A QUAL2K WATER QUALITY ANALYSIS OF THE RIO BLANCO WATERSHED NEAR JALISCO, MEXICO

by

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1 Abstract

This report summarizes the steps taken in attempting to delineate the Rio Blanco watershed in Jalisco, Mexico northwest of Guadalajara. Rio Blanco is a water source for the people living along the river and it is also used for irrigation. The river is severely polluted due to dumping by residents, factories, and farming activities. In order to better understand the water quality issues in the river, a QUAL2Kw model was constructed; however, the results of the model were limited by the lack of data needed for input into QUAL2Kw. The model results do not necessarily represent the exact conditions present in Rio Blanco; yet, the model is beneficial in showing what information needs to be gathered to use QUAL2Kw in the future to model the water quality issues in Rio Blanco.

2 Introduction

The Rio Blanco watershed is located northwest of Guadalajara, in Jalisco, Mexico. It covers an area of about 60 mi^2, and there are approximately 100,000 people currently residing within its boundaries. The water from Rio Blanco is currently used as a water source for those living in the area, as well as agricultural irrigation.

There are currently many problems with water quality within the watershed. Multiple point sources of pollution exist, which have severely degraded the water quality. Some of the pollution sources include:

- Fertilizers and pesticides from agricultural production
- Residential wastewater is drained directly into the river without treatment
- Cattle, chicken, and pig farms dump animal waste directly into the river
- Small factories and residents dump their waste directly into the river

This pollution is a serious problem for those who live in and around the Rio Blanco watershed. Since the 1960's there has been a drastic decline in wildlife along the river. Today, it is difficult to find any type of aquatic animal life. In the mid 1970's, the water quality began to decline rapidly, resulting in poor health and cholera outbreaks. To help resolve the problem, three water treatment plants have been built on the river, however, one is not working, one is operating at 45% capacity, and the other's effectiveness is not known. Another treatment plant with a capacity of 150 liters per second has been proposed, but nothing has been done due to the expense. The large costs associated with implementing water treatment, and the social apathy towards its need has led to the continued decline of the watershed.

As part of project, our goals were to develop a delineated watershed model using WMS and to use actual source data to run a water quality analysis using the computer code QUAL2Kw. These efforts were hampered by a lack of data from the students at the ITESO in Mexico.

3 WMS Hydrologic Model

In order to track the sources and causes of the pollution in the river, a WMS model was created. Initially, a contamination contour map was proposed, but due to lack of sufficient information, this was not completed.

3.1 Delineating the Rio Blanco Watershed

Our counterparts in Mexico provided us with an initial DEM and delineation for the Rio Blanco watershed. Because of issues with the format of the DEM, we downloaded a DEM from the INEGI (National Institute of Geographic and Informational Statistics) website for the area of the watershed. Using WMS, we were able to delineate the watershed based on the elevation data obtained from INEGI. This original delineation is seen in Figure 1. Figure 2 shows the original WMS watershed delineation with a smoothed DEM.

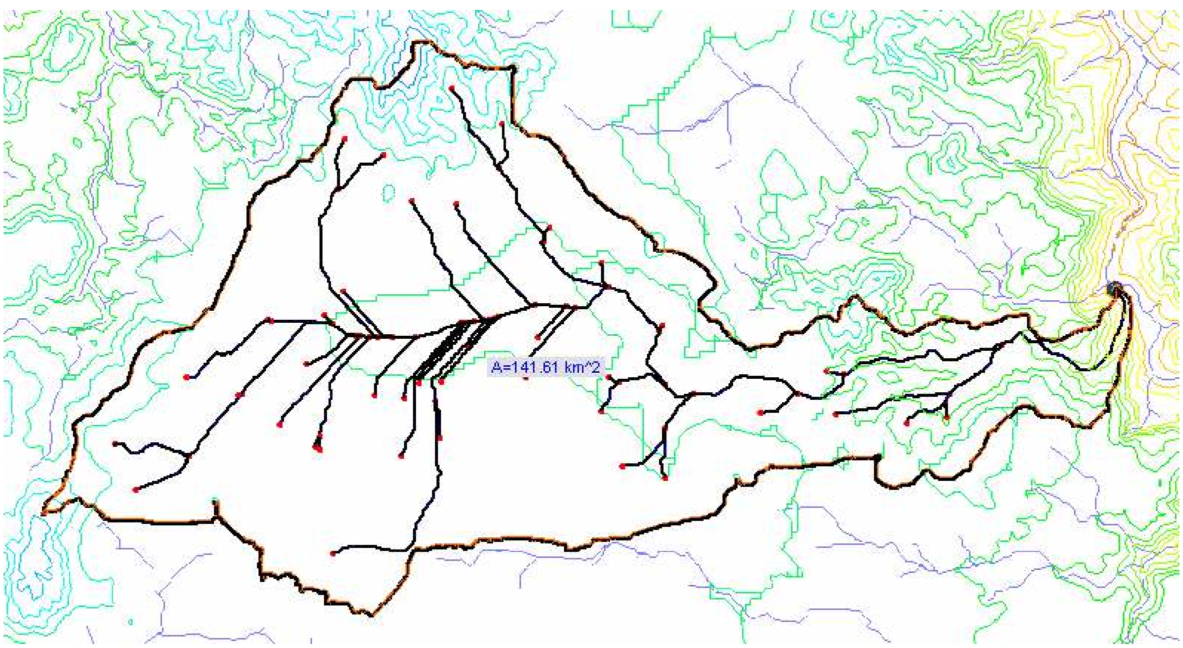

Figure 1 Initial WMS delineation derived using WMS

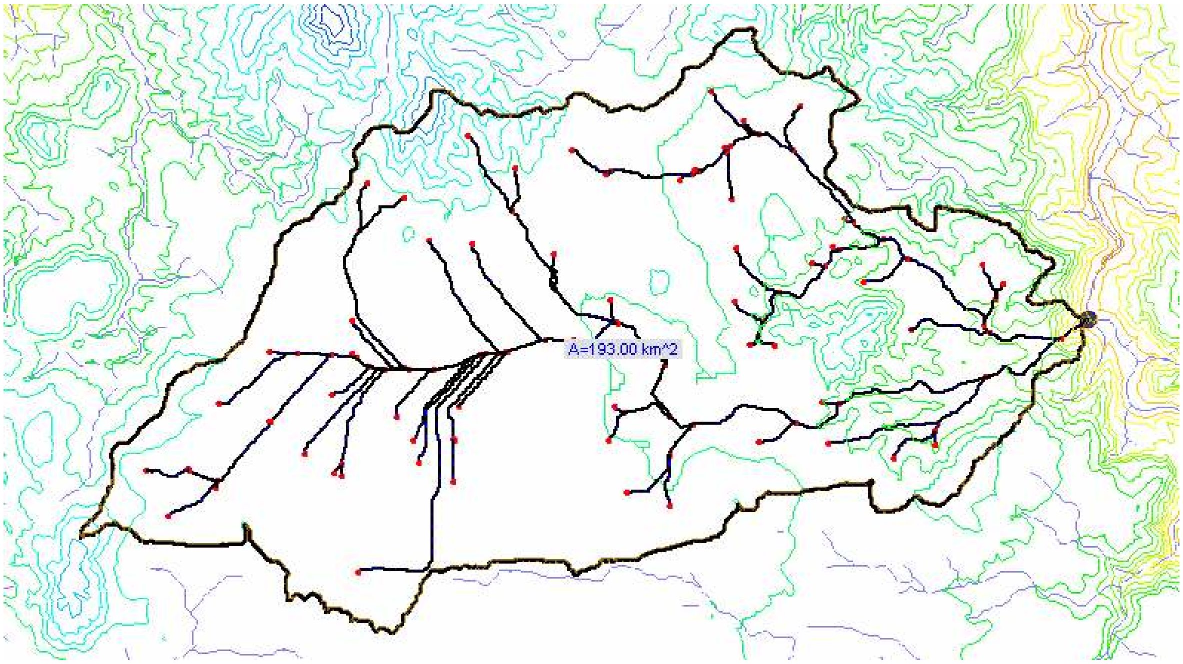

Figure 2 WMS delineation using a smoothed DEM

The delineation that the ITESO students sent us, seen in Figure 3, did not match the initial delineation that we derived using WMS. This difference was due to the diversion of water to areas outside the watershed and errors in the DEM data. In our face-to-face collaboration with the students from ITESO, some of the issues involved in the development of a meaningful WMS model were discussed and investigated. Such issues included incompatible soils information, a lack of precipitation data, an unclear idea of land use, a poor understanding of the goals and means of accomplishing them, and difference in our delineation and the Mexican one. After gaining a better understanding of the goals, we planned to run a simulation in WMS with hourly or daily rainfall values. Up to this point, we have not received the required information to run such a model and will not be able to include results for it. Using Google Earth and our knowledge of the area, we were able to alter the initial WMS delineation of the watershed to match the delineation we received from Mexico.

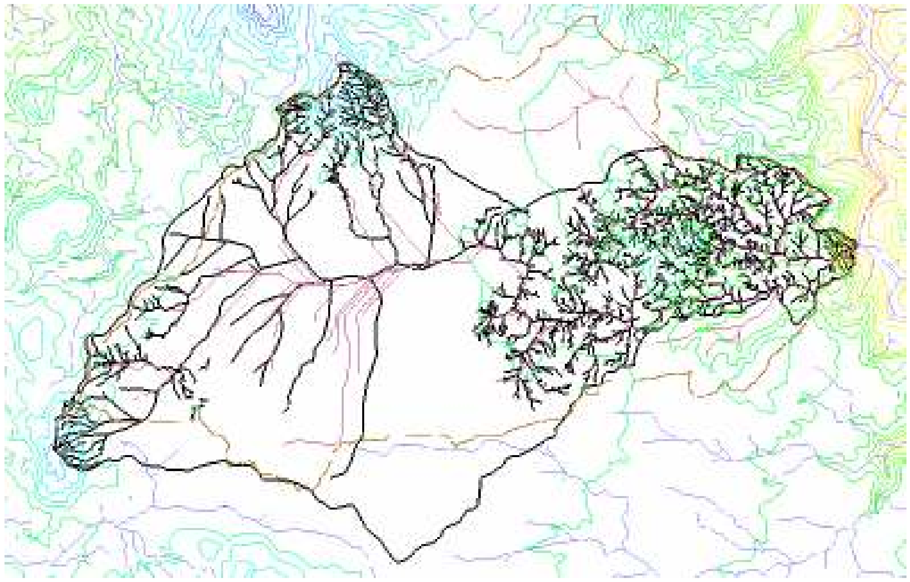

Figure 3 ITESO delineation of the Rio Blanco watershed w/ smoothed delineation in the background

3.2 GIS Data

In order to better understand the characteristics of the watershed, the students from ITESO compiled numerous data files for use in Arc Map. Using this data, we a better understanding of the land use and vegetation in the area, the elevations we would be dealing with, and the general layout of the watershed. Initially, there was an abundance of data that needed to be sorted through. We found what we thought was the pertinent information, and mapped it in Arc Map. A lot of useful information was sent to us; however, we encountered trouble when trying to use this data because much of it was in units or systems that are not used in the United States. For this reason, much of our time was spent translating, converting, and making sure that what we thought the data said was what it actually said. Figure 4 and Figure 5 are maps we compiled from the maps we received from Mexico.

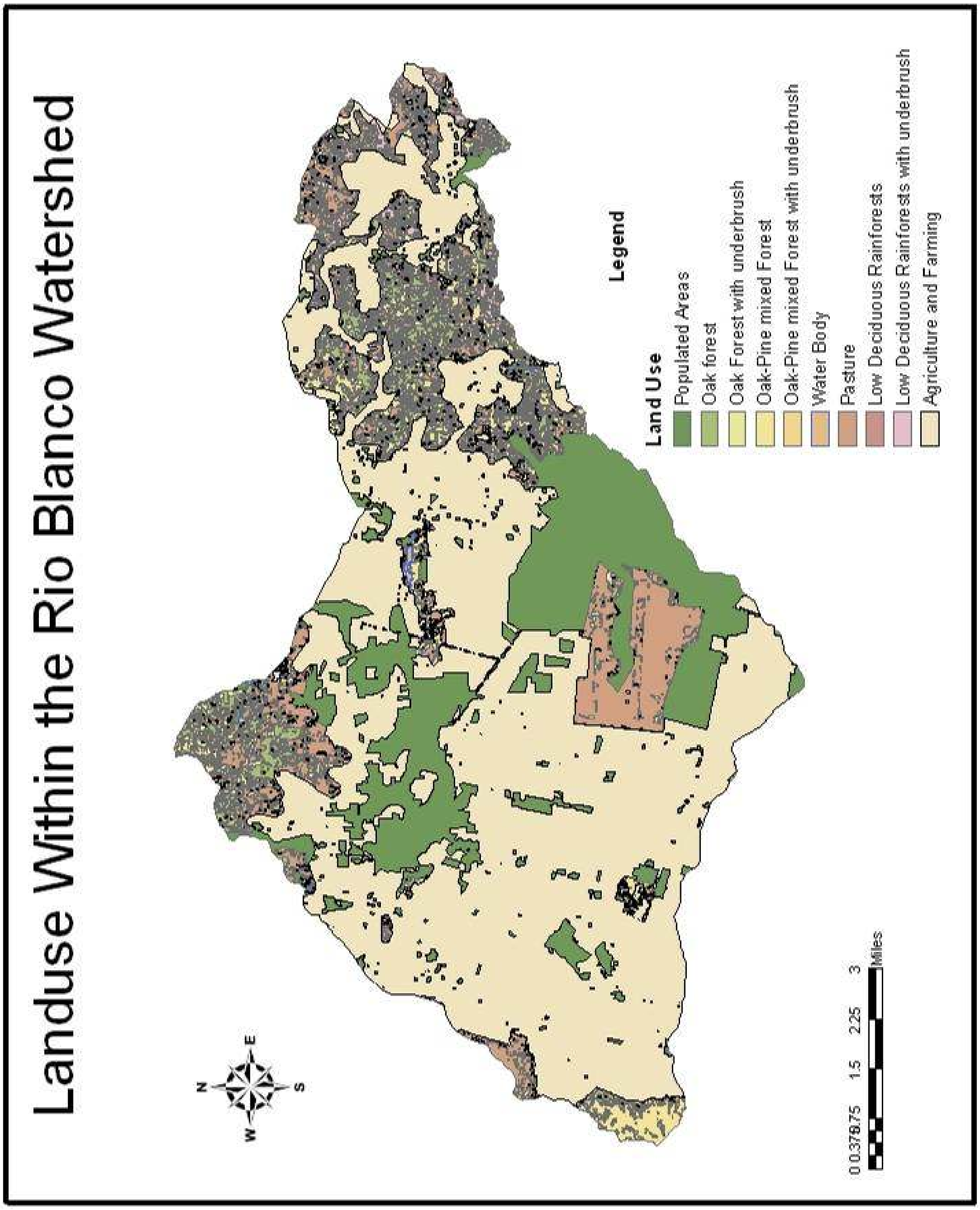

Figure 4 Land use within the Rio Blanco watershed

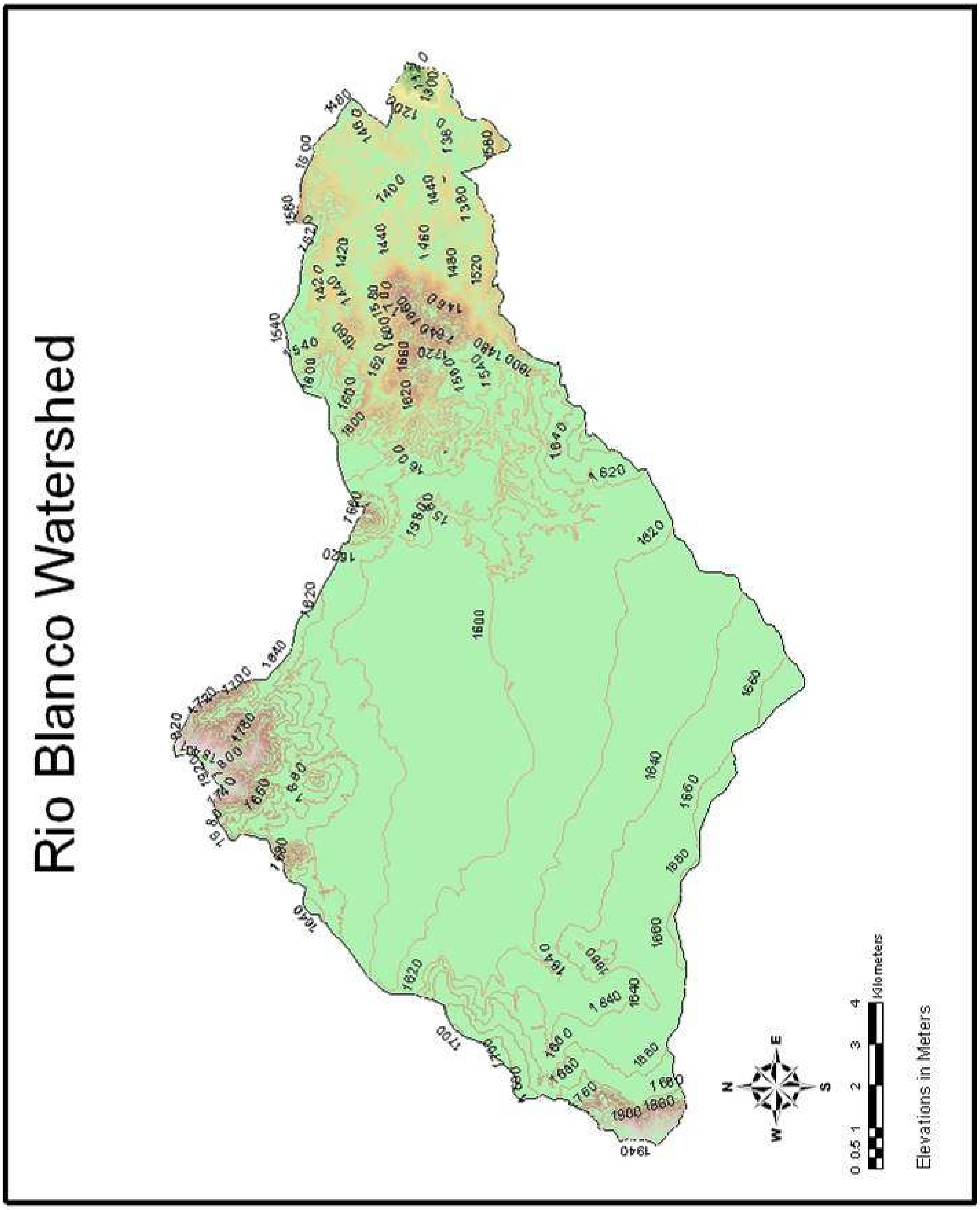

Figure 5 Rio Blanco watershed

4 QUAL2Kw Water Quality Model

As part of our report, we wanted to generate a QUAL2Kw water quality model to help the students at ITESO learn how they could use such a model to map and monitor the water quality issues faced on the Rio Blanco. These efforts, however, we again largely hampered by a lack of data available to conduct a full analysis.

4.1 A Brief History of QUALK and QUAL2Kw

QUAL2K is a computer model developed by Greg Pelletier and Steve Chapra used to simulate water quality in streams and rivers. In 1987, the predecessor to QUAL2K, QUAL2E, was originally released. QUAL2K maintains much of the functionality of QUAL2E, but improves the model interface, implementing the interface into Microsoft Excel using Visual Basic. QUAL2K also provides expanded capabilities for: segmenting river systems into river reaches; inputting carbonaceous BOD as slowly and rapidly oxidizing forms; and specifying bottom algae growth, pH, and pathogen quantities. QUAL2Kw is related to QUAL2K, but includes new elements not found in QUAL2K. QUAL2Kw is available for download from the Washington State Department of Ecology at the following link: http://www.ecy.wa.gov/programs/eap/models.html.

4.2 Methods in Developing a QUAL2Kw Model

QUAL2Kw is an advanced water quality model and requires a large amount of input. Included in the Appendix is a list of the possible inputs for QUAL2Kw and the units the parameters must be in. Some of the parameters are optional; however, the model is only improved as more information about the river reaches is known. For the water quality model developed for Rio Blanco, we had very few of the actual parameters required to obtain a meaningful QUAL2Kw model, and therefore the default values assigned in QUAL2Kw were assumed for several values.

QUAL2Kw allows the user to discretize a river or stream to simulate how the different reaches may vary in size, elevation, and concentration of contaminants. QUAL2Kw allows the user to specify information for each reach, such as the gauged flows or the amounts of concentrations enter each reach. For our QUAL2Kw model, we decided to divide the primary reach of the Rio Blanco into 13 different units approximately 2.5 kilometers in length. The locations of the points used to discretize the watershed are seen in Figure 6. At the downstream end of the Rio Blanco is a waterfall that empties into the Rio Santiago. This waterfall, seen in Figure 7, is important to note because the water quality parameters will be affected as the water is re-aerated as it falls into the Rio Santiago. Figure 8 shows a model depiction of the discretized river, showing the gauging stations and the inflow points. The geographic coordinates of the points used to discretize the river are seen in Table 1. This table also includes information relating to the river elevation and length of the reach.

Figure 6 Locations of points used to discretize the Rio Blanco

Figure 7 Waterfall at the downstream end of the Rio Blanco

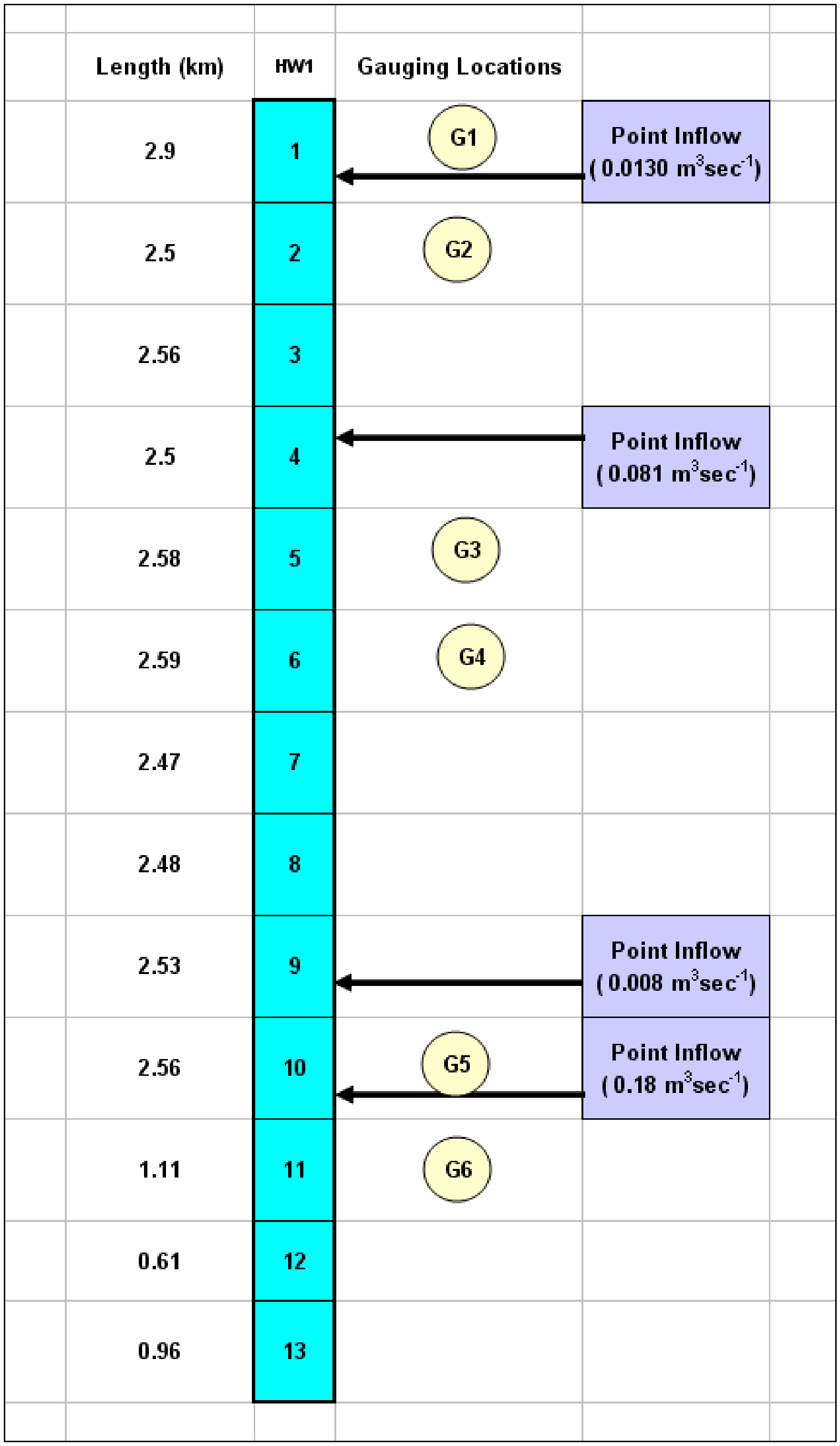

Figure 8 Depiction of the Rio Blanco discretization, including gauging stations and point inflows

Table 1 Location of the points used to discretize the Rio Blanco

Reach	*Lat (North)*			*Long (West)*			*Length*	*Elev*	*Remarks*
	D	*M*	*S*	*D*	*M*	*S*	*(km)*	*(m)*	*Stream or Tributary*
1	*20*	*45*	*24*	*103*	*32*	*53*		*1655*	
2	20	46	19	103	31	44	2.9	1630	Stream
3	20	47	40	103	32	3	2.5	1605	Stream
4	20	47	28	103	29	38	2.56	1592	Stream
5	20	47	40	103	28	12	2.5	1592	Stream
6	20	47	57	103	26	48	2.58	1591	Stream
7	20	47	24	103	25	53	2.59	1577	Stream
8	20	46	47	103	25	2	2.47	1575	Stream
9	20	46	43	103	23	43	2.48	1557	Stream
10	20	47	15	103	22	27	2.53	1439	Stream
11	20	47	30	103	21	8	2.56	1375	Stream
12	20	47	42	103	20	40	1.11	1365	Stream
13	20	48	9	103	19	59	0.96	940	Junction to Outlet

After discretizing the Rio Blanco, the upstream parameters were assumed based on the given information relating to the fecal coli forms, total suspended solids, pH, total nitrogen, and BOD at the gauging location situation furthest upstream. These parameters represent only a small fraction of the parameters required to generate a beneficial model. The missing parameters were assumed to be the default values in QUAL2Kw. Although this is a rough estimation to use so few parameters, such estimation was required in order to run QUAL2Kw. The upstream information was input into QUAL2Kw, along with the river reach information seen in Table 1 and the point sources seen in Figure 8. After inputting these parameters, QUAL2Kw was then run and graphs were developed to show how the different river parameters varied over the course of the river.

4.3 QUAL2Kw Model Results

QUAL2Kw can generate various plots that reflect the variation of water quality parameters along the length of a river or stream and diel variation for some of the parameters. Our water quality modeling of Rio Blanco was carried out with limited water quality data. Many parameters had to be assumed and some of the typical values were used as model input. The following plots show the variation of water quality parameters along the river.

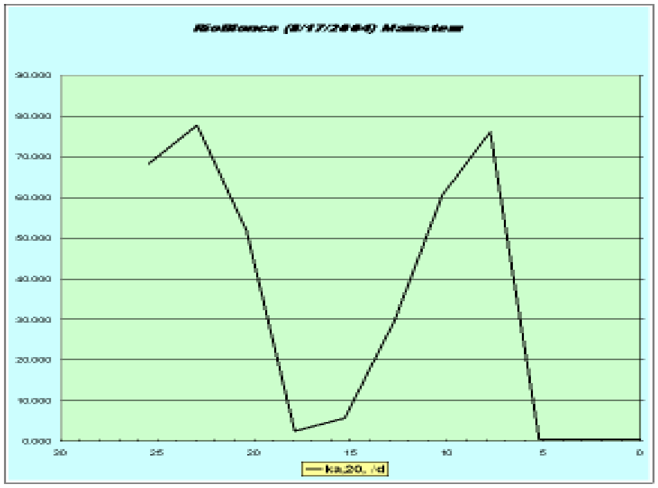

Figure 9 Re-aeration along the length of the river

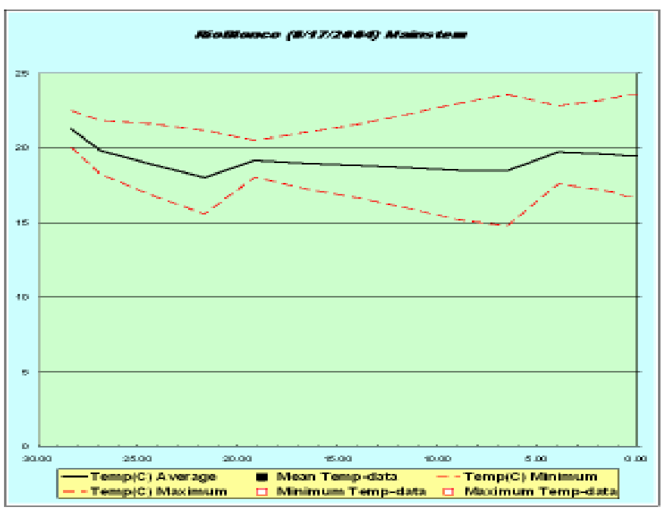

Figure 10 Variation of water temperature along the Rio Blanco

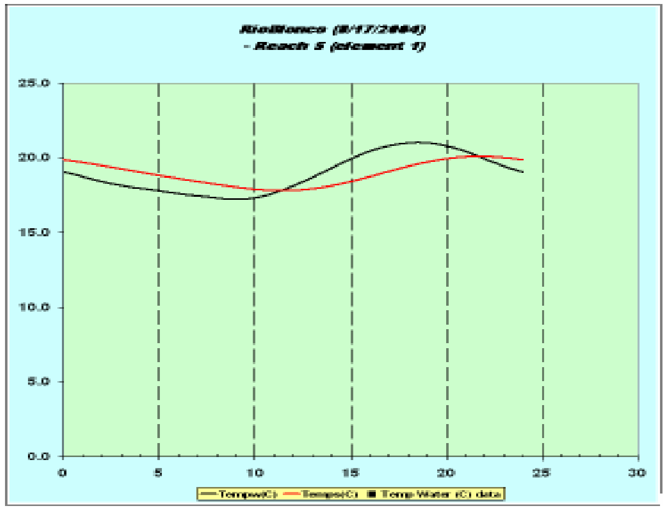

Figure 11 Variation of temperature with time

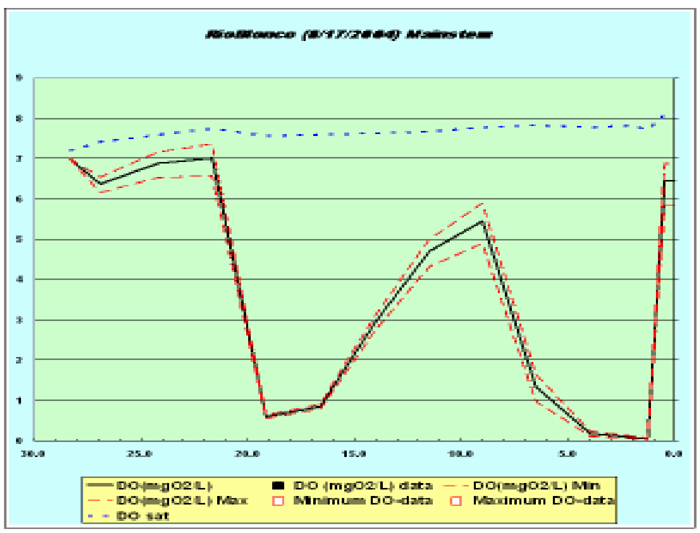

Figure 12 Variation of dissolved oxygen along the length of the Rio Blanco

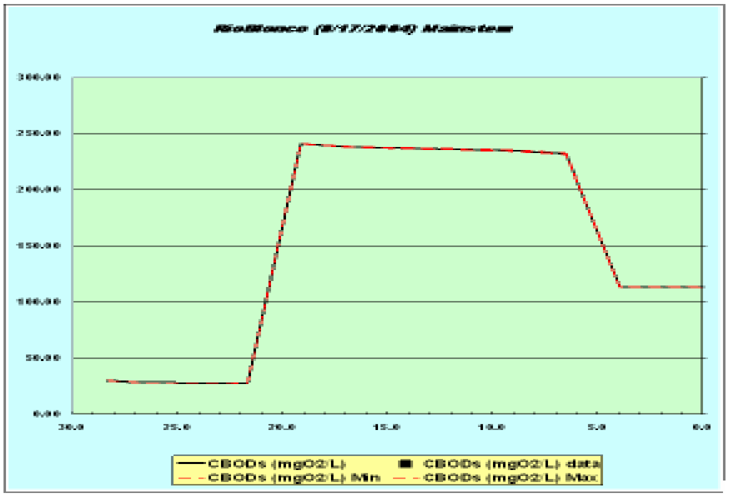

Figure 13 Variation of CBOD along the Rio Blanco

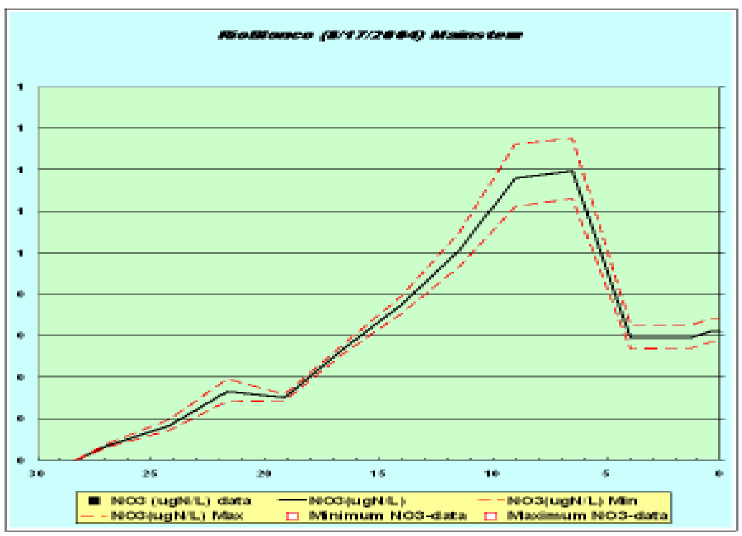

Figure 14 Variation of NO_3 along the Rio Blanco

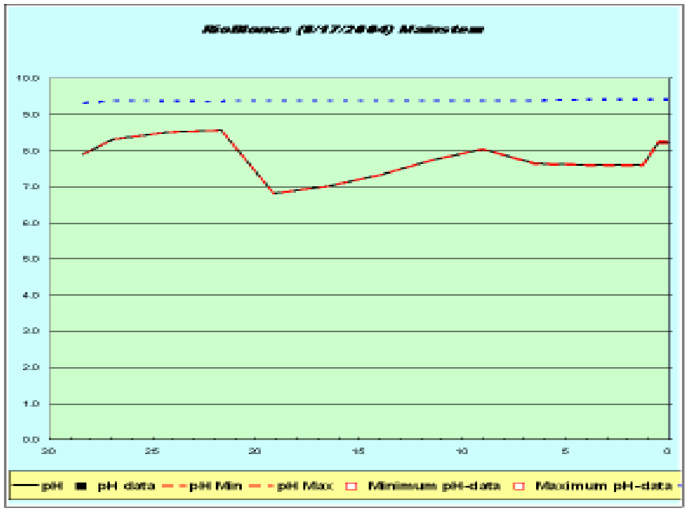

Figure 15 Variation of pH along the Rio Blanco

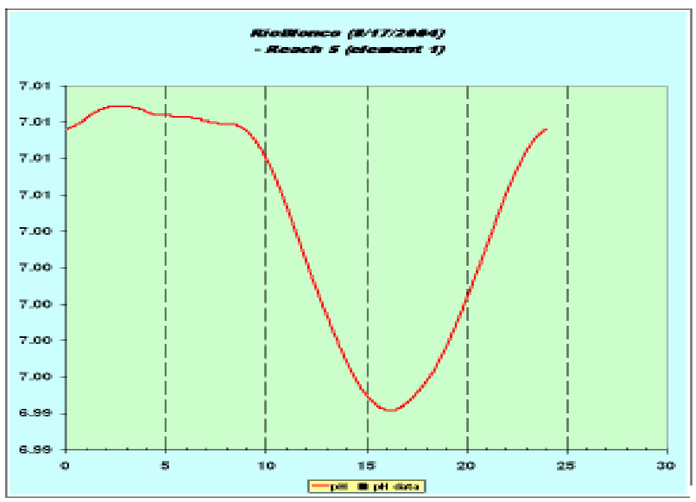

Figure 16 Variation of pH with time

4.4 Discussion of Results

Due to the large number of assumptions that were made in creating the QUAL2Kw model, the results seen in the plots above do not represent exactly what is occurring in Rio Blanco. In creating the QUAL2Kw model some of the most important parameters were missing, including temperature and reaction rates. The only information that was available to us for use in QUAL2Kw were Lat/Long of different locations, suspended solid, nitrogen, pH and BOD information. All other parameters were assumed and some typical values were used. The following list shows the parameters for which the assumed values were used.

- Channel cross section
- Temperature (Air and Dew Point)
- Inorganic Solids
- Dissolved Oxygen
- Phosphorus
- Phytoplankton
- Alkalinity
- Manning's n
- Wind speed
- Cloud cover and hours of sunshine
- Amount and quality of inflow sources
- All the reaction rates

After many runs and evaluation of the model performance, the following parameters are found to be most sensitive.

1. Head water information:
    - Latitude, Longitude and elevation
    - Temperature
    - Dissolved Oxygen
    - BOD
    - Nitrogen
    - Phosphorous
    - Alkalinity
    - pH
2. Reach information:
    - Latitude, Longitude and Elevation
    - Hydraulic features like Weir information or Rating curve information or Manning's n
    - Bottom Algal information
    - Air and Dew Point temperature
    - Wind speed and day light information
    - Source information (Rate and quality of Inflow and outflows)
    - Chemical reaction rates.

QUAL2Kw can be a very useful tool in analyzing and resolving the water quality issue in Rio Blanco. It can not only model the actual (present) scenario of the quality but can also predict future quality conditions. Further, QUAL2Kw can be used to analyze various solution measures like insertion of weir/drop structures (to enhance aeration), flow augmentation (to decrease the concentration of pathogens and pollutants) and/or to propose some primary treatment before disposal to stream.

Before good output and solution measure can be expected from QUAL2Kw, however, some of the most sensitive parameters must be collected. The model should be verified by validation for different time periods and a sensitivity analysis should be carried out. If cautiously formulated, QUAL2Kw can be used as a very good tool for solving water quality problem in Rio Blanco.

5 Conclusion

As part of this report, we have had the opportunity to collaborate with students in Mexico at the ITESO to better understand the water quality issues of Rio Blanco. This river is severely polluted and requires further investigation to better understand what efforts could be made to improve the situation. In preparing this report, we were limited in the degree we were able to assist them due to the lack of information available. As a group we hoped to prepare a WMS hydrologic model, however, this effort was hampered by difficulties in preparing a delineated watershed which accurately matched the delineated watershed prepared by the students at ITESO. Precipitation data also was not available. One of the primary goals of our project was to use QUAL2Kw to analyze the water quality in Rio Blanco. Again, we were only provided with limited data for limited areas along Rio Blanco, thus limiting our ability to create an effective QUAL2Kw model. Using the provided information and many of the program values, we were able to create a QUAL2Kw model of Rio Blanco. This model should not be interpreted as fully representing the conditions in Rio Blanco, but instead as a demonstration of the abilities of QUAL2Kw to analyze water quality in a river. QUAL2Kw could be used to further understand the water quality problems in Rio Blanco. More information is needed, yet QUAL2Kw should be considered as viable tool that could be used in further analyses of the water quality in Rio Blanco.

References

Pelletier, G. & Chapra, S. (2004). *Qual2Kw User Manual (Version 5.1): A modeling framework for simulating river and stream water quality.* Olympia, WA. Washington State Department of Ecology

Appendix A.

This Appendix includes a list of the input data required for QUAL2Kw. The water quality data provided by the ITESO is also included in this Appendix.

Table 2 List of input parameters for QUAL2Kw

Headwater Water Quality Hourly Data	
Parameter	***Unit***
Temperature	C
Conductivity	umhos
Inorganic Solids	mgD/L
Dissolved Oxygen	mg/L
CBOD slow	mg O_2/L
CBOD fast	mg O_2/L
Organic Nitrogen	µg N/L
NH4-Nitrogen	µg N/L
NO3-Nitrogen	µg N/L
Organic Phosphorus	µg P/L
Inorganic Phosphorus (SRP)	µg P/L
Phytoplankton	µg A/L
Detritus (POM)	mg D/L
Pathogen	cfu/100 mL
Alkalinity	mg $CaCO_3$/L
pH	

Downstream Water Quality Hourly Data	
Parameter	***Unit***
Temperature	C
Conductivity	umhos
Inorganic Solids	mgD/L
Dissolved Oxygen	mg/L
CBOD slow	mgO2/L
CBOD fast	mgO2/L
Organic Nitrogen	µg N/L
NH4-Nitrogen	µg N/L
NO3-Nitrogen	µg N/L
Organic Phosphorus	µg P/L
Inorganic Phosphorus (SRP)	µg P/L
Phytoplankton	µg A/L
Detritus (POM)	mg D/L
Pathogen	cfu/100 mL
Alkalinity	mg $CaCO_3$/L
pH	

Reach Water Quality Hourly Data (Optional)	
Parameter	***Unit***
Bottom alage coverage	
Bottom SOD coverage	
Prescribed SOD	g $O_2/m^2/d$
Prescribed CH_4 flux	g $O_2/m^2/d$
Prescribed NH_4 flux	g $N/m^2/d$
Prescribed inorganic phosphorus	g $N/m^2/d$

Reach Rates	
Parameter	***Unit***
Presribed reaeration	/day
ISS settling velocity	m/day
Slow BOD hydrolosis rate	/day
Slow BOD oxidation rate	/day
Fast CBOD oxidation rate	/day
Organic Nitrogren hydrolosis rate	/day
Organic Nitrogren settling velocity	m/day
Ammonium nitrification rate	/day
Nitrate denitrification rate	m/day
Nitrate sediment denitrification transfer coefficient	m/day
Organic Phosphorus hydrolosis rate	/day
Organic Phosphorus settling velocity	m/day
Inorganic Phosphorus settling velocity	m/day
Phytoplankton maximum growth rate	/day
Phytoplankton settling velocity	m/day
Bottom algae maximum growth rate	mg A/m^2/d
Detritus dissolution rate	/day
Detritus settling velocity	m/day
Detritus fraction fast CBOD	

Rates	
Parameter	***Unit***
Stoichiometry	
Carbon	g C
Nitrogen	g N
Phosphorus	g P
Dry weight	g D
Chlorophyll	g A
Inorganic Suspended Solids	
Settling velocity	m/day
Oxygen	
Reaeration model	
Temperature correction	
Reaeration wind effect	
O_2 for carbon oxidation	g O_2/g C
O_2 for NH_4 nitrification	g O_2/g N
Oxygen inhib model CBOD oxidation	
Oxygen inhib parameter CBOD oxidation	L / mg O_2
Oxygen inhib model nitrification	
Oxygen inhib parameter nitrification	L / mg O_2
Oxygen enhance model denitrification	
Oxygen enhance parameter denitrification	L / mg O_2
Oxygen inhib model phyto respiration	
Oxygen inhib parameter phyto respiration	L / mg O_2
Oxygen enhance model bottom algae respiration	
Oxygen enhance parameter bottom algae respiration	L / mg O_2

Slow CBOD	
Hydrolosis rate	/day
Temperature correction	
Oxidation rate	/day
Temperature correction	
Fast CBOD	
Oxidation rate	/day
Temperature correction	
Organic Nitrogen	
Hydrolosis	/day
Temperature correction	
Settling velocity	m/day
Ammonium	
Nitrification	/day
Temperature correction	
Nitrate	
Denitrification	/day
Temperature correction	
Sediment denitrification transfer coefficient	m/day
Temperature correction	
Organic Phosphorus	
Hydrolosis	/day
Temperature correction	
Settling velocity	m/day
Inorganic Phosphorus	
Settling velocity	m/day
Inorganic Phosphorus sorption coefficient	L / mg D
Sediment Phosphorus oxygen attenuation half sat const	mg O_2/L
Phyroplankton	
Maximum growth rate	/day
Temperature correction	
Respiration rate	/day
Temperature correction	
Death rate	/day
Temperature correction	
Nitrogen half saturation constant	µg N/L
Phosphorus half saturation constant	µg P/L
Inorganic carbon half saturation constant	moles/L
Light model	
Light constant	langleys/day
Ammonia preference	µg N/L
Settling velocity	m/day
Bottom Algae	
Growth model	
Maximum growth rate	mg A/m^2/d or /day
Temperature correction	
First-order model carrying capacity	mgA/m^2
Respiration rate	/d
Temperature correction	

Excretion rate	/d
Temperature correction	
Death rate	/d
Temperature correction	
External nitrogen half saturation constant	µg N/L
External phosphorus half saturation constant	µg P/L
Inorganic carbon half saturation constant	moles/L
Light model	
Light constant	langleys/d
Ammonia preference	µg N/L
Subsistence quota for nitrogen	mg N/mg A
Subsistence quota for phosphorus	mg P/mg A
Maximum uptake rate for nitrogen	mg N/mg A/d
Maximum uptake rate for phosphorus	mg P/mg A/d
Internal nitrogen half saturation constant	mg N/mg A
Internal phorphorus half saturation constant	mg P/mg A
Detritus (POM)	
Dissolution rate	/day
Temperature correction	
Fraction of dissolution to fast CBOD	
Settling velocity	m/day
Pathogens	
Decay rate	/day
Temperature correction	
Settling velocity	m/day
Light efficiency factor	
pH	
Partial pressure of carbon dioxide	ppm

Light and Heat	
Parameter	***Unit***
Photosynthetically Available Radiation	
Background light extinction	/m
Linear chlorophyll light extinction	1/m-(ugA/L)
Nonlinear chlorophyll light extinction	1/m-(ugA/L)2/3
ISS light extinction	1/m-(mgD/L)
Detritus light extinction	1/m-(mgD/L)
Solar shortwave radiation model	
Atmospheric attenuation model for solar	
Bras solar parameter (used if Bras solar model is selected)	
Atmospheric turbidity coefficient (2=clear, 5=smoggy, default=2)	
Ryan-Stolzenbach solar parameter (used if Ryan-Stolzenbach solar model is selected)	
Atmospheric transmission coefficient (0.70-0.91, default 0.8)	
Downwelling atmospheric longwave IR radiation	
Atmospheric longwave emissivity model	
Evaporation and air convection/conduction	
Wind speed function for evaporation and air convection/conduction	
Sediment thermal diffusivity	cm2/s
Sediment density	g/cm3
Water density	g/cm3

Sediment heat capacity	cal/(g oC)
Water heat capacity	cal/(g oC)
Sediment diagenesis model	
Compute SOD and nutrient fluxes	
Diffuse Sources	
Diffuse Abstraction	m^3/S
Diffuse Inflow	m^3/S
Spec Condition	umhos
Inorganic SS	mg D/L
CBOD slow	mg O_2/L
Dissolved Oxygen	mg/L
CBOD slow	mg O_2/L
CBOD fast	mg O_2/L
Organic N	µg N/L
Ammon N	µg N/L
Nitrate N	µg N/L
OrganicP	µg P/L
Inorganic P	µg P/L
Phytoplankton	µg N/L
Detritus	mgD/L
Pathogen	cfu/100 mL
Alk	mg $CaCO_3$/L
pH	

Table 3 Water quality information

Huevos de Helminto (Hv/gr)

Fecha / Punto	*Nextipac I*	*Nextipac II*	*Magdalena*	*La escoba*	*Rio Blanco*	*Cola de Caballo*
22-24 de oct/02	98.00	586.00	-	negativo	65.00	1,303.00
29-30 de oct/02	negativo	abundantes	negativo	negativo	negativo	abundantes
5-8 de nov/02	98.00	abundantes	negativo	negativo	33.00	500.00
12-18 de nov/02	negativo	359.00	65.00	negativo	negativo	negativo
22-26 de nov/02	negativo	1,900.00	negativo	negativo	300.00	500.00
7-12 de mzo/03	130.00	1,020.00	negativo	31.00	negativo	31.00
6-19 de jun/03	negativo	negativo	330.00	260.00	760.00	negativo
24- de jul/03	310.00	600.00	1,600.00	770.00	260.00	350.00
28 de ago-03 de sep/03	2,000.00	500.00	1,950.00	530.00	550.00	16,500.00

Coliformes fecales (NMP/100 ml)

Fecha / Punto	*Nextipac I*	*Nextipac II*	*Magdalena*	*La escoba*	*Rio Blanco*	*Cola de Caballo*
22-24 de oct/02	93	110,000	930	4,600,000	1,000,000,000	15,000,000
29-30 de oct/02	400	46,000	93	9,000,000	46,000	930,000
5-8 de nov/02	150	400	100	230,000	700,000	1,500,000
12-18 de nov/02	93	93	150	28,000	210,000	28,000
22-26 de nov/02	150	93	23	280,000	150,000	43,000
7-12 de mzo/03	930	15,000	110,000	1,100,000	1,000,000	15,000
6-19 de jun/03	2,400,000	110,000	110,000	1,200,000	1,100,000	930,000
24- de jul/03	2,100,000	120,000	150,000	4,000,000	240,000	20,000
28 de ago-03 de sep/03	2,400,000	240,000,000	11,000,000	1,500,000	1,100,000	2,400,000

Solidos Suspendidos Totales (ppm)

Fecha / Punto	*Nextipac I*	*Nextipac II*	*Magdalena*	*La escoba*	*Rio Blanco*	*Cola de Caballo*
22-24 de oct/02	50.0	58.0	<30	593.00	468.0	40.0
29-30 de oct/02	55.0	32.0	<30	542.0	254.0	<30
5-8 de nov/02	100.0	<30	58.00	226.0	188.0	<30
12-18 de nov/02	<30	50.0	<30	664.0	146.0	<30
22-26 de nov/02	<30	32.0	<30	422.0	242.0	<30
7-12 de mzo/03	55.0	69.0	<30	560.0	278.0	56.0
6-19 de jun/03	1,780.0	1,540.0	784.0	590.0	407.0	31.0
24- de jul/03	150.0	210.0	81.0	1,174.0	1,092.0	2,776.0
28 de ago-03 de sep/03	45.0	72.5	254.0	125.0	<30	49.0

Grasas y Aceites (ppm)

Fecha / Punto	*Nextipac I*	*Nextipac II*	*Magdalena*	*La escoba*	*Rio Blanco*	*Cola de Caballo*
22-24 de oct/02	51.03	2.87	3.20	68.93	<0.10	7.40
29-30 de oct/02						

	75.13	0.50	27.76	120.22	9.40	0.90
5-8 de nov/02	3.30	1.40	2.60	3.70	20.40	1.90
12-18 de nov/02	1.80	1.30	2.50	17.70	<0.410	<0.10
22-26 de nov/02	0.40	<0.10	<0.10	56.70	6.40	0.50
7-12 de mzo/03	<0.10	2.40	2.10	31.40	11.50	<0.10
6-19 de jun/03	14.20	18.90	<0.10	50.40	3.00	1.70
24- de jul/03	<0.10	0.20	<0.10	<0.10	0.70	1.20
28 de ago-03 de sep/03	<0.10	<0.10	<0.10	1.80	<0.10	0.30

pH

Fecha / Punto	***Nextipac I***	***Nextipac II***	***Magdalena***	***La escoba***	***Rio Blanco***	***Cola de Caballo***
22-24 de oct/02	7.74	6.95	7.68	6.45	6.97	7.37
29-30 de oct/02	7.35	7.64	7.64	6.36	6.88	7.22
5-8 de nov/02	7.62	7.50	7.68	6.55	7.42	7.71
12-18 de nov/02	7.47	7.32	7.79	5.95	7.55	7.70
22-26 de nov/02	7.49	7.15	7.65	6.44	6.94	7.62
7-12 de mzo/03						
6-19 de jun/03	8.18	8.10	7.02	6.31	7.25	7.40
24- de jul/03	8.12	7.51	7.94	6.69	7.43	7.54
28 de ago-03 de sep/03	6.65	7.31	7.34	7.34	7.43	7.71

Nitrógeno Total (ppm)

Fecha / Punto	***Nextipac I***	***Nextipac II***	***Magdalena***	***La escoba***	***Rio Blanco***	***Cola de Caballo***
22-24 de oct/02	2.65	7.74	0.37	25.66	32.97	20.96
29-30 de oct/02	1.38	6.46	0.59	28.00	27.84	15.95
5-8 de nov/02	14.92	13.70	1.17	19.95	27.20	6.29
12-18 de nov/02	0.96	9.44	0.43	38.67	67.30	8.98
22-26 de nov/02	5.83	2.34	1.05	74.31	79.32	4.90
7-12 de mzo/03						

	0.81	21.67	0.26	69.00	64.27	50.34
6-19 de jun/03	468.40	431.00	7.93	20.71	48.47	31.21
24- de jul/03	7.80	11.88	0.99	3.29	2.94	4.86
28 de ago-03 de sep/03	1.57	12.26	0.56	24.66	0.66	12.26

DBO_5 (ppm)

Fecha / Punto	*Nextipac I*	*Nextipac II*	*Magdalena*	*La escoba*	*Rio Blanco*	*Cola de Caballo*
22-24 de oct/02	120.00	44.00	40.00	533.00	1,021.00	45.00
29-30 de oct/02	15.00	30.00	35.00	296.00	272.00	55.00
5-8 de nov/02	<10	19.00	<10	200.00	67.50	<10
12-18 de nov/02	<10	35.00	<10	656.00	196.50	56.00
22-26 de nov/02	<10	17.00	<10	352.00	204.00	25.00
7-12 de mzo/03	14.50	65.50	<10	380.00	143.00	42.00
6-19 de jun/03	34.00	118.00	24.00	864.00	32.00	16.00
24- de jul/03	17.00	47.00	12.00	188.00	28.00	24.00
28 de ago-03 de sep/03	22.00	26.00	17.00	94.00	<10	<10