Memorandum

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SUBJECT: **SRCSD DO Continuous Monitoring Preliminary Results and Ambient DO Datasets Assessment**

Executive Summary

The Sacramento Regional County Sanitation District (SRCSD or District) performed a Low Dissolved Oxygen Prevention Assessment (LDOPA) to determine the extent the Sacramento Regional Wastewater Treatment Plant (SRWTP) may be affecting dissolved oxygen in the Sacramento River downstream from the point of discharge. As part of the LDOPA, SRCSD developed a Streeter-Phelps type model in an effort to assess critical conditions and future discharge scenarios. In support of the LDOPA model, available data sources of dissolved oxygen in the Sacramento River were evaluated. In comparing the available data from different programs at different locations along the river, there were inconsistencies in the datasets and between the programs.

As a result, SRCSD initiated the Lower Sacramento River Dissolved Oxygen Data Evaluation in an attempt to determine which data sets may be appropriate to use in the LDOPA model development. The dissolved oxygen data assessment evaluated available data sets with respect to equipment used, calibration methods and frequency. This data assessment showed that there is too high a level of uncertainty associated with the majority of available dissolved oxygen data for use in the District's modeling efforts due to instrumentation and calibration protocols used for data collection.

To determine the best picture of dissolved oxygen in the river downstream from the discharge, the District developed a monitoring plan to collect high quality continuous dissolved oxygen data. The Regional Water Board reviewed and approved the dissolved oxygen monitoring plan in an e-mail dated March 25, 2010. Following the monitoring plan, SRCSD has deployed five YSI optical dissolved oxygen sensors on the Lower Sacramento River at Freeport, Hood, Walnut Grove, Isleton and Rio Vista. Through performing bi-monthly site visits the District has found that maintaining a temperature controlled air saturated control sample of water allows the deployed probed to be rapidly verified and calibrated as necessary. Additionally, maintaining an optical dissolved oxygen sensor on the boat over the site visits (6^{th} Sonde) allows a cross-reference check of each deployed probe. Winkler titrations have been conducted according to USGS guidelines as part of the site visits but have not proven to provide reliable measurement of the dissolved oxygen in the river. In addition, Clark cell technology for dissolved oxygen measurement does not appear to provide as consistent results as the optical sensors now deployed by the District.

SRCSD previously used the Clark cell sensors because they carry USEPA approval, where as the optical sensors currently do not. SRCSD pursued and acquired USEPA approval in March 2010 to use the optical sensors for dissolved oxygen monitoring in the Sacramento River. To date the SRCSD DO monitoring data provide a consistent picture of dissolved oxygen as the river flows from the SRWTP discharge at Freeport to Rio Vista. The measurement of dissolved oxygen at Rio Vista is consistent between the SRCSD, USGS, and California Data Exchange Center (CDEC) programs. However, the CDEC dissolved oxygen data at Hood are inconsistent with the corresponding SRCSD data. The CDEC dissolved oxygen data consistently measure lower and drift low compared to SRCSD data. By using a temperature controlled air saturated control sample for calibration and a 6^{th} Optical Sonde for cross reference checking, the SRCSD is building a high quality data set at five stations monitoring dissolved oxygen over 30 miles of the Sacramento River.

In development of the LDOPA model, the District considered the SRCSD and USGS data available at Freeport, Hood and Rio Vista. The available data at Freeport were generally at or above saturation concentrations, but contained a high level of variability. As both the SRCSD and USGS data were collected using the Clark cell style sensors, the data at Freeport were not directly used. Instead the model input was set to the saturation concentration calculated from river temperature. Therefore, the Freeport condition was set to reflect a conservative estimate of the available data. Available Rio Vista data generally track well with the SRCSD and USGS data. The LDOPA model utilized Rio Vista data from CDEC for calibration and validation. The available dissolved oxygen data for Hood were largely inconsistent with near saturation levels measured at Freeport. The difference between the dissolved oxygen concentration data at Freeport and Hood or Rio Vista and Hood could not be represented by an oxygen sag calculation based on current understanding of sources of oxygen demanding substances in the river. Therefore, the Hood data were deemed inconsistent with the other data sets and not used in LDOPA model development. It was this inconsistency between monitoring locations that prompted the data assessment and monitoring program described in this memo.

Introduction

As part of the Sacramento Regional Sanitation District's (District) NPDES permit renewal for the Sacramento Regional Wastewater Treatment Plant (SRWTP), Larry Walker Associates (LWA)

performed a Low Dissolved Oxygen Prevention Assessment[1] (LDOPA) in support of an antidegradation analysis (ADA) for increasing the District's NPDES permitted capacity from 181 mgd to 218 mgd (average dry weather flow). The District submitted an Administrative Draft LDOPA on May 20, 2009 and received Central Valley Regional Water Quality Control Board (Regional Water Board) staff comments[2] in a letter dated October 8, 2009. A mathematical modeling tool was developed by LWA for the District to perform the LDOPA. To the extent possible, the model utilized ambient data to calibrate, validate, and provide upstream boundary conditions for the modeling effort. As noted above, the ambient dissolved oxygen data collected by the different agencies is not entirely consistent between programs. In addition, comparison of data between stations was also inconsistent with respect to expected degradation/reduction of DO levels downstream of Freeport. In their comments, Central Valley Water Board staff also expressed concern over the apparent inconsistencies of the ambient dissolved oxygen data that has been collected in the Sacramento River by various agencies. These issues were discussed in a meeting between the District and Central Valley Water Board staff on October 30, 2009 and the District submitted a proposed approach to resolving the identified issues with its response letter on November 30, 2009. The approach included conducting a monitoring program to collect reliable dissolved oxygen (DO) data and assessing the existing data sets in an effort to determine which data sets have adequate precision and accuracy for use in characterizing DO levels in the Sacramento River downstream of the SRWTP discharge. A workplan to conduct continuous DO monitoring in the Lower Sacramento River was submitted to the Regional Board on March 3, 2010 and was approved by the Regional Board on March 25, 2010.

The purpose of this memorandum is to present preliminary results from the DO monitoring program and to present the assessment of the available data sets for dissolved oxygen collected in the Sacramento River.

SRCSD Continuous Dissolved Oxygen Monitoring Update

The dissolved oxygen measurements in the Sacramento River are not necessarily consistent and are even contradictory between monitoring programs. To investigate dissolved oxygen and the measuring techniques required to produce high quality precise and accurate dissolved oxygen data in the Sacramento River the SRCSD has developed and implemented a dissolved oxygen monitoring program. SRCSD provided the Regional Water Board a proposed work plan describing monitoring dissolved oxygen, temperature, pH, and electrical conductivity (EC) using continuous sensors at five locations in the Sacramento River. The Regional Water Board reviewed and approved the proposed monitoring plan. Briefly, the monitoring includes five continuous sensors intended to measure the spatial and temporal variability of dissolved oxygen concentrations and associated water quality parameters in the river downstream of the SRWTP outfall. Specific objectives are:

- Characterize longitudinal patterns of dissolved oxygen in the lower Sacramento River from Freeport to Rio Vista.

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[1] Sacramento Regional County Sanitation District, "Low Dissolved Oxygen Prevention Assessment – Administrative Draft", dated May 20, 2009.

[2] Letter from Kenneth D. Landau, Assistant Executive Officer CVWB to Robert Seyfried, Senior Engineer SRCSD on Evaluation of Administrative Draft – Low Dissolved Oxygen Prevention Assessment Study: Sacramento Regional County Sanitation District, Sacramento County, dated October 8, 2009.

- Characterize the dissolved oxygen in terms of the saturation concentration.
- Generate a reliable data set to facilitate robust calibration and validation of the District's LDOPA model.
- Provide data to put grab sample and continuous monitoring data of river water collected by various programs in the context of the true diurnal and seasonal variability actually experienced in the river.

After receiving Regional Water Board approval of the monitoring work plan, SRCSD deployed five YSI 660XL sensors equipped with optical dissolved oxygen probes. Locations of the probes are shown in **Figure 1**. Descriptions of the monitoring locations are as follows:

- Sacramento River at Freeport Bridge pier (River Mile 46) – upstream of the SRWTP outfall;
- Sacramento River at Hood (River Mile 38) – downstream of the SRWTP outfall and at the location of a California Department of Water Resources (DWR) continuous monitoring station;
- Sacramento River at Walnut Grove Bridge (River Mile 26) – downstream of the SRWTP outfall and just downstream of the Delta Cross-Channel Canal;
- Sacramento River at Isleton Bridge (River Mile 18) – downstream of the SRWTP outfall and upstream of the influence of the Yolo Bypass, Cache Slough, and Steamboat Slough; and
- Sacramento River at Rio Vista Bridge (River Mile 13) – downstream of the SRWTP outfall and at the location of a DWR continuous monitoring station.

The initial deployment of the probes occurred April 13, 2010. As part of the monitoring program, SRCSD staff conduct site visits to each station at two week intervals to inspect and recalibrate the sensors as necessary.

For the Sacramento River Dissolved Oxygen Monitoring Study, continuous optical dissolved oxygen sensor units are used in lieu of the traditional Clark Cell dissolved oxygen sensors. While measuring dissolved oxygen with optical sensors has not been fully approved by the United States Environmental Protection Agency (USEPA) for compliance monitoring, the technology is becoming the new standard (USGS, 2006), and formal approval of the technology is expected in December 2010. SRCSD received approval from USEPA in March 2010 to utilize the optical dissolved sensors for ambient dissolved oxygen monitoring in the Sacramento River. The optical sensor device is less prone to drift compared to the Clark Cell sensors because the Clark Cell sensors rely on a plastic replaceable membrane that can foul or become damaged over time. Additionally, optical sensors do not require flowing water during measurement. DWR switched its continuous dissolved oxygen monitoring system at the Sacramento River at Hood to optical sensors in February 2008 and at the Rio Vista station in April 2008.

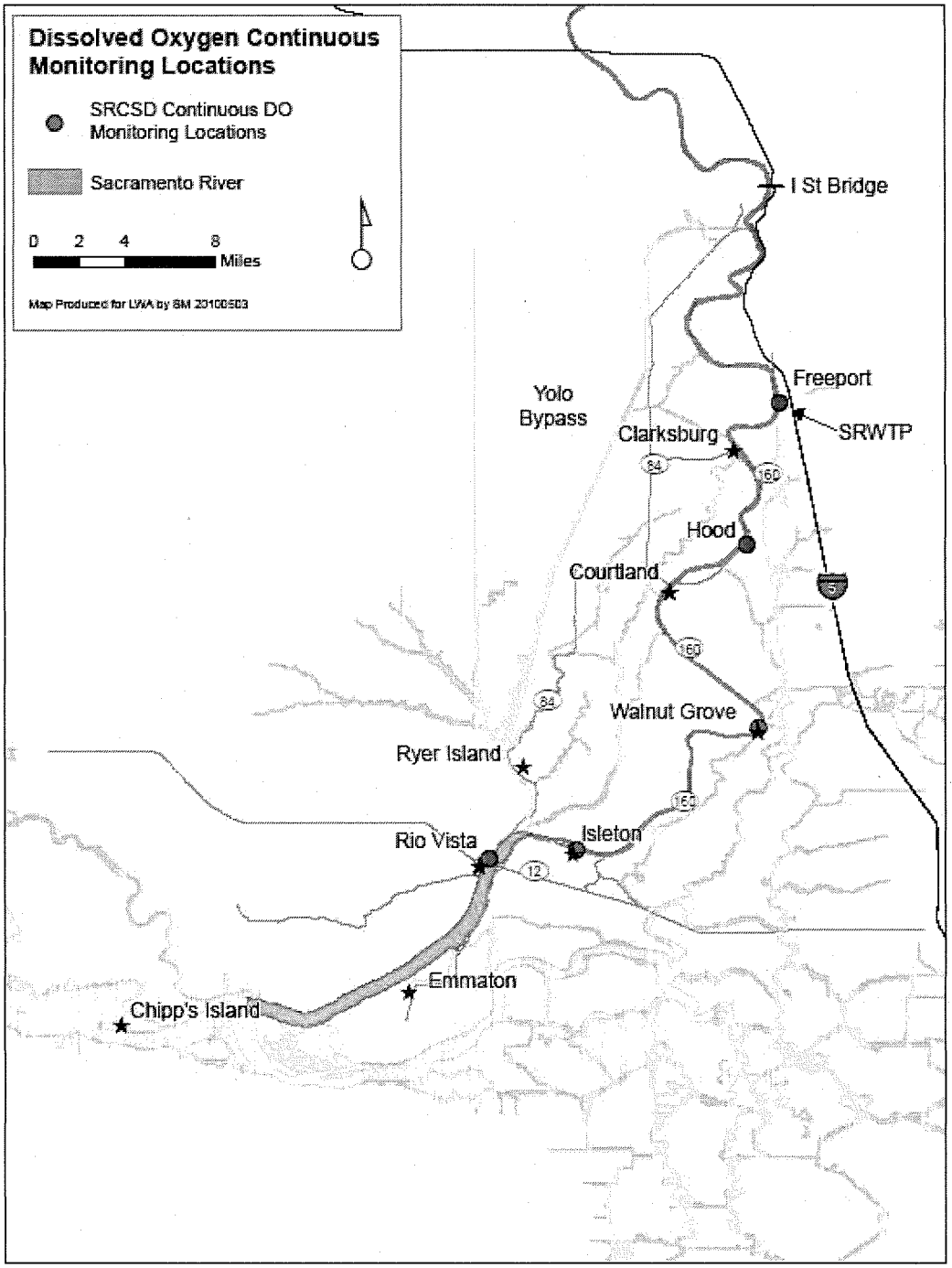


Figure 1: SRCSD Continuous Sensor Deployment Locations.

Sensor Calibration

Sensor calibration is conducted for this monitoring program using an air saturated temperature controlled water sample maintained on the sampling boat and an additional field meter. Winkler titrations are also performed at each site. A field meter is used to collect water quality measurements for dissolved oxygen, electrical conductivity, temperature, pH, and turbidity during each site visit. A grab sample is also collected for analysis of dissolved oxygen using the modified Winkler method (SM 4500-O C). These Winkler titrations are currently being performed on the SRCSD boat used for the site visits. The modified Winkler method, which is used by USGS, is applicable to most wastewater and ambient water samples that contain nitrate nitrogen and not more than 1 mg/L of ferrous iron unless additional chemicals are added prior to titration. To conduct the Winkler titration, three samples are collected in 300 mL BOD containers. The monitoring plan originally called for measuring two of the samples and running the third if the first two do not agree. However, the Winkler titration is based on a color change that is gradual and affected by background and weather conditions during the site visit such as sunlight, overcast, etc., making the exact endpoint difficult to determine. Therefore, results from the Winkler titrations have proven sufficiently variable that the field crew now routinely analyzes all three samples. Winkler titration results are not used in the sensor calibration due to the difficulty in obtaining consistent results due to the slight color change being affected by the ambient lighting.

To provide a consistent standard to check the deployed sensors, a temperature controlled dissolved oxygen saturated control sample is maintained throughout the field visits. Simply providing bubbled air through a volume of water did not result in sufficiently consistent readings between the deployed probes, as temperature variation due to solar heating or ambient cooling resulted in changes in the saturation concentration that required increased levels of air bubbling to maintain saturation. The levels of bubbling exceeded the capacity of the available equipment. By maintaining the temperature of the saturated dissolved oxygen control sample in the container, the dissolved oxygen concentration in the container is easily controlled by the field crew. At each station, the deployed probe is removed from the river and placed in the saturated dissolved oxygen standard allowing all deployed probes to be compared to a known concentration. Additionally, a sixth calibrated probe is carried throughout the calibration visit to measure the dissolved oxygen concentration in the container and river at each site to record possible variation in control sample dissolved oxygen concentration between sites and to allow each deployed probe to be compared to the readings of the sixth probe which provides a comparison between each of the deployed probes on each visit.

The results of a calibration site visit performed May 25, 2010 for the Hood station are displayed on **Figure 2**. The SRCSD continuous dissolved oxygen data are displayed concurrently with the CDEC continuous measurements on the Figure. The first component of the site visit is to measure the river dissolved oxygen with the extra dissolved oxygen probe (6^{th} probe), which is calibrated to the temperature controlled saturated dissolved oxygen control sample. The deployed probe is then placed in the control sample and its reading checked to ensure the saturation concentration is being measured. Finally, Winkler titrations are performed on samples of the river water. Winkler results do not reflect the concentration of dissolved oxygen in the river. Note the SRCSD probe deployed at Hood responded to the control volume, measuring near the saturation concentration, and the 6^{th} probe measured river oxygen concentrations consistent with the deployed probe. However, as

evidenced in **Figure 2**, the CDEC dissolved oxygen measurements are consistently lower than the SRCSD levels. If the deployed sensor is not measuring the saturation concentration in the control sample, or levels not consistent with the 6th probe, the deployed sensor is recalibrated. Site visits are currently preformed for all deployed SRCSD sensors at a two week interval.

SRCSD Dissolved Oxygen Continuous Monitoring Results

Dissolved oxygen data collected to date for the monitoring sites are presented in **Figures 3** to **5**. Note that the stations at Walnut Grove and Isleton are not equipped with telemetry so data are downloaded at each site visit. For each station the available verification with the saturated control sample and 6th Sonde are overlaid on the plots.

Figure 3 presents the SRCSD period of record of dissolved oxygen measurements, site visit history, and corresponding CDEC measurements at Hood. Note daily average dissolved oxygen concentrations are overlaid on the continuous data in **Figure 3** as a reference to compare the SRCSD and CDEC data. Additionally, there are considerable differences between the levels of dissolved oxygen being recorded by the SRCSD and CDEC programs at the Hood station.

Figure 4 presents the SRCSD period of record dissolved oxygen for the Rio Vista station with associated site visit calibration data. Additionally, the CDEC data recorded at Rio Vista are overlaid on the figure. Note that as with the Hood station, the CDEC data exhibit a greater variation about the daily mean value; however, the data from the SRCSD and CDEC programs at Rio Vista correspond better than for the Hood station.

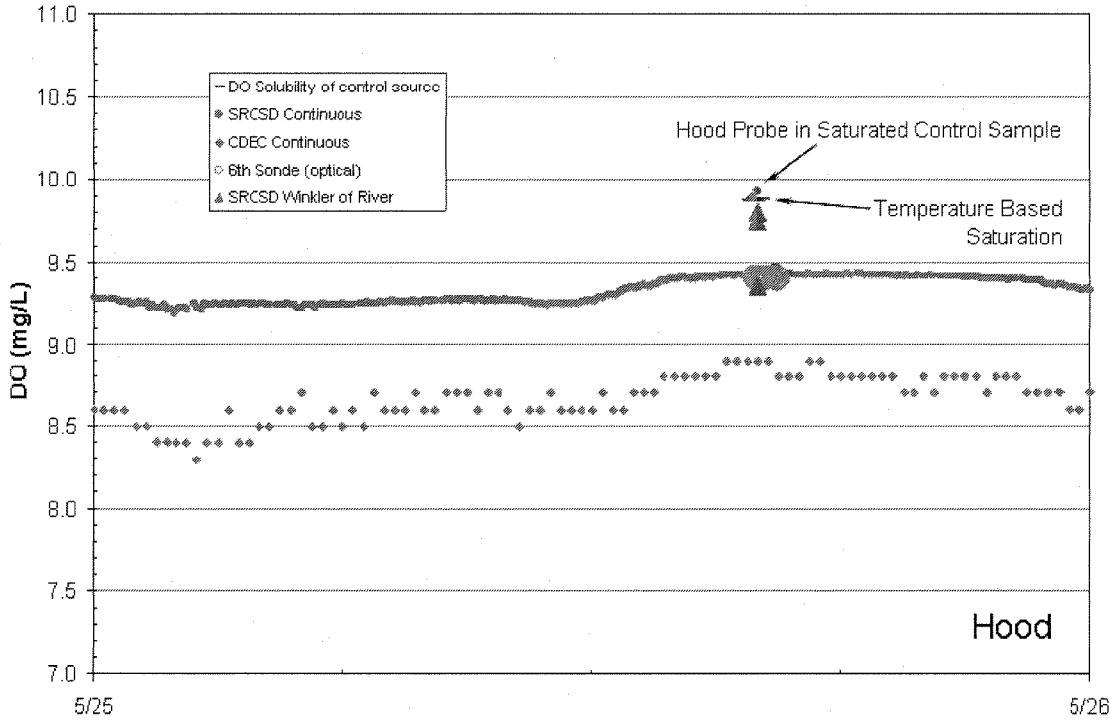


Figure 2: Dissolved Oxygen Probe Calibration Site Visit, May 25, 2010 for the Hood Station.

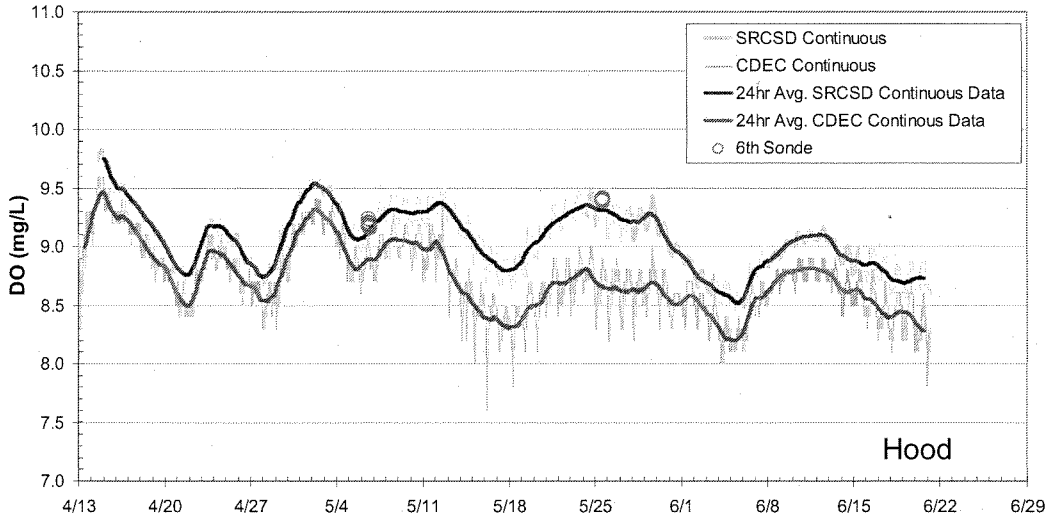


Figure 3: Period of Record for SRCSD Dissolved Oxygen Measurements and Calibration History at Hood.

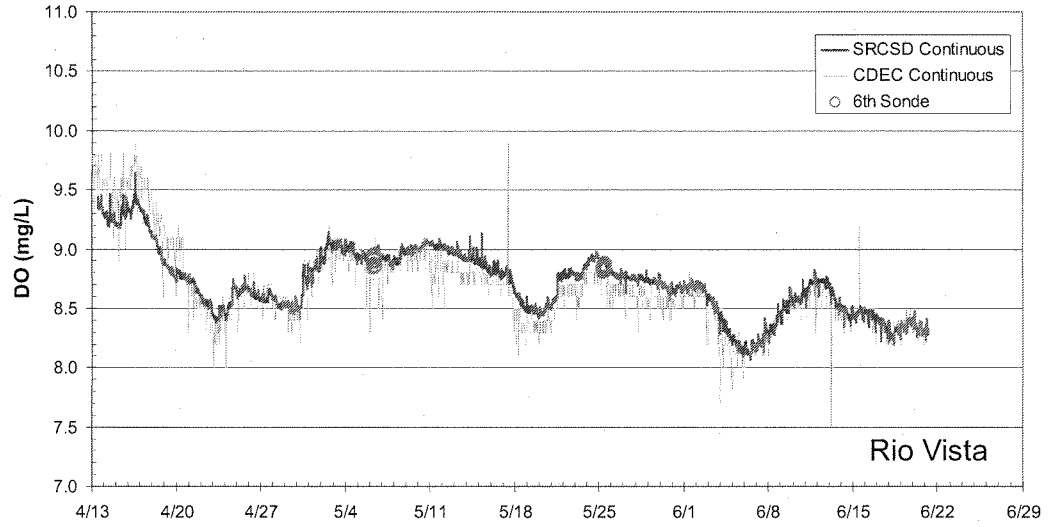


Figure 4: Period of Record for SRCSD Dissolved Oxygen Measurement and Calibration History at Rio Vista.

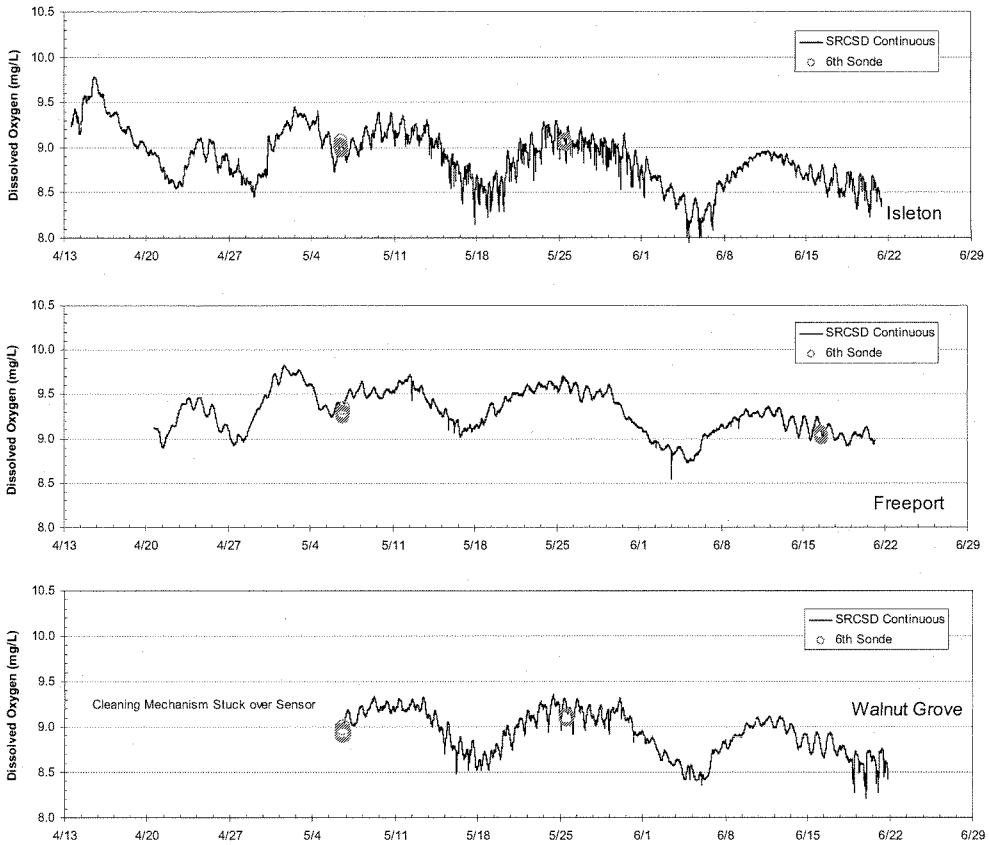


Figure 5: SRCSD Continuous Dissolved Oxygen Measurement for Sacramento River at Freeport, Isleton and Walnut Grove.

Inspection of the data shown in **Figures 3** to **5** reveals that the dissolved oxygen concentration generally decreases as the Sacramento River flows from Freeport to Rio Vista. To facilitate a comparison between the dissolved oxygen from the monitored stations, the data from each station can be plotted as the time the parcel of water passed Freeport by subtracting the flow time between Freeport and the station. By plotting the data as "Freeport Time" the change in dissolved oxygen of a parcel of water is directly apparent as it moves downstream. The available dissolved oxygen data from each of the five stations monitored by the SRCSD are plotted in **Figure 6**.

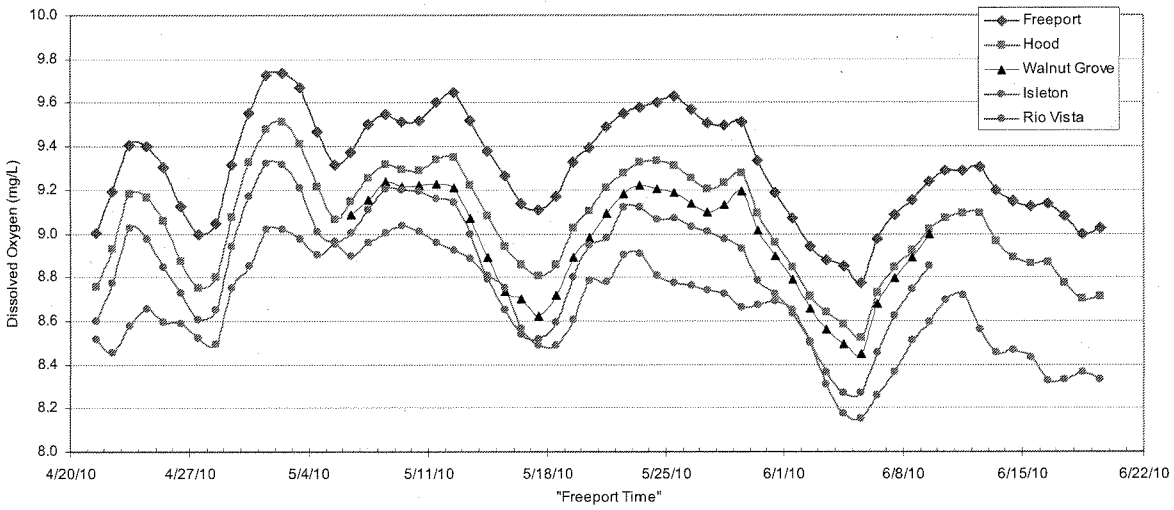
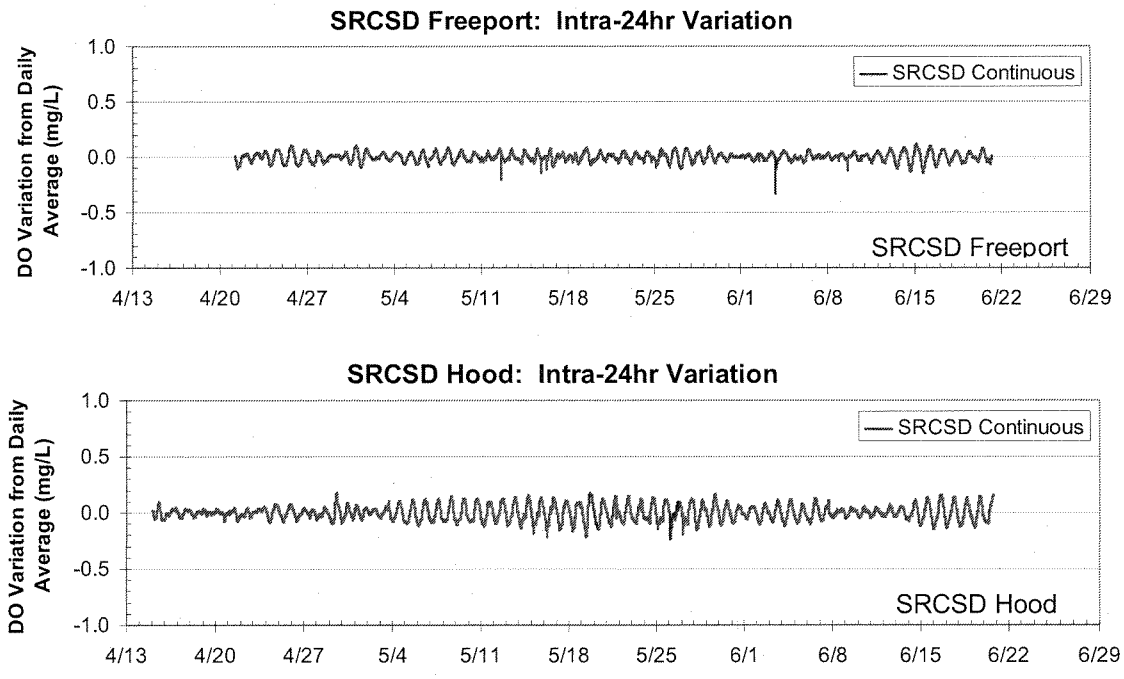


Figure 6: SCRSD Continuous Dissolved Oxygen Concentrations Presented as time discharged at Freeport, "Freeport Time".

To assess the intra-day variability, the daily average dissolved oxygen may be subtracted from the individual measurements. The intra-day variability for each of the monitored sites is presented in **Figure 7**. The variation tends to increase as the river flows from Freeport to Isleton, however once the river widens at Rio Vista, the variation decreases substantially.



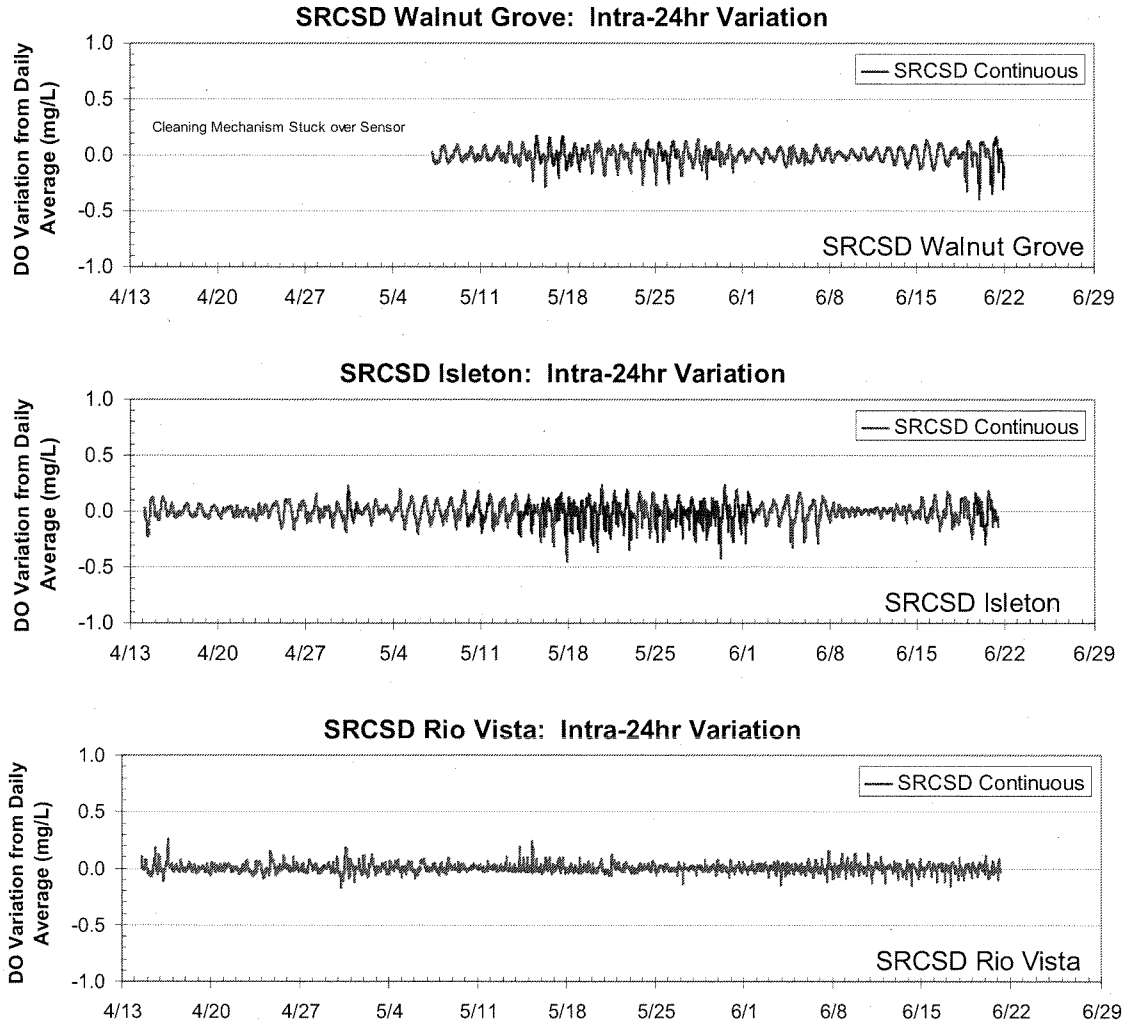


Figure 7: Intra-day Variation of Dissolved Oxygen at SRCSD Continuous Monitoring Locations.

The SRCSD data are compared to the data from CDEC at Hood and Rio Vista in **Figure 8**. The sensor manufacturer specifies the dissolved oxygen measurements should be within ±0.1 mg/L, so that two probes similarly calibrated, measuring the same water should fall within the highlighted box on **Figure 8**. The readings at Hood are consistently different between the two programs; however the SRCSD and CDEC data correspond well for the Rio Vista station.

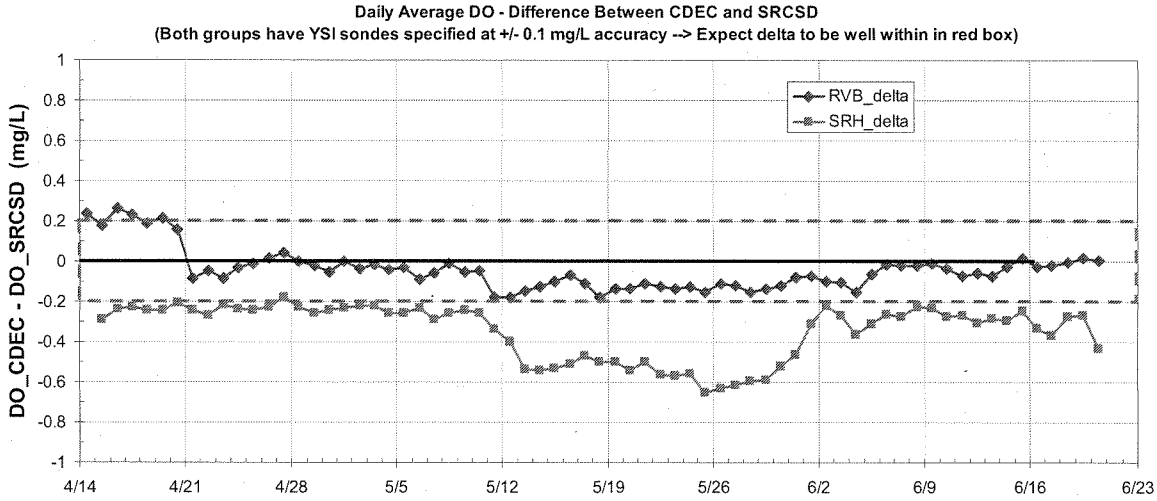


Figure 8: Differential Between CDEC and SRCSD Continuous Data at Hood and Rio Vista Stations on the Sacramento River.

Summary of SRCSD Continuous Dissolved Oxygen Monitoring

Utilizing the temperature controlled air saturated control sample as a verification/calibration standard along with employing a 6th Sonde for cross-reference checking the deployed optical sensors has allowed SRCSD to collect high quality dissolved oxygen data in the Sacramento River that are consistent across five stations. SRCSD previously used the Clark cell sensors as they carry USEPA approval, where as the optical sensors currently do not. SRCSD pursued and acquired USEPA approval to use the optical sensors for dissolved oxygen monitoring in the Sacramento River. To date the SRCSD data provide a consistent picture of dissolved oxygen as the river flows from the SRWTP discharge at Freeport to Rio Vista. The measurement of dissolved oxygen at Rio Vista is consistent between the SRCSD and CDEC programs. However, the CDEC dissolved oxygen data at Hood are inconsistent with the corresponding SRCSD data. The CDEC dissolved oxygen data are consistently measuring low and drift low compared to SRCSD data. By using a temperature controlled air saturated control sample for calibration and a 6th Sonde for cross reference checking, the SRCSD is building a high quality data set of five stations monitoring dissolved oxygen over 30 miles of the Sacramento River.

Dissolved Oxygen Data Assessment

Several Agencies conduct ambient dissolved oxygen monitoring in the Sacramento River including the District, the Sacramento Coordinated Monitoring Program (CMP), Department of Water Resources (DWR), environmental monitoring program (EMP) performed jointly by DWR and the United States Bureau of Reclamation, U.S. Geologic Survey (USGS), Regional Water Board, and the City of Rio Vista. The District compiled data collected by the different agencies to use in the 2009 LDOPA model development. Review of the data identified some inconsistencies as discussed above prompting an assessment of the monitoring procedures and data collected by the different programs. Specifically, the data collection methods were evaluated with respect to the accuracy and precision of the data collected.

Dissolved oxygen data are desired for several purposes in the LDOPA model development including: calibration of model parameters and constants, validation of model performance, and setting upstream boundary conditions. Because the data are used in different ways to fulfill these activities, there are different requirements in data quality for the different activities. For example the calibration of model parameters may require the difference in concentrations between two sites on the river or may require the difference in concentration between two times at the same location. To have confidence in the differences in concentrations between two sites, data from both sites need to be both accurate and precise.

Accurate data reflects the correct absolute value of the concentrations (i.e. the data set has the correct mean, but may have high variability), whereas precise data capture changes in concentration correctly (i.e. the data set has a small standard deviation, but may have an incorrect mean). Accurate and precise data have both the correct mean with a small standard deviation around the mean. Only precise data is required for data sets where the difference in concentration at different times for the same location is used for modeling purposes. Calibration of the model could be accomplished with data that are only precise; however, the different data sets would have to be treated separately. If data sets were both accurate and precise, the data could be pooled and the calibration would likely result in a more robust model. If data from several programs is used for validation of the model each data set must be precise and accurate so that both the absolute value of the dissolved oxygen and changes over time and conditions can be compared to model output. If one program collects data at several locations along the river at the same accuracy, the data would at least need to be precise so that measured changes in dissolved oxygen may be compared to modeled changes in dissolved oxygen. Upstream boundary conditions (i.e. model input) need to be both precise and accurate so that model calculations of the changes that occur downstream can be considered precise and accurate. In every modeling effort, the available data sets for calibration, validation, and model inputs range in quality, and the data need to be treated appropriately.

The District developed an approach to evaluating available DO data and discussed this approach with Regional Water Board staff on December 14, 2009. The assessment approach included a review of the standards of practice and methods of determining dissolved oxygen concentrations, identification of programs with dissolved oxygen data sets, evaluation of the dissolved oxygen as recorded by different programs, and ranking of the data sets in three categories: (1) accurate and precise, (2) precise but not necessarily accurate, and (3) potentially not precise and not accurate. This approach was used to compare the data sets from the various agencies to determine the quality of the data and the suitability of the data for calibration of model constants, validating the modeling effort, and setting the upstream boundary conditions.

The tasks that comprised this effort were:

1. Define proper DO measurement protocols
2. Review equipment used to measure DO
3. Identify and review programs monitoring DO in the Sacramento River
4. Evaluate data sets collected by the identified programs
5. Develop ranking method for data set evaluation
6. Rank monitoring programs with respect to data quality

The results for each task are described below. It should be noted that for Task 3, review of monitoring programs was expected to include a field visit to observe monitoring stations and protocols for the various programs. However, it was not possible to arrange site visits with the subject programs as discussed more under Task 3 below.

Task 1: Dissolved Oxygen Measurement Protocols

Standard Methods 4500-O G[3], and the USGS National Field Manual (NFM) Chapter 6 provides guidance for the collection of dissolved oxygen data[4]. The USGS NFM contains guidance for four types of procedures used to measure dissolved oxygen including the amperometric, luminescent-sensor, spectrophometric and iodometric methods. The procedures for each method are reviewed below. The USGS guidance was used as the basis for defining measurement protocols for dissolved oxygen by either grab or continuous monitoring.

Amperometric Method

The amperometric method is the most commonly used method by the USGS. It consists of a temperature-compensating meter connected to a polarographic-membrane type of sensor. The sensor was developed by Dr. Leyland Clark and is sometimes referred to as a Clark Polarographic Sensor or Clark cell sensor. It is made up of electrolyte solutions, membranes, and thermistor thermometers. This sensor is easy to use for both discrete and in situ measurements, but because of the multiple sensing components it does require a certain amount of maintenance. The main performance issue with amperometric sensors is calibration drift resulting from loose or damaged membranes or by sensor contact with hydrogen sulfide. Loss of performance can go unnoticed due to lack of indications from the sensor readings.

The amperometric method requires frequent calibration depending on the specific model used, but for reliable data, generally calibration on the day of sampling is recommended. The owner's manual for each field meter should always be referenced.

Luminescent-sensor Method

The luminescent-sensor method measures light emission characteristics of a luminescent-based reaction at the sensor-water interface. USGS use of this method is relatively new so there are not years of historical use. An ideal aspect of the luminescent-sensor method is that it does not have any consumables such as membranes or solutions. Therefore regular maintenance and inspection of the membrane is no longer needed. Another benefit to this method is that it does not actually consume oxygen at the sensor-water interface, thus it is ideal for slow or stagnant water as no stirring is required. Also no sources of interference in natural aquatic systems have been discovered. The luminescent-sensor method is also called an optical ROX (Reliable Oxygen Sensor) by YSI, a major manufacturer.

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[3] Clesceri, L.S., A.E. Greenberg, A.D. Eaton, Standard Methods for the Examination of Water and Wastewater, 20th ed.

[4] Lewis,M.E., 2006, Dissolved Oxygen (version 2.1): U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chap. A6., section 6.2, June, accessed Nov. 4, 2009 from http://pubs.water.usgs.gov/twri9A6/ (http://water.usgs.gov/owq/FieldManual/Chapter6/6.2_contents.html)

Sensors using the luminescent-sensor method normally come pre-calibrated by the manufacturer so calibration is only needed periodically. Nonetheless, sensor readings should be verified before each sampling event.

One or two point calibration for both amperometric and luminescent-sensor methods

The luminescent-sensor and amperometric method both require one or two point calibration, depending on the specific sensor model. The one-point calibration method uses air saturated water or water saturated air for a calibration point of 100 percent saturation. Two point calibration uses calibration points at zero percent as well as 100 percent saturation. Two point calibrations are ideal for low dissolved oxygen situations.

It is important to check dissolved oxygen meter calibration at each field site, as this will insure accurate and consistent data. Amperometric instruments should also be recalibrated each time the meter is powered off.

Spectrophometric Method

The spectrophometric method provides accurate DO measurements in suboxic waters with a range of 0.1 mg/L to 1.0 mg/L. Rhodazine-D colorimetric method minimizes atmospheric interaction with sampled water. This method is typically used for groundwater sampling but it can also be adapted for anoxic lakes and reservoirs. Since the Sacramento River has high dissolved oxygen levels and is never anoxic, this technique is not a suitable method for use in the Sacramento River.

Iodometric (Winkler) Method

The Winkler method is ideal for calibration of instruments in a laboratory setting but it falters in its ease of use in the field. As noted above, the Winkler titration is based on a color change that is gradual and affected by background and weather conditions including whether it is sunny or overcast, etc., making the exact endpoint difficult to determine. The USGS uses the Alsterberg-Azide modification to the Winkler titration procedure for iodometric determination of dissolved oxygen which should yield an accuracy of 0.05 mg/L. There are three main issues with this method:

- The accuracy of the measurements is dependent on the experience and technique of the data collector, thus extensive training and practice is required. This also poses a problem as each recorded data value will have a different percent error.
- Environmental interference requires advanced knowledge of sample chemistry.
- This method may make it difficult to not expose the sample to environmental oxygen, while in the field.

This method requires an intricate sampling procedure to minimize error.

The luminescent-sensor method is arguably the best method for measuring dissolved oxygen as it is as accurate as the amperometric method but also provides sensors that require less maintenance, reducing possible drift and calibration issues. Although the iodometric (Winkler) method is very accurate, it lacks the ease of implementation that the field sensors allow.

Task 2: Equipment to Measure Dissolved Oxygen

Programs collecting dissolved oxygen in the Sacramento River may either be collecting grab measurements or recording continuous measurements. The types of equipment/manufacturers

utilized in dissolved oxygen measurement by these programs are listed below along with relevant equipment specifications.

When comparing the possible dissolved oxygen field meters it is important to note a few of the important specifications. The range will describe the values of dissolved oxygen in which the sensor can operate. Since the water bodies of interest all fall within a common range this value does not play a significant role in the assessment. Accuracy of an instrument varies based on the measured value of dissolved oxygen. Instruments become less accurate as DO readings surpass 20 mg/L, but for this case the accuracy of the instrument in conditions less than 20 mg/L will be noted. Lastly the resolution of the meter describes the sensitivity of the instrument.

YSI Multi-Parameter 600XL

Steady state polarographic (amperometric)
Range 0 to 50 mg/L
Accuracy 0 to 20 mg/L (1 percent of the reading or 0.1 mg/L, whichever is greater); 20 to 50 mg/L (15 percent of the reading)
Resolution 0.01 mg/L

YSI Multi-Parameter 550A

Steady state polarographic (amperometric)
Range 0 to 50 mg/L
Accuracy 0 to 20 mg/L (2 percent of the reading or 0.3 mg/L, whichever is greater); 20 to 50 mg/L (6 percent of the reading)
Resolution 0.01 mg/L

YSI Multi-Parameter 556XL

Steady state polarographic (amperometric)
Range 0 to 50 mg/L
Accuracy 0 to 20 mg/L (2 percent of the reading or 0.2 mg/L, whichever is greater); 20 to 50 mg/L (6 percent of the reading)
Resolution 0.01 mg/L

YSI 6150 ROX Dissolved Oxygen Sensor

Luminescent-sensor Method
Range 0 to 50 mg/L
Accuracy 0 to 20 mg/L (1 percent of the reading or 0.1 mg/L, whichever is greater); 20 to 50 mg/L (15 percent of the reading)
Resolution 0.01 mg/L

While all four sensors will give accurate and precise results, the YSI 556XL and YSI 550A specifications show that they read slightly less accurately than their counterparts (2 percent deviation of the reading versus 1 percent). The remaining sensors are identical in specifications. Since the ROX dissolved oxygen sensor uses a luminescent-sensor method, it would be the preferred choice for collecting accurate and precise data.

Task 3: Programs Monitoring Dissolved Oxygen

As noted above, the following agencies have conducted DO monitoring in the Sacramento River: the District, CMP, EMP, DWR, USGS, Regional Water Board and the City of Rio Vista. The monitoring programs were reviewed with respect to protocols and equipment used, as discussed below. Due to similarities in sampling conditions, data from the District and EMP were included in the CMP and DWR datasets, respectively.

USGS

The United States Geological Survey has dissolved oxygen data for the Sacramento River at Freeport site that dates from 2006 to 2008. The data was gathered using a YSI Multi-Parameter 600XL probe which had been calibrated the morning of each sampling event. The USGS regularly sampled during the morning between 10 am and 12 pm and the sample was taken mid-channel at a depth of 1 to 2 feet.

CMP/SRWTP Receiving Water Monitoring

The Coordinated Monitoring Program has monitored data for dissolved oxygen at Freeport since 1997. The CMP also uses a YSI Multi-Parameter 600XL probe and they perform a calibration before each planned sampling event. The CMP samples in the morning (10-12 pm), at mid-channel and at a depth of 2 to 5 feet.

Regional Water Board

The Regional Water Board collected dissolved oxygen data for an ammonia study at various sites along the Sacramento River during the summer of 2009. They sampled using a YSI Multi-Parameter 556 hand held probe. The sampling was performed mid-channel at an unknown depth and time.

DWR (CDEC)

DWR's CDEC (California Data Exchange Center) program has installed continuous sensors at the Rio Vista and Hood sites. At the Sacramento River at Hood site between December 1999 and February 2008, the water sample was pumped through tubing from the river to a dissolved oxygen sensor located in an above-river sampling enclosure. The tubing was placed at a depth of one meter (3.2 ft) and was mounted on a float to keep a constant depth despite the fluctuating tides. After February 2008, the sensor was itself mounted on a float, eliminating the need to pump the sample through tubing. This new setup recorded values, constantly at a depth of one meter. Because of the inconsistencies in the CDEC data recorded at Hood with Freeport data and with the SRCSD Continuous Monitoring at Hood, a site visit to better understand the monitoring setup at Hood was requested but was not conducted. Communication with DWR staff regarding the Hood monitoring station is found in Appendix B.

The Sacramento River at Rio Vista site pumped the river sample to the sensor starting in 1984 and continued with this method through April of 2008, at this point they also placed the sensor on a float in the river. Other than the noted differences in dates, the setup at Rio Vista is the same as the site at Hood.

For both monitoring sites at Rio Vista and Hood, since April 2008, CDEC uses a YSI probe with an optical ROX sensor. Prior to that time DWR used a Clark sensor.

City of Rio Vista

The City of Rio Vista conducted river sampling roughly every three months for a two year period. The data begins in 2006 and goes through 2008. They measured dissolved oxygen using a YSI Multi-Parameter 550A hand held probe.

EMP

The Environmental Monitoring Program is carried out jointly by the Department of Water Resources and the United States Bureau of Reclamation. The EMP collects automated dissolved oxygen readings from the bank of the Sacramento River at Hood. The data begins in 1998 and continues through 2009. There is no knowledge of their equipment type, sampling time, or calibration procedures.

Table 1 compares the DO monitoring programs collecting data in the Sacramento River.

Table 1 Collection Agencies and Methods

	USGS	CMP/SRWTP	Regional Water Board	EMP	DWR (CDEC)	City of Rio Vista
Date Range	2006 to 2008	1997 to Present	2009	1998 to 2009	1999 to Present	2006 to 2008
Site	Freeport, and Rio Vista	Freeport and RM44	Multiple Sacramento River Locations	Hood	Hood and Rio Vista	Rio Vista
Field Meter Type and Model	YSI Multi-Parameter 600XL	YSI Multi-Parameter 600XL	YSI Multi-Parameter 556	-	YSI Clark/ Optical ROX[1]	YSI Multi-Parameter 550A
Method	Clark (amperometric)	Clark (amperometric)	Clark (amperometric)	-	Clark/ROX[1] (amperometric / luminescent)	Clark (amperometric)
Sample Frequency	Bi-Monthly	Weekly	Bi-Weekly	Bi-Monthly	Hourly	Periodically
Time of Calibration	Morning of sampling event	Morning of sampling event	Morning of sampling event	-	Periodically[2]	-
Sample Location	Mid-Channel	Mid-Channel	Mid-Channel	Bank	Near Bank	Bank
Depth of Sample	1 to 2 feet	2-5 feet	-	-	~3 feet	2 feet
Time of Sampling	Morning (10-12 pm)	Morning (10-12 pm)	-	-	Continuous (hourly)	-

[1] DWR changed sensor from Clark to optical in 2008
[2] Calibration schedule has not been provided

Task 4: Evaluation of Program Data Sets

The next step in determining the reliability of each dataset was to compare multiple sources in order to observe any trends or similarities. The consistency of the data over space and time and in

comparison with other parameters was evaluated for each program. To the extent possible, each data set was:

- Analyzed to determine correlations with environmental factors such as river flow rate, river temperature, time of sample collection, and tidal cycles;
- Processed via time series analysis to determine long term trends, frequencies of observed variability, and seasonality;
- Compared to other data sets monitoring in similar locations and time frames; and
- A one-way analysis of variance (ANOVA) was performed to compare two datasets in order to determine statistical significance. For example, based on a 95 percent confidence interval the CMP and USGS data were well correlated.

Overall, it was difficult to reach definitive conclusions regarding the quality of the data beyond the comparisons in technology and calibration methods discussed above. A discussion of the data collected by each agency is found in Appendix A. Communication regarding calibration and other aspects of the monitoring programs are found in Appendix B. The data for each of the programs is found in Appendix C.

Tasks 5 and 6: Ranking of Programs

Data from the different programs were assessed based on the accuracy/reliability of the protocols and equipment used and the quality of the resulting data. The ranking is based on the accuracy and precision of program implementation by the monitoring agencies. Each program was evaluated on how well they adhere to the ideal methods (i.e., most accurate probes, adhering to calibration and sampling protocols, producing calibration records, etc.). Accuracy takes into account the specifications of the sampling instrument as well as the statistical analysis of the data. Precision depends on how often calibrations were performed and how well the monitoring SOPs followed the recommended guidelines set forth by the USGS and EPA as appropriate.

USGS. This dataset was collected using correct sampling procedures and recommended instrumentation. Therefore it was determined to be accurate and precise.

CMP/SRWTP Receiving Water Monitoring. The collection of these values followed the correct sampling protocol as did their sampling devices. In comparison the data also corresponded linearly to the USGS results. However, the readings have a greater range than the corresponding USGS measurements. Therefore it was determined to be precise but potentially not accurate.

Regional Water Board. The Regional Water Board used an older model YSI instrument, compared to the new ROX sensor, in collecting the dissolved oxygen results, but they did follow correct methods. Although the methods were followed there is not a significant amount of data and thus it is difficult to be sure of consistency. The data is ranked as accurate and precise but its usefulness will be limited by the amount of data. Therefore it was determined to be accurate and precise.

DWR (CDEC). This data is handled differently because it is a continuous sensor. Although calibration and maintenance was performed, it was not done as often as other datasets. One significant issue with this dataset was the method of pumping the sample to the sensor prior to

2008. As the USGS dissolved oxygen handbook states, "Dissolved oxygen must be measured in situ. Never measure DO in subsamples from a sample splitter." Although they are now measuring samples in situ with a luminescent-sensor sampler, the data before 2008 should not be regarded as accurate. The methods since 2008 now match the recommended protocol by USGS making the data more accurate, but the large sensor drift in December of 2008 and unclear calibration history should also be noted. Therefore, it was determined to be precise but potentially not accurate.

City of Rio Vista. The instrumentation used at Rio Vista is a slightly older and less precise YSI model, compared to the ROX sensor, but more importantly there is no information on calibration. Therefore, this data cannot be deemed as accurate but it is precise.

EMP. The data is collected by an automated device, but there is no knowledge of specifications or calibration, therefore this data cannot be deemed as precise or accurate.

Data Assessment Summary

Table 2 summarizes the conclusions found after analyzing the data from the multiple monitoring agencies. The identified issues are accuracy of the data from DWR, EMP and the City of Rio Vista because either there was a lack of calibration information or there was evidence that calibration SOPs had not been followed. The EMP data at Hood was considered to be imprecise because of the lack of information regarding the sampling equipment. The SRCSD Continuous DO monitoring described in this memo following the recommended procedures (which is ongoing) will help with creating an accurate and precise dataset for future use.

Table 2 Monitoring Agencies and Conclusions

Monitoring Agency	Site	Conclusion
USGS	Freeport and Rio Vista	Accurate and precise
CMP/SRWTP	Freeport and RM44	Precise but potentially not accurate
Regional Board	Multiple Sacramento River Locations	Accurate and precise
DWR (CDEC)	Hood and Rio Vista	Precise but potentially not accurate
City of Rio Vista	Rio Vista	Precise but not accurate
EMP	Hood	Neither precise nor accurate

Conclusion

In developing both the 2009 and 2010 versions of SRCSD Low Dissolved Oxygen Prevention Assessment (LDOPA) model, Freeport dissolved oxygen is modeled as the temperature dependent saturation concentration rather than using either USGS and SRCSD data. However, available data from USGS and SRCSD indicate conditions generally at or above saturation. The current DO continuous monitoring data at Freeport indicate that DO is typically at 95%-98% of saturation indicating that using saturation values at Freeport is a reasonable assumption for the model. Based on the data assessment and the current DO monitoring program, sufficient questions remain about the available dissolved oxygen data for the Sacramento River at Hood and these data were not used in LDOPA model development. Available data from USGS and DWR for dissolved oxygen at Rio Vista were utilized to calibrate and validate the LDOPA model. The data assessment and the

current DO monitoring program indicate that this data is accurate and precise and, therefore, appropriate for use in model validation. Ambient data at Emmaton and the Confluence of the Sacramento River and San Joaquin River were also used in model validation. This data is collected by the municipal water quality investigation (MWQI) program run by DWR, however, no information is currently available about the quality of this data.

Appendix A: DO Data Collection Programs

USGS

The United States Geologic Survey has recent data at both the Freeport and Rio Vista sites as shown in Figures A1 and A2. A few of the outliers within the Freeport dataset were investigated in order to be certain that no errors were recorded. The USGS confirmed successful sampling on those days and field logs did not show any indications of mishandling. That said, the observed outliers appear to be inconsistent with other observed values, with no rationale supporting their validity.

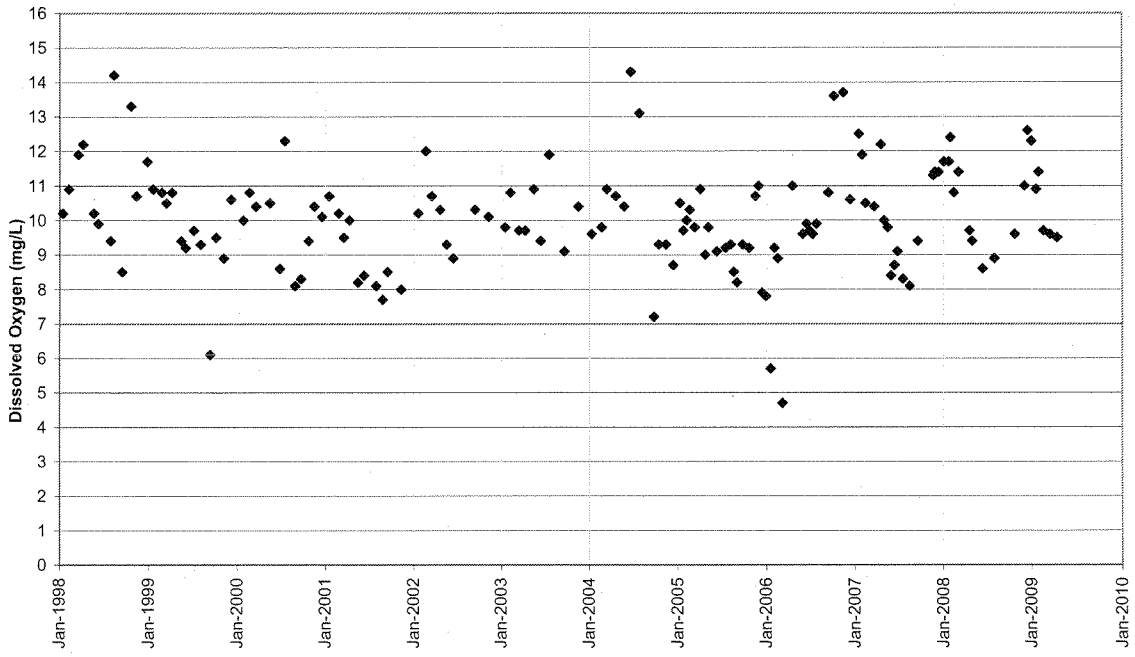

Figure A1. USGS Dissolved Oxygen in Sacramento River at Freeport 1998 to 2009

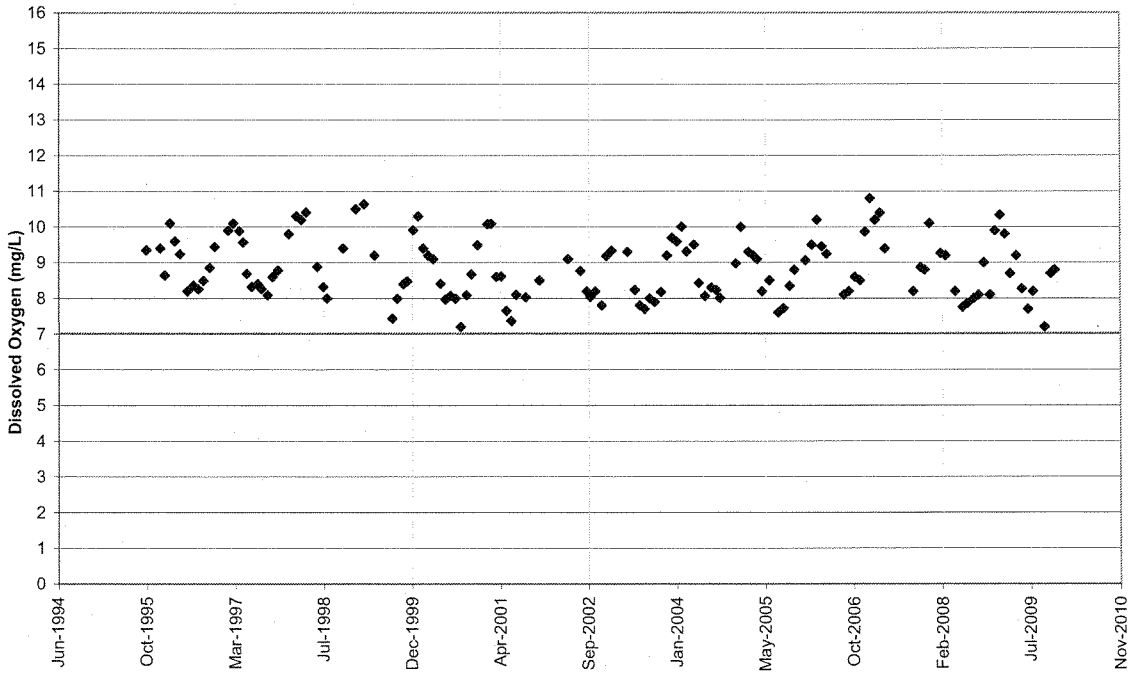

Figure 9A2. USGS Dissolved Oxygen in Sacramento River at Rio Vista 1995 to 2009

CMP/SRWTP Receiving Water Monitoring

The Coordinated Monitoring Program (CMP) conducted sampling at both Freeport and River Mile 44 as shown in Figures A3 and A4. River Mile 44 is located downstream from Freeport and the two datasets can be compared to see downstream trends. The data points that are below 7 mg/L at both Freeport and River Mile 44 were taken on the same day in April of 2000.

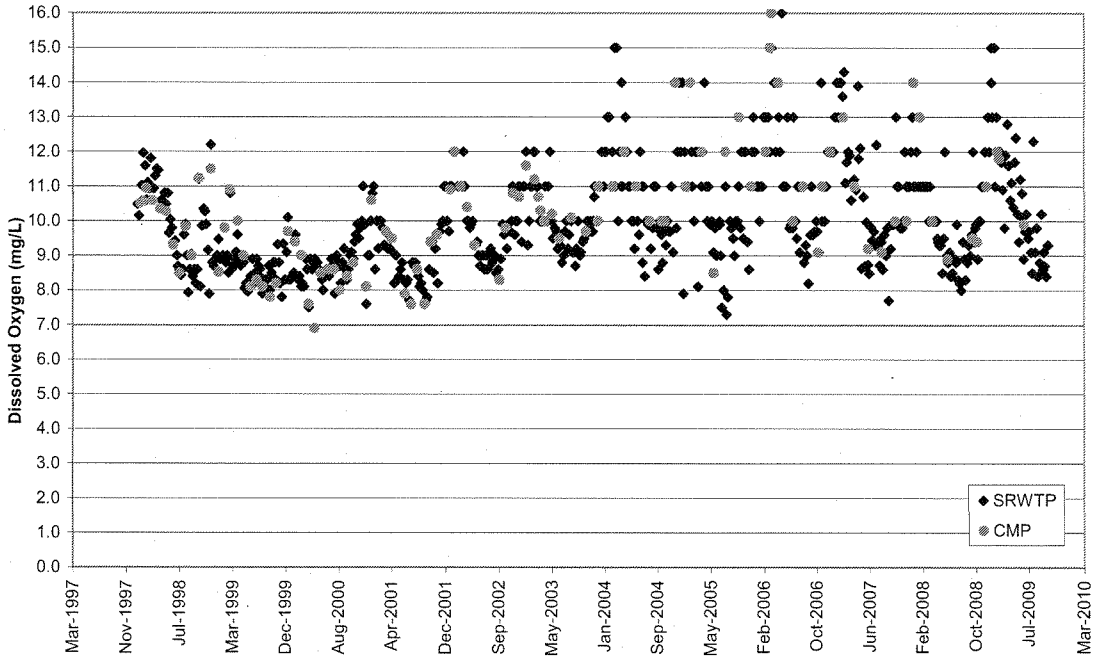

Figure A3. CMP and SRWTP Dissolved Oxygen in Sacramento River at Freeport 1998 to 2009

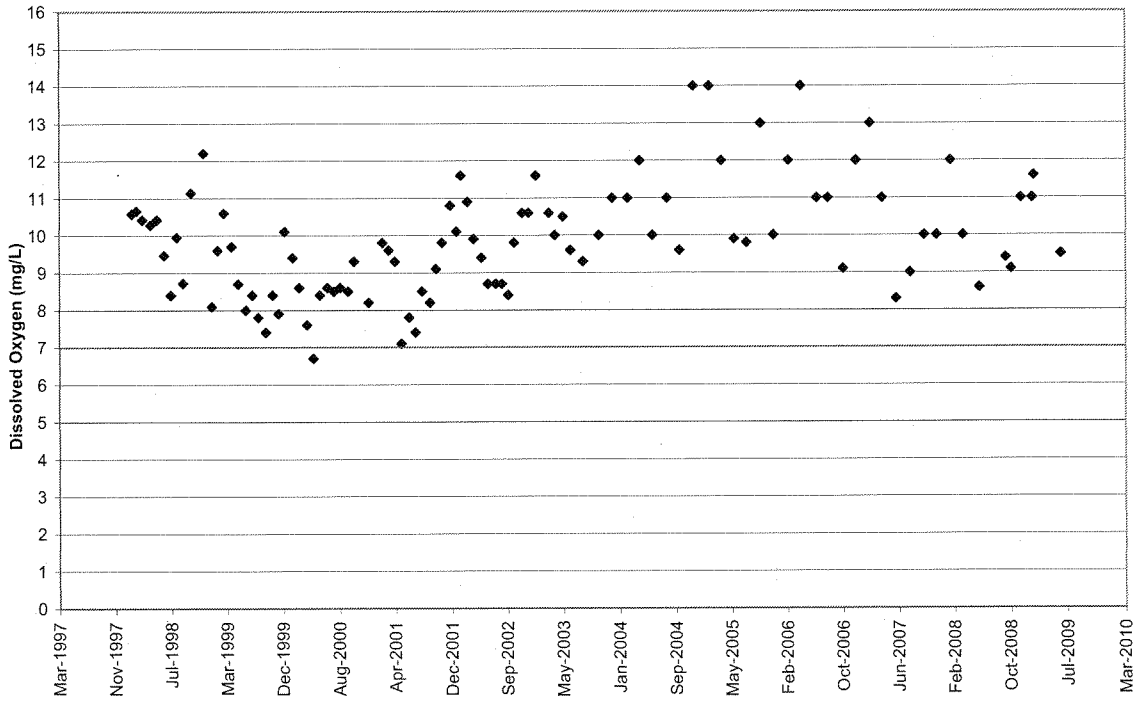

Figure 10A4. CMP Dissolved Oxygen in Sacramento River at River Mile 44 1998 to 2009

In order to assess the consistency of the CMP/SRWTP data, Figure shows a comparison with the USGS data at Freeport. Since the two dataset's sampling events do not always fall on the same day; data points were compared if they were within 4 days or less of each other. Note that while the general trend is a 1:1 relationship, there is considerable variation between the individual readings.

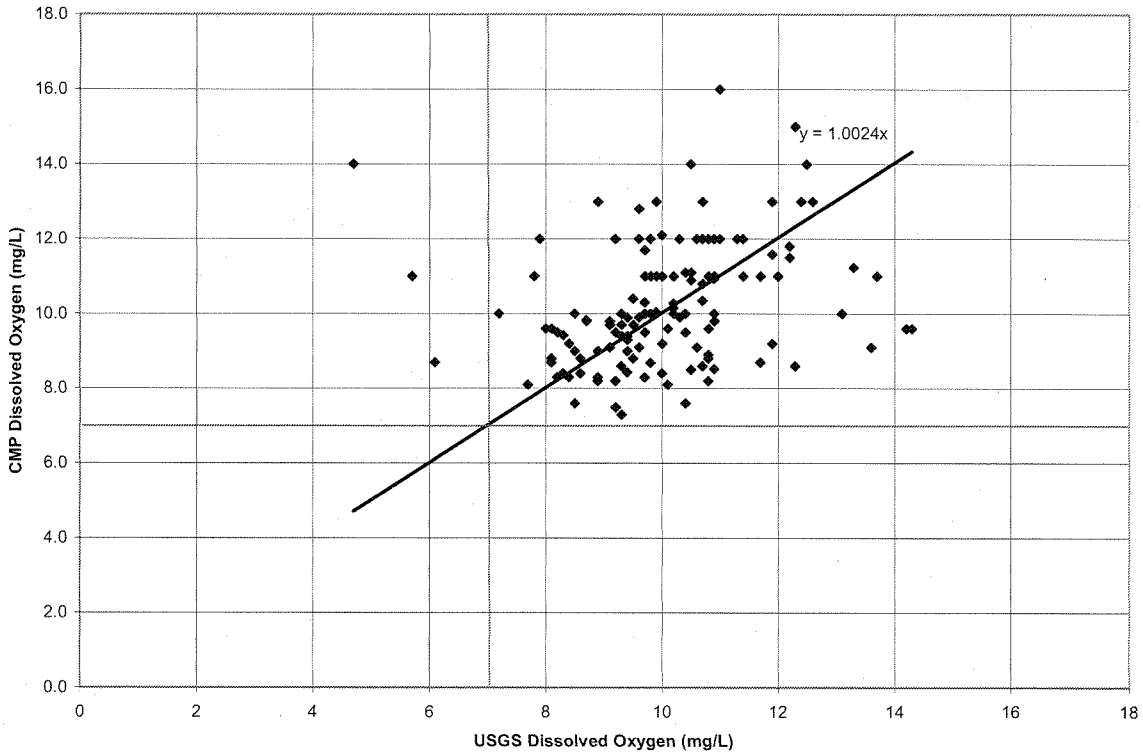

Figure A5. CMP vs. USGS Dissolved Oxygen in Sacramento River at Freeport 1998 to 2009

Regional Water Board

The Regional Water Board only collected one set of data during the summer months of 2009 but they collected data at multiple locations in the river. Figure shows the dissolved oxygen data plotted over distance down the river.

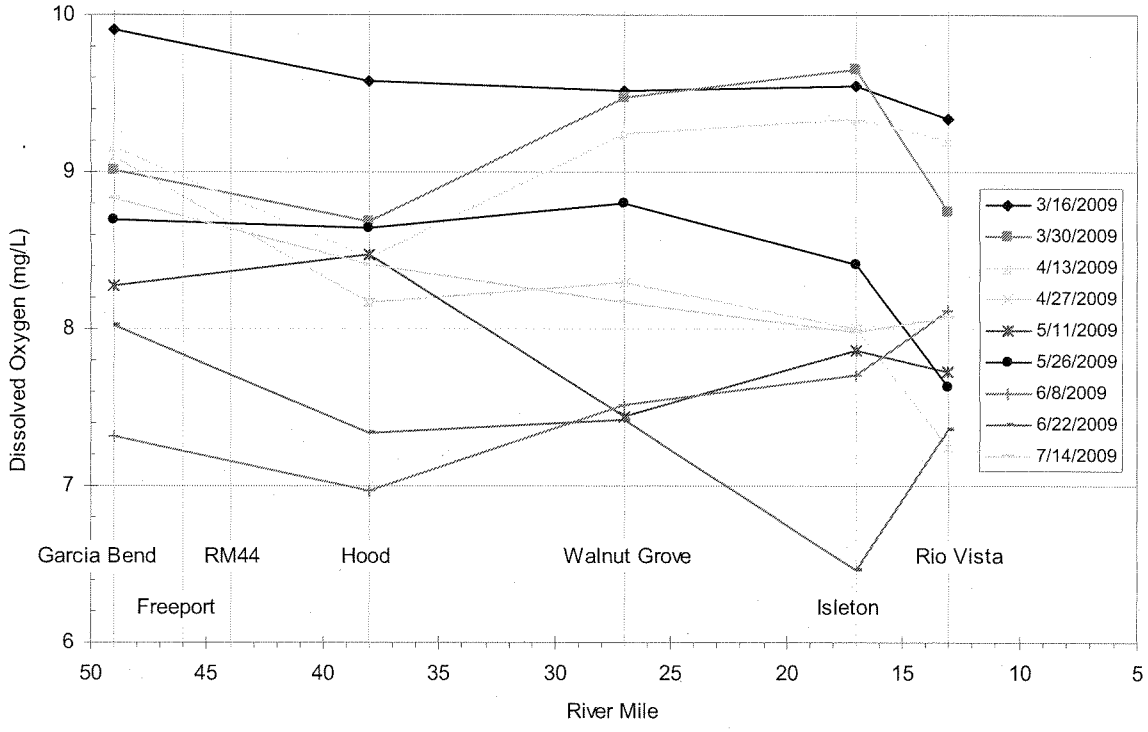

Figure A6. Regional Board Dissolved Oxygen in the Sacramento River 2009

DWR (CDEC)

Figures A7 through A11 display the CDEC data at Rio Vista and Hood. Each Sacramento River site has a chart displaying daily averages for the past two years and a chart showing hourly values for a one month period. In February of 2008, the sensor at Hood went from a Clark style DO sensor that required water to be pumped past its membrane to an in-situ ROX sensor (purple line shows this change). The site at Rio Vista (Figure A10) underwent similar changes in April of 2008 (also marked by the purple line). While using a Clark style sensor the river water was pumped to the sensor, after changing to the optical style probes (ROX), the probes were suspended 1 m below floats located within a protective housing[5]. The data for both river sites contains outliers where the sensor received abnormally high or low values. Sacramento River at Hood had some data points registered greater than 25 mg/L and Sacramento River at Rio Vista had a few values that dipped below 3 mg/L.

The CDEC sites are maintained by DWR with frequent servicing. Documentation of servicing is found in Appendix B. The dissolved oxygen at Hood is at times significantly adjusted at the site

[5] Email communication between Mike Dempsey and Mitchell Mysliwiec, Nov. 12, 2009. See Appendix B for this communication

visits based on field measurement comparisons. However, the data collected and stored in the CDEC database is not back corrected to account for the recalibrations of the sensors. The dissolved oxygen service history for the CDEC Sacramento River at Hood (SRH) station from March to December 2008 is listed in Table A1. [6]. The SRH dissolved oxygen probe was adjusted down to 7.35 mg/L from 8.0 mg/L on December 4, 2008. On December 8, 2008 an independent researcher noted the dissolved oxygen readings at Hood were significantly too low. On December 10, 2008 DWR field crews confirmed the sensor was reading 2 mg/L lower than a field measured Winkler method and made the appropriate adjustment to the probe (displayed as orange line). The instrument used to adjust down the SRH sensor on December 4, 2008 was found to be defective, and the data collected between December 4 and December 10 are marked invalid[7], but there was no mention of the validity of the pre-December 4, 2008 data.

Table A1. CDEC Sacramento River at Hood (SRH) Dissolved Oxygen Service History between March and December 2008

Date	Action	Comment
March 4, 2008	Verified DO at 9.0 mg/L	Replaced Instrument
April 2, 2008	Adjust DO from 8.1 to 9.2 mg/L	---
April 28, 2008	Adjust DO from 6.6 to 7.8 mg/L	Replaced Instrument
April 30, 2008	Winkler Verified at 6.9 mg/L	Confirm new sensor
May 5, 2008	Verified DO at 7.6 mg/L	---
June 5, 2008	Verified DO at 7.0 mg/L	Replaced Instrument
June 30, 2008	Verified DO at 7.0 mg/L	---
August 4, 2008	Adjust from 7.5 to 7.2 mg/L	Replaced Instrument
September 5, 2008	Verified DO at 7.0 mg/L	---
October 10, 2008	Verified DO at 7.3 mg/L	---
November 3, 2008	Verified DO at 6.8 mg/L	---
November 17, 2008	Winkler Verified at 7.3 mg/L	---
December 3, 2008	Verified DO at 7.8 mg/L	---
December 4, 2008	Adjust from 8.0 to 7.35 mg/L	
December 10, 2008	Adjust from 7.3 to 9.3 mg/L	Winkler Verified at 9.3 mg/L

[6] Email communication between Mike Dempsey and Kathleen Harder, Feb 25, 2009.

[7] Email communication between Mike Dempsey and David Huston, Feb 3, 2009.

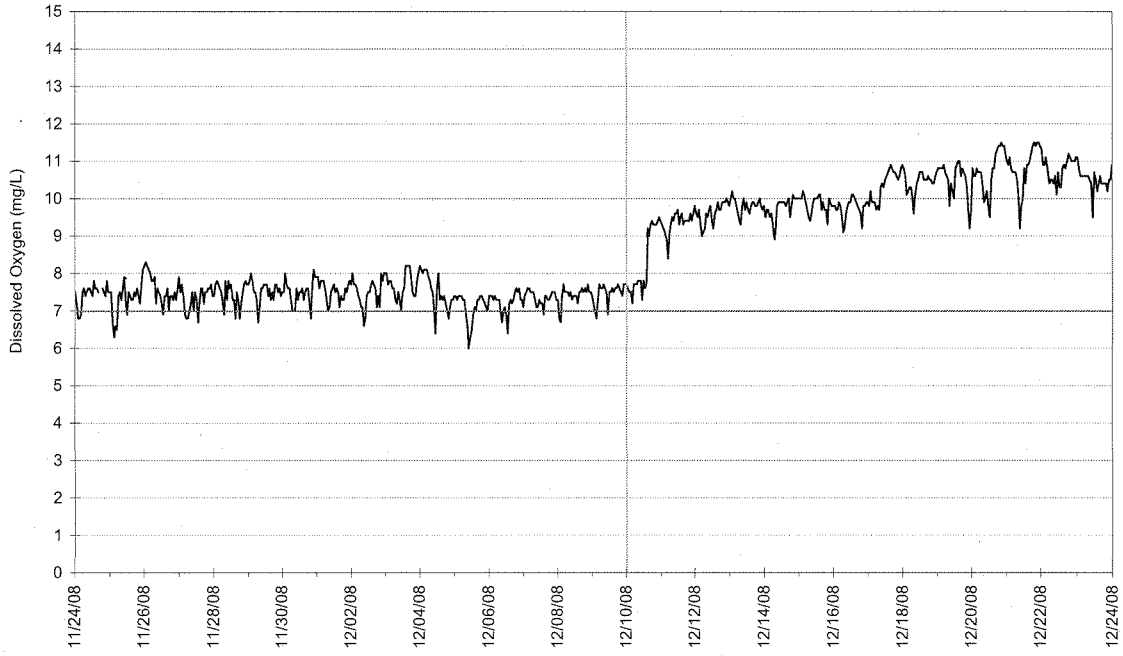

Figure A7. CDEC Dissolved Oxygen in the Sacramento River at Hood November to December 2008

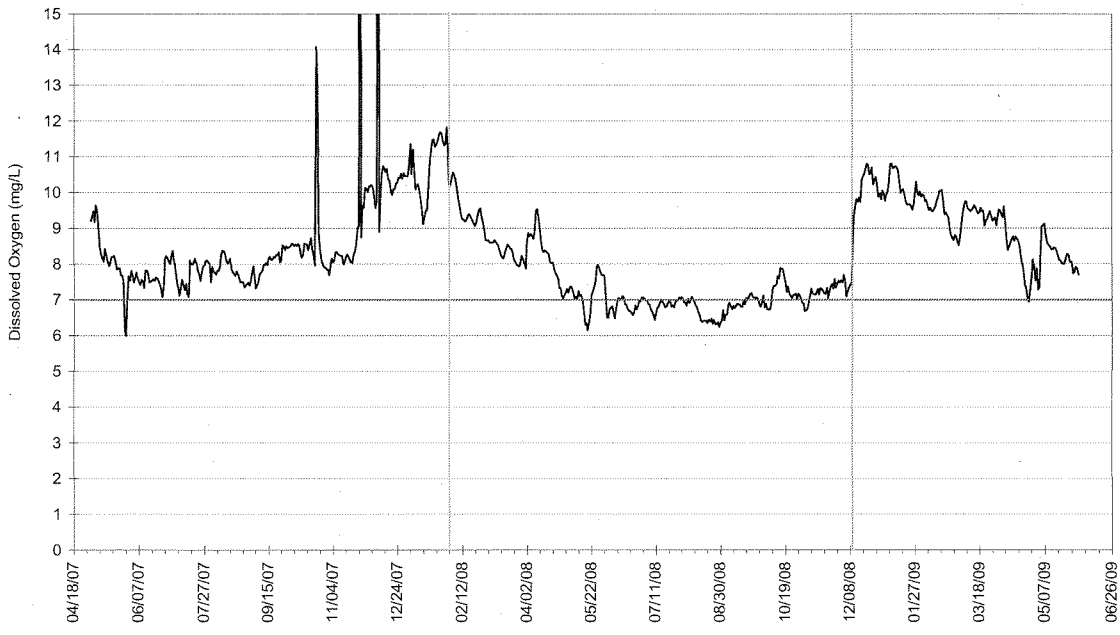

Figure A8. CDEC Dissolved Oxygen in the Sacramento River at Hood Daily Averages 2007 to 2009

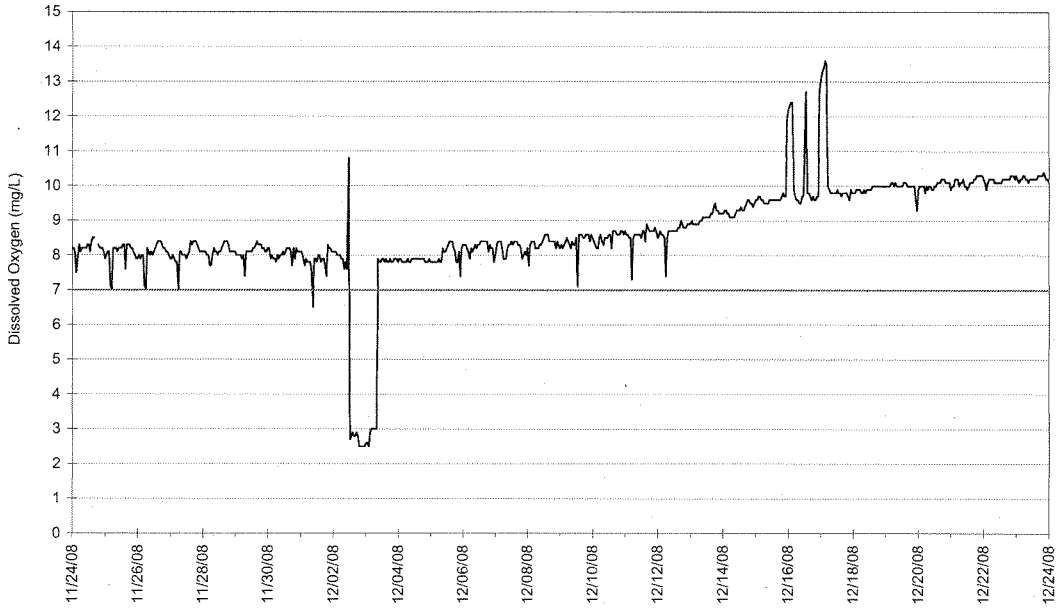

Figure A9. CDEC Dissolved Oxygen in the Sacramento River at Rio Vista November to December 2008

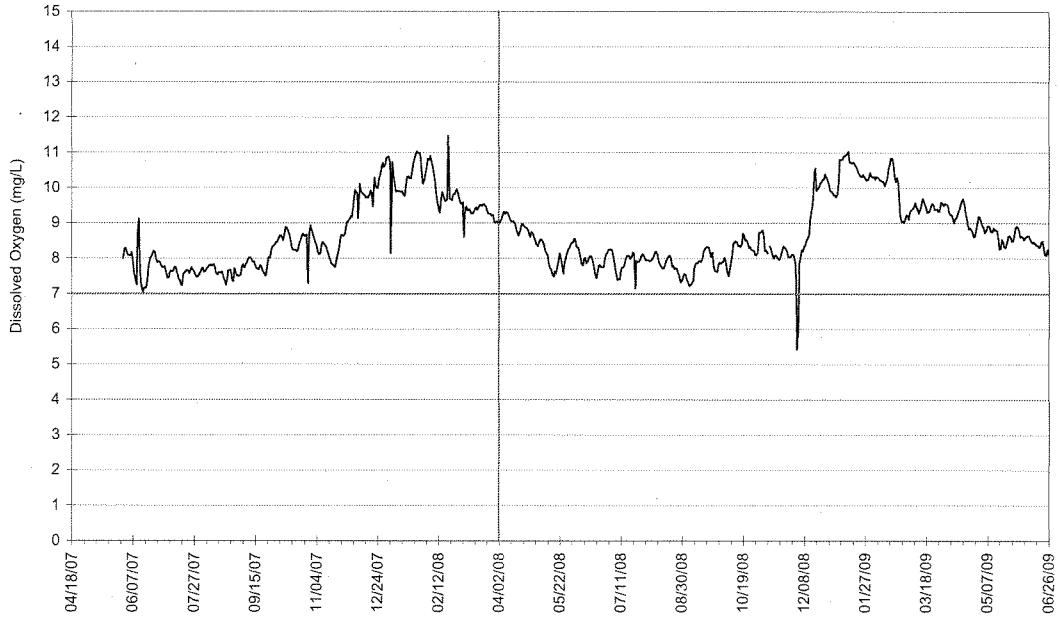

Figure A10. CDEC Dissolved Oxygen in the Sacramento River at Rio Vista Daily Averages 2007 to 2009

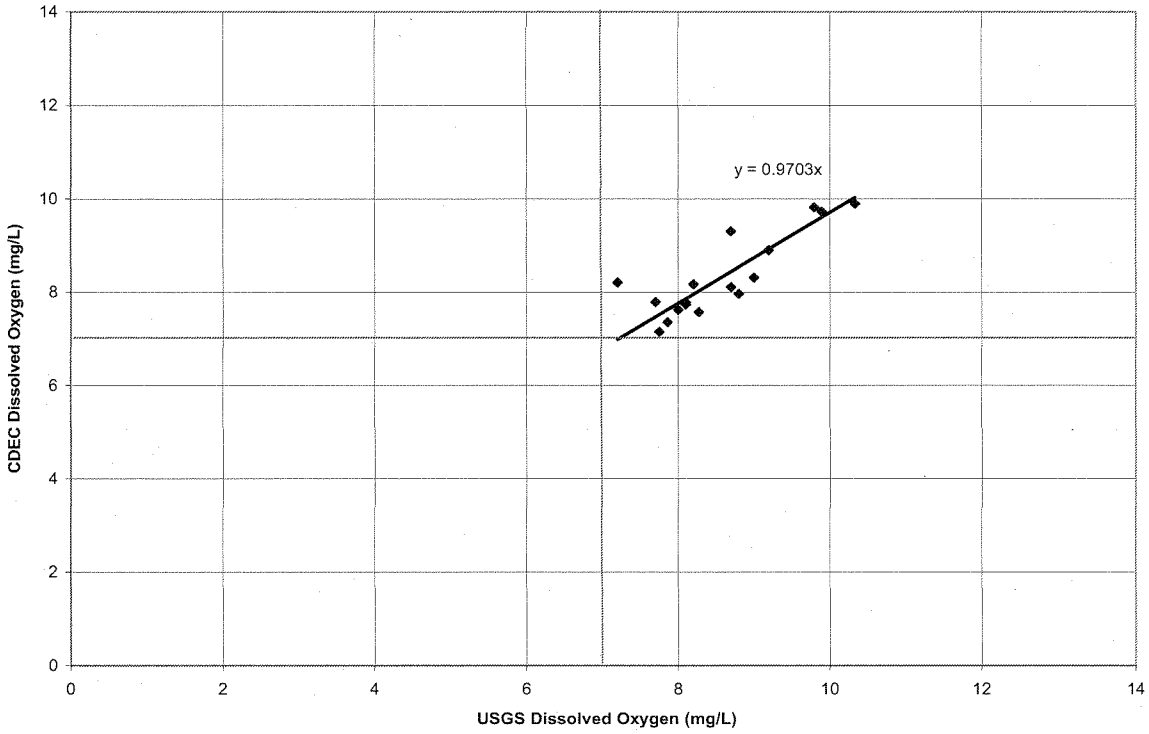

Figure A11. CDEC vs. USGS Dissolved Oxygen in Sacramento River at Rio Vista 2007 to 2009

The USGS data is spread out over 15 years whereas the CDEC data only goes back to 2007, so there are very few USGS data points that correlate to the same date as CDEC's. This small sample size has an r^2 value of 0.72 which shows good correlation

City of Rio Vista

The City of Rio Vista collected data at two Sacramento River sites. Station R1 is located west of its effluent discharge point and R2 is located east of the discharge. Figure A12 displays the data obtained at the two sites.

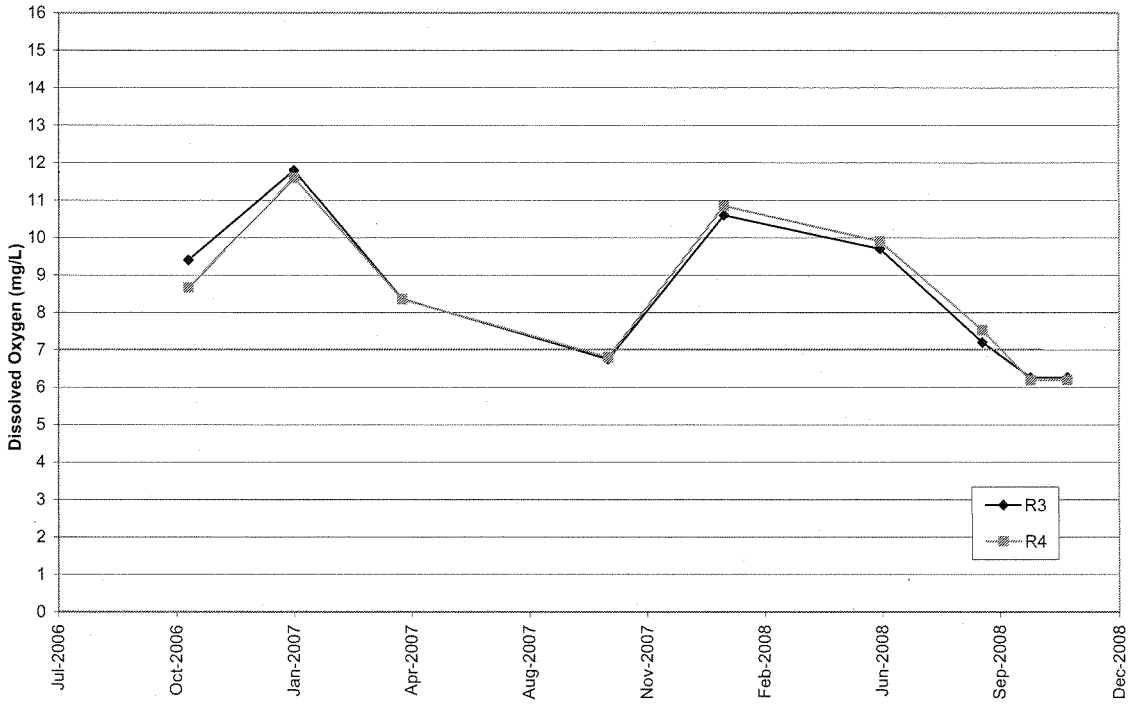

Figure A12. City of Rio Vista Dissolved Oxygen in Sacramento River at Rio Vista 2006 to 2008

EMP

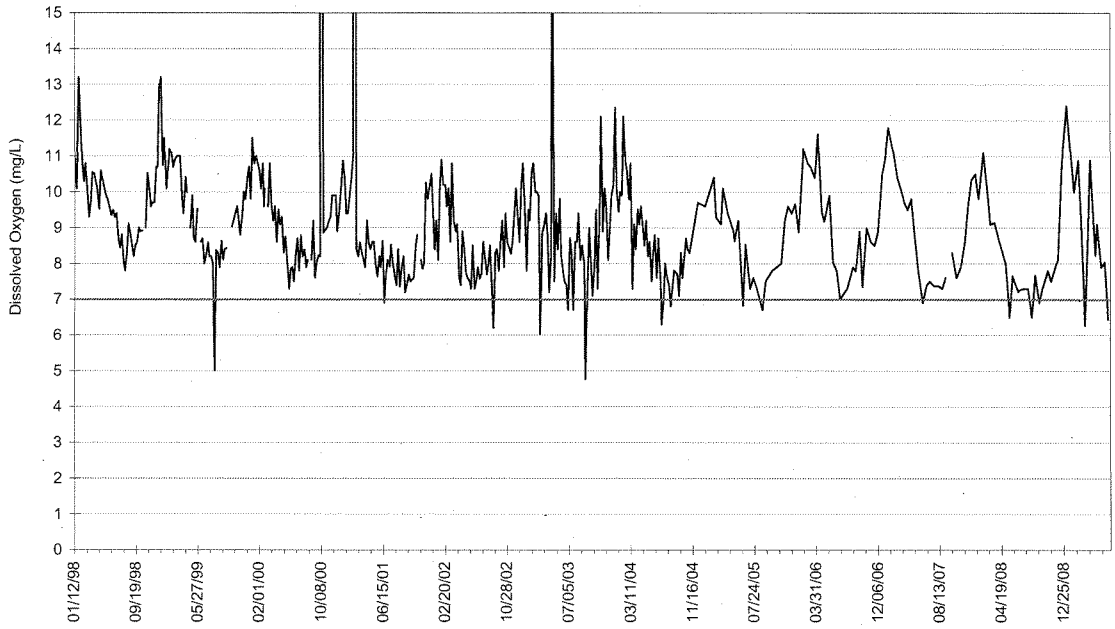

Figure 11A13. EMP Dissolved Oxygen in Sacramento River at Hood from 1998 to 2009

The EMP collects data in the Sacramento River at Hood dating back to 1998 and is presented in Figure A13.

Appendix B:
Supporting Documentation

From: "Dempsey, Mike" <mdempsey@water.ca.gov>
To: "Kathleen Harder" <kharder@waterboards.ca.gov>
CC: "Aldrich, Jay" <jaldrich@water.ca.gov>, "Rayfuse, Michael" <mrayfuse@wat...
Date: 2/25/2009 2:20 PM
Subject: RE: FW: DO water quality data at Hood on the Sacramento River

Kathy, the following is the service record for DO at the Hood location for the dates you provided.

3/4/2008	verified DO at 9.0 mg/L *replaced instrument
4/2/2008	adjust DO up to 9.2 mg/L from 8.1 mg/L
4/28/2008	adjust DO up to 7.8 mg/L from 6.6 mg/L *replace instrument
4/30/2008	verified DO with Winkler at 6.9 mg/l *confirm new sensor
5/5/2008	verified DO at 7.6mg/L *no adjustment
6/5/2008	verified DO at 7.0 mg/L *replace instrument
6/30/2008	verified DO at 7.0 mg/L *no adjustment
8/4/2008	adjust DO down to 7.2 mg/L from 7.5 mg/L *replace inst.
9/5/2008	verified DO at 7.0 mg/L *no adjustment
10/10/2008	verified DO at 7.3 mg/L *no adjustment
11/3/2008	verified DO at 6.8 mg/L *no adjustment
12/3/2008	verified DO at 7.8 mg/L *no adjustment

The data on CDEC did not get corrected in 2008 and we are in the process of implementing a method that we can back fill QA/QC'd data to CDEC in 2009. I can provide QA/QC'd data for 2008 if needed.

We have added redundant water quality instruments at most compliance stations during 2008 to allow us to switch to a backup instrument if the primary instrument fails and to use the data from the backup instrument to backfill the CDEC information. We understand that most observers use CDEC as their primary source for data so we strive to keep the CDEC data as accurate as possible.

Any other help let me know.

Mike..

-----Original Message-----
From: Kathleen Harder [mailto:kharder@waterboards.ca.gov]
Sent: Wednesday, February 25, 2009 1:16 PM
To: Dempsey, Mike
Subject: Re: FW: DO water quality data at Hood on the Sacramento River

Mike

Thanks for the information. Was the DO calibrated between 3/2008 through 12/2008? Can I depend on the DO data during this to be correct?

Thanks Kathy

Kathleen Cole Harder
Central Water Quality Control Board - 5 S
(916) 464-4778
kharder@waterboards.ca.gov

>>> "Dempsey, Mike" <mdempsey@water.ca.gov> 2/3/2009 2:13 PM >>>
David,

SRH is maintained by DES Real-time section. For the period in question we had a station visit on 12/4/2008 where the DO was adjusted down to 7.35 mg/L. On 12/08/2008 an independent researcher verified the DO at 9.3 mg/L. We responded on 12/10/2008 and checked the DO calibration using a Winkler titration and adjusted the DO up to 9.3 mg/L from 7.3 mg/L. The station was verified correct prior to the 12/04/2008 adjustment on 11/17/2008 with a Winkler at 7.3 mg/L which agreed with the recorded data.

The instrument used on 12/4/2008 was found to be defective so we will eliminate all DO data from the12/04/2008 adjustment to 12/10/2008 adjustment in our QA/QC.

I hope this answers Kathy's questions and if there is anything else she needs please have her contact me.

Mike.....

From: Huston, Dave
Sent: Tuesday, February 03, 2009 9:01 AM
To: Parker, David
Cc: Dempsey, Mike
Subject: RE: DO water quality data at Hood on the Sacramento River

Hey David,

I don't who's station this is, but I CC: Mike Dempsey (DES). I think he might know.

Good luck.

Dave

****

Dave Huston

Water Resources Engineer, P.E.

CA Dept. of Water Resources

Division of Planning and Local Assistance

Central District

3500 Industrial Blvd.

West Sacramento, CA. 95691

(916) 376-9654 (W)

(916) 376-9676 (Fax)

****

From: Parker, David
Sent: Monday, February 02, 2009 8:29 AM
To: Huston, Dave
Subject: FW: DO water quality data at Hood on the Sacramento River

Hello Dave,

This user is referring to the Sacramento River at Hood [SRH] station on the CDEC website.

http://cdec4gov.water.ca.gov/jspplot/jspPlotServlet.jsp?sensor_no=8317&e

nd=12/11/2008+10:59&geom=small&interval=2&cookies=cdec01

Do you have any information on this?

David Parker

CDEC

David, SRH is a DES station. The station was serviced on 12/4/2008 and the DO was adjusted to 7.38 mg/L. An independent researcher verified the DO 12/08/2008 at 9.3 mg/L which prompted a visit by staff on 12/10/2008 who verified the DO value at 9.5 mg/L and made the adjustment. The instrument used on 12/4/2008 used to make the original adjustment was found to be defective.

From: Kathleen Harder [mailto:kharder@waterboards.ca.gov]
Sent: Friday, January 30, 2009 10:56 AM
To: webmaster@flood.water.ca.gov
Subject: DO water quality data at Hood on the Sacramento River

Between 12/9/2008 and 12/11/2008 there was a big jump in the DO data. Is there any reason for this jump? Was the equipment serviced during this time?

Thanks Kathy

Kathleen Cole Harder
Central Water Quality Control Board - 5 S
(916) 464-4778
kharder@waterboards.ca.gov

From: "Dempsey, Mike" <mdempsey@water.ca.gov>
To: "Kathleen Harder" <kharder@waterboards.ca.gov>
Date: 8/3/2009 10:29 AM
Subject: RE: DO at Hood

Hi Kathleen,

I have been re-tasked to deal with our station infrastructure. After 30+ years some of the mounting hardware and walkways are beginning to fail. I have passed your request up to my new section chief and he will be assigning time for me to work on it.

A quick answer to your three questions are.

1. yes, DO data for Hood from 2004 to present is credible and can be found on BDAT with a QA/QC flag of "G" should be considered credible the data on CDEC is not QA/QC'd and should be used as such

2. Rio Vista is the same as Hood data.

3. At select station locations we run redundant water quality instruments. (Rio Vista and Hood are such locations) if a sensor is found to be suspect on the primary instrument and OK on the backup instrument, the signal from the station to CDEC is changed from the primary instrument to the backup instrument and the data on CDEC is replaced with the data from the backup instrument for the period of time when the primary instrument had failed. This is a post process to the CDEC database. Ie. If we see two days of suspect data from the primary instrument and during that same two day period the backup instrument is OK we will load the period of record from the backup instrument to CDEC and overwrite the data that was collected "Real-time" from the primary instrument. This way we try to keep our data to CDEC as clean as possible. We will keep the data coming from the backup instrument until normal monthly instrument exchanges where both instruments are exchanged with newly calibrated instruments or we will replace the instruments earlier if we see both the primary and backup instrument fail. At this time we do discrete station verifications the first and third week of the month and if necessary replace any defective sensors during this visit.

As always I have your request flagged and will keep you informed of the status.

Mike...

-----Original Message-----
From: Kathleen Harder [mailto:kharder@waterboards.ca.gov]
Sent: Friday, July 03, 2009 9:01 AM
To: Dempsey, Mike
Subject: Fwd: DO at Hood

Please don't forget me.

Kathy

Kathleen Cole Harder
Central Water Quality Control Board - 5 S
(916) 464-4778
kharder@waterboards.ca.gov

>>> Kathleen Harder 6/24/2009 11:08 AM >>>
Mike attached is the email detailing the calibration of the dissolved oxygen sondes for 2008 Hood. I need:

1. What dissolved oxygen data at Hood is credible from June 2004 to present.
2. I'm also looking at dissolved oxygen at Rio Vista. Is that information credible?
3. Would you describe the new set-up since January 2009 that allows for back-up data if the original data appears suspect.

Thanks Kathy

Kathleen Cole Harder
Central Water Quality Control Board - 5 S
(916) 464-4778
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Good morning Mitch,

To answer your questions depends on the dates. At the Hood station the water was pumped to the DO sensor from December 1999 to February 2008.
The pump was mounted on a float that took the sample water from a constant depth of one meter. Since February 2008 the DO sensor is mounted on a float directly in the river channel at a constant depth of one meter.

The Rio Vista station is exactly the same set up as the Hood station the only difference would be the dates. Rio Vista pump system starts in 1984 and was switched to in-situ April 2008.

As to the station visits I will have to check on that and get back to you.

Mike...

-----Original Message-----
From: Mitch Mysliwiec [mailto:MitchM@lwa.com]
Sent: Wednesday, November 11, 2009 4:01 PM
To: Dempsey, Mike
Cc: Jeff Walker
Subject: RE: Questions on SRH, RVB DO data from CDEC

Hi Mike,

We are looking again at different DO data sets and have a couple more questions for you.

1) What is the physical configuration of the sampling/probe? (do you pump water into the sample shed or are the probes lowered into the river?) Is the set up the same for Hood and Rio Vista?

2) would it be possible to tag along or perhaps arrange a site visit to Hood and Rio Vista?

Thanks Mike,
Mitch

-----Original Message-----
From: Dempsey, Mike [mailto:mdempsey@water.ca.gov]
Sent: Tuesday, February 17, 2009 8:03 AM
To: Jeff Walker
Cc: Mitch Mysliwiec; Breuer, Rich; Gehrts, Karen; Aldrich, Jay; Rayfuse, Michael
Subject: RE: Questions on SRH, RVB DO data from CDEC

Hi Jeff,

I know you will not be back until 2/23 but here is what I found from the station records. The erroneous adjustment to SRH DO was made on 12/4/2008 @1330 PST. It was adjusted from 8.0 mg/L to 7.3 mg/L. It was last verified correct on 12/3/2008 at a value of 7.8 mg/L. It was noted on a separate visit from a UCD researcher that her DO check of 9.3 mg/L did not match the CDEC value of 7.3 mg/L for her visit of 12/08/2008.
Staff was sent to the site on 12/10 and verified via Winkler method a value of 9.3 mg/L vs. the site instrument value of 7.3 mg/L and was adjusted up to 9.3 mg/L @ 1345 PST.

I believe that the change you saw at SRH for 2/2/09 was the result of a program change in the data logger that resulted in data being sent to CDEC in the wrong order thus giving a sensor other than DO in the expected column. Once that was noted the data order was corrected and resent to CDEC.

Here is a link to the Spec sheet for the YSI sonde we use. Some sites have the rapid pulse DO sensor while the sites you ask about, SRH and RVB, use the optical ROX sensor.

https://www.ysi.com/DocumentServer/DocumentServer?docID=EMS_E52

Any other questions let me know.

Mike..

-----Original Message-----
From: Jeff Walker [mailto:JeffW@lwa.com]
Sent: Thursday, February 12, 2009 11:44 AM
To: Dempsey, Mike
Cc: Mitch Mysliwiec
Subject: RE: Questions on SRH, RVB DO data from CDEC

Mike,
Thanks for getting back to me so quickly and on a day off too! I am out next week, but will get back in touch with you the week of Feb 23.

Thanks again,
Jeff

-----Original Message-----
From: Dempsey, Mike [mailto:mdempsey@water.ca.gov]
Sent: Thursday, February 12, 2009 11:38 AM
To: Jeff Walker
Subject: RE: Questions on SRH, RVB DO data from CDEC

Jeff

Yes we maintain a database of QA/QC'd data. There has been a large change in personell who maintained the BDAT database and we are bringing new personell up to speed as quickly as we are able. Until that time we strive to make the CDEC site a accurate as possible. We have just programed our loggers to resend corrected data to CDEC when we find errors. I am currently on a holiday plus mandatory furlough day and the soonest I can properly respond to your request will be Tuesday.

For quick answers to some of your SRH DO concerns is there was an erroneous adjustment made to DO and was corrected later in the week. When I get back in the office I will look at the feeild notes and let you know the corrections .

We just completed the upgrade of our legacy equipment the end of 2008. Prior to that time we were usig a Clark style DO sensor. We are now using the new optical DO sensor. I have been testing and evaluating the optical vs. Clark since 2006 and have found them to be very stable at all our Delta locations with less than a 3 percent drift over a year deployment.

We have moved into a new building in West Sacramento and I have a new contact number 916 376 9775. They did not turn off my old number and send a message for the number so I think your voice mail is still waiting at the old number.

Please contact me on tuesday.

Mike

Sent from my GoodLink synchronized handheld (www.good.com)

-----Original Message-----
From: Jeff Walker [mailto:JeffW@lwa.com]
Sent: Thursday, February 12, 2009 11:00 AM Pacific Standard Time
To: Dempsey, Mike
Subject: Questions on SRH, RVB DO data from CDEC

Mike,

I wanted to following up on a phone message I left you earlier in the week. Also, thanks for allowing us to place a sonde on the DWR Hood station in November.

For an unrelated project, I was checking out the online DO data at Rio Vista and Hood and am feeling it would be safer to talk to the scientists directly rather than blindly take the preliminary data off the public CDEC server. I wanted to check and see if you are the best contact for this, or if not, if you could point me to someone I could talk to.

My goal is to get a good set of DO data for the Sacramento River going back 3-4 years if possible. What I see in the raw online data is that every so many months, there appears to be discrete 10-20% steps in the readings, where for example, Hood DO from 2/1/08 to 12/11/08 seems to be ~1.5 mg/L lower than data before/after. In my phone message I mentioned a step in Hood DO on 2/2/09, although that now seems to have been corrected on CDEC. I'm wondering what your take is on these steps? Further, if these steps represent a calibration issue, I'm wondering if you have the ability to correct them out of the historical data, and/or what you would consider to be the accuracy of the historical data for various periods of time.

I was also curious about what the specs are for your DO sensors, how often you calibrate, and if you are using the Clark Cell rapid pulse DO sensors, or the newer style optical DO sensors?

Any information you can provide would be helpful,

Thanks,

Jeff

Jeffrey D. Walker, Ph.D.

Larry Walker Associates

530-753-6400

From: "Dempsey, Mike" <mdempsey@water.ca.gov>
To: "Kathleen Harder" <kharder@waterboards.ca.gov>
CC: "James D Marshall" <jdmarshall@waterboards.ca.gov>, "Breuer, Rich" <rich...
Date: 12/8/2009 11:14 AM
Subject: RE: DO at Hood

Hi Kathy,
I am out on a boat run today. When I get back in the office I will check on the visit sheets and let you know what I find.
To answer your questions;
1. Since 2009 the sensors are in the water. We no longer pump to a flow chamber.
2. The station is verified the first and third weeks of the month with freshly calibrated hand held instruments. If there is a significant DO offset (greater than .4 mg/L) a winkler is run and the DO recalibrated. A winkler verification is also done montly as part of the descete WQ sampling run.
3. I will need to check the visit sheets to see what if any adjustments were made

Mike

Michael Dempsey

Sent from my GoodLink synchronized handheld (www.good.com)

-----Original Message-----
From: Kathleen Harder [mailto:kharder@waterboards.ca.gov]
Sent: Tuesday, December 08, 2009 10:04 AM Pacific Standard Time
To: Dempsey, Mike
Cc: James D Marshall
Subject: DO at Hood

Mike

I know you are busy and this is not a priority, but I need your help. Based on CDEC data and other dissolved oxygen (DO) data collected by other agencies, I believe the dissolved oxygen at Hood is falling below 7.0 mg/L which is a violation of our Basin Plan water quality objectives. Sacramento Regional County Sanitation District (SRCSD) believes the CDEC data is too low by 1.5 -1.7 mg/L at Hood. Although at times, the CDEC data may be off, I believe the majority of time the CDEC data is correct. The data is used in a model to determine what the dissolved oxygen demand is and will be based on the amount of SRCSD effluent discharged to the Sacramento River and at what ammonia concentration. SRCSD will be conducting an evaluation of DO data, including the CDEC data. I would like to use the BDAT data that undergoes QA/QC but unfortunately the database ends in early 2008. Would you help me with the following information:

1. What is the continuous DO monitoring set-up? Is the DO measured directly in the river or is it pumped to a chamber for monitoring?
2. In 2009 the instruments are checked every other week. Is the verification of the DO done by the Winkler method, if not how?
3. Are both DO instruments recording similar concentrations?

Please call me if you can. I'm meeting with SRCSD on Monday and would like to have this information before we meet.

Kathy

Kathleen Cole Harder
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Appendix C: DO Data from Different Programs

(provided on CD only)