APPENDIX F: NEW RIVER DO QUAL2K MODEL

New River QUAL2K Water Quality Model for the New River Dissolved Oxygen TMDL

Final Report
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Prepared for:

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and

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1.0. EXECUTIVE SUMMARY

This report describes model assumptions and calibration of the QUAL2K water quality model of the New River from the International Boundary to the outlet at the Salton Sea. Additional data was received from the Regional Board New River Implementation Monitoring Program, the International Boundary and Water Commission, as well as from USGS from their pesticide monitoring program. First priority in model calibration was the determination of temperature, dissolved oxygen, carbonaceous BOD, and ammonia. Secondary was the consideration of other nutrients, conductivity, suspended solids, alkalinity and pH. Phytoplankton, detritus, and pathogens were not calibrated due to limited data and other modeling limitations.

Calibration of the QUAL2K model was completed for the study date of July 17, 2006 corresponding to critical conditions of 30.5 °C headwaters temperature. Validation was performed for additional conditions of June 2006 at a headwaters temperature of 28.5 °C.

TMDL scenarios were evaluated to measure the potential improvement based on the Mexicali II Wastewater Conveyance and Treatment Project (USEPA, 2003) diversion of wastewater flows out of the New River basin upstream of the International Boundary. Following review by the Regional Board and EPA Region 9 and comments on calibration and scenario results, additional scenarios were devised in order to meet the water quality objective of 5.0 mg/L dissolved oxygen in the New River.

Results of model scenarios indicate that measurable water quality improvements have been achieved with implementation of the first phase of the Mexicali II project that was operational as of December 2006. Reduced BOD and improved DO at the International Boundary have resulted in improved conditions in the New River formerly exhibiting dissolved oxygen in the range of 0-1 mg/L for 30 km downstream of the International Boundary; however, dissolved oxygen is projected to remain between 1-2 mg/L in this reach during critical conditions. In order to meet the water quality objective of 5.0 mg/L throughout the entire New River, additional improvements would be necessary both in water quality at the International Boundary and in effluent quality from U.S. wastewater facilities and agricultural drains north of the border.

2.0. QUAL2K MODEL SETUP

2.1. QUAL2K Model Geometry

Stream lengths were calculated by GIS layers for the National Hydrography Dataset (NHD) divided at major road crossings, drains or major tributary inputs, and other landmarks of hydraulic interest such as WWTPs or weirs/drop structures. Based on the longitudinal slope data, a total of 33 segments were determined to be the minimum necessary to accurately represent the New River system from the International Boundary to the outlet at Salton Sea. The calculated stream lengths, segment designations, and additional elements are shown in Table 2-1. The number of elements (segments for internal calculations) was determined such that the range of element length is 0.45-2.75 km. Total segment lengths range from 0.45 to 11 km.

Table 2-1. Model segmentation, reach lengths, upstream distance from Salton Sea, calculation elements per segment, and weir definition for the New River QUAL2k model.

Reach#	Upstream	Downstream	Length (km)	Upstream (km)	#Elements	Weir
1	USGS_IB	Calexico WWTP	1.08	104.934	2	
2	Calexico WWTP	All-Am_Canal	1.65	103.286	3	
3	All-Am_Canal	CA_Hwy_98	3.22	100.069	3	
4	CA_Hwy_98	Clark_Rd	3.24	96.828	3	
5	Clark_Rd	Ferrell/Brucheri	2.71	94.118	3	
6	Ferrell/Brucheri	Lyons_Rd	2.94	91.173	3	
7	Lyons_Rd	Brockman_Rd	4.38	86.795	4	
8	Brockman_Rd	Greeson_Drn	1.88	84.915	3	
9	Greeson_Drn	Wormwood_Drn	5.82	79.098	5	
10	Wormwood_Drn	Drew_Rd	0.66	78.439	1	
11	Drew_Rd	Fig_Drn	1.01	77.429	2	
12	Fig_Drn	Interstate-8	1.76	75.673	3	
13	Interstate-8	Hwy80_EvanHewes	2.33	73.338	2	
14	Hwy80_EvanHewes	Seeley WWTP	0.82	72.514	1	12x2m
15	Seeley WWTP	BullheadSlough	1.37	71.149	2	
16	BullheadSlough	SaltCr_Slough	7.86	63.286	4	
17	SaltCr_Slough	Worthington_Rd	1.22	62.061	2	
18	Worthington_Rd	Rice3_Drn	7.31	54.752	4	
19	Rice3_Drn	Rice+ForresterRd	3.50	51.255	3	
20	Rice+ForresterRd	Keystone_Rd	5.19	46.066	5	
21	Keystone_Rd	N.Central_Drn	0.45	45.621	1	
22	N.Central_Drn	Hwy96	11.00	34.625	4	
23	Hwy96	Drop4	3.03	31.600	1	16x3m
24	Drop4	Drop3	2.53	29.074	1	16x2m
25	Drop3	Brawley WWTP	1.28	27.799	2	
26	Brawley WWTP	Spruce_Drn	2.12	25.680	2	
27	Spruce_Drn	Drop2	1.55	24.134	1	18x2m
28	Drop2	Kalin_Rd	9.86	14.271	5	
29	Kalin_Rd	Timothy2_Drn	1.62	12.649	3	
30	Timothy2_Drn	Gentry_Rd	1.73	10.916	3	
31	Gentry_Rd	Lack_Rd	4.38	6.536	4	
32	Lack_Rd	USGS_outlet	1.73	4.802	3	
33	USGS_outlet	Salton_Sea	4.80	0.000	4	

Widths were initially determined from USGS cross-section measurements used to develop rating tables at gauging sites (10254970 International Boundary and 10255550 Near Westmoreland).

Widths were interpolated between these known cross sections. Additional cross-section measurements were obtained from USGS based on recent flow gauge stations implemented at Lack Road and at Drop 4 near Brawley. Cross-section profiles were analyzed for conversion into model geometry in the form of generalized Manning trapezoids with a bottom width and channel side-slope. Side-slopes for the four cross-sections described above were found to be consistently in the range 0.24 (H/L), a typical angle of repose for a sandy channel.

Weir widths were estimated from aerial orthophotography downloaded from the USGS site (seamless.usgs.gov). An example of weir widths is shown in Figure 2-1 below. Weir heights were estimated to be consistent with determined stream elevations from GIS, but could be refined with local knowledge. QUAL2K assumes weirs to be of the "sharp-crested" variety for empirical re-aeration calculations, so a valid "effective" height for a different type of weir (determining how much aeration is observed at a weir based on the empirical formulation for sharp-crested weirs) may not necessarily correspond to the exact measured height.

Figure 2-1: Drop 2 structure from USGS digital orthophotography in GIS.

2.2. QUAL2K Headwater Water Quality Inputs

Critical conditions for dissolved oxygen usually occur at times of high temperature and/or low streamflow. High temperature decreases oxygen solubility while increasing BOD decay rates and oxygen consumption. Low streamflow generally corresponds to higher concentrations of oxygen-consuming wastewater, slower average flow velocity, less re-aeration, and greater proportional impact of BOD and sediment oxygen demand. As discussed with EPA Region 9 and the Regional Board, critical conditions in the New River are defined as the warmest summer period that includes the months of July and August.

For the QUAL2k initial calibration, the date of July 17, 2006 was chosen in order to correspond to a Regional Board sampling event. Water temperatures at the International Border in July and August frequently exceed 30 ℃. Unfortunately, BOD5 samples were not analyzed for July and August, so the model input was estimated at 50 mg/L BOD5, determined from the range 40-70 mg/L BOD5 measured at all other times. Setmire (1984) observed intra-day fluctuations of water quality indicative of changing discharge conditions across the International Border. Therefore, it seems likely that the New River at present may continue to experience intra-day fluctuations in the range of 40-70 mg/L. In any case, caution should be taken in assuming whether model BOD5 on any given day might remain constant at the value of one analyzed sample. There is higher certainty that it would be within the range of historical samples. Input BOD5 was partitioned to 30 mg/L CBODslow and 20 mg/L CBODfast. The slow vs. fast fractions are used separately in the model calculations for oxygen consumption, based on different user-defined rates of first-order CBOD decay of 0.2/day and 0.4/day respectively. Headwaters characteristics used in the model are shown in Table 2-2. These headwater characteristics were obtained from measurements by the Regional Board.

Table 2-2. Flow and water quality parameters for model headwater (inflow) for July 17, 2006

Headwater Parameter	Units	Value
Streamflow	m^3/s	3.625 (128 cfs)
Temperature	℃	30.50
Conductivity	Umhos	5786.00
Inorganic Solids	mg/L	46.00
Dissolved Oxygen	mg/L	0.66
CBODslow (est.)	mgO_2/L	30.00
CBODfast (est.)	mgO_2/L	20.00
Organic Nitrogen	ugN/L	5890.00
NH4-Nitrogen	ugN/L	8161.00
NO3-Nitrogen	ugN/L	200.00
Organic Phosphorus	ugP/L	3400.00
Inorganic Phosphorus (SRP)	ugP/L	5160.00
Phytoplankton	ugA/L	4.00
Detritus (POM)	mgD/L	0.00
Pathogen	cfu/100 mL	0.00
Alkalinity	$mgCaCO_3/L$	233.00
pH	s.u.	7.82

2.3. QUAL2K Tributary and Wastewater Inflows

Tributary/drain and wastewater inflows account for approximately two-thirds of the flow of the New River at its outlet at Salton Sea. Domestic WWTPs provide accurate flow averages as a part of monthly Discharge Monitoring Reports, which were obtained from EPA's PCS database. Flows and water quality parameters for the two largest WWTPs (Calexico and Greeley) were obtained from PCS for July 2006. Monthly flow estimates for the remaining minor WWTPs were taken from the Regional Board draft TMDL, and nutrient values were assumed based on best professional judgment. WWTP and tributary/drain assumptions for July 17, 2006 calibration date are shown in Table 2-3 below. These values are input into the Point Sources model tab because each tributary is essentially similar to a point source.

Table 2-3. Flow and water quality parameters for model tributary/drain and WWTP inputs

Point source / drain inflow	km	Inflow (m3/s)	Inflow (cfs)	Temp (°C)	Cond (umhos)	ISS (mg/L)	DO (mg/L)	CBOD (mg/L)	org-N (ug/L)	NH3 (ug/L)	Nox (ug/L)	org-P (ug/L)	PO4 (ug/L)
Calexico_WWTP	104.93	0.1116	3.94	30.83	4000	28.30	4.07	29.90	2000	3940	13680	3240	3150
Greeson_Drain	84.92	0.9590	33.87	29.65	2672	130.00	4.09	2.00	2600	1900	1700	210	400
Wormwood_Drain	79.10	0.9590	33.87	29.65	2672	130.00	4.09	2.00	2600	1900	1700	210	400
Fig_Drain	77.43	0.5319	18.78	28.81	1792	130.00	4.55	2.00	2600	2200	2940	180	460
Seeley_WWTP	72.51	0.0057	0.20	30.00	4000	50.00	10.10	30.80	2000	2000	2000	2000	2000
Bullhead_Slough	71.15	1.5930	56.26	29.65	1936	130.00	7.45	2.00	2600	880	1700	210	400
SaltCreek_Slough	63.29	1.5930	56.26	29.65	1936	130.00	7.45	2.00	2600	880	1700	210	400
CentinelaPrisonWWTP	63.29	0.0263	0.93	30.00	4000	50.00	5.00	10.00	2000	2000	2000	2000	2000
ElCentroWWTP	62.37	0.0048	0.17	30.00	4000	50.00	5.00	6.40	2000	2000	2000	2000	2000
DateGardensMHP +McCabeSchools	54.75	0.0005	0.02	30.00	4000	50.00	4.30	8.20	2000	2000	2000	2000	2000
Rice_Drain	51.25	0.8866	31.31	29.09	1936	300.00	7.45	2.00	2920	880	2260	290	220
N.Central_Drain	45.62	0.6632	23.42	29.59	2164	17.00	1.24	2.00	3000	2400	0	80	810
Drop3_Drain	29.07	0.6632	23.42	29.65	2672	130.00	4.09	2.00	2600	1900	1700	210	400
Brawley_WWTP	27.80	0.1665	5.88	31.70	4000	12.90	3.40	11.20	3310	35140	1620	2000	2000
Spruce_Drain (Aug06)	25.68	0.6632	23.42	32.71	4171	38.00	7.25	2.00	930	0	12180	100	0
Timothy2_Drain	12.65	3.9009	137.76	29.28	2165	170.00	5.78	2.00	1200	0	2000	290	120
WestmorelandWWTP	10.08	0.0070	0.25	30.00	4000	50.00	4.40	24.40	2000	2000	2000	2000	2000

color key:

(green)	measured value for July06
(light blue)	average value
(yellow)	assumed same as other measured inputs
(pink)	estimated value based on data from other treatment plants with similar treatment capabilities
(red)	Unusually high measured value for a treatment plant, used in the model because its correct value could not be verified

Drain water quality data were obtained from two Annual Reports from Imperial Irrigation District's Revised Drain Water Quality Improvement Plan, required under the New River Siltation TMDL. The IID Annual Reports provide monthly measurements of field parameters and laboratory analyses for nutrients, with the notable exceptions of BOD and COD. For those drains that were not measured, reasonable values were used from nearby drains, with care taken to use most representative, i.e. not outlier data.

Drain flows, since they are not measured by IID, had to be estimated by other means.

Fortunately, Setmire (1984) published multiple longitudinal transects of the New River. Total flows were back-calculated from the difference between the two USGS gages at the International Border and near Westmoreland. Known domestic point sources were subtracted from the total. Inflows for the remaining drains were calculated from the difference between the Setmire measured flows in 1984, scaled proportionally to the measured USGS streamflow from July 17, 2006. Results for the drain flow analysis are shown in Table 2-4.

Table 2-4. Estimated tributary/drain flows from analysis based on scaled flows from Setmire (1984)

Landmark	Measured Flow CFS (Setmire 1984)	Inflows	Flow CFS scaled to 2006 USGS	CFS-total non-WWTP	CFS non-WWTP	CFS-each
Calexico	115		128.0			
		CalexicoWWTP 4.6 CFS				
Clark	130		162.8			
Lyons	150		187.8			
		Greeson, Wormwood		67.7	67.8	33.9
Drew	160		200.3			
		Fig		18.8	18.7	18.7
Hwy80-EvanHewes	175		219.1			
		SeeleyWWTP, BullheadSlough, SaltCrSlough		112.5	112.7	56.2
Worthington	265		331.8			
		Rice3		31.3	31.4	31.4
Keystone	290		363.1			
		N.Central, BrawleyWWTP, Spruce, Drop3		70.3	70.3	23.3
Rutherford(D2)	350		438.3			
		Timothy2		137.7	137.7	137.7
Gentry	450		563.5			
WestmorelandUSGS	460		576.0			

2.4. QUAL2K Weather

Weather inputs for the critical conditions day were derived from the CIMIS Meloland station rather than NCDC due to superior data availability. Air temperature, dew point and wind speed are used in calculations for heat transfer, evaporation, and surface re-aeration. An example of air temperature and dewpoint is shown in Figure 2-2 below.

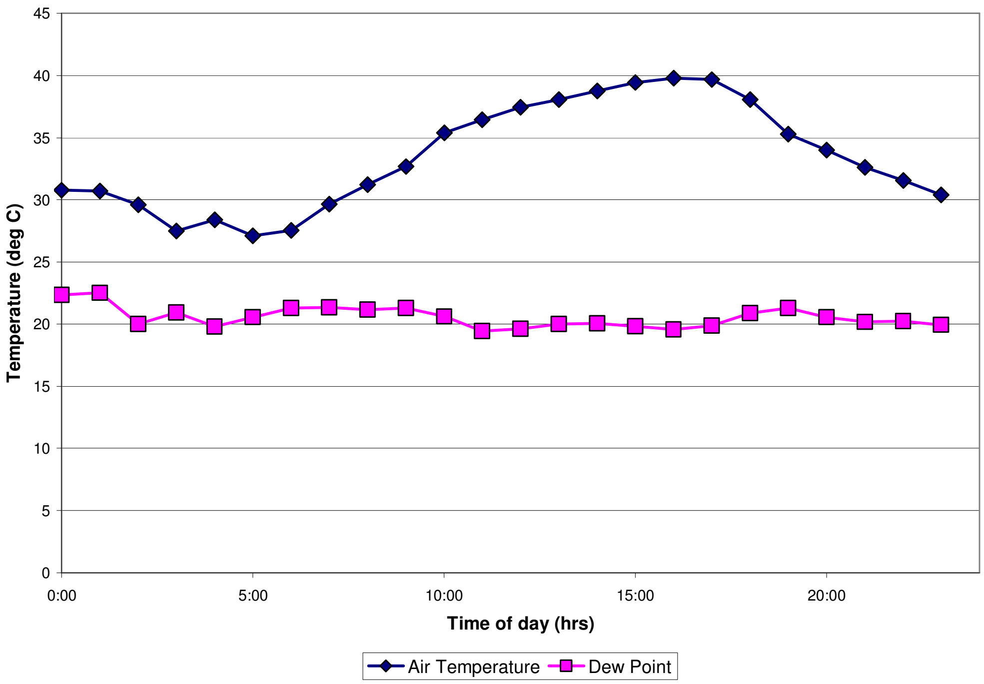

Figure 2-2. Air temperature and dew point on July 17, 2006 from Meloland CIMIS weather station.

3.0. QUAL2K CALIBRATION

3.1. Geometric considerations for Manning Flow equation

When calibrating the QUAL2K model, it became apparent that DO levels in the New River are most sensitive to residence time and stream velocity. Velocity also determines re-aeration (turbulent oxygen diffusion from the atmosphere) from the empirical function known as the O'Connor/Dobbins formulation. Observed sensitivity to CBOD decay rates, aeration formulation, and characterization of CBOD inputs (fast or slow) were less than the sensitivity to channel slopes, Manning geometry, and calculated velocity. Residence time and stream velocity were determined explicitly by the Manning equation for open channel flow (as in Chapra et al.[2006]):

$$Q \text{ [m3/s]} = (S_0^{1/2} * A_c^{5/3}) / (n * P^{2/3})$$

Where S_0 is the bottom slope [m/m], A_c is channel cross-sectional area [m^2], P is the wetted perimeter, and n is a non-dimensional roughness coefficient. Velocity is simply the calculated unit flow per cross-sectional area.

Channel slope was determined by GIS interpretation of DEM data, constrained by the known datums at the two USGS gages. Actual surveys of weirs or bridges, if obtained, could potentially be more accurate for assessing individual segments. In calibrating the model, a redoubled effort was made to ensure that segment elevations and therefore slopes were as accurate as possible with the method used, based on the limitations of the GIS data.

As a calibration factor, Manning's roughness parameter *n* was chosen to be 0.045, consistent with a "clean, winding channel with some weeds" (Chow et al. 1988, cited in Chapra et al. 2006). Bottom width, as shown in Table 3, ranges from 5.0m at the International Border to 14.0m at the USGS site near Westmoreland. Surface width varies as a function of flow and depth, in accordance with the user-specified sideslope of 0.24 m/m.

Fortunately, Setmire (1984) conducted a dye study in order to characterize time-of-travel in the New River under similar flow conditions. Model results for time-of-travel are shown in Figure 3-1. Measurement points from Setmire (1984) are at the USGS site near Westmoreland (4.8 km from Salton Sea), Worthington Rd (62.0 km), and Keystone Rd. (46.0 km).

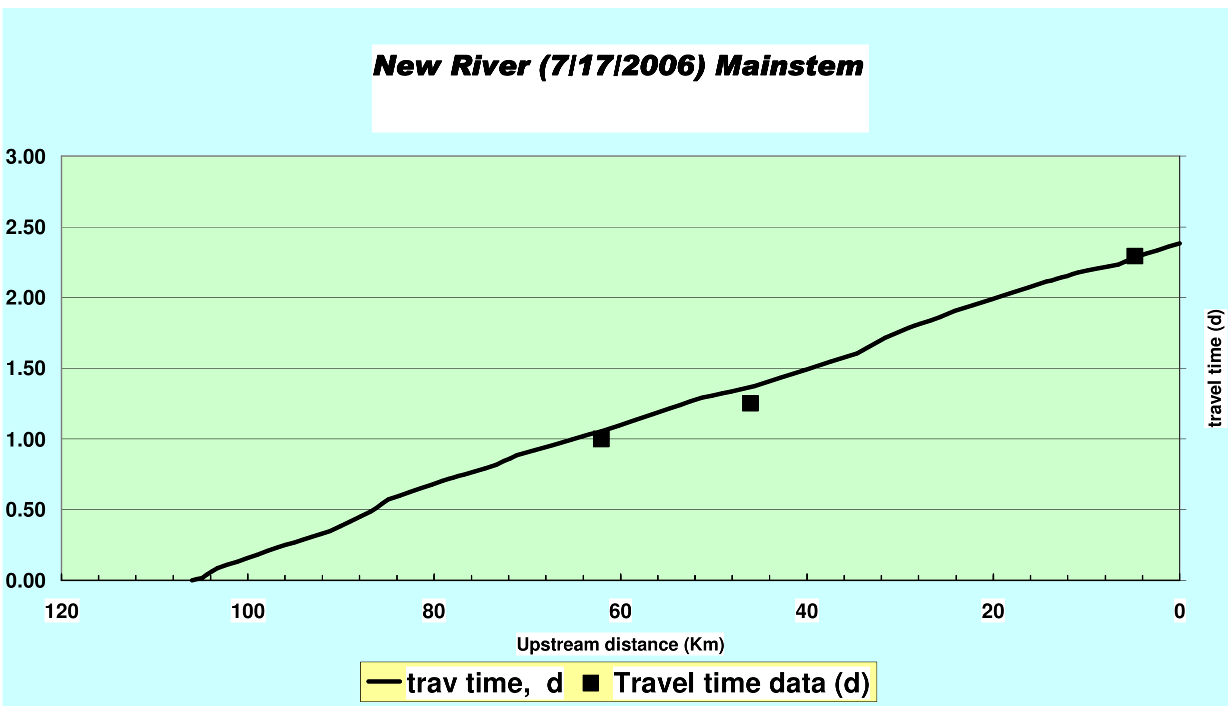

Figure 3-1. QUAL2K model time-of-travel (days) as a function of kilometers in the New River calculated based on segment Manning geometries (slope, width, *n*) compared to dye-study data measured by Setmire (1984).

QUAL2K streamflow calibration is shown in Figure 3-2 below.

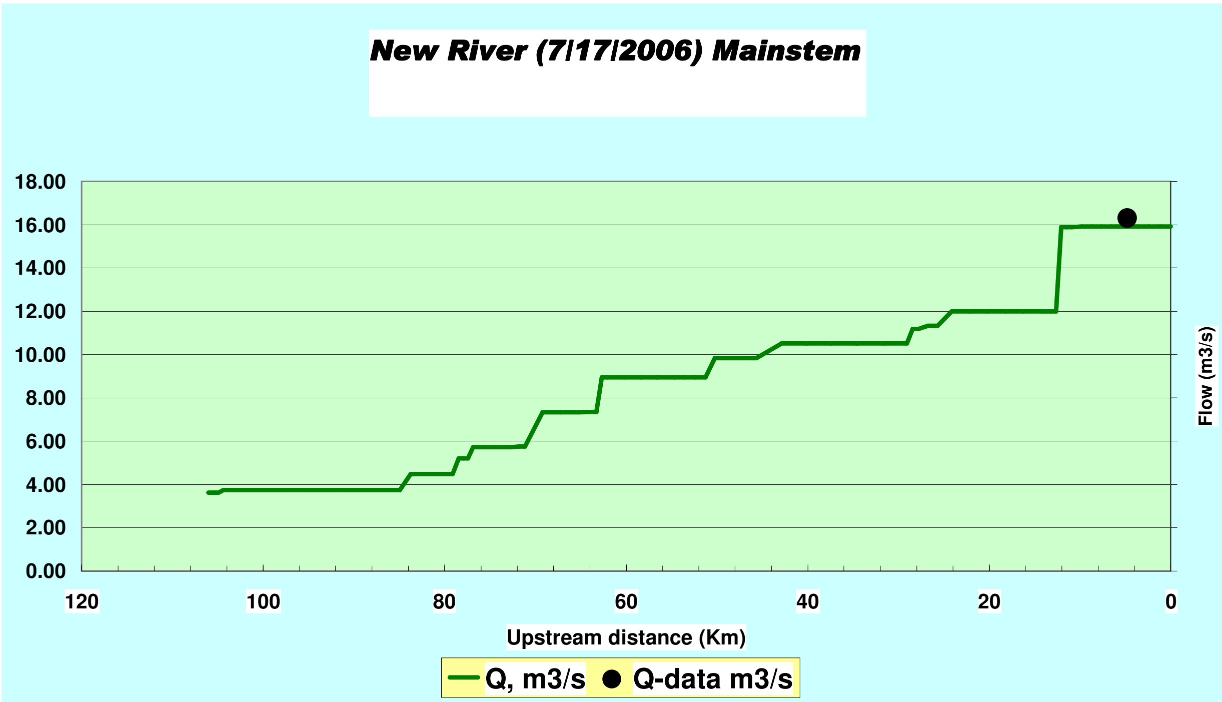

Figure 3-2. QUAL2K model longitudinal streamflow (m3/s) for July 17, 2006 as a function of kilometers from the outlet.

Table 3-1. Manning formula parameters for QUAL2K stream segments.

Reach#	Manning formula parameters		
	Roughness *n*	**Bottom Width (m)**	**Sideslopes (m/m)**
1	0.045	5.00	0.24
2	0.045	5.07	0.24
3	0.045	5.20	0.24
4	0.045	5.33	0.24
5	0.045	5.44	0.24
6	0.045	5.56	0.24
7	0.045	5.74	0.24
8	0.045	5.82	0.24
9	0.045	6.06	0.24
10	0.045	6.08	0.24
11	0.045	6.13	0.24
12	0.045	6.20	0.24
13	0.045	6.29	0.24
14	0.045	6.33	0.24
15	0.045	6.38	0.24
16	0.045	6.70	0.24
17	0.045	6.75	0.24
18	0.045	7.05	0.24
19	0.045	7.20	0.24
20	0.045	7.41	0.24
21	0.045	7.43	0.24
22	0.045	7.88	0.24
23	0.045	8.00	0.24
24	0.045	8.48	0.24
25	0.045	8.72	0.24
26	0.045	9.12	0.24
27	0.045	9.42	0.24
28	0.045	11.29	0.24
29	0.045	11.60	0.24
30	0.045	11.93	0.24
31	0.045	12.76	0.24
32	0.045	13.09	0.24
33	0.045	14.00	0.24

3.2. **Dissolved Oxygen Calibration**

Once the model geometry was refined in terms of widths and slopes, and the appropriate time-of-travel was achieved, the calibration process concentrated on water quality model calibration. The adjustments in the hydrodynamic calibration improved the dissolved oxygen results compared to the values obtained in the first runs of the model, requiring only minor adjustments of the water quality rates in order to achieve a satisfactory dissolved oxygen calibration. The final results for dissolved oxygen are shown in Figure 3-3 below.

Headwaters DO input is 0.66 mg/L as measured on July 17, 2006. Model results show pronounced, extremely-low levels below 1 mg/L for the first 30 km downstream of the International Border. The first Regional Board monitoring site is at Evan Hewes Highway at 73.3 km, with measured DO of 0.98 mg/L. Immediately downstream of the highway, there is a rock weir that is described in Setmire (1984) which re-aerates the New River to approximately 2.5 mg/L according to QUAL2K. Despite additional inflows of higher DO, carbonaceous decay and further loads of carbonaceous and nitrogenous matter continues to deplete DO until the weirs at Drop4, Drop3, and Drop2, at 31.6 km, 29.0 km, and 24.1 km, respectively. Measured DO at Drop2 was 5.21 mg/L.

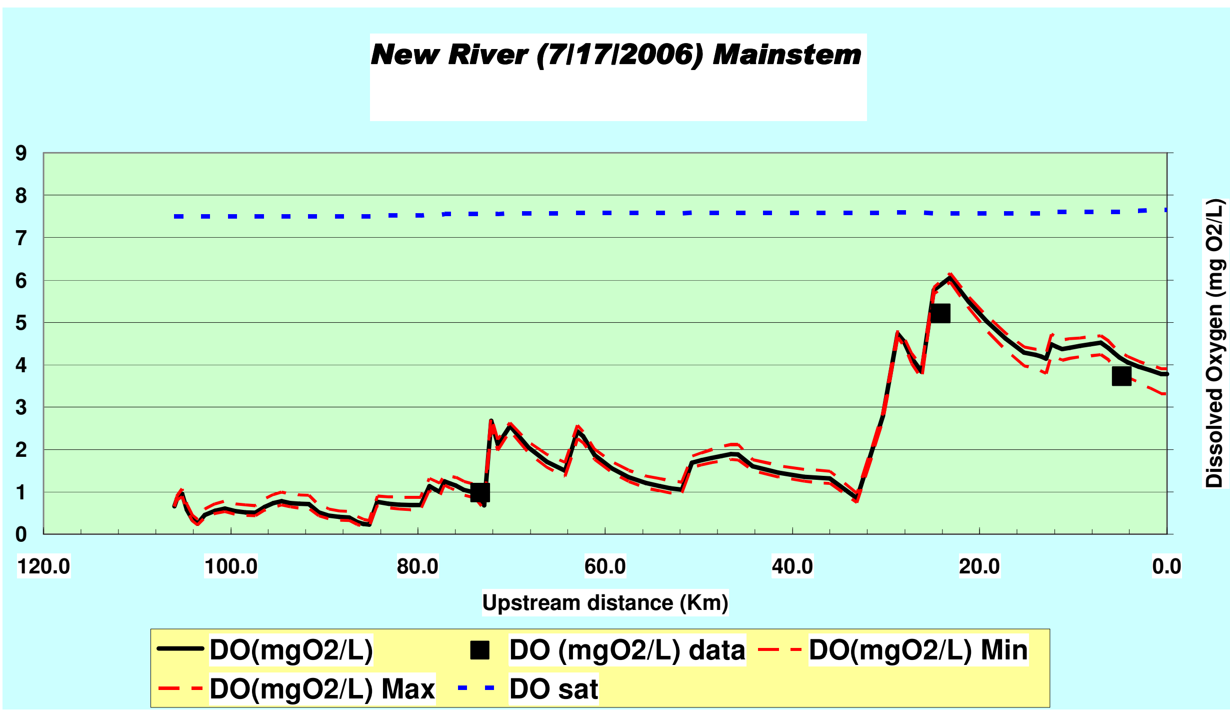

Figure 3-3. QUAL2K model longitudinal dissolved oxygen (mg/L) for July 17, 2006 as a function of kilometers from the outlet. (0.0=outlet at Salton Sea)

For the initial calibration, the headwaters input DO was defined in QUAL2K as 0.66 mg/L assumed constant for the entire day of July 17, 2006. Additional continuous DO and temperature data were used to define a diurnal range of fluctuation for model input.

The water quality calibration concentrated on dissolved oxygen because it was the only data available. A specific adjustment of the calibration based on CBODu and ammonia was therefore not possible. Nevertheless, for illustration purposes both profiles are shown in Figures 3-4 and 3-

5.

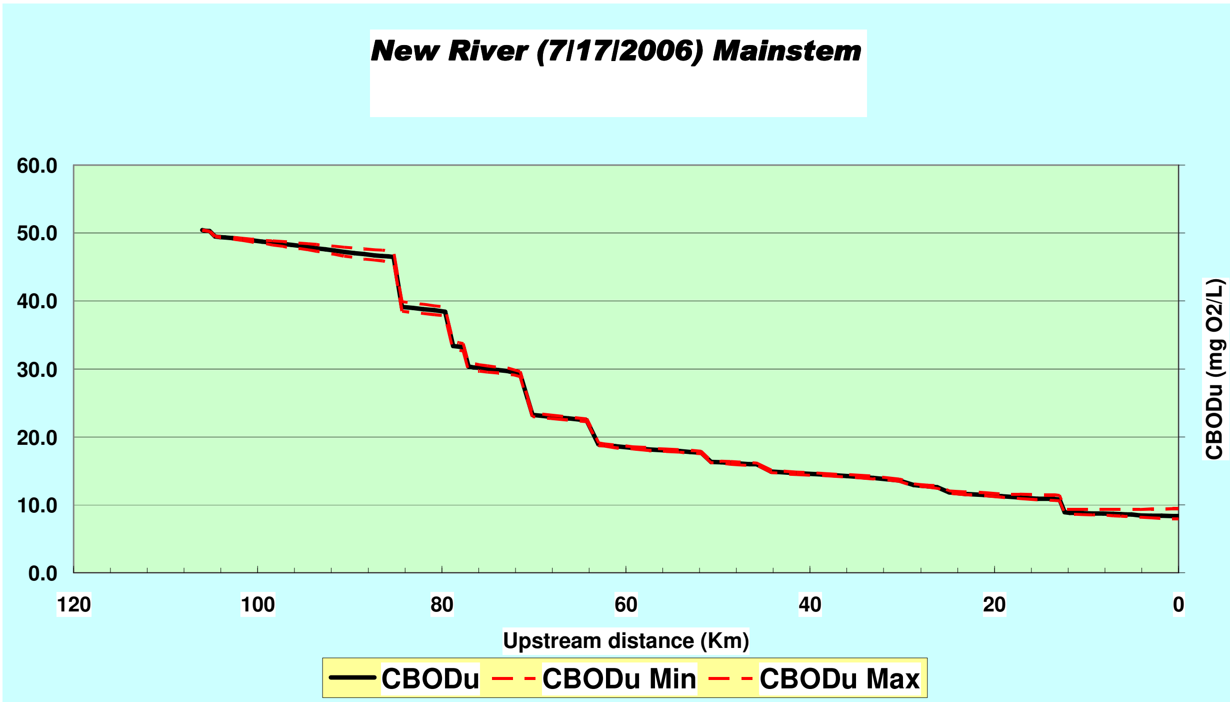

Figure 3-4. QUAL2K model longitudinal CBODu (mg/L) for July 17, 2006

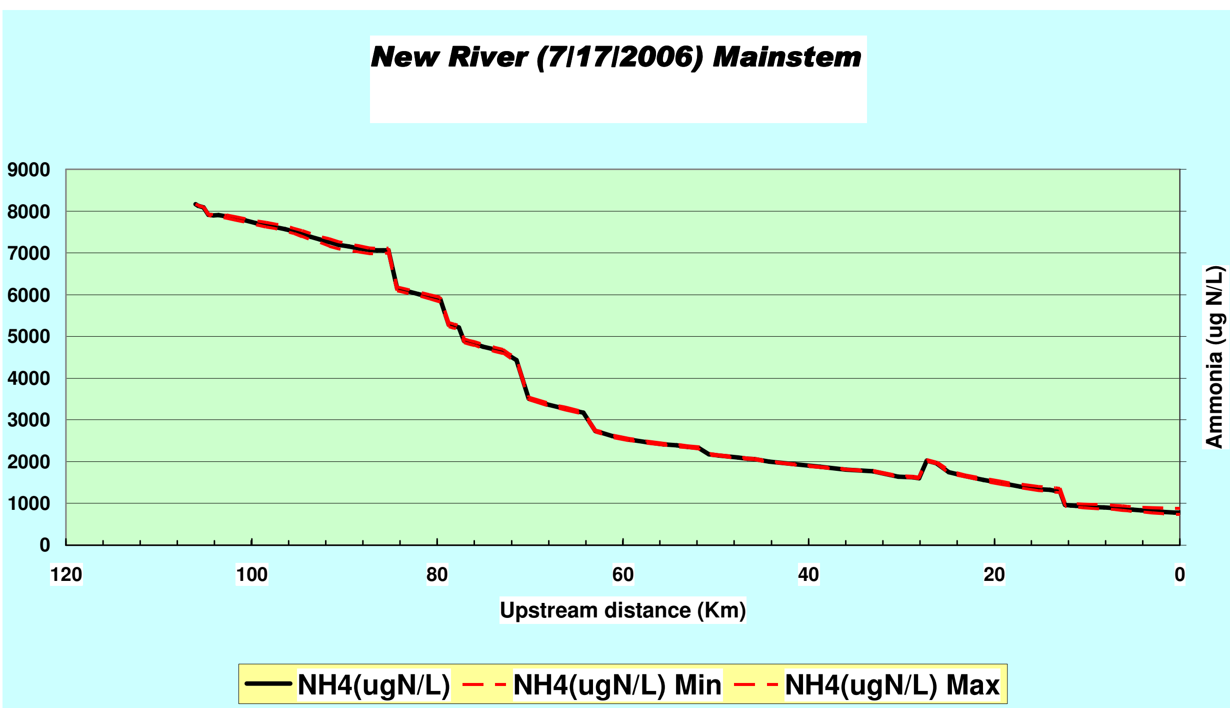

Figure 3-5. QUAL2K model longitudinal ammonia (mg/L) for July 17, 2006

3.3. QUAL2K Water Column Rates

QUAL2K model was calibrated by adjusting coefficients and rates in order to reproduce time of travel and dissolved oxygen in the longitudinal profile. Literature values were used as a first approximation and their value fine tuned through the process of calibration. The final value for the water quality rate values are given in Table 3-2.
The water quality calibration was done only through dissolved oxygen longitudinal profile because it was the only data available. Nevertheless, dissolved oxygen is affected by carbonaceous and nitrogen oxygen demand sources present in the system and these processes were simulated in the modeling process, and their rates adjusted through the calibration process.

Table 3-2. QUAL2K Final Water Column Rates Values

Parameter	***Value***	***Units***
Stoichiometry:		
Carbon	**40**	**gC**
Nitrogen	**7.2**	**gN**
Phosphorus	**1**	**gP**
Dry weight	**100**	**gD**
Chlorophyll	**1**	**gA**
Inorganic suspended solids:		
Settling velocity	**0.3**	**m/d**
Oxygen:		
Reaeration model	**O'Connor-Dobbins**	
Temp correction	**1.05**	
Reaeration wind effect	**Banks-Herrera**	
O2 for carbon oxidation	**2.69**	**gO_2/gC**
O2 for NH4 nitrification	**4.57**	**gO_2/gN**
Oxygen inhib model CBOD oxidation	**Exponential**	
Oxygen inhib parameter CBOD oxidation	**0.60**	**L/mgO2**
Oxygen inhib model nitrification	**Exponential**	
Oxygen inhib parameter nitrification	**0.60**	**L/mgO2**
Oxygen enhance model denitrification	**Exponential**	
Oxygen enhance parameter denitrification	**0.60**	**L/mgO2**
Oxygen inhib model phyto resp	**Exponential**	
Oxygen inhib parameter phyto resp	**0.60**	**L/mgO2**
Oxygen enhance model bot alg resp	**Exponential**	
Oxygen enhance parameter bot alg resp	**0.60**	**L/mgO2**
Slow CBOD:		
Hydrolysis rate	**0.1**	**/d**
Temp correction	**1.07**	
Oxidation rate	**0.2**	**/d**
Temp correction	**1.047**	
Fast CBOD:		
Oxidation rate	**0.4**	**/d**

Temp correction	**1.047**	
Organic N:		
Hydrolysis	**0.2**	**/d**
Temp correction	**1.07**	
Settling velocity	**0.1**	**m/d**
Ammonium:		
Nitrification	**1**	**/d**
Temp correction	**1.07**	
Nitrate:		
Denitrification	**0**	**/d**
Temp correction	**1.07**	
Sed denitrification transfer coeff	**0**	**m/d**
Temp correction	**1.07**	
Organic P:		
Hydrolysis	**0.2**	**/d**
Temp correction	**1.07**	
Settling velocity	**0.1**	**m/d**
Inorganic P:		
Settling velocity	**2**	**m/d**
Inorganic P sorption coefficient	**0**	**L/mgD**
Sed P oxygen attenuation half sat constant	**0.05**	**mgO_2/L**
Phytoplankton:		
Max Growth rate	**2.5**	**/d**
Temp correction	**1.07**	
Respiration rate	**0.2**	**/d**
Temp correction	**1.07**	
Death rate	**0.2**	**/d**
Temp correction	**1.07**	
Nitrogen half sat constant	**25**	**ugN/L**
Phosphorus half sat constant	**5**	**ugP/L**
Inorganic carbon half sat constant	**1.30E-05**	**moles/L**
Light model	**Half saturation**	
Light constant	**100**	**langleys/d**
Ammonia preference	**25**	**ugN/L**
Settling velocity	**0.5**	**m/d**
Bottom Algae:		
Growth model	**Zero-order**	
Max Growth rate	**50**	**$mgA/m^2/d$ or /d**
Temp correction	**1.07**	

First-order model carrying capacity	1000	mgA/m^2
Respiration rate	0.1	/d
Temp correction	1.07	
Excretion rate	0.05	/d
Temp correction	1.07	
Death rate	0.1	/d
Temp correction	1.07	
External nitrogen half sat constant	300	ugN/L
External phosphorus half sat constant	100	ugP/L
Inorganic carbon half sat constant	1.30E-05	moles/L
Light model	Half saturation	
Light constant	100	langleys/d
Ammonia preference	25	ugN/L
Subsistence quota for nitrogen	0.72	mgN/mgA
Subsistence quota for phosphorus	0.1	mgP/mgA
Maximum uptake rate for nitrogen	72	mgN/mgA/d
Maximum uptake rate for phosphorus	5	mgP/mgA/d
Internal nitrogen half sat constant	0.9	mgN/mgA
Internal phosphorus half sat constant	0.13	mgP/mgA
Detritus (POM):		
Dissolution rate	0.5	/d
Temp correction	1.07	
Fraction of dissolution to fast CBOD	1.00	
Settling velocity	0.1	m/d
Pathogens:		
Decay rate	0.8	/d
Temp correction	1.07	
Settling velocity	1	m/d
Light efficiency factor	1.00	
pH:		
Partial pressure of carbon dioxide	347	ppm

3.4. **QUAL2K Validation**

The QUAL2K model was tested for another time period, June 13, 2006. Headwater conditions were 28.5 °C and 70.0 mg/L total BOD5 and 0.29 mg/L DO. Tributary and headwater flows were adjusted for a headwaters flow of 153 CFS and 593 at the outlet USGS gage. Water quality inputs were adjusted accordingly.

It was determined that with the calibrated weir widths and heights, the calculated reaeration rate underestimated DO at Drop 2 where it was measured to be 7.73. Other dates of lower temperatures and non-critical conditions featured a similar phenomenon—where DO conditions are measured to be nearly saturated at the Drop 2 sampling site. This indicates significant reaeration from the weirs at Drop 2 and Drop 4. The weir reaeration formula in the model may not be robust to calculate reaeration at these points, under such severe conditions. For the QUAL2K model, reach reaeration factor ka was specified for the Drop 2 and Drop 4 reaches as 30/day and 40/day, respectively. Results for the validation run with adjustments are shown in Figure 3-4, below.

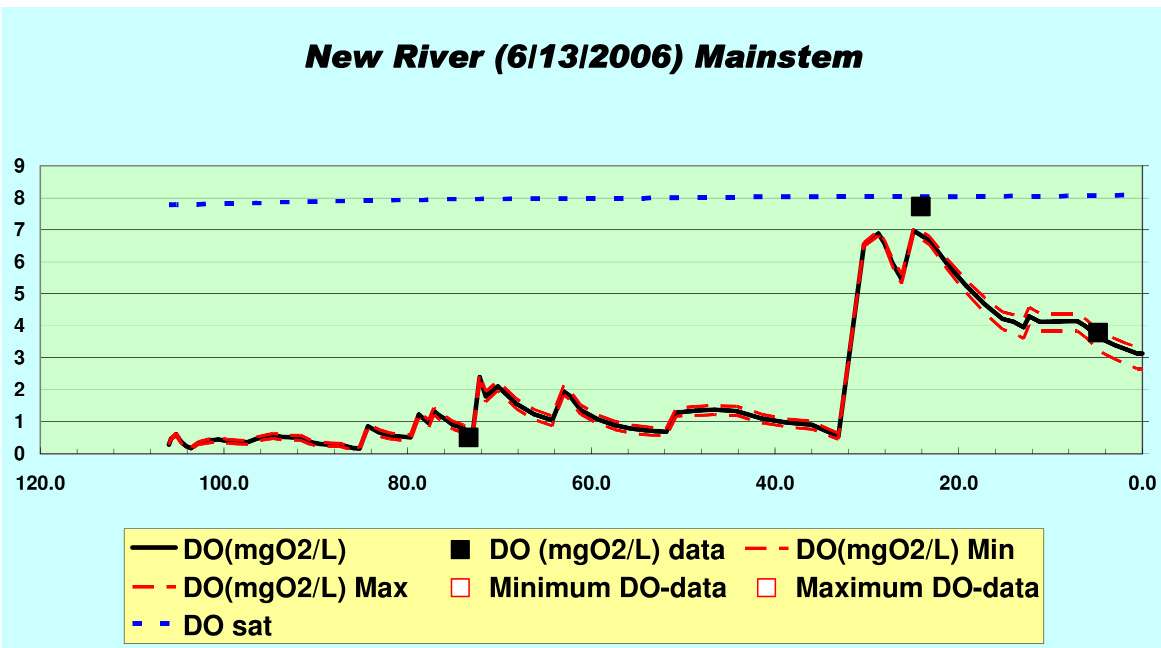

Figure 3-4. QUAL2K model longitudinal dissolved oxygen (mg/L) for June 13, 2006 as a function of kilometers from the outlet.

3.5. **QUAL2K Sensitivity Analysis**

The QUAL2K model was run to test the sensitivity of DO results to parameter input variability. Parameters tested were headwaters dissolved oxygen, CBOD, and ammonia; and segment sediment oxygen demand. In addition, a scenario was included with 30 percent reduction in drain flows to characterize the effects of possible future irrigation allocation reductions. Sensitivity to input CBOD (baseline, 50 percent and 150 percent) at the headwaters is shown in Figure 3-5.

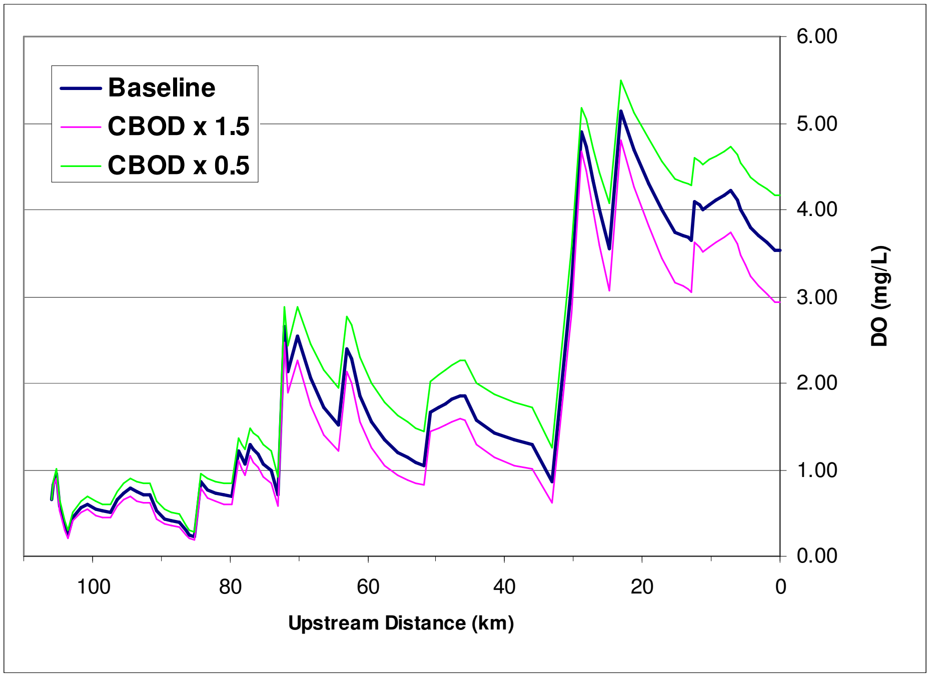

Figure 3-5. Model dissolved oxygen sensitivity to CBOD in headwaters.

This implementation of the QUAL2K is relatively insensitive to the SOD values used and more sensitive to CBOD inputs and NH4. Headwaters dissolved oxygen boundary effects are only seen in the first 5-10 km at the calibration condition, but are more apparent farther downstream in the more oxygen-sensitive condition of TMDL scenarios (i.e., with less BOD and higher overall DO, there is a greater effect of altering the headwaters condition). Reducing drain flows by 30 percent resulted in a decrease in DO values in the range of 0-8 percent.

4.0. TMDL MODEL SCENARIOS

4.1. Evaluation of Mexicali II Wastewater Conveyance Project

As requested by the Regional Board and EPA Region 9, TMDL scenarios were prepared based on the current condition, and two future scenarios based on projected flow and pollutant reductions based on the Mexicali II project (USEPA, 2003). Furthermore, since the above scenarios do not meet the 5.0 mg/L water quality objective for dissolved oxygen, an additional TMDL scenario was prepared that is projected to meet the objective. All scenarios were run at the critical condition of headwater temperature at 30.5 deg C. Headwaters DO is assumed to be 5.0 mg/L per international agreement as a baseline.

The Current Condition is based on a recent flow average (157443 AF/y or 217.3 CFS) and average BOD5 of 36.4 mg/L. Since the scenario definition is based on average flows, rather than a specific date in time, the "Current Condition" will hereinafter be described as the "Model Baseline" scenario. As is customary in TMDL analysis, the model baseline scenario includes WWTP flows at permit limits for flow and 30-day-average BOD5, while retaining the average characterized value for other constituents (discharged NH4, DO, etc.). Permit limits for the wastewater facilities are shown in Table 4-1 below.

Table 4-1. Permit limits for NPDES WWTP facilities discharging to the New River.

NPDES facility	Km from outlet	Permit Flow (MGD)	Permit Flow (CMS)	Permit BOD5 (30-day avg. mg/L)
Calexico_WWTP	104.9	4.3	0.1884	30
Seeley_WWTP	72.5	0.2[1]	0.0088	45
CentinelaPrisonWWTP	63.3	0.6	0.0263	45
ElCentroWWTP	62.4	8.0	0.3505	30
Date Gardens MHP	54.8	0.01[1]	0.0004	30
McCabe Union	54.8	0.0015[1]	0.00007	30
Brawley_WWTP	27.8	5.9	0.2585	45
WestmorelandWWTP	10.1	0.5	0.0219	30

[1] NPDES permit limit not available, average used

The first Future Condition is based on an estimated flow reduction of 13.7 MGD from the Mexicali II project, which diverts wastewater out of the New River basin. The first phase of the Mexicali II project was put into operation in approximately December, 2006 (Regional Board, personal communication). The Regional Board provided 2007 sampling data from IBWC that indicates average BOD5 of 19.5 mg/L, which is a significant reduction from baseline. Reductions were estimated for nutrient constituents of NH4 50 percent, and other nutrients reduced 25 percent based on interpretation of projections from the Mexicali II Environmental Assessment (USEPA, 2003). Modeled estimated nutrient reductions may be adjusted by EPA or Regional Board staff based on additional monitoring data that will become available.

The second Future Condition is based on a total flow reduction of 20.1 MGD due to the next phase of the Mexicali II project due to be completed by 2014. BOD5 is estimated to be approximately 15 mg/L with reductions in NH4 and other nutrients 60 percent and 40 percent, respectively. These reductions may be adjusted or refined with further analysis of additional data, but are thought to be reasonable based on existing data.

Current (model baseline), Future Condition 1 and Future Condition 2 scenarios are detailed in Table 4-2, below. All three of these scenarios consist of altered flow, DO, and constituent values at the headwaters (International Border). No changes were made to flows or pollutant loadings north of the border.

Table 4-2. Scenarios for Model Baseline, Future Condition 1, and Future Condition 2. Constituent values are estimated for the headwaters at the International Boundary based on Mexicali II phase 1 and 2.

Scenario	Flow (CMS)	Flow (CFS)	DO (mg/L)	CBOD (mg/L)	NH4 (mg/L)	N-org (mg/L)	NO3-N (mg/L)	P-org (mg/L)	SRP (mg/L)
Baseline	6.15	217.3	5.0	36.4	9.30	3.65	0.23	1.47	1.70
Future 1	5.55	196.1	5.0	19.5	4.65	2.74	0.17	1.10	1.28
Future 2	5.27	186.2	5.0	15.0	3.72	2.19	0.14	0.88	1.02

Results of the Model Baseline, Future Condition 1, and Future Condition 2 are shown in Figure 4-1, below.

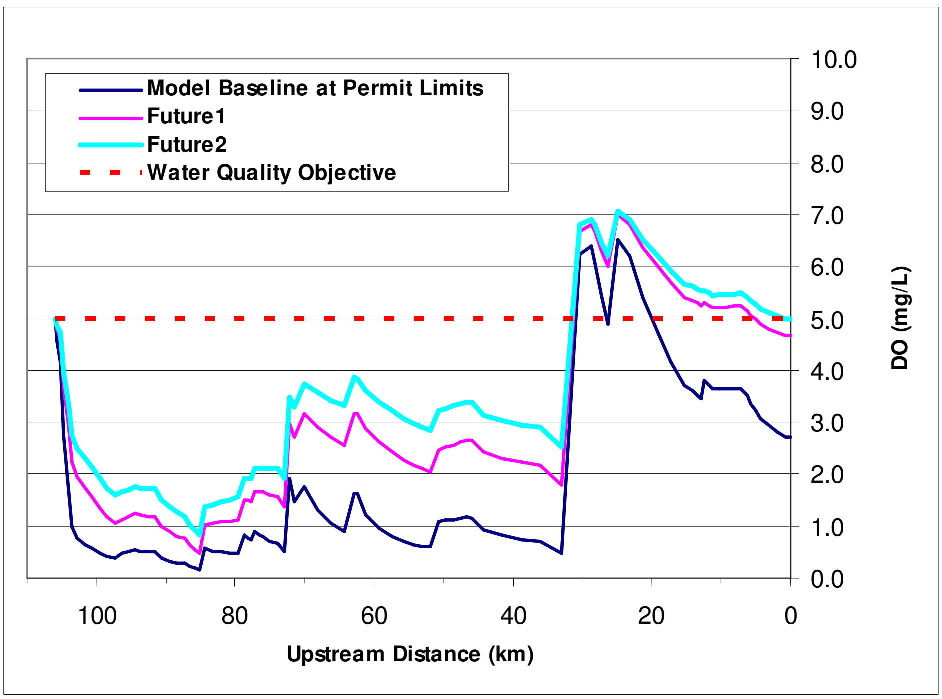

Figure 4-1. QUAL2K model longitudinal dissolved oxygen (mg/L) for Baseline, Future1, and Future2 scenarios as a function of kilometers from the outlet (0.0 = outlet at Salton Sea).

A few conclusions may be drawn from the model results of these three scenarios. First, neither of the scenarios based on the Mexicali II project meet the 5.0 mg/L water quality objective. Second, the Future Condition 2 scenario does result in DO greater than 5.0 mg/L downstream of the Drop 4 structure, but only in the final 30 km to the outlet at the Salton Sea.

The critical spatial region for lowest instream DO is the 30 km from the International Boundary upstream of the rock weir at Seeley. This region exhibits modeled dissolved oxygen in the range of 1.0-2.0 mg/L primarily due to CBOD decay and nitrification of NH4. Therefore, in order to reach the TMDL water quality objective of 5.0 mg/L, further reductions are necessary—either at the International Boundary or from the Calexico WWTP which is the only NPDES facility in this region, and the only inflow for the first 20 km.

4.2. TMDL Reductions Necessary to Meet Water Quality Objective

As a first step, an effort was made to determine if attainment of the water quality objective of 5.0 mg/L is possible from reductions at the International Boundary alone (the model headwaters condition). Headwater NH4 was reduced to 0.5 mg/L and CBOD reduced to 8.0 mg/L (approximate reductions of 87 percent and 47 percent, respectively from Future Condition 2 at the International Boundary). Results of this first step are shown in Figure 4-2 below.

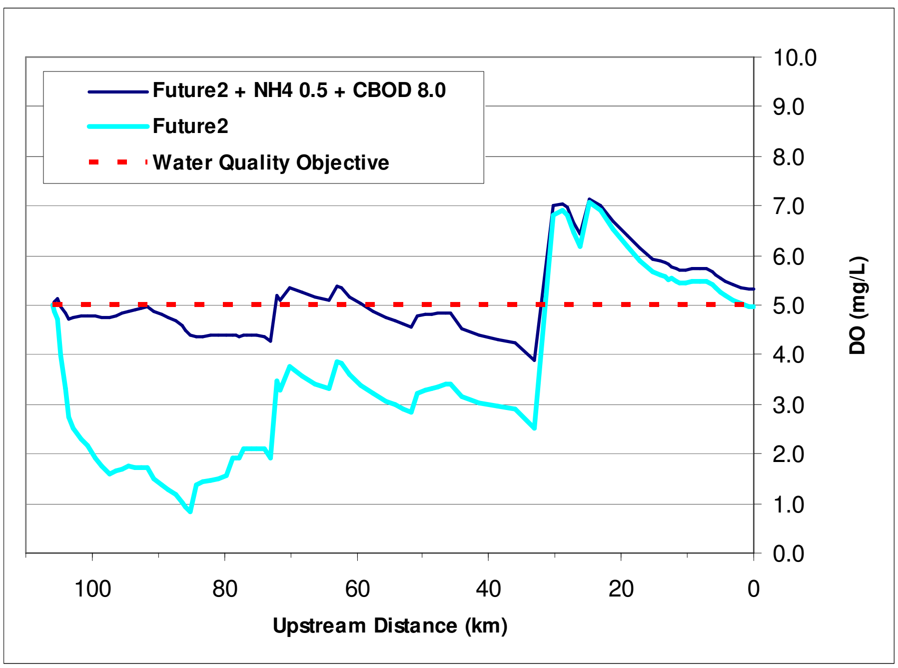

Figure 4-2. QUAL2K model longitudinal dissolved oxygen (mg/L) for the Future2 scenario compared to the further reduction of headwater CBOD to 8.0 mg/L and NH4 to 1.0 mg/L

It was discovered that, clearly, 5.0 mg/L can not be attained from the International Boundary to km70 based on the headwaters conditions and with additional loading from the WWTP at Calexico. With reduction of ammonia to zero at the International Boundary, 5.0 mg/L could be attained to km80 (data not shown) but further reductions would be necessary (allocated to Calexico WWTP or the drains) to maintain 5.0 mg/L downstream of km80.

Regardless, only with a headwaters dissolved oxygen greater than 5.0 mg/L would there be any assimilative capacity for headwaters CBOD and NH4 and inflow from the Calexico WWTP. At this point, a difficult decision must be made in order to maintain 5.0 mg/L in the upper section of the New River: 1) Maintain a minimum DO of 5.0 mg/L at the International Boundary, plus reduce headwaters NH4 to near zero and allocate some reductions to the Calexico WWTP, or 2) Require additional assimilative capacity at the International Boundary with a DO of 5.5 mg/L or greater, plus additional reductions to headwater CBOD, NH4, and/or reduced allocation to the Calexico WWTP, and/or requiring 5.0 mg/L from Calexico WWTP and tributary irrigation drains.

For reference, existing Calexico WWTP (km105) and Greeson Drain (km85) inflows were measured at approximately 4.0 mg/L DO in July 2006. Wormwood Drain enters at km79.6 and DO was assumed to be equal to Greeson Drain at 4.0 mg/L.

In order to achieve 5.0 mg/L in the upper section of the New River (International Boundary to 50 km) it is necessary to increase tributary inflow DO to at least 5.0 mg/L and reduce NH4 loading from Calexico WWTP and other slough or drain inflows to no greater than 1.0 mg/L NH4. This scenario is shown in Figure 4-3 below. To summarize, the necessary conditions for the scenario results shown in magenta are as follows:

- International Boundary DO at 5.5 mg/L
- International Boundary CBOD at 8.0 mg/L
- International Boundary NH4 at 1.0 mg/L
- Calexico WWTP, Greeson Drain, and Wormwood Drain DO at 5.0 mg/L
- Calexico WWTP, Greeson Drain, and Wormwood Drain NH4 at 1.0 mg/L

The resulting DO concentrations in the New River exceed the water quality objective to approximately km45, but further reductions are necessary to exceed 5.0 mg/L below that point.

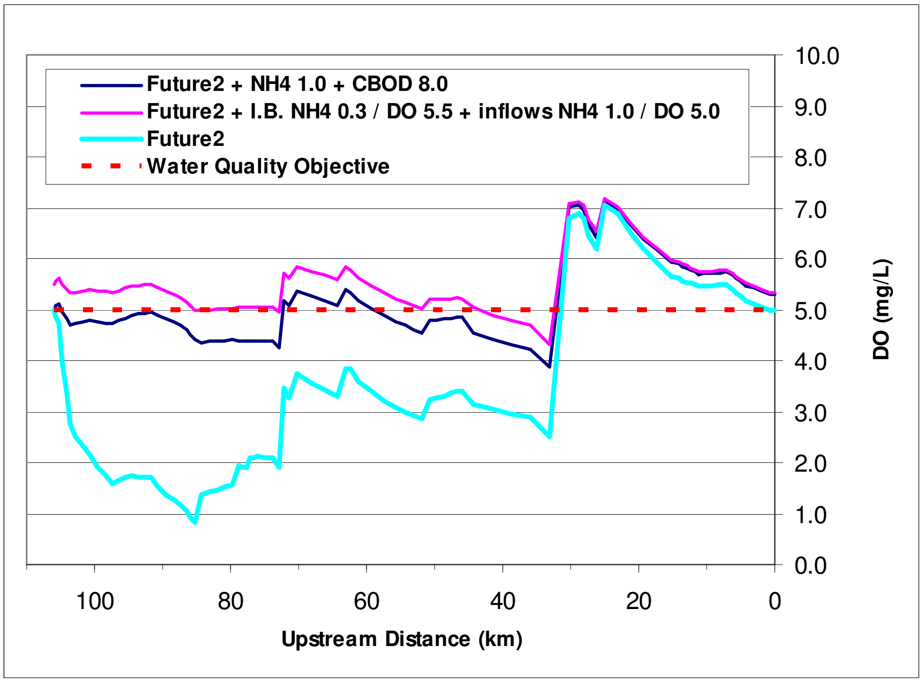

Figure 4-3. QUAL2K model longitudinal dissolved oxygen (mg/L) for the Future2 scenario compared to extensive further changes, including headwaters at 5.5 mg/L and U.S. drain and WWTP reductions.

Further reductions to headwaters and point sources were made in order to reach the water quality objective of 5.0 mg/L throughout the New River. These include:

- International Boundary DO at 6.0 mg/L
- International Boundary CBOD at 5.0 mg/L
- International Boundary NH4 at 0.3 mg/L
- All inflow (WWTP, Drains) DO at 5.0 mg/L
- Calexico WWTP, El Centro WWTP, and ALL drain NH4 at 0.7 mg/L
- Calexico WWTP, El Centro WWTP CBOD at 15 mg/L
  (current permits 30 mg/L BOD5)

Results of this analysis is denoted in green in Figure 4-4 below in the TMDL scenario.

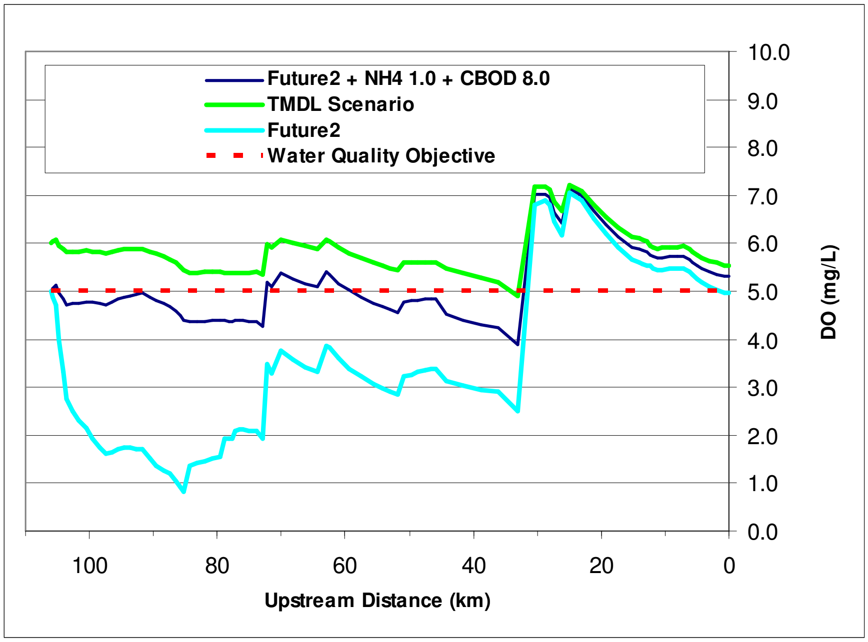

Figure 4-4. QUAL2K model longitudinal dissolved oxygen (mg/L) for extensive further changes, including headwaters at 6.0 mg/L and U.S. drain and WWTP reductions.

At the present condition (Future Condition 1) of the New River near the International Boundary with low DO and elevated CBOD and NH4, any reduction to U.S. WWTP permit limits or improvements in drain water quality would not likely result in a discernable improvement in New River dissolved oxygen. Yet, in the hypothetical TMDL scenario, even with major reductions at the headwaters, a significant reduction in CBOD and/or NH4 would still be necessary to achieve 5.0 mg/L.

The constituent values indicated above are examples based on the current implementation of the model. Regional Board and USEPA staff are encouraged to utilize the QUAL2K model to examine alternatives for TMDL allocations. Adaptive management is recommended based on accumulation of new critical conditions data collected in summer 2007 and in the future.

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Attachment A to Appendix F

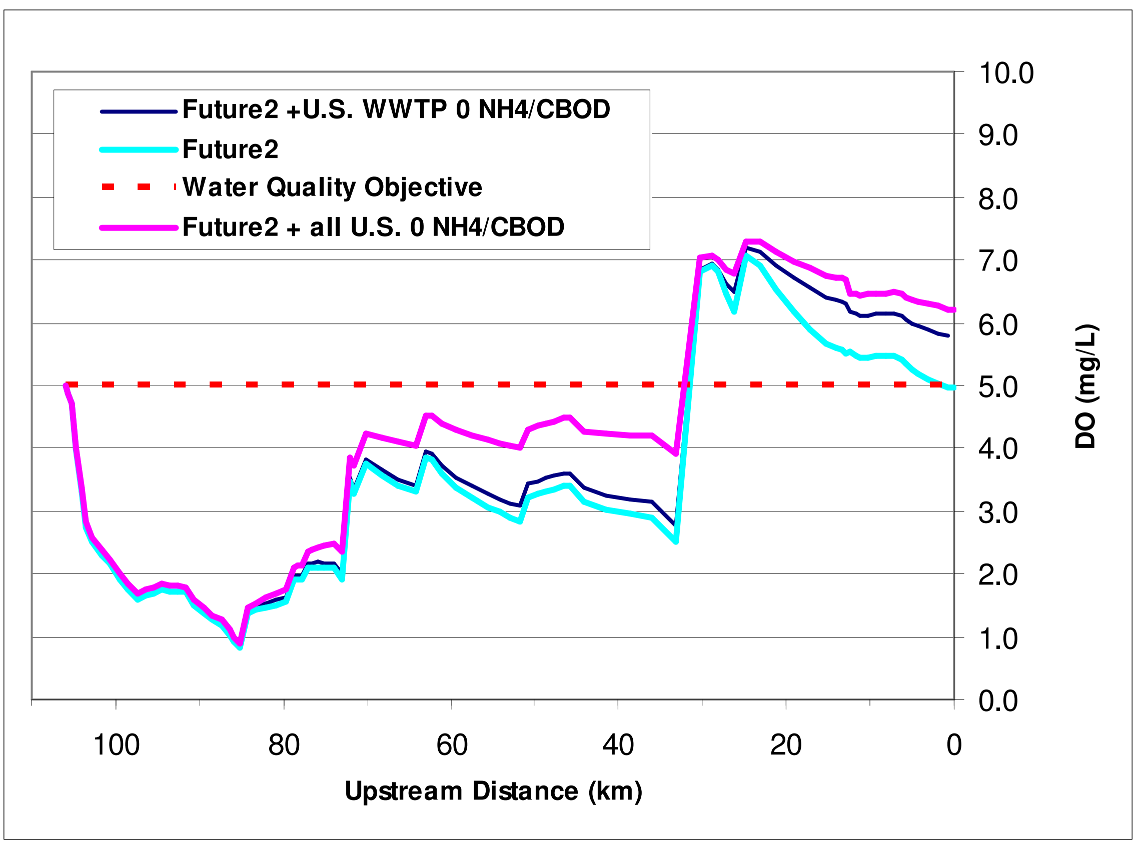
Flow Origins and Sensitivity to U.S. Reductions

The major influence to the upper New River is the International Boundary inflow, which is 100 percent of the model headwaters 106 km from the Salton Sea. At the Future Condition 2 scenario (full implementation of Mexicali II project) this is approximately 5.3 m^3/s. By comparison, the Calexico WWTP is less than 0.2 m^3/s entering at km105. Greeson Drain (0.96 m^3/s at km85) is the only additional modeled inflow prior to km80. Other flows are shown in Table 2-3 of the Final Modeling Report.

Two additional scenarios were modeled to determine the maximum sensitivity of New River DO to reductions in U.S. WWTPs and drain/tributary inputs. These scenarios confirm that most of the oxygen depletion in the upper river is due to oxygen-consuming NH4 and CBOD from the International Boundary (I.B.).

The figure below shows model Future Condition 2 scenario with:

A) all U.S. WWTP discharges changed to 0 CBOD and 0 NH4 (dark blue)
B) all U.S. WWTP, also all drain/tributary inputs changed to 0 CBOD and 0 NH4 (magenta)



The proportions of the flow origins may give some insight into sensitivity of New River DO conditions to each source.