SJR DWSC Flow and RRI DO for 2004[1]

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This report presents the 2004 dissolved oxygen concentrations that have been recorded at the California Department of Water Resources (DWR) Rough and Ready Island (RRI) monitoring station on the San Joaquin River (SJR) Deep Water Ship Channel (DWSC). (see Figure 1.) It also discusses the role of SJR DWSC flow as a cause of DO concentrations below the water quality objective (WQO) and provides information on approaches that can be used to control the DO WQO violations. This report is a supplement to the "Issues Report" (Lee and Jones-Lee, 2000), "Synthesis Report" (Lee and Jones-Lee, 2003a) which covers the studies conducted during the period of 1999 through the winter 2003, and the "Supplement to the Synthesis Report" (Lee and Jones-Lee, 2004a). Lee (2003) and Lee and Jones-Lee (2003b, 2004b,c,d) provide additional information on the low DO water quality problem pertinent to these issues. This report also presents information pertinent to the Lee and Jones-Lee (2004b) comments on the Delta Improvements Package (DIP) and information pertinent to the San Joaquin River Water Quality Management Group's effort to develop an approach to meeting the requirements of the Salt TMDL as they may impact the low DO problem in the DWSC.

In the fall 2004 Lee and Jones-Lee made invited presentations on the SJR DWSC low DO problem and its management at the Society for Environmental Toxicology and Chemistry (SETAC) World Congress held in Portland, OR. The PowerPoint slides from this presentation are available as Lee and Jones-Lee (2004e) at
http://www.members.aol.com/annejlee/LowDOSummaryDec2004.pdf.
They present a summary of the current understanding of the low DO problem, responsible parties, recommended approaches for solving the problem and areas that need additional attention as part of conducting the Phase I TMDL.

Winter 2004 Low-DO Problem

Figure 2 presents the DO concentrations recorded at the DWR RRI monitoring station on the SJR DWSC for the period January through December 2004. The daily changes in DO relate to algal photosynthetic activity in the surface waters, which causes the afternoon DO concentrations to increase; and algal and bacterial respiratory activities, which cause the early morning DO concentrations to decrease. The spikes in the figure relate to DWR staff adjustments of the DO recording equipment and do not reflect actual DO conditions.

Examination of Figure 2 shows that there were several days when the DO at this location was just under the 5 mg/L WQO in January and February 2004. Several daily DO low values of about 4 mg/L occurred. Past studies (see Lee and Jones-Lee, 2003a) have shown that the RRI

[1] Reference as: Lee, G. F., and Jones-Lee, A., "SJR DWSC Flow and RRI DO for 2004," Report of G. Fred Lee & Associates, El Macero, CA, January (2005).

Figure 1
Map of the SJR DWSC and its Watershed

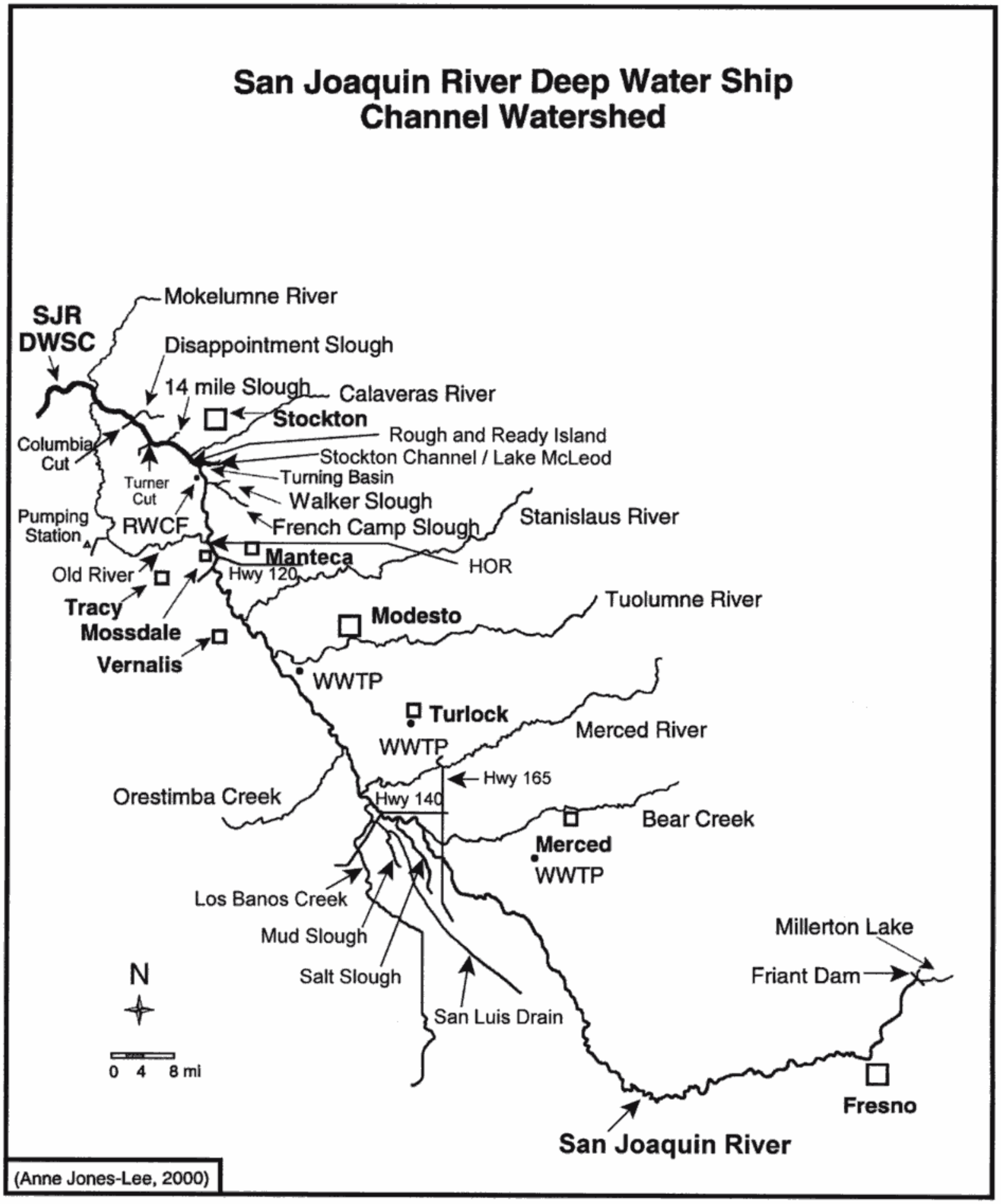
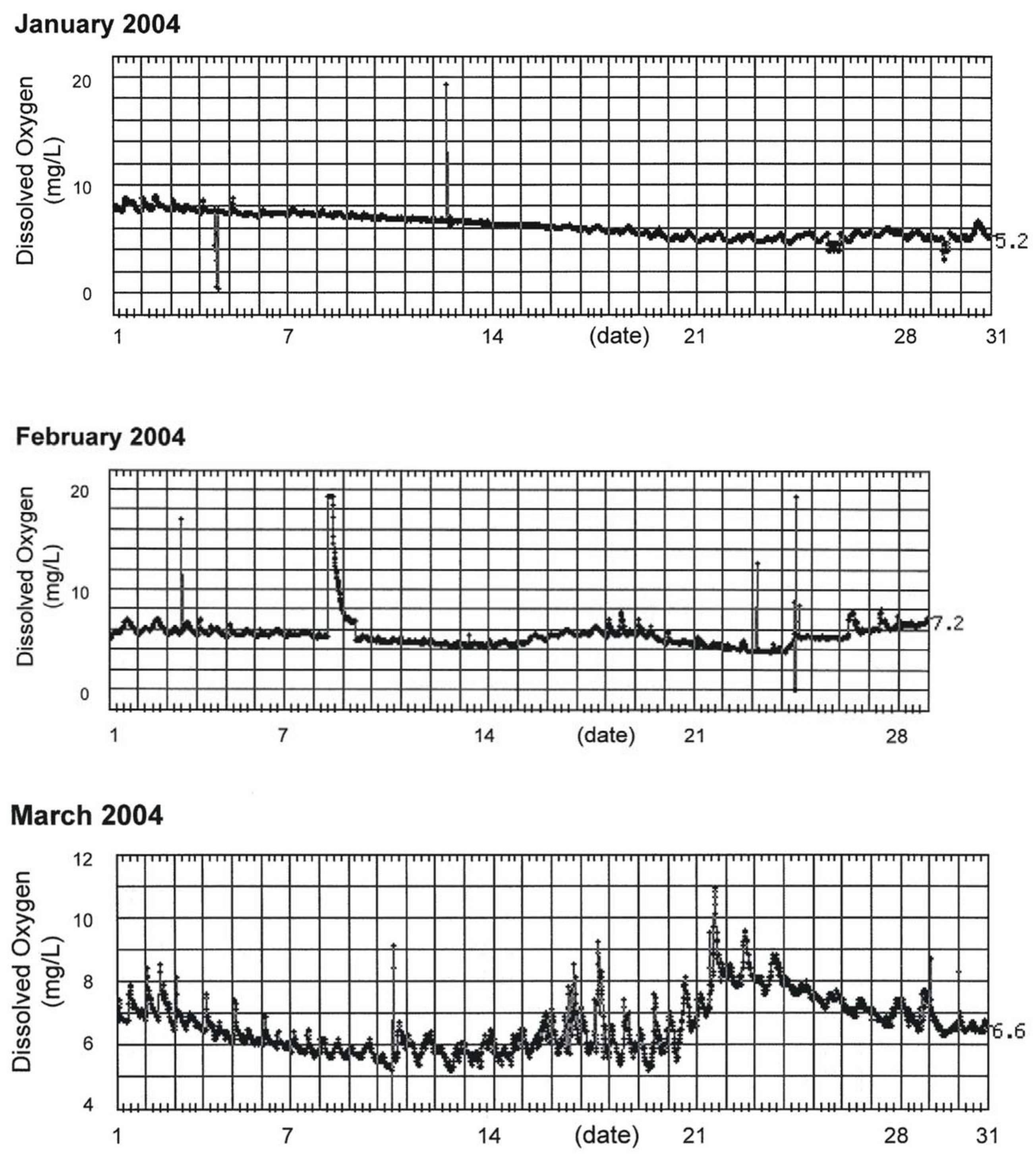


Figure 2
SJR DWSC RRI DO 2004



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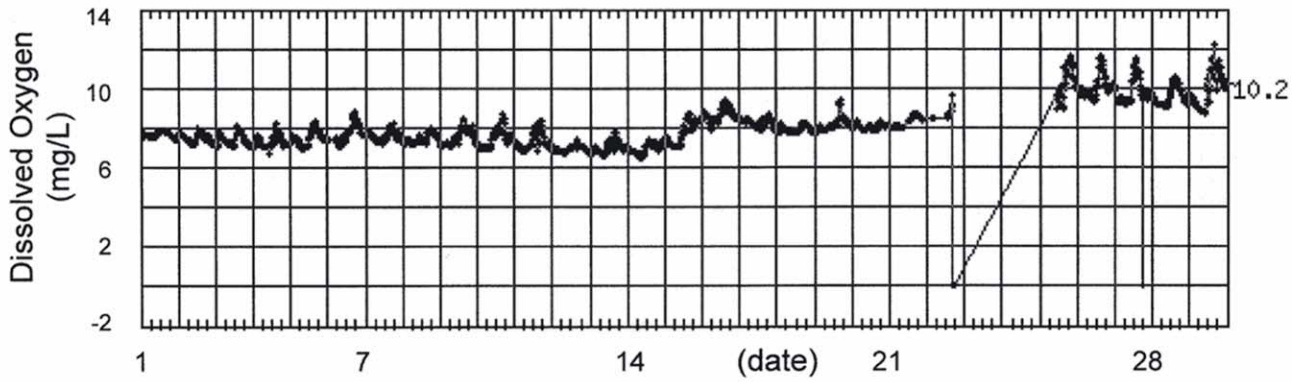

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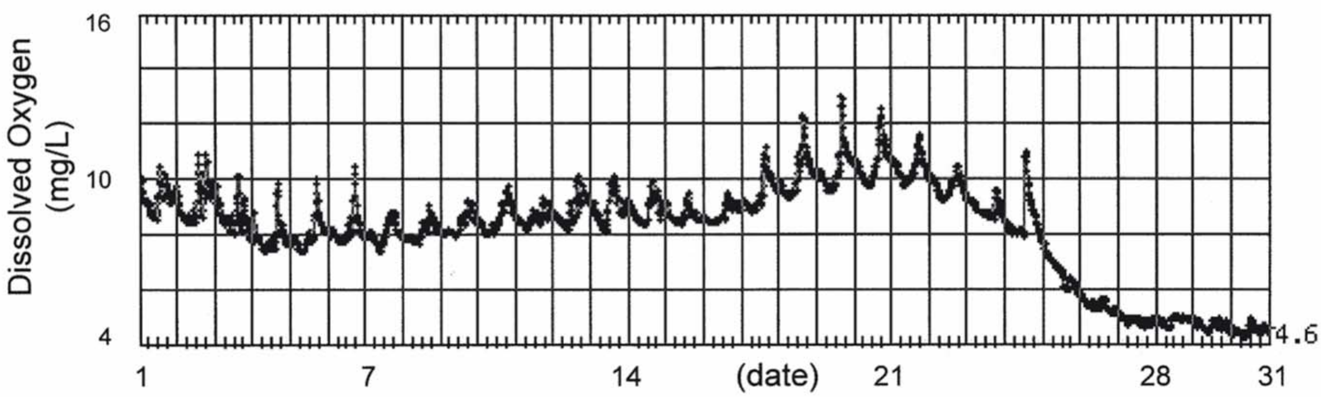

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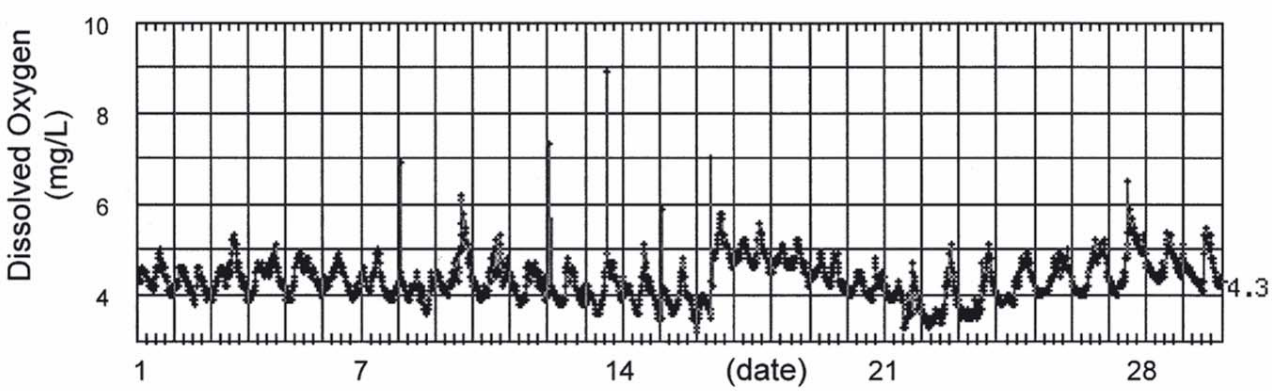

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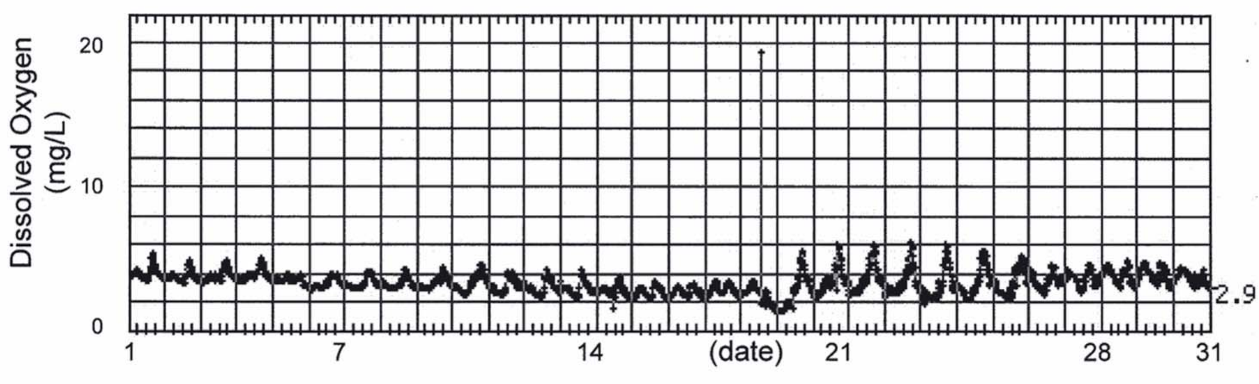

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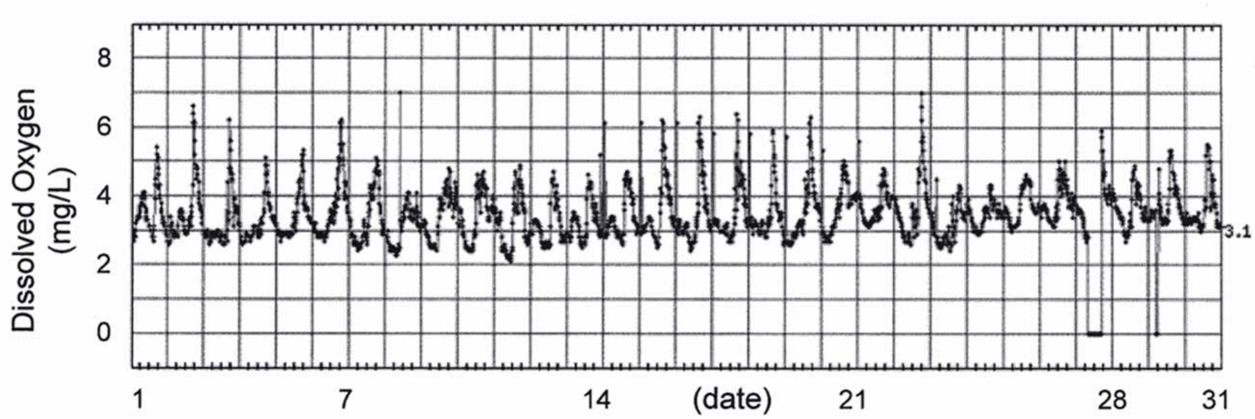

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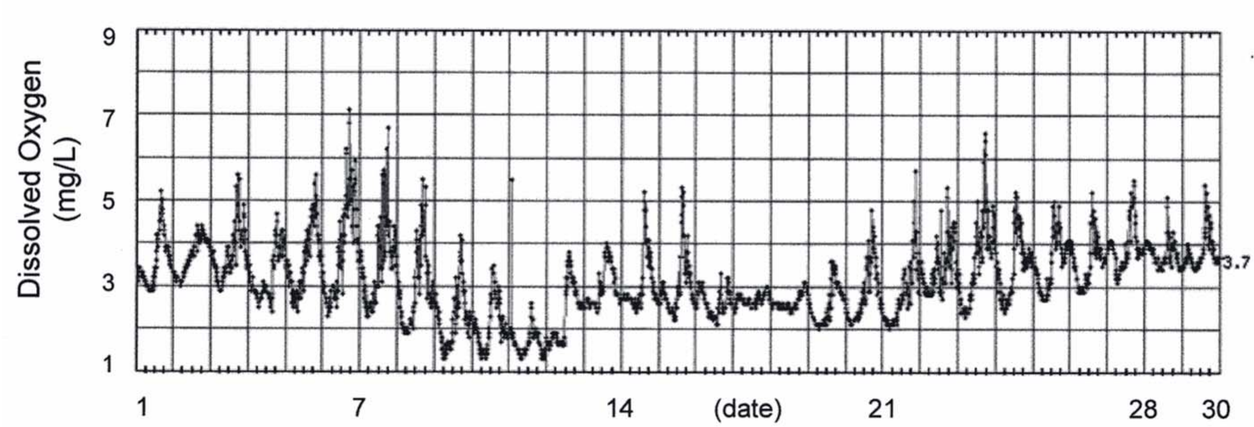

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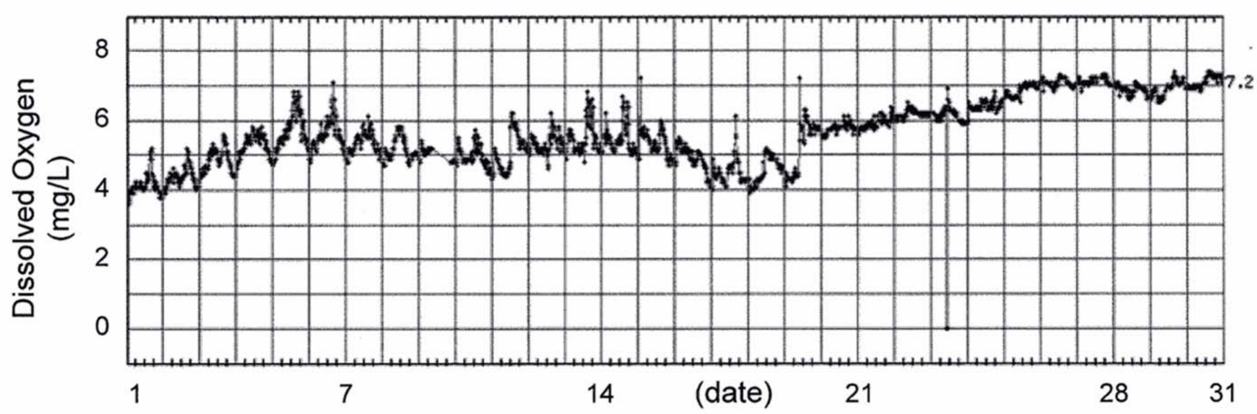

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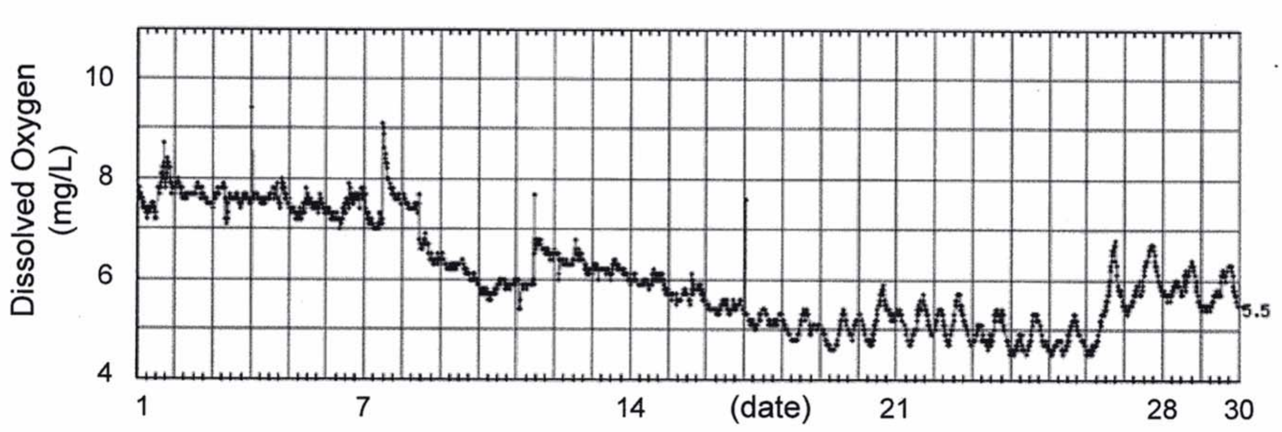
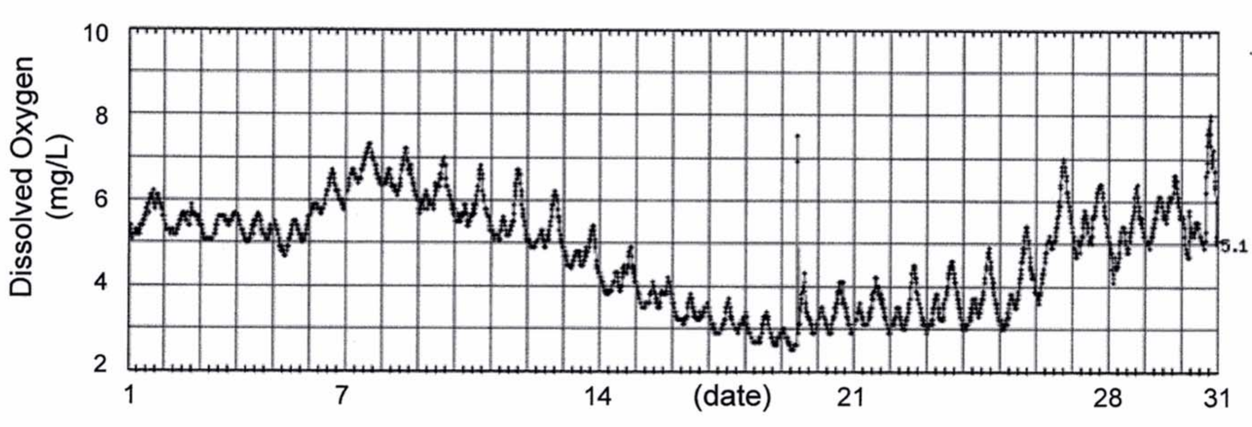


December 2004



monitoring station measures a somewhat integrated DO of the upper part of the water column. The surface waters would have a DO in late afternoon somewhat higher than the RRI recorded value. Further, the DO near the bottom of the DWSC is often about 1 mg/L below the RRI measured value. Also, while not a factor in January and February 2004, during elevated flows of the SJR through the DWSC the location of the low DO minimum is downstream of the RRI near Turner Cut.

The DO WQO violations found in January and February 2004 have also occurred in other years, although the 2004 WQO violations were not as severe as in some years. During 2003 there were several days in February when the DO in the DWSC at RRI was at or near zero. DO concentrations (less than about 3 mg/L) for this period of time would be lethal to many forms of aquatic life. Fish kills occurred in the low-DO period that occurred in February 2003.

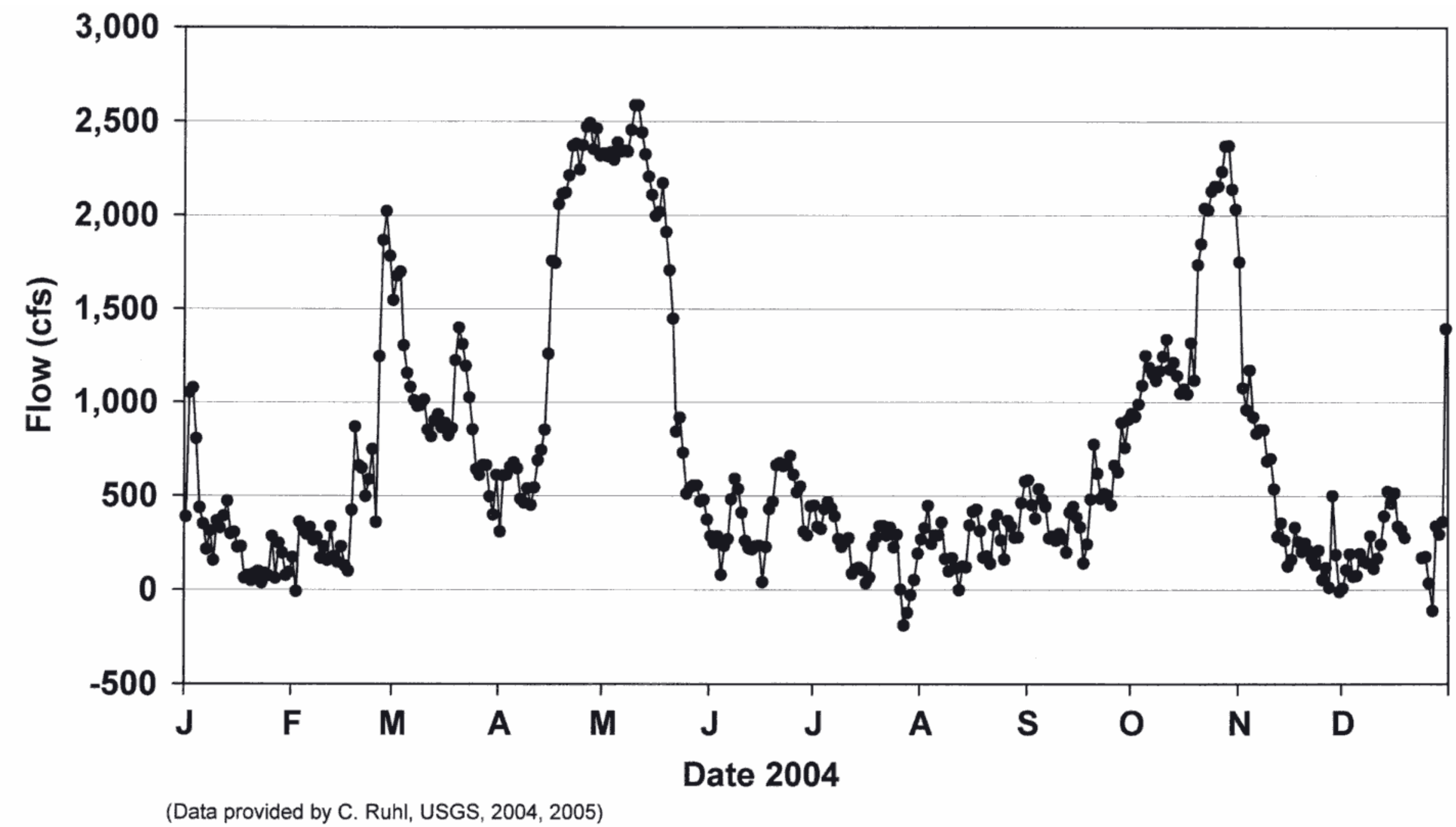
The oxygen demand that leads to DO WQO violations during January and February each year is related to ammonia in the city of Stockton domestic wastewater discharges to the SJR just upstream of the DWSC ("RWCF" in Figure 1). While, during the summer and early fall, the algae that develop in the SJR upstream of the DWSC are a significant source of oxygen demand that leads to DO WQO violations, during the late fall and winter the algae do not develop to a significant extent in the SJR upstream of the DWSC, due to low temperatures/low rates of growth and the shortened period of daylight. This means that there is little or no need to attempt to control nutrients and algae that develop in the SJR DWSC watershed during late fall, winter and spring. The focus of nutrient/algae control should be directed to controlling the nutrients that develop into algae that contribute to the DO WQO violations in the DWSC. This is primarily a summer-fall problem.

Associated with the low-DO events in the DWSC in the winter are low SJR flows through the DWSC. Figure 3 presents the flow of the SJR through the DWSC in 2004. The SJR flow through the DWSC beginning in mid-January 2004 through early February 2004 was, at times, below a few hundred cfs with some values near zero. During this time the SJR Vernalis flow was at least 1,600 cfs. (see http://waterdata.usgs.gov/nwis/dv?dd_cd=04_00060_00003&format=gif&period=365&site_no=11303500).

This means that the federal (Tracy) and state (Banks) Delta export projects were drawing essentially all of the SJR Vernalis water to the export pumps. This is another example of the federal and state export projects' drawing essentially all of the SJR Vernalis water to the pumps, through the Head of Old River (HOR) thereby leaving little SJR flow through the DWSC, which leads to the DO water quality objective violations in the DWSC.

Lee (2003), Lee and Jones-Lee (2003a, 2004a,b) have pointed out that if a large part of the SJR Vernalis flow were allowed to pass through the DWSC before it is drawn to the export pumps, the winter low-DO problems would be greatly reduced and likely eliminated. While this may not be possible with the current Head of Old River (see Figure 1) temporary barrier, since it would require that this HOR barrier be in place (which could aggravate flooding), it would be possible when the permanent barriers are in place in 2007. From the information available (Lee et al., 2004a,b), allowing the majority of the SJR Vernalis water to pass through the DWSC

Figure 3. Tidally Averaged Daily Flow
San Joaquin River near Garwood Bridge, Stockton
2004



before being drawn to the export pumps would not be adverse to the water quality of the exported water or the water in the South Delta channels. As discussed by Lee et al. (2004b) there is need to determine if under certain conditions there could be DO problems in some Central Delta channels

At the CVRWQCB July 8, 2004, hearing on the SJR DO TMDL Basin Plan amendment, the city of Stockton announced that the City has committed to nitrifying its domestic wastewater effluent to achieve a 30-day average ammonia nitrogen concentration of 2 mg/L. This is the concentration that the CVRWQCB has established as the City's domestic wastewater NPDES permitted ammonia discharge. According to R. Murdoch of the City, Stockton will be spending $42 million to nitrify its wastewater effluent, where this treatment should be implemented in about two years. Table 1 presents the city of Stockton domestic wastewater effluent ammonia and other characteristics. The reduction of the City's domestic wastewater ammonia concentrations, which are at times in the mid- to high twenties, to 2 mg/L, coupled with increased SJR flow through the DWSC associated with the operation of the permanent HOR barrier, should essentially/possibly eliminate the winter low-DO problem in the DWSC.

It has been suggested that the winter low-DO problem in the SJR DWSC will not occur in future years when the city of Stockton controls the ammonia discharges to the 2 mg/L monthly average discharge NPDES limit that the CVRWQCB as placed on the cities wastewater discharges. It is important to understand however, that this limit is based on meeting the ammonia concentrations in the lower SJR and upper DWSC that will not lead to violations of the ammonia toxicity water quality criterion established by the US EPA. This limit is based on a monthly average ammonia concentration. With respect to the violations of the DO water quality objective, there can only be one violation of this objective by any magnitude at any location in the DWSC every three years. Violations that occur more frequently will require further control of DO concentrations in the DWSC. Under low flow conditions with the allowed excursions and still maintain the 2 mg/L ammonia monthly average discharge limit, there can be DO depletions below the water quality objective in the DWSC that would require further oxygen demand control beyond that needed if the SJR Vernalis flows were allowed to pass through the DWSC before export pumping.

It will be important that the SJR DWSC flows during all times of the year, including the winter be managed in such a way as to achieve maximum steady flow. There is need for further study to define the minimum flows of the SJR through the DWSC that can be allowed and avoid DO water quality objective violations. For planning purposes, the issue of flow of the SJR through the DWSC should be addressed as a separate issue, not as a secondary issue to salt TMDL flows. The flow needed to meet both of these TMDLs, will need to be addressed by the state Water Resources Control Board as part of the D 1641 water rights hearings where the required flows to optimize solving the salt TMDL and the low DO TMDL to the maximum extent possible through management of SJR and South Delta flows.

There is concern, about the California Bay-Delta Authority (CBDA)/DWR current proposed plan (CBDA, 2004) to initiate increased pumping at the Banks pumping station to 8,500 cfs before the permanent HOR barrier is in place, as part of implementing the proposed Delta Improvements Package (DIP). At the DIP workshops, mention was made by DWR staff that the increased pumping at Banks would occur during the winter. Until the permanent HOR barrier is in place and operated to significantly restrict the amount of SJR Vernalis flow that is drawn into the South Delta at the HOR split, and the city of Stockton wastewater effluent is nitrified to achieve a 30-day average ammonia of 2 mg/L, the implementation of the DIP proposed increased Banks pumping would likely lead to even greater low-DO problems in the DWSC during the winter. Also of concern is whether increasing the Banks export of South Delta water to 8,500 cfs at any time during the year, as part of the interim and full implementation of the DIP, will further aggravate the water quality problems of the type discussed by Lee and Jones-Lee (2004c) caused by the state and federal export projects' pumping of South Delta water to Central and Southern California and the San Francisco Bay region.

Table 1
Characteristics of City of Stockton Domestic Wastewater Effluent

Monthly Averages Effluent						
Month-Yr	Flow (mgd)	CBOD (mg/l)	Ammonia (mg/l)	TKN (mg/l)	Nitrate (mg/l)	Nitrite (mg/l)
May-02	37.34	3.5	2.0	4.3	7.9	0.040
Jun-02	33.00	3.9	2.6	5.0	5.2	0.070
Jul-02	38.49	4.3	2.3	5.0	1.1	0.056
Aug-02	34.48	4.0	10.8	13.9	<0.2	0.060
Sep-02	38.01	4.1	23.9	26.4	<0.2	0.120
Oct-02	33.70	4.0	27.1	30.2	<0.2	0.040
Nov-02	38.08	4.7	27.9	31.6	<0.2	0.040
Dec-02	38.67	3.7	26.6	30.8	0.3	0.060
Jan-03	33.76	4.3	24.9	29.5	0.4	0.090
Feb-03	28.11	7.2	26.3	31.7	0.5	0.110
Mar-03	25.27	5.1	25.9	31.5	<0.2	0.170
Apr-03	27.70	3.4	24.0	28.1	0.5	0.300
May-03	28.20	2.3	26.6	30.0	0.3	0.200
Jun-03	29.34	4.2	11.1	14.3	4.7	1.070
Jul-03	34.18	3.3	3.5	6.3	4.3	0.220
Aug-03	35.10	3.6	3.6	6.3	4.2	0.130
Sep-03	40.10	3.5	3.4	5.8	3.0	<0.100
Oct-03	36.50	3.8	6.7	9.4	4.0	<0.100
Nov-03	37.60	3.9	12.6	14.4	2.6	<0.100
Dec-03	44.70	2.4	17.8	19.8	1.9	<0.100
Jan-04	45.30	5.7	23.6	26.0	0.4	<0.100
Feb-04	40.40	7.8	24.9	28.5	0.2	<0.100
Mar-04	38.90	2.9	15.6	16.5	4.6	0.400
Apr-04	31.90	7.9	12.9	18.5	3.5	0.200
May-04	33.10	8.1	14.2	17.8	3.5	0.250
Jun-04	29.60	7.9	13.5	16.7	2.9	0.200
Jul-04	31.70	9.8	10.1	13.3	1.0	0.150
Aug-04	32.20	9.5	11.3	16.5	0.6	0.100
Sep-04	31.60	9.3	13.2	18.0	0.8	0.230
Oct-04	27.60	8.5	15.3	18.1	1.6	0.570
Nov 04	28.10	7.1	19.3	20.1	1,3	0.130

Provided by G. Lockwood, CVRWQCB

Late Spring/Summer 2004 Low-DO Problem

Examination of Figure 2 shows that beginning in late May 2004, the RRI DO decreased to less than the WQO of 5 mg/L. Some of the June and July DO concentrations recorded at RRI are at or below 3 mg/L, which would be lethal to some forms of fish and other aquatic life. It should be understood that low DO can be lethal to fish, especially larval fish, without the appearance of a "fish kill," in which large numbers of dead fish are floating in the waterbody.

Figure 3 shows that the decrease in DO below the WQO occurred when the flows of the SJR through the DWSC decreased from the Vernalis Adaptive Management Program (VAMP) elevated flows. As discussed by Lee and Jones-Lee (2004a), a recurring pattern of low DO occurs in the DWSC in late May to early June following the termination of the VAMP flows, the removal of the HOR barrier, and the resumption of elevated state and federal export projects' pumping of South Delta water at Tracy and Banks. Also during this time, South Delta agricultural irrigation draws SJR Vernalis water into the South Delta. During the VAMP elevated flow period from early March to mid-May 2004, the SJR Vernalis flow was in general over 3,000 cfs. By early July 2004, the SJR Vernalis flow was decreased to about 1,200 cfs. During the 2004 VAMP, the state and federal water projects were projected to maintain an average pumping rate of 1,500 cfs (SJRGA, 2004). By mid-July 2004 the total projects' export pumping was over 11,000 cfs.

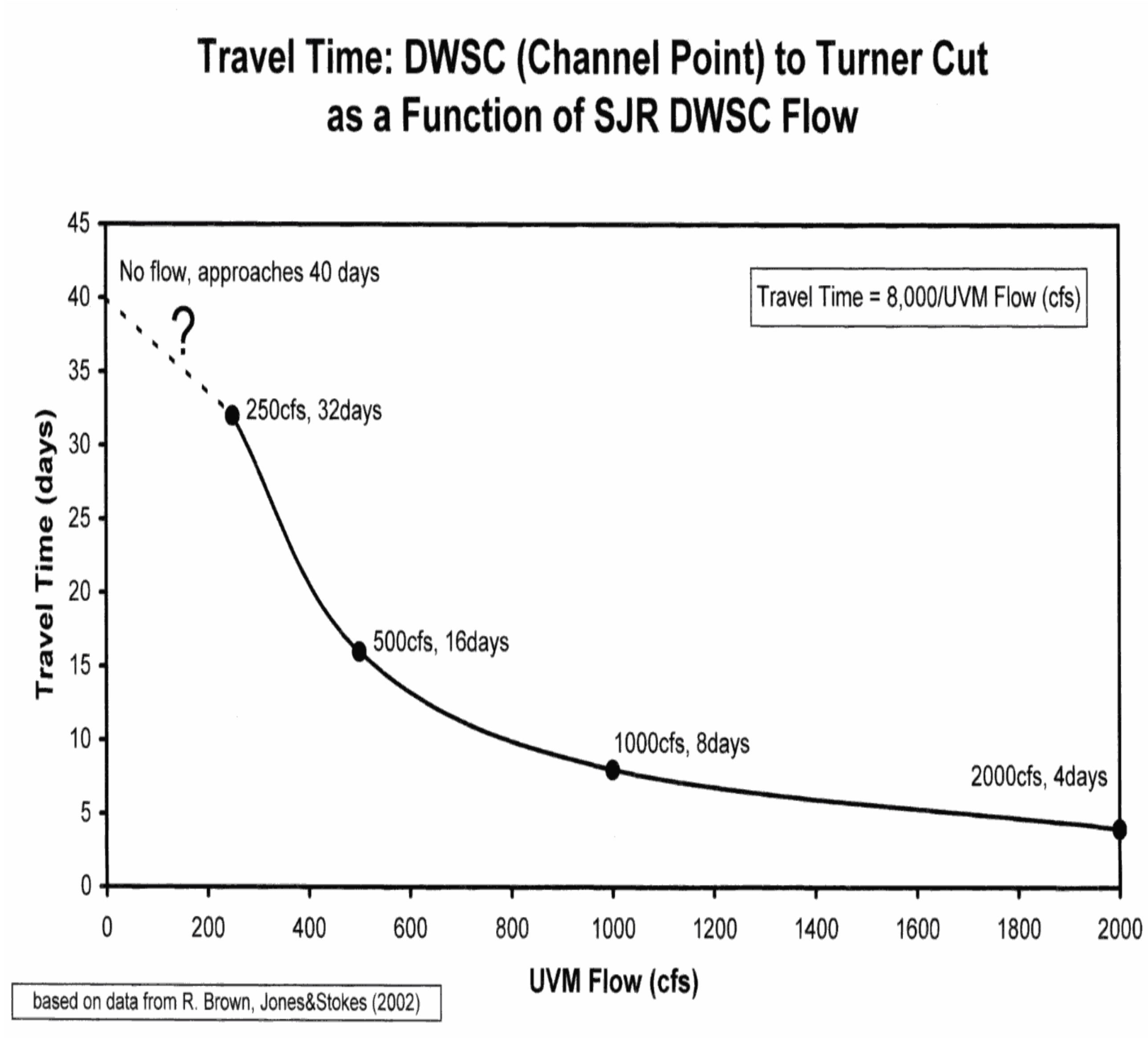
Figure 2 shows that the DO WQO violations which started in early June 2004 persisted through late October, 2004. Examination of Figure 3 shows that the SJR DWSC flows during this period were typically less than a few hundred cfs with many of the flows near zero and several were negative (upstream). During this period, the SJR Vernalis flows were typically greater than a 1,000 cfs with the exception of one short period during mid August where the SJR Vernalis flow decreased to 900 cfs for one to two days. Again, as has been observed, there has been consistent pattern over the past 10 years where the export projects drawing most of the SJR Vernalis water into the South Delta created the situation in the DWSC where the city of Stockton wastewater effluent ammonia and other oxygen demand constituents from the city and other sources remain in the critical reach (Channel Point to Turner Cut) of the DWSC for long periods of time.

Figure 4 from the Synthesis report shows how the travel time in the DWSC between Channel Point/Port of Stockton and Turner Cut varies with SJR DWSC flows. With SJR DWSC flows greater than about 1,000 cfs, the oxygen demand that enters the DWSC near Channel Point would be transported to Turner Cut where it is mixed with Sacramento River water in less than a week. Under these flow conditions much of the oxygen demand added to the DWSC is transported through the critical reach without exerting the oxygen demand. However, with SJR DWSC flows of a hundred or so cfs, the travel time (period of time for oxygen demand exertion in the DWSC) approaches a month. It is for this reason that it is essential to keep the SJR DWSC flows at least 1,500 cfs. Failure to do so will mean that the stakeholders responsible for funding the correction of the low DO problem will be spending funds for DO WQO violation control beyond that needed to solve the low DO problem in the most cost effective manner.

Fall/Winter 2004 DO Problem

During late October through mid-November 2004, when the SJR flows through the DWSC were at least 1,000 cfs, there were no DO WQO violations of the 6 mg/L WQO. However, in mid November when again the export project pumps were sucking most of the 1,500 cfs or more of SJR Vernalis water into the South Delta, DO WQO violations occurred again with some DO concentrations at the RRI monitoring station sufficiently low to be lethal to some fish and other aquatic life.

Figure 4



UVM flow is the SJR DWSC flow

Implications for Managing the DWSC Low-DO Problem

The 2004 low-DO problem that occurred in the DWSC was the same as in previous years, with DO concentrations below the WQO during the winter, summer and fall associated with the state and federal export projects' drawing essentially all of the SJR Vernalis water into the South Delta at the Head of Old River. During the summer, South Delta irrigation also contributes to the diversion of SJR Vernalis water into the South Delta. These diversions, coupled with the city of Stockton's discharging elevated ammonia to the SJR just upstream of the DWSC, leads to DO concentrations in the DWSC below the WQO. The interim implementation of the increased pumping at Banks, as originally proposed in the DIP, will lead to even greater low-DO problems in the DWSC than have existed in recent years. At the January 12, 2005 meeting of the CBDA Water Supply Subcommittee R. Ott of CBDA presented a review of the current status of the DIP. Included in this presentation was a schedule of planned implementation of various components of the DIP. The handout provided by Ott included,

"*Transitional implementation of 8,500 cfs, dredging/diversion improvements, 2006-7.*"
"Complete Construction of permanent operable barriers by December 2007."
"Fully operate under 8,500 cfs by January 1, 2008."

It was indicated by a person in the audience at the Subcommittee meeting that the current Banks operation would remain the same as it has been in recent years, i.e., no interim increase in pumping to 8,500 cfs until the permanent operable barriers are in place. If this approach is followed and the permanent barriers are operated to keep essentially all of the SJR Vernalis flow to pass through the DWSC, the cost of controlling the low DO problem in the DWSC can be reduced.

The winter, summer, and fall oxygen demand exertion in the DWSC can, to a considerable extent, be controlled through increased flow of the SJR through the DWSC, thereby reducing the travel time of oxygen demand in the critical reach of the DWSC and exporting the algae into the Central Delta, where, from the information available (Lee et al., 2004b), it does not appear to cause water quality problems. In fact, the algae that are exported into the Central Delta from SJR DWSC upstream sources, as well as those that develop in the DWSC, could help support the food web in the Central Delta. Any oxygen demand that is exerted in the DWSC that causes DO WQO violations that cannot be controlled through increased flow of the SJR through the DWSC, and through Mud and Salt Slough headwaters nutrient/algae control, can be alleviated through aeration. As discussed by Lee and Jones-Lee (2004d), there is need for studies of these issues as part of conducting the Phase I TMDL.

A key component of the Salt TMDL and the DIP should be increased flow of the SJR Vernalis water through the DWSC. Based on the current information, a substantial increase in SJR DWSC flow to on the order of at least 1,500 cfs (when SJR Vernalis water is available), can be accomplished without significant adverse impact to stakeholders. An immediate review of this issue should be conducted, with full stakeholder input, in order to define any issues that will need study during the Phase I TMDL. Of particular concern is the potential for secondary biological impacts associated with flow, nutrient control, aeration, etc.

Aeration of the DWSC can be implemented to control DO WQO violations in the DWSC. As part of implementing the Phase I TMDL, it will be important to change the current CVRWQCB DO WQO to allow averaging of the diel DO concentrations and to allow low DO near the bottom of the DWSC, without causing WQO violations. This approach is allowed by the US EPA and has been adopted by a number of states. Failure to make this change in the DO

WQO will likely significantly increase the cost of nutrient/algae control and aeration to eliminate DO WQO violations that occur at any time and location.

Lee and Jones-Lee (2004c) have developed a comprehensive review of the current water quality problems in the Delta as evidence by existing TMDLs. As they discuss, several of these TMDLs are impacted by the state and federal South Delta export projects. Lee and Jones-Lee (2005) discuss the need to address these issues by the CVRWQCB as part of DO and Salt TMDLs and by the SWRCB as part of its D 1641 water rights review. Included within this review should be consideration of the requirements imposed by the U.S. Congress (2004) passage of HR 2828 Water Supply Reliability and Environmental Improvement Act. HR 2828, states,

"*D) PROGRAM TO MEET STANDARDS-*

> *(i) IN GENERAL- Prior to increasing export limits from the Delta for the purposes of conveying water to south-of-Delta Central Valley Project contractors or increasing deliveries through an intertie, the Secretary shall, not later than 1 year after the date of enactment of this Act, in consultation with the Governor, develop and initiate implementation of a program to meet all existing water quality standards and objectives for which the Central Valley Project has responsibility.*"

Lee and Jones-Lee (2004c) have discussed how the export projects are impacting WQO violations in the Delta. There is need to begin to address these issues as part of any further water diversions/flow manipulation in the Delta and its tributaries.

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