Yakima River Basin Study

Yakima River Basin Water Resources Technical Memorandum

U.S. Bureau of Reclamation
Contract No. 08CA10677A ID/IQ, Task 1

Prepared by

Anchor QEA

U.S. Department of the Interior
Bureau of Reclamation
Pacific Northwest Region
Columbia-Cascades Area Office

State of Washington
Department of Ecology
Office of Columbia River

March 2011

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The mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to Indian tribes and our commitments to island communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

The Mission of the Washington State Department of Ecology is to protect, preserve and enhance Washington's environment, and promote the wise management of our air, land and water for the benefit of current and future generations.

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1.0 Introduction

This technical memorandum describes the surface and groundwater resources of the Yakima River Basin, water development history for the U.S. Bureau of Reclamation's (Reclamation) Yakima Project, and Yakima Project facilities and operations, including effects on flows and fisheries. Also described are Columbia River water resources, management and preliminary water availability analysis results.

This technical memorandum is composed largely of summary information from existing documents, edited slightly for clarity. All documents are listed in the reference section. In some sections where the information is primarily from a single source, a citation is provided at the beginning of each section in lieu of referencing each document within every paragraph. New analysis was conducted for Columbia River water availability (see Table 10 and Figures 2 and 3 in Section 3.4, with accompanying narrative).

2.0 Yakima River Basin Water Resources

2.1 Yakima River Basin Characteristics

All information in Section 2.1 is from the Yakima River Basin Water Storage Feasibility Study: Final Planning Report/Environmental Impact Statement, Volume 1 (Reclamation 2008).

The Yakima River Basin (see Figure 1) is located in central Washington, bounded by the Cascade Range on the west, the Wenatchee Mountains on the north, the Columbia River drainage on the east, and by the Horse Heaven Hills on the south. The Yakima River originates in the Cascade Mountains near Snoqualmie Pass and flows southeast for approximately 215 miles to its confluence with the Columbia River near Richland, Washington. The Yakima River Basin encompasses roughly 6,155 square miles and includes portions of Kittitas, Yakima, Benton, and Klickitat Counties.

The basin varies considerably from the higher mountain altitudes (elevation 8,184 feet in the Cascades) to the semiarid lower Yakima Valley (elevation 340 feet at the Yakima River confluence with the Columbia River). The western and northern mountains annually receive approximately 140 inches of precipitation, compared to the lower valley, which often receives less than 10 inches. The higher elevation areas in the northern and western areas are mostly forested and used for timber harvest, cattle grazing, fish and wildlife habitat, and recreation. Approximately one-fourth of this area is designated as wilderness. The middle elevations are primarily used for dry land and irrigated agriculture, cattle grazing, wildlife, and military training. The lower elevations in the eastern and southern portions of the basin, including the study area, are primarily used for irrigated agriculture. Agriculture is the main economy of the basin.

The Yakima River and its tributaries are the primary sources for surface water in the basin. Major tributaries include the Kachess, Cle Elum, Teanaway, and Naches rivers. The Naches River, which joins the Yakima River at the City of Yakima, has several tributaries including the American, Bumping, and Tieton Rivers. The Yakima River and its tributaries historically provide spawning and rearing habitat for anadromous fish. Natural streamflow conditions prevail only in the upper, uncontrolled reaches of the Yakima River system because of storage development and use of water for irrigation.

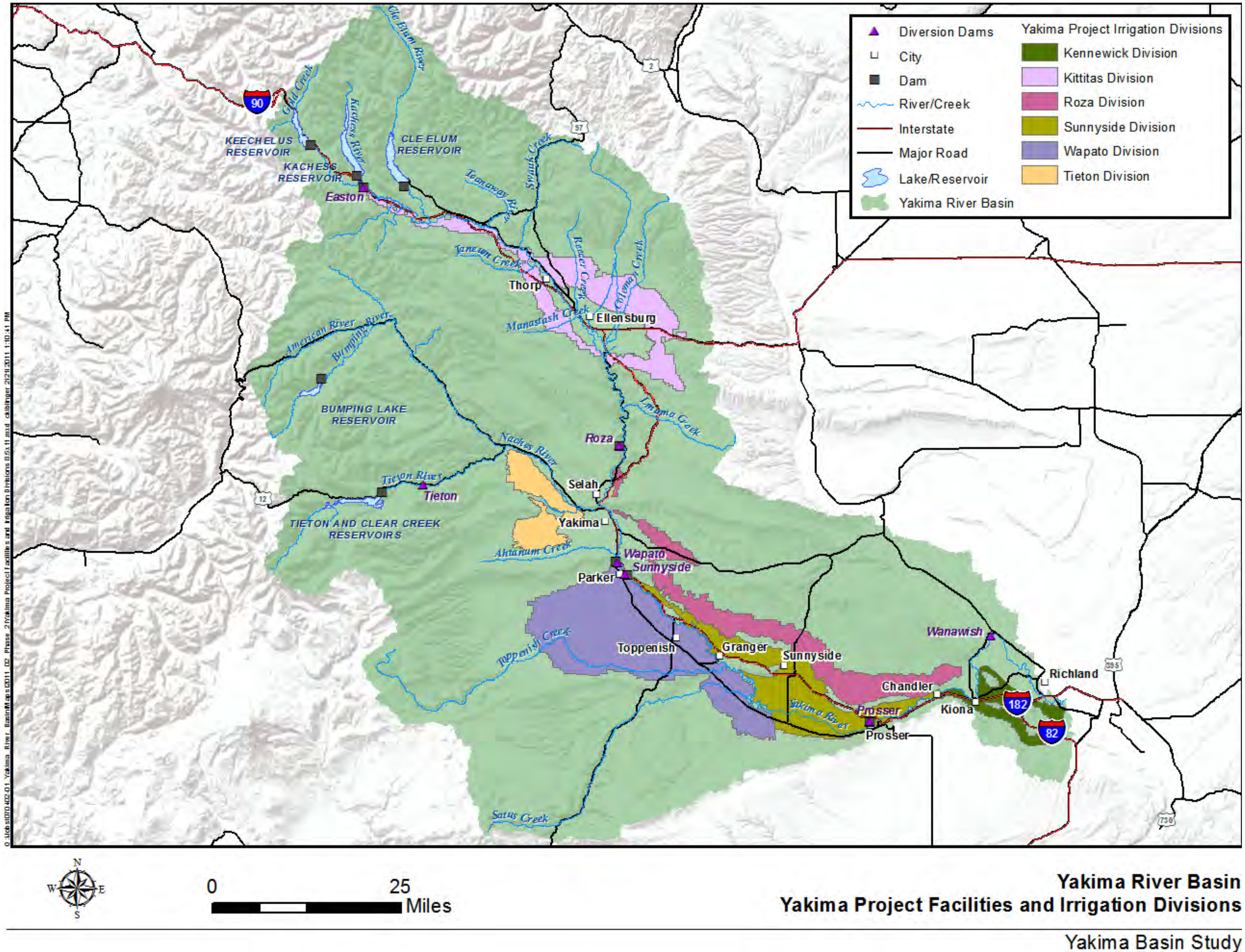

Figure 1. Key characteristics of Yakima River basin

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2.2 Water Development History

All information in Section 2.2 is from the Yakima River Basin Water Storage Feasibility Study: Final Planning Report/Environmental Impact Statement, Volume 1 (Reclamation 2008) except where noted.

This section provides a brief overview of water development in the Yakima Basin, and dates of key events that have occurred since the 1850s.

1850s

Development of irrigation in the Yakima River Basin began.

1902

An estimated 122,000 irrigated acres were served by natural flows in the rivers and tributaries. The natural flow, however, was inadequate to assure a dependable water supply.

1903

A petition dated January 28, 1903, from citizens of Yakima County to the Secretary of the Interior requested United States involvement in irrigation. Further irrigation development was not possible unless two things occurred: (1) existing water users had to agree to limit their water use during the low-flow periods of late summer and early fall and (2) water storage was necessary to capture early-season runoff for supplying irrigation water throughout the growing season. The limitation on water use was accomplished by “limiting agreements” with more than 50 appropriators on the Yakima and Naches Rivers.

1905

The development of storage was made possible by the Washington Legislature in March 4, 1905, by granting to the United States the right to exercise eminent domain in acquiring lands, water and property for reservoirs, and other irrigation works (Chapter 90.40 Revised Code of Washington [RCW]).
Under this law, a withdrawal of the unappropriated waters of the Yakima River and its principal tributaries was filed by the United States on May 10, 1905.

These actions led to authorization of the Yakima Project on December 12, 1905.

Using the provisions of RCW Chapter 90.40, the Secretary of the Interior withdrew all the unappropriated waters of the Yakima River and tributaries for the benefit of the proposed Yakima Reclamation Project. The withdrawal was effective from its May 10, 1905 initiation to its December 31, 1951 expiration.

During those 46 years, water rights were established under Washington law for the developed project facilities.

1945

Disputes over water use from the Yakima River during years of low runoff resulted in litigation in the Federal Court. In 1945, the District Court of Eastern Washington issued a decree under Civil Action No. 21 called the *1945 Consent Decree*, which established the rules under which Reclamation should operate the Yakima Project to meet the water needs of both the irrigation districts that predated the Yakima Project, and the rights of divisions formed in association with the Yakima Project.

The consent decree determined water delivery entitlements for all major irrigation systems in the Yakima River Basin, except for lower reaches of the Yakima River near the confluence with the Columbia River. It states the quantities to which all water users are entitled (maximum monthly and annual diversion limits) and defines a method of prioritization to be placed in effect during water-deficient years. Section 2.3.4 has additional information on irrigation entitlements.

1977

The consent decree controlled distribution of Yakima Project water in the Yakima River Basin from 1945 to 1977. In the spring of 1977, with a drought imminent, Reclamation predicted the proratable water users would receive only 15 percent of their normal water supply. Some proratable water users brought action in the U.S. District Court for the Eastern District of Washington to modify the 1945 Consent Decree and make all water right holders proratable. The Yakama Nation sought to intervene and also filed a separate action in U.S. District Court to have its treaty-reserved water rights determined. In light of this dilemma, United States District Judge Marshall Neill suggested a State court general adjudication to finally determine water rights in the Yakima River Basin.

On October 12, 1977, the State of Washington Department of Ecology filed an adjudication of the Yakima River system in the Superior Court of Yakima County (Superior Court), naming the United States and all persons claiming the right to use the surface waters of the Yakima River system as defendants. The purpose of this adjudication was to determine all existing surface-water rights within the basin, and to correlate each right in terms of priority with all other rights.

At about the same time, the Yakama Nation filed an action in U.S. District Court to determine the priority and water rights of the Yakama Nation under the Treaty of 1855. The Federal case was remanded to the State case, and the filing by the Yakama Nation did not proceed.

1979

The Yakima River Basin Water Enhancement Project (YRBWEP) (Public Law [P.L.] 96-162) was initiated by Congress in 1979 in recognition of the extreme water shortage problems of the basin. Since then, State and Federal YRBWEP feasibility study activities have been ongoing with the objectives to develop and implement a comprehensive solution for efficient management of Yakima Basin water supplies.

1981/1982

In a February 13, 1981, letter to the State of Washington Department of Ecology, referenced *Withdrawal of Waters for Yakima River Basin Water Enhancement Study*, Reclamation filed notice that it ". . . intends to make examinations and surveys for the utilization of the unappropriated waters of the Yakima River and its tributaries for multipurpose use under the Federal Reclamation laws."

Reclamation certified on January 16, 1982, that a project to utilize unappropriated waters was feasible and that investigations would be made in detail. Pursuant to RCW 90.40.030, this certification of feasibility continued the withdrawal of unappropriated waters until January 18, 1985. Reclamation has continuously renewed this withdrawal, and it remains active.

1984
Early in YRBWEP implementation, fish passage problems were identified as needing immediate attention. Congressional legislation authorized YRBWEP Phase 1 (P.L. 98-381), which primarily involved rebuilding fish ladders and constructing fish screens on river diversions.

1990
A partial summary judgment of the Superior Court entered on July 17, 1990, defined the treaty reserved rights of the Yakama Nation. The Yakama Nation rights to flow in the mainstem Yakima River were unanimously affirmed by the Washington Supreme Court on appeal. The treaty rights were divided into separate rights for fish and agriculture. The State Supreme Court determined that various acts of Congress, agencies, and decisions of various tribunals had defined and limited the treaty irrigation rights of the Yakama Nation. This right translated into existing nonproratable irrigation rights with 1855 priority and proratable irrigation rights with a priority date of 1905.

The flow right was held to be the "specific minimum instream flow necessary to maintain anadromous fish life in the river, according to the annual prevailing conditions as they occur and determined by [Reclamation] in consultation with the Yakima River Basin System Operations Advisory Committee, Irrigation Districts and Company managers and others" (see Section 2.3.5 for discussion of target flows). This decision was later extended to include all tributaries that support fish at the Yakama Nation's usual and accustomed fishing locations. The priority date for the treaty fishing right is "time immemorial."

1993
The relationship of the 1945 Consent Decree to the State's adjudication proceeding was addressed by the Superior Court in 1993 (Memorandum Opinion Re: Threshold Issues). The court held that the consent decree, in and of itself standing alone, did not establish any water rights. However, it did "memorialize the appropriations thereto made" (pre-1945). Water right claimants had the burden of addressing changes in the appropriations after 1945. The court further stated: "Once this case is concluded . . . the final judgment herein would supersede that (1945) Decree."

1994
Congress passed legislation for YRBWEP Phase 2 (P.L. 103-434), which provided for significant water conservation and acquisition activities; studies to define the long-term water needs of fish and irrigators; improvements to the Wapato Irrigation Project; and development of an interim plan for management of basin water supplies.

Today
The Superior Court has issued all Conditional Final Orders (CFO) which confirm the surface water rights for the Yakima River basin, including the Yakima Project. Reclamation currently delivers water to Yakima Project water users under the authority of Federal contracts, the 1945 Consent Decree and its CFO from the adjudication.

2.3 Yakima Project

All information in Section 2.3 is from the Interim Comprehensive Basin Operating Plan for the Yakima Project (Reclamation 2002), except where noted.

The Yakima Project provides irrigation water for a comparatively narrow strip of fertile land that extends for 175 miles on both sides of the Yakima River in south-central Washington State. The irrigable lands eligible for service under Reclamation's Yakima Project total approximately 465,000 acres. The project has seven divisions – a reservoir storage division and six water delivery divisions: Kittitas (59,123 acres), Tieton (27,271 acres), Sunnyside (103,562 acres), Roza (72,511 acres), Kennewick (19,171 acres), and Wapato. The Wapato Division is operated by the Bureau of Indian Affairs (BIA), but receives most of its water supply from the project for irrigation of 136,000 acres of land. Over 45,000 acres not included in the seven divisions are irrigated under supplemental water supply contracts with Reclamation. Storage reservoirs on the project are Bumping Lake, Clear Creek, Tieton, Cle Elum, Kachess, and Keechelus reservoirs.

Other project features include five diversion dams, 420 miles of canals, 1,697 miles of laterals, 30 pumping plants, 144 miles of drains, nine power plants (three in private ownership), plus fish passage and protection facilities constructed throughout the project.

2.3.1 Main Storage Reservoirs

The five main water storage facilities used to supplement the unregulated flow from the Yakima River are Keechelus, Kachess, Cle Elum, Rimrock and Bumping reservoirs. The five major storage facilities/reservoirs store runoff during the winter and spring/summer seasons for later release to supply irrigation demands during the summer/fall low-flow runoff periods. The total storage of the five major storage reservoirs is slightly more than 1 million acre-feet. These reservoirs are operated in a coordinated manner to supply the needs of the system as a whole. Releases from each reservoir are balanced to meet system-wide demands in conjunction with natural runoff and return flow available in the basin. No one reservoir is designated to supply the needs of one particular area, irrigation district, or division. Table 1 lists the storage capacity and average annual runoff for the five main storage reservoirs. Other water storage is provided through snowpack (often called the "sixth reservoir") and Clear Creek Lake, a small lake above Rimrock Lake mostly used for recreation. These reservoirs are described in more detail in the sections below.

Table 1. System Storage Capacity and Average Annual Runoff

Reservoir	Drainage Area (square miles)	Capacity (acre-feet)	Average Annual Runoff (acre-feet) *	Ratio of Average Runoff to Capacity
Keechelus	54.7	157,800	244,764	1.5:1
Kachess	63.6	239,000	213,398	0.9:1
Cle Elum	203.0	436,900	672,299	1.5:1
Bumping	70.7	33,700	209,492	6.2:1
Rimrock	187.0	198,000	367,966	1.8:1
Total	579.0	1,065,400	1,707,920	1.6:1

* Period of Record = 1920-1999
Source: Reclamation 2002

Keechelus Lake

Keechelus Lake is located 10 miles northwest of the town of Easton and is the furthest upstream reservoir on the Yakima River system at River Mile (RM) 214.5 on the Yakima River. Keechelus Lake was constructed over a natural lake and is impounded by Keechelus Dam, an earth-fill dam 128 feet high and 6,650 feet wide at the crest. Keechelus Lake has an active capacity of 157,800 acre-feet at an elevation of 2,525 feet (Ecology 2009).

Kachess Lake

Kachess Lake is located approximately 2 miles northwest of Easton in the upper Yakima River Basin. It releases water into the Kachess River, which flows into the Yakima River at RM 203.5. Kachess Lake was constructed over a natural lake and is impounded by Kachess Dam, an earth-fill dam 115 feet high and 1,400 feet wide at the crest. Kachess Lake has an active capacity of 239,000 acre-feet at an elevation of 2,268 feet (Ecology 2009).

Cle Elum Lake

Cle Elum Lake is located 8 miles northwest of the town of Cle Elum in the upper Yakima River Basin. It releases water into the Cle Elum River, which flows into the Yakima River at RM 185.6. Cle Elum Lake was constructed over a natural lake and is impounded by Cle Elum Dam, an earth-fill dam 165 feet high and 1,801 feet wide at the crest. Cle Elum Lake has an active capacity of 436,900 acre-feet at an elevation of 2,250 feet (Ecology 2009).

Bumping Lake

Bumping Lake is located on the Bumping River in the Naches River basin approximately 29 miles northwest of the town of Naches. The Bumping River flows into the Naches River at RM 44.6. Bumping Lake was constructed over a natural lake and is impounded by Bumping Dam, an earth-fill dam 60 feet high and 2,925 feet wide at the crest. Bumping Lake has an active capacity of 33,700 acre-feet at an elevation of 3,435 feet (Ecology 2009).

Rimrock Lake

Rimrock Lake is located on the Tieton River in the Naches River basin about 40 miles northwest of the City of Yakima. The Tieton River flows into the Naches River at RM 17.5. Rimrock Lake is impounded by Tieton Dam, an earth-fill dam constructed with a concrete core 319 feet high and 920 feet wide at the crest. Rimrock Lake has an active capacity of 198,000 acre-feet at an elevation of 2,935 feet (Ecology 2009).

Sixth Reservoir (Snowpack)

Only 30 percent of the average annual total natural runoff can be stored in the storage system, therefore, the Yakima Project depends heavily on the timing of spring/summer runoff (snowmelt and rainfall). The early spring/summer natural flow is utilized to supply most river basin demands through June in an average year. The majority of spring/summer runoff is from snowmelt, therefore snowpack is often called the sixth reservoir. In most years, the five major reservoirs are operated to peak storage in June (average mid-June, period of record 1940-1999), around the same time the major natural runoff ends.

Clear Creek Lake

Clear Creek Lake is a small, 5,300 acre-foot lake located above Rimrock Reservoir. Although the lake has little capacity to supplement water supply, in short water years it is possible to provide some benefit to downstream storage demands to offset minimum storage requirements in Rimrock Lake for irrigation and fisheries.

2.3.2 Total Water Supply Available

Total water supply available (TWSA) is defined in the 1945 Consent Decree as “That amount of water available in any year from natural flow of the Yakima River, and its tributaries, from storage in the various Government reservoirs on the Yakima watershed and from other sources, to supply the contract obligations of the United States to deliver water and to supply claimed rights to the use of water on the Yakima River and its tributaries, heretofore recognized by the United States.”

Reclamation interprets the above to mean “. . . the total water supply available for the Yakima River Basin above PARW (the United States Geological Survey (USGS) gage at Parker referred to as “Parker gage”, located below Union Gap and the Sunnyside Diversion Dam), for the period April through September,” expressed in a mathematical formula, reading as follows:

	April 1 through July 31 forecast of runoff
+	August 1 through September 30 projected runoff
+	April 1 reservoir storage contents
+	Usable return flow upstream from Parker gage
=	TWSA

TWSA provides an estimated total water volume available for use in determining the instream flow targets for each year in accordance with the operating criteria of the YRBWEP legislation. The total demand to be placed against this TWSA for irrigation, regulation, and flows passing Parker gage averages 2.7 million acre-feet (including Title XII target flows) in a normal year.

Return flow resulting from irrigation diversions above Sunnyside Dam are an integral part of the TWSA estimate. The return flow depends on the quantity and location of diversion and loss, which is also controlled by amount, time, and availability of runoff. The return flow will vary from year to year, but the usable portion is a fairly uniform base flow that is generated by fairly stable upstream diversion rates. The return flow volume projected to be usable is 400,000 acre-feet in high runoff years, 375,000 acre-feet in average years, and 350,000 acre-feet in low runoff years.

Each year Reclamation develops monthly runoff forecasts beginning in January and typically ending in July. Early forecasts (January and February) are primarily used in flood-control operations. By March, forecasts become more suitable for TWSA estimation. The forecasts are made for anticipated precipitation levels of 50 percent, 100 percent, and 150 percent of normal.

The average annual unregulated flow of the Yakima River Basin at Parker gage totals approximately 3.4 million acre-feet, ranging from a high of 5.6 million acre-feet (1972) to a low of 1.5 million acre-feet (1977). The surface-water entitlements above the Parker gage total 2.41 million acre-feet. Of that total, the five Yakima Project divisions diverting above the Parker gage have 1.94 million acre-feet of entitlements. The average diversions of the five Yakima Project divisions above Parker total 1.77 million acre-feet (period of record, 1990 through 2009) and have declined since the early 1990s. The average diversion in the last five non-drought years has totaled 1.6 million acre-feet.

Table 2. Historical April 1 TWSA Estimates

Year	Total (acre-feet)
1977	2,037,000
1978	2,678,000
1979	2,657,000
1980	3,147,000
1981	2,367,000
1982	3,256,000
1983	3,392,000
1984	2,786,000
1985	3,111,000
1986	2,668,000
1987	2,559,000
1988	2,253,000
1989	3,071,000
1990	3,268,000
1991	2,962,000
1992	2,422,000
1993	1,974,000
1994	2,016,000
1995	3,044,000
1996	2,872,000
1997	4,542,000
1998	2,982,000
1999	4,198,000
2000	3,305,000
2001	1,678,000
2002	3,316,000
2003	2,644,000
2004	2,553,000
2005	1,717,000

Sources: Reclamation 2002; Reclamation 2008a.

The diversions in drought years are less – 1.21 million acre-feet in 2001 and 1.25 million acre-feet in 2005 (see Technical Memorandum 2.1, *Water Needs for Out-of-Stream Uses*). These volumes do not include other requirements for water in the basin including instream flow, hydroelectric generation, and municipal and industrial uses. Table 2 lists historical TWSA estimates.

2.3.3 Current Operations

Operational Objectives

The operational objectives of the current Yakima Project are to:

- Store as much water as possible up to the reservoir system's full active capacity (approximately 1 million acre-feet) following the end of the irrigation season through early spring.
- Provide target flows and diversion entitlements downstream from the dams, meeting Title XII flows (see Section 2.3.4.1) at Sunnyside and Prosser Diversion Dams.
- Provide reservoir space for flood-control operations.

Meeting Irrigation Demands

All information in this sub-section is from the Yakima River Basin Water Storage Feasibility Study: Final Planning Report/Environmental Impact Statement, Volume 1 (Reclamation 2008).

The irrigation season starts around April 1. During the initial part of the irrigation season through late June, irrigation diversion demands and the Title XII target instream flows at Sunnyside Diversion Dam are generally adequately met by: (1) unregulated runoff from tributaries downstream from the five reservoirs; (2) incidental releases from the reservoirs (for target flows and flood control); and (3) irrigation return flows. Once these flows fail to meet diversion demands and Title XII instream target flows, reservoir releases are made, resulting in depletions in the stored water supply. This is commonly referred to as the beginning of the storage control period. The storage-control period typically begins around June 24.

From the beginning of the storage-control period until early September, releases from Cle Elum Lake are used in coordination with releases from Keechelus and Kachess Lakes to meet mainstem Yakima River water entitlements from the Cle Elum River confluence (RM 179.6) to Sunnyside Diversion Dam (RM 103.8). These entitlements amount to approximately 1.46 million acre-feet to supply diversions, mostly from Roza Diversion Dam downstream, including Roza Division, Wapato Irrigation Project, and Sunnyside Division. A peak of approximately 3,600 cubic-feet per second (cfs) for irrigation is moved through this area.

About September 1, Cle Elum Lake releases are reduced substantially over a 10-day period, and releases from Rimrock Lake are increased substantially to meet the September and October irrigation demands downstream from the confluence of the Naches and Yakima rivers. This is referred to as the "flip-flop" operation, which was instituted to encourage spring Chinook to spawn at a lower streamflow that requires less stored water to be released during the egg incubation period to protect spawning nests (redds). Affected spring Chinook spawning reaches are the Yakima River, from Easton Dam to the City of Ellensburg, and the Cle Elum River, downstream from the dam.

A similar operation, referred to as "mini flip-flop," is performed between Keechelus and Kachess Lakes in years of sufficient water supply for similar reasons as downstream from Easton and Cle Elum Dams. Irrigation releases from Keechelus Lake are greater than from Kachess Lake from June through August. Then, in September and October, irrigation releases from Keechelus Lake are decreased and correspondingly increased from Kachess Lake.

Storage Carryover

During the summer/fall period of operations, it is desirable to maximize storage carryover by the end of the irrigation season (October 21). The Yakima Basin storage system is designed only to store the current year's spring/summer runoff and deliver it to meet irrigation demands in July through October. If only minimal storage (52,000 acre-feet) is left on October 21, the winter and spring/summer periods of operation require a tighter control over reservoir releases, lower base river flows, and variability during these time periods. A maximized storage carryover helps ease those operations and meet demands during a dry year. The impacts of the drought year of 1977 were reduced because of favorable carryover storage from 1976. The 1994 drought was disastrous because there was virtually no carryover after the drought years of 1992 and 1993. A good carryover also helps assure sufficient spring Chinook incubation flow below the upper Yakima mainstem dams. The effects of operations on fisheries are discussed further in Section 2.4.2.

2.3.4 Irrigation Entitlements

The total of April through September "entitlement diversions" (existing contractual obligations) is approximately 2.31 million acre-feet. October entitlements total approximately 120,000 acre-feet. To date, entitlement in March is not completely quantified; however, some irrigation entities have rights that include flood water use. Entitlement diversions represent only the irrigation water entitlements stipulated in the 1945 Consent Decree for the mainstem Yakima River and do not include irrigation diversions on tributaries or adjudicated streams such as Big Creek, Little Creek, Teanaway River, Taneum Creek, Manastash Creek, Wenas Creek, Cowiche Creek, Ahtanum Creek, and others. Table 3 lists the irrigation entitlements recognized by the 1945 Consent Decree.

Table 3. April to September Irrigation Entitlements Recognized by 1945 Consent Decree

Month	Monthly Total (acre-feet)	Accumulated Total (acre-feet)
April	254,830	254,830
May	415,100	669,930
June	440,390	1,110,320
July	457,840	1,568,160
August	443,880	2,012,040
September	297,430	2,309,470

Source: Reclamation 2002

The water entitlements are divided into two classes – nonproratable and proratable. Nonproratable entitlements, generally held by water users that existed before the Yakima Project, are to be served first from TWSA (Reclamation 2008). All other Yakima Project water rights are proratable, which means they are of equal priority. Any shortages that may occur are shared equally by the proratable water users (Reclamation 2008).

Some major entities, such as the Roza Irrigation District and the Kittitas Reclamation District, have no natural flow rights and thus their entire water supply is contracted. Other entities needing a supplemental supply are furnished contract water under terms of the Federal Warren Act of February 21, 1911, which authorized Reclamation to contract for the sale of supplemental water from available supplies. These contracts specify the annual and monthly entitlements (non-proratable and proratable). Construction and operation and maintenance costs of the storage facilities are paid by the entity in proportion to their entitlement.

Table 4 lists the Yakima Project irrigation districts and their Yakima Project water rights divided into non-proratable water rights (priority date prior to May 10, 1905) and proratable water rights (priority date of May 10, 1905).

Table 4. Yakima Project Irrigation District Water Rights (acre-feet per year)

District	Non-proratable Water Rights	Proratable Water Rights	Total Water Rights
Wapato Irrigation Project	305,613	350,000	655,613
Sunnyside Division	289,646	157,776	447,422
Roza Irrigation District	0	393,000	393,000
Kittitas Reclamation District	0	336,000	336,000
Yakima-Tieton Irrigation District	75,865	30,425	106,290
Kennewick Irrigation District	18,000	84,674	102,674

Source: Ecology 2010

Prorationing and Drought Response

Prorationing is necessary when the TWSA is not adequate to meet all irrigation entitlements. Historically, the prorationing period has not started until the date of storage control. The amount of proration is determined monthly, biweekly, or as needed, by project operations and this information is provided to water-using entities at manager meetings. The nonproratable users can divert their full irrigation entitlements, which are deducted from the water supply available for irrigation, with the remainder available for proratable irrigation entitlements.

Prorationing has been imposed an average of about once every four years in the last 20 years. Proratable water users received 58 percent of their proratable entitlement in 1992, 67 percent in 1993, and 37 percent in 1994. In 2001 proratable water users received a 37 percent supply and in 2005 a 42 percent supply (Reclamation 2008).

Historically, Reclamation has followed a specific framework when faced with below-average years. The basic concepts of this policy are as follows:

1. Share flood-water and return flow during the main runoff period.
2. Discourage storage releases during the tail end of the main runoff period (when runoff is unable to meet full demand).
3. Allow water users to shape, via requests in advance, their estimated water supply use pattern during the period of heavy reservoir release (after the main runoff period).
4. Maintain control during end-of-season (October) operations.

An emergency drought relief provision established under Chapter 173-166 WAC, Revised Code of Washington, authorizes Ecology to determine when water-supply conditions are expected to be 75 percent of the normal supply and cause undue hardship to water users. This definition was established by the Washington State Legislature in 1989 (RCW 43.83B.400). Following governor approval, Ecology can issue a drought condition order. This order:

- Allows water users to obtain water from alternate groundwater and surface-water sources
- Allows temporary water transfers and transactions
- Provides funding assistance to public bodies for projects and measures designed to help alleviate drought conditions relating to agriculture and fisheries.

In the Yakima Project, the drought condition criteria of 75 percent of normal water supply translates roughly to less than a 45- to 50-percent proration level for proratable water entitlements (Reclamation 2008).

During the water-short years of 1994, 2001, and 2005, emergency water-right transfers were authorized for the declared drought condition. These transfers were intended to alleviate hardships, reduce burdens on water users (irrigation), and increase efficient and maximum use of the water supply during drought conditions.

In 1994, in anticipation of water shortages for irrigation within the Yakima Basin, Reclamation proposed an Emergency Inter-District Water Transfer Program and developed criteria for the transfers. These transfers were voluntary, between willing lessees and lessors, and only for temporary water supply during the 1994 water year. The transfers were consistent with appropriate State and Federal law, and had the concurrence of the irrigation districts in which they occurred. The rights of other water users (third parties) were not to be impaired.

Such transfers were limited to lands that had legal water rights and were being irrigated in full compliance with applicable laws, regulations, and contracts (including the Reclamation Reform Act). These legal responsibilities were not to be diminished by the transfers. Transfers had to be within the capability of Reclamation to deliver, and were considered on a first-come, first-served basis. Transfers were subject to Reclamation’s responsibility to protect and maintain resources (including water, fisheries, wildlife, and cultural) held in trust by the United States for the Yakama Nation.

A Water Transfer Advisory Committee was established to review transfer requests as they were received and to make recommendations on these requests to Reclamation. The committee was composed of irrigation district managers from the transferring and receiving districts, an official from the Yakima Basin Joint Board (association of Yakima Project irrigation districts), a representative of Washington State Department of Fish and Wildlife (WDFW), U.S. Fish and Wildlife Service, and the Yakama Nation. The Committee functioned in an advisory capacity to Reclamation who held the responsibility of the final approval. The last emergency water transfers totaled only 3,739 acre-feet, all involving transfers to the Roza Irrigation District.

To facilitate processing of transfer applications more effectively during the 2001 water-short year, a water transfer process was developed involving a subcommittee of the YRBWEP Conservation Advisory Group, Washington Department of Ecology (Ecology), and Reclamation. Consultation also occurred with State, Federal, and tribal fish and wildlife agencies, and included a review and approval by the Superior Court conducting the basin adjudication. This expedited approval process was in place effective April 2001, and water transfers started May 1. Water transfers totaled 23,039 acre-feet, indicating that this procedure was effective in expediting the processing of transfers. Most participants appeared satisfied with the 2001 process.

In the 2005 drought, a similar process was used, resulting in seasonal transfers of 39,654 acre-feet of water (Ecology 2005).

2.3.5 Target Flows

Historical Target Flows Developed Through System Operation Advisory Committee

Target flows for the Yakima Basin have been developed through the System Operation Advisory Committee (SOAC). The SOAC is an advisory committee to Reclamation consisting of fishery biologists representing the U.S. Fish and Wildlife Service, Yakama Nation, Washington State Department of Fish and Wildlife, and irrigation entities represented by the Yakima Basin Joint Board. Reclamation also provides a fishery biologist as a liaison to the committee. Since 1981, the SOAC has provided information, advice, and assistance to Reclamation on fish-related issues associated with the operation of the Yakima Project. Historical target flows are presented in Table 5.

Table 5. Historical Yakima Project Target Flows

River Reach	Fall Target Flow and Dates	Winter Target Flow and Dates
Keechelus Reservoir Outflow	60-100 cfs – Sep 1-Oct 20	15-100 cfs – Oct 21-Mar 31
Yakima River – Crystal Springs to Lake Easton	60-100 cfs – Sep 1-Oct 20	30-100 cfs – Oct 21-Mar 31
Kachess Reservoir Outflow	Not Applicable (NA)	5-50 cfs – Oct 21-Mar 31
Yakima River – Easton Dam to Cle Elum River	150-300 cfs – Sep 10-Oct 20	80-300 cfs – Oct 21-Mar 31
Cle Elum Reservoir Outflow	150-650 cfs – Sep 10-Oct 20	60-300 cfs – Oct 21-Mar 31
Yakima River – Cle Elum River to Teanaway River	400-800 cfs – Sep 10-Oct 20	200-325 cfs – Oct 21-Mar 31
Yakima River – Roza Dam to Wenas Creek	200-300 cfs minimum – Jul 1-Oct 20	NA
Bumping Reservoir Outflow	NA	50-120 cfs – Oct 21-Mar 31
Rimrock Reservoir Outflow	NA	15-50 cfs – Oct 21-Mar 31
Naches River – Wapatox Canal to Wapatox Return	NA	100-125 cfs – Oct 21-Mar 31
Yakima River at Parker	NA	300 cfs minimum – Mar 15-Oct 21

Source: Reclamation 2002

Title XII Target Flows

One of the purposes of the YRBWEP is to implement water conservation measures to reduce out-of-stream irrigation water diversions from the Yakima River and its tributaries. Savings achieved through improvements to water delivery systems and changes in operation and management would result in more water remaining in the stream to improve flows for fish and wildlife and the reliability of the irrigation water supply.

Phase II of the YRBWEP was authorized by Title XII of the Act of October 31, 1994 (108 Stat. 4550, Public Law 103-434). Title XII established new instream target flows to be maintained past the Sunnyside and Prosser diversion dams using criteria based on TWSA. The streamflow targets range from 300 cfs to 600 cfs, depending on the estimate of TWSA. Reclamation interprets the requirement for target flows as being subject to reasonable fluctuations due to project operations, not instantaneous flows to be uniformly maintained at all times. However, for any period exceeding 24 hours, flows cannot fall below 65 percent of target flow at the Sunnyside Diversion Dam (Parker gage) or more than 50 cfs below target flow at Prosser Diversion Dam.

In meetings of the Instream Flow Needs subcommittee there was general discussion about the use of water allocated to Title XII flows. Subcommitee members stated that there should be more flexibility in its use. For example, pulse flows in spring should be provided if SOAC believes they would benefit fisheries more than a constant discharge during summer. Table 6 lists the Title XII instream flows.

Table 6. Title XII Target Flows Based on TWSA

TWSA (million acre-feet)				Parker and Prosser Flows (cfs)	Title XII Minimum Flow Past Parker Gage July-September Demand (acre-feet)
Apr-Sept	May-Sept	Jun-Sept	Jul-Sept		
3.20	2.90	2.4	1.9	600	117,000
2.90	2.65	2.2	1.7	500	100,000
2.65	2.40	2.0	1.5	400	84,000
Less than above TWSA				300	68,000

Source: Reclamation 2008

Phase II of the YRBWEP also provides that, as conservation measures are implemented under the conservation program and irrigation water demands are thereby reduced, the target flows will be increased by 50 cfs for each 27,000 acre-feet of diversion reduction during non-prorated water years. Such increases, however, may not lower the volume of water that otherwise would have been diverted in years when the water supply is prorated. During those years, the target flows obtained through water conservation would be increased above 300 cfs only where irrigation return flows previously entered the Yakima River downstream of Parker gage. Although diversion reductions would be accounted for, a "block of water" would not be set aside under TWSA for maintaining target flows at Parker gage. Title XII target flows (supplemented by conserved water) would continue to be met from TWSA the same way irrigation demands are met under the 1945 Consent Decree. Water entitlements stipulated in the decree are not changed by Title XII.

2.4 Anadromous Fish

2.4.1 Population Conditions

All information in Section 2.4.1 is from the Yakima River Basin Integrated Water Resource Management Alternative: Final Environmental Impact Statement (Ecology 2009) except where noted.

Anadromous salmonid fish currently using the Yakima Basin include the Mid Columbia River Evolutionarily Significant Unit steelhead (Federally listed as threatened), spring and fall Chinook, coho (reintroduced) and sockeye (reintroduced). The Pacific lamprey – the only non-salmonid anadromous fish species currently using the Yakima Basin – is a Federal species of concern.

Steelhead

Steelhead are found in throughout the basin, including the Satus, Toppenish, Naches, upper Yakima, and Ahtanum watersheds. Steelhead enter the Yakima River in greatest numbers from September through November and again from February through April. Steelhead hold in the mainstem until moving into tributaries throughout the basin to spawn. Adults spawn from February through June, mostly in tributaries, and fry emerge from the gravel from May into July. They spend from one to three years in fresh water before beginning to migrate to the ocean in spring.

Over the 10-year period from 1997 to 2006, steelhead basin-wide escapement (the portion of fish population that returns to streams to spawn) has averaged 2,339 fish, ranging from 1,070 in 1998-1999 to 4,525 in 2001-2002. The run is dominated by wild fish, but also includes a hatchery component of 8 percent over the period of record and 3 percent between 1999 and 2007. The hatchery component is attributed to strays returning from outside the basin.

Spring Chinook

The Yakima River Basin spring Chinook population consists of the upper Yakima, Naches River Basin, and American River spawning groups. About 60 to 70 percent of the population returns to the upper Yakima River (Keechelus Dam to Ellensburg) and Cle Elum River annually. Adult spring Chinook return to the Yakima River from late April through June, and spawning occurs from August to September. Juveniles migrate downstream from the time of emergence through summer and fall. After spending one year in fresh water, spring Chinook begin their seaward migration, with the majority passing Prosser Diversion Dam (RM 47) in April. Returning adults spend one to three years in the ocean before returning to spawn.

Over the 10-year period from 1997 to 2006, spring Chinook basin-wide escapement averaged 10,264 fish, ranging from 1,903 in 1998 to 23,265 in 2001.

Fall Chinook

Fall Chinook inhabit approximately 100 miles of the lower Yakima River from Sunnyside Dam to the Columbia River confluence. In some years, fall Chinook have been documented spawning in the reach between Union Gap and Selah and in the lower Naches River downstream from the City of Naches. The Yakama Nation has been acclimating and releasing fall Chinook into the Naches River at Gleed for several years. The Yakama Nation and WDFW plan to transition the releases upstream of Union Gap from fall to summer Chinook salmon as part of their plans to reintroduce extirpated (locally extinct) summer Chinook to the middle Yakima River and lower Naches River. Marion Drain also supports a self-sustaining fall Chinook population.

Typically, the mainstem Yakima spawning run begins in early September, peaks in late September, and concludes by the second week of November. Typical emergence timing for Yakima River fish occurs from late March through May. Marion Drain fish spawn at the same time as Yakima River fish, but because of warmer water temperatures, they emerge in mid-February to late March.

Over the 10-year period from 1997 to 2006, fall Chinook basin-wide escapement averaged 2,830 fish, ranging from 1,120 in 1997 to 6,241 in 2002 (Reclamation and Ecology 2008). The Prosser count represents an estimated 30 to 40 percent of the total count, since the majority of spawning occurs downstream of Prosser Dam. Marion Drain escapement fell sharply after 1988 and remains relatively low.

Coho

Although endemic coho were extirpated from the Yakima River Basin in the early 1980s, natural reproduction of hatchery-reared coho is now occurring in both the Yakima and Naches rivers. The Yakama Nation has released between 85,000 and 1.4 million coho smolts in the Yakima Basin annually since 1985. The majority of coho spawning and rearing occurs in the upper Wapato reach below Parker Dam, in the lower Naches River between Cowiche Dam and the City of Naches, and in the upper Yakima River near Ellensburg. Spawning has also been documented in several tributaries (e.g., Ahtanum, Tanuem, lower Satus, Cowiche, and Nile creeks) as the Yakama Nation expands its supplementation program into historic areas.

Over the 10-year period from 1997 to 2006, coho basin-wide escapement averaged 3,438 fish, ranging from 818 in 2002 to 6,216 in 2000 (Reclamation and Ecology 2008). The Prosser count represents an estimated 30 to 40 percent of the total count, since the majority of spawning occurs downstream from Prosser Dam.

Sockeye

The four natural glacial lakes in the Yakima River Basin historically supported sockeye salmon. Construction of crib dams at the lake outlets contributed to the extirpation of sockeye from the basin in the early 1900s. In spring 2005, Reclamation constructed an interim downstream fish-passage facility at Cle Elum Dam that allowed the Yakama Nation to reintroduce sockeye into Cle Elum Reservoir above the dam starting with 500 pairs of adult sockeye in 2009. The Wenatchee and Lake Osoyoos stocks were trapped at Priest Rapids Dam (Reclamation and Ecology 2010).

Pacific Lamprey

In eastern Washington, Pacific lamprey historically occurred in the Yakima River Basin and in numerous other Columbia River basins, including the Spokane River and Asotin Creek. Current knowledge of Pacific lamprey in the Yakima River Basin is limited to incidental observations of approximately five adults annually at the Prosser adult fish passage facility since 1985. The Yakama Nation is studying lamprey in the Yakima River Basin and the potential for providing passage for them at existing dams. Data from Columbia River dams suggest that the number of adult Pacific lampreys counted at each project is trending downward, although annual numbers fluctuate widely. Data indicate that large declines occurred during the late 1960s and 1970s, and that current counts continue to be well below historical levels.

2.4.2 Effects on Anadromous Fisheries from Operations

All information in Section 2.4.2 is from the Yakima River Basin Water Storage Feasibility Study: Final Planning Report/Environmental Impact Statement, Volume 1 (Reclamation 2008) except where noted.

Habitat

Anadromous fish require certain habitat conditions. Flows, hydrology, sediment, large woody debris, and channel conditions all affect salmonid growth and survival (Ecology 2009).

Flow/Hydrology

The results of other studies suggest that the natural, unregulated flow regime of the Yakima River and its tributaries was the master variable that nourished the distribution and abundance of riverine species and sustained the ecological integrity of the ecosystem via physicochemical processes that provide riverine structure and function. Flow variability provides ecological benefits to floodplain ecosystems and the terrestrial and aquatic organisms that depend on them. The natural timing of variable flows provides numerous environmental cues for fish to spawn, hatch eggs, rear, move to off-channel floodplain habitats for feeding or reproduction, and migrate upstream or downstream.

Under current conditions, river flows are altered substantially as a result of storing water in the reservoirs in the winter and diverting water in the spring, summer, and fall to meet entitlements, primarily for irrigation. Flow regimes that deviate substantially from the natural condition, as is currently the case in the Yakima River Basin, are well understood to produce a diverse array of ecological consequences. While a range of flows is vital to the structure and function of aquatic ecosystems, stable base flows are important in supporting high growth rates for fish that are timed with periods of high ecosystem production (i.e., late spring through early fall). Thus, natural streamflow variability has a controlling effect on the biology of native aquatic species and the physical and chemical ecosystem attributes they depend on for survival. Current conditions have inverted and truncated the natural flow regime, producing river systems that are out of phase with their natural runoff regimes.

Temperature

Perhaps no other environmental factor has a more pervasive influence on salmonids and other aquatic biota than temperature. Temperature influences all aspects of fish life as well as macroinvertebrates and primary producers (e.g., algae, bacteria) that dwell in streams and serve as food for fish. The majority of aquatic organisms are coldblooded, meaning that their body temperatures and metabolic demands are determined by the temperature of the environment in which they live. Slight changes in stream temperatures that differ from the natural condition can alter the processes listed above and most often adversely affect native aquatic species.

Quantitatively defining the effects of temperature on key biological functions is essential for understanding how temperature contributes to fish success, how it places species at risk, and how moderating and controlling the thermal regime can contribute to recovering impaired populations. However, it is a widely held view that high water temperatures are one of the most harmful environmental variables affecting salmonid extent, biomass, and survival. The factors that drive stream temperature are altered by dams, riparian vegetation removal, water withdrawal and regulation, irrigated agriculture, channel engineering (e.g., straightening, channelization, diking, revetments), urbanization, increasing impervious surfaces, and floodplain development.

All of these factors occur in the Yakima River Basin to some extent and have altered the temperature regime from predevelopment, natural conditions. Water temperature, especially in the lower Yakima River, has consistently been acknowledged as a factor affecting salmonids, especially during some life stages. High temperatures at the mouth of the Yakima River may affect anadromous fish, including migrating smolts and adults. In the upper parts of the basin, bottom draw release structures, like those used at Keechelus, Kachess, Cle Elum, Rimrock, and Bumping Dams, provide thermally homogeneous, cold discharge to the Yakima, Kachess, Cle Elum, Tieton, and Bumping rivers, which may interfere with certain aspects of salmonid ecology in the Yakima River Basin (e.g., migration cues, spawn timing, and growth).

Sediment

Suspended sediment is a naturally variable phenomenon in riverine ecosystems, and increased concentrations above background levels are most strongly correlated with erosional processes and elevated discharge observed during spring runoff or discrete precipitation events. Heavy loads of suspended sediments directly impact salmonids, which avoid impacted habitats. Impacts can include mortality (in extreme cases), a skewed distribution of prey species within the habitat, reduced feeding and growth, and reduced tolerance to disease.

Sediment and bedload movement occur naturally, and it is acknowledged that transport of some sediment (fine sediments to cobble) is beneficial to the ecological health of a river system. However, irrigated agricultural activities have altered the timing, volume, and magnitude of sediment movement in the river by modifying the magnitude and timing of river flows.

Large Woody Debris

In recent years, the relationship between large woody debris (loosely defined as trees greater than 4 inches in diameter, greater than 6 feet long, with or without the root wad attached), riparian vegetation, and fish habitat has received much emphasis in the Pacific Northwest. Flow regime alteration by impoundment and diversion can affect the cycling of organic and inorganic materials, including large woody debris, which is an important element in the creation of complex habitats and pools.

Recruitment of large woody debris likely has been affected by many human activities in the Yakima River Basin. First, headwater source areas were removed from the river continuum by construction of the storage dam embankments on the Yakima, Kachess, Cle Elum, Tieton, and Bumping rivers. Natural lakes on all these streams, except the Tieton, may have acted to some extent as large woody debris “traps” before the dams were built. The system diversion structures may impede the transport of large woody debris farther down, but to a large extent it is simply passed over these structures as part of operations. Secondly, flow regulation and extraction has contributed to impaired floodplain function along alluvial reaches of the river. The growth and survival of cottonwoods (Populus spp.), a primary species along the alluvial floodplain reaches of the Yakima River Basin, are important to the aquatic ecosystem.

Channel Condition and Dynamics

Truncation of flood peaks by capturing them in reservoirs reduces the duration, magnitude, and spatial extent of floodplain inundation. This alters the quantity, quality, and timing of groundwater discharge to the river and diminishes the availability, extent, and temporal duration of off-channel habitats for anadromous and resident fish. Among the myriad habitat attributes of these floodplain ecosystems, off-channel areas provide complex, diverse habitats for cold-water fish. Flood flows form and maintain the channel network, including side channels. In turn, side channels and sloughs provide a large area of edge habitat and slower water velocities favored by early salmonid life stages. Spring brooks that receive discharging groundwater provide low-velocity, thermally moderate, food-rich habitat for juvenile fish.

For salmonids in the Yakima River Basin, these side-channel complexes likely help increase productivity, carrying capacity, and life history diversity by providing suitable habitat for all life stages in close physical proximity. Floodplain disconnection combined with flow regulation has reduced river floodplain interactions in the Yakima River Basin. Of particular importance has been the loss of habitat complexity, including connectivity between off-channel and mainstream habitats, which directly relates to the ability of the ecosystem to support salmonid populations, including steelhead and bull trout.

Flood control dikes and levees, and railroad and highway construction, have disrupted the lateral connectivity between wetted areas that occurred historically. This deprivation of lateral connectivity has resulted in loss of habitat, reduced vertical connectivity, loss of or changes in nutrient flux, and reduction in the tempering affect of groundwater on stream temperature. The result has been a significant loss, compared to pristine conditions, of horizontal and vertical connectivity; diminished habitat heterogeneity through the loss of off-channel habitat; and a general loss of ecosystem function.

Habitat Alterations

Alterations in the aquatic ecosystem have affected the habitat of anadromous fish in the Yakima River Basin. In its most basic form, regulation alters streamflow volume, sediment transport, floodplain connectivity, and water temperature. The Yakima River Basin has experienced well over 100 years of Euro-American development, with a marked increase after the advent of storage reservoirs and watercourse (e.g., canals, drains, ditches, laterals) development in the early 20th century. Consequently, there is a long history of forest practices and floodplain development for irrigated agriculture, urban centers, roadways, railways, and housing. As development progressed, so did the magnitude and extent of floodplain revetments (e.g., levees, road and railway prisms, riprap, etc.) intended to protect local infrastructure.

However, floodplain activities and revetments have armored, shortened, realigned, and simplified many miles of mainstem and tributary habitat in the Yakima River Basin. Consequently, channel form and processes have been altered, and the potential for normal riparian processes (e.g., shading, bank stabilization, and large woody debris recruitment) to occur is diminished. Ultimately, the once diverse and extensive assemblage of riparian and aquatic habitats in the Yakima River and its tributaries has become simplified.

As a result of irrigation development in the Yakima River Basin, including development of the Yakima Project, runoff in the system has become highly regulated for multiple purposes. Regulation of streamflow for flood control, irrigation, or other purposes alters the physical environment of the system.

Effects of Diversions on Fisheries

The six major Yakima Project diversion dams (Easton, Roza, Sunnyside, Wapato, Prosser, and Yakima-Tieton) and other non-Reclamation-operated facilities (Wapatox and Wanawish) have a significant influence on fisheries resources. Reclamation-operated diversion dams are maintained within National Marine Fisheries Service (NMFS or NOAA) criteria. However, all diversion dams affect fishery resources regardless of how well they are operated or maintained. These effects include passage/entrainment problems at ladders, screens and bypasses (including delays); predation below dams or at bypass returns; adverse maintenance schedules and operating protocols; disruption of bed load transport and deposition; and impediments to transport of large woody debris (Reclamation 2002).

Similar effects occur on tributaries with diversions with an additional problem of dewatering stream reaches downstream from diversions.

2.5 Resident Fish

All information in Section 2.5 is from the Yakima River Basin Integrated Water Resource Management Alternative: Final Environmental Impact Statement (Ecology 2009) except where noted.

Resident native salmonids in the Yakima River Basin include the Columbia River Distinct Population Segment bull trout (*Salvelinus confluentus*), westslope cutthroat trout (*Oncorhynchus clarki lewisi*), rainbow trout (*Oncorhynchus mykiss*), kokanee (*Oncorhynchus nerka*), mountain whitefish (*Prosopium williamsoni*), and pygmy whitefish (*Prosopium coulteri*), and eastern brook trout (*Salvelinus fontinalis*), a nonnative (introduced) salmonid. Of these species, those of special concern are bull trout (Federally threatened) and pygmy whitefish (State sensitive).

Thirty-seven resident non-salmonid species are present in the Yakima River Basin. The most abundant of these in the upper Yakima River Basin are speckled dace *(Rhinichthys osculus*), longnose dace (*Rhinichthys cataractae*), redside shiners (*Richardsonius balteaus*), northern pikeminnow (*Ptychocheilus oregonensis*), largescale suckers (*Catostomus macrocheilus*), bridgelip suckers (*Catostomus columbianu*s), and sculpins (*Cottus sp*.). Burbot (*Lota lota*) is present in Keechelus, Kachess, and Cle Elum lakes. The mountain sucker (*Catostomus platyrhynchus*) is less abundant and a species of special concern (State candidate).

Three bull trout life history forms are present in the Yakima River Basin: adfluvial, fluvial, and resident. Adfluvial (lake-rearing) stocks occur in the Rimrock, Bumping, Kachess, and Keechelus reservoirs. Fluvial (river-rearing) bull trout are present in the mainstem Naches and Yakima rivers, and migrate into spawning tributaries in late summer to spawn in September and early October. A resident stock occurs in the upper Ahtanum basin (North, South, and Middle Forks of Ahtanum Creek), but does not often enter the mainstem of Ahtanum Creek. Fluvial/resident forms are present in the Naches River drainage and in the North Fork Teanaway drainage. Adfluvial bull trout enter reservoir tributaries early in summer, to hold and eventually to spawn in the fall. Fluvial bull trout move throughout river systems and spawn in tributaries in the summer. The lack of upstream/downstream fish-passage facilities at the reservoirs prevents adfluvial fish from interbreeding with downstream fluvial populations.

The WDFW Salmon and Steelhead Stock Inventory program characterizes bull trout stocks in the Yakima River Basin. Stocks upstream from Rimrock Lake are characterized as healthy; Bumping Lake bull trout stock as depressed; Yakima River, Ahtanum Creek, North Fork Teanaway, Kachess Lake, and Keechelus Lake stocks as critical; and Cle Elum Lake bull trout stocks as unknown. Bull trout in the Naches River fluvial group are characterized as depressed in Rattlesnake Creek and the American River, and critical in Crow Creek. Only a few historical catch records indicate the presence of bull trout in Yakima River tributaries, and relatively few fish were noted in these records.

Effects on Resident Fisheries from Operations

Effects on habitat conditions for native resident fish in the river systems are the same as described in Section 2.4.2. Resident fish are also present in the storage reservoirs. Reservoir operations may affect productivity of the reservoirs for fish and their food base and access from the reservoir to tributary spawning streams (Reclamation 2008).

2.6 Water Uses Outside the Yakima Project

In addition to water supplied by Reclamation through the Yakima Project, water is used for irrigation, municipal and industrial purposes through individual surface and groundwater rights throughout the basin. Groundwater is discussed in more detail below. For additional information on water needs not served by the Yakima Project see the technical memorandum, *Water Needs for Out-of- Stream Uses*.

2.7 Groundwater

All information in Section 2.7 is from the Yakima River Basin Water Storage Feasibility Study: Final Planning Report/Environmental Impact Statement, Volume 1 (Reclamation 2008).

Groundwater is the principal source of drinking water in the Yakima River Basin for about 330,000 people, or roughly 80 percent of the population in a three-county area. At least 45,000 wells withdraw water in the basin. Crop irrigation, the largest use of groundwater, is pumped from about 2,300 irrigation wells.

The headwaters of the Yakima River Basin are on the forested east slope of the Cascade Range, where annual precipitation is more than 100 inches. However, the sedimentary and metamorphic rocks in the upper basin are generally poor aquifers; and groundwater recharge in the upper basin is not available to the majority of wells in the lower basin. The lower Yakima River Basin is generally arid, with an annual precipitation of less than 10 inches. Mean annual recharge to the basin has increased about 31 percent since predevelopment conditions due to the application of irrigation water to croplands.

The addition of surface-water storage and conveyance facilities could affect the groundwater resource by providing the opportunity for water to seep into the ground. This additional seepage could have either beneficial or detrimental effects, depending on the quantity and location.

2.7.1 Description

Basaltic rocks that underlie the majority of the Yakima River Basin are part of the larger Columbia River Basalt Group (CRBG). The CRBG includes more than 300 individual basalt flows that erupted from fissures in the eastern part of the Columbia Plateau during the Miocene Epoch (6 to 17 million years ago). Individual flows range from a few feet to more than 300 feet thick, with an average about 100 feet. The CRBG hosts multiple aquifers in various layers and formations that are collectively called the Columbia Plateau Aquifer System, which underlies about 63,000 square miles in central and eastern Washington, north-central and eastern Oregon, and a small portion of northwestern Idaho.

The Columbia Plateau Aquifer System lies in the Columbia Intermontane physiographic province, which has been divided into three subprovinces: the Yakima Fold Belt, the Palouse, and the Blue Mountains. The three subprovinces are largely defined by structural differences.

The Yakima River Basin lies within the Yakima Fold Belt, which has experienced more tectonic folding and faulting than the other areas. The topography of the Yakima Fold Belt consists of northwest-southeast-trending ridges (anticlines) separated by broad, flat valleys (synclines) that were folded and faulted under north-south compression.

Interbedded sediments between some of the basalt flows are assigned to the Ellensburg Formation and are mainly found between flows of the Saddle Mountains Basalt. Toward the end of the volcanism period, there were longer intervals of time between subsequent basalt flows for deposition to occur. The interbed materials were derived chiefly from volcanic activity and erosion from the Cascade Range and from the anticlinal ridges. The interbeds are relatively thin, compared to the thick sequence of basalts, and are generally fine-grained, weakly consolidated, and have low permeability. However, in some areas, the interbeds are coarse-grained and serve as aquifers.

Folding, faulting, and other large-scale geologic deformation can affect regional groundwater flow direction, influence hydraulic gradients, and create flow conduits or barriers. At least some of the faults in the Yakima Fold Belt are proven hydraulic barriers. Others appear to be conductive and may connect deep basaltic formations with shallower formations and surface springs. Folding increases the occurrence of fractures on the anticlinal ridges and tends to enhance aquifer hydraulic conductivity.

Groundwater within the basalts is controlled primarily by the physical characteristics of the rock units, the geometry and relationship between rock units, and the geologic structure. The physical characteristics of the basaltic flows (density and texture, fractures, and internal structures) are important in determining their hydraulic properties. Internal structures found in the flows may influence both the ease of water movement and direction of flow through the formation.

Individual basalt flows typically exhibit features that are formed from the emplacement and cooling of the flow. These features may include a vesicular (having many small cavities) flow top, dense flow interior, and vesicular or brecciated (having many sharp, angled fragments) flow bottom. If the basalt flowed into a body of water or encountered saturated sediments, a pillow-shaped structure is often formed, and the space between the pillows is usually composed of palagonite (hydrated basaltic glass). “Pillow basalts” generally exhibit high hydraulic conductivity values. Hydraulic conductivity (permeability) is a measure of the ease with which water flows through geologic layers. Below the basalt flow top, in the dense interior portion of the flow, the basalt has very low horizontal conductivity, and the flow interiors often serve as confining beds that separate adjacent aquifers.

The flow bottom has hydraulic properties similar to the flow top, and the combination of flow top and adjacent flow bottom is called an “interflow.” The interflow zone generally has high horizontal conductivity and is where most of the horizontal groundwater flow occurs within the basalt units. The basaltic flows and permeable interflow zones are often laterally continuous for tens of miles.

The thickness and extent of basalt flows and the occurrence or absence of fine-grained sedimentary interbeds also influence groundwater movement. At the distal (furthest) ends of the basalt flows or where erosion has interrupted the continuity of flows, interbedded sediments are able to commingle and may serve as a vertical conduit between previously separated flow systems.

Groundwater flow is generally from the anticlinal ridges toward the streams and rivers in the synclinal valleys. Shallow groundwater flow is usually vertically downward from the surface to the underlying basalt units. However, because of the geologic structure of the synclinal basins, a number of areas have upward flow and artesian wells in the lower valleys.

Groundwater flow systems that are local, intermediate, and regional in scale within the Yakima River Basin are recharged by various mechanisms. Local and intermediate flow systems are recharged through basalts that are exposed to precipitation at the ground surface on the anticlinal ridges and through groundwater exchange with other basins and formations. On a regional scale, basaltic units are recharged along the western margin of the Columbia Plateau where the basalts interfinger with prebasaltic rocks and sediments at higher elevations in the Cascade Range.

Much of the natural recharge (from precipitation) occurs in the upper basin and is not available to the bedrock aquifers where most pumping takes place. The lower, arid portion of the Yakima River Basin generally receives about 6 to 10 inches of precipitation annually, and most groundwater recharge is from application and distribution of irrigation water.

Approximately 45 percent of the water diverted for irrigation is eventually returned to the river system as surface-water inflows and groundwater discharge. Irrigation return flows to the lower Yakima River account for about 75 percent of the streamflow downstream from the Parker gage.

Aquifer discharge occurs principally to major surface drainage systems (i.e., Yakima and Columbia rivers) and through irrigation well pumping. Annual pumping in the Yakima River Basin increased almost 270 percent from 1960 to 2000. Approximately 395,096 acre-feet were pumped in 2000 – 60 percent for agricultural and 12 percent for municipal water supply. The annual quantities appropriated in State water right certificates and permits are about 529,231 acre-feet.

2.7.2 Groundwater-Surface Water Relationship

The relationship between groundwater and surface water is important to managing the water resources and making decisions regarding potential impairment of existing rights by new rights. In areas where there is hydraulic continuity (an exchange of water) between a groundwater system and a surface-water body, pumping groundwater may potentially reduce groundwater discharge into surface water, or in extreme cases, divert surface water into a groundwater system, thereby reducing flows in surface waters. This could affect established water rights to the surface water source and instream flows for fish. If a well is in one of the few areas where there is no hydraulic continuity, groundwater may be withdrawn with no effect on surface waters. Management of surface waters can also affect the groundwater supply. In areas where irrigation occurs, part of the applied irrigation water percolates into the ground and recharges the aquifers (Ecology 2009).

2.7.3 Groundwater Rights

Estimating groundwater rights is more difficult than surface-water rights. As with surface-water rights, anyone who acquired a groundwater right prior to adoption of the Ground Water Code (Chapter 90.44 RCW) in 1945 has been required to file a water right claim, which is on record with Ecology. While helpful to a certain extent, these claims represent only what a water right user asserts is their water right. The rights have not been adjudicated and confirmed by a court.

For groundwater rights acquired after 1945, Ecology has a record of certificates granted. For rights not yet perfected, Ecology has a record of permits issued.

The core problem in adequately quantifying and cataloging existing groundwater rights is the statutory exemption in RCW 90.44.050. Anyone who constructs a well must file a construction notice with Ecology, but there is very little information regarding use of the exempt wells. Some exempt wells may no longer be used, and the amount of groundwater being withdrawn by wells that are still in use is unknown (Ecology 2009).

Exempt Wells

RCW Chapter 90.44.050 does not require groundwater wells to have a groundwater right if the withdrawal meets one of the following conditions:

- The withdrawal is used for stock-watering purposes.
- The withdrawal is used for the watering of a lawn or non-commercial garden smaller than 0.5 acres.
- The withdrawal is used for single domestic, group domestic, or industrial purposes in an amount less than 5,000 gallons/day.

This exemption makes it difficult to quantify groundwater rights used because some exempt wells may no longer be in use while others may be in use but the amount of groundwater being used is unknown (Ecology 2009).

Upper Kittitas County Groundwater Rule

In 2007, Ecology received a petition from water right holders in Kittitas County seeking a temporary moratorium on new groundwater wells in the county. The petitioners were concerned that rapid residential growth and use of the exempt wells rule would impair senior water rights and streamflows in the Kittitas and Yakima valleys. On April 7, 2008, Ecology and Kittitas County signed a memorandum of agreement to cooperatively manage exempt groundwater wells until additional information is known about the aquifers and water supplies in upper Kittitas County. Since then, nine emergency rules have been adopted by Ecology to "withdraw from appropriation all unappropriated groundwater within upper Kittitas County pending completion of a groundwater study. New groundwater withdrawals will be limited to those that are water budget neutral" (WAC 173-539A-010). A final withdrawal rule approved by Ecology on December 22, 2010 (effective January 22, 2011) prevents new uses of water that would negatively affect flows and existing water rights. New developments relying on groundwater would have to demonstrate the use of groundwater is water budget neutral to be approved. Ecology and USGS are expected to complete an agreement to study groundwater aquifers within the upper Kittitas County area (Ecology 2010).

Drought-Relief Wells

Some Roza Irrigation District farmers pump groundwater using drought-relief wells to supplement their supply during drought conditions. The Wapato Irrigation Project also pumps groundwater into canals during droughts.

3.0 Columbia River Basin Water Resources

3.1 Columbia River Basin Characteristics

The Columbia River Basin extends from the Canadian Rockies in British Columbia to the Pacific Ocean and encompasses portions of Washington, Oregon, Idaho, Montana, Wyoming and Nevada and portions of British Columbia. The majority of the Columbia River Basin in Washington is arid to semi-arid. Dominant vegetation is shrub-steppe in the lowlands and forest in mountainous areas. At the Washington-Oregon border, the Columbia River turns to flow west through an entrenched channel through the Cascade Range known as the Columbia River Gorge. The eastern end of the Gorge is arid and becomes increasing humid to the west, with vegetation changing from shrub-steppe to coniferous forest (Ecology 2007).

Most of the Columbia River Basin is farmed or ranched. A wide variety of crops are raised, including potatoes, sugar beets, hops, fruit, vegetables, mint, wine grapes, hay, corn, wheat, barley, and lentils. Most of these crops are irrigated. A variety of livestock are also raised in the basin. Logging was historically important in the mountains that fringe the basin and in the Columbia River Gorge area, and forest management practices are still active in many areas.

The Columbia River is home to a rich variety of salmon species and other fish and wildlife populations. Historically salmon were very abundant in the basin and were the foundation of the diets, culture, and economy of native people (National Research Council 2004). Salmon numbers have declined significantly since the late 1800s. Several species and populations are listed as threatened or endangered under the Endangered Species Act. The construction of dams and land-use changes have blocked access to habitat and altered streamflows and vegetation, contributing to the decline of salmon (Ecology 2007).

3.2 Water Development in the Columbia River Basin

The Columbia River has been extensively modified for a variety of beneficial uses, including flood control, hydropower, navigation, irrigation, and recreation. Major development began in the 1930s with the construction of Bonneville Dam on the lower Columbia River east of Portland, Oregon, and Grand Coulee Dam on the upper river west of Spokane, Washington. Although constructed to serve multiple purposes, the driving forces behind development of Columbia River dams were hydropower and, to a lesser extent, flood control. With its solid rock channel, low levels of silt, and relative steepness, the Columbia River was well suited for large-scale hydropower development. World War II increased pressure to further tap the river’s hydroelectric power production potential, and between 1944 and 1945, Congress authorized several water projects in the basin, including Hungry Horse Dam. In the five years following the war, Chief Joseph, Albeni Falls, Libby, John Day, and The Dalles dams were all authorized (Volkman 1997; National Research Council 2004).

Support for Federal dams in the Columbia River Basin declined during the 1950s, but licenses were issued to county public utility districts to construct Priest Rapids, Rocky Reach, Wanapum, and Wells dams, located in Central Washington just east of the Yakima River Basin. Upstream dams that augmented storage and power production capabilities were constructed pursuant to the Columbia River Treaty signed between Canada and the U.S. in 1961. These included Libby Dam in Montana and Arrow Lakes, Duncan, and Mica dams in Canada.

The treaty focused primarily on addressing two main water uses: hydropower and flood control (National Research Council 2004). Hydropower dams in the Columbia Basin are part of the Federal Columbia River Power System (FCRPS) and are managed and operated by Bonneville Power Administration (BPA), Reclamation, and the U.S. Army Corps of Engineers. The FCRPS is a coordinated system for operating the Columbia River dams to maximize power production while meeting the other treaty requirements and complying with Federal flood-control and fish and wildlife statutes (Federal Columbia River Power System 2001).

The Columbia River has been developed into a highly regulated river system, with a variety of Federal and State agencies and private utilities operating dams on the river for many uses, and international and tribal interests involved in managing the river. Several treaties, statutes, and management agreements guide river management and operations (Federal Columbia River Power System 2001).

Table 7 lists the major owners and/or operators of water developments in the Columbia River Basin and their primary roles. Table 8 lists other agencies that act in regulatory or advisory capacities.

Table 7. Columbia River Water Managers

Owner/Operator	Primary Role
U.S. Army Corps of Engineers	•Federal project operator •Power generation •Flood control •Navigation •Participates in coordinated operations of Columbia River Treaty Reservoirs
U.S. Bureau of Reclamation	•Federal project operator •Power generation •Irrigation •Columbia Basin Project •Flood control
Irrigation Districts (private)	•Irrigation
Public and Private Utilities	•Power generation and distribution
British Columbia Hydro and Power Authority	•Flood control •Power generation
Bonneville Power Administration	•Power marketing •Transmission facilities •Funds fish and wildlife mitigation programs under the Northwest Power Planning and Conservation Act •Participates in coordinated operations of Columbia River Treaty Reservoirs

Source: Ecology 2007; Mellema, pers. comm. 2011

Table 8. Agencies with Regulatory or Advisory Capacities

Agency	Primary Role
Federal Energy Regulatory Commission	• Regulates interstate activities of electric and natural gas utilities and non-Federal hydropower producers
U.S. Department of State	• Interacts with Canada on international treaty matters
National Marine Fisheries Service and U.S. Fish and Wildlife Service	• Enforces Endangered Species Act and implements recovery plan
Environmental Protection Agency	• Regulates water quality
State Resource Agencies	• Water rights, land use, fish and wildlife management

Source: Ecology 2007

Several native tribes have reservations and historic use areas in the Columbia River Basin. The tribes have historic and treaty rights to take fish from the Columbia River and its tributaries, and have treaty rights to fish, hunt, and gather in usual and accustomed places. The Federal government has a trust responsibility to provide services that protect and enhance the treaty rights of native people. The tribes implement fish and wildlife management programs in the Columbia River Basin and participate in river governance decisions.

Operation of Federal reservoirs is regulated by the authorizing legislation, which specifies the purpose of each reservoir. Federal flood-control statutes also regulate uses of reservoirs authorized for flood control. To implement the varied management objectives, the river system is operated as the Coordinated Columbia River System. Table 9 lists other laws and agreements that influence management of Columbia River water.

Table 9. Laws and Agreements Influencing River Management

Law or Agreement	Effect on River Management
Endangered Species Act	A Biological Opinion that was developed to recover listed salmon species is the subject of ongoing legislation. The Biological Opinion includes increased and more carefully timed flows, increased spill, and reservoir drawdown.
Columbia River Treaty	The treaty between the United States and Canada affects flood control and hydropower production.
Pacific Northwest Coordination Agreement	The agreement establishes a coordinated planning process to implement the Columbia River Treaty.
Columbia Storage Power Exchange and the Canadian Entitlement Allocation Agreements	The agreements divide the power benefits from the Columbia River Treaty between Federal and non-Federal project operations.
Non-Treaty Storage Agreement	The agreement allocates the additional power generated at Mica Dam that is not part of the Columbia River Treaty.
Pacific Northwest Electric Power Planning and Conservation Act, 1980	The Northwest Power and Conservation Council, composed of representatives appointed by the governors of Montana, Idaho, Washington and Oregon, developed a Fish and Wildlife Program and a Regional Electric Power and Conservation Plan that changed how the Coordinated Columbia River System is operated.

Source: Ecology 2007

3.3 Columbia River Basin Water Management Program

In 2006, the Washington Legislature passed the Columbia River Basin Water Management Act (RCW 90.90), which requires Ecology to "aggressively pursue the development of water supplies to benefit both instream and out-of-stream uses." The act also established the Columbia River Basin Water Supply Development Account and authorized its use to develop water supplies in the Columbia River Basin through measures that include storage, conservation, and other actions designed to provide access to new water supplies. Two-thirds of the funds in the account must be used to support development of storage facilities; the remaining one-third can be used for other components. The act also authorized Ecology to enter into voluntary regional agreements to provide new water for out-of-stream use, streamline the application process, and protect instream flow (Ecology 2007).

Ecology developed the Columbia River Basin Water Management Program to facilitate implementation of the act. To assess the impacts of projects that make up the program, Ecology prepared the *Columbia River Basin Water Management Program, Final Programmatic Environmental Impact Statement* in 2007. Ecology listed three early actions within the Columbia River Basin Water Management Program, two of which were developed in cooperation with Reclamation. The early actions are drawing down Lake Roosevelt, determining a supplemental feed route to Potholes Reservoir, and completing the Columbia-Snake River Irrigators Association voluntary regional agreement (Ecology 2007).

3.4 Preliminary Water Availability Analysis for Columbia River

The Columbia River has been previously examined as a potential source of water for the Yakima River Basin (Reclamation 2008). To estimate the water available for this purpose, supply and demand estimates must be made for the Columbia River.

This section summarizes the study team's preliminary analysis of Columbia River water availability, using readily available information on target flows, restrictions on withdrawals, and out-of-stream demands. To prepare a complete water availability analysis, other limitations would also need to be identified and factored into the analysis. These may include fish-flow needs for rearing in certain months, water temperature conditions, and cumulative effects from other proposed Columbia River water withdrawals. The analysis also should consider implications of future additional water withdrawals in light of complex linkages among Federal, State, local, interstate, and international and private activities.

According to the Columbia River Water Supply Inventory (Ecology 2006), out-of-stream demands represent approximately 4 to 6 percent of Columbia River supply when comparing use estimates and Columbia River flow rates at Priest Rapids. This same report estimated instream demands ranging from 76 to 98 percent of Columbia River supply. Instream demands are determined using Biological Opinion flow objectives (established in 2000; most recent update in 2010 [NMFS 2010]) and minimum instream flows set by State administrative rule (WAC 173-563).

The Columbia River Basin Water Management Act currently restricts water availability in the Columbia River in July and August by requiring that any water rights issued under voluntary regional agreements result in no negative impact on instream flows (RCW 90.90) during those months. The requirement for protecting flows in July and August does not apply to all aspects of the Columbia River Basin Water Management Program. The Washington legislature selected the July and August period based on its interpretation of information contained in the National Research Council report, *Managing the Columbia River: Instream Flows, Water Withdrawals and Salmon Survival* (National Research Council 2004).

The Federal Columbia River Power System 2008 Biological Opinion prepared by the National Marine Fisheries Service establishes seasonal target flows downstream from Priest Rapids, McNary, and Bonneville Dams. The Columbia River water availability analysis was based on the target flows established in the 2008 Biological Opinion (NMFS 2008). A remand of the 2008 Biological Opinion in 2010 resulted in the release of a 2010 Supplemental Biological Opinion (NMFS 2010); however, the Columbia River target flow remained the same as those in the 2008 Biological Opinion (Graves, pers. comm. 2010).

Target flows facilitate spawning and downstream passage of juveniles and accommodate returning adult salmon and steelhead. Flow objectives are in place to protect fall Chinook spawning, incubation, and rearing downstream from Priest Rapids Dam at Vernita Bar. Table 10 and Figure 2 show these seasonal target flows.

Table 10. Seasonal Target Flows and Planning Dates for Mainstem Columbia River

Columbia River Location	Fall through Spring Targets		Summer Targets	
	Dates	Flow (cfs)	Dates	Flow (cfs)
At Priest Rapids Dam – transport target[1]	4/10-6/30	135,000	NA[2]	NA
At Priest Rapids Dam – spawning target[3]	12/1-5/31	50,000-70,000	NA	NA
At Priest Rapids Dam – summer minimum flows[4]	NA	NA	9/1-10/31	55,000[4]
At McNary Dam – transport target[1]	4/10-6/30	220,000-260,000[5]	7/1-8/31	200,000
At Bonneville Dam – spawning target[1]	11/1-4/30	125,000[6]	NA	NA

Source: Reclamation 2008.

Notes:

[1] Per National Marine Fisheries Service Biological Opinion (NMFS 2008).

[2] Not applicable.

[3] Minimum discharge required by Priest Rapids license is 36,000 cfs. Higher minimums at 50,000-70,000 cfs required for December 1-May 31. Monthly flow levels determined pursuant to Hanford Reach Fall Chinook Protection Program (Hanford Reach Agreement) signed in 2004. On April 10-June 30, the 135,000 cfs minimum would apply, subject to in-season decisions pursuant to the Biological Opinion.

[4] Minimum average weekly flows required by Chapter 173-563 WAC is 40,000 cfs September 1-October 15 and 70,000 cfs October 16-31. For this water availability analysis, a minimum of 55,000 cfs was assumed (Mellema, pers. comm. 2011).

[5] Objective varies according to water volume forecasts.

[6] Dam is operated to a tailwater elevation of approximately 11.5 feet. Objective varies based on actual and forecasted water conditions.

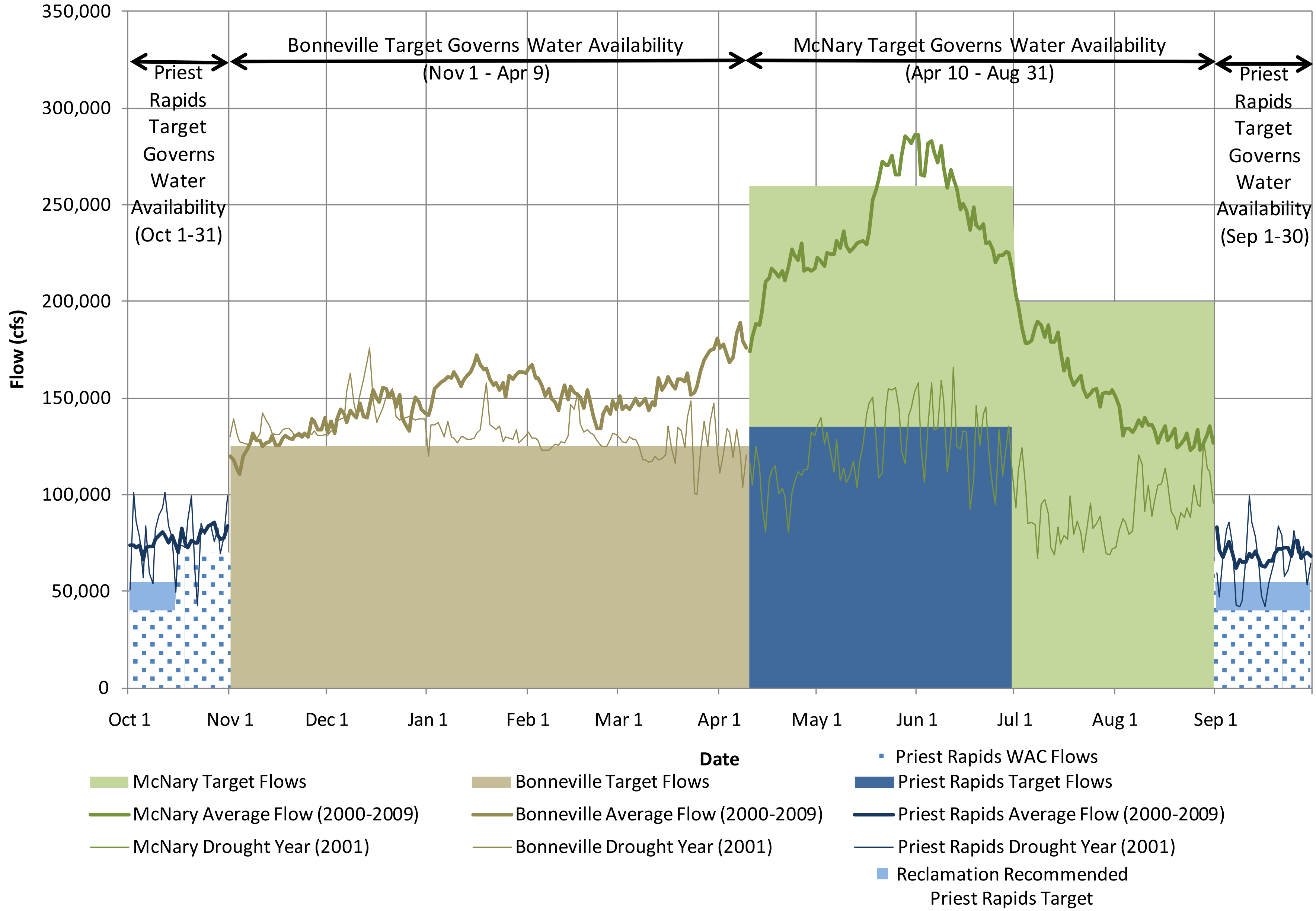

Figure 2. Target flows on the Columbia River and water availability above target flows

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The study team used output from BPA's Hyd-Sim computer model to estimate Columbia River water availability. This model includes the current Federal Columbia River Power System (FCRPS) operating requirements and historic hydrologic flow conditions for water years 1929-1998. The Hyd-Sim model outputs monthly average flows at different locations within the FCRPS, except April and August which are split into half-months to create a more realistic hydrograph (Reclamation 2008a).

Output from the updated model was subtracted from target flows to estimate water availability in the Columbia River. Table 11 shows the results of this analysis.

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Table 11. Estimated Columbia River Volumes Available for Pumping (acre-feet) for the Hyd-Sim Model's 70-year Period of Record (1929-1998)

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr 1-15	Apr 16-30	May	Jun	Jul	Aug 1-15	Aug 16-31	Sep	Total
1929	1,365,153	0	0	0	0	0	0	0	0	0	0	0	0	1,066,230	2,431,383
1930	1,280,694	0	0	0	0	0	0	0	0	0	0	0	0	1,215,265	2,495,958
1931	896,271	0	0	0	0	0	0	0	0	0	0	0	0	805,820	1,702,091
1932	1,030,632	0	0	0	0	0	0	760,528	3,176,047	3,275,435	0	0	0	1,416,809	9,659,450
1933	1,067,705	0	1,559,420	2,993,994	2,506,997	3,481,965	314,909	0	0	3,866,702	6,332,268	9,534	0	1,366,735	23,500,228
1934	1,973,367	3,072,881	6,151,811	7,507,388	5,112,455	5,858,414	2,291,533	1,425,867	2,027,320	0	0	0	0	1,334,302	36,755,338
1935	1,486,255	0	403,880	2,342,568	3,759,553	1,630,191	382,595	0	0	0	225,387	0	0	867,240	11,097,670
1936	1,085,321	0	0	0	20,568	359,625	0	0	376,505	0	0	0	0	646,807	2,488,826
1937	1,004,791	0	0	61,380	0	0	0	0	0	0	0	0	0	1,164,656	2,230,826
1938	1,281,369	0	1,148,113	3,623,875	1,332,334	3,092,570	332,462	578,289	4,178,750	175,468	0	0	0	1,325,749	17,068,978
1939	1,119,080	0	0	0	0	85,195	60,647	0	0	0	0	0	0	756,756	2,021,679
1940	1,265,594	136,739	764,365	555,857	0	1,070,713	164,984	0	0	0	0	0	0	1,081,318	5,039,569
1941	851,586	323,671	724,652	0	0	2,453,052	0	0	0	0	0	0	0	1,340,302	5,693,262
1942	460,104	431,185	1,268,847	2,984,664	0	501,597	0	0	0	972,437	0	0	0	1,186,931	7,805,766
1943	1,198,690	0	559,724	2,270,937	20,956	3,461,157	1,310,008	1,501,335	2,337,412	6,739,168	689,788	0	0	408,850	20,498,025
1944	751,353	0	0	0	0	0	0	0	0	0	0	0	0	1,316,720	2,068,072
1945	856,803	0	0	0	0	0	0	0	0	0	0	0	0	721,829	1,578,632
1946	529,034	0	1,102,017	681,625	258,960	4,158,679	552,004	812,859	7,238,298	438,016	0	0	0	880,664	16,652,156
1947	688,254	183,249	2,887,683	3,557,523	2,455,659	4,723,498	688,684	0	1,469,314	807,840	584,215	0	0	764,062	18,809,982
1948	3,228,772	2,551,765	2,423,405	4,353,438	0	3,170,461	343,243	22,691	4,321,643	14,338,328	2,719,441	9,445	0	1,499,672	38,982,303
1949	1,569,180	0	716,918	333,416	0	4,620,564	423,403	785,803	3,198,819	650,905	0	0	0	598,693	12,897,700
1950	802,544	0	479,869	2,712,812	2,714,786	4,645,975	891,089	0	1,966,247	10,988,228	2,798,376	9,474	0	1,081,793	29,091,192
1951	1,793,462	2,273,000	4,150,393	5,241,852	5,083,404	5,467,792	1,336,470	1,018,977	5,085,640	0	3,191,514	0	0	817,106	35,459,612
1952	2,502,094	1,124,680	2,446,545	4,237,123	2,437,808	2,435,190	457,677	613,483	4,678,752	662,904	0	0	0	612,533	22,208,789
1953	880,312	0	0	0	1,422,535	2,542,728	66,231	0	838,574	4,016,509	1,970,175	0	0	802,078	12,539,142
1954	1,458,450	223,997	2,118,162	1,992,518	3,453,746	5,413,532	165,043	0	1,681,566	5,041,991	7,553,055	955,776	9,948	3,610,154	33,677,937
1955	1,698,446	1,261,300	1,693,536	236,190	547,581	0	0	0	0	4,139,527	6,957,546	61,509	0	783,842	17,379,476
1956	1,770,383	2,557,289	3,473,678	5,123,511	4,603,017	3,336,494	800,801	2,705,729	8,211,785	6,158,236	4,239,455	0	0	877,279	43,857,657
1957	1,507,125	0	2,035,484	1,539,901	0	2,729,507	955,657	0	3,323,911	6,523,664	0	0	0	834,986	19,450,235
1958	769,398	0	0	1,171,683	816,631	4,639,960	533,471	0	2,822,252	1,918,382	0	0	0	800,653	13,472,431
1959	1,125,402	1,105,909	2,983,191	4,758,055	3,643,129	3,725,766	1,047,905	0	2,919,785	7,510,477	967,594	0	0	3,521,767	33,308,980
1960	3,886,889	4,096,640	4,041,014	3,602,760	2,442,797	842,318	2,693,909	185,061	0	623,878	43,150	0	0	976,061	23,434,476
1961	1,353,981	128,482	207,587	2,046,409	2,630,351	4,920,344	821,413	0	573,596	9,468,004	0	0	0	564,062	22,714,229
1962	644,981	0	712,315	3,033,768	806,541	151,916	1,042,737	1,354,379	311,626	1,027,858	0	0	0	504,425	9,590,546
1963	1,295,118	1,315,472	2,970,362	3,007,129	1,894,052	2,477,358	0	0	0	0	43,212	0	0	810,572	13,813,276
1964	871,719	0	672,357	1,704,584	824,892	0	0	0	0	7,032,663	4,470,305	9,593	0	1,472,229	17,058,342
1965	2,328,880	647,698	2,868,840	4,600,983	4,843,072	3,883,635	0	926,759	4,932,558	1,655,240	556,532	0	0	565,666	27,809,864
1966	1,357,050	0	877,488	2,614,911	1,456,520	0	1,856,814	0	0	0	430,703	0	0	726,224	9,319,712
1967	914,808	0	1,515,718	4,392,844	3,878,416	4,894,073	275,557	0	759,516	8,510,594	3,443,357	0	0	1,130,441	29,715,323
1968	1,373,869	193,109	1,177,453	3,026,586	2,869,408	3,655,977	0	0	0	605,761	2,187,522	0	0	2,172,377	17,262,062
1969	2,129,886	2,108,462	2,270,262	4,288,682	5,099,316	2,929,115	1,415,502	1,617,759	5,310,168	1,008,671	1,086,917	0	0	691,951	29,956,691
1970	1,336,304	0	0	1,016,944	0	2,838,027	124,324	0	0	1,639,321	0	0	0	157,113	7,112,033
1971	575,560	0	167,322	3,049,052	5,485,954	3,303,349	667,656	149,272	6,672,374	5,816,686	4,190,658	326,136	0	947,489	31,351,508
1972	1,083,357	78,230	1,206,854	3,287,697	3,638,361	8,502,173	2,293,939	0	6,166,910	10,756,627	6,841,783	770,953	0	1,051,083	45,677,966
1973	1,142,220	43,481	1,739,939	1,654,498	0	284,496	0	0	0	0	0	0	0	536,917	5,401,551
1974	693,962	0	2,054,082	6,966,016	7,916,000	4,335,576	1,107,275	1,242,886	6,527,824	10,473,586	6,936,615	341,996	0	983,367	49,579,186

Table 11. Estimated Columbia River Volumes Available for Pumping (acre-feet) for the Hyd-Sim Model's 70-year Period of Record (1929-1998)

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr 1-15	Apr 16-30	May	Jun	Jul	Aug 1-15	Aug 16-31	Sep	Total
1975	512,830	0	1,043	1,657,014	1,410,338	2,971,590	0	0	2,524,130	4,002,016	5,210,119	0	0	1,105,909	19,394,989
1976	1,895,660	2,598,215	4,812,683	4,391,248	3,638,694	4,824,714	859,221	665,072	4,742,894	1,416,690	4,338,584	1,436,173	993,770	4,482,383	41,096,001
1977	1,351,035	0	61,380	61,380	0	0	0	0	0	0	0	0	0	1,047,341	2,521,136
1978	233,981	0	758,227	1,036,524	0	2,771,061	1,422,779	0	2,384,245	0	1,297,573	0	0	2,714,283	12,618,673
1979	1,962,994	0	0	0	1,077,088	1,658,672	0	0	1,101,280	0	0	0	0	739,768	6,539,801
1980	1,037,568	0	0	57,022	0	1,538,919	429,135	0	4,911,014	1,449,657	0	0	0	984,258	10,407,573
1981	1,295,855	37,719	4,045,372	5,413,962	2,722,159	2,457,532	0	0	0	4,945,763	2,763,450	9,563	0	1,006,652	24,698,027
1982	1,456,609	599,643	1,589,005	2,304,696	4,492,802	6,448,276	614,315	0	2,988,408	8,479,647	3,017,932	98,515	0	2,257,556	34,347,405
1983	1,624,544	1,024,115	1,719,929	3,036,898	2,472,735	6,064,712	832,818	0	2,319,366	1,504,424	2,679,544	38,075	0	1,077,516	24,394,677
1984	900,138	3,079,355	1,404,620	3,781,438	1,361,107	2,546,165	1,246,836	688,387	0	2,129,193	3,112,089	0	0	820,492	21,069,820
1985	923,217	1,187,822	1,210,352	1,573,108	322,439	2,462,627	0	112,622	1,334,217	0	0	0	0	294,208	9,420,612
1986	1,140,809	1,323,194	0	2,281,556	804,878	6,055,383	942,440	667,092	0	477,695	0	0	0	388,120	14,081,166
1987	480,605	488,149	260,006	73,717	335,357	1,000,433	0	0	0	0	0	0	0	746,836	3,385,103
1988	948,014	0	0	0	0	0	0	0	0	0	0	0	0	1,267,299	2,215,313
1989	1,040,759	0	0	0	0	0	869,022	1,189,634	592,747	0	0	0	0	677,398	4,369,559
1990	888,046	0	2,239,511	2,715,697	3,834,785	2,779,593	286,278	673,240	0	3,361,446	0	0	0	658,627	17,437,222
1991	761,787	2,439,202	2,422,607	4,071,029	4,263,502	3,560,715	1,247,608	0	1,127,612	391,030	5,253,207	9,504	0	919,987	26,467,791
1992	1,007,921	0	0	0	373,832	2,673,160	0	0	0	0	0	0	0	980,991	5,035,904
1993	1,211,703	0	0	0	0	0	0	0	0	0	0	0	0	254,291	1,465,994
1994	874,849	0	0	0	0	0	0	0	0	0	0	0	0	1,013,067	1,887,916
1995	1,196,603	0	0	111,650	733,915	3,824,342	883,605	0	1,239,262	1,973,981	0	0	0	1,196,672	11,160,030
1996	1,469,805	3,692,898	7,122,106	5,583,861	6,070,514	7,723,323	1,223,076	2,118,828	3,982,150	3,607,184	5,696,064	9,415	0	919,571	49,218,794
1997	1,272,960	151,589	2,117,856	5,162,795	5,667,243	5,528,374	1,473,655	1,874,813	9,597,009	10,521,760	6,033,777	48,292	0	2,389,840	51,839,960
1998	3,990,498	2,045,558	1,108,707	2,965,022	1,491,502	1,444,824	0	0	2,303,591	3,622,687	43,212	0	0	595,604	19,611,205
Average	1,282,357	607,496	1,320,667	2,183,597	1,786,410	2,642,249	539,268	338,448	1,889,359	2,638,947	1,541,502	59,199	14,339	1,104,804	17,948,640
Minimum	233,981	0	0	0	0	0	0	0	0	0	0	0	0	157,113	1,465,994
Maximum	3,990,498	4,096,640	7,122,106	7,507,388	7,916,000	8,502,173	2,693,909	2,705,729	9,597,009	14,338,328	7,553,055	1,436,173	993,770	4,482,383	51,839,960

The study team assumed the requirement of no impact on Columbia River instream flows in July and August would apply in this analysis. Assuming that no pumping from the Columbia River would be allowed during that time period, the mean (average) amount of water available was estimated to be 16.3 million acre-feet annually, with a range of 1.5 to 45.8 million acre-feet.

Figure 3 shows Columbia River water availability using maximum transfer rates of 500, 1,000, and 2,000 cfs and assuming no water is available in July and August. The median (50 percent exceedance) availability of water is estimated as follows:

- 230,000 acre-feet per year using a pumping rate of 500 cfs
- 460,000 acre-feet per year using a pumping rate of 1,000 cfs
- 900,000 acre-feet per year using a pumping rate of 2,000 cfs

For planning an expensive pumping scheme, a higher reliability than 50 percent is desired. The availability of water using 95 percent reliability (less than only once in 20 years) ranges from about 60,000 to 240,000 acre-feet per year for pumping rates from 500 to 2,000 cfs.

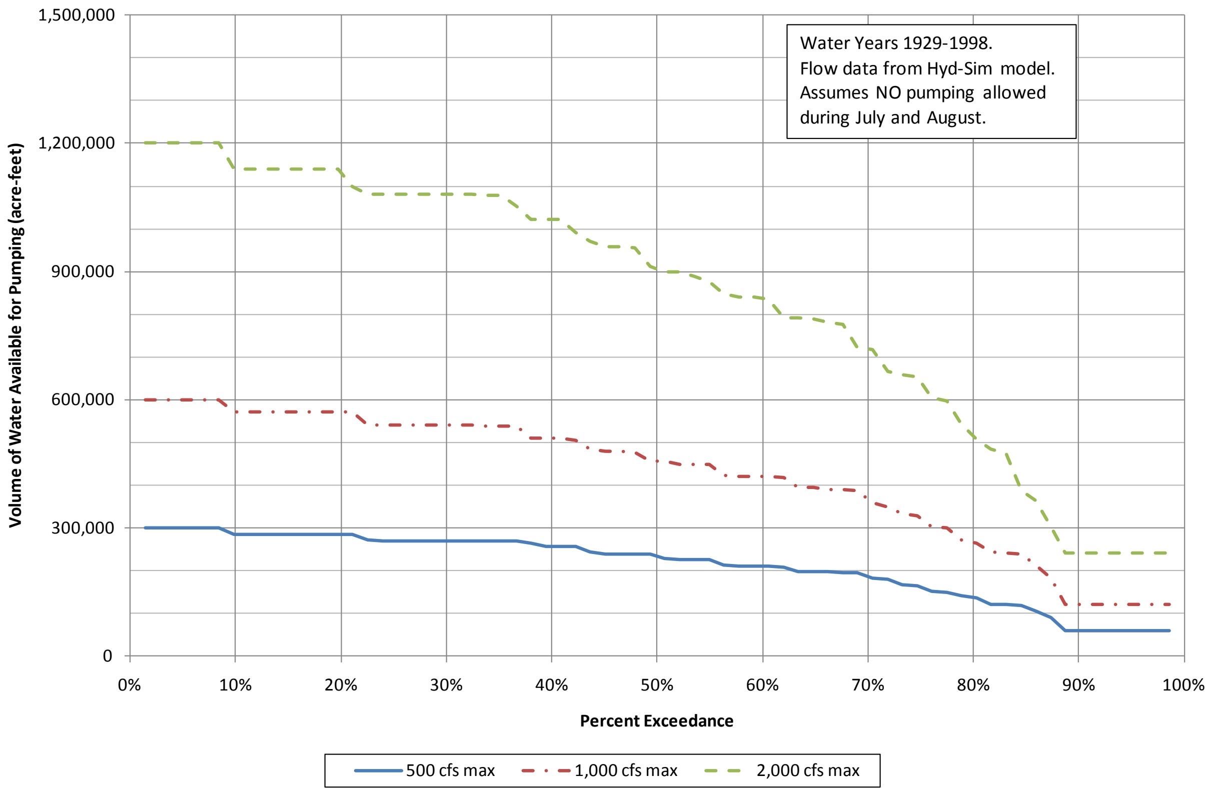

Figure 3. Percent exceedance of volume of water available from the Columbia River

As a comparison, the study team analyzed the water available in the Columbia River during the irrigation season (April-September) using the same assumptions in case a pumping scheme was proposed without sufficient water storage to carry water over from winter or from previous years. The mean water available in the Columbia River during the irrigation season was estimated to be 6.5 million acre-feet with a range of 0.3 to 25.9 million acre-feet.

Figure 4 shows Columbia River water availability during the irrigation season using maximum transfer rates of 500, 1,000, and 2,000 cfs and assuming no water is available July and August.

The availability is much less than if year-round pumping were allowed or planned for. The median availability of water is estimated as follows:

- 90,000 acre-feet per year using a pumping rate of 500 cfs
- 180,000 acre-feet per year using a pumping rate of 1,000 cfs
- 360,000 acre-feet per year using a pumping rate of 2,000 cfs.

At 95 percent reliability the water availability ranges from about 30,000 to 120,000 acre-feet per year using pumping rates of 500 to 2,000 cfs.

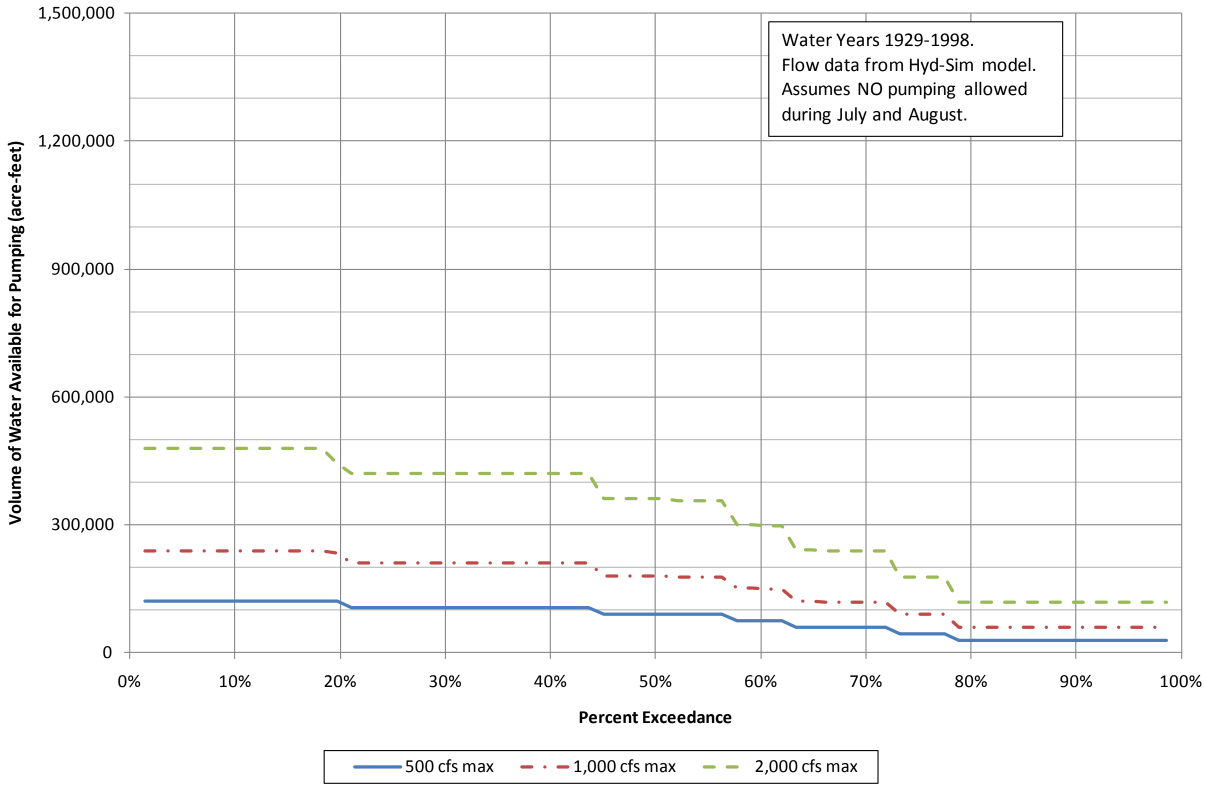

Figure 4. Percent exceedance of volume of water available from the Columbia River within the irrigation season

Water is available in September for all 70 modeled water years. In 14 of the 70 modeled water years September was the only month where water was available during the irrigation season. From this, it is expected that Columbia River water would not be available for direct use during the majority of the irrigation season during drought years.

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