Appendix F: Potential Effect of Diversions on Folsom Reservoir Coldwater Pool

Potential Changes to Folsom Reservoir Cold Water Pool Associated with Diversion of Permit 21112

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1.0 Introduction

The U.S. Bureau of Reclamation (Reclamation) proposes to enter into a 40-year Warren Act Contract with the El Dorado Irrigation District (EID) to convey up to 17,000 acre-feet per year (afy) of non-Project water (i.e., water not part of the Central Valley Project [CVP]) through Folsom Reservoir for municipal and industrial (M&I) uses in the western portion of El Dorado County. This supply is available to EID through State Water Resources Control Board Permit 21112. Table 1 lists the timing and magnitude of these proposed diversions as allowed under this permit.

Table 1: Year 2001-22 El Dorado Hills Service Area Diversion Patterns (AF)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Permit 21112 Diversion Pattern[1]	694	575	609	914	1,793	2,470	2,774	2,672	1,810	1,184	778	727	17,000
Permit 21112 Diversion Pattern 50%	347	288	304	457	897	1,235	1,387	1,336	905	592	389	364	8,500
Permit 21112 Diversion Pattern 30%	208	173	183	274	538	741	832	802	543	355	233	218	5,100
1. As provided in Tables 1-3 of State of California State Water Resources Control Board Order WR 2001-22, adjusted for full supply amount.													

Seasonal releases from Folsom Reservoir are managed, to the extent possible, to provide suitable thermal conditions in the lower American River (LAR) for both fall-run Chinook salmon and Central Valley steelhead. Depending on conditions in any one year (carryover storage, inflow, water demands, reservoir stratification, etc.) and reservoir outlet configuration, Folsom Reservoir's coldwater pool is not always large enough to maintain coldwater releases during both (or either) of the warmest months (July through September) to provide maximum thermal benefits to rearing juvenile steelhead, and/or during October and November to benefit fall-run Chinook salmon immigration, spawning, and embryo incubation. Consequently, LAR temperature management is annually prescribed based on current conditions in an attempt to provide thermal benefits to both fall-run Chinook salmon and steelhead, within the constraints of coldwater pool availability.

This memorandum documents the analysis undertaken to evaluate conveying up to 17,000 afy of non-Project water on Reclamation's ability to manage the Cold Water Pool (CWP) in Folsom Reservoir for the benefit of aquatic resources in the American River below Nimbus Dam.

2.0 Folsom Reservoir Temperature Regime and Cold Water Pool Management

2.1 Overview of Folsom Reservoir Temperature Operation

Folsom Reservoir fills during the spring and early summer with snowmelt runoff from the upper American River basin. Early in this period, the reservoir is well mixed with a fairly uniform water temperature profile from top to bottom. However, as the runoff decreases and the surface temperature of the reservoir increases, the reservoir stratifies with warmer water near the surface and colder water on the bottom. Figure 1 illustrates this progression of stratification through the year using 2006 water temperature profile data collected at the dam.

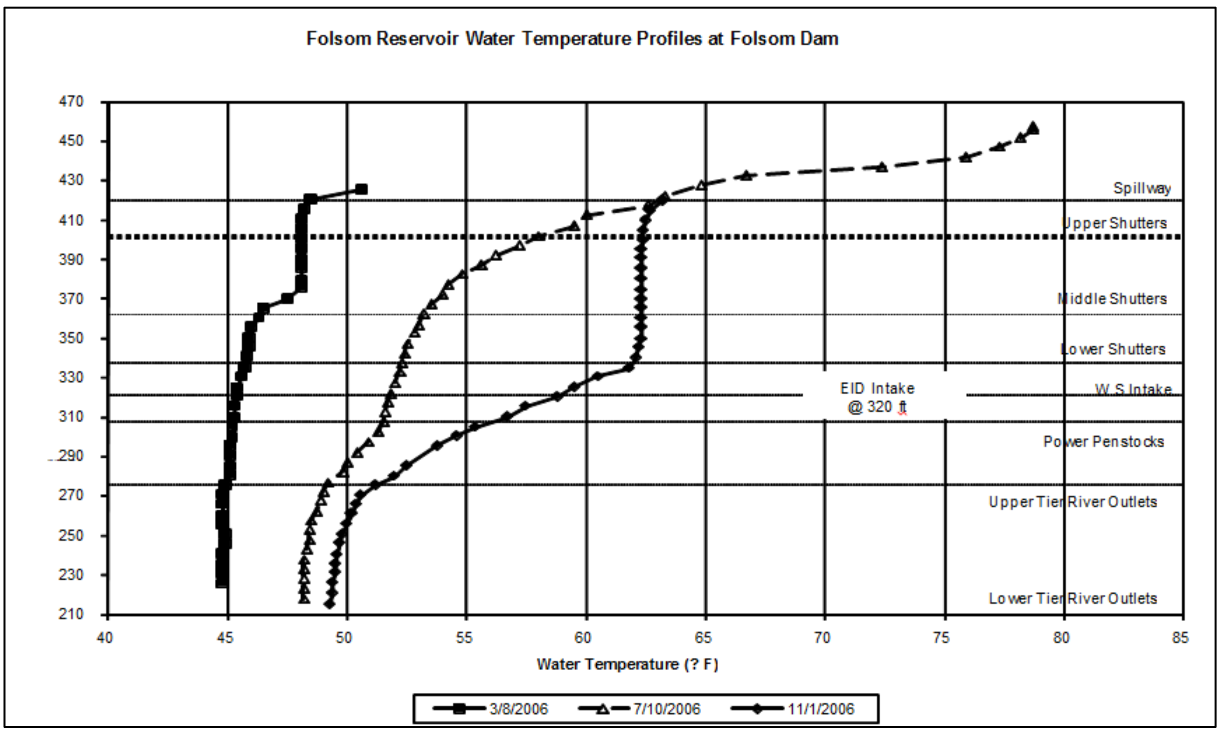

Figure 1: Folsom Reservoir Water Temperature Profiles

Figure 1 also identifies the various Folsom Reservoir elevations from which releases can be made. The power penstocks at Folsom Reservoir, the main release points from the reservoir, are fitted with a shutter system that can selectively withdraw water at multiple elevations, thereby adjusting the water temperature of the release. Management of the Folsom Reservoir CWP involves positioning the shutters to obtain a release temperature that is cold enough to manage the desired temperature for present downstream aquatic resources needs but high enough to preserve the CWP to meet water temperature requirements later in the year. With the shutters fully withdrawn, the release is directly through the power penstocks at a centerline elevation of 307 feet. As long as the CWP is above this elevation, the shutters can be adjusted to facilitate releases at temperatures necessary to meet downstream water temperature targets and avoid foregone hydropower generation.

Once the CWP cannot be accessed through the power penstock outlets, the Folsom Dam upper and/or lower river outlets can be used for water temperature management. These outlets are used only when absolutely necessary, as water released through the river outlets bypasses the Folsom Power Plant and results in foregone generation. The upper and lower river outlets are at centerline elevations of 278 and 208 feet, respectively.

2.2 Downstream Water Temperature Requirements

Water temperature requirements for the LAR were identified in the 2009 National Marine Fisheries Service Biological Opinion (BO) for the Continued Long-Term Operations of the Central Valley Project and the State Water Project (CVP/SWP OCAP) and associated reasonable and prudent alternatives (RPA).

Water temperature models are utilized to forecast monthly target water temperatures in the LAR at Watt Avenue. The Automated Temperature Selection Procedure (ATSP) monthly temperature schedule is a management tool incorporated into temperature models of Folsom Reservoir and the Lower American River to simulate a “balanced” use of the Folsom Reservoir CWP. The schedule recognizes a water temperature priority to protect juvenile steelhead during over-summer rearing while balancing the needs of fall-run Chinook salmon spawning. To the extent possible, Reclamation operates Folsom Dam and Nimbus Dam to maintain daily average water temperatures for the LAR at Watt Avenue from June 1 through November 30 to achieve the balanced management objectives for juvenile steelhead and fall-run Chinook salmon. A “schedule” of water temperatures is specified as the preferred monthly water temperature targets. Table 2 presents 2 examples from the 78 monthly target water temperature sequences contained in the ATSP schedule; showing a range of monthly water temperature targets.

For the current analysis presented in this Technical Memorandum, the Folsom Reservoir CWP is assumed to consist of all water at or below 60°F, as suggested by Reclamation (email comments from Reclamation, 8/28/2007). This value will give a conservative estimate of the CWP available in Folsom Reservoir that could be used for the benefit of the downstream aquatic resources.

Table 2: Lower American River ATSP Water Temperature Targets (°F) at Watt Avenue

Schedule	May	Jun	Jul	Aug	Sep	Oct	Nov
1	63	63	63	63	63	56	56
28	66	66	66	66	66	65	59

Water temperature targets that address fall–run Chinook spawning and incubation start in late October or early November (October 16-November 30 timeframe). Reclamation works to provide suitable water temperatures as early as possible, after November 1, to help avoid water temperature related pre-spawning mortality of adults and reduced egg viability. Typically, the ambient air temperature controls the LAR water temperatures in mid-to late-November when decreased air temperatures limit the in-river heating.

There are no water temperature targets identified in the December through April period because the low water temperature of Folsom Reservoir releases and the lack of in-river heating (during this period cooling may occur as the water moves downstream) of the water in the Lower American River maintain water temperatures sufficiently cool to meet the requirements of all species life stages.

3.0 Analysis Procedure

When analyzing the project Reclamation must consider its ability to manage the CWP such that it can meet desirable Watt Avenue water temperature target, to protect downstream aquatic resources. Potential challenges to this management are most likely to occur near the end of October when the CWP is at a relatively low level and the downstream water temperature requirements become lower, requiring a lower water temperature release.

To evaluate this project, the analysis presented in this Technical Memorandum estimated changes in the volume of water below 60°F in the Folsom Reservoir CWP attributed to the proposed diversion. The daily volume of water removed at the EID intake was computed using an Excel-based spreadsheet tool developed for the analysis of the EID Temperature Control Device (HDR 2009). The results from the Excel-based spreadsheet tool were used to compute the total monthly diversion volume for water less than 60ºF, assuming the EID diversions shown in Table 1.

The volume of water below 60°F removed as a result of the proposed EID diversion, was subtracted from the original profile, and used to: 1) estimate a new lower elevation for the 60°F isotherm at the dam, 2) estimate a revised water temperature at the centerline of the power penstocks, and 3) used as an indicator of the potential change in river outlet use at the end of October. A subsequent analysis estimated an equivalent number of days release for the volume change to the CWP as an indicator of foregone generation.

3.1 Folsom Reservoir Temperature Profile Data

The analysis is based on water temperature profile data furnished by Reclamation. Data is collected by Reclamation at six locations in Folsom Reservoir, as follows:

- Site A 38°47.0107' N; 121°06.3991' W (North Fork arm near Anderson Creek)
- Site B 38°44.1948' N; 121°05.6332' W (Red Buoy in front of EID's intake, South Fork arm)
- Site C 38°44.0027' N; 121°08.6959' W (North Fork arm off Mooney Ridge)
- Site D 38°42.7674' N; 121°07.3176' W (South Fork arm off Mormon Island Dam)
- Site E 38°46.0292' N; 121°07.3141' W (North Fork arm)
- Site Dam 38°42.5401' N; 121°09.3220' W (White buoy in front of dam)

For the time period 2002 through 2010, water temperature profiles were collected by Reclamation at irregular intervals of approximately 3-5 weeks. For this study, Site B was assumed to represent the water temperature profile at the EID water supply intake. The water temperature profiles from Site B were used to estimate the potential diversion of below 60ºF water at the EID intake, described in Section 3.3 of this Technical Memorandum. Water temperature data from Site D located at the South Fork arm off Mormon Island Dam was used when no data was available at Site B.

Water temperature profile data from the dam, "Site Dam", at elevation 307 feet msl was assumed to represent the water temperature at the centerline of the power penstocks. The water temperature profiles from this site were used to estimate the November 1st elevation of 60ºF water and the volume of less than 60ºF water in the reservoir, described in 3.5 of this Technical Memorandum. Figure 2 shows an example of the fall reservoir condition water temperature profiles at the dam, used in the analysis.

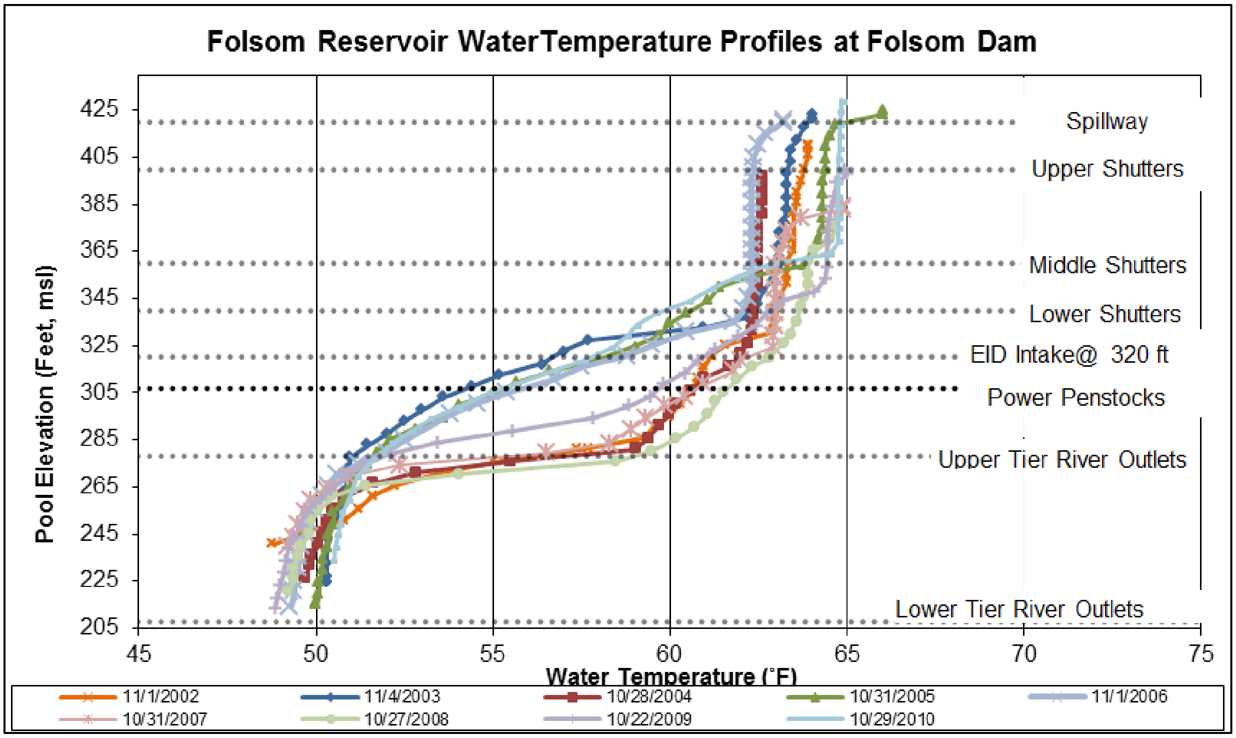

Figure 2: Folsom Reservoir Water Temperature Profiles on or about November 1

3.2 Inflow Changes to the CWP

The project consists of diverting EID water supply that is available under Permit 21112 at Kyburz Diversion Dam and El Dorado Powerhouse, located on the South Fork of the American River, at an alternative location at Folsom Reservoir using the existing EID water supply intake. This operation could modify water temperatures in Folsom Reservoir by increasing the volume of cold water inflow available to develop and sustain the CWP that would otherwise not be available if such supplies were diverted at the Kyburz Diversion Dam and El Dorado Powerhouse.

For this analysis, the upstream supply entering the reservoir increases the Folsom Reservoir CWP by the volume of water below 60ºF not removed by the project at the upstream location. The water temperature of this source was estimated using the USGS Gage 11446030-South Fork American River at Pilot Hill, which includes water temperature data from August 1999 to the present. Figure 3 shows average daily water temperatures at the gage for the 2002 – 2010 period.

The additional inflow to the CWP was estimated by adding up the daily inflow volume, based on the EID water supply that is available under Permit 21112 at Kyburz Diversion Dam and El Dorado Powerhouse, for each day that the water temperature was less than 60ºF to get a monthly total volume increase to the CWP. The results of this calculation are shown in Table 3. The consistent volume totals for March, April, and May in most years indicates that the full Permit 21112 supply in these months is consistently below 60ºF.

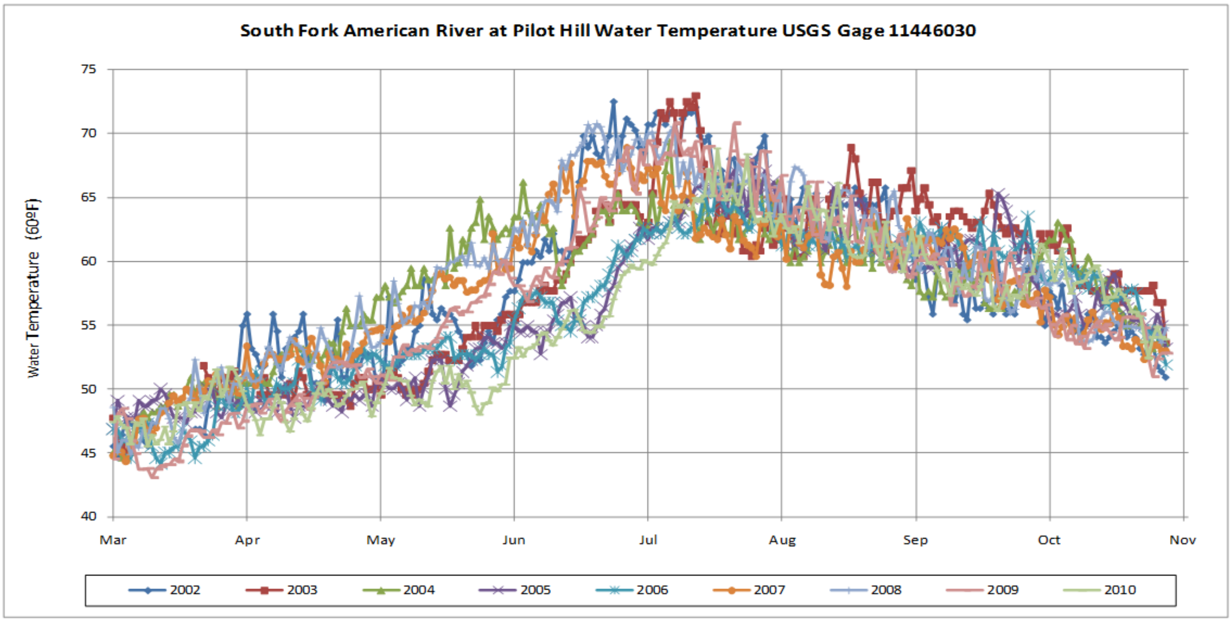

Figure 3: Water Temperature of South Fork American River Inflow to Folsom Reservoir

Table 3: Additional Below 60ºF South Fork American River Inflow to Folsom Reservoir (AF)

	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Total
2002	609	914	1,793	576	0	86	1,568	1,184	6,730
2003	609	914	1,793	1,235	0	0	60	879	5,489
2004	609	914	1,099	329	0	690	1,749	840	6,229
2009	609	914	1,793	2,223	0	172	603	1,184	7,498
2006	609	914	1,793	2,058	0	0	181	1,146	6,701
2007	609	914	1,735	82	0	690	844	1,184	6,058
2008	609	914	1,388	0	0	0	294	248	3,452
2009	609	914	1,817	1,070	0	172	1,206	1,184	6,973
2010	609	914	1,875	2,470	269	86	1,508	1,031	8,761

3.3 Diversion of Below 60°F Water from the CWP

EID's current water supply intakes withdraw water from Folsom Reservoir at an elevation of 320 feet. A comparative assessment of the volume and temperature of water removed at this elevation was estimated with an Excel-based spreadsheet tool using temperature data collected by Reclamation at the EID intake location (Site B) and diversion data provided by EID. An intake elevation at 320 feet and a target diversion temperature of 60°F were parameters specified in the spreadsheet tool.

The spreadsheet tool models the operation of the EID intake for the historical 2002 through 2010 period using EID Warren Act Contract demands to convey up to 17,000 afy as outlined in Table 1. As part of the current evaluation, three diversion scenarios were compared consisting of 100% demand (17,000 afy), 50% demand (8,500 afy), and 30% demand (5,100 afy) during the May through October period. The total monthly volume of diverted water less than 60ºF is shown in Table 4a-c for each of the scenarios.

Table 4.a: Estimated Total Folsom Reservoir EID Diversion Below 60°F (AF); 100%

	May	Jun	Jul	Aug	Sep	Oct	Total
2002	1,793	2,470	2,774	2,672	664	0	10,373
2003	1,793	2,470	2,774	2,672	1,810	1,184	12,703
2004	1,793	2,470	2,774	1,207	0	0	8,244
2005	1,793	2,470	2,774	2,672	1,810	1,184	12,703
2006	1,793	2,470	2,774	2,672	1,810	1,184	12,703
2007	1,793	2,470	2,774	2,500	0	0	9,537
2008	1,793	2,470	2,774	172	0	0	7,209
2009	1,793	2,470	2,774	2,672	1,026	0	10,735
2010	1,793	2,470	2,774	2,672	1,810	1,184	12,703

Table 5.b: Estimated Total Folsom Reservoir EID Diversion Below 60°F (AF); 50%

	May	Jun	Jul	Aug	Sep	Oct	Total
2002	897	1,235	1,387	1,336	332	0	5,186
2003	897	1,235	1,387	1,336	905	592	6,352
2004	897	1,235	1,387	603	0	0	4,122
2005	897	1,235	1,387	1,336	905	592	6,352
2006	897	1,235	1,387	1,336	905	592	6,352
2007	897	1,235	1,387	1,250	0	0	4,768
2008	897	1,235	1,387	86	0	0	3,605
2009	897	1,235	1,387	1,336	513	0	5,367
2010	897	1,235	1,387	1,336	905	592	6,352

Table 6.c: Estimated Total Folsom Reservoir EID Diversion Below 60°F (AF); 30%

	May	Jun	Jul	Aug	Sep	Oct	Total
2002	538	741	832	802	199	0	3,112
2003	538	741	832	802	543	355	3,811
2004	538	741	832	362	0	0	2,473
2005	538	741	832	802	543	355	3,811
2006	538	741	832	802	543	355	3,811
2007	538	741	832	750	0	0	2,861
2008	538	741	832	52	0	0	2,163
2009	538	741	832	802	308	0	3,220
2010	538	741	832	802	543	355	3,811

3.4 Potential Changes to Folsom CWP

As discussed in Section 3.2, the project will modify inflow to Folsom Reservoir, some portion of which will be below 60ºF, resulting in a net increase in the CWP associated with EID delivery of the Permit 21112 water supply to Folsom Reservoir. The project will also result in increased diversion at the EID water supply intake, some of which will be below 60ºF and is assumed to decrease the CWP, as described in Section 3.3. The change in CWP volume at the EID intake and at the dam is presented for each year, individually, from 2002 through 2010 and does not represent a continuous simulation of the 2002-2010 time periods. The November time period was selected to evaluate the change caused by the project, because the ability to manage the CWP when at a relatively low volume and downstream water temperature requirements are low, typically requires a lower release temperature. Two methods were used to evaluate the potential changes to the CWP and power penstock release water temperatures as described below.

3.4.1 Changes to Folsom CWP with Upstream Inflow

The first method included the total below 60ºF inflow to Folsom Reservoir, that would have otherwise been withdrawn at Kyburz Diversion Dam and El Dorado Powerhouse, to determine the net increase to the CWP for all three scenarios (100%, 50%, and 30%) assuming that all of the below 60ºF water entering Folsom Reservoir would be available if not diverted at the upstream locations.

The spreadsheet tool used to estimate water volumes at the EID intake (Site B) and the water temperature gage data for Pilot Hill were derived using a daily timestep and are presented as monthly totals in this Technical Memorandum. The potential change to the Folsom CWP is the difference between these two volumes of water during the May through October time period. The monthly change in

CWP volume was calculated by subtracting the increase in the CWP due to below 60ºF inflow, (summarized in Table 3) from the reduction in CWP at the EID intake, (summarized in Tables 4a-c). Table 5a-c summarizes the results of this assessment considering the potential inflow change on the CWP at the dam with upstream supply entering the reservoir.

3.4.2 Changes to Folsom CWP without Upstream Inflow

This study also analyzed changes to the CWP without consideration of any increase due to below 60ºF inflow. The potential change to the Folsom CWP is the total volume of the EID diversion at the EID intake (Site B) during the May through October time period. The results of this computation are also shown in Table 5a-c.

Table 5.a: Net Change in Folsom Reservoir Cold Water Pool Volume (AF), 100% EID Diversion

Date	Nov 1rst Elev <60ºF[1] (ft msl)	Nov 1rst <60ºF Storage [2] (AF)	Diversion May-Nov 1rst <60ºF [3] (AF)	Adjusted Inflow <60ºF Mar-Nov 1rst [4] (AF)	Modified Nov 1rst <60ºF Storage (AF)	Net Change in CWP Volume [5] (AF)
11/1/2002	295.4	36,251	10,373	6,730	32,608	-3,643
11/4/2003	331.3	91,817	12,703	5,489	84,603	-7,214
10/28/2004	296.1	37,009	8,244	6,229	35,014	-2,015
10/31/2005	334.5	98,825	12,703	7,498	93,620	-5,205
11/1/2006	328.1	85,239	12,703	6,701	79,237	-6,002
10/31/2007	300.1	41,465	9,537	6,058	37,986	-3,479
10/27/2008	284.3	25,570	7,209	3,452	21,813	-3,757
10/22/2009	310.1	54,718	10,735	6,973	50,956	-3,762
10/29/2010	340.9	114,226	12,703	8,761	110,284	-3,942

[1] Temperature and elevation measured at the Dam.
[2] Storage based on Reclamation Storage-Elevation Table.
[3] Temperature at EID Intake, volume computed.
[4] Temperature at Pilot Hill Gage, volume computed.
[5] Diversion minus Adjusted Inflow.

Table 5.b: Net Change in Folsom Reservoir Cold Water Pool Volume (AF), 50% EID Diversion

Date	Nov 1rst Elev <60ºF[1] (ft msl)	Nov 1rst <60ºF Storage[2] (AF)	Diversion May-Nov 1rst <60ºF[3] (AF)	Adjusted Inflow <60ºF Mar-Nov 1rst[4] (AF)	Modified Nov 1rst <60ºF Storage (AF)	Net Change in CWP Volume[5] (AF)
11/1/2002	295.4	36,251	5,186	6,730	37,795	1,544
11/4/2003	331.3	91,817	6,352	5,489	90,954	-863
10/28/2004	296.1	37,009	4,122	6,229	39,116	2,107
10/31/2005	334.5	98,825	6,352	7,498	99,971	1,146
11/1/2006	328.1	85,239	6,352	6,701	85,588	349
10/31/2007	300.1	41,465	4,768	6,058	42,755	1,290
10/27/2008	284.3	25,570	3,605	3,452	25,417	-153
10/22/2009	310.1	54,718	5,367	6,973	56,324	1,606
10/29/2010	340.9	114,226	6,352	8,761	116,635	2,409

[1] Temperature and elevation measured at the Dam. [2] Storage based on Reclamation Storage-Elevation Table.
[3] Temperature at EID Intake, volume computed. [4] Temperature at Pilot Hill Gage, volume computed.
[5] Diversion minus Adjusted Inflow.

Table 5.c: Net Change in Folsom Reservoir Cold Water Pool Volume (AF), 30% EID Diversion

Date	Nov 1rst Elev <60ºF[1] (ft msl)	Nov 1rst <60ºF Storage[2] (AF)	Diversion May-Nov 1rst <60ºF[3] (AF)	Adjusted Inflow <60ºF Mar-Nov 1rst[4] (AF)	Modified Nov 1rst <60ºF Storage (AF)	Net Change in CWP Volume[5] (AF)
11/1/2002	295.4	36,251	3,112	6,730	39,869	3,618
11/4/2003	331.3	91,817	3,811	5,489	93,495	1,678
10/28/2004	296.1	37,009	2,473	6,229	40,765	3,756
10/31/2005	334.5	98,825	3,811	7,498	102,512	3,687
11/1/2006	328.1	85,239	3,811	6,701	88,129	2,890
10/31/2007	300.1	41,465	2,861	6,058	44,662	3,197
10/27/2008	284.3	25,570	2,163	3,452	26,859	1,289
10/22/2009	310.1	54,718	3,220	6,973	58,471	3,753
10/29/2010	340.9	114,226	3,811	8,761	119,176	4,950

[1] Temperature and elevation measured at the Dam. [2] Storage based on Reclamation Storage-Elevation Table.
[3] Temperature at EID Intake, volume computed. [4] Temperature at Pilot Hill Gage, volume computed.
[5] Diversion minus Adjusted Inflow.

3.5 Quantification of Power Penstock Release Temperatures

A reduction of the CWP volume could potentially increase the water temperature at any given elevation in the reservoir. To ascertain the probability of foregone power generation, for this analysis it is assumed that after the less than 60ºF water is removed from the reservoir at the EID intake, the CWP at the Dam Site would be at a modified elevation. Reclamation's Area Capacity tables were used to estimate the modified elevation of the 60°F isotherm, based on the volume of the CWP after the less than 60ºF is water removed at the EID intake.

The new (effective) water temperature at the centerline of the power penstocks was then estimated based on the shift in elevation of the CWP, using the water temperature profiles recorded at the Dam Site. For example, if the elevation reduction of the CWP was 5 feet, the modified water temperature at the power penstock would be the water temperature shown at 312 feet (307 + 5 = 312) on Reclamation’s water temperature profile, measured on the date closest to November 1. For this analysis, the change in water temperature at the centerline of the penstocks was estimated as follows:

- Assume the temperature change in the CWP occurred uniformly with no remixing or re-stratification of the CWP.
- Estimate the volume of water less than 60ºF from the Dam Site water temperature profile and area capacity tables.
- Estimate the water temperature at the penstock elevation (307 feet) from the Dam Site water temperature profile.
- Compute a “modified” storage as the sum of the storage less than 60ºF at the Dam Site plus the net CWP volume removed by the project, as measured at the EID intake.
- Get the “effective” power penstock elevation that corresponds to this new storage from the elevation-storage tables.
- Estimate the “modified” temperature at the “modified” elevation from the Dam Site water temperature profile. This represents the temperature of the water that would be at the elevation of the centerline of the penstocks with the project in place.
- Compute the change in temperature at the elevation of the power penstock with the project in place.

3.5.1 Changes to Folsom Power Penstock Temperature with and without Upstream Inflow

As described in Section 3.4, two methods were used to determine the potential changes to the CWP and power penstock release water temperatures. The first method included the total, below 60ºF inflow to Folsom Reservoir, that would have otherwise been withdrawn at Kyburz Diversion Dam and El Dorado Powerhouse, to determine the net change to the CWP assuming that the below 60ºF water entering Folsom Reservoir would be available if not diverted at the upstream locations, summarized in Table 6a-c. The second method included the increased diversion at the EID water supply intake, without consideration of any increase to the CWP due to below 60ºF inflow entering Folsom Reservoir, summarized in Table 7a-c.

Table 6.a: Estimated Water Temperature Change at Penstock, November 1st; 100% EID Diversion, With Inflow

	Original			Modified					
Profile Date	Temp at Penstock (307 ft) (ºF)	Elev <60ºF (ft msl)	<60ºF Storage (AF)	<60ºF Storage (AF)	<60ºF Elevation (ft msl)	Adjustment to Elevation at Power (feet)	Effective Elevation at Power (ft msl)	Temp at Penstock (ºF)	Change (ºF)
11/1/2002	60.7	295.4	36,251	32,608	291.9	3.5	310.5	60.8	0.1
11/4/2003	54.3	331.3	91,817	84,603	327.9	6.4	313.4	55.4	1.1
10/28/2004	60.7	296.1	37,009	35,014	294.3	1.8	308.8	60.8	0.1
10/31/2005	55.3	334.5	98,825	93,620	332.1	2.4	309.4	55.6	0.3
11/1/2006	55.9	328.1	85,239	79,237	325.0	3.1	310.1	56.7	0.8
10/31/2007	60.8	300.1	41,465	37,986	296.9	3.2	310.2	61.2	0.4
10/27/2008	61.6	284.3	25,570	21,813	279.6	4.7	311.7	62.0	0.4
10/22/2009	59.7	310.1	54,718	50,956	307.4	2.7	309.7	60.0	0.3
10/29/2010	55.3	340.9	114,226	110,284	339.3	1.6	308.6	55.6	0.3

Table 6.b: Estimated Water Temperature Change at Penstock, November 1st; 50% EID Diversion, With Inflow

	Original			Modified					
Profile Date	Temp at Penstock (307 ft) (ºF)	Elev <60 ºF (ft msl)	<60 ºF Storage (AF)	<60 ºF Storage (AF)	<60 ºF Elevation (ft msl)	Adjustment to Elevation at Power (feet)	Effective Elevation at Power (ft msl)	Temp at Penstock (ºF)	Change (ºF)
11/1/2002	60.7	295.4	36,251	37,795	296.8	(1.4)	305.6	60.6	(0.1)
11/4/2003	54.3	331.3	91,817	90,954	330.9	0.4	307.4	54.4	0.1
10/28/2004	60.7	296.1	37,009	39,116	298.0	(1.9)	305.1	60.5	(0.2)
10/31/2005	55.3	334.5	98,825	99,971	335.0	(0.5)	306.5	55.2	(0.1)
11/1/2006	55.9	328.1	85,239	85,588	328.3	(0.2)	306.8	55.8	(0.1)
10/31/2007	60.8	300.1	41,465	42,755	301.1	(1.0)	306.0	60.7	(0.1)
10/27/2008	61.6	284.3	25,570	25,417	284.2	0.1	307.1	61.6	0.0
10/22/2009	59.7	310.1	54,718	56,324	311.2	(1.1)	305.9	59.6	(0.1)
10/29/2010	55.3	340.9	114,226	116,635	341.8	(0.9)	306.1	55.1	(0.2)

Table 6.c: Estimated Water Temperature Change at Penstock, November 1st; 30% EID Diversion, With Inflow

	Original			Modified					
Profile Date	Temp at Penstock (307 ft) (ºF)	Elev <60 ºF (ft msl)	<60 ºF Storage (AF)	<60 ºF Storage (AF)	<60 ºF Elevation (ft msl)	Adjustment to Elevation at Power (feet)	Effective Elevation at Power (ft msl)	Temp at Penstock (ºF)	Change (ºF)
11/1/2002	60.7	295.4	36,251	39,869	298.6	(3.2)	303.8	60.5	(0.2)
11/4/2003	54.3	331.3	91,817	93,495	332.1	(0.8)	306.2	54.2	(0.1)
10/28/2004	60.7	296.1	37,009	40,765	299.4	(3.3)	303.7	60.4	(0.3)
10/31/2005	55.3	334.5	98,825	102,512	336.1	(1.6)	305.4	55.1	(0.2)
11/1/2006	55.9	328.1	85,239	88,129	329.5	(1.4)	305.6	55.5	(0.4)
10/31/2007	60.8	300.1	41,465	44,662	302.6	(2.5)	304.5	60.5	(0.3)
10/27/2008	61.6	284.3	25,570	26,859	285.8	(1.5)	305.5	61.5	(0.1)
10/22/2009	59.7	310.1	54,718	58,471	312.7	(2.5)	304.5	59.5	(0.2)
10/29/2010	55.3	340.9	114,226	119,176	342.8	(1.9)	305.1	54.9	(0.4)

Table 7.a: Estimated Water Temperature Change at Penstock, November 1st; 100% EID Diversion, Without Inflow

	Original			Modified					
Profile Date	Temp at Penstock (307 ft) (ºF)	Elev <60ºF (ft msl)	<60ºF Storage (AF)	<60ºF Storage (AF)	<60ºF Elevation (ft msl)	Adjustment to Elevation at Power Penstock (feet)	Effective Elevation at Power (ft msl)	Temp at Penstock (ºF)	Change (ºF)
11/1/2002	60.7	295.4	36,251	25,878	284.6	10.8	317.8	61.1	0.4
11/4/2003	54.3	331.3	91,817	79,114	324.9	6.4	313.4	55.4	1.1
10/28/2004	60.7	296.1	37,009	28,785	287.9	8.2	315.2	61.5	0.8
10/31/2005	55.3	334.5	98,825	86,122	328.5	6.0	313.0	56.4	1.1
11/1/2006	55.9	328.1	85,239	72,536	321.3	6.8	313.8	57.2	1.3
10/31/2007	60.8	300.1	41,465	31,928	291.2	8.9	315.9	61.9	1.1
10/27/2008	61.6	284.3	25,570	18,361	275.1	9.2	316.2	62.3	0.7
10/22/2009	59.7	310.1	54,718	43,983	302.1	8.1	315.1	60.5	0.8
10/29/2010	55.3	340.9	114,226	101,523	335.7	5.2	312.2	56.3	1.0

Table 7.b: Estimated Water Temperature Change at Penstock, November 1st; 50% EID Diversion, Without Inflow

	Original			Modified					
Profile Date	Temp at Penstock (307 ft) (ºF)	Elev <60 ºF (ft msl)	<60 ºF Storage (AF)	<60 ºF Storage (AF)	<60 ºF Elevation (ft msl)	Adjustment to Elevation at Power Penstock (feet)	Effective Elevation at Power (ft msl)	Temp at Penstock (ºF)	Change (ºF)
11/1/2002	60.7	295.4	36,251	31,065	290.3	5.1	312.1	60.8	0.1
11/4/2003	54.3	331.3	91,817	85,465	328.2	3.1	310.1	54.8	0.5
10/28/2004	60.7	296.1	37,009	32,887	292.1	4.0	311.0	61.0	0.3
10/31/2005	55.3	334.5	98,825	92,473	331.6	2.9	309.9	55.7	0.4
11/1/2006	55.9	328.1	85,239	78,887	324.8	3.3	310.3	56.7	0.8
10/31/2007	60.8	300.1	41,465	36,697	295.8	4.3	311.3	61.4	0.6
10/27/2008	61.6	284.3	25,570	21,965	279.9	4.4	311.4	62.0	0.4
10/22/2009	59.7	310.1	54,718	49,351	306.2	3.9	310.9	60.1	0.4
10/29/2010	55.3	340.9	114,226	107,874	338.4	2.5	309.5	55.8	0.5

Table 7.c: Estimated Water Temperature Change at Penstock, November 1st; 30% EID Diversion, Without Inflow

	Original			Modified					
Profile Date	Temp at Penstock (307 ft) (ºF)	Elev <60 ºF (ft msl)	<60 ºF Storage (AF)	<60 ºF Storage (AF)	<60 ºF Elevation (ft msl)	Adjustment to Elevation at Power Penstock (feet)	Effective Elevation at Power (ft msl)	Temp at Penstock (ºF)	Change (ºF)
11/1/2002	60.7	295.4	36,251	33,139	292.4	3.0	310.0	60.8	0.1
11/4/2003	54.3	331.3	91,817	88,006	329.5	1.8	308.8	54.6	0.3
10/28/2004	60.7	296.1	37,009	34,536	293.8	2.3	309.3	60.8	0.1
10/31/2005	55.3	334.5	98,825	95,014	332.8	1.7	308.7	55.5	0.2
11/1/2006	55.9	328.1	85,239	81,428	326.2	1.9	308.9	56.4	0.5
10/31/2007	60.8	300.1	41,465	38,604	297.6	2.5	309.5	61.1	0.3
10/27/2008	61.6	284.3	25,570	23,407	281.7	2.6	309.6	61.8	0.2
10/22/2009	59.7	310.1	54,718	51,498	307.8	2.3	309.3	59.9	0.2
10/29/2010	55.3	340.9	114,226	110,415	339.4	1.5	308.5	55.6	0.3

3.5.2 Changes to Folsom Power Penstock Bypass Flows

Reclamation has suggested that the number of days of release resulting from a change in the CWP is an appropriate method to assess potential changes in

Reclamation's CWP operations (email comments from Reclamation, 8/28/2007). Table 8a summarizes the number of days of release at 1,500 cfs (typical fall release schedule from Folsom Reservoir) represented by each of the computed changes in CWP and considering inflow changes to the CWP assuming that all of the below 60ºF temperature water entering Folsom Reservoir would be available if not diverted at the upstream locations. Table 8b summarizes the number of days of release at 1,500 cfs represented by each of the computed changes in CWP without consideration of inflow changes to the CWP due to upstream supply entering the reservoir.

Table 8.a: CWP Volume Change and Days Release at 1,500 cfs, with Inflow

	30% Diversion		50% Diversion		100% Diversion	
Year	CWP Decrease (AF)	Equivalent Days	CWP Decrease (AF)	Equivalent Days	CWP Decrease (AF)	Equivalent Days
2002	-3,618	(1.2)	-1,544	(0.5)	3,643	1.2
2003	-1,678	(0.6)	863	0.3	7,214	2.4
2004	-3,756	(1.3)	-2,107	(0.7)	2,015	0.7
2005	-3,687	(1.2)	-1,146	(0.4)	5,205	1.7
2006	-2,890	(1.0)	-349	(0.1)	6,002	2.0
2007	-3,197	(1.1)	-1,290	(0.4)	3,479	1.2
2008	-1,289	(0.4)	153	0.1	3,757	1.3
2009	-3,753	(1.3)	-1,606	(0.5)	3,762	1.3
2010	-4,950	(1.7)	-2,409	(0.8)	3,942	1.3

Table 8.b: CWP Volume Change and Days Release at 1,500 cfs, without Inflow

	30% Diversion		50% Diversion		100% Diversion	
Year	CWP Decrease (AF)	Equivalent Days	CWP Decrease (AF)	Equivalent Days	CWP Decrease (AF)	Equivalent Days
2002	3,112	1.0	5,186	1.7	10,373	3.5
2003	3,811	1.3	6,352	2.1	12,703	4.3
2004	2,473	0.8	4,122	1.4	8,224	2.8
2005	3,811	1.3	6,352	2.1	12,703	4.3
2006	3,811	1.3	6,352	2.1	12,703	4.3
2007	2,861	1.0	4,768	1.6	9,357	3.1
2008	2,163	0.7	3,605	1.2	7,209	2.4
2009	3,220	1.1	5,367	1.8	10,735	3.6
2010	3,811	1.3	6,352	2.1	12,703	4.3

4.0 Summary of Results

Water temperature changes within the CWP identified in this analysis were used as an indicator of whether the water temperatures at the power penstocks would be expected to: increase, remain unchanged, or decrease, and provide insight regarding the magnitude of change compared to historic conditions. In traditional Folsom Reservoir and LAR water temperature modeling, water temperature changes of less than 0.3ºF are assumed to be less than the lower limit of accuracy of commonly used water temperature monitoring equipment. Therefore, water temperature changes that were within 0.2 ºF of historic conditions were considered to represent no measurable change in water temperature while temperature differences of 0.3 ºF or more were evaluated further as presented below.

4.1 Penstock Temperature Change with Upstream Inflow

Assessment of the 100% EID diversion, with consideration of upstream supply, shows that the change in water temperature at the power penstock is 0.3ºF or more for seven of the ten years (2003, 2005, 2006, 2007, 2008, 2009, and 2010). However, the water temperature at the power penstock remains at or below 60ºF in four of these years (2003, 2005, 2006, and 2010) and the change in release temperature through the penstocks due to the project indicates a high probability that an adequate supply of cool water remains for fall temperature operations (comments from Reclamation, 8/15/ 2011).

In 2002, 2004, 2007, 2008 and 2009 the cold water pool is located below the power penstock elevation and Reclamation must evaluate its options to meet all Project purposes and requirements.

The assessment of the 50% and 30% EID diversion, with consideration of the upstream supply less than 60ºF, shows that the estimated water temperature change at the power penstock is less than 0.3ºF and therefore were considered to represent no measurable change in water temperature at the penstocks.

4.2 Penstock Temperature Change with No Upstream Inflow

In all of the years analyzed, the 50% and 100% EID diversion, without consideration of increased upstream supply, would be detectable based on the estimated change in water temperature at the power penstocks compared to historic conditions. In years with favorable Folsom Lake storage and high cold-water pool volumes (2003, 2005, 2006, and 2010), the water temperature at the power penstock remains at or below 60ºF, which indicates an adequate supply of cool water remains for fall temperature operations (comments from Reclamation, 8/15/ 2011). In 2002, 2004, 2007, 2008 and 2009 the cold water pool is located below the power penstock elevation and Reclamation must evaluate its options to meet all Project purposes and requirements.

The assessment of the 30% EID diversion, without consideration of upstream supply, shows that the change in water temperature at the power penstock is 0.3ºF or more for 2003, 2006, 2007, and 2010. The water temperature at the power penstock remains at or below 60ºF for three of these years (2003, 2006, and 2010) which indicates an adequate supply of cool water remains for fall temperature operations (comments from Reclamation, 8/15/ 2011). In 2002, 2004, 2007, 2008 and 2009 the cold water pool is located below the power penstock elevation and Reclamation must evaluate its options to meet all Project purposes and requirements.

4.3 Power Penstock Bypass Flows

In addition to the assessment of the change in water temperature at the power penstock, Reclamation has suggested that any change in CWP volume equivalent to 4 days release at 1,500 cfs has the potential trigger an adjustment of downstream target temperatures (email comments from Reclamation 8/28/2007).

The equivalent number of days release using the 100% EID diversion, without consideration of the upstream below 60ºF inflow, varies from 2.4 to 4.3 days, as shown on Table 8b. However, in the years in which the 4 day release is exceeded (2003, 2005, 2006, and 2010) the water temperature at the power penstock is less than 60ºF which indicates an adequate supply of cool water remains for fall temperature operations (comments from Reclamation, 8/15/ 2011). In 2002, 2004, 2007, 2008 and 2009 the cold water pool is located below the power penstock elevation and Reclamation must evaluate its options to meet all Project purposes and requirements.

The equivalent number of days release for the 50% and 30% EID diversion scenarios, without consideration of inflow, varies from 0.7 to 2.1 days, far below the 4 days suggested to have the potential to trigger an adjustment of downstream target temperatures, with the maximum numbers of days release occurring when the water temperature at the power penstock is less than 60ºF which again indicates an adequate supply of cool water remains for fall temperature operations (comments from Reclamation, 8/15/ 2011). See Tables 8a and 8b.

The equivalent number of days release for the EID 100% diversion scenario with consideration of the upstream below 60ºF inflow, varies from 0 to 2.4 days, below the 4 days suggested to have the potential to trigger an adjustment of downstream target temperatures. The maximum number of days release (2.4 days) occur when the water temperature at the power penstock is less than 60ºF which indicates an adequate supply of cool water remains for fall temperature operations (comments from Reclamation, 8/15/ 2011). The changes are all zero or negative using the 50% and 30% EID diversion with consideration of the upstream below 60ºF inflow (see Tables 8a and 8b).