5.0 ANALYSIS OF PROJECT EFFECTS ON HYDROLOGY

5.1 DESCRIPTION AND PURPOSE

The purpose of this study is to determine how much control and what effects the PacifiCorp Klamath Hydroelectric Project facilities and operations have on the hydrology of the Klamath River. To address this purpose, this study assesses the hydrologic regime and controlling factors in the Project area, including the effects of Project operations. This hydrology study also provides information for supporting other resources, including water quality, fluvial geomorphology, fish and wildlife habitat, riparian resources, recreation, and visual/aesthetics values.

At present, USBR has management control of specific Upper Klamath Lake elevations and specific flow releases at Iron Gate dam. Since 1997, USBR has defined Klamath Irrigation Project operations through annual operations plans. Each annual plan defines how Upper Klamath Lake and flows downstream of Iron Gate dam will be regulated for that year, based on hydrological and environmental conditions. To assist USBR in achieving its plan, PacifiCorp has signed annual agreements with USBR. Each annual agreement states that PacifiCorp will operate its Project in accordance with the annual plan. USBR has recently developed a long-term operations plan so that new plans do not have to be written each year.

5.2 OBJECTIVES

The objectives and key questions addressed by this study are as follows:

- Provide a detailed explanation and understanding of flow regulation into, within, and downstream of the Project area. What are the relative roles and responsibilities of USBR, PacifiCorp, and others for such flow regulation?

- What are the potential effects of PacifiCorp operations and activities on the long-term hydrologic regime, including the magnitude, duration, and timing of monthly discharges and annual high flows?

- What are the potential effects of PacifiCorp operations and activities on the short-term hydrologic regime, including the magnitude, duration, and rate of change of daily and hourly fluctuations in river flows and reservoir water levels?

- Provide hydrologic data and information as needed to support other studies that will further evaluate Project flow effects and potential modifications on other resources (such as water quality, fisheries and fish passage, terrestrial resources, recreation).

5.3 RELICENSING RELEVANCE AND USE IN DECISIONMAKING

This study helps PacifiCorp address certain agency/stakeholder management objectives and resources issues related to Project effects on river hydrology and flow management. A number of factors, many outside PacifiCorp's control, contribute to the river flow conditions within and downstream of the Project area. The information obtained in this study helps to determine how PacifiCorp's Project operations contribute to these conditions.

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Relicensing of the Project also requires 401 certifications from relevant state agencies that the Project complies with requirements of the federal Clean Water Act. This task helps PacifiCorp to assess hydrologic effects as they relate to water quality objectives and standards as promulgated by these agencies. Water quality is directly affected by hydrologic conditions. For example, a river's volume and rate of discharge can determine the concentration of water quality constituents (such as total suspended solids) and the river's capacity to assimilate loading of potential pollutants (such as nutrients). This hydrology study provides data and information of use to studies of other resources, such as water quality, fish and wildlife habitat, riparian resources, and recreation.

5.4 METHODS AND GEOGRAPHIC SCOPE

5.4.1 Explanation of Facilities and Operational Issues Associated with the Project

In May 2002, PacifiCorp issued a report that provides a detailed explanation of flow regulation and operation into, within, and downstream of the Project area (PacifiCorp, 2002). In particular, the report describes the respective roles and responsibilities of USBR and PacifiCorp for lake, reservoir, and river flow operations, and how these operations are coordinated. Specific details are provided on the operations at each facility and relevant agreements and obligations. The report includes the following.

1. A copy of the 1956 contract, amendments, and renewals between PacifiCorp and USBR is provided.

   In 1956, a contract between PacifiCorp and USBR was signed whereby, among other issues, PacifiCorp was obligated to operate the Link River dam for USBR. The Link River dam is owned by USBR, and PacifiCorp owns West Side and East Side powerhouses and canals. The implications of this contract extend beyond the mere operation of the dam by PacifiCorp for USBR, hence the importance of providing and describing the contract.

2. A summary of the implications of the 1956 contract to PacifiCorp's operation of the Klamath Hydroelectric Project is described. Specifically:

   a. Why PacifiCorp is obliged to operate Iron Gate dam to meet minimum flows as directed by USBR

   b. Why PacifiCorp is obliged to operate according to USBR target elevations for Upper Klamath Lake

   c. Why Link River dam is not included in the current FERC Project boundary and the East Side and West Side powerhouses are included

3. For a better understanding of Project operations and issues to follow, the document describes how water is routed through the Project area and why PacifiCorp routes the water in such a fashion. This description includes a table of existing minimum instream flow requirements and lengths of each bypass reach.

4. The historical operational flexibility of Upper Klamath Lake is described. Since the listing of two species of endangered suckers that inhabit Upper Klamath Lake and subsequent Biological Opinions, PacifiCorp's flexibility to operate the lake for the benefit of

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hydroelectric production has been lost in favor of maintaining target lake levels for ESA compliance.

5. The purpose of Keno dam is described. The purpose (benefits) of Keno dam has been questioned because it is not a hydroelectricity-producing facility. Yet this structure serves other purposes, such as diversion points for irrigation, that may not be readily apparent.

6. Specifics of how and why Keno reservoir is operated to maintain a constant elevation are explained, as are the implications of doing so.

   PacifiCorp and USBR entered into a contract in 1968, when Keno dam was built, that specified constraints on reservoir operations for the benefit of USBR's Klamath Irrigation Project.

7. The contract (cited above) between PacifiCorp and USBR describing the operational arrangements of Keno reservoir is provided.

8. The purpose of drawing down Keno reservoir is explained, as are the frequency, magnitude, and duration of such events. The implications of not drawing down the reservoir are also described.

   On an annual or sometimes biannual basis in the spring, Keno reservoir is drawn down approximately 2 feet to accommodate irrigators wishing to perform maintenance on their pumps.

9. The Spring Creek diversion is described, as are its historical operation and current status related to water rights.

   The Spring Creek diversion is one that, at times in the past, has diverted water for the benefit of hydroelectricity production at the Fall Creek powerhouse. This operation diverts water from the Jenny Creek drainage into the Fall Creek drainage.

10. A description of Project structures pertinent to hydrologic control is provided, such as depth of intake structures relative to reservoir elevation and hydraulic capacity of turbines.

5.4.2 Analysis of Effects of PacifiCorp Operations on Existing and Future Hydrologic Regimes

5.4.2.1 Effects on the Short-Term (Daily and Hourly) Hydrologic Regime

Exploration of Existing Hourly Data

This study includes analysis of the effects of Project operations on the short-term (daily and hourly) hydrologic regime using several recent years of operations data. PacifiCorp maintains a database containing hourly operations data at the Project facilities for the period from about 1990 to present. The database includes hourly data on river flow, reservoir elevation, flow through turbines, and spill. This study uses several recent years of these data to depict the various modes of Project operations and relates these operations to specific effects on short-term (daily and hourly) changes in river flow and reservoir water levels.

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Six recent water years of hourly data form the basis of this analysis: 1991, 1992, 1994, 1997, 1998, and 1999. These water years represent a variety of water year types.[1] The 1991 data represent a "dry" water year, 1992 and 1994 a "critically dry" water year, 1997 a "normal" water year, 1998 a "wet" water year, and 1999 an "extremely wet" water year.

For each facility, graphs were produced that display by water year the time-series of daily range in hourly river flows, reservoir elevations, turbine flows, and spills in the bypass reaches. The data sets for these parameters are overlaid on one another to clearly depict hydrologic changes occurring concurrently. For example, data for flow through the turbines are graphed against reservoir elevation fluctuation to depict the effect that one has upon the other. These graphs provide a trend analysis of the type and timing of various operation modes at each facility (such as run-of-river operation, one-turbine peaking operation, two-turbine peaking operation), as well as transitions between operation modes.

The data are also used to calculate statistics that summarize the magnitude, frequency, duration, and timing of river flow, reservoir elevation, flow through turbines, and spill. For example, the magnitude and frequency of flow and stage changes are calculated at gauged river locations to characterize the effects of flow fluctuations. These summary statistics allow for straightforward comparisons of different situations, such as different years, seasons, and operation modes.

The extent of control exerted by Project operations on the short-term (daily and hourly) hydrologic regime is determined and described by two primary means. Graphs and summary statistics (as described above) are compared for locations that represent the inflow and outflow from Project facilities. The differences observed from these comparisons indicate potential net Project effects.

<u>Flow and Hydrodynamics Modeling</u>

As outlined in Section 4.0, PacifiCorp has developed a comprehensive package of water quality models to assess Project water quality effects and potential management scenarios. A key component of the numerical models are hydrodynamic flow-routing models. For riverine reaches, the hydrodynamic model RMA-2 was used.[2] RMA-2 is a model specifically designed to assess flow response in complex river systems. For Project reservoirs, the model CE-QUAL-W2 was used.[3] CE-QUAL-W2 effectively simulates the routing of flow through reservoir geometry and predict reservoir water surface elevations.

RMA-2 solves the full-flow equations known as the St. Venant Equations (also called the shallow water equations). These equations use all terms of the conservation of momentum formulation and provide a complete description of dynamic flow conditions. RMA-2 has an option to represent steep river systems without using unrealistic bed roughness parameters. This steep river system formulation is critical in representing proper transit time, which is paramount to modeling water quality. The model has been widely applied (it is one of the most used full

[1] Per definition of water year type as developed by Hardy and Addley (2001).

[2] RMA-2 was used in combination with RMA-11 to provide a complete and comprehensive water quality model. RMA-11 uses the geometry and output of RMA-2 and solves the advection-diffusion equation to determine the fate and transport of up to 16 water quality constituents.

[3] Different models were selected for riverine reaches and reservoirs because of fundamental differences in their geometric, hydraulic, and water quality characteristics. See Section 4.0 (Appendix 4A) of this FTR for further discussion of model purpose and selection.

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hydrodynamic models in the United States) to a variety of river and estuary systems in the United States as well as internationally.

These models were used to examine the short-term hydrology and hydrodynamics effects of Project operations scenarios, together with examination of water quality effects based on 2000 and 2001 conditions. PacifiCorp has assessed four basic operations scenarios: (1) existing conditions, (2) steady flow condition, (3) a hypothetical without-Project condition, and (4) a second hypothetical without-Project II condition. These scenarios and their associated modeling assumptions are described in detail in Appendix 4A of this FTR. The characteristics of the four basic scenarios are summarized below.

Existing Conditions Scenario

The EC scenario models the actual conditions in the Klamath River during 2000 and 2001, including actual operation at PacifiCorp's Project facilities. All projects were assumed to be in place and operating under 2000 and 2001 conditions.

Steady Flow Scenario

The SF scenario models alternative flows to those recorded in 2000 and 2001. All projects were assumed to be in place but were not assumed to be operating under historical 2000 and 2001 conditions. Instead, a steady flow run-of-river type of operation was assumed (i.e., no peaking). The reservoirs were operated with approximately no change in water surface elevation for the entire year. Calculations started by assuming that dam releases from Iron Gate reservoir were the same as those used in the EC scenario (so as to maintain instream flows as stipulated in USBR's Klamath Project Operations Plan), calculating overall smoothed EC accretions/depletions for each reach and then moving upstream using a water balance method between each reservoir up to Link dam.

Without-Project Scenario

The WOP scenario models the Klamath River as though there are no PacifiCorp facilities (i.e., dams, reservoirs, power canals, powerhouses) in place or operating in the Klamath River downstream of Link dam. The reservoirs were replaced with river reaches, with the geometry of the reaches estimated from the deepest points in the bathymetry of each reservoir. River widths within the reservoirs were a linear interpolation between the river width in the element immediately preceding the reservoir and the river width in the element immediately following the reservoir. The same channel lengths as with the EC river miles were assumed, except for Copco reservoir, where the river was lengthened to capture the sinuosity of the old river bed under the reservoir.

Without-Project II Scenario

All conditions in the WOP II scenario are the same as the WOP scenario with the exception of the hydrology. The primary purpose of this scenario was to smooth out the flow variability (evident in the WOP scenario) being routed down the river during summer periods. These variations, which are most prominent between Julian day 200 and 250, orginate with USBR project operations and maintenance of Keno reservoir at a stable water surface elevation during operations. The fluctuation over the span of a few days can exceed 500 cfs. The original WOP

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scenario assumed that all USBR project operations were consistent with historical conditions, in which case the flow variations that were historically "re-regulated" by system reservoirs were routed down the river. Stakeholder input identified this as an unrealistic without-Project operation and requested that attempts be made to smooth the hydrograph that was routed down the river.

Other Scenarios

Stakeholders have indicated or suggested that PacifiCorp should examine other types of scenarios. In fact, PacifiCorp is in the process of conducting two additional specific scenarios for use by the Plenary Group in completing a Systems Landscape Options Matrix. These include a SLOM scenario that assumes Copco and Iron Gate developments are removed, and a SLOM scenario that assumes Iron Gate is removed. Results of these two additional SLOM scenarios should be available for use in the Plenary Groups's SLOM analysis in about February 2004.

5.4.2.2 Effects on the Long-Term (Monthly, Seasonal, and Annual) Hydrologic Regime

This study includes analysis of the effects on flows in the Project area resulting from historical and proposed operations of USBR's Klamath Irrigation Project. USBR's KPOPSIM model is used as the analytical tool to evaluate semimonthly, monthly, seasonal, and annual impacts on Klamath River flows. This analysis also accounts for the effects of PacifiCorp facilities operations relative to effects from USBR's Klamath Irrigation Project operations.

The KPOPSIM model incorporates the USBR Klamath Irrigation Project (Upper Klamath Lake, Gerber reservoir, and Clear Lake) and the PacifiCorp Klamath Hydroelectric Project (Klamath River operations between Link River dam and Iron Gate dam). See the KPOPSIM model documentation[4] for a complete description of model setup, assumptions, and spatial representations of the modeled area. Gerber reservoir and Clear Lake have very little, if any, impact on the Klamath River; therefore, they are not included in the KPOPSIM simulation. PacifiCorp facilities on the Klamath River include Keno, J.C. Boyle, Copco, and Iron Gate reservoirs.

The natural flow regime has been approximated at a monthly (August-February) and semi-monthly (March-July) time scale using inflows to Upper Klamath Lake and accretions between Link River dam and Iron Gate dam. The resulting flow approximation is used in the model to simulate the overall effects to the system. Klamath Irrigation Project effects are separated from PacifiCorp Project effects, using measured operational data from PacifiCorp. The PacifiCorp operational data consist of flows and reservoir stage changes at Copco, J.C. Boyle, and Iron Gate reservoirs. Using the measured data to dissaggregate Project flow and reservoir storage changes from the assumed accretions, PacifiCorp's operational impacts are distinguished from USBR's Klamath Irrigation Project operational impacts. For the analysis presented herein, inflow and accretion data used to support the KPOPSIM model are based on historical hydrologic data for Water Years 1961-98.

There are four primary operating factors for the Klamath River. At the request of the U.S. Department of the Interior, these demands have been prioritized. First, the Upper Klamath

[4] U.S. Bureau of Reclamation. August 10, 1998. U.S. Bureau of Reclamation Home Page. Available: <http://www.mp.usbr.gov/kbao/models/index.html> Accessed: February 25, 2003.

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Lake Biological Opinion minimum lake elevations must be met. Second, Klamath River minimum flow targets below Iron Gate dam must be met. Third, priority is given to irrigation deliveries to the USBR Klamath Irrigation Project. And fourth, ADY canal deliveries to the Lower Klamath Lake and Lower Klamath Lake National Wildlife Refuge must be fulfilled.

KPOPSIM analyses were performed as follows:

- KPOPSIM simulations were based on the assumption that the USBR-recommended targets to simulate probable future flow conditions (i.e., targets for Upper Klamath Lake and Klamath River flows below Iron Gate dam based on the 2002 Biological Opinion).
- PacifiCorp Project reservoir inflows, outflows, and storage changes were itemized at the same semimonthly (February through July) and monthly (June through January) time steps in KPOPSIM. These data (obtained for Copco, J.C. Boyle, and Iron Gate reservoirs for the period 1961 through 1998) were incorporated in KPOPSIM's assumed accretions from Link River dam to Iron Gate dam. Project operations impacts were then distinguished from USBR's Klamath Irrigation Project operational impacts by performing KPOPSIM model runs where the PacifiCorp flow and reservoir storage changes were disaggregated from the assumed accretions.
- An approximate natural flow below Iron Gate dam was computed using historical inflow to Upper Klamath Lake, plus historical accretions from Link River dam to Iron Gate dam. (This value was used to measure the relative impacts of the Klamath Irrigation Project and the PacifiCorp Project operations on approximate natural flow conditions below Iron Gate dam.)
- Monthly, semimonthly, and annual effects of USBR's Klamath Irrigation Project and PacifiCorp's Project operations were quantified for five water year types:[5] (1) critically dry, (2) dry, (3) normal, (4) wet, and (5) extremely wet.
- USGS data were analyzed to determine the relative contribution of flow from Iron Gate dam to lower basin flows in different water year types.
- An analysis was conducted to determine the approximate total contribution of flow from tributaries and springs within the Project area.

5.4.2.3 Other Hydrologic Analyses

Flood Frequency Analysis

The Flood Frequency Analysis (FFA) program from the U.S. Army Corps of Engineers Hydrologic Engineering Center (HEC) was used to compute flood frequencies. HEC-FFA computes flood frequencies in accordance with Guidelines for Determining Flood Flow Frequencies (U.S. Water Resources Council, 1982). This guideline is designed for computing flood flow frequency curves where systematic stream gauging records of sufficient length (at least 10 years) to warrant statistical analysis are available as the basis for determination.

Annual peak discharge information for the period of record from USGS gauges in the Project area (Table 5.7-1) were used in this analysis. A statistical analysis of these data is the primary

[5] Per definition of water year type as developed by Hardy and Addley (2001).

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basis for the determination of the flow frequency curve for each gauge location. The Pearson Type III distribution with log transformation of the flood data (log-Pearson Type III) was assumed as the basic distribution for defining the annual flood series.

Table 5.7-1. USGS flow gauging data for the Klamath River and Fall Creek in the Project area.

USGS Gauge	Drainage Area (square miles)	Gauge Number	Daily Flow Period of Record	Annual Peak Flow Period of Record
Link River at Klamath Falls	3,810	11507500	10/1/1961-present	5/12/1904-present
Klamath River at Keno	3,920	11509500	6/1/1904-9/30/1913, 10/1/1929-present	3/28/1905-9/30/1913, 10/1/1929-present
Klamath River at Spencer Bridge near Keno	4,050	11510500	10/1/1913-9/30/1931	4/21/1914-12/15/1930
Klamath River Downstream from J.C. Boyle Powerhouse	4,080	11510700	1/1/1959-9/30/1971 10/1/1974-9/30/1979 10/1/1982-9/30/1987 10/1/1988-present	1/1/1959-9/30/1971 10/1/1974-9/30/1979 10/1/1982-9/30/1987 10/1/1988-present
Klamath River below Fall Creek near Copco	4,370	11512500	10/1/1923-9/30/1961	1/2/1924-12/1/1960
Klamath River Downstream of Iron Gate Dam	4,630	11516530	10/1/1960-present	12/1/1960-present
Fall Creek at Copco	14.6	11512000	4/1/1933-9/30/1959	12/27/1928-7/2/1959

<u>Low Flow Frequency Analysis</u>

A frequency analysis of low flows was performed using DFLOW 3, a Windows-based revision of the DFLOW computer code developed by U.S. EPA in the early 1990s to estimate design stream flows for use in water quality studies. Low flow statistics were calculated as annual x-day average low flows whose return period is y years, i.e., the xQy low flow. For example, the 3Q5 is the 3-day average low flow that occurs every 5 years, corresponding to the 3-day flow with a 20 percent chance of occurrence every year. These flows were estimated from the daily flow record for the period of record from gauges in the Project area (Table 5.7-1). The DFLOW 3 analysis fits the historical low flow data to a log Pearson Type III distribution probability density function and then computes from this function the flow whose probability of not being exceeded is 1/year.

5.4.3 Geographic Scope

The hydrologic analyses described in this study are most focused on the Project area from Link River dam to just below the Iron Gate dam and powerhouse. It is in this area that Project operations have the most direct and varied potential effects on flows. However, some tasks described in the study plan incorporate a broader basinwide area to enhance perspective and context for the Project setting and potential Project hydrologic effects. For example, the evaluation of responsibilities and coordination of USBR and PacifiCorp on river flow operations addresses Upper Klamath Lake because lake volume and level are important factors for operations at Link River dam. In addition, the assessment of effects on the long-term (monthly, seasonal, and annual) hydrologic regime includes an analysis of data from USGS gauges in the

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lower basin to quantify the relative contribution of flow from Iron Gate dam to lower basin flows in different water year types. The geographic scope for water quality modeling, which includes CE-QUAL-W2 and RMA-2 flow and hydrodynamic modeling, includes the Klamath River from Link River dam (RM 254.3) to Turwar (about RM 6).

5.5 RELATIONSHIP TO REGULATORY REQUIREMENTS AND PLANS

This study helps PacifiCorp to address certain regulatory requirements and planning objectives related to Project effects on river hydrology and flow management. The information derived from this study is used to address FERC requirements (18 CFR 4.51 and 16.8) for information on water uses in the Project area and coordination of Project operations with other water resources projects. This study also provides flow information as needed to support FERC requirements (18 CFR 4.51 and 16.8) for analyses of water quality, fisheries, recreation, and other resources.

Relicensing of the Project requires 401 certifications from relevant agencies that the Project complies with requirements of the federal Clean Water Act. This study provides information to help assess hydrologic effects as they relate to water quality objectives and standards promulgated by these agencies. Water quality is directly affected by hydrologic conditions. For example, a river's volume and rate of discharge can determine the concentration of water quality constituents (such as total suspended solids) and the river's capacity to assimilate loading of potential pollutants (such as nutrients).

The information in this study is used to help address compliance with management objectives from various resource agencies, tribes, and other stakeholders. Such objectives relate to flow use and protection, and flows needed to support water quality, fisheries, wildlife and botanical resources, and recreation resources. This information also helps PacifiCorp and stakeholders to develop PM&E measures to meet the intention of these regulations and management objectives.

5.6 TECHNICAL WORK GROUP COLLABORATION

PacifiCorp has worked with stakeholders to establish a more collaborative process for planning and conducting studies needed to support Project relicensing documentation. As part of this collaborative process, a Water Quality Work Group was formed and met approximately monthly as needed to plan and discuss water quality studies and results, including this study.

5.7 RESULTS AND DISCUSSION

5.7.1 Project Area's Natural Hydrologic Factors and Flow Regime

The annual and seasonal trends in gauged runoff and flow patterns on the Klamath River generally reflect climatic conditions and cycles (Balance Hydrologics, 1996; Ayers Associates, 1999). Precipitation in the basin is distinctly seasonal, with 60 percent of the total annual precipitation falling from November to March. December and January are the wettest months; the driest months are between June and September. Annual precipitation patterns historically define distinct dry and wet cycles that are closely related to runoff and the river's flow regime. The most recent climatic trends include wet periods (1885-1915 and 1940-1975) and dry periods (1915-1940 and 1975-1994). General decreases in runoff and discharge over the last 20 years also coincide with a generally decreasing trend in precipitation patterns.

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The installation of the Copco dams (1918 and 1925) followed by the Link River dam (1921), J.C. Boyle dam (1958), Iron Gate dam (1962), and Keno dam (1967) have had an effect on storage capacity and flow in the Klamath River. In addition, extensive diversions in the upper basin include the A canal (1907), the Lost River diversion canal (1912), the North canal diversion, and the ADY diversion.

As summarized in Table 5.7-2, the reservoirs in the upper basin currently are capable of storing about 40 percent of the mean annual flow at the Iron Gate gauge site. However, most of this storage is provided by Upper Klamath Lake, as the other reservoirs operated by PacifiCorp have a limited ability to store, and therefore affect, the river's overall flow regime. The ability of the reservoirs in the upper basin to alter the river's flow regime further diminishes with distance downstream. For example, the reservoirs are capable of storing less than 5 percent of the mean annual runoff at the Klamath gauge site near the mouth of the Klamath River at Klamath, California (Table 5.7-2).

Table 5.7-2. Reservoir storage capacities as a percent of mean annual runoff for facilities in the Upper Klamath River basin.

Dam/Reservoir	Year Completed	Reservoir Total Storage Capacity (acre-feet)	Storage Capacity as a Percent of Mean Annual Runoff at Two Gauge Sites* (acre-feet)	
			Iron Gate Dam (RM 190)	**Klamath, California (RM 5)**
Copco No. 1	1918	77,000	4.9	0.6
Link/Upper Klamath Lake	1921	465,000	29.4	3.7
Copco No. 2	1925	55	<0.1	<0.1
J.C. Boyle	1958	3,377	0.2	<0.1
Iron Gate	1962	58,000	3.7	0.4
Keno	1967	18,500	1.2	<0.1
Total		621,932	39.4	4.9

*USGS gauges: No. 11516530 downstream of Iron Gate dam, and No. 11530500 at Klamath, California.

At present, river flows are basically dictated and regulated by USBR's annual Klamath Project Operations Plans to meet Upper Klamath Lake level targets and instream flow needs downstream from Iron Gate (see further detailed descriptions of this process in section 5.7.3). The overall effects of the Upper Klamath River basin operations and diversions have generally resulted in an increase in winter flows and a decrease in late-spring and early-summer flows in the river just downstream from Iron Gate dam (Balance Hydrologics, 1996; Ayers Associates, 1999).

Some accretion of flow occurs over the 64 miles of river where the Project facilities are located. Natural springs contribute an assumed relatively constant flow to the Klamath River channel between J.C. Boyle dam (RM 225) and its powerhouse (RM 220). These springs contribute about 220 to 270 cfs. Tributaries to the Klamath River in the Project area between Link River dam and Iron Gate dam are relatively small. The largest include Spencer Creek (approximately 20 to 200 cfs), which flows into J.C. Boyle reservoir; Shovel Creek (10 to 100 cfs), which enters the river just upstream from Copco reservoir; and Fall Creek (30 to 100 cfs) and Jenny Creek (30 to

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500 cfs), which flow into Iron Gate reservoir. Spencer Creek, Shovel Creek, and Jenny Creek all have irrigation diversions that remove some water from them. The largest diversion is by USBR, on Jenny Creek, where water is transferred out of the basin to the Rogue River Valley.

5.7.2 Project Area River Flows

5.7.2.1 Hydrologic Data Sources for the Klamath River in the Project Area

Four currently operating key USGS gauging stations are located in the Klamath River in the near vicinity of the Project:

- Link River at Klamath Falls (No. 11507500, RM 253.5)
- Near Keno dam (No. 11509500, RM 232)
- Downstream from J.C. Boyle powerhouse (No. 11510700, RM 220)
- Downstream from Iron Gate dam just downstream from Bogus Creek (No. 11516530, RM 190).

Table 5.7-1 summarizes the drainage area and the period of record of the data for each of these gauges and three other discontinued USGS flow gauge sites in the Project area: Klamath River at Spencer Bridge (No. 11510500, RM 226.1); Klamath River below Fall Creek near Copco (No. 11512500, RM 196); and Fall Creek (No. 11512000, near the mouth of the creek).

5.7.2.2 Klamath River and Fall Creek Average Daily Flow Rates

Graphs of average daily flow by month at the four key USGS gauges on the Klamath River in the Project area are provided in Appendix 5A. Figure 5.7-1 depicts annual hydrographs of average daily flow over the period 1967-1999 for the four key USGS gauges. To illustrate flow variation in recent years, Figure 5.7-2 shows the annual hydrograph of average daily flow for the Keno gauge (No. 11509500), together with annual hydrographs for 1991 (a critical dry year) and 1998 (a wet year).

Graphs of average daily flow by month at the Fall Creek USGS gauge are provided in Appendix 5B.

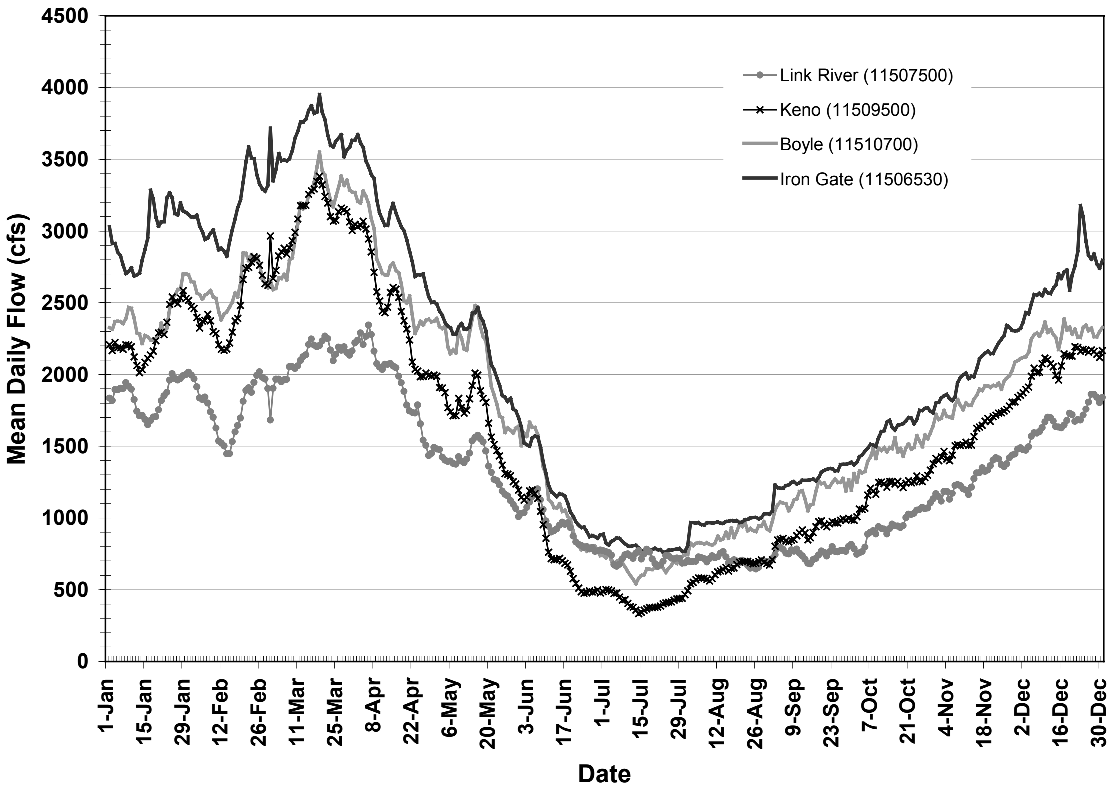

Figure 5.7-1. Annual hydrographs of average daily flows for the period 1967-1999 at four gauging stations on the Klamath River in the Project area.

5.7.2.3 Klamath River and Fall Creek Daily Flow Duration Curves by Month

Appendix 5A provides daily flow duration curves, by month, at the four key USGS gauges on the Klamath River in the Project area. Appendix 5B provides daily flow duration curves, by month, at the Fall Creek USGS gauge. These curves indicate the percent of days for a particular month that a given flow has been equaled or exceeded.

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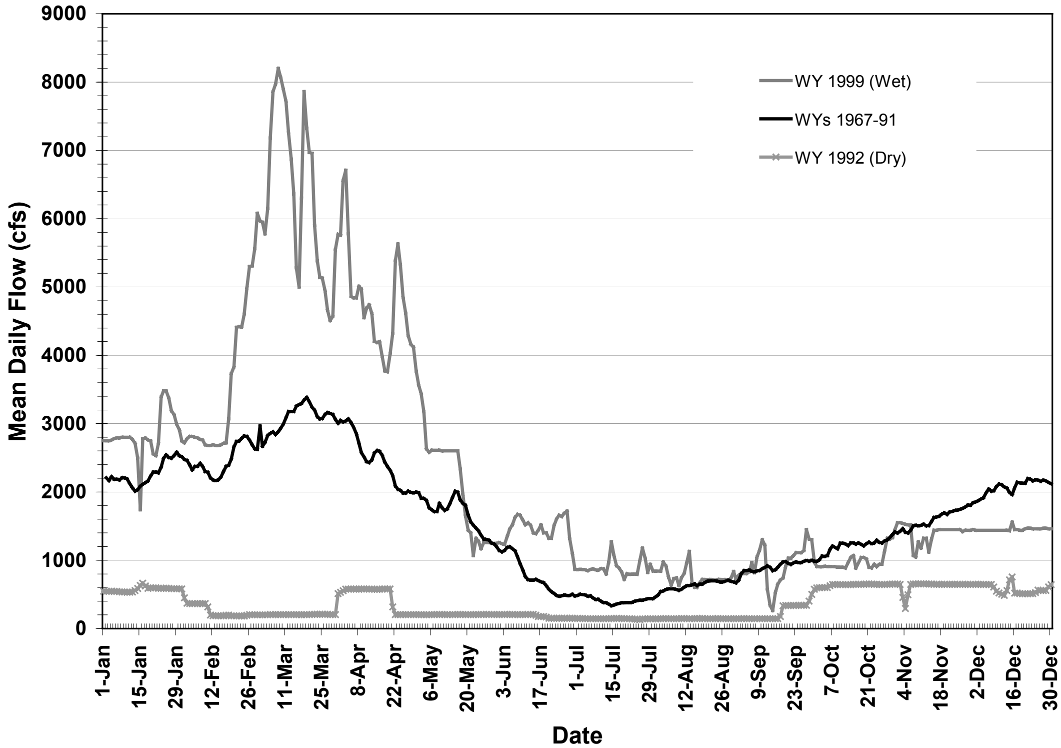

Figure 5.7-2. Annual hydrographs of average daily flows in the Klamath River at Keno (USGS Gauge No. 11509500) for the period 1967-1999, a dry year (1992), and a wet year (1999). The dry and wet water year classifications are based on USBR's classification system.

5.7.2.4 Water Year Type and Average Annual Flows in the Klamath River Since 1990

Water year type classifications have been defined by USBR (2003)[6] for Klamath Irrigation Project Operations Plans and by Hardy and Addley (2001). These water year types are based on net inflow to Upper Klamath Lake for the April-September period, as defined in Table 5.7-3. Water year types and mean annual discharge since 1990 at USGS gauges in the Project area are listed in Table 5.7-4.

[6] Per the Klamath Project 2003 Operations Plan (April 10, 2003)

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Table 5.7-3. Klamath River water year classifications.

Year Type	Upper Klamath Lake Net Inflow from April through September (acre-feet)
Hardy and Addley (2001) Classification *	
Extremely Wet	Above 785,000
Wet	785,000 to greater than 568,500
Normal	568,500 to greater than 445,000
Dry	445,000 to greater than 270,000
Critically Dry	270,000 or less
USBR Classification (per Klamath Project 2003 Operations Plan)	
Wet	Above 785,200
Above Average	785,200 to greater than 568,600
Average	568,500 to greater than 458,400
Below Average	458,300 to greater than 286,800
Dry	Less than 286,800

* The Upper Klamath Lake net inflow values assumed for the Hardy and Addley (2001) classification were estimated from Hardy and Addley (2001, Table 19, page 97).

Table 5.7-4. Mean annual discharge and water year types since 1990 at USGS gauges in the Project area.

Year	Water Year Type		Annual Mean Discharge (cfs)			
	USBR (2003) System	Hardy and Addley (2001) System	At Link River (USGS Gauge No. 11507500)	At Keno (USGS Gauge No. 11509500)	Below J.C. Boyle Powerhouse (USGS Gauge No. 11510700)	At Iron Gate Dam (USGS Gauge No. 11516530)
1990	Below average	Dry	815	969	1,213	1,351
1991	Dry	Critically dry	494	467	698	827
1992	Dry	Critically dry	555	356	578	649
1993	Above average	Wet	1,397	1,569	1,850	2,046
1994	Dry	Critically dry	615	482	691	784
1995	Average	Normal	1,092	1,217	1,550	1,802
1996	Above average	Wet	1,891	2,247	2,577	2,983
1997	Average	Normal	1,705	2,021	2,351	2,626
1998	Above average	Wet	1,832	2,545	2,788	3,058
1999	Wet	Extremely wet	1,762	2,283	2,592	2,881
2000	Average*	Normal*	1,377	1,487	1,782	1,968
2001	Below average*	Dry*	911	971	1,227	1,341

*USBR (2003) and Hardy and Addley (2001) did not define water year types for 2000 and 2001. Water year types are estimated here based on comparison with other years. Year 2000 is most similar to 1993 and 1995, and 2001 is most similar to 1990.

5.7.3 Current and Historical Flow Management in the Klamath Hydroelectric Project Area

PacifiCorp's May 2002 report provides a detailed explanation of flow regulation and operation into, within, and downstream of the Project area. In particular, the report describes the relative roles and responsibilities of USBR and PacifiCorp regarding lake, reservoir, and river flow operations, and how these operations are coordinated. Specific details are provided on the operations at each facility and relevant agreements and obligations. The report's contents are not reproduced here but can be accessed at PacifiCorp's website (PacifiCorp, 2002). The document provides detailed results and discussion pertinent to this topic as part of this hydrology study.

In recent years, a number of studies and agency reports have provided significant analyses of the flow regime and management in the Upper Klamath River basin of southern Oregon and northern California. Generally, these studies address two topics—the hydrologic regime of the Upper Klamath River basin, and the management of the irrigation and hydroelectric projects in the basin. In most cases, the goal of these documents was either to report past project management and perceived impacts or to develop a framework for evaluating future operations policy to quantify and minimize impacts. The purpose of this section is to summarize the key findings in these reports as related to river flow management in the Project area.

5.7.3.1 USBR Klamath Irrigation Project

The document titled Klamath Project: Historic Operation (USBR, 2000) provides a concise discussion of the history of USBR's Klamath Irrigation Project. Although some diversions were built earlier, the Klamath Irrigation Project officially began in 1905. At that time, the U.S. government took appropriation of all remaining water within the basin and also purchased several existing senior rights. Land was set aside through arrangements with Oregon and California state governments. Work on the first canal began in 1906. The project was intended to divert water from Upper Klamath Lake to the Lost River basin for irrigation use and to provide flood control in the Klamath basin. Approximately 200,000 acres of cropland were irrigated in 1999. It was acknowledged in the Klamath River Basin Compact (August 30, 1957; 71 Stat. 497) that the Lost River has been made a tributary of the Klamath River by Project operations.

In general, the contract holders for the Klamath Irrigation Project are irrigation districts and similar water conservation entities. In all, over 250 contracts for water service are administered through Klamath Irrigation Project operations. In an average year, the Klamath Irrigation Project can provide water supply to meet its obligations to contract holders with no restrictions to timing and quantity. This is a key component of the Klamath Irrigation Project appropriation scheme. The water service contracts typically stipulate acres irrigated, not volume of water delivered. In addition to these long-term and/or perpetual contracts, a number of temporary contracts for surplus water are negotiated based on the expected availability of water in a given year. Four national wildlife refuges near or within the Klamath Irrigation Project boundaries also receive water supplies.

Operation of the Klamath Irrigation Project changed as the number of control structures increased with completion of different components of the system. Consumptive use from the Klamath Irrigation Project has also increased as the number of irrigated acres has grown. Finally, further understanding of the hydrologic variability of the basin and downstream effects of the Klamath Irrigation Project has led to changes in operational policy. Currently, the Klamath

Irrigation Project provides year-round irrigation delivery to various contract holders, with flood irrigation in late fall for Lower Klamath Lake areas, spring and summer deliveries to irrigation districts, and flood control operations during winter and spring runoff seasons. Upper Klamath Lake is operated to stay within guidelines established for irrigation storage, flood protection, ESA needs, and tribal trusts. Water not allocated to these needs is released to the Klamath River. This release is about 900,000 acre-feet in an average year. The Klamath Irrigation Project uses 350,000 to 400,000 acre-feet for irrigation and refuge operations in an average year.

5.7.3.2 PacifiCorp Klamath Hydroelectric Project

The PacifiCorp Project consists of six hydroelectric power-generating facilities. The first, Link River dam, was constructed as a result of a 1917 agreement between PacifiCorp's predecessor, Copco, to regulate flows out of Upper Klamath Lake. This agreement gave Copco significant flexibility in operating the dam for hydropower generation, as long as all irrigation project requirements were met. This flexibility allowed for use of some lake storage to augment flows for generation. This flexibility remained largely intact until 1992, when the operation of the dam was restricted more significantly to protect endangered species.

The new policies required that certain Upper Klamath Lake levels be met, thus reducing the capability of Upper Klamath Lake to store spring flood flows. This has resulted in increased water spilled. In 1996, as a result of these and downstream minimum flow requirements and the related potential liability for ESA-related charges, PacifiCorp contemplated rescinding its 1956 operations contract with USBR. In 1997, an agreement was reached whereby USBR assumed all responsibility for Upper Klamath Lake levels and downstream flow requirements (below Iron Gate dam). This means that PacifiCorp has no more than an average 7-day storage capacity (12,000 acre-feet) in its entire Project system. Essentially, under historical operations, the PacifiCorp Project had some capacity for longer term (monthly, seasonal) storage to balance available water for hydropower. Under current practice, with little or no control over storage in Upper Klamath Lake or downstream flows below Iron Gate dam, the PacifiCorp Project only has the ability to influence flows at daily or hourly time steps.

In late winter and spring, particularly for average or wetter years, Project reservoirs are typically full, resulting in run-of-river operations through the Project area. In summer and fall, when average flows are below the capacity of the turbines, PacifiCorp manages flows to maximize power generation. Typically, this might involve holding half the "natural" flow in a reservoir, filling during the night, and releasing 1.5 times the "natural" flow during the day, to increase the flow through the turbines during the time when electricity demand is relatively high. This results in a shift in time of 12 hours and a change in magnitude of 50 percent of the natural flow. Because the hydraulic capacity of the J.C. Boyle powerhouse is about 2,850 cfs and the Copco No. 2 powerhouse is about 3,200 cfs, any larger flows would not be subject to this peaking action. Minimum instream flows and prescribed ramping rates also constrain this approach, based on FERC license requirements and ESA considerations. With downstream flow requirements below Iron Gate Dam typically at approximately 1,000 cfs, this effectively limits the range of possible operational effects to no more than +/- 2,000 cfs (3,000-1,000 cfs) from "natural" flow, within the 1,000-3,000 cfs range. Temporally, this maximum effect can only be in place for up to 3.5 days, assuming active storage is empty, before reservoirs would fill to run-of-river conditions. The largest impact of this peaking behavior is the wide fluctuation between high and low flow that can occur during a single day.

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5.7.3.3 Flow Management Effects

Three key studies—Balance Hydrologics (1996), Ayres Associates (1999), and Hardy and Addley (2001)— provide analyses of basin hydrology and the effects on hydrology of flow management in the Klamath River basin. Each study included analysis that sought to illuminate flow management effects by comparing a "natural" hydrology condition to the current flow regulation regime. These three studies focus mainly on the effects on hydrology of flow management from the Klamath Irrigation Project. While the current flow regulation regime includes both irrigation and hydropower components, these studies emphasize the irrigation project component, probably for a couple of reasons. First, the PacifiCorp Project requires little to no consumptive use. Second, less than 1 percent of total basin storage is "actively" stored by PacifiCorp Project components, while over 80 percent of the total storage capacity is contained within Upper Klamath Lake, managed by USBR. The lack of active storage under PacifiCorp's control means that comparatively little effect on the basin flow regime is caused by Project operations, and as such no work was done to explicitly quantify hydrologic impacts of those operations.

<u>Balance Hydrologics (1996)</u>

The Balance Hydrologics report (1996), prepared on behalf of the Yurok Tribe, discusses findings regarding the impact of the Klamath Irrigation Project on instream flows below Iron Gate dam. This report attempts to quantify the extent to which the Klamath Irrigation Project has affected seasonal flows in the river. In general, the report describes an increase in winter flows and a decrease in late-spring and summer flows. The report also makes the link between subsurface storage in the upper basin and base flows in the Klamath River, suggesting that consumptive irrigation use diminishes the buffer subsurface flows historically provided, and surface flows are correlated to precipitation in the basin over the previous several years.

This report uses USGS gauge data recorded from 1905 to 1912 at Keno, Oregon, supplemented by records from several other sites downstream, to estimate a without-project hydrologic record. Rainfall records are used to quantify long-term wet and dry periods in the past century. In particular, these include severe drought in the 1840s; wet periods in the 1860s, 1905-1917, and 1951-1984; and dry periods in 1872-1890 and 1918-1950.

Balance Hydrologics offers several recommendations for improving river flow conditions, including increasing storage in Upper Klamath Lake, artificially recharging runoff to groundwater, conjunctive use of groundwater in certain areas to augment surface flow irrigation, and improving irrigation efficiencies.

<u>Ayers Associates (1999)</u>

The Ayres Associates (1999) report was prepared for the U.S. Fish and Wildlife Service to evaluate Klamath River geomorphology, and to determine if channel geometry and sediment dynamics are changing, particularly downstream of Iron Gate dam. As part of this evaluation, the report presents additional analyses of the hydrologic data in the basin, and examines the analysis and conclusions of Balance Hydrologics (1996), agreeing with many but taking issue with some. Ayres Associates disagrees with the correlation procedure for previous year precipitation and subsequent runoff volume, and also disputes the adjustment used to index the relatively short pre-Project gauge data record to normalize it against average expected flows. Ayres Associates recalculated the index to show that the pre-Project data are nearly average, not slightly wet, as Balance Hydrologics reported. This change implies that flows in the basin were not diminishing over time, as Balance Hydrologics suggested. Ayres Associates concurs that seasonal shifts are discernible with respect to peak flows and volumes. In addition, peak discharges have increased in magnitude and frequency since construction of Iron Gate dam, but it is not clear that these changes are related to the Klamath Irrigation Project, as opposed to land use changes, such as timber harvest. Ayres Associates concurs with the Balance Hydrologics' finding of shifts in seasonal averages, with higher winter flows and lower summer flows.

Hardy and Addley (2001)

The Hardy and Addley (2001) report was prepared by the Institute for Natural Systems Engineering at Utah State University for the U.S. Department of the Interior to evaluate instream flow requirements downstream of Iron Gate dam. There have been two phases to the project: an initial evaluation of the basin (Phase I), and a more detailed habitat analysis and modeling effort (Phase II). In Phase II, Hardy and Addley estimated the "natural" hydrology regime prior to the Klamath Irrigation Project ("unimpaired no-project flows") and other flow management scenarios generated through model simulations, including data from the KPOPSIM and MODSIM models of the basin. Four different flow scenarios were considered:

1. Unimpaired no-Project flows
2. USGS-simulated historical Project operations
3. Klamath Irrigation Project operations with current FERC and USFWS requirements
4. Klamath Irrigation Project operations based on the Phase I instream flow requirements[7]

Examples of the results of these simulations are shown in Figure 5.7-3 and 5.7-4 for Klamath River locations at Iron Gate dam (RM 189.5) and Orleans (RM 59.1), respectively.

The main thrust of Hardy and Addley's (2001) hydrologic work was to develop suitable year classifications for the Klamath River and establish instream flow targets that would produce acceptable anadromous fish life stages conditions. Hardy and Addley's computation of unimpaired flows was deemed essential for depicting historical flow versus fishery conditions, the relationships of which were used to establish subsequent instream flow target releases from Iron Gate dam. These scenarios were all developed on a monthly or semimonthly time scale.

Hardy and Addley used several models and the outputs from other existing models to make the analyses. They combined the use of KPSIM (a.k.a. KPOPSIM) and MODSIM to produce model flow output and test impacts to other Klamath Irrigation Project functions. The output from MIKE 11 was used to assist in computing unimpaired Klamath River flows. The USGS System Impact Assessment Model (SIAM) model was used to test temperature/flow relationships. The application of the models and the development of unimpaired flow data are discussed briefly below.

[7] Several flow-statistic methods were evaluated for determining recommended monthly instream flow needs as part of Phase I. In general, these methods, including the Hoppe method, New England flow policy, Northern Great Plains Resource Program method, and others, use either flow exceedance relationships or mean annual volume to estimate the necessary flow conditions for fish habitat.

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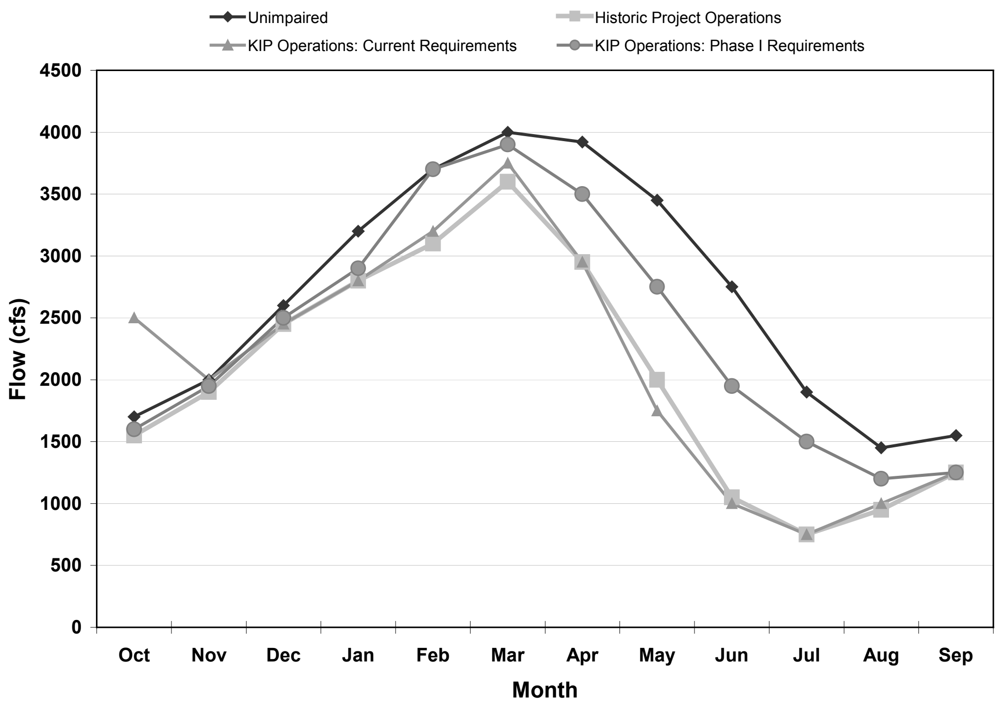

Figure 5.7-3. Mean monthly flow of Klamath River at Iron Gate dam for four flow scenarios simulated by Hardy and Addley (2001). Flow in October (FERC) is from Upper Klamath Lake evaluations. (Source: Hardy and Addley, 2001).

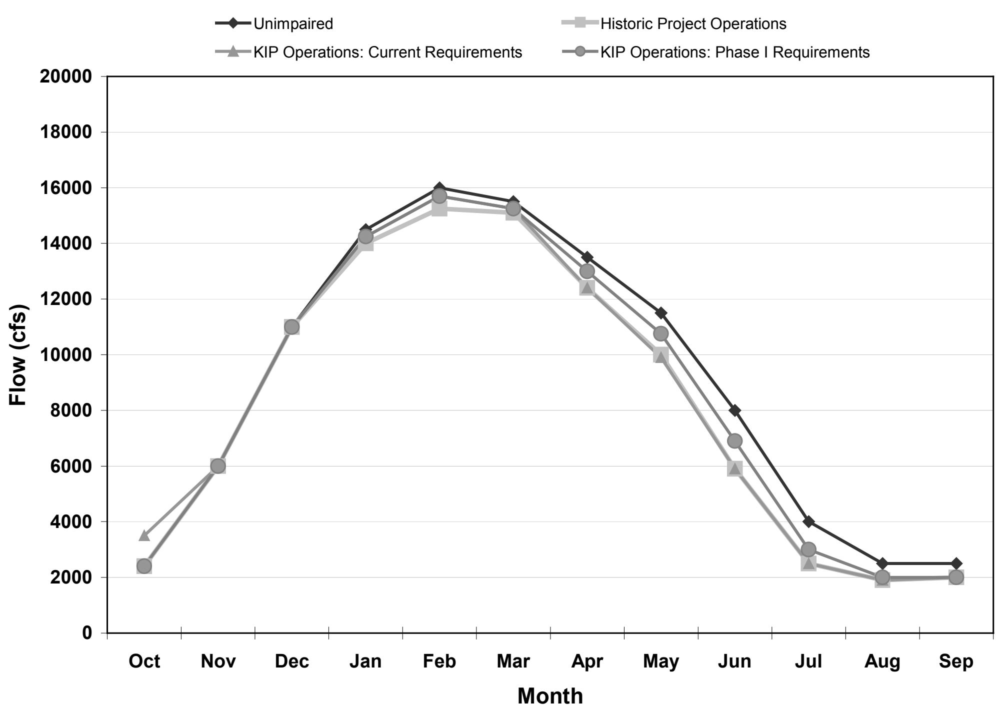

Figure 5.7-4. Mean monthly flow of Klamath River at Orleans for four flow scenarios simulated by Hardy and Addley (2001). (Source: Hardy and Addley, 2001).

MODSIM is an off-the-shelf model developed at Colorado State University approximately 30 years ago. It is a popular decisionmaking tool that permits the user to establish prioritization of water supply features to meet varying demands in a linear system. Colorado State University developed a MODSIM model specifically for the Klamath River for the purpose of analyzing potential water sources to meet increased flow releases below Iron Gate dam. PacifiCorp's J.C. Boyle, Copco, and Iron Gate reservoirs were included in this analysis. In their model applications, Hardy and Addley concluded that MODSIM has limited capability to simulate the river system above Iron Gate dam to realistically reflect actual Klamath Irrigation Project operations. Instead, they used KPSIM to "front-load" flows for the USGS SIAM model.

MIKE 11, a flow routing model, was used by Hardy and Addley to de-operate Upper Klamath Lake historical storage regulation. The outflow from Upper Klamath Lake is controlled by Link River dam. Before the dam's construction in the early 1900s, the outflow from Upper Klamath Lake was controlled by a rock reef located just upstream of the existing dam. The portion of the Klamath River between the reef and the Link dam location contained a series of cataracts known as Klamath Falls. In computing "unimpaired flow" below Link dam, Hardy and Addley used the output from MIKE 11 modeling to yield more accurate daily "unimpaired flows" at Link dam by accounting for these pre-construction features.

Hardy and Addley's 2001 analysis found that the difference between estimated average annual flow (1.8 million acre-feet) prior to the Klamath Irrigation Project and current conditions (1.5 million acre-feet) represents the consumptive use in the basin by irrigators and other users. Some seasonal shifts and changes in peak and trough magnitudes can be seen at the monthly time scale, similar to those concluded by the Balance Hydrologics (1996) and Ayres Associates (1999) studies.

5.7.4 Effects of PacifiCorp Operations on the Short-term (Hourly and Daily) Hydrologic Regime of the Klamath River

The Project is composed of a series of reservoirs and reaches that step down from Upper Klamath Lake to Iron Gate dam. Each reservoir has certain operating rules connected by a varying degree with other reservoirs in the system. As discussed in section 5.7.1, the reservoirs under PacifiCorp control contain a relatively small volume available for active storage (about 10 percent of mean annual runoff at Iron Gate dam, and about 1 percent at Klamath, California). The effects on Klamath River and basin hydrology from operating the reservoirs are most relevant at a short time period (daily and hourly), low volume scale.

Hourly data were compiled for several recent characteristic years (1991, 1992, 1997, 1998, and 1999) at various facilities in the Project area. The data constitute a substantial number of collected measurements, approximately 500,000. To facilitate examination, the data were organized in two ways, either as a "snapshot" of typical operational characteristics or as a "summary" describing maximum, minimum, and average values for each water year type. Snapshot figures have been selected to illustrate typical operations patterns observed under different seasonal conditions. These types of figures have been created for each component of the Project system, including reservoirs, peaking reaches, and bypass reaches.

In general, these figures show that macro-scale hydrologic variability has little effect on reservoir operations at extremes because the active storage volume within each Project reservoir is small.

In addition, the Project reservoirs typically operate across the entire operations range over the course of a water year and, in some cases, much more frequently. This is another consequence of the small storage volume, which allows the reservoir to refill quickly under most macro-hydrologic conditions. In wet years, it is more likely that available river flows exceed power-house total turbine hydraulic capacities[8] in such a way that some or all Project reservoirs will spill, sending additional flows through the downstream bypass reaches. In drier years, peaking operations will be more frequent to maximize power production at peak times of day. Ramping rates and minimum flows are regulated and adhered to. Except in run-of-river conditions, reservoir discharges are balanced to avoid releasing more flow than turbines can handle.

5.7.4.1 Link River

Flow-Related Operations in Link River

The Link River reach includes the relatively short 1.2-mile reach of the Klamath River from Link River dam (RM 254.3) to the inlet to Lake Ewauna (about RM 253.1). Link River dam is located at the outlet from Upper Klamath Lake. USBR owns the dam and PacifiCorp operates it, as specified by USBR. Link River dam operates principally to maintain Upper Klamath Lake elevations and to provide needed instream flows in the Klamath River downstream of Iron Gate dam. Link River dam also provides control for diversion of flow to USBR's Klamath Irrigation Project and to PacifiCorp's East Side and West Side powerhouses.

The East Side powerhouse is operated continuously at a constant discharge from Upper Klamath Lake, as specified by USBR. The powerhouse generates power with flows provided from Upper Klamath Lake to meet downstream needs, including USBR's Klamath Irrigation Project and ESA flows downstream of Iron Gate dam. The exception to this type of operation is during late July into October when the powerhouse operates in a diurnal fashion, reducing flows through the powerhouse at night to 200 cfs, and the West Side facility is shut down. This operation minimizes potential entrainment of ESA-listed Lost River and shortnose suckers.

The East Side powerhouse has a single vertical Francis turbine with a hydraulic capacity of about 975 cfs. The West Side powerhouse is operated when outflows from Upper Klamath Lake requested by USBR exceed about 1,300 cfs (the sum of the hydraulic capacities of East Side and West Side, and the minimum instream flow below Link River dam). Under these conditions, West Side is generally operated at a fixed discharge (full gate, about 250 cfs) for an extended period. The West Side powerhouse has a single horizontal Francis turbine with a hydraulic capacity of about 250 cfs. Under cooperative agreement with ODFW, a minimum flow of at least 90 cfs is currently maintained in Link River between Link River dam and the East Side powerhouse. PacifiCorp currently maintains a minimum flow of 450 cfs in Link River below the East Side powerhouse. Maximum ramping rates are 100 cfs per 30 minutes when flows are 500 to 1,500 cfs, 50 cfs per 30 minutes when flows are 300 to 500 cfs, and 20 cfs per 5 min when flows are less than 300 cfs. These rates are stipulated by the 2001 Biological Opinion on ESA consultation for shortnose and Lost River suckers.

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[8] Powerhouse total turbine hydraulic capacities at Project facilities on the Klamath River are approximately as follows: Iron Gate – 1,735 cfs, Copco 1 and 2 – 3,200 cfs, J.C. Boyle – 2,850 cfs, East Side – 1,200 cfs, West Side – 250 cfs.

Flow Conditions in Link River

Upper Klamath Lake's outflow is the dominant flow source to Link River and all downstream reaches through the Project area. Upper Klamath Lake provides a very large active storage volume that can be controlled by Link River dam. Operation of Link River dam using the lake's large active storage volume largely dictates the long-term (annual, seasonal) hydrograph and magnitude of high flow events that pass through the system. This operation is also the predominant means of providing stable instream flows downstream of Iron Gate dam. Characteristics of Upper Klamath Lake and its storage capacity are listed in Table 5.7-5.

Recent annual trends in Upper Klamath Lake elevations and flows in Link River are depicted in Figure 5.7-5. In recent years, Upper Klamath Lake has been operated mostly between lake elevations of about 4,139 and 4,143 feet mean sea level (msl) in response to biological needs of ESA-listed fish species. In prior years, Upper Klamath Lake was operated within a wider range in lake elevations of between about 4,136 and 4,143 feet msl. Even in recent years (when Upper Klamath Lake has been operated between a narrower range of lake elevations in response to biological needs of ESA-listed fish species), the lake makes up 93 percent of the total available active storage upstream of Iron Gate dam. The Keno, J.C. Boyle, Copco, and Iron Gate reservoirs combined account for the remaining 7 percent of the total available active storage upstream of Iron Gate dam (Figure 5.7-6).

Table 5.7-5. Upper Klamath Lake characteristics.

Surface area (acres)	77,593
Maximum / mean depth (feet)	50 / 7.8
Normal full lake elevation (feet msl)	4,143.3
Normal minimum lake elevation (feet msl)	4,136.0
Normal annual operating fluctuation (feet)	7.3
Normal active storage capacity (acre-feet)	486,800
Active storage retention time (days)	
At 500 cfs	490
At 1,100 cfs (≈ mean flow)	223
At 6,000 cfs (extreme event)	41

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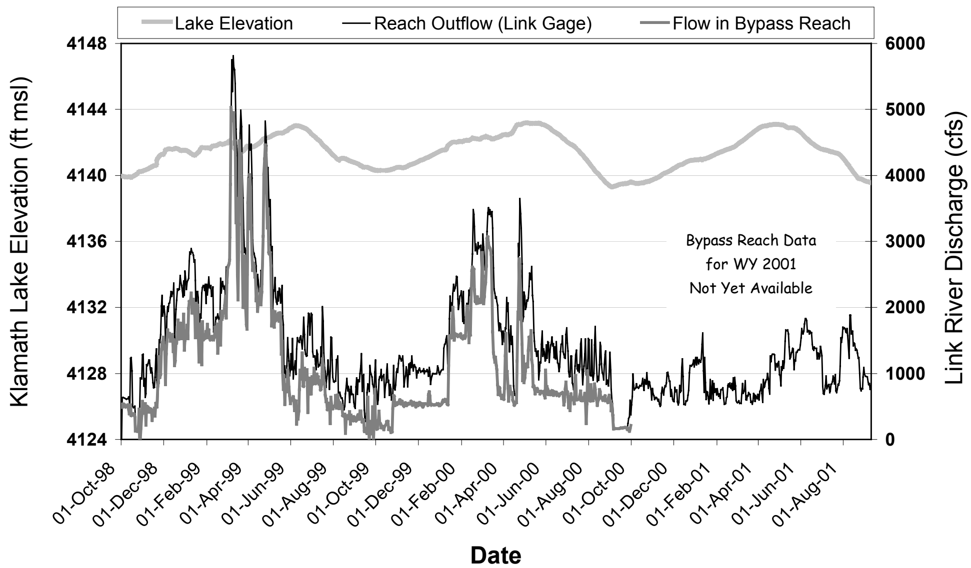

Figure 5.7-5. Daily average Upper Klamath Lake elevation and estimated discharge in Link River for Water Years 1999-2001.

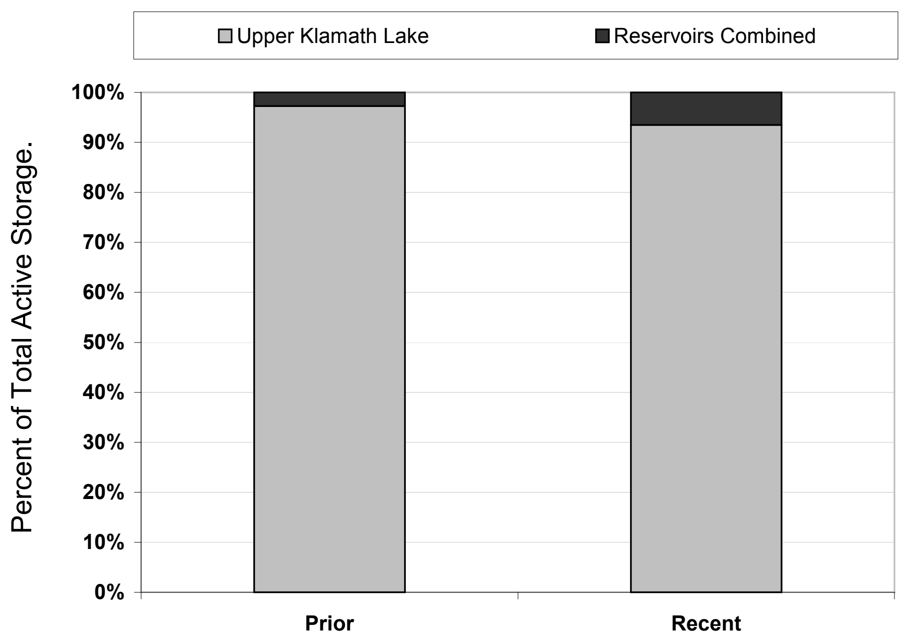

Figure 5.7-6. Percent of total active water storage in Upper Klamath Lake and Project reservoirs (combined) based on operations in recent (1998-present) and prior years.

Annual Trend in Flow Conditions

Annual hydrographs of the 10, 50, and 90 percent exceedance levels of mean daily flows for the period 1967-1999 in the Link River (USGS Gauge No. 11507500) are shown in Figure 5.7-7. The period of highest flows typically occurs during winter and spring, but flows have varied widely in magnitude from year to year during this period. The period of lowest flows occurs in summer and early fall, and year-to-year variation is less during this period.

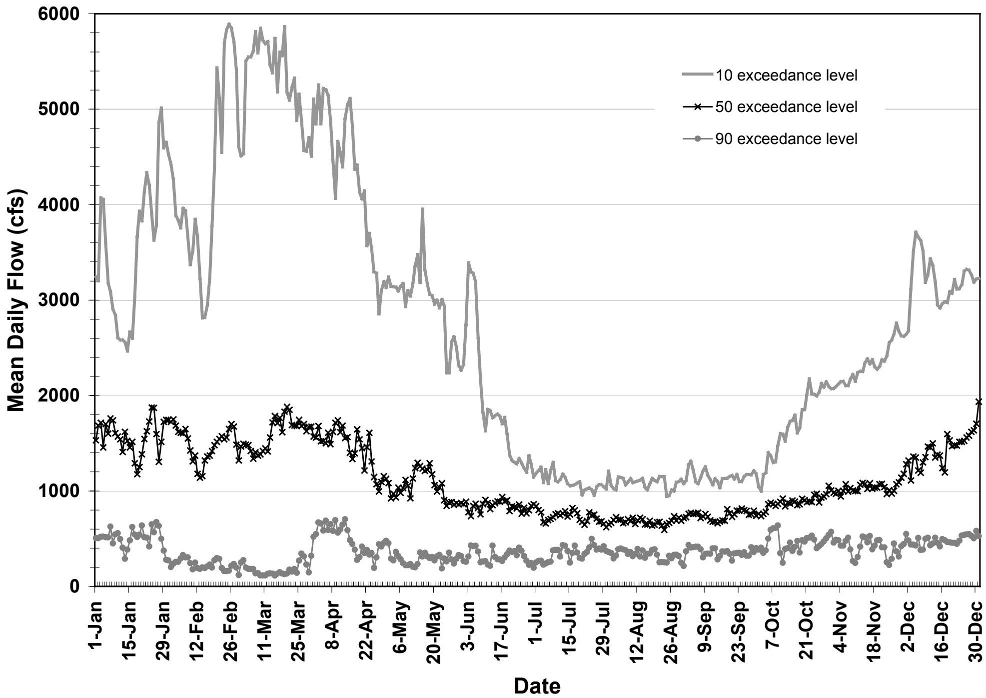

Figure 5.7-7. Annual hydrographs of the 10, 50, and 90 percent exceedance levels of mean daily flows for the period 1967-1999 in the Link River (USGS Gauge No. 11507500).

Annual Peak Flow Conditions

The annual peak flow series for the period of record 1904-present at the Link River USGS gauge (No. 11507500) is shown in Figure 5.7-8. Peak annual flows by return interval and exceedance probability (as estimated using HEC-FFA) are listed in Table 5.7-6. The highest peak flow (9,400 cfs) at the Link River USGS gauge was recorded in May 1904 and represented a near 50-year flood event. Other peak flows in excess of a 10-year event (6,920 cfs) were recorded (in descending order of magnitude) in March 1972, March 1986, April 1974, March 1984, January 1970, January 1997, May 1969, and January 1965.

Peak flows in the Link River bypass reach (Table 5.7-6) are conservatively estimated by simply subtracting the hydraulic capacity of the East Side powerhouse (1,050 cfs) from the values for the gauge location (the gauge is located between the East Side and West Side powerhouse locations). The results indicate that peak flows in the bypass reach are reduced by about 27 percent at the 2-year event, 16 percent at the 10-year event, and 10 percent at the 50-year event.

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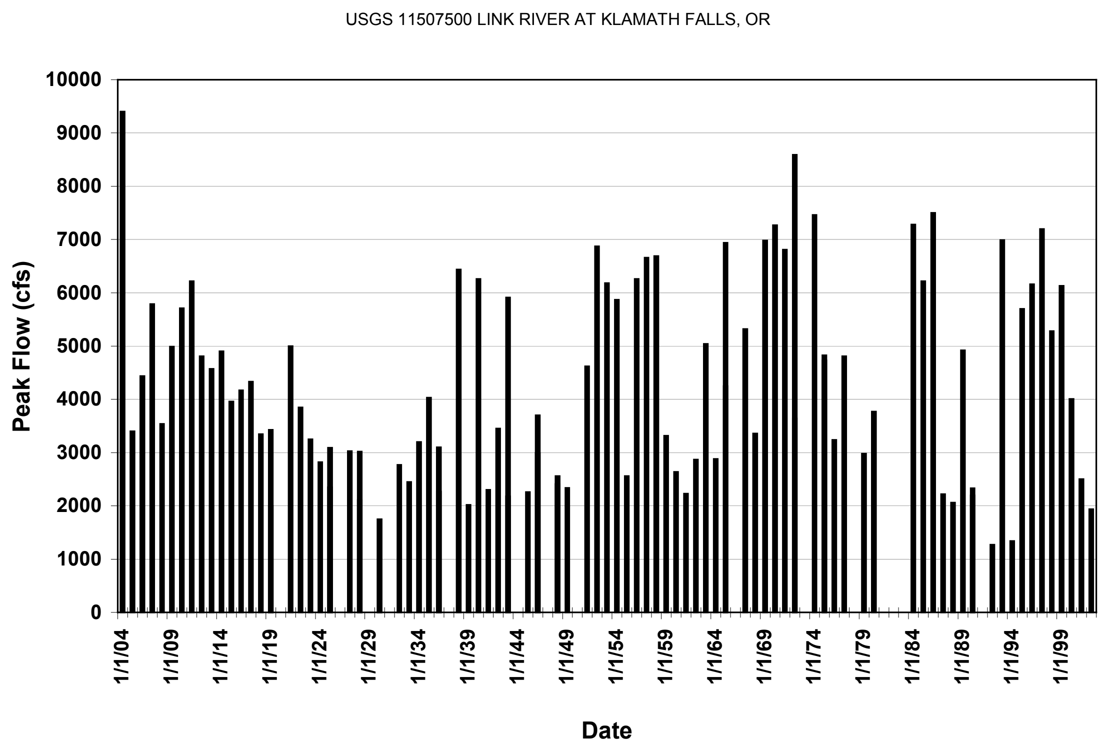

Figure 5.7-8. Peak annual flow series for the period of record 1904-present at the Link River USGS gauge (No. 11507500).

Table 5.7-6. Peak annual flows by return interval and exceedance probability for the Link River USGS gauge (No. 11507500) as estimated using HEC-FFA. Peak annual flows for the Link River bypass reach are conservatively estimated by simply subtracting the hydraulic capacity of the East Side powerhouse (1,050 cfs) from the values for the gauge location.

		Estimated Peak Annual Flows (cfs)	
Return Period (years)	**Exceedance Probability (%)**	**Link River Gauge**	**Link River Bypass (est.)**
100	1.0	11,000	9,950
50	2.0	9,740	8,690
20	5.0	8,130	7,080
10	10.0	6,920	5,870
5	20.0	5,690	4,640
2	50.0	3,890	2,840
1.25	80.0	2,630	1,580

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Annual Low Flow Conditions

The low flow frequency statistics for the daily flow period of record 1961-present at the Link River USGS gauge (No. 11507500) are listed in Table 5.7-7. Flows listed are averaged over the number of days in the first column of the table. This corresponds to the xQy notation. For example, for Link River, the 7Q10 (the 7-day average low flow that occurs every 10 years) is 92 cfs, corresponding to the 7-day flow with a 10 percent chance of occurrence every year.

Table 5.7-7. Annual low flow (cfs) statistics for the Link River USGS gauge (No. 11507500) as estimated using DFLOW 3.

	Annual Percent Chance of Occurrence			
Days	**50**	**20**	**10**	**5**
1	161	96.3	73.3	58.4
3	182	107	79.9	62.8
5	196	114	85.6	67.8
7	215	123	92.1	72.6
30	394	247	188	148

Flow Changes

Changes in rate of flow and water level (i.e., stage) in Link River are examined and described as part of the analysis of flow ramping effects on fish in the Aquatics FTR.

5.7.4.2 Keno

Flow-Related Operations at the Keno Development

Lake Ewauna/Keno reservoir is formed by Keno dam on the Klamath River at approximately RM 233. Lake Ewauna proper is a wide, relatively shallow body of water extending from about RM 251 to 253, while Keno reservoir is a narrower reach between RM 233 and 251. The impoundment, formed in 1967, is approximately 20 miles in length.

Keno is a reregulating facility with no generating capability. It is operated as a diversion dam to control Keno reservoir for agricultural diversions by USBR's Klamath Irrigation Project. PacifiCorp has a cooperative agreement with ODFW for a minimum instream flow release of 200 cfs from Keno dam. There is currently no required FERC ramp rate below Keno dam. However, PacifiCorp manages flow ramp rates to no more than 500 cfs per hour or 9 inches per hour.

Because the Keno facility is operated to maintain Keno reservoir at an approximately constant elevation, reservoir levels rarely fluctuate more than 0.5 foot seasonally (Table 5.7-8 and Figure 5.7-9). The steady reservoir elevation allows USBR to manage its irrigation water through its diversion channels from Keno reservoir, and enables PacifiCorp to more effectively plan downstream load following operations at the J.C. Boyle powerhouse . The reservoir may be drawn down a few feet for 1 to 2 days each year (usually during March-April) to allow irrigators

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to access pumps and canals for maintenance. Because of relatively small active storage, Keno reservoir has a modest effect on the general shape and trend of annual hydrographs (Figure 5.7-9). Characteristics of Lake Ewauna/Keno reservoir and its storage capacity are listed in Table 5.7-9.

Table 5.7-8. Keno reservoir water surface elevation exceedance based on six recent water years of hourly data (1991, 1992, 1994, 1997, 1998, and 1999).

Exceedance Level (%)	Water Surface Elevation (ft)
Maximum	4,086
10	4,085.62
25	4,085.54
50	4,085.45
75	4,085.34
90	4,085.15
Minimum	4,085

Inflows within the Lake Ewauna/Keno reservoir reach include releases from Upper Klamath Lake, municipal wastewater discharges, industrial discharges, and agricultural return flow, as well as natural inflow from adjacent areas (Figure 5.7-10, Table 5.7-10). Agricultural returns consist primarily of two point sources: the Lost River diversion canal (RM 249.7) and the Klamath Straits Drain (RM 240.2). Principal diversions include the Lost River diversion canal, North canal, and ADY canal. The Lost River diversion canal can discharge water to the Klamath River as well. Link River inflow makes up just under 80 percent of the total inflow, and agricultural returns account for about 20 percent. Municipal and industrial inflows are about 1 percent. Inflow quantities may vary widely on a day-to-day or week-to-week basis.

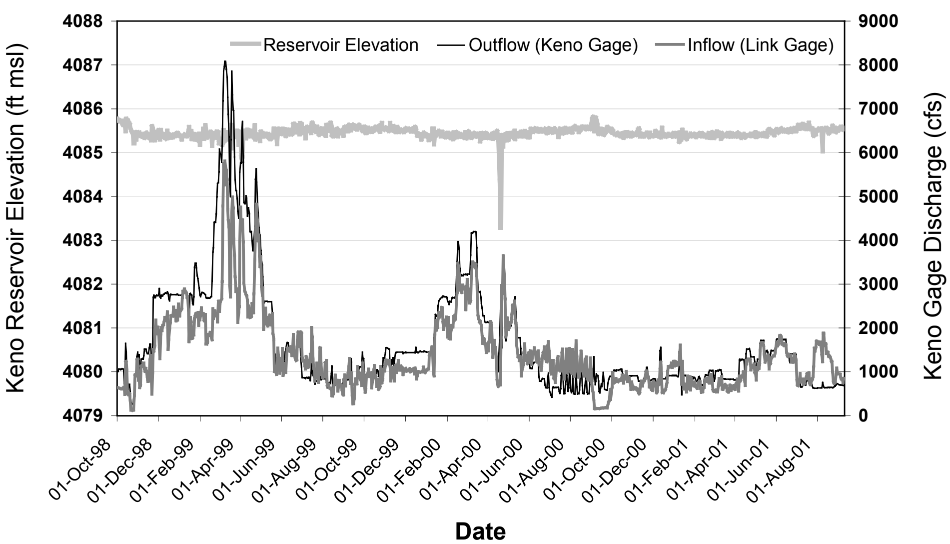

Figure 5.7-9. Daily average Keno reservoir elevation and estimated reservoir inflow and outflow for Water Years 1999-2001.

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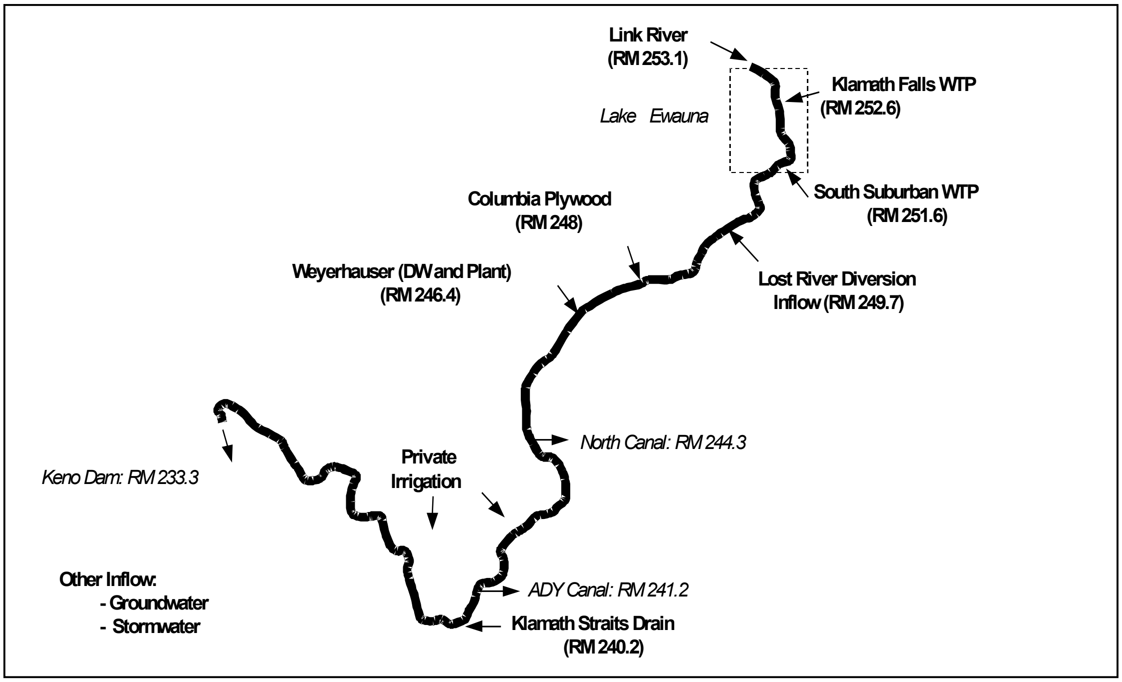

Figure 5.7-10. Lake Ewauna/Keno reservoir inflow locations.

Table 5.7-9. Lake Ewauna/Keno reservoir physical and operational characteristics.

Impoundment length (miles)	20.1	Normal full pool elevation (feet msl)	4.086
Impoundment length (RM)	233-253.1	Normal minimum pool elevation (feet msl)	4,085
Surface area (acres)	2,475	Normal annual operating fluctuation (feet)	1.0
Maximum/mean depth (feet)	20/7.5	Average daily operating fluctuation (feet)	0.5
Total storage capacity (acre-feet)	18,500	Normal active storage capacity (acre-feet)	2,475 (est.)
Total retention time (days)		Active storage retention time (days)	
At 710 cfs	13	At 710 cfs	1.7
At 1,600 cfs (≈ mean flow)	6	At 1,600 cfs (≈ mean flow)	0.8
At 10,000 cfs (extreme event)	1	At 10,000 cfs (extreme event)	0.1

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Table 5.7-10. Lake Ewauna/Keno reservoir inflow locations and quantities.

Inflows	RM	Representative Flow*	% of Total*
Link River	253.1	800	77.8
Klamath Falls WTP	252.6	4.5	0.4
South Suburban WTP	251.6	2.2	0.2
Lost River Diversion Canal	249.7	100	9.7
Columbia Plywood	248	n/a	-
Weyerhauser (Domestic and Plant)	246.4	2.0	0.2
Klamath Straits Drain	240.2	120	11.7
Private Irrigation	-	n/a	-
Groundwater	-	n/a	-
Stormwater	-	n/a	-
Total		1028.7	100

Source: Values adapted from ODEQ, 1995.

*Based on available flow data, i.e., not including private irrigation return, groundwater, and stormwater.

Flow Conditions in the Keno River Reach

The Keno River reach includes the 5-mile river reach of the Klamath River from Keno dam (RM 233) to the upper end of J.C. Boyle reservoir (about RM 228). The flow conditions in the Keno River reach consist predominantly of releases from Keno dam, as described above and shown in Figure 5.7-9. Because of its relatively small active storage, Keno reservoir has a modest effect on the general shape and trend of the hydrograph of reservoir inflows. Therefore, Keno dam is essentially operated as a run-of-river facility so that inflows to Keno reservoir are passed through Keno dam with little alteration. No significant tributaries enter the reach.

Although Keno reservoir levels are relatively constant (rarely fluctuating more than 0.5 foot) and Keno dam is essentially operated as a run-of-river facility, short-term fluctuations in flow are evident at times (Figure 5.7-11). Such fluctuations are mainly due to the effects of diversions and return flows from the Klamath Irrigation Project.

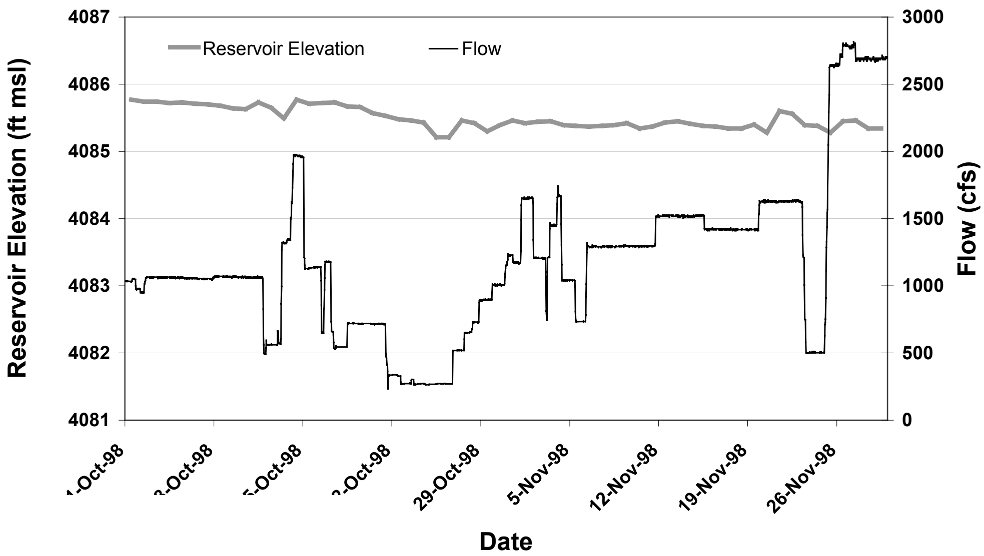

Figure 5.7-11. Keno reservoir elevation and hourly discharge below Keno dam during October and November 1998.

Modeled Project Effects

Graphs of RMA2 model output of hourly flow (cfs) in the Keno reach of the Klamath River (at RM 232.9) are shown for existing conditions, steady flow, and the two without-Project scenarios (WOP and WOP II) in Appendix 5C. Of the four scenarios, the comparison between existing conditions and WOP scenarios shown in those figures best illustrates the effects on flow caused by Project facilities and operations in the Keno reach.[9] Graphs comparing model output of flow for existing conditions and WOP scenarios are shown in Figures 5.7-12 and 5.7-13 for 2000 and 2001 conditions, respectively.

In general, Project facilities and operations have a modest effect on the magnitude, timing, and duration of flow in the Keno reach compared to WOP conditions. Because the water level in the Keno reservoir is generally maintained at a constant level, the reservoir operates in a run-of-river mode whereby the reservoir's outflow mimics its inflow.

Figures 5.7-12 and 5.7-13 reveal some moderation in short-term WOP flow fluctuations under existing operation conditions. The short-term WOP fluctuations are primarily an artifact of various flow inputs to and outputs from Keno reservoir, mainly from Klamath Irrigation Project operations. This moderation in short-term WOP flow fluctuations indicates that Keno reservoir's active storage, although rather limited,[10] provides some dampening of these flow fluctuations.

[9] The comparison of existing conditions and WOP scenarios is used in this analysis as the best comparison for isolating Project effects on flow from both Project facilities (i.e., structures) and their operations. The SF scenario is intended to help assess the effects due to Project operations only. The WOP II scenario was requested by stakeholders. Stakeholders have suggested that, in a real without-Project situation, flow fluctuations at Keno from USBR's Klamath Irrigation Project operations would be discontinued in favor of smoother flow changes. Such smoother flow changes are assumed in the WOP II scenario. However, because the WOP II scenario required significant changes to the model's flow boundary conditions, a comparison of existing conditions and WOP II scenarios includes substantial differences that are not attributable to Project effects. The comparison of existing conditions and WOP II scenarios is thus less useful for isolating Project effects on flow.

[10] Keno reservoir's active storage is only about 2,475 acre-feet. Of this total, only about 1,250 acre-feet are typically used on a daily basis—equivalent to about a half-day's storage at a flow of 1,000 cfs.

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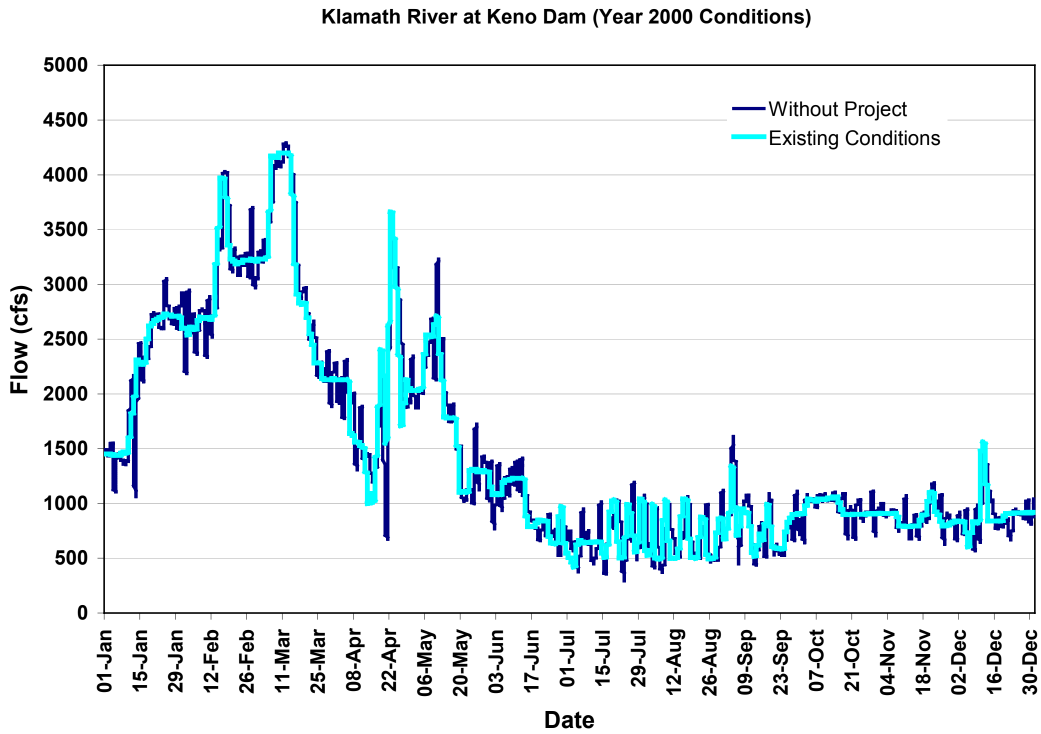


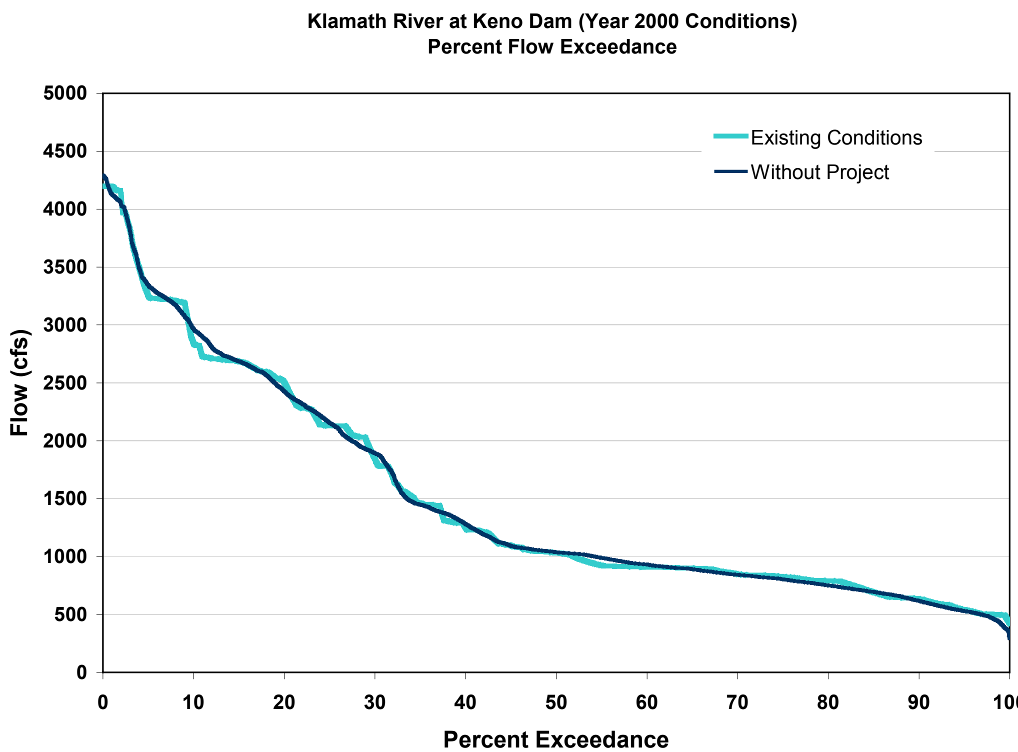
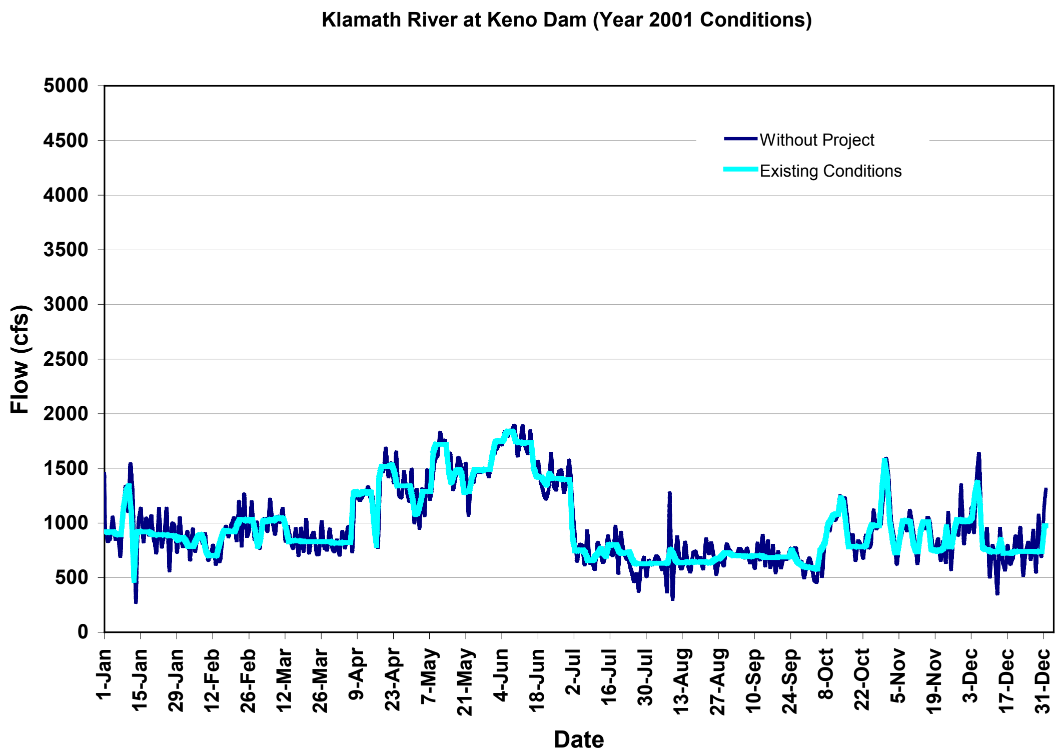


Figure 5.7-12. RMA2 model output of hourly flow for 2000 in the Keno reach of the Klamath River (at Keno dam) for existing conditions and a hypothetical without-Project scenario (WOP). The model output is displayed as an annual time series in the top plot and as a flow duration curve in the bottom plot.



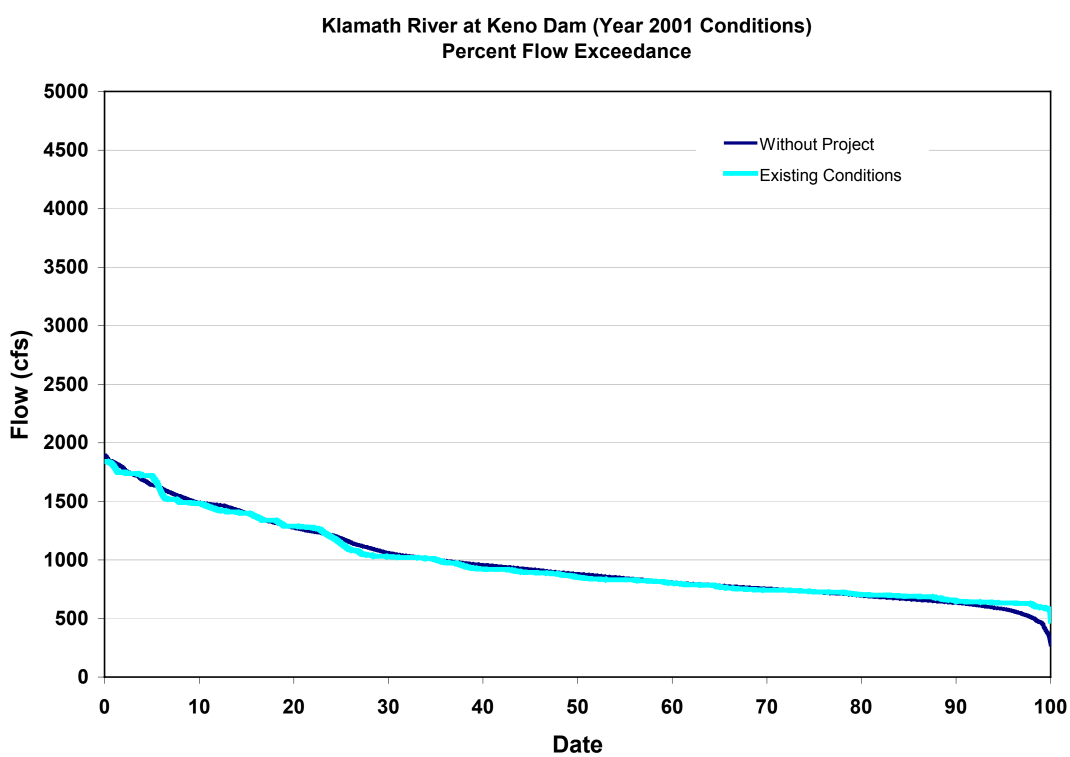


Figure 5.7-13. RMA2 model output of hourly flow for 2001 in the Keno reach of the Klamath River (at Keno dam) for existing conditions and a hypothetical without-Project scenario (WOP I). The model output is displayed as an annual time series in the top plot and as a flow duration curve in the bottom plot.

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Annual Trend in Flow Conditions

Annual hydrographs of the 10, 50, and 90 percent exceedance levels of mean daily flows for the period 1967-1999 in the Klamath River at the Keno USGS gauge (No. 11509500) are shown in Figure 5.7-14. The period of highest flows typically occurs during winter and spring, but flows have varied widely in magnitude from year to year during this period. The period of lowest flows occurs in summer and early fall, and year-to-year variation is less during this period.

Annual Peak Flow Conditions

The peak flow series for the period of record 1904-1913 and 1929-present at the Klamath River at the Keno USGS gauge (No. 11509500) are shown in Figure 5.7-15. Peak annual flows by return interval and exceedance probability (as estimated using HEC-FFA) are listed in Table 5.7-11. The highest peak flow (10,300 cfs) at the Keno USGS gauge was recorded in February 1986 and represented about a near 20-year flood event. Other peak flows in excess of a 10-year event (8,710 cfs) were recorded (in descending order of magnitude) in February 1982, March 1972, January 1997, February 1996, April 1974, December 1983, March 1983, and March 1993.

Annual Low Flow Conditions

The low flow frequency statistics for the daily flow period of record 1904-1913 and 1929-present at the Klamath River at Keno USGS gauge (No. 11509500) are listed in Table 5.7-12. Flows listed are averaged over the number of days in the first column of the table. This corresponds to the xQy notation. For example, for the Klamath River at Keno, the 7Q10 (the 7-day average low flow that occurs every 10 years) is 172 cfs, corresponding to the 7-day flow with a 10 percent chance of occurrence every year.

Flow Changes

Changes in rate of flow and water level (i.e., stage) in the Keno reach of the Klamath River are examined and described as part of the analysis of flow ramping effects on fish in the Aquatics Technical Report.

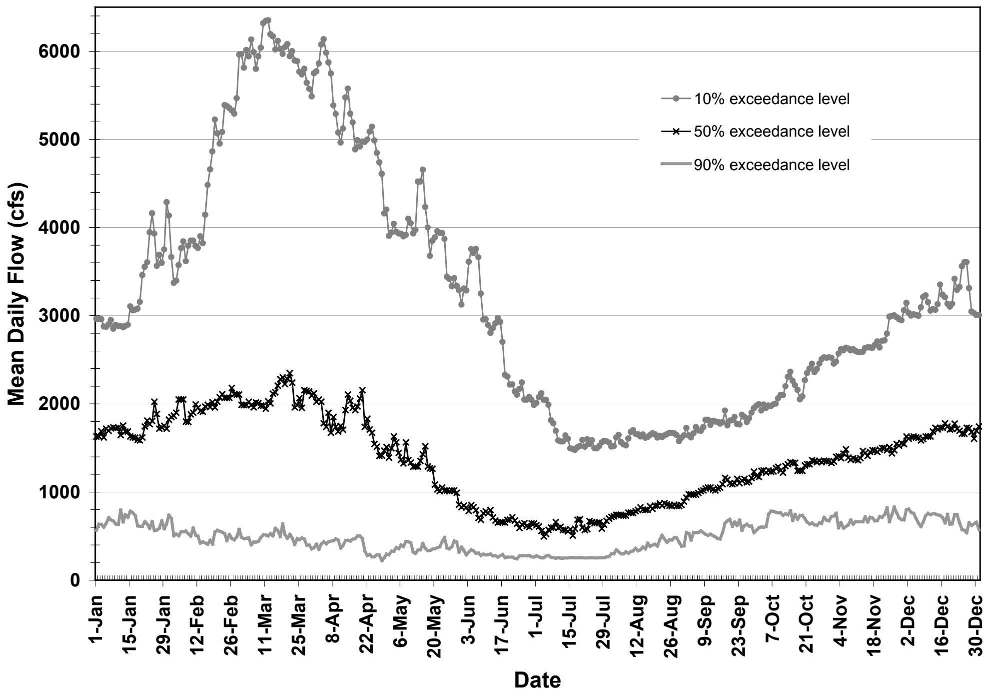

Figure 5.7-14. Annual hydrographs of the 10, 50, and 90 percent exceedance levels of mean daily flows (cfs) for the period 1967-1999 in the Klamath River at Keno (USGS Gauge No. 11509500) .

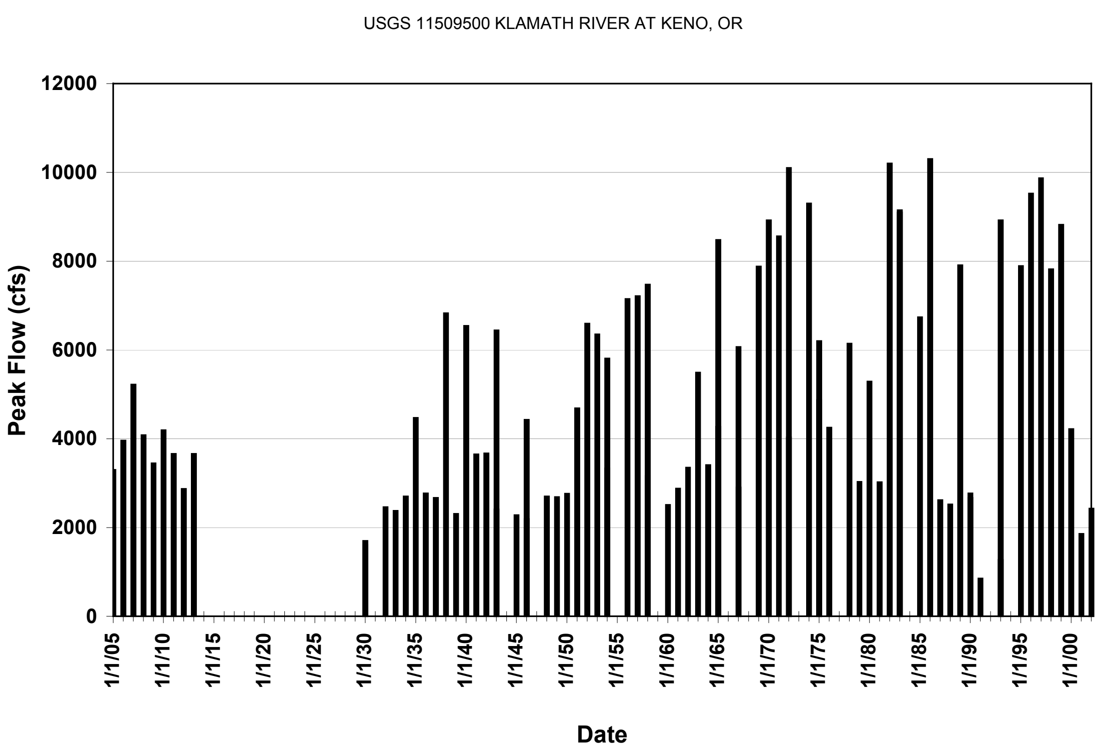

Figure 5.7-15. Peak annual flow series for the period of record 1904-1913 and 1929-present at the Klamath River at Keno USGS gauge (No. 11509500)

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Table 5.7-11. Peak annual flows by return interval and exceedance probability for the Klamath River at Keno USGS gauge (No. 11509500) as estimated using HEC-FFA.

Return Period (years)	Exceedance Probability (%)	Estimated Peak Annual Flows at Keno Gauge (cfs)
100	1.0	14,800
50	2.0	12,900
20	5.0	10,500
10	10.0	8,710
5	20.0	6,920
2	50.0	4,380
1.25	80.0	2,700

Table 5.7-12. Annual low flow statistics for the Klamath River at Keno USGS gauge (No. 11509500) as estimated using DFLOW 3.

	Annual Percent Chance of Occurrence			
Days	**50**	**20**	**10**	**5**
1	300	167	124	96.9
3	350	202	152	121
5	370	216	165	133
7	387	226	172	137
30	468	285	219	176

5.7.4.3 J.C. Boyle

Flow-Related Operations at the J.C. Boyle Development

The J.C. Boyle Development consists of the J.C. Boyle reservoir, dam, and powerhouse. The J.C. Boyle reservoir includes the portion of the mainstem Klamath River from J.C. Boyle dam (RM 224.7) to the upper end of the reservoir (RM 228) near the mouth of Spencer Creek. J.C. Boyle reservoir is the smallest of PacifiCorp's three mainstem reservoirs and has relatively short flow retention rates (about 1 day at the average flow of 1,600 cfs, and about 2.5 days at 700 cfs). Because of its relatively small active storage, J.C. Boyle reservoir has a modest effect on the general shape and peak magnitude of annual hydrographs (Figure 5.7-16). Characteristics of J.C. Boyle reservoir and its storage capacity are listed in Table 5.7-13.

The J.C. Boyle powerhouse is located 4.3 miles downriver from the dam at RM 220.4. The powerhouse is generally operated in a peaking mode when river flows are less than about 3,000 cfs (i.e., hydraulic turbine capacity). This generally occurs throughout the year outside the spring months when flows are highest (Figures 5.7-17). The occurrence of peaking versus—constant generation or spill during the year varies by water year type (see Table 5.7-14). In particularly dry years, peaking can occur nearly year-round.

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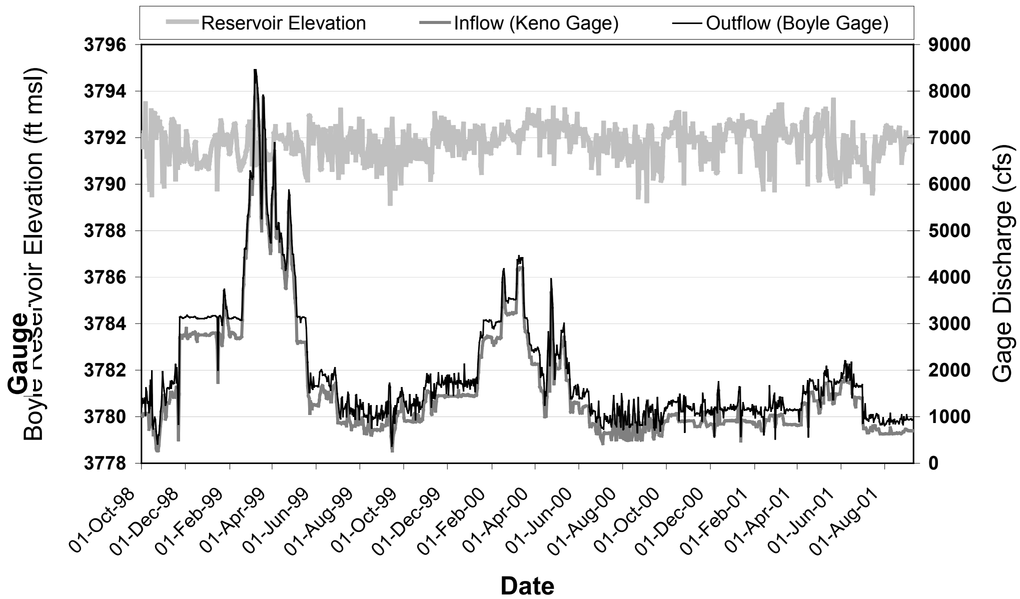

Figure 5.7-16. Daily average J.C. Boyle reservoir elevation and estimated reservoir inflow and outflow for Water Years 1999-2001.

Table 5.7-13. J.C. Boyle reservoir physical and operational characteristics.

Impoundment length (miles)	3.3	Normal full pool elevation (feet msl)	3,793.5
Impoundment length (RM)	224.7-228	Normal minimum pool elevation (feet msl)	3,788.0
Surface area (acres)	420	Normal annual operating fluctuation (feet)	5.5
Maximum / mean depth (feet)	40/8.3	Average daily operating fluctuation (feet)	2.0
Total storage capacity (acre-feet)	3,495	Normal active storage capacity (acre-feet)	1,724
Total retention time (days)		Active storage retention time (days)	
At 710 cfs	2.5	At 710 cfs	1.2
At 1,600 cfs (≈ mean flow)	1.1	At 1,600 cfs (≈ mean flow)	0.5
At 10,000 cfs (extreme event)	0.2	At 10,000 cfs (extreme event)	0.1

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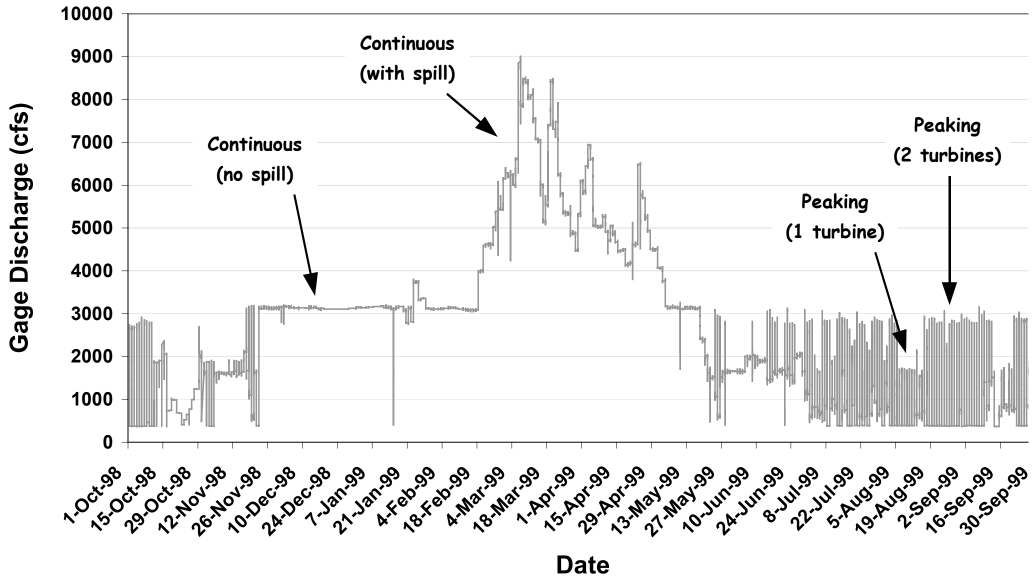

Figure 5.7-17. Hourly discharge below the J.C. Boyle powerhouse during Water Year 1999.

Table 5.7-14. Number of days of J.C. Boyle Development peaking and spill operations by year based on recent water years of hourly data.

Year	Water Year Type (USBR)	No. of Days 1-Unit Peaking	No. of Days 2-Unit Peaking	No. of Days Constant Generation	No. of Days with Spill
1991	Dry	283	35	47	16
1992	Dry	233	2	130	0
1997	Average	93	161	111	86
1998	Above average	12	188	165	122
1999	Wet	21	94	259	101
2000	Average	70	196	99	43
2001	Below average	165	151	49	0

Daily peaking typically occurs when river flows are less than the maximum powerhouse hydraulic capacity of 2,850 cfs, although the typical maximum powerhouse flow is 2,500 cfs to maximize turbine efficiency. During peaking, the reservoir is drawn down to augment inflows and allow operation of the turbine-generators at high loads near peak efficiency (Figure 5.7-18). During off-peak hours, inflows to J.C. Boyle reservoir are stored in the reservoir at night when generation is not occurring, thereby raising the reservoir water level. Daily inflows can be fully regulated with a 2-foot reservoir water level fluctuation. On an annual basis, reservoir levels rarely fluctuate more than about 2.5 feet (Table 5.7-15).

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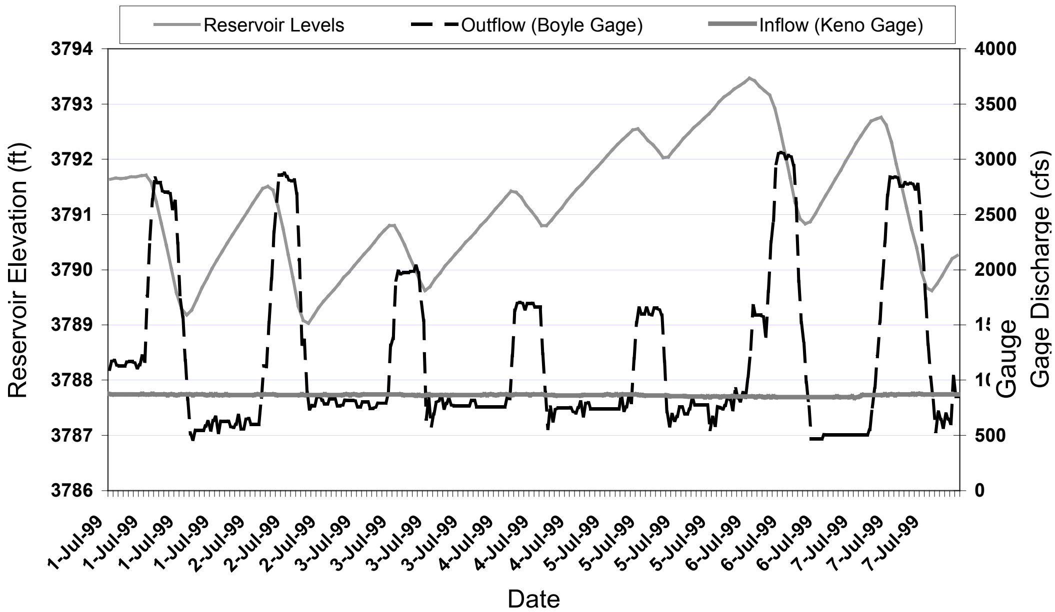


Figure 5.7-18. Hourly J.C. Boyle reservoir elevation and estimated reservoir inflow and outflow during July 1-7, 1999.

Table 5.7-15. J.C. Boyle reservoir water surface elevation exceedance based on six recent water years of hourly data (1991, 1992, 1994, 1997, 1998, and 1999).

Exceedance Level (%)	Water Surface Elevation (ft)
Maximum	3,793.5
10	3,792.5
25	3,792
50	3,791.5
75	3,791
90	3,790
Minimum	3,788

Flow Conditions in the J.C. Boyle Bypass and Peaking Reaches

The reach of the Klamath River between the dam and powerhouse is referred to as the J.C. Boyle bypass reach (RM 220.4 to 224.7). The 16.4-mile river reach of the Klamath River from the J.C. Boyle powerhouse (RM 220.4) to the upper end of Copco reservoir (at about RM 204) is referred to as the J.C. Boyle peaking reach (RM 220.4 to 224.7).

No major tributaries occur in the J.C. Boyle bypass reach. The existing FERC-stipulated minimum flow requirement is 100 cfs at the dam. Natural springs contribute an estimated 200 to 270 cfs (mean of 220 cfs) to the river channel in the bypass reach (Figure 5.7-19). PacifiCorp based these estimates on measurements at the USGS gauge (No. 11510700) just downstream of the J.C. Boyle powerhouse during occasions when the powerhouse was not operating, subtracting 100 cfs from the gauge readings to account for minimum instream flow releases from J.C. Boyle dam.

Several small tributaries occur in the J.C. Boyle peaking reach, but they contribute only a minor amount to the overall flow of the Klamath River. Shovel Creek, a key tributary for trout spawning and rearing, enters the river at about RM 206.4. The minimum flow in the peaking reach is about 320 cfs, consisting of the existing FERC-stipulated minimum flow requirement of 100 cfs in the upstream bypass reach below the dam and spring water accretion. The existing FERC-stipulated maximum flow ramping rate is 9 inches per hour as measured at the USGS gauge (No. 11510700) just downstream of the J.C. Boyle powerhouse.

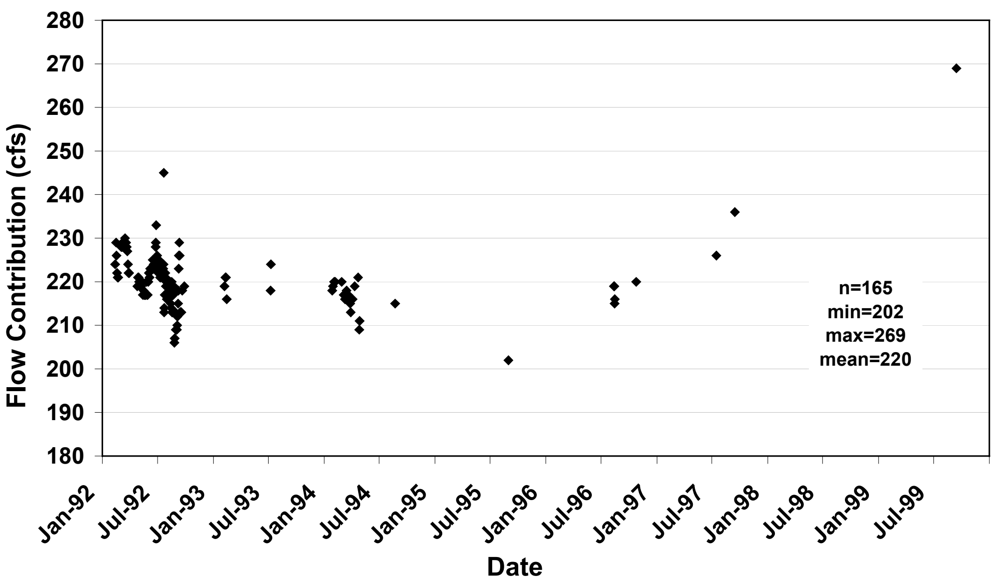
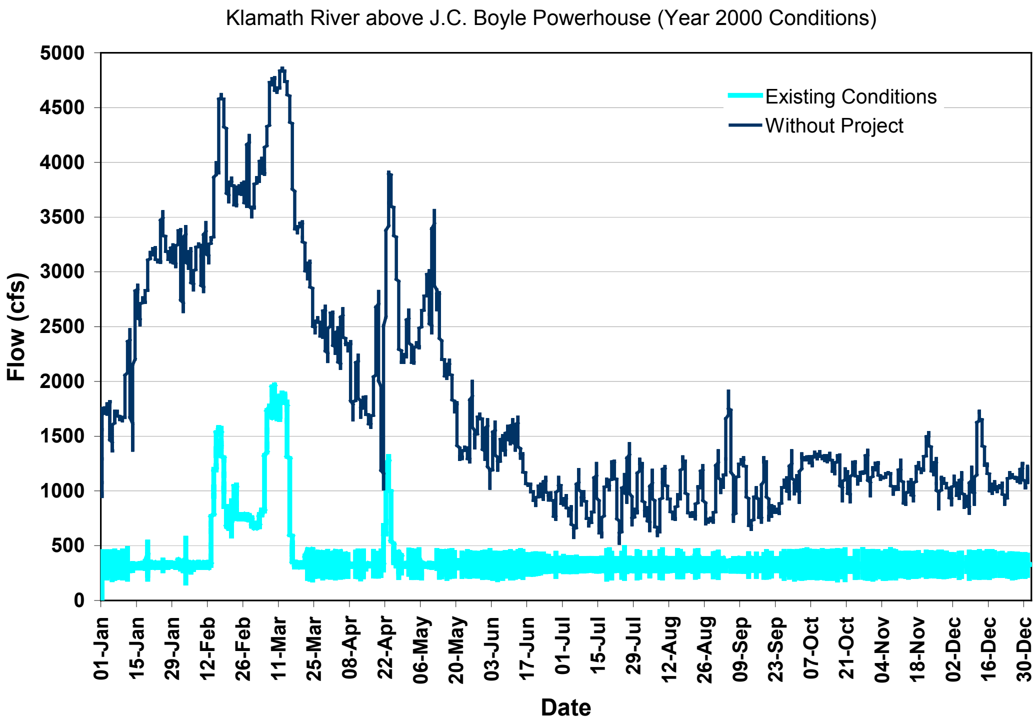


Figure 5.7-19. Estimated flow contribution of springs in the J.C. Boyle bypass reach.

Modeled Project Effects

Graphs of RMA2 model output of hourly flow (cfs) in the J.C. Boyle bypass and peaking reaches of the Klamath River are shown for existing conditions, steady flow, and the two without-Project (WOP and WOP II) scenarios in Appendix 5C. Of the four scenarios, the comparison between existing conditions and WOP scenarios shown in those figures best illustrates the effects on flow caused by Project facilities and operations in the J.C. Boyle bypass and peaking reaches. Graphs comparing model output of flow for existing conditions and WOP scenarios in the J.C. Boyle bypass reach just above the J.C. Boyle powerhouse (RM 221) are shown in Figures 5.7-20 and 5.7-21 for 2000 and 2001 conditions, respectively. Graphs comparing model output of flow for existing conditions and WOP scenarios in the J.C. Boyle peaking reach at Stateline (RM 209.2) are shown in Figures 5.7-22 and 5.7-23 for 2000 and 2001 conditions, respectively.

Figures 5.7-20 and 5.7-21 illustrate the reduction in flows in the J.C. Boyle bypass reach resulting from diversion of flow at J.C. Boyle dam to the power conduit and powerhouse.



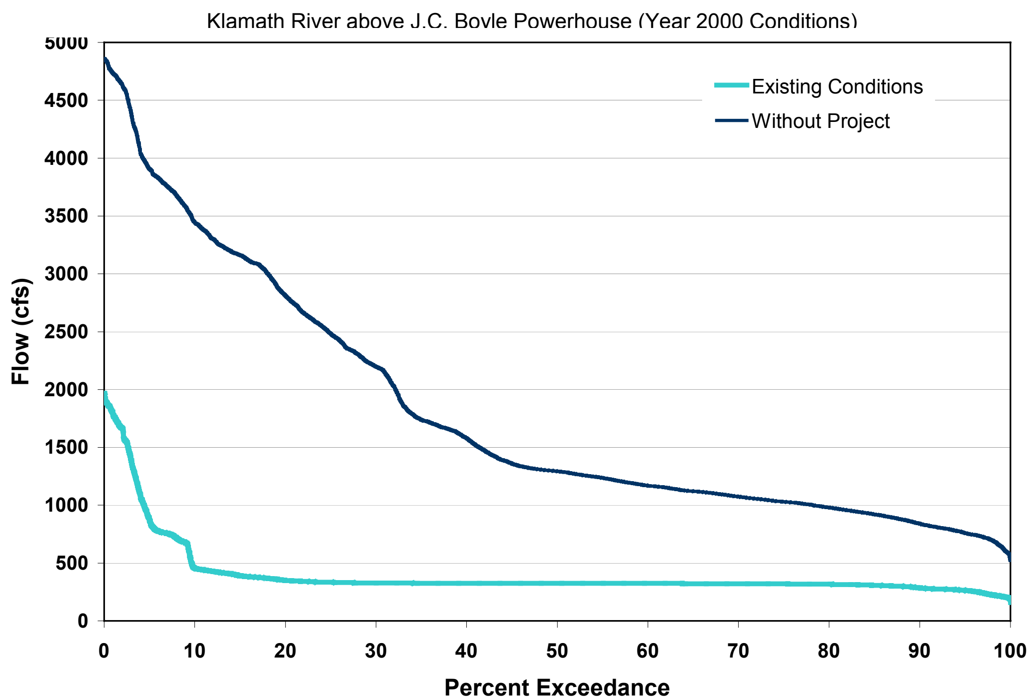


Figure 5.7-20. RMA2 model output of hourly flow for 2000 in the Klamath River above the J.C. Boyle powerhouse for existing conditions and a hypothetical without-Project scenario (WOP). The model output is displayed as an annual time series in the top plot and as a flow duration curve in the bottom plot.

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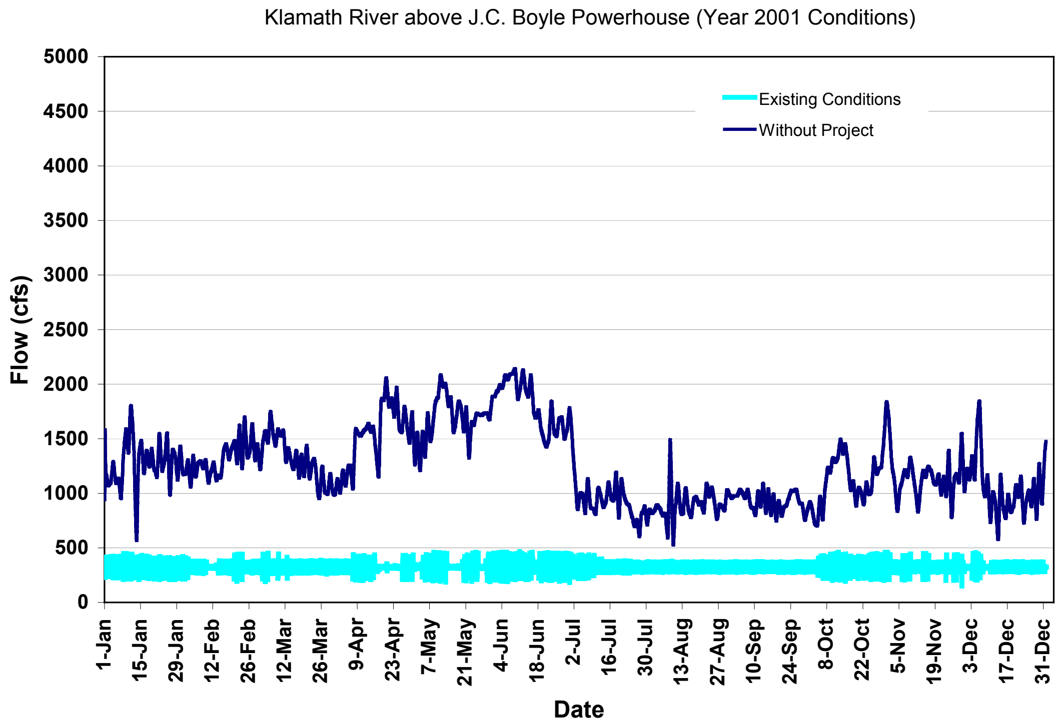

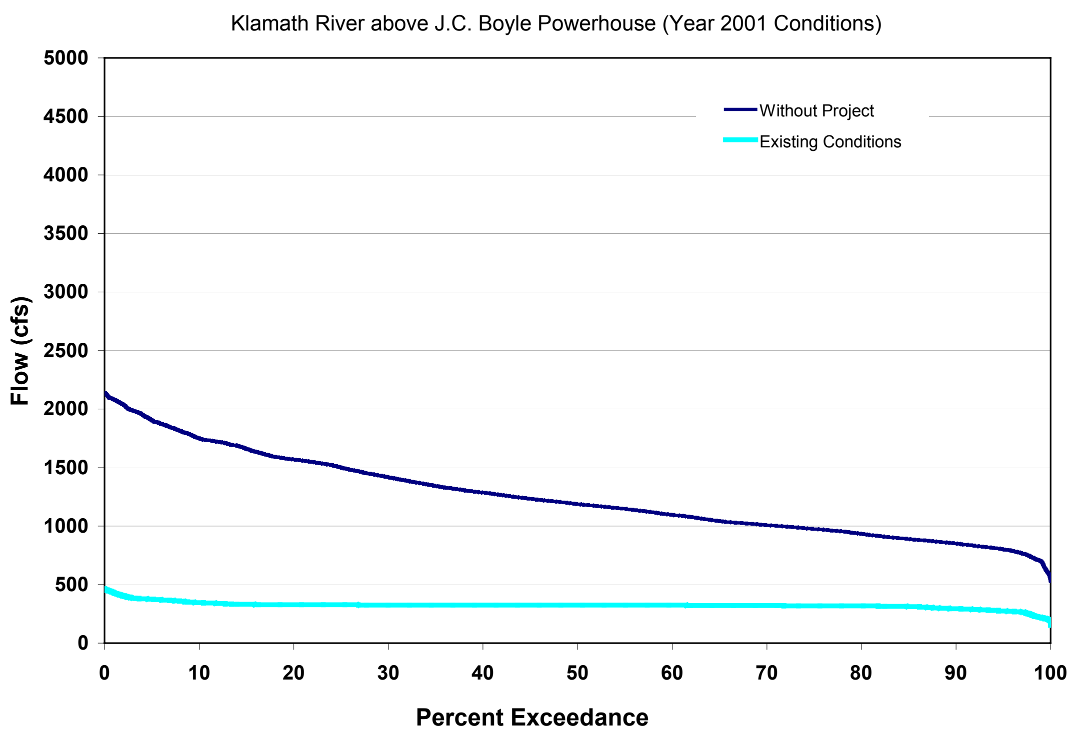

Figure 5.7-21. RMA2 model output of hourly flow for 2001 in the Klamath River above the J.C. Boyle powerhouse for existing conditions and a hypothetical without-Project scenario (WOP). The model output is displayed as an annual time series in the top plot and as a flow duration curve in the bottom plot.

Compared to WOP conditions, the magnitude of this diversion varies from about 300 cfs to 2,800 cfs (the powerhouse hydraulic capacity). During the two modeled years (2000 and 2001), diversion of flow occurred 100 percent of the time. During 2000, spill from J.C. Boyle dam occurred between mid-February and mid-March, resulting in a flow of up to about 2,000 cfs in the lower end of the bypass reach. At all other times in 2000 and throughout 2001, a constant minimum flow occurred in the bypass reach, resulting in a flow of about 325 cfs in the lower end of the bypass reach (comprising an instream flow release of 100 cfs at the dam and about 225 cfs of spring flow accretion).[11]

Figures 5.7-22 and 5.7-23 illustrate the fluctuation in flows in the J.C. Boyle peaking reach under existing conditions from hydropeaking operations at J.C. Boyle powerhouse when river flows are less than about 3,000 cfs. During 2000, river flows exceeded 3,000 cfs from about mid-January through March, during which time the J.C. Boyle powerhouse was generating continuously and spill was occurring from J.C. Boyle dam. During the remainder of 2000, peaking operations occurred. For example, during June through November, peaking occurred daily with flows varying from a base flow of about 325 cfs to generation flows of about 1,500 cfs or 2,800 cfs, depending on whether peaking involved one-turbine or two-turbine operations. During 2001, river flows remained below 3,000 cfs, and peaking operation occurred throughout 2001 except for brief periods in February, April, May, and December. As a result of peaking operations, the magnitude and duration of flows are more variable under existing conditions than under WOP conditions at river flows less than about 3,000 cfs (as shown in bottom plots in Figures 5.7-22 and 5.7-23).

[11] Note that the minimum flows depicted for existing conditions in Figures 5.7-20 and 5.7-21 show a rather consistent “oscillation” between about 250 and 500 cfs. This is due to a temporary backwater effect in the very lower end of the J.C. Boyle bypass reach during hydropeaking generation startup at the J.C. Boyle powerhouse detected by the RMA2 hydrodynamic model.

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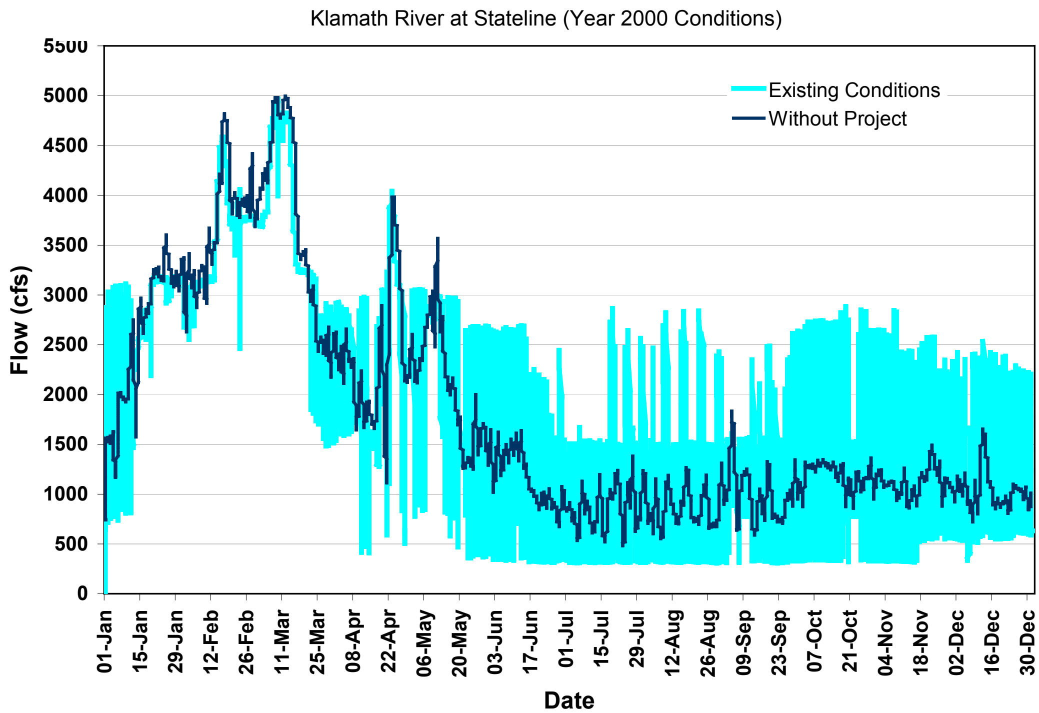


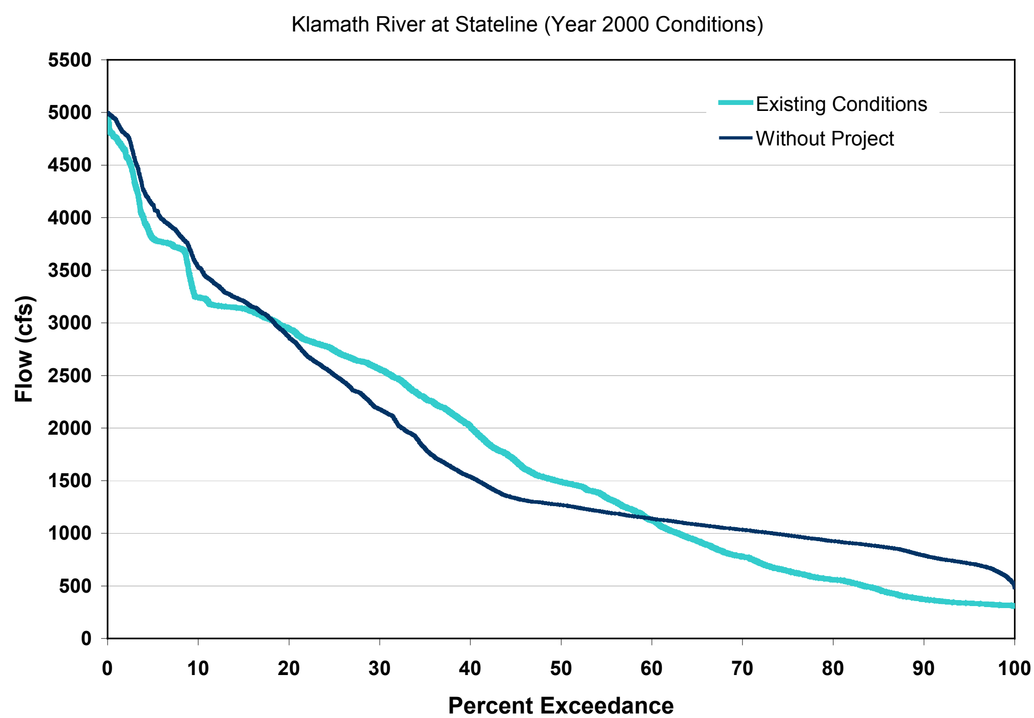
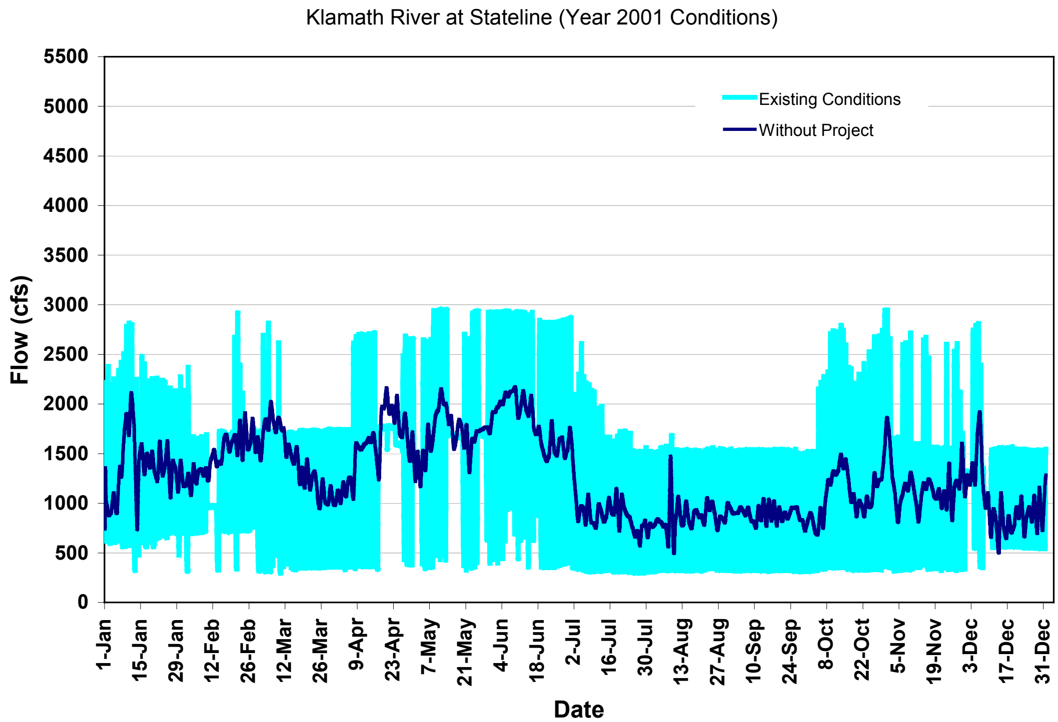


Figure 5.7-22. RMA2 model output of hourly flow for 2000 in the Klamath River at stateline for existing conditions and a hypothetical without-Project scenario (WOP). The model output is displayed as an annual time series in the top plot and as a flow duration curve in the bottom plot.



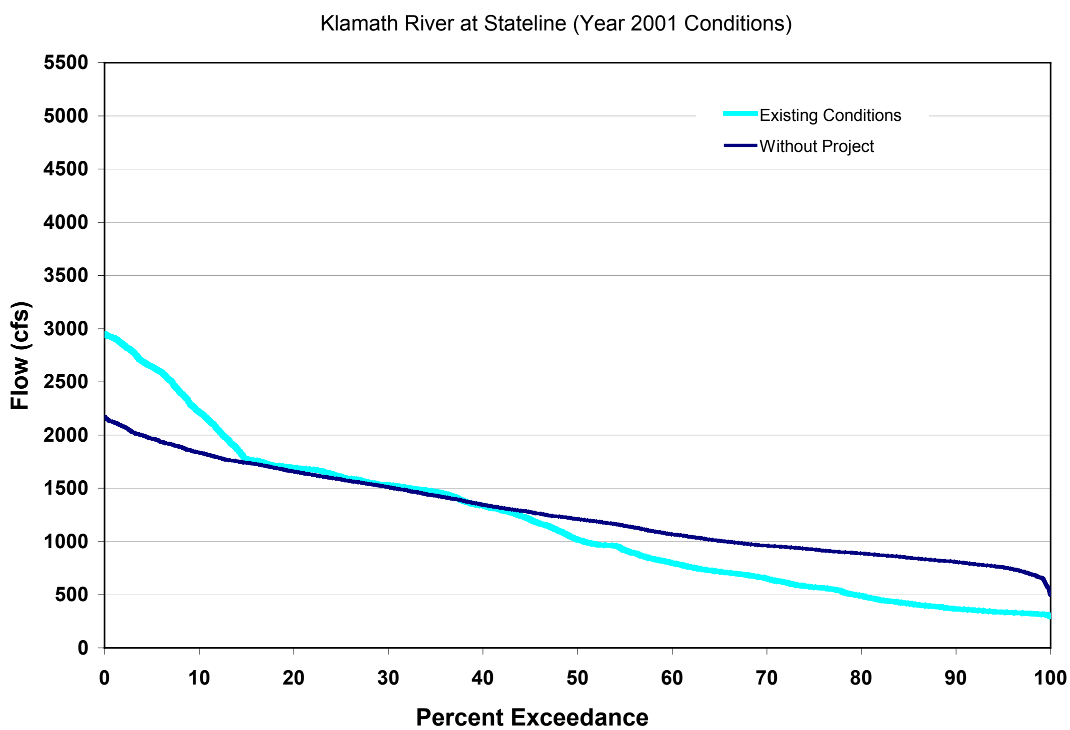


Figure 5.7-23. RMA2 model output of hourly flow for 2001 in the Klamath River at stateline for existing conditions and a hypothetical without-Project scenario (WOP I). The model output is displayed as an annual time series in the top plot and as a flow duration curve in the bottom plot.

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Annual Trend in Flow Conditions

Annual hydrographs of the 10, 50, and 90 percent exceedance levels of mean daily flows for the period 1967-1999 in the Klamath River below the J.C. Boyle powerhouse at USGS Gauge No. 11510700 are shown in Figure 5.7-24. The period of highest flows typically occurs during winter and spring, but flows have varied widely in magnitude from year to year during this period. The period of lowest flows occurs in summer and early fall, and year-to-year variation is less during this period.

Annual Peak Flow Conditions

The peak flow series for the period of record 1959-present at the Klamath River below the J.C. Boyle powerhouse USGS gauge (No. 11510700) are shown in Figure 5.7-25. Peak annual flows by return interval and exceedance probability (as estimated using HEC-FFA) are listed in Table 5.7-16. The highest peak flow (11,600 cfs) at the Klamath River USGS gauge below the J.C. Boyle powerhouse was recorded in February 1996 and represented a near 20-year flood event. Other peak flows in excess of a 10-year event (10,900 cfs) were recorded (in descending order of magnitude) in January 1997 and March 1972.

Peak flows in the J.C. Boyle bypass reach (Table 5.7-16) are conservatively estimated by simply subtracting the hydraulic capacity of the J.C. Boyle powerhouse (2,850 cfs) from the values for the gauge location. The results indicate that peak flows in the bypass reach are reduced by about 52 percent at the 2-year event, 26 percent at the 10-year event, and 17 percent at the 50-year event.

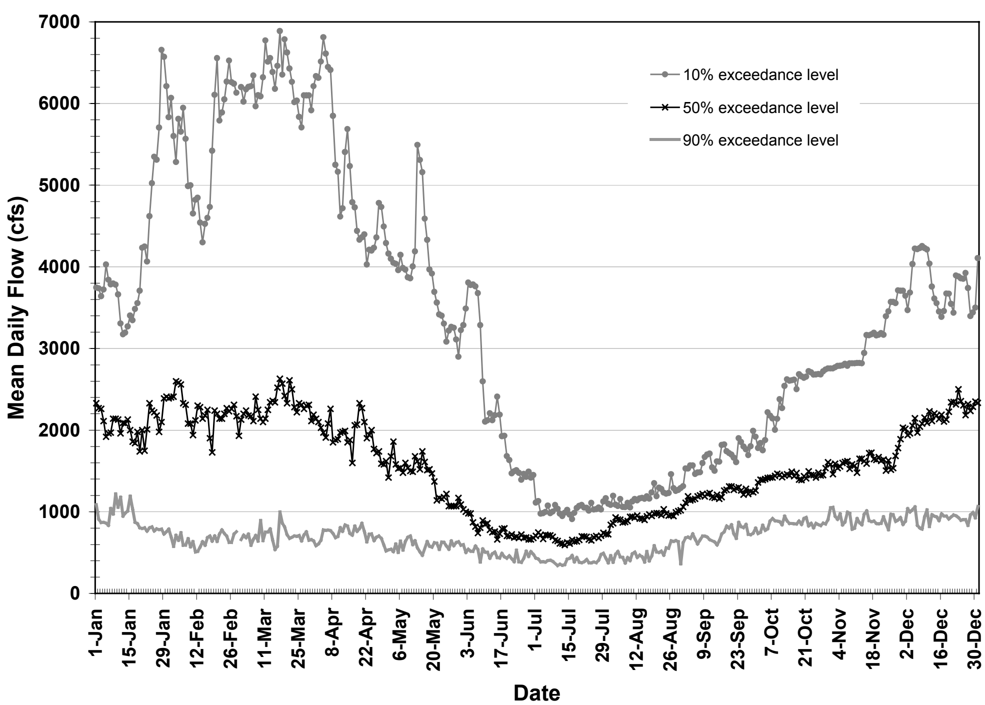

Figure 5.7-24. Annual hydrographs of the 10, 50, and 90 percent exceendance levels of mean daily flows (cfs) for the period 1967-1999 in the Klamath River below the J.C. Boyle powerhouse (USGS Gauge No. 11510700) .

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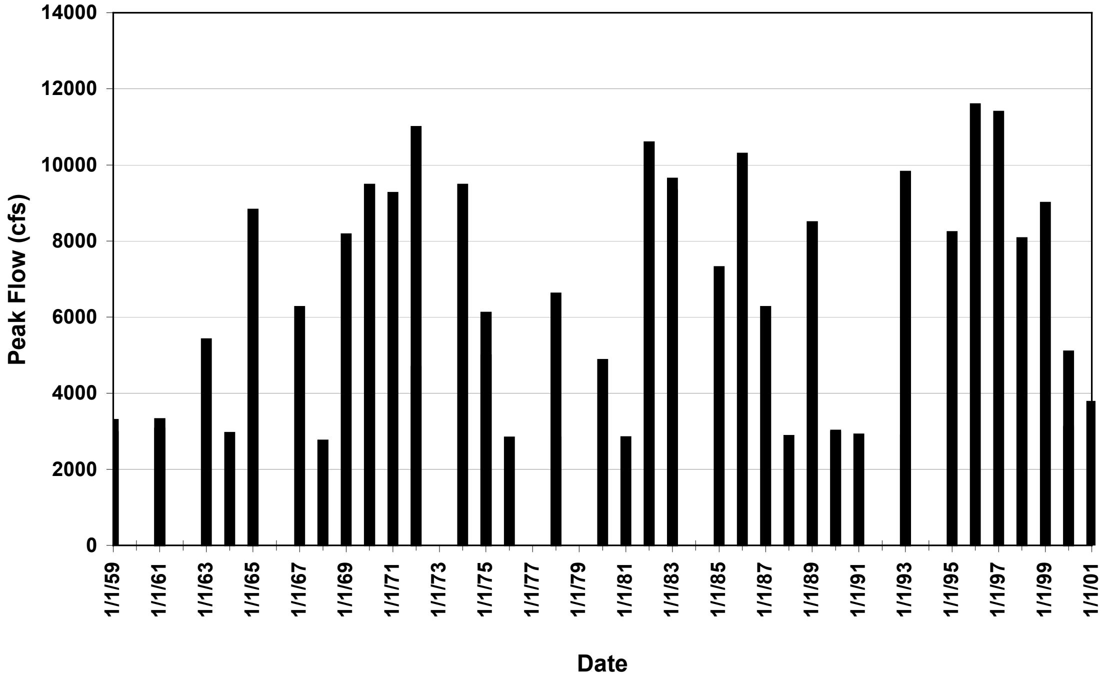

Figure 5.7-25. Peak annual flow series for the period of record 1959-present at the Klamath River below the J.C. Boyle powerhouse (USGS Gauge No. 11510700).

Table 5.7-16. Peak annual flows by return interval and exceedance probability for the Klamath River below the J.C. Boyle powerhouse (USGS Gauge No. 11510700) as estimated using HEC-FFA. Peak annual flows for the J.C. Boyle bypass reach are conservatively estimated by simply subtracting the hydraulic capacity of the J.C. Boyle powerhouse (2,850 cfs) from the values for the gauge location.

		Estimated Peak Annual Flows (cfs)	
Return Period (years)	**Exceedance Probability (%)**	**J.C. Boyle Gauge**	**J.C. Boyle Bypass (est.)**
100	1.0	19,600	16,750
50	2.0	16,800	13,950
20	5.0	13,400	10,550
10	10.0	10,900	8,050
5	20.0	8,640	5,790
2	50.0	5,530	2,680
1.25	80.0	3,540	690

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Annual Low Flow Conditions

The low flow frequency statistics for the daily flow period of record 1959-present at the Klamath River below the J.C. Boyle powerhouse (USGS gauge No. 11510700) are listed in Table 5.7-17. Flows listed are averaged over the number of days in the first column of the table. This corresponds to the xQy notation. For example, for the Klamath River below the J.C. Boyle powerhouse, the 7Q10 (the 7-day average low flow that occurs every 10 years) is 397 cfs, corresponding to the 7-day flow with a 10 percent chance of occurrence every year.

Table 5.7-17. Annual low flow statistics for the Klamath River below the J.C. Boyle powerhouse (USGS Gauge No. 11510700) as estimated using DFLOW 3.

	Annual Percent Chance of Occurrence			
Days	**50**	**20**	**10**	**5**
1	385	316	296	286
3	454	350	317	296
5	520	405	367	343
7	553	436	397	372
30	637	506	460	430

Flow Changes

Changes in rate of flow and water level (i.e., stage) in the J.C. Boyle reaches of the Klamath River are examined and described as part of the analysis of flow ramping effects on fish in the Aquatics FTR.

5.7.4.4 Copco

Flow-Related Operations at the Copco Development

The Copco Development consists of the Copco reservoir, Copco No. 1 dam and powerhouse, the smaller Copco No. 2 diversion pool and dam, and the Copco No. 2 powerhouse. The Copco No. 1 reservoir includes the portion of the mainstem Klamath River from Copco No. 1 dam (RM 198.6) to the upper end of the Copco No. 1 reservoir at about RM 204. Copco No. 1 reservoir typically fluctuates about 6.5 feet annually between normal minimum and full pool elevations (Figure 5.7-26). Because of relatively small active storage, Copco No. 1 reservoir has a modest effect on the general shape and peak magnitude annual hydrograph (Figure 5.7-26). Characteristics of Copco reservoir and its storage capacity are listed in Table 5.7-18.

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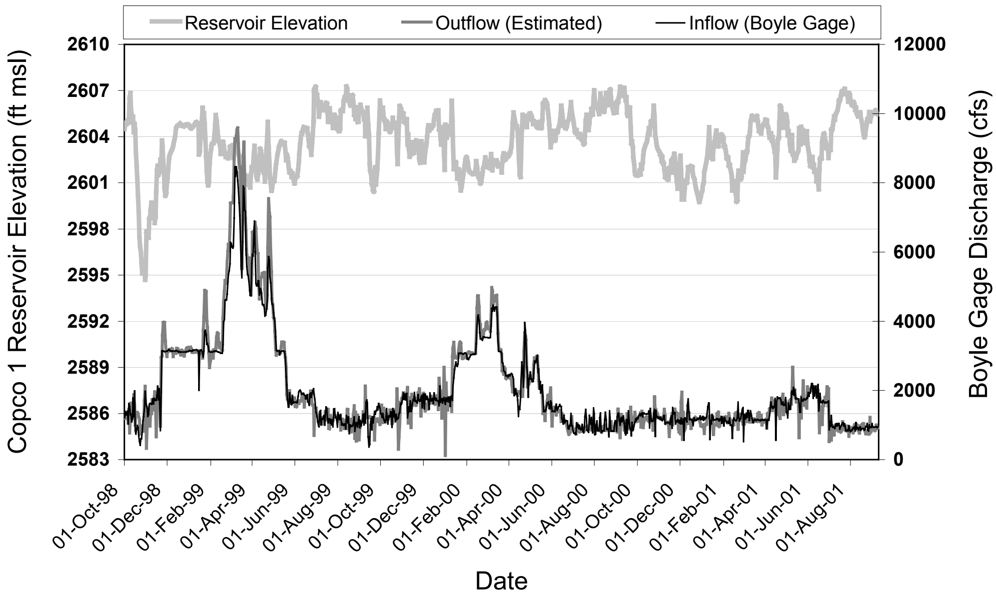

Figure 5.7-26. Daily average Copco No. 1 reservoir elevation and estimated inflow and outflow discharge for Water Years 1999-2001.

Table 5.7-18. Copco No. 1 reservoir physical and operational characteristics

Impoundment length (miles)	5.4	Normal full pool elevation (feet msl)	2607.5
Impoundment length (RM)	198.6-204	Normal minimum pool elevation (feet msl)	2601.0
Surface area (acres)	1,000	Normal annual operating fluctuation (feet)	6.5
Maximum/mean depth (feet)	108 / 47	Average daily operating fluctuation (feet)	0.5
Total storage capacity (acre-feet)	46,867	Normal active storage capacity (acre-feet)	6,235
Total retention time (days)		Active storage retention time (days)	
At 710 cfs	32	At 710 cfs	4.3
At 1,600 cfs (≈ mean flow)	12	At 1,600 cfs (≈ mean flow)	1.6
At 10,000 cfs (extreme event)	2	At 10,000 cfs (extreme event)	0.3

The Copco No. 1 powerhouse is located at the base of Copco No. 1 dam. The powerhouse is generally operated in a peaking mode when river flows are less than about 3,200 cfs (i.e., hydraulic turbine capacity). A more constant generation mode with spill generally occurs during the spring months when river flows exceed about 3,200 cfs (Figures 5.7-26 and 5.7-27). This generally occurs throughout the year outside the spring months when flows are highest (Figure 5.7-27). The occurrence of peaking versus constant generation or spill during the year depends on water year type (Table 5.7-19). In particularly dry years, peaking can occur nearly year-round.

Daily peaking is accomplished by using the storage available in Copco No. 1 reservoir. Off-peak inflows are stored in the reservoir, raising the reservoir water level. During peaking, the reservoir is drawn down to augment inflows and allow operation of the turbine-generators at high loads near peak efficiency (Figure 5.7-28). Peaking operation typically results in a 0.5-foot daily

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fluctuation in reservoir level. On an annual basis, reservoir levels rarely fluctuate more than about 6 feet (Table 5.7-20). One or both of the turbine-generators are typically started in the morning to early afternoon and ramped up to best efficiency or full load output. The unit(s) are maintained at near-constant load, ramped back down later in the day, and shut off at night (Figure 5.7-28).

Copco No. 2 powerhouse operation follows that of Copco No. 1. When river flows are less than about 3,200 cfs, flows in the bypass reach are about 5 to 10 cfs just below Copco No. 2 dam. Copco No. 1 and No. 2 dams spill additional flow to the bypass reach when river flows are greater than about 3,200 cfs. The discharge from Copco No. 2 powerhouse goes directly into the head end of Iron Gate reservoir.

Table 5.7-19. Number of days of Copco development peaking and spill operations by year.

Year	Water Year Type (USBR)	No. of Days 1-Unit Peaking	No. of Days 2-Unit Peaking	No. of Days Constant Generation	No. of Days with Spill
1991	Dry	NA	NA	NA	7
1992	Dry	NA	NA	NA	0
1997	Average	245	89	31	106
1998	Above average	95	224	46	128
1999	Wet	111	237	17	112
2000	Average	15	325	25	59
2001	Below average	6	276	83	0

NA = Not available

Table 5.7-20. Copco reservoir water surface elevation exceedance based on six recent water years of hourly data (1991, 1992, 1994, 1997, 1998, and 1999).

Exceedance Level (%)	Water Surface Elevation (ft)
Maximum	2,607.5
10	2,606.1
25	2,605.0
50	2,604.1
75	2,602.6
90	2,601.8
Minimum	2,601

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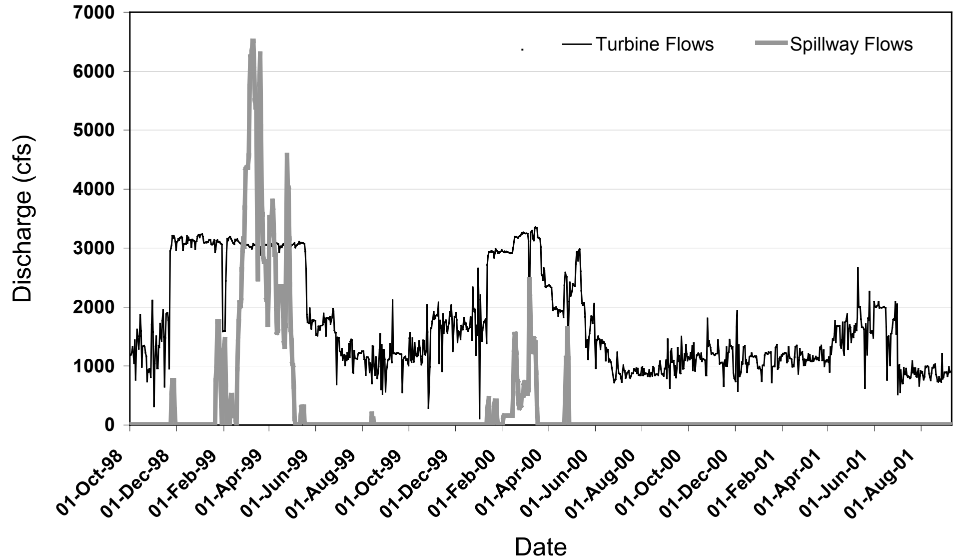

Figure 5.7-27. Daily average spillway and turbine discharges from the Copco No. 1 dam and powerhouse for Water Years 1999-2001.

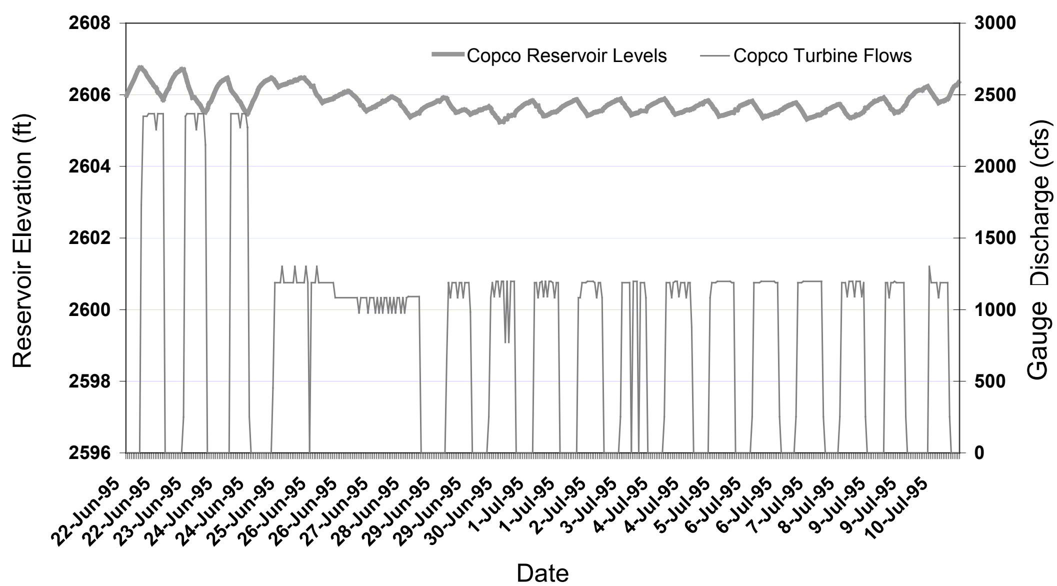

Figure 5.7-28. Hourly Copco No. 1 reservoir elevations and Copco No. 1 powerhouse discharge during June 22-July 10, 1995.

Flow Conditions in the Copco Bypass Reach

The relatively short reach of the Klamath River between Copco No. 2 dam and powerhouse is referred to as the Copco bypass reach (RM 196.8 to 198.3). No major tributaries occur in this Copco bypass reach, and there are no existing instream flow or ramp rate requirements. PacifiCorp maintains a minimum instream flow of 5 to 10 cfs as a standard operating practice.

Modeled Project Effects

Graphs of RMA2 model output of hourly flow (cfs) in the Klamath River at Copco No. 1 dam are shown for existing conditions, steady flow, and the two without-Project scenarios (WOP and WOP II) in Appendix 5C. RMA2 was not used to specifically model the relatively short 1.5-mile Copco bypass reach. Therefore, to represent existing conditions, flows for the bypass reach were estimated by subtracting a continuous diversion of up to 3,200 cfs (i.e., the Copco No. 2 powerhouse hydraulic capacity) from the modeled flows at Copco No. 1 dam. In addition, a minimum instream flow of about 20 cfs was assumed in the bypass reach.

Graphs comparing estimated flow for existing conditions and WOP scenarios in the Copco bypass reach (about RM 197) are shown in Figure 5.7-29 for 2000 (top plot) and 2001 (bottom plot) conditions. Graphs comparing model output of flow for existing conditions and WOP scenarios in the Klamath River just below the Copco No. 2 powerhouse (RM 196.7) are shown in Figure 5.7-30 for 2000 (top plot) and 2001 (bottom plot) conditions. The Klamath River just below the Copco No. 2 powerhouse (RM 196.7) is actually at the head end of Iron Gate reservoir, and therefore is not actually a riverine section.

Figure 5.7-29 illustrates the reduction in flows in the Copco bypass reach from diversion of flow at Copco No. 2 dam to the power conduit and powerhouse. Compared to WOP conditions, the magnitude of this diversion varies up to 3,200 cfs (the Copco No. 2 powerhouse hydraulic capacity). During 2000, spill from Copco No. 1 and No. 2 dams occurred between mid-February and mid-March, resulting in a flow of up to about 2,000 cfs in the bypass reach. At all other times in 2000 and throughout 2001, only the minimum flow occurred in the bypass reach.

Figure 5.7-30 illustrates the fluctuation in flows below the Copco No. 2 powerhouse under existing conditions from hydropeaking operations at Copco No. 2 powerhouse when river flows are less than about 3,200 cfs. During 2000, river flows exceeded 3,200 cfs from about mid-January through March, during which time the Copco No. 2 powerhouse was generating continuously and spill up to about 5,000 cfs was occurring at Copco No. 1 and No. 2 dams. During the remainder of 2000, peaking operations occurred, except for brief periods in early September and November. When peaking operations occurred, the peaking took place daily with flows varying from a base flow of about 20 cfs to generation flows of about 2,600 cfs to 3,000 cfs. During 2001, river flows remained below 3,200 cfs and peaking operations occurred throughout the year except for brief periods in January, May, June, October, and November.

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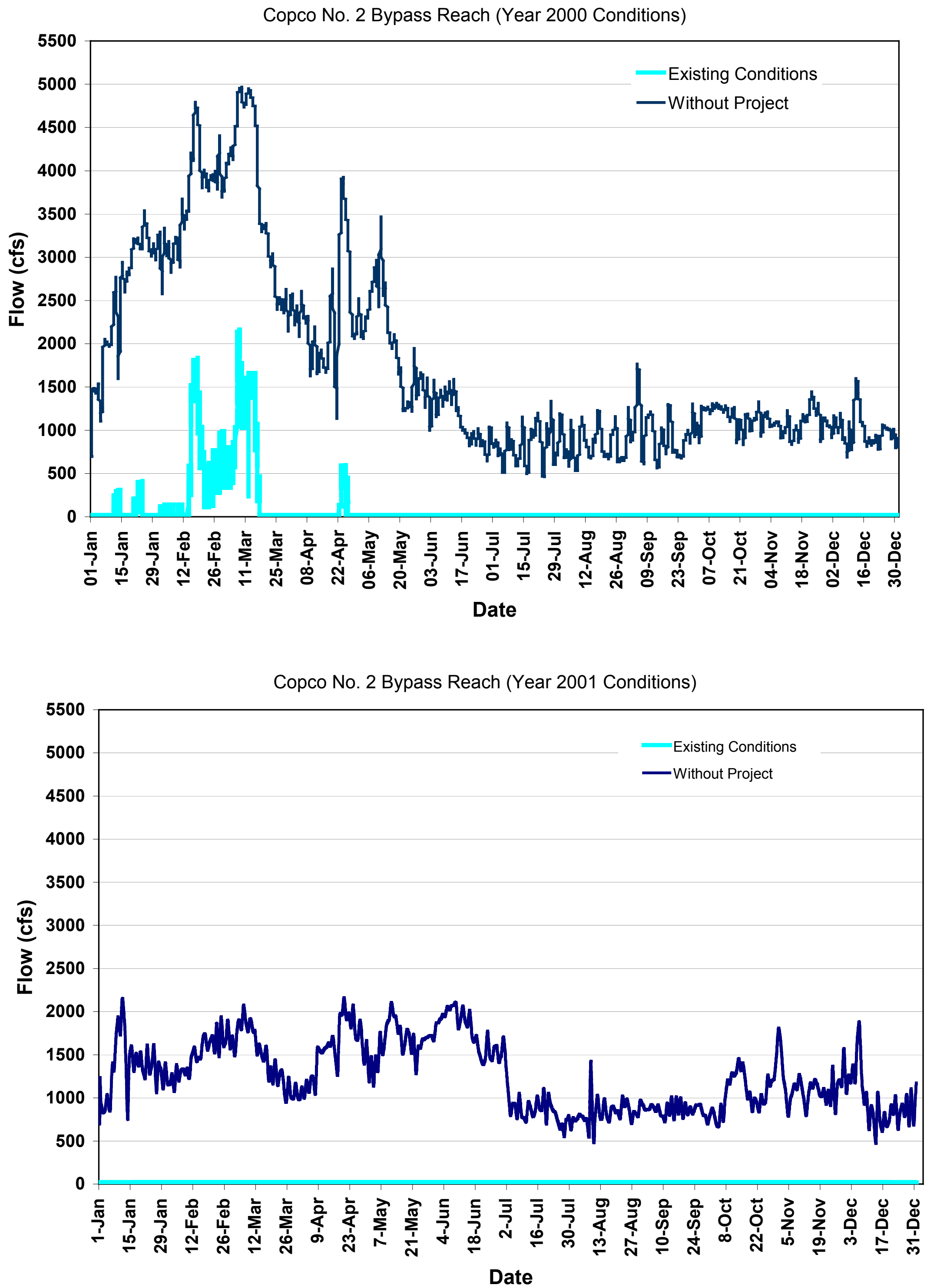

Figure 5.7-29. RMA2 model annual time series output of hourly flow in the Klamath River in the Copco No. 2 bypass reach for 2000 (top plot) and 2001 (bottom plot) for existing conditions and a hypothetical without-Project scenario (WOP).

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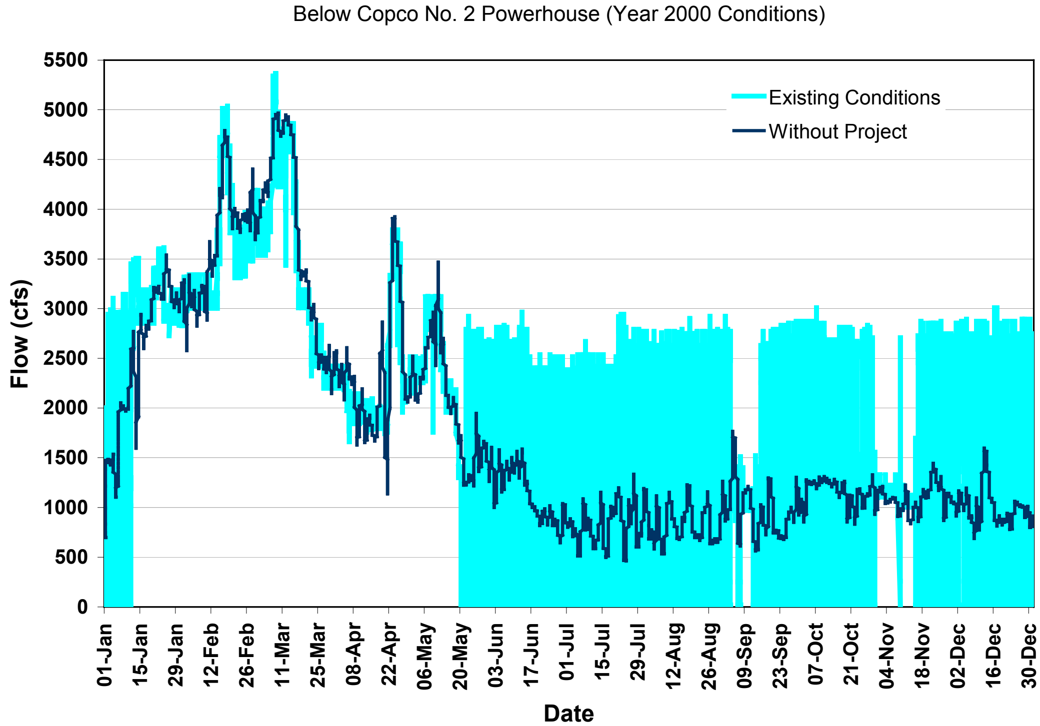

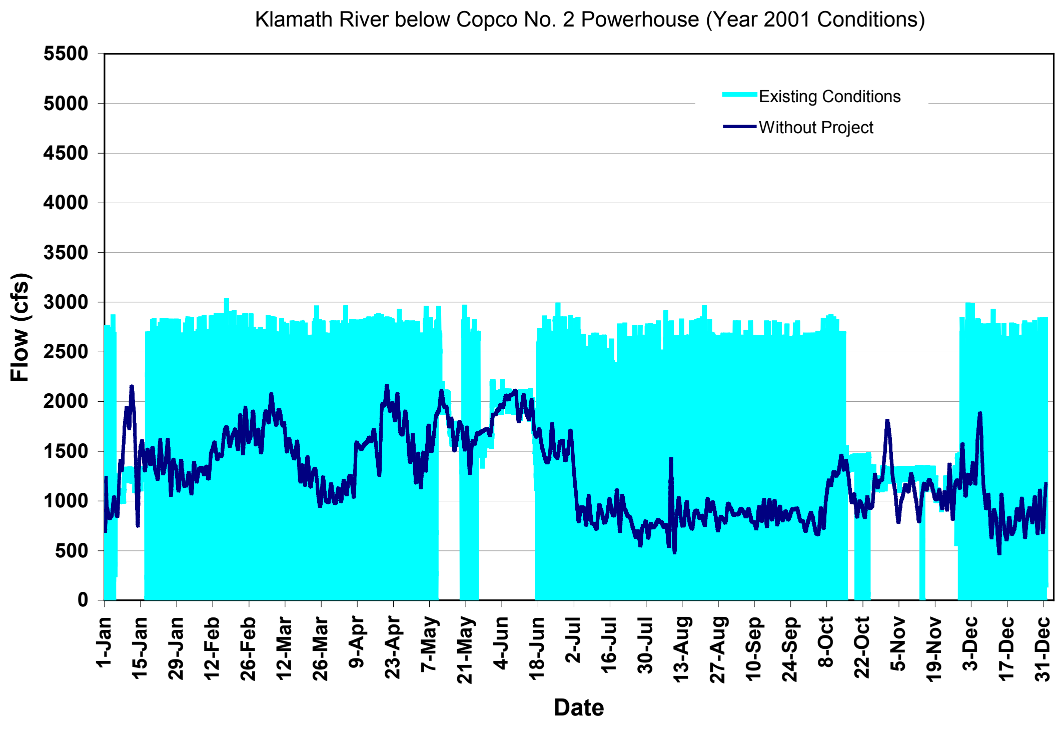

Figure 5.7-30. RMA2 model annual time series output of hourly flow in the Klamath River below the Copco No. 2 powerhouse in 2000 (top plot) and 2001 (bottom plot) for existing conditions and a hypothetical without-Project scenario (WOP).

Annual Peak Flow Conditions

The peak flow series for the period of record 1924-1960 at the Klamath River near the Copco USGS gauge (No. 11512500) are shown in Figure 5.7-31. Peak annual flows by return interval and exceedance probability (as estimated using HEC-FFA) are listed in Table 5.7-21. The highest peak flow (12,000 cfs) at the Klamath River near the Copco USGS gauge was recorded in December 1955 and represented a near 20-year flood event. The only other peak flow in excess of a 10-year event (9,700 cfs) was recorded in April 1938.

Peak flows in the Copco bypass reach (Table 5.7-21) are conservatively estimated by simply subtracting the hydraulic capacity of the Copco No. 2 powerhouse (3,200 cfs) from the values for the gauge location. The results indicate that peak flows in the bypass reach are reduced by about 66 percent at the 2-year event, 33 percent at the 10-year event, and 17 percent at the 50-year event.

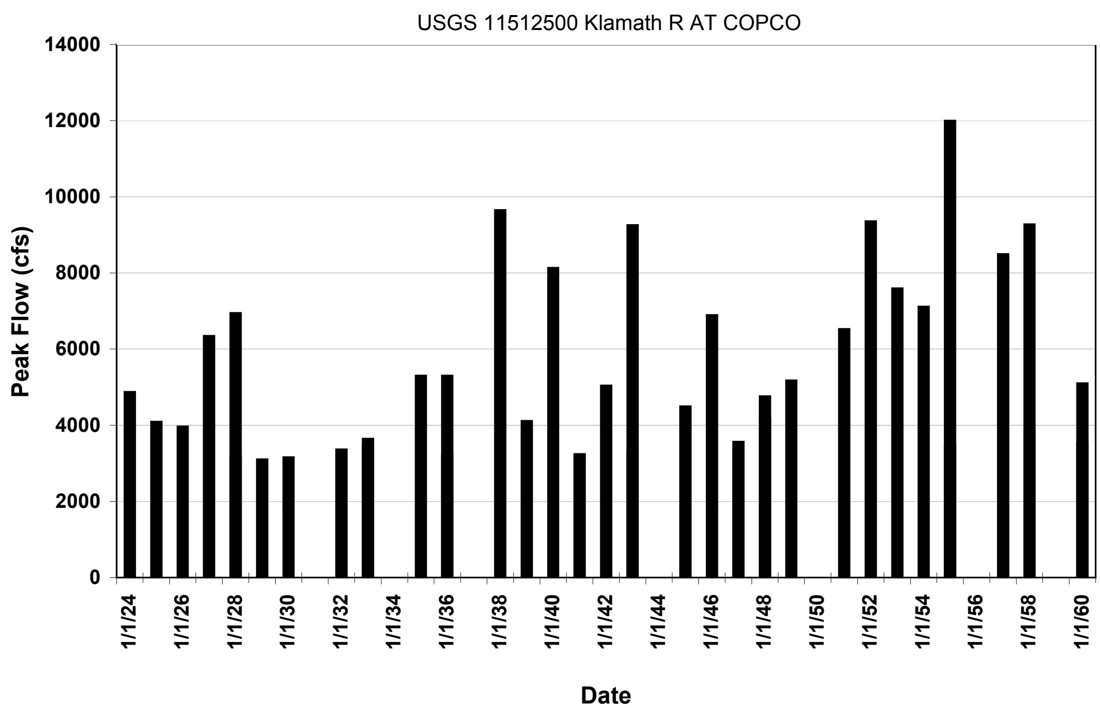

Figure 5.7-31. Peak annual flow series for the period of record 1924-1960 at the Klamath River below Fall Creek near Copco (USGS Gauge No. 11512500).

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Table 5.7-21. Peak annual flows by return interval and exceedance probability for the Klamath River below Fall Creek near Copco (USGS Gauge No. 11512500) as estimated using HEC-FFA. Peak annual flows for the Copco bypass reach are conservatively estimated by simply subtracting the hydraulic capacity of the Copco No. 2 powerhouse (3,200 cfs) from the values for the gauge location.

		Estimated Peak Annual Flows (cfs)	
Return Period (years)	**Exceedance Probability (%)**	**Copco Gauge**	**Copco Bypass (est.)**
100	1.0	22,100	18,900
50	2.0	18,400	15,200
20	5.0	14,200	11,000
10	10.0	9,700	6,500
5	20.0	7,600	4,400
2	50.0	4,825	1,625
1.25	80.0	3,475	275

Annual Low Flow Conditions

The low flow frequency statistics for the daily flow period of record 1924-1960 at the Klamath River near Copco (USGS Gauge No. 11512500) are listed in Table 5.7-22. Flows listed are averaged over the number of days in the first column of the table. This corresponds to the xQy notation. For example, for the Klamath River near Copco, the 7Q10 (the 7-day average low flow that occurs every 10 years) is 431 cfs, corresponding to the 7-day flow with a 10 percent chance of occurrence every year.

Table 5.7-22. Annual low flow statistics for the Klamath River near Copco (USGS Gauge No. 11512500) as estimated using DFLOW 3.

	Annual Percent Chance of Occurrence			
Days	**50**	**20**	**10**	**5**
1	244	156	126	106
3	509	325	256	210
5	686	467	380	320
7	767	528	431	364
30	888	622	506	422

5.7.4.5 Iron Gate

Flow-Related Operations at the Iron Gate Development

The Iron Gate Development consists of Iron Gate reservoir, dam, and powerhouse. The Iron Gate reservoir includes the portion of the mainstem Klamath River from Iron Gate dam (RM 190) to

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the upper end of the Iron Gate reservoir at about RM 196.8. Iron Gate reservoir typically fluctuates about 8 feet annually between normal minimum and full pool elevations (Figure 5.7-32). Because of its relatively small active storage, Iron Gate reservoir has a modest effect on the general shape and peak magnitude of annual hydrographs (Figure 5.7-32). Characteristics of Iron Gate reservoir reservoir and its storage capacity are listed in Table 5.7-23.

The Iron Gate powerhouse is located at the base of Iron Gate dam. Iron Gate is generally operated in a relatively constant generation mode to provide stable flows below Iron Gate dam. Spill generally occurs during the winter and spring months when river flows exceed the turbine hydraulic capacity (about 1,735 cfs) (Figure 5.7-33).

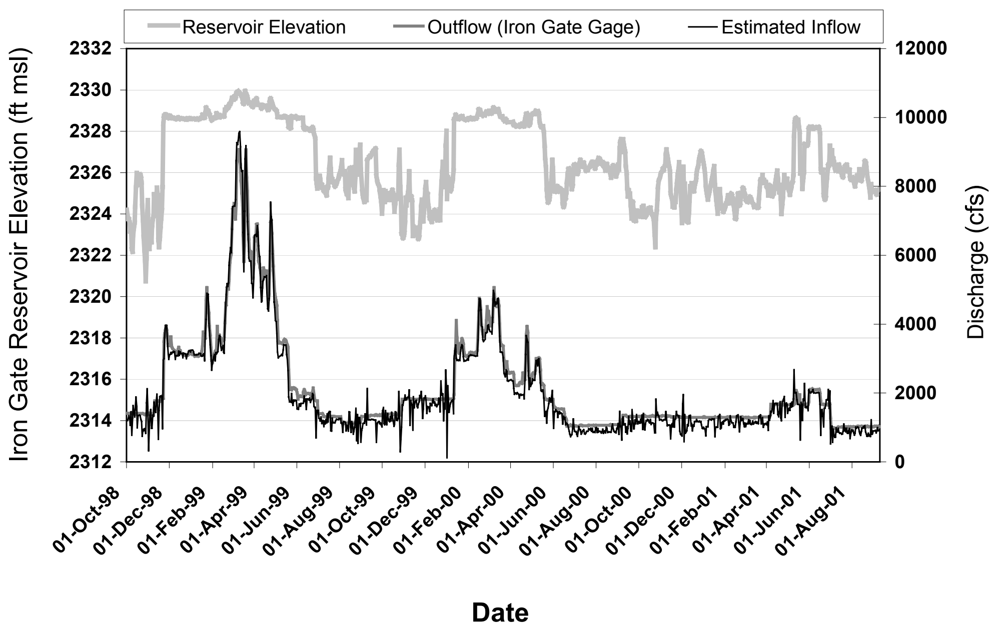

Figure 5.7-32. Daily average Iron Gate reservoir elevation and estimated reservoir inflow and outflow for Water Years 1999-2001.

Table 5.7-23. Iron Gate reservoir physical and operational characteristics

Impoundment length (miles)	6.8	Normal full pool elevation (feet msl)	2,328.0
Impoundment length (RM)	190-196.8	Normal minimum pool elevation (feet msl)	2,324.0
Surface area (acres)	944	Normal annual operating fluctuation (feet)	4.0
Maximum / mean depth (feet)	167/62	Average daily operating fluctuation (feet)	0.5
Total storage capacity (acre-feet)	58,794	Normal active storage capacity (acre-feet)	3,790
Total retention time (days)		Active storage retention time (days)	
At 710 cfs	42	At 710 cfs	2.7
At 1,600 cfs (≈ mean flow)	16	At 1,600 cfs (≈ mean flow)	1.0
At 10,000 cfs (extreme event)	3	At 10,000 cfs (extreme event)	0.2

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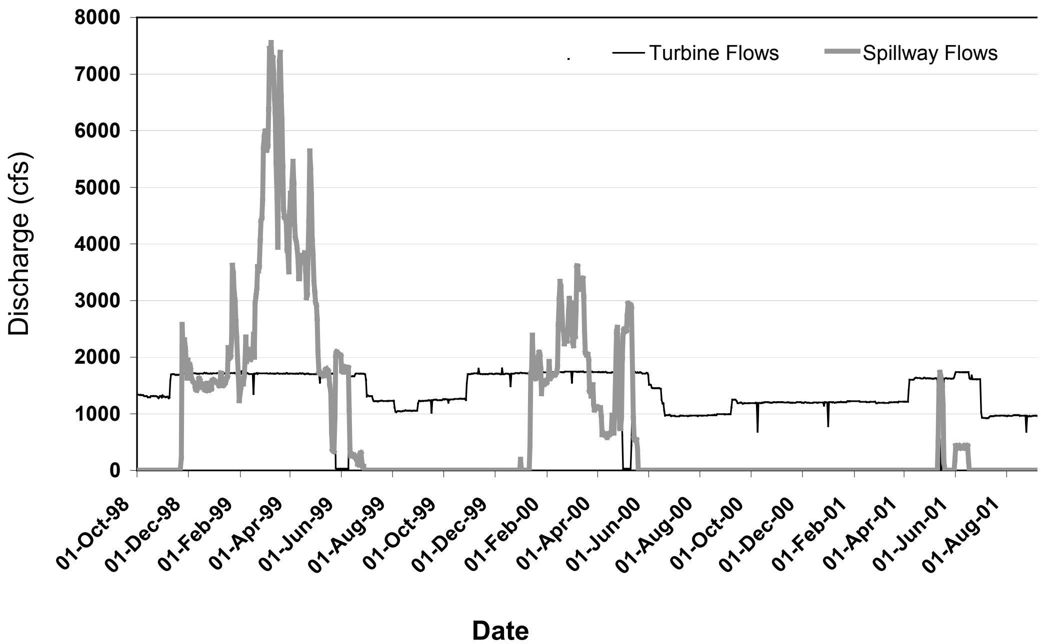

Figure 5.7-33. Daily average spillway and turbine discharges from the Iron Gate dam and powerhouse for Water Years 1999-2001.

FERC-stipulated minimum flow requirements are 1,300 cfs from September through April, 1,000 cfs in May and August, and 710 cfs in June and July. Since 1996, however, USBR's annual Project Operations Plans have dictated instream flow releases. The latest (Klamath Project Operations Plan (April 10, 2003) states that USBR will ensure that Klamath River flows at Iron Gate dam will meet or exceed the flows listed in Table 5.7-24.

FERC-stipulated changes in flow rate (i.e., ramp rate) caused by releases at Iron Gate dam and powerhouse are limited to the lesser of a 3-inch-per-hour or 250-cfs-per-hour rate. However, USBR's 2003 Operations Plan includes the following downramping criteria at Iron Gate dam: (1) decreases in flows of 300 cfs or less per 24-hour period and no more than 125 cfs per 4-hour period when Iron Gate dam flows are above 1,750 cfs; and (2) decreases in flow of 150 cfs or less per 4-hour period and no more than 50 cfs per 2-hour period when Iron Gate dam flows are 1,750 cfs or less.

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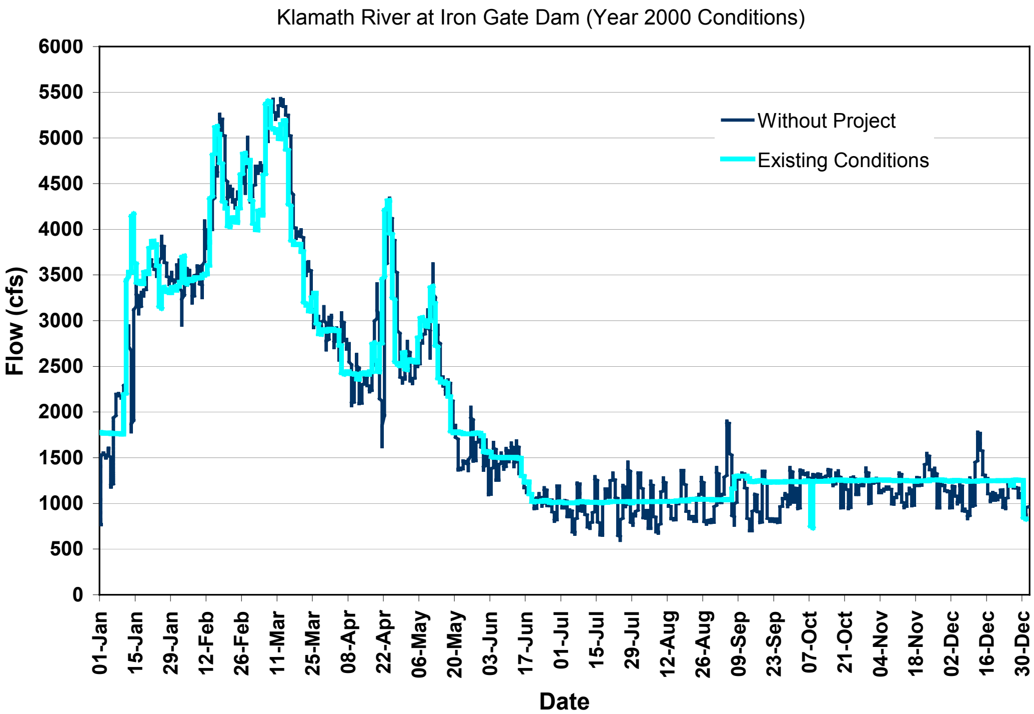
Table 5.7-24. Klamath River flows at Iron Gate dam stipulated in USBR's Klamath Project 2003 Operations Plan (April 10, 2003).

	Water Year Type and Flow (cfs)				
Period	**Wet**	**Above Average**	**Average**	**Below Average**	**Dry**
April 1-15	5,932	2,955	1,863	1,826	822
April 16-30	5,636	2,967	2,791	1,431	739
May 1-15	3,760	2,204	2,784	1,021	676
May 16-31	2,486	1,529	1,466	1,043	731
June 1-15	1,948	1,538	829	959	641
June 16-30	1,921	934	1,163	746	617
July 1-15	1,359	710	756	736	516
July 16-31	1,314	710	735	724	515
August	1,149	1,039	1,040	979	560
September	1,341	1,316	1,300	1,168	731
October	1,430	1,346	1,345	1,345	907
November	1,822	1,414	1,337	1,324	899
December	1,822	1,387	1,682	1,621	916
January	2,792	1,300	3,618	1,334	1,030
February	4,163	1,300	1,300	1,806	673
March 1-15	8,018	1,953	2,143	2,190	688
March 16-31	6,649	4,009	2,553	1,896	695

Modeled Project Effects

Graphs of RMA2 model output of hourly flow (in cfs) in the Klamath River at Iron Gate dam (RM 190) and at Seiad Valley (RM 129) are shown for existing conditions, steady flow, and the two without-Project scenarios (WOP and WOP II) in Appendix 5C. Of the four scenarios, the comparison between existing conditions and WOP scenarios shown in those figures best illustrates the effects on flow caused by Project facilities and operations in the Klamath River downstream of Iron Gate dam. Graphs comparing model output of flow for existing conditions and WOP scenarios in the Klamath River at Iron Gate dam (RM 190) are shown in Figures 5.7-34 and 5.7-35 for 2000 and 2001 conditions, respectively. Graphs comparing model output of flow for existing conditions and WOP scenarios in the Klamath River at Seiad Valley (RM 129) are shown in Figures 5.7-36 and 5.7-37 for 2000 and 2001 conditions, respectively.



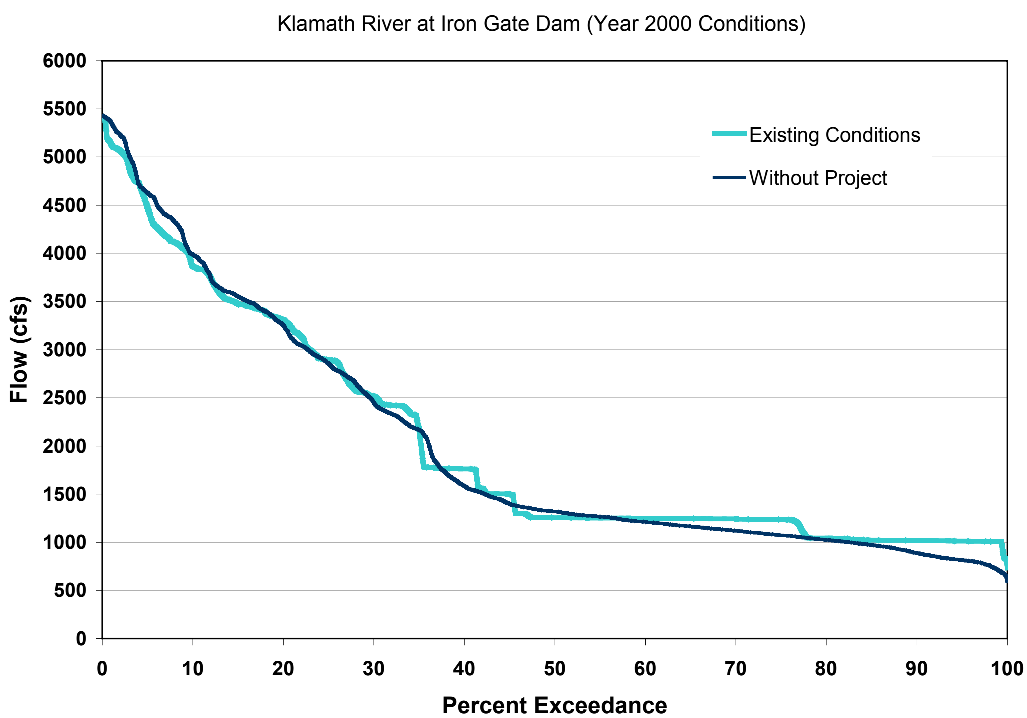
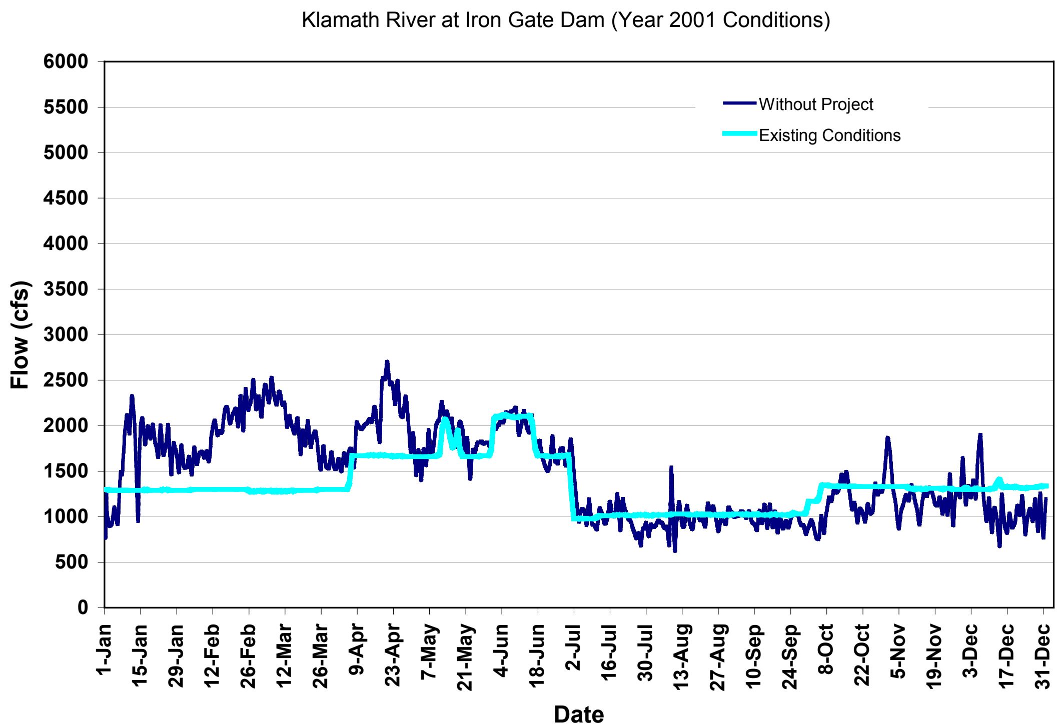


Figure 5.7-34. RMA2 model output of hourly flow for 2000 in the Klamath River below Iron Gate dam for existing conditions and a hypothetical without-Project scenario (WOP). The model output is displayed as an annual time series in the top plot and as a flow duration curve in the bottom plot.



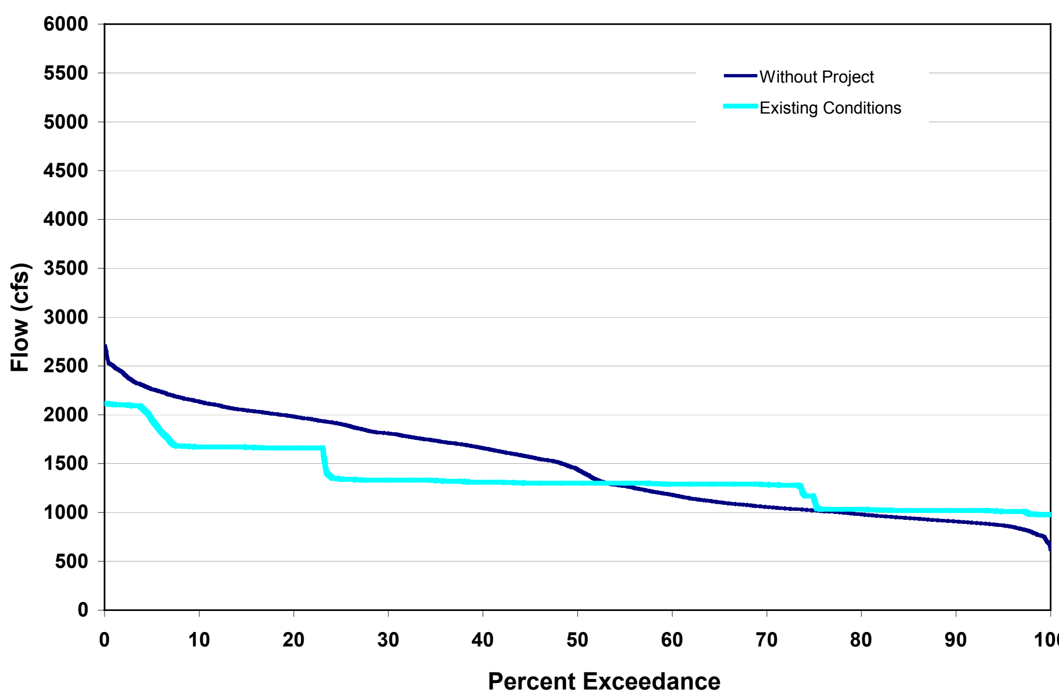


Figure 5.7-35. RMA2 model output of hourly flow (cfs) for 2001 in the Klamath River below Iron Gate dam for existing conditions and a hypothetical without-Project scenario (WOP). The model output is displayed as an annual time series in the top plot and as a flow duration curve in the bottom plot.

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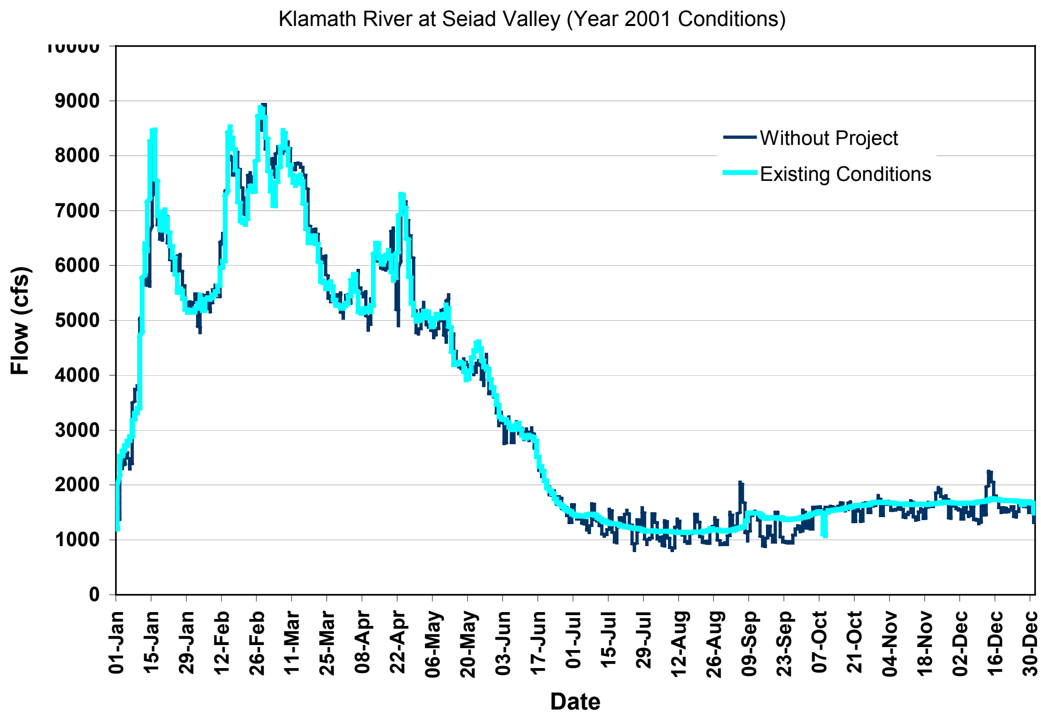


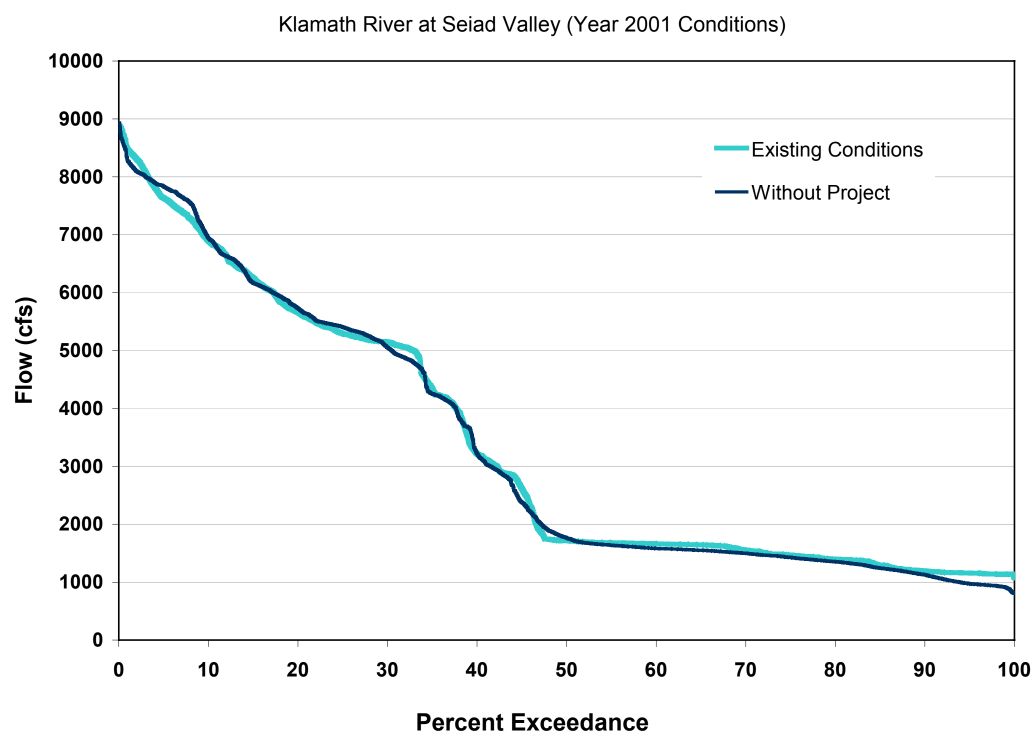
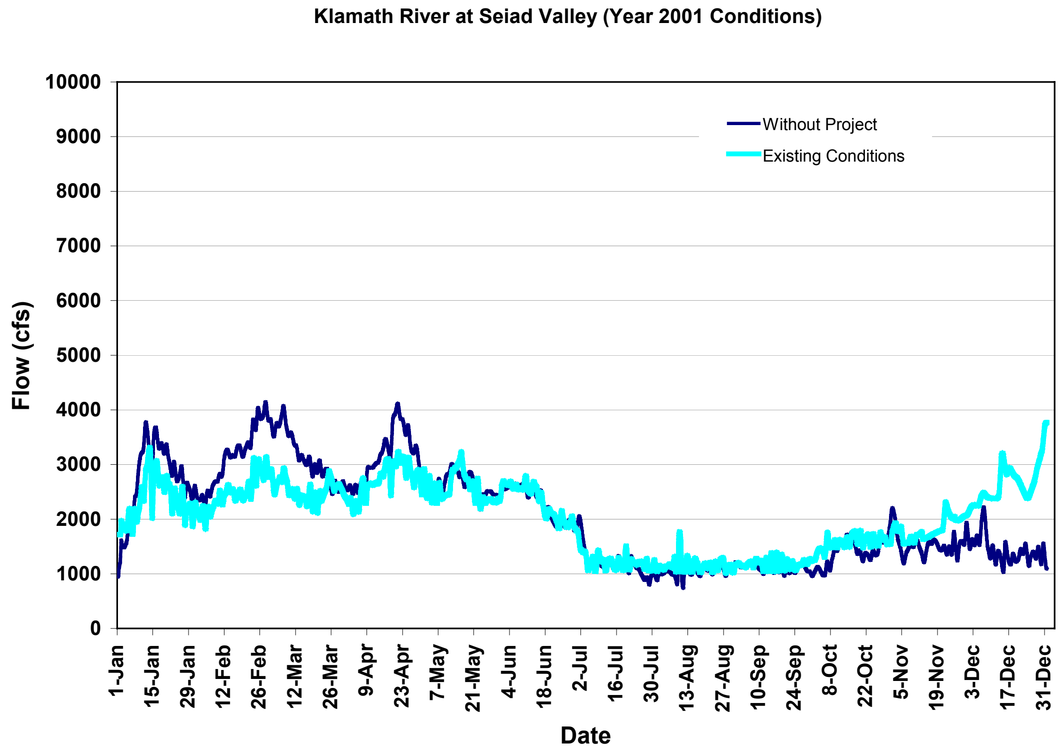


Figure 5.7-36. RMA2 model output of hourly flow for 2000 in the Klamath River at Seiad Valley for existing conditions and a hypothetical without-Project scenario (WOP). The model output is displayed as an annual time series in the top plot and as a flow duration curve in the bottom plot.



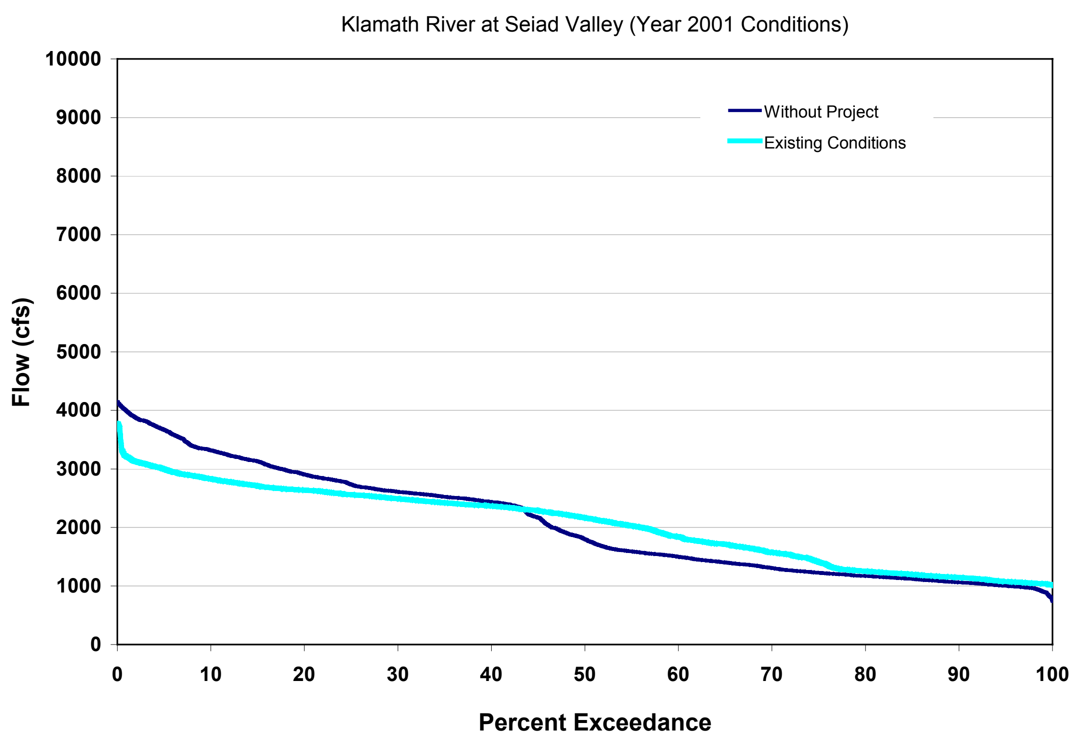


Figure 5.7-37. RMA2 model output of hourly flow for 2001 in the Klamath River at Seiad Valley for existing conditions and a hypothetical without-Project scenario (WOP). The model output is displayed as an annual time series in the top plot and as a flow duration curve in the bottom plot .

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In general, the Iron Gate facilities and operations have a regulating effect on the magnitude and duration of flows when compared to WOP conditions. The Iron Gate reservoir acts to moderate flow fluctuations entering the reservoir from Copco No. 2 powerhouse operations, especially when the Copco No. 2 powerhouse is operated in peaking mode (see Figure 5.7-30). Figures 5.7-34 and 5.7-35 reveal regulation and moderation in short-term WOP flow fluctuations under existing operations conditions. This reflects that Iron Gate dam and powerhouse are operated to provide relatively stable instream flow releases to the river according to annual operations plans for the Klamath Irrigation Project, based on current and expected hydrologic conditions and consistent with Biological Opinions[12] issued by the U.S. Fish and Wildlife Service (USFWS) and the National Oceanic and Atmospheric Administration (NOAA-Fisheries). A similar regulation and moderation effect is illustrated in Figures 5.7-36 and 5.7-37 in the Klamath River at Seiad Valley, although significant accretion is evident, particularly during winter and spring, from the much larger basin drainage area that contributes flows to the river at Seiad Valley.

Flow Conditions in the Klamath River below Iron Gate Dam

This reach includes the Klamath River downstream of Iron Gate dam. Most of the discussion presented below focuses on the Klamath River from Iron Gate dam (RM 190) to Seiad Valley at about RM 129. The upstream flow condition for the Iron Gate dam (RM 190.1) to Seiad Valley (RM 129) reach consists predominantly of releases from Iron Gate reservoir. The Shasta and Scott rivers are two primary tributaries within the reach, entering at approximately RM 176 and RM 143, respectively. Smaller notable tributaries include Bogus, Cottonwood, Beaver, Horse, Seiad, and Grider creeks.

Accretion of flow in the reach varies by time of year and runoff conditions. Between Iron Gate dam and Seiad Valley, the total mean annual flow approximately doubles, with the bulk of the inflow contributed by the Scott River. During high flow conditions, peak flows can increase two- to threefold between Iron Gate dam and Seiad Valley (compare flow peaks in Figure 2.7-38). However, during summer low flow periods, the river flow does not substantially increase (compare low flows in Figure 2.7-38).

Annual Trend in Flow Conditions

Annual hydrographs of the 10, 50, and 90 percent exceedance levels of mean daily flows for the period 1967-1999 in the Klamath River at Iron Gate dam (USGS Gauge No. 11516530) are shown in Figure 5.7-39. The period of highest flows typically occurs during winter and spring, but flows have varied widely in magnitude from year to year during this period. The period of lowest flows occurs in summer and early fall, and year-to-year variation is less during this period.

[12] U.S. Fish and Wildlife Service and National Marine Fisheries Service Biological Opinions on Klamath Project Operations.

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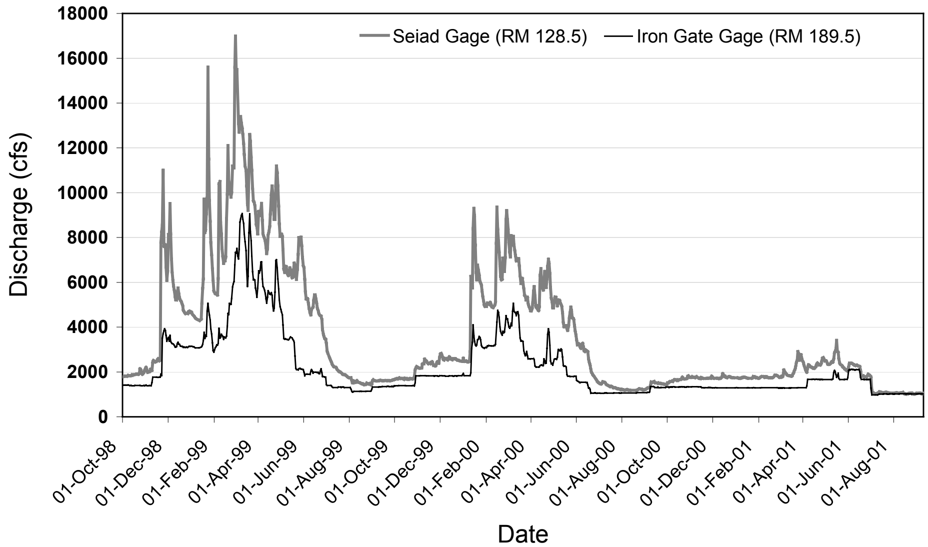

Figure 5.7-38. Daily average Iron Gate and Seiad Valley discharge for Water Years 1999-2001.

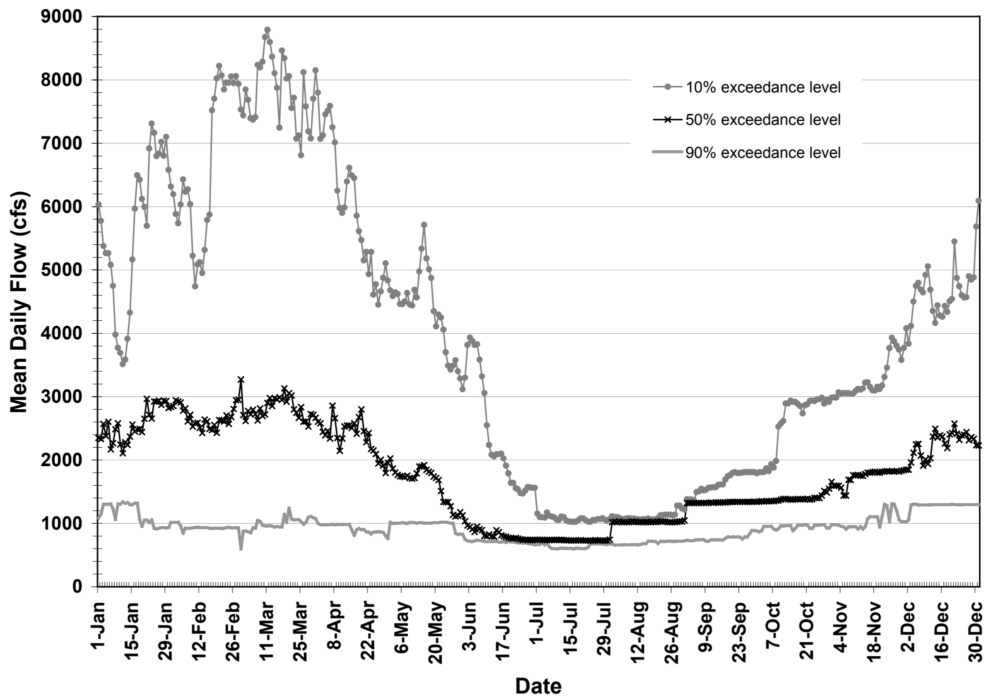

Figure 5.7-39. Annual hydrographs of the 10, 50, and 90 percent exceedance levels of mean daily flows (cfs) for the period 1967-1999 in the Klamath River below Iron Gate dam (USGS Gauge No. 11516530) .

Klamath River Flows at Iron Gate: Contribution to Total Basin Flows

The total drainage area of the Klamath River basin is about 12,100 square miles (as measured at RM 5.9 at USGS Gauge No. 11530500 at Klamath, California). The drainage basin area upstream from Iron Gate dam covers 4,630 square miles, extending throughout Klamath County, Oregon, and Siskiyou County, California. The drainage basin areas upstream from the J.C. Boyle powerhouse and Keno dam cover about 4,080 and 3,920 square miles, respectively, within Klamath County. However, the operations and diversions for irrigation and wildlife refuge maintenance from Upper Klamath Lake largely control drainage flows within the basin. Ninety-eight percent of the available 472,240 acre-feet of active storage in the basin area is contained in Upper Klamath Lake.

Table 5.7-25 summarizes the drainage area and the period of record for other gauges for the Klamath River and major tributaries downstream of the Project area. Data from these other gauges were used to compare contribution of flow measured at Klamath River below Iron Gate dam (and key tributaries and accretions) to flow measured at Klamath River near the mouth (at Klamath, California). Results are depicted in Figure 5.7-40 for Water Year 1992, a critically dry water year. The results indicate that the contribution of flow at Iron Gate dam to flow near the mouth varies substantially on a seasonal basis—from only a few percent during the higher flow spring period to about 45 percent during the low flow summer period.

Table 5.7-25. Other USGS flow gauging data for the Klamath River and major tributaries downstream of the Project area.*

USGS Gauge	Drainage Area (square miles)	Gauge Number	Period of Record
Shasta River near Yreka, CA	793	11517500	10/01/1933-present
Scott River near Fort Jones, CA	653	11519500	10/01/1941-present
Klamath River near Seiad Valley, CA	6,940	11520500	10/01/1921-present
Salmon River at Somes Bar, CA	751	11522500	10/01/1911-present
Klamath River at Orleans, CA	8,475	11523000	10/01/1927-present
Klamath River near Klamath, CA	12,100	11530500	10/01/1910-present

*Includes only those gauges that have a period of record extending to present.

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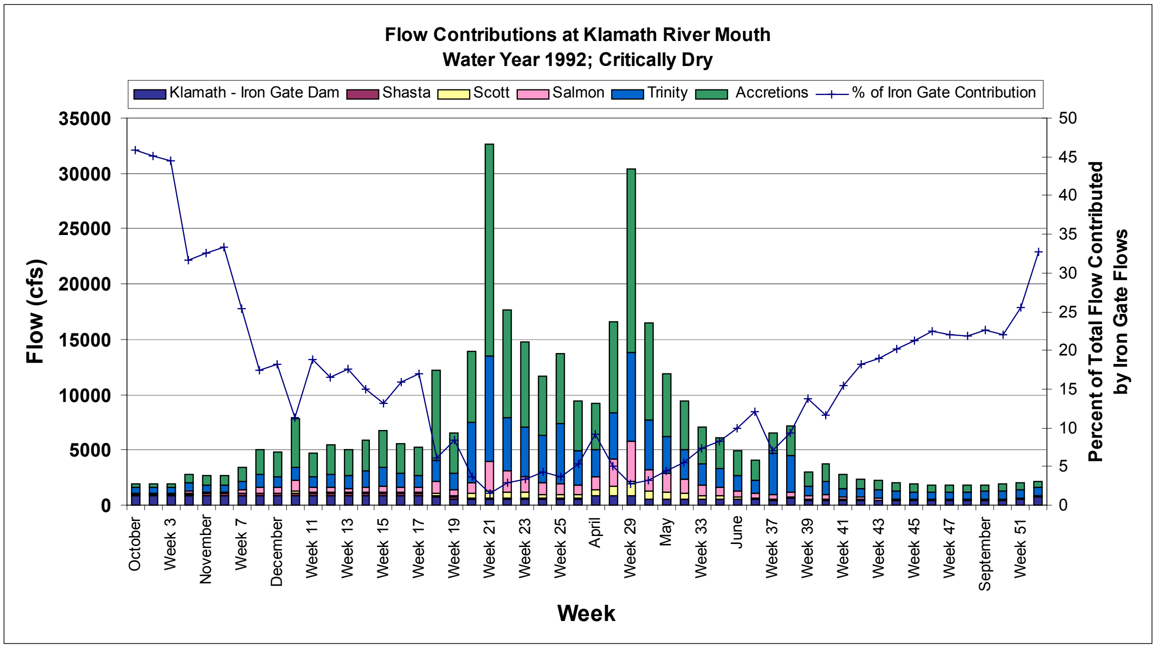

Figure 5.7-40. Contribution of flow measured at Klamath River below Iron Gate dam (and key tributaries and accretions) to flow measured at Klamath River near the mouth (at Klamath, California).

Annual Peak Flow Conditions

The peak flow series for the period of record 1960-present at the Klamath River downstream of Iron Gate dam (USGS Gauge No. 11516530) are shown in Figure 5.7-41. Peak annual flows by return interval and exceedance probability (as estimated using HEC-FFA) are listed in Table 5.7-26. The highest peak flow (29,400 cfs) at the Klamath River downstream of the Iron Gate dam USGS gauge was recorded in December 1965 and represented about a near 50-year flood event. Other peak flows in excess of a 10-year event (17,600 cfs) were recorded (in descending order of magnitude) in January 1997, January 1974, and February 1982.

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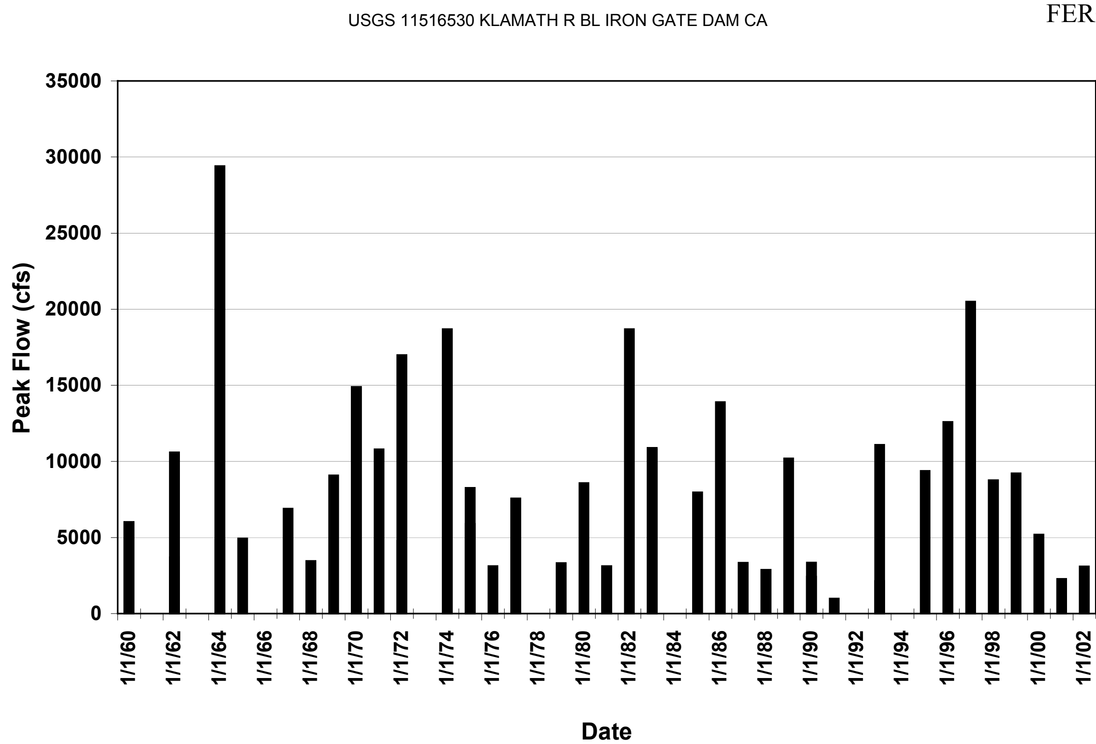

Figure 5.7-41. Peak annual flow series for the period of record 1960-present at the Klamath River downstream of Iron Gate dam (USGS Gauge No. 11516530).

Table 5.7-26. Peak annual flows by return interval and exceedance probability for the Klamath River at the Klamath River downstream of Iron Gate dam (USGS Gauge No. 11516530) as estimated using HEC-FFA.

Return Period (years)	**Exceedance Probability (%)**	**Estimated Peak Annual Flows at Iron Gate Gauge (cfs)**
100	1.0	38,200
50	2.0	31,100
20	5.0	23,000
10	10.0	17,600
5	20.0	12,700
2	50.0	6,830
1.25	80.0	3,600

Annual Low Flow Conditions

The low flow frequency statistics for the daily flow period of record 1960-present at the Klamath River downstream of Iron Gate dam USGS Gauge No. 11516530) are listed in Table 5.7-27. Flows listed are averaged over the number of days in the first column of the table. This corresponds to the xQy notation. For example, for the Klamath River downstream of Iron Gate dam, the 7Q10 (the 7-day average low flow that occurs every 10 years) is 570 cfs, corresponding to the 7-day flow with a 10 percent chance of occurrence every year.

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Table 5.7-27. Annual low flow statistics for the Klamath River downstream of Iron Gate dam (USGS Gauge No. 11516530) as estimated using DFLOW 3.

	Annual Percent Chance of Occurrence			
Days	**50**	**20**	**10**	**5**
1	689	593	562	543
3	694	597	565	547
5	700	601	569	549
7	703	603	570	550
30	757	637	579	532

Flow Changes

Changes in rate of flow and water level (i.e., stage) in Klamath River below Iron Gate dam are examined and described as part of the analysis of flow ramping effects on fish in the Aquatics Technical Report.

5.7.5 Effects of PacifiCorp Operations on the Long-Term (Seasonal and Annual) Hydrologic Regime of the Klamath River

As described in Section 5.4, the effects of the Project on the long-term (monthly, seasonal, and annual) hydrologic regime was examined using KPOPSIM model simulations. KPOPSIM was used to assess the impacts of historical operations on Klamath River flows below Iron Gate dam attributable to both USBR's Klamath Irrigation and PacifiCorp's operations of J.C. Boyle, Copco, and Iron Gate reservoirs.

For purposes of analysis, the Klamath Irrigation Project effects on Klamath River flows were limited to the historical operations of Upper Klamath Lake. Link dam, built by USBR in the early 1900s, provides regulation in upper Klamath Lake and was one of the initial features of the Klamath Irrigation Project. The 541,000 acre-foot (ac-ft) upper Klamath Lake provides deliveries to USBR's A canal directly out of the lake, and downstream deliveries to Lost River diversion canal to Station 48, North canal, and ADY canal out of the afterbay created by Keno dam. An average of 370,000 ac-ft of water have been delivered from upper Klamath Lake-regulated releases to agricultural deliveries in the Klamath Irrigation Project in recent years.

The balance of the Klamath Irrigation Project is located in the remote Langell Valley region. Langell Valley demands are met by Lost River regulatory facilities at Gerber and Clear Lake reservoirs. This portion of the USBR project has little or no impact on the Klamath River and thus was excluded from the analysis.

PacifiCorp flow regulation facilities on the Klamath River include J.C. Boyle reservoir (1,512 ac-ft), Copco reservoir (46,867 ac-ft), and Iron Gate reservoir (58,794 ac-ft). These facilities are operated for energy generation purposes and, except for minimal lake evaporation, do not have a consumptive use impact on the river.

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5.7.5.1 KPOPSIM Analyses of Flow Effects

The KPOPSIM analyses of flow effects for this study considered one key flow point: the Klamath River at Iron Gate dam. This represents the most downstream point of Project flow regulation facilities on the Klamath River and therefore is the point at which PacifiCorp operations effects on the long-term (monthly, seasonal, and annual) hydrologic regime would be greatest. Analyses were performed for the hydrologic period, Water Years 1961 through 1997. Complete and accurate data are available for this period. Furthermore, Iron Gate was completed in 1962, with full operations beginning in 1963.

Table 5.7-28 presents KPOPSIM-modeled monthly flows for the Klamath River below Iron Gate dam in terms of 1,000 acre-feet per month (1,000 ac-ft/mo) for the 1961-97 period. (A flow of 1,000 ac-ft/mo equals approximately 17 cfs.) Table 5.7-29 presents the flow effects (in 1,000 ac-ft/mo) predicted by KPOPSIM for the 1961-1997 period attributable to USBR's Klamath Irrigation Project operations. Klamath Irrigation Project operations are computed as follows:

- (-) Historical Upper Klamath Lake storage change (including net lake evaporation and A canal operations)
- (+) Easterly deliveries through Lost River diversion channel to Station 48 for irrigation demands
- (+) Deliveries to North canal for irrigation demands
- (+) Deliveries to ADY canal for irrigation and refuge demands

Table 5.7-30 presents the flow effects predicted by KPOPSIM for the 1961-1997 period resulting from PacifiCorp's operations at J.C. Boyle, Copco, and Iron Gate reservoirs. (Calendar year 1988 data were not available.) These flow effects are due to monthly reservoir storage changes, since PacifiCorp's operations do not involve consumptive water use.

Table 5.7-31 presents the KPOPSIM-modeled flows for the Klamath River below Iron Gate dam for the 1961-1997 period adjusted for the operations of the Klamath Irrigation Project and PacifiCorp facilities. This represents flow without either the Klamath Irrigation Project or the hydroelectric Project. It is referred to as the No-Projects flow condition and approximates a "near natural" flow condition.[13]

[13] This "near-natural" flow represents the flow conditions at Iron Gate dam with the operations by regulatory and consumptive use facilities from Upper Klamath Lake to Iron Gate Dam for the 1961-97 period removed.

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Table 5.7-28. KPOPSIM-modeled monthly flows (1,000 ac-ft/mo) for the Klamath River below Iron Gate dam for 1961-1997.

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Total
1961	89.9	102.1	155.2	109.0	105.8	123.3	104.5	96.9	82.5	60.5	67.3	82.2	1,179.2
1962	117.3	134.1	122.1	117.3	98.2	103.1	156.7	85.2	55.3	47.1	59.5	77.9	1,173.8
1963	154.4	169.7	225.2	129.3	125.9	156.7	228.5	180.6	51.0	45.7	65.1	93.7	1,625.8
1964	108.3	144.3	178.8	180.6	104.6	100.3	165.4	65.3	59.8	52.7	66.0	81.5	1,307.6
1965	109.1	111.6	409.2	583.6	507.8	387.8	132.8	112.4	51.5	45.4	74.3	122.1	2,647.6
1966	172.1	249.2	187.0	157.1	85.8	109.2	147.7	63.7	42.4	44.8	64.7	78.1	1,401.8
1967	96.8	106.9	188.7	190.6	184.7	125.8	146.3	260.1	92.0	44.7	62.5	78.0	1,577.1
1968	101.7	107.4	167.6	115.0	107.0	151.2	77.7	62.6	42.1	45.1	45.9	62.4	1,085.7
1969	85.0	80.7	92.1	140.7	177.8	162.4	322.0	185.1	66.7	45.1	62.9	79.3	1,499.8
1970	107.3	165.0	160.8	327.6	313.9	266.2	84.0	89.7	51.6	43.9	62.7	77.9	1,750.6
1971	84.8	175.7	253.5	247.0	198.2	299.6	411.9	305.8	126.4	47.8	62.4	91.7	2,304.8
1972	169.3	187.5	232.3	252.2	202.0	663.0	216.6	150.5	46.8	44.2	63.3	97.6	2,325.3
1973	110.1	168.2	208.4	202.5	147.6	147.2	84.4	63.6	44.4	43.4	43.1	43.1	1,306.0
1974	82.0	132.1	250.7	379.9	225.6	348.8	409.0	186.8	52.7	45.3	63.3	79.0	2,255.2
1975	103.8	161.1	184.6	189.7	193.3	286.0	255.4	239.2	78.1	47.8	67.5	95.9	1,902.4
1976	149.6	187.8	234.0	192.6	154.6	157.9	107.8	70.0	43.6	44.2	64.8	85.0	1,491.9
1977	112.4	177.7	116.5	101.8	74.1	44.5	45.3	62.4	44.1	44.2	44.2	60.3	927.5
1978	81.3	82.7	240.0	267.4	190.6	219.4	212.8	131.0	45.9	45.0	64.0	78.9	1,659.0
1979	81.7	96.6	112.2	124.7	94.5	159.7	82.8	96.9	43.5	45.1	62.9	77.6	1,078.2
1980	80.4	79.6	88.3	208.8	200.8	198.3	102.5	100.0	44.5	45.9	64.6	80.2	1,293.9
1981	82.5	79.9	90.1	83.9	85.5	111.7	92.0	63.5	44.7	45.3	63.5	54.5	897.1
1982	52.4	77.7	235.9	234.3	376.1	425.8	355.3	150.4	47.8	87.9	63.9	80.0	2,187.5
1983	115.3	179.7	249.8	189.1	294.6	472.4	318.5	256.3	154.2	55.5	62.4	93.2	2,441.0
1984	168.9	247.9	414.2	246.8	215.6	355.1	308.9	231.9	117.4	46.8	63.3	99.6	2,516.4
1985	206.2	312.6	244.5	131.7	97.9	160.5	264.5	84.1	65.2	44.4	62.2	97.9	1,771.7
1986	103.0	126.7	175.8	145.4	351.4	461.1	177.6	102.5	44.7	44.8	62.4	83.6	1,879.0
1987	110.8	109.7	131.8	112.4	148.3	162.7	86.5	62.3	44.0	49.3	57.5	79.3	1,154.6
1988	82.5	79.2	93.3	103.4	123.0	118.4	69.3	59.8	49.3	38.9	59.9	61.8	938.8
1989	63.8	69.4	81.4	98.7	117.9	350.1	278.2	151.7	54.8	45.5	63.7	79.6	1,454.8
1990	85.0	83.3	94.8	111.4	100.2	125.3	91.9	63.5	50.7	44.8	60.2	69.5	980.6
1991	82.7	78.8	99.7	82.0	43.0	56.8	46.3	53.8	40.3	33.5	39.8	44.6	701.3
1992	54.1	51.9	54.7	54.6	29.1	31.4	44.0	31.5	30.1	26.3	24.5	32.0	464.2
1993	55.6	54.4	56.2	62.2	50.5	310.9	308.9	164.6	143.3	42.6	63.9	80.9	1,394.0
1994	84.6	84.1	85.3	69.3	40.5	39.4	34.0	44.7	41.9	35.3	39.1	53.8	652.0
1995	57.6	54.1	58.1	73.2	63.5	259.0	191.5	199.9	63.8	45.8	64.0	80.3	1,210.8
1996	82.2	79.1	104.1	239.3	515.1	310.2	200.4	203.7	92.6	62.3	63.3	78.4	2,030.8
1997	82.3	86.6	224.3	593.2	298.9	177.6	135.6	127.5	72.1	50.1	63.1	61.4	1,972.6
Average (1963-88, 1990-97)	103.4	130.0	177.2	194.5	181.8	225.6	178.4	129.3	63.0	46.5	59.3	77.3	1,566.5

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Table 5.7-29 . Monthly flow changes (in 1,000 ac-ft/mo) due to Klamath Irrigation Project operations predicted by KPOPSIM for the Klamath River below Iron Gate dam for the 1961-97 period.

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Total
1961	-17.3	-58.4	-34.9	-29.2	-113.1	-92.0	-37.2	-34.1	-14.2	30.4	-0.2	-6.9	-407.2
1962	-6.1	-4.9	-38.6	-13.9	-104.8	-113.4	-76.7	-73.8	3.7	22.7	2.0	3.7	-400.3
1963	-79.2	-12.2	-25.4	-10.9	-149.8	-27.3	-24.6	-27.6	-21.0	1.4	19.6	14.8	-342.3
1964	-11.7	-17.0	40.4	0.5	-42.8	-97.8	-72.9	-73.2	-69.1	0.6	5.6	14.1	-323.2
1965	16.3	-45.3	-260.8	51.5	70.6	90.6	-115.7	-106.4	-62.7	-28.7	-26.9	28.2	-389.2
1966	44.5	75.3	9.0	-14.1	-63.4	-134.2	-87.8	-61.9	-30.1	1.2	23.1	-15.2	-253.4
1967	0.4	-40.6	-30.1	-23.8	-20.6	-120.5	-82.3	-44.4	-68.7	10.9	22.8	13.0	-383.8
1968	-16.8	2.3	11.9	-47.0	-136.9	-45.7	-14.8	-30.5	3.3	7.5	-33.5	-23.6	-323.7
1969	-20.6	-61.8	-63.7	-94.8	-12.4	-89.2	-72.5	-60.7	-59.5	6.0	18.3	6.1	-504.8
1970	-18.3	39.0	-70.7	-151.8	14.6	-19.0	-68.4	-67.7	-32.6	1.4	40.5	-4.5	-337.6
1971	-37.1	-49.8	16.9	-76.7	-51.6	-80.3	2.2	-70.3	-66.3	-41.8	-0.3	-39.1	-494.2
1972	29.2	-3.8	24.5	-51.1	-69.9	-15.5	-62.8	-75.5	-64.6	-5.4	-15.9	-6.9	-317.6
1973	-23.7	2.4	-18.7	-21.4	-40.3	-54.4	-54.3	-51.1	9.9	12.4	-6.7	-42.0	-287.8
1974	-48.5	-126.1	-44.1	-44.2	-20.5	-41.4	-26.1	-81.6	-85.9	-42.3	-17.2	-18.4	-596.2
1975	-21.4	19.3	-2.4	-9.5	-42.7	-70.9	-47.5	-72.0	-97.9	-30.9	-12.8	-17.6	-406.2
1976	-0.4	10.9	17.7	-16.2	-36.1	-67.7	-76.9	-73.1	-38.9	-17.2	-65.5	-15.8	-379.2
1977	-11.0	37.3	-12.5	-21.0	-56.4	-103.8	-42.8	-57.2	-12.8	33.4	1.7	-27.6	-272.7
1978	-20.7	-68.8	-47.4	-35.1	-35.8	-57.1	-40.1	-42.7	-29.4	-10.1	12.2	-33.7	-408.6
1979	-14.8	-9.6	-28.4	-51.0	-68.0	-48.2	-60.5	-46.4	8.4	12.9	16.3	2.4	-286.9
1980	-39.8	-79.7	-86.9	-97.9	-50.3	-29.7	-60.7	-43.8	-32.3	5.8	38.2	-4.5	-481.5
1981	-8.1	-43.4	-70.9	-64.6	-91.2	-39.4	-35.1	-31.4	5.3	19.1	36.3	0.3	-323.2
1982	-56.0	-125.1	-94.8	10.0	-113.9	36.8	-19.6	-82.4	-94.8	1.9	3.3	-20.9	-555.5
1983	-17.3	20.1	8.2	-38.2	-80.2	-26.1	-47.9	-56.5	-57.9	-52.2	-35.6	-15.5	-399.2
1984	26.8	26.3	-2.7	-32.9	-52.4	-69.8	-42.5	-56.3	-67.5	-33.9	-19.4	-39.4	-363.5
1985	13.1	27.4	31.8	-38.1	-77.5	-90.9	-61.8	-67.8	-32.1	-0.3	-9.2	-38.9	-344.4
1986	-32.8	-29.8	16.9	-84.3	-97.9	-2.5	-44.1	-70.3	-46.9	-4.1	9.5	-44.5	-430.7
1987	-22.8	-42.1	-19.3	-63.2	-42.7	-64.6	-59.1	-27.7	-28.9	-21.1	-0.8	-3.2	-395.5
1988	-11.0	-33.0	-95.9	-75.9	-59.7	-67.4	-57.7	-40.8	-39.5	30.9	21.4	2.3	-426.2
1989	-22.3	-93.5	-55.2	-50.2	-31.9	-105.3	-63.0	-61.5	-19.7	16.0	8.7	-26.3	-504.1
1990	-28.9	-34.4	-32.6	-32.4	-41.3	-90.4	-51.9	-42.5	-20.3	7.0	-4.6	-8.3	-380.5
1991	-11.5	-26.7	-1.9	-54.7	-77.6	-115.5	-73.7	-62.3	-17.8	0.6	4.4	-14.4	-450.9
1992	-22.7	-61.5	-64.0	-61.5	-65.3	-74.6	-47.5	-13.8	10.4	-11.1	6.1	-11.6	-417.1
1993	-19.8	-52.8	-67.2	-73.2	-79.8	-151.1	-43.0	-71.5	-10.7	2.9	16.6	16.3	-533.4
1994	-21.4	-9.0	-39.9	-54.7	-67.5	-80.2	-56.8	-38.3	8.5	23.1	11.8	13.2	-311.2
1995	-11.7	-57.6	-52.1	-130.6	-146.1	-72.0	-51.0	-19.0	-51.2	-3.7	40.1	20.5	-534.3
1996	-6.4	-24.0	-142.7	-50.7	-41.2	-28.8	-53.4	-45.0	-10.4	7.7	3.3	-1.7	-393.3
1997	-29.9	-76.2	-136.7	-16.9	-20.9	-49.5	-78.4	-48.1	-18.6	-9.0	-4.0	-34.6	-522.6
Average (1963-88, 1990-97)	-15.8	-25.4	-37.5	-45.5	-57.8	-58.5	-53.8	-55.1	-35.9	-4.7	2.3	-10.7	-398.3

Table 5.7-30. Monthly flow changes (in 1,000 ac-ft/mo) due to PacifiCorp's operations at J.C. Boyle, Copco, and Iron Gate reservoirs predicted by KPOPSIM for the Klamath River below Iron Gate Dam for the 1961-97 period.

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Total
1961	No data												
1962	No data												
1963	0.00	1.05	-2.41	1.30	1.35	-0.93	-0.94	3.21	1.17	-0.69	0.41	1.48	4.98
1964	3.75	-7.40	-2.10	5.85	0.48	-5.56	2.07	1.00	-1.60	4.91	10.49	-5.93	5.97
1965	-9.08	1.67	0.07	-1.03	-0.11	-1.94	7.57	7.58	-0.21	3.08	0.42	-1.20	6.81
1966	-4.09	-12.40	0.06	3.09	-0.14	-2.26	0.58	8.78	-0.67	2.49	-4.52	2.77	-6.31
1967	-5.96	0.36	-2.63	-0.24	-1.89	1.66	-2.14	-3.04	4.77	6.94	7.69	-8.04	-2.53
1968	-3.96	-4.39	1.32	3.61	-2.42	5.68	-6.03	2.15	1.08	7.50	-3.06	3.50	4.99
1969	1.05	-4.16	-6.91	0.95	-0.31	-3.99	-0.17	-0.05	1.30	2.13	10.62	-8.06	-7.61
1970	-7.57	3.42	-1.84	2.06	-3.62	4.03	1.08	-1.62	0.17	4.84	-4.99	3.50	-0.54
1971	-2.11	-2.83	0.25	0.98	0.55	0.56	-0.80	0.21	-1.69	5.29	-0.40	1.34	1.34
1972	-4.28	0.11	-0.82	-0.94	-0.45	3.15	-1.62	1.70	0.81	4.85	6.02	-9.28	-0.75
1973	-1.74	-2.79	-0.08	-0.37	-2.01	4.61	1.62	-0.19	-4.30	6.64	2.29	-9.51	-5.83
1974	2.00	1.45	-2.24	2.30	-2.53	-0.93	0.35	0.68	0.47	1.66	0.13	5.89	9.22
1975	-1.11	-4.08	-0.90	-0.46	-0.01	0.58	0.24	-3.56	1.15	-0.01	2.63	1.74	-3.80
1976	-4.29	1.17	0.52	0.35	-1.28	-1.30	0.77	1.24	1.62	4.76	-6.36	0.49	-2.31
1977	-2.67	2.16	1.43	-2.24	3.93	-0.92	-2.97	0.89	-1.86	-0.13	1.34	5.99	4.95
1978	-2.01	-4.14	1.37	-2.10	0.07	0.22	-0.66	2.02	-1.06	3.08	-1.87	2.00	-3.07
1979	-1.60	-1.21	-0.52	-0.09	3.61	-1.58	0.73	0.07	-3.01	2.67	-1.30	4.16	1.91
1980	-0.50	-4.53	1.05	-1.09	1.39	-2.04	-1.01	4.40	-3.72	3.76	-2.07	1.00	-3.36
1981	-0.66	0.82	0.61	-0.64	1.16	-3.22	2.69	0.52	-3.04	2.57	1.17	0.22	2.19
1982	-2.26	3.40	-4.15	-0.48	0.23	0.50	-0.81	-1.50	-0.54	-0.87	2.27	1.99	-2.22
1983	-0.14	-0.86	0.64	-0.95	0.65	-0.61	-1.15	1.47	-1.29	0.74	-2.39	0.49	-3.39
1984	2.43	0.53	-0.38	0.15	-0.26	0.25	-1.32	-0.10	-1.54	0.43	-1.09	1.79	0.87
1985	0.79	1.40	-0.58	-0.42	-1.15	1.17	-0.63	-1.45	0.39	0.35	-0.45	2.67	2.08
1986	-1.31	-0.04	0.77	-0.49	0.59	-0.48	1.25	-2.19	-0.28	0.46	0.14	2.00	0.42
1987	1.51	-2.04	-1.62	0.18	0.86	0.15	3.84	-5.34	-0.44	0.83	-0.43	1.14	-1.36
1988	-0.33	1.51	1.76	No data									2.93
1989	No data			0.00	-1.20	-1.07	-0.68	2.83	-0.84	1.12	-2.25	4.22	2.13
1990	-1.87	2.38	1.70	-4.97	1.46	-3.36	6.24	-4.57	0.02	3.14	-2.72	0.56	-1.99
1991	0.81	-0.06	-2.80	3.40	0.52	-0.91	-0.44	-1.81	0.56	-0.07	-0.37	1.60	0.43
1992	0.54	4.84	1.08	0.87	-4.83	-2.02	-2.32	0.51	3.30	0.80	-1.07	1.00	2.70
1993	-0.17	-0.27	0.80	-2.96	2.18	-3.12	-1.20	-1.67	2.66	-0.81	0.60	2.54	-1.42
1994	-2.25	1.24	2.79	-1.13	0.25	-1.11	-3.91	0.34	-0.10	0.69	2.34	1.34	0.48
1995	2.23	-0.29	0.66	-8.23	3.67	1.55	-4.31	0.11	0.98	-0.50	3.08	0.04	-1.00
1996	-1.52	2.32	-3.82	3.64	0.05	-4.51	0.28	1.66	1.17	0.65	1.38	-0.30	0.99
1997	-1.91	0.37	-7.08	6.27	-1.44	0.68	-3.17	3.48	0.39	-2.51	3.70	1.00	-0.23
Average (1963-88, 1990-97)	-1.45	-0.69	-0.78	0.19	0.02	-0.48	-0.19	0.45	-0.10	2.11	0.72	0.30	0.08

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Table 5.7-31. Monthly flows (in 1,000 ac-ft/mo) from KPOPSIM for the Klamath River below Iron Gate dam for the 1961-97 period adjusted for the operations of the Klamath Irrigation Project and PacifiCorp facilities.

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Annual
1961	No computation - No data for PacifiCorp Operations												
1962	No computation - No data for PacifiCorp Operations												
1963	233.6	180.9	253.0	138.9	274.4	184.9	254.1	204.9	70.8	45.0	45.1	77.4	1,963.1
1964	116.2	168.7	140.5	174.3	146.9	203.6	236.3	137.5	130.5	47.2	49.9	73.3	1,624.9
1965	101.9	155.2	670.0	533.1	437.3	299.2	241.0	211.2	114.4	71.0	100.7	95.1	3,030.0
1966	131.7	186.3	178.0	168.1	149.3	245.7	234.9	116.8	73.1	41.1	46.1	90.5	1,661.5
1967	102.3	147.1	221.5	214.6	207.2	244.6	230.7	307.6	155.9	26.8	32.0	73.0	1,963.5
1968	122.5	109.5	154.4	158.4	246.3	191.2	98.5	90.9	37.8	30.1	82.4	82.5	1,404.4
1969	104.6	146.6	162.7	234.6	190.5	255.6	394.6	245.9	124.9	37.0	34.0	81.3	2,012.2
1970	133.2	122.6	233.3	477.4	302.9	281.2	151.3	159.1	84.0	37.6	27.2	78.9	2,088.8
1971	124.0	228.4	236.4	322.7	249.3	379.3	410.5	375.8	194.4	84.3	63.1	129.5	2,797.6
1972	144.4	191.2	208.6	304.2	272.3	675.3	281.0	224.3	110.6	44.8	73.2	113.8	2,643.6
1973	135.5	168.6	227.2	224.3	189.9	197.0	137.0	114.9	38.8	24.3	47.5	94.6	1,599.6
1974	128.5	256.7	297.0	421.8	248.6	391.1	434.7	267.8	138.2	86.0	80.3	91.5	2,842.2
1975	126.3	145.9	187.9	199.7	236.0	356.3	302.6	314.7	174.8	78.7	77.7	111.8	2,312.4
1976	154.3	175.8	215.8	208.4	192.0	226.9	183.9	141.9	80.8	56.6	136.7	100.3	1,873.4
1977	126.1	138.3	127.5	125.0	126.6	149.3	91.1	118.8	58.7	10.9	41.2	81.9	1,195.3
1978	104.0	155.6	286.0	304.6	226.3	276.3	253.5	171.7	76.4	52.0	53.7	110.6	2,070.7
1979	98.1	107.4	141.1	175.8	158.9	209.4	142.6	143.3	38.2	29.5	47.9	71.0	1,363.2
1980	120.7	163.8	174.1	307.8	249.7	230.0	164.2	139.4	80.5	36.4	28.5	83.7	1,778.8
1981	91.3	122.5	160.4	149.1	175.6	154.3	124.5	94.4	42.5	23.6	26.0	53.9	1,218.1
1982	110.7	199.4	334.8	224.7	489.8	388.5	375.7	234.3	143.1	86.9	58.4	98.9	2,745.2
1983	132.7	160.5	241.0	228.3	374.1	499.2	367.6	311.3	213.4	107.0	100.4	108.2	2,843.6
1984	139.6	221.1	417.2	279.6	268.3	424.6	352.7	288.3	186.4	80.2	83.7	137.2	2,879.0
1985	192.3	283.8	213.3	170.2	176.5	250.2	326.9	153.4	96.9	44.3	71.9	134.2	2,114.0
1986	137.1	156.5	158.1	230.2	448.7	464.0	220.4	174.9	91.9	48.4	52.7	126.1	2,309.3
1987	132.1	153.8	152.7	175.4	190.1	227.2	141.8	95.4	73.4	69.5	58.7	81.4	1,551.5
1988	93.8	110.7	187.4	No computation - No data for PacifiCorp Operations through December 1988									
1989				148.9	151.0	456.5	341.9	210.3	75.4	28.3	57.3	101.6	1,571.3
1990	115.8	115.3	125.7	148.8	140.0	219.1	137.6	110.5	71.0	34.7	67.5	77.2	1,363.1
1991	93.4	105.5	104.3	133.3	120.1	173.2	120.4	117.9	57.5	33.0	35.8	57.4	1,151.8
1992	76.2	108.6	117.6	115.3	99.2	108.0	93.8	44.8	16.4	36.6	19.5	42.6	878.6
1993	75.5	107.5	122.6	138.3	128.1	465.1	353.1	237.8	151.4	40.5	46.7	62.0	1,928.8
1994	108.2	91.9	122.4	125.1	107.7	120.7	94.7	82.7	33.5	11.5	24.9	39.3	962.7
1995	67.1	111.9	109.5	212.0	205.9	329.5	246.9	218.8	114.0	50.0	20.8	59.7	1,746.1
1996	90.2	100.9	250.6	286.4	556.3	343.5	253.5	247.1	101.8	53.9	58.6	80.4	2,423.1
1997	114.1	162.4	368.0	603.8	321.2	226.4	217.1	172.1	90.3	61.6	63.3	95.0	2,495.4
Average (1963-88, 1990-97)	120.7	156.1	215.6	239.8	239.6	284.6	232.4	183.9	99.0	49.1	56.2	87.7	1,964.7

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Figures 5.7-42, 5.7-43, and 5.7-44 depict the relative effects of Klamath Irrigation Project and PacifiCorp Project operations on Klamath River flows at Iron Gate dam. The major line in Figures 5.7-42, 5.7-43, and 5.7-44 presents the No-Projects flow condition for the 1961-97 period in average monthly cfs. (Note: No PacifiCorp operations records were available for the periods October 1961 to September 1962 and January 1988 to December 1988.) Each graph also contains a second line presenting the flows with PacifiCorp operations only, and a third line presenting the flows with Klamath Irrigation Project operations only. Figure 5.7-42 presents this information in cfs for the period 1961-1972; Figure 5.7-43 presents this information in cfs for the period 1973-1984; and Figure 5.7-44 presents this information in cfs for the period 1985-1997.

Figures 5.7-45 and 5.7-46 present the same information as Figures 5.7-42, 5.7-43, and 5.7-44 summarized by water year type for the forecast year period (February through January). Monthly impacts of both Klamath Irrigation Project and PacifiCorp Project operations were averaged for the five hydrologic year types as defined by Hardy and Addley (2001).[14] Water year types are defined in Table 5.7-3.

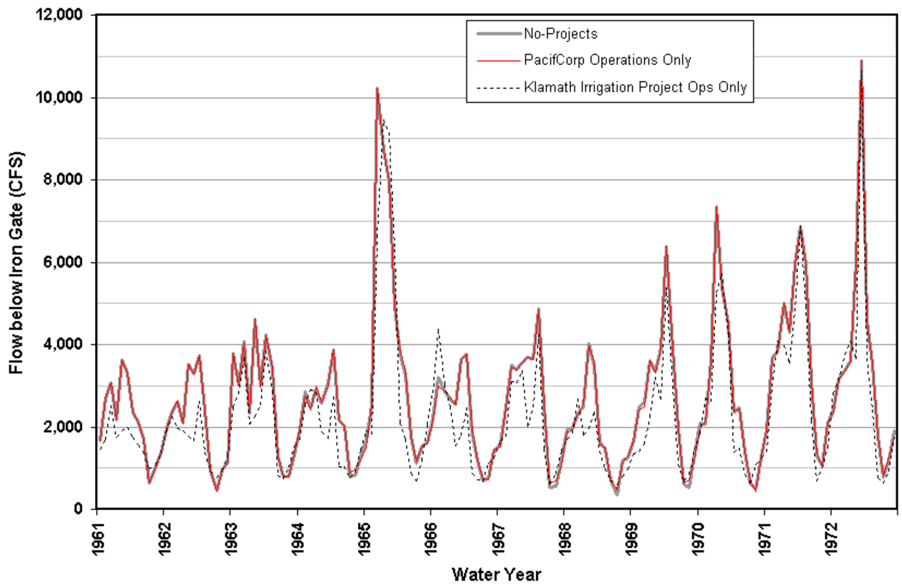

Figure 5.7-42. Klamath River flow below Iron Gate dam for Water Years 1961-1972 as simulated by KPOPSIM for three scenarios: (1) No-Projects, (2) PacifiCorp Hydroelectric Project operations only, and (3) Klamath Irrigation Project operations only.

[14] Four water year types are assumed in the KPOPSIM model used in this analysis: above average, below average, dry, and critical. These year types are based on net inflow to Upper Klamath Lake for the April-September period. The KPOPSIM water year types were converted to the five water year classifications of Hardy and Addley (2001) based on a comparison with the USBR four water year classifications presented in Hardy and Addley (2001, Table 19, page 97).

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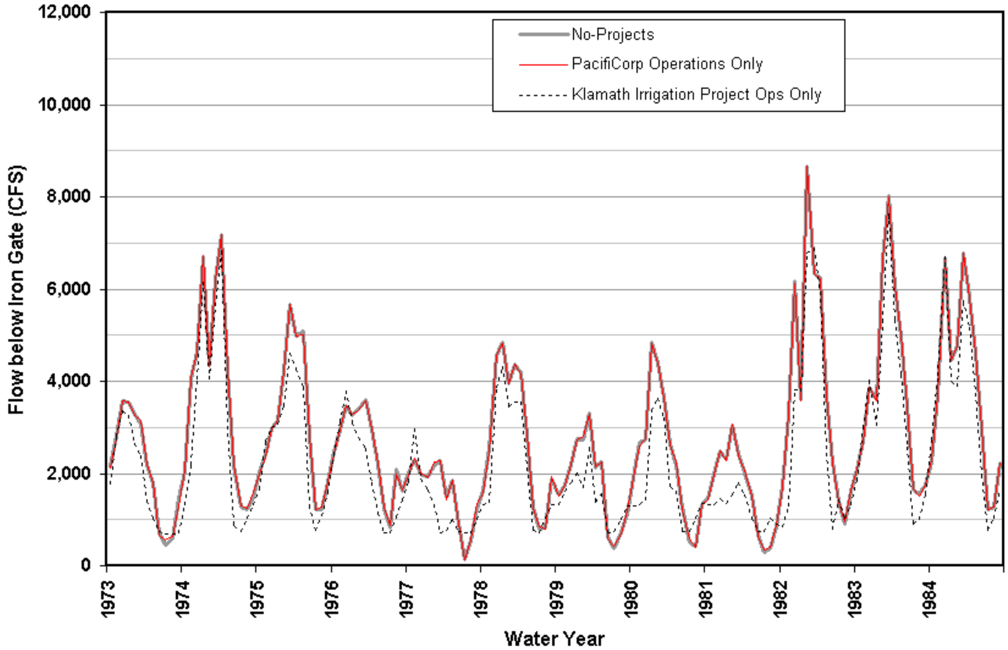

Figure 5.7-43. Klamath River flow below Iron Gate dam for Water Years 1973-1984 as simulated by KPOPSIM for three scenarios: (1) No-Projects, (2) PacifiCorp Hydroelectric Project operations only, and (3) Klamath Irrigation Project operations only.

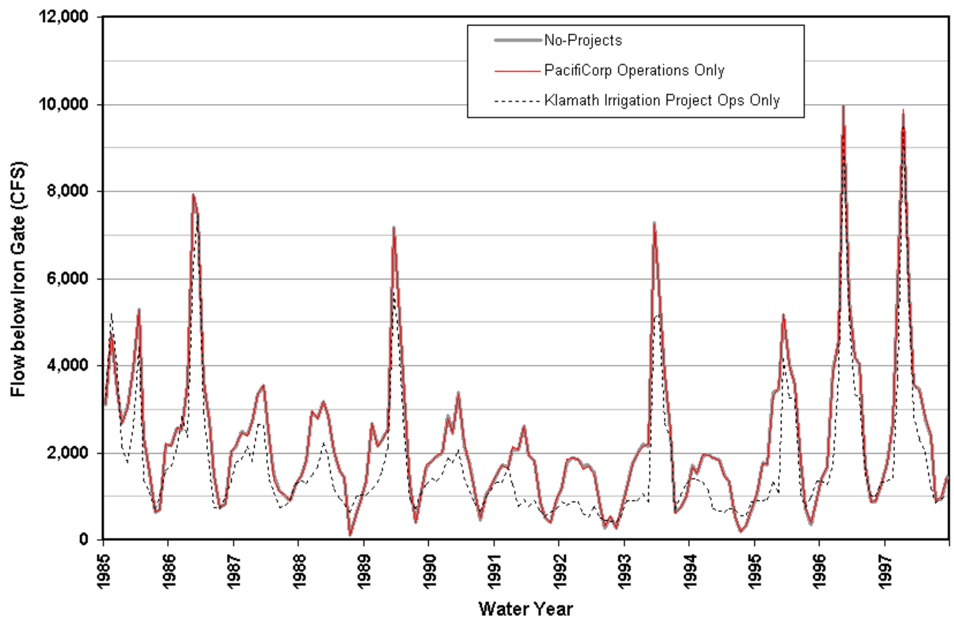

Figure 5.7-44. Klamath River flow below Iron Gate dam for Water Years 1985-1997 as simulated by KPOPSIM for three scenarios: (1) No-Projects, (2) PacifiCorp Hydroelectric Project operations only, and (3) Klamath Irrigation Project operations only.

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Figure 5.7-45 presents the percent increase or decrease in monthly flows in the Klamath River below Iron Gate dam due to Klamath Irrigation Project operations only (as compared to No-Projects flows) as simulated by KPOPSIM by water year type. The results indicate that monthly flows in the Klamath River below Iron Gate dam are lower with Klamath Irrigation Project operations than the No-Projects river flows by an average of about 20 to 35 percent in November through June, and as much as 64 percent in February, of critically dry years. Conversely, the results indicate that monthly flows are higher with Klamath Irrigation Project operations than the No-Projects river flows by an average of about 25 to 35 percent in July and August, and as much as 100 percent in July of dry years. These results reflect that the Klamath Irrigation Project stores, or consumptively uses, river water in all spring and winter months of all years.

Figure 5.7-46 presents the percent increase or decrease in monthly flows in the Klamath River below Iron Gate dam due to PacifiCorp's Project operations only (as compared to No-Projects flows) as simulated by KPOPSIM by water year type. The results indicate that monthly flows in the Klamath River below Iron Gate dam are changed little, if at all, in most months with Project operations compared to the No-Projects river flows. On average, monthly flows in the Klamath River due to PacifiCorp operations differ from No-Projects flows by 1 percent or less in most months of the five water year types. These results reflect that the PacifiCorp operational effects are not nearly as great as Klamath Irrigation Project operational effects. This is due to the nonconsumptive nature of PacifiCorp operations (except for minor evaporation) and to the relatively small active storage capacities of PacifiCorp's reservoir facilities.

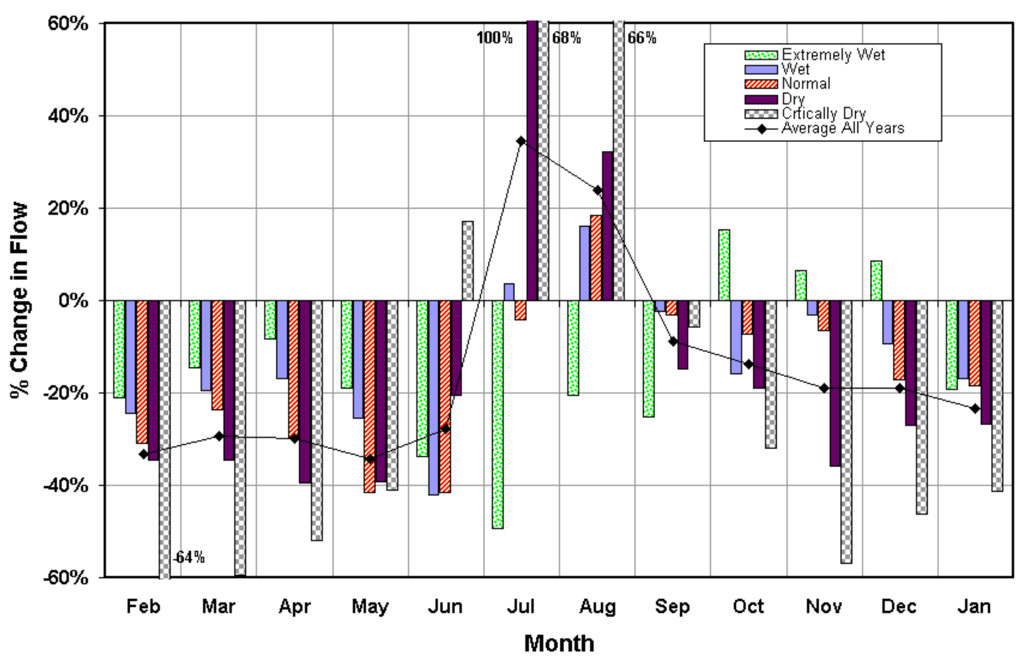

Figure 5.7-45. Percent increase or decrease in monthly flows in the Klamath River below Iron Gate dam due to Klamath Irrigation Project operations only (as compared to No-Projects flows) for Water Years 1961-97 as simulated by KPOPSIM.

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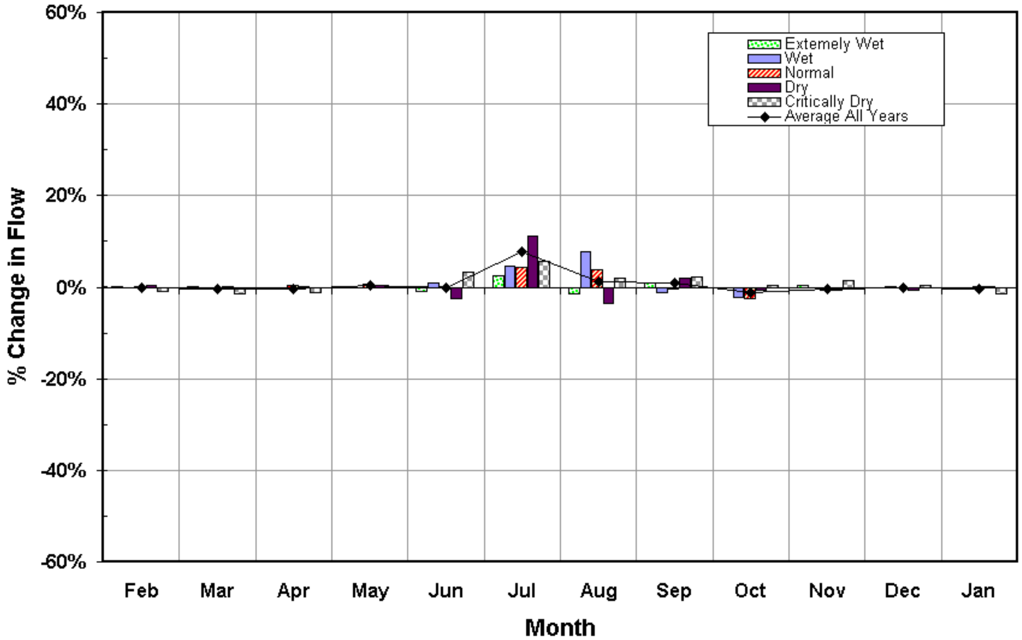

Figure 5.7-46. Percent increase or decrease in monthly flows in the Klamath River below Iron Gate dam due to PacifiCorp Hydroelectric Project operations only (as compared to No-Projects flows) for Water Years 1961-97 as simulated by KPOPSIM.

5.7.6 Effects of PacifiCorp Operations on Hydrology of Fall Creek, Spring Creek, and Jenny Creek

5.7.6.1 Flow Operations and Conditions

The Fall Creek Development is located on Fall Creek, a tributary of the Klamath River, approximately 0.4 mile south of the Oregon-California border. The Fall Creek Development consists of two small diversion dams, an earthen ditch, a penstock, and a powerhouse. Built in 1903, the Fall Creek hydroelectric facility is one of PacifiCorp's oldest. The dam on Fall Creek is a log crib, earth-filled diversion dam. Waterway length from dam to penstock intake is approximately 4,560 feet.

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

A USGS gauge station (No. 11512000) operated on Fall Creek from April 1934 to September 1959. A diversion structure at Spring Creek, a tributary to nearby Jenny Creek, has existed since at least the 1950s to carry flow into Fall Creek to increase hydropower production. In 1984, this structure and canal were rebuilt by PacifiCorp to upgrade the diversion. About this same time, a party filed a claim for 8 cfs. In 2002, after following the full adjudication process through the State of Oregon and a subsequent appeal process, PacifiCorp was granted a right to 16.5 cfs from Spring Creek. PacifiCorp estimates that the minimum observed flow in Spring Creek, which is,

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in fact, spring-fed, is approximately 5 cfs. Therefore, it was assumed that the current and future hydrologic condition in Fall Creek would be appropriately represented by the sum of this diversion and measured flows from the 1934-1959 USGS gauge period of record.

Owing to uncertainty, both in application of historical flows to expected future conditions and in the variability of Spring Creek diversion flows, hydrologic evaluation of the basin used an overall flow duration curve that was created using the daily record. Exceedances were calculated using monthly average flow data. The 90 percent, 50 percent, and 10 percent exceedance values for Fall Creek flow, corresponding to wet, average, and dry conditions, are reported for three scenarios: (1) period of record only, representing historical Fall Creek conditions without diversion; (2) 5 cfs diverted, representing the minimum expected diversion flow plus historical conditions; and (3) 16.5 cfs diverted, the sum of historical conditions and the maximum allowed diversion. Although it is likely that the range of diversions, 5 to 16.5 cfs, follows a seasonal pattern, with higher flows in later winter and spring and low flows in late summer and autumn, no data were available to confirm this. For that reason, the range of diversions and water year types were overlain to provide a range of flow values and associated exceedances, regardless of time of year.

As an example, Figure 5.7-47 shows the 50 percent (median) monthly flow values for Fall Creek. Appendix 5B provides the 90 percent, 50 percent, and 10 percent exceedance values for Fall Creek flow, corresponding to wet, average, and dry conditions, reported for the three scenarios.

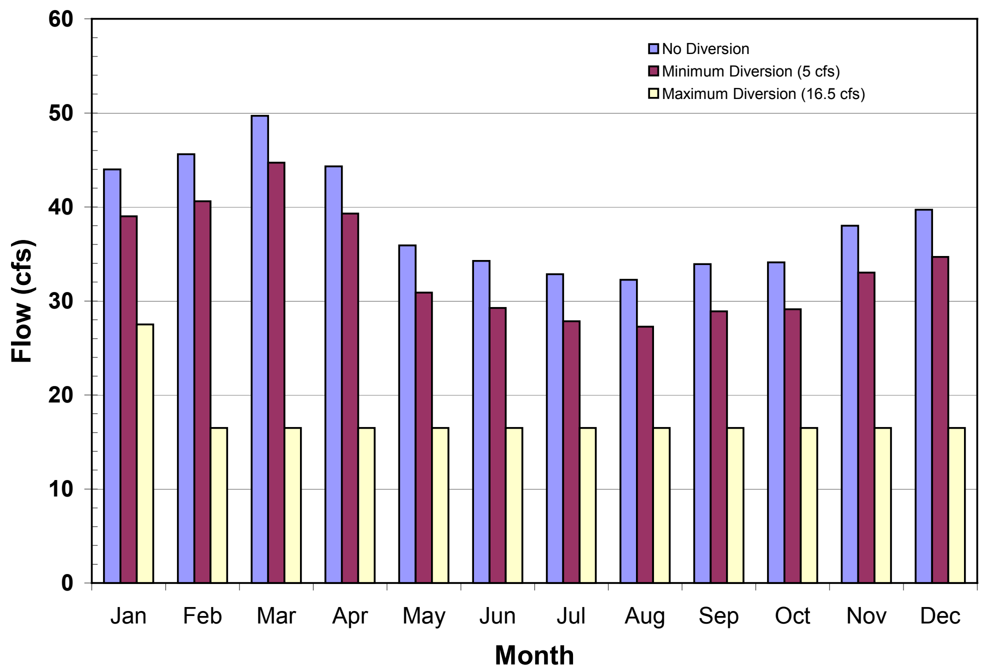

Figure 5.7-47. Estimated monthly median flow values for Fall Creek based on available data from USGS Gauge No. 11512000 for the period of record, April 1934 to September 1959. Spring Creek flow is diverted to Fall Creek throughout the year .

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Annual Peak Flows in Fall Creek

The peak flow series for the period of record 1933-1959 at Fall Creek near Copco (USGS Gauge No. 11512000) is shown in Figure 5.7-48. Peak annual flows by return interval and exceedance probability (as estimated using HEC-FFA) are listed in Table 5.7-32. The highest peak flow (875 cfs) at USGS Gauge No. 11512000 was recorded in December 1955 and represented a near 50-year flood event. The only other peak flow in excess of a 10-year event (392 cfs) was recorded in January 1948.

Peak flows in the Fall Creek bypass reach (Table 5.7-32) are conservatively estimated by simply subtracting the hydraulic capacity of the Fall Creek powerhouse (50 cfs) from the values for the gauge location. The results indicate that peak flows in the bypass reach are reduced by about 38 percent at the 2-year event, 13 percent at the 10-year event, and 6 percent at the 50-year event.

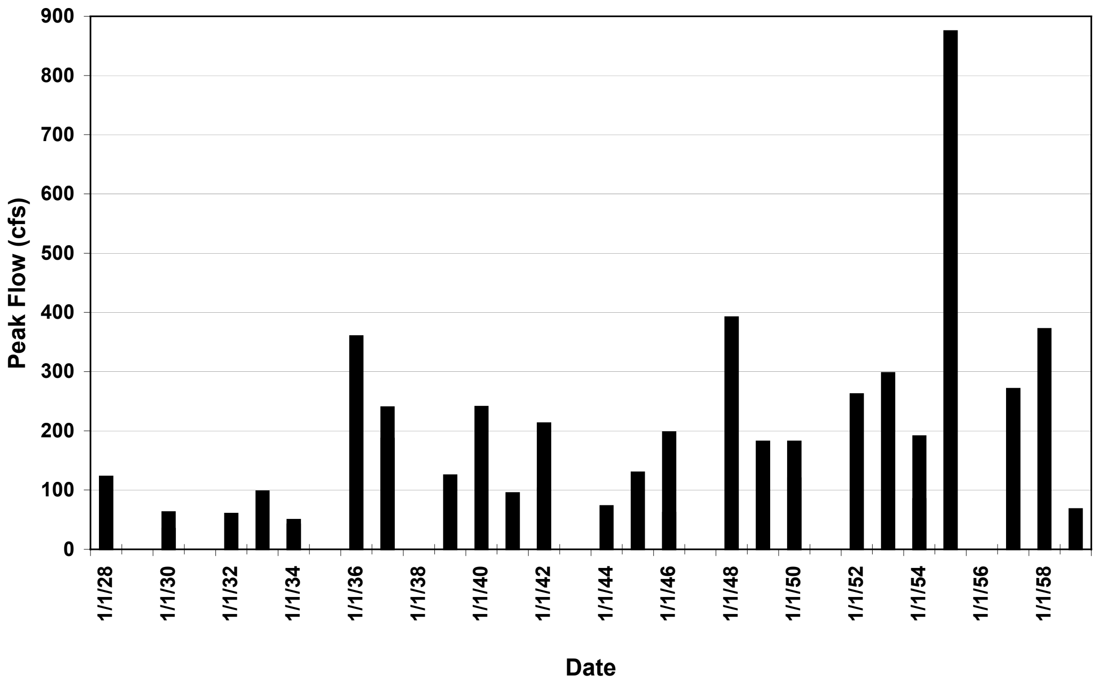

Figure 5.7-48. Peak annual flow series for the period of record 1928-1959 at the Fall Creek near Copco USGS Gauge No. 11512000).

Table 5.7-32. Peak annual flows by return interval and exceedance probability for the Fall Creek near Copco (USGS Gauge No. 11512000) as estimated using HEC-FFA.

		Estimated Peak Annual Flows (cfs)	
Return Period (years)	**Exceedance Probability (%)**	**Fall Creek Gauge**	**Fall Creek Bypass (est.)**
100	1.0	1,050	1,000
50	2.0	800	750
20	5.0	542	492
10	10.0	392	342
5	20.0	270	220
2	50.0	130	80
1.25	80.0	73	23

Annual Low Flows in Fall Creek

The low flow frequency statistics for the daily flow period of record 1933-1959 at Fall Creek near Copco (USGS Gauge No. 11512000) are listed in Table 5.7-33. Flows listed are averaged over the number of days listed in the first column of the table. This corresponds to the xQy notation. For example, for Fall Creek near Copco, the 7Q10 (the 7-day average low flow that occurs every 10 years) is 25.9 cfs, corresponding to the 7-day flow with a 10 percent chance of occurrence every year.

Table 5.7-33. Annual low flow statistics for Fall Creek near Copco (USGS Gauge No. 11512000) as estimated using DFLOW 3.

	Annual Percent Chance of Occurrence			
Days	**50**	**20**	**10**	**5**
1	30.2	26.8	25.4	24.4
3	30.6	27.2	25.7	24.6
5	30.8	27.3	25.8	24.7
7	30.6	27.3	25.9	24.8
30	31.4	27.9	26.4	25.3

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