RECLAMATION

Managing Water in the West

Special Study: Evaluation of Dilution Flow to Meet Interior South Delta Water Quality Objectives

To Meet Water Rights Order 2010-002 Requirement 7

April 8, 2011

U.S. Department of the Interior

Bureau of Reclamation

Mid-Pacific Region

SRCSD-23

This page was intentionally left blank.

Contents

This page was intentionally left blank.

Abbreviations and Acronyms

CDEC	California Data Exchange Center
CDO	Cease and Desist Order WR 2010-002
cfs	cubic feet per second
CVP	Central Valley Project
Deputy Director	Deputy Director of the California State Water Resources Control Board
DMC	Delta-Mendota Canal
Draft Objectives Technical Report	"Draft Technical Report on the Scientific Basis for Alternative San Joaquin River Flow and Southern Delta Salinity Objectives"
DWR	California Department of Water Resources
EC	electrical conductivity
mmhos/cm	millimhos per centimeter
µS/cm	micromhos per centimeter
QA/QC	quality assurance/ quality control
Reclamation	Bureau of Reclamation
Study	Special Study to Meet Water Rights Order 2010-002 Requirement 7
Study Plan	Special Study Plan to Meet Water Rights Order 2010-002 Requirement 7
SWP	State Water Project
TAF	thousand acre-feet
USBR	Bureau of Reclamation
Vernalis	Lower San Joaquin River at Vernalis
Water Board	California State Water Resources Control Board
WR	water right
WQCP	Water Quality Control Plan for the Sacramento and San Joaquin River Basins, 4^{th} Edition

Purpose

On January 5, 2010 the California State Water Resources Control Board (Water Board) issued WR 2010-002, amending Cease and Desist Order WR 2006-006 (CDO) regarding compliance of the federal and state water projects with the South Delta agricultural objectives for salinity. Requirement 7 of this order states:

> *DWR and USBR shall study the feasibility[1] of controlling salinity by implementing measures other than the temporary barriers project, recirculation of water through the San Joaquin River, and construction and operation of the permanent, operable gates. For each measure studied, DWR and USBR shall evaluate the extent to which the measure could control salinity at each of the interior southern Delta compliance locations, whether implementation of the measure would result in compliance with the interior southern Delta salinity objective at each of the locations, the technical and regulatory feasibility of the measure, the costs of the measure, and any potential impacts of the measure, including potential impacts to water quality, fishery resources, or water supplies. The study shall include, but is not limited to, an evaluation of the installation of low lift pumps at one or more of the temporary barriers. In addition, DWR and USBR shall evaluate, through modeling, whether compliance with the interior southern Delta salinity objective could be achieved by increasing flows in the San Joaquin River. In evaluating the feasibility of increasing flows in the San Joaquin River, DWR and USBR shall (1) evaluate the feasibility of both increased releases from CVP and SWP facilities and purchases or exchanges of water from third parties, and (2) evaluate the potential impacts of increasing flows on water supplies, including water supplies needed to protect fishery resources. Within 60 days from the date of this order, DWR and USBR shall submit a study plan to the Deputy Director for Water Rights for the Deputy Director's review and approval. The Deputy Director may direct DWR and USBR to make any changes to the study plan necessary to ensure a meaningful evaluation of alternative salinity control measures. In addition, the Deputy Director may require DWR and USBR to conduct the study in phases, to refine or augment the study based on the results of an earlier phase, or to evaluate a combination of alternative salinity control measures designed to improve or achieve compliance with the interior southern Delta salinity objective. DWR and USBR shall make any changes to the study plan that the Deputy Director requires within the period that the Deputy Director specifies, and shall conduct the study in accordance with the approved study plan. Within 180*

---

[1] This report is intended to meet the requirement of the State Board and is not intended to meet the federal requirements of a formal Feasibility Study as the United States Congress has not authorized such a study. A feasibility determination in a formal Federal Feasibility Study would be based upon the technical, environmental, economic, and financial feasibility of a proposed action. The study required by the State Board is primarily focused on the technical aspects of using increased flows to meet south Delta water quality objectives.

days from the Deputy Director's approval of the study plan, DWR and USBR shall submit a report to the Executive Director that describes the study and its results.

The California Department of Water Resources (DWR) and Bureau of Reclamation (Reclamation) submitted a Study Plan to Meet Water Rights Order 2010-002 Requirement 7 (Study Plan) to the Water Board on March 8, 2010. On June 21, 2010 the Water Board responded with requested revisions to the Study Plan. DWR and Reclamation addressed this request through a Revised Study Plan submitted on August 3, 2010 (Appendix A). On September 21, 2010, the Water Board approved the Study Plan (Appendix B), requiring the final study to be submitted in March 2011. The Water Board subsequently granted an extension to April 2011.

On October 29, 2010, the Water Board released a "Draft Technical Report on the Scientific Basis for Alternative San Joaquin River Flow and Southern Delta Salinity Objectives" (Draft Objectives Technical Report). The Draft Objectives Technical Report included an evaluation of the relationship between Vernalis and South Delta locations, and some of this information is referred to in this Special Study.

DWR and Reclamation have divided the work to meet the requirement into two separate reports. DWR is submitting a separate study on the installation of low lift pumps at one or more of the temporary barriers. This Special Study report by Reclamation meets the remaining objectives of the requirement.

Organization of Study

The flow evaluation documented in this special study report occurred in three separate phases. The first phase explored the relationship between salinity at Vernalis on the San Joaquin River and salinity at the south Delta standard locations. The second phase uses these results to evaluate the range of additional flows measured at Vernalis that would be needed to meet the South Delta salinity standards. The third phase was a reconnaissance-level study of evaluating the availability of additional flows.

A. Salinity Relationship

In the Study Plan, Reclamation proposed a process for determining relationships between the San Joaquin River at Vernalis and the other southern Delta locations' salinity (EC) by:

1. Collecting recent (2000-2009) high frequency salinity data at Vernalis and South Delta compliance monitoring locations.
2. Analyzing data to determine lag times between stations.
3. Employing lag times to develop best-fit relationships between EC at Vernalis and South Delta locations as well as confidence bounds for the best-fit relationships.
4. Using the developed best-fit relationships to design salinity targets at Vernalis to meet South Delta EC objectives.

The analysis performed in this portion of the study provides analytical evidence, through historic data, supporting the difficulty in developing a simple correlation between the Vernalis and the three interior Southern Delta compliance locations. Occurrences of EC exceedance in the Southern Delta did not correlate with water year types or drier months. Lag times were also explored for their potential relationship to flow at Vernalis but no distinct relationship was observed. Best-fit relationships developed and tested for EC at Vernalis and the South Delta locations proved to be an inefficient approach, as there are many times when the surrogate EC is applied even when the south Delta is not in danger of exceeding EC objectives. The use of salinity surrogates developed from linear regression equations highlights the potential inexactness of this approach due to other unknown variables which seem to influence Southern Delta salinity.

The Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary (WQCP) dated December 13, 2006 specifies the southern Delta salinity objectives as 30-day running mean daily EC of 700 umhos/cm from April through August and of 1000 umhos/cm from September through March for all water year types. There are four southern Delta salinity compliance locations: the San Joaquin River at Vernalis (VNS), Old River near Middle River (or Union Island, UNI), San Joaquin River at Brandt Bridge (BDT), and Old River near Tracy (OLD). Figure 1 maps these locations as well as other Delta features.

Since the development of the Study Plan, the Water Board completed step 1 in its Draft Objectives Technical Report and determined best-fit relationships based on monthly average salinity at each location. The Water Board then determined that, for the purposes of estimating water supply costs (assuming that all the south Delta EC standards would be met through flow), that the best-fit relationship at Old River near Tracy should be further adjusted so that a certain Vernalis salinity would better guarantee a level of salinity at that location.

In light of the effort by the Water Board to reevaluate the basis of South Delta salinity objectives and to reevaluate implementation alternatives, Reclamation adjusted its approach in an effort to more fully explore a pragmatic relationship between South Delta locations to both meet salinity objectives but also to maximize the efficiency of any flow releases to reliably meet salinity objectives. This analysis and its results are the topic of Section A, Salinity Relationship.

1. Recent Data

Daily salinity (EC in umhos/cm) and flow data for San Joaquin River at Vernalis is publicly available on the California Data Exchange Center (CDEC) database at http://cdec.water.ca.gov/ (VER sensor number 100 and VNS sensor number 41). Daily salinity data for Union Island (or Old River near Middle River, ROLD 69) is publicly available on the CDEC database (UNI sensor number 100). Daily salinity data for San Joaquin River at Brandt Bridge (RSAN073) is publicly available on the CDEC database (BDT sensor number 100) starting in April of 2005. Daily salinity data for Old River near Tracy (ROLD59) is publicly available on the CDEC database (OLD sensor number 100) starting in April of 2005. Brandt Bridge and Old River data prior to April of 2005 was obtained from DWR (some of it through the Water Board). Because the Water Board collected this same period of data for is Draft Objectives Technical Report, Reclamation obtained the data used as the basis of this report to ensure that the analysis in this Study is based on the same data set. Reclamation can make the collected data available upon request.

In addition to salinity data, Reclamation compiled daily San Joaquin River and Sacramento flows, export pumping rates, and temporary barrier status as additional variables of potential interest. Appendix C contains daily time series of the 30-day running averages of salinity and flow, along with temporary barrier operations' status by water year for water years 2000 through 2010.

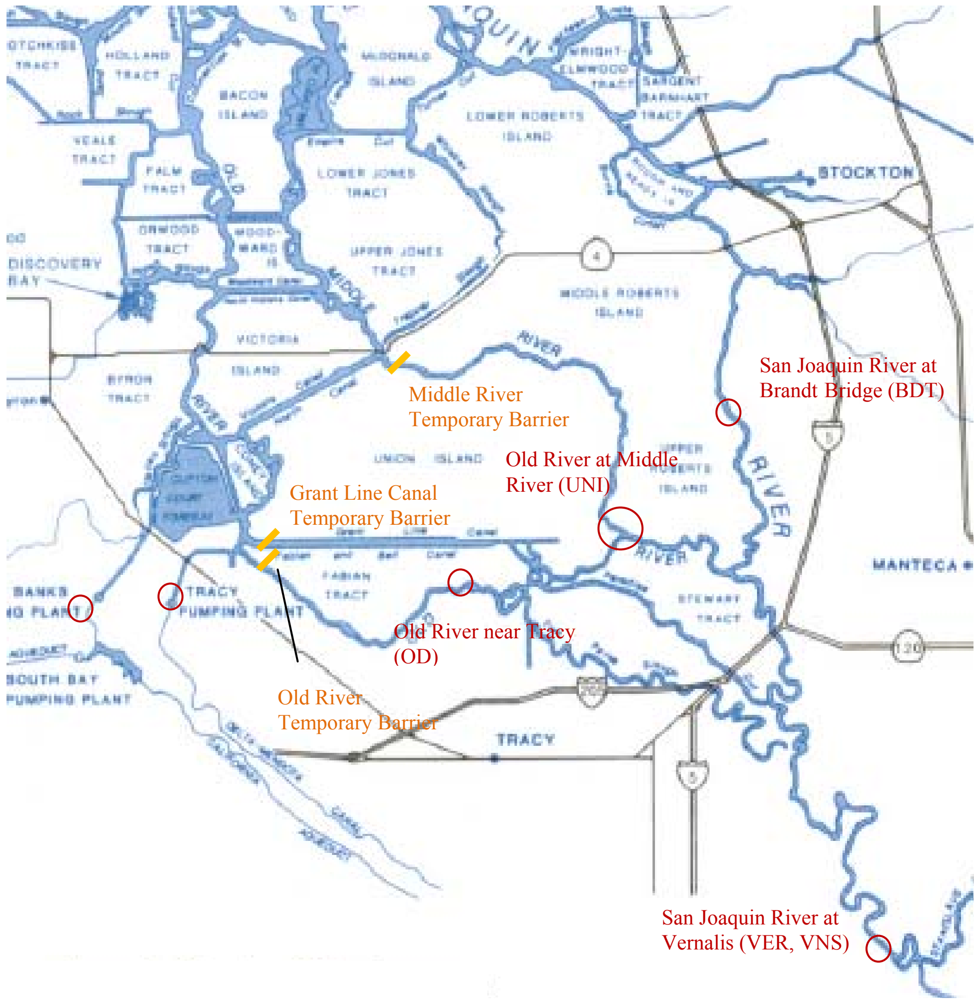


Figure 1: Map of Southern Delta Water Quality Objective Compliance Locations, Export Pumps, and Temporary Barriers (figure from Delta Atlas)

Reclamation first examined the salinity data sets. The water quality objective calls for a 30-day running average, so both daily and averaged data was examined. As a first step, frequency boxplots were developed from the data for the four compliance locations. Boxplots, or box-and whisker plots, are visual depictions of data sets, highlighting the median (or central data point) of the data set, with a box capturing between 25% and 75% of the data, and then with lines marking the outermost 10%, 5% and 1% of the data, as well displaying dots representing data that is likely outliers (Helsel, 2006). A normal distribution is a box centered around the median, with line demarcations equally spaced on either side. Boxplots are a quick way to visually determine how close data sets are to a normal distribution, how well individual data sets' distributions match, and whether data sets are skewed high or low, or contain significant outliers. Normal distributions are important because non-statistical mathematical applications are based on normal distributions of data.

Figures 2 through 4 illustrate daily data over the entire year, and for the two seasonal periods of the objective. The two seasonal periods were examined because salinity at Vernalis has been an operational control over the selected period of data, and as a first step, one might assert that the any difference from normality in a data set may be explained by the difference in operational objectives.

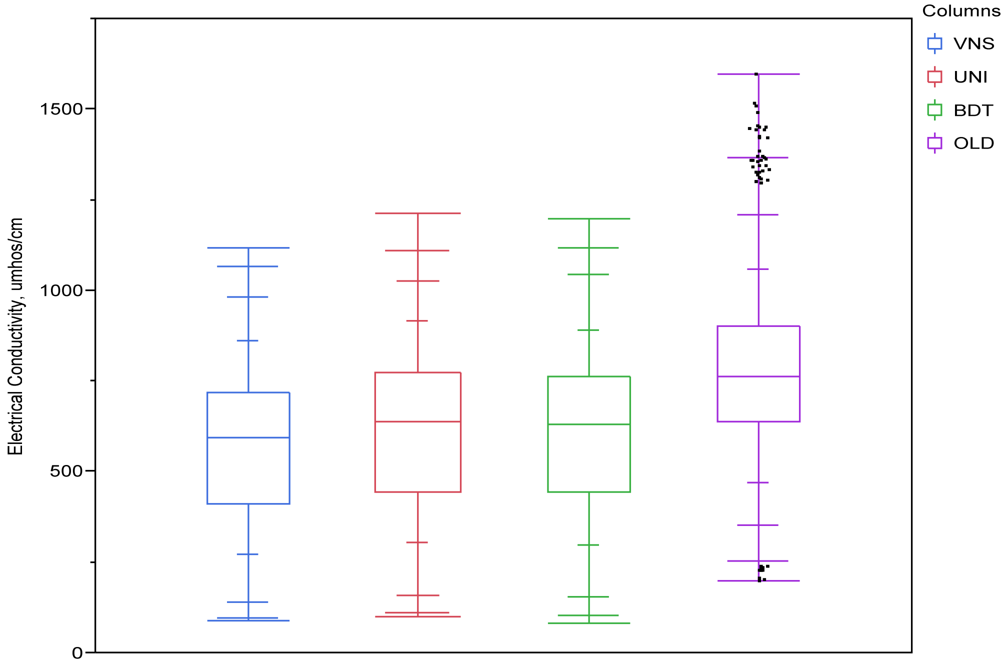


Figure 2: Boxplot Statistics of Daily Data (WY2000 - 2010)

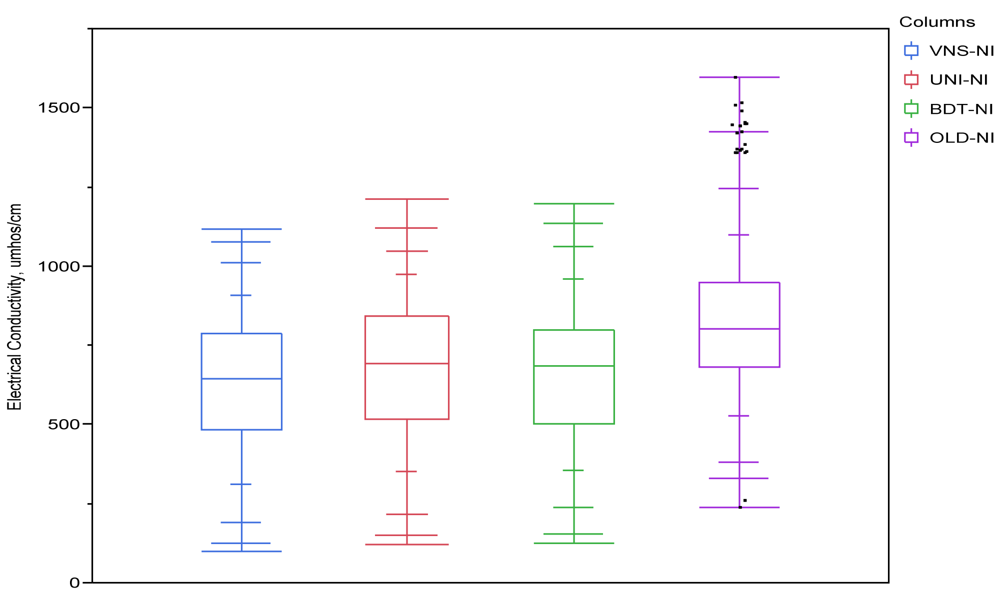


Figure 3: Boxplot Statistics of Non-irrigation Season Daily Data (WY2000-2010)

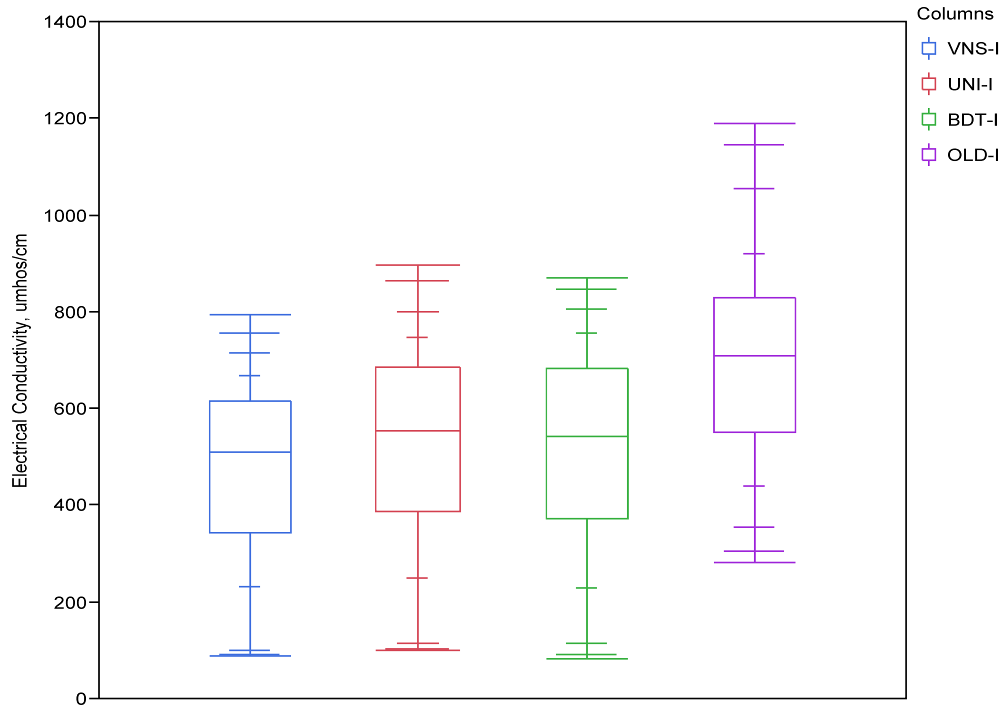


Figure 4: Boxplot Statistics of Irrigation Season Daily Data (WY2000-2010)

Compliance with the water quality objective at Vernalis may affect skew by limiting the range of data on the higher end, especially during the irrigation season when the objective is lower, more restrictive. A comparison of Figures 3 and 4 appear to confirm this, with Figure 4 boxplots showing a larger range in the lower data range and a shortened range in the higher data range. The non-irrigation season boxplots show a similar pattern for Vernalis, Old River near Middle River, and San Joaquin River near Brandt Bridge that is closest of the boxplots to normal. This suggests that linear regressions are probably appropriate for these data sets. The irrigation season boxplots for these same stations with their skew to the lower data range suggest that linear regressions may be more influenced by the lower end of the data range. The boxplots for Old River near Tracy under both seasons are different than the other stations, with a data range significantly higher than the other locations, with greater skew into the higher range of data, and a number of high outliers in the non-irrigation season. The differences between EC data at this station and the other stations become more obvious with additional analysis.

2. Affects of Averaging

The South Delta standards were most recently documented in the WQCP, on page 13 in Table 2. The measurement unit is defined as the "maximum 30-day running average of mean daily EC (mmhos/cm)" and footnoted further:

> *Determination of compliance with an objective expressed as a running average begins on the last day of the averaging period. The averaging period*

commences with the first day of the time period for the applicable objective. If the objective is not met on the last day of the averaging period, all days in the averaging period are considered out of compliance.

The water quality objective is, therefore, 1000 umhos/cm 30-day running average of mean daily EC from September 1 through April 29 and a 700 umhos/cm 30-day running average of mean daily EC objective from April 30 through August 31.

Reclamation has been operating the Central Valley Project (CVP) to meet the Vernalis salinity objective since the mid-1990s. To ensure compliance, the 30-day running average of salinity at Vernalis is calculated every day and operations are conducted to meet a 30-day running average that is lower than the objective, since the lower San Joaquin River is highly dynamic in regards to flow and salinity upstream of its confluence with the Stanislaus River. This operation uses a "salinity buffer" – an operational salinity goal at Vernalis that is lower than the salinity objective in order to ensure compliance with the objective.

The analysis documented in this Study uses the 30-day running average of mean daily EC as its basic variable of salinity in all three locations. Daily data can frequently exceed the objective values without violating the actual objective. Since the remainder of this study explores 30-day running average mean daily data, boxplots were created for the new data sets, in Figures 5 through 7. These boxplots are similar to the previous plots, but are more compressed due the nature of averaging (smoothing out the highest variations in the data set), resulting in a slightly larger group of mid-range of data (the "boxes"), and some low range outliers in the non-irrigation season data, which could be expected based on the low skew in the daily data sets.

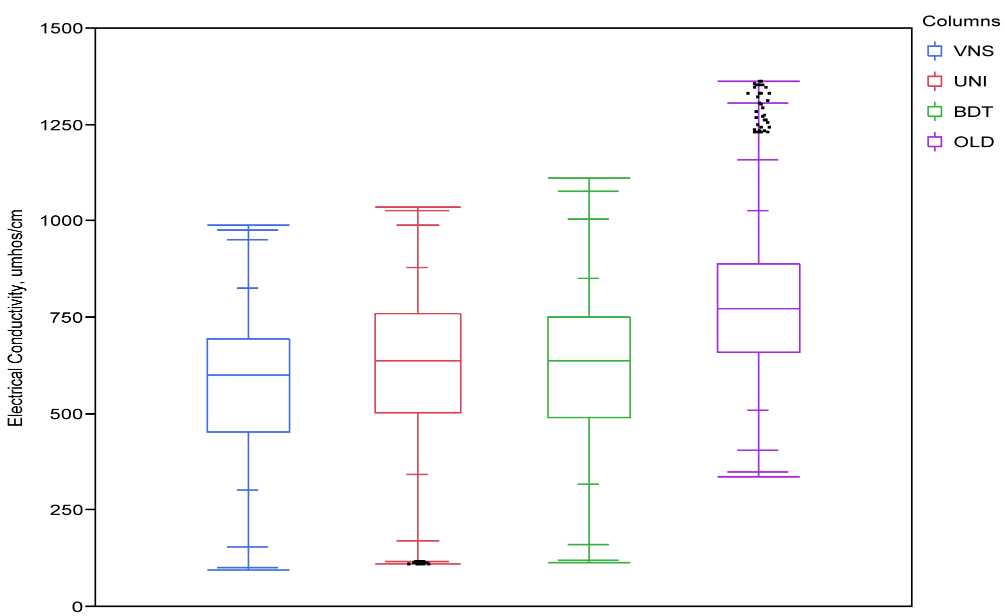


Figure 5: Boxplot Statistics of 30-Day Averaged Daily Data (WY2000-2010)

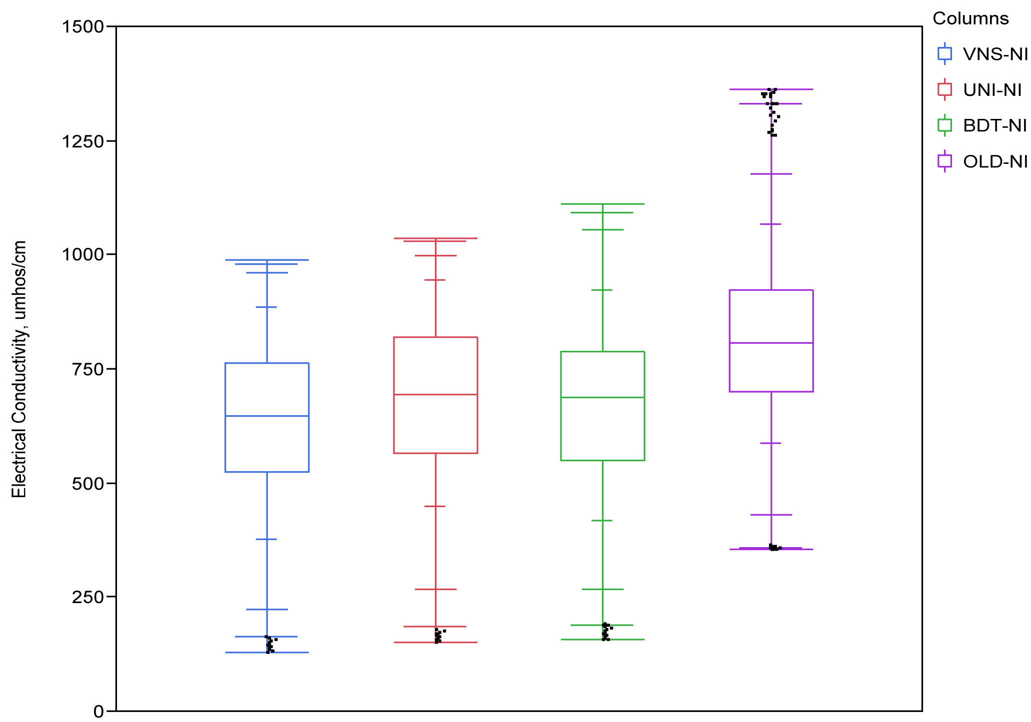


Figure 6: Boxplot Statistics of 30-Day Averaged Daily Non-Irrigation Season Data (WY2000-2010)

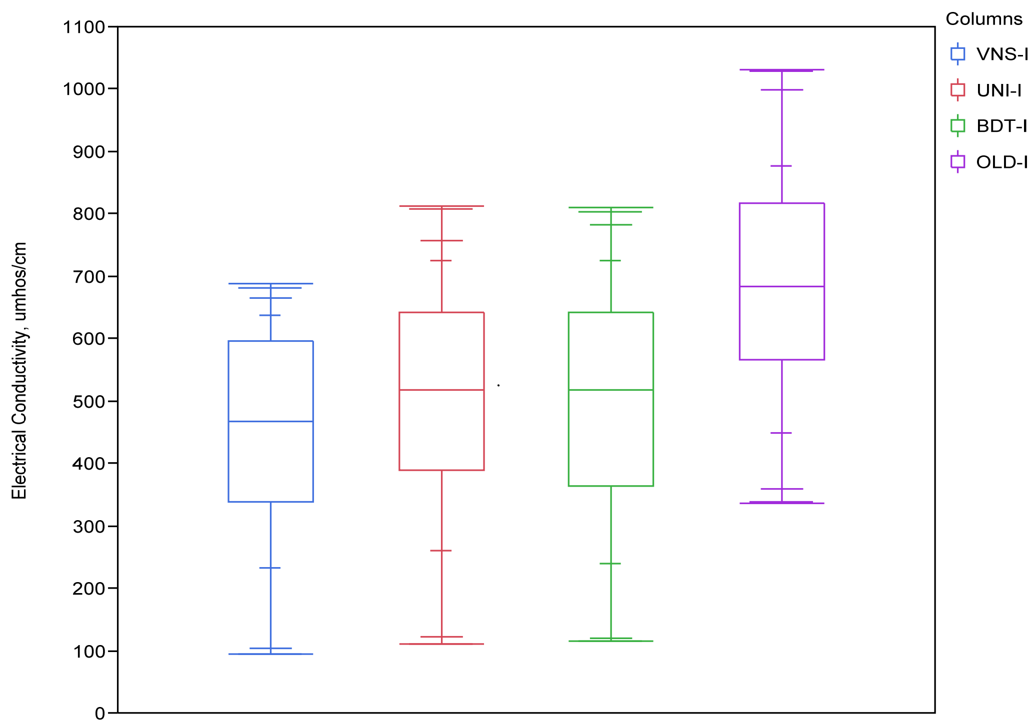


Figure 7: Boxplot Statistics of 30-Day Averaged Daily Irrigation Season Data (WY2000-2010)

3. South Delta Salinity History

This analysis examines the recent history of salinity at the south Delta compliance locations to determine what could be learned about patterns of and conditions under which the water quality objectives are exceeded. At the outset, the 30-day running averages were examined for the extent and timing of days when the objectives were exceeded in water years 2000 through 2010. The initial results are documented in Table 1 and Figures 8 and 9.

Table 1: Pattern of South Delta salinity objective exceedances (WY 2000 through WY2010)

Station	# Days Exceeded	Total Days	Percent of Days	# Months Exceeded	Total Months	Percent of Months
Union Island (ROLD69)	278	4145	6.7%	18	134	13.4%
Brandt (RSAN073)	316	4072	7.8%	19	134	14.2%
Old River at Middle (ROLD59)	852	3463	24.6%	42	113	37.2%
Vernalis	0	4145	0%	0	124	0%

The Water Board attached the three interior South Delta stations' salinity objectives to the state and federal project water rights permits, many have assumed that salinity in the south Delta salinity is predominantly a dependent variable of Vernalis salinity. If south Delta salinity were solely dependent on Vernalis salinity, one would expect to see very clear relationships, as well as similar patterns and relationships between the south Delta stations. For example, the patterns in Figures 9 and 10 illustrate that there are likely factors affecting south Delta salinity differently under the same salinity conditions at Vernalis, and thus the stations do not exhibit similar patterns of occurrence of EC exceedances either annually or monthly. Notice as well that there is not a strict correlation between occurrences of EC exceedance and water year types or typically drier months.

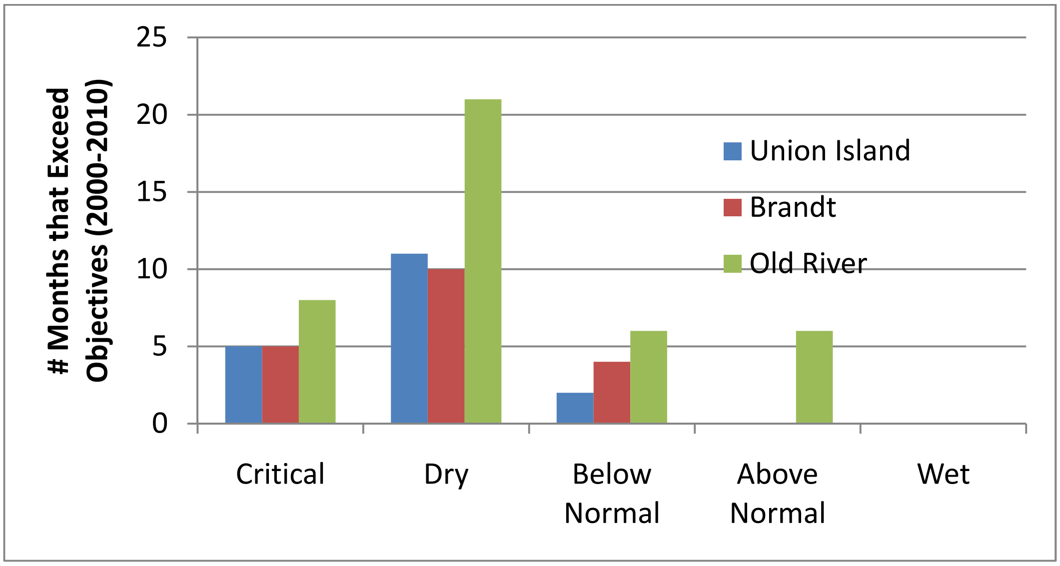


Figure 8: Pattern of Monthly Exceedances by Water Year Type (2000-2010)

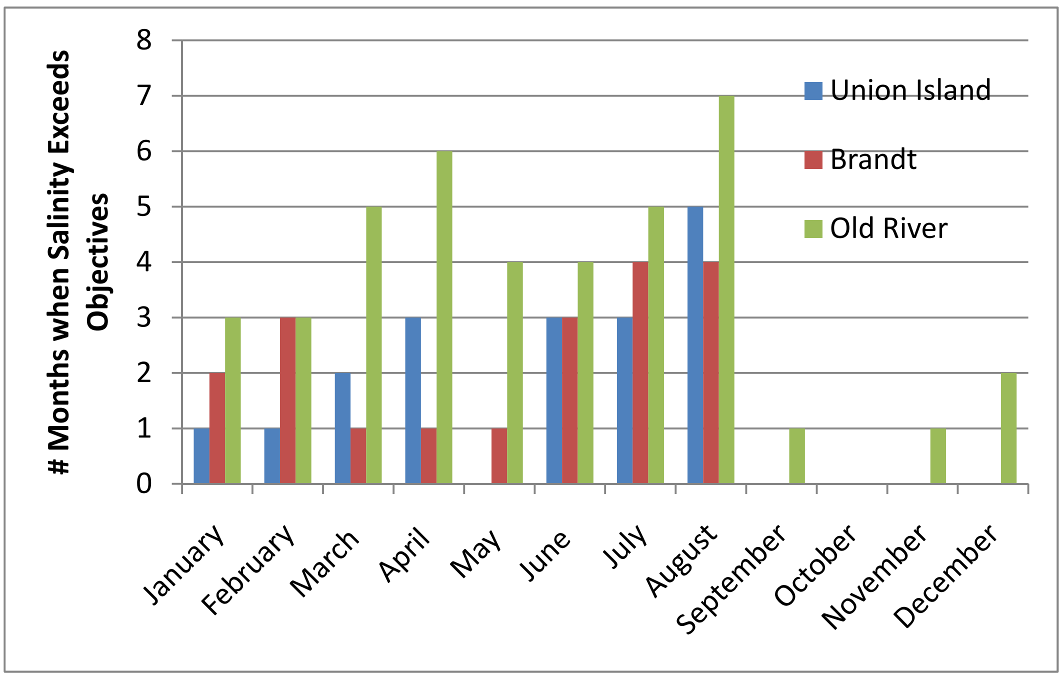


Figure 9: Pattern of Monthly Exceedances by Month (2000-2010)

4. Lag Time Analysis

Lag time is the amount of time it takes for water from Vernalis to travel to one of the South Delta locations. A lag time analysis was completed in order to investigate whether better aligning the salinity signals[2]. between locations would improve the best-fit linear regressions. The analysis was conducted by first examining the daily data at each location and visually comparing it to the Vernalis data that had been lagged by 1 to 10 days. Daily data was plotted by quarter so that it could be visually compared with different lag times to determine which variation of the lagged Vernalis EC time series appeared to be the best fit with the south Delta EC time series of interest. Because the data is in daily time steps, lag times was only examined with whole day time steps. On some occasions, it was clear that the best fit was between 0 and 1 day, and in those cases an estimate of 0 days was made. Where the signals could not be aligned, no estimate was made. The plots used to make this visual analysis are contained in Appendix D. Results are presented in Table 2.

Lag times were also explored for their relationship to flow at Vernalis in order to determine whether certain lag time assumptions should be made for discrete ranges of flow; however no distinct relationship was observed. Figures 10 through 12 illustrate the relationship between Vernalis flow and lag time between Vernalis and the other South Delta locations. The longest lag time between Vernalis and Old River near Middle River location is 4 days and occurs only when daily Vernalis flow is under 1.8 TAF (about 900 cfs, Figure 10). The longest lag time between Vernalis and the San Joaquin River at Brandt Bridge location is 3 days, but it is not as strictly correlated with Vernalis flow rate (Figure 11). The Old River near Tracy location has the largest variation in lag time from Vernalis (visually estimated high of 8 days) and is the most difficult location to estimate lag time based on the method employed (Figure 12). As an example, the salinity signal at Old River near Tracy frequently diverges from the salinity signal at Vernalis during the late spring and summer. Splitting this data into seasons resulted in similar results.

The role of operations of the temporary barriers in the travel time between locations was also explored. This examination revealed that barriers are in operation during the longest residence times (most significantly the Middle River Barrier), but more analysis (and possibly additional DSM2 modeling) would be needed to determine how barrier implementation affects lag times between locations and whether it is significant to south Delta salinity. Lag times could also be influenced by tidal fluctuations, export pumping rates, and/or Sacramento River flows, but these were not investigated during this study. An overall average lag time would not ensure objective compliance.

[2] Salinity signal is the pattern and trend of high frequency salinity data over a period of record.

Table 2: Estimates of lag time between Vernalis and other South Delta locations

Month/ Yr	VNS ave daily flow, cfs	Lag, days			Month / Yr	VNS ave daily flow, cfs	Lag, days		
		UNI	BDT	OLD			UNI	BDT	OLD
10/99	2,532	1	1		4/02	2,598	2	1	
11/99	2,158	1	1		5/02	2,739	2	1	2
12/99	1,688	1			6/02	1,407	2	2	
1/00	2,136	1	1		7/02	1,227	1	2	4
2/00	7,559	1	1	ND	8/02	1,116	2	2	2
3/00	12,098	1	1		9/02	1,175	1	1	?
4/00	5,013	1	1		10/02	1,705	2	1	4
5/00	4,814	1	1		11/02	1,715	2	1	4
6/00	2,772	1	1		12/02	1,988	1	1	2
7/00	1,898	2	2	4	1/03	1,913	1	3	3
8/00	2,171	2	ND	4	2/03	1,879	1	1	
9/00	2,330	1	ND	3	3/03	2,193	1	2	
10/00	2,826	2	1	7	4/03	2,668	1	1	8
11/00	2,526	1	1	7	5/03	2,625	1	1	?
12/00	2,238	1		2	6/03	2,034	1	1	?
1/01	2,442	1	2	2	7/03	1,321	2	2	4
2/01	3,092	1	1	2	8/03	1,281	2	2	4
3/01	3,430	1	1	2	9/03	1,308	2	3	4
4/01	3,008	1	1	2	10/03	1,999	2	1	5
5/01	3,527	2	1	4	11/03	1,647	1		
6/01	1,549	3	2	4	12/03	1,503			
7/01	1,400	3	3	6	1/04	1,792	1		
8/01	1,330	2	2	6	2/04	2,201	1	2	
9/01	1,376	2	2	?	3/04	3,361	1	1	
10/01	2,003	2	1	6	4/04	2,751	1	1	ND
11/01	2,096	1	2	6	5/04	2,647	1	1	ND
12/01	2,064	1	2	6	6/04	1,404	2	1	ND
1/02	2,662	1	1	ND	7/04	1,147	2	3	ND
2/02	1,898	1	2	2	8/04	1,125	2	3	ND
3/02	2,134	1	2	2	9/04	1,121	2	3	ND

Bold indicates months where exceedances occur.
Italics indicate guess on very limited matches.
blank indicates an educated guess could not be made based on lack of obvious patterns in two data sets.
ND indicates data is not available.

Table 2: Cont'd: Estimates of lag time between Vernalis and other South Delta locations

Month / Yr	**VNS ave daily flow, cfs**	**Lag, days**			**Month / Yr**	**VNS ave daily flow, cfs**	**Lag, days**		
		UNI	**BDT**	**OLD**			**UNI**	**BDT**	**OLD**
10/04	1,768	3	1		11/07	1,657		1	6
11/04	1,623	1	1		12/07	1,432	2		
12/04	1,567	1			1/08	2,291	2	2	3
1/05	5,011	1	1	1	2/08	2,315	2	2	3
2/05	5,373	1	1	1	3/08	2,165	2	2	3
3/05	7,547	1	ND	ND	4/08	2,368	2	2	4
4/05	9,974	1	1	ND	5/08	2,750	2	*2*	4
5/05	10,467	1	1	ND	6/08	1,155	2		*4*
6/05	10,317	1	1	ND	7/08	896	4		
7/05	4,742	1	1	ND	8/08	865	4		
8/05	2,769	1	1	ND	9/08	801	4		
9/05	2,298	1	1	ND	10/08	1,006	3	2	4
10/05	2,363	2	1	ND	11/08	1,087	2	3	3
11/05	2,028	1	1	ND	12/08	1,192	2	3	
12/05	3,516	1	1	ND	1/09	1,151	2	3	2
1/06	13,193	0	1	ND	2/09	1,501	1	3	3
2/06	6,494	0	1	ND	3/09	1,489	1	2	3
3/06	11,760	0	1	ND	4/09	1,540	2	2	*2*
4/06	28,149	0	0	ND	5/09	2,185	2	2	
5/06	26,699	0	0	ND	6/09	1,301	2	3	
6/06	16,067	0	0	ND	7/09	705	4		
7/06	5,812	1	1	ND	8/09	599	4		
8/06	3,663	1	1	3	9/09	884	4		
9/06	3,058	1	1	3	10/09	1,803	1	2	
10/06	3,648	1	1	1	11/09	1,357	1	1	
11/06	2,501	1	1	1	12/09	1,316	2	3	
12/06	2,329	1	2		1/10	2,066	1	1	2
1/07	2,448	1	1	2	2/10	2,533	1	2	2
2/07	2,501	1	1	2	3/10	2,998	1	1	1
3/07	2,507	1	2	3	4/10	4,354	1	1	1
4/07	2,512	1	1	3	5/10	4,889	1	1	1
5/07	3,010	2	1		6/10	3,894	1	1	1
6/07	1,874	1	1	3	7/10	1,852	2		
7/07	1,007	2		3	8/10	1,143	2		
8/07	1,006	2		3	9/10	1,713	2	2	2
9/07	1,013	2		3	AVE		1.5	1.5	3.3
10/07	1,539	3	1	6					

Bold indicates months where exceedances occur.
Italics indicate guess on very limited matches.
blank indicates an educated guess could not be made based on lack of obvious patterns in two data sets.
ND indicates data is not available.

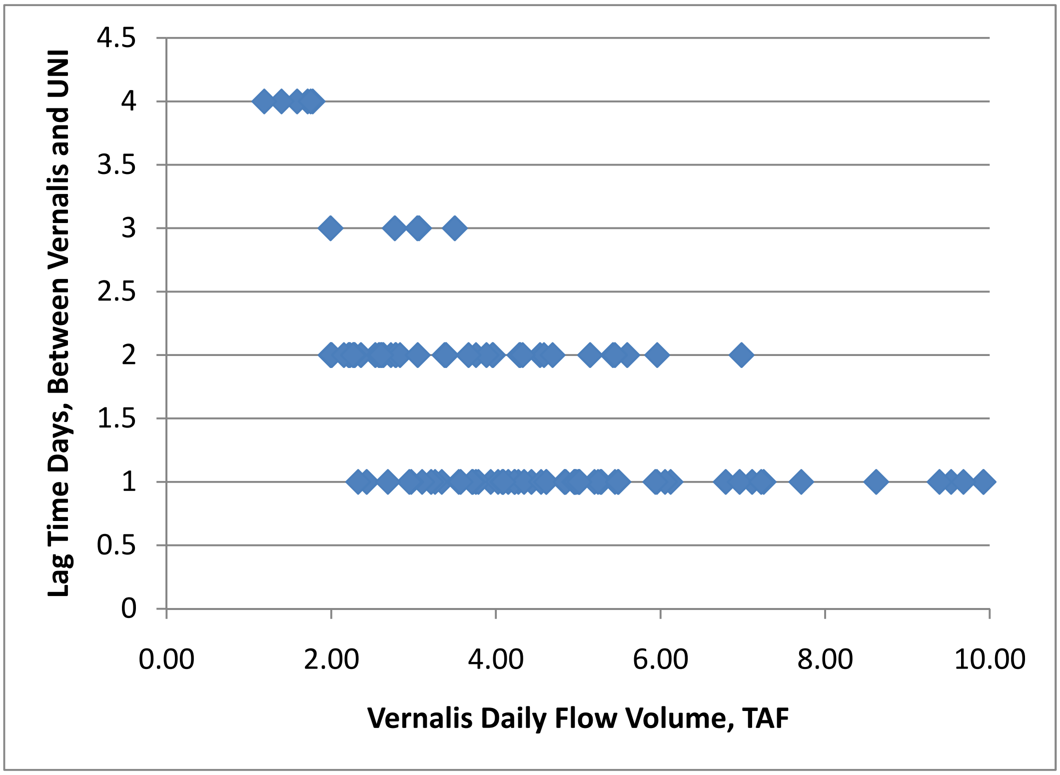


Figure 10: Lag Time between Vernalis and Old River near Middle River as a function of Vernalis Flow

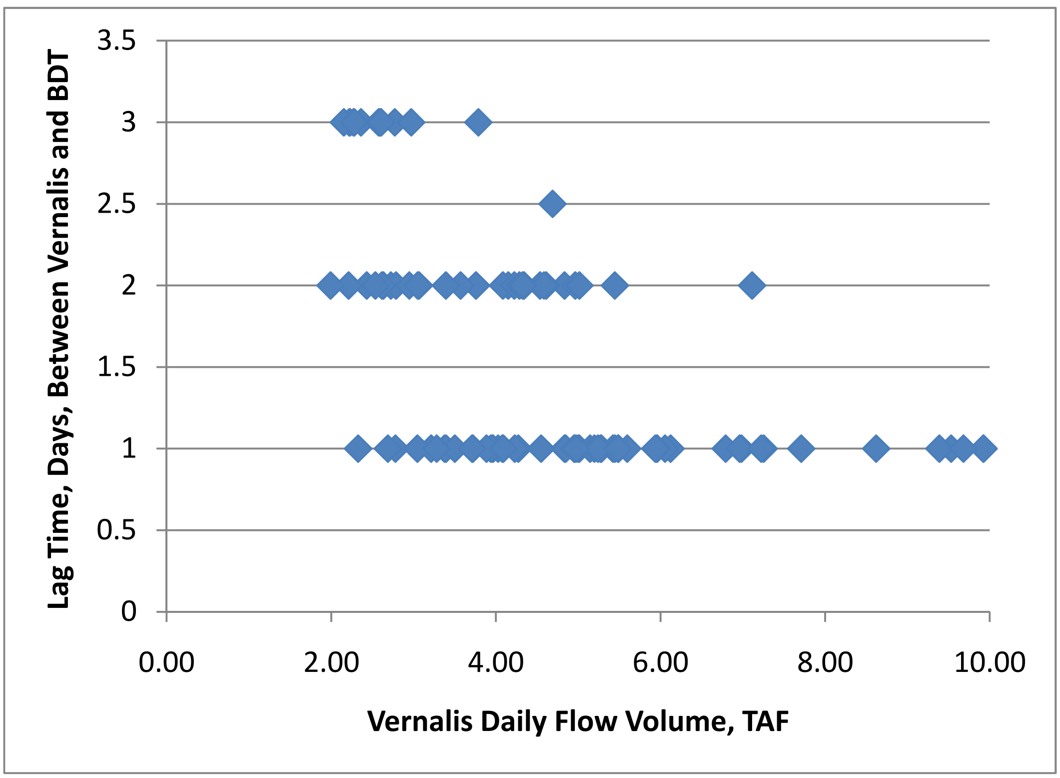


Figure 11: Lag Time between Vernalis and San Joaquin River at Brandt Bridge as a function of Vernalis flow

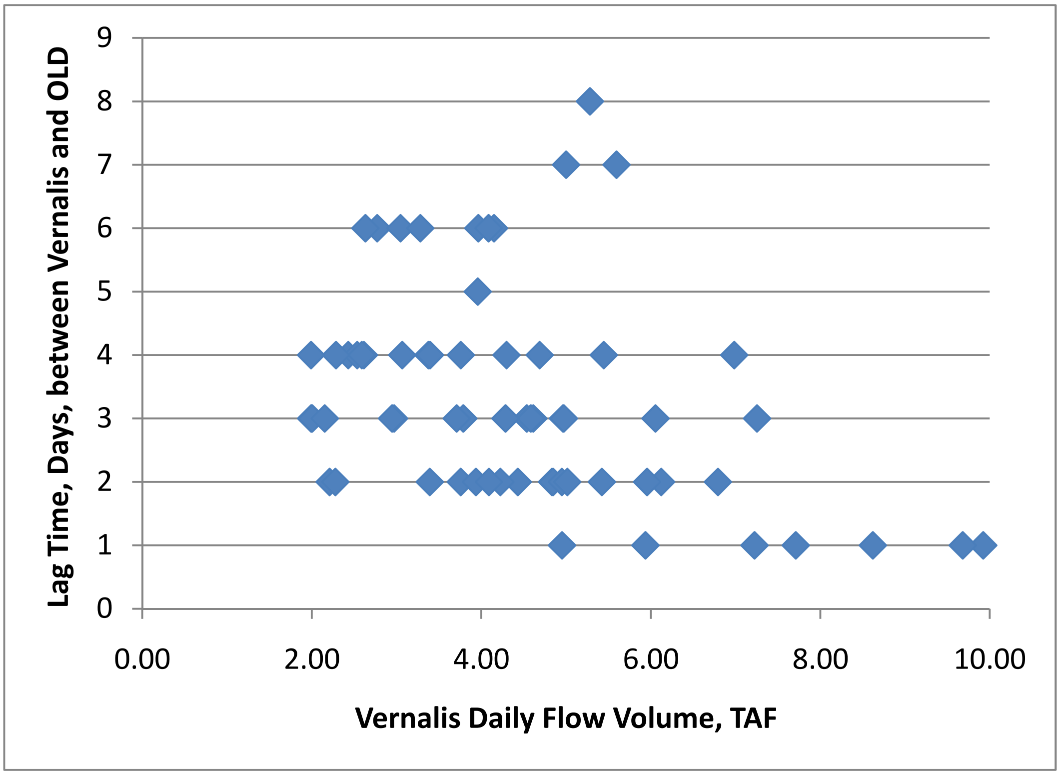


Figure 12: Lag Time between Vernalis and Old River near Tracy as a function of Vernalis flow

5. Best Fit Relationships and Confidence Intervals

As mentioned in sub-section 2, Reclamation has been operating the CVP to meet the Vernalis salinity objective since the mid-1990s. To ensure compliance, the 30-day running average of salinity at Vernalis is calculated daily, salinity upstream of the confluence of the Stanislaus River with the San Joaquin River is examined, and required dilution releases are calculated and released in accordance with expected lag time. A salinity buffer, through the use of a lower salinity goal than the actual objective, is incorporated into these operational calculations in order to ensure that the Vernalis salinity objective is reliably met. This salinity buffer is needed because the lower Stanislaus River and the lower San Joaquin River are both highly dynamic in regards to flow and salinity due to riparian diversions, irrigation returns, and groundwater interaction.

In light of this operational experience, Reclamation developed best fit relationships (simple linear regressions) between 30-day running averages of daily mean EC at Vernalis and EC at the other south Delta locations. Lag times were incorporated to determine if this improved the linear regression fit, and Reclamation focused on the higher ranges of data in each of the two seasons, assuming the goal of this exercise is to develop conditions to ensure compliance with south Delta EC objectives. For example, Reclamation currently operates the CVP to meet the Vernalis objective all of the time with a confidence level of 100%.

In the Draft Objectives Technical Report, the Water Board developed linear best-fit relationships between monthly averages of EC at Vernalis and EC at each of the south Delta locations. The best-fit relationship between EC at Vernalis and EC at Old River near Tracy was adjusted (through the increase of the intercept) to ensure that the fit would result in a compliance rate of 85%. This adjustment was made because of the poor fit between the two locations. The Draft Objectives Technical Report also divided the data between the two objective compliance periods. These actions suggest either a significant transience or poor correlation in the relationship between EC at Vernalis and EC at Old River near Tracy and the potential benefits in examining the relationships by season and by data range. Both of these are further explored in this Study.

a. Old River near Middle River

Vernalis and Old River near Middle River salinity data was analyzed by year and month to evaluate consistency of annual linear best-fit relationships (i.e. to determine the accuracy of a long-term linear best-fit relationship), and also to determine at what times objectives are exceeded – the time periods when having an accurate relationship is most important. Data was also evaluated to determine whether employing the observed lag time improves the best-fit relationship (the R^2)[3].

For example, the best-fit relationship for the 30-day running average data (WY2000-2010) with no lag time is:

Old River near Middle River EC = 1.015 * Vernalis EC + 39.9, R^2=0.96

Compares to a similar analysis using monthly averages:

Old River near Middle River EC = 1.01 * Vernalis EC + 43.42, R^2=0.96

Using either equation, the surrogate Vernalis salinity is 650 umhos/cm for the 700 umhos/cm at Old River near Middle River salinity objective and 946 umhos/cm for the 1000 umhos/cm. When the same data used to develop the first relationship is split into the two compliance periods (September 1 through April 29 and April 30 through August 31), the two resulting relationships are, in order:

Old River near Middle River EC = 1.0119 * Vernalis EC + 37.328, R^2=0.95

Old River near Middle River EC = 1.0897 * Vernalis EC + 15.213, R^2=0.95

Using these equations, the surrogate salinity target at Vernalis for the salinity objective at Old River near Middle River (Vernalis surrogate target) would be 951 umhos/cm for the September 1 through April 29 period and 628 umhos/cm for the April 30 through August 31 period. As a quick test of this surrogate, Vernalis and Old River near Middle River EC data pairs were examined where

[3] R^2 is the coefficient of determination (a popular measure in regression analysis) a measure of how well the least squares equation performs as a predictor of the dependent variable.

1) occurrences of EC at Old River near Middle River exceeding the objective and corresponding EC at Vernalis and 2) occurrences of EC at Vernalis below the surrogate salinity target and corresponding EC at Old River near Middle River. Based on application of the Irrigation Season Vernalis surrogate target (628 umhos/cm) to historic data, 92 of the historic 214 occurrences of EC objective exceedances would still occur. For this same scenario, the Vernalis surrogate target was unnecessarily triggered 72 times. Application of the Non-Irrigation season surrogate (951 umhos/cm) to historic data, 20 of the historic 64 occurrences of EC objective exceedances would still occur. For this season scenario, the Vernalis surrogate target was unnecessarily triggered 52 times. This discussion highlights the potential inexactness of this approach.

Linear regressions between EC at Vernalis and EC at Old River near Middle River were created for the entire data set, and then by water year segments, Figure 13. Estimated monthly lag times were then applied to the data to determine if correcting the data for travel time would improve the linear regressions. Table 3 displays the results, illustrating a slight improvement in the fit of the long-term best fit, and varying results for individual years. Table 4 displays surrogate Vernalis EC targets resulting from the regressions. In general the employment of the lag time in the analysis does not seem critical to these annual or long term best-fit relationships.

To further explore the relationship between salinity at Vernalis and salinity at Old River near Middle River, monthly data within each year was visually inspected to determine short term patterns around occurrences of exceedances. Appendix E contains these figures. For the Old River near Middle River location, these figures illustrate that the patterns of summer exceedance occurrences data patterns occur generally in the center of the linear regression plots whereas the winter occurrences of exceedances occur in concert with high salinity at Vernalis (in the upper right quadrant of the linear regression plots). While winter exceedances tend to occur along the linear regression, summer occurrences of exceedances occur distinctly outside of the linear regression. This suggests that adjusting the x-value (EC at Vernalis) to improve the y-value (EC at Old River near Middle River) would not be enough to ensure a reduction in or elimination of summer occurrences of exceedances.

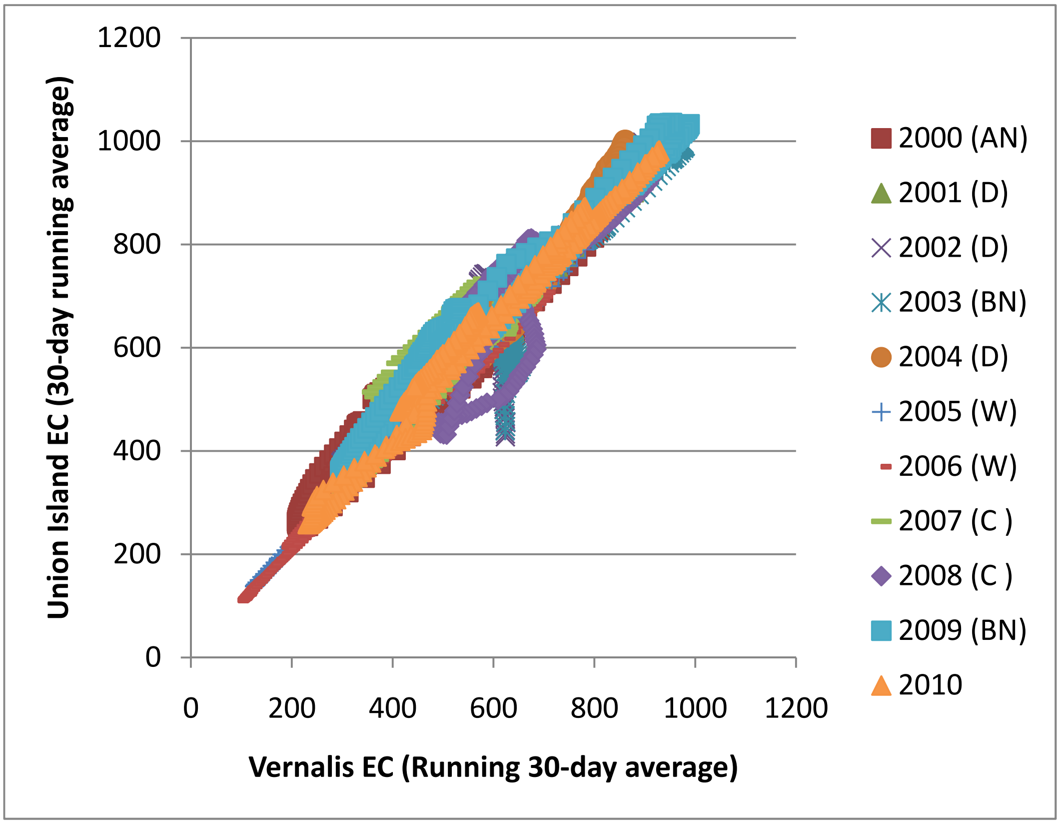


Figure 13: Annual Profiles of Vernalis vs. Old River near Middle River Electrical Conductivity

Table 3: Best Fit Relationships for Vernalis and Old River near Middle River and effect of Lag

	With Lag			Without Lag		
	Slope	**Intercept**	**R^2**	**Slope**	**Intercept**	**R^2**
Long-term	1.0151	39.776	0.9586	1.015	39.902	0.9572
WY 2000	0.917	89.518	0.9529	0.9174	89.697	0.9552
WY 2001	0.982	63.042	0.9609	0.9835	60.922	0.9528
WY 2002	0.9753	74.761	0.8868	0.9755	75.58	0.8831
WY 2003	0.9544	59.215	0.9245	0.957	56.286	0.9199
WY 2004	1.1169	-9.2347	0.9637	1.116	-9.062	0.9616
WY 2005	1.0538	8.8568	0.9901	1.0579	8.4942	0.9882
WY 2006	1.0028	18.733	0.9954	1.0031	18.993	0.9941
WY 2007	0.975	59.242	0.9097	0.9773	57.412	0.9189
WY 2008	0.9585	80.202	0.7992	0.9674	74.952	0.8121
WY 2009	0.9162	129.47	0.981	0.9127	132.87	0.9751
WY 2010	1.0289	39.153	0.9881	1.0266	39.541	0.9841

Table 4: Best Fit Relationships for Vernalis and Old River near Middle River and effect of Lag

	Vernalis surrogate (With Lag)		Vernalis surrogate (Without Lag)	
	For 700 EC	**For 1000 EC**	**For 700 EC**	**For 1000 EC**
Long-term	650	946	650	946
WY 2000	666	993	665	992
WY 2001	649	954	650	955
WY 2002	635	939	640	948
WY 2003	671	986	673	986
WY 2004	635	904	635	904
WY 2005	656	941	654	937
WY 2006	679	979	679	978
WY 2007	657	965	658	964
WY 2008	647	960	646	956
WY 2009	623	950	621	950
WY 2010	642	934	643	936

b. San Joaquin River at Brandt Bridge

Vernalis and San Joaquin River at Brandt Bridge salinity data was analyzed by year and month to evaluate consistency of annual linear best-fit relationships (i.e. to determine the accuracy of a long-term linear best-fit relationship), and also to determine at what times objectives are exceeded – the time periods when having an accurate relationship is most important. Data was also evaluated to determine whether employing the observed lag time improves the best-fit relationship (the R^2).

For example, the best-fit relationship for the 30-day running average data (WY2000-2010) with no lag time is:

SJ River at Brandt Bridge EC = 0.9866 * Vernalis EC + 44.613, R^2=0.90

Compares to a similar analysis using monthly averages:

SJ River at Brandt Bridge EC = 1.00 * Vernalis EC + 33.64, R^2=0.93

Using either equation, the surrogate Vernalis salinity is about 665 umhos/cm for the 700 umhos/cm San Joaquin River at Brandt Bridge salinity objective and 967 umhos/cm for the 1000 umhos/cm objective. When the same data used to develop the first relationship is split into the two compliance periods (September 1 through April 29 and April 30 through August 31), the two resulting relationships are, in order:

SJ River at Brandt Bridge EC = 0.9614 * Vernalis EC + 56.284, R^2=0.87

SJ River at Brandt Bridge EC = 1.1117 * Vernalis EC – 3.6812, R^2=0.92

Using these equations, the surrogate salinity target at Vernalis for the salinity objective at San Joaquin River at Brandt Bridge (Vernalis surrogate target) would be 982 umhos/cm for the September 1 through April 29 period and 633 umhos/cm for the April 30 through August 31 period. As a quick test of this surrogate, Vernalis and San Joaquin River at Brandt Bridge EC data pairs were examined where 1) occurrences of EC at San Joaquin River at Brandt Bridge exceeding the objective and corresponding EC at Vernalis and 2) occurrences of EC at Vernalis below the surrogate salinity target and corresponding EC at San Joaquin River at Brandt Bridge. Based on application of the Irrigation Season Vernalis surrogate target (633 umhos/cm) to historic data, 104 of the historic 192 occurrences of EC objective exceedances would still occur. For this same scenario, the Vernalis surrogate target was unnecessarily triggered 72 times. Application of the Non-Irrigation season surrogate (982 umhos/cm) to historic data, 99 of the historic 107 occurrences of EC objective exceedances would still occur. This is similar to the analysis for the Old River near Middle River location.

Linear regressions between EC at Vernalis and EC at San Joaquin River at Brandt Bridge were created for the entire data set, and then by water year segments, Figure 14. Estimated monthly lag times were then applied to the data to determine if correcting the data for travel time would improve the linear regressions. Table 5 displays the results, illustrating a slight improvement in the fit of the long-term best fit, and varying results for individual years. Table 6 displays surrogate Vernalis EC targets resulting from the regressions. In general the employment of the lag time in the analysis does not seem critical to these annual or long term best-fit relationships.

To further explore the relationship between salinity at Vernalis and salinity at San Joaquin River at Brandt Bridge, monthly data within each year was visually inspected to determine short term patterns around occurrences of exceedances. Appendix E contains these figures. For the San Joaquin River at Brandt Bridge location, these figures illustrate that the patterns of summer exceedance occurrences data patterns occur generally in the center of the linear regression plots whereas the winter occurrences of exceedances occur in concert with high salinity at Vernalis (in the upper right quadrant of the linear regression plots). While winter exceedances tend to occur along the linear regression, summer occurrences of exceedances occur distinctly outside of the linear regression. This suggests that adjusting the x-value (EC at Vernalis) to improve the y-value (EC at San Joaquin River at Brandt Bridge) would not be enough to ensure a reduction in or elimination of summer occurrences of exceedances.

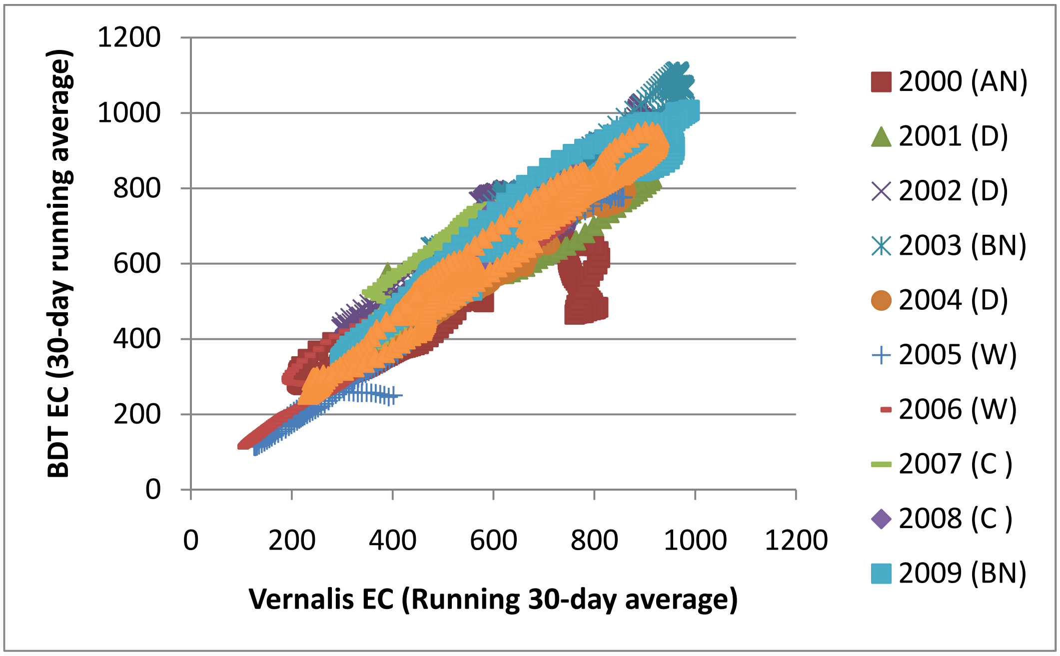


Figure 14: Annual Profiles of Vernalis vs. San Joaquin River at Brandt Bridge Electrical Conductivity

Table 5: Best Fit Relationships for Vernalis and San Joaquin River at Brandt Bridge and effect of Lag

	With Lag			**Without Lag**		
	Slope	**Intercept**	**R^2**	**Slope**	**Intercept**	**R^2**
Long-term	0.9883	44.092	0.9027	0.9866	44.613	0.9021
WY 2000	0.5522	203.92	0.6038	0.5508	204.66	0.6009
WY 2001	0.9176	78.584	0.8883	0.9217	75.591	0.8895
WY 2002	0.9273	133.93	0.8487	0.9261	132.94	0.8447
WY 2003	1.0672	47.537	0.9641	1.0612	50.312	0.959
WY 2004	0.8739	66.539	0.9498	0.8715	67.646	0.9475
WY 2005	1.0545	-15.653	0.9506	1.0545	-15.653	0.9506
WY 2006	0.9418	43.661	0.9699	0.9418	43.661	0.9699
WY 2007	1.0231	58.265	0.9205	1.0224	58.566	0.92
WY 2008	0.9905	77.343	0.9324	0.9916	76.775	0.9331
WY 2009	0.9262	87.525	0.9681	0.9278	85.069	0.9681
WY 2010	0.9797	41.737	0.9886	0.9714	46.197	0.9821

Table 6: Best Fit Relationships for Vernalis and San Joaquin River at Brandt Bridge and effect of Lag

	Vernalis surrogate (With Lag)		Vernalis surrogate (Without Lag)	
	For 700	**For 1000**	**For 700**	**For 1000**
Long-term	664	967	664	968
WY 2000	898	1442	899	1444
WY 2001	677	1004	677	1003
WY 2002	610	934	612	936
WY 2003	611	892	612	895
WY 2004	725	1068	726	1070
WY 2005	679	963	679	963
WY 2006	697	1015	697	1015
WY 2007	627	920	627	921
WY 2008	629	932	629	931
WY 2009	661	985	663	986
WY 2010	672	978	673	982

c. Old River near Tracy

Vernalis and Old River near Tracy salinity data was analyzed by year and month to evaluate consistency of annual linear best-fit relationships (i.e. to determine the accuracy of a long-term linear best-fit relationship), and also to determine at what times objectives are exceeded – the time periods when having an accurate relationship is most important. Data was also evaluated to determine whether employing the observed lag time improves the best-fit relationship (the R^2).

For example, the best-fit relationship for the 30-day running average data (WY2000-2010) with no lag time is:

Old River near Tracy EC = 0.83 * Vernalis EC + 265.16, R^2=0.58

Compares to a similar analysis using monthly averages:

Old River near Tracy EC = 0.97 * Vernalis EC + 146.49, R^2=0.75

Using either equation, the surrogate Vernalis salinity is about 881 umhos/cm for the 1000 umhos/cm Old River near Tracy salinity objective, but 524 umhos/cm for the 700 umhos/cm objective using the first equation and 571 umhos/cm using the second. When the same data used to develop the first relationship is split into the two compliance periods (September 1 through April 29 and April 30 through August 31), the two resulting relationships are, in order:

Old River near Tracy EC = 0.8637 * Vernalis EC + 236.7, R^2=0.58

Old River near Tracy EC = 0.8669 * Vernalis EC + 260.53, R^2=0.43

Using these equations, the surrogate salinity target at Vernalis for the salinity objective at Old River near Tracy (Vernalis surrogate target) would be 884 umhos/cm for the September 1 through April 29 period and 507 umhos/cm for the April 30 through August 31 period. As a quick test of the Vernalis surrogate target for this location, Vernalis and Old River near Tracy EC data pairs were examined where 1) occurrences of EC at Old River near Tracy exceeding the objective and corresponding EC at Vernalis and 2) occurrences of EC at Vernalis below the surrogate salinity target and corresponding EC at Old River near Tracy. Based on application of the Irrigation Season Vernalis surrogate target (507 umhos/cm) to historic data, 119 or the historic 460 occurrences of EC objective exceedances would still occur. For this same scenario, the Vernalis surrogate target was unnecessarily triggered 146 times. Application of the Non-Irrigation season surrogate (884 umhos/cm) to historic data, 158 of the historic 381 occurrences of EC objective exceedances would still occur. For this season scenario, the Vernalis surrogate target was unnecessarily triggered 48 times.

Linear regressions between EC at Vernalis and EC at Old River near Tracy were created for the entire data set, and then by water year segments, Figure 15. Estimated monthly lag times were then applied to the data to determine if correcting the data for travel time would improve the linear regressions. Table 7 displays the results, illustrating a slight improvement in the fit of the long-term best fit, and varying results for individual years. Table 8 displays surrogate Vernalis EC targets resulting from the regressions. In general the employment of the lag time in the analysis does not seem critical to these annual or long term best-fit relationships, in spite of the observation of longer and more variable lag times between Vernalis and the Old River near Tracy station.

To further explore the relationship between salinity at Vernalis and salinity at Old River near Tracy, monthly data within each year was visually inspected to determine short term patterns around occurrences of exceedances. Appendix E contains these figures. For the Old River near Tracy location, these figures illustrate that the patterns of summer exceedance occurrences data patterns occur generally in the center of the linear regression plots whereas the winter occurrences of exceedances occur in concert with high salinity at Vernalis (in the upper right quadrant of the linear regression plots). While winter exceedances tend to occur along the linear regression, summer occurrences of exceedances occur distinctly outside of the linear regression. This suggests that adjusting the x-value (EC at Vernalis) to improve the y-value (EC at San Joaquin River at Brandt Bridge) may not be enough to ensure a reduction in or elimination of summer occurrences of EC exceedance.

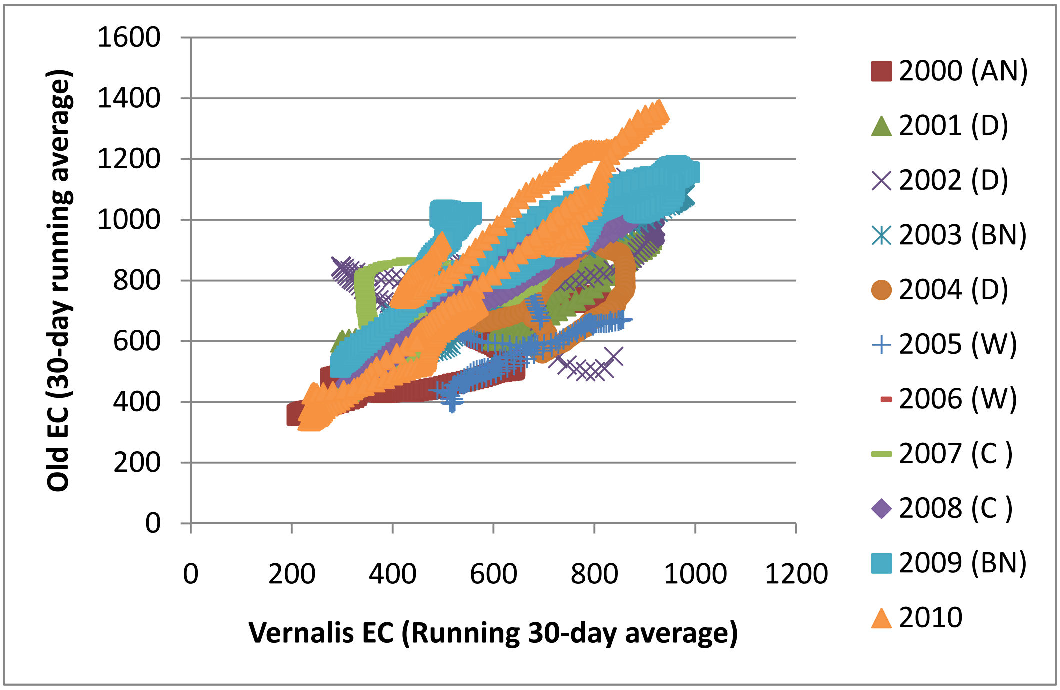


Figure 15: Annual Profiles of Vernalis vs. Old River near Middle River Electrical Conductivity

Table 7: Best Fit Relationships for Vernalis and Old River near Middle River and effect of Lag

	With Lag			**Without Lag**		
	Slope	**Intercept**	**R^2**	**Slope**	**Intercept**	**R^2**
Long-term	0.8516	249.78	0.612	0.8304	265.16	0.5839
WY 2000	0.6378	267.03	0.722	0.6625	245.1	0.7415
WY 2001	0.5352	443.16	0.6261	0.5441	435.85	0.6144
WY 2002	0.4073	543.11	0.3161	0.3927	552.08	0.2935
WY 2003	0.9191	187.55	0.9664	0.909	200.41	0.9271
WY 2004	0.3394	537.29	0.1137	0.3149	555.59	0.1049
WY 2005	0.4667	296.27	0.2099	0.4462	310.73	0.1932
WY 2006	0.1719	443.63	0.1075	0.2648	409.89	0.1917
WY 2007	0.8372	280.94	0.6351	0.8153	291.65	0.6011
WY 2008	0.9331	235.89	0.8444	0.9398	232.31	0.8572
WY 2009	0.6946	481.09	0.7004	0.6928	482.84	0.7011
WY 2010	1.3739	41.672	0.9026	1.3769	39.404	0.9103

Table 8: Best Fit Relationships for Vernalis and Old River near Middle River and effect of Lag

	Vernalis surrogate (With Lag)		Vernalis surrogate (Without Lag)	
	For 700	For 1000	For 700	For 1000
Long-term	529	881	524	885
WY 2000	679	1149	687	1139
WY 2001	480	1040	485	1037
WY 2002	385	1122	377	1141
WY 2003	558	884	550	880
WY 2004	479	1363	459	1411
WY 2005	865	1508	872	1545
WY 2006	1491	3237	1096	2229
WY 2007	501	859	501	869
WY 2008	467	769	498	817
WY 2009	315	747	313	746
WY 2010	479	698	480	698

6. Other Factors

This Study has focused on the relationship between EC at Vernalis and EC at each of the south Delta locations. This presumes that EC at Vernalis is the primary influencing factor on EC at each of the south Delta locations. Based on the linear regressions and other analyses completed, it is possible that there are other factors influencing EC at south Delta. In Appendix E, the EC at Old River near Tracy regression plots illustrate the many times when EC at Old River near Tracy does not appear to be correlated to EC at Vernalis. Given the short time frame of this study (180 days), Reclamation made cursory examinations of three potential factors: San Joaquin River flow, Sacramento flow, and combined exports. Scatter plots were made of daily EC at each of the south Delta locations versus each of the potential factors' daily data to visually determine if there were any promising relationships.

Data was examined over the entire time period (WY 2000 – WY 2010) as well as the two compliance seasons. San Joaquin River flow has a consistent relationship that is strong in the lowest EC ranges, similar to Figure 16. Sacramento River flow has a clear relationship only in the irrigation season and strongest in the lowest EC ranges, as seen in Figure 17. Export pumping does not seem to have any relationship to EC; all scenarios were similar to Figure 18. Plotting 30-day running averages instead of daily data did not improve the visualizations.

Local discharges are a potential factor that was not explored. Local discharges are not well characterized, resulting, in part, for DSM2 under predictions of salinity in the south Delta. DWR has studied this issue in more detail[4]. DWR

[4] Sources of Salinity in the South Sacramento-San Joaquin Delta (DWR, May 2007) is one such report.

has also examined the flow splits between Delta channels, which may be another influencing factor in EC patterns in the south Delta.

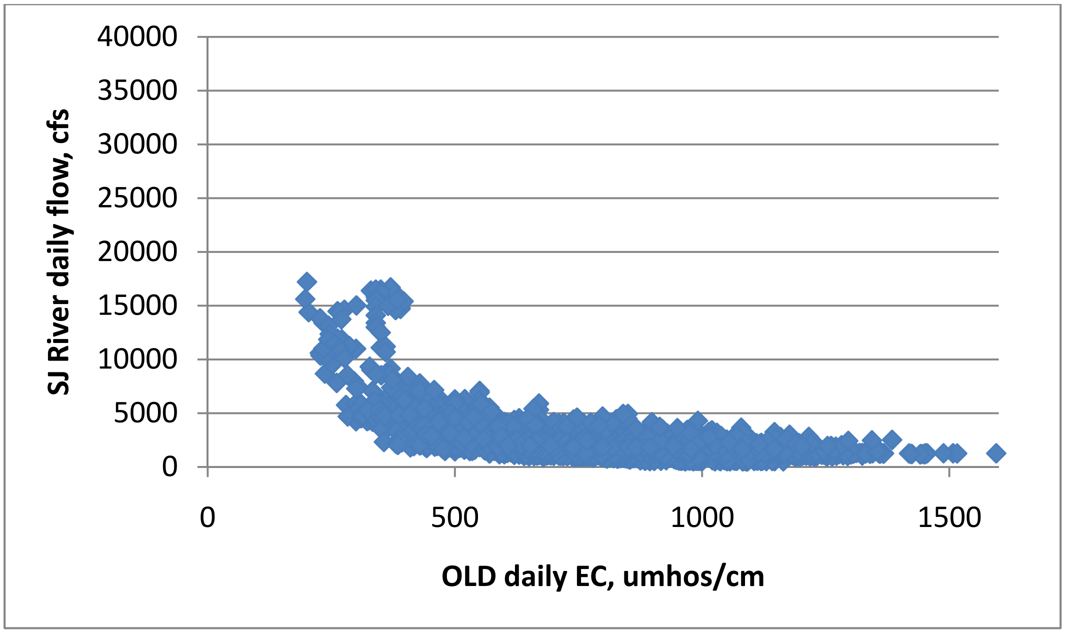


Figure 16: EC at Old River near Tracy Salinity versus San Joaquin River flow (WY2000-2010)

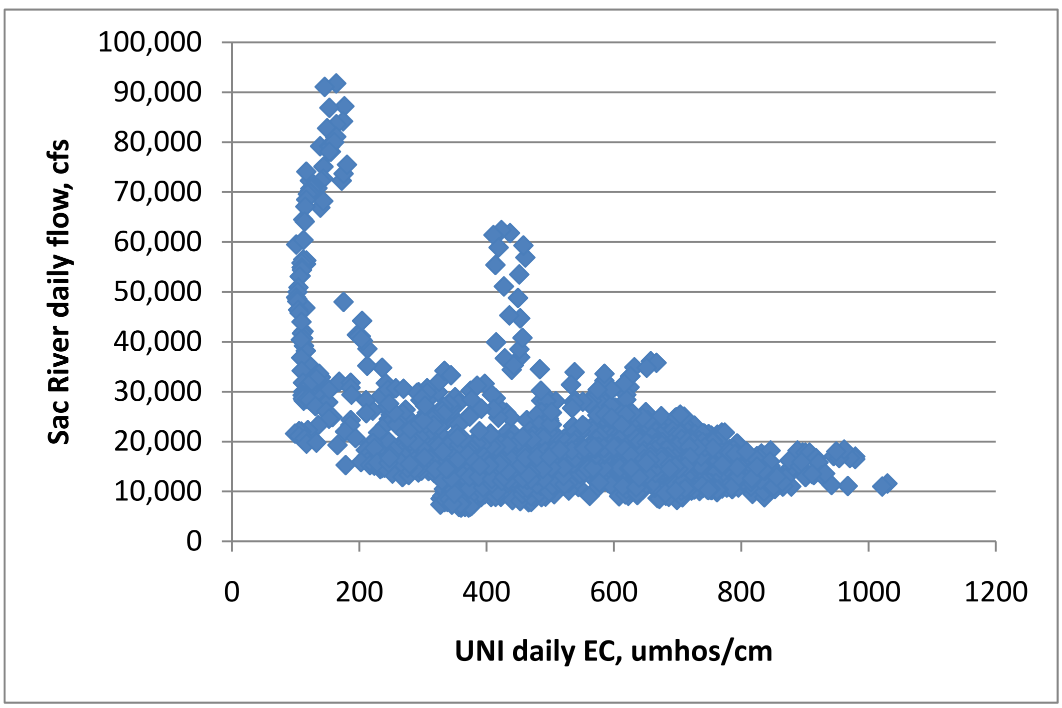


Figure 17: EC at Old River near Middle River versus Sacramento River flow (Irrigation Season, WY2000-2010)

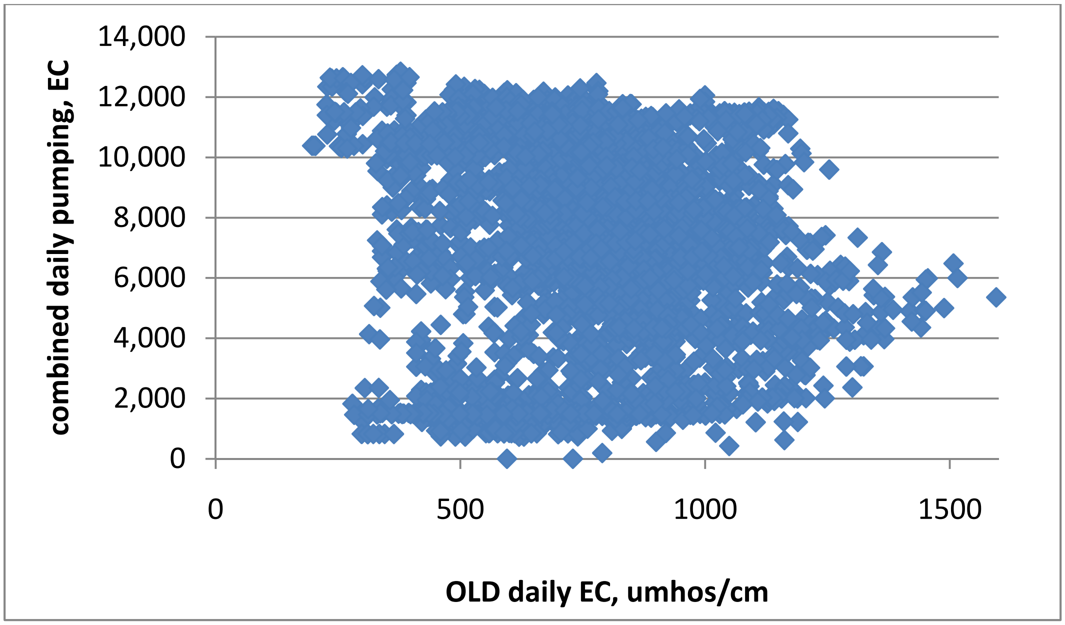


Figure 18: EC at Old River near Tracy versus Combined Exports (Irrigation Season WY2000-2010)

7. Vernalis Surrogate Salinity Targets

The desired outcome of this regulatory exercise is to determine a surrogate EC target at Vernalis that could be operated to in order to reliably achieve water quality objectives at the three South Delta locations. Developing an accurate understanding of the relationship between EC at Vernalis and the EC at each of the south Delta locations, especially in the salinity ranges that are currently higher than the objectives is key. Two considerations in this task include understanding the reliability (repeatability) of this relationship and minimizing the possibility that the estimated surrogate EC target at Vernalis is invoked when the EC at south Delta locations is not in danger of exceeding the objectives. This study therefore focuses on the data ranges of interest in the actual historical data set rather than the linear regressions to develop surrogate targets

Reclamation originally proposed to use best-fit relationships and confidence intervals to estimate surrogate salinity targets at Vernalis, but after examining the data (especially the Old River near Tracy data distributions [Appendix E]), this study takes a more basic approach based on historic 30-day running average EC data[5], focusing on those data values near and above the objective.

For each south Delta location, the EC averages that exceeded the 700 umhos/cm and 1000 umhos/cm objectives and the corresponding EC averages at Vernalis were isolated. These subsets of data pairs were then sorted by the corresponding EC at Vernalis to produce frequency plots of the EC at Vernalis when each of the south Delta objectives are exceeded (so all of the average EC values for days when the objective was exceeded), shown in Figures 19-24. These frequency

[5] For the remainder of this report "EC" and "data" refer to 30-day running averages.

plots were then used to select EC values at Vernalis that correspond with 0%, 5%, 10% and 15% frequency of occurrences of exceedance of EC objectives at each south Delta location. The resulting EC values at Vernalis are summarized in Table 9.

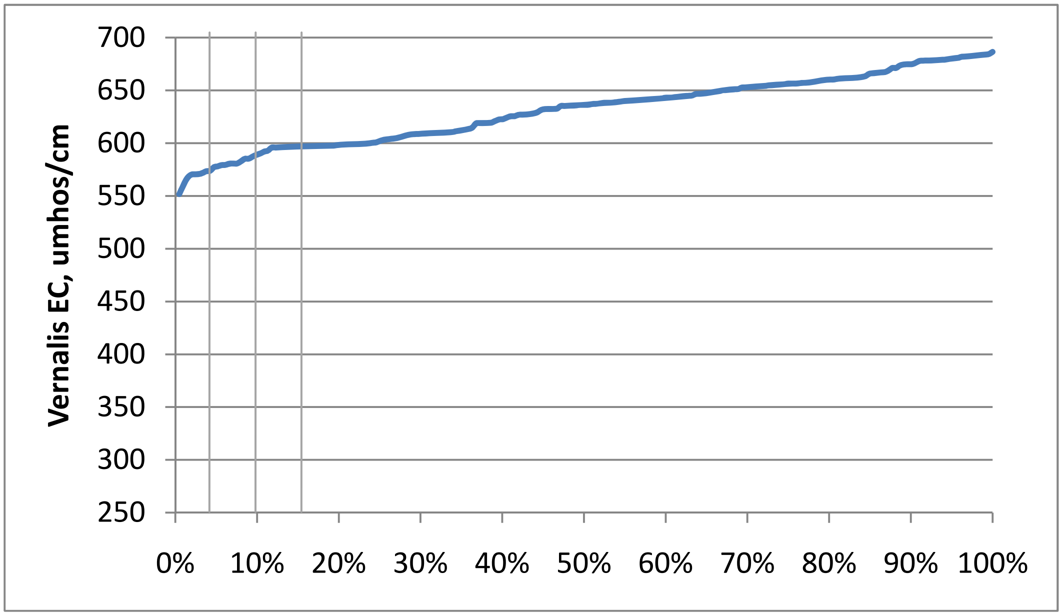


Figure 19: Vernalis EC Values when Old River near Middle River Irrigation Season Objective Exceeded

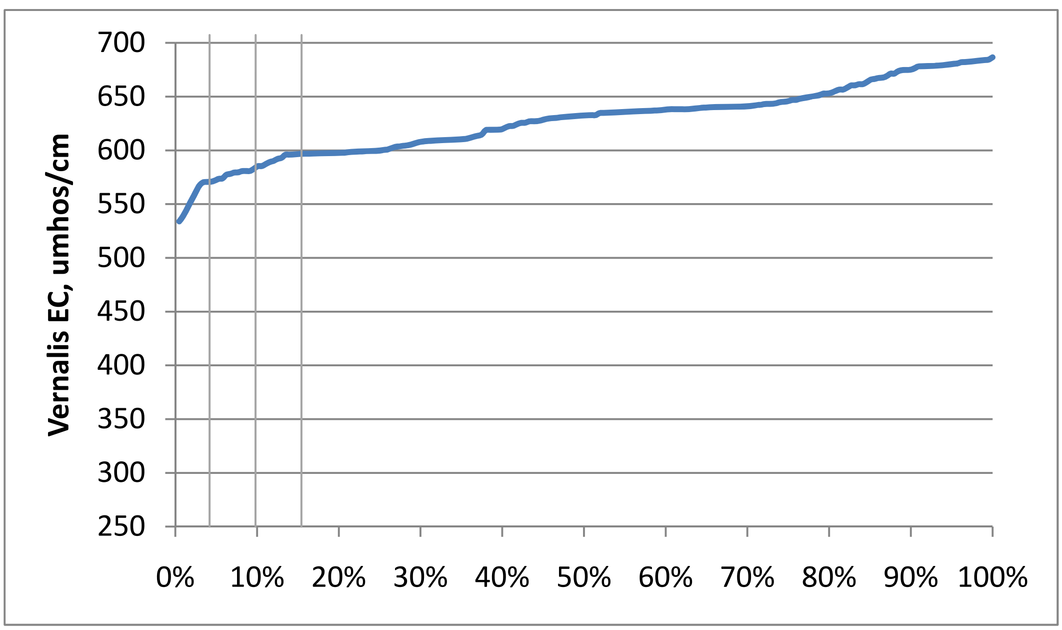


Figure 20: Vernalis EC Values when San Joaquin River at Brandt-Bridge Irrigation Season Objective Exceeded

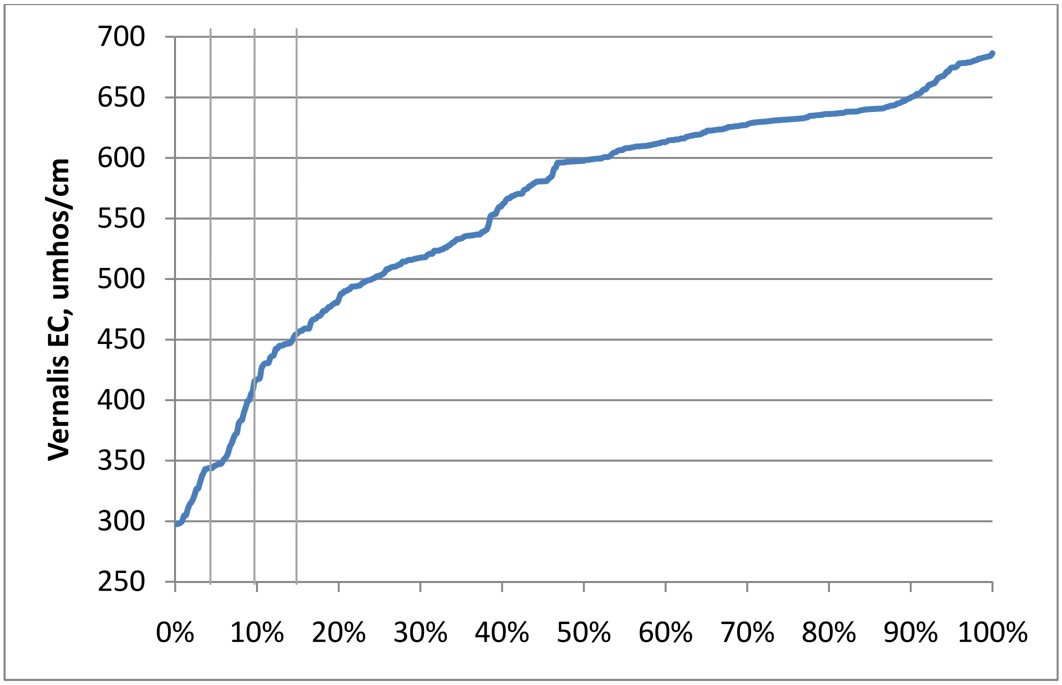


Figure 21: Vernalis EC Values when Old River near Tracy Irrigation Season Objective Exceeded

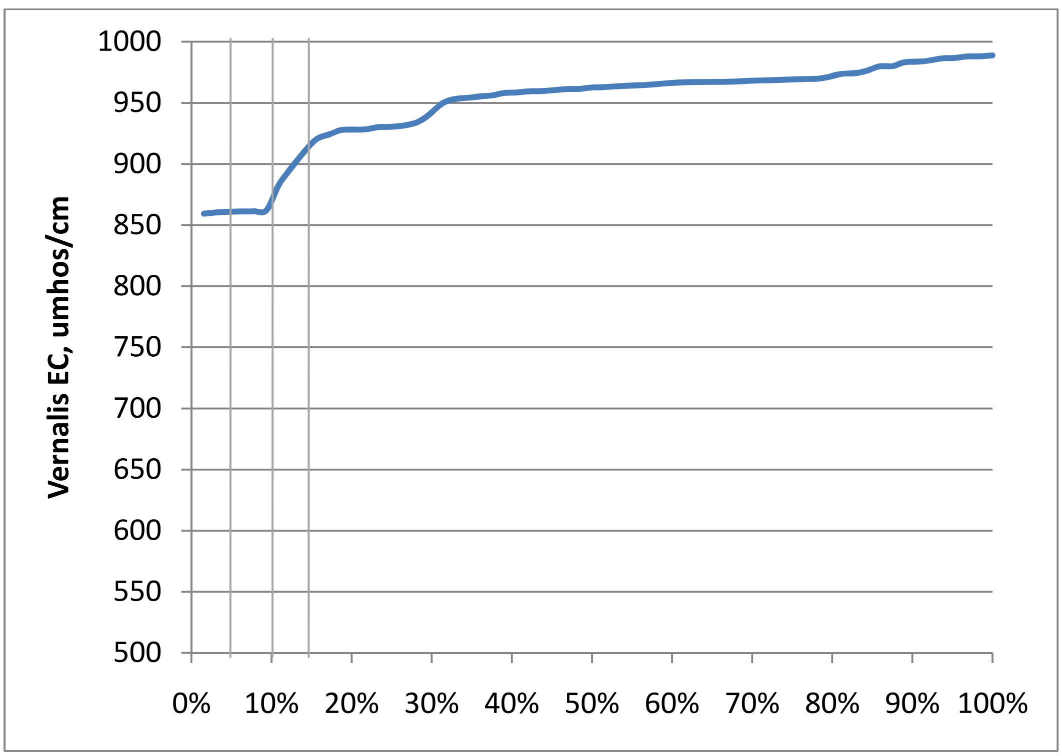


Figure 22: Vernalis EC Values when Old River near Middle River Non-Irrigation Season Objective Exceeded

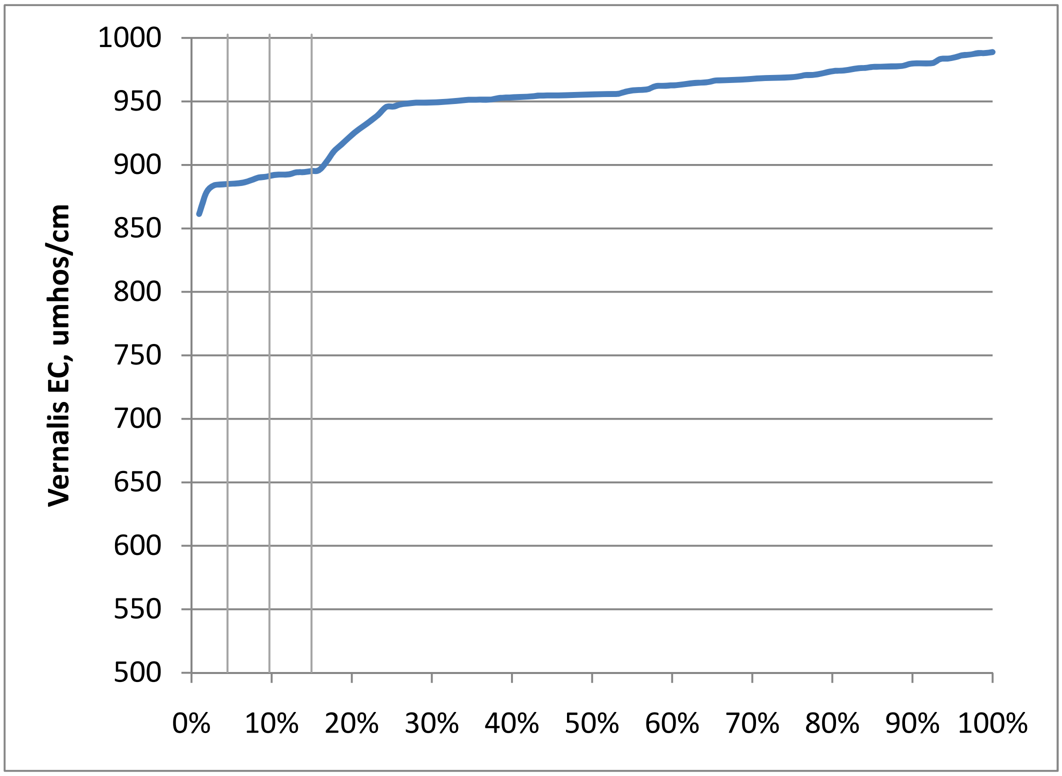


Figure 23: Vernalis EC Values when San Joaquin River at Brandt-Bridge Non-Irrigation Season Objective Exceeded

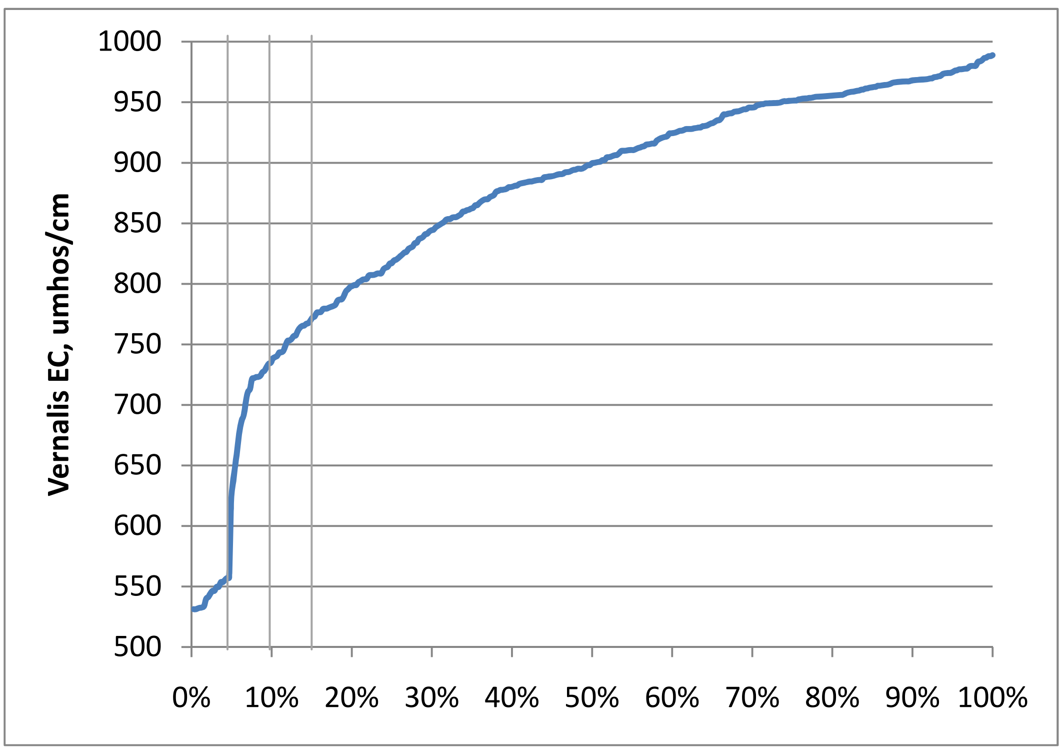


Figure 24: Vernalis EC Values when Old River near Tracy Non-Irrigation Season Objective Exceeded

Table 9: Surrogate EC Target at Vernalis estimated to comply with EC objectives in south Delta. Bold values indicate the surrogate values selected for target analysis.

	Irrigation Season Surrogate EC Target at Vernalis				**Non-Irrigation Season Surrogate EC Target at Vernalis**			
Compliance Rate	**100%**	**95%**	**90%**	**85%**	**100%**	**95%**	**90%**	**85%**
Old River near Middle River	**552**	577	589	596	**859**	861	**862**	910
San Joaquin River at Brandt Bridge	534	572	**583**	596	861	885	891	895
Old River near Tracy	**298**	**346**	**416**	455	**531**	**623**	**735**	770

Based on these estimates, a smaller set of surrogate EC targets were selected to use for the remainder of the Study. The following sections of the Study estimate the use of dilution flow to obtain the surrogate EC targets at Vernalis. As the surrogates for the EC at Old River near Middle River and at San Joaquin River at Brandt Bridge sites are close, the most restrictive values were selected for the 90% and the 100% compliance rate estimates. For the EC at Old River near Tracy, where there exists a wider range of values, the 100%, 95% and 90% compliance rate estimates were used. These are highlighted in bold text in Table 9.

B. Dilution Flow Estimates

In the Study Plan, Reclamation proposed estimating the volume of dilution flow to meet the estimated surrogate EC targets at Vernalis (surrogate for compliance with the south Delta EC objectives). The Study Plan included use of the CALSIM database and evaluating:

1. The general seasonality of increased dilution needs.
2. The general hydrologic conditions (through Water Year classifications).
3. The relationship of volume of flows with the origins (salinity) of potential additional flows.

The second phase of the Study examined factors that could influence flow such as seasonality, flow conditions in receiving water and salinity of dilution water. Analysis of the period of record using the range of surrogate EC targets developed in the previous section demonstrated the inefficiency of the use of a surrogate EC target at Vernalis, as dilution flows were released when they were not needed to meet the south Delta EC objectives. In addition, salinity of potential dilution flows were investigated and shown to have significant influence in the volume of flows needed to meet the surrogate EC at Vernalis. Finally, a spreadsheet model was developed and used to characterize the range of volumes necessary to meet various surrogate EC targets at Vernalis under historic and simulated conditions. The volumes ranged from 100-200 thousand acre feet to meet the most lenient surrogates and up to 1.4 million acre feet of very low salinity water to meet the most stringent surrogates.

Seasonality and hydrologic conditions over the past ten years were evaluated and identified in Section A.3. The CALSIM database does not evaluate Southern Delta salinity and the DSM2 model has a general tendency to under-predict salinity in the South Delta, therefore historic patterns of flow and salinity throughout the basin were relied upon to develop crude dilution flow estimates. At some point a CALSIM daily time step model could be explored to evaluate these results under changed operational scenarios (depending on how well the model tracks salinity), but for the purpose of this report actual data from the past ten years was utilized, and a daily time step spreadsheet model was developed.

1. General Seasonality of Dilution Flows

To this point, this report explored the seasonality of occurrences of exceedance of South Delta salinity objectives and developed a range of surrogate EC targets at Vernalis. In order to explore the seasonality of the potential increases in dilution flows, Reclamation examined the record of the 30-day running average of EC at Vernalis from WY 2000 through WY 2010. Specifically, data was examined for the timing of EC values at Vernalis when those values were above the different surrogate EC targets at Vernalis. The results, along with the percentage of the entire record that these represent, are tabulated in Table 10.

As the data was examined, it was also observed that when EC at Vernalis was above the surrogate EC target, the corresponding EC at the south Delta location did not necessarily exceed the salinity objective. At those times, a surrogate EC target at Vernalis was unnecessary as the EC at the south Delta location was not threatening to or exceeding its objective. Thus, if the surrogate EC target had been in effect, release of dilution flows would be unnecessary. The number of days when this scenario occurs is tabulated in Table 11.

Table 10: Number of Days when EC at Vernalis is above EC at Surrogate EC Target at Vernalis (WY 2000-2010)

Non-Irrigation Season			Irrigation Season		
Surrogate EC Target at Vernalis	**Number of Days Vernalis is above Target**	**Percent of Days Vernalis is above Target**	**Surrogate EC Target at Vernalis**	**Number of Days Vernalis is above Target**	**Percent of Days Vernalis is above Target**
862	310	12%	583	366	27%
859	324	12%	534	500	37%
735	818	31%	416	818	60%
623	1522	57%	346	1006	74%
531	1970	74%	298	1119	82%
Total Days in Period:	2654			1364	

Table 11: Number of Months Dilution Flow Required to Meet Surrogate EC Target at Vernalis, Compared with Number of Months Objectives are Exceeded by Month (top half of table) and by WY Type (bottom half of table), for WY2000-2010

	EC Objective			**Surrogate EC Target at Vernalis**				
	UNI	**BDT**	**OLD**	**862**	**859**	**735**	**623**	**531**
Oct	0	0	0	0	0	0	5	7
Nov	0	0	1	0	0	1	8	11
Dec	0	0	2	1	1	9	11	11
Jan	1	2	3	3	3	9	9	11
Feb	1	3	3	5	5	8	10	10
Mar	2	1	5	4	4	7	8	10
				583	**534**	**416**	**346**	**298**
Apr	3	1	6	4	5	8	8	9
May	0	1	4	1	3	7	9	9
Jun	3	3	4	4	5	8	8	8
Jul	3	4	5	6	8	11	11	11
Aug	5	4	7	7	9	10	11	11
				862	**859**	**735**	**623**	**531**
Sept	0	0	1	0	0	0	6	8
No. of Months with EC Objective or Target Exceedances within Each Water Year Type:								
	EC Objective			**Surrogate EC Target at Vernalis**				
	UNI	**BDT**	**OLD**	**862/ 583**	**859/ 534**	**735/ 416**	**623/ 346**	**531/ 298**
W	0	0	0	0	0	6	11	13
AN	0	0	6	4	6	13	17	21
BN	2	4	6	11	15	19	23	24
D	11	10	21	14	15	26	33	35
C	5	5	8	6	7	14	20	23

2. The Influence of Flow and Salinity on Dilution Flow Volumes

While the estimation of dilution flow to meet the surrogate EC targets at Vernalis is complicated (Section B.3), it is instructive to illustrate the dynamics of the use of dilution flow to meet salinity objectives. The greatest influencing variable is the salinity concentration of the dilution water (providing dilution), which grows asymptotically as its salinity concentration approaches the EC target. To illustrate these dynamics, dilution flow requirements to reduce Vernalis EC from 1000 umhos/cm to 630 umhos/cm were calculated based on dilution salinity. Figure 25 illustrates the results for three different flow rates at Vernalis. Essentially, as the dilution flow salinity approaches the target salinity, the dilution flow needs significantly increase. When dilution source salinity is low (in this case lower than 60% of the target salinity), it has little influence on the amount of dilution flow required. Therefore, the ideal source of dilution flows are influenced by the surrogate EC targets, in that the ideal sources of dilution flows are 60% or lower than the EC targets.

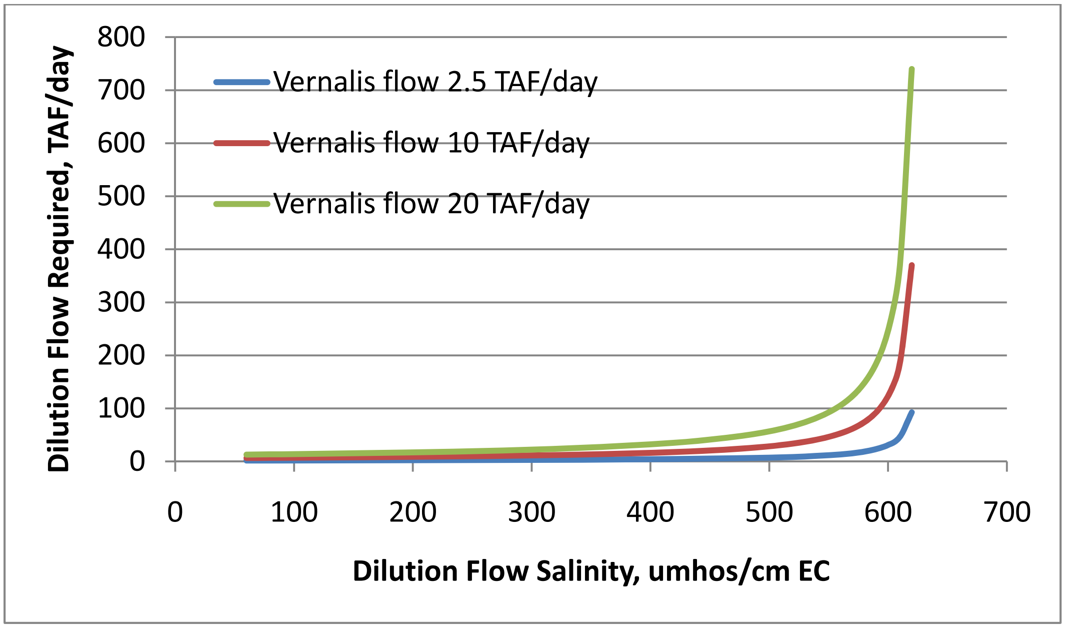


Figure 25: Dilution Flow as a Function of Dilution Salinity at Varying Vernalis Flow Rates

3. Range of Dilution Flow Needs to Meet Vernalis Surrogate EC Targets (based on Recent Data)

In order to translate the Vernalis surrogate EC targets into dilution flow requirements, information on potential sources of dilution flow were obtained and a daily spreadsheet model was developed. Daily EC at Ripon on the Stanislaus River, EC at Modesto on the Tuolumne River, and EC near Stevinson on the Merced River were obtained. Daily EC values measured at Check 21 on the Delta-Mendota Canal (DMC) were also obtained to simulate the use of DMC recirculation.

The daily spreadsheet model was used to determine the volume of water needed to meet each of the surrogate EC targets at Vernalis under historic water quality conditions. Daily EC and flow at Vernalis were used to determine when dilution flow was needed and to calculate how much dilution was needed. A 30-day running average was calculated and changed as dilution flow was added. The daily spreadsheet model was run for each of the potential dilution flow sources separately (the use of dilution flow sources was not optimized). Dilution flow sources, described in the previous paragraph, were limited only by their estimated capacity constraints.

As described earlier, operators target a lower salinity target to ensure fluctuations in flow and water quality will not prevent compliance with the target; however, for this study, the spreadsheet model targeted the surrogate EC. Dilution flows were assumed to offset salinity at Vernalis immediately (in reality, they would take 2 to 3 days to effect dilution). Increases in storage releases would probably change the water quality in the tributaries, but these relationships were not developed for this study, so this factor was not included. While water quality changes due to storage releases, operational salinity goals (buffers), and travel time are critical factors, they were not included in the model.

Historic salinity and physical volume capacities of the tributaries and the Delta-Mendota Canal (DMC, for recirculation) were used to determine the ability of dilution flow to affect the desired salinity dilution. To develop the dilution flow constraints for the spreadsheet model, information was obtained from the Delta-Mendota Canal Recirculation Feasibility Study, Plan Formulation Report, which summarized average historic monthly tributary flow in Appendix F and described recirculation facility capacity in Chapter 1. Table 12 presents these details.

Table 12: Dilution Flow Capacity Constraints

	Capacity, TAF/day	**Highest historic average monthly flow, cfs**
Stanislaus at Ripon	9.0	4,537 (April 2006)
Tuolumne at Modesto	15.56	7,847 (May 2006)
Merced at Stevinson	9.27	4,675 (April 2006)
DMC Wasteway	8.53	4,300 (capacity)

One additional observation from the spreadsheet model is the need, during some periods, to "chase" the 30-day running average surrogate EC target at Vernalis with dilution flow over a period of time. Essentially, a day's maximum release of dilution flow may not be adequate to meet the 30-day target. The EC then remains above the target for that day, and, combined with high EC the next day requires a second day of a maximum dilution flows. This pattern continues until either the salinity upstream of Vernalis improves or the objective season changes to the higher surrogate EC target.

The results of the spreadsheet modeling are presented in several tables and figures in Appendix F. Tables 13 and 14 summarize the annual dilution flow estimates per dilution flow source, and, where the surrogate EC target at Vernalis is still exceeded, the number of daily occurrences within the month. Depending on the dilution source, the dilution flows estimated to meet the least stringent surrogate EC targets at Vernalis range from no flow in wet years to 200 to 300 thousand acre feet in drier years (neglecting Recirculation as a source, estimated to be 2 to 3 times these flows due to higher EC). To meet the Old River near Tracy surrogates, this range dramatically increases to 1 to 2 million acre feet in drier years. Appendix F contains tables of the monthly dilution flows requirements estimated with the spreadsheet model.

Table 13: Annual Estimated Dilution Flow (TAF) from Individual Dilution Sources (TAF) to Meet the various Surrogate EC Targets at Vernalis for the EC Objectives at San Joaquin River at Brandt Bridge and Old River near Middle River (Values in Parentheses are the Number of Days when the Surrogate Cannot Be Met through Dilution Source)

Year	Stanislaus		Merced		Tuolumne		Recirculation	
	90%	100%	90%	100%	90%	100%	90%	100%
2000-AN	22	51	42	92	25	58	74	162
2001-D	68	129	127	264	137	284	389	722 (4)
2002-D	46	78	70	224	63	115	275	470
2003-BN	87	178	116	285	108	227	321	447
2004-D	38	74	68	149	56	117	150	316
2005-W	0	0	0	0	0	0	0	0
2006-W	0	0	0	0	0	0	0	0
2007-C	18	37	38	84	26	51	117	255
2008-C	28	58	38	90	40	91	320	708 (25)
2009-BN	32	61	32	86	34	77	640 (56)	729 (57)
2010-AN	13	22	14	26	13	22	133	172

Table 14: Annual Estimated Dilution Flow (TAF) from Individual Dilution Sources (TAF) to Meet the various Surrogate EC Targets at Vernalis for the EC Objectives at Old River near Tracy (Values in Parentheses are the Number of Days when the Surrogate Cannot Be Met through Dilution Source)

Year	Stanislaus			Merced		
	90%	**95%**	**100%**	**90%**	**95%**	**100%**
2000-AN	510	644	1,097 (4)	887	1,190 (53)	1,832 (104)
2001-D	374	908	1,357 (1)	790	1,364 (31)	1,753 (75)
2002-D	723	756	1,358	1,544	1,373 (49)	1,925 (65)
2003-BN	1,035	974	1,501	2,167	1,480 (38)	2,099 (44)
2004-D	307	748	1,247	574	1,270	1,834 (72)
2005-W	77	385	667	72	346	607
2006-W	1	93	274	1	138	479 (27)
2007-C	235	402	831	353	730	1,295 (23)
2008-C	291	602	1,013	425	816	1,320
2009-BN	285	528	833	347	653	1,002
2010-AN	148	479	931	192	618	1,177
	Tuolumne			**Recirculation**		
2000-AN	**90%**	**95%**	**100%**	**90%**	**95%**	**100%**
2001-D	1,078	763	1,560	1,447 (126)	1,032 (146)	1,032 (175)
2002-D	668	1,626	2,400 (32)	1,457 (68)	1,928 (217)	2,039 (308)
2003-BN	1,254	1,324	2,342	3,091 (138)	2,064 (211)	2,354 (318)
2004-D	1,630	1,445	2,266	4,531 (189)	2,247 (217)	2,471 (306)
2005-W	471	1,177	2,028	1,209 (97)	2,215 (200)	2,409 (271)
2006-W	76	429	837	506 (89)	1,020 (67)	1,245 (160)
2007-C	1	90	364	3	606 (49)	606 (76)
2008-C	359	614	1,417	776	1,194 (118)	1,741 (276)
2009-BN	463	943	1,652	1,145 (92)	2,035 (185)	2,211 (330)
2010-AN	400	757	1,215	1,545 (166)	2,013 (243)	2,106 (313)
	152	500	1,065	876	1,425 (147)	1,426 (218)

4. Range of Dilution Flow Needs to Meet Vernalis Surrogate EC Targets (based on CALSIM model)

Reclamation also post-processed two CALSIM II model runs as an additional step to estimate dilution flows. The 2002 CALSIM II Benchmark Study (2001 LOD) and the 2009 CALSIM II SWP Delivery Reliability Study (2005 LOD) were obtained and the output of flow and salinity at Vernalis and flow releases for water quality from New Melones. The primary difference in these two CALSIM studies is incorporation of recent biological opinions for the state and federal water projects.

Monthly salinity at Vernalis was examined to determine when dilution flows would be required to meet the surrogate EC targets at Vernalis. Dilution flow was assumed to have 60 umhos/cm EC, representing eastside reservoir water quality. An operational salinity buffer of 25 umhos/cm EC was also incorporated as representative of operating conditions. Dilution flow availability was not constrained and may represent more water than is physically available.

Average, maximum and minimum monthly results grouped by water year type are presented in Tables 15 and 16, and monthly averages by water year type are illustrated in Figures 26 through 35. Appendix G contains time series plots of the post-processing results. These results are similar to the estimates made using the historic data, showing 100-200 thousand acre feet required to meet the most lenient surrogates and up to 1.4 million acre feet of very low salinity water to meet the most stringent surrogates, with the largest volumes of water required during the driest seasons and years when it is least likely to be available.

Table 15: Average Annual Estimated Dilution Flow (TAF/year) by Water Year Type to Meet Surrogate EC Targets at Vernalis (using the 2002 CALSIM II Benchmark Study at 2001 LOD)

	Modeled Existing Release, TAF/year	**Flow to Meet 862/583 Targets**	**Flow to Meet 859/534 Targets**	**Flow to Meet 735/416 Targets**	**Flow to Meet 623/346 Targets**	**Flow to Meet 531/298 Targets**
Wet	5	29	43	150	357	691
Above Normal	16	58	93	272	604	1,091
Below Normal	34	87	133	396	832	1,352
Dry	100	94	148	439	829	1,311
Critical	75	136	198	474	815	1,213

Table 16: Average Annual Estimated Dilution Flow (TAF/year) by Water Year Type to Meet Surrogate EC Targets at Vernalis (using the 2009 CALSIM II SWP Delivery Reliability Study (2005 LOD)

	Modeled Existing Release, TAF/year	**Flow to Meet 862/583 Targets**	**Flow to Meet 859/534 Targets**	**Flow to Meet 735/416 Targets**	**Flow to Meet 623/346 Targets**	**Flow to Meet 531/298 Targets**
Wet	2	10	27	194	556	1,139
Above Normal	9	46	77	294	671	1,232
Below Normal	28	126	177	471	881	1,416
Dry	54	144	200	503	898	1,409
Critical	115	156	212	495	848	1,278

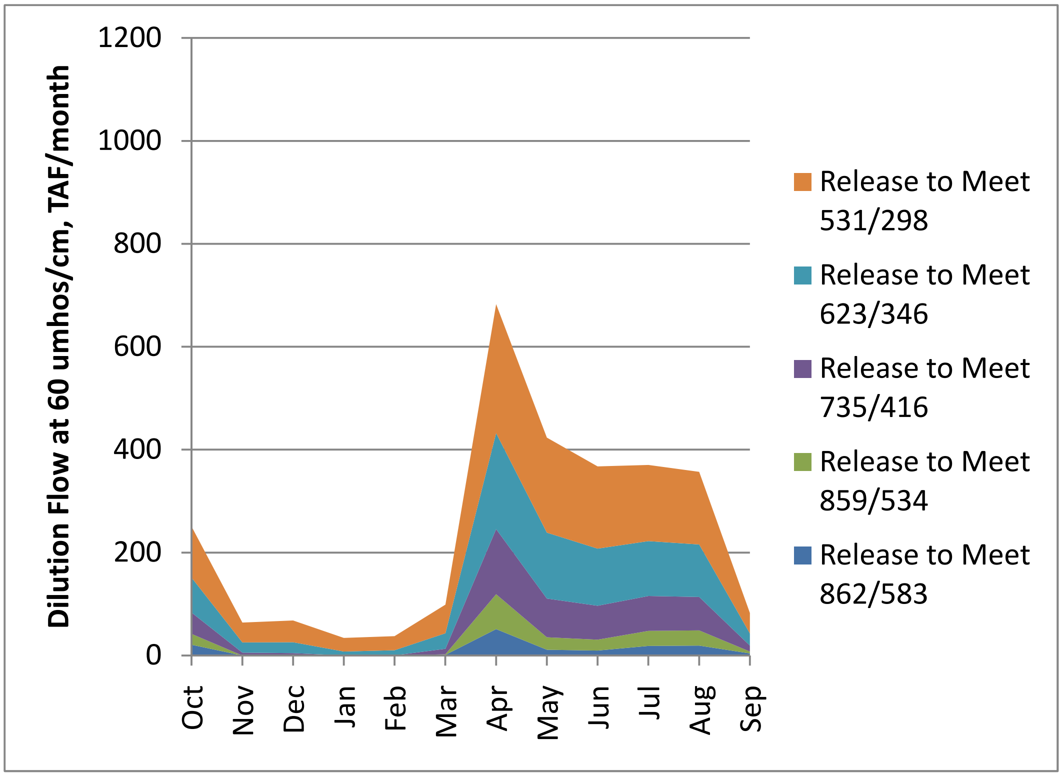


Figure 26: Average Monthly Volume of Dilution Flow in Critical Years (2002 CALSIM II Study)

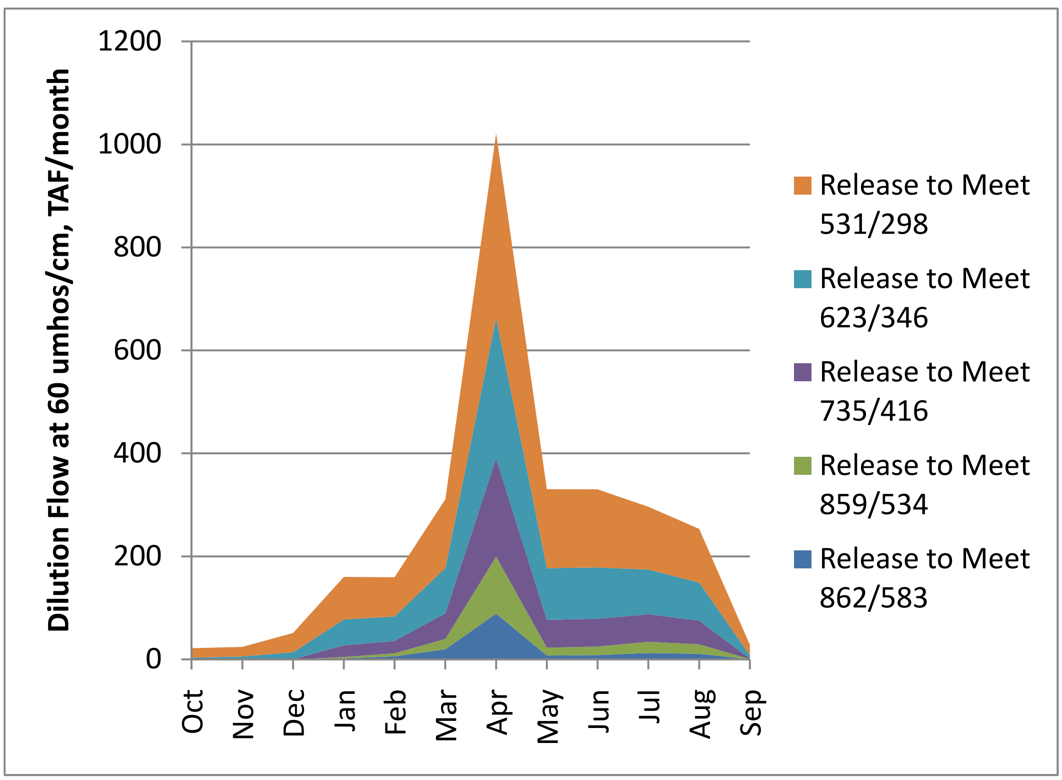


Figure 27: Average Monthly Volume of Dilution Flow in Critical Years (2009 CALSIM II Study)

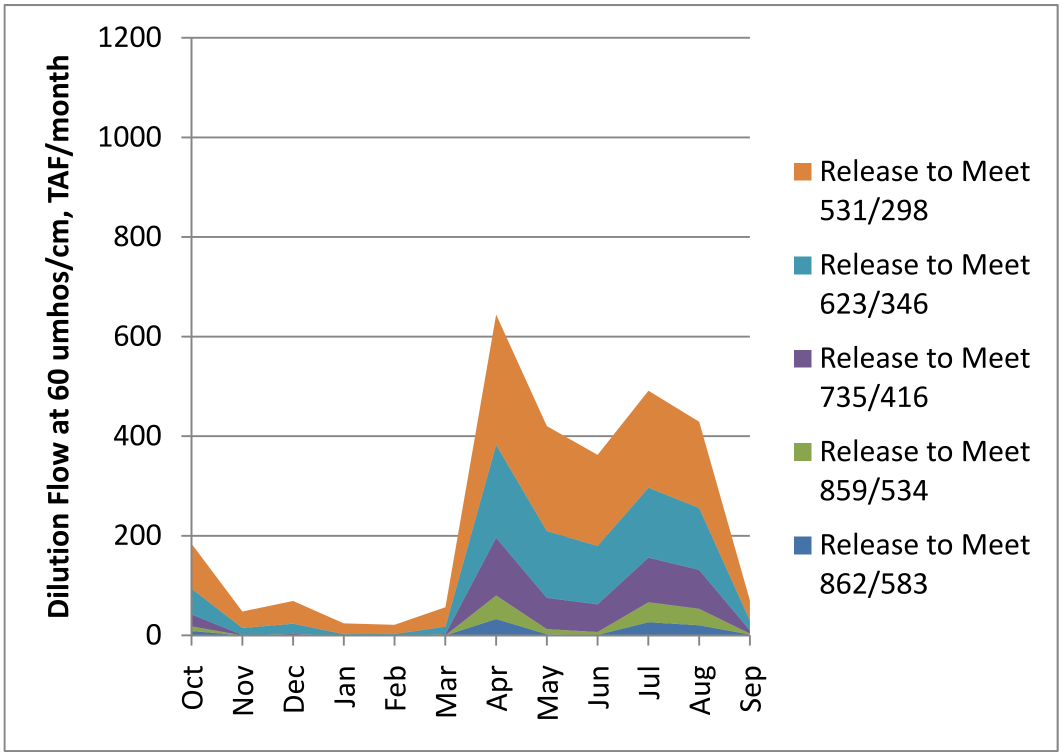


Figure 28: Average Monthly Volume of Dilution Flow in Dry Years (2002 CALSIM II Study)

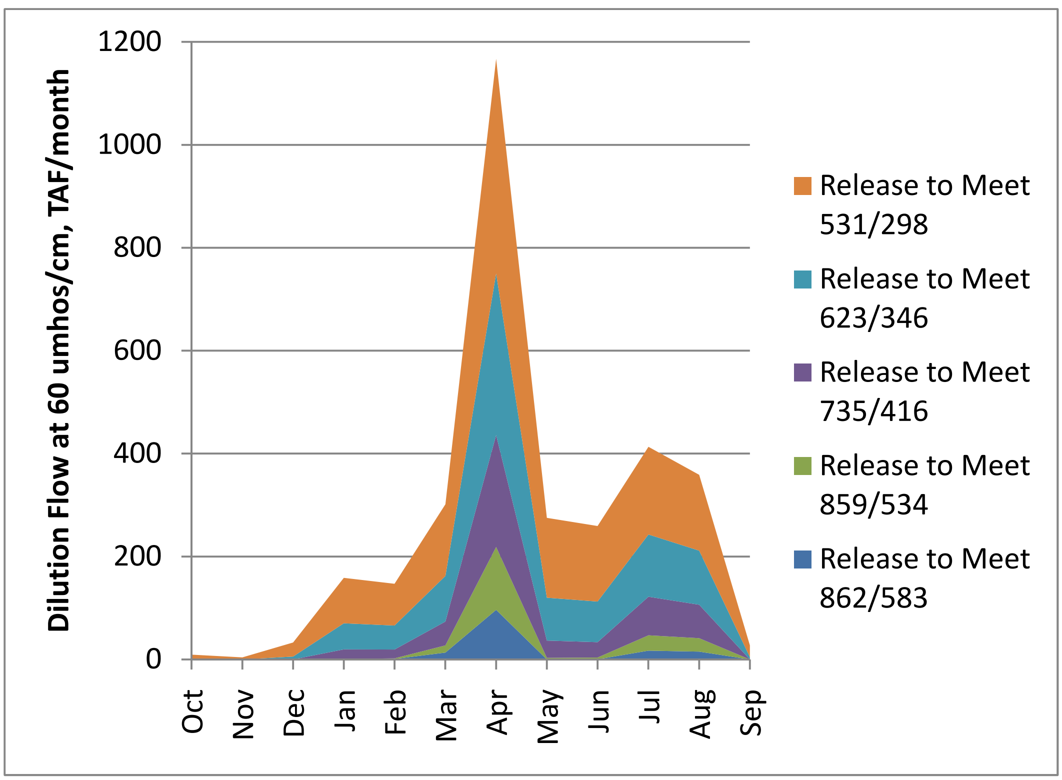


Figure 29: Average Monthly Volumes of Dilution Flow in Dry Years (2009 CALSIM II Study)

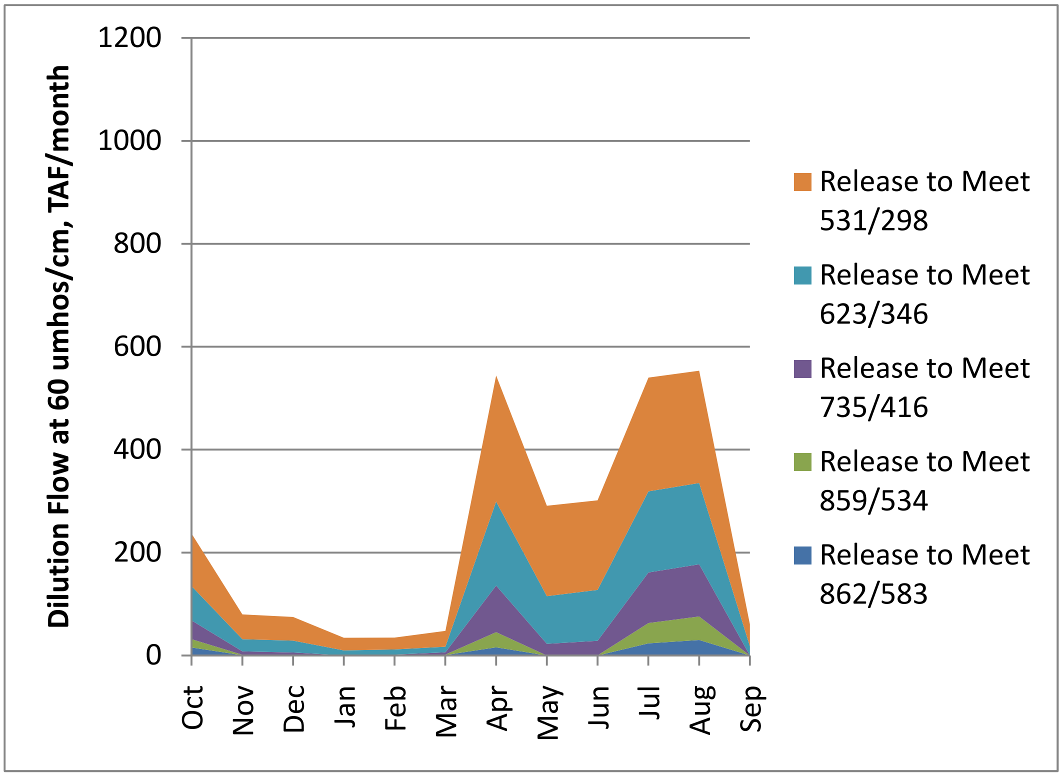


Figure 30: Average Monthly Volume of Dilution Flow in Below Normal Years (2002 CALSIM II Study)

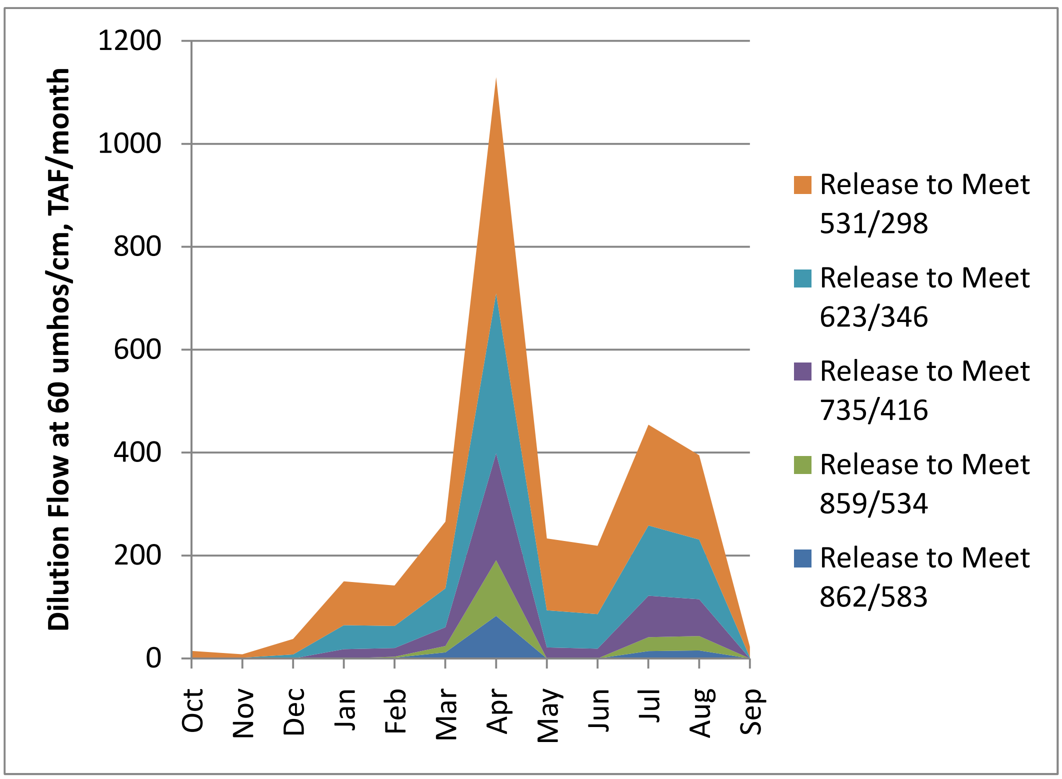


Figure 31: Average Monthly Volumes of Dilution Flow in Below Normal Years (2009 CALSIM II Study)

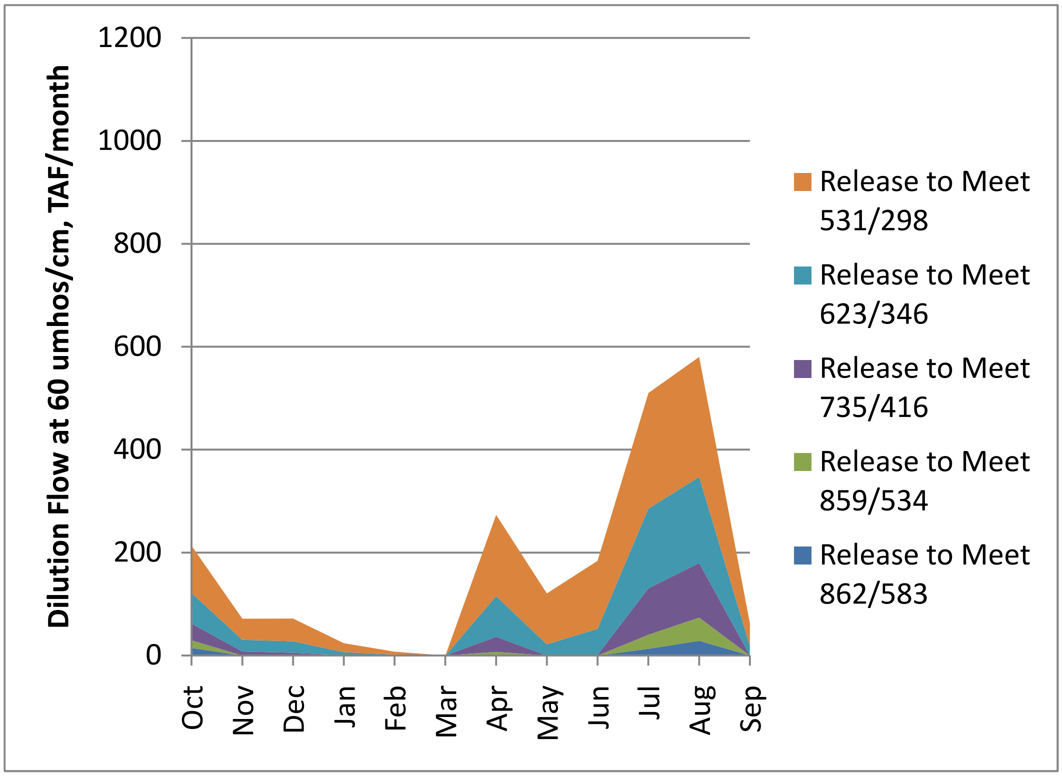


Figure 32: Average Monthly Volume of Dilution Flow in Above Normal Years (2002 CALSIM II Study)

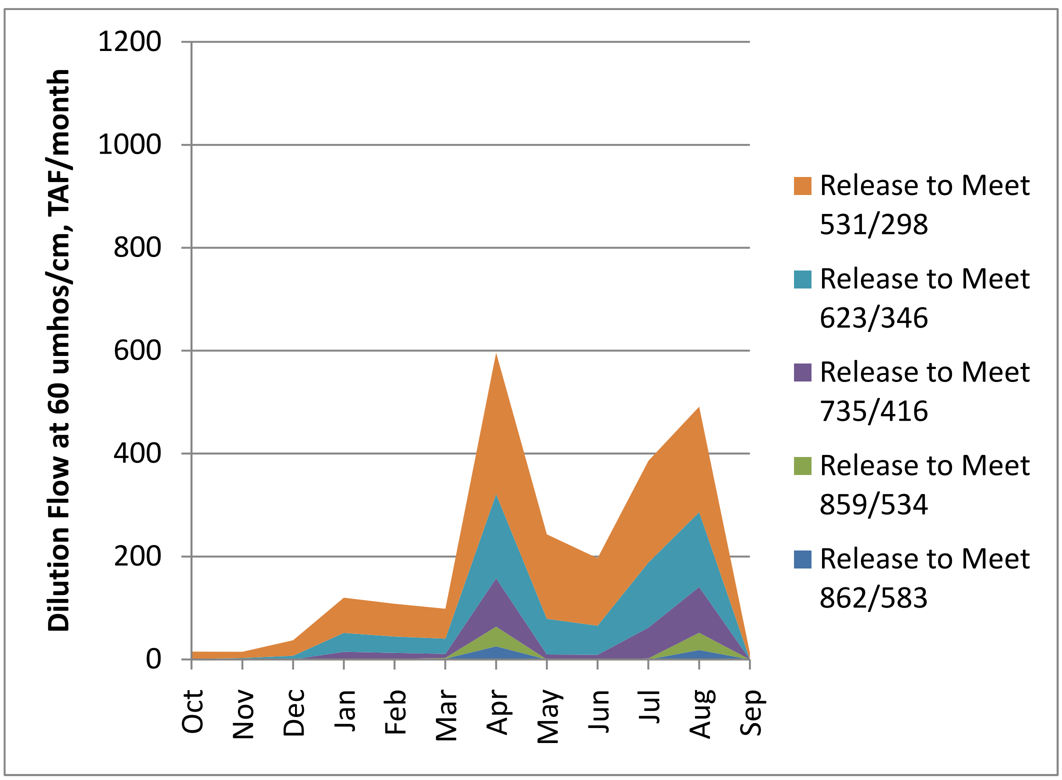


Figure 33: Average Monthly Volumes of Dilution Flow in Above Normal Years (2009 CALSIM II Study)

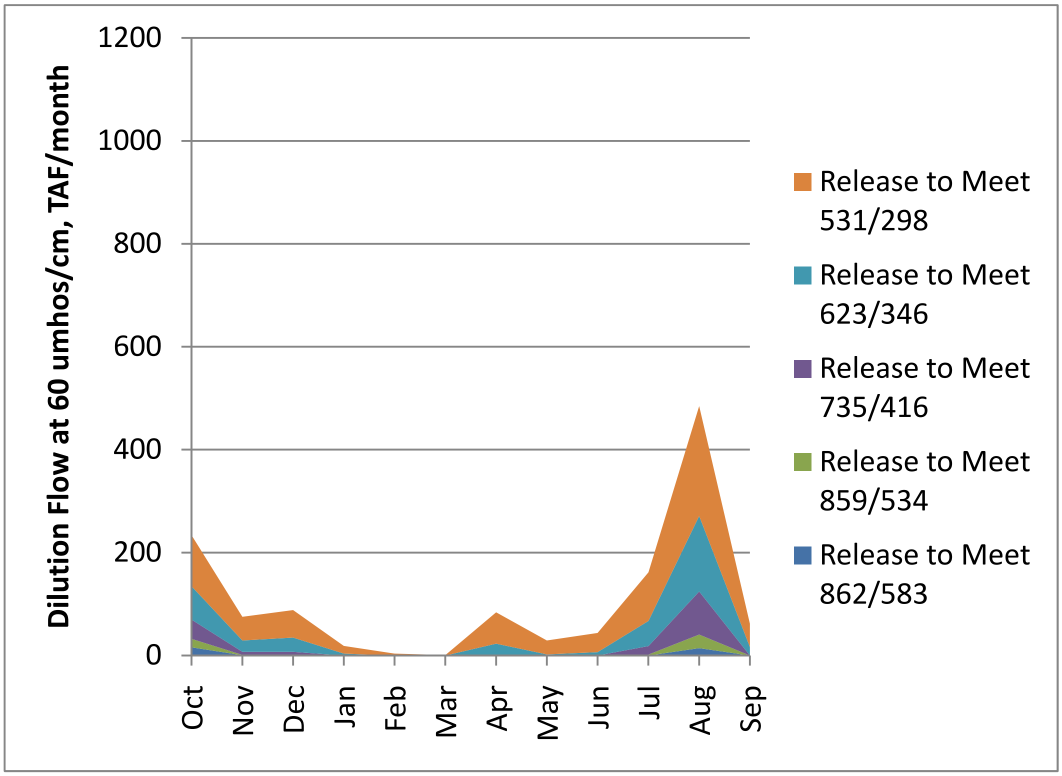


Figure 34: Average Monthly Volume of Dilution Flow in Wet Years (2002 CALSIM II Study)

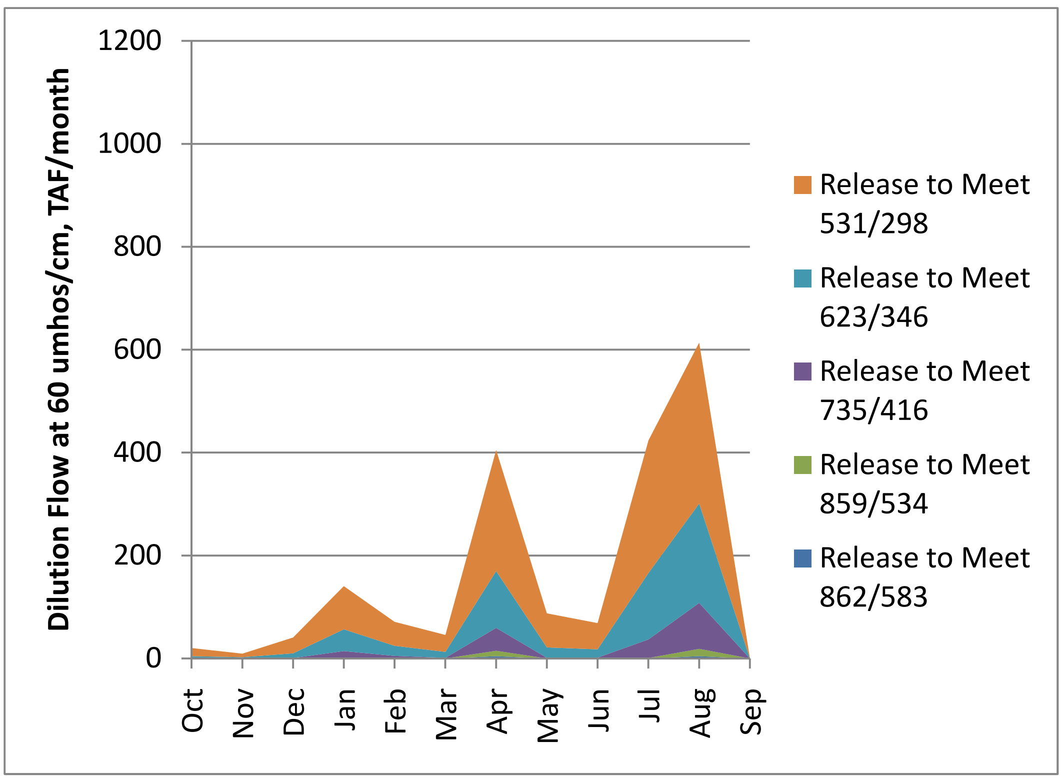


Figure 35: Average Monthly Volumes of Dilution Flow in Wet Years (2009 CALSIM II Study)

C. Availability of Dilution Flows

In the Study Plan, Reclamation and DWR stated that the Study would use the results of Phase 2 (described in Section B) to perform a reconnaissance-level evaluation of flows to improve compliance. Per the State Board's specific directions:

> *…phase 3 … will be completed if the results of phase 2 indicate that increased flows will improve salinity, and completion of phase 3 is not dependent on the specificity of information developed in phase 2; phase 3 will include an evaluation of both the feasibility of increased releases from CVP and SWP facilities and purchases or exchanges of water from third parties; and phase 3 will also include an evaluation of the impacts of increased flows on water supplies, including water supplies needed to protect fishery resources.*

The analysis presented in this Study suggest that using dilution flows to achieve full compliance with the South Delta objectives would likely require an unreasonable amount of water.

The technical analysis performed in this Study is not supportive of acquiring dilution flows to meet the South Delta objectives, but instead raises further questions as to best means to improve salinity in the South Delta. Using two methods to estimate dilution flows to meet the surrogate EC targets at Vernalis range from no flow in wet years to 1 to 2 million acre feet in drier years.

Reclamation also notes that the greatest monthly estimates of dilution flow occur in July and August, when Reclamation is diverting water on either the Stanislaus or Upper San Joaquin Rivers. Rather than determine the ability to purchase or release additional flow for this purpose, Reclamation proposes that the Water Board integrate this issue into current regulatory process such as CV-SALTS and the Board's recently noticed effort to reevaluate Lower San Joaquin River salinity standards.

References

Helsel, Dennis, Applied Environmental Statistics (Groundwater Modeling Short courses), International Ground Water Modeling Center, Colorado School of Minds, 2006

Bureau of Reclamation, Delta-Mendota Canal Recirculation Feasibility Study, Plan Formulation Report, 2010

California Department of Water Resources, Bureau of Reclamation, Quarterly CDO Status Reports to SWRCB, 2010

California Department of Water Resources, Sources of Salinity in the South Sacramento-San Joaquin Delta, May 2007

California Department of Water Resources, The State Water Project Delivery Reliability Report 2009, August 2010

California State Water Resources Control Board, Draft Technical Report on the Scientific Basis for Alternative San Joaquin River Flow and Southern Delta Salinity Objectives, 2010

California State Water Resources Control Board, Water Quality Control Plan for the Sacramento and San Joaquin River Basins, 4th Edition, 2006

This page was intentionally left blank.

Appendix A

Draft Feasibility Study Plan

Draft Feasibility Study Plan
To Meet Water Rights Order 2010-002 Requirement 7
Submitted March 5, 2010
Revised August 2, 2010
By
Bureau of Reclamation
And
California Department of Water Resources

On January 5, 2010 the State Water Resources Control Board of the State of California adopted Cease and Desist Order WR 2010-002, amending WR 2006-006. This Cease and Desist Order concerns compliance of the federal and state water projects with the South Delta agricultural standards. Requirement 7 of this order states:

> DWR and USBR shall study the feasibility of controlling salinity by implementing measures other than the temporary barriers project, recirculation of water through the San Joaquin River, and construction and operation of the permanent, operable gates. For each measure studied, DWR and USBR shall evaluate the extent to which the measure could control salinity at each of the interior southern Delta compliance locations, whether implementation of the measure would result in compliance with the interior southern Delta salinity objective at each of the locations, the technical and regulatory feasibility of the measure, the costs of the measure, and any potential impacts of the measure, including potential impacts to water quality, fishery resources, or water supplies. The study shall include, but is not limited to, an evaluation of the installation of low lift pumps at one or more of the temporary barriers. In addition, DWR and USBR shall evaluate, through modeling, whether compliance with the interior southern Delta salinity objective could be achieved by increasing flows in the San Joaquin River. In evaluating the feasibility of increasing flows in the San Joaquin River, DWR and USBR shall (1) evaluate the feasibility of both increased releases from CVP and SWP facilities and purchases or exchanges of water from third parties, and (2) evaluate the potential impacts of increasing flows on water supplies, including water supplies needed to protect fishery resources. Within 60 days from the date of this order, DWR and USBR shall submit a study plan to the Deputy Director for Water Rights for the Deputy Director’s review and approval. The Deputy Director may direct DWR and USBR to make any changes to the study plan necessary to ensure a meaningful evaluation of alternative salinity control measures. In addition, the Deputy Director may require DWR and USBR to conduct the study in phases, to refine or augment the study based on the results of an earlier phase, or to evaluate a combination of alternative salinity control measures designed to improve or achieve compliance with the interior southern Delta salinity objective. DWR and USBR shall make any changes to the study plan that the Deputy Director requires within the period that the Deputy Director specifies, and shall conduct the study in accordance with the approved study plan. Within 180 days from the Deputy Director’s approval of the study plan, DWR and USBR shall submit a report to the Executive Director that describes the study and its results.

This document outlines a feasibility study designed to meet this requirement to the best ability of the Bureau of Reclamation (Reclamation) and the Department of Water Resources (DWR) within the given time frame. It is the understanding of Reclamation and DWR that this study plan is due to the State Water Resources Control Board (State Board) on March 5, 2010 (60 days following January 5) and that the study must be completed within 180 days of the study plan approval by the Deputy Director of the State Board. On June 21, 2010, the State Board requested that changes be made to the proposed study plan. The feasibility study consists of two major pieces: the evaluation of installing low-head pumps at one or more temporary barrier sites and the evaluation of flows.

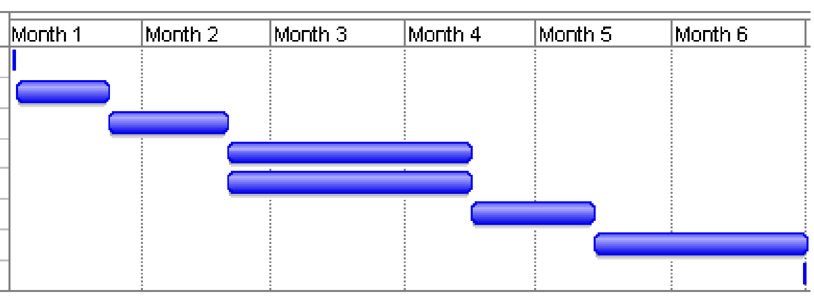
The flow evaluation will occur in three separate phases. The first phase is to determine the relationship between salinity at Vernalis on the San Joaquin River and salinity at the south Delta standard locations. The second phase is to use this relationship to evaluate the range of additional flows at Vernalis needed to meet South Delta salinity standards. The third phase will consist of a reconnaissance-level feasibility evaluation.

Evaluation of Installing Low-head Pumps at One or More Temporary Barrier Sites

In theory, low-head pumps can be utilized to induce flow upstream past one or more of the barriers to help improve circulation and water quality. However, based on a preliminary analysis performed several years ago by the DWR's Delta Modeling Section, it was concluded that such an option would not be practical due to the leakiness of the rock barriers. Low-head pumps would be most effective when used in conjunction with a sealed hydraulic structure such as those proposed for the permanent gates under SDIP. In spite of this earlier analysis, DWR will perform a more extensive modeling analysis in coordination with the South Delta Water Agency, and investigate the costs and practicality of constructing permanent pumping facilities or installing an array of temporary pumps. The modeling analysis will evaluate both the extent to which the pumps could control salinity and whether the pumps could result in compliance with the salinity objective. Review of regulatory requirements and permitting will be done. An assessment of mitigation needed to address construction/installation impacts as well as re-directed adverse impacts of the pumps on downstream water levels and diverters will be conducted.

The modeling analysis of the low-head pumps will generally follow the timeline below, depending upon availability of staff and workload:

ID	Task Name
1	SWRCB Plan Approval
2	Develop Assumptions
3	Initial Model Assumption Testing
4	Cost and Permitting Analysis
5	Detailed Hydrodynamic Model Runs
6	Post Processing
7	Analysis and Report Preparation
8	Transmit to SWRCB



<u>**Reconnaissance Evaluation of San Joaquin River Flows to Improve Compliance**</u>

Phase 1: Relationship of South Delta salinity to Vernalis salinity

Reclamation and DWR will analyze recent salinity data to estimate historical relationships between Vernalis and Southern Delta standard locations by:

1. Collecting recent (2000-2009) high frequency salinity data at Vernalis and South Delta standard locations.
2. Evaluate data to determine appropriate lag times.
3. Employ lag times to develop best-fit relationships and confidence bounds between locations.
4. Use developed best-fit relationships to estimate water quality targets required at Vernalis to meet South Delta standards.

Phase 2: Evaluate Range of Additional Required Vernalis Flows

Reclamation and DWR will use the results of Phase 1 (Target quality at Vernalis) to develop estimates of water needs, using the CALSIM database, and evaluating:

1. The general seasonality of increased dilution needs
2. The general hydrologic conditions (through Water Year classifications)
3. The relationship of volume of flows with the origins (salinity) of potential additional flows.

Phase 3: Evaluate Availability of Additional Required Vernalis Flows

Reclamation and DWR will use the results of Phase 2 to perform a reconnaissance-level evaluation of flows to improve compliance. Per the State Board's specific directions, "phase 3 … will be completed if the results of phase 2 indicate that increased flows will improve salinity, and completion of phase 3 is not dependent on the specificity of information developed in phase 2; phase 3 will include an evaluate of both the feasibility of increased releases from CVP and SWP facilities and purchases or exchanges of water from third parties; and phase 3 will include an evaluation of the impacts of increased flows on water supplies, including water supplies needed to protect fishery resources."

Schedule for Reconnaissance Evaluation of Flows to Improve Compliance

	Month:					
Task	1	2	3	4	5	6
Phase 1						
Phase 2						
Phase 3 Table of Flow needs						
Report Completion						
Internal Review/Surnaming						

This page was intentionally left blank.

Appendix B

SWRCB Letter Accepting Feasibility Study Plan

Linda S. Adams
Secretary for Environmental Protection

State Water Resources Control Board

Division of Water Rights
1001 I Street, 14th Floor ♦ Sacramento, California 95814 ♦ 916.341.5300
P.O. Box 2000 ♦ Sacramento, California 95812-2000
Fax: 916.341.5400 ♦ www.waterboards.ca.gov/waterrights

Arnold Schwarzenegger
Governor

SEP 2 1 2010

Katherine F. Kelly, Chief
Bay-Delta Office
California Department of Water Resources
1416 Ninth Street
Sacramento, CA 95814

Richard J. Woodley
Regional Resources Manager
Bureau of Reclamation, Mid-Pacific Region
2800 Cottage Way
Sacramento, CA 95825

Dear Ms. Kelly and Mr. Woodley:

REVISED FEASIBILITY STUDY PLAN PURSUANT TO ORDER WR 2010-0002

This letter responds to the August 3, 2010 correspondence submitting a revised feasibility study plan (Plan) and timeline for activities in the Plan prepared by the Department of Water Resources (DWR) and the United States Bureau of Reclamation (Reclamation) to comply with Condition A.7 of the State Water Resources Control Board (State Water Board) Order WR 2010-0002 (Order). The Plan details how DWR and Reclamation will evaluate the feasibility of installing low-lift pumps at one or more of the temporary barriers and the feasibility of increasing flows in the San Joaquin River to ensure compliance with the interior southern Delta salinity objective.

You state in your Plan that, in theory, low-lift pumps can be utilized to induce flow upstream past one or more of the barriers to help improve circulation and water quality. You also state that past modeling indicated that low-lift pumps would be impractical due to the leakiness of the temporary rock barriers. In spite of this earlier analysis, DWR now proposes to perform a more extensive modeling analysis in coordination with the South Delta Water Agency, and investigate the costs and practicality of constructing permanent pumping facilities or installing an array of temporary pumps.

Per your Plan, evaluation of San Joaquin River flows will be done in a phased approach. Phase 1 will determine the relationship between salinity at Vernalis on the San Joaquin River and salinity at the south Delta standard locations. Phase 2 will use this relationship to evaluate the range of additional flows at Vernalis needed to meet south Delta salinity standards. Phase 3 will evaluate availability of additional required Vernalis flows.

We note that the proposed modeling analysis of low-lift pumps "will evaluate both the extent to which the pumps could control salinity and whether the pumps could result in compliance with the salinity objective." We also note in Phase 3 of the flow analysis you "will use the results of

Phase 2 to perform a reconnaissance-level evaluation of flows to improve compliance." The proposed modeling and flow analyses are substantially in compliance with Condition A.7 of the Order. The Plan is conditionally approved, provided that the Deputy Director for Water Rights may require you to augment or revise your reconnaissance-level evaluation of flows as needed to determine the feasibility of achieving compliance with the interior southern Delta salinity objective, per Condition A.7.

Within 180 days from the date of this letter which constitutes the Deputy Director's conditional approval of the Plan, DWR and Reclamation shall submit a report to the Executive Director that describes the study and its results.

If you have any questions, or would like to discuss this matter further, please contact Patricia Fernandez, Senior Water Resources Engineer, at (916) 319-9141 or pfernandez@waterboards.ca.gov or Dana Heinrich, Staff Counsel IV, at (916) 341-5188 or dheinrich@waterboards.ca.gov.

Sincerely,

Victoria A. Whitney

Victoria A. Whitney
Deputy Director for Water Rights

cc: (Electronic mail)

Erick D. Soderlund
Department of Water Resources
1416 Ninth Street, Room 1104
Sacramento, CA 95814
esoderlund@water.ca.gov

Michael Jackson
P.O. Box 207
429 W. Main Street
Quincy, CA 95971
mjatty@sbcglobal.net
Rep: Calif. Sportfishing Protection Alliance

Jon D. Rubin
Diepenbrock Harrison
400 Capitol Mall, Suite 1800
Sacramento, CA 95814
jrubin@diepenbrock.com
Rep: San Luis & Delta-Mendota Water Authority and Westlands Water District

Dante John Nomellini, Esq.
Nomellini, Grilli & McDaniel
P.O. Box 1461
Stockton, CA 95201
ngmlplcs@pacbell.net
Rep: Central Delta Water Agency

Carl P. A. Nelson
Bold, Polisner, Maddow, Nelson & Judson
500 Ygnacio Valley Road, Suite 325
Walnut Creek, CA 94596-3840
cpanelson@bpmnj.com
Rep: Contra Costa Water District

Paul R. Minasian
Minasian Law Firm
P.O. Box 1679
Oroville, CA 95965
pminasian@minasianlaw.com
Rep: San Joaquin River Exchange Contractors Water Authority

Continued on next page.

SEP 2 1 2010

Amy L. Aufdemberge
Assistant Regional Solicitor
Room E-1712
2800 Cottage Way
Sacramento, CA 95825
Amy.Aufdemberge@sol.doi.gov
Rep: U.S. Bureau of Reclamation

John Herrick
South Delta Water Agency
4255 Pacific Ave., Suite 2
Stockton, CA 95207
Jherrlaw@aol.com
Rep: South Delta Water Agency

Thomas J. Shephard, Sr.
P.O. Box 20
Stockton, CA 95201
tshephard@neumiller.com
Rep: County of San Joaquin

Patrick Porgans
Patrick Porgans and Associates, Inc.
P.O. Box 60940
Sacramento, CA 95860
porgansinc@sbcglobal.net

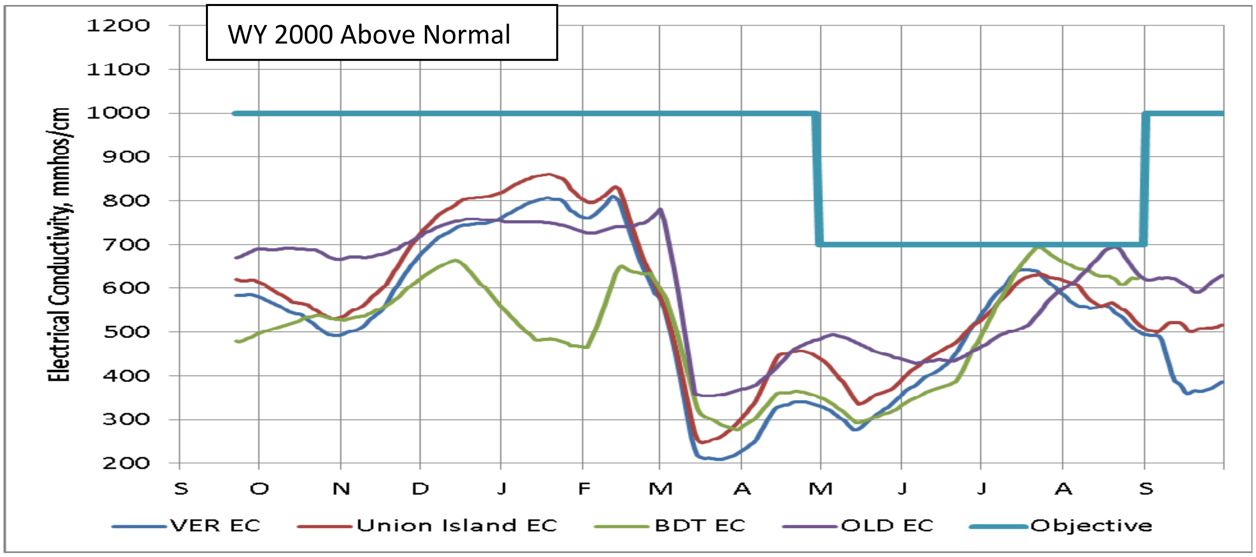
Tim O'Laughlin
O'Laughlin & Paris LLP
P.O. Box 9259
Chico, CA 95927-9259
towater@olaughlinparis.com
Rep: San Joaquin River Group Authority

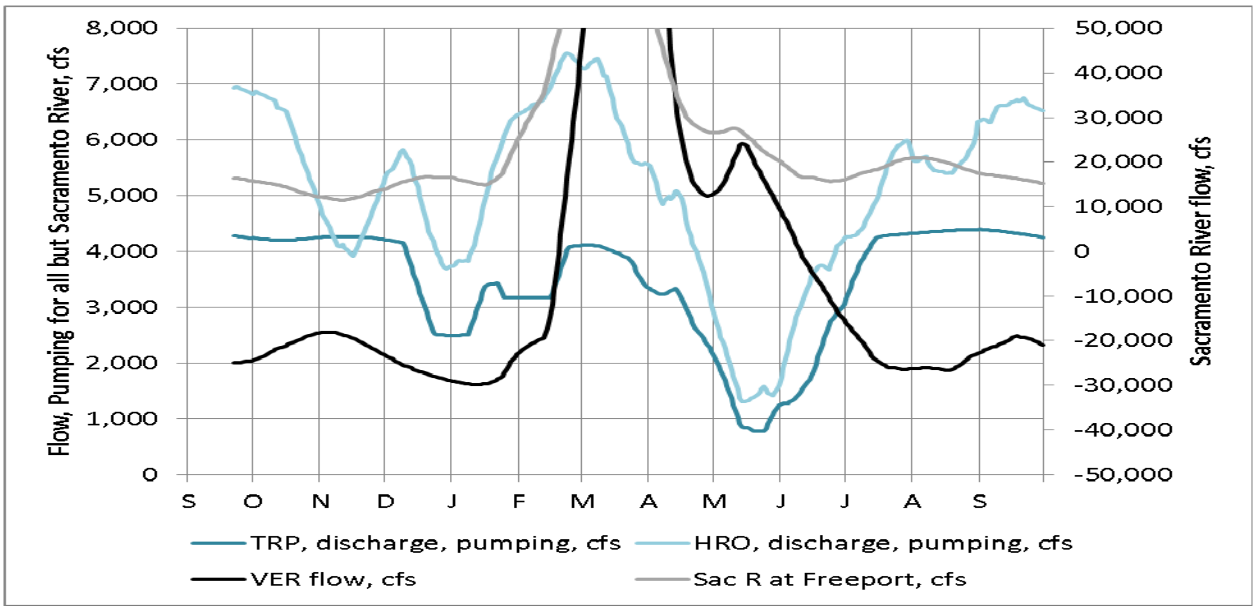
Julia R. Jackson
P.O. Box 148
Quincy, CA 95971
Julia.r.jackson@gmail.com
Rep: California Water Impact Network

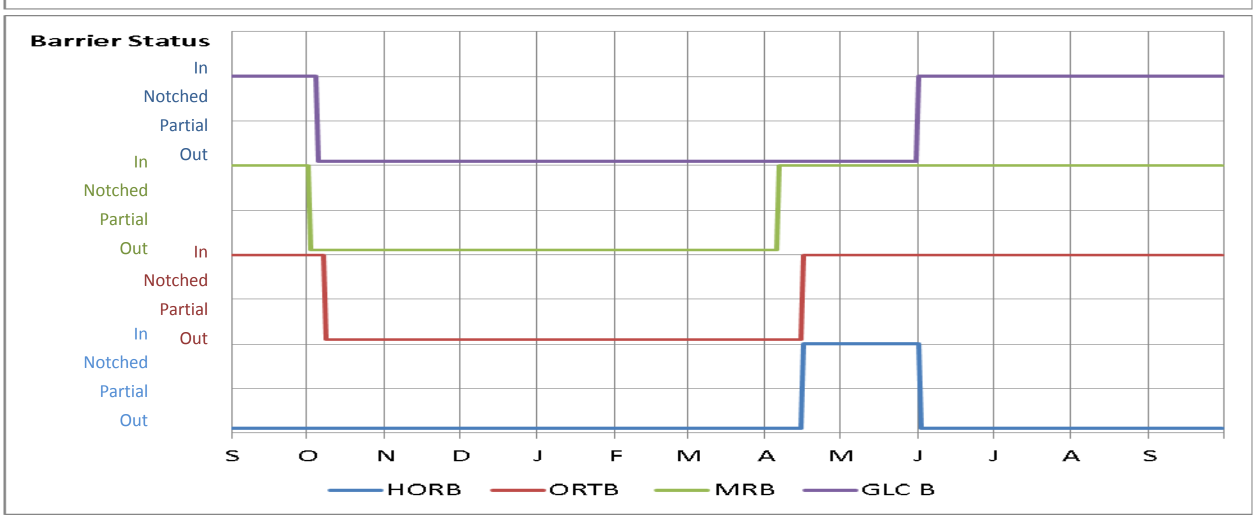
Karna Harrigfeld
Herum Crabtree
2291 W. March Lane, Suite B100
Stockton, CA 95207
kharrigfeld@herumcrabtree.com
Rep: Stockton East Water District

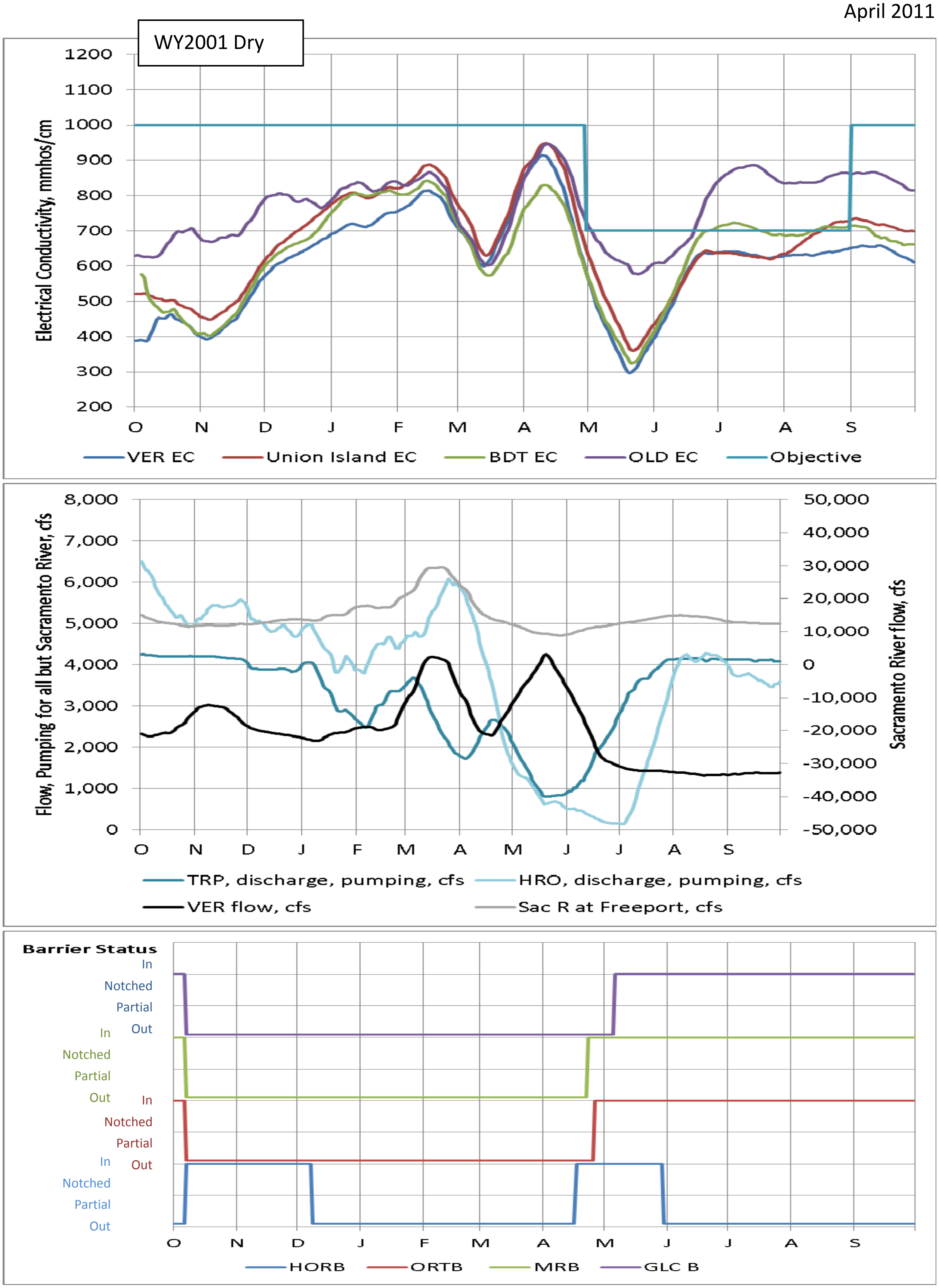
Appendix C

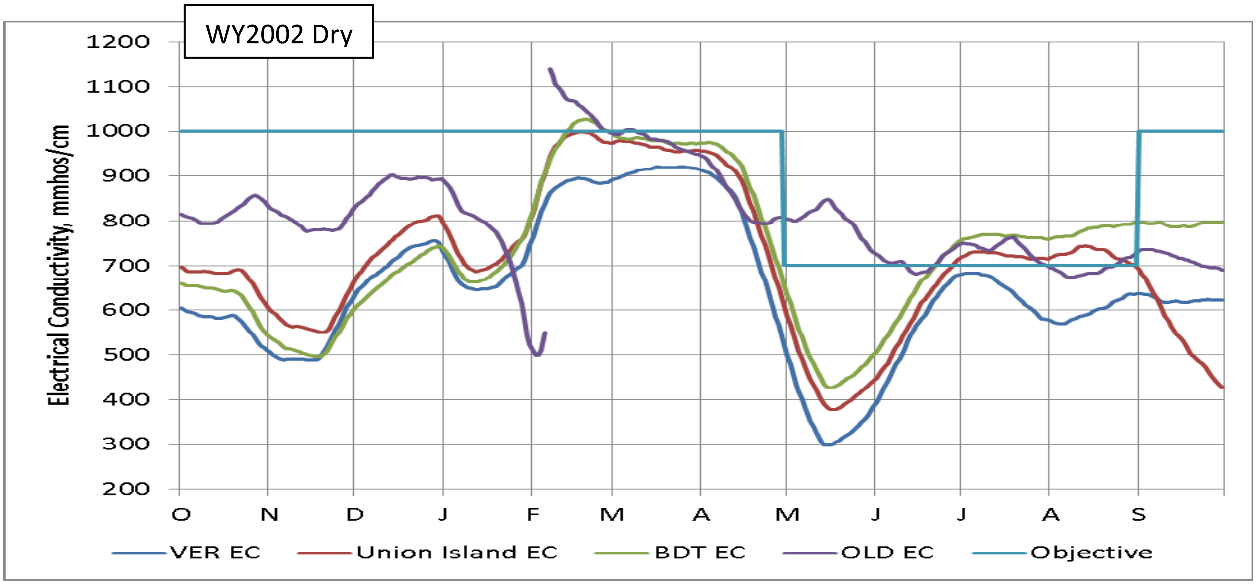
Time Series Plots of Daily South Delta Salinity, Delta Flow, and Temporary Barriers Data

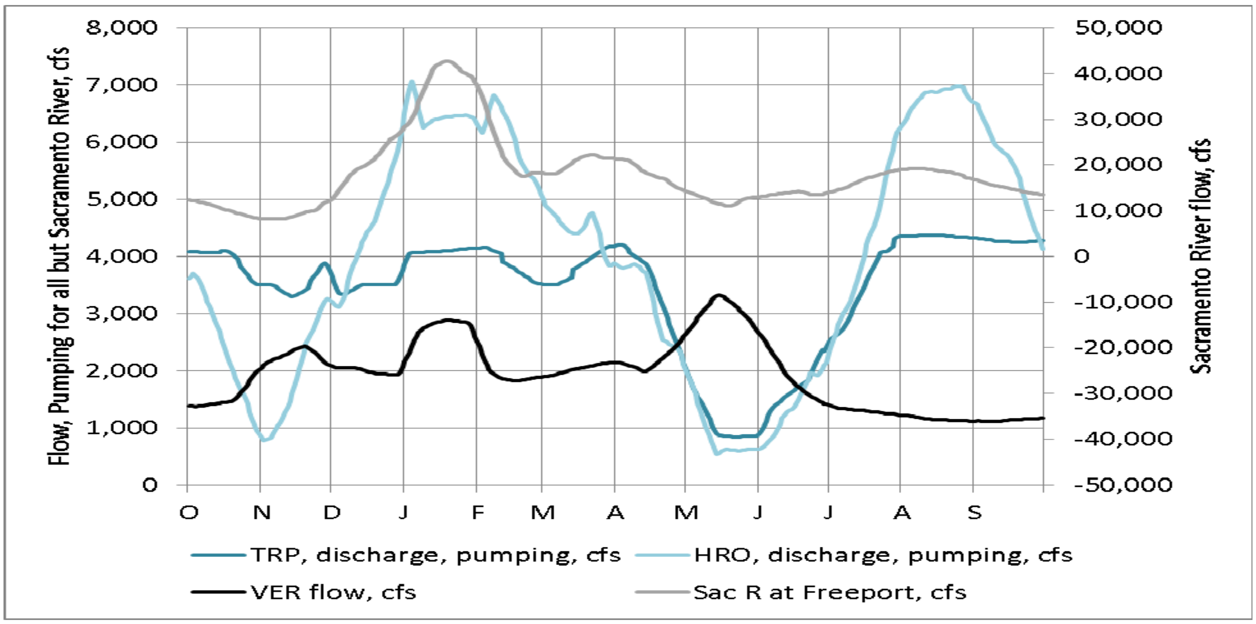

WY 2000 Above Normal
Electrical Conductivity, mmhos/cm
1200
1100
1000
900
800
700
600
500
400
300
200
S O N D J F M A M J J A S
VER EC
Union Island EC
BDT EC
OLD EC
Objective

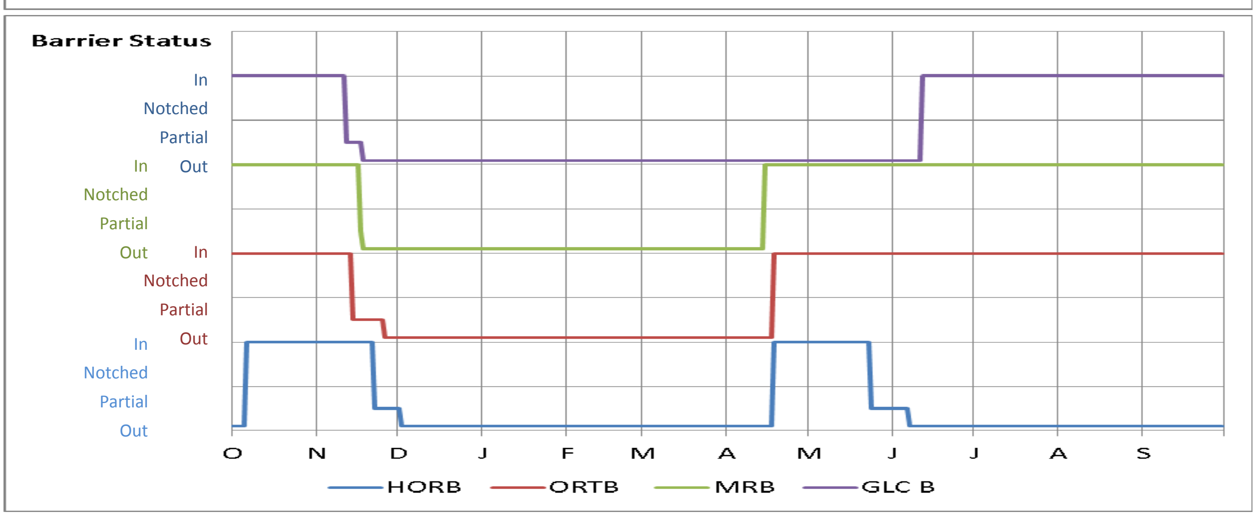

Flow, Pumping for all but Sacramento River, cfs
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
Sacramento River flow, cfs
50,000
40,000
30,000
20,000
10,000
0
-10,000
-20,000
-30,000
-40,000
-50,000
S O N D J F M A M J J A S
TRP, discharge, pumping, cfs
HRO, discharge, pumping, cfs
VER flow, cfs
Sac R at Freeport, cfs

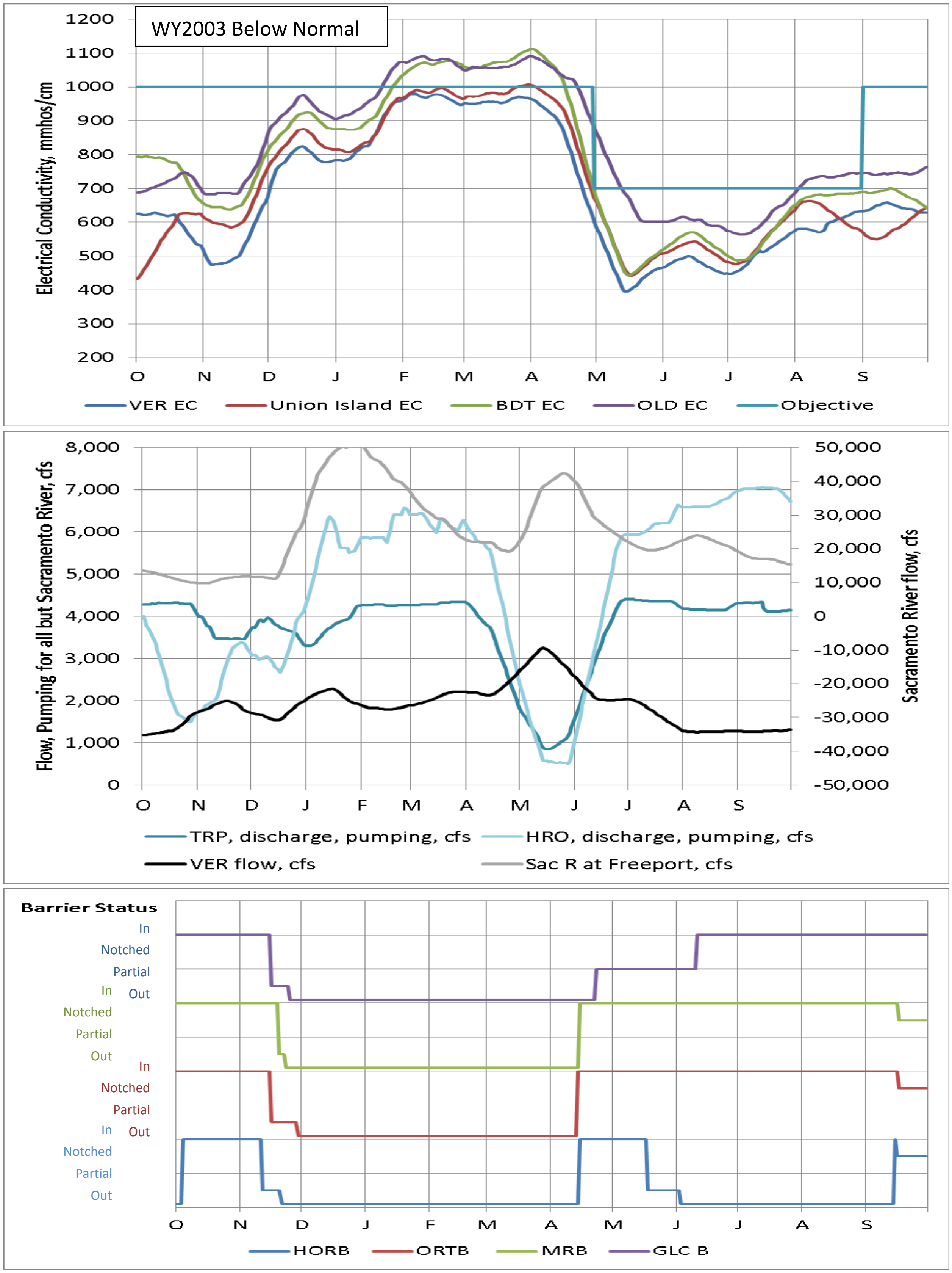

Barrier Status
In
Notched
Partial
Out
In
Notched
Partial
Out
In
Notched
Partial
Out
In
Notched
Partial
Out
S O N D J F M A M J J A S
HORB
ORTB
MRB
GLC B

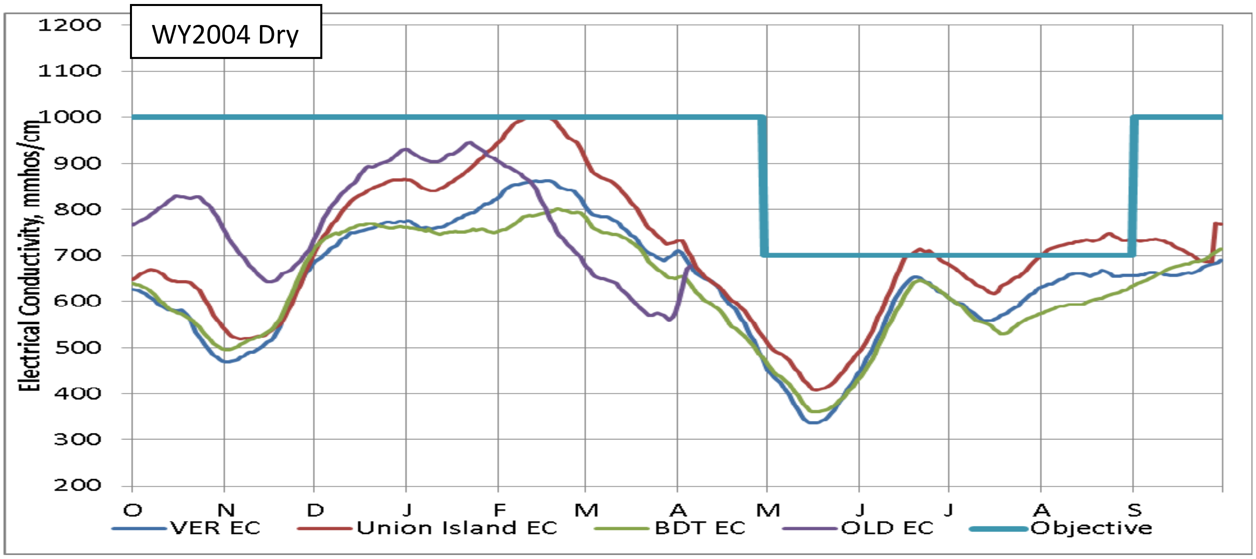

WY2001 Dry
Electrical Conductivity, mmhos/cm
1200
1100
1000
900
800
700
600
500
400
300
200
O N D J F M A M J J A S
VER EC
Union Island EC
BDT EC
OLD EC
Objective
Flow, Pumping for all but Sacramento River, cfs
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
50,000
40,000
30,000
20,000
10,000
0
-10,000
-20,000
-30,000
-40,000
-50,000
Sacramento River flow, cfs
O N D J F M A M J J A S
TRP, discharge, pumping, cfs
HRO, discharge, pumping, cfs
VER flow, cfs
Sac R at Freeport, cfs
Barrier Status
In
Notched
Partial
Out
O N D J F M A M J J A S
HORB
ORTB
MRB
GLC B

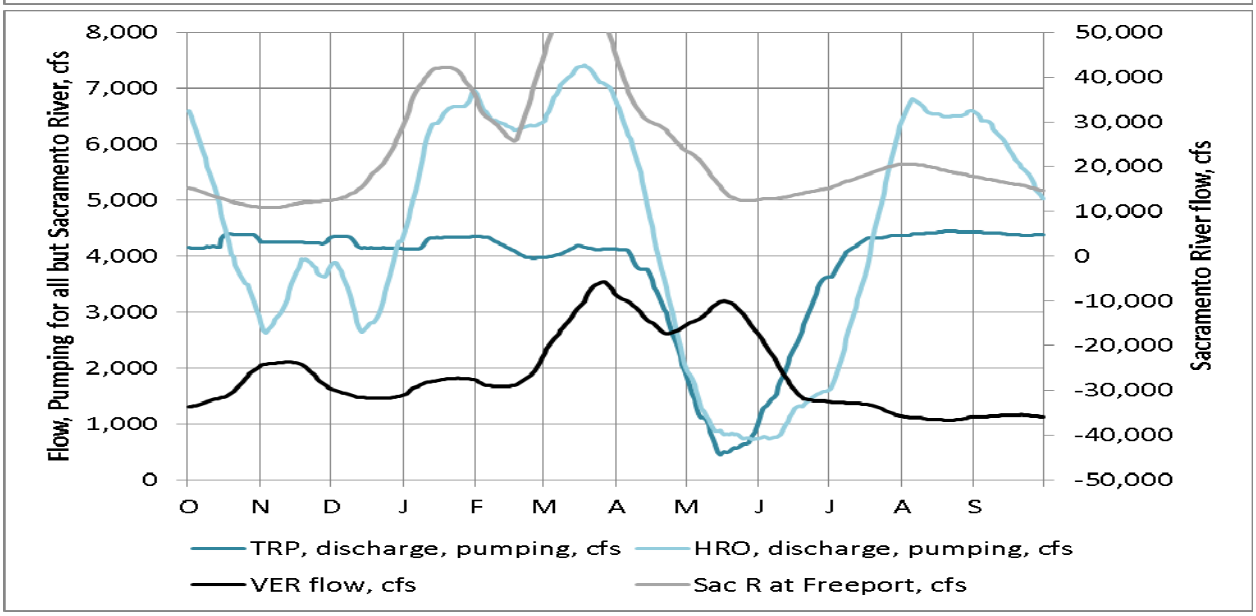

WY2002 Dry
Electrical Conductivity, mmhos/cm
1200
1100
1000
900
800
700
600
500
400
300
200
O N D J F M A M J J A S
VER EC
Union Island EC
BDT EC
OLD EC
Objective

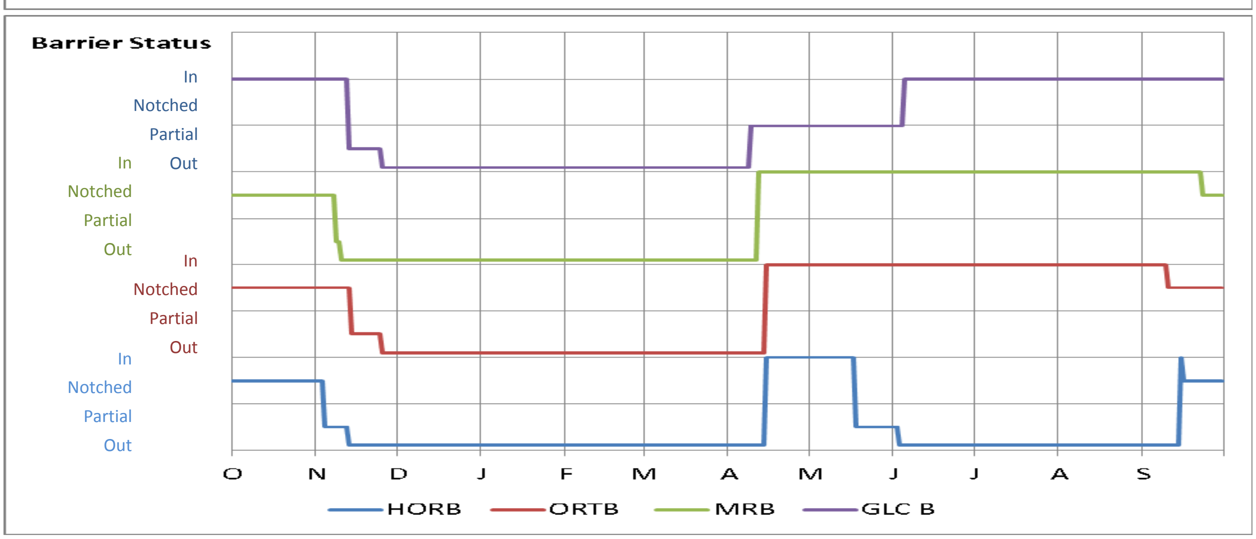

Flow, Pumping for all but Sacramento River, cfs
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
Sacramento River flow, cfs
50,000
40,000
30,000
20,000
10,000
0
-10,000
-20,000
-30,000
-40,000
-50,000
O N D J F M A M J J A S
TRP, discharge, pumping, cfs
HRO, discharge, pumping, cfs
VER flow, cfs
Sac R at Freeport, cfs

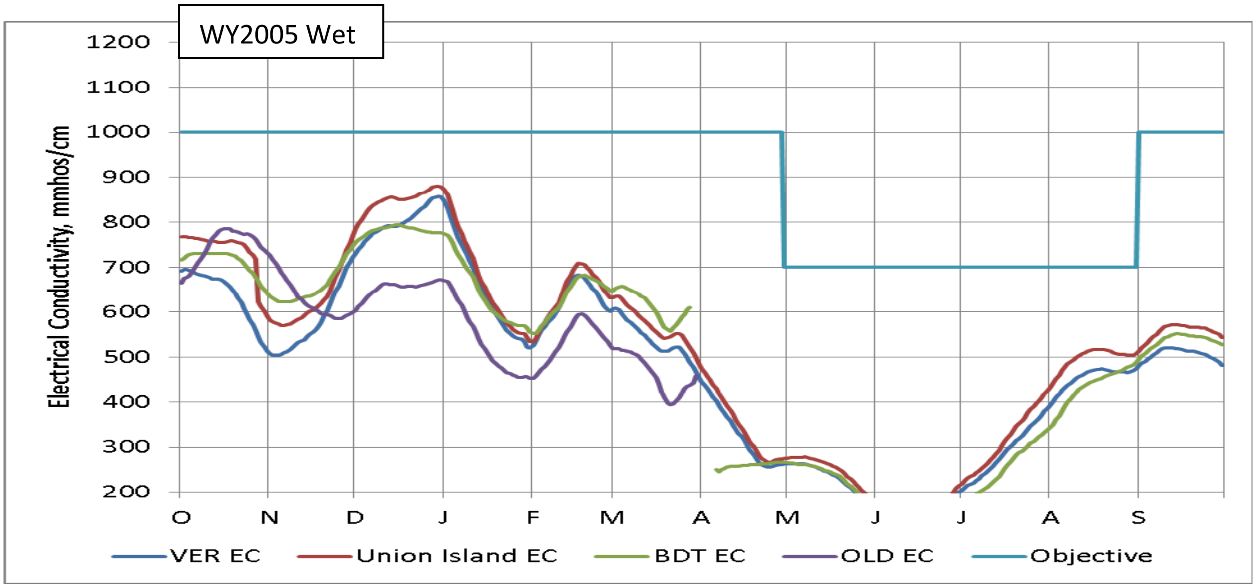

Barrier Status
In
Notched
Partial
Out
In
Notched
Partial
Out
In
Notched
Partial
Out
In
Notched
Partial
Out
O N D J F M A M J J A S
HORB
ORTB
MRB
GLC B

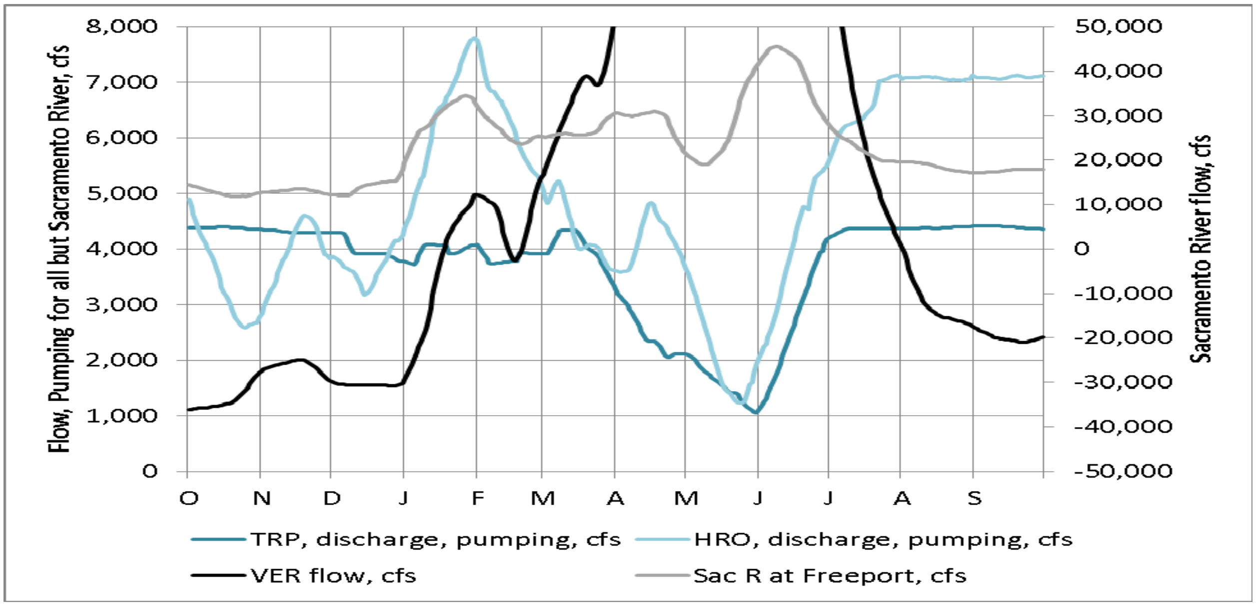

WY2003 Below Normal
Electrical Conductivity, mmhos/cm
1200
1100
1000
900
800
700
600
500
400
300
200
O N D J F M A M J J A S
VER EC
Union Island EC
BDT EC
OLD EC
Objective
Flow, Pumping for all but Sacramento River, cfs
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
Sacramento River flow, cfs
50,000
40,000
30,000
20,000
10,000
0
-10,000
-20,000
-30,000
-40,000
-50,000
O N D J F M A M J J A S
TRP, discharge, pumping, cfs
HRO, discharge, pumping, cfs
VER flow, cfs
Sac R at Freeport, cfs
Barrier Status
In
Notched
Partial
Out
O N D J F M A M J J A S
HORB
ORTB
MRB
GLC B

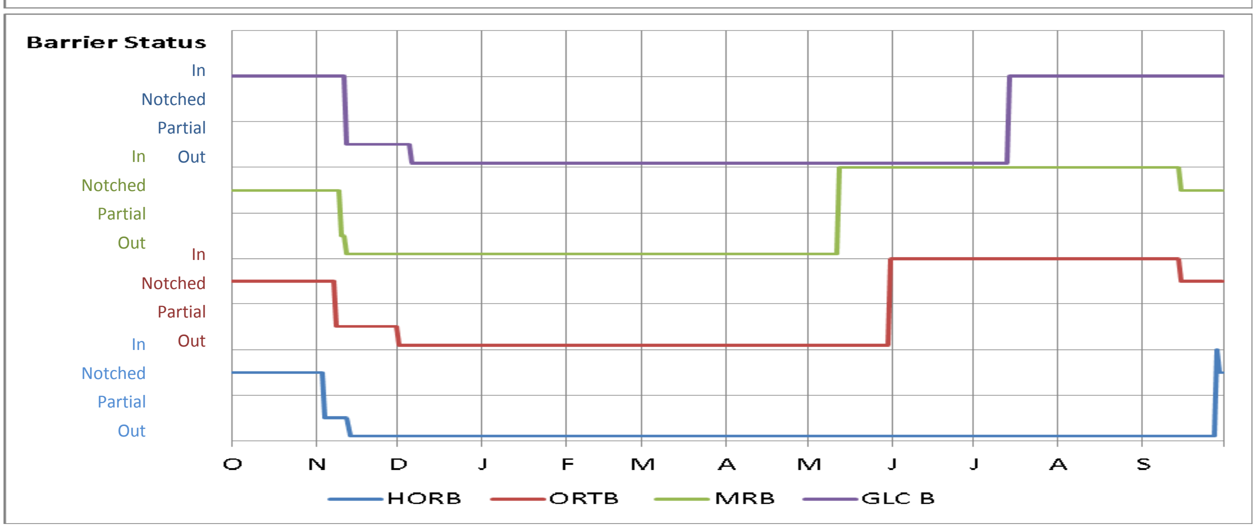

WY2004 Dry
Electrical Conductivity, mmhos/cm
1200
1100
1000
900
800
700
600
500
400
300
200
O N D J F M A M J J A S
VER EC
Union Island EC
BDT EC
OLD EC
Objective

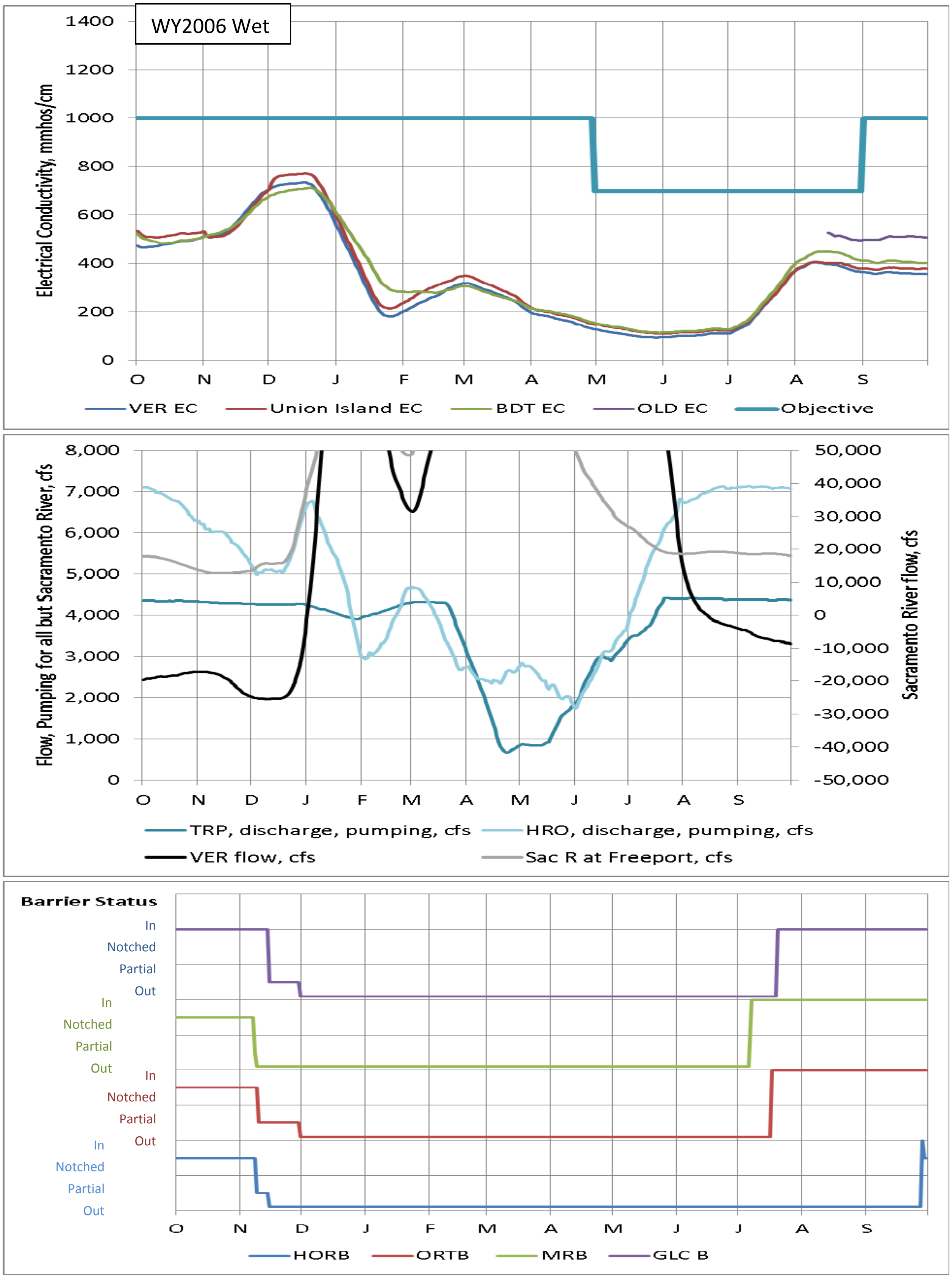

Flow, Pumping for all but Sacramento River, cfs
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
Sacramento River flow, cfs
50,000
40,000
30,000
20,000
10,000
0
-10,000
-20,000
-30,000
-40,000
-50,000
O N D J F M A M J J A S
TRP, discharge, pumping, cfs
HRO, discharge, pumping, cfs
VER flow, cfs
Sac R at Freeport, cfs

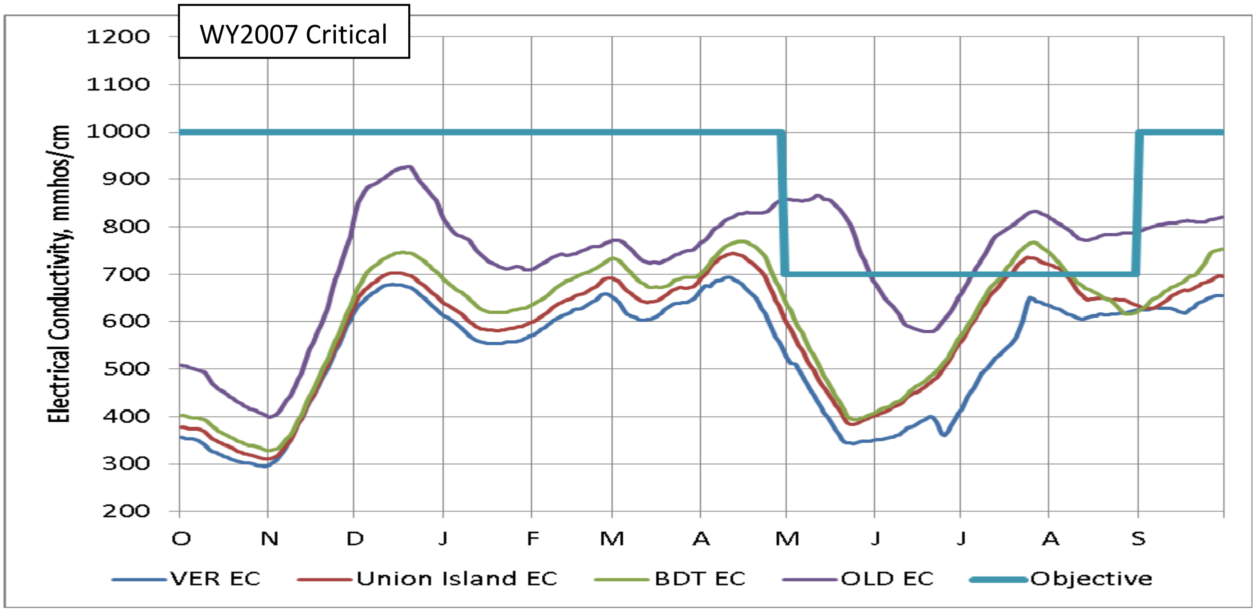

Barrier Status
In
Notched
Partial
Out
In
Notched
Partial
Out
In
Notched
Partial
Out
In
Notched
Partial
Out
O N D J F M A M J J A S
HORB
ORTB
MRB
GLC B

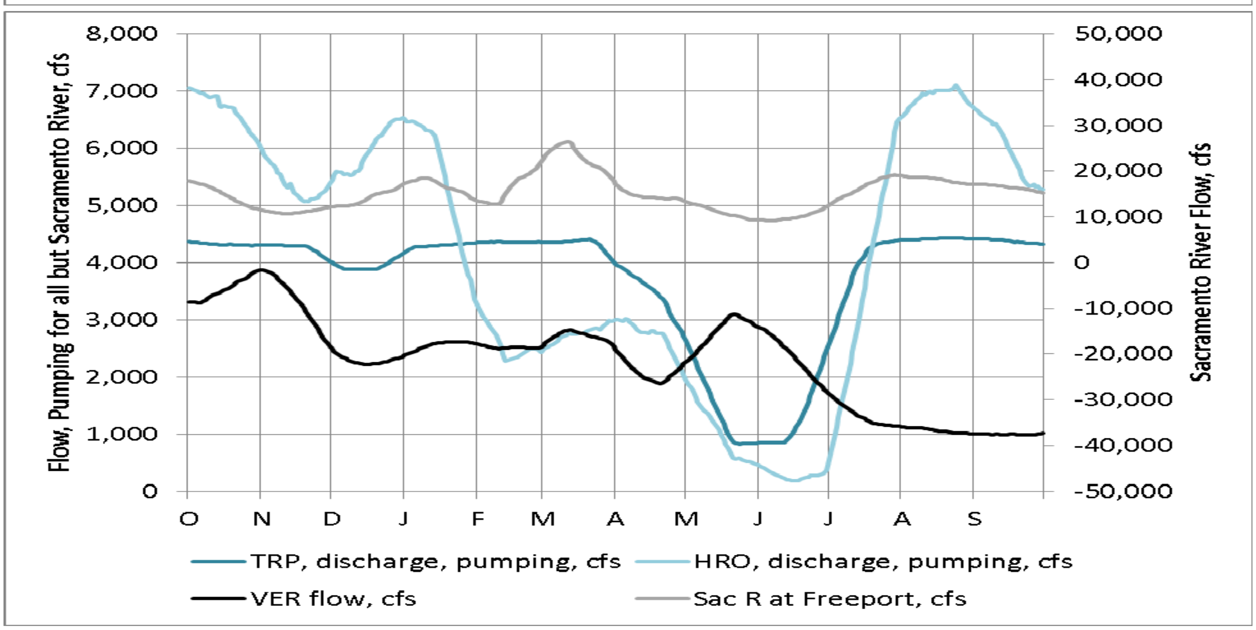

WY2005 Wet
Electrical Conductivity, mmhos/cm
1200
1100
1000
900
800
700
600
500
400
300
200
O N D J F M A M J J A S
VER EC
Union Island EC
BDT EC
OLD EC
Objective

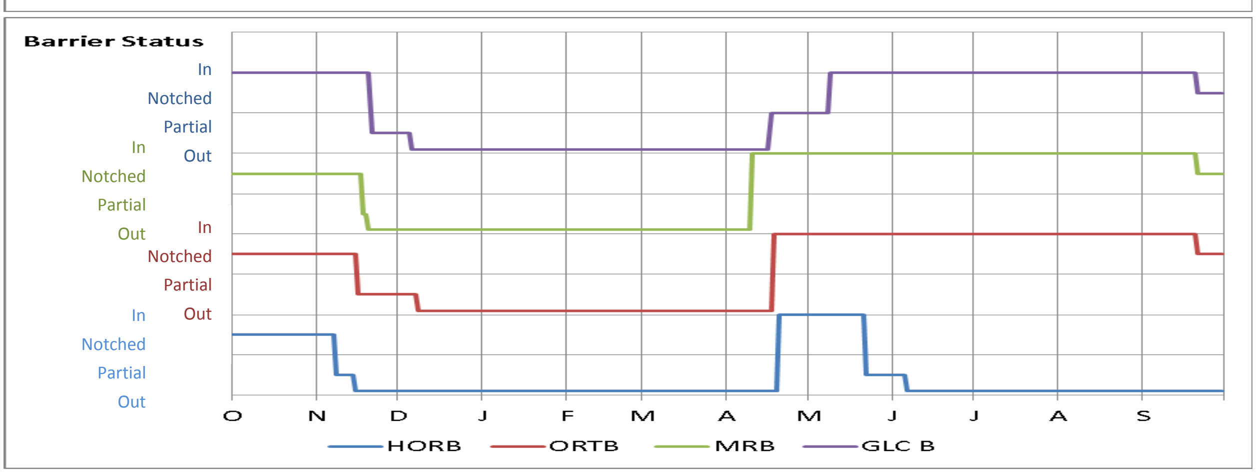

Flow, Pumping for all but Sacramento River, cfs
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
50,000
40,000
30,000
20,000
10,000
0
-10,000
-20,000
-30,000
-40,000
-50,000
Sacramento River flow, cfs
O N D J F M A M J J A S
TRP, discharge, pumping, cfs
HRO, discharge, pumping, cfs
VER flow, cfs
Sac R at Freeport, cfs

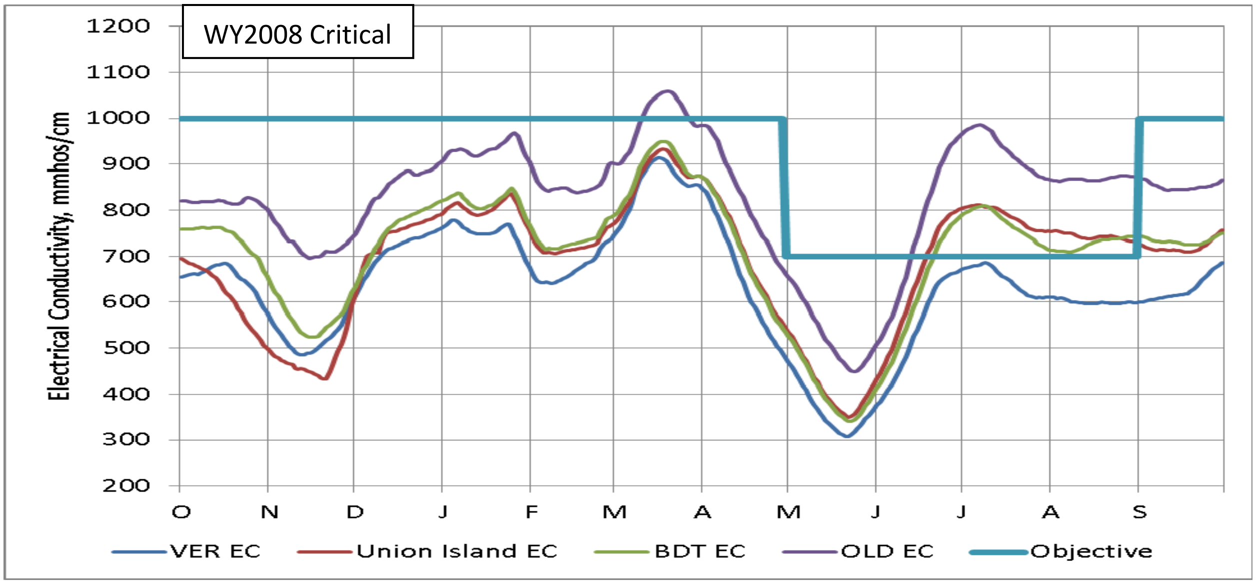

Barrier Status
In
Notched
Partial
In Out
Notched
Partial
Out In
Notched
Partial
In Out
Notched
Partial
Out
O N D J F M A M J J A S
HORB
ORTB
MRB
GLC B

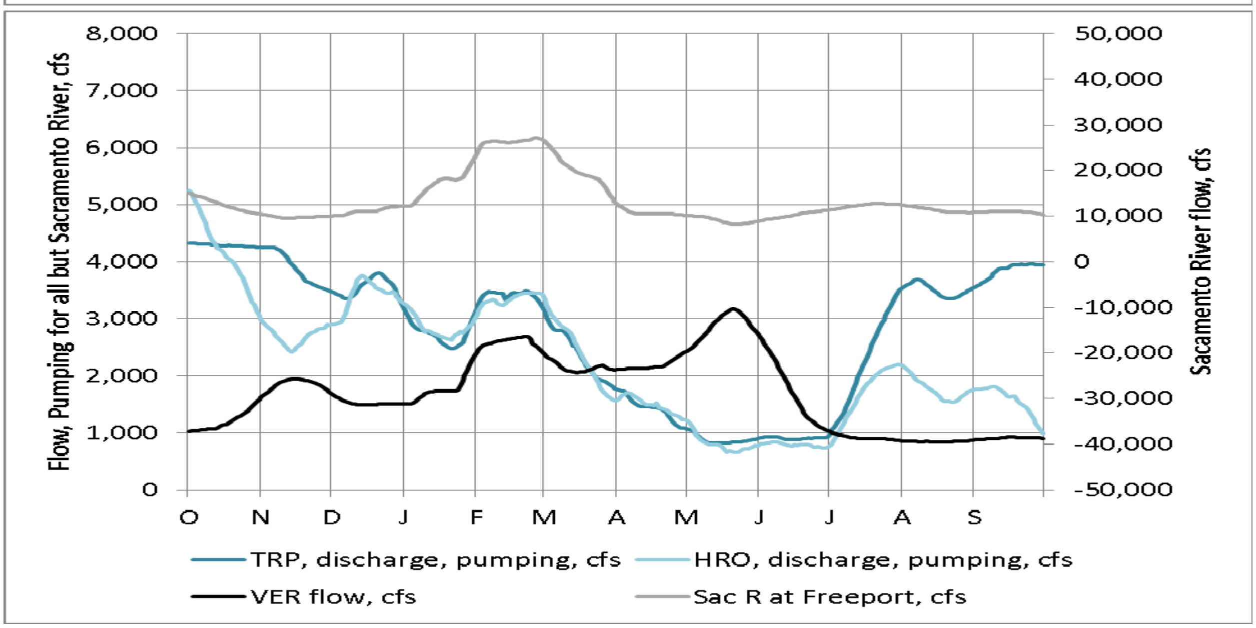

WY2006 Wet
Electrical Conductivity, mmhos/cm
1400
1200
1000
800
600
400
200
0
O N D J F M A M J J A S
VER EC
Union Island EC
BDT EC
OLD EC
Objective
Flow, Pumping for all but Sacramento River, cfs
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
Sacramento River flow, cfs
50,000
40,000
30,000
20,000
10,000
0
-10,000
-20,000
-30,000
-40,000
-50,000
O N D J F M A M J J A S
TRP, discharge, pumping, cfs
HRO, discharge, pumping, cfs
VER flow, cfs
Sac R at Freeport, cfs
Barrier Status
In
Notched
Partial
Out
O N D J F M A M J J A S
HORB
ORTB
MRB
GLC B

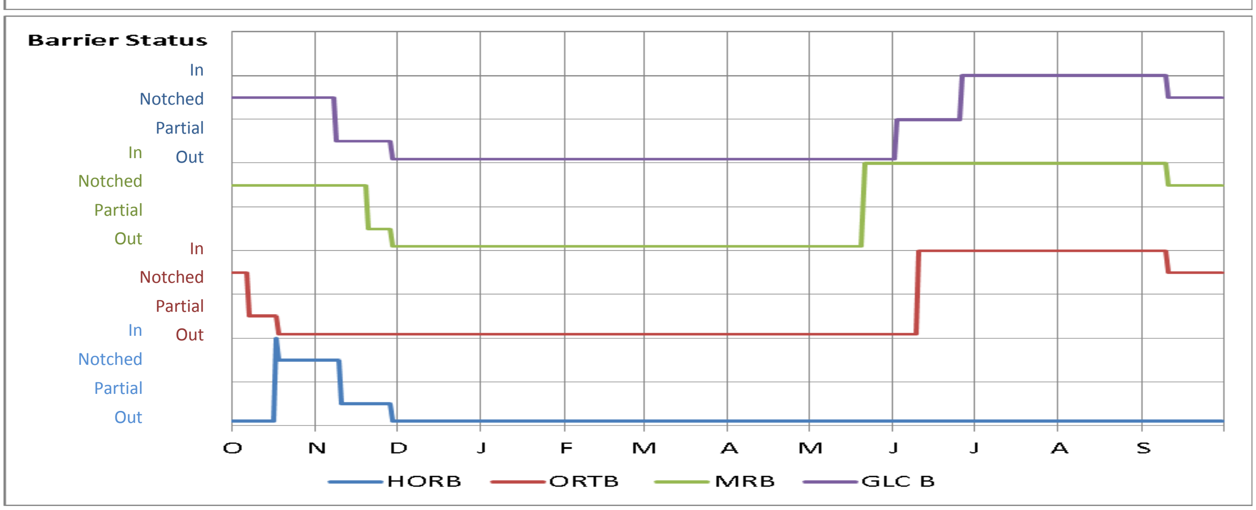

WY2007 Critical
Electrical Conductivity, mmhos/cm
1200
1100
1000
900
800
700
600
500
400
300
200
O N D J F M A M J J A S
VER EC
Union Island EC
BDT EC
OLD EC
Objective

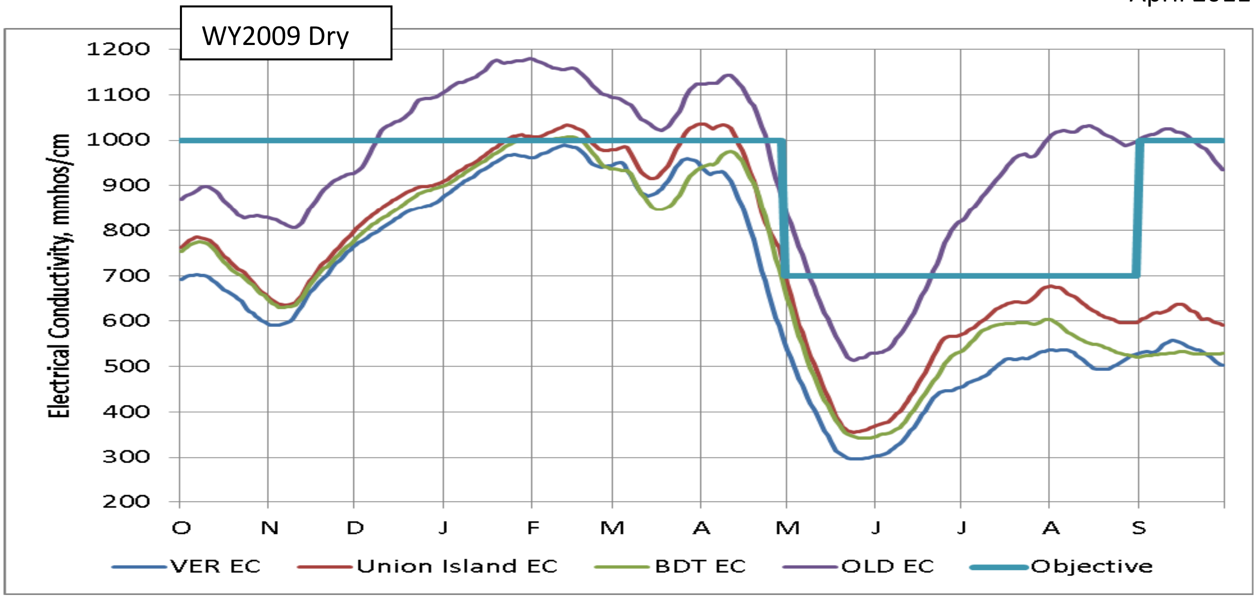

Flow, Pumping for all but Sacramento River, cfs
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
Sacramento River Flow, cfs
50,000
40,000
30,000
20,000
10,000
0
-10,000
-20,000
-30,000
-40,000
-50,000
O N D J F M A M J J A S
TRP, discharge, pumping, cfs
HRO, discharge, pumping, cfs
VER flow, cfs
Sac R at Freeport, cfs

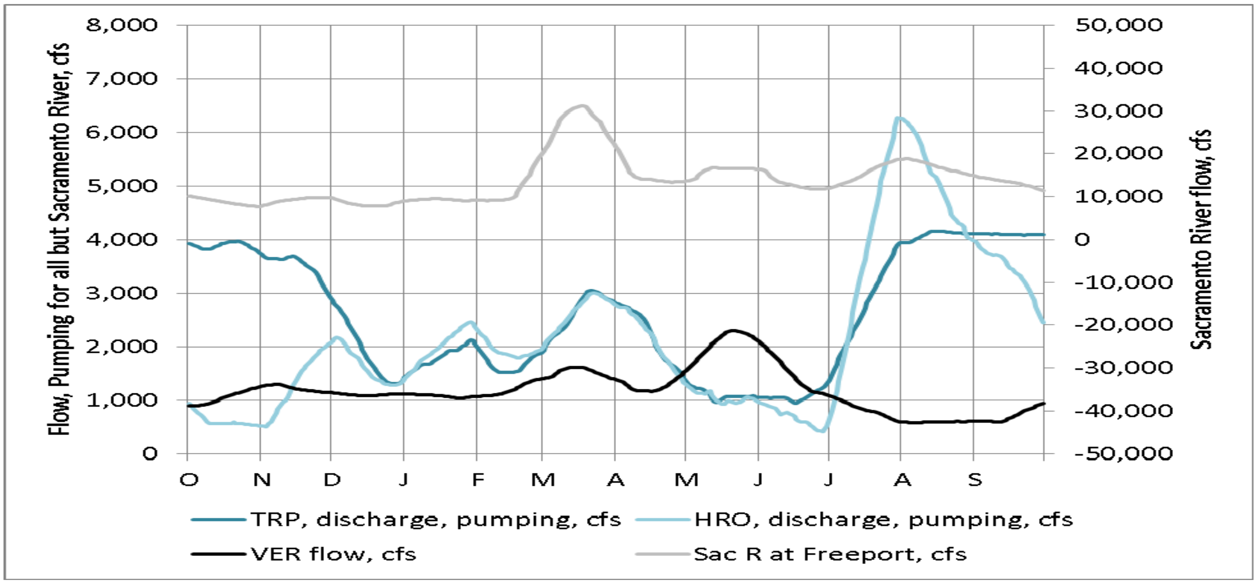

Barrier Status
In
Notched
Partial
Out
In
Notched
Partial
Out
In
Notched
Partial
Out
In
Notched
Partial
Out
O N D J F M A M J J A S
HORB
ORTB
MRB
GLC B

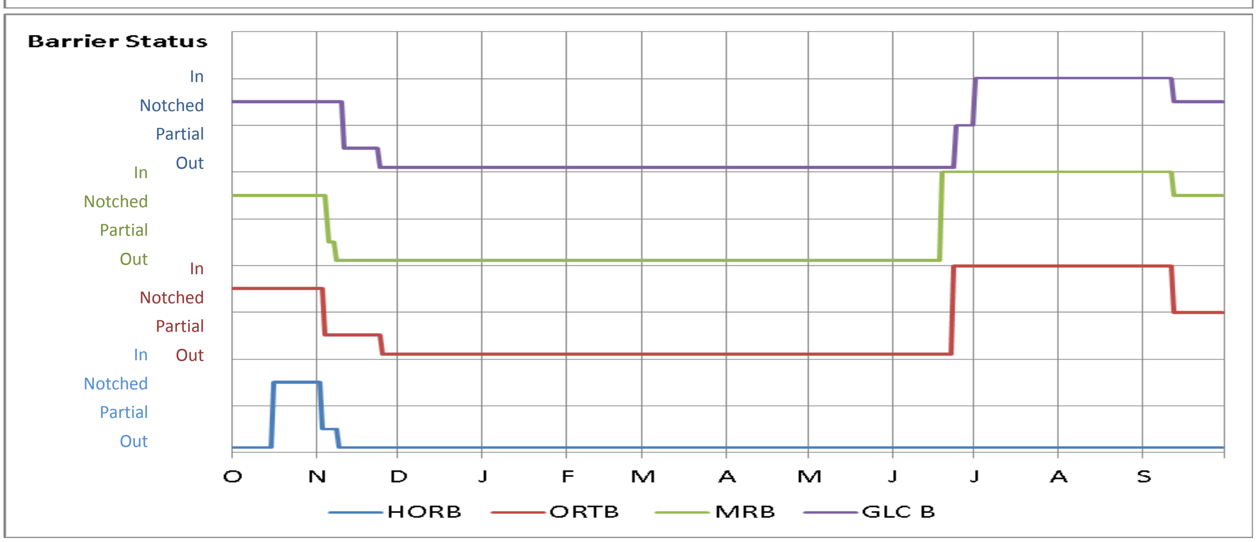

WY2008 Critical
Electrical Conductivity, mmhos/cm
1200
1100
1000
900
800
700
600
500
400
300
200
O N D J F M A M J J A S
VER EC
Union Island EC
BDT EC
OLD EC
Objective

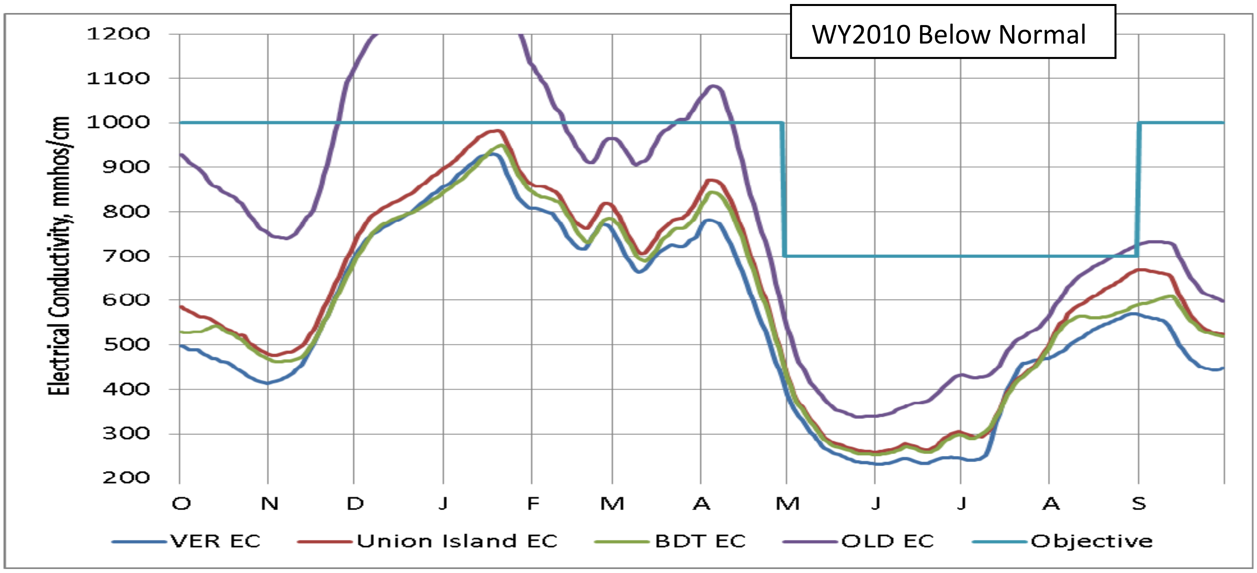

Flow, Pumping for all but Sacramento River, cfs
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
Sacramento River flow, cfs
50,000
40,000
30,000
20,000
10,000
0
-10,000
-20,000
-30,000
-40,000
-50,000
O N D J F M A M J J A S
TRP, discharge, pumping, cfs
HRO, discharge, pumping, cfs
VER flow, cfs
Sac R at Freeport, cfs

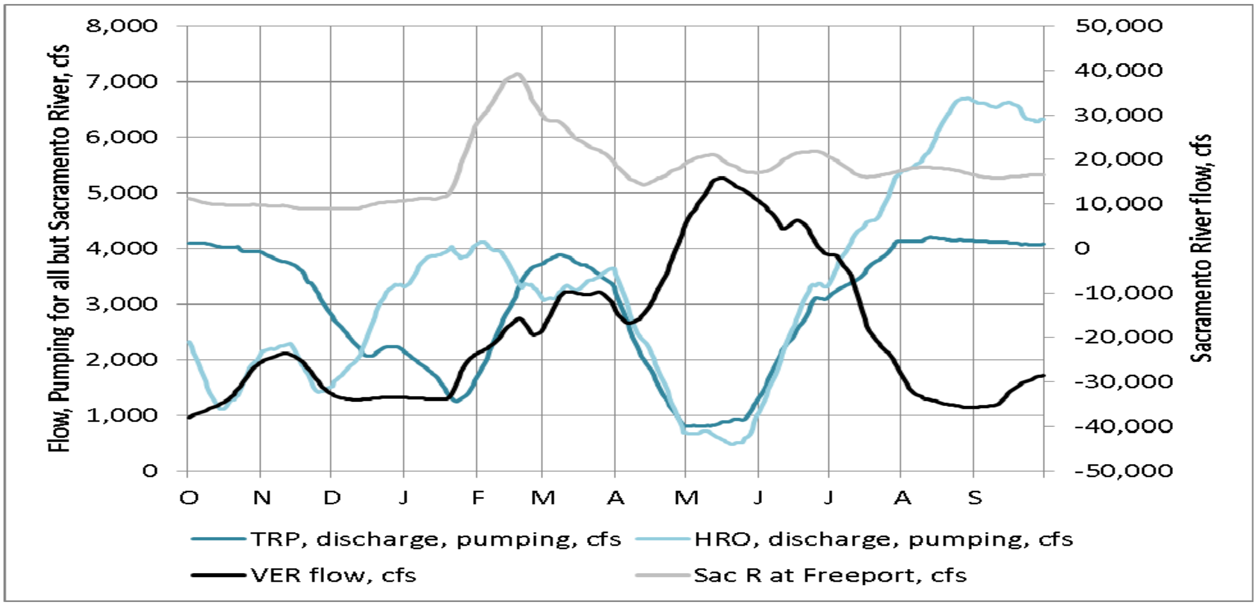

Barrier Status
In
Notched
Partial
Out
In
Notched
Partial
Out
In
Notched
Partial
Out
In
Notched
Partial
Out
O N D J F M A M J J A S
HORB
ORTB
MRB
GLC B

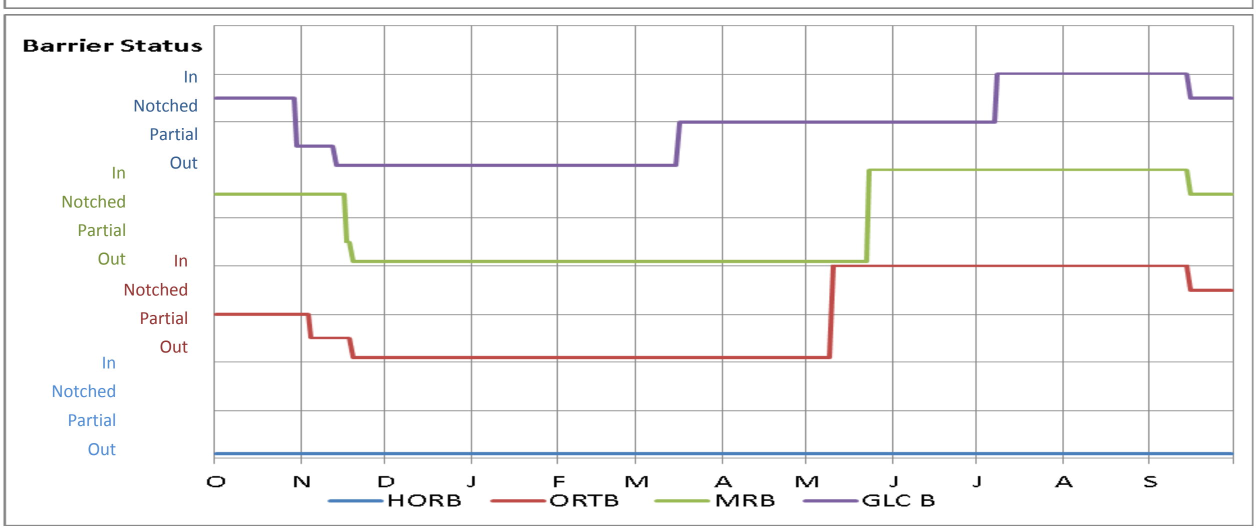

WY2009 Dry
Electrical Conductivity, mmhos/cm
1200
1100
1000
900
800
700
600
500
400
300
200
O N D J F M A M J J A S
VER EC
Union Island EC
BDT EC
OLD EC
Objective


Flow, Pumping for all but Sacramento River, cfs
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
Sacramento River flow, cfs
50,000
40,000
30,000
20,000
10,000
0
-10,000
-20,000
-30,000
-40,000
-50,000
O N D J F M A M J J A S
TRP, discharge, pumping, cfs
HRO, discharge, pumping, cfs
VER flow, cfs
Sac R at Freeport, cfs


Barrier Status
In
Notched
Partial
Out
In
Notched
Partial
Out
In
Notched
Partial
Out
In
Notched
Partial
Out
O N D J F M A M J J A S
HORB
ORTB
MRB
GLC B


WY2010 Below Normal
Electrical Conductivity, mmhos/cm
1200
1100
1000
900
800
700
600
500
400
300
200
O N D J F M A M J J A S
VER EC
Union Island EC
BDT EC
OLD EC
Objective


Flow, Pumping for all but Sacramento River, cfs
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
Sacramento River flow, cfs
50,000
40,000
30,000
20,000
10,000
0
-10,000
-20,000
-30,000
-40,000
-50,000
O N D J F M A M J J A S
TRP, discharge, pumping, cfs
HRO, discharge, pumping, cfs
VER flow, cfs
Sac R at Freeport, cfs


Barrier Status
In
Notched
Partial
Out
In
Notched
Partial
Out
In
Notched
Partial
Out
In
Notched
Partial
Out
O N D J F M A M J J A S
HORB
ORTB
MRB
GLC B