Methodology for Flow and Salinity Estimates in the Sacramento-San Joaquin Delta and Suisun Marsh

25th Annual Progress Report
October 2004

Chapter 4:
Modeling Dissolved Oxygen and Temperature in DSM2 Planning Studies

Author: Hari Rajbhandari

4 Modeling Dissolved Oxygen and Temperature in DSM2 Plannning Studies

4.1 Introduction

DSM2 was used to simulate dissolved oxygen (DO) in the Delta as part of the technical studies for the In-Delta Storage Project Feasibility Study (DWR, 2004). The goal of the In-Delta Storage Project is to provide water supply through using Bacon and Webb Tract Islands as intermittent reservoirs in order to supplement the Delta water supply and provide operational flexibility. The DSM2 study assessed potential DO and temperature impacts of releases from the islands over the standard 16-year sequence of hydrology from CALSIM II output used in Delta planning studies. DSM2 had been used in the past to model how low DO levels in the Deep Water Ship Channel (DWSC) near Stockton respond to increased San Joaquin River flow (Rajbhandari, 2004); however, because of data availability, this study was based on simulating a few recent years. Thus, for the In-Delta Storage Project, boundary conditions needed to be established in order to simulate DO and temperature once hydrodynamics had been modeled over the 1975 – 1991 planning period (Figure 4.1). This chapter describes the procedure used to develop the boundary conditions to enable DSM2 simulation of DO and temperature under a typical planning scenario.

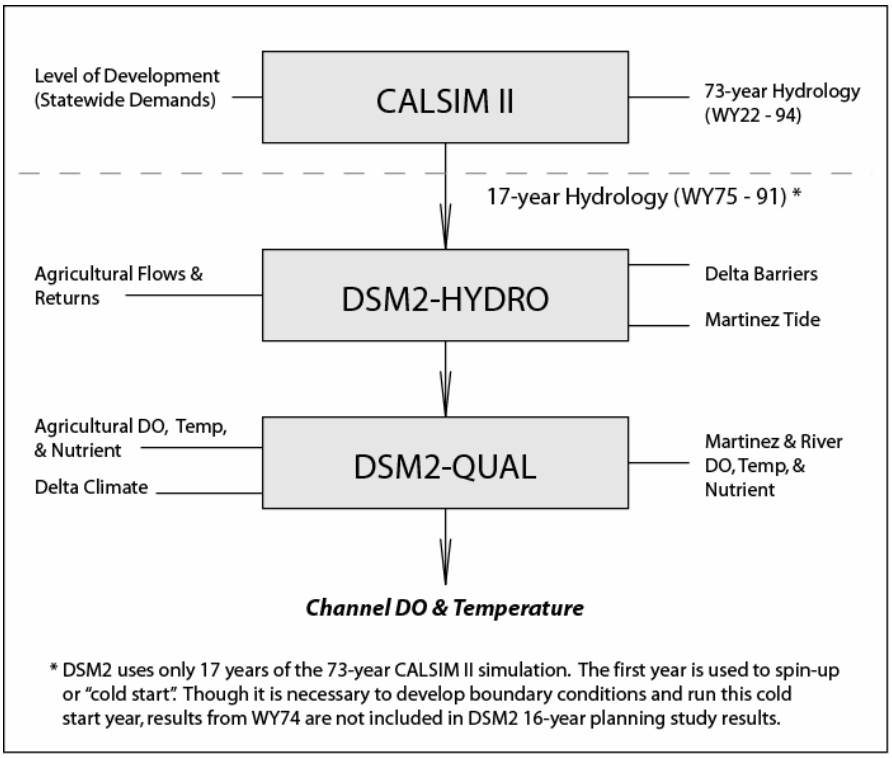

Figure 4-1: Planning Study Methodology.

4.2 General Methodology

4.2.1 DO Modeling Data Requirements

The input parameters needed to model DO include water temperature, biochemical oxygen demand (BOD), chlorophyll, organic nitrogen, ammonia nitrogen, nitrite nitrogen, nitrate nitrogen, organic phosphorus, and dissolved phosphorus (ortho-phosphate). A conceptual model showing the interaction among water quality variables in DSM2 is shown in Figure 4.2, with temperature affecting the rates of mass transfer. Recent work on calibration and validation of DSM2 for DO is documented in Rajbhandari et al. (2002). The conceptual and functional descriptions of constituent reactions represented in DSM2 are generally based on QUAL2E (Brown and Barnwell, 1987) and Bowie et al. (1985).

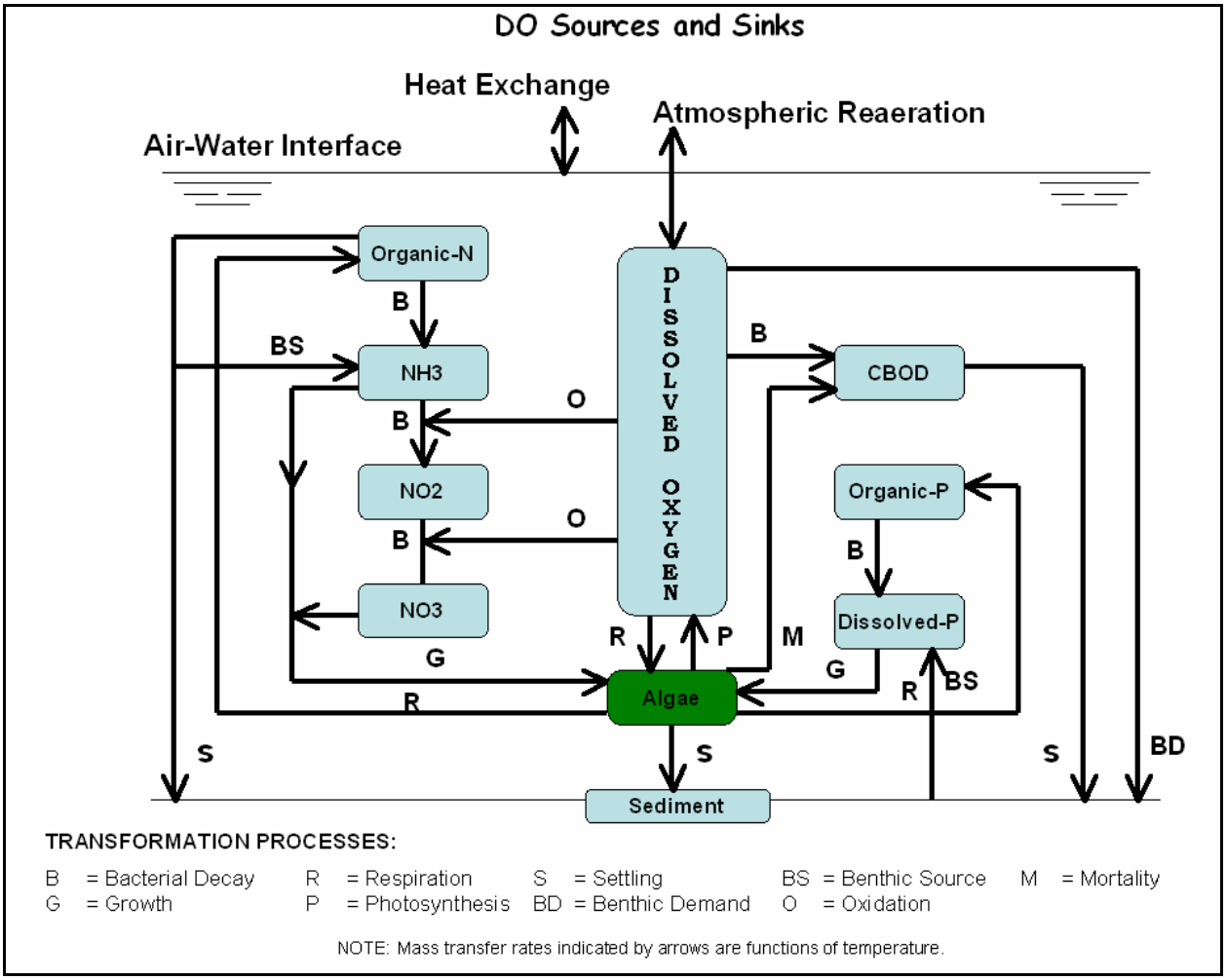

Figure 4.2: DO and Interaction Among Water Quality Parameters.

For DSM2 Delta water quality simulations, water quality data typically need to be provided for the major sources of inflow (the Sacramento River, San Joaquin River, Yolo Bypass, and Cosumnes/Mokelumne rivers), the downstream boundary at Martinez, and the agricultural return

flows within the Delta. Significant point sources may also be included, such as was the City of Stockton's Regional Wastewater Control Facility (RWCF). When simulating electrical conductivity (EC) in CASIM II–based planning studies, established flow-EC relationships at the Delta boundaries can be readily used to generate boundary EC, but no such relationships exist for the water quality parameters used in simulating DO. Thus, methods were developed to use available historical data to generate the data needed for modeling DO with DSM2 under hypothetical Delta hydrologies. For the purposes of this paper, this data is categorized according to water temperature and DO, nutrients, and climate. RWCF effluent water quality is considered separately.

4.2.2 Water Temperature and DO

Nearly continuous hourly water temperature and DO were available from 1997 through 2000 at Mossdale and Martinez and from 1999 through 2001 at Freeport. Although some water temperature and DO data from 1983 to present exist, no relationships with flow were observed so use of historic data was limited to more recent years. Daily average values were calculated from this data and used as boundary input: Mossdale data was used for Vernalis input and Freeport data was used for input at Sacramento, the Yolo Bypass, and Cosumnes/Mokelumne rivers. Daily average values from recent years were then assigned to individual years in planning studies by first assigning historical year 2000, a leap year, to leap years in the planning studies (1976, 1980, 1984, 1988), then assigning other historical years to years in planning studies in a repetitive sequencing (Table 4.1).

Table 4.1: Assignment of Historical Data to Planning Year for Water Temperature and DO.

Planning Year	Historical Year	Historical Year
	San Joaquin River Boundary Martinez Boundary	Sacramento River Boundary
1974	1998	1999
1975	1999	1999
1976	**2000**	**2000**
1977	1997	2001
1978	1998	1999
1979	1999	1999
1980	**2000**	**2000**
1981	1997	2001
1982	1998	1999
1983	1999	1999
1984	**2000**	**2000**
1985	1997	2001
1986	1998	1999
1987	1999	1999
1988	**2000**	**2000**
1989	1997	2001
1990	1998	1999
1991	1999	1999

Leap years highlighted in bold.

Water temperature and DO in agriculture drainage were assumed to be a constant 22°C and 5.1 mg/L respectively, based on estimates from Municipal Water Quality Investigation Data Request (1995).

4.2.3 Nutrients

Estimates of nutrient data for the model boundary at Vernalis were based on various sources. Jones and Stokes (1998) computed the concentrations of ammonia and BOD data at Mossdale as the flow-weighted monthly average values. These values were reported for each month during 1987-1995. As shown in Figure 4.3, monthly average chlorophyll from 1983 – 2001 at Vernalis was taken from Nieuwenhuyse (2002). Averages of these monthly values were used for each year in the planning study (Table 4.2). Nitrite nitrogen, nitrate nitrogen, organic nitrogen, phosphate, and organic phosphorus at Vernalis were estimated based on averaging the San Joaquin River Total Maximum Daily Load study measurements sampled at weekly intervals in 1999 (Table 4.3).

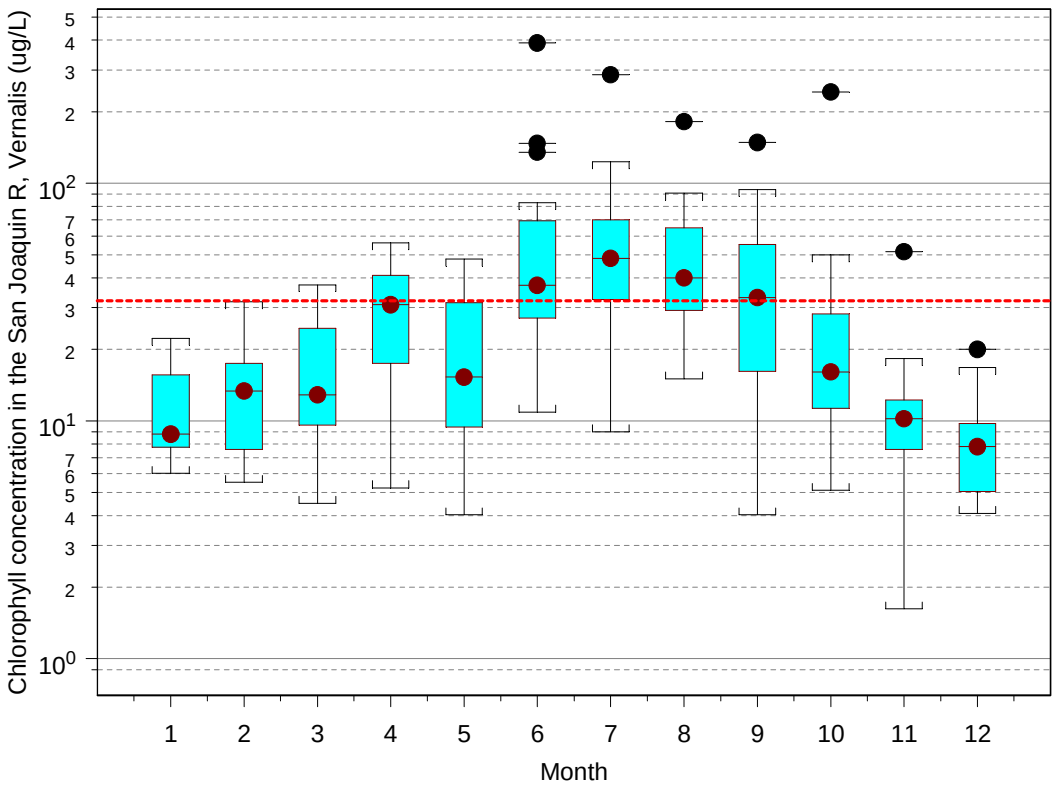

Figure 4.3: Summary Statistics for Monthly Average Chlorophyll Concentration in the San Joaquin River at Vernalis, 1983-2001. (Nieuwenhuyse, E.E.V., 2002)

Table 4.2: Monthly-Varying Nutrient Data at Vernalis.

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Ammonia-N (mg/L)	0.39	0.31	0.09	0.03	0.02	0.01	0.02	0.03	0.02	0.02	0.05	0.07
BOD (mg/L)	2.1	2.2	2.8	3.4	4.0	6.0	6.2	5.4	4.9	4.0	2.1	1.7
Chlorophyll (µg/L)	9	15	13	31	15	35	50	40	32	17	10	8

Table 4.3 presents nutrient data at Freeport on the Sacramento River that were approximated from a U.S. Geological Survey report (USGS, 1997) and data at Martinez that was obtained from DWR (1997). Chlorophyll data for the Sacramento River and Martinez were approximated based on data reported by DWR (1999). Estimates of water quality associated with agricultural drainage return flows at internal Delta locations based DWR's Bulletin 123 (1967) are shown in Table 4.4.

Table 4.3: Constant Nutrient Data at Sacramento and San Joaquin Rivers and Martinez.

Parameter	**Sacramento River Input** (mg/L)	**Martinez** (mg/L)	**San Joaquin River** (mg/L)
Organic nitrogen as N	0.2	0.2	0.5
Ammonia as N	0.1	0.05	-[1]
Nitrite as N	0.01	0.01	0.20
Nitrate as N	0.1	0.1	1.70
Organic Phosphorus as P	0.01	0.01	0.10
Phosphate as P	0.03	0.03	0.15

1. Ammonia data for the San Joaquin River is shown in Table 4.2.

Table 4.4: Nutrient Data for Delta Agriculture Drainage.

Parameter	**Value**
Ammonia as N	0.31 mg/L
BOD	3.9 mg/L
Algae as chlorophyll	10.0 µg/L
Organic nitrogen as N	1.4 mg/L
Nitrite as N	0.02 mg/L
Nitrate as N	1.3 mg/L
Organic phosphorus as P	0.09 mg/L
Phosphate as P	0.4 mg/L

4.2.4 Climate Data

Air temperature, wetbulb temperature, wind speed, cloud cover, and atmospheric pressure are input for DSM2 simulation of water temperature in the Delta channels. Data at hourly intervals were available only at two stations in the Delta – at Sacramento and Stockton airports. Depending upon the location of interest in any given study, either data from the Sacramento airport or the Stockton airport may be used.

Hourly data was available from the National Climatic Data Center for the period of 1997-2000. The historical values for a given year were assigned to year in the planning studies based upon Table 4.5 by the same criteria as was done with water temperature and DO in Table 4.1. These data are shown in Figures 4.4a and 4.4b for air temperature and Figures 4.5a and 4.5b for wetbulb temperature.

Table 4.5: Assignment of Historical Data to Planning Year for Climate Data.

Planning Year	Historical Year
1974	1998
1975	1999
1976	**2000**
1977	1997
1978	1998
1979	1999
1980	**2000**
1981	1997
1982	1998
1983	1999
1984	**2000**
1985	1997
1986	1998
1987	1999
1988	**2000**
1989	1997
1990	1998
1991	1999

Leap years highlighted in bold.

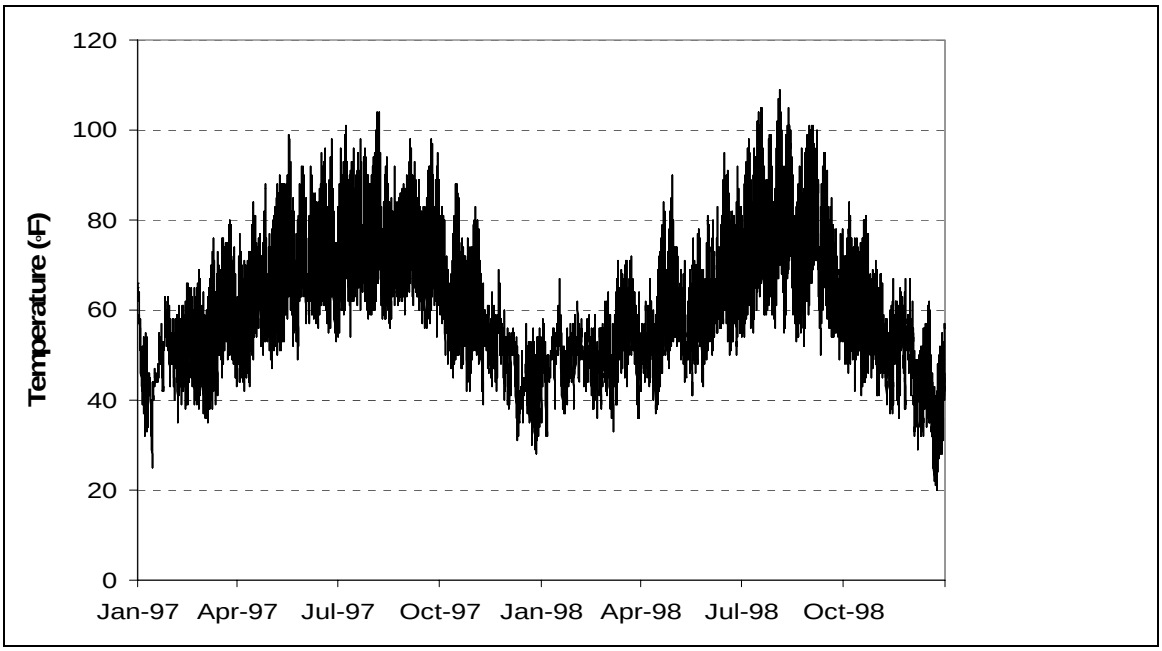

Figure 4.4a: Hourly Air Temperature at Stockton (1997-1998).

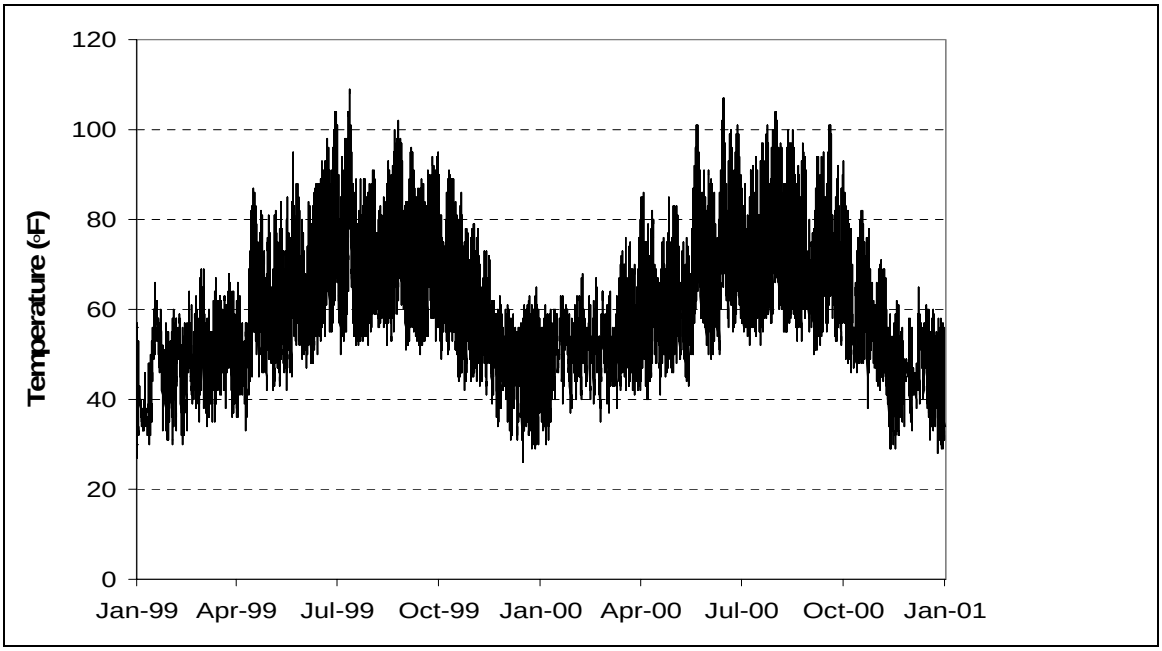

Figure 4.4b: Hourly Air Temperature at Stockton (1999-2000).

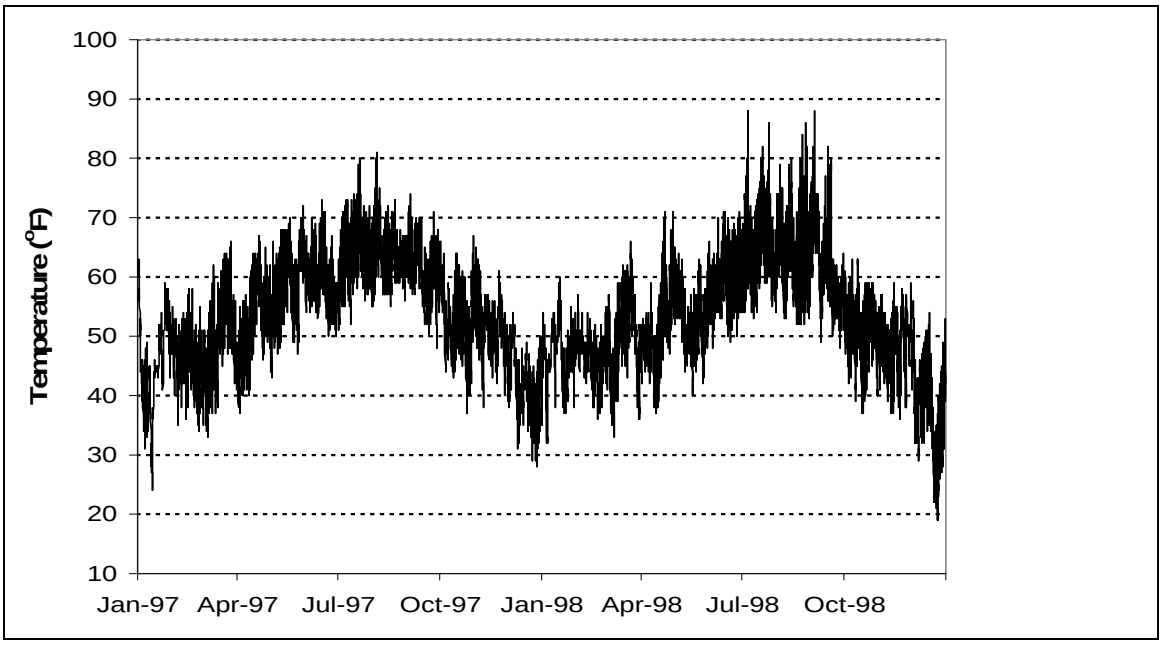

Figure 4.5a: Hourly Wetbulb Temperature at Stockton (1997-1998).

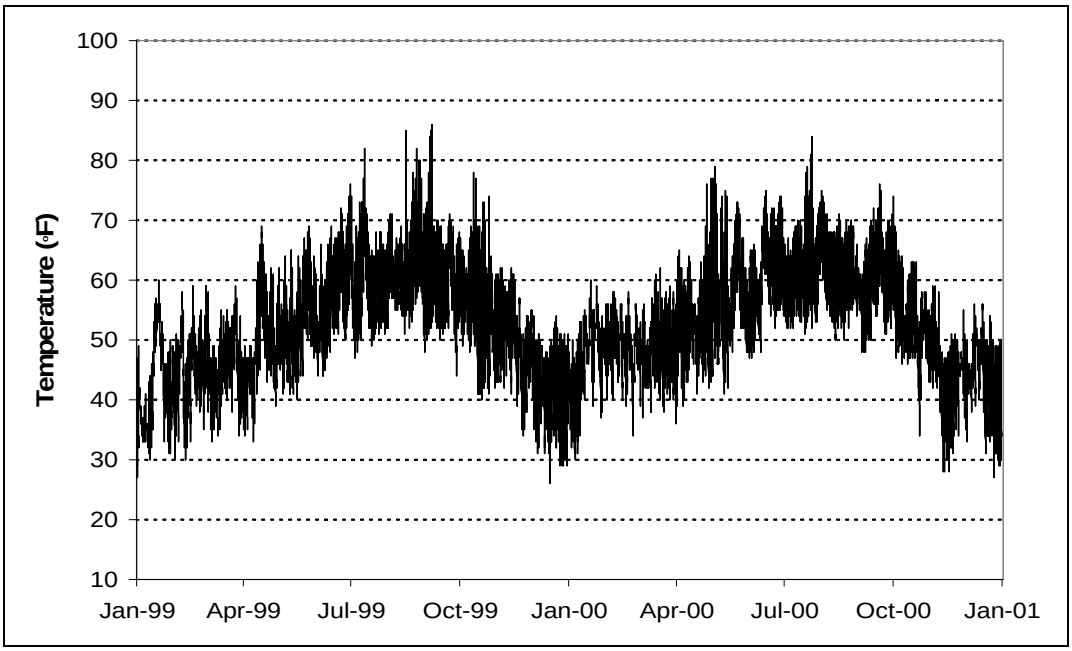

Figure 4.5b: Hourly Wetbulb Temperature at Stockton (1999-2000).

4.2.5 Stockton Regional Wastewater Control Facility Effluent Data

Data on effluent flows from the City of Stockton's Regional Wastewater Control Facility (RWCF) were obtained from the City of Stockton Municipal Utilities Department (Huber, 2001). Flow and temperature data were available on a daily basis, and organic nitrogen, nitrite nitrogen, and nitrate nitrogen data were available on weekly intervals. These data were used to generate average monthly estimates. Monthly average estimates of ammonia and BOD were based on 1987-1995 monthly data reported by Jones and Stokes (1998). Table 4.6 presents the resulting data used in simulating DO in DSM2 from the various sources. In addition, fixed values for the entire planning period were used for chlorophyll, phosphate, organic phosphorus, and DO based on limited data from 1999. These values were 40 µg/L , 0.05 mg/L, 0.35 mg/L, and 7.5 mg/L respectively. Because much of these data were derived from different sources, and inevitable loss of some important daily or even seasonal variations due to different averaging processes, the data in the present form should be used with discretion. Depending upon the geographical location of a particular project, these data may need to be recomputed. For example, for the studies in the San Joaquin River near the Stockton Deep Water Ship Channel, these data should be further refined.

Table 4.6: Generated Stockton RWCF Effluent Data.

Month	Organic-N (mg/L)	Nitrate-N (mg/L)	Nitrite-N (mg/L)	Ammonia-N (mg/L)	BOD (mg/L)	Temp (ºC)	Flow (cfs)
Jan	4.5	0.84	0.12	16.6	14	11.2	57
Feb	4.4	1.95	0.17	16.5	16	13.5	58
Mar	4.8	3.21	0.36	11.8	14	16.1	47
Apr	3.7	8.26	0.21	4.8	9	19.5	48
May	3.6	6.50	0.08	2.4	7	21.6	44
June	3.0	3.80	0.03	1.6	6	25.7	45
July	2.9	1.21	0.01	1.5	5	26.2	43
Aug	3.5	0.38	0.07	5.6	6	25.9	51
Sept	4.1	0.32	0.08	12.5	9	24	46
Oct	3.9	0.29	0.08	16.1	9	19.1	44
Nov	4.4	0.31	0.09	16.0	13	13.5	53
Dec	4.3	0.47	0.15	15.0	14	11	58

4.3 Resulting Input Data for DSM2 Simulation of DO in Planning Studies

4.3.1 San Joaquin River at Vernalis

Since continuous data were not available for the San Joaquin River at Vernalis, hourly values of DO and temperature available from the nearby station at Mossdale (RSAN087) were used to approximate these quantities for the boundary inflow at Vernalis. Since the flows at Vernalis are

primarily unidirectional, and the hydraulic residence time is relatively short, this assumption seems appropriate. These data, available in the IEP web site from 1984 to the present, are plotted in Figures 4.6a and 4.7a for the period 1984-1991. As described earlier, for the missing data during 1984-1991, and for 1974-1983, daily values obtained by averaging hourly values of 1997-2000 were used (Figures 4.6b and 4.7b, and Table 4.1).

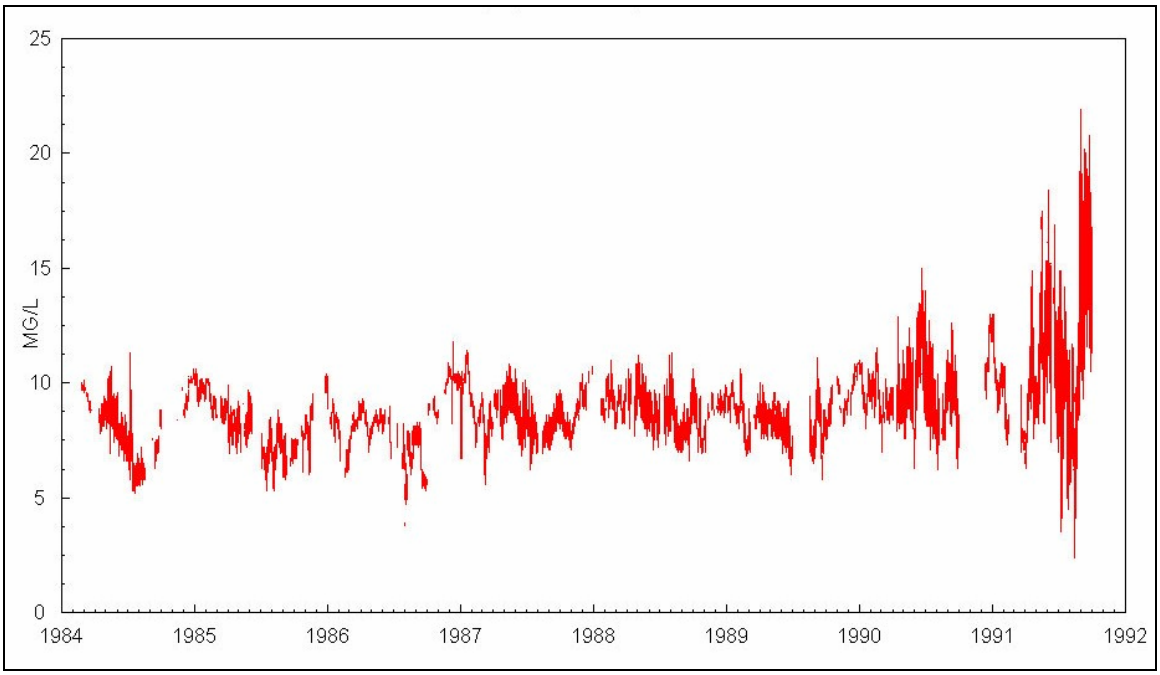

Figure 4.6a: Hourly Dissolved Oxygen at Mossdale used as Vernalis Bondary Condition (1984-1991).

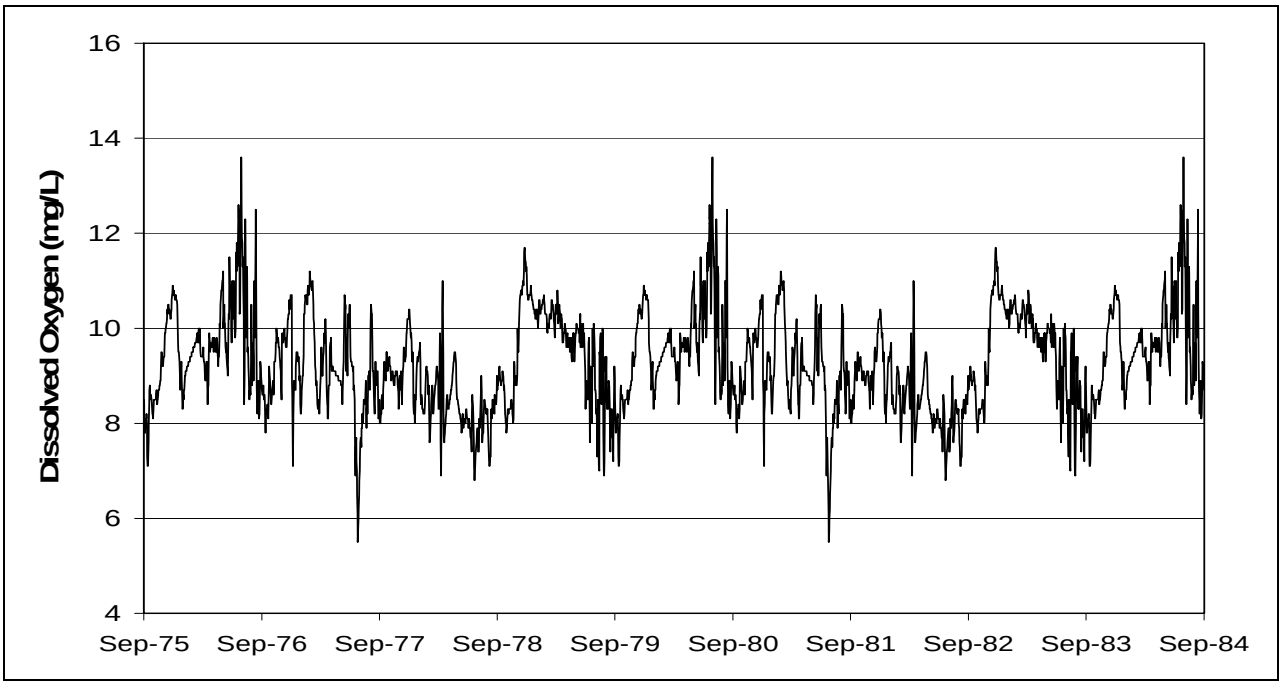

Figure 4.6b: Generated Daily Dissolved Oxygen at Vernalis (1975-1984).

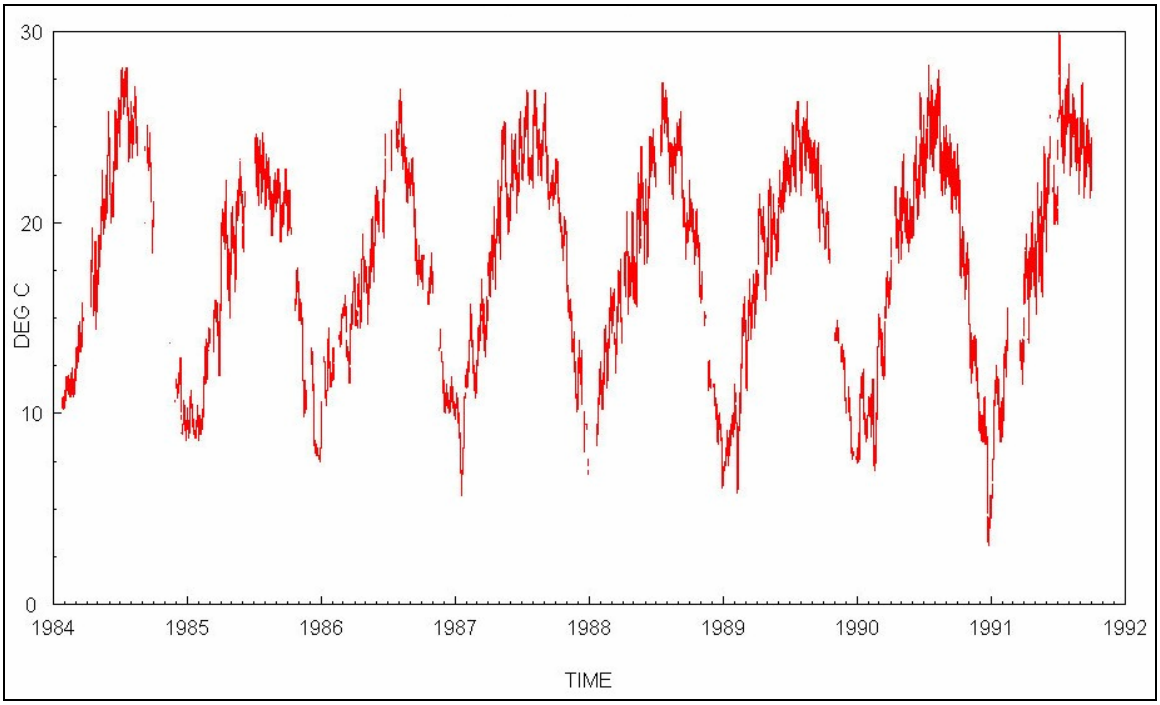

Figure 4.7a: Hourly Temperature at Mossdale used as Vernalis Boundary Condition (1984-1991).

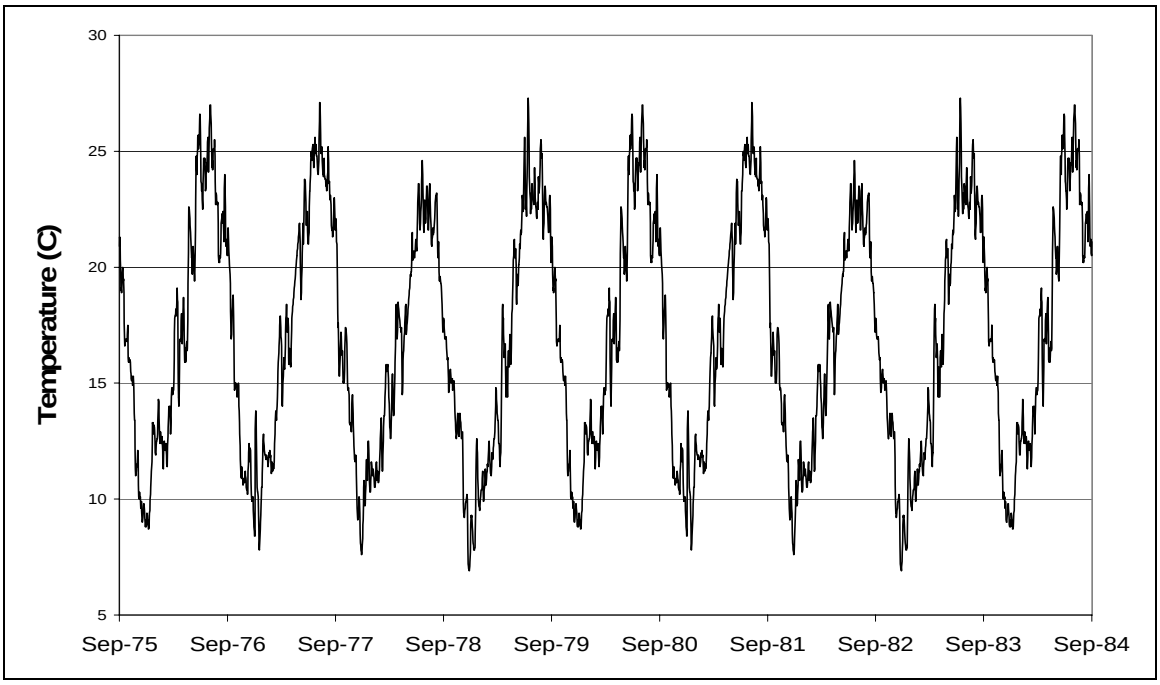

Figure 4.7b: Generated Daily Temperature at Vernalis (1975-1984).

4.3.2 Sacramento River at Freeport

As described in Section 4.2.2, daily average DO and water temperature data for the Sacramento River boundary was generated by averaging hourly data at Sacramento River at Freeport (RSAC142). These data were based on the available data from 1999 to 2001 (Figures 4.8 and 4.9).

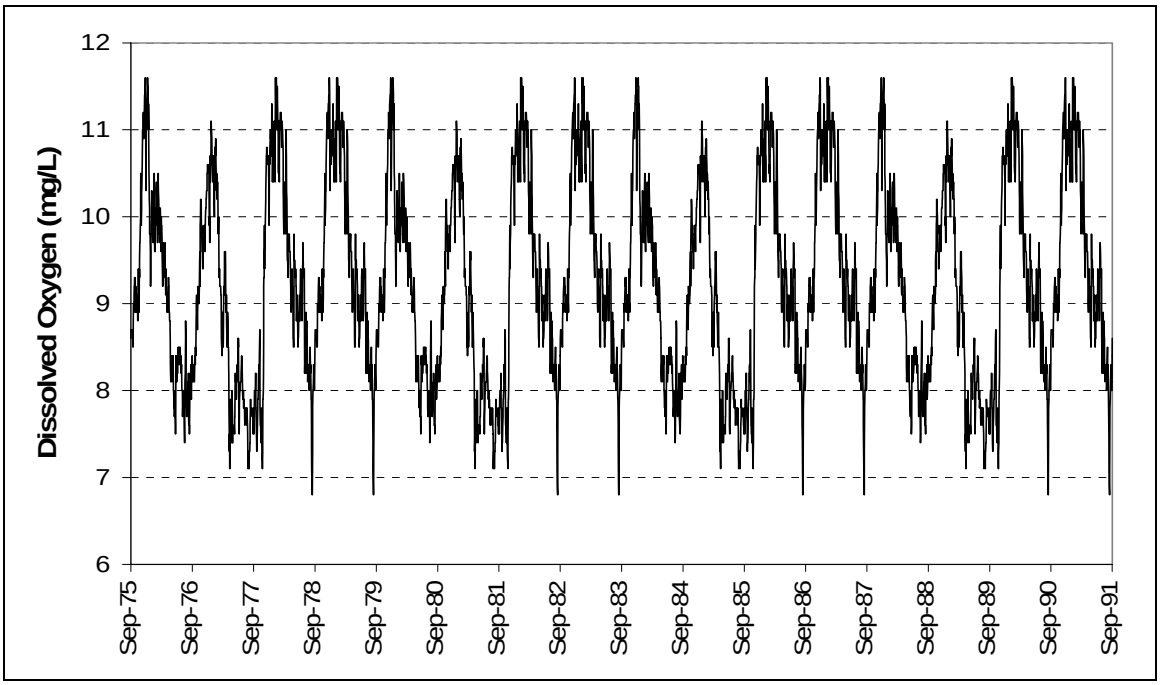

Figure 4.8: Generated Daily Dissolved Oxygen at Sacramento River, Freeport (1975-1991).

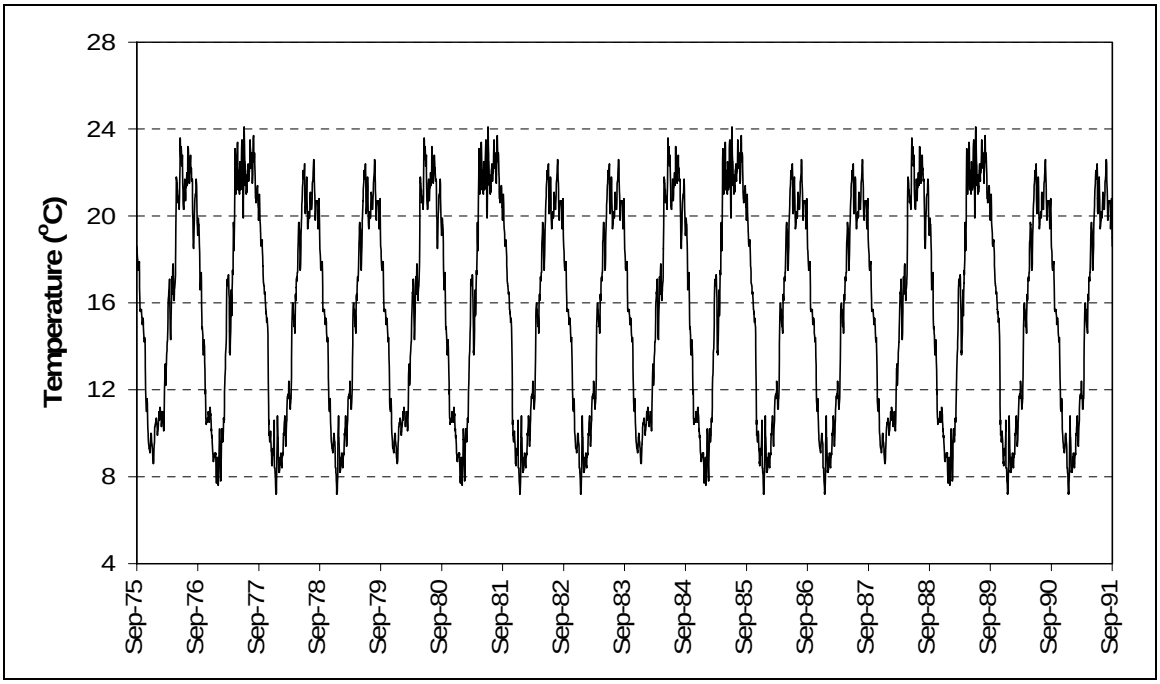

Figure 4.9: Generated Daily Temperature at Sacramento River, Freeport (1975-1991).

4.3.3 Martinez

Hourly DO and water temperature at Martinez (RSAC054), available from 1984 onwards, was used for the downstream boundary (Figures 4.10 and 4.12). As explained in Section 4.2.2, for the data missing during that period and for the entire 1974-1983 period, daily average values computed from 1997-2000 were generated both for DO and temperature (Figures 4.11 and 4.13).

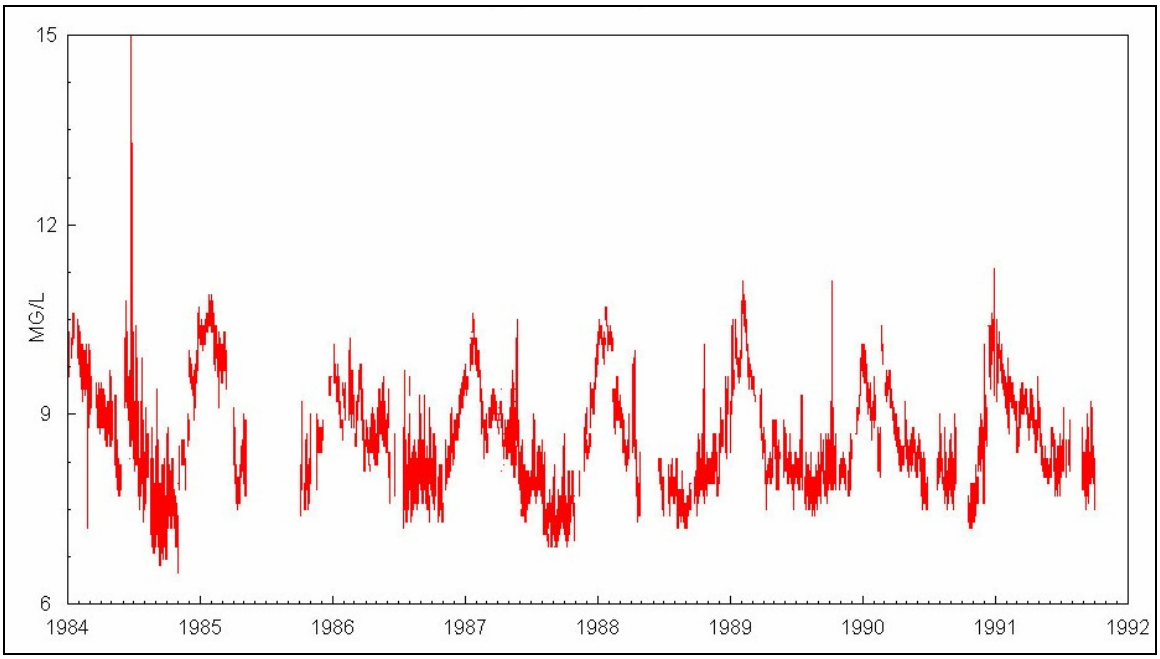

Figure 4.10: Hourly Dissolved Oxygen at Martinez (1984-1991).

Figure 4.11: Generated Daily Dissolved Oxygen at Martinez used for the Period 1975-1983.

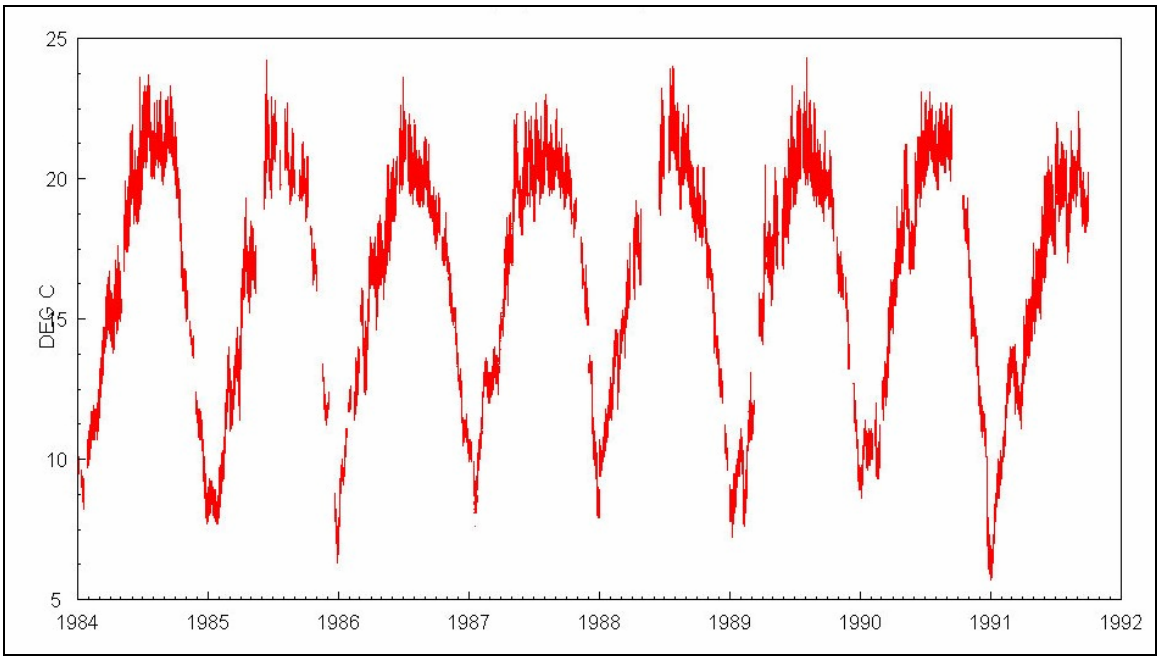

Figure 4.12: Hourly Temperature at Martinez (1984-1991).

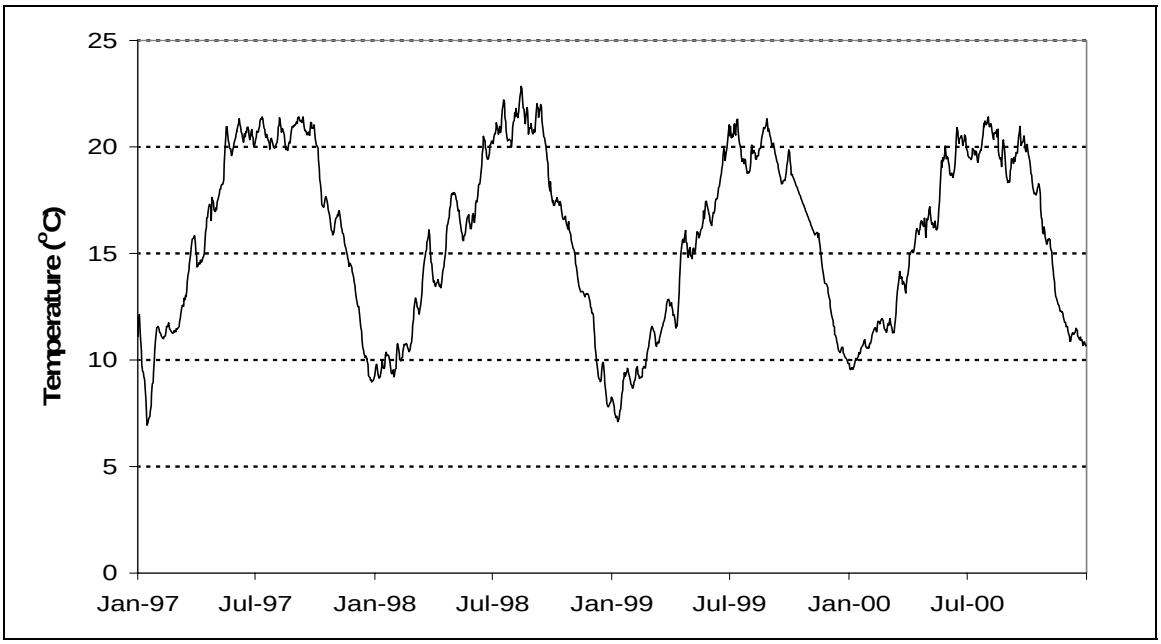

Figure 4.13: Generated Daily Temperature at Martinez used for the Period 1975-1983.

4.4 Conclusions

The current efforts to develop the planning study data series for DO and temperature simulations provide an important milestone. Considering the extent of missing data, it is expected that further data refinement will continue. In using the data in the present form, careful consideration should be made based on the geographical location and the nature of the study. For the preliminary assessments of the DO and temperature impact studies, these data sets should be appropriate in most cases.

For the future updates, grab samples at biweekly or monthly intervals collected at several locations in the Delta since 1975 can be utilized to provide an approximate monthly variation of nutrient data.

4.5 References

Bowie, G.L., W.B. Mills, D.B. Porcella, C.L. Campbell, J.R. Pagenkopt, G.L. Rupp, K.M. Johnson, P.W.H. Chan, and S.A. Gherini. (1985). *Rates, Constants and Kinetics Formulations in Surface Water Quality Modeling, 2nd Ed.* US EPA. Athens, Georgia. EPA 600/3-85/040.

Brown, L.C. and T.O. Barnwell. (1987). *The Enhanced Stream Water Quality Models QUAL2E and QUAL2E-UNCAS; Documentation and Users Manual*. US EPA. Athens, Georgia. EPA 600/3-87/007.

California Department of Water Resources. (1967). "Delta and Suisun Marsh Water Quality Investigation." *Bulletin 123.* California Department of Water Resources. Sacramento, CA.

California Department of Water Resources. (2004). *In-Delta Storage Program State Feasibility Study*. Draft Report on Water Quality. Division of Planning and Local Assistance. Sacramento, CA.

California Department of Water Resources. (1999). *Water Quality Conditions in the Sacramento-San Joaquin Delta During 1995.* Division of Local Assistance. Sacramento, CA.

California Department of Water Resources. (1997). *Water Quality Conditions in the Sacramento-San Joaquin Delta During 1993.* Division of Local Assistance. Sacramento, CA.

Huber, L. (2001). City of Stockton Municipal Utilities Department. Personal Communication.

Interagency Ecological Program. http://iep.water.ca.gov/data.html

Jones & Stokes Associates. (1998). *Potential Solutions for Achieving the San Joaquin River Dissolved Oxygen Objectives*. Prepared for De Cuir & Somach and City of Stockton Department of Municipal Utilities.

Municipal Water Quality Investigation Data Request. (1995). "Internal California Department of Water Resources Memorandum to P. Hutton from R. Woodard, February 1 and 15." Sacramento, CA.

Nieuwenhuyse, E.E.V. (2002). *Statistical Model of Dissolved Oxygen Concentration in the San Joaquin River Stockton Deepwater Channel at Rough and Ready Island, 1983-2001*. Report to the San Joaquin Dissolved Oxygen TMDL Technical Advisory Committee. U.S. Bureau of Reclamation.

Rajbhandari, H. L., P. Nader and P. Hutton. (2002). *DSM2 Studies to Investigate the Use of Auxiliary Flow Pumps across South Delta Flow Structures*. Report to San Joaquin River Dissolved Oxygen TMDL Stakeholder Process Technical Advisory Committee. CALFED Directed Action Project. Sacramento, CA.

Rajbhandari, H.L. (2004). *Model Assessment of Dissolved Oxygen and Flow Dynamics in the San Joaquin River near Stockton, California*. Proceedings of the 8th International Conference on Estuarine and Coastal Modeling held in Nov 3-5, 2003, Monterey, Calif. [In press]

US Geological Survey. (1997). "Water Resources Data, California, Water Year 1997." Vol. 4.