SAN JOAQUIN RIVER DISSOLVED OXYGEN TMDL
IMPLEMENTATION ALTERNATIVES AND ASSOCIATED HYPOTHESES

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Note: This draft is as complete as I can make it at this time. These are the hypotheses as I understand them from my reading of the literature and participating in technical discussions. Many can be stated more clearly. I am sure others are missing. I used a couple different styles for stating a hypothesis. Some are written as statements of fact. Others I modified with the word "can" because it didn't seem clear to me that the result would always occur. This needs help. Please use this draft to stimulate your thinking and help us write this more clearly, completely and logically. Thank you. Kevin
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ALGAL LOAD REDUCTION by LOCATION

City of Stockton sewage ponds

- The operation of the sewage ponds can lead to the release of CBOD and ammonia loads that can quickly impact D.O. levels.

DWSC itself

- Motile algae grow in the DWSC.
- Motile algae die in the DWSC and add to D.O. demand.
- Motile algae are net producers of oxygen to the DWSC.

Eastside tributaries Stanislaus, Tuolumne and Merced Rivers

- Little algal load reaches the SJR from these tributaries.
    - Question: Are these numbers below correct?
      4-8% of the SJR load comes form the Stanislaus
      4-8% of the SJR load comes from the Tuolumne
      6-12% of the SJR load comes from the Merced

French Camp Slough, Calaveras River

- These two tributaries add algal load to the river.
- The impacts of this load is greater in low SJR flow conditions.

Mud and Salt Sloughs including Grasslands

- These tributaries add 40-60% of the algal load that reaches the DWSC.
- The algal load from these watersheds grows with time. The lower the flows, the longer the residence and growth time, and the larger the algal load that reaches the DWSC.

Sewage treatment plants connected to the mainstem SJR (e.g. Lathrop, Manteca, Turlock, and Modesto

- Algae grows in sewage treatment ponds.
- When the ponds discharge to the river or a tributary, they add algal load to the river.

SJR above Lander Ave (including upstream eastside tributaries, Eastside Bypass, mainstem)

- Algal loads from above Lander Ave have the greatest distance to travel and the most time to grow and double.
- Between 20 and 30% of the algal load arriving at the DWSC originates in SJR above Lander Ave.

The South Delta from the Tracy Pumps north to the DWSC including City of Tracy

- Algal load grows in this part of the Delta.
- If/when water from this area flows up Old River to the San Joaquin, it will add algal load to the SJR that will result in D.O. demand in the DWSC.

Stockton sloughs and the Turning Basin.

- Algal growth occurs in Stockton Sloughs and the Turning Basin.
- Algal loads enter the DWSC from these locations.

West side north of Mud and Salt Slough to South Delta

- Lands to the north of Mud and Salt Slough produce algal loads that reach the SJR.
- The further south the load drainage is located, the longer the residence time and the more growth and D.O. demand that will result.

ALGAL LOAD REDUCTION by PRECURSOR

Overall

- Nitrogen and phosphate are needed for algal growth.
- Nitrogen is well over growth limiting levels in the SJR and throughout almost all of the watershed. (Percent reduction needed to be limiting in SJR?)
- Phosphate is well over limiting levels in the SJR but can be at limiting levels in parts of the watershed. (Percent reduction needed to be limiting in SJR?)
- In subwatersheds where either nutrient is limiting, less algal biomass will reach the SJR than in those areas where the nutrients are not growth limiting.
- Reduction in nutrients reaching the Delta could result in decreased plankton levels and could be harmful to aquatic health and fisheries in the waterways downstream of the DWSC.

Airborne – nutrients

- Nitrogen from the air, primarily from car exhaust, adds to nitrogen loading throughout the watershed. (Percentage of overall N load?)
- If nitrogen from airborne pollution were stopped, nitrogen would still be unlimited.

Feedlot – nutrients

- Nutrients escape from some feedlots through surface water discharge, more often during storm events than during the dry season.
- Nutrients from some feedlots enter into groundwater sources.

Groundwater - nutrients

- Nutrients are in groundwater supplies in the SJR watershed.
- Nutrients in groundwater sources enter the SJR. (Amount of groundwater inflow.)

- Nutrients in groundwater add to the nutrient load in subwatersheds through upwelling and groundwater pumping.

Irrigation runoff – nutrients
- Irrigation runoff water that enters tail water drains has a nutrient load.
- Good management practices can reduce the amount of nutrients in the runoff.
- Algal growth can begin immediately in drainage water when nutrients are available.

Sediment phosphate
- Phosphate is bound to sediment but in its bound form is not immediately available for algal growth as dissolved soluble phosphate.
- Phosphate laden sediment is found throughout much of the watershed.
- Phosphate from sediment is an ongoing source of algal useable phosphate as it releases from sediments in streams and drainages over time.
- Reduction in sediment phosphate would, over time, expand the zones in which phosphate is limiting to algal growth.

Sewage treatment facility nutrients
- Sewage treatment facilities that discharge to a stream, add nutrients to that stream.
- Sewage treatment facilities discharge applied to the land can add nutrient loads to groundwater supplies.

Wildlife refuges and wetlands drainage
- Wetland drainage can be a source of nutrient loading.
- Wetland drainage can be a source of algal loading.

AMMONIA and NBOD REDUCTION by LOCATION

Overall
- The nitrification of ammonia consumes oxygen from the water.
- The nitrification of ammonia adds algal growth available nutrients.

DWSC algae
- Some algae in the DWSC produce ammonia.
- Some algae in the DWSC increase the nitrification process, which increases D.O. demand.

French Camp Slough
- Ammonia from French Camp Slough reaches the DWSC.
- Dairies and feedlots are a source of the ammonia in French Camp Slough.
- Ammonia in French Camp Slough reduces the amount of dissolved oxygen from this drainage that enters the DWSC.

Harding Drain
- Ammonia from Harding Drain reaches the DWSC.
- Ammonia from Harding Drain reduces the amount of dissolved oxygen that reaches the DWSC.

- A source of the ammonia in Harding Drain comes from the Turlock sewage treatment facility.
- A source of the ammonia in Harding Drain comes from the feedlots and dairies in the drainage.

Manteca WTP
- Ammonia from Manteca's sewage treatment facility reaches the DWSC.
- Ammonia from Manteca's sewage treatment facility reduces the amount of dissolved oxygen that reaches the DWSC.

Modesto WTP
- Ammonia from Modesto's sewage treatment facility reaches the DWSC.
- Ammonia from Modesto's sewage treatment facility reduces the amount of dissolved oxygen that reaches the DWSC during its winter discharge directly to the river.

Stockton WTP
- Ammonia from Stockton's sewage treatment facility enters the DWSC often at the 20 mg/l level.
- Ammonia from Stockton's sewage treatment facility is a major source of oxygen demand in the DWSC especially during the fall.
- If the Stockton treatment facility's discharge level requirements for ammonia drop to 2 mg/l, the oxygen demand impacts would almost disappear.

NON-AMMONIA, NON-ALGAL LOAD REDUCTION

Ag irrigation drainage – CBOD
- Non-algal carbon sources in Ag drainage water reach the DWSC where it adds to oxygen demand.

Ag stormwater runoff – CBOD
- Non-algal carbon sources in Ag stormwater runoff reach the DWSC where it adds to oxygen demand.

Chemical runoff from the Port
- Ferrous iron and sulfides are pollutant loads that exert oxygen demand when they reach the DWSC. These may come from shipping operations, storm water runoff or other, as yet unknown sources.

Riparian vegetation – CBOD
- Decaying leaves and other carbon sources from riparian vegetation reach the DWSC where it adds to oxygen demand.

SOD (suspended) in DWSC
- Sediment at the bottom of the DWSC produces oxygen demand when it is stirred up by tides, flows, ship traffic or other factors.

SOD (bedded) in DWSC
- Sediment Oxygen Demand from "bedded" sources can add to D.O. problem at times.

Urban dry season runoff – CBOD

- Runoff from Stockton city streets during the dry season carries with it sources of carbon that add to the oxygen demand in the DWSC.
- Runoff from streets from upstream cities during the dry season carries with it sources of carbon that add to the oxygen demand in the DWSC

Urban stormwater runoff – CBOD

- During storm events, runoff occurs on Stockton city streets that adds oxygen demanding loads to the DWSC.
- During storm events, runoff from upstream cities reaches the DWSC and brings with it oxygen demanding loads.

Urban wastewater drainage – CBOD

- Urban sewage treatment facilities add non-algal CBOD loads that cause oxygen demand in the DWSC.

Wildlife refuges and wetlands drainage

- Drainage from wetlands adds non-algal CBOD loads to streams and ultimately to the DWSC.

SECONDARY FACTORS THAT INFLUENCE ALGAL PRODUCTION

Herbivore grazing (e.g. clams, zooplankton)

- Increased populations of clams, zooplankton and other algal herbivores upstream of the DWSC would result in less algal biomass entering the DWSC.
- Pollutants such as pesticides can harm algal herbivore populations.
- Agricultural irrigation and storm water runoff adds chemicals to streams that that harm algal herbivores.
- Urban dry season and storm water runoff adds chemicals to streams that that harm algal herbivores.

Light reduction by sediment in DWSC - reduced O2 production

- Fine sediments block light penetration in the upper levels of the DWSC and reduce the amount of oxygen that can be produced by motile algae.
- Fine sediments block light penetration in the upper levels of the DWSC and increase the amount of time algal decay can exert oxygen demand.

Light reduction by sediment in SJR upstream of DWSC - reduced algal growth

- Sediments in the San Joaquin River block light penetration and reduce algal growth rates and the amount of algae that reaches the DWSC.
- Since the eastside rivers during the summer and fall tend to be low in turbidity (suspended solids), they tend to dilute the turbidity within the SJR, thereby promoting algal growth in the SJR because of the potential for increased light penetration below where the eastside rivers enter the SJR.

Light reduction by shading

- Shaded drainages and streams reduce the amount of light available for algal growth.

- Less light available results in less algae biomass reaching the DWSC.

Light reduction in the San Luis Drain
- Covering the San Luis Drain and blocking out light will stop the algal growth that occurs there.
- Less algal biomass exiting the San Luis Drain will result in less algal load reaching the DWSC.

WATER TEMPERATURE REDUCTION OPTIONS

Overall
- Water at lower temperatures holds more dissolved oxygen. The warmer the water, the less oxygen holding capacity it has.
- Lower water temperatures reduce algal growth rates.

Ag drainage flows
- Ag drainage flows can increase the water temperature in the SJR.
- The warmer ag drainage water is, the more algal growth that will occur in the drains rsulting in larger loads reaching the SJR.

Dam releases of colder water
- Dam operations can result in colder water flowing in the SJR tributaries.
- Colder water in the tributaries can reduce the amount of algal growth that occurs in these streams.
- Colder water in the tributaries can cool the water in the SJR and lower algal growth rates there.

Sediment reduction and improved water temp
- Sediment laden water absorbs more heat than clearer water.

Shading and riparian forest
- Shade over a stream, drainage ditch or other water body in which algae grows can lower the water's temperature.
- Shade over a stream can retain heat that would otherwise dissipate at night and negate the cooling benefits that are gained during the day.
- Riparian forests can reduce air temperatures over water bodies above and beyond the shading benefits.

FLOWS/RESIDENCE TIME IMPROVEMENTS

Overall
- Higher flows in the SJR deliver larger algal loads to the DWSC.
- Higher flows in the SJR reduce residence time during which algal and CBOD loads can exert oxygen demand in the DWSC.
- Lower flows in the SJR increases the amount of time that algal loads can grow.
- Lower flows in the SJR downstream of Old River increase residence time in the DWSC and increase the time during which algal and CBOD loads can exert oxygen demand there.
- Abrupt lowering of flows can exacerbate low DO conditions by leaving a high algal load in the DWSC with little flow to move it out.

Delta Tidal (Agricultural) Barriers and low head pumping

- Operations of tidal barriers in the south Delta can result in more water flowing down the DWSC.
- Low head pumping at the Head of Old River Barrier in conjunction with the operations of the tidal barriers can increase the amount of water flowing through the DWSC.
- Flows entering the SJR from the South Delta via Old River can result in algal load from this area exerting oxygen demand in the DWSC.

Eastside tributary flows (Stanislaus, Tuolumne and Merced)

- Fall pulse flows from eastside tributary streams can result in reduced residence time and improved oxygen conditions in the DWSC.
- Fall pulse flows from eastside tributary streams can result in lower water temperatures in the SJR and DWSC and improved oxygen conditions.
- Flows from the eastside tributaries can provide dilution and reduced travel time benefits that result in improved dissolved oxygen conditions in the DWSC.
- Diversions from dams on these tributaries result in less flows in the SJR and DWSC.
- When higher tributary VAMP flows during spring are followed by low flows in the tributaries, increased residence time and higher water temperatures can occur in the SJR and DWSC leading to D.O. problems in the DWSC.

Efficiency to load and flow improvements in subwatersheds

- Improved agricultural water use efficiency can reduce or eliminate the amount of water at the end of fields and in drainage ditches in which algal growth can occur. This can result in lower algal loads reaching the SJR.
- If improvements in water use efficiency resulted in more water flowing down a tributary stream, algae would have less residence time in that stream resulting in smaller algal loads eventually reaching the SJR and DWSC.
- Many water use efficiency measures result in less sediment, pesticides, and other D.O. related load sources from reaching a waterway that connects to the SJR.

Export pumping rates and timing

- High export pumping rates reduce the amount of SJR water that flows through the DWSC when the Head of Old River Barrier is not in place.
- High export pumping rates can draw algal and BOD load from the DWSC into the South Delta and cause DO depletion problems there.
- High export pumping rates in the late fall and winter can exacerbate the ammonia caused DO demand problems in the DWSC.

Head of Old River Barrier (HORB) operations

- The HORB can be operated to increase flows that reach the DWSC.
- Operational changes to the HORB can result in abrupt lowering or raising of flows in the DWSC.

Sacramento River flows at the Delta Cross Channel

- Tidal action moves Sacramento River water up into the DWSC and improves D.O. conditions there.

SJR - drainages and diversions below Old River–(e.g. French Camp Slough, Calaveras River)
- Diversions from the SJR below Old River reduce the algal load that reaches the DWSC.
- Diversions increase residence time in the SJR and in the DWSC.
- Drainage return flows below Old River provide additional algal and CBOD load to the DWSC.
- Drainage returns increase flow in the SJR and in the DWSC.

SJR - drainages and diversions above Old River to Lander Ave.
- Diversions between Lander Ave and Old River reduce the algal load that reaches the DWSC.
- Diversions increase residence time in the SJR and in the DWSC.
- Drainage returns to the SJR in this stretch of river add algal and CBOD load to the DWSC.
- Drainage returns increase flow in the SJR and in the DWSC.

SJR - Friant Dam releases
- Anadromous fishery restoration flows from Friant Dam would decrease residence time in the SJR below Lander Ave and in the DWSC.
- Flows from Friant Dam could increase the amount of algal load that reaches the DWSC.

SJR - Groundwater inflow
- Groundwater inflow into the SJR decreases residence time in the SJR and in the DWSC.

SJR - Recirculation (e.g Newman Wasteway, Mendota Pool)
- Recirculation of Delta water to the SJR via the Newman Wasteway or other means would decrease residence time in the SJR and DWSC.
- The recirculated Delta water would also bring an algal load with it.

SJR - Sewage treatment effluent flows
- Effluent flows from the City of Stockton during extreme low flow conditions in the SJR can decrease residence time in the DWSC.
- Effluent flows from upstream sewage treatment facilities that reach the SJR add to flow and decrease residence time in the SJR and DWSC.

DWSC GEOMETRY - REDUCTION OF VOLUME OPTIONS

Burns Cut extends to Turner Cut and isolates entire low DO section of DWSC.
- Isolating the DWSC upstream of Turner from the SJR river will eliminate low DO problems for aquatic life in the lower SJR.
- Isolating the DWSC from the SJR could result in continued D.O. and aquatic health problems in the DWSC.

Burns Cut isolates upper Three Miles of DWSC
- Moving SJR water through Burns Cut would result in less of the DWSC having low DO conditions that harm migrating salmonids.

- Bypassing the Channel Point to Burns Cut confluence with SJR flows could result in other harmful effects to aquatic life in this section of the DWSC.

DWSC fills in over time

- Reductions in DWSC volume results in decreased residence time in the DWSC.
- Reductions in DWSC depth results in less stratification in the DWSC.