Yakima River Basin Integrated Water Resource Management Plan

Technical Memorandum:

Hydrologic Modeling of Winter Streamflows and Kachess Inactive Storage Tunnel Alternative

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

Prepared by

HDR Engineering, Inc. Anchor QEA



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



State of Washington Department of Ecology Office of Columbia River

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Contents

1.0	Intr	oduction	1				
2.0	Use of Initial Conserved Water to Increase Winter Instream Flows						
	2.1	Instream Flow Modeling Approach and Assumptions	3				
	2.2	Instream Flow Modeling Results	4				
3.0	Ability to Meet KRD Needs with Kachess Inactive Storage Tunnel Alternative						
	3.1	Kachess Tunnel Modeling Approach and Assumptions	12				
	3.2	Kachess Tunnel Modeling Results	13				
4.0	Refe	erences	18				
5.0	List of Preparers						

List of Tables

Table 1. Existing and Proposed Winter Instream Flows	3
Table 2. Summary of Winter Instream Flow Modeling Results	5
Table 3. Water Supply Effects of Increased Instream Flows	5
Table 4. Effects of Increased Instream Flows on Drought Year Reservoir Storage	6
Table 5. Kachess Inactive Tunnel and Revised Operations - Water Supply Results	.14

List of Figures

Figure 1.	Yakima River System in Area of Analysis	.2
Figure 2.	Flow versus Exceedance Curve – Cle Elum River	.7
Figure 3.	Flow versus Exceedance Curve – Tieton River	.7
Figure 4.	Flow versus Exceedance Curve – Yakima River, Keechelus Reach	8
Figure 5.	Drought Year Flow and Reservoir Storage - Cle Elum River and Reservoir	9
Figure 6.	Drought Year Flow and Reservoir Storage - Tieton River and Rimrock Reservoir1	0
Figure 7.	Drought Year Flow and Reservoir Storage - Tieton River and Rimrock Reservoir1	1
Figure 8.	Effects of Kachess Tunnel Option and Revised Operations on KRD Deliveries1	5
Figure 9.	Effects of Kachess Inactive Tunnel and Revised Operations on Flow in the Keechelus	
Reach (Dr	ought Years 1992, 1993, 1994)1	6
Figure 10	. Effects of Kachess Inactive Tunnel and Revised Operations on Flow in the Keechelus	5
Reach (Dr	ought Years 2001, 2004, 2005)1	7

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1.0 Introduction

This technical memorandum summarizes the methods, assumptions and results of a hydrologic analysis of streamflows in the Yakima River water supply system in central Washington. This analysis was completed by HDR Engineering, Inc. to support discussions by the U.S. Bureau of Reclamation, Washington State Department of Ecology, and a stakeholder group that was convened to examine operational issues under the proposed Yakima River Basin Integrated Water Resource Management Plan (Integrated Plan).

The goals of the Integrated Plan are to protect, mitigate and enhance fish and wildlife habitat; provide increased operational flexibility to manage instream flows to meet ecological objectives; and improve the reliability of the water supply for irrigation, municipal supply and domestic uses (Reclamation and Ecology, 2012).

This technical memorandum focuses on hydrologic analyses of two specific issues:

- Potential to increase winter instream flows below reservoirs using conserved irrigation water
- Ability to meet water needs of the Kittitas Reclamation District (KRD) during periods when Kachess Reservoir is drawn down below the inactive storage level under the tunnel alternative for the proposed Kachess Inactive Storage Project

A hydrologic model developed by Reclamation using RiverWare software from the Center for Advanced Decision Support for Water and Environmental Systems was used to evaluate these issues. Features of the water supply system in the area of these analyses are shown in Figure 1.



Figure 1. Yakima River System in Area of Analysis

2.0 Use of Initial Conserved Water to Increase Winter Instream Flows

Approximately 30,000 acre-feet of irrigation water has been conserved by the Benton and Sunnyside Valley irrigation districts. Staff from the National Marine Fisheries Service and other resource agencies requested information on whether this conserved water could be used before construction of the physical features proposed in the Integrated Plan to increase winter instream flows in certain critical reaches without adversely impacting the reliability of water supply deliveries. The table below summarizes the reaches that were evaluated, the existing winter instream flows, and proposed increases in instream flows.

Reach Evaluated	Existing Winter Instream Flow (cfs) ¹	Proposed Winter Instream Flow (cfs)
Cle Elum River	220	300 (baseflow)
Yakima River – Keechelus Reach	100	120 (baseflow)
Tieton River	75	125 (baseflow)
All Three Reaches Combined	Simultaneous achievement	Simultaneous achievement
	of values above	of values above

Table 1. Existing and Proposed Winter Instream Flows

cfs = cubic feet per second

2.1 Instream Flow Modeling Approach and Assumptions

To estimate the system's ability to meet the increased instream flows without adversely impacting water supply deliveries it was first necessary to develop an existing-conditions model of the Yakima Basin. This was accomplished by modifying the Integrated Plan version of the Yakima River Basin RiverWare model to turn off all of the elements that are not currently constructed. These include:

- Keechelus to Kachess Pipeline
- Kachess Inactive Storage
- Cle Elum Dam Raise
- Wymer Off-stream Storage
- Bumping Lake Reservoir Enlargement
- Groundwater Infiltration
- Water Conservation

This existing-conditions model was then run to develop a set of baseline results representative of current water delivery and instream flow conditions. It was then modified to include 30,000 acre-

¹ Existing target flows for Cle Elum range from 180 to 240 cfs, but the model only considers 180 to 220 cfs. Target flow at Keechelus is between 80 and 100 cfs, but can vary to higher levels to meet the target flow at Easton. The 50 to 100 cfs target for the Tieton is a very recent development. It has historically been 50 cfs. Flows here can go higher, to meet the Naches target flow.

feet of water conservation in Benton and Sunnyside Valley irrigation districts and increased winter instream flow requirements at the three reaches listed above.

The model was run to simulate these changes separately for each reach and for all three at the same time. It was assumed that water saved through the conservation projects would be used to satisfy winter flows. The model's summer flow targets at the Parker stream gage were not increased commensurate with water savings, even though this is how the system is currently managed (the Parker gage is a key control point for Yakima River operations). Conserved water was used instead to meet winter instream flow targets.

In initial simulations, the increased winter instream flows were turned off during critical drought years. In subsequent runs, it was found that this did not significantly affect the water supply results, so the instream flows were left on throughout the simulation period. The increased instream flows did have an effect on the beginning of irrigation season storage in the reservoirs, particularly in drought years. This is summarized in Table 4, below. On April 1 of drought years 1994, 2001, and 2005, storage in each of the reservoirs that are used to satisfy the higher instream flows are lower. This reflects a decreased available water supply for that irrigation season. At the end of the irrigation season, the storage volumes are essentially the same, because all of the storage has been utilized, and the reservoirs are essentially empty.

2.2 Instream Flow Modeling Results

In general, the model shows that the Yakima system is able to distinctly improve the percentage of time that instream flows are satisfied without significant impacts on water supply conditions in most years. Prorationing² is decreased by 1 or 2 percent on average. In critically dry years, the reservoir storage available at the start of the irrigation season is lower, resulting in reduced deliveries to prorated water users. Prorationing is decreased by between 2 and 4 percent. Flow at Parker increases by less than 1 percent on average, and by about 6 percent in a drought year. The increased instream flows are not met in all drought years, because the reservoirs ran out of water at the end of the water year, after which the releases were equal to inflows until inflow increased (usually in November). The increased flow targets are satisfied 85 to 95 percent of the time without increasing the percentage of time that the existing instream flows are met. These results are summarized in Tables 1 through 4 below and in Figures 2 through 7.

These results reflect the condition where none of the physical improvements from the Integrated Plan have been constructed. Additional hydrologic modeling would be needed to evaluate the effects of phased development of the Integrated Plan on instream flows and water supply reliability.

² Under dry-year conditions, certain water users may receive reduced (prorated) supplies. A lower prorationing percentage indicates less water is available to those users. The Integrated Plan establishes a goal that prorationing will not fall below 70%.

Scopario	Percent o	f Time Target Flow Equaled	or Exceeded
Scenario	Cle Elum River (300 cfs)	Tieton River (125 cfs)	Keechelus Reach (120 cfs)
Existing	38.7	57.4	45.1
Cle Elum	90.0	57.6	44.9
Tieton	39.3	95.5	45.4
Keechelus	38.8	57.3	87.1
Combined	89.0	95.2	87.0

Table 2. Summary of Winter Instream Flow Modeling Results

cfs = cubic feet per second

Table 3. Water Supply Effects of Increased Instream Flows

Hydrologic Indicator	Existing Existing with Combined Proposed Instream Flows					WS				
	Average 1981-2005	Drought Year 1994	Drought Year 2001	Drought Year 2005	Wet Year 1997	Average 1981-2005	Drought Year 1994	Drought Year 2001	Drought Year 2005	Wet Year 1997
April 1 TWSA (maf)	2.77	1.74	1.72	1.69	4.50	2.73	1.71	1.67	1.62	4.49
April-September flow volume at Parker gage (kaf)	584	272	214	213	1,853	588	284	228	221	1,867
March-October flow volume at Parker gage (kaf)	867	408	331	317	2,492	877	432	353	333	2,474
April-September diversion volume upstream of Parker gage (maf)	1.68	1.28	1.31	1.29	1.80	1.64	1.25	1.26	1.23	1.78
September 30 non- Bumping or Wymer reservoir contents (kaf)	192	39	43	46	482	184	40	46	46	479
October 31 non- Bumping or Wymer reservoir contents (kaf)	186	64	64	50	588	177	64	66	51	579
September 30 Bumping and Wymer reservoir contents (kaf)	14	5	6	9	18	13	5	6	10	18
April-September flow volume at mouth of Yakima River (kaf)	851	367	288	322	2,182	854	380	301	328	2,195
Irrigation proration level	79%	21%	29%	27%	100%	77%	19%	25%	23%	100%

TWSA = Total Water Supply Available Maf = million acre-feet

Kaf = thousand acre feet

Difference* in Reservoir Storage at Beginning and End of Irrigation Season for Existing and Early Action ISF Simulations (acre-feet)							
	1994 Wa	ater Year	2001 Wa	iter Year	2005 Water Year		
	April 1	October 1	April 1	October 1	April 1	October 1	
Difference in Cle Elum Reservoir Storage	-9,365	739	-32,010	-420	-25,441	176	
Difference in Rimrock Reservoir Storage	-8,251	0	-10,904	0	-23,552	-13	
Difference in Keechelus Reservoir Storage	-8,425	81	-4,897	337	-13,461	62	
Difference in Total of All Reservoirs Storage	-26,193	1,157	-43,743	2,807	-62,516	866	

Table 4. Effects of Increased Instream Flows on Drought Year Reservoir Storage

*Difference is ISF storage minus Existing storage



Figure 2. Flow versus Exceedance Curve – Cle Elum River



Figure 3. Flow versus Exceedance Curve – Tieton River



Figure 4. Flow versus Exceedance Curve – Yakima River, Keechelus Reach





Slot: Tieton 20_8 below Tieton DamGage Outflow







Figure 6. Drought Year Flow and Reservoir Storage – Tieton River and Rimrock Reservoir







Figure 7. Drought Year Flow and Reservoir Storage – Tieton River and Rimrock Reservoir

3.0 Ability to Meet KRD Needs with Kachess Inactive Storage Tunnel Alternative

One of the projects in the Integrated Plan is designed to provide access to storage capacity in Kachess Reservoir that is inaccessible using the existing Kachess Dam outlet works. This project has two alternatives: a Pump Station Alternative and Tunnel Alternative. System performance under the Integrated Plan was initially evaluated under the Pump Station Alternative, which assumed the Kachess Inactive Storage Project would use a 1,200-cfs pump station to release water when the reservoir was at or below the current inactive storage level. The Tunnel Alternative was not evaluated at that time using RiverWare modeling.

The Tunnel Alternative would deliver water into the Yakima River downstream from the KRD diversion at Lake Easton. Therefore, in order to supply water to meet KRD demands when Kachess Reservoir is at or below the inactive storage level, Reclamation would need to release water from Keechelus Reservoir upstream from Lake Easton, rather than from Kachess Reservoir. A brief modeling evaluation of the Tunnel Alternative estimated the effects on instream flow in the Keechelus Reach and on water supply reliability for KRD.

3.1 Kachess Tunnel Modeling Approach and Assumptions

The Integrated Plan RiverWare Model was modified to simulate release of water through a gravity-flow tunnel when Kachess Reservoir is drawn down below the inactive storage level. Releases through the tunnel were modeled with variable flow quantities based on the water level in Kachess Reservoir, with water released to a point on the Yakima River downstream from Lake Easton. Various operational changes were implemented in the model to maintain enough water in Keechelus Reservoir during drought years to supply KRD demand at the Lake Easton diversion. These included:

- Keechelus Reservoir does not participate in mini flip-flop³ operations during drought years.
- Keechelus is used to supply KRD demands and minimum instream flows below Lake Easton during drought years.
- Kachess Reservoir is used in mini flip-lop operations for irrigation supply.
- Water transferred from Keechelus Reservoir to Kachess Reservoir through the Keechelus-to-Kachess (K-to-K) Tunnel is shut down during drought years unless excess supply is spilled from Keechelus Reservoir.
- In drought years, Kachess Reservoir will supply the full demand to KRD and other irrigation systems as long as active pool water is available in this reservoir.
- Once Kachess Reservoir reaches inactive storage level, Keechelus must supply the full KRD demand and minimum flow at Lake Easton.

³ The mini flip flop is an operational practice that involves reducing high flows in the Keechelus reach by conveying water in the K to K Pipeline and releasing water from Kachess Reservoir to meet demands below Easton and from July to the end of the irrigation season.

The model years where Keechelus Reservoir is operated according to these operational assumptions are 1992 to 1994, 2001, and 2004 to 2005.

3.2 Kachess Tunnel Modeling Results

The simulation model results show that the revised operations of Keechelus Reservoir and the Kto-K Tunnel during drought years are able to match the Integrated Plan objectives for deliveries to KRD, except for deficiencies of up to 20,500 acre-feet in 2004 when water available from Keechelus Reservoir is exhausted in September. There are essentially no adverse impacts to water supply reliability elsewhere in the system.

From a fisheries perspective, the simulation indicates that the system can maintain the current minimum instream flow objectives in the Yakima River in the Keechelus-to-Easton diversion-dam reach. However, drought years will have much higher flows in the Keechelus Reach. Conversations with resource agencies indicate that these high, late summer flows could have negative impacts on fish spawning in the Keechelus Reach, forcing fish to spawn below Lake Easton.

It is also important to note that achieving these revised operational results will require forecasting of hydrologic conditions and implementation of revised operation over multiple years of drought. These revised operations may need to start when a minor drought occurs, in anticipation of further, sequential drought years. The results are summarized in Tables 4 and 5 and Figures 5 through 7.

Additional hydrologic modeling could be completed to evaluate the use of a Kachess Inactive Storage Tunnel outlet system. Other alternative operations may be employed to deliver KRD supplies with somewhat reduced late-summer releases from Keechelus Reservoir.

Hydrologic Indicator	Integrated Plan with Kachess Tunnel and Revised Operations					Integrated Plan				
	Average 1981-2005	Drought Year 1994	Drought Year 2001	Drought Year 2005	Wet Year 1997	Average 1981-2005	Drought Year 1994	Drought Year 2001	Drought Year 2005	Wet Year 1997
April 1 TWSA (maf)	3.02	2.29	2.46	2.37	4.73	3.00	2.22	2.45	2.32	4.73
April-September flow volume at Parker gage (kaf)	599	204	170	139	1,935	605	245	198	181	1,937
March-October flow volume at Parker gage (kaf)	900	356	305	262	2,636	907	400	335	310	2,638
April-September diversion volume upstream of Parker gage (maf)	1.70	1.53	1.55	1.53	1.73	1.69	1.52	1.55	1.53	1.73
September 30 non-Bumping or Wymer reservoir contents (kaf)	367	-21	106	71	709	348	-121	75	-19	709
October 31 non-Bumping or Wymer reservoir contents (kaf)	348	-6	107	69	803	329	-120	74	-26	802
September 30 Bumping and Wymer reservoir contents (kaf)	230	68	145	144	267	229	56	145	144	267
April-September flow volume at mouth of Yakima River (kaf)	862	306	246	253	2,260	867	349	272	293	2,262
Irrigation proration level	92%	70%	70%	70%	100%	92%	70%	70%	70%	100%

Table 5. Kachess Inactive Tunnel and Revised Operations - Water Supply Results

TWSA = Total Water Supply Available maf = million acre feet

kaf = thousand acre feet





Figure 8. Effects of Kachess Tunnel Option and Revised Operations on KRD Deliveries







Figure 9. Effects of Kachess Inactive Tunnel and Revised Operations on Flow in the Keechelus Reach (Drought Years 1992, 1993, 1994)







Figure 10. Effects of Kachess Inactive Tunnel and Revised Operations on Flow in the Keechelus Reach (Drought Years 2001, 2004, 2005)

4.0 References

Bureau of Reclamation and Washington State Department of Ecology (Reclamation and Ecology). 2012. *Yakima River Basin Integrated Water Resource Management Plan Framework for Implementation Report*. October 2012. U.S. Department of the Interior, Bureau of Reclamation, and Washington State Department of Ecology.

5.0 List of Preparers

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