RECLAMATION
Managing Water in the West

Bureau of Reclamation
Klamath Basin Area Office
Klamath Project Revised Water Management Procedure
Variable Base Flow Procedure

Introduction

Reclamation has developed the Variable Base Flow (VBF) procedure for the operations of the Klamath Project (Project) in order to comply with the requirements of the 2010 National Marine Fisheries Service (NMFS) biological opinion (BO), reasonable and prudent alternative (RPA), and Incidental Take Statement and associated Terms and Conditions. The VBF procedure was developed based on these objectives: (1) provide more certainty in obtaining minimum Upper Klamath Lake (UKL) elevations, as outline in Table 2-1 of the 2008 U.S. Fish and Wildlife Service (Service) BO (i.e. targeting UKL elevations for the end of September that will be greater than 4138 feet in most years, etc.); and (2) meet the needs of coho salmon through flows outlined in Table 18 of the 2010 NMFS BO and RPA. The following sections describe the elements of the VBF procedure in more detail.

Variable Base Flow Modeling Procedure: March through September Time Period

For March through May, an initial flow will be determined for each half month time period based on the most current 50% exceedance inflow forecast through September. For June through September, an initial flow will be determined based on the June 1st 50% exceedance inflow forecast through September. Table 1 relates forecasts from percent of average to flows in cubic-feet-per-second (cfs). These initial base flows for March through September will range between the 95% and 40% exceedance values from Table 18 in the 2010 NMFS RPA with the exception of June. In June the initial base flow will range between the 95% and 30% exceedance flows from Table 18 in the 2010 NMFS RPA.

Table 1: Forecast and VBF Table to Determine Base Flows in Each Time Step

Current Apr - Sept 50% Exceedance Forecast in March	**March I**	**March II**	**Current 50% Exceedance Forecast**	**April I**	**April II**	**May I**	**May II**	**June I**	**June II**	**July I**	**July II**	**August**	**September**
(% Average)	(cfs)	(cfs)	(% Average)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)
0%	1275	1275	0%	1325	1325	1175	1175	1025	1025	805	805	942	1000
43%	1275	1275	37%	1325	1325	1175	1175	1025	1025	805	805	942	1000
50%	1333	1333	47%	1383	1383	1255	1255	1099	1099	838	838	947	1000
53%	1392	1392	51%	1442	1442	1335	1335	1173	1173	872	872	952	1000
63%	1450	1450	56%	1500	1500	1415	1415	1246	1246	905	905	957	1000
71%	1567	1567	70%	1500	1500	1509	1509	1320	1320	925	925	964	1003
76%	1683	1683	73%	1500	1500	1603	1603	1379	1379	945	945	971	1006
80%	1905	1905	76%	1500	1500	1670	1670	1439	1439	973	973	984	1012
82%	2128	2128	78%	1500	1500	1736	1736	1498	1498	1001	1001	997	1018
90%	2350	2350	85%	1500	1500	1803	1803	1522	1522	1029	1029	1010	1024
97.0%	2510	2510	89%	1745	1745	1865	1865	1546	1546	1034	1034	1013	1029
97.5%	2670	2670	93%	1989	1989	1928	1928	1570	1570	1040	1040	1017	1034
103%	2830	2830	99%	2234	2234	1990	1990	1594	1594	1045	1045	1021	1038
107%	2990	2990	103%	2478	2478	2053	2053	1616	1616	1051	1051	1024	1043
113%	3150	3150	114%	2723	2723	2115	2115	1638	1638	1056	1056	1028	1048
119%	3164	3164	117%	2877	2877	2379	2379	1660	1660	1063	1063	1032	1054
124%	3177	3177	134%	3030	3030	2642	2642	1682	1682	1070	1070	1035	1060
128%	3346	3346	140%	3182	3182	2748	2748	1702	1702	1074	1074	1037	1064
139%	3516	3516	150%	3333	3333	2854	2854	1723	1723	1078	1078	1039	1067
151%	3685	3685	160%	3485	3485	2960	2960	1743	1743	1082	1082	1041	1071

As hydrological input into UKL occurs each month, additional releases may be made when UKL elevations are above identified Threshold Elevations. The Threshold Elevations for UKL were developed through an iterative process in order to approximate the 2010 NMFS RPA Table 18 flows, while maintaining the 2008 Service BO minimums for UKL more often. The threshold elevations are shown below in Table 2. Above these elevations, flows will be released to mimic the natural inflow pattern into UKL.

Table 2: Threshold Elevations for UKL

Time Period	Threshold Elevations for UKL (in feet)
October	4141.7
November	4141.7
December	4142.0
January	4142.3
February	4142.6
March I	4142.6
March II	4142.9
April I	4143.0
April II	4142.9
May I	4142.6
May II	4142.4
June I	4142.5
June II	4142.5
July I	4141.8
July II	4141.8
August	4141.0
September	4141.0

In periods when Threshold Releases are being made during March, April and May, a maximum flow release will be determined. Threshold Releases will not be increased above the maximum unless required for flood control. Therefore, the elevation of UKL will increase above the threshold elevations shown above if the flows at IGD are at the maximum flow. Maximum flows will be determined based on the current percent of average forecast shown in Table 3.

For example, if the May-September 50% exceedance inflow forecast is 134% of average, the maximum flow for May would be 3,480 cfs. If flows in May began to exceed this number while the lake was below the flood control limit of 4143.1 ft, then flows would be limited to 3,480 cfs in order to fill UKL. Once flows dropped below the maximum flow, the operations would return to normal as described above. If the forecast falls between two forecasts on Table 3, the maximum value will be interpolated. For example, if the March forecast was 115% of average, then the maximum would be 3,957 cfs.

Table 3: Forecast and Maximum Flows for March through May

	March	April	May
Current 50% Exceedance Forecast	Max Flow (cfs)	Max Flow (cfs)	Max Flow (cfs)
≤114%	3940	3930	3225
117%	3990	4065	3390
134%	4160	4230	3480
140%	4285	4425	3615
150%	4355	4585	3710
160+%	4460	4790	3845

The June 5% - 25% exceedance flows from Table 18 in the NMFS RPA increase rapidly from the 30% exceedance. Due to the unnatural curve of this increase and the significance of determining when flows above the 30% exceedance should occur, the timing of these higher flows will be determined through further discussions with representatives from Reclamation, the Service, NMFS and other key stakeholders. This team will determine when flows at or above the 25% exceedance would be warranted.

Variable Base Flow Modeling Procedure: October through February Time Period
For the October through February time period, the base flows will be equal to the 95% exceedance flows from Table 18 of the NMFS RPA. This time period includes the use of the 18.6 TAF of available water as required in RPA A.1of the 2010 NMFS BO/Incidental Take Statement for flow variability. The recommended use of this volume will be determined by the flow variability technical team.

Irrigation Demand
Annual irrigation demand and its monthly distribution are based on amount of precipitation experienced in specified months prior to the irrigation season (as shown in Table 4). These precipitation/annual demand relationships are shown below in Table 4. However, irrigation deliveries are determined by the actual available water, and can be lower than the demand.

When determining the amount of water that is expected to be available for the irrigation season, the planning model considers the water necessary to meet the 95% exceedance flows from Table 18 in NMFS' RPA and the end-of-September storage corresponding to the minimum Upper Klamath Lake elevation from the 2008 Service BO.

If the amount of water available to irrigation is less than the expected full irrigation demand, then the deliveries are reduced through the application of a "delivery factor" – a value between 0.0 and 1.0. A target delivery is calculated as the product of the delivery factor and the demand, allowing the target delivery to match the expected available water. The delivery factor calculation is updated each month. For example, in April, the delivery factor is calculated based on the April through September forecast, the 95% exceedance flows for April through September, and the minimum UKL elevation for September. In June, the calculation would change to be based on the expected June through September inflow forecast, the 95% exceedance flows for June through September, and the minimum UKL elevation for September.

If the timing of any time-step's water supply cannot meet the target delivery that is calculated from the seasonal delivery factor and the demand, a shortage to the demand will result. For example, if the inflow forecast was high, but April began with a UKL elevation at or below the BO minimum, the model could calculate a delivery factor of 1.0, or 100%, for April through September but would create a project shortage in April until the UKL elevation was above the minimum elevation.

Table 4: Agriculture and Refuge Demands

Feb-Mar Precipitation (inches)	Apr-Mar Area A1 Demand (TAF)	Apr-Mar Refuge Demand (TAF)	Oct-Jan Precipitation (inches)	Apr-Mar Area A2 Demand (TAF)
0.00 - 1.999	340	30	0.00 - 3.99	105
2.00 - 2.749	310	25	4.00 - 6.99	95
2.75 - 3.299	300	20	7.00 - 9.99	90
$\geq$ 3.3	275	15	$\geq$ 10.0	80

Summary

The VBF procedure attempts to meet the 2010 NMFS RPA exceedance Table 18 values by first calculating a base flow for each month, then releasing additional river flows (up to the maximum flow) based on meeting and/or exceeding UKL Threshold Elevations. The expected available water for irrigation for each month is based on expected inflows, Iron Gate Dam flows, and minimum UKL elevations. The VBF procedure also incorporates operational controls to address flood control realities on UKL. Lastly, any differences, by exceedance, between Table 18 and the modeled flows under the VBF procedure may be further reduced or eliminated through real-time operations that cannot be analyzed in a long-term planning model. Detailed modeling results are included in Appendix A. All modeling used to create these results was completed using the Water Resources Integrated Modeling System (WRIMS) modeling software. This model used the same inflow and project demand assumptions as previous WRIMS models for the Klamath Basin.

Refer to the Variable Base Flow Procedure dated July 29, 2011 for the appendices, as Appendix A and Appendix B remain unchanged from the July 29, 2011 Variable Base Flow Procedure. Appendix A contains the exceedance tables and graphs and Appendix B contains a *"Clarification of Uncommon Terms Used"* in this document.