APPENDIX A

COLDWATER STORAGE ANALYSIS

SWRI SURFACE WATER RESOURCES, INC.

455 CAPITOL MALL, SUITE 600
SACRAMENTO, CALIFORNIA 95814
TELEPHONE: (916) 325-4050
FAX: (916) 446-0143

MEMORANDUM

DATE: Thursday, January 25, 2001 **Ref: 887**

TO: Ric Reinhardt

CC: Tim Washburn

FROM: Robert Leaf
Buzz Link

RE: Consideration of the "Rule Restriction" with Regard to Impacts of Larger Outlets on American River Temperatures

Relevant Excerpts from "Operation Plan to Minimize Impact of Larger Outlets on American River Flows":

The Folsom Dam gated outlet capacity is limited to 33,000 cfs +/- when the reservoir pool is below elevation 418' (509,000 acre-feet storage = 466,000 acre-feet space). The current flood space ranges from 400,000 acre-feet space (elevation 426') to a maximum of 675,000 acre-feet space (elevation 388'). The inability of Folsom Dam to release more than 33,000-cfs +/- when the pool is below elevation 418' is the major constraint on the dam's capability to provide flood protection for Sacramento. The Folsom Dam Modification Project corrects this deficiency by increasing the outlet capacity through enlarging the outlets and providing the capability to release the downstream channel capacity (115,000 cfs) at elevation 418'.

The potential for increased downstream channel scour and transport of gravel in the American River downstream of Folsom Dam due to the more frequent occurrence of high flows has been raised as an issue for the Folsom Dam Modification Project. The concern is that for relative frequent flood events (2 to 10-year average exceedance intervals) the changed outlet capacity at Folsom Dam will result in greater flows downstream.

An operating "Rule Restriction" was developed to mitigate any potential impacts due to increased flows in the American River. The Rule would limit Folsom Lake outflows to 60% of inflow unless the forecast or actual inflow exceeded 150,000 cfs.

Consideration of the "Rule Restriction" with Regard to Impacts of Larger Outlets on American River Temperatures:

Following up on our previous correspondence, the following considerations are intended to completely address potential temperature impacts due to the Folsom Dam modification and operations of the larger outlets under the proposed " 60% of inflow Rule Restriction".

While favorable meteorological and hydrological conditions can cause temperature stratification of Folsom Lake to occur during any month of the year, significant stratification, stable enough for beneficial cold-water pool conservation measures, is not likely to occur any earlier in the year than in March. Any amount of temperature stratification during this part of the season will be highly dependent on and sensitive to continued favorable meteorological influences and minimal hydrological disturbances.

During some level of hydrologic event, high flows passing through Folsom Lake would hydraulically disrupt the stability of temperature stratification in the reservoir. Using fundamental fluid mechanics principals, taking into consideration: 1) average flow-through velocity; 2) depth of flow; and 3) change in temperature over depth, a gross approximation of the stability of temperature stratification in a water body can be determined. Folsom Lake under conditions of a flow of 33,000 cfs with water surface at elevation 418 feet, with a temperature change of 6 degrees Fahrenheit throughout its depth would likely not maintain this level of stratification. This level of flow is the discharge capacity of all eight existing outlets combined.

As this level of release is maintained, stratification in Folsom Lake would weaken in the following way: 1) a well behaved cold water plunge line could not be maintained within the tributary arms of Folsom Lake under continued high inflows due to depth limitations; 2) toward the center of the reservoir, where depth would allow for the cold inflows to plunge, the now mixed flows from each tributary arm are no cooler in temperature than the bulk of the contents of the reservoir; 3) with high releases being made through the outlets, a wide and deep flow region develops behind Folsom Dam drawing various amounts of flow from the entire depth of the reservoir.

At a continuous flow of 33,000 cfs the volumetrically averaged residence time of Folsom Lake, at this water surface elevation, is roughly 8 days. The probability of a 33,000 cfs seven-day event occurring is similar to that of a 70,000 cfs one-day event (20% probability of exceedance/5-year averaged exceedance interval). It is our expectation that temperature stratification, if any, could only weakly persist under this level of inflow/release. If, over the time period of the event, cold-water pool conservation measures could be implemented (i.e. releases over the spillways instead of through the outlets), cold-water pool gains for use during summer temperature control operations would be negligible. Any impact of the larger outlets on cold-water pool conservation would similarly be negligible under events greater than those associated with a 5-year averaged exceedance interval.

In order to test the effect of the enlarged outlets on cold-water pool conservation with flow events that are less than those associated with a 5-year averaged exceedance

interval, a historical flow event was selected and considered for a variety of release options. The USAEWES Environmental Laboratory (Vicksburg, MS) has developed a model for estimating the release temperature for selective withdrawal from a stratified reservoir (the SELECT model, version 1.3). The Folsom Lake storage and release for March 13, 1995 was used for the analysis in conjunction with a temperature profile collected on March 23, 1999 (profile data was unavailable for March of 1995).

Actual operations show that on March 13, 1995, Folsom Lake storage was 572.9 taf, powerplant release was 7,592 cfs, outlet works release was 24,236 cfs and spillway release was 7,164 cfs. The water temperature profile for March 23,1999 displays a stratified reservoir with the elevation/temperature relationships shown in **Table A**. This profile was selected because it showed the greatest stratification among the data for temperature profiles available for this time of year at Folsom Lake.

A comparison between the present outlet works configuration condition (releases from the locations where they actually occurred on March 13, 1995) with the enlarged outlet works configuration (powerplant release of 7,592 cfs and remaining 31,400 cfs released through the enlarged upper tier outlets) finds that the resultant release temperatures are quite similar. Using the present outlet works, spillway, and powerplant the resultant temperature of the combined 38,992 cfs release was 8.32 °C; using the enlarged outlet works and the powerplant with no spillway release, the resultant temperature of the combined 38,992 cfs release was 8.14 °C. This difference is small and the resultant effect on the cold-water resource would be small. (see **Table A**)

Table A

RELEASE LOCATION	ELEVATION (FT MSL)	TEMPERATURE (°C)	RELEASE (CFS) EXISTING OUTLETS	RELEASE (CFS) ENLARGED OUTLETS
Spillway	418	10.4	7,164	--
Powerplant	375	8.9	7,592	7,592
Existing Upper tier	275	7.6	12,118	--
Enlarged Upper Tier	268	7.5	--	31,400
Existing Lower Tier	205	7.3	12,118	--
Total Release			38,992	38,992
Resultant Release Temperature			8.32 °C	8.14 °C

Based on the results of this comparison which simulates conditions of strong reservoir stratification for the time of year coupled to operations with and without releases from the spillway and no recognition that reservoir mixing is likely with an inflow of 33,000 cfs or more leads to the conclusion that the enlarged outlet works will have an insignificant effect on cold-water pool management capabilities.

The two scenarios modeled assumed the same rate of total release. Consider, however, the proposed "Rule Restriction". The Rule would limit Folsom Lake outflows to 60% of inflow unless the forecast or actual inflow exceeded 150,000 cfs. The inflow to Folsom Lake preceding March 13, 1995 actually peaked (daily average) in excess of 54,000 cfs. Spillway releases were not actually made until the following two days. The actual inflow on March 13, 1995 was less than the total release for the same day. With the enlarged

outlets and the proposed Rule, under 54,000 cfs, releases would be limited to 32,400 cfs. A slight lag time, as occurred in actual operations would also be reasonable to assume. **Table B** presents a comparison similar to that shown in **Table A** except that releases for March 13, 1995 under the enlarged outlets have also been reduced in magnitude. Instead of taking 60% of inflow for March 13, 1995, a more conservative estimate of 60% of the release was assumed (considering the lagging of the preceding days high flow event).

Using the present outlet works, spillway, and powerplant the resultant temperature of the combined 38,992 cfs release was 8.32 °C; using the enlarged outlet works and the powerplant with no spillway release, the resultant temperature of the combined 23,395 cfs release (60% of 38,992 cfs) was 8.21 °C. This difference is small and the resultant effect on the cold-water resource would be small.

Table B

RELEASE LOCATION	ELEVATION (FT MSL)	TEMPERATURE (°C)	RELEASE (CFS) EXISTING OUTLETS	RELEASE (CFS) ENLARGED OUTLETS WITH RULE RESTRICTION
Spillway	418	10.4	7,164	--
Powerplant	375	8.9	7,592	7,592
Existing Upper tier	275	7.6	12,118	--
Enlarged Upper Tier	268	7.5	--	15,803
Existing Lower Tier	205	7.3	12,118	--
Total Release			38,992	23,395
Resultant Release Temperature			8.32 °C	8.21 °C

Even though difference in the resultant release temperature is small, the reduction in the release for this day is reduced by 40%. Assuming that Folsom Lake has maintained some temperature stratification through this event, the total volume of cold-water pool within Folsom Lake has increased in size by more than 30,000 AF.

Assume for the example releases shown in **Table B** that the water surface elevation was lower than 418 feet as required for beginning to operate the spillway gates. If in the case of the existing outlets, inflows exceeded the capacity of the outlets and the powerplant, CVP operators would have to wait until Folsom Lake filled enough to begin operating the spillway gates. In the case of the enlarged outlets with the Rule (60% of inflow), the operators would have to wait until Folsom Lake filled enough to begin operating the spillway gates or until inflow to the reservoir increased so that releases could increase. In the comparison in **Table B**, Folsom Lake would be gaining 30,000 AF per day. Once the spillway gates became operable, releases could be made through the gates, conserving cold-water pool (if temperature stratification persisted). Reclamation's standard operating procedure for cold-water pool conservation is to make releases from the spillways whenever possible. The enlarged outlets operated under the Rule would likely result in substantial cold-water pool conservation during many events less than those associated with a 5-year averaged exceedance interval. In events in which the transition of operations to the spillway gates is limited, cold-water pool loss impacting summer temperature control operations would be negligible.