Issues in Controlling the Residual Oxygen Demand in the SJR DWSC That Leads to DO WQO Violations

G. Fred Lee, PhD, PE, BCEE, F.ASCE and Anne Jones-Lee, PhD
G. Fred Lee & Associates
El Macero, California
gfredlee@aol.com www.gfredlee.com
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Introduction

The San Joaquin River (SJR) Deep Water Ship Channel (DWSC) near Stockton, CA has, for decades, experienced low dissolved oxygen (DO) conditions that result in violations of the state water quality objective (WQO) for DO and adversely affect aquatic life in the area. The Central Valley Regional Water Quality Control Board (CVRWQCB) has adopted a TMDL to control the DO WQO violations. Through a $2-million, two-year CALFED-sponsored study of the low-DO problem in the DWSC in the early 2000s it was found that the primary sources of oxygen demand in the SJR DWSC at that time were ammonia discharged in the city of Stockton's domestic wastewaters and the algae that develop in the SJR upstream of the DWSC. As PIs for that study, Lee and Jones-Lee developed a synthesis report and report supplement that discuss the studies and findings:

Lee. G. F., and Jones-Lee, A., "Synthesis and Discussion of Findings on the Causes and Factors Influencing Low DO in the San Joaquin River Deep Water Ship Channel near Stockton, CA: Including 2002 Data," Report Submitted to SJR DO TMDL Steering Committee/Technical Advisory Committee and CALFED Bay-Delta Program, G. Fred Lee & Associates, El Macero, CA, March (2003).
http://www.gfredlee.com/SJR-Delta/SynthesisRpt3-21-03.pdf

Lee, G. F. and Jones-Lee, A., "Supplement to Synthesis Report on the Low-DO Problem in the SJR DWSC," Report of G. Fred Lee & Associates, El Macero, CA, June (2004).
http://www.gfredlee.com/SJR-Delta/SynthRptSupp.pdf

Additional information on factors impacting the low dissolved oxygen problem in the DWSC is available on the authors' website [www.gfredlee.com] in the Watersheds Studies section, San Joaquin River Watershed Program-Delta subsection at http://www.gfredlee.com/psjriv2.htm.

The implementation of nitrification treatment of the city of Stockton's domestic wastewaters in 2007 greatly reduced the occurrence and magnitude of violations of the water quality objective for DO in the DWSC. However because that measure has not eliminated DO WQO violations, there may be need to also control some of the algae-related oxygen demand in the DWSC that causes DO depletion below the WQO.

According to C. Foe's "Strawman" analysis (summarized by Lee and Jones-Lee, 2003, 2004), the primary source of the "seed" algae that lead to the high algae-associated oxygen demand that enters the DWSC is the algal growth that occurs in Mud and Salt Sloughs in the Grasslands Bypass area. Subsequent studies confirmed the role of Mud and Salt Sloughs in providing seed

algae that lead to a significant oxygen demand in the DWSC. Information on these studies is available in the report:

> Stringfellow, W., Herr, J., Litton, J.G., Brunell, M., Borglin, M.S., Hanlon, J., Chen, C., Graham, J., Burks, R., Dahlgren, R., Kendall, C., Brown, R., and Quinn, N., "Investigation of river eutrophication as part of a low dissolved oxygen total maximum daily load implementation" Water Science & Technology WST 59.1 (2009) http://www1.pacific.edu/eng/EERP/Pubs/2009_Stringfellow%20et%20al._Water-ci_Technol.pdf

Background information on the CVRWQCB's review and actions is available on the San Joaquin River Dissolved Oxygen TMDL website:
http://www.swrcb.ca.gov/centralvalley/water_issues/tmdl/central_valley_projects/san_joaquin_oxygen/index.shtml

Aeration of the SJR DWSC to Reduce DO WQO Violations

The CVRWQCB has been evaluating the efficacy of aeration of the DWSC channel as a means of eliminating, or at least reducing, the magnitude of DO deletion below the WQO. The California Department of Water Resources (DWR) conducted a pilot study of such aeration, the final report for which is available in a series of reports on the SJR Technical Work Group website at
[http://www.sjrdotmdl.org/aeration.htm/]. The DWR and the ICI/Brown reports show that while aeration can significantly reduce the occurrence and magnitude of DO depletion below the WQO in the DWSC at a cost of $2,400 to 2,500 per day of operation, it will not prevent violation of the DO WQO in the DWSC as long as the regulations forbid any violation of the DO WQO by any amount at any time.

The ICI/Brown report, cited below, provides important information on potential approaches for use of aeration in the SJR DWSC TMDL DO implementation.

> Brown, R., "Possible SJR DO TMDL Implementation Procedures," Prepared for California Department of Water Resources, ICF International Sacramento, CA, December (2010) http://www.sjrdotmdl.org/library_folder/01-11/Appendix-A.pdf

In the introduction to that report Brown stated, "*This appendix supplements the Stockton Deep Water Ship Channel Demonstration Dissolved Oxygen Aeration Facility Project Final Report prepared by ICF International. It provides information about a possible scenario of how the Demonstration Aeration Facility (Aeration Facility) could be operated in the future as part of the San Joaquin River (SJR) Dissolved Oxygen (DO) Total Maximum Daily Load (TMDL) implementation program.*"

As discussed in the Lee and Jones-Lee (2003) synthesis report (referenced above) there are numerous issues that the CVRWQCB should evaluate before finalizing the SJR DWSC low-DO TMDL that is intended to eliminate the WQO DO violations in the DWSC. In their more recent report cited below, Lee and Jones-Lee (2010) provide an updated discussion of a variety of issues that need to be evaluated in developing the implementation plan for eliminating the DO WQO violations in the SJR DWSC.

> Lee, G. F., and Jones-Lee, A., "Issues in Controlling the Residual Oxygen Demand in the

SJR DWSC That Leads to DO WQO Violations," Report of G. Fred Lee & Associates, El Macero, CA, November 3 (2010) updated February (2011). http://www.gfredlee.com/SJR-Delta/Residual-Ox-Demand-DWSC.pdf

A set of PowerPoint slides summarizing that report is available as:

Lee, G. F., Jones-Lee, A., "Issues in Controlling Residual Oxygen Demand in SJR DWSC That Leads to Violations of DO WQO," PowerPoint slides, G. Fred Lee & Associates, El Macero, CA, February (2011). http://www.gfredlee.com/SJR-Delta/Issues-Ox-Demand-DWSC-Ppt.pdf

A summary of several of these potential TMDL implementation is presented below/

Controlling Phosphorus Impacts on Excessive Fertilization

Dr. G. Fred Lee has spent more than five decades investigating and developing control programs for excessively fertile waterbodies such as the SJR and DWSC. Lee and Jones-Lee developed a comprehensive report for the CVRWQCB on controlling pollutants, including phosphorus, in agricultural discharges, that was made available as:

Lee, G. F. and Jones-Lee, A., "Review of Management Practices for Controlling the Water Quality Impacts of Potential Pollutants in Irrigated Agriculture Stormwater Runoff and Tailwater Discharges," California Water Institute Report TP 02-05 to California Water Resources Control Board/Central Valley Regional Water Quality Control Board, 128 pp, California State University Fresno, Fresno, CA, December (2002). http://www.gfredlee.com/SurfaceWQ/BMP_Rpt.pdf

Included in that report was a discussion of the use of alum (aluminum sulfate) for binding algal-available phosphorus into unavailable forms, as part of domestic wastewater treatment for reducing P loads to waterbodies. Lee has also conducted studies on treating waterbodies with alum to control phosphorus and thereby control algal growth in the waterbody. This is a well-proven technology that can be effective at some locations/situations in controlling excessive growths of planktonic algae.

In their Synthesis Report Lee and Jones-Lee indicated that it may be possible to reduce the amount of "seed" algae that develops in Mud and Salt Sloughs by controlling algal-available phosphorus (largely soluble ortho P) discharged by agricultural sources in the Mud and Salt Slough watersheds. They proposed the conduct of studies to evaluate the potential efficacy and reliability of treating those agricultural discharges with alum to convert the algal-available phosphorus to unavailable forms. They discussed these issues more recently in a presentation at the Bay Delta Science Conference:

Lee, G. F., and Jones-Lee, A., "Review of Potential for Controlling P Discharges from Mud and Salt Sloughs for Reducing Algal-Related Oxygen Demand Load to SJR DWSC," PowerPoint slides presented at Bay-Delta Science Conference, Sacramento, CA, September 29 (2010). http://www.gfredlee.com/SJR-Delta/SJR-DO-BayDeltaConf.pdf

It has been found that algal growth in waterbodies such as lakes and rivers can be reduced by reducing phosphorus input, even in waterbodies in which the phosphorus concentrations are well-above growth-rate-limiting levels. Lee and his associates described how planktonic algal

chlorophyll levels in lakes respond in a predictable and quantifiable way to reductions in phosphorus load:

> Rast, W., Jones, A., and Lee, G. F., "Predictive Capability of US OECD Phosphorus Loading-Eutrophication Response Models," Journ. Water Pollut. Control Fed. 55(7):990-1003 (1983). http://www.gfredlee.com/Nutrients/PredictiveCapabilityOECD.pdf

At the California Water Environmental Modeling Forum (CWEMF) Delta Nutrient Water Quality Modeling Workshop, Dr. Erwin Van Nieuwenhuyse, Fishery Biologist with the US Bureau of Reclamation Division of Environmental Affairs, Sacramento, CA made a presentation entitled, "Impact of Sacramento River Input of Phosphate to the Delta on Algal Growth," in which he discussed the impact of altering phosphorus loads to the Delta on phytoplankton biomass. His presentation is available at
CWEMF website, http://cwemf.org/Calendar/index.htm.

> Van Nieuwenhuyse, E., "Response of Summer Chlorophyll Concentration to Reduced Total Phosphorus Concentration in the Rhine River (Netherlands) and the Sacramento–San Joaquin Delta (California, USA)," Can. J. Fish. Aquat. Sci. 64:1529-1542 (2007).

Van Nieuwenhuyse reported that planktonic algal chlorophyll levels decreased in both the Rhine River in Europe and the Sacramento–San Joaquin Delta upon reduction of phosphorus loads to the waterbody. It is therefore expected that reducing algal-available phosphorus levels in the ag discharges to the Mud and Salt Slough will effect a decrease planktonic algal growth in those waterbodies, and reduce the algae-related oxygen demand load to the DWSC.

In the 1960–1970s a number of studies were conducted in the US and other countries on controlling excessive algal growth in waterbodies by treatment with alum. During the 1960–early 1970 the Wisconsin Department of Natural Resources (WDNR) conducted studies on lake rehabilitation, which included phosphorus inactivation using alum for whole-lake treatment. WDNR published its findings, including information on the use of alum to control phytoplankton in lakes in:

> Dunst, R., et al., "Survey of Lake Rehabilitation Techniques and Experiences," Technical Bulletin no. 75, Wisconsin Dept. Natural Resources, Madison, WI (1974).

During the 1980s the US EPA Office of Water held a series of annual conferences on lake restoration techniques. A summary of those studies was presented by Funk and Gibbons (1979).

> Funk, W., and Gibbons, H., "Lake Restoration by Nutrient Inactivation," In: Lake Restoration, Proc. Int. Conf., EPA 440/5-79-001, US EPA Office of Water, Washington, DC, March (1979). http://www.gfredlee.com/SJR-Delta/Funk-Gibbons-Lake-Restor.pdf

Elements of Upstream P Control Suggested Study

As discussed in the Lee and Jones-Lee Synthesis Report, the evaluation of the potential effectiveness of controlling algal-available P in agricultural discharges in Mud and Salt Slough watersheds for improving the DO condition of the DWSC should begin with review of existing data. The goal would be to gather the data necessary to develop reliable nutrient export coefficients (mass of P discharged per unit area of land per unit time, e.g., g P/m^2 of farm land area monitored/day). Quantifying the export of algal-available nutrients from the watershed areas will enable targeted P management and an on-going assessment of the efficacy of the

nutrient control measures as they are undertaken. Of particular importance would be data on the concentrations of total and soluble orthophosphate (soluble ortho P) in agricultural discharges at edges of the fields before they enter drainage waterways, the flows at the time of sampling, and the types of crops and farming practices characterizing the drainage area at the time of sampling, especially for the critical period of May through October. It is during that period that the SJR algal biomass is a significant component of the load of oxygen demand entering the DWSC. Inadequacies in existing data should be identified based on this review, and targeted studies should be effected to gather needed information to develop meaningful export coefficients.

Rast and Lee described how such information can be used to define the export of nutrients from agricultural lands in

Rast, W., and Lee, G. F., "Nutrient Loading Estimates for Lakes," Journ. Environ. Engr. 109(2):502-518 (1983).
http://www.gfredlee.com/Nutrients/NutrientLoadingEstRast.pdf

From their examination of about 100 watersheds across the US, Rast and Lee (1983) found that agricultural lands typically export about 0.05 g P/m^2/yr. The phosphorus export coefficients for the agricultural activities in Mud and Salt Slough watersheds will likely differ somewhat from those typical values because of different types of farming practices and discharges from subsurface drains; G. F. Lee has observed substantial growth of filamentous algae in Grasslands Bypass drainage ditches just downstream of subsurface drain discharges indicating that the subsurface drains discharge large amount of algal-available P.

From the phosphorus export coefficients for various types of farming activities/settings and the total areas of these various types of farming activities in the Grasslands Bypass area it will be possible to estimate the total soluble P load to Mud and Salt Sloughs. Those load estimates can then be compared to the total P loads computed from measured at downstream stations in Mud and Salt Sloughs. J. McGahan, Drainage coordinator for the Grasslands farmers, would be a valuable resource in the selection of sampling sites, estimation of discharge flows, etc.

After quantification of the phosphorus export from the ag land, Lee and Jones-Lee's proposed study would examine the major sources of soluble ortho P to Mud and Salt Sloughs to evaluate optimum sites for pilot studies of drainage-based phosphorus control. Pilot studies could include evaluation of the use of constructed wetlands with and without alum addition to remove P from the ag discharges. Waters downstream of the pilot P removal study areas would be monitored for the occurrence of planktonic algae in the channel receiving the treated ag discharges.

Impact of Flow and Other Factors on DWSC DO Depletion

At the SJR Technical Work Group (TWG) meeting in June 2010, G. Fred Lee raised a number of issues that could impact the control of algal-related DO depletion in the DWSC. A summary of those issues was presented in his report,

Lee, G. F., and Jones-Lee, A., "Background Information on SJR Upstream Oxygen Demand Control Issues," Prepared for San Joaquin River Technical Work Group, Report of G. Fred Lee & Associates, El Macero, CA, July 11 (2010).
http://www.gfredlee.com/SJR-Delta/Bkgrnd-SJR-DO.pdf

Lee and Jones-Lee provided considerable information in their Synthesis Report and follow-on studies, on the impact of flow of the SJR through the DWSC on DO depletion in the DWSC. They demonstrated the importance of SJR DWSC flow, and the factors influencing that flow such as the operation of the US Bureau of Reclamation (USBR) and California Department of Water Resources (DWR) south Delta water diversions, on DO depletion in the DWSC.

In connection with their review of the CA State Water Resources Control Board's (SWRCB) development of Delta flow criteria, Lee and Jones-Lee submitted the following discussion:

> Lee, G. F., and Jones-Lee, A., "Discussion of Water Quality Issues That Should Be Considered in Evaluating the Potential Impact of Delta Water Diversions/Manipulations on Chemical Pollutants on Aquatic Life Resources of the Delta," Report of G. Fred Lee & Associates, El Macero, CA, February 11 (2010).
> http://www.gfredlee.com/SJR-Delta/Impact_Diversions.pdf
>
> Lee, G. F., and Jones-Lee, A., "Comments on Water Quality Issues Associated with SWRCB's Developing Flow Criteria for Protection of the Public Trust Aquatic Life Resources of the Delta," Submitted to CA State Water Resources Control Board as part of Public Trust Delta Flow Criteria Development, by G. Fred Lee & Associates, El Macero, CA, February 11 (2010).
> http://www.gfredlee.com/SJR-Delta/Public_Trust_WQ.pdf

Those comments and report provide information on how flow through SJR DWSC impacts DO in the DWSC, as well as on the impact of flow into and through the Delta channels on water quality in the Delta.

The current Bay Delta Conservation Plan (BDCP)/Delta Stewardship Council is deliberating the management of Delta water exports to central and southern California and the San Francisco Bay area while protecting the aquatic life and other resources of the Delta. Lee and Jones-Lee recommended that the Stewardship Council include in those deliberations consideration of how manipulations of Sacramento River flow into and around the Delta impact the low-DO problem in the DWSC and other water quality issues in the Delta. In the early 2000s it was found that achieving SJR DWSC flows of about 1,200 cfs eliminated the DO WQO violations in the DWSC. It appears that now, with city of Stockton's nitrifying it domestic wastewater effluent, maintaining a SJR DWSC flow of about 1,000 cfs would eliminate DO WQO violations. There is need for better definition of that relationship to enable BDCP and the Delta Stewardship Council to establish sufficient flow of the SJR through the DWSC to eliminate exceedances of DO WQOs in the DWSC.

Other Factors Influencing DO Depletion in the DWSC

At the June and October SJR TWG meetings G. Fred Lee mentioned several other factors that could significantly impact the achievement of compliance with the DO WQO in the DWSC. Those issues were discussed in the Lee and Jones-Lee Synthesis Report and are briefly summarized below.

DO Water Quality Objective for the DWSC. The current DO WQO for the DWSC is 5 mg/L for December through August, and 6 mg/L for September through November, at any location in the

Channel, with no more than one violation every three years. That requirement will be difficult to achieve. In their Synthesis Report cited above, Lee and Jones-Lee discussed implications of exceedances of the DO WQO concentrations by a mg/L or so for aquatic life resources of the Delta. It was concluded that a small number of small low-level DO concentration violations will not significantly adversely affect the aquatic life resources of the DWSC and Delta. The US EPA allows, and several states have adopted, an averaging of DO concentrations for evaluating compliance with the DO WQO.

With regard to the 6 mg/L DO objective applicable during September through November, as discussed by Lee and Jones-Lee in their 2003 Synthesis Report the higher DO objective was adopted by the SWRCB to incorporate some anticipatory time/conditions so that adjustments could be made in time to try to achieve the 5 mg/L DO objective. With adequate monitoring of DO and a plan to operate the aerator when the DO approaches 5 mg/L there should be no need today to have the extra 1 mg/L cushion for prevention of violation of the 5 mg/L, especially if DO averaging were adopted.

SJR Watershed Home-Stream Chemical Signal. In their investigation of DO depletion in the DWSC Lee and Jones-Lee found that during the summer and fall the USBR and DWR south Delta export projects draw all the SJR DWSC flow down Turner Cut (located about 7 miles down the SJR DWSC from the Port of Stockton). In their Synthesis Report Lee and Jones-Lee (2003) pointed out that the diversion of SJR flow down Turner Cut prevents the home-stream chemical signal from reaching San Francisco Bay where it would otherwise guide fall run Chinook salmon to their home-stream waters for spawning in the SJR watershed from which they originated. This interference in the homing process increases the "straying" of Chinook salmon and thereby can inhibit spawning. These issues are discussed in:

> Lee, G. F., and Jones-Lee, A, "Review of Impacts of Delta Water Quality and Delta Water Exports on the Decline of Chinook Salmon in the SJR Watershed," Comments submitted to NMFS Southwest Fisheries Science Center, NOAA, Santa Cruz, CA, by G. Fred Lee & Associates, El Macero, CA, August (2008).
> http://www.gfredlee.com/SJR-Delta/Salmon-NOAAcom.pdf

and in the comments submitted to the SWRCB in Delta Public Trust flow requirements referenced above. While the homing interference is not a DWSC DO issue, management strategies for each can affect the other. The SWRCB and DFG should work with BDCP and Delta Stewardship Council to require the maintenance of adequate SJR DWSC flow to minimize DO depletion in the DWSC below the WQO and to maintain transport of water down the SJR channel to the confluence with the Sacramento River in the western Delta for the protection of Chinook salmon migration.

Need for Evaluation of Chinook Salmon Migration through DWSC under Depressed DO Conditions. The original impetus for development of the SJR DWSC DO TMDL was the report by California Department of Fish and Game staff that the fall-run of Chinook salmon was inhibited by DO concentrations below 5 mg/L. Based on discussions with A. Mearns of NOAA, an expert on Chinook salmon homing migration issues, there is reason to question whether DO depression of a mg/L or so was a real, significant factor inhibiting migration through the DWSC. It is suggested that DFG consider whether a DO concentration of about 4 to 5 mg/L for short

periods of time, such as early morning and/or near the sediments, is a significant factor influencing Chinook salmon migration to their home stream waters.

Development of Nutrient Criteria for the SJR. The US EPA is aggressively pursuing requiring states to develop nutrient criteria to be implemented into numeric water quality standards for nitrogen and phosphorus in an effort to control excessive fertilization of waterbodies. Volume 13, no. 3 of the Lee and Jones-Lee Stormwater Runoff Water Quality Newsletter (NL 13-3) summarized some of the activities being undertaken in various areas of the US toward the development of nutrient criteria. That Newsletter is available at http://www.gfredlee.com/Newsletter/swnewsV13N3.pdf.

In 2008 Lee and Jones-Lee organized the California Water and Environmental Modeling Forum one-day workshop on nutrient-related water quality problems in the Delta and its tributaries. The presentations at that workshop discussed nutrient-related water quality problems in the Delta including the SJR DWSC. Presentation slides from the workshop are available on the CWEMF website at: http://www.cwemf.org/workshops/NutrientLoadWrkshp.pdf.

At this time the SWRCB is developing nutrient water quality criteria for coastal bays and estuaries. Ultimately that effort will be expanded to include inland waters such as the upper Delta and the SJR. Based on experience in developing nutrient criteria in other areas of the US it is anticipated that the SJR and DWSC will be found to be excessively fertile based on planktonic algal biomass (planktonic algal chlorophyll in those waterbodies often exceeds 50 µg/L). Independent of the impact of the algae on DO depletion in the DWSC, the classification of these waters as excessively fertile could readily result in the requirement to control nutrient discharges from ag sources in the Grasslands Bypass area to lower the planktonic algal chlorophyll in the SJR. These issues should be considered in developing nutrient management programs for the DWSC.

The CVRWQCB has required that significant reductions be made in the selenium discharged to Mud and Salt Sloughs from ag discharges. Because reduction in phosphorus loads can occur as a result of selenium control, it is suggested that phosphorus also be monitored as part of meeting the CVRWQCB requirements for selenium load reduction to Mud and Salt Sloughs. Such information could be informative in guiding the development of phosphorus control programs for controlling the algal "seed" in the Mud and Salt Sloughs.

Issues that Need Attention/Evaluation

- Evaluation of the impact of algae-related oxygen demand load to the DWSC on DO depletion below the WQO in the DWSC as a function of SJR flow through the DWSC.
- Determination of how the cost of aerator operation changes with reduced algae-related oxygen demand load.
- Relationship between reduction of algal biomass in Mud and Salt Sloughs and reduction of algae-related oxygen demand load to the DWSC as a function of flow of the SJR through the DWSC.
- Relationship between phosphorus control in agricultural discharges in the Mud and Salt Slough watersheds and algal "seed" that develops in the discharges of those sloughs to the SJR.

- Relationship between the cost of controlling phosphorus discharges and the cost of operation of the aerator.
- The CVRWQCB/SWRCB should work to have the BDCP/Delta Stewardship Council allocate sufficient SJR DWSC flow to eliminate the DO WQO violations in the DWSC.
- The CVRWQCB should adopt a Basin Plan amendment to allow averaging of the DO concentration with depth and over the diurnal/diel cycle.
- The SWRCB should remove the 6 mg/L DO WQO during September through November and adopt a daily average over depth in the DWSC of 5 mg/L.
- DFG should reevaluate whether a daily diurnal/diel average with depth of DO at 5 mg/L is a significant barrier to Chinook salmon homing migration through the DWSC.
- SWRCB should work to allow a substantial part of the SJR DWSC flow to continue down the SJR channel to its confluence with the Sacramento River to enable the home-stream water signal to be transported to the upper parts of San Francisco Bay.

Adoption of these recommendations could significantly facilitate compliance with the DO WQO in the DWSC and/or reduce the amount of algae-related DO depletion below the current WQO that occurs, or the WQO objective that is ultimately adopted by the regulatory agencies. Implementation of one or more of these recommendations could also significantly reduce the cost of aeration of the DWSC.

It is suggested that the CVRWQCB/DFG appoint an advisory committee to work with the agency's staff to formulate an approach to address these and others issues that may evolve from deliberations of this advisory committee and the agencies management.

Summary

In summary, the DWR and the ICI/Brown reports on the evaluation of the aerator shows that while the operation of the aerator can significantly reduce the occurrence and magnitude of DO depletion below the WQO in the DWSC at a cost of $2,400 to 2,500 per day of operation, it will not prevent DO depletion below the WQO in the DWSC under the current regulatory requirements.

It is possible that revising the regulatory requirements such as making provision for DO WQO averaging, and maintaining adequate SJR DWSC flow, can greatly reduce the need/cost for operation of the aerator and the need for upstream seed algae control from Mud and Salt Sloughs.

Changes in flow of the Sacramento River into and around the Delta (peripheral canal) can impact DO depletion in the DWSC and aerator operation.

Future nutrient criteria for the SJR to control algae is a major factor that will need to be considered.

Question and comments on these issues should be directed to G. Fred Lee at gfredlee@aol.com.