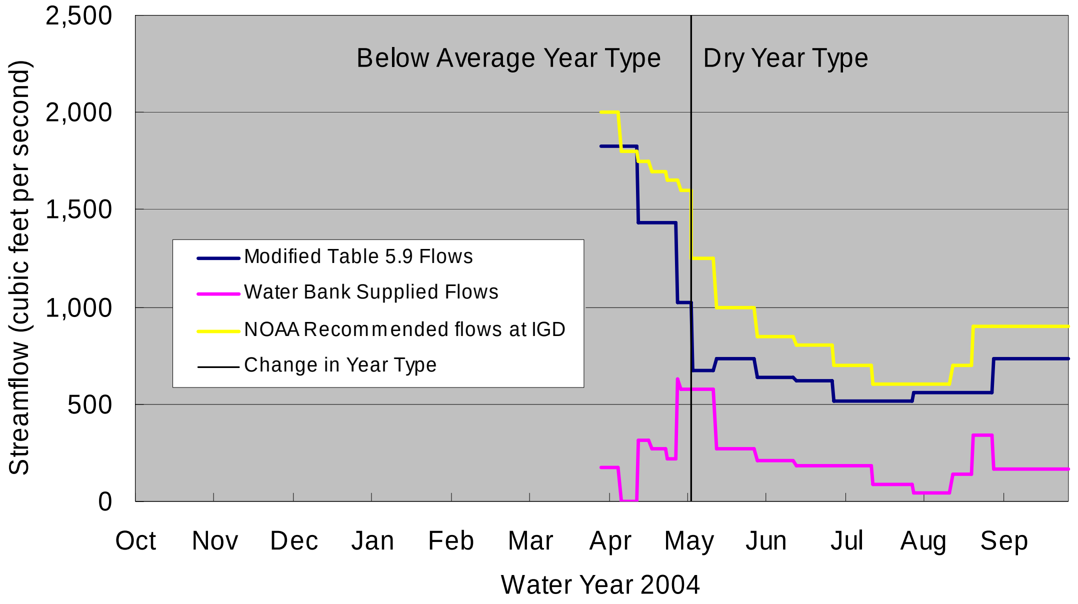


Figure 7. -- Comparison of water year 2004 daily mean flows of the Klamath River below Iron Gate Dam, and flow requirements with water-bank augmentation

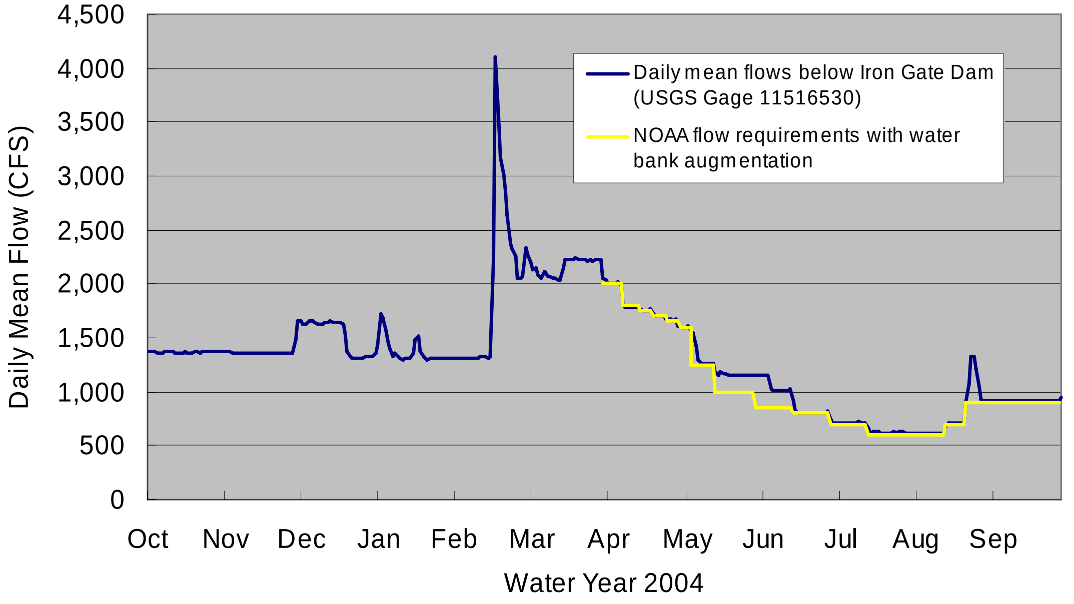


Figure 8. -- Median daily flows for the Klamath River below Iron Gate Dam (WY 1961-1999) by water year types specified in the biological opinion (NOAA, 2002)

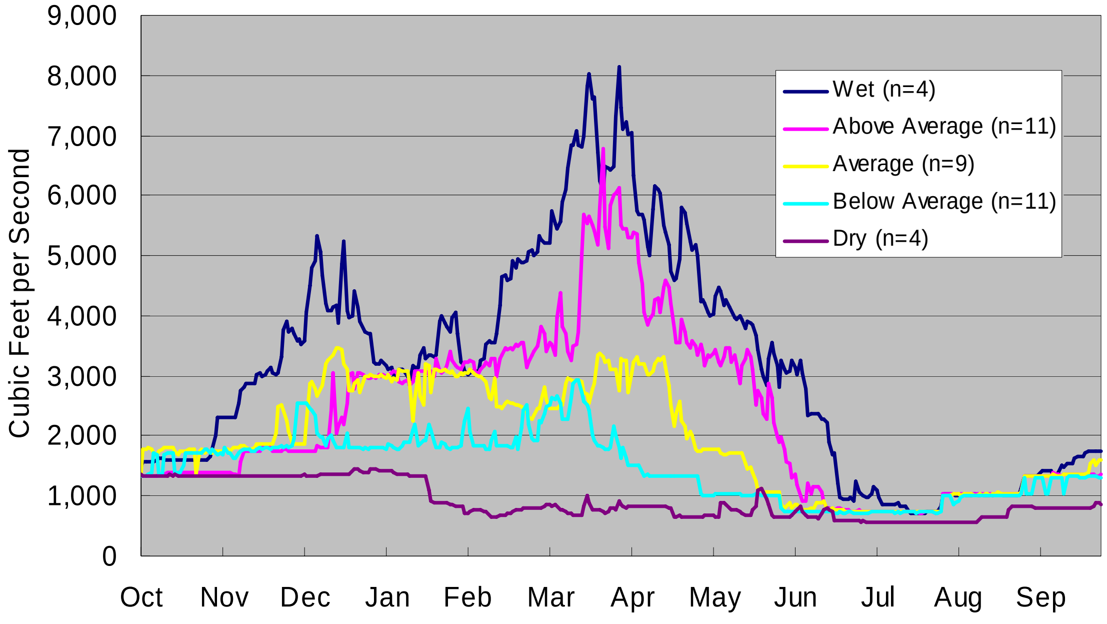


Figure 9a.-- Medians of observed mean monthly flows for the Klamath River below Iron Gate Dam, California (11516530) of wet water year types from 1961-99 and 1990-99.

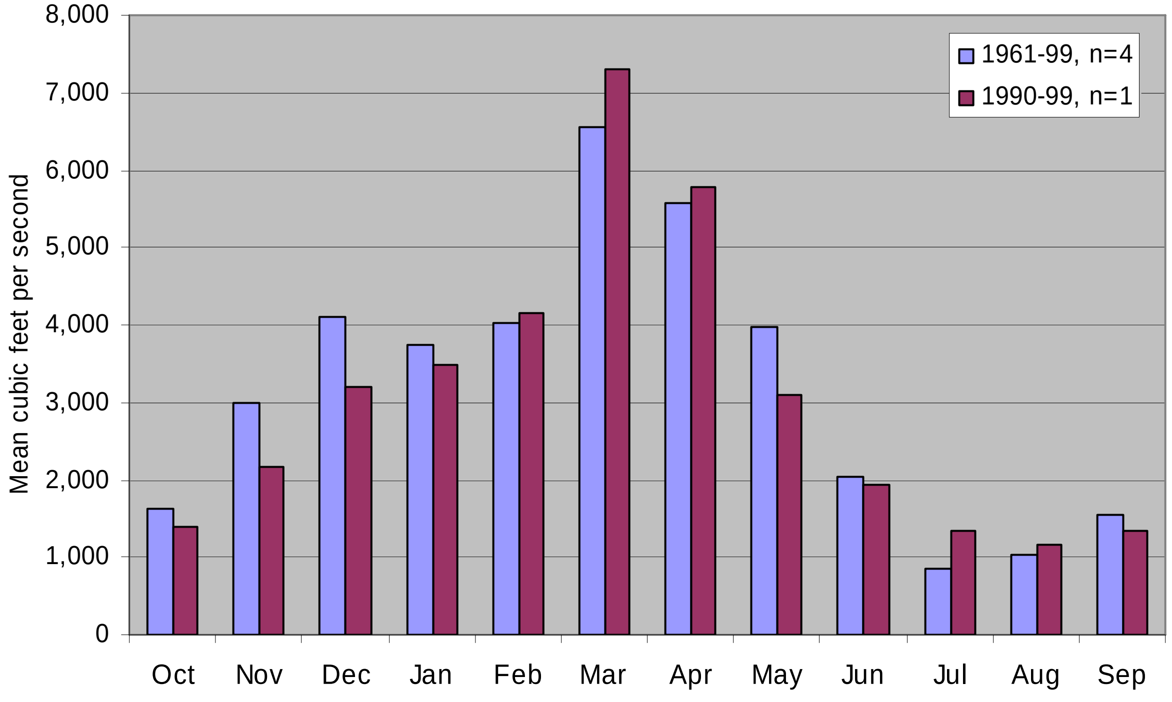


Figure 9b.--Medians of observed mean monthly flows for the Klamath River below Iron Gate Dam, California (11516530) of above average water year types from 1961-99 and 1990-99.

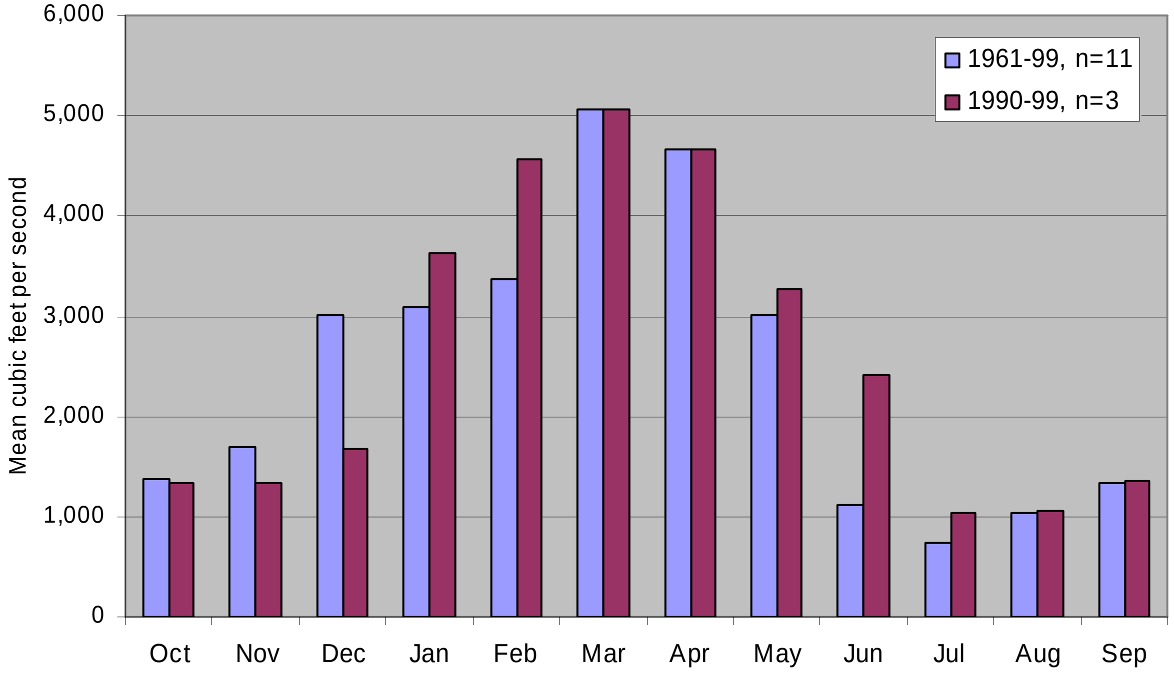


Figure 9c.--Medians of observed mean monthly flows for the Klamath River below Iron Gate Dam, California (11516530) of average water year types from 1961-99 and 1990-99.

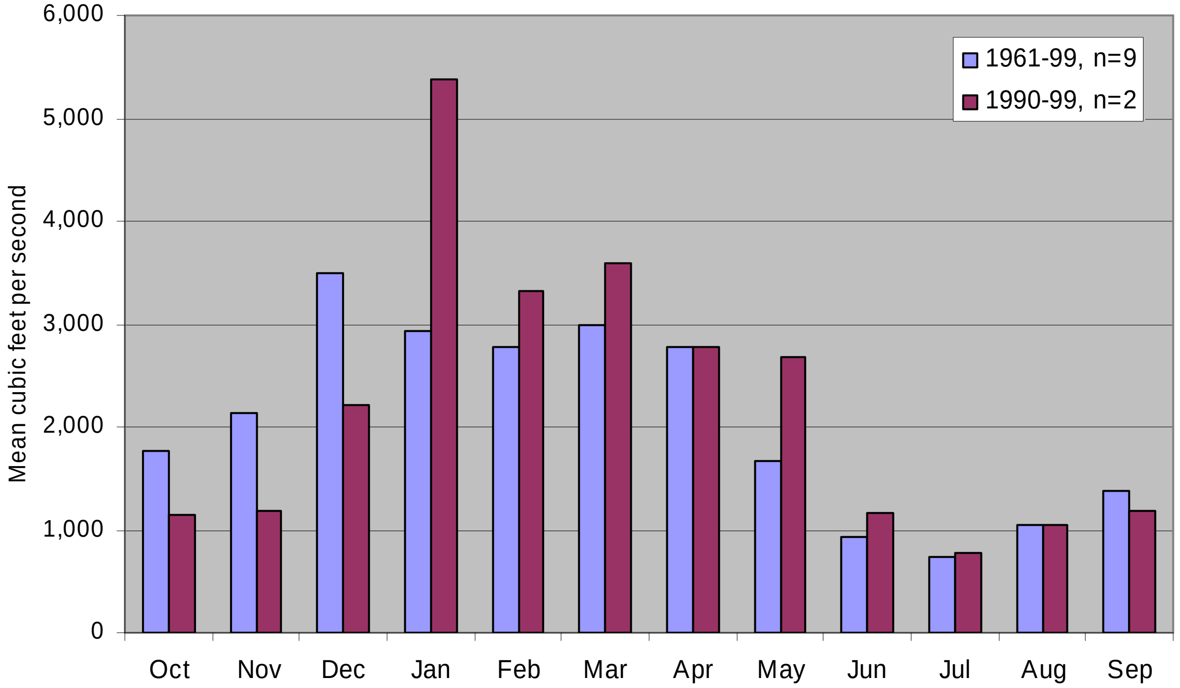


Figure 9d.--Medians of observed mean monthly flows for the Klamath River below Iron Gate Dam, California (11516530) of below average water year types from 1961-99 and 1990-99.

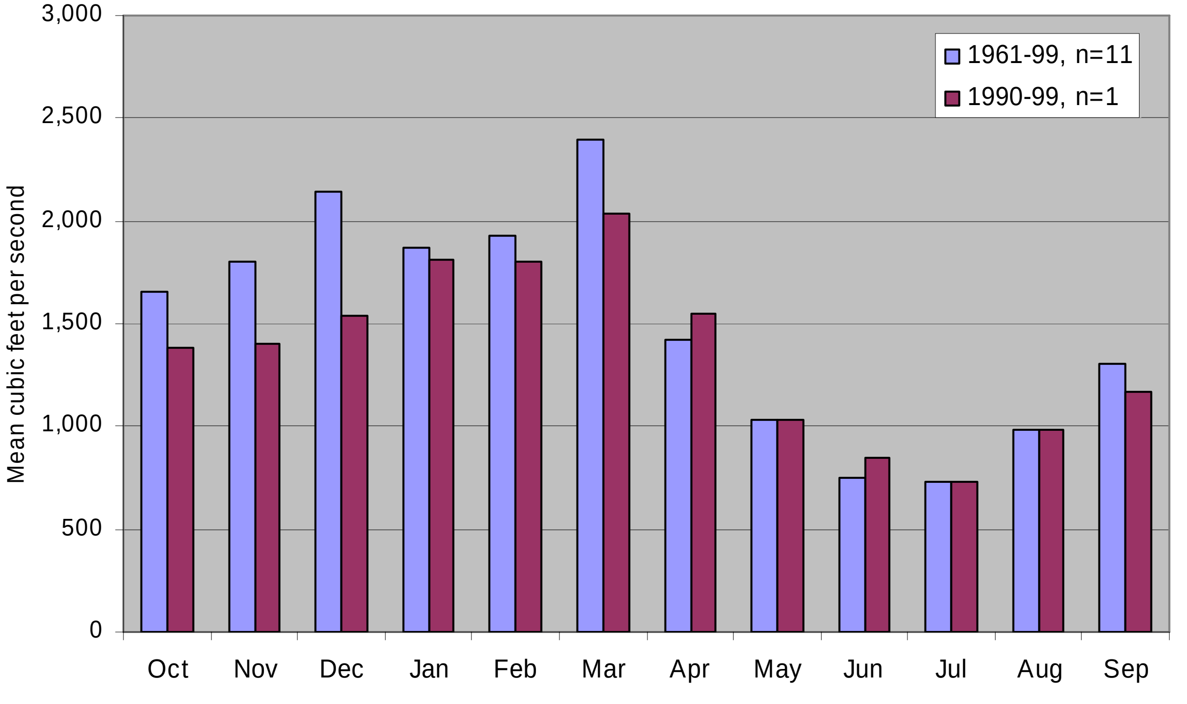


Figure 9e.--Medians of observed mean monthly flows for the Klamath River below Iron Gate Dam, California (11516530) of dry water year types from 1961-99 and 1990-99.

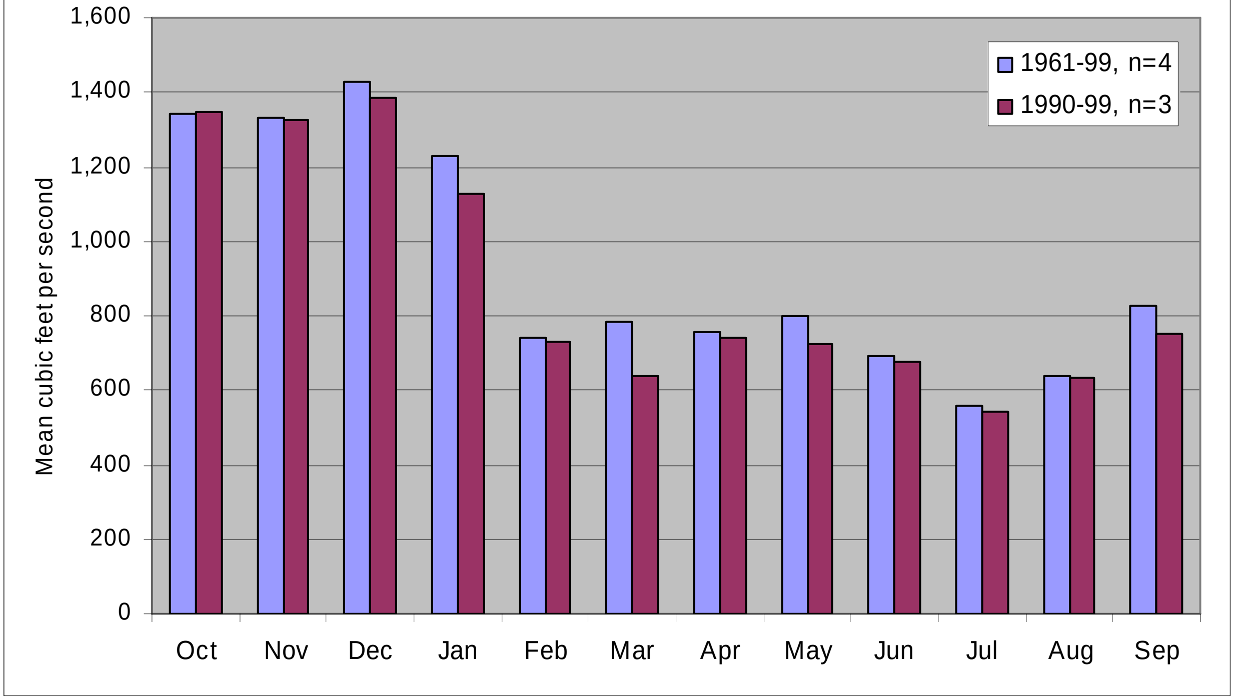


Figure 10.--Box plots of observed daily mean flows for the Klamath River below Iron Gate Dam, California (11516530).

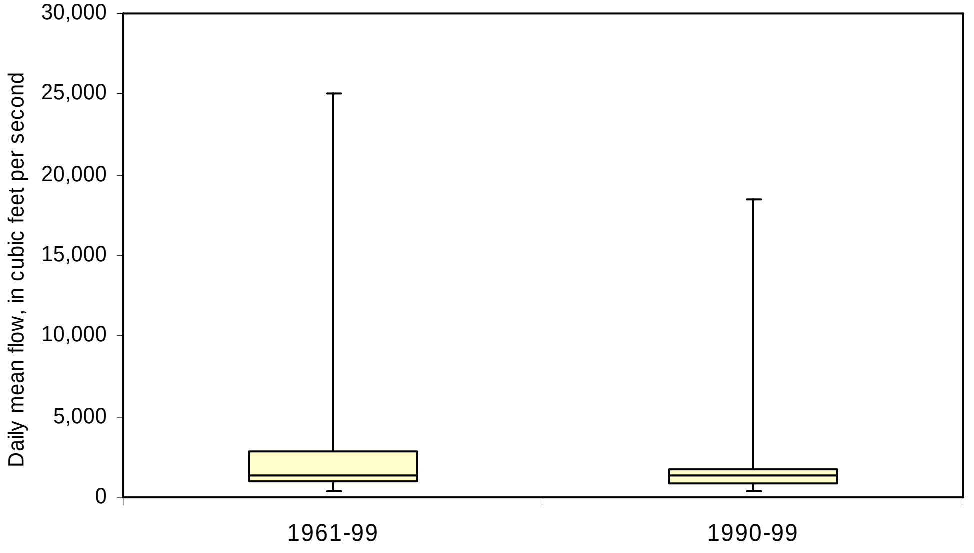


Figure 11.--Streamflow exceedance curves of observed daily mean flows for the Klamath River below Iron Gate Dam, California (11516530) for 1961-99 and 1990-99.

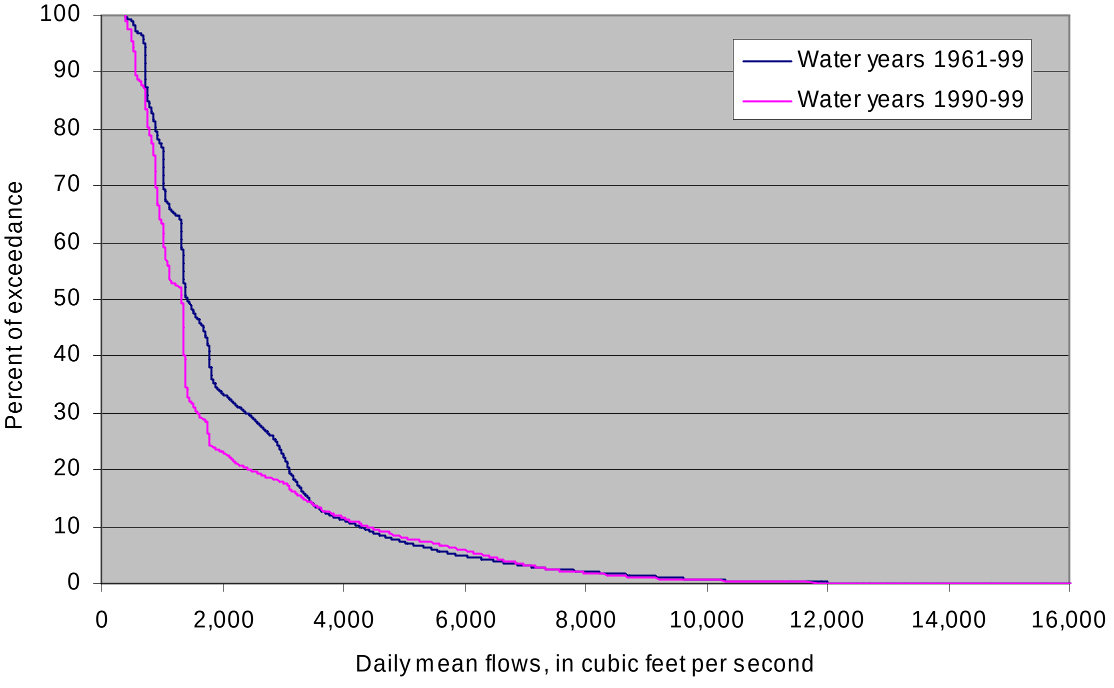


Figure 12.--Box plots of observed mean monthly flows for the Klamath River below Iron Gate Dam, California (11516530).

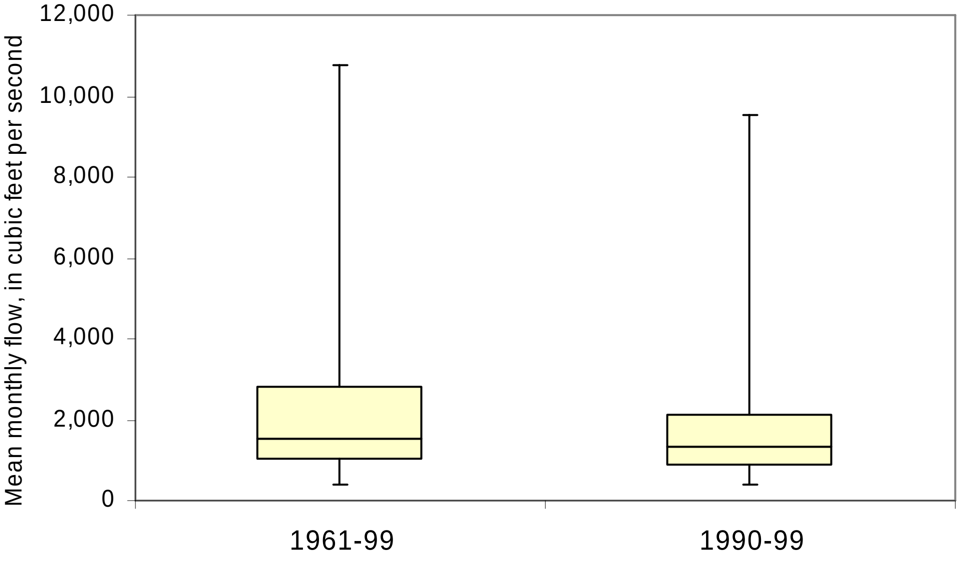


Figure 13.--Box plots of observed mean annual flows for the Klamath River below Iron Gate Dam, California (11516530).

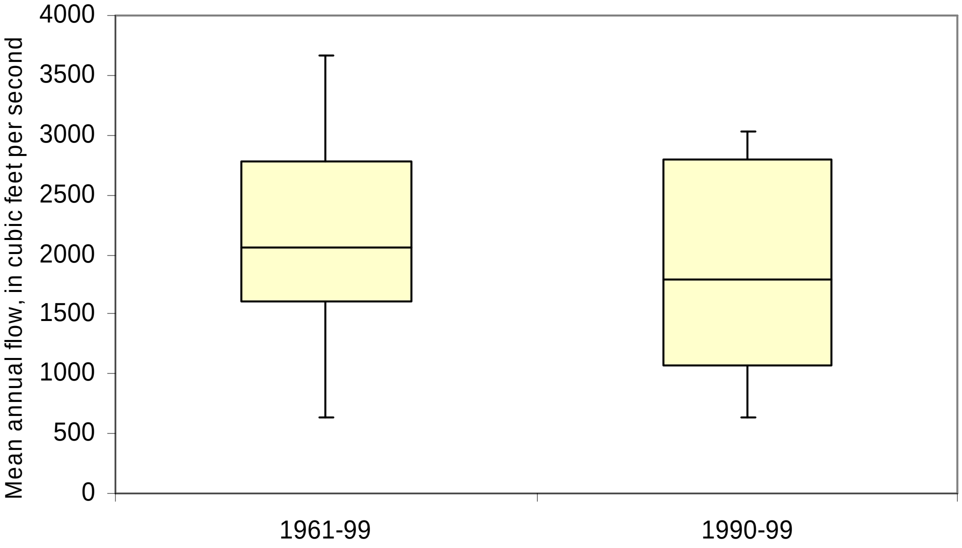


Figure 14a. -- Comparison of flow requirements and observed median montlhy flows at Iron Gate Dam. Wet Water Year Type (n=4)

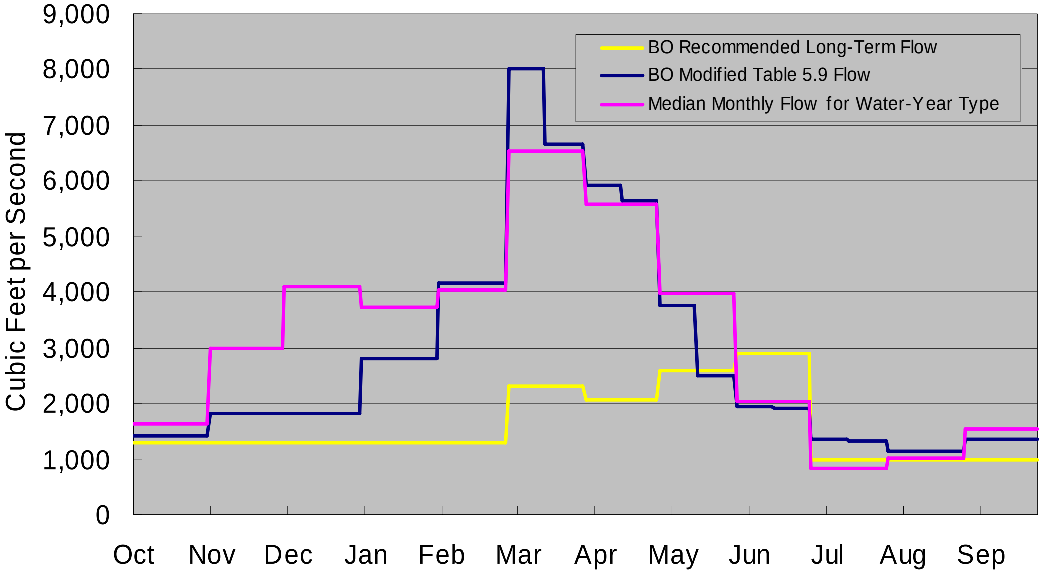


Figure 14b. -- Comparison of flow requirements and observed median montlhy flows at Iron Gate Dam. Above Average Water Year Type (n=11)

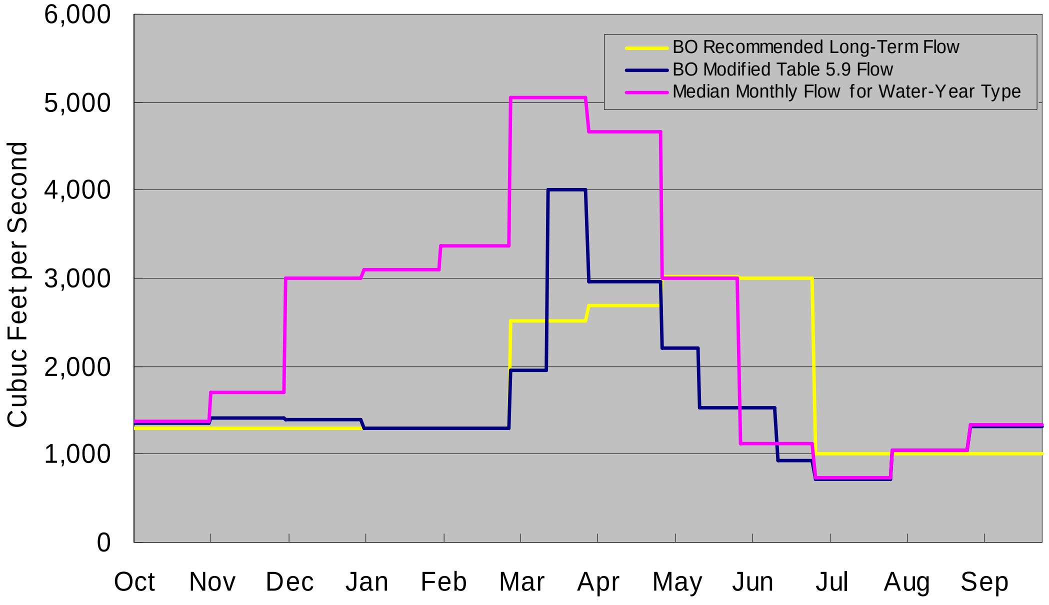


Figure 14c. -- Comparison of flow requirements and observed median montlhy flows at Iron Gate Dam. Average Water Year Type (n=9)

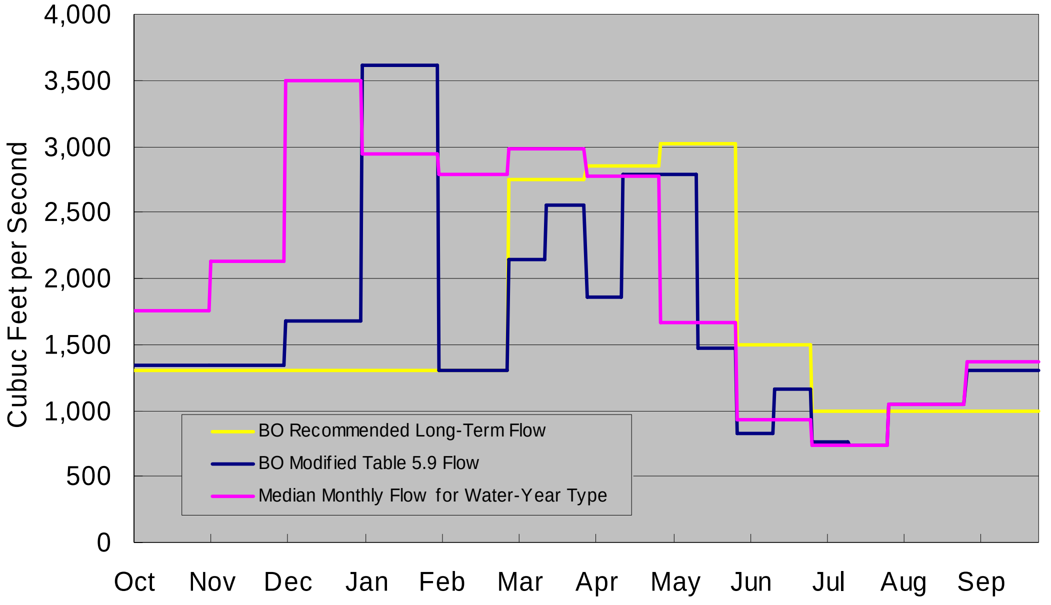


Figure 14d. -- Comparison of flow requirements and observed median montlhy flows at Iron Gate Dam. Below Average Water Year Type (n=11)

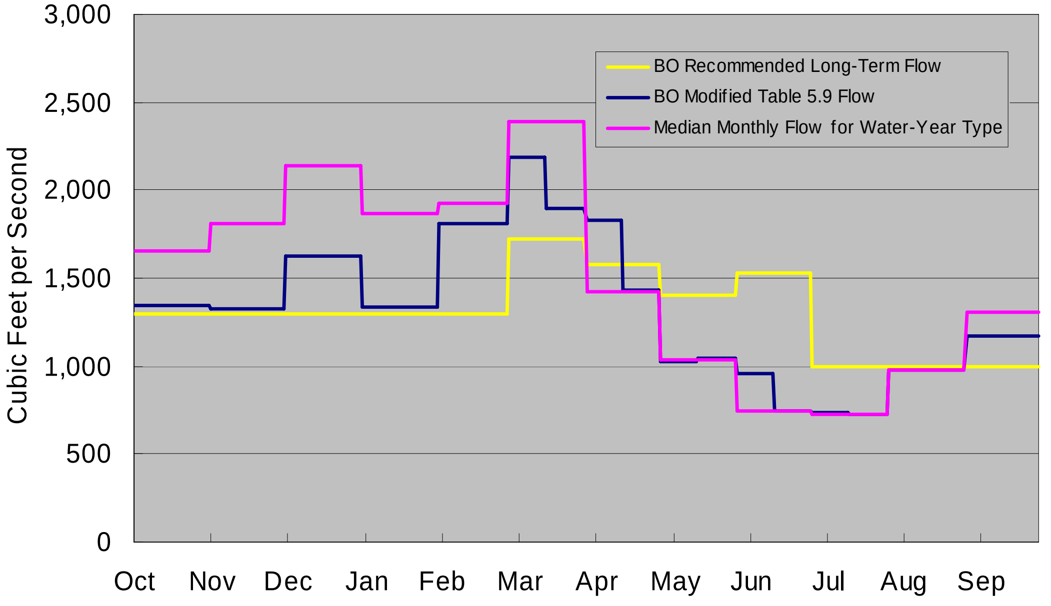


Figure 14e. -- Comparison of flow requirements and observed median montlhy flows at Iron Gate Dam. Dry Water Year Type (n=4)

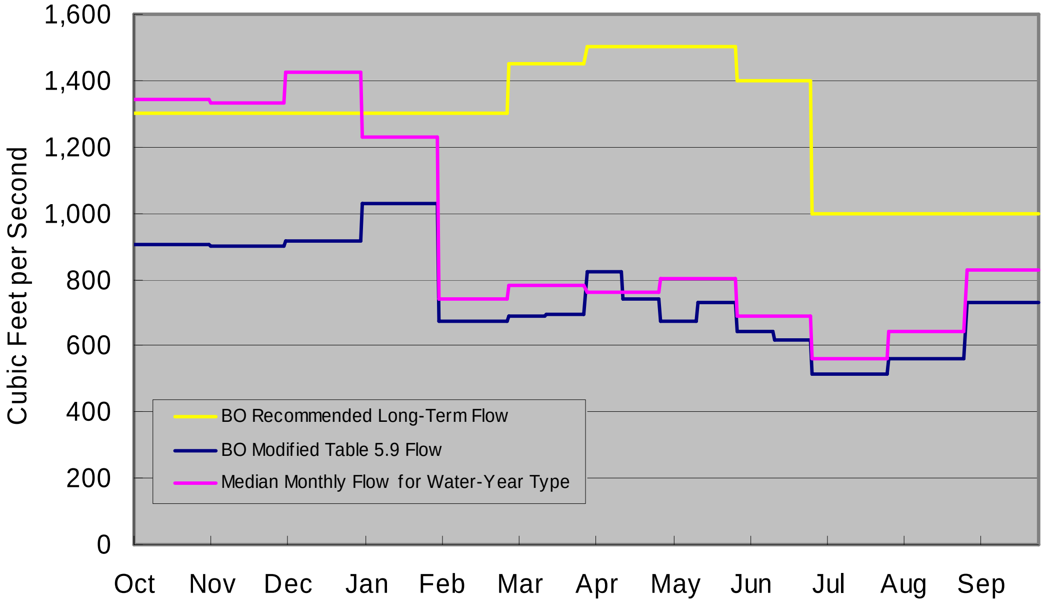


Figure 15.--Klamath River flow at Keno (11509500) and accretion from groundwater and tributaries between Keno and Iron Gate Dam (11516530), 1961-2004.

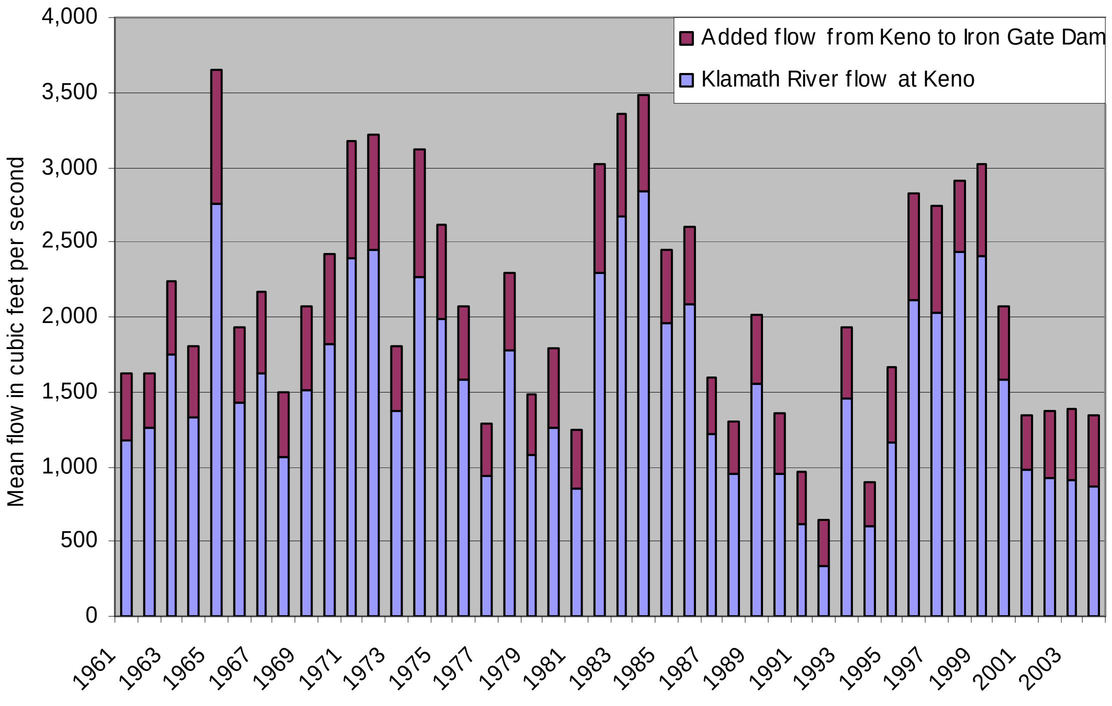


Figure 16.--Mean-monthly Klamath River accretion from groundwater and tributaries between Keno (11509500) and Iron Gate Dam (11516530), 1961-2004.

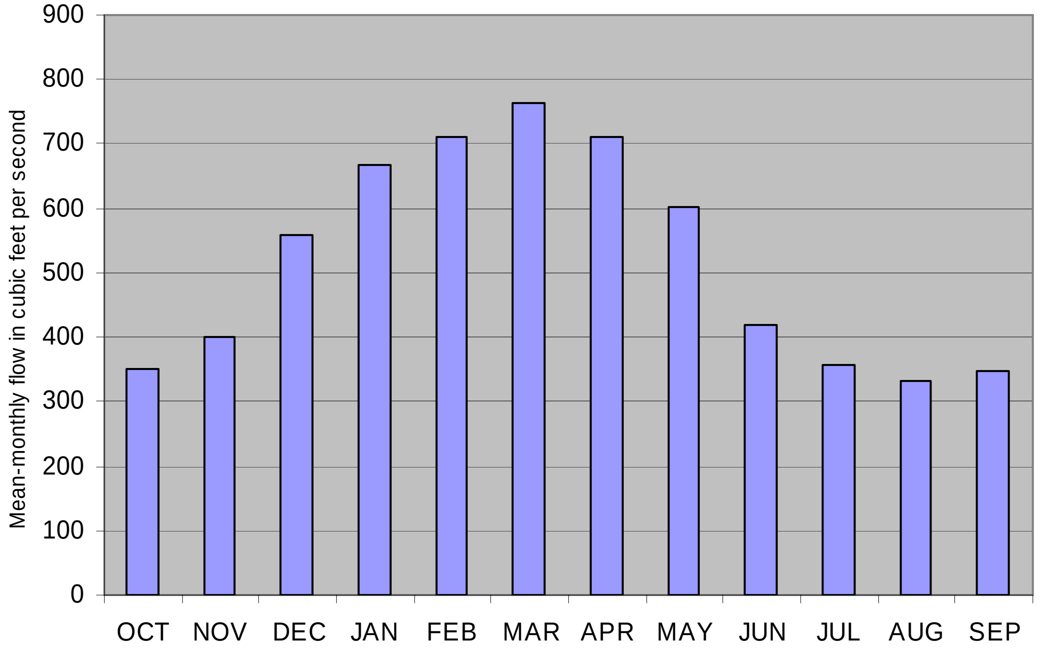


Figure 17a.--Comparison of required and observed flows for wet water year types.

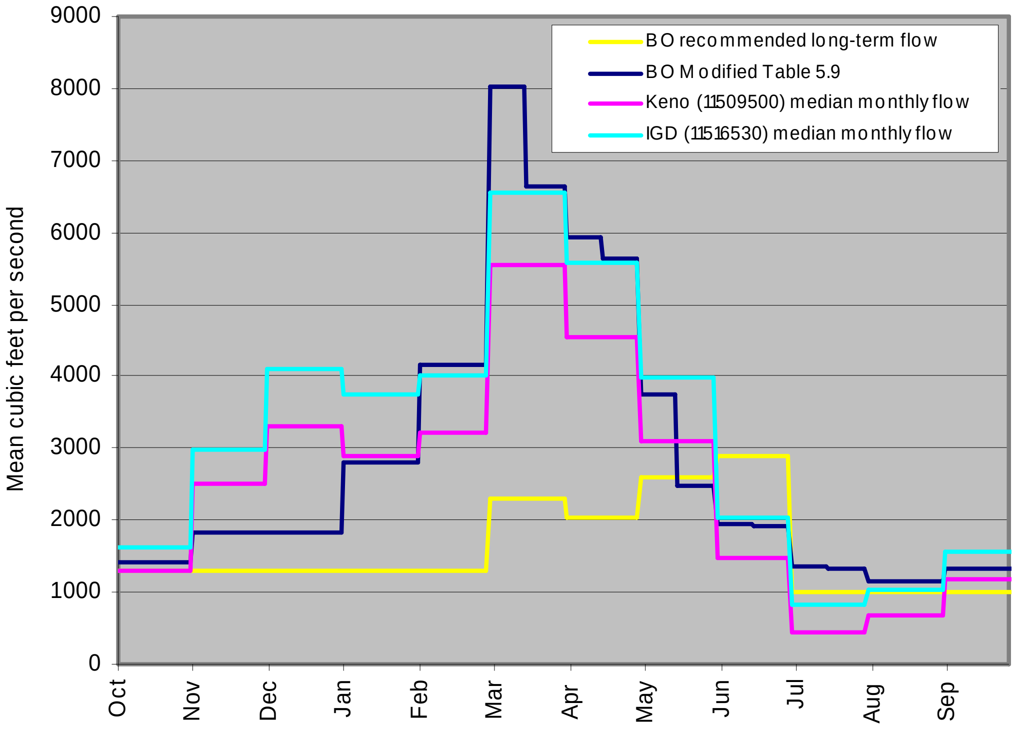


Figure 17b.--Comparison of required and observed flows for above average water year types.

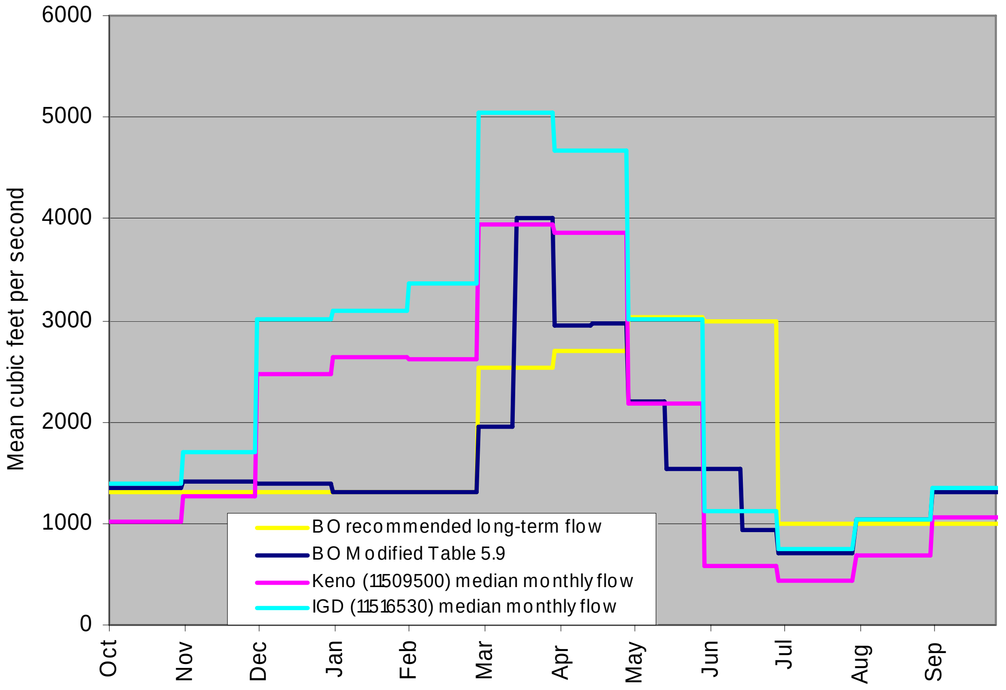
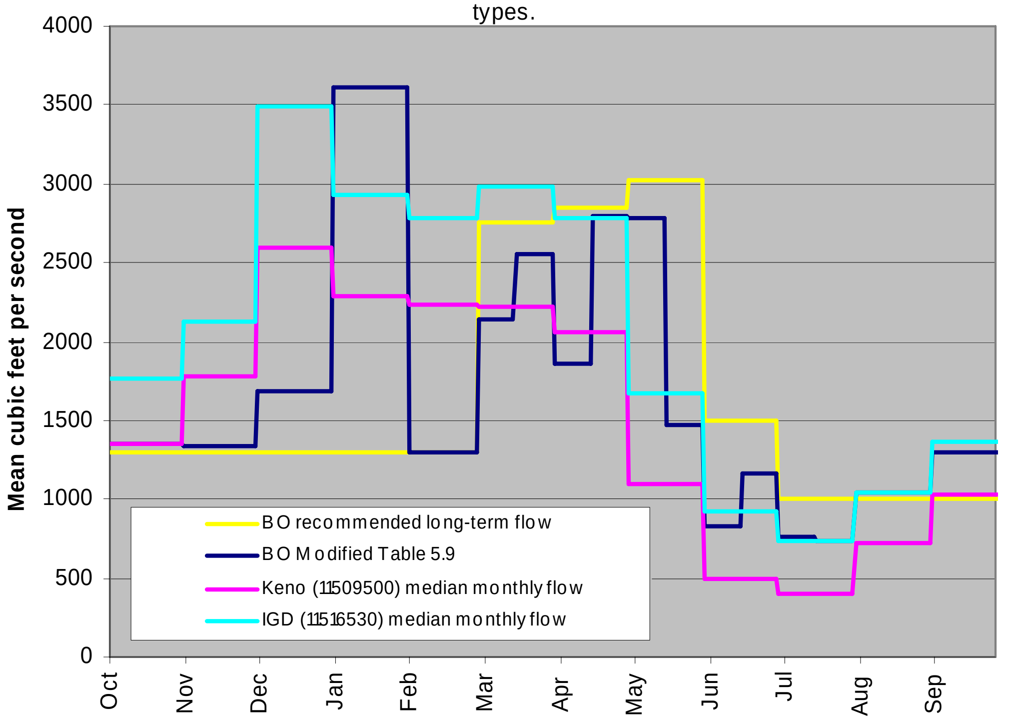


Figure 17c.--Comparison of required and observed flows for average water year types.



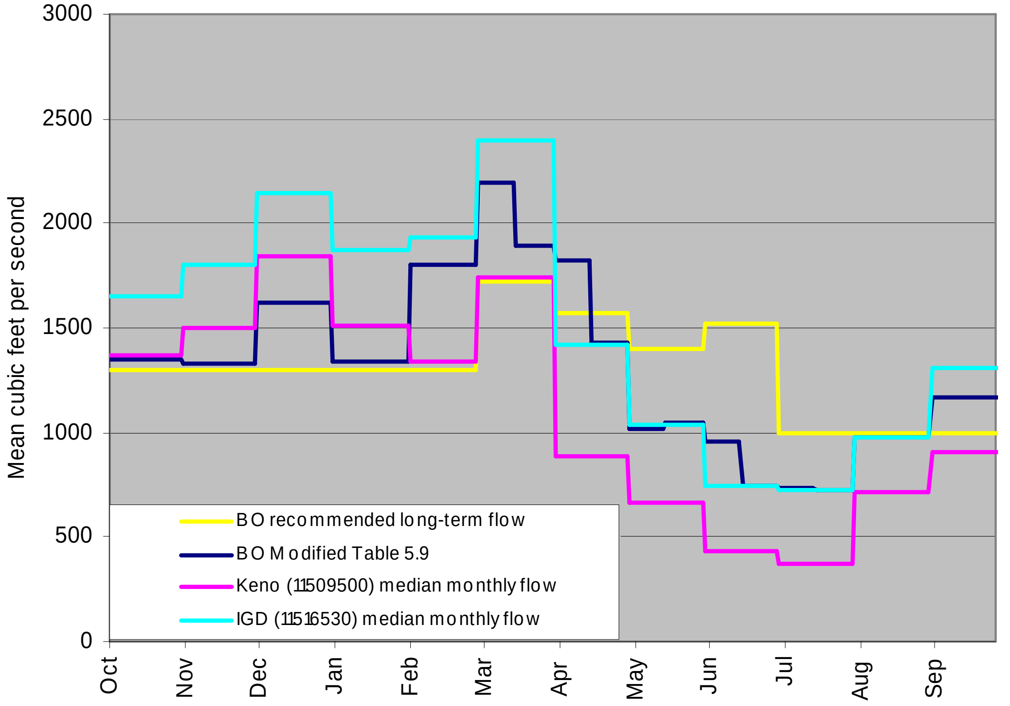


Figure 17d.--Comparison of required and observed flows for below average water year types.

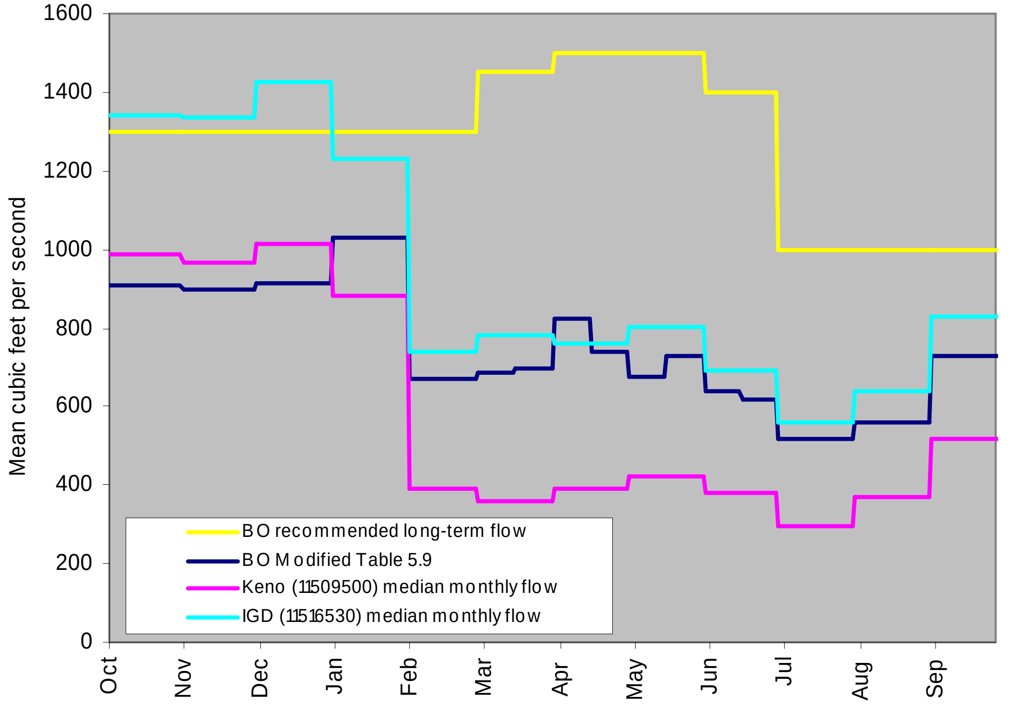


Figure 17e.--Comparison of required and observed flows for dry water year types.

Figure 18a.--Computed monthly surplus and deficit for wet water year types.

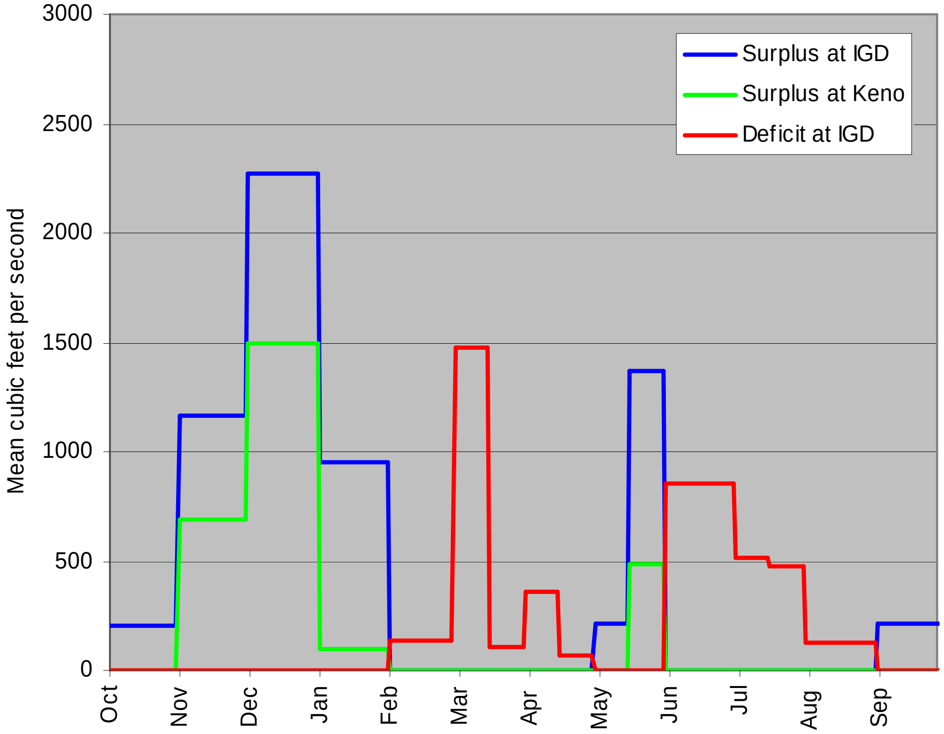


Figure 18b.--Computed monthly surplus and deficit for above average water year types.

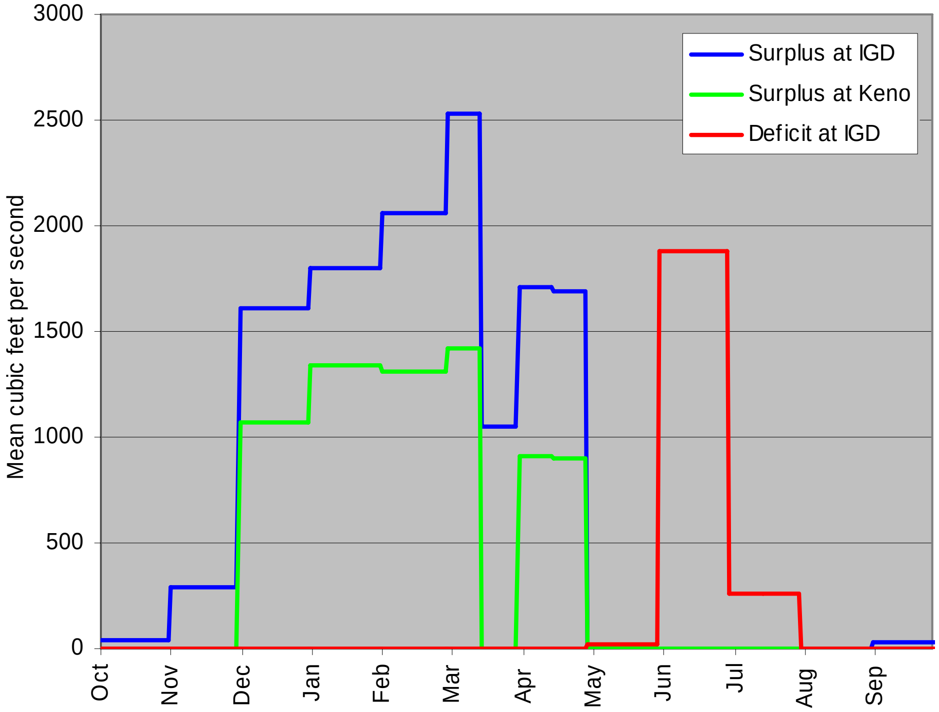


Figure 18c.--Computed monthly surplus and deficit for average water year types.

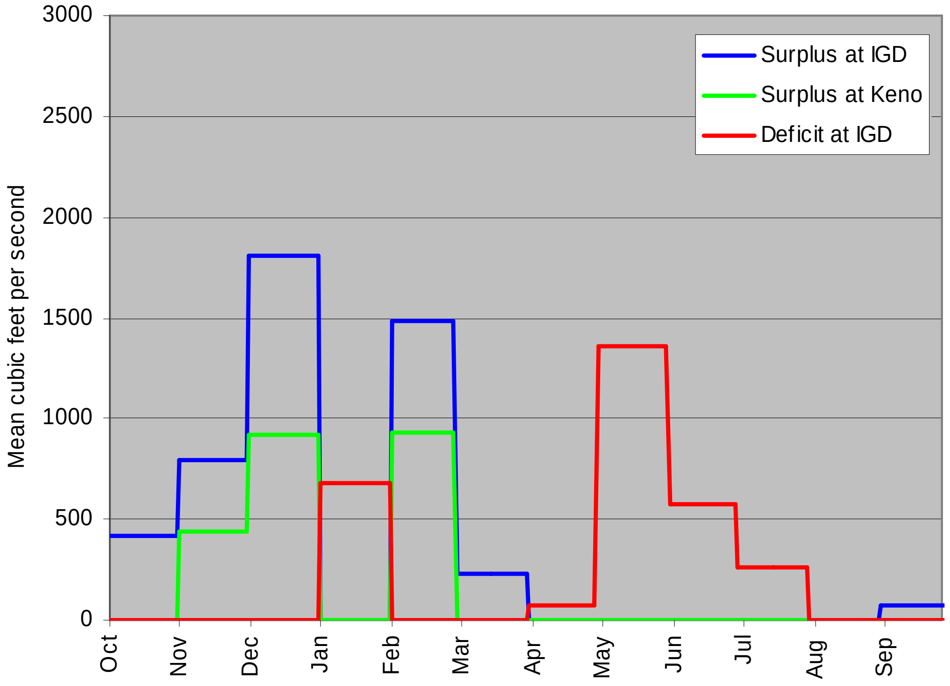


Figure 18d.--Computed monthly surplus and deficit for below average water year types.

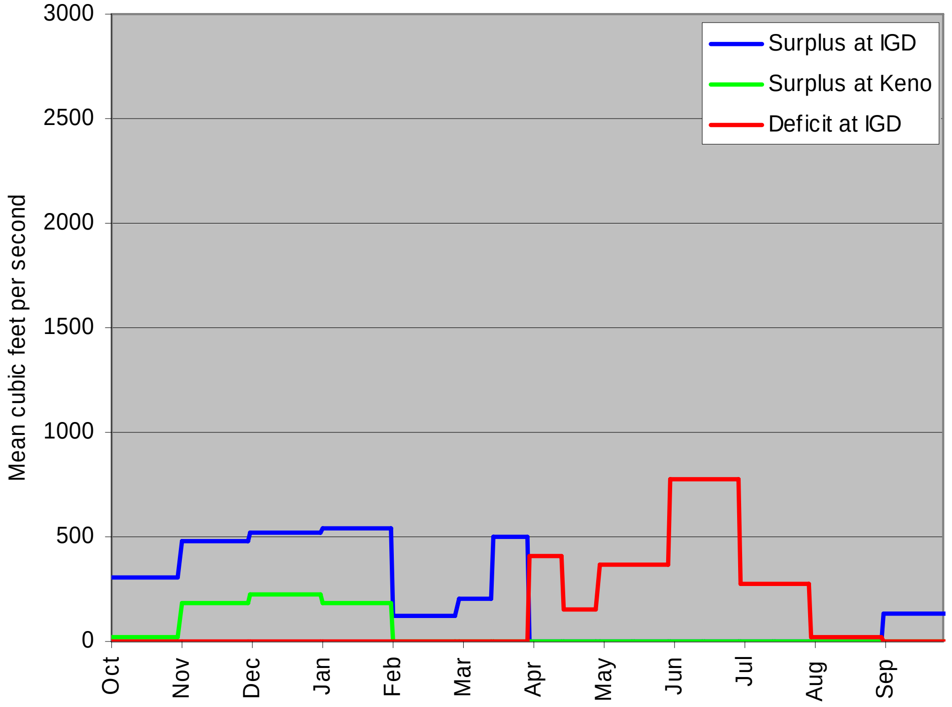


Figure 18e.--Computed monthly surplus and deficits for dry water year types.

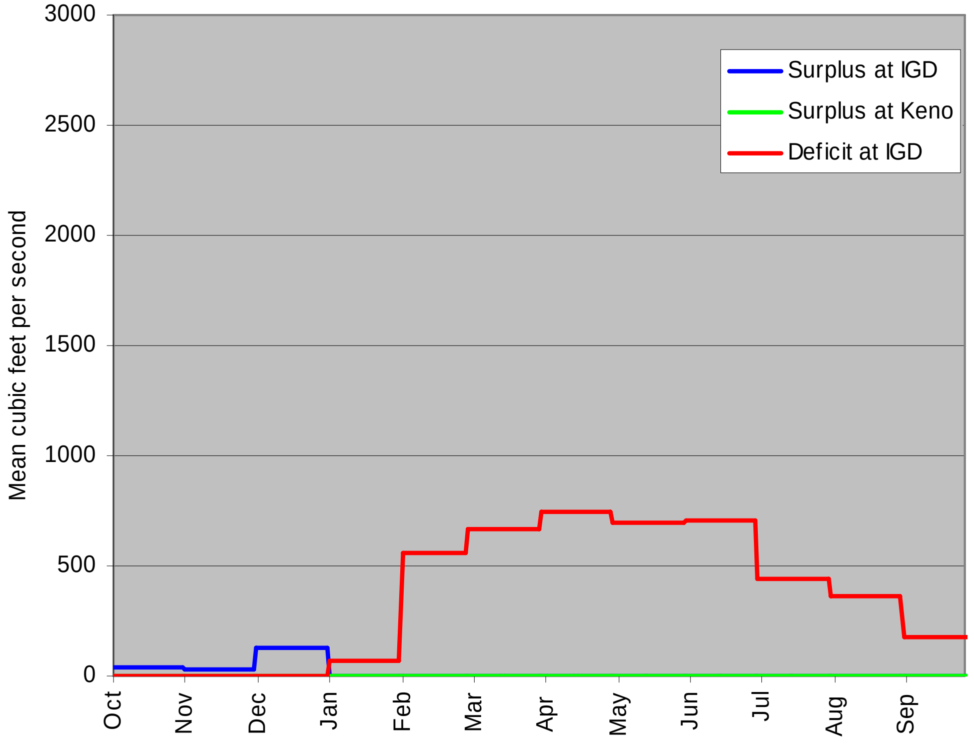


Figure 19.--Klamath River annual flow below Iron Gate Dam (11516530) for water years 1961-2004.

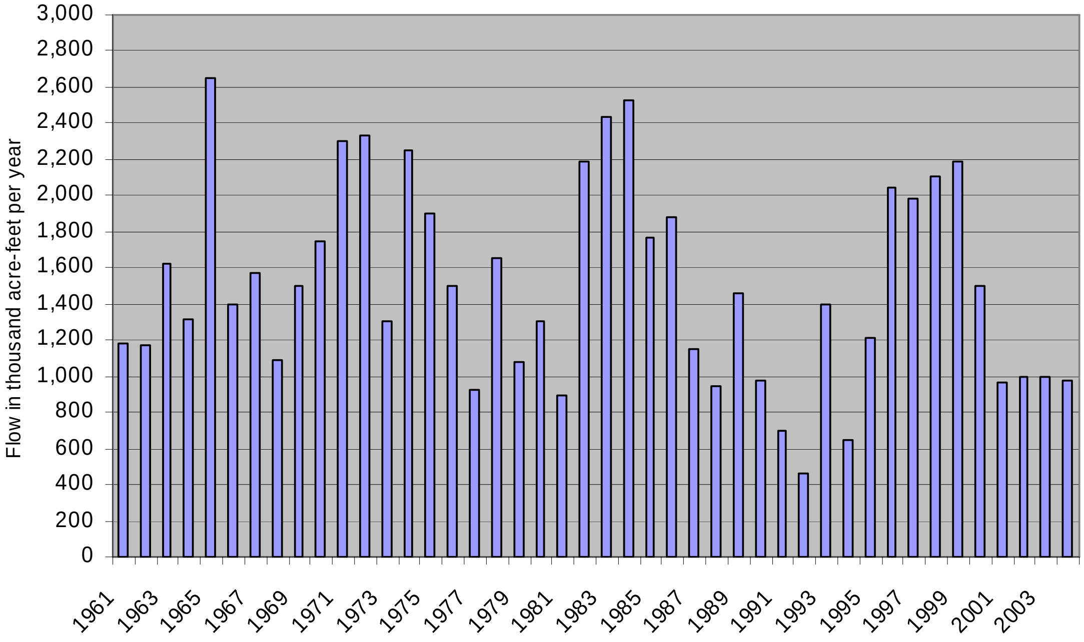


Figure 20.--Comparison of cumulative mean annual Klamath River flows below Iron Gate Dam (11516530) with cumulative annual total precipitation for 1961-2004.

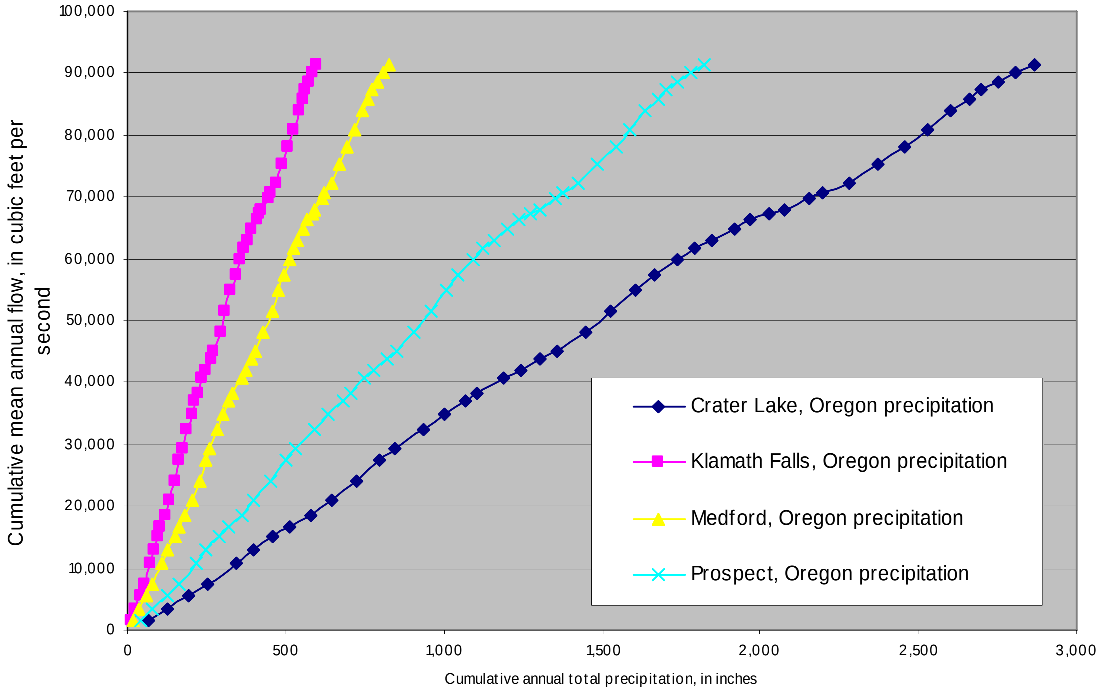


Figure 21a.--Total Klamath Project gross annual water year diversions as measured by the U.S. Bureau of Reclamation.

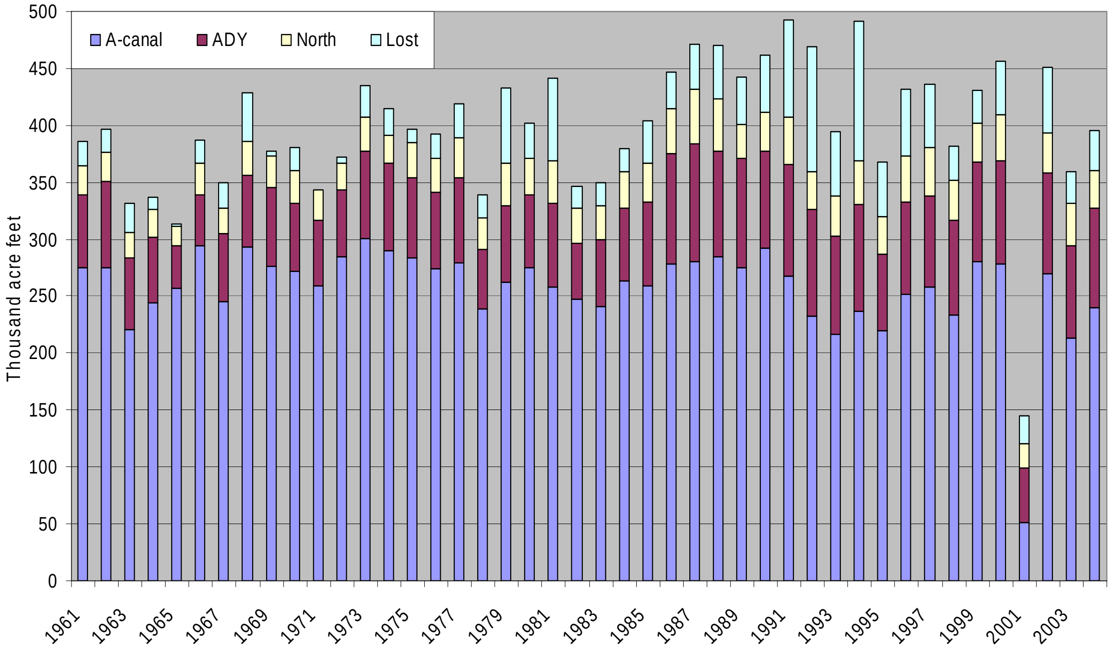


Figure 21b. Total Klamath Project Net Annual Water Year Diversions

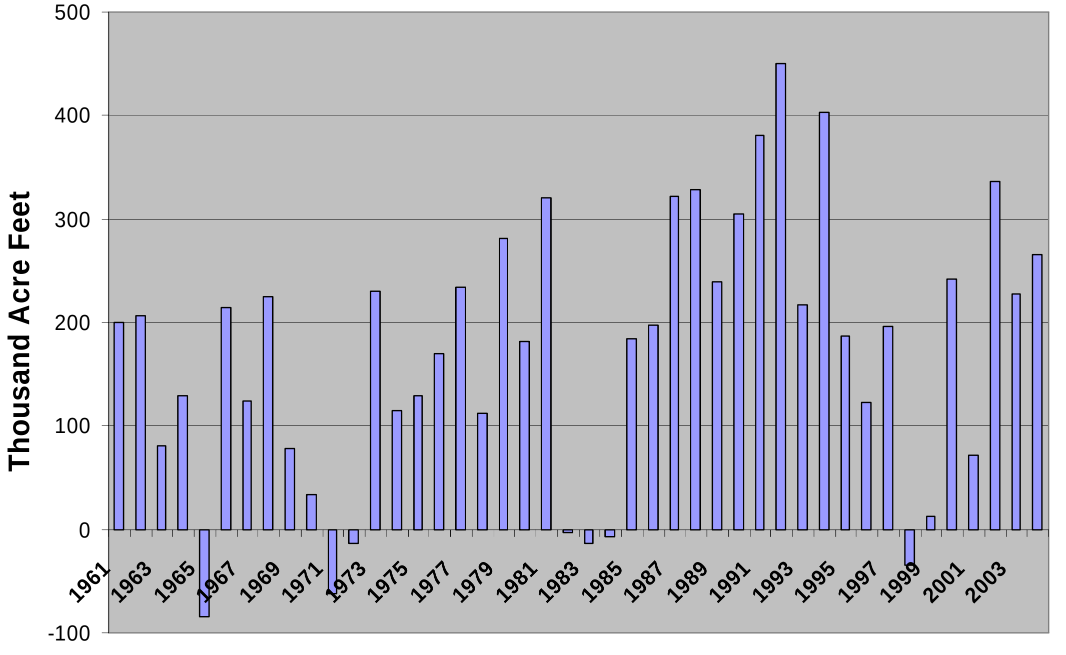


Figure 22. Total Annual Klamath Project Return Flows from BOR measurements

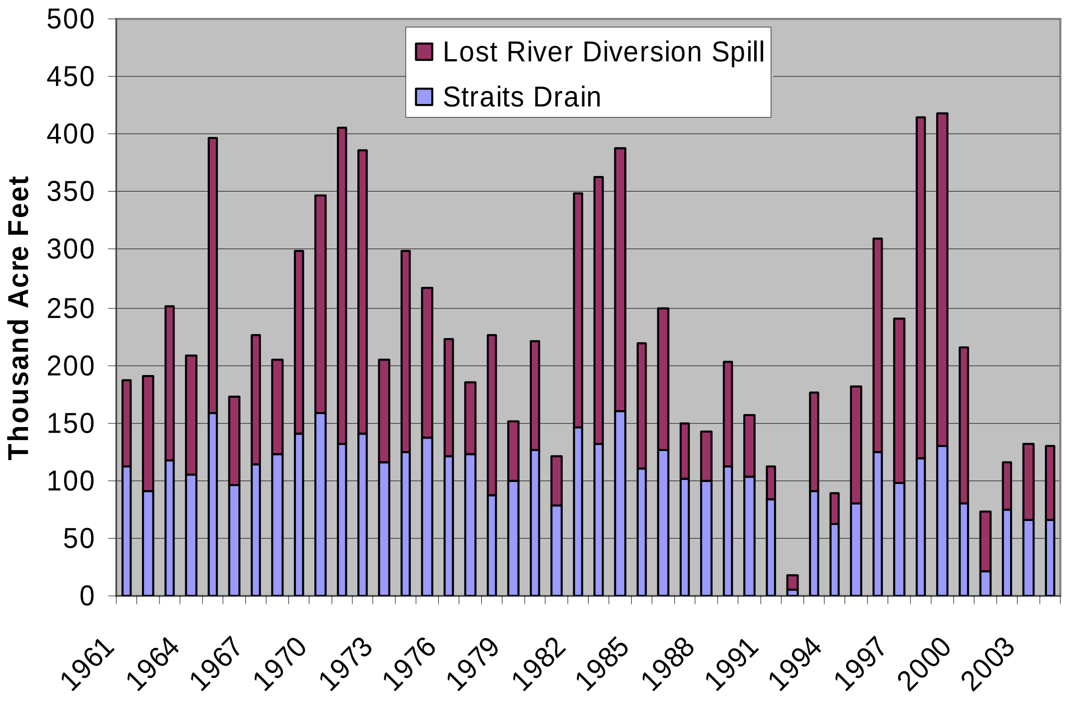


Figure 23. April-September BOR measured total gross diversions versus net inflow to Upper Klamath Lake (includes refuge deliveries)

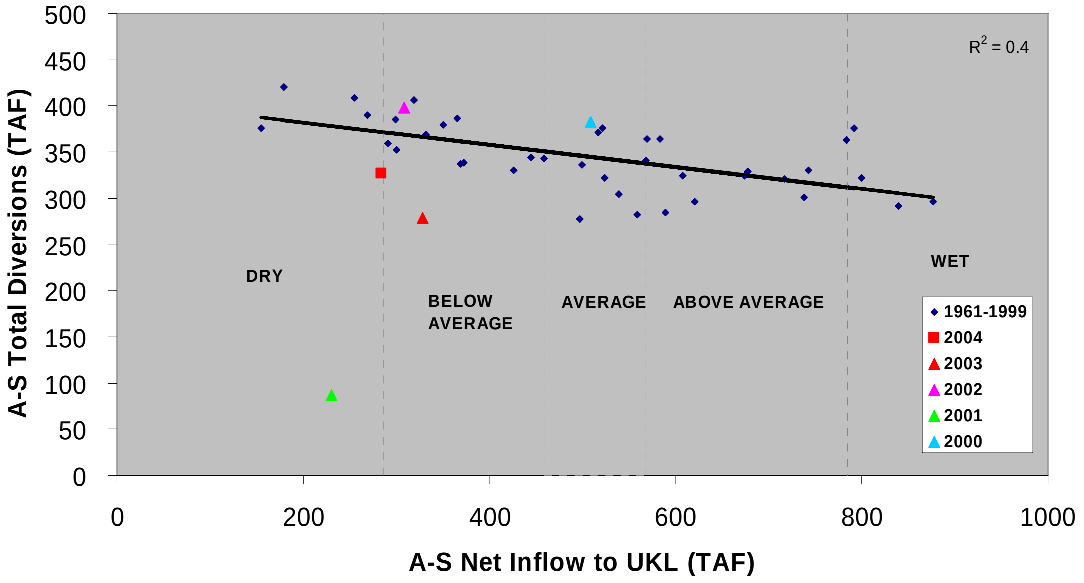


Figure 24. April-September total returns measured by BOR versus net inflow to Upper Klamath Lake

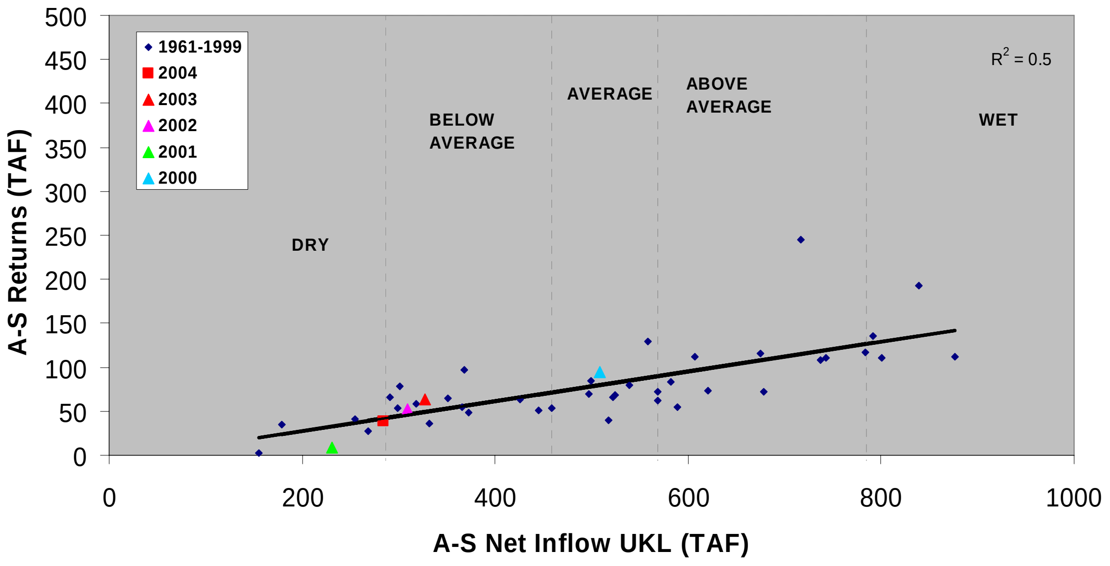


Figure 25. April-September net diversions measured by BOR versus net inflow to Upper Klamath Lake (includes refuge deliveries)

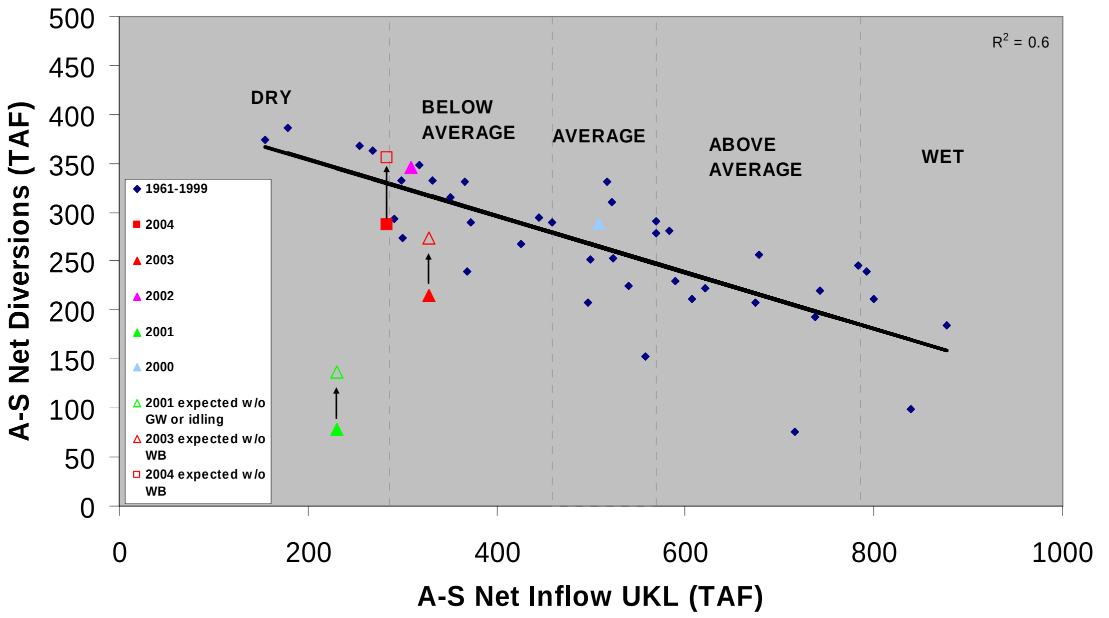


Figure 26.--Plot of residuals of predicted minus observed April-September net project diversions for regression shown in Figure 25 (1961-1999).

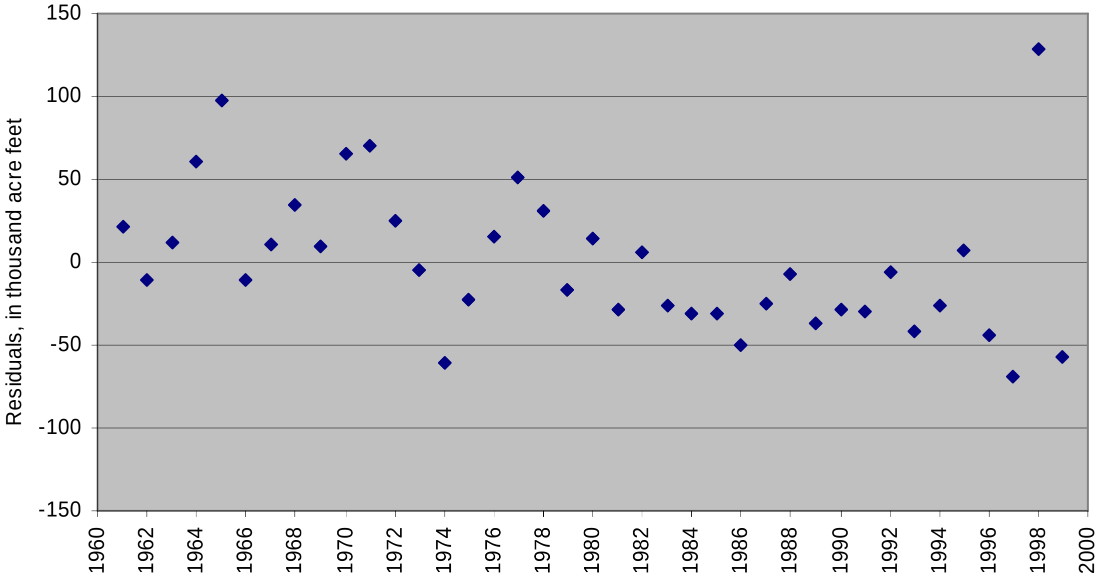
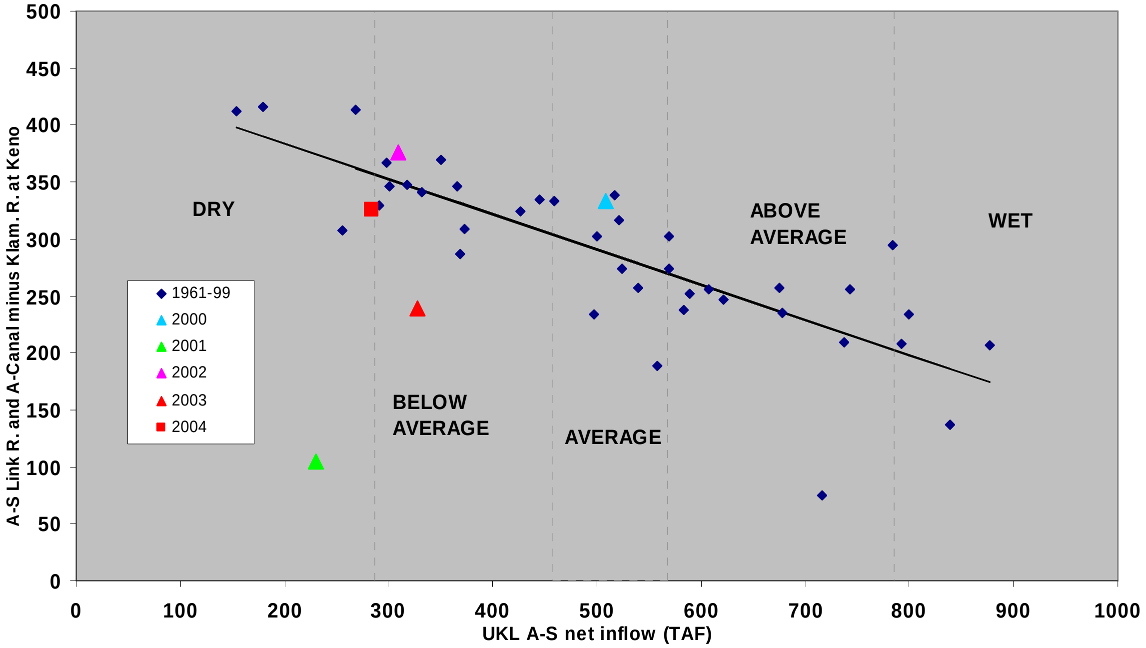


Figure 27. Computed net diversions from April-September Link River plus A-Canal minus Klamath River at Keno



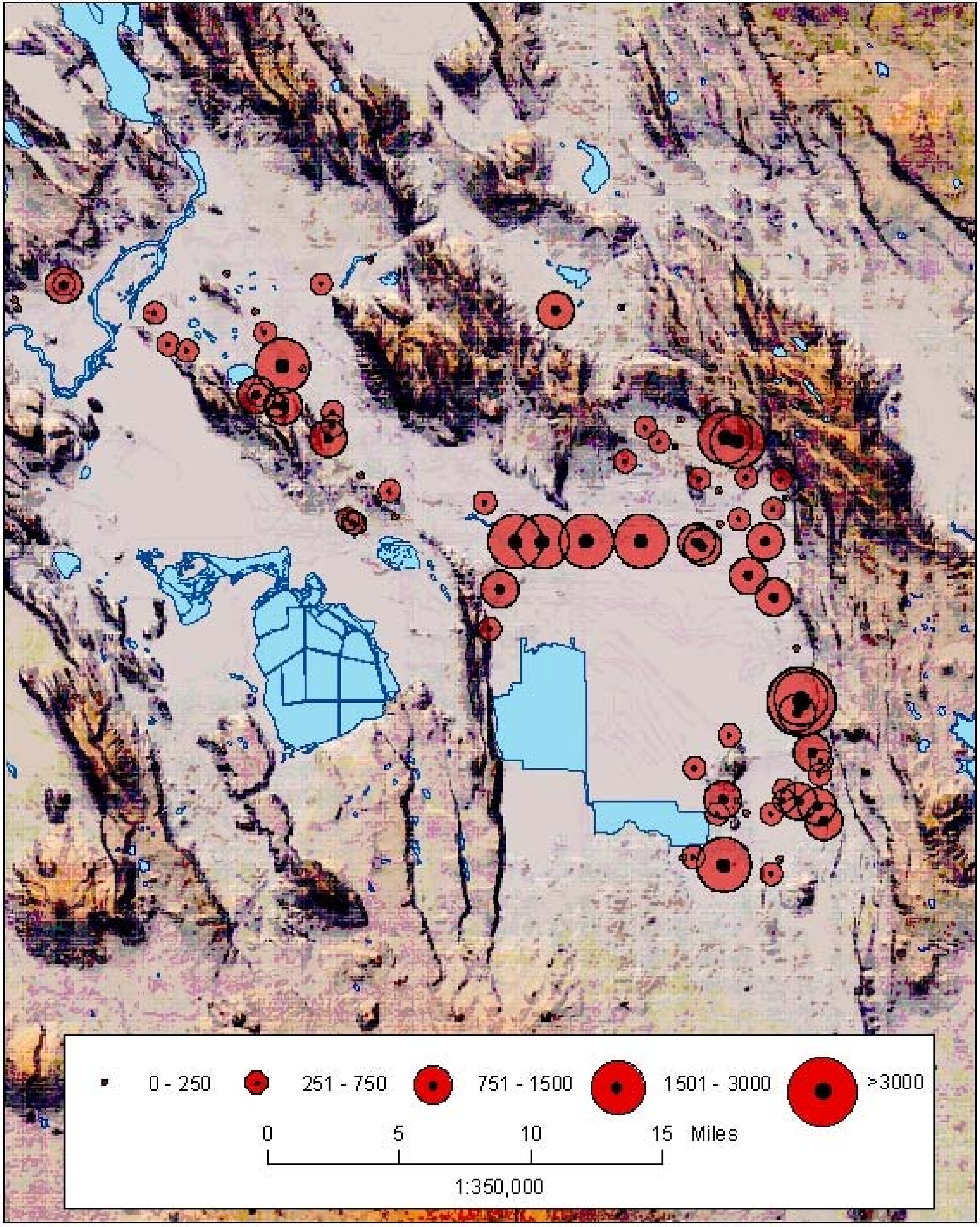


Figure 28a. Locations of wells included in the 2003 water bank and the amounts of ground water pumped from each (in acre feet). The estimated total pumpage (55,687 acre feet) exceeds the water actually purchased (23,192 acre feet).

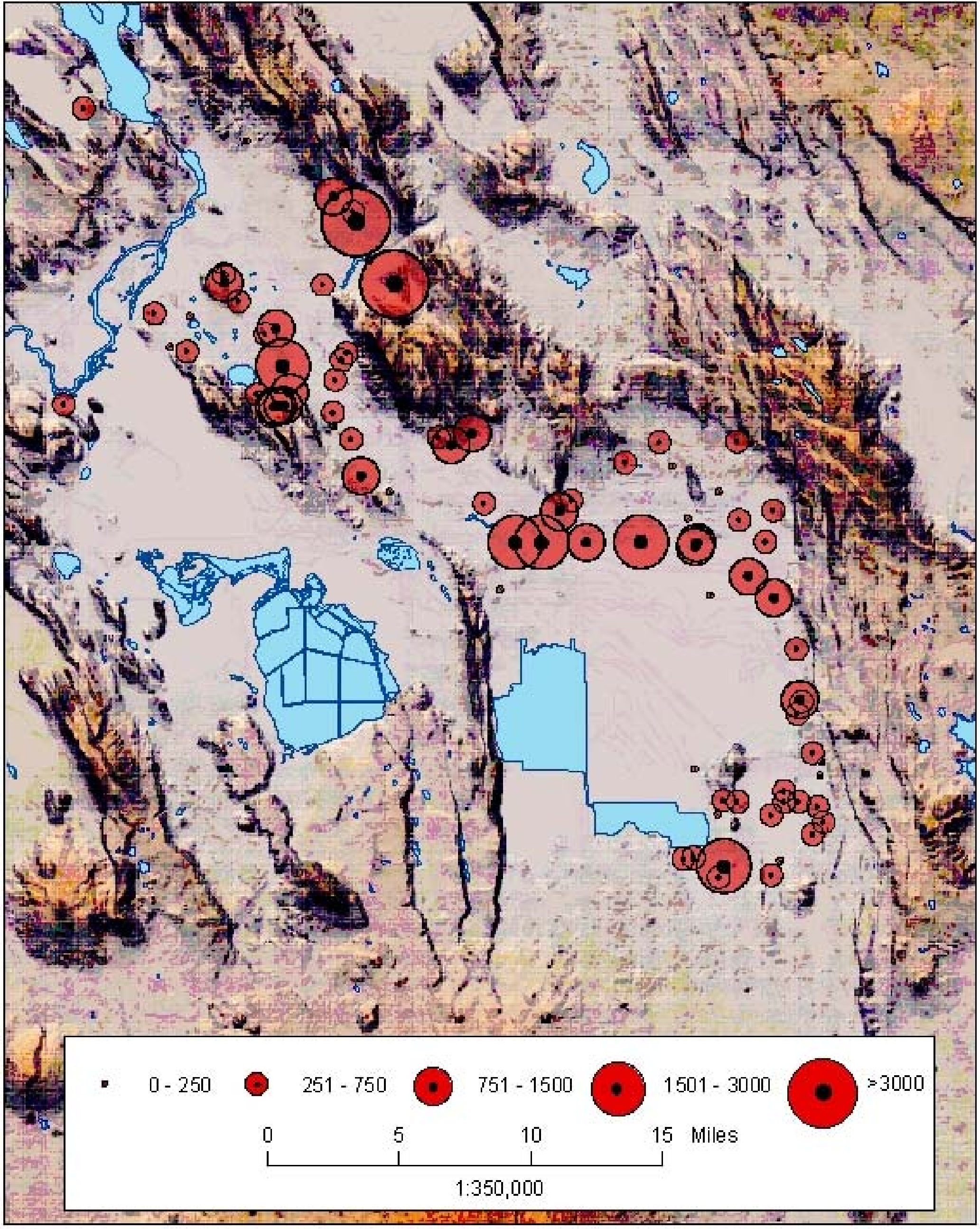


Figure 28b. Locations of wells included in the 2004 water bank and the amounts of ground water pumped from each (in acre feet). The estimated total pumpage (75,716 acre feet) exceeds the water actually purchased (58,143 acre feet).

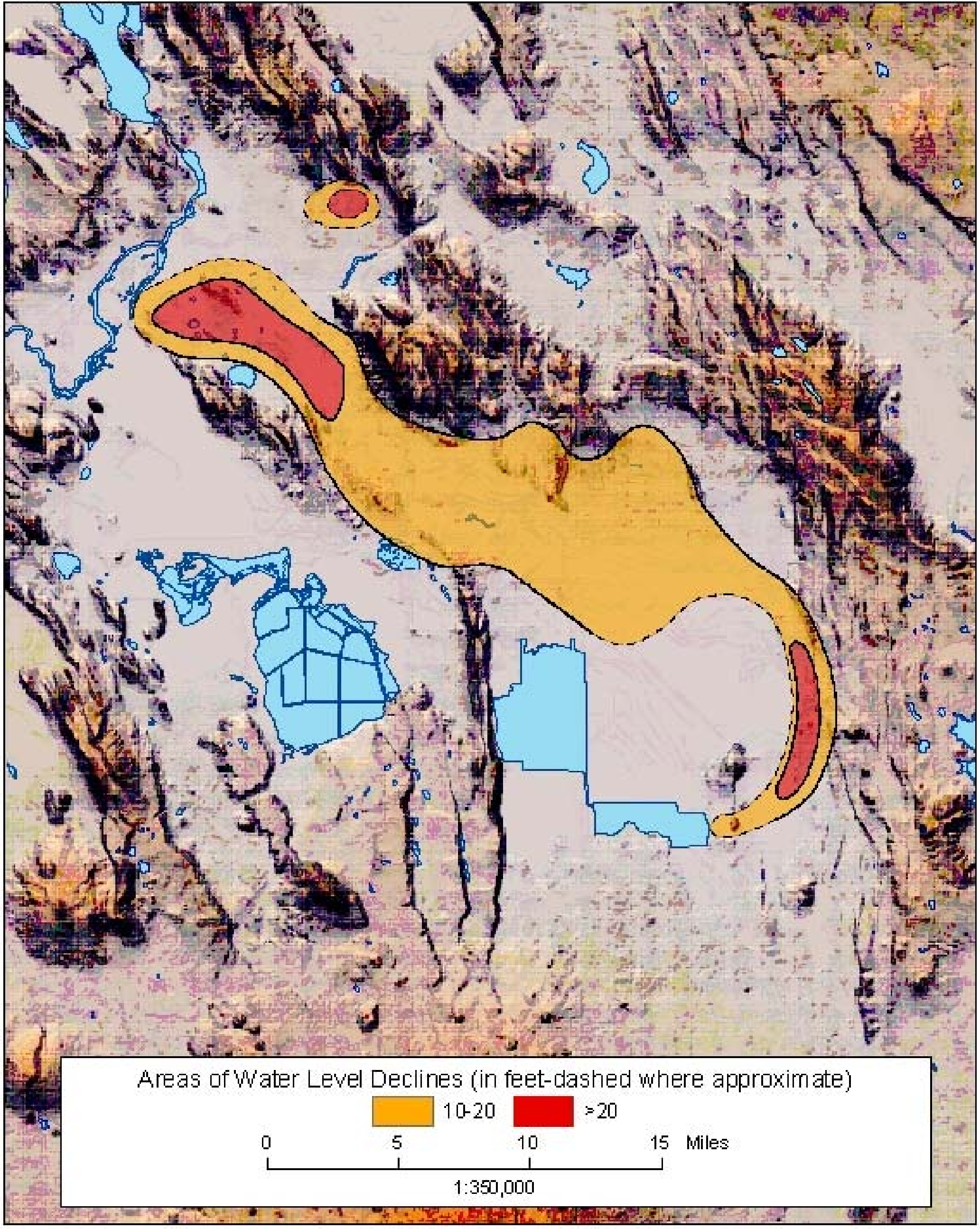


Figure 29. The magnitude and distribution of seasonal water-level declines observed between spring and fall 2004. The shading reflects the maximum declines observed in particular areas. Many wells in each area may show smaller declines, particularly those completed in, or hydraulically connected to, the shallow aquifer system.

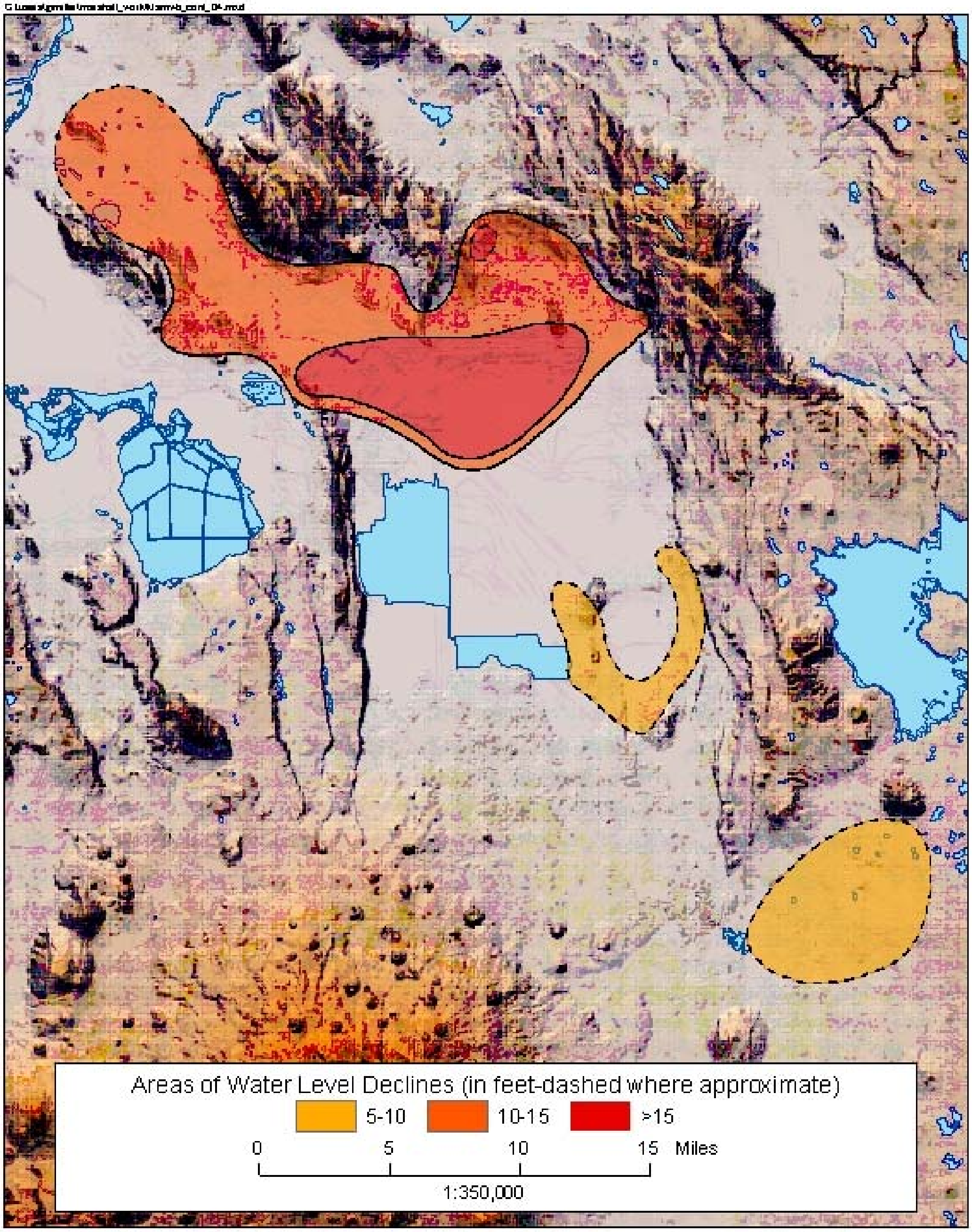


Figure 30. The magnitude and distribution of water-level declines observed during the three-year period from spring 2001 to spring 2004. The shading reflects the maximum declines observed in particular areas. Many wells in each area may show smaller declines, particularly those completed in, or hydraulically connected to, the shallow aquifer system. Part of the observed decline can be attributed to drought.

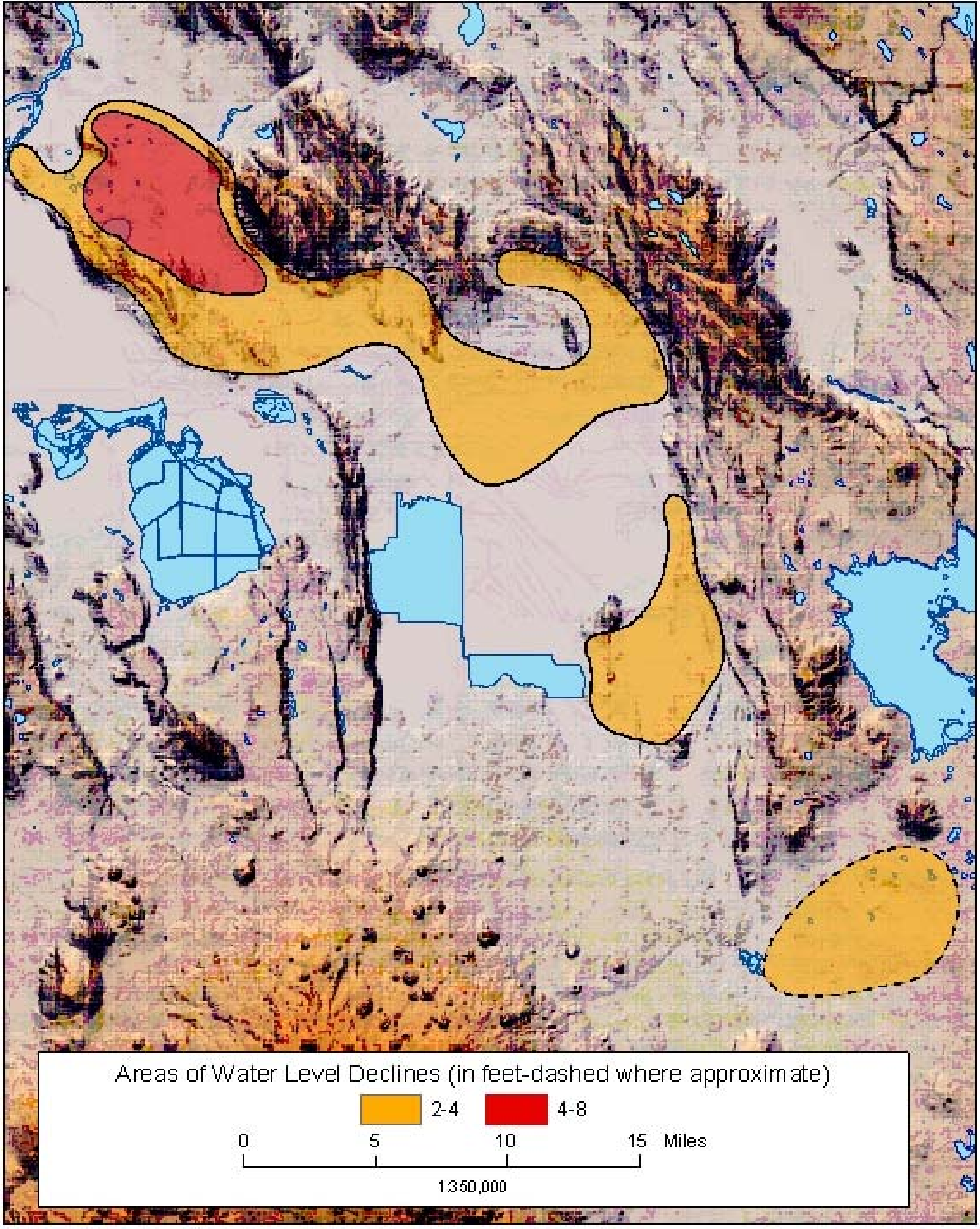


Figure 31. The magnitude and distribution of water-level declines observed during the one-year period from spring 2003 to spring 2004. The shading reflects the maximum declines observed in particular areas. Many wells in each area may show smaller declines, particularly those completed in, or hydraulically connected to, the shallow aquifer system. Part of the observed decline can be attributed to drought.

Table 1. 2003 Upper Klamath Basin Water Bank information from BOR

Fact Sheet (12/18/03)
2003 Klamath Project Pilot Water Bank

58,581 AF $4,445, 032

CROP IDLING

Proposals

Applications Submitted	335
Contracts Offered	244
Contracts Executed	223
Contracts Active	222

Acreage

Total submitted		23,093
Included in program		14,431
By State:	CA	2,316
	OR	12,115
By Cover:	Alfalfa	4,151
	Annual Crops	4,384
	Pasture/Hay	5,727
	Mint	169
	Horseradish	-0-

Water (acre-feet)

Total submitted		49,273
Total purchased		35,389
Average per active contract		159
Average acre-feet per acre		2.45
By State:	CA	5,169
	OR	30,220
By Cover:		
	Alfalfa	10,057 (2.42 af/ac)
	Annual Crops	8,556 (1.95 af/ac)
	Pasture/Hay	16,318 (2.85 af/ac)
	Mint	458 (2.71 af/ac)

Cost ($)

Total obligated	
(@ $187.50/acre)	$2,705,636
Average per active contract	$12,188
Average per acre-foot	$76.45

GROUNDWATER

Proposals

Applications Submitted	187
Contracts Offered	96
Contracts Executed	92
Contracts Active	91

Acreage

Total submitted		24,122
Included in program		11,039
By State:	CA	5,133
	OR	5,907
By Cover:	Alfalfa	5,710
	Annual Crops	2,814
	Pasture/Hay	1,687
	Mint	303
	Horseradish	525

Water (acre-feet)

Total submitted		54,877
Total purchased		23,192
Average per active contract		263
Average acre-feet per acre		2.17
By State:	CA	9,242
	OR	13,950
By Cover:		
	Alfalfa	12,396 (2.17 af/ac)
	Annual Crops	4,674(1.66 af/ac)
	Pasture/Hay	4,259 (2.52 af/ac)
	Mint	702 (2.32 af/ac)
	Horseradish	1,160 (2.21 af/ac)

Cost ($)

Total obligated	
(@ $75/acre-foot)	$1,739,396
Average per active contract	$19,114
Average per acre	$157.57

NOTE: These data are preliminary and are subject to revision

Table 2. 2004 Upper Klamath Basin water bank information from BOR

Fact Sheet
2004 Klamath Project Pilot Water Bank

	Dryland Operations		Groundwater Substitution	Groundwater Pumping*					Total
	Rangeland Trust	Dryland Operations		Mid-Basin Group 60	Mid-Basin Group 75	Copic Bay Group	Tulelake Irr. Dist.	Other	
Applications	-	277	172	-	-	-	-	-	449
Acreage	-	33,841	33,667	-	-	-	-	-	67,508
Acre-feet	-	75,637	79,271	-	-	-	-	-	154,908
Contracts	1	52	41	29	30	14	1	2	170
Total Acreage	11,133	4,364	6,874	-	-	-	-	-	22,371
Acre-feet	11,578	11,004	15,919	10,092	12,300	6,181	12,600	1,051	80,725
Avg. acreage	11,133	84	168	-	-	-	-	-	11,385
Avg. acre-feet	11,578	212	388	348	410	442	12,600	526	475
Acreage									
On-Project	0	3,891	5,779	-	-	-	-	-	9,670
Off-Project	11,133	472	1,095	-	-	-	-	-	12,700
Acreage By State									
Oregon	11,133	3,659	3,987	-	-	-	-	-	18,779
California	0	705	2,887	-	-	-	-	-	3,592
Acreage By Crop									
Alfalfa	0	1,508	2,971	-	-	-	-	-	4,479
Annual Grains	0	1,024	493	-	-	-	-	-	1,517
Horseradish	0	0	611	-	-	-	-	-	611
Mint	0	186	118	-	-	-	-	-	304
Onions	0	0	84	-	-	-	-	-	84
Pasture/Hay	11,133	1,618	2,366	-	-	-	-	-	15,117
Potatoes	0	29	156	-	-	-	-	-	185
Strawberry	0	0	74	-	-	-	-	-	74
Water (af)									
On-Project	0	9,670	13,486.00	10,092.00	12,300.00	6,181.00	12,600.00	174.00	64,503.00
Off-Project	11,578	1,335	2,433.00					877.00	16,223.00
Water By State (af)									
Oregon	11,578	9,094	7,581.00	10,092.00	12,300.00			877.00	51,522.00
California	0	1,910	8,338.00			6,181.00	12,600.00	174.00	29,203.00
Water By Crop (af)									
Alfalfa	0	4,085	-	-	-	-	-	-	-
Annual Grains	0	1,523	-	-	-	-	-	-	-
Horseradish	0	0	-	-	-	-	-	-	-
Mint	0	478	-	-	-	-	-	-	-
Onions	0	0	-	-	-	-	-	-	-
Pasture/Hay	11,578	4,864	-	-	-	-	-	-	-
Potatoes	0	53	-	-	-	-	-	-	-
Strawberry	0	0	-	-	-	-	-	-	-
Avg. AF/ac	1.04	2.52	2.32	-	-	-	-	-	-
Cost									
Total paid	$690,221.20	$637,257.50	$967,505.86	$605,520.00	$922,476.22	$463,541.50	$945,015.00	$61,010.19	$5,292,547.47
Avg. $/contract	$690,221.20	$12,254.95	$23,597.70	$20,880.00	$30,749.21	$33,110.11	$945,015.00	$30,505.10	$31,132.63
Avg. $/acre	$62.00	$146.03	$140.75	-	-	-	-	-	-
Avg. $/acre-foot	$59.61	$57.91	$60.78	$60.00	$75.00	$75.00	$75.00	$58.04	$65.56

Table 3. Water year classification for 1990-99 and 1961-99 periods based on Upper Klamath Lake net inflows. [1990-99 period shaded in blue; TAF=thousand acre feet.]

Water year type River 5-type categories	Water Year	Lake inflows April-Sept. (TAF)	Water year type Lake 4-type categories
Wet	**1983**	876.5	***Above average***
	1971	838.8	
	1984	800.1	
	1999	791.9	
Above average	**1974**	783.5	
	1975	743.2	
	1982	737.7	
	1998	716.6	
	1993	677.9	
	1969	674.5	
	1967	620.8	
	1972	607.3	
	1963	589.4	
	1989	582.7	
	1996	568.9	
Average	**1985**	568.5	
	1965	558.3	
	1978	539.6	
	1995	523.8	
	1986	521.6	
	1997	517.2	
	1976	499.7	***Below average***
	1964	496.7	
	1962	458.3	
Below average	**1966**	444.7	
	1961	426.2	
	1980	372.7	
	1970	368.5	
	1987	366.1	
	1973	350.7	
	1979	331.4	
	1990	318.5	
	1977	300.8	***Dry***
	1988	298.7	
	1968	291.2	
Dry	**1981**	268.7	
	1991	255.1	
	1994	179.1	***Critical dry***
	1992	154.6	

Table 4. Descriptive statistics of daily mean flows for the Klamath River below Iron Gate Dam, California (11516530) for water years 1961-99 and 1990-99.

Water years: 1961-99	
Mean	2150.34
Standard Error	15.36
Median	1410
Mode	1340
Standard Deviation	1833.71
Sample Variance	3362508.76
Kurtosis	10.32
Skewness	2.59
Range	24611
Minimum	389
Maximum	25000
Sum	30629402
Count	14244

Water years: 1990-99	
Mean	1894.51
Standard Error	31.03
Median	1330
Mode	1350
Standard Deviation	1875.48
Sample Variance	3517426.05
Kurtosis	8.01
Skewness	2.57
Range	18111
Minimum	389
Maximum	18500
Sum	6918737
Count	3652

Table 5. Monthly flow requirements and observed median flows for each year type (TAF).

Flows from Table 5.9 of the 2002 Biological Assessment modified according to the 2002 Biological Opinion

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Wet	87.9	108.4	112.0	171.7	231.2	449.6	344.2	190.8	115.1	82.1	70.6	79.8
Above Average	82.8	84.1	85.3	79.9	72.2	185.3	176.2	114.1	73.5	43.7	63.9	78.3
Average	82.7	79.6	103.4	222.5	72.2	144.8	138.5	129.4	59.2	45.8	63.9	77.4
Below Average	82.7	78.8	99.7	82.0	100.3	125.3	96.9	63.5	50.7	44.9	60.2	69.5
Dry	55.8	53.5	56.3	63.3	37.4	42.5	46.4	43.3	37.4	31.7	34.4	43.5

Target flows from Table 9 of the 2002 Biological Opinion

	oct	nov	dec	jan	feb	mar	apr	may	jun	jul	aug	sep
Wet	79.9	77.4	79.9	79.9	72.2	141.4	122.0	159.9	172.6	61.5	61.5	59.5
Above Average	79.9	77.4	79.9	79.9	72.2	155.3	160.7	186.0	178.5	61.5	61.5	59.5
Average	79.9	77.4	79.9	79.9	72.2	169.1	169.6	186.0	89.3	61.5	61.5	59.5
Below Average	79.9	77.4	79.9	79.9	72.2	106.1	93.7	86.1	90.7	61.5	61.5	59.5
Dry	79.9	77.4	79.9	79.9	72.2	89.2	89.3	92.2	83.3	61.5	61.5	59.5

Greater of Flow Requirements

	oct	nov	dec	jan	feb	mar	apr	may	jun	jul	aug	sep
Wet	87.9	108.4	112.0	171.7	231.2	449.6	344.2	190.8	172.6	82.1	70.6	79.8
Above Average	82.8	84.1	85.3	79.9	72.2	185.3	176.2	186.0	178.5	61.5	63.9	78.3
Average	82.7	79.6	103.4	222.5	72.2	169.1	169.6	186.0	89.3	61.5	63.9	77.4
Below Average	82.7	78.8	99.7	82.0	100.3	125.3	96.9	86.1	90.7	61.5	61.5	69.5
Dry	79.9	77.4	79.9	79.9	72.2	89.2	89.3	92.2	83.3	61.5	61.5	59.5

Median monthly flows at Iron Gate Dam for years in year type (from USGS data)

	oct	nov	dec	jan	feb	mar	apr	may	jun	jul	aug	sep
Wet	100.6	177.7	251.6	230.2	223.5	402.3	331.3	244.0	121.9	51.7	62.8	92.4
Above Average	85.0	101.3	184.6	190.6	186.7	310.8	277.4	185.0	66.7	45.5	63.9	80.0
Average	108.3	126.7	214.8	180.5	154.7	183.5	165.4	102.4	55.3	45.4	64.0	81.5
Below Average	101.7	107.4	131.8	115.0	107.1	147.2	84.4	63.6	44.4	44.8	60.2	77.5
Dry	82.6	79.3	87.7	75.7	41.0	48.1	45.2	49.2	41.1	34.4	39.4	49.2

Table 6. Differences between flow requirements and median observed flows at IGD for each year type (TAF).

Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
	Observed Median Flows minus Modified Table 5.9 Flows (TAF)												
Wet	12.7	69.3	139.6	58.5	-7.7	-47.2	-12.8	53.3	6.8	-30.5	-7.8	12.6	246.8
Above Average	2.2	17.2	99.3	110.6	114.5	125.4	101.2	70.9	-6.8	1.8	0.0	1.7	638.1
Average	25.6	47.1	111.4	-41.9	82.5	38.8	27.0	-26.9	-3.9	-0.4	0.1	4.1	263.3
Below Average	19.0	28.6	32.1	33.0	6.8	21.9	-12.5	0.1	-6.3	0.0	0.0	8.0	130.5
Dry	26.8	25.9	31.4	12.3	3.6	5.5	-1.3	5.9	3.7	2.7	5.0	5.7	127.3
	Observed Median Flows minus Biological Opinion Table 9 Flows (TAF)												
Wet	20.7	100.4	171.7	150.2	151.3	260.9	209.4	84.2	-50.6	-9.8	1.4	32.9	1122.5
Above Average	5.0	24.0	104.7	110.6	114.5	155.5	116.7	-1.0	-111.8	-16.0	2.4	20.5	525.1
Average	28.3	49.3	134.9	100.6	82.5	14.4	-4.2	-83.6	-34.0	-16.1	2.5	22.0	296.8
Below Average	21.8	30.0	51.8	35.0	34.9	41.1	-9.3	-22.5	-46.4	-16.7	-1.3	18.0	136.6
Dry	2.7	2.0	7.7	-4.3	-31.2	-41.1	-44.1	-43.0	-42.2	-27.1	-22.0	-10.3	-252.9
	Observed Median Flows minus the greater of the flow requirements (TAF)												
Wet	12.7	69.3	139.6	58.5	-7.7	-47.2	-12.8	53.3	-50.6	-30.5	-7.8	12.6	189.3
Above Average	2.2	17.2	99.3	110.6	114.5	125.4	101.2	-1.0	-111.8	-16.0	0.0	1.7	443.4
Average	25.6	47.1	111.4	-41.9	82.5	14.4	-4.2	-83.6	-34.0	-16.1	0.1	4.1	105.5
Below Average	19.0	28.6	32.1	33.0	6.8	21.9	-12.5	-22.5	-46.4	-16.7	-1.3	8.0	50.0
Dry	2.7	2.0	7.7	-4.3	-31.2	-41.1	-44.1	-43.0	-42.2	-27.1	-22.0	-10.3	-252.9
	Average Historic Gross Diversions (TAF)												
Wet	20.3	6.5	10.7	12.0	3.0	1.9	12.3	42.2	70.0	83.6	65.6	47.8	376.0
Above Average	17.1	6.8	10.6	13.6	6.5	3.5	11.7	45.8	73.4	81.7	67.4	47.3	385.3
Average	15.1	6.0	5.7	12.9	9.2	4.3	19.3	52.7	69.1	84.8	59.3	43.1	381.5
Below Average	18.4	7.3	9.4	13.2	8.4	5.6	36.2	54.8	74.3	83.8	66.5	47.0	424.9
Dry	18.5	10.2	15.8	12.8	8.0	9.5	45.2	56.8	85.0	88.2	78.0	45.4	473.7

Table 7.--Matrix of water surplus and deficit for the Klamath River below Iron Gate Dam (11516530) for each water year type based on flow record analyses.

Water year type	Wet	Above average	Average	Below average	Dry
Surplus at IGD[1] (TAF)[2]	341.29	557.70	285.95	149.19	12.42
Surplus at Keno[3] (TAF)	153.21	319.84	135.04	36.91	0.00
DEFICIT (TAF)[4]:	158.19	128.78	179.69	103.62	265.59
Net surplus at IGD (TAF)	183.10	428.92	106.26	45.56	-253.17
Net surplus at Keno (TAF)	-4.98	191.06	-44.65	-66.72	-265.59

[1] Calculation based on the sum of monthly flows at Keno that exceed the minimum flow requirements at Iron Gate Dam plus flow accretion between Keno and Iron Gate Dam.

[2] TAF=Thousand acre feet.

[3] Calculation based on the sum of monthly flows at Keno that exceed the minimum flow requirements at Iron Gate Dam without flow accretion between Keno and Iron Gate Dam.

[4] Calculation based on the sum of monthly minimum flow requirements that exceed flow at Iron Gate Dam.

Table 8. Calculated potential flow at Iron Gate Dam (TAF)

Lake Year Type	A	B	C	D	E	F	G	H
	*Potential water from change in lake storage for year type	Median net inflow to lake for year type	Median flows from Lost River Diversion and Klamath Straight Drain for year type	Median accretions between Keno and Iron Gate for year type	Median diversions to A, North, and Ady Canals for year type	Potential available flow at Keno based on median values for year type (A+B+C)-E	Potential available flow at Iron Gate based on median values for year type (A+B+C+D)-E	Observed median flow at Iron Gate for year type
Above Average								
Oct	6.8	84.0	14.4	21.2	18.9	86.3	107.5	86.0
Nov	-41.1	122.7	18.5	25.9	6.3	93.7	119.6	111.6
Dec	-48.7	157.0	26.5	37.4	8.9	126.0	163.3	214.8
Jan	-36.9	157.2	30.2	40.0	11.1	139.4	179.4	213.6
Feb	-30.6	170.1	37.2	42.7	4.6	172.1	214.7	202.2
Mar	-46.4	230.6	53.4	56.4	2.2	235.4	291.8	310.8
Apr	-31.0	212.6	26.2	53.6	12.0	195.8	249.3	264.5
May	-15.5	190.9	18.8	40.6	51.3	142.9	183.5	185.0
Jun	38.7	94.7	7.2	27.6	72.7	68.0	95.6	66.7
Jul	84.7	38.6	6.0	24.1	84.8	44.5	68.6	45.7
Aug	71.7	36.9	9.4	22.1	67.0	51.1	73.2	63.9
Sep	48.3	62.7	18.8	22.1	46.8	83.0	105.1	80.9
Below Average								
Oct	6.5	85.5	15.5	21.0	15.5	92.0	113.0	108.3
Nov	-13.1	116.4	19.5	21.7	6.1	116.7	138.4	134.1
Dec	13.1	129.7	24.1	31.6	7.6	159.2	190.8	155.2
Jan	-46.5	126.7	19.2	32.2	13.6	85.8	117.9	157.0
Feb	-155.4	133.4	22.1	30.4	8.1	-8.0	22.4	105.9
Mar	-77.3	149.2	28.0	35.1	2.3	97.6	132.7	147.2
Apr	-7.7	116.0	6.8	34.5	23.7	91.4	125.9	102.5
May	7.7	96.6	9.3	31.4	53.5	60.1	91.5	70.0
Jun	46.4	57.2	6.7	23.2	76.0	34.4	57.6	44.5
Jul	103.8	30.5	6.3	22.2	85.2	55.5	77.7	45.1
Aug	75.7	30.0	9.2	17.6	65.9	49.0	66.6	62.8
Sep	46.7	54.3	15.2	20.8	43.0	73.2	94.0	78.1
Dry								
Oct	0.0	66.5	13.7	19.1	19.6	60.7	79.7	82.7
Nov	-51.8	87.6	13.8	21.5	9.3	40.3	61.8	79.9
Dec	-47.0	104.7	13.3	26.6	11.8	59.2	85.8	99.7
Jan	-41.1	106.5	14.6	23.9	12.7	67.2	91.1	101.8
Feb	-7.0	121.4	20.0	25.8	8.3	126.1	151.9	85.5
Mar	-93.8	110.9	21.3	28.0	10.6	27.9	55.9	111.7
Apr	-38.6	79.8	8.5	19.9	38.2	11.4	31.3	69.3
May	-15.5	72.5	10.2	23.7	48.3	18.9	42.6	62.4
Jun	69.2	30.2	7.6	18.9	79.7	27.4	46.3	44.2
Jul	85.7	10.7	5.0	18.3	95.2	6.1	24.4	44.2
Aug	88.1	17.9	8.0	16.4	72.8	41.2	57.5	45.9
Sep	51.8	37.7	9.0	19.4	54.0	44.5	63.9	60.3
Critically Dry								
Oct	-11.5	66.1	5.0	16.4	20.5	39.1	55.5	69.3
Nov	-48.7	72.3	4.2	21.5	7.5	20.3	41.9	68.0
Dec	-51.6	86.8	5.4	21.7	17.8	22.8	44.5	70.0
Jan	-80.8	85.1	6.2	19.5	15.4	-4.8	14.7	61.9
Feb	-70.0	70.7	8.6	16.8	10.0	-0.7	16.1	34.8
Mar	-67.8	79.6	5.8	19.5	10.8	6.7	26.3	35.4
Apr	7.7	65.0	4.5	16.0	59.6	17.6	33.7	39.0
May	37.9	36.8	5.8	19.0	68.6	12.0	31.0	38.1
Jun	92.2	7.8	3.1	16.9	81.4	21.6	38.6	36.0
Jul	80.8	9.0	2.7	16.5	80.1	12.3	28.8	30.8
Aug	82.5	7.4	1.7	16.4	76.9	14.6	31.0	31.8
Sep	29.3	24.7	0.7	16.9	31.6	23.0	39.9	43.0

*Water to or from lake storage calculated using elevation criteria from 2004 operations plan.

Table 9. Calculated potential flow minus flow requirements for all combinations of year types (TAF).

Lake year type	Potential available flow at Iron Gate based on median values for year type	Potentially available flow at Iron Gate minus Modified Table 5.9 flows for each river year type (negative values indicate deficit)					Potentially available flow at Iron Gate minus Biological Opinion target flows for each river year type (negative values indicate deficit)					Potentially available flow at Iron Gate minus the greater of Modified Table 5.9 or Biological Opinion target flows for each river year type (negative values indicate deficit)					Average Historic Gross Diversions by Lake Year Type	
		Wet	Above average	Average	Below average	Dry	Wet	Above average	Average	Below average	Dry	Wet	Above average	Average	Below average	Dry		
Above Average																		**Above Average**
Oct	107.5	19.5	24.7	24.8	--	--	27.5	27.5	27.5	--	--	19.5	24.7	24.8	--	--	17.1	Oct
Nov	119.6	11.2	35.5	40.1	--	--	42.3	42.3	42.3	--	--	11.2	35.5	40.1	--	--	6.9	Nov
Dec	163.3	51.3	78.1	59.9	--	--	83.4	83.4	83.4	--	--	51.3	78.1	59.9	--	--	9.0	Dec
Jan	179.4	7.8	99.5	-43.0	--	--	99.5	99.5	99.5	--	--	7.8	99.5	-43.0	--	--	12.3	Jan
Feb	214.7	-16.5	142.5	142.5	--	--	142.5	142.5	142.5	--	--	-16.5	142.5	142.5	--	--	6.5	Feb
Mar	291.8	-157.7	106.5	147.0	--	--	150.4	136.6	122.7	--	--	-157.7	106.5	122.7	--	--	3.7	Mar
Apr	249.3	-94.9	73.1	110.9	--	--	127.3	88.7	79.7	--	--	-94.9	73.1	79.7	--	--	14.1	Apr
May	183.5	-7.2	69.4	54.2	--	--	23.7	-2.5	-2.5	--	--	-7.2	-2.5	-2.5	--	--	46.4	May
Jun	95.6	-19.5	22.0	36.4	--	--	-77.0	-82.9	6.3	--	--	-77.0	-82.9	6.3	--	--	72.1	Jun
Jul	68.6	-13.6	24.9	22.7	--	--	7.1	7.1	7.1	--	--	-13.6	7.1	7.1	--	--	83.2	Jul
Aug	73.2	2.5	9.3	9.2	--	--	11.7	11.7	11.7	--	--	2.5	9.3	9.2	--	--	65.8	Aug
Sep	105.1	25.3	26.8	27.7	--	--	45.6	45.6	45.6	--	--	25.3	26.8	27.7	--	--	46.2	Sep
		-191.8	**712.3**	**632.4**			**684.0**	**599.4**	**665.9**			**-249.2**	**517.6**	**474.6**			**383.3**	
Below Average																		**Below Average**
Oct	113.0	--	--	30.3	30.3	--	--	--	33.1	33.1	--	--	--	30.3	30.3	--	17.1	Oct
Nov	138.4	--	--	58.8	59.6	--	--	--	61.0	61.0	--	--	--	58.8	59.6	--	5.9	Nov
Dec	190.8	--	--	87.4	91.2	--	--	--	110.9	110.9	--	--	--	87.4	91.2	--	8.2	Dec
Jan	117.9	--	--	-104.5	35.9	--	--	--	38.0	38.0	--	--	--	-104.5	35.9	--	14.5	Jan
Feb	22.4	--	--	-49.8	-77.9	--	--	--	-49.8	-49.8	--	--	--	-49.8	-77.9	--	8.6	Feb
Mar	132.7	--	--	-12.1	7.3	--	--	--	-36.4	26.6	--	--	--	-36.4	7.3	--	3.3	Mar
Apr	125.9	--	--	-12.6	29.0	--	--	--	-43.7	32.1	--	--	--	-43.7	29.0	--	27.5	Apr
May	91.5	--	--	-37.8	28.0	--	--	--	-94.5	5.4	--	--	--	-94.5	5.4	--	57.8	May
Jun	57.6	--	--	-1.6	6.9	--	--	--	-31.6	-33.1	--	--	--	-31.6	-33.1	--	72.7	Jun
Jul	77.7	--	--	31.9	32.8	--	--	--	16.2	16.2	--	--	--	16.2	16.2	--	83.3	Jul
Aug	66.6	--	--	2.7	6.4	--	--	--	5.2	5.2	--	--	--	2.7	5.2	--	63.4	Aug
Sep	94.0	--	--	16.6	24.5	--	--	--	34.5	34.5	--	--	--	16.6	24.5	--	45.2	Sep
				9.3	**274.1**				**42.8**	**280.1**				**-148.5**	**193.5**		**407.4**	
Dry																		**Dry**
Oct	79.7	--	--	--	-3.0	24.0	--	--	--	-0.2	-0.2	--	--	--	-3.0	-0.2	18.0	Oct
Nov	61.8	--	--	--	-17.0	8.3	--	--	--	-15.6	-15.6	--	--	--	-17.0	-15.6	9.1	Nov
Dec	85.8	--	--	--	-13.9	29.5	--	--	--	5.8	5.8	--	--	--	-13.9	5.8	11.3	Dec
Jan	91.1	--	--	--	9.1	27.8	--	--	--	11.2	11.2	--	--	--	9.1	11.2	11.9	Jan
Feb	151.9	--	--	--	51.6	114.5	--	--	--	79.7	79.7	--	--	--	51.6	79.7	8.0	Feb
Mar	55.9	--	--	--	-69.4	13.4	--	--	--	-50.1	-33.2	--	--	--	-69.4	-33.2	6.9	Mar
Apr	31.3	--	--	--	-65.6	-15.1	--	--	--	-62.4	-58.0	--	--	--	-65.6	-58.0	36.5	Apr
May	42.6	--	--	--	-20.9	-0.7	--	--	--	-43.5	-49.6	--	--	--	-43.5	-49.6	53.1	May
Jun	46.3	--	--	--	-4.4	8.9	--	--	--	-44.5	-37.0	--	--	--	-44.5	-37.0	79.1	Jun
Jul	24.4	--	--	--	-20.4	-7.3	--	--	--	-37.1	-37.1	--	--	--	-37.1	-37.1	86.8	Jul
Aug	57.5	--	--	--	-2.6	23.1	--	--	--	-3.9	-3.9	--	--	--	-3.9	-3.9	69.2	Aug
Sep	63.9	--	--	--	-5.6	20.4	--	--	--	4.4	4.4	--	--	--	-5.6	4.4	50.1	Sep
					-162.1	**246.7**				**-156.1**	**-133.4**				**-242.7**	**-133.4**	**440.0**	
Critically Dry																		**Critically Dry**
Oct	55.5	--	--	--	--	-0.3	--	--	--	--	-24.4	--	--	--	--	-24.4	18.6	Oct
Nov	41.9	--	--	--	--	-11.6	--	--	--	--	-35.5	--	--	--	--	-35.5	8.5	Nov
Dec	44.5	--	--	--	--	-11.8	--	--	--	--	-35.4	--	--	--	--	-35.4	12.4	Dec
Jan	14.7	--	--	--	--	-48.6	--	--	--	--	-65.2	--	--	--	--	-65.2	12.5	Jan
Feb	16.1	--	--	--	--	-21.3	--	--	--	--	-56.1	--	--	--	--	-56.1	8.9	Feb
Mar	26.3	--	--	--	--	-16.2	--	--	--	--	-62.9	--	--	--	--	-62.9	8.4	Mar
Apr	33.7	--	--	--	--	-12.8	--	--	--	--	-55.6	--	--	--	--	-55.6	41.6	Apr
May	31.0	--	--	--	--	-12.3	--	--	--	--	-61.3	--	--	--	--	-61.3	53.6	May
Jun	38.6	--	--	--	--	1.1	--	--	--	--	-44.7	--	--	--	--	-44.7	79.5	Jun
Jul	28.8	--	--	--	--	-2.9	--	--	--	--	-32.7	--	--	--	--	-32.7	88.1	Jul
Aug	31.0	--	--	--	--	-3.4	--	--	--	--	-30.5	--	--	--	--	-30.5	70.7	Aug
Sep	39.9	--	--	--	--	-3.6	--	--	--	--	-19.6	--	--	--	--	-19.6	47.7	Sep
						-143.8					**-524.0**					**-524.0**	**450.4**	

Surpluses and deficits based on modified Table 5.9 flows.		River Year Type				
		Wet	Above avg.	Average	Below Avg.	Dry
Lake Year Type	Above avg.	**-192**	**712**	**632**	**--**	**--**
	Below avg.	**--**	**--**	**9.3**	**274**	**--**
	Dry	**--**	**--**	**--**	**-162**	**247**
	Critical	**--**	**--**	**--**	**--**	**-144**

Surpluses and deficits based on biological opinion Table 9 flows.		River Year Type				
		Wet	Above avg.	Average	Below Avg.	Dry
Lake Year Type	Above avg.	**684**	**599**	**666**	**--**	**--**
	Below avg.	**--**	**--**	**43**	**280**	**--**
	Dry	**--**	**--**	**--**	**-156**	**-133**
	Critical	**--**	**--**	**--**	**--**	**-524**

Surpluses and deficits based on the greater of the flow requirements.		River Year Type				
		Wet	Above avg.	Average	Below Avg.	Dry
Lake Year Type	Above avg.	**-249**	**518**	**475**	**--**	**--**
	Below avg.	**--**	**--**	**-149**	**194**	**--**
	Dry	**--**	**--**	**--**	**-243**	**-133**
	Critical	**--**	**--**	**--**	**--**	**-524**

Table 10. Potential water surplus or deficit for combinations of water-year types (TAF). Figures represent potential available water based on operational criteria lake storage and medain flow and diversion measurements for particular year types, minus the flows reqired by the operational criteria, biological opinion, or the greater of the two. (-- indicates that combination or year types does not exist.)

Table 11.--Monthly differences between PacifiCorp and USGS (11507500) flow records at Link River at Klamath Falls, Oregon in thousand acre feet.

[Computed as: PacifiCorp-USGS; WY=water year. Both flow records include Keno Canal flows, added to Link River flows, for the period shown.]

WY	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	August	Sept.
1961	0	0	0	0	0	0	1	0	0	1	0	0
1962	1	2	1	1	1	2	0	0	1	1	1	0
1963	1	2	3	5	2	5	5	6	3	2	2	4
1964	4	5	12	9	6	1	6	2	2	0	2	3
1965	3	1	7	38	33	15	1	1	0	0	0	0
1966	2	5	0	0	1	1	0	4	3	3	3	-1
1967	1	8	4	3	3	1	2	11	3	0	0	1
1968	1	2	3	1	1	6	1	2	3	-1	0	0
1969	0	1	2	1	3	1	-11	2	1	1	0	1
1970	1	3	1	7	2	0	1	0	0	0	0	1
1971	2	0	2	0	-1	-3	-2	-1	1	0	1	0
1972	-1	-1	-1	-1	-3	-21	-1	5	4	2	1	-1
1973	3	8	9	8	4	6	6	6	6	6	3	2
1974	3	3	5	6	5	2	2	8	6	3	1	0
1975	0	0	0	0	1	-1	1	8	6	4	1	0
1976	1	0	-1	0	-1	-1	0	2	3	1	0	3
1977	1	5	3	3	3	2	1	1	3	4	2	0
1978	0	2	5	5	4	4	7	6	1	0	0	0
1979	2	2	1	0	0	1	3	6	5	5	5	5
1980	3	1	2	8	3	-1	-1	0	2	4	4	4
1981	-1	-2	-2	-1	-1	-3	-2	-1	-2	-4	-2	-1
1982	0	0	-3	-4	-5	6	8	7	1	2	1	3
1983	5	11	4	0	-1	-2	-3	-2	-3	-3	-2	-4
1984												
1985												
1986												
1987												
1988												
1989												
1990												
1991												
1992												
1993												
1994												
1995												
1996												
1997												
1998												
1999												
2000												
2001												
2002												
2003												

Note: Water years 1984-2003 are not included because the USGS published flow record did not include Keno Canal flows during that period.

Table 12.--Monthly differences between PacifiCorp and USGS (11509500) flow records at Klamath River at Keno, Oregon in thousand acre feet.
[Computed as: PacifiCorp-USGS; WY=water year.]

WY	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	August	Sept.
1961	0	0	0	0	0	0	0	0	0	0	0	0
1962	0	0	0	0	0	0	0	0	0	0	0	0
1963	0	0	0	0	0	0	0	0	0	0	0	0
1964	0	0	0	0	0	0	0	0	0	7	0	0
1965	0	0	0	0	0	0	0	0	0	0	0	0
1966	0	0	0	0	0	0	0	0	0	0	0	0
1967	0	0	0	0	0	0	0	0	0	0	0	0
1968	0	0	0	0	0	0	0	0	0	0	0	0
1969	0	0	0	0	0	0	0	0	0	0	0	0
1970	0	0	0	0	0	0	0	0	0	0	0	0
1971	0	0	0	0	0	0	0	0	0	0	0	0
1972	0	0	0	0	0	0	0	0	0	0	0	0
1973	0	0	0	0	0	0	0	0	0	0	0	0
1974	0	0	0	0	0	0	0	0	0	0	0	0
1975	0	0	0	0	0	0	0	0	0	0	0	0
1976	0	0	0	0	0	0	0	0	0	0	0	0
1977	1	0	0	0	0	0	1	4	2	1	0	2
1978	9	4	-7	-8	-7	-7	-8	-2	2	1	4	4
1979	4	1	-1	-3	0	-6	3	-1	2	1	4	5
1980	4	2	-25	-2	1	0	3	2	2	1	6	6
1981	7	6	6	6	5	2	3	4	3	1	5	4
1982	3	2	3	-7	4	21	18	1	1	1	5	4
1983	3	4	6	1	-2	16	18	6	3	2	2	2
1984	-2	0	22	6	6	16	6	0	0	-1	1	1
1985	1	9	2	0	2	0	-1	0	0	0	2	2
1986	2	0	0	0	6	21	7	3	0	0	-3	4
1987	2	3	3	3	3	5	3	3	0	0	2	4
1988	5	4	3	3	1	1	2	1	1	-1	3	2
1989	3	4	3	3	-5	11	10	0	-1	-2	2	3
1990	3	4	3	-3	0	-4	1	1	0	-1	2	1
1991	4	4	1	0	-1	0	-1	0	0	-1	0	0
1992	3	2	2	2	1	0	1	0	0	0	0	1
1993	3	2	2	2	1	20	15	5	6	1	4	4
1994	2	3	4	3	0	0	0	0	1	0	0	2
1995	2	2	2	1	0	6	-1	4	0	0	2	18
1996	31	11	2	6	23	18	7	8	3	4	2	4
1997	7	4	1	-1	22	1	3	4	6	3	5	6
1998	7	6	-5	0	0	6	9	20	8	1	0	2
1999	4	0	4	5	16	20	17	7	5	9	10	10
2000	5	3	3	3	7	6	2	3	7	5	5	6
2001	3	3	2	3	3	3	1	1	1	3	3	2
2002	3	3	3	5	-1	4	2	4	2	1	0	1
2003	3	2	2	1	1	4	6	4	3	3	4	4

Table 13.--Monthly differences between PacifiCorp and USGS (11516530) flow records at Klamath River below Iron Gate Dam, California in thousand acre feet.
[Computed as: PacifiCorp-USGS; WY=water year.]

WY	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	August	Sept.
1961	0	0	0	0	0	0	0	0	0	0	0	0
1962	0	0	0	0	0	0	0	0	0	0	0	0
1963	0	0	0	0	4	0	0	0	0	0	0	0
1964	0	0	0	0	-4	0	0	0	0	0	0	0
1965	0	0	0	0	0	0	0	0	0	0	0	0
1966	0	0	0	0	0	0	0	0	0	0	0	0
1967	0	0	0	0	6	0	0	0	0	0	0	0
1968	0	0	0	0	-4	0	0	0	0	0	0	0
1969	0	0	0	0	0	0	0	0	0	0	0	0
1970	0	0	0	0	0	0	0	0	0	0	0	0
1971	0	0	0	0	7	0	0	0	0	0	0	0
1972	0	0	0	0	-7	0	0	0	0	0	0	0
1973	0	0	0	0	0	0	0	0	0	0	0	0
1974	0	0	0	0	0	0	0	0	0	0	0	0
1975	0	0	0	0	7	0	0	0	0	0	0	0
1976	0	0	0	0	-6	0	0	0	0	0	0	0
1977	0	0	0	0	0	0	0	0	0	0	0	0
1978	0	0	0	0	0	0	0	0	0	0	0	0
1979	0	0	0	0	3	0	0	0	0	0	0	0
1980	0	0	0	0	-7	0	0	0	0	0	0	0
1981	0	0	0	0	0	0	0	0	0	0	0	0
1982	0	0	0	0	0	0	0	0	0	0	0	0
1983	0	0	0	0	10	0	0	0	0	0	0	0
1984	0	0	0	0	-8	0	0	0	0	0	0	0
1985	0	0	0	0	0	0	0	0	0	0	0	0
1986	0	0	0	0	0	0	0	0	0	0	0	0
1987	0	0	0	0	5	0	0	0	0	0	0	0
1988	0	0	0	0	-5	0	0	0	0	0	0	0
1989	0	0	0	0	0	0	0	0	0	0	0	0
1990	0	0	0	0	0	0	0	0	0	0	0	0
1991	0	0	0	0	2	0	0	0	0	0	0	0
1992	0	0	0	0	-1	0	0	0	0	0	0	0
1993	0	0	0	0	0	0	0	0	0	0	0	0
1994	0	0	0	0	0	0	0	0	0	0	0	0
1995	0	0	0	0	2	0	0	0	0	0	0	0
1996	0	0	1	0	-4	-11	0	2	1	-2	-2	0
1997	0	0	9	6	-9	-6	-3	-2	0	0	-2	0
1998	0	0	0	7	1	7	1	11	-4	-4	-4	-4
1999	0	1	-1	0	3	-6	-17	-11	0	0	0	0
2000	1	0	0	1	14	-1	2	0	0	0	0	0
2001	0	1	2	2	2	2	3	3	2	0	0	0
2002	0	0	1	1	1	0	0	0	0	0	0	0
2003	0	0	1	1	-1	1	-3	-2	-1	0	0	0

Table 14.--Monthly differences between computed and USGS (11509500) flows at Klamath River at Keno, Oregon in thousand acre feet.
[Computed as: Computed Keno-USGS; WY=water year]

WY	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	August	Sept.
1961	0	-3	-6	0	-6	-3	3	21	7	13	9	4
1962	4	2	0	-1	-6	-8	6	5	9	12	9	5
1963	5	6	9	10	0	8	2	6	10	11	9	7
1964	5	7	11	11	5	-2	6	6	4	9	9	8
1965	10	2	24	51	30	-17	-5	8	6	11	8	10
1966	15	5	10	10	3	2	11	7	7	11	8	9
1967	1	9	2	4	1	0	1	7	9	10	11	4
1968	2	5	6	3	1	40	6	8	7	9	7	6
1969	2	0	0	0	0	-4	-4	12	6	10	12	7
1970	2	7	0	4	-3	2	4	6	8	10	12	8
1971	4	2	2	-1	4	0	-5	3	10	10	12	8
1972	3	6	6	1	2	1	2	13	13	14	9	5
1973	4	6	11	9	3	8	10	16	17	19	12	8
1974	7	2	4	-4	2	0	13	13	13	10	11	9
1975	2	5	7	3	-1	-13	0	14	13	10	11	7
1976	4	5	5	7	3	-1	5	15	12	15	4	8
1977	1	10	5	2	2	2	5	7	25	23	15	8
1978	6	3	-4	-3	3	1	8	6	9	14	10	-2
1979	8	4	0	-2	-3	-3	0	8	9	8	6	6
1980	0	-3	-5	-6	-9	-4	1	5	7	8	8	3
1981	2	1	-3	-2	-5	-4	1	7	8	7	9	7
1982	-2	-8	-14	-1	-3	4	0	17	6	6	5	4
1983	3	15	0	-3	-12	-9	-2	5	4	3	0	-4
1984	-3	-12	-27	-18	-19	-14	-13	1	-1	1	1	-6
1985	-21	-24	-18	-11	-8	-13	-13	-1	0	5	2	-4
1986	-5	-8	-8	-6	-18	-11	-1	0	3	3	-2	-3
1987	-14	-6	-5	-7	-4	-6	10	4	3	1	-3	-2
1988	-1	-2	-10	-7	-11	-8	-4	4	4	16	3	4
1989	0	-5	-5	-10	-15	-33	-19	2	6	5	3	0
1990	-1	2	-1	-6	-5	-11	0	1	-3	2	1	-2
1991	-1	-4	1	-2	-5	-10	-5	-5	2	5	1	-3
1992	-7	-10	-15	-13	-5	-13	-8	-1	0	1	3	-1
1993	-3	-4	-5	-7	-7	-6	-12	-2	4	6	2	5
1994	0	-1	0	-6	-3	-5	-3	-4	3	4	2	-1
1995	-2	-5	-4	-9	-4	-9	-3	3	1	2	3	18
1996	30	6	-9	-11	-6	-4	3	6	4	-1	0	8
1997	5	-2	-10	-20	-4	0	-3	2	0	0	4	0
1998	-1	-6	-14	-26	-22	-18	-9	5	-3	-7	-7	-1
1999	-4	-14	-6	-11	-12	-17	-10	0	-3	4	-2	5
2000	0	-8	-9	-3	-2	-5	-1	1	4	1	2	9
2001	-1	-3	-3	-6	-3	-4	-5	1	3	4	5	0
2002	-1	-4	-2	7	-10	-6	-5	1	4	4	3	1
2003	-3	-1	-4	-8	-3	-5	1	3	5	4	2	3

Table 15. Estimated ground-water pumping in 2000

Sub Basin	Area irrigated with ground water (acres)	Estimated pumpage (TAF)
Upper Williamson River	2,100	4,600
Sprague River	4,100	11,000
Wood River	340	990
Upper Lost River	7,920	21,100
Lower Lost River	4,420	10,700
Lower Klamath Lake	4,300	13,200
Butte Valley	32,000	75,600
Total	**55,180**	**137,190**

Table 16. Pumping due to the Water Bank and Ground-Water Acquisition programs, and by the Tule Lake Irrigation District (TAF).

	2001	2002	2003	2004
Reported pumpage from private wells	58,974	-	38,915	62,857
Pumpage from Tule Lake Irrigation Dist. wells	10,262	18,569	16,752	12,859
***Total water actually pumped**	**69,236**	**18,569**	**55,667**	**75,716**
**Total water actually purchased	58,974	-	23,192	58,143

*These totals include only pumping related to government sponsered programs.

**Total water pumped exceeds the amount actually purchased and included in water bank.