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TECHNICAL MEMORANDUM

Date:	December 5, 2018
To:	Project File
From:	Chris Connor, Chris Campbell
Project:	18-1011 – Yolo Bypass Design and Support
Subject:	Model Boundary Conditions Update

INTRODUCTION

Previous TUFLOW hydrodynamic modeling to support the Yolo Bypass Salmonid Habitat Restoration and Fish Passage Project relied on boundary conditions prepared for water years (WY) 1997 through 2012 (refer to the June 2017 report for more details). Results from the TUFLOW hydrodynamic modeling were subsequently used to support fish benefits and fish entrainment modeling efforts. There are continued efforts to refine the fish entrainment modeling by validating the SRH-2D hydrodynamic model to the February-March timeframes in WYs 2015 and 2016 to supplemental stage and ADCP data collected by DWR and USGS. There are also other efforts by DWR to better understand the processes affecting food web production supported by flow releases through the Yolo Bypass as part of their North Delta Food Web Action.

In summary, a complete set of boundary conditions were prepared for WYs 2013 through 2017. Table 1 provides a summary of the sources and data types that were used for each boundary condition for WYs 2013 through 2017 and notes any changes in the source or type. Table 2 summarizes the dates of missing data for each boundary condition. Beyond small data gaps at select gauges due to missing or erroneous data that were generally backfilled by interpolation techniques, the largest set of missing gauge data was for KLOG (WYs 2013 through 2015) and Steelhead Creek (WY 2013), which is further described below. This update also included refinements for Putah Creek low flows per the flow requirements mandated in the Putah Creek Accord of 2000 (see Appendix A).

The following details the preparation of TUFLOW model boundary conditions for WYs 2013 through 2017.

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UPSTREAM BOUNDARIES

1. Feather River and Sutter Bypass
    a. Due to a lack of gauges in the vicinity of their confluence, the flow contributions from the Feather River and the Sutter Bypass were previously estimated using gauge data per Method #1, which was validated using gauge data from Method #2 (refer to the June 2017 report for more details). Method #1 inflows were previously used because it directly used measured flows at Fremont Weir and Verona. However, the flow split between the Feather River and Sutter Bypass was based on Method #2.
    b. Method #1 Gauges
        i. Sacramento River below Wilkins near Grimes
            1. USGS gauge 11390500
                a. 15-minute data converted to hourly
        ii. Knights Landing Outfall Gates (KLOG)
            1. Per the Site Report for Colusa Basin Drain at Knights Landing (gauge A02945), on 8/4/2012, construction to replace the KLOG structure and controller began, with the removal of the gate sensor occurring on 8/14/2012. As a result, **no data is available for WYs 2013 through 2015**; however, flow data for WYs 2016 and 2017 were obtained on 8/31/2018 from Lester Grade of the DWR North Region office. Table 2 provides a reference for available data.
                a. Daily data was converted to hourly (12/1/2015 – 9/30/2017
        iii. Fremont Weir (East End) – Sacramento River Spill
            1. CDEC gauge FRE (not the Water Data Library gauge A02930 because the record is unavailable).
                a. Hourly data
        iv. Sacramento River at Verona
            1. USGS gauge 11425500
                a. 15-minute data converted to hourly
    c. Method #2 Gauges
        i. Butte Slough near Meridian
            1. DWR gauge A02972
                a. 15-minute data converted to hourly
        ii. Tisdale Weir near Grimes
            1. DWR gauge A02960
                a. 15-minute data converted to hourly
        iii. Feather River at Gridley
            1. DWR gauge A05165
                a. 15-minute data converted to hourly
        iv. Yuba River at Marysville
            1. USGS gauge 11421000
                a. 15-minute data converted to hourly
        v. Bear River near Wheatland
            1. USGS gauge 11424000
                a. 15-minute data converted to hourly
    d. Computed inflows
        i. A scatter plot of the inflows computed by both methods is shown in Figure 1. Given the potential uncertainty in gauged flows (i.e., rating curve error and

hysteresis, lack of gauged inflows for Wadsworth Canal, and inflow estimation for Natomas Cross Canal) and simplified routing (i.e., translation) for purposes of these calculations, it is shown that Method #1 reasonably predicts the inflow at the Feather/Sutter model boundary as validated by Method #2. Method #1 inflows will be used in the TUFLOW model because it directly uses measured flows at Fremont Weir and Verona, except in WYs 2013 through 2015 when KLOG has missing data, whereby Method #2 will be used. However, the flow split between the Feather River and Sutter Bypass will continue to be based on Method #2.

2. Sacramento Weir
    a. USGS gauge 11426000
        i. 15-minute data converted to hourly
3. Natomas Cross Canal
    a. Natomas Cross Canal is calculated by applying a constant multiplier to Steelhead Creek (see American River 1a).
        i. Hourly data

WESTSIDE TRIBUTARIES

1. Westside Tributaries
    a. Knights Landing Ridge Cut
        i. DWR gauge A02939
            1. 15-minute data converted to hourly
        ii. Note: future flows should be based on gauge readings from the Wallace Weir facility after the rating system has been verified (in progress)
    b. Cache Creek Settling Basin
        i. USGS gauge 11452901 (total flow)
            1. 15-minute data converted to hourly
    c. Putah Creek
        i. US Bureau of Reclamation - Solano Project: Lake Berryessa Daily Operations; Lake Solano Daily Operations
        ii. Inflows were calculated based on Management Strategy equations as documented in the June 2017 report. However, low flow corrections were applied per Appendix A to include low flow requirements mandated in the Putah Creek Accord of 2000 as well measured low flows less than 100 cfs at I-80 by SCWA since July 2008. Note: measured low flows still need to be applied to WYs 2013 through 2017 pending receipt of data from SCWA.
            1. Daily data converted to hourly
    d. Willow Slough
        i. Inflows were calculated based on Management Strategy equations as documented in the June 2017 report.

AMERICAN RIVER

1. American River
    a. Steelhead Creek (formerly called Natomas East Main Drainage Canal)

i. Stage Data obtained from Sac County ALERT gage CO4, sensor 1692. A rating curve developed by DWR's Division of Environmental Service (DES) was applied to convert stage to flow data, as per the June 2017 report. For dates where sensor 1692 was missing data, data was estimated following the guidelines outlined in the June 2017 report, which was to adopt the minimum flows. Data available for WY 2014-2017. WY 2013 was backfilled for the majority of the WY due to both ALERT gages reporting erroneous data.
    1. Hourly data

b. American River at Fair Oaks
    i. USGS gage 11446500
        1. 15-minute data converted to hourly

DELTA SLOUGHS

1. Due to the lack of gage data available for the delta sloughs, estimation techniques developed during the previous round of data collection were used to backfill missing data.
    a. Gage data
        i. Lindsey Slough at Hastings Bridge (LSHB)
            1. Gage data supplied by SCWA, 10/2/2015 – 5/8/2016
        ii. Barker Slough Pumping Plant (BKS)
            1. Gage data obtained from CDEC
                a. Daily Data converted to hourly
        iii. Barker Slough Doppler Station at SCWA gauge Doppler (DOP)
            1. Gage data supplied by SCWA, 10/3/2015 – 5/10/2016
        iv. Delta cross channel and Georgiana Slough outflow
            1. Data obtained from DWR's Dayflow program
                a. Daily data converted to hourly
        v. North Bay Aqueduct
            1. Data obtained from DWR's Dayflow program
                a. Daily Data converted to hourly
        vi. Upper Cache Slough
            1. Gage data not available for entire period of record. Gage Data previously obtained from DWR's North Central Regional Office. Daily inflow was split equally between Cache Slough and Hass Slough.
    b. Estimated inflows
        i. Cache Slough
            1. Daily Data estimated for 10/1/2013 – 9/30/2017, converted to hourly
        ii. Haas Slough
            1. Daily Data estimated for 10/1/2013 – 9/30/2017, converted to hourly
        iii. Calhoun Cut
            1. Daily flow computed using real data for 10/2/2015 – 5/8/2016, converted to hourly
            2. Daily flow estimated for 10/1/2012 – 10/1/2015, 5/9/2015 – 8/14/2017, converted to hourly
        iv. Campbell Lake

1. Daily flow computed using real data for 10/3/2015 – 5/10/2016, converted to hourly
2. Daily flow estimated for 10/1/2012 – 10/2/2015, 5/11/2015 – 8/14/2017, converted to hourly

DOWNSTREAM BOUNDARY

1. Rio Vista Downstream Stage
    a. DWR gauge B91212
        i. 15-minute data (in NAVD88) converted to hourly

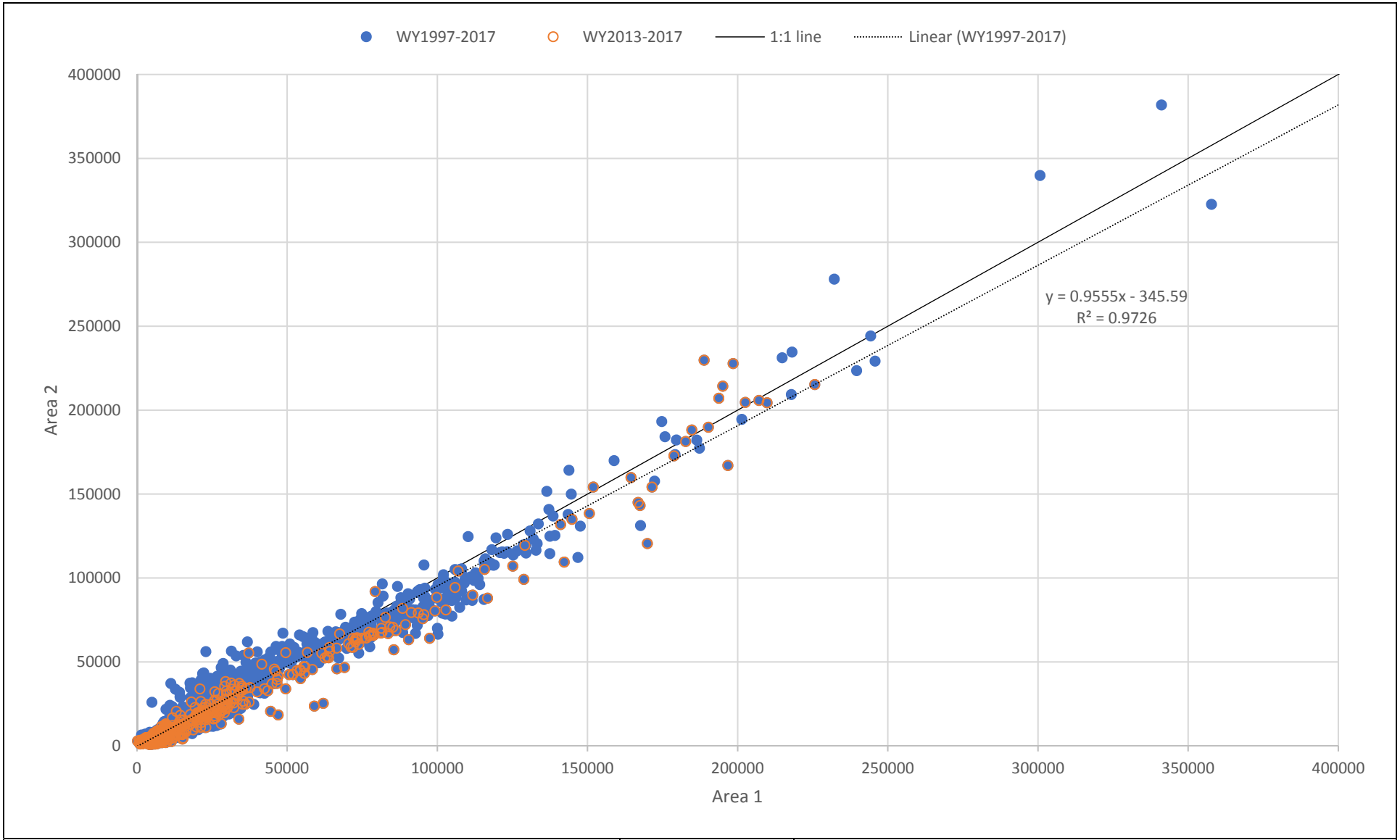
Table 1. Summary of model boundary conditions for WYs 2013 through 2017

Boundary Conditions	Source	Data type[2]
Upstream Boundaries		
Sacramento River inflow below Wilkins Slough near Grimes	USGS 11390500	Gauged flow
Feather River and Sutter Bypass inflows	This study[1]	Estimated flow based on data from USGS 11390500, USGS 1142500, A02930, A02945, Arcade Creek/EMC02 gauges
Natomas Cross Canal inflow	This study[1]	Estimated flow based on data from Arcade Creek/EMC02 gauge
Sacramento Weir inflow	USGS 11426000	Gauged flow
Westside Tributaries		
Knights Landing Ridge Cut inflow	~~DWR A02930 and this study[1]~~ DWR A02939	Gauged flow ~~and estimated flow based on data from A02976, A02945 and A02930 gauges~~
Cache Creek Settling Basin	USGS gauge 11452901	~~Estimated flow based on data from USGS 11452500 gauge~~ Gage data for total flow became available 02/18/2009
Willow Slough Bypass inflow	Yolo Bypass Management Strategy	Estimated flow
Putah Creek inflow	Yolo Bypass Management Strategy	Estimated flow based on USBR reservoir operations data
American River		
American River inflow	USGS 11446500	Gauged flow
Steelhead Creek (formerly called Natomas East Main Drainage Canal) inflow	This study[1]	Estimated flow from City of Sacramento's Arcade Creek/EMC02 gauge
Delta Sloughs		
Delta Cross Channel and Georgiana Slough outflow	DWR's Dayflow program	Gauged flow and estimated flow
Haas Slough, Cache Slough, Barker Slough, and Calhoun Cut	This study[1]	Estimated flow based on data from DWR's UCS and BKS and SCWA's DOP and LSHB gauges
Municipal / Agricultural Intakes and Drains		
Delta Island Consumptive Use (DICU) inflow/outflow	DWR's Delta Simulation Model II (DSM2)	Estimated flow
North Bay Aqueduct	DWR's Dayflow program	Gauged flow and estimated flow
Downstream Boundary		
Rio Vista downstream stage	DWR B91212	Gauged stage
Notes:		

[1] Estimated as a part of the current study and largely relying on verification of local gauge records and extrapolation for the period of analysis
[2] Time series data for daily flows (in cfs) and stages (in feet, NAVD88) were compiled in HEC-DSS, converted to an hourly time step to maintain daily average conditions in TUFLOW, and exported to CSV.

Table 2. Summary of Missing Gauge Data for WYs 2013 through 2017

Gauge Data	Dates Missing
Upstream Boundaries	
Sacramento River inflow below Wilkins Slough near Grimes	---
Sacramento River at Verona	9/26/2013
Feather River at Gridley	4/18/2017-4/26/2017
Yuba River at Marysville	12/2/2012-12/15/2012; 2/27/2017-3/2/2017; 3/3/2017
Bear River near Wheatland	10/12/2014-11/6/2014; 11/10/2014; 9/1/2016-10/4/2016
Natomas Cross Canal inflow	10/1/2012 – 10/26/2013
Sacramento Weir inflow	---
Knight's Landing Outfall Gates	WYs 2013-2015; 6/1/2017-6/4/2017
Westside Tributaries	
Knights Landing Ridge Cut inflow	---
Cache Creek Settling Basin	---
Willow Slough Bypass inflow	---
Putah Creek inflow	---
American River	
American River inflow	-
Steelhead Creek (formerly called Natomas East Main Drainage Canal) inflow	10/1/2012 – 10/26/2013
Delta Sloughs	
Delta Cross Channel and Georgiana Slough outflow	---
Haas Slough, Cache Slough, Barker Slough, and Calhoun Cut	Estimated flow based on data from DWR's UCS and BKS and SCWA's DOP and LSHB gauges
Municipal / Agricultural Intakes and Drains	
Delta Island Consumptive Use (DICU) inflow/outflow	---
North Bay Aqueduct	---
Downstream Boundary	
Rio Vista downstream stage	---



Notes:

Yolo Bypass Design and Support

Feather – Sutter flow scatter plot

Project No. 18-1011 | Created By: CMC | **Figure 1**

18-1011_YBM_LT_BCs_Fig01_2018-1126.docx
12/5/2018

APPENDIX A
PUTAH CREEK LOW FLOW CORRECTIONS

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TECHNICAL MEMORANDUM

Date:	April 20, 2016 (Revised November 16, 2018 per Final Report)
To:	Project File
From:	Sridhar Ponangi, Chris Campbell
Project:	12-1024 – Lower Putah Creek Restoration Project
Subject:	Long-term Low Flow Corrections

1 INTRODUCTION

As part of the Yolo Bypass Management Strategy (Management Strategy) prepared by Jones & Stokes (2001), measured and estimated hydrology for the flood control weirs and Westside tributaries was compiled for WY 1968 through WY 1998. cbec extended this data set through WY 2012 in support of the Yolo Bypass Salmonid Habitat Restoration and Fish Passage (YBSHRFP) Project using measured data and refinements to the Management Strategy flow estimation techniques. The final long-term record used in the YBSHRFP and herein is from WY 1997 through WY 2012 for the months of October through May.

As described herein, the Lower Putah Creek long-term boundary conditions were further refined by modifying the Management Strategy estimation techniques and better representing minimum flows and pulses as provided by the Putah Creek Accord of 2000 (Accord).

2 MANAGEMENT STRATEGY EQUATIONS

The Management Strategy estimated inflows to the Yolo Bypass from Lower Putah Creek are based on release and spill at Monticello Dam and PDD. During times of no active rainfall-runoff (Condition 1) or if Monticello Dam is spilling (Condition 3), inflow to the Yolo Bypass equals PDD releases minus 30 cfs for seepage and evapotranspiration losses. When there is active rainfall-runoff (Condition 2), defined as Interdam Runoff in excess of 100 cfs, then inflow to the Yolo Bypass equals two times the PDD releases minus 30 cfs to account for losses. The Management Strategy provides a more detailed discussion of these assumptions.

Interdam Runoff is defined as the difference between (a) Berryessa release plus spill and (b) Putah Diversion Dam release after diversion to the Putah South Canal.

3 MODIFICATIONS TO MANAGEMENT STRATEGY EQUATIONS

Management Strategy equations developed for Lower Putah Creek in 2001 are based on data for WY 1968 through WY 1998. As such, the method does not account for minimum flows required by the Accord. Therefore, revisions to the estimated flows, especially the minimum flows, are needed.

Changes to the Management Strategy equations to improve the Lower Putah Creek flow estimates into the Yolo Bypass included:

- Modified losses
- Accord minimum flows and pulse flows
- Travel time to account for routing from PDD to the Yolo Bypass

SCWA started measuring flows starting 2008. However, the SCWA gauge is rated for flows only up to 100 cfs. Therefore, in addition to the changes to Management Strategy equations, measured flows were retained for below 100 cfs.

3.1 MODIFIED LOSSES

The Management Strategy equations assume a constant flow loss of 30 cfs between PDD and the Yolo Bypass to reflect seepage losses, tributary inflows, irrigation diversions, evapotranspiration, and channel storage. cbec modified the losses to account for variability on a monthly and WY type basis. These loss estimates were derived by comparing the flows estimated using Management Strategy equations to the SCWA measured flows for Lower Putah Creek at I-80 (PC-80) recorded between July 2008 and March 2013. The SCWA gauge is only rated for flows up to 100 cfs, so flows above 100 cfs were not used to estimate the losses.

As mentioned above, the losses were classified based on WY type. However, the monthly losses were grouped from December to November of the following WY rather than the typical October to September. This modification was based on observed flow data that exhibited losses during October and November months consistent with the prior WY. For example, observed flow data exhibited greater losses extending past the end of dry WY into the months of October and November. Similarly, smaller losses were observed during the months of October and November following a normal/wet WY.

The losses were estimated to be even lower during wet years with flood events occurring late in winter or early spring (e.g., WY 2011). This was also evidenced by higher than typical stage recorded during April through June at Lisbon Weir (LIS) gauge (see Table 1). This WY type was termed "Late Wet" and had lower losses during April - June period than typical normal/wet years and was hence assigned lower losses. **Error! Reference source not found.** summarizes the monthly losses for the WY types.

Table 1. Mean Daily Stage for Yolo Bypass gauge at Lisbon Weir

Timing Assumption	Water Year type	Water Year	Date	Mean Stage (ft, NAVD88)[1]	Date	Mean Stage (ft, NAVD88)[1]	Date	Mean Stage (ft, NAVD88)[1]
Late	Wet	2011	4/1/2011	17.2	5/1/2011	5.2	6/1/2011	5.6
Late	Wet	2006	4/1/2006	14.8	5/1/2006	14.0	6/1/2006	5.2
Late	Wet	1999	4/1/1999	11.1	5/1/1999	5.1	6/1/1999	5.0
Late	Wet	1998	4/1/1998	15.7	5/1/1998	7.1	6/1/1998	9.4
Normal	Wet	1997	4/1/1997	4.6	5/1/1997	4.0	6/1/1997	4.5

Notes:
[1] Daily mean stage

Table 2. Estimated Lower Putah Creek losses

Month[1]	Dry / Critical	Below Normal / Above Normal / Wet	Late Wet
December	15	15	15
January	10	10	10
February	5	5	5
March	0	5	5
April	0	10	0
May	5	10	0
June	15	20	5
July	20	20	15
August	25	20	20
October	30	20	20
November	22	20	15

Notes:
[1] The monthly losses were grouped from December to November of the following year

3.2 ACCORD MINIMUM FLOWS AND PULSE FLOWS

Following the Accord, water releases from PDD to the creek were modified to maintain minimum flows for fish, water rights at Interstate 80, and to maintain continuous flow downstream to RM 0. This included coordinated efforts between SCWA operating PDD pulse flows and Los Rios Check Dam operators managing the flashboards during the Fall and Spring pulses. As such, the Management Strategy equations were modified to capture the required minimum flows in Lower Putah Creek as provided by the Accord. For the purposes of this study, even though the Accord was not effective until 2000, the minimum flows were incorporated into Management Strategy equations for all WYs to reflect present day operations in the analysis.

3.3 TRAVEL TIME

A 2-day lag was incorporated into the Management Strategy equation to account for travel time from PDD to I-80.