Appendix A YAKIMA RIVER BASIN WATER ENHANCEMENT PROGRAM ACTIVITIES OCCURRING BETWEEN 1986 AND 1994

Early Implementation Program

This Appendix describes the activities occurring between 1986 and 1994 when Phase II of the Yakima River Basin Water Enhancement Program (YRBWEP) was authorized by Title XII of the Act of October 31, 1994.

In 1986, emphasis shifted to seeking congressional authorization of an early implementation program consisting primarily of nonstorage measures. This early implementation program would be an integral part of the overall YRBWEP. As a result, further work on the *Feasibility Planning Report/Environmental Impact Statement* was deferred.

In June 1986, an early implementation program, consisting primarily of nonstorage elements, was developed and a report entitled, *Preliminary Evaluation of Non-Storage Elements Being Considered for Early Implementation*, was prepared. In June 1986, Senate Bill 2519 and House Resolution 4997 were introduced in the 99th Congress, 2d Session. The Senate Subcommittee on Water and Power of the Committee on Energy and Natural Resources conducted a hearing in July 1986, in Yakima, Washington, to receive input on this proposed legislation. Action on the bills during the residual part of the 99th congressional session did not occur.

In June 1987, legislation to authorize a similar early implementation program was introduced in the 100th Congress, 1st Session (Senate Bill 1435 and House Resolution 2814). Senate subcommittee field hearings were held in October 1987, in Yakima, Washington.

Policy Group

In 1987, a "Policy Group" was structured to provide a forum for oversight of the YRBWEP with respect to (1) plan proposals, (2) guidance on matters of a policy nature, and (3) public involvement participation. The Policy Group included the following:

- Senator Daniel Evans
- Senator Brock Adams
- Congressman Sid Morrison
- Melvin Sampson, Chairman, Yakama Indian Nation
- Andrea Riniker, Director, Washington State Department of Ecology
- Alan Pettibone, Director, Washington State Department of Agriculture
- John Keys, Regional Director, Bureau of Reclamation

One of the Policy Group's first actions was to form ad hoc work groups to address issues, evaluate alternatives, and provide recommendations in the following four areas:

- Instream Flows and Fish Production Objectives
- Off-reservation Storage Site Selection
- Water Conservation
- Legal and Institutional

These work groups were functional during October 1987 through February 1988. They submitted their reports to the Policy Group at a February 1988 meeting. This was a key meeting regarding legislative action, as the decision was made to pursue the following legislative proposals:

- Early implementation legislation (Senate Bill 1435 and House Resolution. 2814) as it may subsequently be modified
- Comprehensive Federal legislation.

Comprehensive Federal Legislation

A preliminary draft of legislation providing for a comprehensive solution to the water supply needs of the Yakima River Basin was provided to the Policy Group by Senator Evans in March 1988. Senator Evans indicated he was prepared to introduce the draft legislation, or an amended draft, if there was agreement that it at least constitutes a workable framework. As the result of input, an amended draft was prepared and on April 25, 1988, Senate Bill 2322 and House Resolution 4953 were introduced in the 100th Congress, 2d Session. Hearings were held in Washington, D.C., on June 28, 1988, by the Senate Subcommittee on Water and Power of the Senate Committee on Energy and Natural Resources.

Following introduction, and as the result of numerous discussions with various basin interests, five modified drafts were prepared from June through the first of

September 1988, in an effort to move toward acceptable comprehensive Federal legislation. The last draft of comprehensive Federal legislation stipulated the volume of water to be available to the Yakama Indian Reservation, to off-reservation irrigation entities, and for instream flows. It also authorized early implementation elements, on-reservation programs, a Basin Conservation Program, and construction of additional off-reservation storage.

However, after extensive efforts to reach consensus on comprehensive Federal legislation, Senator Evans announced in the fall of 1988 that he was abandoning further work on the proposed legislation. This was attributed primarily to the view of some off-reservation irrigators that they should continue the adjudication process rather than pursue a stipulated settlement.

Enhancement Roundtable Group

Following termination of efforts to secure comprehensive Federal legislation, and with the announcement by Senator Evans he would not seek reelection, Congressman Morrison initiated discussions with the Directors of the State of Washington Departments of Ecology, Agriculture, and Fisheries, the Washington Governor's Office, and the Regional Director of the Bureau of Reclamation. The objective of these discussions was to structure a proposed forum for discussion among all of the parties from which a recommended course of action could be developed.

As the result of this effort, the Enhancement Roundtable Group was formed, consisting of the following representatives:

- Congressman Sid Morrison, representing the Washington Congressional Delegation
- Melvin Sampson, Chairman, Tribal Council, Yakama Indian Nation
- T.C. Richmond, Special Assistant to the Governor representing the respective state agencies
- Gene McIntire, President, Yakima River Basin Association of Irrigation Districts, representing the basin irrigators
- John Keys, Regional Director, Bureau of Reclamation.

A Technical Activities Group to provide guidance and oversight on YRBWEP work activities was also structured as a component of the Enhancement Policy Group. A representative of the irrigators, the Yakama Nation, the State, Bonneville Power Administration, and Reclamation comprised this group.

The first meeting of the Enhancement Roundtable Group occurred in April 1989. Two subsequent meetings were held in July and October 1989. The major thrust of these meetings was toward development of draft Federal legislation to authorize a "pilot" water conservation program (Phase II of YRBWEP).

There appeared to be considerable support for Phase II. However, at the October 1989, meeting, the irrigator's representative voiced concern with the legislation in view of the motion for partial summary judgment filed by several irrigation districts in the Adjudication Court with respect to the waters claimed on behalf of the Yakama Nation. Unsuccessful attempts were made to resolve the impasse on the proposed legislation. Consequently, a "hold" was placed on further Phase II legislative activities pending a decision by the Adjudication Court on the motion for a partial summary judgment.

Phase II Federal Legislation

A summary judgment addressing the waters claimed on behalf of the Yakama Nation was issued by the Adjudication Court May 29, 1990. Following this, there was renewed interest in proceeding with the Phase II legislative concept. The Enhancement Roundtable Group met in August 1990. The outgrowth of this meeting was a goal to have an acceptable draft of Phase II legislation available in late 1990, for possible early introduction in the next session of the Congress. House Resolution 3097 and Senate Bill 1609 were introduced in July 1991, by Congressman Morrison and Senator Gorton, respectively.

By resolution dated April 8, 1992, the Tribal Council indicated its support for the bill as modified by its suggested changes. This resolution was followed by meetings of tribal representatives with congressional staff in Washington, D.C.

Legislation authorizing Phase II of the YRBWEP was enacted as Title XII of the Act of October 31, 1994, Public Law 103-434. Title XII directs the Secretary of the Interior (acting through Reclamation), in consultation with the State of Washington, the Yakama Nation, Yakima River basin irrigators, and other interested parties, to establish and administer a Yakima River Basin Water Conservation Program (Basin Conservation Program) for the purpose of evaluating and implementing measures to improve the availability of water supplies for irrigation and the protection and enhancement of fish and wildlife resources, including wetlands, while improving the quality of water in the Yakima Basin.

Pursuant to Title XII, the Basin Conservation Program is to encourage and provide funding assistance in the following four phases of water conservation: development of water conservation plans, investigation of specific potential water

conservation measures identified in the plans, implementation of water conservations measures determined to be feasible, and post-implementation monitoring and evaluation of implemented measures.[1]

Instream target flows were established for Yakima project operations at Sunnyside and Prosser Diversion Dams. Criteria are included for increasing target flows as a result of water savings realized through the Basin Conservation Program.

Title XII also directs Reclamation to facilitate water and water right transfers, water banking, dry-year options, the sale and leasing of water, and other innovative allocation tools to maximize existing Yakima River Basin water supplies.

Appropriated funds may be used by Reclamation to purchase or lease land, water, or water rights from any entity or individual willing to limit or forego water use on a temporary or permanent basis. These activities are not subject to the cost-sharing provisions of the Basin Conservation Program.

Funds are provided for improvements to the Wapato Irrigation Project and other on-reservation measures. In addition, there is authorization for flow enhancement of Yakima River Basin tributaries; modification of the radial gates at Cle Elum Dam to provide an additional 14,600 acre-feet of storage capacity in Cle Elum Lake; and for augmentation of Kachess Reservoir-stored water by diverting flows of Cabin and Silver Creeks' excess-to-system demands. Also, Reclamation was to prepare an Interim Comprehensive Operating Plan providing a general framework for operation of the Yakima project. This plan was completed in 2002.

Title XII also provides for completion of two reports, with recommendations which shall provide a basis for the third phase of the YRBWEP. These reports are (1) to address the adequacy of the water supply available to sustain the agricultural economy of the Yakima River Basin, and (2) to evaluate what is necessary to have biologically-based instream target flows. Title XII indicates these reports and recommendations therein shall provide the basis for the third phase of the YRBWEP. The irrigation water supply report has not been prepared. The biologically-based target flow report was published May 1999.

[1] House Document 108-644 supporting Title XII states, in part: "The authorized level of funding is not expected to be sufficient to meet all needs to demonstrate conservation potential and test various measures. Information from the Conservation Program is expected to be sufficient to determine the scope of a complete conservation program for authorization in a future and final phase of the enhancement project."

Appendix B COMPARISON OF COST ESTIMATES USED IN THE YAKIMA RIVER BASIN WATERSHED MANAGEMENT PLAN AND THE YAKIMA RIVER BASIN APPRAISAL ASSESSMENT

In the reports written for the Yakima River Basin Watershed Planning Unit and Tri-County Water Resources Agency in the preparation of the *Yakima River Basin Watershed Management Plan*, Montgomery Water Group, Inc., used construction cost estimates prepared by Reclamation for Bumping Lake enlargement and Wymer dam, reservoir, and pumping plant as a part of the mid-1980s Yakima River Basin Water Enhancement Project investigations. These cost estimates were based on April 1985 prices, which Montgomery Water Group, Inc., indexed to 2001 prices (month not indicated) for Bumping Lake enlargement, and July 2002 prices for Wymer dam, reservoir and pumping plant.

The April 1985 cost estimates were subsequently reevaluated by Reclamation, and high, most probable, and low estimates were prepared based on July 1985 prices. This range of cost estimates reflected different assumptions regarding the extent of excavation, haul distance for the embankment dams, and other items. For the *Yakima River Basin Storage Alternatives Appraisal Assessment* (*Yakima Appraisal Assessment*), the most probable construction cost estimates are used.

The following is a comparison of the April 1985 and July 1985 estimates of construction pay items for Bumping Lake enlargement and Wymer dam, reservoir and pumping plant.

Bumping Lake Enlargement

The report entitled, *Storage Strategies, Yakima River Watershed Basin* (Montgomery Water Group, Inc., 2002) shows the April 1985 cost estimates developed by Reclamation in Table 4-3 of that report. The cost estimates shown in Table 4-3 include construction pay items, plus cost additives for contractor mobilization and unlisted items. Further, the total $134,510,000 in the table includes contingencies and $4 million more for the dam structure. The $4 million addition is not explained.

The July 1985 Reclamation "most probable" cost estimate is used in this *Yakima Appraisal Assessment* and indexed to July 2004 to be comparable to the Black Rock Alternative cost estimate shown in the *Summary Report, Appraisal Assessment of the Black Rock Alternative*, December 2004 (Table B-1).[2]

Table B-1. Bumping Lake Enlargement Cost Estimates

Item	April 1985 (dollars)	July 1985 (dollars)
Dam Structure	72,013,000	74,594,000
Spillway	4,020,000	4,136,000
Outlet Works	8,470,000	8,146,000
Breach Existing Dam	273,000	273,000
Subtotal of Pay Items	84,776,000	87,149,000
Added Costs for Table 4-3		
Mobilization costs	4,233,000	
Unlisted Items	13,221,000	
Contingencies	28,280,000	
Dam Structure	4,000,000	
Total shown on Table 4-3 of *Storage Strategies*	134,510,000	

Wymer Dam, Reservoir and Pumping Plant

The *Yakima River Basin Watershed Management Plan Technical Memorandum, Wymer Dam and Reservoir Project Review* (Montgomery Water Group, Inc., 2002), shows in Table 5-1 the April 1985 cost estimates prepared by Reclamation. The cost estimates shown in Table 5-1 of that memorandum include construction pay items, plus cost additives for contractor mobilization. Mobilization estimates have been removed for comparison purposes.

The July 1985 Reclamation "most probable" cost estimate is used in the *Yakima Appraisal Assessment* (Table B-2) and is indexed to July 2004 to be comparable

[2] The Black Rock Alternative field construction cost estimates are based on June 2004 price levels. However, the Bureau of Reclamation Cost Trends are reported on a quarterly basis (January, April, July, and October), so July 2004 was used, as a close approximation of June 2004 prices.

to the Black Rock Alternative cost estimate shown in the *Black Rock Summary Report*, December 2004.

Table B-2. Wymer Dam, Reservoir, and Pumping Plant Cost Estimates

Item	April 1985 (dollars)	July 1985 (dollars)
Dam Structure	100,506,000	74,646,000
Spillway	18,813,000	16,874,000
Outlet Works	5,767,000	5,624,000
Pumping Plant and Switchyard	16,694,000	17,058,000
Subtotal of Pay Items	141,780,000	114,202,000
Total mobilization costs	7,058,000	
Subtotal of pay items plus mobilization shown on Table 5-1 of *Wymer Dam and Reservoir Project Review*	148,838,000	

Montgomery Water Group, Inc., further includes a "budget estimate" of $10 million for possible Interstate Highway and Lmuma Creek bridge crossing reconstruction or relocation costs. As noted in section 6.2.1.6, a restriction placed on Wymer reservoir operation is that the maximum water surface cannot exceed elevation 1740 feet, to prevent inundation of the east lane of Interstate Highway 82 crossing Lmuma Creek about 5 miles upstream of the damsite.

As-built drawings of the Lmuma Creek Bridge were obtained from the Washington Department of Transportation. These indicated that the bottom elevation of the bridge is at elevation 1743.8 feet.

Montgomery Water Group, Inc., also noted that control of the water temperature released from Wymer reservoir to the Yakima River might be needed to meet State water quality standards for dissolved oxygen and temperature. If a multilevel outlet works tower were necessary, they estimated the additional cost at $14 million. Montgomery Water Group, Inc., indicated, however, this cost is much less than the allowance for unlisted items or the contingency used and is probably covered by these if a multilevel outlet structure is needed.

Appendix C YAKIMA RIVER BASIN STORAGE ASSESSMENT YAKIMA PROJECT RIVERWARE MODEL – JANUARY 2006

Yakima Project RiverWare Model

The system operation studies conducted by Reclamation for this assessment involve the use of the Yakima Project RiverWare (Yak-RW) model. This model is a daily time-step reservoir and river operation simulation computer model of the Yakima Project created with the RiverWare software. The software was developed at the Center for Advanced Decision Support for Water and Environmental Support at the University of Colorado, in cooperation with Reclamation and the Tennessee Valley Authority.

The RiverWare modeling software uses an object-oriented modeling approach in which objects represent features of the project such as storage reservoirs, stream reaches, diversions, and canals. Each object contains its own physical processes, algorithms and data. For instance, reservoir objects include elevation-volume data, flood-control rule curve information, and outflow data. Objects are interconnected into a "network" which represents the flow of water from one object to another.

The network file of the Yak-RW model consists of the five major project reservoirs (Keechelus, Kachess, Cle Elum, Bumping, and Rimrock) and fifty-six major and minor river diversions and canal systems. River diversions represented in the model include associated canal losses, on-farm losses, and return flows with each diversion. The network also includes simulation of Kittitas Reclamation District's 1146 Wasteway to assist in the "mini flip-flop" fall operation, and the Roza and Chandler power plants.[3] The RiverWare network diagram is available upon request.

The hydrologic base for the Yak-RW model is represented by the 23 water years of 1981 through 2003 (November 1, 1980, through October 31, 2003). This 23-year period includes 17 nonproration water years (wet and average water supply conditions) and 6 proration years (dry water supply conditions). This

[3] The Wapatox Powerplant was acquired by Reclamation in 2003 and is no longer in operation. The "power water" diversion now remains in the Naches River.

represents the longest dry cycle (1992-1994) and the largest single dry year (2001) in combination with wet and average water supply conditions. The period of record used is appropriate as it has a range of wet, dry, and average years. It is standard practice by hydrologists to have 20 years of record (minimum) for a modeling study to capture a range of flows with a standard variability to be statistically valid.

Table C-1 shows the April 1 Total Water Supply Available (TWSA) estimate, when water proration was necessary, and the proratable water supply available in these years.[4]

Table C-1. Yakima River Basin Water Supply Conditions (1981-2003)

Water Year	Historic April 1 TWSA (million acre-feet)	Proratable Water Supply Available (%)
1981	2.52	100
1982	3.43	100
1983	3.39	100
1984	3.31	100
1985	2.77	100
1986	2.49	90*
1987	2.37	68
1988	2.47	90
1989	2.84	100
1990	3.15	100
1991	3.06	100
1992	2.15	58
1993	2.16	67
1994	1.83	37
1995	2.97	100
1996	3.21	100
1997	4.59	100
1998	3.13	100
1999	3.94	100
2000	3.17	100
2001	1.79	37
2002	3.31	100
2003	2.64	92*

* Proration was not declared in these years, as there was an informal agreement to keep diversions near the average.

[4] The proratable water supply available is expressed as a percent of the total proratable water entitlements.

The daily diversion of each of the 56 diverters used in the Yak-RW model is determined as follows:

Five Yakima Project Divisions and Two Major Canals - - The average daily irrigation diversion for each of the 5 Yakima Project divisions above Parker (Kittitas, Roza, Tieton, Wapato, and Sunnyside) and for 2 major canals (Westside Irrigation Company and Naches-Selah Irrigation District) were determined by using the daily measured diversions for 7 non-proration water years of 1991, and 1995-2000.[5] An irrigation season average daily demand curve of flow (cfs) vs. day was then developed.

Forty-Nine Other Diverters - - For the 49 other diverters, the average daily irrigation diversion of each diverter was computed by: (1) extracting the daily flow from the irrigation demand curve of the Westside Irrigation Company for Yakima River diverters above Roza Diversion Dam, and the Naches-Selah Irrigation District for Yakima River and Naches River diverters below Roza Diversion; and (2) multiplying this daily flow figure by the ratio the specific diverter's water entitlement is to the water entitlement of either the Westside Canal Company or the Naches-Selah Irrigation District. This procedure is illustrated below:

$$\text{cfs from demand curve of representative entity} \times \frac{\text{water right of diverter}}{\text{water right of representative entity}}$$

Figure C-1 is the nonproration water year irrigation demand curve for the five Yakima Project divisions and the two major canals. March flood waters are included in this figure.

[5] These 7 nonproration years are representative of a full water supply and diversions.

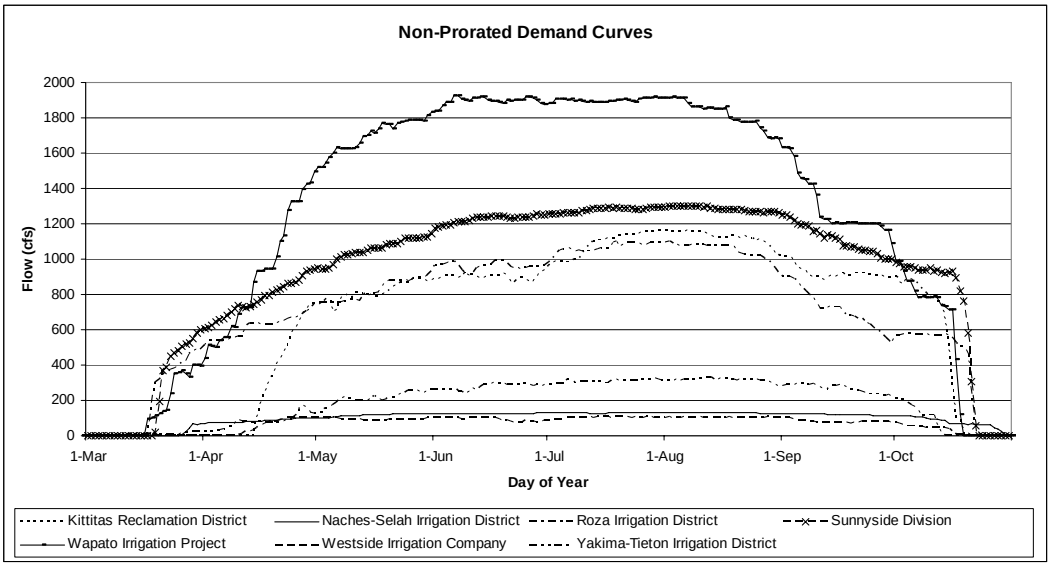

Figure C-1. Nonproration Water Year Irrigation Average Daily Demand Curves

In proration water years, the diversions are limited to water rights adjusted by the Natural Runoff Proportion (NRP) or water rights adjusted by the proration level.[6] However, at no time between April and September are diversions set greater than the average nonproration year computed average diversion shown in figure 24. Further, in years of proration, October diversions at no time are set greater than the October irrigation demand curve shown in Figure C-2.

[6] Natural Runoff Proportion (NRP) attempts to maximize the use of natural runoff (the unregulated runoff below storage reservoirs) and return flows and, at the same time, minimize storage releases to meet demands. The major water users above Parker voluntarily agree to share natural runoff and return flow supply proportionally based on their water rights. If reservoir releases are called for prior to storage control and formal prorationing, they will be deducted from the requesting entity's water bucket when prorationing formally begins.

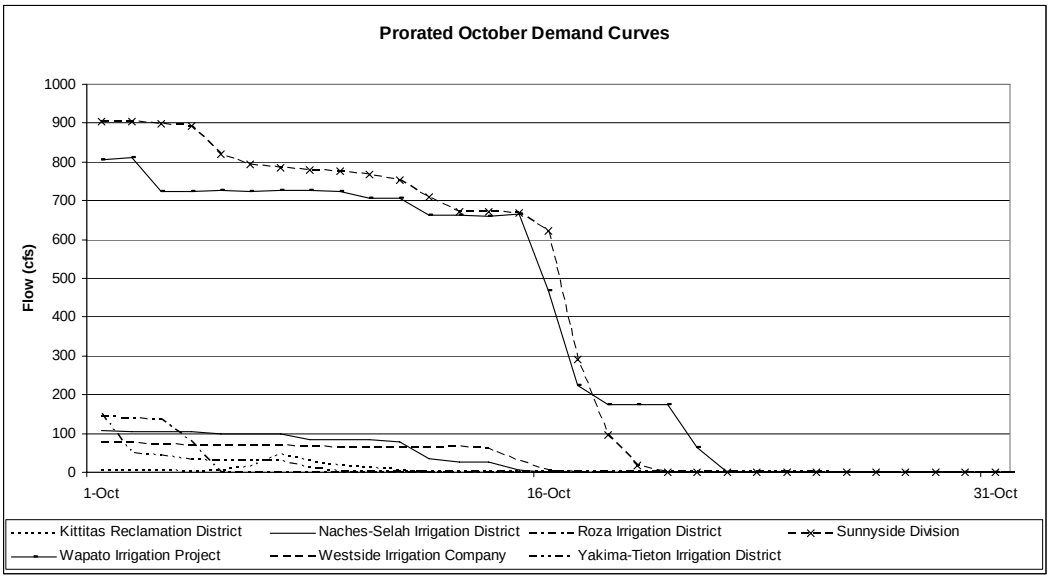

Figure C-2. Prorated Water Year October Irrigation Average Daily Demand Curves

Table C-2 shows the computed 7-year average April-October diversions and the water rights for the five Yakima Project divisions above Parker, and for the Westside Irrigation Company and the Naches-Selah Irrigation District. The water entitlements represent the total irrigation season entitlements as summarized in Chapter 5 of the *Interim Comprehensive Basin Operating Plan* (Bureau of Reclamation, 2002). Water entitlements for all entities included in the Yak-RW model can be found in Table C-5 at the end of this Appendix.

Table C-2. Average April-October Nonproration Diversion and Water Entitlements for Seven Entities

Entity	Average April-October Diversion (acre-feet)	Water Entitlement for Determining Proration Level and Nonproratable Supply (acre-feet)		
		Nonproratable	Proratable	Total
Kittitas Reclamation District	334,100	- - - -	336,000	336,000
Roza Irrigation District	339,700	- - - -	375,000	375,000
Yakima-Tieton Irrigation District	92,200	75,865	20,746	96,611[7]
Wapato Irrigation Project	604,800	305,613	350,000	655,613
Sunnyside Division	435,422[8]	315,836	142,684	458,520
Westside Irrigation Company	33,100	31,128	8,200	39,328
Naches-Selah Irrigation District	47,500	49,658	4,486	54,144

How the Model Works (Operating Rules)

The Yak-RW model is based on current Yakima Project operations (ruleset) described in the *Interim Comprehensive Basin Operating Plan, Chapter 5: Current Project Operations*. The model operation of items such as the current minimum target flows downstream of existing dams, the flip-flop operation, and the Title XII instream target flow operations, begun at different times during the period of record, have been included in the model for the entire 23 years. Because of this, as well as adjustments made during the "hands-on operation,"

[7] Through a Water Right Settlement among the Yakima-Tieton Irrigation District, the Washington State Department of Ecology, the United States, and the Yakama Nation, up to 96,611 acre-feet was confirmed to the United States on behalf of the Yakima-Tieton Irrigation District from the Tieton River for the period of April-October. The quantities set forth in the 1945 Consent Decree are to be used in determining proration, as limited by the foregoing volume.

[8] The average April-October diversion for the 7 years is 444,300 acre-feet. However, through a Water Right Settlement Agreement filed with the Superior Court for Yakima County, the Sunnyside Division agreed to a diversion of 435,422 acre-feet, with a further reduction by December 31, 2016. Thus, the water right is used for the diversion volume. The quantities set forth in the 1945 Consent Decree are used in determining proration, but the total to be diverted is limited to 435,422 acre-feet.

there will be differences in the modeled results, such as proration levels, when compared to historic operations.

The primary ruleset components and how they are applied in the model follow:

First, the total water supply available (TWSA) estimated to be available above Parker for the April 1 to September 30 irrigation season is computed from calibrated inflows, modeled reservoir contents, and estimated irrigation return flows. TWSA is used to set instream target flows at Parker in accordance with Title XII and determine the water supply available to meet irrigation water rights; the latter is used to determine if irrigation proration will be necessary.

The water supply available for irrigation is determined by reducing TWSA by flows estimated to pass Parker and the volume of stored water required (76,000 acre-feet) to meet irrigation demands from October 1 to the end of the irrigation season, which is generally October 15 to 20. The irrigation proration level is calculated as the water supply available for irrigation, less the April-through-September nonproratable water rights, divided by the April-through-September proratable water rights.

Prior to using the proration level to limit irrigation diversions, an estimate of natural runoff to meet irrigation demands is made. If the natural runoff can be used to meet up to 75 percent of the irrigation demands, then this is done. However, once 75 percent of the demands cannot be met from the natural runoff, proration is declared and the proration level is used to limit the demands.

> *At this point, the current day's irrigation demands and the Parker instream target flows are known.*

Second, operating guidelines for each reservoir are determined based on the flood control system rule curve and a targeted September 1 reservoir volume. The winter and spring operating guidelines (November 1 through June 30) are based on the "Flood Control Rule Curve," dated February 25, 1974, which is premised on attempting to maintain flows at Parker to no more than 12,000 cfs during the nonirrigation season, and 17,200 cfs during the irrigation season, including diversions of 5,200 cfs above Parker. These rule curves attempt to fill each reservoir on or near June 30.

After determining the required system storage space from the flood control rule curve, the space requirement within each reservoir is determined as follows: Keechelus, 13 percent; Kachess, 12 percent; Cle Elum, 42 percent; Bumping, 13 percent; and Rimrock, 20 percent.

Once the system is on storage control (generally about June 24), operating guidelines are used to draft from the reservoirs.[9] The goal of these guidelines is to maximize storage carryover by first using water from the reservoirs with the highest refill ratios, and to allow for flip-flop operations, which are achieved by targeting September 1 elevations at each reservoir. The basic concept is to call on Cle Elum and Keechelus Reservoirs to meet Yakima River irrigation demands prior to September 1. After September 1, Kachess Reservoir is used to meet Yakima River irrigation demands above the Naches River confluence, and Rimrock Reservoir is used to meet Yakima River irrigation demands below the Naches River confluence.

At this point, the day's desired reservoir elevations are known.

Third, once the Parker instream target flows, irrigation diversion allocations, and desired reservoir elevations are determined, releases from each reservoir can be calculated. The volume to be released from a particular reservoir each day is subject to minimum flow requirements below project dam(s), desired reservoir elevations, maximum channel capacities, downstream irrigation demands and the point(s) of diversion, and instream target flows at Parker. Minimum flow requirements and instream target flows are shown in Table C-3; Parker target flows are shown in Table C-4.

At this point, water releases from each reservoir are known.

Lastly, once releases have been made at each reservoir, river reach flows can be determined. The model is able to control the operation of the Kittitas Reclamation District's 1146 Wasteway to bypass fall reservoir releases around the Easton Reach and for operation of the Roza and Chandler Power Plants.

[9] The system is on storage control when the Yakima River flow at Parker can be controlled to the Title XII target flows only by using supplemental storage releases. Once unregulated streamflow fails to meet diversion demand and target flows downstream, reservoirs release water to meet these demands, causing a depletion of reservoir storage.

Table C-3. Minimum Target Flows Used by the Model

River Location	Daily Flows (cfs)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Tieton Dam	45	45	45	45	45	45	45	45	45	45	45	45
Bumping Dam	130	130	130	130	130	130	130	130	130	130	130	130
Keechelus Dam	80	80	80	80	80	80	80	80	100	100	80	80
Kachess Dam	15	15	15	15	15	15	15	15	15	15	15	15
Cle Elum Dam	220	220	220	220	220	220	220	220	220	220	220	220
Easton Diversion Dam	220	220	220	220	220	220	220	220	220	220	220	220
Naches River at Naches	Minimum of natural flow right or 450 cfs											
Parker				Title XII flows								

Table C-4. Parker Instream Target Flows

Total Water Supply Estimate (million acre-feet)				Parker Flow (cfs)
April thru Sept.	May thru Sept.	June thru Sept.	July thru Sept.	
3.2	2.9	2.4	1.9	600
2.9	2.65	2.2	1.7	500
2.65	2.4	2.0	1.5	400
Less than above				300

Table C-5. Entitlements Used in the Yakima RiverWare Model (acre-feet)

	Total	Annual		April		May		June		July		August		September		October	
		Non-Pro	Pro	Non-Pro	Pro	Non-Pro	Pro	Non-Pro	Pro	Non-Pro	Pro	Non-Pro	Pro	Non-Pro	Pro	Non-Pro	Pro
Anderson Ditch	1,570	1,570	0	140	0	330	0	270	0	260	0	310	0	130	0	130	0
Blue Slough Ditch	4,245	4,245	0	595	0	615	0	595	0	615	0	615	0	595	0	615	0
Boise Cascade	9,259	9,159	100	1,354	15	1,399	15	1,354	15	1,399	15	1,399	15	1,354	15	900	10
Bull Ditch	6,471	6,471	0	1,012	0	1,045	0	1,012	0	1,045	0	1,045	0	1,012	0	300	0
Carmack Parker Ditch	639	639	0	95	0	98	0	95	0	98	0	98	0	95	0	60	0
Cascade Ditch	49,525	49,525	0	8,925	0	9,223	0	8,925	0	8,452	0	5,600	0	5,600	0	2,800	0
Chapman Nelson Ditch	7,641	7,641	0	1,071	0	1,107	0	1,071	0	1,107	0	1,107	0	1,071	0	1,107	0
City of Cle Elum M and I	1,260	1,260	0	180	0	180	0	180	0	180	0	180	0	180	0	180	0
City of Ellensburg M and I	6,000	0	6,000	0	120	0	1,020	0	1,260	0	1,260	0	1,200	0	780	0	360
City of Yakima Irrigation	10,305	8,805	1,500	1,232	225	1,273	262	1,232	342	1,273	218	1,273	218	1,232	165	1,290	70
City of Yakima M and I	9,359	4,859	4,500	681	675	704	788	681	1,028	704	652	704	652	681	495	704	210
Clark Ditch	4,562	4,562	0	714	0	739	0	714	0	739	0	739	0	536	0	381	0
Cobb Upper Ditch	727	727	0	119	0	123	0	119	0	123	0	123	0	60	0	60	0
Congdon Ditch	28,025	23,720	4,305	3,808	690	3,935	713	3,808	690	3,935	713	3,935	713	2,469	446	1,830	340
Ellensburg Mill and Feed Ditch	4,804	4,804	0	702	0	726	0	702	0	726	0	726	0	702	0	520	0
Ellensburg Power Ditch	6,031	6,031	0	928	0	959	0	928	0	959	0	959	0	928	0	370	0
Ellensburg Town Ditch	47,758	47,758	0	7,438	0	7,686	0	7,438	0	7,686	0	7,686	0	5,950	0	3,874	0
Emerick Ditch	687	687	0	119	0	123	0	119	0	123	0	123	0	60	0	20	0
Fogarty Dyer Ditch	3,690	3,690	0	108	0	638	0	717	0	794	0	733	0	480	0	220	0
Foster Naches Ditch	1,510	1,510	0	100	0	280	0	300	0	320	0	270	0	200	0	40	0
Fredricks Hunting Ditch	950	950	0	120	0	130	0	170	0	170	0	180	0	140	0	40	0
Fruitvale Ditch	17,708	17,708	0	2,791	0	2,884	0	2,791	0	2,884	0	2,884	0	2,011	0	1,463	0
Gleed Ditch	22,819	22,819	0	3,618	0	3,738	0	3,618	0	3,738	0	3,738	0	2,475	0	1,894	0
Hubbard Ditch	11,165	11,165	0	1,785	0	1,845	0	1,785	0	1,845	0	1,845	0	1,250	0	810	0
Kelly Lowry Ditch	8,490	8,490	0	1,190	0	1,230	0	1,190	0	1,230	0	1,230	0	1,190	0	1,230	0
Knoke Ditch	1,600	1,600	0	110	0	300	0	350	0	370	0	330	0	120	0	20	0
Kittitas Reclamation District	336,000	0	336,000	0	6,720	0	57,120	0	70,560	0	70,560	0	67,200	0	43,680	0	20,160
Mills and Son Ditch	7,530	7,530	0	1,190	0	1,230	0	1,190	0	1,230	0	1,230	0	1,190	0	270	0
Morrissey Ditch	1,206	1,206	0	178	0	184	0	178	0	184	0	184	0	178	0	120	0
Moxee Irrigation District	5,205	4,245	960	595	86	615	144	595	182	615	182	615	182	595	125	615	59
Naches Cowiche Ditch	15,096	15,096	0	2,380	0	2,460	0	2,380	0	2,460	0	2,460	0	1,726	0	1,230	0
Naches Selah Irrigation District	54,144	49,658	4,486	7,080	674	7,263	811	7,080	901	7,321	1,050	7,321	1,050	6,884	0	6,709	0
Nile Valley Ditch	4,350	4,350	0	230	0	470	0	730	0	980	0	970	0	670	0	300	0
Oconner Ditch	3,100	3,100	0	0	0	330	0	660	0	830	0	740	0	450	0	90	0
Old Union Ditch	17,675	17,675	0	2,813	0	2,907	0	2,813	0	2,907	0	2,907	0	1,875	0	1,453	0
Wapato Irrigation Project	655,613	305,613	350,000	42,843	31,500	44,271	73,500	42,843	70,000	44,271	80,500	44,271	73,500	42,843	21,000	44,271	0
Richartz Ditch	6,364	6,364	0	892	0	922	0	892	0	922	0	922	0	892	0	922	0
Roza Irrigation District	375,000	0	375,000	0	37,500	0	56,250	0	71,250	0	71,250	0	71,250	0	45,000	0	22,500
Selah Moxee Irrigation District	31,774	27,493	4,281	4,284	427	4,427	685	4,284	814	4,427	898	4,427	857	3,320	600	2,324	0

Table C-5. Entitlements Used in the Yakima RiverWare Model (acre-feet) (con't)

	Total	Annual		April		May		June		July		August		September		October	
		Non-Pro	Pro	Non-Pro	Pro	Non-Pro	Pro	Non-Pro	Pro	Non-Pro	Pro	Non-Pro	Pro	Non-Pro	Pro	Non-Pro	Pro
Sinclair Ditch	786	786	0	119	0	123	0	119	0	123	0	123	0	119	0	60	0
South Naches Ditch	22,946	22,946	0	3,689	0	3,812	0	3,689	0	3,812	0	3,812	0	3,272	0	860	0
Stanfield Ditch	1,600	1,600	0	30	0	280	0	370	0	430	0	330	0	100	0	60	0
Stevens Ditch	1,950	1,950	0	60	0	410	0	350	0	410	0	320	0	290	0	110	0
Sunnyside Division	458,520	315,836	142,684	47,070	7,840	48,636	27,874	47,066	31,234	48,637	31,443	48,637	31,443	47,070	12,850	28,720	0
Taylor Ditch	8,000	8,000	0	1,190	0	1,230	0	1,190	0	1,230	0	1,230	0	1,190	0	740	0
Tenant Ditch	1,570	1,570	0	110	0	210	0	220	0	410	0	320	0	230	0	70	0
Yakima-Tieton Irrigation District	114,049	75,865	38,181	0	6,000	15,372	6,641	14,876	7,141	15,372	6,641	15,372	6,641	14,876	5,117	0	0
Tjossem Ditch	4,771	4,771	0	756	0	781	0	756	0	781	0	781	0	756	0	160	0
Vertrees 1 Ditch	2,164	2,164	0	181	0	407	0	400	0	551	0	428	0	177	0	20	0
Vertrees 2 Ditch	704	704	0	107	0	111	0	107	0	111	0	111	0	107	0	50	0
Wapatox Ditch	20,230	20,230	0	3,064	0	3,167	0	3,064	0	3,167	0	3,167	0	3,064	0	1,537	0
Westside Irrigation Company	39,328	31,128	8,200	4,760	550	4,919	1,550	4,760	1,500	4,919	1,550	4,919	1,550	4,760	1,500	2,091	0
Woldale Ditch	12,973	12,973	0	2,023	0	2,091	0	2,023	0	2,091	0	2,091	0	1,547	0	1,107	0
Younger Ditch	3,010	3,010	0	40	0	440	0	780	0	790	0	740	0	180	0	40	0
Union Gap Irrigation District	25,303	20,697	4,606	3,273	571	3,382	734	3,273	785	3,382	812	3,382	872	2,279	582	1,726	250
Total	2,497,761	1,216,958	1,280,803														

Appendix D YAKIMA RIVER BASIN STORAGE ASSESSMENT INTEGRATED OPERATION SCENARIO AND COMPARISON OF RESULTS -- JANUARY 2006

Purpose of Appendix D

Appendix D provides more detailed information on the integrated operation scenario, the results of the three operation studies conducted for the integrated operation scenario, and a comparison of the results with the current operation scenario.

Scenario Definition

Different operation scenarios can be analyzed with the Yak-RW model by modifying network object data and by adding new objects and data, such as additional storage reservoirs. Following is a discussion of the two operation scenarios and the operation studies conducted for the *Yakima Appraisal Assessment*.

The two operation scenarios are:

- Current Operation Scenario – The current operation scenario represents management of the existing Yakima Project as reflected in Appendix C.
- Integrated Operation Scenario – Integrated operation whereby the three Yakima basin storage alternatives are integrated with the existing Yakima Project facilities.

In addition to the two operation scenarios, a natural (unregulated) flow regime was developed for the mainstem Yakima and Naches Rivers and for the Bumping River. This represents an estimated unregulated Yakima Project streamflow regime unimpeded by reservoir impoundments or altered by diversions and the associated irrigation return flows.

Integrated Operations

Criteria

The primary criteria used for the three storage alternatives included in the integrated operation scenario are shown below:

Bumping Lake Enlargement

Location: On the Bumping River, approximately 4,500 feet downstream from the existing Bumping Dam.

Reservoir Active Capacity: About 415,000 acre-feet (includes replacement capacity of 33,700 acre-feet of the existing reservoir).

Operating Strategy: Maximize storage carryover for use in dry water supply years.

Wymer Dam, Reservoir, and Pumping Plant

Location: Near Yakima River at confluence of Lmuma Creek.

Reservoir Active Capacity: 175,000 acre-feet.

Pumping Plant and Reservoir Discharge Capacity: 400 cfs.

Operating Strategy:

Inflow: Limited to nonprorated water supply years. Pumping to Wymer reservoir occurs when Yakima River flows are:

- Greater than 1,475 cfs upstream of Roza Diversion Dam during the nonirrigation season; and
- Greater than Title XII flows over Sunnyside Diversion Dam during the irrigation season.[10]

Outflow: Limited to prorated water supply years and when reservoir releases are required for meeting Title XII target flows at Sunnyside Diversion Dam. Using Wymer reservoir to meet these instream flows permits stored water in the other reservoirs to be used to assist in improving the irrigation proratable water supply throughout the basin.

[10] Maximum generation at Roza Powerplant requires a flow of 1,075 cfs. In addition, 400 cfs is required at Roza Diversion Dam to divert the power water.

Keechelus-to-Kachess Pipeline

Pipeline Capacity: Ranges from 100 cfs at Keechelus Reservoir elevation 2450 feet, to 210 cfs at elevation 2517 feet (see table 6-4 of *Yakima Appraisal Assessment*).

Operating Strategy: Operate through June 1 and September 30 to siphon Keechelus Dam releases to Kachess Reservoir.

For the integrated operation scenario, the focus is on meeting current instream flow requirements downstream of the dams, Title XII instream target flows, and the irrigation water supply goal. Specific criteria are not included in the integrated operation scenario in an attempt to move the Yakima and Naches Rivers' flow regimes toward the natural (unregulated) hydrograph. Rather, the Yak-RW model uses the post-TWSA to set Title XII target flows over Sunnyside and Prosser diversion dams. This results in higher Title XII flows in some years, depending on the extent of the increase in TWSA and the Title XII criteria threshold levels. These additional flows are then equated to a block of stored water which could be used for other fishery purposes if desired. In this manner, the water supply available for specific fishery operations is identified.

Total Water Supply Available and Proration

For the integrated operation scenario, three operation studies were conducted in which the following "thresholds" of proration were used:

- Integrated 100-percent operation which represents the present proration process where there is no constraint in any year on the proratable entitlements, except as limited by the volume of TWSA.
- Integrated 70-percent operation, where the allotment in any prorated year is limited to the water that would have been available without the storage alternatives, and capped at 70 percent of the proratable entitlements with the storage alternatives, except as limited by the volume of TWSA.
- Integrated 50-percent operation, where the allotment in any prorated year is limited to the water that would have been available without the storage alternatives, and capped at 50 percent of the proratable entitlements with the storage alternatives, except as limited by the volume of TWSA.

To determine the 70-percent and 50-percent thresholds, a "post-" and "pre-" TWSA was computed. The post-TWSA computation includes the stored water available in the existing storage system, plus the stored water available in the

storage alternatives. The pre-TWSA computation considers only the stored water available in the existing storage system. The other components of TWSA remained the same. These TWSA computations are shown below:

Post-TWSA = Prior day contents of Keechelus, Kachess, Cle Elum, Rimrock, Bumping Lake enlargement and Wymer + total runoff above Parker + usable return flow above Parker.

Pre-TWSA = Prior day contents of Keechelus, Kachess, Cle Elum, Rimrock, and Existing Bumping Lake + total runoff above Parker + usable return flow above Parker.

The proration thresholds and the allotment of the proratable irrigation TWSA used in the integrated operation scenario are illustrated Table D-1.

The integrated operation scenario included operation studies with three "thresholds" of water supply—100-percent, 70-percent, and 50-percent. Table ES-3 uses two examples of proration levels (80-percent and 40-percent) to illustrate what the proratable supply would be with application of the 100-percent, 70-percent, and 50-percent, criteria. For example, if the computed proration level without the three storage alternatives would have been 80 percent (or any supply over the threshold level), irrigators would receive up to 100 percent of their proratable rights under the integrated 100-percent scenario (if the supply is available), 80 percent under the integrated 70-percent scenario, and 80 percent under the integrated 50-percent scenario. In other words, proratable irrigators would receive what they would have received without any program in place, under any of the integrated operations.

On the other hand, if, without the three storage alternatives, the proratable supply is 40 percent (or any supply less than the integrated operation threshold), they would receive up to that threshold level, *i.e.*, 50 percent under the integrated 50-percent scenario, and 70 percent under the integrated 70-percent scenario, and 100 percent under the integrated 100-percent scenario, if the supply is available.

Table D-1. Example of Proratable Supply Provided With The Three Storage Alternatives

Computed Proration Level Without Three Storage Alternatives	Integrated 100%	Integrated 70%	Integrated 50%
80%	up to 100% (if available)	80%	80%
40%	up to 100% (if available)	70% (if available)	50% (if available)

The computed pre-TWSA may not be the same as in the current operation scenario TWSA. This is because the integrated system operation of the Yakima Project results in differences in the contents of the existing storage system.

Comparison of Results of Integrated Operation Studies

Irrigation Water Supply

Integrated 100-Percent Operation Study

One-year droughts which follow 2 or more wet years could see a 40-percent improvement in the proratable water supply over the current operation scenario. This is demonstrated by drought year 2001, where the current operation scenario proratable supply available is 41 percent, and the integrated 100-percent operation study is 84 percent.

Proratable water supply conditions are improved in some years of a prolonged dry period such as 1992-1994. The additional storage alternatives provided a full (100-percent) proratable supply in 1992 and increased the 1993 supply from 54 percent (current operation) to 74 percent. However, this results in the enlarged Bumping Lake reservoir and Wymer reservoir being significantly drawn down. The April 1 TWSA for the 1994 irrigation season is about the same as the current operation scenario. This shows there was not enough runoff to build up the stored water supply following the 1992 and 1993 dry years, and the proratable water supply provided in 1994 is only 27 percent (a 1-percent increase from the current operation scenario).

Integrated 70-Percent Operation Study

One-year droughts which follow 2 or more wet years could see about a 30-percent improvement. This is demonstrated by drought year 2001, where the modeled current operation proration level is 41 percent, and the integrated 70-percent operation proration level is brought up to 70 percent.

Irrigation water supply conditions are improved in the prolonged 3-year dry period of 1992-1994. The additional storage alternatives increased the proratable water supply in 1992 and 1993 to not less than 70 percent. The 1994 proratable water supply was increased to 66 percent; 4 percentage points below the 70-percent threshold. It is estimated the 4-percent difference equals about 50,000 acre-feet.

Integrated 50-Percent Operation Study

The integrated 50-percent operation study results in a proratable water supply within the same range as the integrated 70-percent operation study in years 1992

and 1993. For the third year of the 3-year dry period, the proratable water supply provided is at the 50-percent threshold.

Summary of Results

Table D-2 provides information on the annual water supply conditions above Parker. The information in the table is described below:

Column 1, *Water Year*: The Water Year of the 23-year historical period used in the Yak-RW model.

Column 2, *Current*: This is the current operation scenario April 1-September 30 TWSA estimate produced by the Yak-RW model.

Column 3, *100 percent*: This is the April 1-September 30 TWSA estimate produced by the Yak-RW model for the integrated 100-percent operation scenario.

Column 4, *70 percent*: This is the April 1-September 30 TWSA estimate produced by the Yak-RW model for the integrated 70-percent operation scenario.

Column 5, *+TWSA*: The increase in the April 1-September 30 TWSA estimate between the integrated 70-percent operation scenario and the current operation scenario is shown in this column.

Column 6, *50 percent*: This is the April 1-September 30 TWSA estimate produced by the Yak-RW model for the integrated 50-percent operation study.

Columns 7-10, *Proratable Water Supply Provided*: These columns show the volume of the water supply provided to proratable entitlements for the current and integrated operation scenarios.

Table D-2. Yakima Project Current and Integrated Operation Scenarios--TWSA and Proratable Supply

Water Year	April 1 – September 30 TWSA (million acre-feet)					Proratable Water Supply Provided (%)			
	Current Operation Scenario	Integrated Operation Scenario				Current Operation Scenario	Integrated Operation Scenario		
		100%	70%	+TWSA	50%		100%	70%	50%
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1981	2.48	2.85	2.86	.38	2.86	95	100	91	91
1982	3.39	3.79	3.83	.46	3.85	100	100	100	100
1983	3.30	3.88	3.89	.56	3.89	100	100	100	100
1984	3.23	3.79	3.79	.56	3.79	100	100	100	100
1985	2.74	3.27	3.27	.53	3.27	100	100	100	100
1986	2.50	3.00	3.00	.50	3.00	92	100	89	88
1987	2.26	2.64	2.82	.56	2.82	65	100	70	69
1988	2.33	2.47	2.84	.51	2.84	73	90	89	87
1989	2.66	2.73	3.10	.44	3.11	98	100	100	100
1990	3.10	3.16	3.50	.40	3.52	100	100	100	100
1991	3.01	3.41	3.57	.55	3.57	100	100	100	100
1992	2.14	2.56	2.65	.52	2.64	69	100	70	65
1993	2.07	2.23	2.57	.50	2.62	54	74	72	75
1994	1.74	1.75	2.14	.41	2.16	26	27	66	50
1995	2.90	3.01	3.07	.17	3.19	100	100	100	100
1996	3.22	3.64	3.65	.45	3.77	100	100	100	100
1997	4.50	4.99	4.99	.49	5.01	100	100	100	100
1998	3.15	3.68	3.68	.53	3.68	100	100	100	100
1999	3.99	4.48	4.49	.50	4.48	100	100	100	100
2000	3.26	3.78	3.78	.52	3.78	100	100	100	100
2001	1.81	2.35	2.34	.53	2.33	41	84	70	50
2002	3.23	3.39	3.57	.33	3.77	100	100	100	100
2003	2.56	2.84	2.97	.41	3.06	97	100	92	92

Instream Flows

Table D-3 summarizes the annual increase in the Title XII volume estimated to be provided from stored water for the integrated operation scenario.

Title XII instream target flows at Parker ranges from 300 cfs to 600 cfs, depending on the estimated TWSA "threshold level" (see Table 4-1). With addition of the three storage alternatives, the "storage content" portion of the TWSA estimate increases and may result in moving the target flow from one threshold level to the next. When this occurs in the integrated operation

scenarios, the instream flow at Parker is increased. At such time as unregulated flow fails to meet diversion demands and Title XII target flows, reservoir releases are required.

Table D-3 summarizes the average increased flow rate (cfs) and the number of days at the increased flow rate resulting from the three integrated operation scenarios. Also shown is the volume (acre-feet) of the increase flow estimated to be provided from stored water. In some years, it may be possible to use this increased volume for other fishery purposes rather than for increased Title XII instream target flows.

Figures of Current and Integrated Operation Scenarios

The following tables and figures comparing current and integrated operation scenarios are included for information:

Table	Contents
Table D-4	Yakima River Flows Available for Wymer – Integrated 50% Operation Study
Table D-5	Yakima River Flows Available for Wymer – Integrated 100% Operation Study
Table D-6	Inflow and Releases from Wymer – Integrated 50% Operation Study
Table D-7	Inflow and Releases from Wymer – Integrated 100% Operation Study
Figure	**Contents** *Current and Integrated (100%, 70%, 50%) Scenarios*
Figure D-1	Storage Contents for Water Years 1981-2003 – Total System
Figure D-2	Storage Contents for Water Years 1981-2003 – Bumping Lake
Figure D-3	Storage Contents for Water Years 1981-2003 – Wymer
Figure D-4	Storage Contents for Water Years 1989-1996 – Total System
Figure D-5	Storage Contents for Water Years 1989-1996 – Bumping Lake
Figure D-6	Bumping Lake Outflow for Water Years 1989-1996

Table D-3. Increased Title XII Flows at Parker

Water Year	Average Increased Flow Rate (cfs) and Number of Days at the Increased Flow Rate			Volume of Increased Flow from Stored Water (acre-feet)		
	Integrated 70% Operation	Integrated 50% Operation	Integrated 100% Operation	Integrated 70% Operation	Integrated 50% Operation	Integrated 100% Operation
1981	200 (134 days)	200 (134 days)	200 (131 days)	53,000	53,000	52,000
1982	100 (91 days)	100 (86 days)	100 (91 days)	18,000	17,000	18,000
1983	100 (91 days)	100 (91 days)	100 (91 days)	18,000	18,000	18,000
1984	100 (111 days)	100 (111 days)	100 (111 days)	22,000	22,000	22,000
1985	300 (133 days)	300 (133 days)	300 (133 days)	79,000	79,000	79,000
1986	200 (164 days)	200 (164 days)	200 (156 days)	65,000	65,000	62,000
1987	100 (171 days)	100 (171 days)	200 (33 days)	32,000	34,000	13,000
1988	100 (151 days)	100 (151 days)	- -	30,000	30,000	- -
1989	200 (118 days)	200 (118 days)	- -	47,000	47,000	- -
1990	200 (126 days)	200 (129 days)	100 (121 days)	50,000	51,000	24,000
1991	200 (118 days)	200 (118 days)	200 (118 days)	47,000	47,000	47,000
1992	100 (126 days)	100 (126 days)	- -	25,000	25,000	- -
1993	100 (116 days)	100 (116 days)	- -	23,000	23,000	- -
1994	- -	- -	- -	- -	- -	- -
1995	- -	100 (101 days)	- -	- -	20,000	- -
1996	200 (129 days)	200 (129 days)	200 (129 days)	51,000	51,000	51,000
1997	- -	- -	- -	- -	- -	- -
1998	300 (119 days)	300 (119 days)	300 (119 days)	71,000	71,000	71,000
1999	- -	- -	- -	- -	- -	- -
2000	200 (108 days)	200 (108 days)	200 (108days)	43,000	43,000	43,000
2001	- -	- -	- -	- -	- -	- -
2002	200 (103 days)	200 (101 days)	100 (106 days)	41,000	40,000	21,000
2003	200 (129 days)	200 (144 days)	100 (136 days)	37,000	57,000	27,000

Table D-4. Yakima River Flows Available for Pumping into Wymer Reservoir with Integrated 50% Operation

Water Year	Monthly flows (acre-feet)												Annual Flow (a-f)
	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	
1981	0	113,049	35,737	86,446	22,330	0	0	0	0	0	0	0	257,562
1982	0	0	31,037	107,298	76,043	26,784	89,866	97,538	18,705	0	0	0	447,270
1983	0	633	84,681	27,030	133,892	76,455	58,950	60,795	14,164	0	0	0	456,600
1984	2,857	0	120,525	35,431	70,926	35,246	2,285	132,880	19,079	0	0	0	419,229
1985	0	0	0	0	0	56,302	7,563	0	0	0	0	221	64,085
1986	8,340	0	0	40,368	120,875	10,513	0	0	0	0	0	0	180,097
1987	14,310	0	0	0	32,906	6,759	3,093	0	0	0	0	0	57,068
1988	0	0	0	1,285	0	29,981	0	0	0	0	0	0	31,266
1989	1,075	3,840	3,248	4,029	5,601	60,251	1,589	0	0	0	0	0	79,633
1990	946	7,801	14,769	21,461	26,347	119,666	136	44,131	6,816	0	0	3,151	245,226
1991	180,520	73,606	99,936	85,700	55,420	94,341	31,848	40,975	14,176	0	0	0	676,521
1992	0	12,657	9,206	17,308	28,729	0	0	0	0	0	0	0	67,900
1993	0	0	0	0	3,918	1,606	3,215	0	0	0	0	0	8,739
1994	0	0	0	0	143	2,753	0	0	0	0	0	0	2,896
1995	409	10,571	12,105	138,108	69,833	11,775	17,404	14,209	0	0	0	0	274,414
1996	113,548	181,069	214,229	345,150	212,284	202,475	31,971	50,728	0	0	0	0	1,351,453
1997	0	0	42,731	85,024	270,063	262,460	320,808	102,221	25,207	0	0	3,224	1,111,739
1998	36,637	1,568	8,311	22,330	56,661	83,310	85,495	26,451	0	0	0	0	320,764
1999	106	21,380	56,294	7,620	40,333	50,012	145,038	86,691	57,879	2,208	0	0	467,560
2000	128,846	134,842	5,066	0	6,361	138,425	26,239	83,665	8,341	0	0	0	531,784
2001	0	0	0	0	0	0	0	0	0	0	0	0	0
2002	733	500	10,781	7,805	11,450	123,680	29,468	139,422	2,692	0	0	0	326,532
2003	0	0	20,128	48,780	60,990	33,191	2,795	0	0	0	0	0	165,883
Avg	21,232	24,414	33,425	47,008	56,744	61,999	37,294	38,248	7,263	96	0	287	328,010
Daily Available for Storage (cfs)													
Avg	357	397	544	846	923	1,042	607	643	118	2	0	5	
Max	10730	11255	6944	15264	11717	9759	11333	5685	2544	602	0	783	
Min	0	0	0	0	0	0	0	0	0	0	0	0	

Table D-5. Yakima River Flows Available for Pumping into Wymer Reservoir with Integrated 100% Operation

Water Year	Monthly flows (acre-feet)												Annual Flow (a-f)
	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	
1981	0	113,049	35,737	86,446	22,330	0	1,857	0	0	0	0	0	259,419
1982	0	0	31,344	107,618	58,129	7,726	65,475	85,742	17,010	0	0	0	373,045
1983	0	633	83,456	27,030	133,892	68,524	58,988	60,795	14,164	0	0	0	447,482
1984	2,857	0	120,525	35,431	70,926	35,246	2,285	132,880	19,079	0	0	0	419,229
1985	0	0	0	0	0	56,302	7,563	0	0	0	0	221	64,085
1986	8,340	0	0	40,368	120,875	10,833	0	0	0	0	0	0	180,417
1987	15,825	0	0	0	33,001	6,793	2,849	0	0	0	0	0	58,468
1988	0	0	0	1,308	0	29,994	0	0	0	0	0	0	31,302
1989	1,087	3,829	3,244	4,027	5,600	60,251	1,588	0	0	0	0	0	79,627
1990	946	7,801	14,769	21,461	25,020	106,921	136	30,025	6,845	0	0	3,151	217,076
1991	176,082	72,743	99,910	85,700	55,420	94,341	31,145	30,760	11,394	0	0	0	657,496
1992	0	12,657	9,206	17,308	28,729	435	0	0	0	0	0	0	68,335
1993	0	0	0	0	3,941	1,615	3,211	0	0	0	0	0	8,768
1994	0	0	0	0	143	2,754	0	0	0	0	0	0	2,897
1995	362	10,203	12,013	138,029	69,809	11,771	17,404	15,091	1,279	0	0	0	275,962
1996	117,226	194,696	203,684	346,599	212,255	202,476	31,972	48,485	0	0	0	0	1,357,394
1997	0	0	42,731	84,670	267,231	262,383	315,319	102,208	25,207	0	0	3,224	1,102,973
1998	36,637	1,568	8,311	22,330	56,661	83,310	85,495	26,451	0	0	0	0	320,764
1999	106	21,380	56,294	7,620	40,333	50,012	145,038	86,691	57,879	2,208	0	0	467,560
2000	128,846	134,842	5,066	0	6,361	138,425	26,239	83,665	8,341	0	0	0	531,784
2001	0	0	0	0	0	0	0	0	0	0	0	0	0
2002	1,150	718	10,960	7,824	2,560	48,140	22,969	91,378	7,791	0	0	0	193,490
2003	0	0	20,128	48,780	58,743	30,018	1,887	0	0	0	0	0	159,556
Avg	21,281	24,962	32,929	47,067	55,303	56,881	35,714	34,529	7,347	96	0	287	316,397
Daily Available for Storage (cfs)													
Avg	358	406	536	847	899	956	581	580	119	2	-	5	
Max	11154	11333	6455	15036	11678	9719	11333	4773	2544	602	0	783	
Min	0	0	0	0	0	0	0	0	0	0	0	0	

Table D-6. Inflows and Releases from Wymer Reservoir with Integrated 50% Operation

Water Year	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Annual	
													Inflow	Release
1981	0	14,853	10,709	11,901	13,796	Rel.	Rel.	Rel.	Rel.	Rel.	Rel.	0	51,259	116,904
1982	0	0	8,727	17,745	24,595	17,157	24,595	16,579	7,013	0	0	0	116,412	0
1983	0	633	21,319	11,208	15,073	Full	Full	Full	Full	Full	Full	Full	48,233	0
1984	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	0	0
1985	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	0	0
1986	Full	Full	Full	Full	Full	Full	Full	Rel.	Rel.	Rel.	Rel.	Rel.	0	97,728
1987	6,550	0	0	0	13,959	6,242	2,895	Rel.	Rel.	Rel.	Rel.	0	29,647	96,000
1988	0	0	0	1,285	0	13,740	0	Rel.	0	0	0	0	15,025	15,597
1989	1,075	3,840	3,166	3,270	5,194	19,290	1,589	0	0	0	0	0	37,424	0
1990	946	5,984	7,143	11,165	18,998	21,721	136	12,985	3,549	0	0	3,151	85,778	0
1991	19,463	21,987	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	41,450	0
1992	Full	Full	Full	Full	Full	Rel.	Rel.	Rel.	Rel.	Rel.	Rel.	Rel.	0	131,294
1993	0	0	0	0	3,918	1,606	3,215	Rel.	Rel.	Rel.	0	0	8,739	42,050
1994	0	0	0	0	143	2,753	Rel.	0	0	0	0	0	2,896	2,380
1995	409	8,913	4,547	22,215	23,910	8,514	10,346	8,320	0	0	0	0	87,174	0
1996	18,638	24,595	24,595	9,087	Full	Full	Full	Full	Full	Full	Full	Full	76,915	0
1997	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	0	0
1998	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	0	0
1999	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	0	0
2000	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	0	0
2001	Full	Full	Full	Full	Full	Rel.	Rel.	Rel.	Rel.	Rel.	Rel.	Rel.	0	134,275
2002	733	500	7,193	5,475	10,732	23,236	16,910	22,265	1,587	0	0	0	88,631	0
2003	0	0	4,823	17,668	18,670	Full	Full	Rel.	Rel.	Rel.	Rel.	0	41,162	80,875
Avg	2,079	3,535	4,010	4,827	6,478	5,163	2,595	2,615	528	0	0	137	31,966	31,178
Daily Inflow (cfs)													**Average Daily (cfs)**	
Avg	335	356	355	346	348	348	331	370	340	0	0	227	348	389
Max	400	400	400	400	400	400	400	400	400	0	0	311	400	400
Min	66	52	57	52	66	53	51	77	97	0	0	80	51	1

Table D-7. Inflows and Releases from Wymer Reservoir with Integrated 100% Operation

Water Year	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Annual Inflow	Annual Release
1981	0	14,853	10,709	11,901	13,796	0	1,601	0	0	0	0	0	52,860	0
1982	0	0	8,727	17,800	19,612	Full	Full	Full	Full	Full	Full	Full	46,140	0
1983	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	0	0
1984	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	0	0
1985	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	0	0
1986	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	0	0
1987	Full	Full	Full	Full	Full	Full	Full	Rel.	Rel.	Rel.	Rel.	Rel.	0	96,882
1988	0	0	0	1,308	0	13,745	0	Rel.	Rel.	Rel.	Rel.	0	15,054	82,512
1989	1,087	3,829	3,163	3,269	5,194	19,290	1,588	0	0	0	0	0	37,421	0
1990	946	5,984	7,143	11,165	18,998	21,721	136	9,144	3,555	0	0	3,151	81,943	0
1991	19,119	24,573	1,286	Full	Full	Full	Full	Full	Full	Full	Full	Full	44,977	0
1992	Full	Full	Full	Full	Full	Full	Rel.	Rel.	Rel.	Rel.	Rel.	Rel.	0	113,337
1993	0	0	0	0	3,941	1,615	3,211	Rel.	Rel.	Rel.	0	0	8,768	59,829
1994	0	0	0	0	143	2,754	Rel.	0	0	0	0	0	2,897	2,881
1995	362	8,764	4,470	22,215	23,908	8,513	10,346	8,696	1,129	0	0	0	88,403	0
1996	18,638	24,595	24,595	8,152	Full	Full	Full	Full	Full	Full	Full	Full	75,980	0
1997	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	0	0
1998	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	0	0
1999	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	0	0
2000	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	0	0
2001	Full	Full	Full	Full	Full	Rel.	Rel.	Rel.	Rel.	Rel.	Rel.	Rel.	0	142,443
2002	1,150	718	7,279	5,480	2,560	17,417	16,581	17,303	3,898	0	0	0	72,386	0
2003	0	0	4,823	17,668	18,670	14,789	1,887	0	0	0	0	0	57,838	0
Avg	1,796	3,622	3,139	4,303	4,645	4,341	1,537	1,528	373	0	0	137	25,420	21,647
Daily Flows (cfs)														
Avg	331	362	337	346	339	333	274	334	333	0	0	0	335	382
Max	400	400	400	400	400	400	400	400	400	0	0	311	400	400
Min	66	54	59	56	69	53	51	72	169	0	0	80	51	3

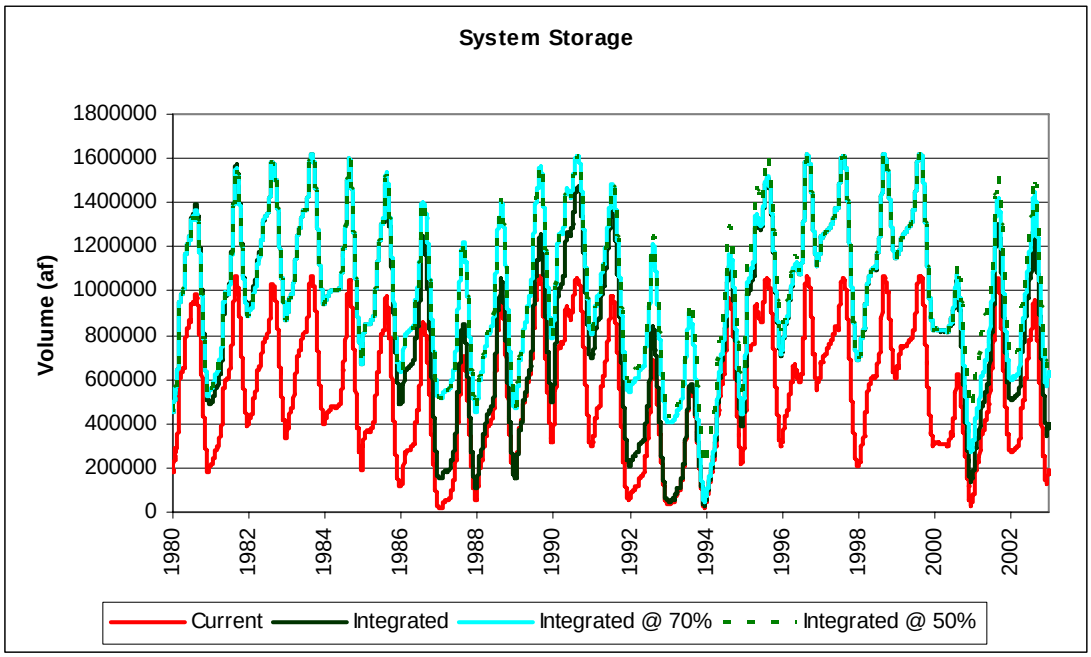

Figure D-1. System Storage Contents for Water Years 1981-2003--Current and Integrated Scenarios

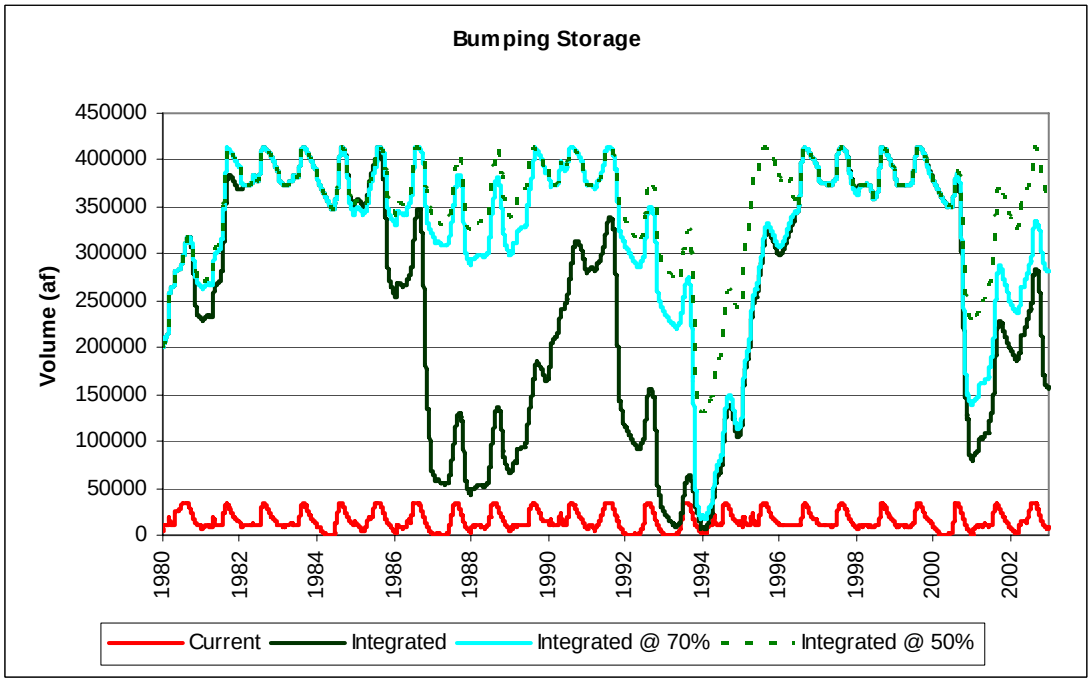

Figure D-2. Bumping Lake Enlargement Storage Contents for Water Years 1981-2003--Current and Integrated Scenarios

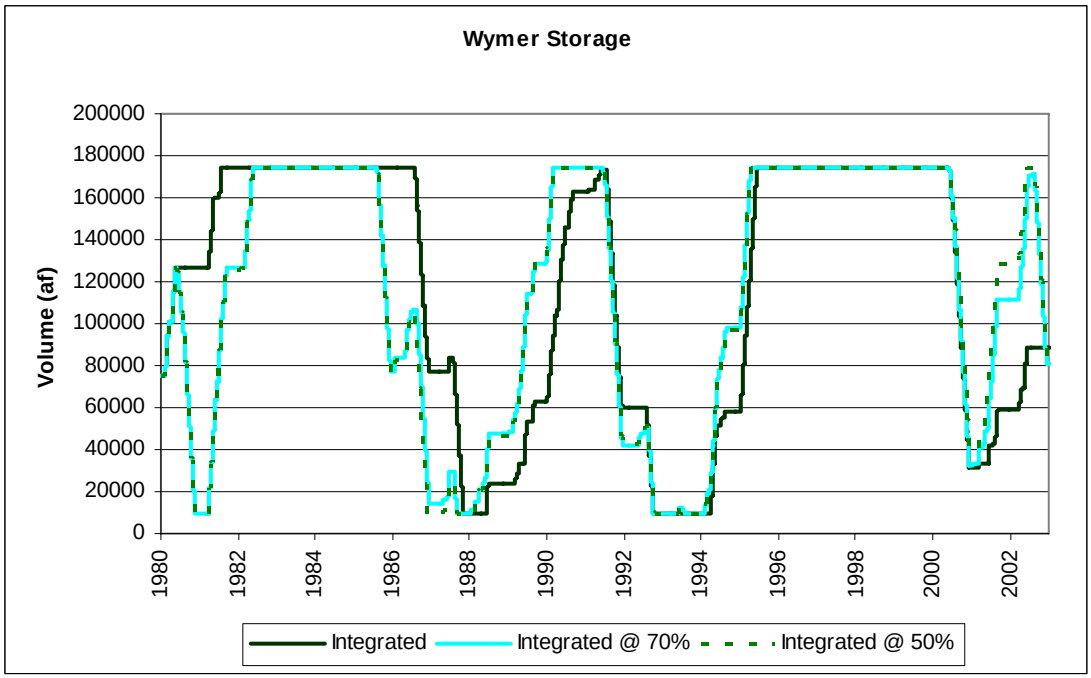

Figure D-3. Wymer Storage Contents for Water Years 1981-2003--Integrated Scenario

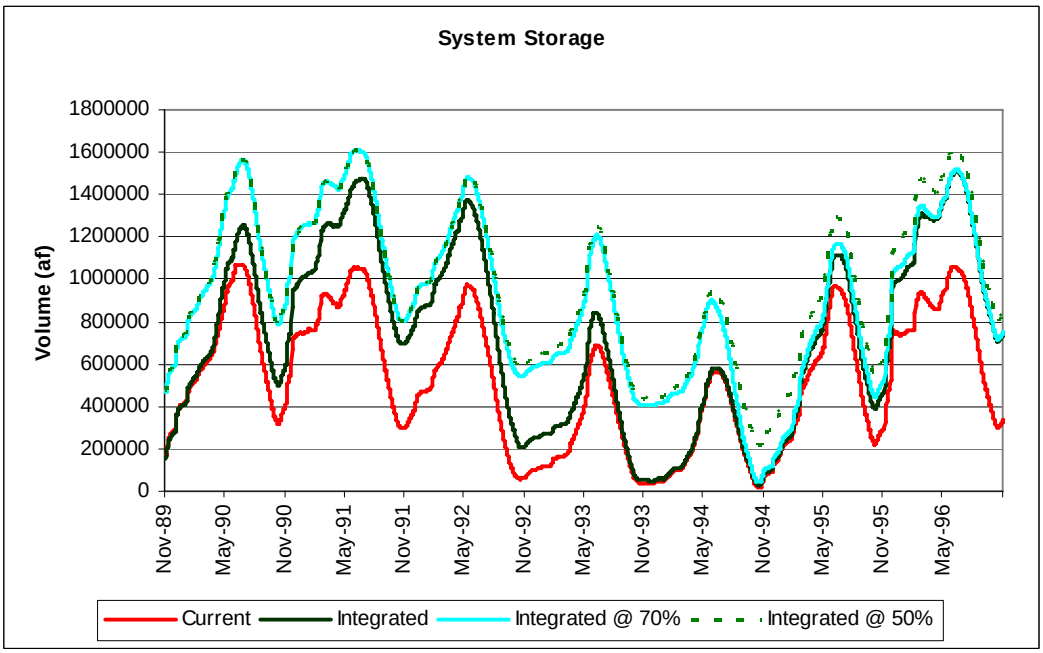

Figure D-4. System Storage Contents for Water Years 1990-1996--Current and Integrated Scenarios

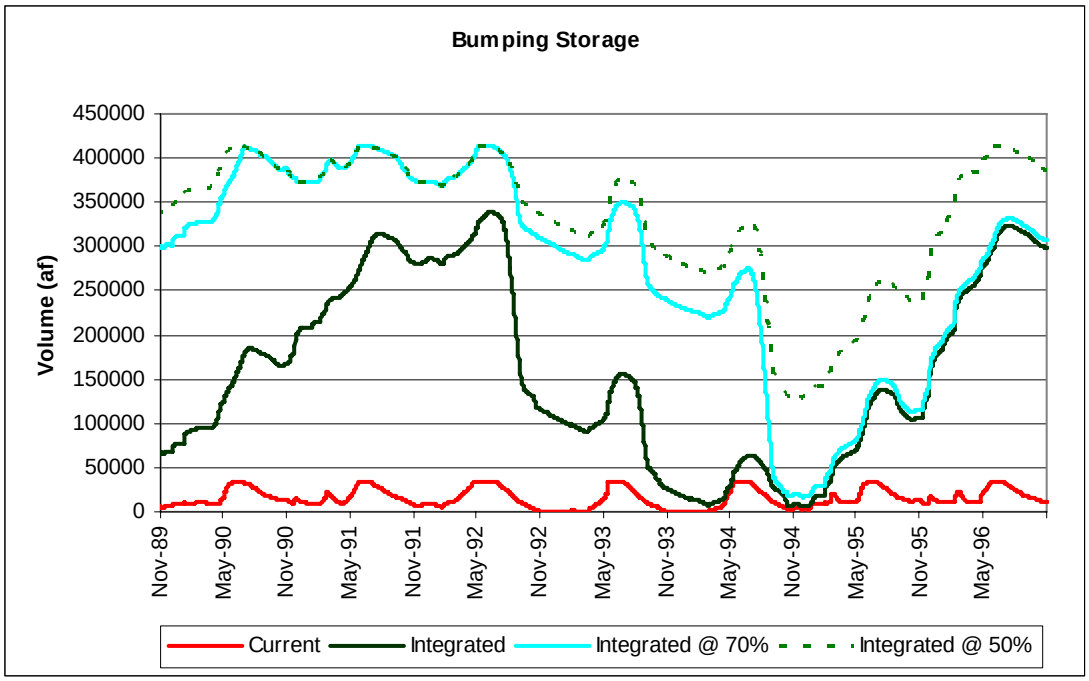

Figure D-5. Bumping Lake Enlargement Storage Contents for Water Years 1990-1996--Current and Integrated Scenarios

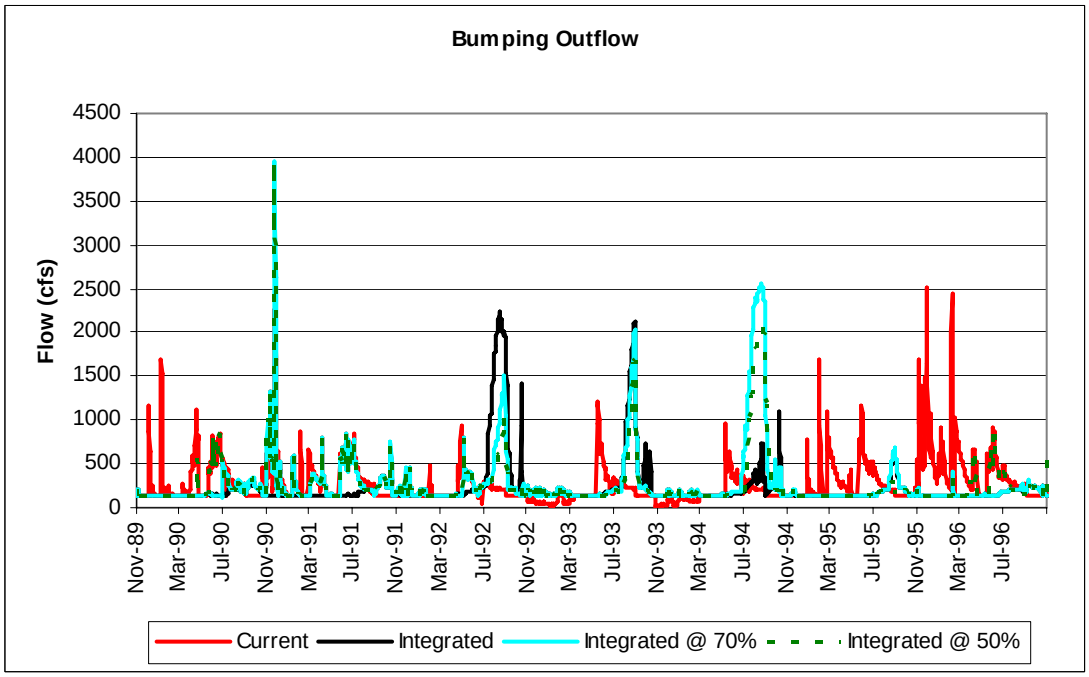

Figure D-6. Bumping Lake Enlargement Outflow for Water Years 1990-1996--Current and Integrated Scenarios

Appendix E YAKIMA RIVER BASIN ALTERNATIVES TECHNICAL INFORMATION AND HYDROLOGIC ANALYSIS AND CORRESPONDENCE

Reclamation distributed the *Yakima River Basin Alternatives Technical Information and Hydrologic Analysis* (technical information) to stakeholders who are responsible for fish production and protection, water distribution, power production, and other water uses in the Yakima River basin, on January 19, 2006 (a list of stakeholders is included in following information).

Between February 3-17, 2006, Reclamation met with the following stakeholders:

- Washington State Department of Ecology
- Washington State Department of Fish & Wildlife
- Yakima Basin Storage Alliance
- Yakima Basin Joint Board Washington State Department of Ecology
- National Marine Fisheries Service

The input received from these stakeholders was used in preparing this *Yakima Appraisal Assessment*. A copy of Reclamation's letters to stakeholders and attached technical information.

United States Department of the Interior

BUREAU OF RECLAMATION
Upper Columbia Area Office
1917 Marsh Road
Yakima, Washington 98901-2058

IN REPLY REFER TO:
UCA-1120
PRJ-1.10

JAN 19 2006

Mr. Louis Cloud
Chairman
Yakama Nation Tribal Council
P.O. Box 151
Toppenish, WA 98948

Subject: Review and Comment of Technical Information and Hydrologic Analysis for Yakima River Basin Alternatives for the Yakima River Basin Water Storage Feasibility Study (Storage Study).

Dear Mr. Cloud:

The Bureau of Reclamation has completed the appraisal level hydrologic analysis of the three Yakima River basin alternatives (Bumping Lake enlargement, Wymer dam, and the Keechelus-Kachess pipeline). We are soliciting input from the stakeholders who are responsible for fish production and protection, water distribution, power production, and other water uses in the Yakima River basin.

We are including the technical information of the hydrologic analysis for your review. We would like to meet and discuss our hydrologic analysis with you by February 10, 2006, if that can be arranged. Your input to our analysis will assist us in developing our recommendations and completing our report on which alternatives to include in the plan formulation phase of the Storage Study.

This meeting will be with you and your staff or other people that you designate. Mr. Kim McCartney, Storage Study Manager, will contact you to set up a time and date for this meeting. He can be reached at 509-575-5848, extension 370.

At this time, we invite you to review the attached technical documentation and prepare your comments on the three alternatives. You can present your comments to us in written form or discuss them with us at the meeting.

Sincerely,

Norbert S. Ries

Acting for Gerald W. Kelso
Area Manager

Enclosures

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YAKIMA RIVER BASIN ALTERNATIVES TECHNICAL INFORMATION AND HYDROLOGIC ANALYSIS

What is the Purpose of this Information?

This information summarizes the current available technical data used to analyze the Bumping Lake enlargement, Wymer dam and reservoir, and the Keechelus-to-Kachess pipeline alternatives of the Yakima River Basin Storage Feasibility Study (Storage Study). The technical information and hydrologic analysis will be used to determine which alternatives, if any, should be studied further in the Plan Formulation Phase of the Storage Study. These alternatives were formulated to determine if they would provide more storage of Yakima River water for the benefit of irrigation, threatened and endangered fish species, and municipal water supply in the basin. Reclamation will use comments on this information by basin entities that are responsible for fish production and protection, water distribution, power production, and other water uses, to decide which alternatives will be carried forward to the Plan Formulation Phase of the Storage Study.

Why a *Yakima River Basin Storage Alternatives Appraisal Assessment* (*Yakima Appraisal Assessment*)?

The Storage Study was authorized to analyze all storage alternatives which would provide benefits to irrigation, threatened and endangered fish, and municipal water supplies. The *Yakima Appraisal Assessment* will evaluate various aspects of alternatives in the Yakima River Basin and will determine if the alternatives are technically viable and could be operated in conjunction with existing Yakima Project storage facilities to meet the Storage Study's water supply goals.

In February 2005, Reclamation released the *Appraisal Assessment of the Black Rock Alternative* (*Black Rock Assessment*) (Bureau of Reclamation, 2004), one alternative of the Storage Study, which provided water with a Columbia River – Yakima River water exchange. The *Black Rock Assessment* outlined the major features of the Black Rock storage alternative, the potential for the alternative to meet the Storage Study goals, and outlined activities needed if the alternative was to move forward in the Storage Study. In the *Black Rock Assessment*, Reclamation concluded that, based on current information, a potential Black Rock storage alternative appeared to be technically viable and could meet the water supply goals of the Storage Study. The Black Rock storage alternative is being carried forward into the Plan Formulation Phase.

What is the Scope of the Yakima Appraisal Assessment?

The scope of the *Yakima Appraisal Assessment* is to review, summarize, and document the pertinent findings of reported prior investigations of Bumping Lake enlargement, Wymer dam and reservoir, and a Keechelus-to-Kachess pipeline. The most up-to-date information regarding

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fish and wildlife resource issues and Yakima Project system operations will be utilized in this analysis. Deficiencies in data for these alternatives will be identified for further consideration. Prior project cost estimates will be indexed to July 2004 prices (similar to Black Rock prices).

The *Yakima Appraisal Assessment* does not quantify annual monetary benefits for any of these alternatives, and does not address whether these alternatives are economically justified. The *Yakima Appraisal Assessment* does not include a cost allocation to reimbursable and nonreimbursable project purposes or an analysis of the ability to repay the reimbursable costs. The environmental, social, and cultural impacts have not been evaluated. This is consistent with the information presented in the *Black Rock Assessment.*

What Did We Do?

Reviewed Prior Reports

Investigations of Bumping Lake enlargement, Wymer dam and reservoir, and Keechelus-to-Kachess pipeline have been conducted by Reclamation and others in the past. The following were reviewed as information sources for the *Yakima Appraisal Assessment*:

- The *Bumping Lake Enlargement Joint Feasibility Report*, initially prepared in 1970 by Reclamation and the U.S. Fish and Wildlife Service, and revised in 1976 to address concerns of compatibility with the proposed Cougar Mountain (William O. Douglas) Wilderness Area then under consideration.

  A revised joint feasibility report was approved by the Secretary of the Interior in 1979. A *Final Environmental Impact Statement* was filed with the Council of Environmental Quality August 27, 1979.

  This report proposed construction of a new Bumping Lake dam downstream of the existing dam, creating a 458,000-acre-foot reservoir. About 324,000 acre-feet of storage capacity would be available to provide minimum flows throughout the Yakima basin for fishery purposes. For example, at Parker, November-June flows of 180 cfs, and July-October flows of 234 cfs, would be provided. The irrigation stored water supply consisted of 133,700 acre-feet, of which 33,700 acre-feet was for replacement of the existing Bumping Lake storage and 100,000 acre-feet to improve the water supply of the Roza Irrigation District in dry years.

- The Yakima River Basin Water Enhancement Project (YRBWEP) investigations were authorized by the Act of December 28, 1979. Various reports were prepared as a part of this study. An initial part of the investigation involved an extensive storage-site inventory and public review process, during which some 35 storage sites were identified and evaluated. The primary report used for the *Yakima Appraisal Assessment* is the YRBWEP's *Plan Formulation Summary* (Bureau of Reclamation and Washington State Department of Ecology, 1986) which considered Bumping Lake enlargement with

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reservoir capacities ranging from 250,000 to 458,000 acre-feet and Wymer dam and reservoir with a capacity of 142,000 acre-feet as the prime storage alternatives.

Monthly target flow recommendations for 13 reaches in the Yakima and Naches Rivers were used in formulating alternative plans. For example, recommended target flows at Parker ranged from 600-800 cfs. The proratable irrigation dry-year water supply was to be not less than 70 percent in a recurrence of the single worst year of record (in this case, 1940).

- The Yakima River Watershed Council's (Watershed Council) draft report, *A 20/20 Vision for a Viable Future of the Water Resources of the Yakima River Basin,* (Yakima River Watershed Council, 1997. The Watershed Council, formed in March 1994, consisted of more than 800 individuals representing water-based interests in the Yakima basin.

  The Watershed Council analyzed a number of storage sites and recommended the following three projects for further consideration: enlargement of Bumping Lake reservoir to a capacity of 400,000 acre-feet; Wymer dam and reservoir, with storage of 142,000 acre-feet; Horsetail reservoir on the Little Naches River, with storage capacity of about 182,700 acre-feet.

- *The Watershed Management Plan, Yakima River Basin* (Yakima River Basin Watershed Planning Unit and Tri-County Water Resources Agency, 2003) was completed in January 2003, under the provisions of the State Watershed Management Act (Chapter 90.82 RCW), enacted in 1997. Under the guidance of the Tri-County Water Resources Agency, a Yakima River Basin Watershed Planning Unit was established in 1998 and, with the assistance of consultants, prepared a *Watershed Assessment* in 2001 (Yakima River Basin Watershed Planning Unit and Tri-County Water Resources Agency, 2001) and the *Watershed Management Plan*. This *Watershed Management Plan* has been characterized as a "road map" for maintaining and improving the Yakima basin's economic base, planning responsibility for expected growth in population, managing water resources for the long term, and protecting the basin's natural resources and fish runs.

  Four in-basin storage alternatives were considered: Bumping Lake enlargement (400,000 acre-feet of storage); Wymer dam and reservoir (142,000 acre-feet of storage); Cle Elum Lake enlargement (an additional 14,500 acre-feet of capacity); and Kachess Lake storage augmentation by flow supplementation from Cabin and Silver Creeks. A fifth storage alternative consisting of a new dam and reservoir in the Black Rock Valley with an annual yield of 250,000-500,000 acre-feet filled by pumping from the Columbia River was also considered.

Conducted Operation Studies

The following two Yakima Project operating scenarios were developed and operation studies prepared:

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1. Current Operating Scenario - Represents current operating criteria and management of the existing Yakima Project system.

2. Integrated Operating Scenario with Three Storage Alternatives - Represents three operation studies using different "thresholds" for allocating the water supply available to meet proratable water entitlements in years when proration is used. They are as follows:

- 100 percent, which represents the present Yakima Project proration process whereby there is no constraint in any year of proration on the amount of the proratable water supply allotted.

- 70 percent, whereby the amount of the proratable water supply allotted in a year of proration is limited to not more than would have been available without the storage alternatives, but not less than 70 percent with the storage alternatives.

- 50 percent, whereby the amount of the proratable water supply allotted in a year of proration is limited to not more than would have been available without the storage alternatives, but not less than 50 percent with the storage alternatives.

In addition, a natural (unregulated) flow regime for the mainstem rivers was developed to represent an estimated natural streamflow regime that predates the Yakima Project, unimpeded by reservoir impoundments or altered by diversions and the associated irrigation return flows.

What Are the Water Supply Goals?

As directed by congressional authorization, the Storage Study is to examine the feasibility and acceptability of storage augmentation for benefit of endangered and threatened fish, irrigated agriculture, and municipal water supply within the Yakima River basin. This general guidance resulted in adoption of the following water supply goals for study purposes:

1. Improve anadromous fish habitat by restoring the flow regime of the Yakima and Naches Rivers to more closely resemble the natural (unregulated) hydrograph.

2. Provide not less than a 70-percent irrigation water supply during dry years at diversions subject to proration.

3. Maintain a full municipal water supply for existing users and provide additional surface water supply for population growth to the year 2020.

Instream Flows

Legal Requirements

A variety of legal requirements exist related to providing and/or maintaining instream flows in the Yakima River basin. Generally, these are based on court orders and Federal legislation

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related to the Yakima Project. The State of Washington has not established minimum instream flows for the Yakima River basin.

Instream flows in the Yakima River basin mandated by the courts are not quantified. Rather, the amount of water available for the fisheries is determined annually, depending on existing prevailing water supply conditions. Specific mandates from the State and Federal courts include orders directed at Reclamation's operation of the Yakima Project to reduce impacts on the fisheries resource, orders with respect to treaty reserved rights for fish, and orders with respect to instream flows to support treaty fishing rights at "usual and accustomed places."

Instream flows included in Title XII of the Act of October 31, 1994 (Public Law 103-464), are quantified "target flows" at two points in the Yakima River basin (Sunnyside and Roza Diversion Dams). The legislation provides that the Yakima Project Superintendent shall estimate the water supply, which is anticipated to be available to meet water rights, and provide instream flows in accordance with the Title XII criteria shown in table 1. This new operational regime was initiated by the Yakima Project Superintendent in 1995.

Table 1. Water Supply Estimates/Instream Flow Targets

Water Supply Estimate for Period (million acre-feet)					Target Flow From Date of Estimate through October Downstream of:	
Scenario	**April through September**	**May through September**	**June through September**	**July through September**	**Sunnyside Diversion Dam (cfs)**	**Prosser Diversio Dam (cfs)**
1	3.2	2.9	2.4	1.9	600	600
2	2.9	2.65	2.2	1.7	500	500
3	2.65	2.4	2.0	1.5	400	400
Less than Scenario 3 water supply					300	300

Title XII target flows do not provide for a natural (unregulated) ecosystem function and cannot be expected to fully achieve the objectives of enhancing and recovering anadromous fish populations. Regulated flows can cause unnatural, severe flow fluctuations below both control points, which may negatively affect fish and invertebrate habitat. Additionally, Title XII target flows at the two control points do not address fish habitat and food web needs at the basin level and, thus, by themselves, cannot be expected to lead to recovery of anadromous fish runs.[1]

Restoring the Natural (Unregulated) Hydrograph

A natural (unregulated) flow pattern, or hydrograph, for the Yakima River basin shows peak streamflows occurring in the spring with the onset of snowmelt. During the seasonal transition from spring to summer, streamflows would decrease steadily until they reached their base flow in September or October. The onset of fall usually brings precipitation in the form of rain, which

[1] *Report on Biologically Based Flows for the Yakima River Basin*, System Operations Advisory Committee, May 1999 (pages 1-4).

causes brief, small increases in streamflows. Below-freezing temperatures dominate during the winter months, resulting in decreased streamflows, which occasionally may spike during the winter due to rain-on-snow events.

Under current Yakima Project operations, streamflows in the mainstem Yakima and Naches Rivers often do not reflect the annual flow patterns or hydrograph described above. Generally, spring peak flows are reduced as streamflow is captured in reservoir storage or is used for irrigation demand. During the summer irrigation season, streamflows in the upper Yakima River generally exceed the estimated unregulated summer low flow, and streamflows in the Yakima River are less than the estimated unregulated low flow below Sunnyside Diversion Dam. The September "flip-flop" river operations, unique to the Yakima River basin and designed to address upper Yakima spring Chinook and incubation flows, result in a decrease in streamflows in the upper Yakima and Cle Elum Rivers and increased streamflows in the Tieton and Naches Rivers. The flip-flop operation is discussed in more detail later in this report.

The Storage Study will evaluate how storage could improve these nonnatural streamflow characteristics throughout the entire Yakima basin mainstem rivers. It should be noted the goal is not to quantitatively match the natural (unregulated) hydrograph, but to mimic the shape of the annual hydrograph to the highest degree possible, while balancing the water supply goal.

Irrigation

The reliability of the surface water supply for irrigation use is of concern because of droughts that periodically occur in the Yakima River basin. Current Yakima Project legal, contractual, and operational parameters provide that when there is a deficiency in the available water supply to meet recognized water rights, senior (nonproratable) water rights are served first, and shortages are assessed against junior (proratable) water rights. In recent years, the Yakima River basin has experienced water shortages in 1987, 1988, 1992, 1993, 1994, 2001, and 2005. The most severe years were 1994, 2001, and 2005, when proratable water rights received a 37-percent supply (1994 and 2001) and a 42-percent supply (2005).

As a part of the work conducted for the *Watershed Management Plan* during the early 2000s, the Yakima River Basin Watershed Planning Unit and the Tri-County Water Resource Agency examined criteria to evaluate water supply strategies and to estimate the amount of water needed to meet irrigation demands. This included work by Northwest Economic Associates conducted for the Tri-County Water Resource Agency in 1997 and by the Yakima River Watershed Council in 1998. Information on both was circulated to irrigation entities and conservation districts in the Yakima basin to solicit comments on an approach to establishing irrigation water supply reliability criteria. It was the opinion of those responding that if a supply of not less than 70 percent of the proratable water rights could be provided in dry years, major economic losses could be averted.

The irrigation water supply goal for the Storage Study is to provide a dry-year supply of not less than 70 percent of the proratable water rights. Table 2 shows the extent of the proratable water

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rights involved upstream from the Parker gauge (RM 104) for the period April through October (irrigation season).

Using the above total proratable water rights, a 70-percent water supply would amount to 896,000 acre-feet. In a dry year (such as 1994 and 2001), when the proratable supply was 37 percent (474,000 acre-feet), an additional 422,000 acre-feet would be needed to provide a 70-percent water supply.

Table 2. Proratable Water Rights

Irrigation Entity	Proratable Acre-Feet Per Year
Major	
Kittitas Division (Kittitas Reclamation District)	336,000
Roza Division (Roza Irrigation District)	375,000
Tieton Division (Yakima-Tieton Irrigation District)	34,835
Wapato Irrigation Project	350,000
Sunnyside Division (Sunnyside Valley Irrigation District and others)	142,684*
Subtotal	**1,238,519**
Others	
Westside Irrigation Company	8,200
City of Ellensburg	6,000
Selah-Moxee Irrigation District	4,281*
Union Gap Irrigation District	4,642
City of Yakima	6,000
Naches-Selah Irrigation District	4,486
Yakima Valley Canal Company	4,305
Other entities (9)	3,441
Subtotal	**41,355**
Total	**1,279,874*** **
*Numbers reflect Reclamation's irrigation proratable allocations from a tabulation dated April 29, 1994.	

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Municipal

Communities in the Yakima River basin rely on a variety of delivery systems to meet the needs for municipal and domestic water supply, landscape irrigation, commercial supply, and industrial supply. Such systems include large municipal systems, small public water systems, individual household wells, and wells provided by self-supplied industrial users. The year 2000 annual use for all systems (except for self-supplied industrial users) was estimated at 116,295 acre-feet in the *Watershed Assessment*.

In determining potential future municipal water supply demands for purposes of the Storage Study, only public water systems serving 1,000 connections or more were considered. On this basis, the year 2000 annual use from both surface and groundwater would be 54,340 acre-feet.

Most of the surface water use in the Yakima River basin for municipal and domestic purposes is diverted by two cities—Cle Elum and Yakima. Their combined year 2000 water use was 19,506 acre-feet, based on information contained in the *Watershed Assessment*. This represents about 36 percent of the total basin use for municipal supply and identifies the importance of groundwater for this category of water use.

To meet ever-increasing population growth and to foster a healthy economic climate for the three counties, an increase to about 30,000 acre-feet of surface water by the year 2020 will be needed to meet future municipal supply needs of the cities of Cle Elum and Yakima. This supply requirement is summarized in table 3.

Table 3. Current and Projected Annual Municipal Water Demands

Public Water Systems Serving 1,000 or More Connections	Year (Annual Acre-Feet)		
	2000	2010	2020
Basin Total (surface and groundwater)	54,340	66,690	83,620
Basin Total (Surface Water)			
City of Cle Elum	897	1,054	1,169
City of Yakima	18,609	22,932	28,119
Total	19,506	23,986	29,288
Percent Surface Supply is of Basin Total	36	34	34

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Yakima Basin Storage Alternatives

Figure 1 shows the general location of the three Yakima basin storage alternatives—Bumping Lake enlargement, Wymer dam and reservoir, and Keechelus-to-Kachess pipeline, in addition to the Black Rock Alternative. A brief description of these alternatives follows:

Bumping Lake Enlargement

The proposed Bumping Lake damsite is about 40 miles northwest of the city of Yakima on the Bumping River (figure 2). It is within the Snoqualmie National Forest in Yakima County, and is located approximately 4,500 feet downstream of the existing Bumping Lake Dam.

The damsite is in a deep steep-walled erosional canyon at an elevation of about 3350 feet. The width of the valley floor at the damsite is about 2,500 feet.

The appraisal-level designs prepared in 1985 provided for a 230-foot-high dam storing 458,000 acre feet at elevation 3560 feet, with a reservoir surface area of 4,120 acres. The design

consisted of a zoned rockfill dam with a concrete cutoff wall into bedrock in the foundation. An uncontrolled overflow crest spillway with chute and stilling basin is on the left abutment. An outlet works tunnel and gate chamber are also in the left abutment.

The primary physical characteristics of the Bumping Lake enlargement project are shown in table 4 and figure 3.

Table 4. Bumping Lake Enlargement Physical Characteristics

Item	Data
Dam (Zoned Rockfill)	
Height (feet)	230
Crest elevation (feet)	3580
Crest length (feet)	3,300
Crest width (feet)	30
Reservoir	
Total capacity (acre-feet)	458,000
Maximum water surface elevation (feet)	3574.2
Surface elevation normal full pool (feet)	3560
Surface area (acres)	4,120
Lands to be secured (acres)	2,800

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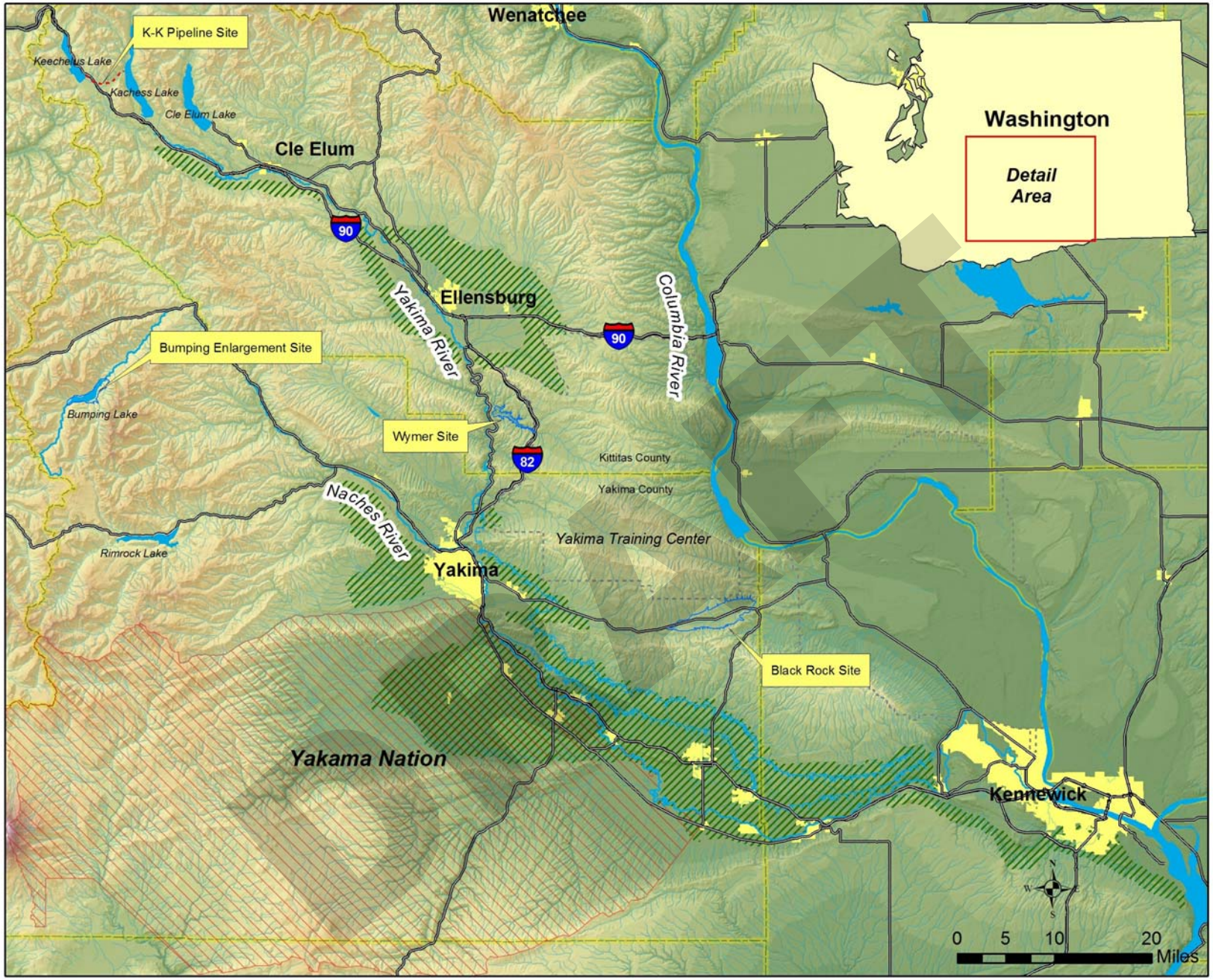

Figure 1. Overview map of the Yakima River Basin Storage Alternatives

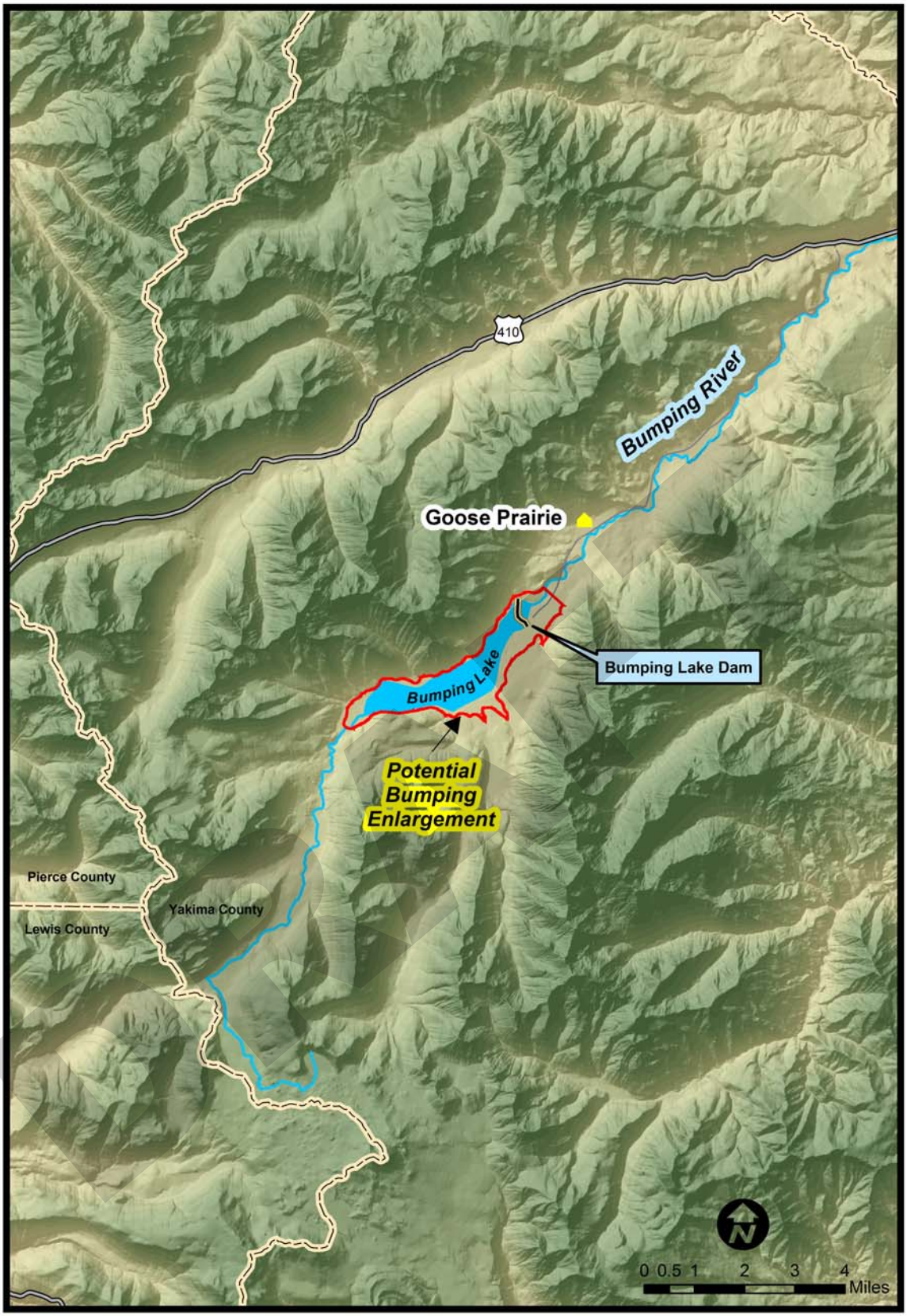

Figure 2. Bumping Lake Enlargement Alternative location map

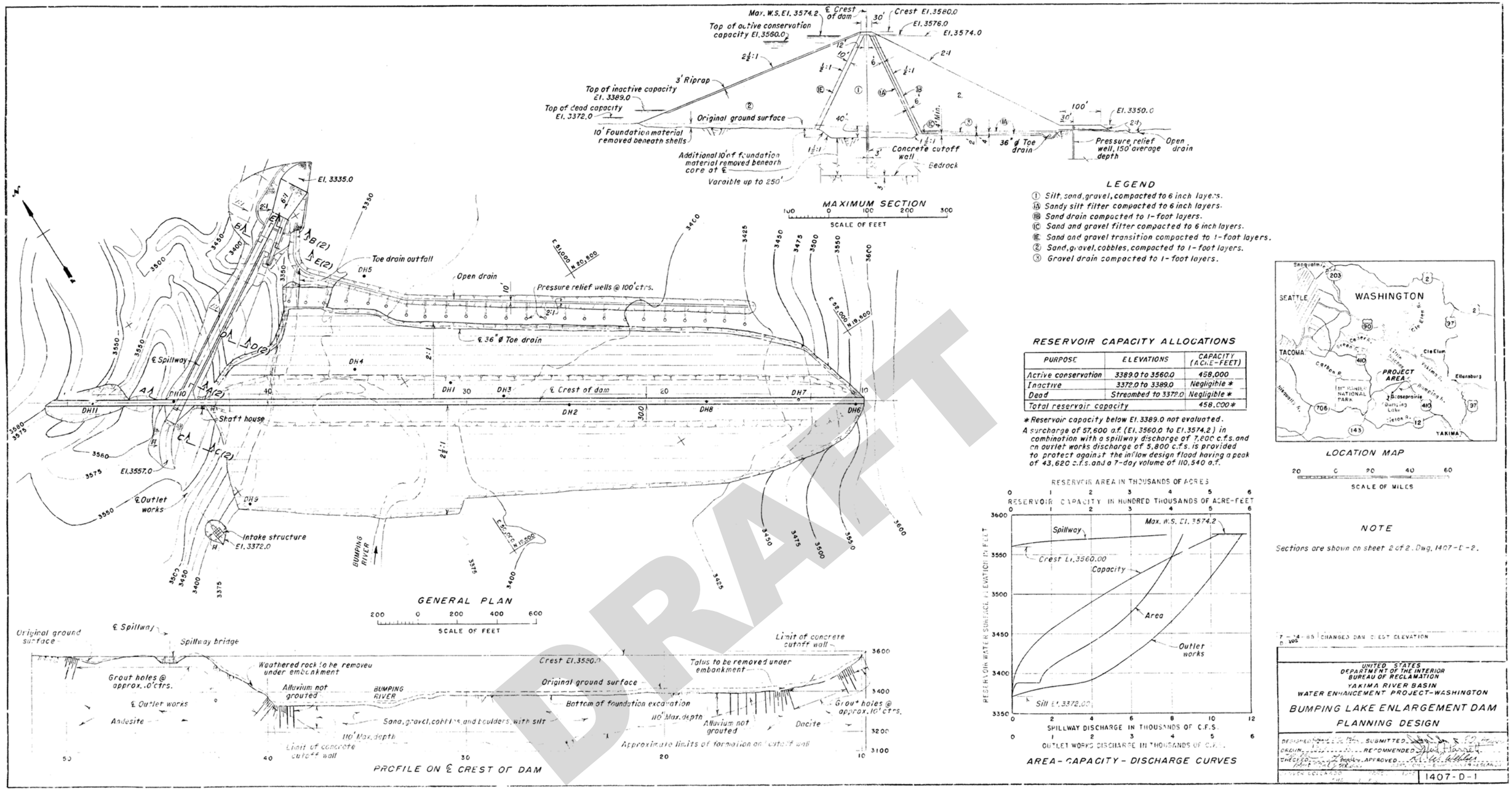

Figure 3. Bumping Dam Enlargement Planning Design (1985)

Wymer Dam, Reservoir and Pumping Plant

Wymer dam and reservoir would be situated in Lmuma Creek Canyon, approximately 15 miles north of Yakima and about ¾ mile upstream of the Lmuma Creek-Yakima River confluence (figure 4). Wymer reservoir would extend upstream about 6 miles on Lmuma Creek and about 2 miles on Scorpion Coulee Creek. This is an off-channel reservoir being filled by pumping from the Yakima River when flows exceed downstream instream target flows and demands, which generally occurs in the spring months. The amount of water available from Lmuma Creek is minimal, so the reservoir would be filled mostly by pumping.

Principal structures of the 1985 appraisal-level designs include two concrete-faced rockfill embankments (Wymer dam and a dike in a saddle on the reservoir rim northeast of the right abutment), a pumping plant on the Yakima River, an inlet conduit to convey discharges from the pumping plant, an outlet conduit from the reservoir to the Yakima River, and a reservoir with an active capacity of about 174,000 acre-feet.

The pumping plant was sited on the east bank of the Yakima River approximately 0.6 mile northwest of Wymer dam. The designs are for an indoor-type structure consisting of five electric motor-driven spiral case pumping units: three units rated at 100 cfs and two units rated at 50 cfs. Pumping capacity will be 400 cfs, with a total head range of 345 to 475 feet. The outlet to the Yakima River will also have a capacity of 400 cfs.

The primary characteristics of the Wymer storage facilities are shown in table 5 and figure 5.

Table 5. Wymer Dam, Dike, Pumping Plant, and Reservoir Characteristics

Item	Data	
	Dam	**Dike**
Dam and Dike (concrete-faced rockfill)		
Height (feet)	415	130
Crest elevation (feet)	1745	1745
Crest length (feet)	2,855	2,310
Crest width (feet)	30	30
Pumping Plant (cfs)	400	
Reservoir	**Elevation (feet)**	**Volume (acre-feet)**
Surcharge	1730-1740	14,400
Active conservation	1450-1730	173,780
Inactive conservation	1351-1450	7,090
Dead storage	1330-1351	210

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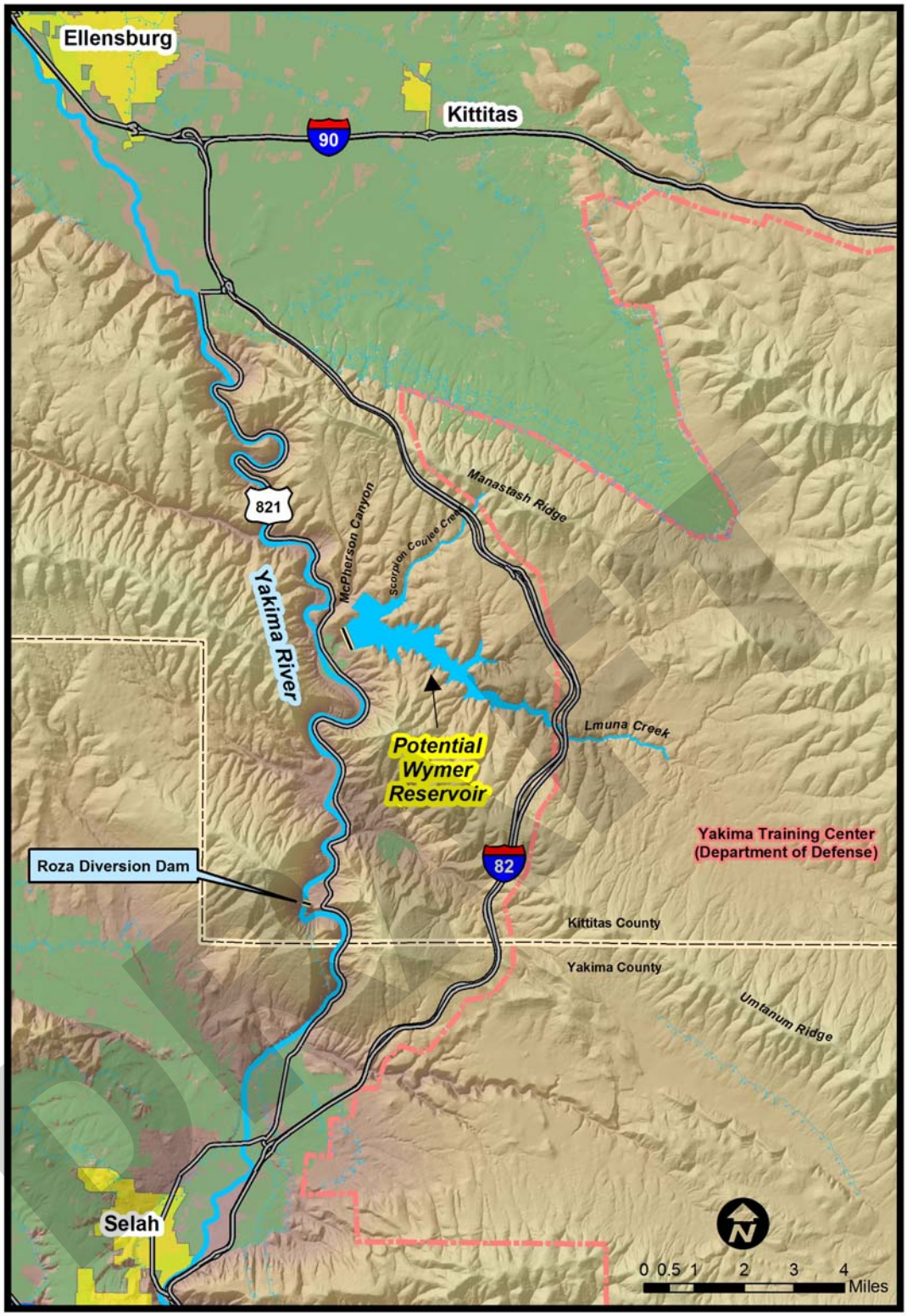

Figure 4. Wymer Reservoir Alternative location map

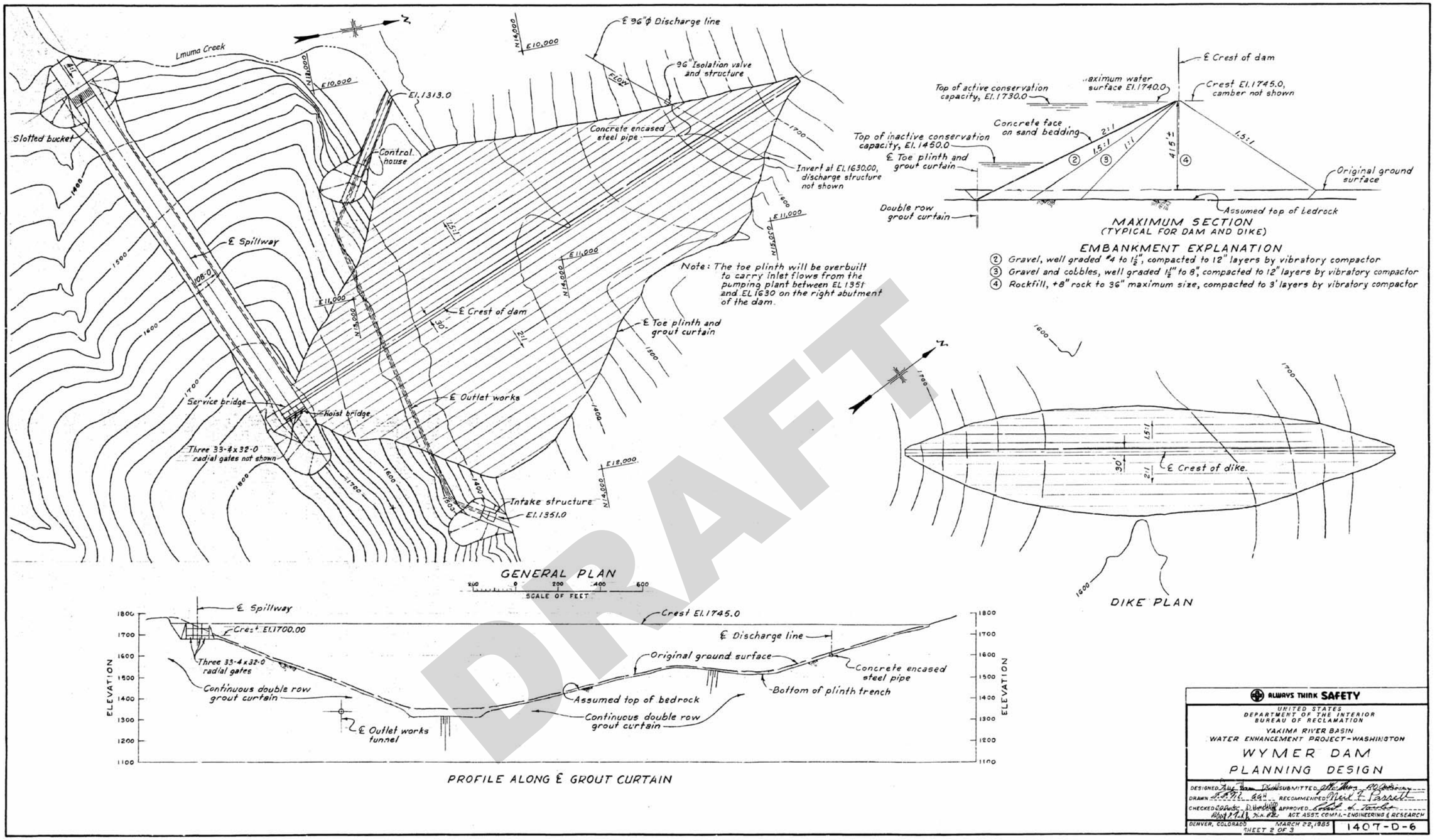

Figure 5. Wymer Dam Planning Design (1985)

Keechelus-to-Kachess Pipeline

Keechelus Dam and Lake and Kachess Dam and Lake are situated in the upper Yakima River watershed upstream of Easton Dam (RM 202.5), the diversion point for the Kittitas Main Canal of the Kittitas Reclamation District. Keechelus Dam was constructed at the downstream end of a natural lake (RM 214.5) near the head of the Yakima River, about 12 miles upstream of Easton Diversion Dam, and Kachess Dam is located on the Kachess River about 1 mile upstream of its confluence with the Yakima River (figure 6).

The average annual runoff in the Keechelus watershed is about 246,000 acre-feet, and the lake has an active storage capacity of 157,800 acre-feet. In contrast, the Kachess watershed has an average annual runoff of about 214,000 acre-feet, but Kachess Lake has an active storage capacity of about 239,000 acre-feet. The concept is to transfer water from Keechelus Lake to Kachess Lake to increase the amount of total stored water. The pipeline could also be used to bypass some of the releases from Keechelus Dam during the irrigation season in the 11-mile Yakima River reach upstream of the Kachess confluence for anadromous fishery management, primarily during September spawning.

The conceptual plan is to modify the outlet works of Keechelus Dam to permit downstream releases as well as releases to a potential gravity flow pipeline (60-inch-diameter), extending about 5 miles to Kachess Lake. The conveyance capacity of the pipeline is approximately 210 cfs at Keechelus Lake full-pool elevation of 2517 feet. Note: A lower reservoir pool elevation will result in a lower flow in the pipeline. Operation of the pipeline would generally be from June 1 through September 30.

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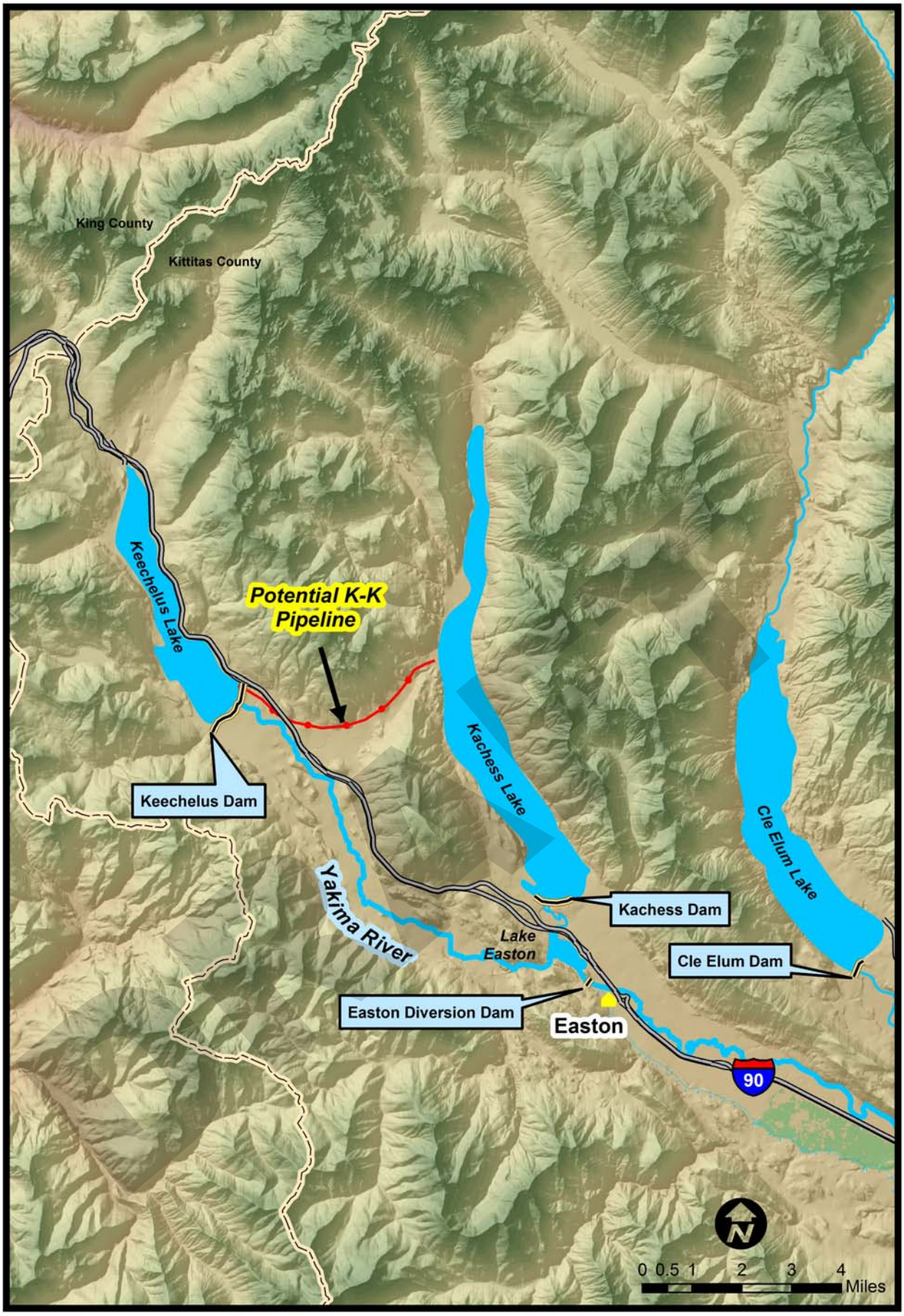

Figure 6. Keechelus-to-Kachess Alternative location map

Historical Hydrograph

Historical Yakima Basin Hydrograph

The character of the Yakima basin's annual hydrological pattern is driven by the accumulation of snow from November to March in the Cascade Mountains along the western and northern boundaries of the basin. The spring snowmelt results in peak freshet events (figure 7) which cause streamflows to rise and fall with alternating warming and cooling weather patterns. During the peak runoff period, above bank-full events (i.e., floods) distribute surface water across the flood plain reaches (i.e., Easton, Cle Elum, Ellensburg, lower Naches, Union Gap and Wapato), which recharge the aquifer. Further, these bank-full events cleanse the stream bottom by flushing fine sediments downstream and depositing them in the depositional zones (i.e., low-gradient reaches) and increasing channel complexity, which allows for increased egg and juvenile over-winter survival, and increased habitat complexity for multiple salmonid species and life stages.

Streamflows begin to decline after the majority of the snowpack has melted by early summer. By late summer, streamflows have reached base flows (summer low flow). Groundwater stored during the spring runoff is typically the primary source of the base flows and provide the cooler water for fishery habitat. Typically, fall precipitation in the form of rain causes streamflows to increase from summer low flows. From fall into winter, flows increase slowly, with small peak flow events that coincide with storm events.

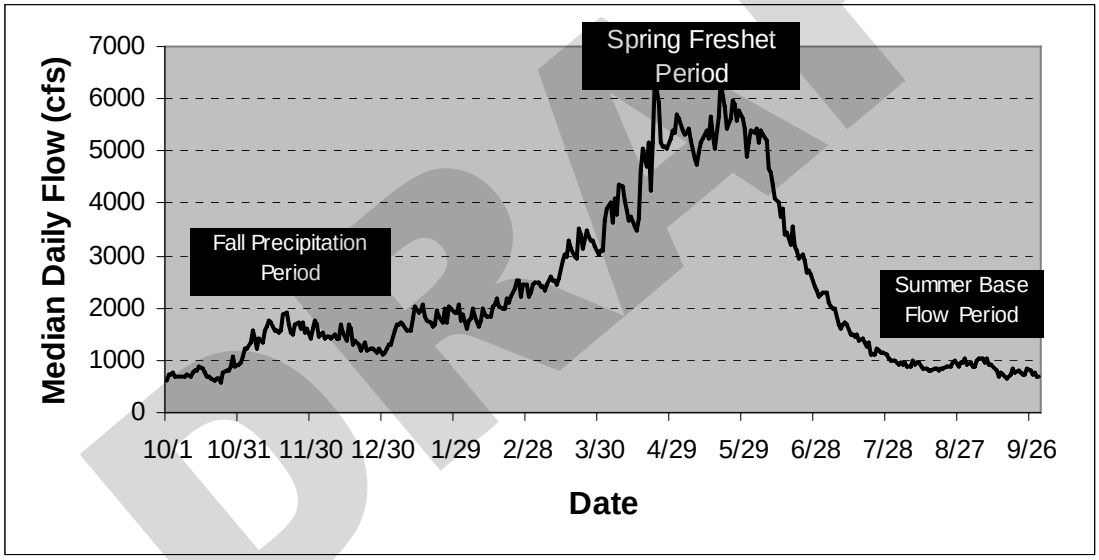

Figure 7. Typical Yakima Basin Annual Hydrograph Under Unregulated Conditions

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Anadromous salmonids residing in the Yakima basin have adapted their life cycle to the previously described annual hydrograph to maximize their survival (i.e., abundance, productivity, and diversity). A description of key adaptations to the annual hydrograph by species or collectively, depending on the life stage, follows.

Spring Freshet Period

The peak flow events that occur in the spring as a result of snowmelt are very important to the smolt life stage for all anadromous salmonids. Smolts can be 3 months, 1 year, 2 year, or 3 years of age, depending on the species. Smolts outmigrate to the ocean and physiologically transition from life in freshwater to life in saltwater. There is a biological window in the spring in which smolts must reach the ocean; failure to do so can result in mortality or failure to smolt.[2]

Smolts outmigrate passively, meaning they allow the current to move them downstream as opposed to actively swimming, and, in fact, they move downstream tail first. Because of this behavior, having spring freshets with accelerated water velocity is important to flush them to the ocean in a timely manner within their biological window of opportunity. Increased water velocities from spring freshets reduce smolt travel time to the ocean, thereby minimizing exposure to these predators while in the river. Increased water turbidity associated with spring freshets decreases the capture efficiency of these predators.

In late spring, when streamflows are still high, spring and fall Chinook and coho begin to emerge from spawning beds. They typically are 30-35 mm in length and weigh less than a gram. Because emergent fry are very vulnerable to predation and physical impingement, it is critical that they initially rear in shallow, slow-velocity habitat (i.e., side channels, bank margins, backwater pools, etc.). These habitat features are most abundant in the flood plains. High spring flows inundate these flood plains, creating essential nursery areas.

Summer Base Flow Period

By summer, juvenile spring Chinook and coho are 50-90 mm in length and prefer deeper, faster water located out from the stream margin, in the mainstem and large side channels. By this time, fall Chinook have smolted and outmigrated to the ocean. Both spring Chinook and coho prefer shear zone (slow-moving) areas in the river, preferably with large, woody debris associated with them. A shear zone (figure 8) runs longitudinally in the river and defines the boundary between fast- (near the middle) and slow-velocity (along the stream edge) water. Juvenile spring Chinook and coho take up residence in the slow-velocity water, preferably downstream of large, woody debris to minimize energy expended to remain stationary. The shear zone provides a feeding lane, whereby a fish will dart out into the faster water to consume a floating insect, then move back to its slow water resident area. As streamflows decline from spring to summer, the amount of shear zone habitat increases and shows a clear distinction between pool, riffle, and glide habitats.

Steelhead emerge from the gravel in June-July as streamflows are decreasing to the summer low-flow period. At emergence, steelhead fry are slightly smaller than salmon fry, averaging 25-30 mm in length. Steelhead fry, like salmon fry, seek out the shallow, slow-velocity habitat that exists along the stream margin in the mainstem, side channels, and off-channel rearing areas.

[2] Failure to smolt is commonly referred to as smolt residualism. Residualism refers to a smolt that fails to reach the ocean and physiologically reverts back to conditions necessary for living in freshwater. This is most common for steelhead. In the case of steelhead, the fish may smolt the following spring or remain in the river as a resident trout.

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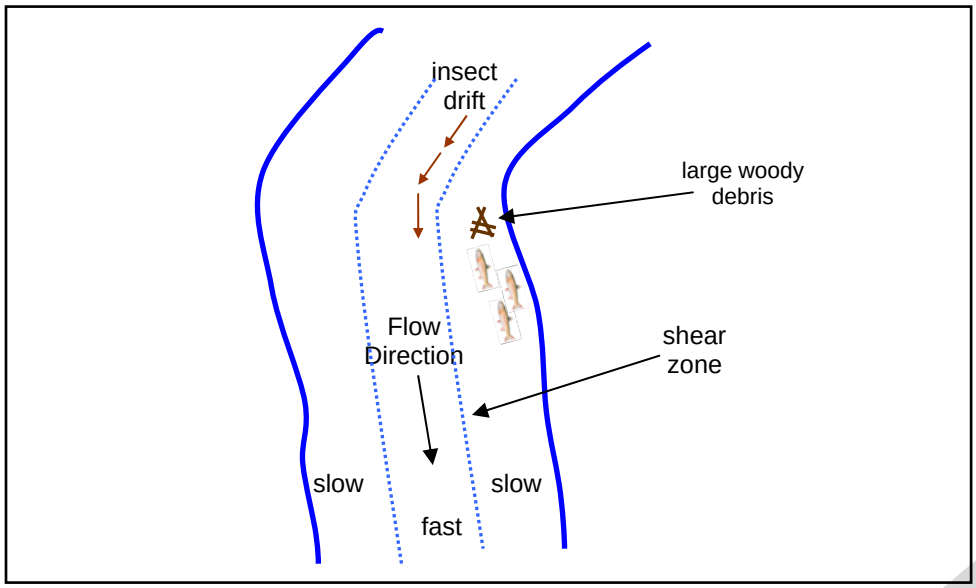

Figure 8. Location of Juvenile Salmonid Rearing Habitat in Relation to the Shear Zone and Feeding Lanes

Fall Precipitation Period

Beginning in late October, Pacific winter storms result in a series of small peak flow events and a trend to higher winter base flows. Increases in fall-winter flows inundate previously dry to minimally wetted side and off-channel habitat. Juvenile salmonids begin to seek over-wintering habitat with the onset of decreasing water temperatures and shorter days. Over-wintering habitat is mainstem, side, and off-channel habitats that provide shelter from winter high-flow events. These are areas that ideally have warmer groundwater inflow. Deep, slow-water velocity with sufficient instream and overhead cover describe the desired habitat features. Depending on the species, the large crevices in the stream substrate provide important over-wintering habitat (e.g., steelhead).

A majority of juvenile spring Chinook in the Yakima basin moves downstream from their natal area and over-winter in the Yakima River between the Naches River confluence and Prosser Diversion Dam. Juvenile coho, even more than spring Chinook, prefer to over-winter in off-channel habitat with ample instream cover. Juvenile coho produced in the three primary mainstem spawning areas of the upper Yakima River near Ellensburg, the lower Naches River, and the Wapato reach of the Yakima River, are thought to over-winter in their natal areas. Steelhead juveniles both outmigrate downstream into the lower Yakima and Naches Rivers and remain in their natal areas to seek out suitable over-wintering habitat.

The Normative Ecosystem Concept

The normative ecosystem concept is predicated on the assumption that by increasing river ecosystem processes and functions, the health of salmonid populations would improve. Improvement means increasing population abundance, productivity, and life history diversity. The normative ecosystem concept encompasses several key physical elements such as habitat

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complexity, the hydrograph, sediment transport, riparian zone, in-channel large woody debris, and nutrient cycles. The degree to which each of these key elements can be restored toward a more historic state, the more normative, or natural-like, the river ecosystem will be. Once a more normative ecosystem is established, there would follow a positive biological response, beginning with primary production (i.e., algae and diatoms), followed by aquatic insects, and then benefits to the fish community. One of the first to introduce the normative ecosystem concept was the Independent Scientific Group (ISG) in *Return to the River* (Williams, et. al., 1996).

The Storage Study is focused solely on evaluating the feasibility of increased water storage in the Yakima basin. Consequently, Reclamation has limited this evaluation to how different Storage Study alternatives affect the current flow regime in the Yakima basin in terms of making the existing hydrograph more natural-like. Achieving a more natural-like, or unregulated, hydrograph is only one, albeit important, element in moving toward a more normative river ecosystem. Clearly of equal importance is the preservation of existing high value habitat and restoring existing habitat. Furthermore, the Storage Study analysis presented in this report is qualitative in nature and is not designed to define natural (unregulated) flows in the basin in quantitative terms. We anticipate the need to quantify natural (unregulated) flows in the basin to complete the Storage Study feasibility report/environmental impact statement.

Many in the scientific community recognize that a more natural (unregulated) flow regime is a key element to achieving a more normative river ecosystem. Excerpts from previous reports follow:

- The ISG (Williams, et. al., 1996) placed the importance of a natural flow regime in the broader context of the normative river concept. As one example of the importance of a natural flow regime, they state:

  > *"At least three generalized actions could begin to rebuild habitat quantity and quality of the mainstem and tributaries:*
  > *(a) reregulate flows to restore the spring high-water peak to revitalize the mosaic of habitats in alluvial riverine reaches; . . ."*

- Influenced by the ISG *Return to the River* (Williams, et. al., 1996) document, the System Operations Advisory Committee (SOAC) state in their 1999 report entitled, *Report on the Biologically Based Flows for the Yakima River Basin* (System Operations Advisory Committee, 1999) as Recommendation 4 to:

  > *"Implement a Normative Flow Regime – Within the various restraints associated with river development, immediately initiate some level of modified flows to incrementally move toward predevelopment hydrologic parameters."*

  Further in this report, SOAC states that:

  > *"The key to recovering anadromous fish populations in the Yakima Basin is to re-establish lost or altered ecosystem functions within the framework of the*

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> *'normative ecosystem concept' (Williams et. al., 1996). A normative ecosystem may be described as an ecosystem that biologically sustains all life stages of diverse salmonid populations. Further, the normative ecosystem is not a static target or a single unique state of the river. It is a continuum of conditions from slightly better than the current state of the river at one end of the continuum, to nearly pristine at the other end. (Williams et al., 1996)."*

- Stanford, et. al., (2002) in their report entitled, *The Reaches Project: Ecological and Geomorphic Studies Supporting Normative Flows in the Yakima River Basin, Washington,* makes the following summary statements:

> "*Through this research effort, we conclude that recovery of salmonid runs in the Yakima is dependent on (1) the provision of normative flows, which we outline, and (2) the protection and enhancement of flood plain habitat."*
>
> *"Normative flows would reconnect the Yakima flood plain ecosystem in all three physical dimensions (laterally, vertically and longitudinally)."*

- In the *Final Plan, Yakima Subbasin Plan* (2004), the Yakima Subbasin Fish and Wildlife Planning Board (YSPB) states as their second guiding principle:

> "*That the quality of water and a near natural timing and quantity of water flow (normative hydrograph) are principle indicators of a healthy river ecosystem."*

- Similarly, in the *Draft Yakima Subbasin Salmon Recovery Plan* (Freudenthal, et. al., 2005), the YSPB states as one of their guiding principles:

> "*The quality of water and a near natural timing and quantity of water flow (normative hydrograph) are principal indicators of a healthy river ecosystem. These indicators must be improved and monitored."*

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System Operation Studies

Hydrologic Model

The system operational analysis conducted by Reclamation for this *Yakima Basin Assessment* involves use of the Yakima Project RiverWare (Yak-RW) model. This model is a daily time-step reservoir and river operation simulation computer model of the Yakima Project, created with the RiverWare software. The software was developed at the Center for Advanced Decision Support for Water and Environmental Support at the University of Colorado in cooperation with Reclamation and the Tennessee Valley Authority.

The RiverWare modeling software uses an object-oriented modeling approach in which objects represent features of the project such as storage reservoirs, stream reaches, diversions, and

canals. Each object contains its own physical processes, algorithms and data. For instance, reservoir objects include elevation-volume data, flood-control rule curve information, and outflow data. Objects are interconnected by a "network" of lines representing the flow of water from one object to another.

The network file of the Yak-RW model consists of the five major project reservoirs (Keechelus, Kachess, Cle Elum, Bumping, and Rimrock) and 56 major and minor river diversions and canal systems. All river diversions, canal losses, on-farm losses, and return flows are represented in the model. The network also includes simulation of Kittitas Reclamation District's 1146 Wasteway to assist in the "mini flip-flop" fall operation, and the Roza and Chandler powerplants.[3]

The hydrologic base for the Yak-RW model is represented by the 23 water years of 1981 through 2003 (November 1, 1980, through October 31, 2003). This 23-year period includes 17 non-proration water years (wet and average water supply conditions) and 6 proration years (dry water supply conditions).

Current Operation Scenario

The objective of the current operation is to fill the reservoir system to its full active capacity of about 1 million acre-feet, while providing "minimum" flows downstream of the dams, meeting Title XII flows at Sunnyside and Prosser Diversion Dams, and providing reservoir space for possible flood control operations. Runoff from the watershed upstream of the five major Yakima Project reservoirs is stored following the end of the irrigation season in October and continuing through the fall, winter, and early spring months to accomplish this objective.

The irrigation season starts about the first of April, though the "priming" of the main conveyance canals generally begins by mid-March. During the initial part of the irrigation season, unregulated runoff from tributaries below the five reservoirs is generally adequate to meet irrigation diversion demands and the Title XII target instream flows at Sunnyside Diversion Dam (Parker gauge, RM 103.7). Irrigation return flows also contribute to meeting irrigation diversion demands. On average, unregulated flows and irrigation return flows are adequate in meeting diversion demands until about June 24. The earliest unregulated flows have been unable to meet demands is April 1, and the latest is August 17.

Once the unregulated flows fail to meet diversion demands and Title XII target flows, reservoir releases must be made, resulting in depletions in the stored water supply. The time when this occurs is commonly referred to as the beginning of the storage control period.

From the beginning of the storage control period until the first of September, releases from Cle Elum Dam are maximized to the extent possible to meet mainstem Yakima River diversion demands extending from the Cle Elum River confluence (RM 179.6) to Sunnyside Diversion Dam (RM 103.8). A major portion of these demands is in the middle Yakima basin, from Roza

[3]The Wapatox Powerplant was acquired by Reclamation in 2003 and is no longer in operation. The "power water" diversion now remains in the Naches River.

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Diversion Dam (RM 127.9) downstream, including the Roza Division, Wapato Irrigation Project (RM 106.7), and the Sunnyside Division. These demands total an annual irrigation water right of about 1.46 million acre-feet, out of a basin total of about 2.34 million acre-feet upstream of the Parker gauge. This results in a high volume of water being transported from the upper to middle basin by the Yakima River. At peak, about 3,600 cfs for irrigation diversion is being moved through this area.

However, about September 1, the Yakima Project moves into what is called the "flip-flop" operation. At this time, Cle Elum Lake releases are significantly reduced over a 10-day period. During this interval, releases from Rimrock Lake are significantly increased to meet the September-through-October irrigation demands downstream of the confluence of the Naches and Yakima Rivers; the major portion of which is the Wapato Irrigation Project and the Sunnyside Division. The purpose of the flip-flop operation is to encourage upper Yakima River spring Chinook to spawn in the main channels of the upper Yakima River (RM 156 to RM 202) and the Cle Elum River, rather than in areas which would be dewatered at the end of the irrigation season when storage accumulation begins. This allows protection of the redds, or incubating eggs, throughout the fall and winter months with a lesser storage release, thus improving the stored water supply for the next irrigation season.[4]

The flip-flop operation during the storage control period is illustrated in table 6.

During this same period (the beginning of storage control to the first of September), a similar operation, referred to as "mini flip-flop," is performed between Keechelus and Kachess Lakes in years of sufficient water supply. Greater releases are initially made from Keechelus Lake to meet the upper basin demands (primarily the Kittitas Reclamation Division), and releases from Kachess Lake are restrained. Then, in September and October, the opposite is done, with greater releases being made from Kachess to meet upper basin demands, and releases from Keechelus reduced to provide suitable spawning flows in the Yakima River reach from Keechelus Dam (RM 214.5) to the backwaters of Lake Easton (about RM 203.5).

Concurrent with the September shift in major water releases from Keechelus Lake to Kachess Lake, Kittitas Reclamation District's main canal (which has excess carrying capacity due to diminishing irrigation demands) is used to convey water for downstream use (such as the Roza Irrigation District) around the Easton Reach. This water reenters the Yakima River through the 1146 Wasteway,[5] approximately 28 miles downstream of Easton Diversion Dam. This operation provides a maximum of 200 cfs spring Chinook spawning flow through the Easton reach.

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[4] A detailed history and description of the "flip-flop" river operation, instituted in the early 1980s, can be found in the *Interim Comprehensive Basin Plan* (Reclamation, 2002).
[5] The 1146 Wasteway conveys excess water from Kittitas Reclamation District's main canal at Station 1146+30 to the Yakima River at RM 173.9.

Table 6. Yakima River Flows and Major Diversions (Easton Diversion Dam to Sunnyside Diversion Dam)

Gauging Station	Mid-July	Mid-August	Mid-September
	(cubic feet per second)		
Yakima River @ Easton Diversion Dam (RM 202.5)	220	360	220
Below Cle Elum Dam	2,830	2,950	220
Yakima River @ Cle Elum (RM 183.1)	+3,210	+3,530	+540
Yakima River @ Umtanum (RM 140.4)	3,640	3,930	1,510
RID Diversion[1] (RM 127.9)	-1,060	-1,080	-730
Yakima River below Roza Dam (RM 127.9)	2,580	2,850	780
Naches River @ Naches (RM 16.8)	+1,270	+990	+2,090
Yakima River below Roza Dam + Naches River @ Naches	3,850	3,840	2,870
WIP Diversion (RM 106.7)	-1,890	-1,850	-1,200
Sunnyside Diversion (RM 103.8)	-1,220	-1,220	-1,060
Other Diversions	-240	-250	-90
Yakima River at Parker (RM 103.7)	500	520	520

[1]For irrigation, diversions for hydrogeneration at Roza Powerplant return to the Yakima River downstream of the Naches River confluence.

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Integrated Operation Scenario

This section provides information on water availability at Bumping Lake enlargement damsite and at the Yakima River Wymer pumping plant site. It also discusses how the available water supply is used in the integrated 70-percent operation.

The results of the integrated operation are then discussed as they relate to meeting the Storage Study's irrigation, instream, and municipal water supply goals.

Water Availability

The unappropriated surface waters of the Yakima River basin have been withdrawn from appropriation by Reclamation. This withdrawal, approved by Washington Department of Ecology, is in effect until January 18, 2008.

Bumping Lake Enlargement. The runoff available from the Bumping River watershed for storage in an enlarged Bumping Lake reservoir is represented by the inflow to the enlarged reservoir, less a minimum instream flow requirement of 130 cfs in the Bumping River downstream of the new dam. The monthly volume during the 1981-2003 period is shown in table 7. The average annual runoff available is illustrated in figure 9.

The monthly volume of water available for storage does not represent the volume actually stored, as the amount actually stored is a function of the manner in which the enlarged reservoir is operated in conjunction with the present Yakima Project facilities.

Table 7. Bumping Lake Enlargement Inflows Available for Storage (Inflow Less Minimum Release)

Water Year	Monthly Volumes (acre-feet)												Annual Volume (a-f)
	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	
1981	11,137	41,043	13,233	15,001	3,463	6,659	19,468	13,498	687	0	0	648	124,836
1982	1,337	3,963	911	27,038	9,416	4,509	37,651	60,260	14,786	345	75	1,347	161,639
1983	1,731	10,131	11,383	3,414	10,567	7,731	43,284	34,721	13,100	178	18	0	136,259
1984	9,780	4,950	17,362	4,167	6,501	5,817	27,017	46,809	15,835	124	0	185	138,546
1985	729	0	0	0	0	12,507	37,770	40,815	2,243	0	0	3,743	97,806
1986	5,997	0	3,595	10,475	19,057	13,648	28,563	20,786	144	0	0	322	102,587
1987	13,175	1,695	62	1,093	11,154	21,331	43,056	10,837	72	0	0	0	102,475
1988	0	1,635	231	37	3,388	21,048	31,570	21,232	2,399	0	0	250	81,791
1989	7,177	3,463	1,396	61	1,373	21,700	32,171	31,056	3,056	0	0	0	101,454
1990	3,140	9,986	14,587	1,867	1,283	29,515	24,826	30,417	7,481	116	0	3,669	126,888
1991	33,989	7,506	6,721	21,701	4,453	11,572	23,992	26,841	13,018	325	0	0	150,118
1992	3,201	3,102	5,454	5,437	9,918	18,429	20,701	2,882	0	0	154	0	69,279
1993	66	0	919	0	4,755	7,952	42,095	12,694	162	0	0	0	68,643
1994	0	0	350	0	3,953	17,504	27,721	10,322	322	0	0	2,286	62,459
1995	1,607	11,278	4,219	31,231	11,202	6,881	38,823	26,361	4,309	0	1	3,106	139,017
1996	51,175	24,737	19,462	45,155	9,241	22,147	22,227	23,518	4,409	66	0	429	222,567
1997	4,006	3,466	14,937	8,944	17,458	19,176	63,677	63,198	27,394	1,180	2,372	15,400	241,208
1998	11,062	4,784	2,848	185	4,102	9,964	46,301	27,007	2,785	0	0	0	109,039
1999	7,287	12,949	8,577	628	494	5,033	28,326	61,505	47,828	11,660	32	155	184,474
2000	24,267	12,369	1,139	364	0	20,035	32,147	33,877	6,092	0	80	162	130,532
2001	0	0	0	0	1,142	4,633	27,049	10,136	380	0	0	191	43,531
2002	7,991	2,665	15,222	3,200	2,485	16,950	32,195	58,987	13,604	0	0	0	153,297
2003	14	272	16,638	12,240	9,733	12,435	25,240	23,769	754	0	0	1,424	102,519
Average	8,647	6,956	6,924	8,358	6,310	13,790	32,864	30,067	7,863	608	119	1,449	123,955
Daily Available for Storage (cfs) by Month													
Average	145	113	113	149	103	232	534	505	128	10	2	24	
Maximum	5,297	4,989	3,450	4,556	1,324	1,390	2,096	2,445	1,158	470	225	2,101	
Minimum	0	0	0	0	0	0	111	0	0	0	0	0	

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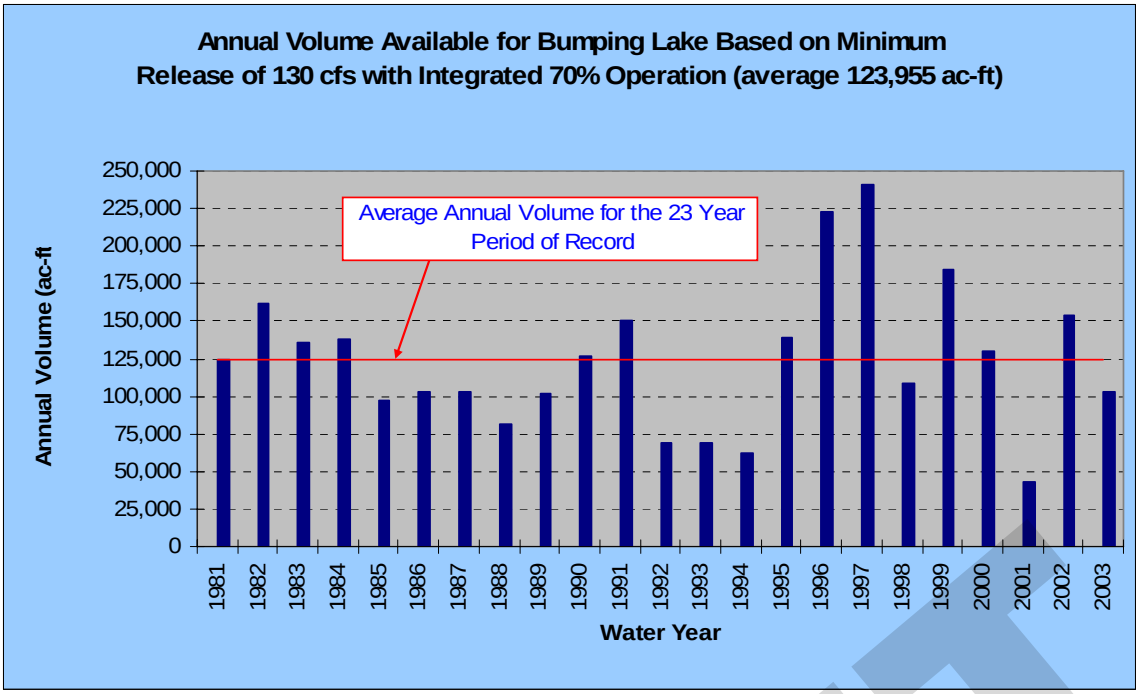

Figure 9. Bumping Lake Inflows Available for Storage (Inflow Less Minimum Releases)

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Wymer Dam and Reservoir. Yakima River flows available for diversion to Wymer reservoir are limited to nonproration water supply years, with pumping occurring when flows are (1) greater than 1,475 cfs upstream of Roza Diversion Dam during the nonirrigation season,[6] and (2) greater than Title XII flows over Sunnyside Diversion Dam during the irrigation season.

Table 8 shows the monthly volume of Yakima River water available for diversion to Wymer reservoir.

Figure10 shows the average annual Yakima River flows available for pumping to Wymer reservoir.

[6] Maximum generation at Roza Powerplant requires a flow of 1,075 cfs. In addition, 400 cfs is required at Roza Diversion Dam to divert the power water.

Table 8. Yakima River Flows Available for Pumping into Wymer Reservoir with Integrated 70% Operation

Water Year	Monthly flows (acre-feet)												Annual Flow (acre-feet)
	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	
1981	0	113,049	35,737	86,446	22,330	0	0	0	0	0	0	0	257,562
1982	0	0	31,037	107,298	81,340	26,643	89,866	97,538	19,235	0	0	0	452,956
1983	0	633	84,681	27,030	133,892	76,455	59,242	60,795	14,164	0	0	0	456,892
1984	2,857	0	120,525	35,431	70,926	35,246	2,285	132,880	19,079	0	0	0	419,229
1985	0	0	0	0	0	56,302	7,563	0	0	0	0	221	64,085
1986	8,340	0	0	40,368	120,875	10,514	0	0	0	0	0	0	180,098
1987	14,331	0	0	0	32,907	6,763	3,102	0	0	0	0	0	57,103
1988	0	0	0	1,286	0	29,998	0	0	0	0	0	0	31,284
1989	1,107	3,864	3,253	4,032	5,602	60,252	1,589	0	0	0	0	0	79,698
1990	946	7,801	14,769	21,461	38,466	119,666	136	37,256	8,315	0	0	3,151	251,968
1991	178,470	73,606	100,179	85,700	55,420	94,341	31,848	40,975	14,176	0	0	0	674,715
1992	0	12,657	9,206	17,308	28,729	0	0	0	0	0	0	0	67,900
1993	0	0	0	0	3,919	1,606	3,208	0	0	0	0	0	8,733
1994	0	0	0	0	143	2,750	0	0	0	0	0	0	2,893
1995	444	10,840	12,173	138,166	69,851	11,777	17,405	14,520	1,307	0	0	0	276,482
1996	119,157	194,790	208,890	346,668	213,774	202,482	31,979	48,485	0	0	0	0	1,366,226
1997	0	0	42,731	84,579	267,528	262,382	315,312	102,213	25,207	0	0	3,224	1,103,177
1998	36,637	1,568	8,311	22,330	56,661	83,310	85,495	26,451	0	0	0	0	320,764
1999	106	21,380	56,294	7,620	39,135	54,360	145,056	86,691	57,879	2,208	0	0	470,728
2000	128,846	134,842	5,066	0	6,361	138,425	26,239	83,665	8,341	0	0	0	531,784
2001	0	0	0	0	0	0	0	0	0	0	0	0	0
2002	916	573	10,900	7,818	2,556	49,348	41,216	138,493	5,112	0	0	0	256,931
2003	0	0	20,128	48,780	59,069	31,437	2,792	0	0	0	0	0	162,206
Ave	21,398	25,026	33,212	47,057	56,934	58,872	37,580	37,824	7,514	96	0	287	325,801
Average Daily Available for Storage (cfs) by Month													
Ave	360	407	540	847	926	989	611	636	122	2	0	5	
Max	11162	11341	6455	15264	11678	9719	11333	5685	2544	602	0	783	
Min	0	0	0	0	0	0	0	0	0	0	0	0	

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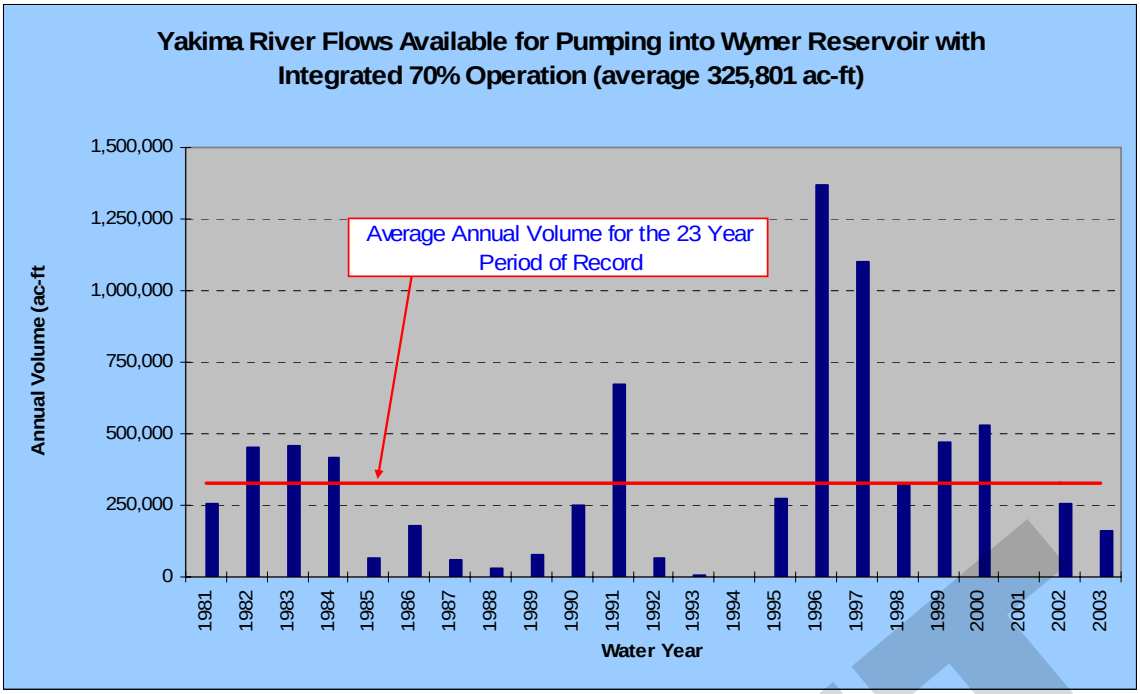

Figure 10. Annual Yakima River Flows Available for Pumping into Wymer Reservoir

Storage Contents

For the integrated operation studies, the emphasis is on meeting instream flow targets downstream of the dams (see table 9), Title XII flows, and the irrigation water supply goal. Specific criteria are not included in the simulated operations in an attempt to move the Yakima and Naches Rivers' flow regime toward the natural (unregulated) hydrograph. To do so would result in not meeting the irrigation water supply goal. Rather, the RiverWare model uses the integrated operation total water supply available (TWSA) to set the Title XII target flows. Additional flows resulting from increased TWSA of the integrated operations (as compared to the current operation) are then equated to a "block of stored water" which could be used for other fishery purposes, if desired (see table 12).

Table 9. Minimum Target Flows Used by the Model

River Location	Daily Flows (cfs)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Tieton Dam	45	45	45	45	45	45	45	45	45	45	45	45
Bumping Dam	130	130	130	130	130	130	130	130	130	130	130	130
Keechelus Dam	80	80	80	80	80	80	80	80	100	100	80	80
Kachess Dam	15	15	15	15	15	15	15	15	15	15	15	15
Cle Elum Dam	220	220	220	220	220	220	220	220	220	220	220	220
Easton Diversion Dam	220	220	220	220	220	220	220	220	220	220	220	220
Naches River at Naches	Minimum of natural flow right or 450 cfs											
Parker				Title XII flows*								
*see table 1 for Title XII instream flows												

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Bumping Lake Enlargement. Figure 11 shows Bumping Lake enlargement storage contents for the 23-year hydrologic period. The increasing line represents inflow available for storage being retained in the reservoir during the storage period beginning about November 1 with maximum reservoir contents usually occurring mid-June to early July. The decreasing lines are the reservoir releases during the storage control period resulting in the lowest reservoir contents occurring at the end of the irrigation season in October.

The operating emphasis of an enlarged Bumping Lake reservoir is on a carryover reservoir to improve the dry-year water supply available for proratable water rights. This results in major reservoir drawdown and minimum reservoir contents in the historical dry water years 1987, 1988, 1992, 1993, 1994, and 2001.

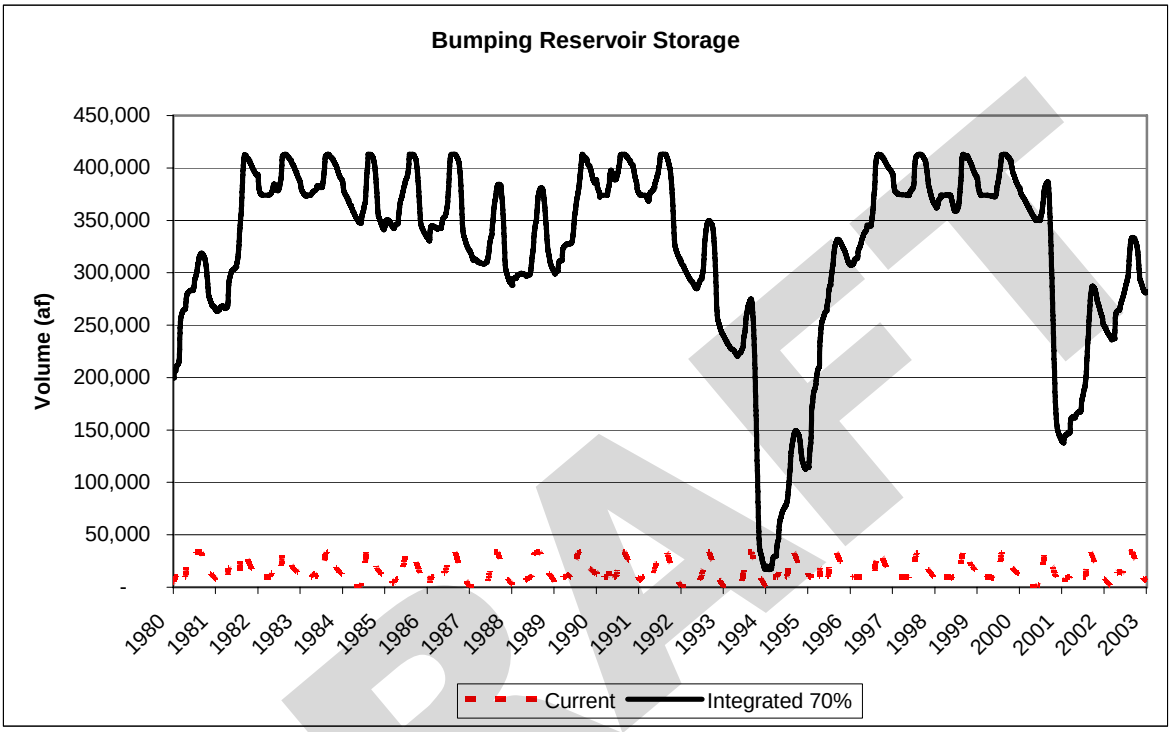

Figure 11. Bumping Lake Enlargement Contents for the Current Scenario and Integrated 70% Operation

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Wymer Dam and Reservoir. Table 10 shows the monthly pumping to Wymer reservoir and the releases back to the Yakima River. For this *Yakima Appraisal Assessment*, the capacity of the Wymer pumping plant and the outlet works is 400 cfs.

Wymer reservoir is filled during the winter and spring months; releases are made in the dry years when stored water is required in meeting Title XII target flows at Sunnyside Diversion Dam. This operation, shown in figure 12, permits retention of stored water in the other Yakima Project reservoirs to improve the dry-year water supply available for all Yakima basin proratable water rights.

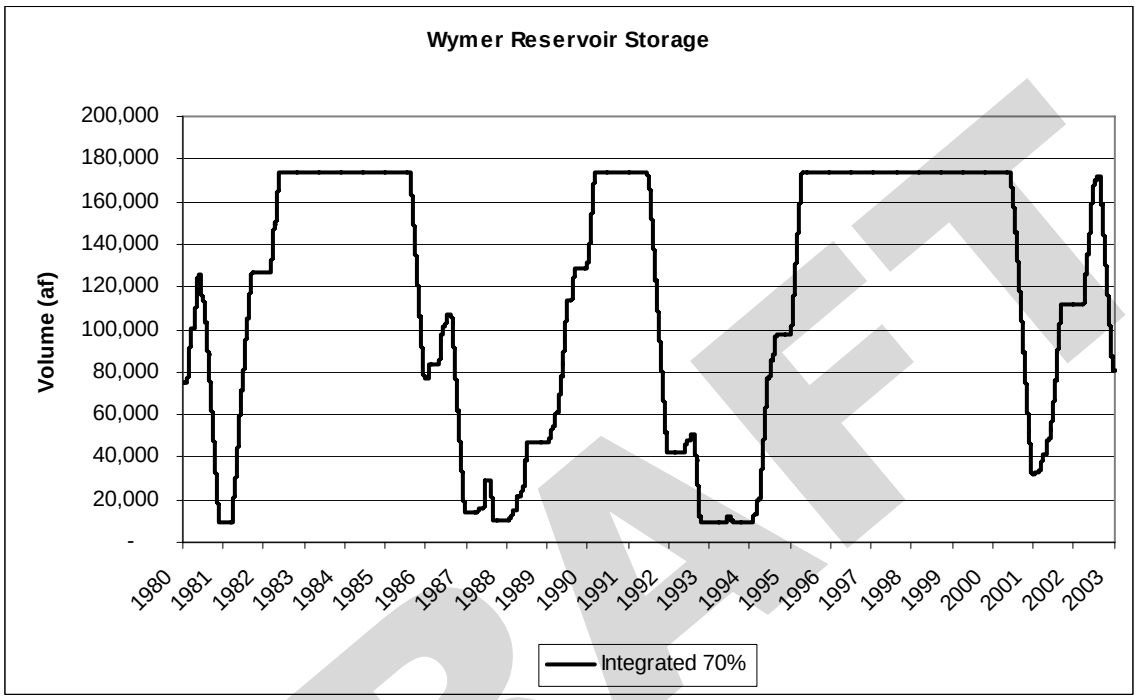

Figure 12. Wymer Reservoir Contents for the Integrated 70% Operation

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Table 10. Inflows and Releases from Wymer Reservoir with Integrated 70% Operation

Water Year	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Annual Inflow	Annual Release
1981	0	14,853	10,709	11,901	13,796	Rel.	Rel.	Rel.	Rel.	Rel.	Rel.	0	51,259	116,904
1982	0	0	8,727	17,745	24,595	17,157	24,595	16,579	7,649	0	0	0	117,048	0
1983	0	633	21,319	11,208	Full	Full	Full	Full	Full	Full	Full	Full	33,160	0
1984	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	0	0
1985	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	0	0
1986	Full	Full	Full	Full	Full	Full	Full	Rel.	Rel.	Rel.	Rel.	Rel.	0	96,926
1987	6,557	0	0	0	13,959	6,245	2,901	Rel.	Rel.	Rel.	Rel.	Rel.	29,662	92,278
1988	0	0	0	1,286	0	13,744	0	Rel.	Rel.	0	0	0	15,030	19,563
1989	1,107	3,864	3,171	3,271	5,195	19,290	1,589	0	0	0	0	0	37,486	0
1990	946	5,984	7,143	11,165	19,471	21,721	136	11,085	3,399	0	0	3,151	84,200	0
1991	19,463	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	19,463	0
1992	Full	Full	Full	Full	Full	Rel.	Rel.	Rel.	Rel.	Rel.	Rel.	Rel.	0	131,988
1993	0	0	0	0	3,919	1,606	3,208	Rel.	Rel.	Rel.	0	0	8,733	41,256
1994	0	0	0	0	143	2,750	Rel.	0	0	0	0	0	2,893	3,174
1995	444	9,022	4,603	22,215	23,911	8,515	10,346	8,696	1,143	0	0	0	88,894	0
1996	18,638	24,595	24,595	Full	Full	Full	Full	Full	Full	Full	Full	Full	67,828	0
1997	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	0	0
1998	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	0	0
1999	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	0	0
2000	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	Full	0	0
2001	Full	Full	Full	Full	Full	Rel.	Rel.	Rel.	Rel.	Rel.	Rel.	Rel.	0	141,795
2002	916	573	7,251	5,479	2,556	17,949	19,835	22,265	2,826	0	0	0	79,649	0
2003	0	0	4,823	17,668	18,670	15,969	2,792	Rel.	Rel.	Rel.	Rel.	0	59,923	80,926
Average	3,434	4,579	7,103	8,495	11,474	12,495	7,267	9,771	2,503	0	0	315	30,227	31,513
Average Daily Inflow (cfs) by Month													**Average Daily (cfs)**	
Average	58	74	116	153	187	210	118	164	41	-	-	5	124	400

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Integrated Total System Storage

Storage contents of the existing five major Yakima Project reservoirs with and without the addition of the three storage alternatives are shown in figure 13.

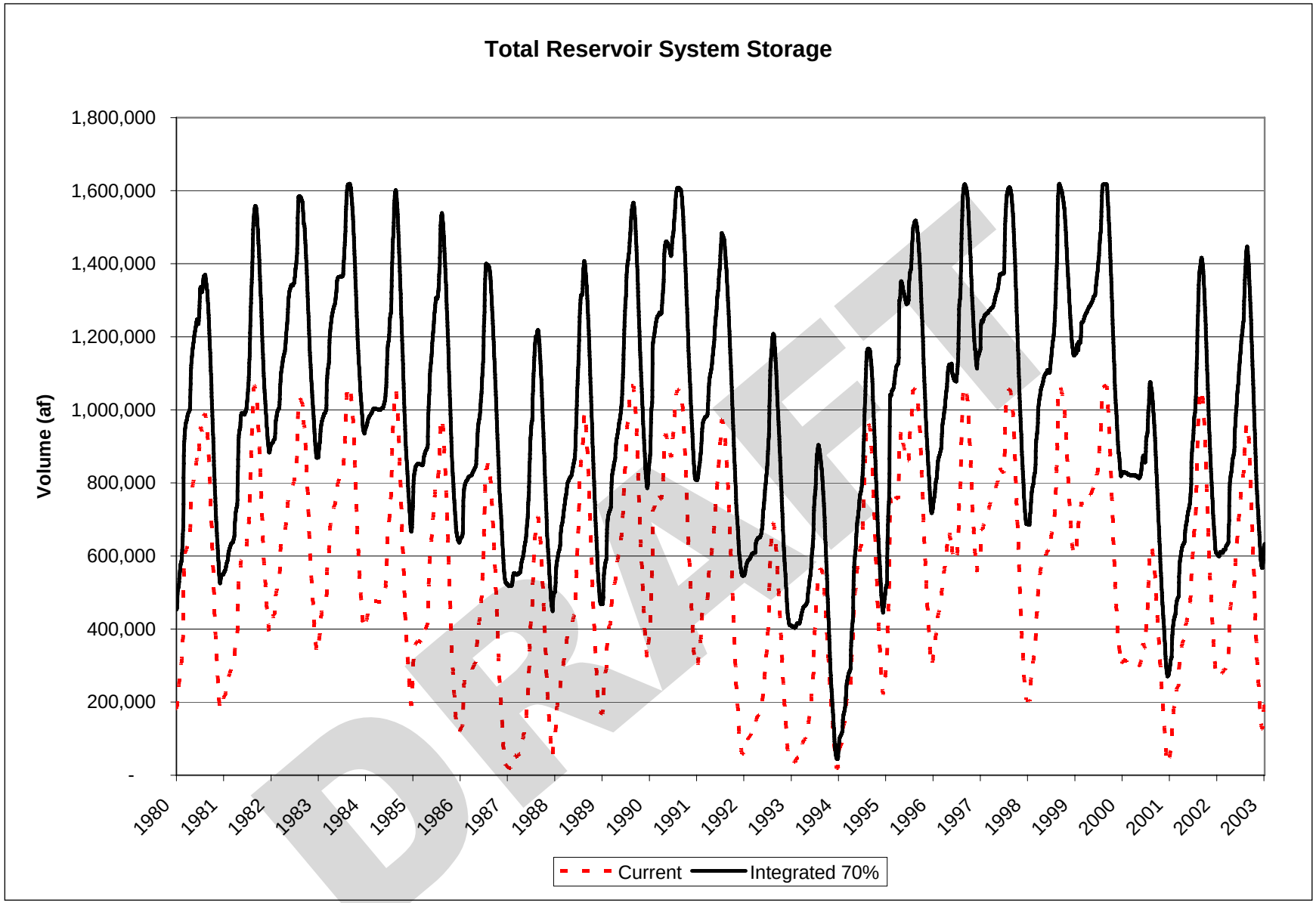

Figure 13. Total Reservoir System Storage - Integrated 70%

System Operation Results

Irrigation Water Supply

The 23-year average TWSA is 3,210,000 acre-feet with the integrated 70-percent operation as compared to the current operation TWSA of 2,850,000 acre-feet. With additional basin storage of 554,300 acre-feet,[7] and an operating plan that uses the additional storage capacity primarily as carryover, the 23-year average TWSA is increased by 360,000 acre-feet.

One-year droughts which follow two or more wet years could see a 30-percent improvement over the current operation proration level. This is demonstrated by drought year 2001, where the current operation proration level was 41 percent, and the integrated 70-percent operation proration level is brought up to 70 percent.

Irrigation water supply conditions are improved in the prolonged dry period, such as 1992-1994. The additional storage alternatives increased the amount of proratable water supply in 1992 and 1993 to not less than 70 percent. The 1994 proratable supply was increased to 66 percent; 4 percentage points less than the 70-percent irrigation supply threshold. It is estimated the 4 percent difference in supply amounts to about 50,000 acre-feet.

Wymer reservoir is filled by pumping from the Yakima River during the winter and spring months. Releases from Wymer reservoir were made during the dry years of 1987, 1988, 1992, 1993, and 2001. Only a minimum release was possible in 1994, because Wymer reservoir was empty in 1993, and there was little excess Yakima River flow in 1994 to pump.

Keechelus-to-Kachess pipeline would be used to capture runoff in only 1 year of the 23-year period—400 acre-feet in 1985. Current reservoir operations maximize carryover storage in Kachess, because it has the lowest inflow-to-total-storage ratio. This reservoir operation results in little benefit from the Keechelus-to-Kachess pipeline for storage augmentation, because, in wet years, Kachess fills from its own watershed. During dry years, there is not enough water in the Keechelus watershed to fill Keechelus reservoir, so no water is sent to Kachess Reservoir.

The Keechelus-to-Kachess pipeline does have a benefit of reducing flows in the Yakima River below Keechelus Dam, because flows can be routed by the pipeline from Keechelus Reservoir through Kachess Reservoir to the Yakima River during the summer months.

Table 11 shows the proration levels for the current and integrated operation studies using the Yak-RW model and the historical water conditions of water years 1981 through 2003. The proration levels generated by the Yak-RW model for the "current operation" are different than actually experienced in prorated years before 1995. This is because current-day operational criteria such as the Title XII instream target flows were implemented in 1995, and minimum

[7] Bumping Lake enlargement active capacity of about 413,000 acre-feet (used in the operation study) less 33,700 acre-feet for the existing Bumping Lake, plus Wymer reservoir active capacity of about 175,000 acre-feet = 554,300 acre-feet (413,000 – 33,700 + 175,000 = 554,300).

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streamflow maintenance releases from existing Yakima Project reservoirs are input into the model for the entire 23-year period.

Table 11. Water Supply Conditions in Yakima Basin Above Parker and Water Supply Available for Proratable Entitlements

		April 1 TWSA (million af)		Proratable Supply (%)			
Water Year	Unregulated Runoff Volume (million af)	Current Operation	Integrated 70% Operation	Current Operation	Integrated 70% Operation	Integrated 50% Operation	Integrated 100% Operation
1981	3.57	2.48	2.86	95	91	91	100
1982	4.26	3.39	3.85	100	100	100	100
1983	3.96	3.33	3.89	100	100	100	100
1984	4.06	3.23	3.79	100	100	100	100
1985	2.80	2.74	3.27	100	100	100	100
1986	3.06	2.50	3.00	92	89	88	100
1987	2.64	2.26	2.82	65	70	69	100
1988	2.75	2.33	2.84	73	89	87	90
1989	3.10	2.66	3.10	98	100	100	100
1990	3.72	3.10	3.50	100	100	100	100
1991	4.02	3.01	3.57	100	100	100	100
1992	2.45	2.14	2.65	69	70	65	100
1993	2.36	2.07	2.57	54	72	75	74
1994	2.06	1.74	2.14	26	66	50	27
1995	4.15	2.90	3.07	100	100	100	100
1996	5.71	3.22	3.65	100	100	100	100
1997	5.70	4.50	4.99	100	100	100	100
1998	3.38	3.15	3.68	100	100	100	100
1999	4.63	3.99	4.49	100	100	100	100
2000	3.66	3.26	3.78	100	100	100	100
2001	1.77	1.81	2.34	41	70	50	84
2002	3.79	3.23	3.57	100	100	100	100
2003	3.06	2.56	2.97	97	92	92	100
Average	3.51	2.85	3.21				

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Instream Water Supply

Title XII Instream Target Flows. Title XII instream target flows at Parker range from 300 cfs to 600 cfs, depending on the estimated TWSA "threshold level" (see table 1 on page 5). The addition of the three storage alternatives increases the "storage content" portion of the TWSA estimate and may result in moving the target flows from one threshold level to the next. When the TWSA estimate increases in the integrated operation studies, the instream flow threshold at Parker is increased. As unregulated flows fail to meet diversion demands and Title XII target flows, reservoir releases are required.

Table 12 summarizes the average increased flow rate (cfs) and the number of days at the increased flow rate, which would be provided from stored water resulting from the three

integrated operation studies. Also shown is the volume (acre-feet) of the increase flow estimated to be provided from stored water. In some years, it may be possible to use this increased volume for other fishery purposes rather than for increased Title XII instream target flows.

Table 12. Increased Title XII Flows at Parker

Water Year	Average Increased Flow Rate(cfs) and Number of Days at the Increased Flow Rate			Volume of Increased Flow from Stored Water (acre-feet)		
	Integrated 70% Operation	Integrated 50% Operation	Integrated 100% Operation	Integrated 70% Operation	Integrated 50% Operation	Integrated 100% Operation
1981	200 (124 days)	200 (124 days)	200 (121 days)	49,000	49,000	48,000
1982	100 (71 days)	100 (71 days)	100 (71 days)	14,000	14,000	14,000
1983	100 (71 days)	100 (71 days)	100 (71 days)	14,000	14,000	14,000
1984	100 (91 days)	100 (91 days)	100 (91 days)	18,000	18,000	18,000
1985	300 (111 days)	300 (111 days)	300(111 days)	66,000	66,000	66,000
1986	200 (154 days)	200 (151 days)	200 (141 days)	61,000	60,000	56,000
1987	100 (141 days)	100 (151 days)	200 (15 days)	28,000	30,000	6,000
1988	100 (136 days)	100 (135 days)	- -	27,000	27,000	- -
1989	200 (118 days)	200 (118 days)	- -	47,000	47,000	- -
1990	200 (108 days)	200 (111 days)	100 (101 days)	43,000	44,000	20,000
1991	200 (98 days)	200 (98 days)	200 (98 days)	39,000	39,000	39,000
1992	100 (111 days)	100 (111 days)	- -	22,000	22,000	- -
1993	100 (96 days)	100 (96 days)	- -	19,000	19,000	- -
1994	- -	- -	- -	- -	- -	- -
1995	- -	100 (95 days)	- -	- -	17,000	- -
1996	200 (111 days)	200 (111 days)	200 (111 days)	44,000	44,000	44,000
1997	- -	- -	- -	- -	- -	- -
1998	300 (101 days)	300 (101 days)	300 (101 days)	60,000	60,000	60,000
1999	- -	- -	- -	- -	- -	- -
2000	200 (89 days)	200 (89 days)	200 (89 days)	35,000	35,000	35,000
2001	- -	- -	- -	- -	- -	- -
2002	200 (81 days)	200 (81 days)	100 (81 days)	32,000	32,000	16,000
2003	200 (121 days)	200 (118 days)	100 (134 days)	47,000	53,000	24,000

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Streamflow Regimes**.** The instream flow water supply goal is to move the current flow regime of the Yakima and Naches Rivers to more closely resemble the natural (unregulated) flow regime.

To determine how well this goal is achieved for the integrated 70-percent operation scenario, five representative hydrographs (figures 15-19) and their associated flow characteristics were analyzed and compared to the current flow regime. This is summarized in table 14. This comparative approach was taken because a quantitative definition of what constitutes a

normative flow regime for the Yakima basin as described by SOAC (1999) has not been determined.

The flows at the gauging stations shown below in table 13 were used to represent the flow regime for the corresponding stream reaches (see also figure 14).

Table 13. Gauging Stations and Stream Reaches

Gauge Station/Hydrograph	Reach Name	Stream Reach
Easton (RM 202.0)	Easton	Yakima River: Easton Dam (RM 202.5) to Cle Elum River confluence (RM 185.6)
Umtanum (RM 140.4)	Ellensburg	Yakima River: Cle Elum River confluence (RM 185.6) to Roza Diversion Dam (RM 127.9).
Bumping Dam outlet (RM 17.0)	Bumping	Bumping River: Bumping Dam (RM 17.0) to American River confluence (RM 0.0)
Naches at Naches River (RM 16.8)	Lower Naches	Naches River: Tieton River confluence (RM 44.6) to the Naches River confluence (RM 0.0)
Parker (RM 108.7)	Wapato	Yakima River: Sunnyside Diversion Dam (RM 103.8) to Granger (RM 83.0)

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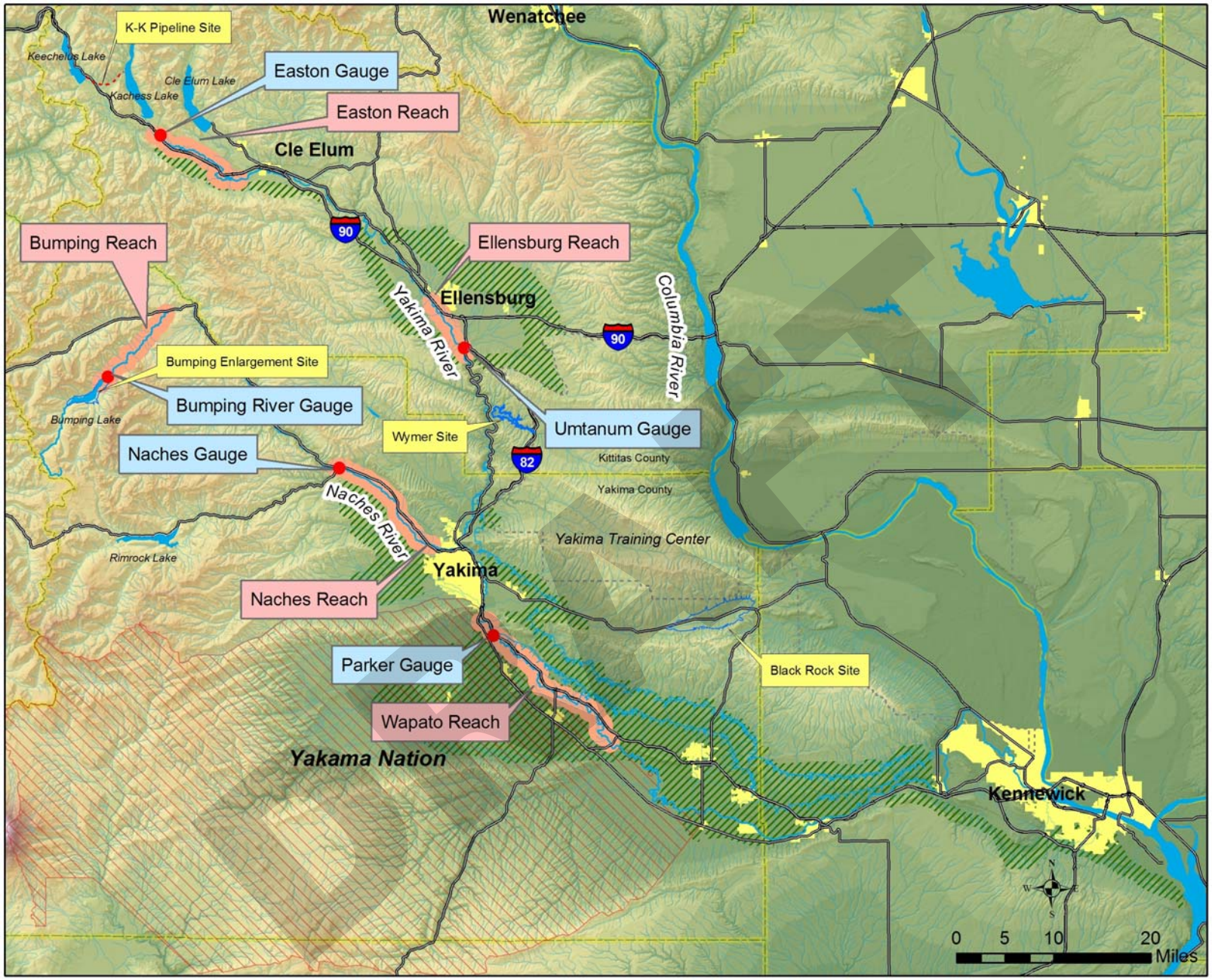

Figure 14. Stream reaches and gauges locations map

Hydrographs. The hydrographs show median monthly flows for the water years 1981 through 2003 for the natural (unregulated) scenario, the current operation scenario, and the integrated 70-percent operation scenario for the five stream reaches identified above. The median monthly flow is the flow which occurs 50 percent of the time for the respective month of the 23-year period of record. Note: This is not the average flow. The hydrographs follow the typical October 1 to September 30 water year. The Yakima basin irrigation season commences April 1 and ends October 15.

The hydrographs illustrate the three scenarios, which are represented by the following:

- Unregulated (black line)—Simulates the natural (unregulated) flow regime from 1981-2003. These flows represent the flow regime that would have happened without any storage reservoirs.

- Current (red line)—Simulates current river operations as described in the *Interim Comprehensive Basin Operating Plan* (Reclamation, 2002).

- Integrated 70-percent (green line)—Simulates the combined effect of Bumping Lake enlargement, Wymer dam and reservoir, and Keechelus-to-Kachess pipeline alternatives with the existing irrigation system and operations.

The vertical lines on the hydrograph represent variations of flow from the 75th percentile (top of the line) to the 25th percentile (bottom of the line). For example, the median flow was 285 cfs for the natural (unregulated) scenario in October at Easton; the 75th-percentile flow was 450 cfs, and the 25th-percentile flow was 157 cfs. The 75th-percentile flow of 450 cfs means that for all the daily mean flows recorded in the month of October for the 23 year period of record, 75 percent of these daily mean flows were less than 450 cfs.

A reach-by-reach discussion of the differences in flow regimes between the current and integrated 70-percent scenarios follows.

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Easton, Yakima River (RM 202.0)
There was essentially no change in the flow regime between the integrated 70-percent and current scenarios for the Easton reach of the Yakima River (figure 15). The monthly median flows between the two scenarios were nearly identical, with differences only occurring in November, December and August, and never deviating more than ±50 cfs in monthly median flow. Similarly, there was no change in the eight qualitative hydrologic flow parameters for the integrated 70-percent scenario compared to the current scenario.

Desired improvements to the current operation to more closely mimic the natural (unregulated) hydrograph at the Easton reach would be:

- Spring peak flows of greater magnitude and, more importantly, better timing with the natural (unregulated) hydrograph, where flows begin to increase in April, peak in May, and decline in June.
- An increase in late fall and winter streamflows that allow for a more natural variation to the daily/weekly flows (opposed to a constant minimum flow).
- A decrease in summer flows.

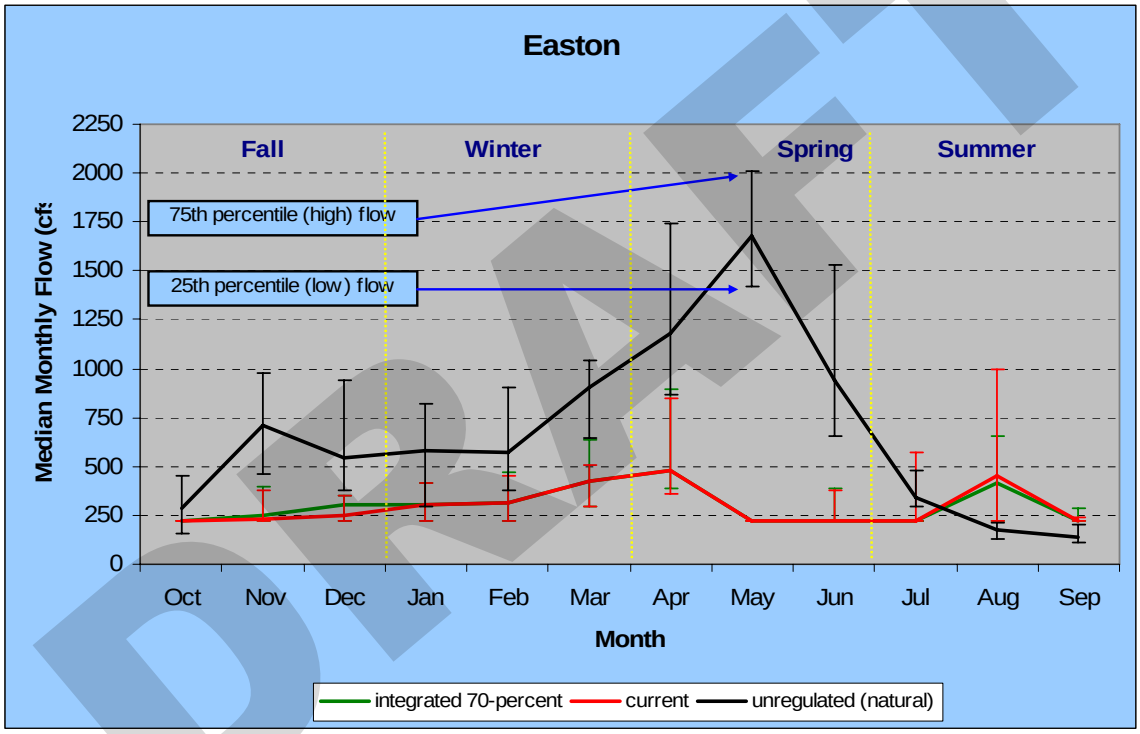

Figure 15. Representative Hydrograph at the Easton, Yakima River, Gauging Station (RM 202.0)

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Umtanum, Yakima River (RM 140.4)
There was no significant change in the flow regime between the current and integrated 70-percent operation scenarios (figure 16). The greatest percent difference for any given month between the two scenarios was -10.8% (-179 cfs) (February). The percent difference in monthly

median flows between the integrated 70-percent and current scenarios is as follows: April, -8.7%; May, +6.5%; and June, +2.8%. Late fall and winter flows for both scenarios are generally within the natural (unregulated) 25th and 75th percentile flow criteria.

However, both operations create flows that significantly deviate from the natural (unregulated) hydrograph during the months of April, May, July, and August. The April-May deviation is due to filling the reservoirs (mainly Cle Elum) to full capacity during the snowmelt period. The July-August deviation is due to transporting irrigation water from Cle Elum Lake via the Yakima River to entities in the middle Yakima basin during the peak irrigation season. The integrated operation does not alleviate or significantly modify the operation that presently exists. The percent change in flow from August to September was -63.4% for the current operations scenario, and -60.7% for the integrated 70-percent operation scenario.

Desired improvements to the current operation to more closely mimic the natural (unregulated) hydrograph at the Umtanum reach would be:

- Timing that is more comparable to the natural (unregulated) hydrograph, meaning flows begin to increase in April, peak in May, and decline in June, with a somewhat greater flow magnitude in April and May.

- Reduced summer flows, especially in July and August that mimic closer to unregulated (natural) summer flow regime, and the elimination or significant reduction in the flip-flop operation.

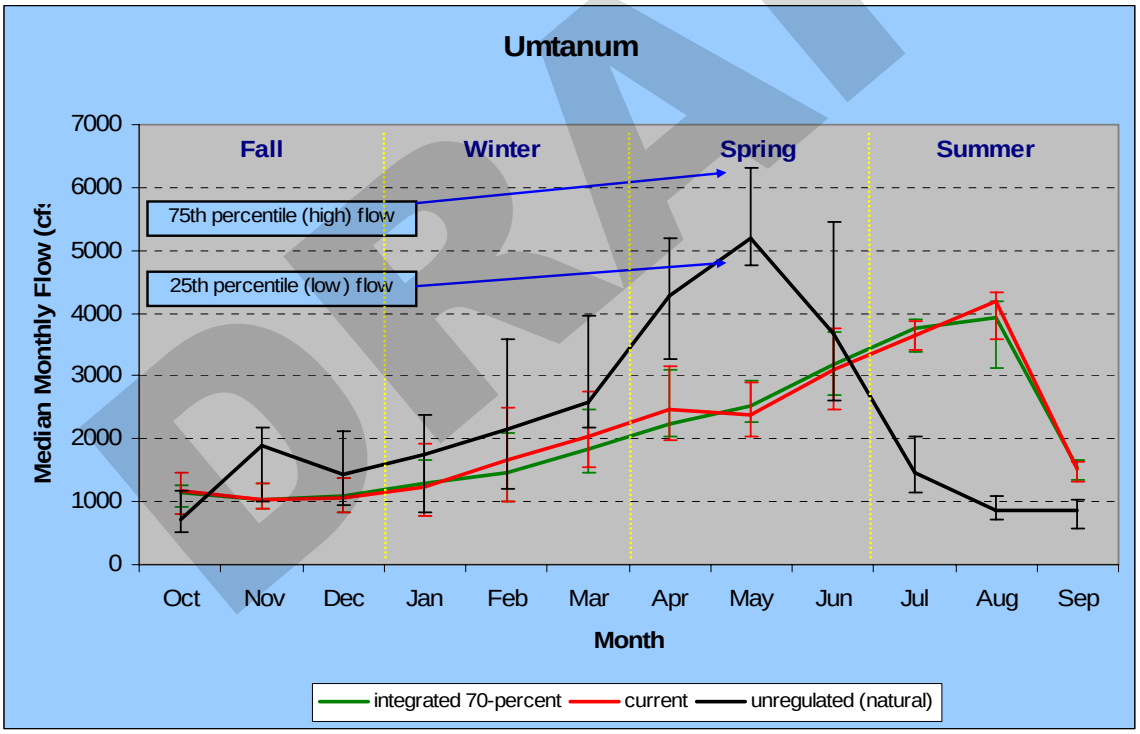

Figure 16. Representative Hydrograph at the Umtanum, Yakima River, Gauging Station (RM 140.4)

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Bumping Dam Outlet, Bumping River (RM 17.0).
The current operation of the Bumping River mimics the natural (unregulated) hydrograph, with the exception of late summer flows (figure 17). The small capacity of the reservoir (33,700 acre-feet) allows the majority of flow in the Bumping River to pass in an unregulated manner, especially during the snowmelt period. In contrast, the integrated 70-percent operation scenario reduced spring flows in May -45.0% (-113 cfs) and June -65.9% (-365 cfs) and winter flows in January -12.8% (-20 cfs), and March -23.3% (-40 cfs) from the current operation. These reductions move the peak flow period to July and August instead of May and June. These reductions in winter and spring flows and the change in timing of the peak flows are due to water being stored in the larger reservoir.

The integrated 70-percent scenario August median flows increased 120.3% (264 cfs) and September median flows increased 85.0% (111 cfs) compared to the current scenario. The reason for increased summer flows is because additional stored water is available to meet irrigation demand in the lower basin, especially in water short years.

It should be noted that changes in the flows in the Bumping River will change flows at all locations below on the Naches and Yakima Rivers.

Desired improvements to the current operation to more closely mimic the natural (unregulated) hydrograph at the Bumping reach would be:

- Reduced summer flows, especially in July, August and September.

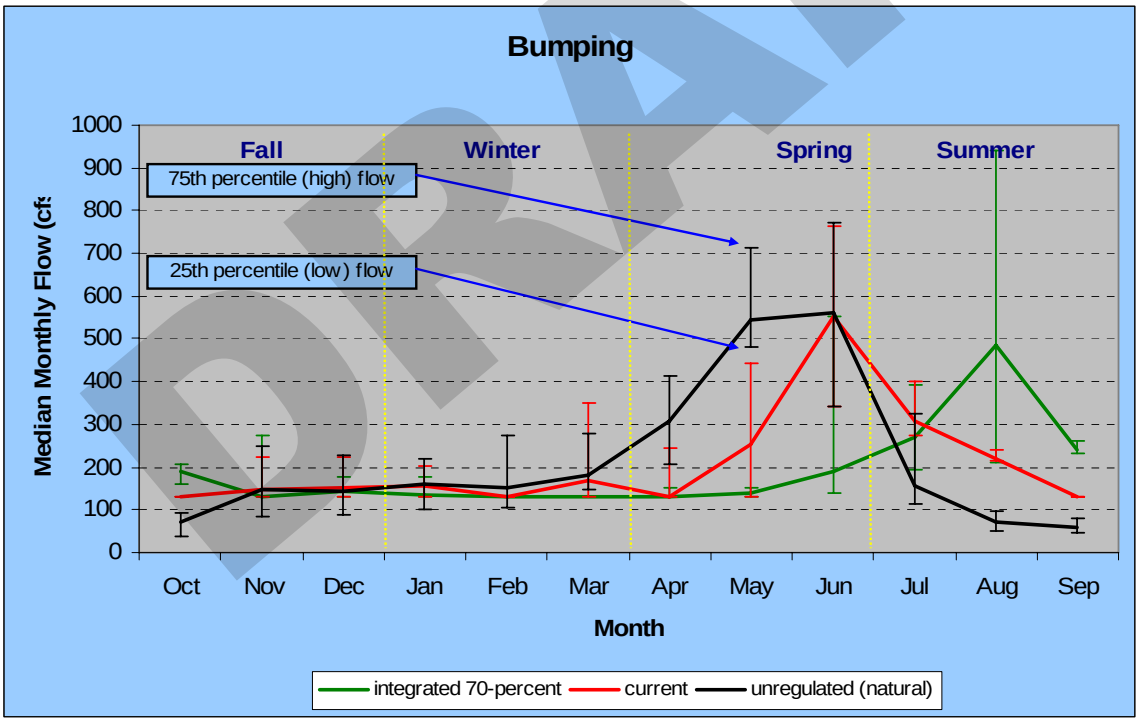

Figure 17. Representative Hydrograph at the Bumping Dam Outlet, Bumping River (RM 17.0)

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Naches @ Naches River (RM 16.8).
The current operation scenario flow regime mimics the unregulated (natural) flow regime in the lower Naches Reach with the exception of August and September flows (figure 18). The integrated 70-percent scenario decreased spring flows in April: -1.9% (-34 cfs); May: -11.7% (-265 cfs); and June: -11.4% (-287 cfs) relative to the current operation scenario.

The integrated 70-percent scenario increased summer and fall flows in July: +12.9% (+150 cfs); August: +115.1% (+557 cfs); September: +8.7% (+157 cfs); and October: +53.4% (+315 cfs) relative to the current operation scenario. As previously mentioned for the Bumping River, the increase in summer flows is due to using the additional storage capacity in Bumping Lake Reservoir to meet irrigation demand in the lower basin, especially in water short years.

In August and September, the integrated 70-percent operation scenario changes the median monthly flows less than the current operation. This is based on the percent change in flows from August to September. The August to September flows increased 264% (484 cfs to 1760 cfs) for the current operation scenario, while the flows increased 84% (1041 cfs to 1914 cfs) for the integrated 70-percent scenario.

Desired improvements to the current operation to more closely mimic the natural (unregulated) hydrograph at the Lower Naches reach would be:

- Reduced summer flows in September to eliminate or significantly reduce the flip-flop operation.

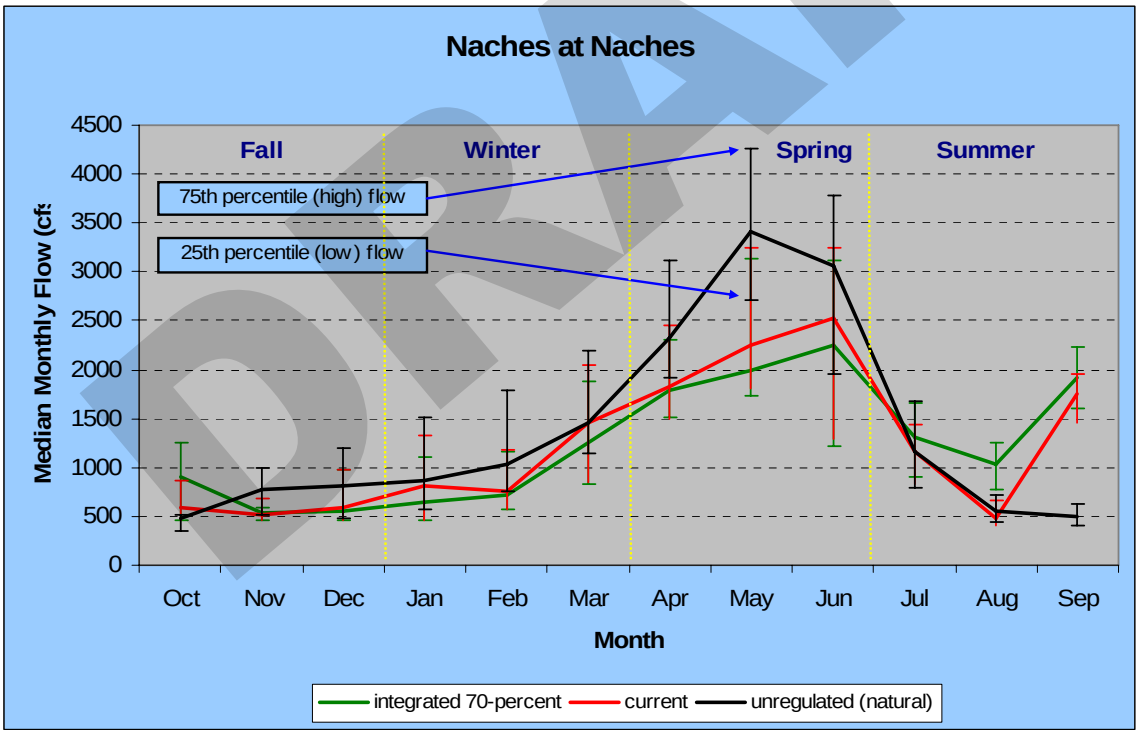

Figure 18. Representative Hydrograph at the Naches @ Naches River Gauging Station (RM 16.8)

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Parker, Yakima River (RM108.7).
There was minimal difference in the flow regime between the integrated 70-percent and current operation scenarios for all seasons (figure 19). Both mimic the natural (unregulated) fall and winter flow regime pattern.

The spring and summer flow magnitudes are less than the natural (unregulated) flows for both the integrated 70-percent and current scenarios. The monthly median flow was reduced -2.8% (17cfs) in May and -35.7% (480 cfs) in June compared to the current operation. For both scenarios, peak flows occur in March at a reduced magnitude and steadily decline April through June, instead of peaking in May with much higher flows in April and June as in the natural (unregulated) scenario.

Summer (July-September) median flows do increase from an average of 313 cfs to 616 cfs (+96%) for the integrated 70-percent scenario compared to the current scenario. This increase is attributable to an average increase in the TWSA for the period of record, which increases the Title XII flows at Parker.

Desired improvements to the current operation to more closely mimic the natural (unregulated) hydrograph at the Parker reach would be:

- Improved timing in the spring seasonal flows, as well as increasing the flow magnitude.
- Increasing the magnitude of the summer seasonal flows.

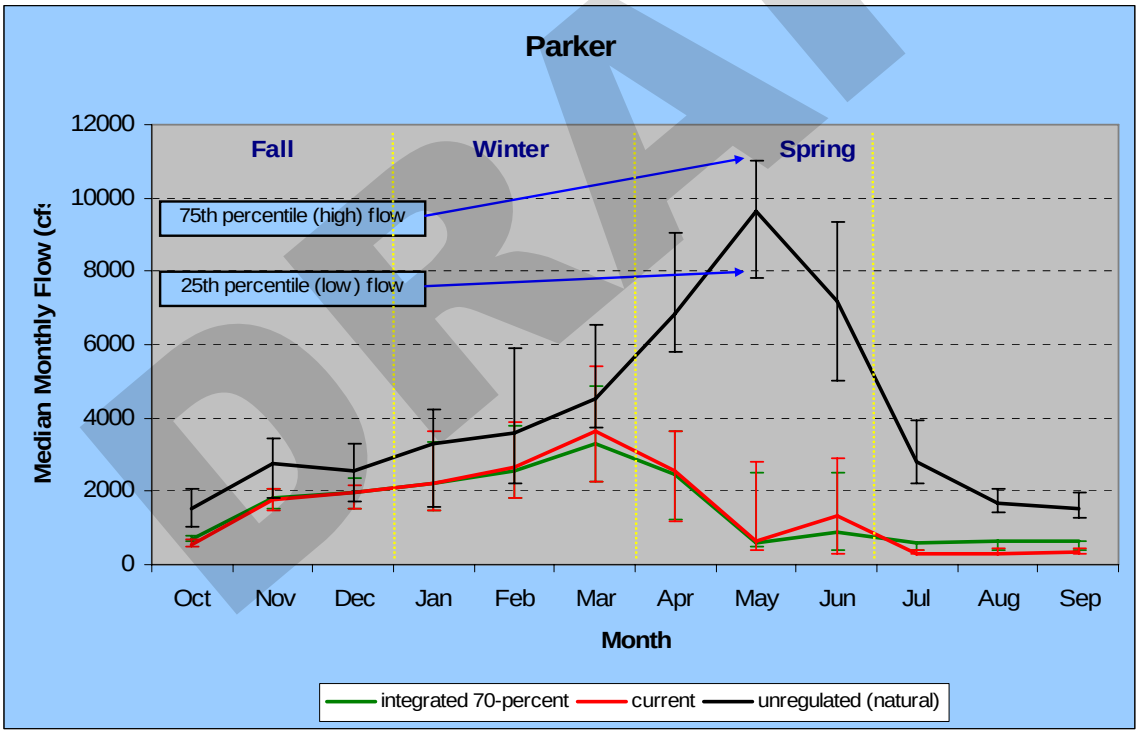

Figure 19. Representative Hydrograph at the Parker, Yakima River, Gauging Station (RM 108.7)

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Hydrologic Flow Parameters.
The information presented in table 14 is derived from the Indicator of Hydrologic Alterations (IHA) model.[8] The IHA model has been used throughout the United States to evaluate river operations and impacts on the riverine ecosystem. The IHA model generates a set of descriptive flow statistics that describe the flow conditions of a particular scenario relative to the natural (unregulated) condition. The IHA model is a diagnostic tool that analyzes which flow parameters are within, or out of, criteria, compared to the natural (unregulated) condition.

Reclamation took the results of the IHA model, compiled it into eight hydrologic flow parameters (similar to IHA parameters), and separated them into three groups. These eight parameters were used in table 14 to show the relative effects of the integrated 70-percent operation scenario compared to current operations. The parameters and groups are shown below.

Group I - - Seasonal Magnitude.
The IHA model evaluates three flow ranges: middle flows ($\geq 25^{th}$ and $\leq 75^{th}$ percentile of occurrence); high flows ($>75^{th}$ percentile of occurrence); and low flows ($<25^{th}$ percentile of occurrence) for a particular scenario relative to the natural (unregulated) condition. This comparison was conducted for each month. In Group I, there are 36 monthly flow parameters and 3 flow ranges for each month (12). These 36 monthly flow parameters were then organized by season; defined as follows: spring (April, May, June); summer (July, August, September); fall (October, November, December); and winter (January, February, March).

Reclamation used the IHA model to compare each of the 36 integrated 70-percent operation scenario monthly flow parameters to the corresponding current operation scenario monthly flow parameters. Reclamation then recorded whether each integrated 70-percent monthly flow parameter was better, worse, or showed no change relative to the corresponding current operation scenario monthly flow parameter. The results were summarized for each season and expressed as a percent of the number of monthly flow parameters that were better, worse, or no change, relative to the current operation scenario.

The "better," "worse," and "no change" categories for Group I and Group II shown in table 14 refers to the comparison of integrated 70-percent operation scenario flow parameters to the current operation scenario. The question being addressed is, "Did flow parameter X get better, worse, or didn't change for the integrated 70-percent operation scenario, compared to the current operation scenario?"

Group II - - Magnitude-Duration.
Group II consists of 30 flow parameters, 15 for the minimum flow parameter, and 15 for the maximum flow parameter. Each minimum and maximum flow parameter is organized into the three IHA flow ranges: middle; high; and low, based on the percentile of occurrence as described above for the Seasonal Magnitude flow parameter. Thus, Group II is made up of six groups (i.e., minimum-IHA middle flow range, minimum-IHA high flow range, minimum-IHA low flow range; and maximum-IHA middle flow range, maximum-IHA high flow range, maximum-IHA low flow range) with five streamflow durations—1-day, 3-day, 7-day, 30-day,

[8] The Nature Conservancy developed the IHA software. The Nature Conservancy's website (http://www.freshwaters.org/tools) provides a download of the software and supporting documents.

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and 90-day. For example, within water year 1984, the model will calculate which 30-day period resulted in the highest or lowest average streamflow. There is no time element associated with these two parameters, meaning it is not known when this event occurred during the water year.

The analysis was conducted similar to that described for Group I, meaning each of the 30 integrated 70-percent operation scenario flow parameters was compared to the corresponding current operation scenario flow parameter. Results from the 30 comparisons were recorded as "better," "worse," or "no change." The results were summarized for the Minimum and Maximum flow parameters and expressed as a percentage in the better, worse, and no change categories.

Group III - - Peak and Base Flow Timing.
The Peak Flow and Base Flow parameters define Group III. The peak and base flows periods are defined by the natural (unregulated) peak and base flows. Peak and base flow timing was analyzed in two steps. Step one determined how many months did peak or base flows occur within the natural (unregulated) defined peak and base flow period. This was summarized in table 14, under Group III, for both the current operation and the integrated 70-percent operation scenarios. For example, the first occurrence in table 14 is for the Bumping gauge, for the Peak Flow parameter for the current operation scenario which reads, "2 of 3." This means for the current operation scenario, two out of a possible three months coincided with the natural (unregulated) peak flow period (April, May and June). The second step compares the Peak and Base Flow parameters between the current operation and integrated 70-percent operation scenarios for each gauge station. In the previous example, the current operation produced peak flows in 2 out of 3 months (i.e., "2 of 3"). The integrated 70-percent operation scenario for the Peak Flow parameter for the Bumping gauge station did not produce any peak flows in that period, which reads "0 of 3." This means that none of the integrated 70-percent operation scenario peak flow months coincided with the natural (unregulated) peak flow period. Therefore, compared to the current operation scenario, the integrated 70-percent operation scenario had two fewer months that coincided with the natural (unregulated) peak flow period. This results in a "worse" rating for this particular item.

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Table 14. Summary of Hydrologic Flow Parameter Comparison Between the Current and Integrated 70-Percent Scenarios for the Bumping, Naches at Naches, Easton, Umtanum, and Parker Gauge Stations

			Bumping	Naches at Naches	Easton	Umtanum	Parker
	Hydrologic Parameters	**Change Category**	**Change in Scores**	**Change in Scores**	**Change in Scores**	**Change in Scores**	**Change in Scores**
Group I	**Seasonal Magnitude Parameters**						
	Spring (Apr-Jun)	Better	0.0%	22.2%	44.4%	22.2%	0.0%
		No change	0.0%	55.5%	55.5%	55.5%	77.8%
		Worse	100.0%	22.2%	0.0%	22.2%	22.2%
	Summer (Jul-Sep)	Better	11.1%	22.2%	11.1%	0.0%	0.0%
		No change	77.7%	33.3%	78.8%	77.8%	100.0%
		Worse	11.1%	44.4%	11.1%	22.2%	0.0%
	Fall (Oct-Dec)	Better	0.0%	33.3%	11.1%	22.2%	22.2%
		No change	33.3%	44.4%	78.8%	66.7%	77.8%
		Worse	66.7%	22.2%	11.1%	11.1%	0.0%
	Winter (Jan-Mar)	Better	0.0%	0,0%	33.3%	22.2%	0.0%
		No change	0.0%	55.5%	67.7%	55.5%	77.8%
		Worse	100.0%	44.4%	0.0%	22.2%	22.2%
Group II	**Magnitude/Duration Parameters**						
	Minimum Flows	Better	0.0%	40.0%	0,0%	0.0%	0.0%
		No change	6.6%	26.7%	86.7%	47.0%	100.0%
		Worse	93.3%	33.3%	13.3%	53.0%	0.0%
	Maximum Flows	Better	46.6%	6.7%	26.7%	6.7%	13.3%
		No change	6.6%	0.0%	73.3%	73.3%	33.3%
		Worse	46.6%	93.3%	0.0%	20.0%	53.3%
Conclusion			**Worse**	**Worse**	**No change**	**No change**	**No change**
Group III	**Peak & Base Flow Timing Parameters**						
	Peak Flow (typically Apr-Jun)	Current: Number of months within unregulated peak flow period	2 of 3	3 of 3	1 of 3	1 of 3	1 of 3
		Integrated 70%: Number of months within unregulated base flow period	0 of 3	3 of 3	1 of 3	1 of 3	1 of 3
		Net Change in Peak Month Timing	-2	0	0	0	0
	Base Flow (typically Aug-Oct)	Current: Number of months within unregulated peak flow period	2 of 3	1 of 3	1 of 3	1 of 3	2 of 3
		Integrated 70%: Number of months within unregulated base flow period	0 of 3	0 of 3	1 of 3	1 of 3	2 of 3
		Net Change in Base Month Timing	-2	-1	0	0	0
Reach Summary Conclusion			**Worse**	**Worse**	**No change**	**No change**	**No change**

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The integrated 70-percent operation scenario shows no significant change in the flow regime of the Yakima River mainstem. In addition, the integrated 70-percent operation scenario moves the mainstem Naches and Bumping River flow regimes further away from a normative flow condition compared to the current operations.

Municipal Water Supply

The *Watershed Management Plan* indicates an additional 30,000 acre-feet will be needed for future (year 2020) municipal surface water needs in the Yakima basin. Currently, the cities of Cle Elum, Ellensburg, and Yakima are the major municipal water diverters.

Since the municipal surface water demand, by scale, is less in comparison to irrigation and instream flow use, the estimated increase in demand has not been included in the operation studies at this time. Future study would consider the needs, benefits, and allocation (water rights) to meet population growth if these Yakima basin storage alternatives proceed to the next phase of the Storage Study.

- END OF DOCUMENT -

DRAFT

United States Department of the Interior
BUREAU OF RECLAMATION
Upper Columbia Area Office
1917 Marsh Road
Yakima, Washington 98901-2058

TAKE PRIDE IN AMERICA

IN REPLY REFER TO:

UCA-1120
PRJ-1.10

MAR 14 2006

Mr. Louis Cloud
Chairman
Yakama Nation Tribal Council
P.O. Box 151
Toppenish WA 98948

Subject: Technical Information and Hydrologic Analysis for Yakima River Basin Alternatives for the Yakima River Basin Water Storage Feasibility Study

Dear Mr. Cloud:

On January 19, 2006, we sent for your review and consideration technical information of our hydrologic analysis of the three Yakima River basin storage alternatives (Bumping Lake enlargement, Wymer dam and reservoir, and Keechelus-to-Kachess pipeline) being considered in the Yakima River Basin Water Storage Feasibility Study (Storage Study). Subsequently, we met with stakeholders (Yakima Basin Joint Board, the Yakima System Operating Advisory Committee, the Yakima Basin Storage Alliance, the Washington Department of Fish and Wildlife, and the National Marine Fisheries Service) during February 3-17, 2006, to discuss this information and to obtain input to assist us in determining the Yakima River basin storage alternatives to include in the Plan Formulation Phase of the Storage Study.

The hydrologic analysis indicates that the three Yakima basin alternatives, operated in conjunction with the existing Yakima Project, would be able to supply 70 percent of the proratable (junior) irrigation water rights in dry years, except in the 1994 drought, when 66 percent of the proratable water rights would be available. The hydrologic analysis also indicates the flow regime of the Yakima and Naches Rivers is not moved in the direction of the natural (unregulated) hydrograph. The natural (unregulated) hydrograph is the template currently being used to evaluate the instream flow water supply goal. In the hydrologic analysis, we have assumed that the municipal water supply goal is achieved by these three alternatives. Additional work on the future municipal water supply needs will occur in the Plan Formulation Phase.

Our analysis showed that the current operational hydrograph of the Bumping and Naches Rivers mimics the shape of the natural (unregulated) hydrograph, and constructing a new larger Bumping Lake dam would move the flow regime even further from the natural (unregulated) hydrograph. In addition, a stakeholder pointed out that the potential new reservoir would inundate some bull trout spawning habitat on Deep Creek and about 1 mile of stream habitat in

the Bumping River. Stakeholders indicated they did not think that Reclamation should consider the enlarged Bumping Lake in the Plan Formulation Phase of the Storage Study.

The integrated hydrologic analysis showed that constructing the Wymer dam and reservoir would not move the hydrograph in the Yakima River toward a natural (unregulated) hydrograph, but would help meet the Title XII target flows at the Parker gauge. Most of the stakeholders expressed the desire to analyze the Wymer reservoir feature again with different parameters to determine if there would be benefits to the fishery that may not be apparent using the natural (unregulated) hydrograph measurement of the benefit.

The modeling Reclamation has done on the Keechelus-to-Kachess pipeline indicates that the additional stored water supply would be negligible.

We heard concerns that the parameters used to indicate whether an alternative creates a return to a more natural (unregulated) hydrograph need to be better defined. For this phase of the Storage Study, those parameters are measured on a broad scale using average annual flows over a 23-year period. The concern was that this broad scale method of measuring parameters will not provide an accurate measurement of benefits to the threatened and endangered fishery in the Yakima River.

We will consider all the concerns we heard as we decide which alternatives should be analyzed in the Plan Formulation Phase of the Storage Study. We will continue to accept comments and or suggestions on this hydrologic analysis. The *Yakima River Basin Storage Alternatives Appraisal Assessment* is due to be released later this spring and will contain our recommendations on which, if any, of these three alternatives will be included in the Plan Formulation Phase of the Storage Study.

If you have any questions or comments, please contact Mr. Kim McCartney at 509-575-5848, extension 370, or at the address above. We are still available and willing to provide the stakeholder groups listed in this letter a presentation on the Hydrologic Analysis and answer any questions.

Sincerely,

/s/ Gerald Kelso

Gerald W. Kelso
Area Manager

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