Need for SJR DWSC WQO TMDL DO Target Review

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In the San Joaquin River (SJR) Deep Water Ship Channel (DWSC) low DO "Issues" and "Synthesis" reports, Lee and Jones-Lee (2000, 2003) raised the issue of whether the current 6 mg/L DO water quality objective (WQO) was needed to protect Chinook salmon migration through the DWSC to the SJR eastside tributary rivers for spawning.

DFG Studies of Chinook Salmon Migration through the DWSC

As they discussed, the DFG studies of Hallock et al. (1970) concluded that DO concentrations below **5 mg/L** could be blocking Chinook salmon migration through the DWSC to the SJR eastside rivers for spawning. They also indicated that other factors such as temperature of the DWSC may be important in blocking the migration of Chinook salmon through the DWSC. Based on the Hallock et al. (1970) studies, some of the San Joaquin River Deep Water Ship Channel low dissolved oxygen problem stakeholders feel that there is need to conduct a comprehensive review of the appropriateness of the 6 mg/L DO water quality objective for the DWSC near Stockton since it will be less difficult and less expensive to achieve a DO WQO of 5 mg/L than the current 6 mg/L. Based on the Hallock et al. (1970) studies, changing the DO WQO for the upper DWSC to the US EPA national water quality DO criterion of 5 mg/L would not impair the ability of Chinook salmon to migrate through the DWSC. The 5 mg/L DO WQO is applicable to the rest of the DWSC during the fall and to all the DWSC for the rest of the year.

Origin of the 6 mg/L DO WQO

The Central Valley Regional Water Quality Control Board (CVRWQCB 2004) staff report for the amendments to the Water Quality Control Plan for the Sacramento River and San Joaquin River Basins for the control program for factors contributing to the dissolved oxygen impairment in the Stockton Deep Water Ship Channel stated,

"*The 6.0 mg/L objective included in the 1991 and 1995 SWRCB water quality control plans was intended to protect fall-run Chinook salmon spawning migration. The technical basis for the objective was an agreement reached in 1969 between the California Department of Water Resources (DWR), California Department of Fish and Game, U.S. Bureau of Reclamation (USBR), and the predecessor to U.S. Fish and Wildlife Service to take specific actions to maintain the DO content in the DWSC above 6 ppm (mg/L). This agreement called for the installation of a temporary rock barrier at the head of Old River to increase San Joaquin River flows past Stockton, thus improving DO levels (SWRCB, 1991,1995).*"

It has been known since the 1960s (DFG et al. 1964) that the USBR Central Valley Project (CVP) export of South Delta water at the Tracy pumps can draw most of the SJR Vernalis water into the South Delta and thereby greatly reduce the flow of the SJR through the DWSC. It has also been known since that time that low SJR flow through the DWSC greatly aggravates the low DO problem in the DWSC. For additional information on the impact of CVP and the DWR State Water Project (SWP) on the low DO problem in the DWSC see the reports of Lee and Jones-Lee (2004, 2005) at www.gfredlee.com in the Watershed Studies section San Joaquin River Watershed Program subsection.

M. Gowdy of the CVRWQCB investigated the background to the State Water Resources Control Board (SWRCB) adoption of the 6 mg/L DO WQO. He provided the following from SWRCB Water Quality Control Plan, 91-15 WR May (1991),

"5.5.2.4 Dissolved Oxygen

No objectives for dissolved oxygen were developed in D-1485.

The Central Valley Basin Plan (1975, Vol. I-4-12) states that: "The following objectives apply to Delta waters: The dissolved oxygen concentrations shall not be reduced below the following levels:

- *7.0 mg/L in the Sacramento River (below the 1.Street Bridge). and in all Delta waters west of the Antioch Bridge; and,*

- *5.0 mg/L in all other Delta waters except for those bodies of water which are constructed for special purposes and from which fish have been excluded or where the fishery is not important as a beneficial use."*

"Temperatures over 65°F have partially blocked migrations in the San Joaquin River past Stockton and ... dissolved oxygen concentrations of less than 5 mg/1 constitute a virtual barrier to adult migrants" (USFWS,31,94). According to Hallock et al. {1970), after four years of investigation, "... no salmon moved past Stockton until the dissolved oxygen had risen to about 4.5 ppm, and the run did not become steady until oxygen levels were above 5 ppm." To address the problem of low dissolved oxygen levels in the San Joaquin River, an agreement was reached in 1969 between the USFWS, USSR, DWR, and DFG, in part, to take specific actions "...to maintain the dissolved oxygen content in the Stockton Ship Channel generally above 6 ppm when necessary " DWR monitors DO levels in the San Joaquin River between Stockton and Turner Cut (Stockton Ship Channel) during the. fall Chinook salmon migration. (Monitoring data are summarized and a report is submitted by DWR to the SWRCB annually in accordance with Water Right Decision 1485, Order 4(f)). If DO levels drop to 6 mg/L, a temporary rock barrier is installed across the head of Old River to increase San Joaquin River flows past Stockton, thus improving DO levels (T,XXXVII,85:4-22).. Better treatment of cannery wastes since1978 (reducing the biochemical oxygen demand) and improved flows and water quality from New Melones Reservoir operations were reported to have helped alleviate this problem (USFWS,31,94). Since then, the Old River barrier has been installed in the fall of 1979,

1981, 1984, 1987, 1988 and 1989 (H. Proctor, DWR, pers. comm.)." Page 5-23
This statement was attached to a Memorandum of Understanding on Interim Measures to Protect Fish in the Sacramento-San Joaquin River Delta Prior to the Construction of the Peripheral Canal.

A review of the SWRCB 1991 Water Quality Control Plan adoption of the 6 mg/L DO water quality objective from September 1 through November 30 was not based on the finding that this DO concentration was necessary to protect Chinook salmon migration through the DWSC. It was based on the inability of DWR to quickly install the rock barrier at the Head of Old River in order to not let the DO in the DWSC fall below the 5 mg/L found by Hallock et al. (1970) needed to allow unimpeded migration through the DWSC. The 6 mg/L was selected as the trigger to indicate that the DO in the DWSC was dropping and the rock barrier needed to be installed. With the development of an operable barrier at the Head of Old River (HOR) in spring 2008 (Marshall 2005), this justification is no longer valid since the operable barrier will enable rapid adjustment of flow of the SJR Vernalis water into the South Delta through HOR.

DFG Studies of Chinook Salmon Spawning in SJR Eastside Rivers
On February 24, 2005 California Bay Delta Authority (CBDA) held a Central Valley Salmonid Escapement Workshop in which the CA Department of Fish and Game (DFG) and other agencies discussed their work on assessing the spawning of Chinook salmon in the Sierra rivers and streams. The workshop presenter's PowerPoint slides are available from davina@calwater.ca.gov. Tim Heyne of DFG presented information on the spawning of Chinook salmon in the SJR watershed tributaries. The presentation by Heyne et al. (2005) is of interest to those concerned with SJR DWSC low DO problem management since it provides information on the potential significance of DO WQO violations in the DWSC that may be influencing Chinook salmon spawning in the SJR east side tributaries.

Heyne et al (2005) presents a slide, "History of Chinook Spawning" that provides year to year spawning variability characteristics in the SJR eastside tributaries for 1953 - 2004. Lee and Jones-Lee (2003) presented the CA Department of Water Resources (DWR) D-1641 Hayes Cruise data for DO in the DWSC for the period 1995-2002. These data show that 1995, 1998 and 2000 were years when there were few, if any, exceedance of the DO water quality objective. The other years had DO concentrations in the surface waters below the WQO. A review of the Chinook spawning data presented by Heyne et al. shows there is no apparent relationship with the occurrence of DO WQO violations in the DWSC and Chinook salmon returning for spawning. Some years such as 2000, showed good Chinook salmon returns yet other years with similar lack of DWSC DO WQO violations did not show Chinook salmon return for spawning to be better than years when there were significant DO WQO violations in the DWSC during the fall. The apparent conclusion is that during the falls when there are significant DO WQO violations in the DWSC do not show an impaired ability of the Chinook salmon to return to their home stream or another SJR eastside tributary for spawning. Heyne (personal comm. 2005) has pointed out that there is typically a three year lag between successful spawning and the

return of adult Chinook to the SJR watershed rivers for spawning. There are several factors that influence this cycle including:

- survival of fry in the upstream spawning waters
- ability to migrate downstream to the SJR and through the Delta to marine waters
- Survival in the marine waters
- migration to the Delta and through the Delta without a home stream water signal
- migration through the Deep Water Ship Channel
- migration to the eastside rivers to suitable spawning areas.
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Heyne et al. (2005) indicated that adult fall run Chinook salmon are spawning in SJR eastside river during the period from October 1 through January with some in February in some years. Heyne (personal comm. 2005) indicated that frequently a month or so may elapse between when adult Chinook salmon enter the DWSC till they reach their spawning areas. Lee and Jones-Lee (2003) have pointed out that DO concentrations in the DWSC below 6 mg/L and in some years below 5 mg/L occur in December. When the DO concentrations fall below 5 mg/L, the late fall run of Chinook salmon could be impaired.

Implementation of the DO WQO

One of the issues of additional concern in controlling the low DO problem in the DWSC is that the 6 mg/L DO WQO is to be implemented at any time and place including early morning and at the sediment water interface. As discussed by Lee and Jones-Lee (2003) meeting this objective with no more than one violation of any amount more than once every three years will be difficult to achieve through oxygen demand source control and/or aeration of the DWSC. This could readily led to chronic problems with violations of the WQO that do not represent impediments to Chinook salmon migration to the spawning areas.

Development of Revised DWSC DO WQO

Dr. G. Fred Lee has been active for many years in the development of US EPA water quality criteria and their implementation into state water quality standards. He was a US EPA peer reviewer of the water quality development approach adopted by the US EPA in 1986. Based on this experience, Lee and Jones-Lee (2003) recommended that a technical advisory panel be appointed to critically review the appropriateness of the DO WQO for the DWSC relative to Chinook salmon migration through the DWSC during September through November. Of particular concern is whether the US EPA (1986, 1987) national water quality criterion for DO of 5 mg/L that can be implemented with an allowed early morning exceedance associated with a diel (day/night) DO changes due to photosynthesis/respiration in the DWSC water column could be implemented without impairing the Chinook salmon migration through the DWSC and be protective of aquatic life related beneficial uses of the upper DWSC. Lee and Jones-Lee (2000) in the SJR DWSC DO TMDL "Issues" report present background information on the development of US EPA national water quality criterion for DO. As discussed the Agency allows some flexibility in the implementation of this criterion including diel early morning excursions of the DO concentration below the national water quality criterion that consider early morning diel photosynthesis/respiration conditions. The US EPA also

allows depressed DO near the sediment water interface associated with sediment oxygen demand.

Seager et al. (2000) investigated the impact of short-term oxygen depletion on fish. They reported that for a given duration, there is a narrow threshold concentration range above which mortality does not occur and below which mortality rapidly becomes high. This threshold concentration range increases as exposure duration increases. Milne (personal comm. 2005) has indicated that some planktonic insect larvae are more sensitive to low DO than many fish.

The US EPA (2000) recommended ambient water quality criteria for dissolved oxygen that will protect coastal and estuarine animals in the Virginian Province (from Cape Cod to Cape Hatteras). These criteria combine features of traditional water quality criteria with a new biological framework that integrates exposure to low dissolved oxygen over time rather than averaging dissolved oxygen exposure conditions into one single value. These criteria include information on short term exposure similar to that experienced in the diel changes in DO that occurs in waters that have high algal productivity. The approach is similar to that reported by Seager et al. (2000). The US EPA marine DO criteria include consideration of mortality and impaired growth rates. As with the freshwater DO criteria, DO concentrations below about 5 mg/L for extended periods of time impairs fish growth rates.

The US EPA (2000) salt water DO criteria include a criterion maximum concentration of 2.7 mg/L to protect fish from mortality and a formula that can be used to establish the allowable low DO for episodic and cyclic exposure that considers that duration of exposure. For protection of fish and other organism growth the criterion continuous concentration is 4.9 mg/L. A formula is presented for the minimum DO that can occur for episodic and cyclic exposure of various durations and still not significantly impair fish growth rates. The US EPA (2000) also provides guidance on implementation of these criteria.

Based on the Hallock et al. (1970) studies, information presented in the US EPA (1986, 1987 and 2000) reports and the authors experience in developing water quality criteria and their implementation, it appears that it may be possible to allow the SJR DWSC DO WQO to be changed to 5 mg/L during the fall months without impairing Chinook salmon migration through the SJR DWSC once the HOR barrier is constructed and it is operated to maintain the flow of the SJR through DWSC to prevent DO concentrations from occurring below the WQO. It also appears that a early morning DO concentration of no less than about 4 mg/L can be allowed for several hours and still protect fish growth rates. These values of suggested DO concentrations should also be protective of zooplankton.

It also appears based on US EPA (2000) that the minimum DO at the sediment water interface should not be less than 2 mg/L to protect benthic organisms.

Need for Expert Panel to Review DWSC DO WQO

The ability to achieve a DO concentration in the DWSC above 5 mg/L in the water column with minor excursions to account for diel photosynthesis/respiration through oxygen demand control from the upstream of the DWSC watershed and aeration will be more easily achieved and less costly than achieving the current 6 mg/L DO WQO that is implemented at any time and place. Because of the lack of technical validity (justification) of the current 6 mg/L DO WQO as being needed to protect Chinook salmon migration through the DWSC to reach SJR eastside rivers for spawning when the operable HOR barrier is installed, it is justified to begin an effort to review the current DWSC DO WQOs. It is suggested that a panel of experts be appointed to review the current information base on factors that are or could influence Chinook salmon migration through the DWSC to the eastside rivers for spawning.

In addition to reviewing the current information base on Chinook salmon homing migration through the DWSC, the proposed DO WQO objective review panel could recommend a course of action to fill information gaps including defining the need for updated studies of the migration of Chinook salmon through the DWSC during the fall months. The ultimate goal of this panel is to establish a DO WQO that puts the SJR DWSC low DO TMDL target (WQO) on a sound technical basis and thereby insure that funds spent on controlling SJR DWSC oxygen demand sources, increased flow of the SJR through the DWSC and aeration of the DWSC to eliminate DO WQO violations in the DWSC would be used in a technically valid cost effective manner.

The Lee (2005) comments to the CVRWQCB on the draft TMDL Basin Plan amendment that was reviewed in January 2005, suggested that Phase I TMDL being developed by the CVRWQCB include a comprehensive review of the DO WQO target for the TMDL. The CVRWQCB (2005) staff responded,

"Response:
The phased TMDL allows for time to evaluate the need for modifications to the dissolved oxygen water quality objectives. The comments provided will be considered as part of determining whether to re-evaluate this objective. It should be further noted that the 6.0 mg/L objective was adopted by the State Water Resources Control Board and would need to be addressed by a change to their Bay-Delta Water Quality Control Plan."

The current information on DO WQOs justifies the CVRWQCB/SWRCB, DFG and the federal agencies (NOAA and US FWS), US EPA and others concerned with restoration of the salmon fishery in the Central Valley initiating a coordinated effort to begin review of the DO WQO target for the Phase I TMDL. The above suggested changes in the DO WQO for the SJR DWSC could be a starting point for the expert panel discussions.

Need for Mixing of the DWSC. There are several other issues that need to be addressed that could be considered by this panel. One of these is the potential value of mixing of the DWSC through installation of aeration tubes placed along the bottom side of the DWSC at several locations between Channel Point and Turner Cut to mix the DWSC. It

appears that gentle mixing of the DWSC to eliminate the periodic diel stratification that occurs in the near surface waters during the day that at times leads to large (several mg/L) diel DO changes due to photosynthesis/respiration could increase the photosynthesis due to periodically bringing algae that are now below the photic zone into the photic zone. Algae will continue to live/photosynthesize if they are periodically exposed to sunlight. By mixing the DWSC, it will likely be possible to keep more of the upstream derived algal oxygen demand load alive that occurs when the algae that enter the DWSC sink below the photic zone and thereby transport them through the DWSC into the Central Delta via Turner Cut. This mixing could also eliminate the temporary near bottom lower DO that at times occurs in the DWSC. Adoption of this approach will help aerate the DWSC following a procedure that will not cause the supersaturation of dissolved gases that would violate the CVRWQCB Basin Plan requirements of not adding a toxicant to the DWSC in toxic amounts.

As discussed by Lee and Jones-Lee (2005) the current Jones & Stokes proposed aeration of the DWSC using pure oxygen in a deep U tube aeration devise will led to CVRWQCB Basin Plan objective violations. That devise as currently designed will lead to dissolved gas supersaturation above the US EPA total dissolved gas criterion of 110%. Dissolve gas concentrations above this amount are toxic to fish. Under current regulations this would be a violation of the CVRWQCB Basin Plan objective. The revised aeration approach needed to avoid dissolved gas supersaturation should include achieving vertical mixing of the DWSC between Channel Point and Turner Cut to prevent the current diel DO changes that occur in the upper two meters of water in the DWSC.

Adverse Impact of Elevated Temperatures. As quoted above the US FWS have reported that temperatures about 65 F (18 C) have partially blocked the migration of Chinook salmon through the DWSC. At times the DWSC water has a temperature in September above 20 C. The expert panel could/should also consider the potential for high temperatures in the DWSC inhibiting the migration of the Chinook salmon through the DWSC.

It is known that the adverse impacts of low DO are aggravated at elevated temperatures. It will be important to consider whether the high temperatures that occur in the DWSC require a more stringent DO WQO than the currently proposed 5 mg/L with limited short term excursions below this WQO.

Port of Stockton. Another area that needs special attention in the aeration/mixing is the Port of Stockton Turning Basin. The studies on this area by Lehman (2003) show strong stratification that leads to low DO in the bottom waters. While the water in this area exchanges to some degree with the main DWSC channel this exchange is not sufficient to vertically mix this area. There may be need for the Port to establish a separate aeration/mixing of this area.

Proposed Approach for Review of the DWSC DO WQO.

If there is interest and support, Drs. G. F. Lee and Jones-Lee could serve as the organizers of the SJR DWSC DO WQO target for the Phase I TMDL review panel. They would

work with CVRWQCB/SWRCB, CBDA, DFG and others interested in developing the review panel and if there is interest and support, be active as coordinators of this effort. It is suggested that CBDA, CVRWQCB/SWRCB, DFG and the SJR DWSC DO TMDL responsible parties that will be paying for solving the DWSC low DO problem fund the support of Drs. Lee and Jones-Lee and the activities of the advisory panel. Once the advisory panel is organized, it could define the funds needed to complete the effort. This could lead to a CBDA proposal, to fund the necessary studies that evolve out of the expert panel deliberations.

Potential Benefits of the DO WQO Review

If the expert panel concluded and/or the follow on studies found that the 6 mg/L DO WQO implemented at any time and place is justified, then the stakeholders would know that funds spent to prevent DO concentrations from falling below the WQO are being used to achieve a necessary objective. However, based on the existing information base, funds used to support the initial expert panel effort and follow on studies could be highly cost effective in reducing the cost of solving the low DO problem in the DWSC if it is found that the US EPA national water quality criterion for DO of 5 mg/L implemented with minor diel excursion in the water column, is protective of Chinook salmon migration through the DWSC to their SJR DWSC watershed east side rivers and the aquatic life resources of the DWSC.

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