2.0 DATA ANALYSIS AND MODEL PREPARATION

In order to model the system, the following data are required:

- Bathymetry of the river;
- Flow, temperature, and water quality characteristics for boundary conditions, major tributaries, and point sources;
- Stage data and tidal information;
- Meteorological conditions.

Many local, state and federal agencies have been collecting data on the Green River. This section of the report reviews the available data, provides an analysis of the data to determine model simulation periods, and documents procedures used in assembling model boundary conditions and tributary data.

2.1 Model Geometry

2.1.1 Bathymetry Data

Middle Green

For a HEC2 river modeling study conducted by King County in the mid-1990's, aerial photogrammetry was used to obtain topography of the floodplain and surrounding area, and a standard field survey was conducted to obtain elevations of river cross sections. King County provided AutoCAD® files with the aerial photogrammetry points, and HEC2 and HEC-RAS files from the previous floodplain work. The HEC data were imported into AutoCAD®, and three-dimensional lines were connected between each HEC2 river cross-section and between each bank point. These lines were used to create a 3-D terrain model of the river and surrounding land.

Lower Green

King County provided river bank and channel elevations for each cross-section from a 1980's HEC2 study. The HEC2 cross-sections are shown on Federal Emergency Management Flood Insurance Rate Maps (FIRMs). To place the cross-sections in the correct location on the river, digital FIRMs (tiff files) were obtained from FEMA. These maps were placed over GIS line work of the Lower Green River. The cross-sections on the FIRMs were then digitized into the drawing, and the section elevations from the HEC2 file were imported onto each cross-section. As with the Middle Green, three-dimensional fault lines were connected between each HEC2 river point and between each bank point. These three-dimensional faults were used to generate a contoured three-dimensional surface of the river and banks.

Digital elevation models (DEMs) of USGS quadrangles were obtained and added to the 3-D surface of the river. With these DEMs, a full model of the river valley and surrounding terrain was created.

A grid of the river and floodplain was generated from the terrain model. This grid consisted of x, y, and z points at three-meter intervals. This grid was then used to generate bathymetry files using SURFER®, a 3D mapping program.

King County also provided aerial photographs taken in 2000. These were used to compare cross-sectional data from the HEC models to river channel locations shown on the aerial photos. The river has changed significantly in three locations: at River Mile (RM) 32.40, downstream from the confluence with Big Soos Creek; near River Mile 36.00; and near RM 38.30. Figure 3 shows the

locations of the revised channel locations. The effects of the new channel at River Mile 32.40 were examined in the Sensitivity Analysis of the report, but the bathymetry of the new channel was not incorporated into the model. The channel changes at River Mile 36.00 and River Mile 38.30 are small and would not affect river hydrodynamics.

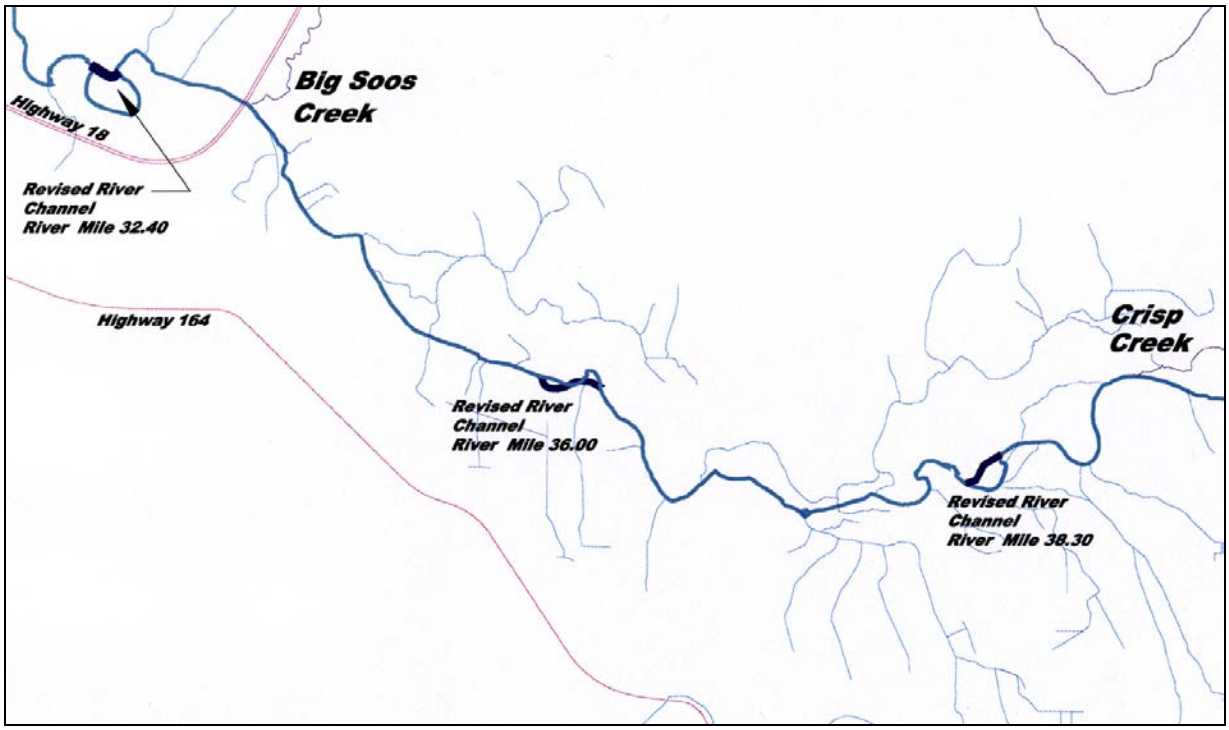

Figure 3: New River Channel Locations

When the consultant for the U.S. Army Corps of Engineers converted the HEC2 files to HEC-RAS, bathymetry discrepancies were noted where data for the Middle Green River and the Lower Green River studies overlap (RAS Notes, 1998). At the upstream end of the Lower Green River study, the river bottom elevation differs by nine feet from Middle Green study data. The Middle Green River HEC2 data were chosen for use in the model through this overlapping area for three reasons:

- The bathymetry data for the Lower Green River was obtained in the early 1980's, and the bathymetry data for the Middle Green River was obtained in the middle 1990's. The more recent data should better reflect current conditions.
- There was more detailed information available on the Middle Green River bathymetry, including information on datum, when the data were obtained, and how the data were obtained. There was no information provided on the bathymetry for the Lower Green River.
- River Mile 33.82 was the upper end of the Lower Green River study data. At this point the Lower Green study lists a river bottom elevation of 61.9, and the Middle Green River study lists an elevation of 69.9, a nine foot elevation difference. River Mile 33.55 was the lower end of the Middle Green River study. At this location the Lower Green River Study and the Middle Green River study both listed a river bottom elevation of 61.9. Therefore, using the Middle Green River data to River Mile 33.55, then switching to Lower Green River data provided a smooth transition between data from the different studies.

2.1.2 Model Grid Development

The river was modeled with 217 longitudinal segments, each approximately 250 meters long. Vertical

grid layers were set at a thickness of 1.0 meter. Figure 4 shows the model segments and the branch locations, and Figure 5 shows a vertical profile of the river bottom created from the digital terrain model. As this figure shows, the river has three distinct slopes through the section being modeled. These slope breaks define three separate reaches that will be modeled as separate water bodies. Additionally, each water body contains separate branches, which are shown in Figure 4.

Table 1 provides a breakdown of the branches in each water body. Note that the segment numbers in Table 1 include the "null" segments that divide each branch.

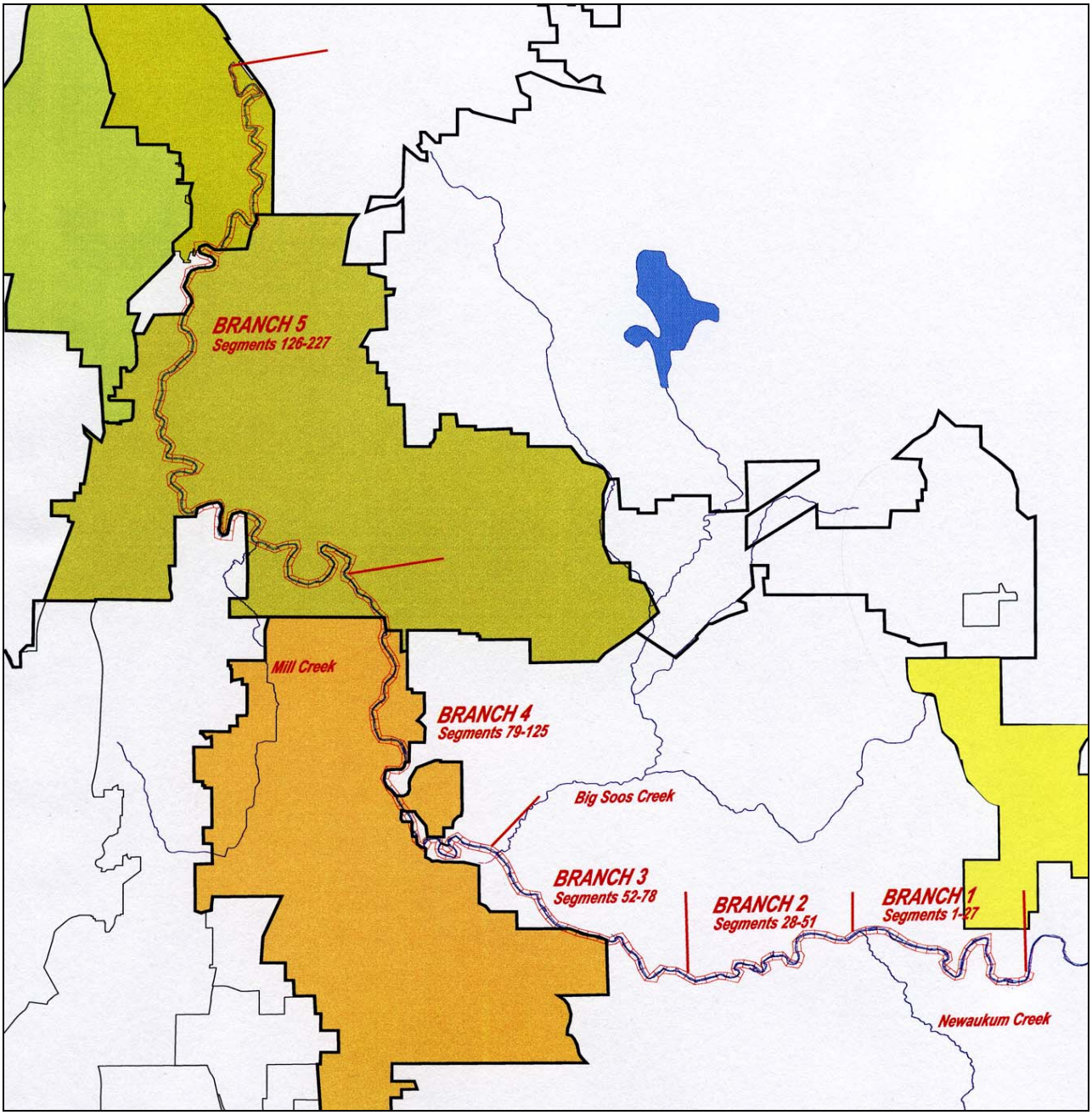

Figure 4: Model Grid Layout

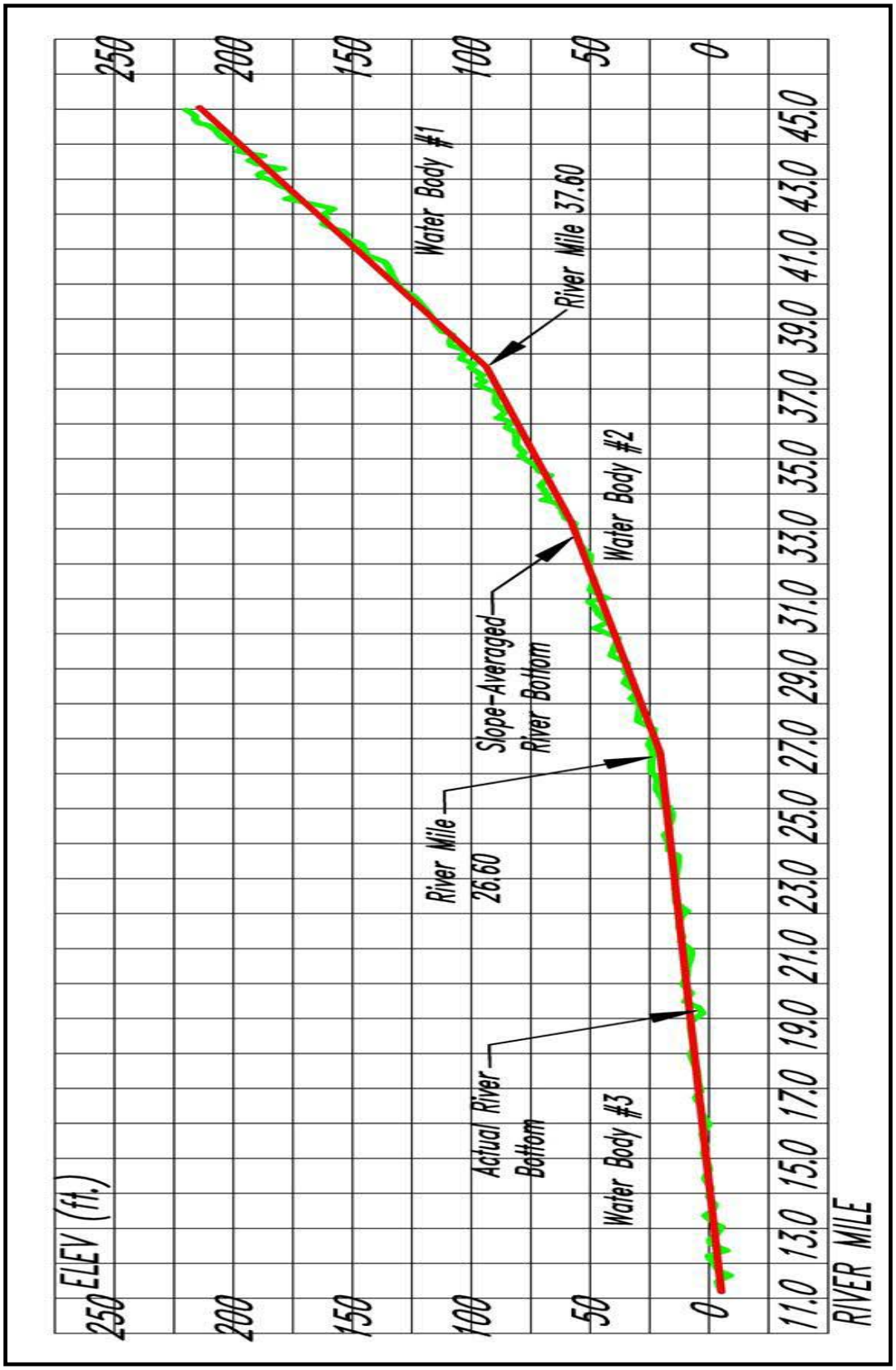

Figure 5: Profile of Actual and Averaged Green River Channel Bottom

Table 1: Water Body Characteristics

Water Body	Description	Branch	Segment Start	Segment End	Number of Segments	Average Slope
1	Flaming Geyser Park to east boundary of Auburn	1	1	27	51	0.31%
		2	28	51		
2	East boundary of Auburn to south boundary of Kent	3	52	78	74	0.13%
		4	79	125		
3	South Boundary of Kent to Tukwila	5	126	227	102	0.03%

2.2 Model Simulation Time Period

There are monitoring sites on the middle and lower reaches of the Green River, and many more on the various tributaries. King County and the United States Geological Survey (USGS) record flow on the river. King County, the Washington Department of Ecology, the University of Washington, and the USGS record temperature on the river, and King County, The Washington Department of Ecology, and the USGS sample water quality constituents. King County reviewed all gages on the river and assembled data from the relevant gages in database files for use in the model. They also compiled pertinent information in a document on bathymetry, meteorology, hydrology, shade, and water quality.

According to the data compilation report, most data were recorded in Pacific Daylight Time, so all other data were converted to this time.

The data compilation report was used to evaluate time periods for running the model. There was water quality data between 1995 and 2001 for the boundaries and most tributaries, and flow data was obtained back to the late 1980's. Temperature data proved to be the limiting factor when determining model calibration periods.

Criteria for choosing model run times included:

- Availability of upstream and downstream boundary condition data
- Availability of data for larger tributaries, including Newaukum Creek, Big Soos Creek, Crisp Creek, and Mill Creek.
- Availability of data for the remaining tributaries.

Table 2 lists the temperature data available for the boundary locations and tributary streams between 1995 and 2001, and Table 3 lists the temperature gages for the same locations, along with the dates of available and missing data.

Based upon information in these two tables and the temperature data constraints, the model run periods were from May 25, 1995 through November 1996, and from April 1, 2001 through July 2002. These time periods correspond to two major temperature studies by King County and have the most temperature data for the boundaries and tributaries. See Appendix E for a map showing the location of all stations and a table which shows the stations used for model data.

Table 2: Temperature Data Summary

Location	1995	1996	1997	1998	1999	2000	2001	2002
U/S Boundary	May - Nov	Jan - Nov	None	None	None	None	Apr - Dec	Jan- Sept
D/S Boundary	June - Dec	Jan - Dec	Jan - Dec	Jan - Dec	Jan - Dec	Jan	None	July – Sept.
Newaukum Creek	None	July - Dec	Jan - Dec	Jan - Oct	None	None	July - Dec	Jan - Sept
Crisp Creek	None	None	Oct - Dec	Jan - Dec	Jan - Dec	Jan - Dec	Jan - Dec	Jan - Aug
Big Soos Creek	Jan - Dec	Jan - Dec	Jan - Dec	Jan - Dec	Jan - Dec	Jan - Dec	Jan - Dec	Jan - Aug
Mill Creek	None	None	None	None	Oct - Dec	Jan - Dec	Jan - Dec	Jan - Aug
Mullen Slough	None	None	None	None	None	None	None	None
Auburn Creek	None	None	None	None	None	None	None	None
Midway Creek	None	None	None	None	None	None	None	None

Table 3: Temperature gages at modeling locations

Location	Time Period of Data	Monitoring Station	Missing Data Periods
Green River Upstream Boundary	May 1995 –Nov. 1999	KC gage at Black Diamond (WHI)	Dec 1999 - April 2001
	July 24, 2001 – Aug. 2, 2002	GDWQA at Whitney Bridge (GRT10 and GRT10_2)	
	Apr 2001– Sept 2002	UW Gage (GR3-4)	
	July 24, 2001 – Oct. 17, 2001	UW Gage (GR5)	
Downstream Boundary	June 1995 – Nov 1996 Jan 1996 – Jan 2000 July 2002 – Sept. 2002	KC Gage (BIC) USGS Gage (12113390) GDWQA gage (GRT18)	January – June 1995 February 2000 – June 2002
Crisp Creek	Oct 1997 – Aug 2002	KC gage at mouth (40d)	1995 to Sept. 1997
Newaukum Creek	July 1996 – Oct 1998 July 2001 – Sept 2002	USGS gage (12108500) GDWQA gage (GRT09)	Nov 1998 to June 2001
Big Soos Creek	Oct 1994 – Aug 2002	KC gage (54A)	Data set is complete
Mill Creek	Oct 1999 – Aug 2002	KC gage (41a)	1995 to Sept 1999
Mullen Slough	July 1996 – Nov 1996	KC gage (FRA)	Nov 1996 to Dec 2002
Midway Creek	None		1995-2002
Auburn Creek	None		1995-2002

2.3 Water Quality Constituents

King County has provided water quality grab samples on the Lower and Middle Green River from 1990 to 2002. Table 4 lists the water quality monitoring sites between the lower and upper boundaries of the project (including tributaries), Table 5 lists constituents of interest that have been sampled, and Table 6 lists the constituents to be modeled.

The Washington Department of Ecology (WDOE) also monitors data at various locations on the Middle and Lower Green River. However, the river locations sampled and the constituents sampled were the same as King County's program, so this information was not used in the model.

Grab sample data were available at the locations in Table 4 on a monthly basis for both model periods. Longitudinal profiles were created using data from the four mainstem monitoring sites. Figure 6 shows a longitudinal profile for dissolved oxygen, and Appendix B contains longitudinal profiles for the remaining constituents listed in Table 5.

Table 4: Water Quality Monitoring Sites

Site ID	Description	RM	Agency
3106	Fort Dent Park	11.70	King County
0311	Interurban Avenue	12.40	King County
G319	Below Mullen Slough	21.30	King County
A319	Auburn-Black Diamond Road	33.80	King County
B319	Above Newaukum Creek	41.40	King County
Mullen1, Mullen2	Mouth of Mullen Slough	N/A	King County
A315	Mouth of Mill Creek	N/A	King County
A320	Big Soos	N/A	King County
0321	Crisp Creek	N/A	King County
0322	Newaukum Creek	N/A	King County

Table 5: Water Quality Constituents sampled by King County

Constituent Name	Constituent Name
Dissolved Oxygen	Temperature
Total Nitrogen	pH
Ammonia Nitrogen	Alkalinity
Nitrite-Nitrate	Conductivity
Total Phosphorus	Fecal Coliform
Ortho Phosphorus	Enterococcus
Turbidity	Escherichia coli.
Total Organic Carbon	Total Suspended Solids
Chlorophyll-A	Dissolved Organic Carbon
	Biochemical Oxygen Demand

Table 6: Water Quality Constituents included in the model			
Constituent	Constituent Name	Constituent	Constituent Name
DO	Dissolved Oxygen, mg/L	TEMP	Temperature, Celsius
NH_4	Ammonia Nitrogen	pH	pH
NO_2-NO_3	Nitrite-Nitrate, mg/L	ALK	Alkalinity, CaCO3mg/L
L/R DOM and POM	Dissolved and Particulate Organic Matter, mg/L	COND	Conductivity, umhos/cm
PO_4	Ortho Phosphorus, mg/L	TIC	Total Inorganic Carbon, mg/L
ISS	Inorganic Suspended Solids, mg/L	ALG1	Algae, mg/L
		COLFRM	Fecal Coliform, ORG/100 ml

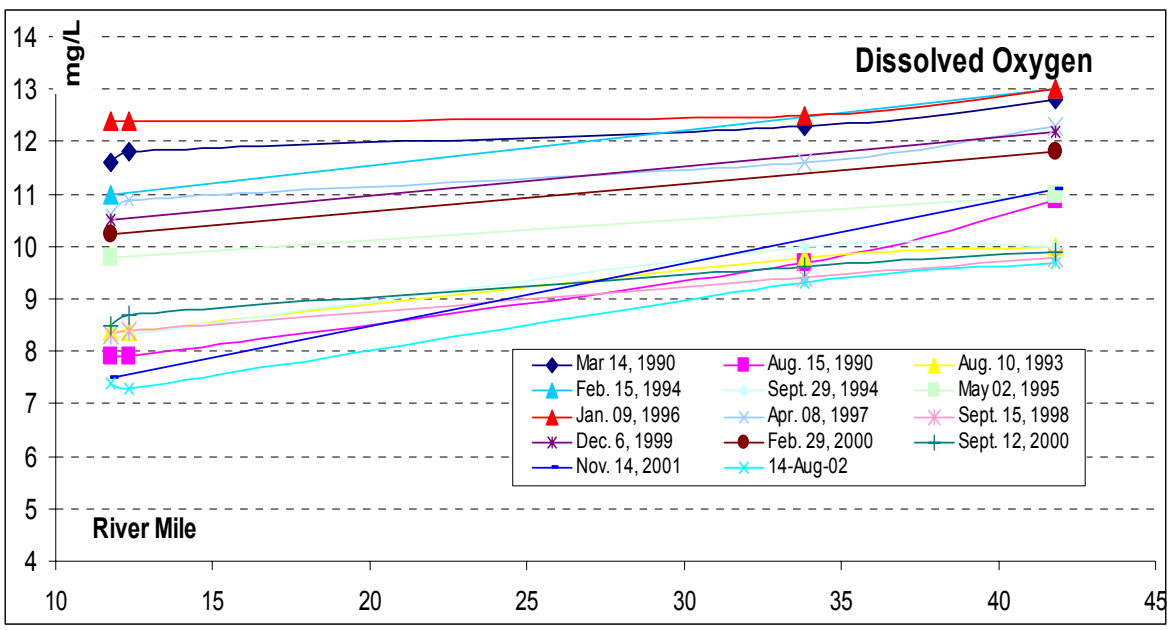

Figure 6: Dissolved Oxygen Longitudinal Profile

2.4 Model Boundary Conditions

The upstream boundary is at River Mile (RM) 45.0, in Flaming Geyser State Park, and the downstream boundary is at RM 11.20, downstream from Fort Dent State Park. The upstream boundary condition is characterized by flow, temperature, and water quality, and the downstream boundary is characterized by water surface elevation, temperature, and water quality.

2.4.1 Upstream Boundary

May 25, 1995 – November 1996

Flow

The closest flow gage to the upstream boundary is a USGS gage (12106700) near Palmer, Washington, approximately 26 km upstream from Flaming Geyser State Park. Flow data were obtained for this gage in 15-minute intervals from October 1994 to December 2002. Because this gage is so far upstream, a time-travel analysis was performed to see how long it takes flow from the Palmer gage to reach the Upstream Boundary. Flow data from the Palmer gage was shifted by six hours to account for travel time. Please see Appendix C for this analysis.

Groundwater and surface water contribute flow to the river between the Palmer gage and the upstream project boundary. There are numerous springs in the Green River Gorge (Luzier, 1969) and near Icy Creek (DeGasperi, 2003). Additionally, there are many small tributaries that flow into the river. To estimate surface water inflows for the area between the gage at Palmer and the upstream boundary, King County hydrologists used the modeling program HSPF (Hydrologic Simulation Program-Fortran) to estimate surface runoff. Daily average flow rates of surface runoff were provided from HSPF models for three basins tributary to the Green River. Figure 7 is a map of the three basins (MG1, MG2, and MG3), with the location of the Palmer gage also shown.

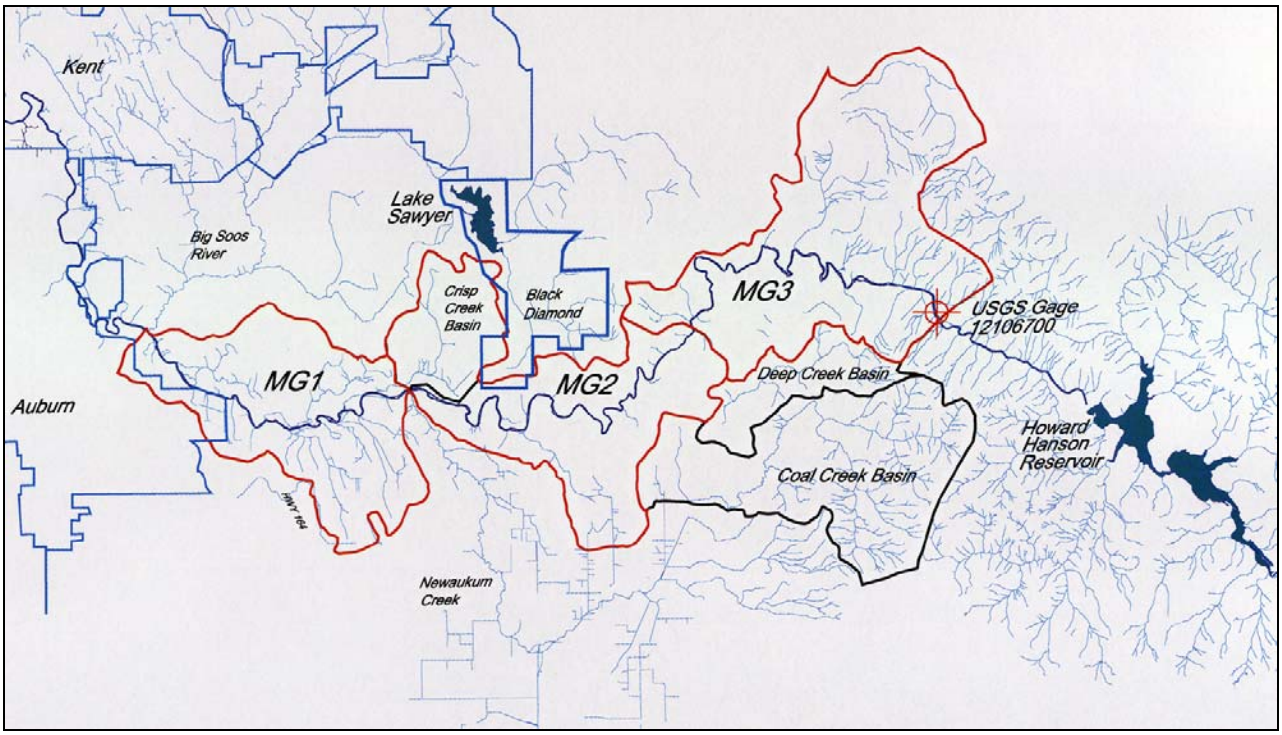

Figure 7: Green River HSPF Basins

All of Basin MG3 is upstream of the upstream project boundary. HSPF flow data for this basin were added to flow from the Palmer Gage. Basin MG2 includes the area tributary to Crisp Creek. This creek has gaged flow data available for input to the model, so it was modeled as a separate tributary. The size of the Crisp Creek Basin is approximately 28% of Basin MG2, so 72% of the HSPF flow for Basin MG2 was added to the Palmer Gage. Daily average values were provided for the HSPF data, and data in 15-minute intervals were obtained for the Palmer Gage, so the daily averaged data were linearly interpolated to 15-minute intervals to match the Palmer Gage.

Basin MG1 is below the upstream boundary and was added to the model as a distributed tributary. This is discussed in Section 2.7

The travel time analysis was also used to see how long it takes flow from the downstream end of Basin MG3 to reach the upstream boundary. The HSPF data for this basin was shifted by four hours before it was added to the upstream boundary flow from the Palmer Gage. Please see Appendix C for more information on establishing these times.

Deep Creek and Coal Creek Basins (See Figure 7) are closed drainages that do not discharge to any water body. King County hydrologists believe groundwater from these two streams makes its way to the Green River (DeGasperi, 2003; Green-Duwamish Watershed Water Quality Assessment, 2002). King County provided HSPF model approximations of surface runoff from these two basins. Although there is no information available indicating that all this flow makes to the Green River, all of the flow was added to flow from the Palmer Gage. Because daily average HSPF data were provided, linear interpolation was used to fill in the data for the 15-minute intervals for the Palmer gage. These flows will be re-examined once the hydrodynamic calibration is undertaken.

Groundwater is a major contributor to the Green River between the USGS gage at Palmer and the upstream boundary of the model. Luzier (1969) estimated that as much as 1.26 cubic meters per second (cms) summer flow and 6.30 cms winter flow contributes to the Middle Green River from springs in the Green River Gorge. These values were added to the flow data from the Palmer Gage, using 1.26 cms from April 1 to September 30, and 6.30 cms from October 1 to March 31. These flows will also be re-examined during model calibration. Figure 8 shows flow data for the model simulation period. Flow data from 1995 – 2002 is shown in Appendix A.

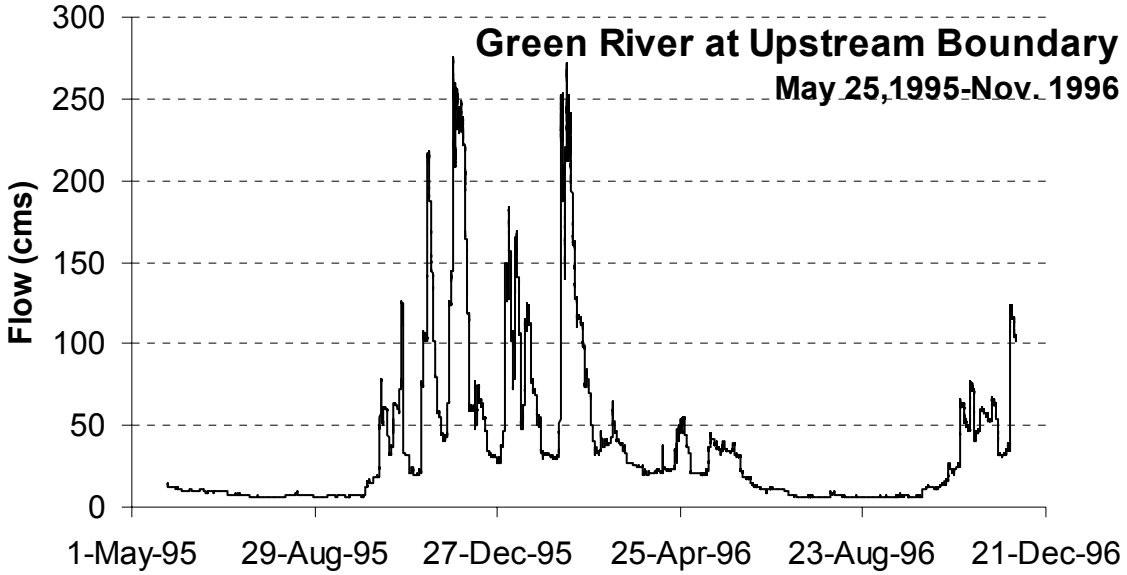

Figure 8: Green River Flow at Upstream Boundary: May 1995 to November 1996

Temperature

Monitoring station WHI is located about four km downstream of the first model segment. Temperature was recorded at this station in 1995 and 1996. This station has two data gaps for the model calibration period: from May 1, 1996 to June 7, 1996, and from July 26, 1996 to August 13, 1996. To fill these data gaps, data from monitoring station 54a, located at the mouth of Big Soos Creek, was correlated with station WHI from July 1995 through October 1995. The temperature relationship between the two stations is as follows:

$$\text{WHI Temp} = (\text{Sta 54a})(1.3412) - 3.1517$$

Figure 9 shows the data for the two stations with the line from the correlation equation, Figure 10 shows the correlated data and monitored data, and Figure 11 shows the temperatures for the model calibration period. Appendix A contains a graph of temperature for all gages used at the upstream boundary from 1995 through September 2002.

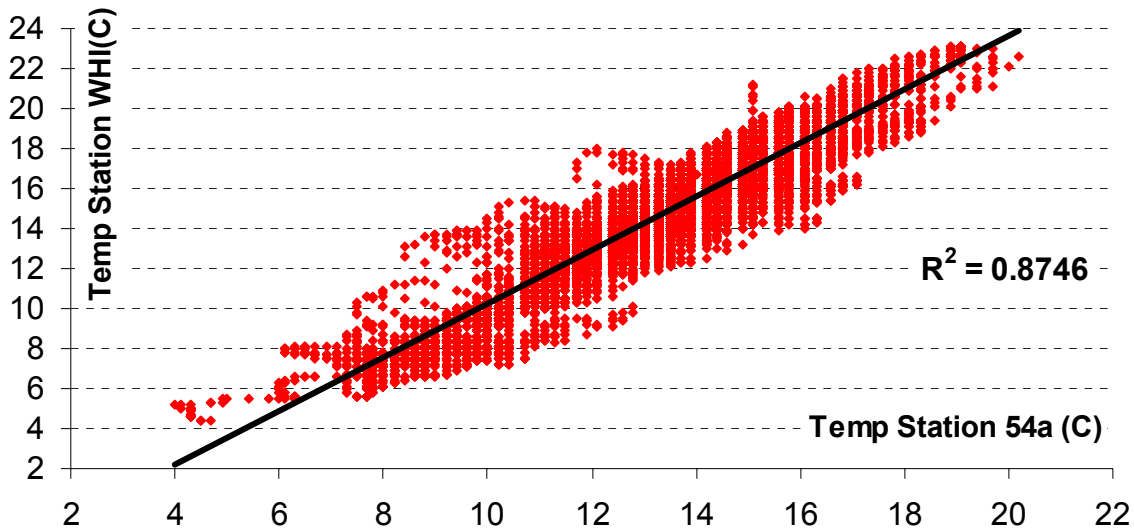

Figure 9: Correlation between Stations WHI and 54a

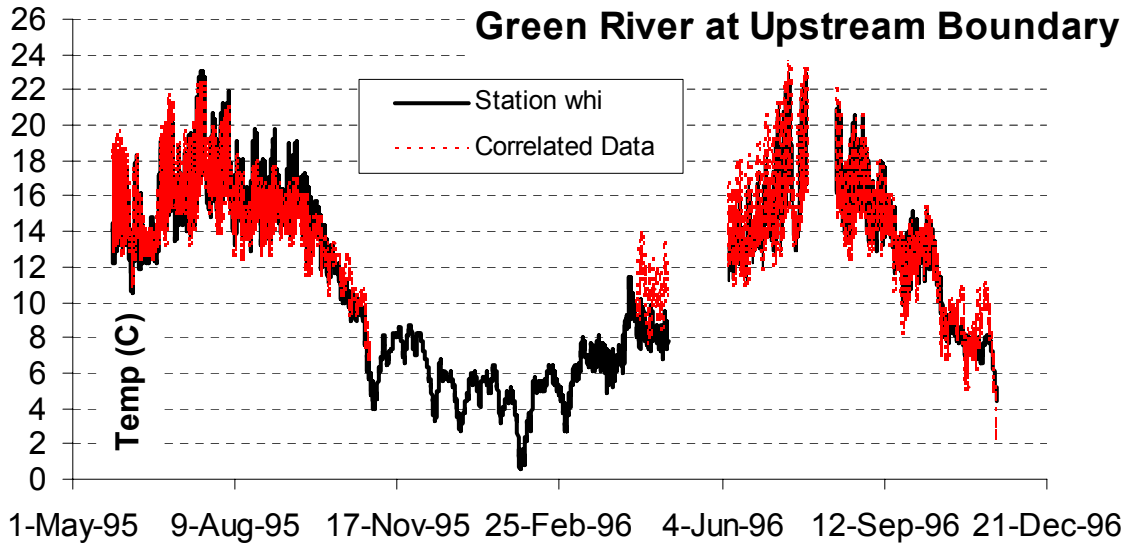

Figure 10 (above): Upstream Boundary: Station versus Correlated Data, 1995-1996

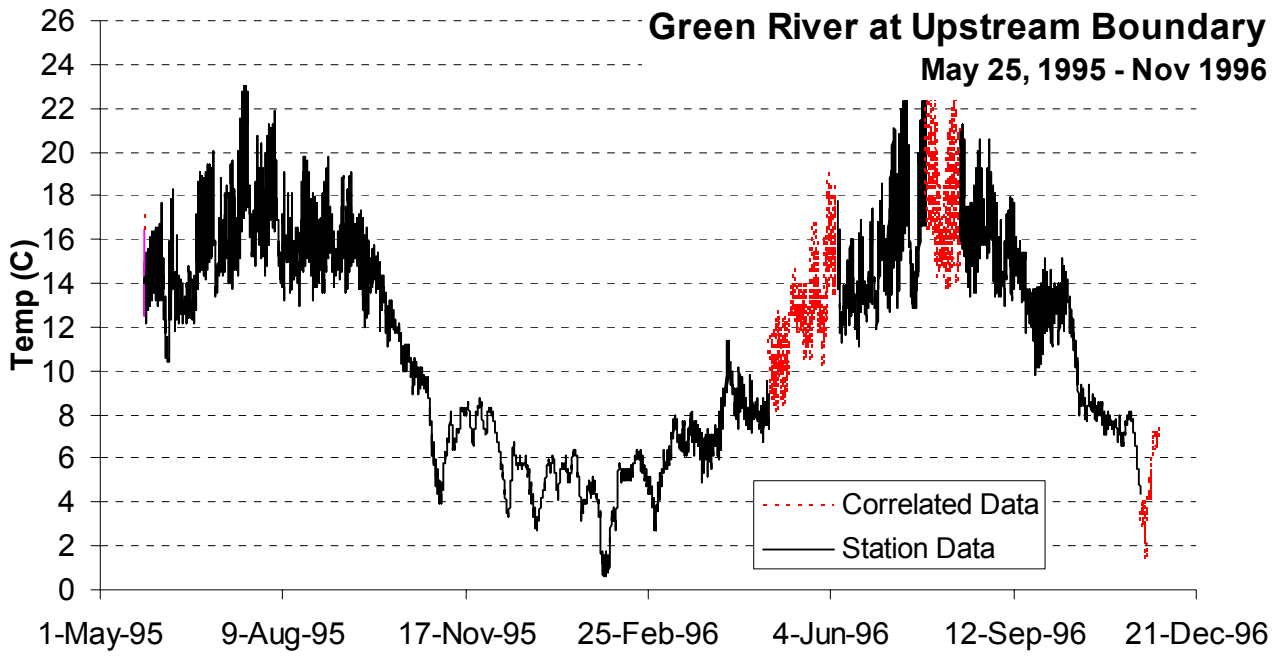

Figure 11: Green River Temperature at Upstream Boundary: May 1995 to November 1996

Water Quality

Water quality data from Sampling Site B319 (located four km below the upstream boundary) was used as the upstream boundary condition. Data were available for all constituents except alkalinity and chlorophyll a. Figure 12 through Figure 26 plot the water quality constituents for the upstream boundary condition for the 1995 - 1996 model calibration period. The procedure used for developing the water quality files, including filling data gaps, is included in Appendix D. Appendix A contains graphs of water quality data from 1995 – 2002 for all of King County's sampling locations.

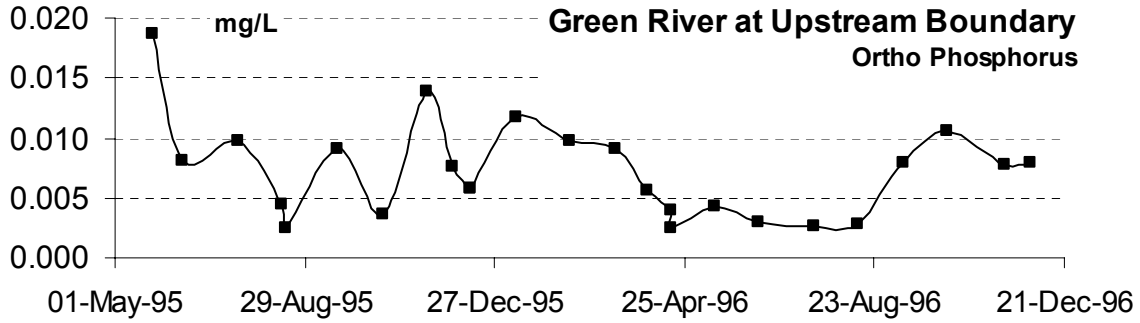

Figure 12: Ortho phosphorus at Upstream Boundary: May 1995 to November 1996

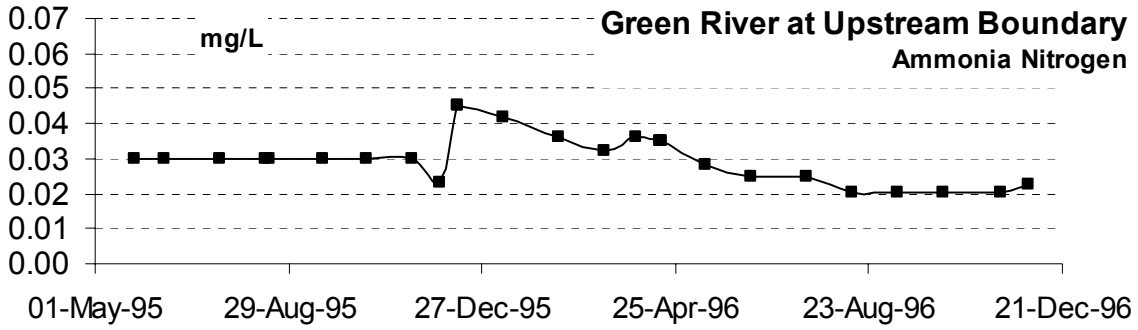

Figure 13: Ammonia at Upstream Boundary: May 1995 to November 1996

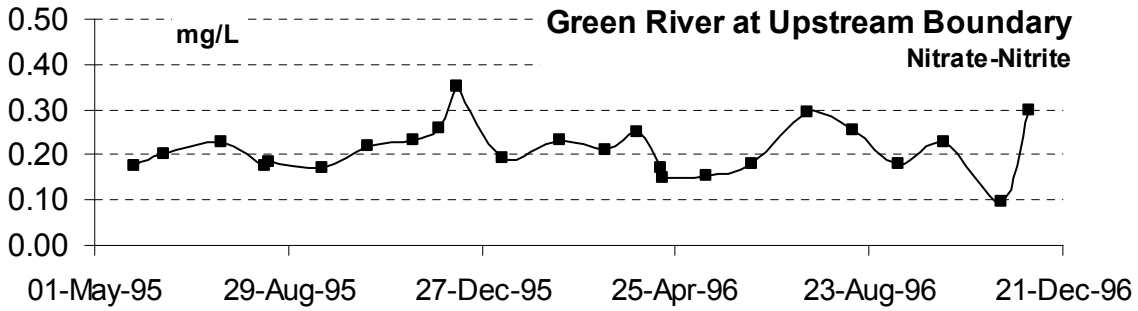

Figure 14: Nitrate-Nitrate at Upstream Boundary: May 1995 to November 1996

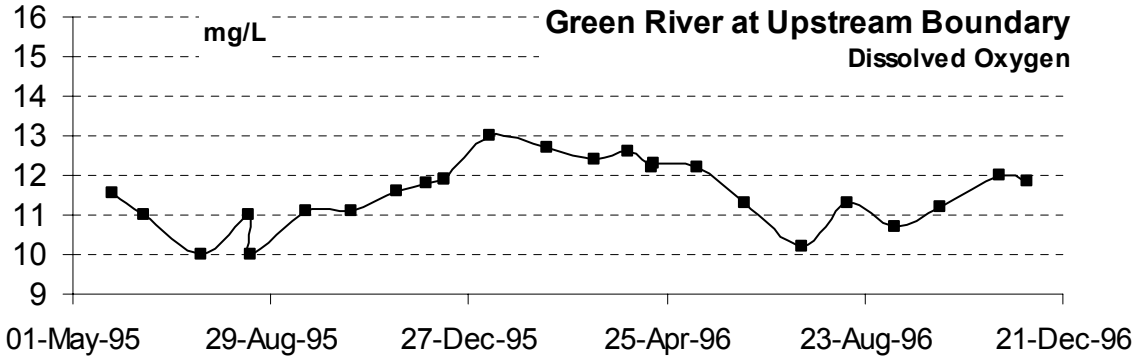

Figure 15: DO at Upstream Boundary: May 1995 to November 1996

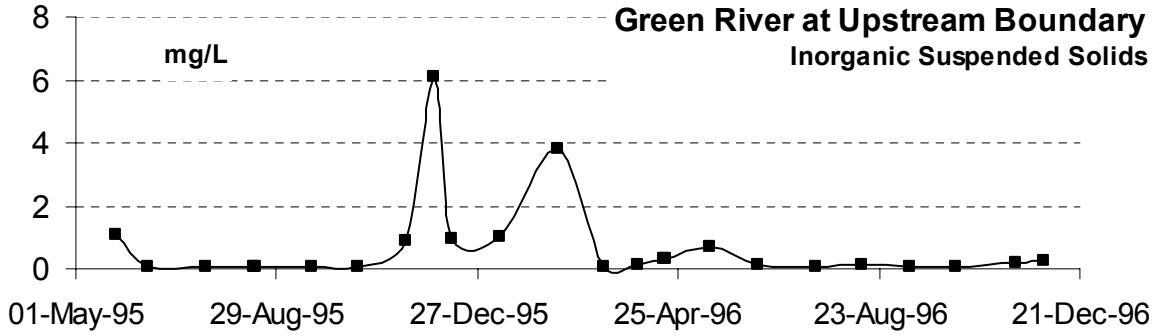

Figure 16: ISS at Upstream Boundary: May 1995 to November 1996

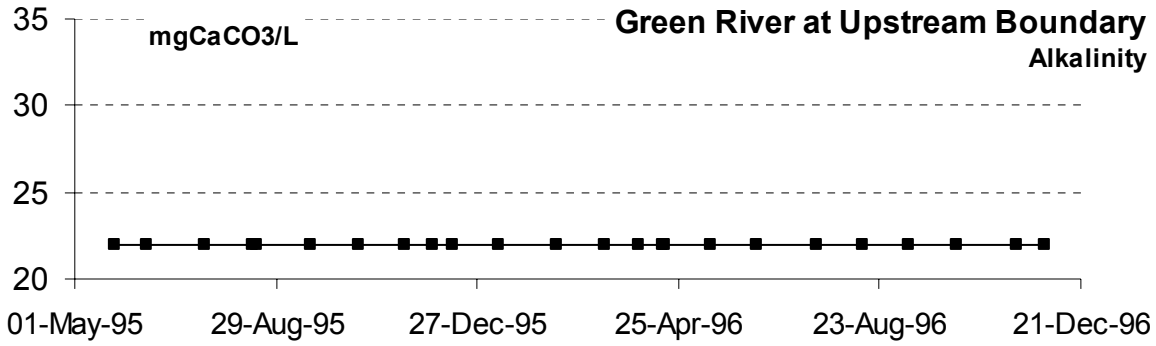

Figure 17: Alkalinity at Upstream Boundary: May 1995 to November 1996

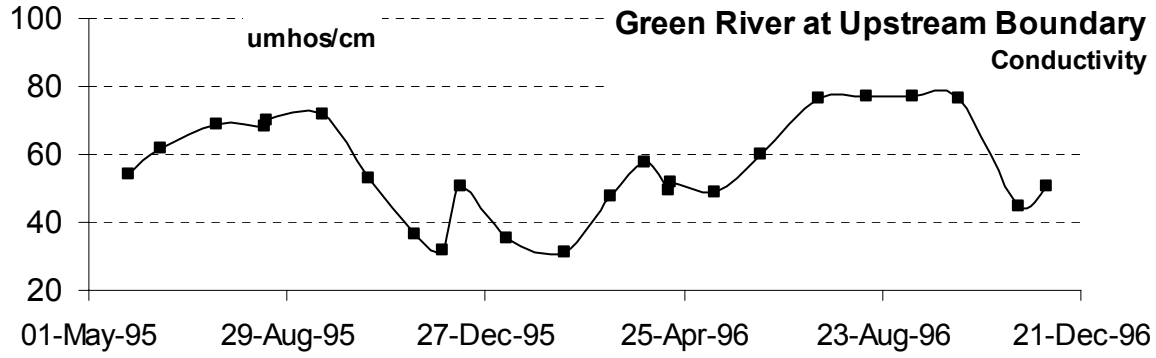

Figure 18: Conductivity at Upstream Boundary: May 1995 to November 1996

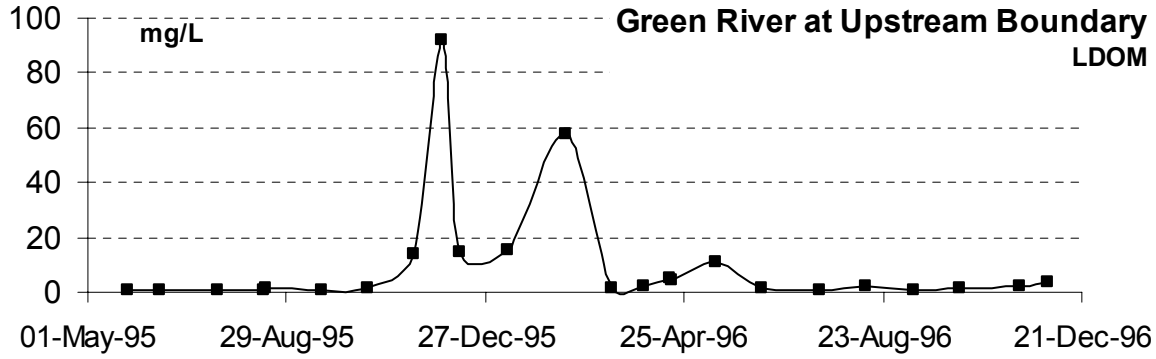

Figure 19: LDOM at Upstream Boundary: May 1995 to November 1996

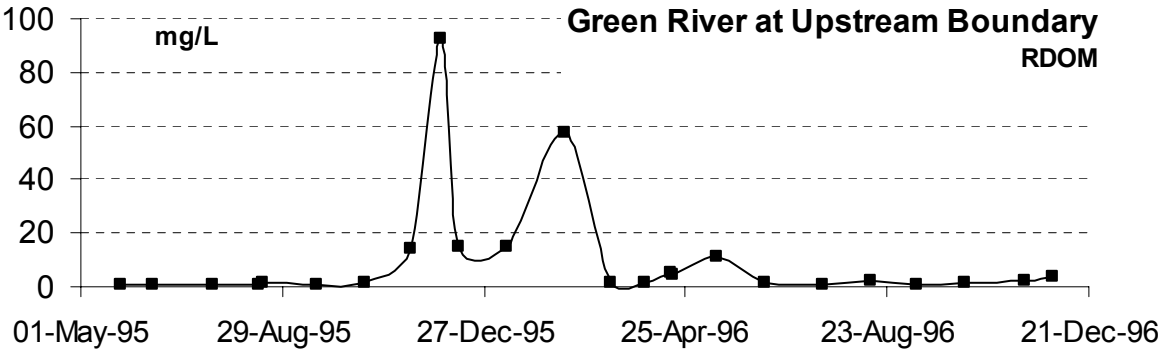

Figure 20: RDOM at Upstream Boundary: May 1995 to November 1996

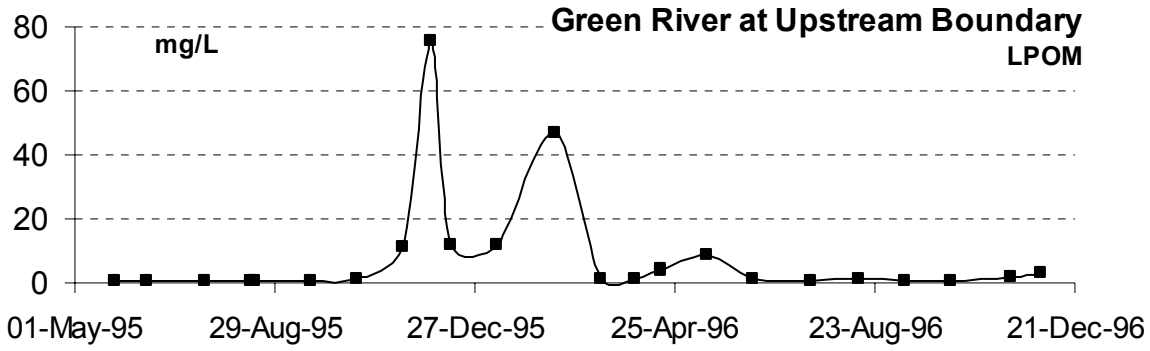

Figure 21: LPOM at Upstream Boundary: May 1995 to November 1996

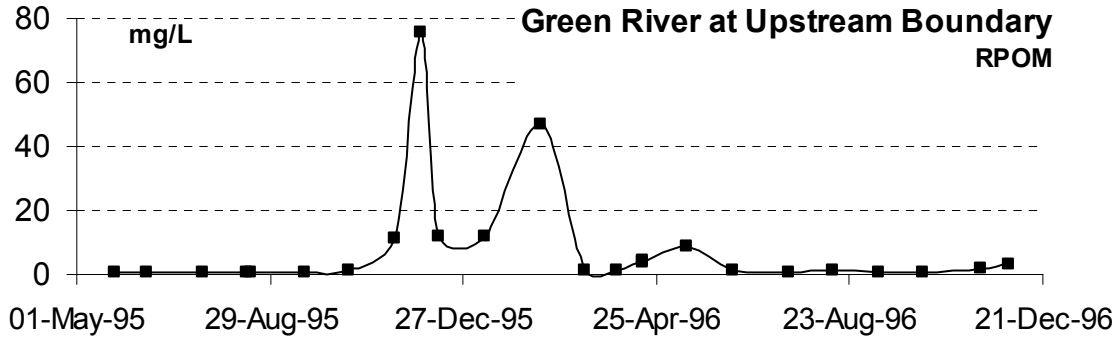

Figure 22: RPOM at Upstream Boundary: May 1995 to November 1996

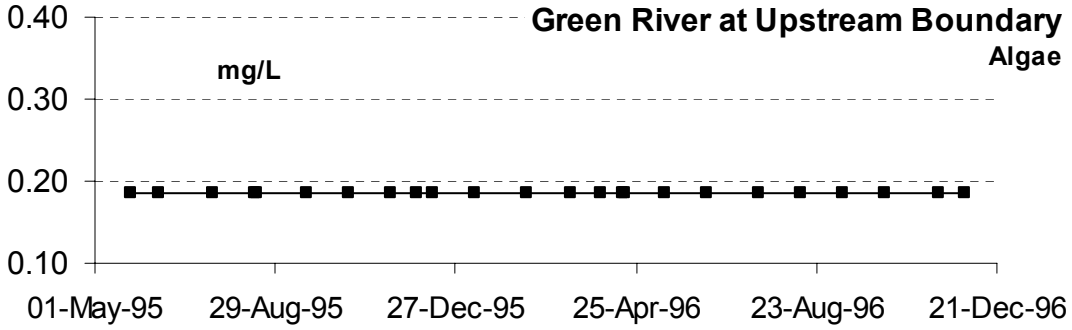

Figure 23: Algae at Upstream Boundary: May 1995 to November 1996

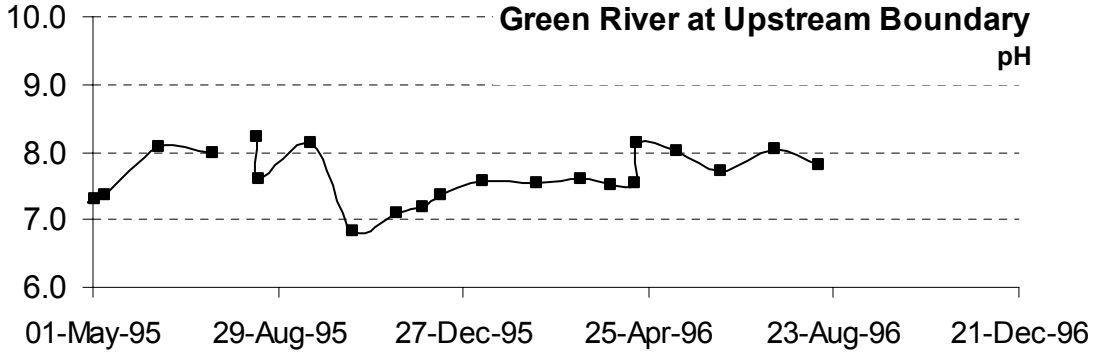

Figure 24: pH at Upstream Boundary: May 1995 to November 1996

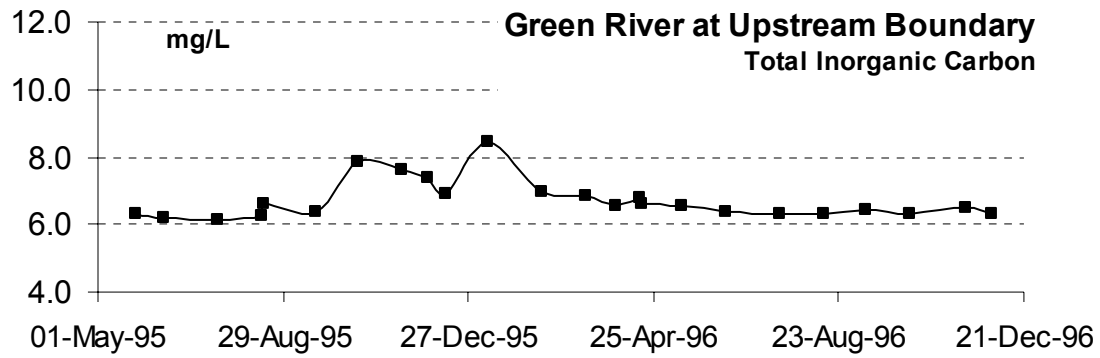

Figure 25: TIC at Upstream Boundary: May 1995 to November 1996

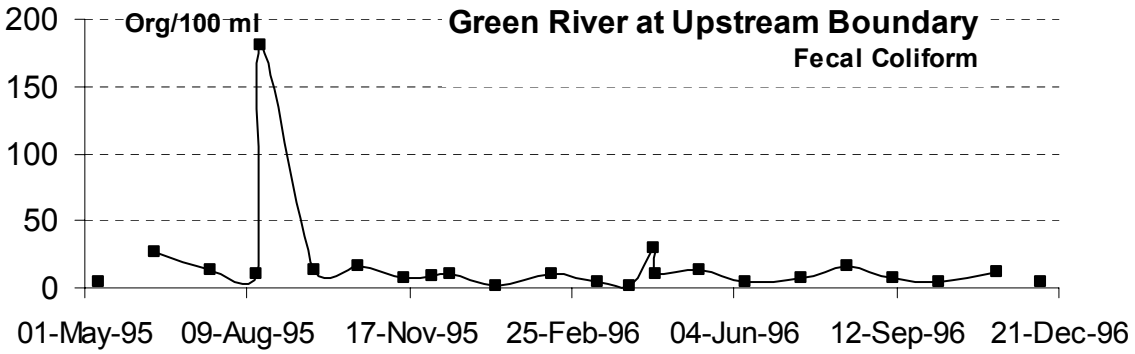

Figure 26: Fecal Coliform at Upstream Boundary: May 1995 - Nov 1996

April 2001 –July 2002

Flow

The Palmer flow gage (USGS 12106700) was used for the upstream boundary condition for the 2001 to 2002 model calibration period. As with the May 1995 – November 1996 calibration period, daily HSPF model output were added to the Palmer gage with the same lag for travel time. Figure 27 shows the estimated flows for the model calibration period.

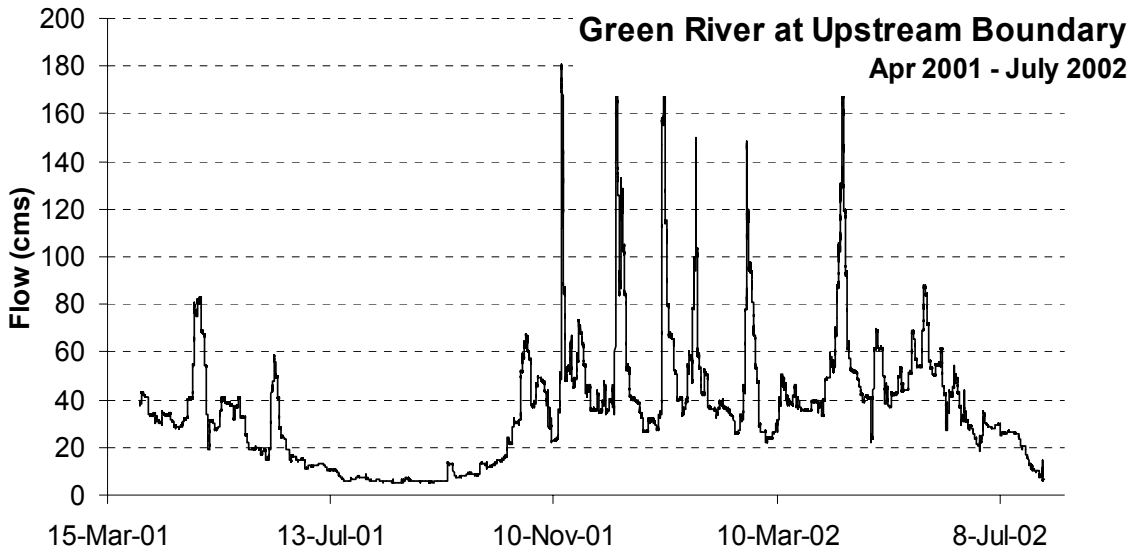

Figure 27: Green River Flow at Upstream Boundary: Apr 2001 – July 2002

Temperature

The University of Washington monitored temperature at Station GR5, which is located at the upstream boundary, and at Station GR3-4, approximately four km downstream of GR5. Temperature data were available at these stations for the following periods:

- At GR5 from July 24, 2001 to October 17, 2001,
- At GR3-4 from March 30, 2001 to June 20, 2001, from July 24, 2001 to October 17, 2001, and from July 29, 2002 to September 12, 2002.

Data were correlated with each other to see how significant the temperature differences are at these stations. As Figure 28 shows the temperature between the two stations is almost identical, so temperature from both stations was used at the upstream boundary. All available data from GR5 was used (July 24, 2001 to October 17, 2001), and data from GR3-4 was used from April 1, 2001 to June 20, 2001.

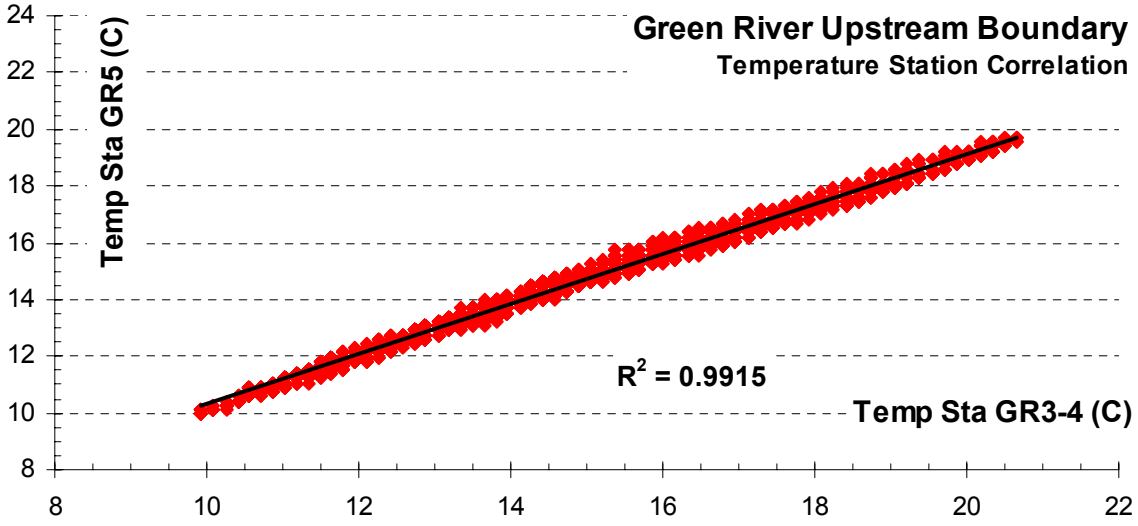

Figure 28 (above): Correlation between Stations GR5 and GR3-4

According to King County, the University of Washington stations record in Coordinated Universal Time (UTC), so these data were converted to Pacific Daylight Time.

At the same location as Station GR3-4, the King County Green-Duwamish Water Quality Assessment program recorded continuous temperature data at Site GRT10 from July 24, 2001 to September 6, 2001, from November 16, 2001 to February 22, 2002, and from March 14, 2002 to August 2, 2002. These data were used at the upstream boundary, and were correlated to data from Station GR3-4. The relationship between GR3-4 and GRT10 is defined as follows:

$$GR3\text{-}4 = (GRT10)(0.8395) + 2.0076$$

Correlated values from GRT10 will then be used between November 16, 2001 and February 22, 2002, and between March 14, 2002 and July 31, 2002. Figure 29 shows the correlation between the two stations and Figure 30 shows temperature data and correlated values.

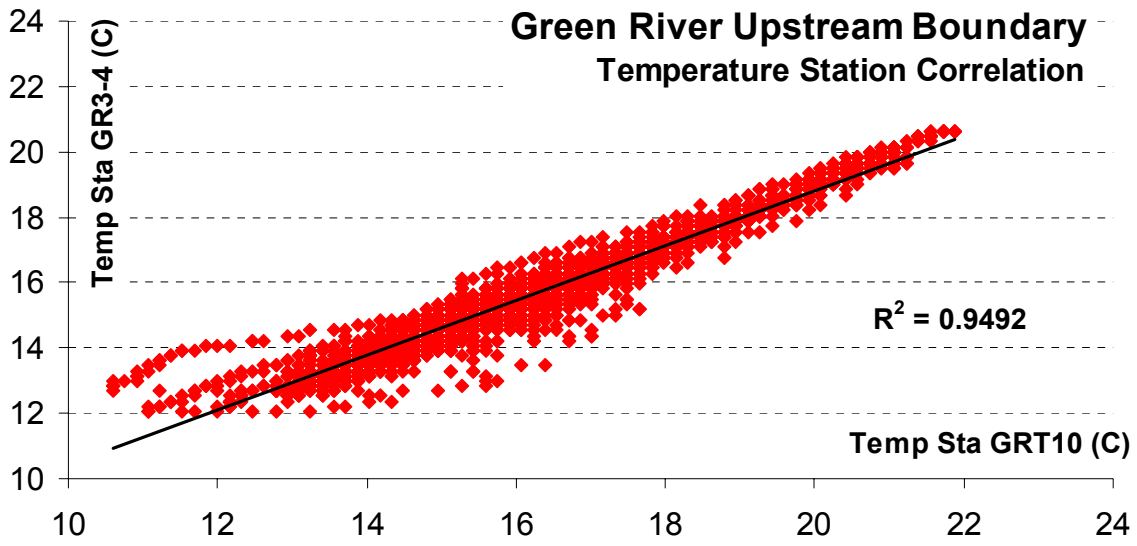

Figure 29: Upstream Boundary: Correlation between Stations GRT10 and GR3-4

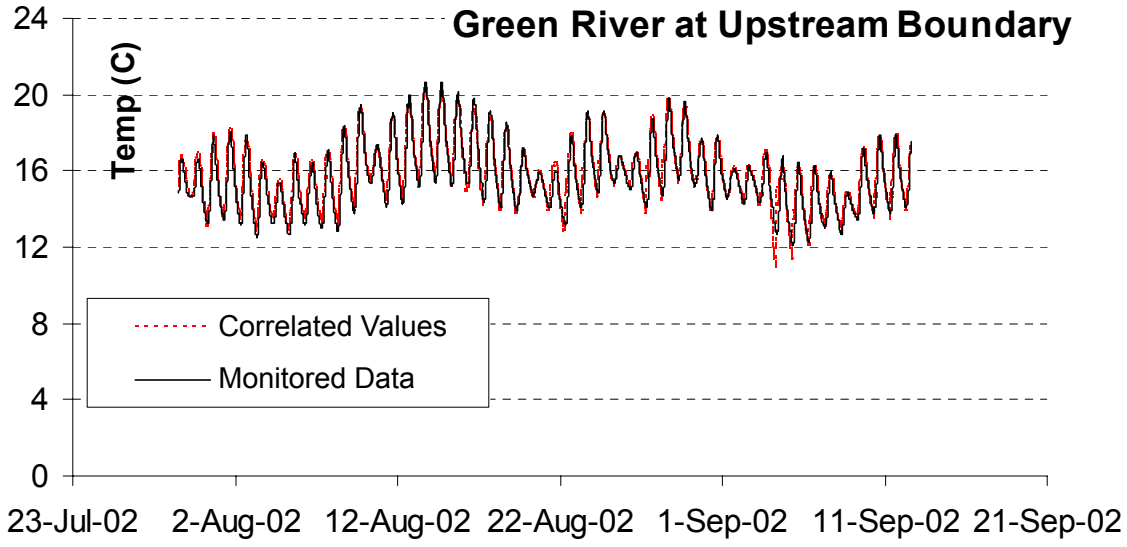

Figure 30 (above): Station GR3-4 Data versus Correlated GRT10 Data, 2001-2002

Figure 31 shows the temperature data at the upstream boundary from the three temperature stations.

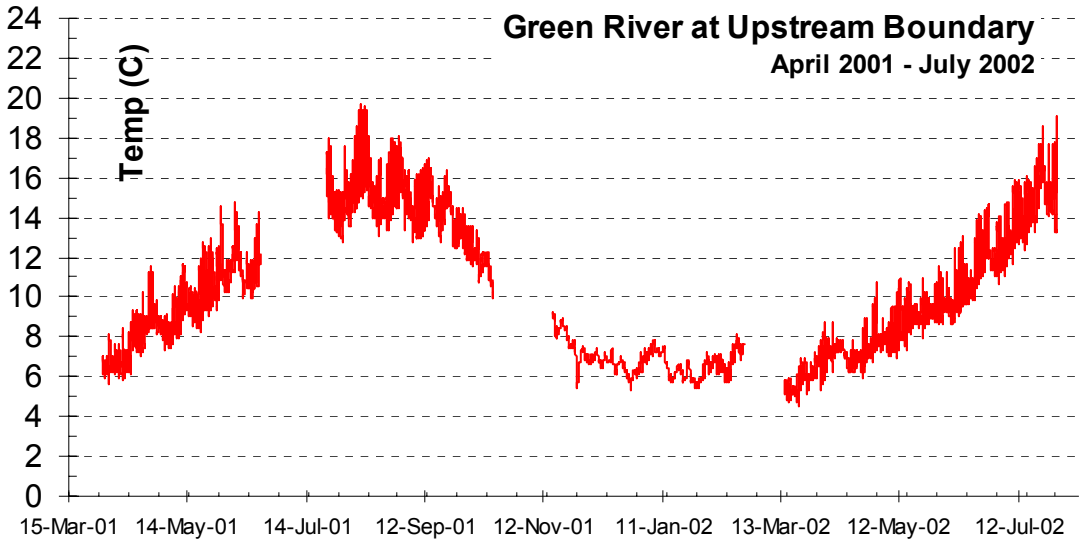

Figure 31: Stations GR5 and GR3-4, 2001-2002

As Figure 31 shows, there are still three data gaps to be filled:

- June 20, 2001 to July 24, 2001
- October 17, 2001 to November 16, 2001
- February 23, 2002 to March 14, 2002

To fill these remaining data gaps, data from two temperature stations located further downstream were used. The University of Washington monitored data at Station GR1, approximately 18 km below the upstream boundary. Data from this station were correlated with temperature data from GR5 to fill both the June 20, 2001 to July 24, 2001 data gap and the February 23, 2002 to March 14, 2002 data gap. Figure 32 shows the correlation between the two stations. The correlation equation is:

$$\text{GR5 correlated values} = (\text{GR1})(0.8099) + 2.18$$

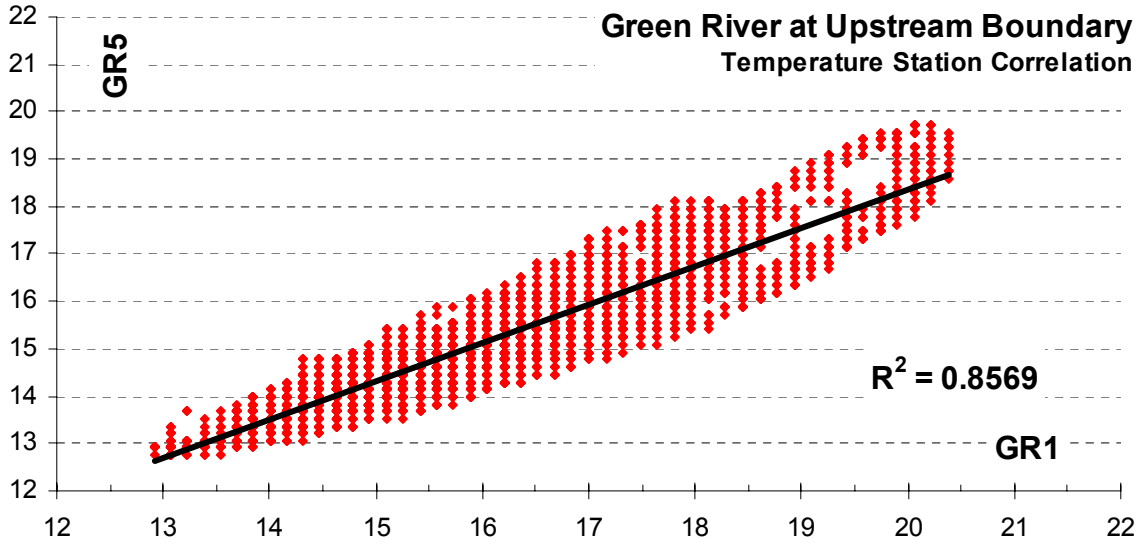

Figure 32 (above): Correlation between GR1 Temperature and GR5, 2001-2002

The King County Green-Duwamish Water Quality Assessment Program monitored temperature at Site GRT04, approximately 17 km below the upstream boundary. Data from this station was correlated with GR5 to fill the last data gap, from October 17, 2001 to November 16, 2001. Figure 33 shows the correlation between the two stations. The correlation equation is:

$$\text{GR5 correlated values} = (\text{GRT04})(0.779) + 2.76$$

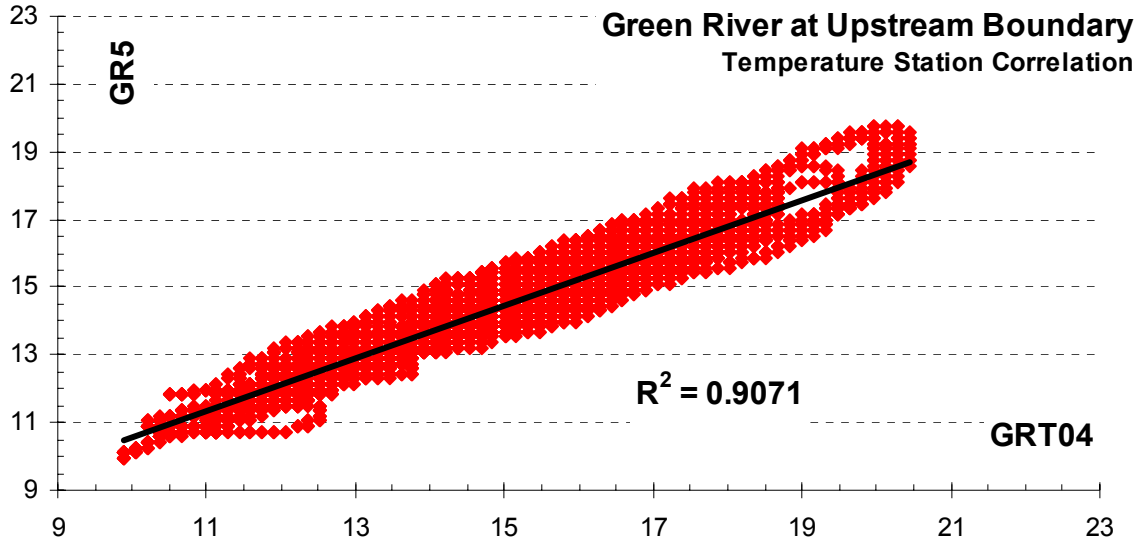

Figure 33: Correlation between GRT04 Temperature and GR5, 2001-2002

Figure 34 shows the assembled temperature data for the upstream boundary for the entire model run period.

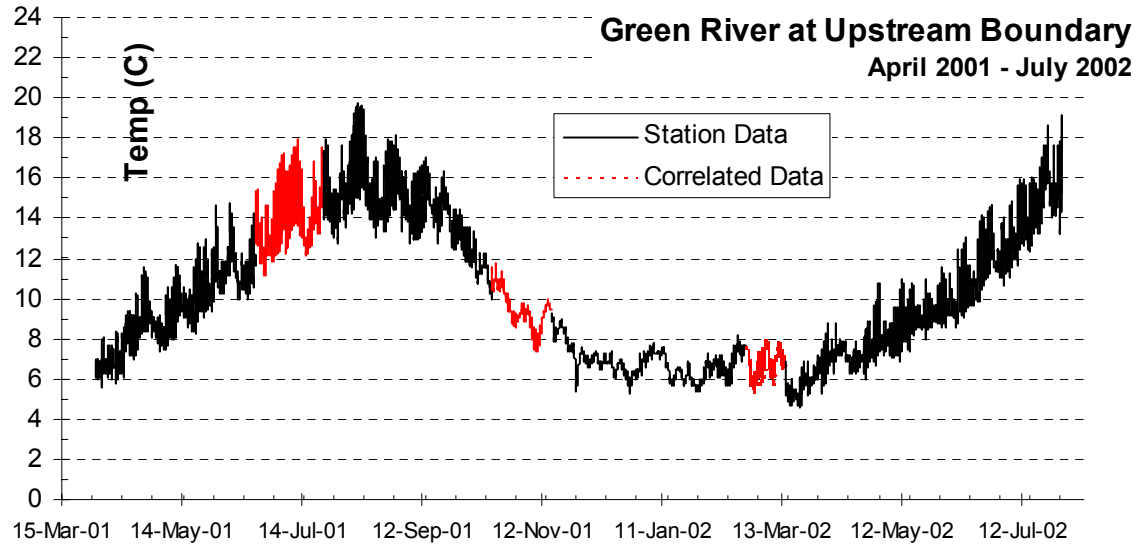

Figure 34: Green River Temperature at Upstream Boundary: Apr 2001 – July 2002

Water Quality

King County sampled water quality constituents downstream from Flaming Geyser State Park near the

temperature stations GR3-4 and GRT10 (Site B319). Data were available for all constituents for the model run period. Figure 35 through Figure 49 show the constituents to be modeled for the model calibration period of April 2001 to June 2002. See Appendix D for procedures used in developing the upstream water quality boundary condition

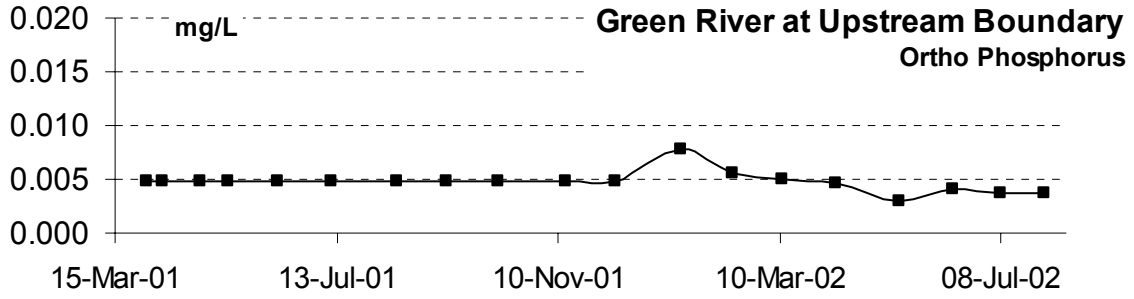

Figure 35: Ortho phosphorus at Upstream Boundary: Apr 2001 – July 2002

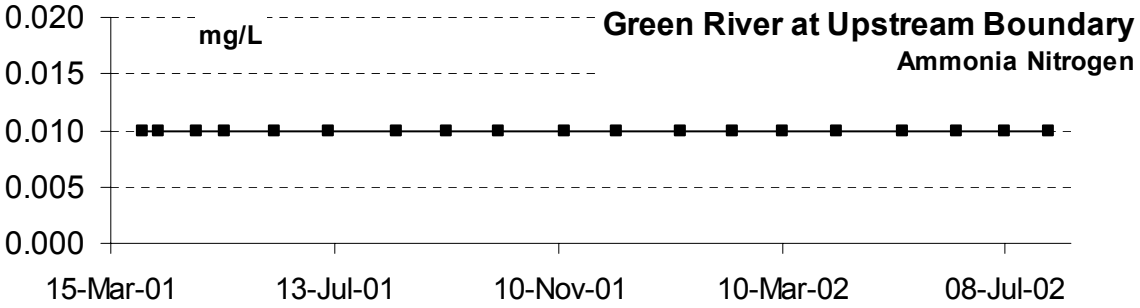

Figure 36: Ammonia at Upstream Boundary: Apr 2001 – July 2002

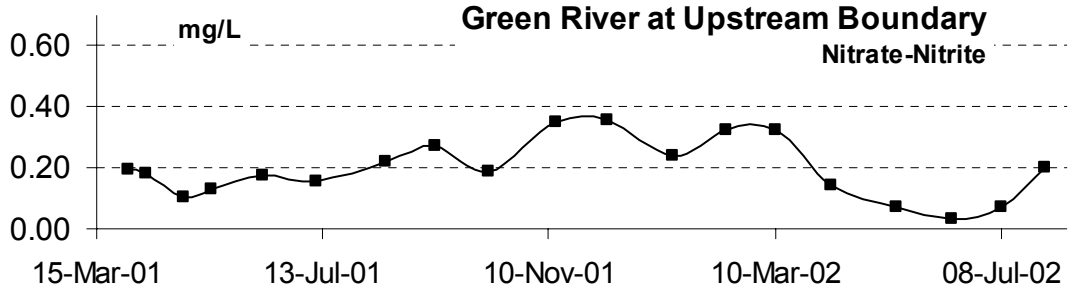

Figure 37: Nitrate-Nitrite at Upstream Boundary: Apr 2001 – July 2002

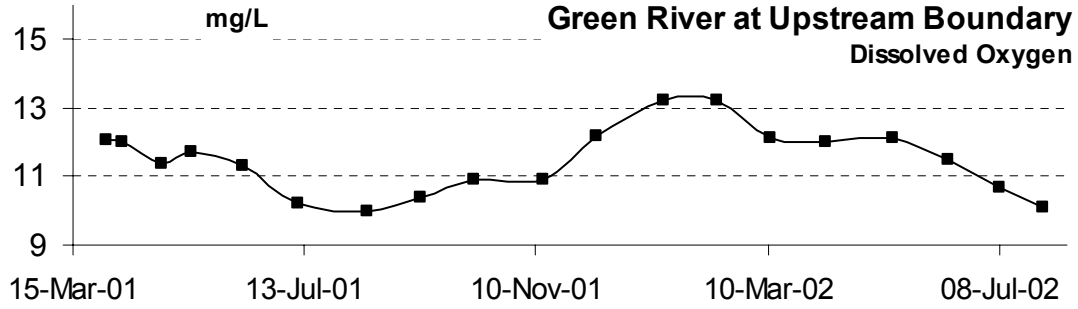

Figure 38: DO at Upstream Boundary: Apr 2001 – July 2002

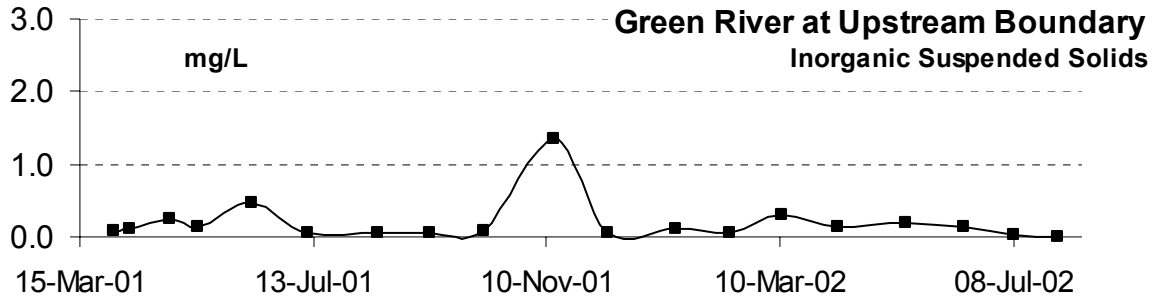

Figure 39: ISS at Upstream Boundary: Apr 2001 – July 2002

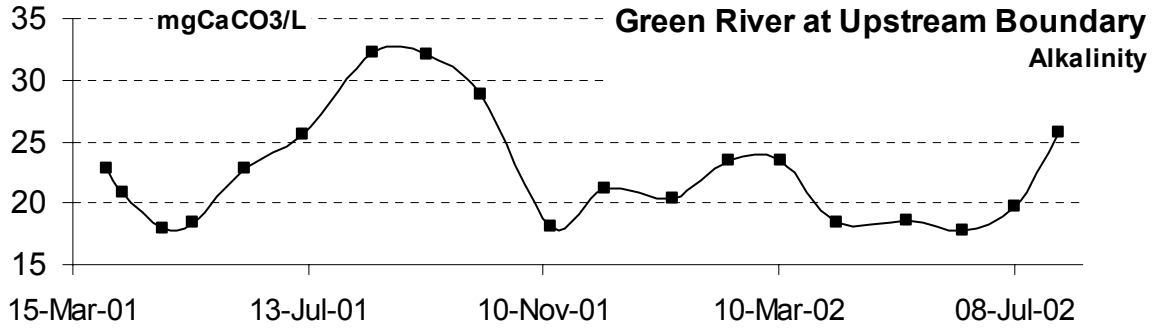

Figure 40: Alkalinity at Upstream Boundary: Apr 2001 – July 2002

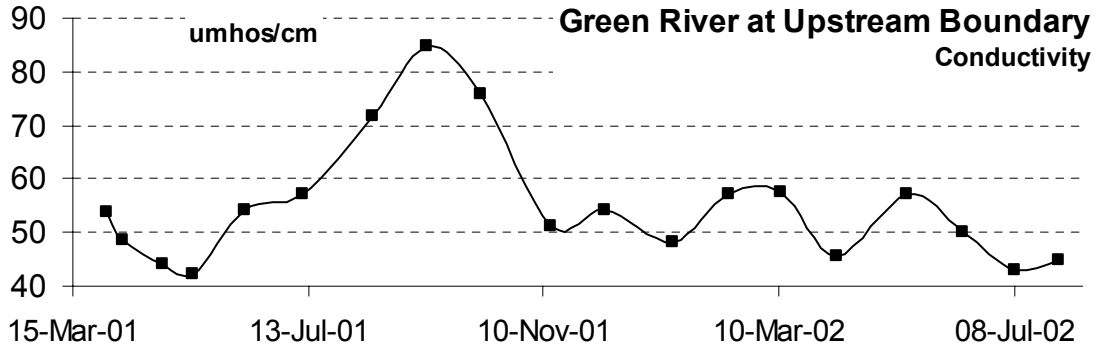

Figure 41: Conductivity at Upstream Boundary: Apr 2001 - July 2002

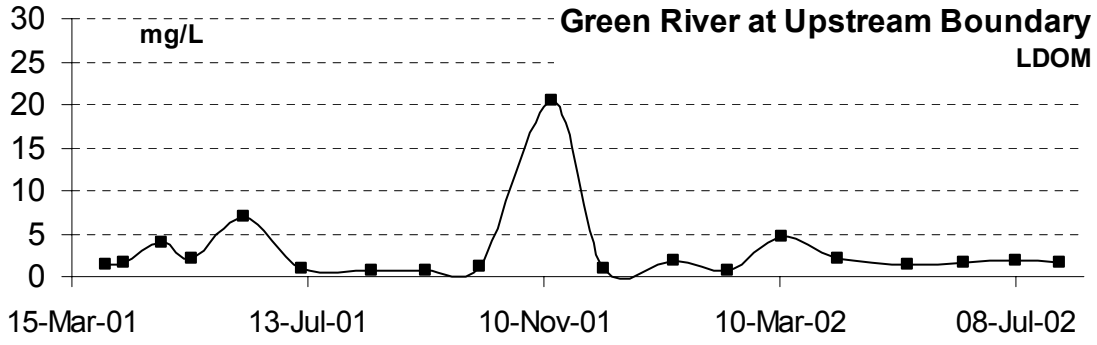

Figure 42: LDOM at Upstream Boundary: Apr 2001 - July 2002

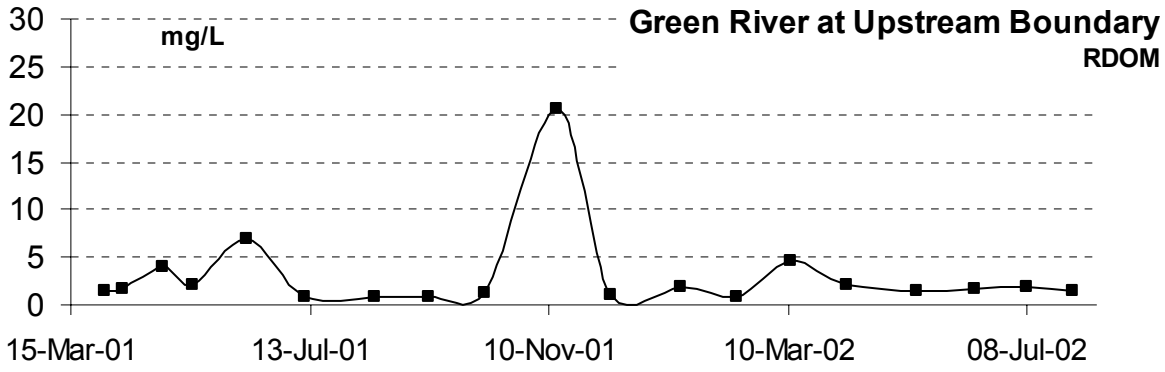

Figure 43: RDOM at Upstream Boundary: Apr 2001 – July 2002

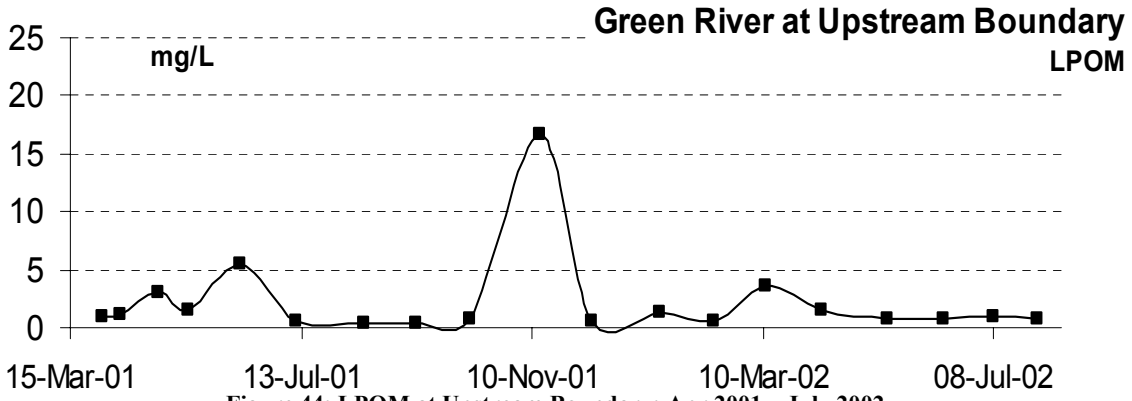

Figure 44: LPOM at Upstream Boundary: Apr 2001 – July 2002

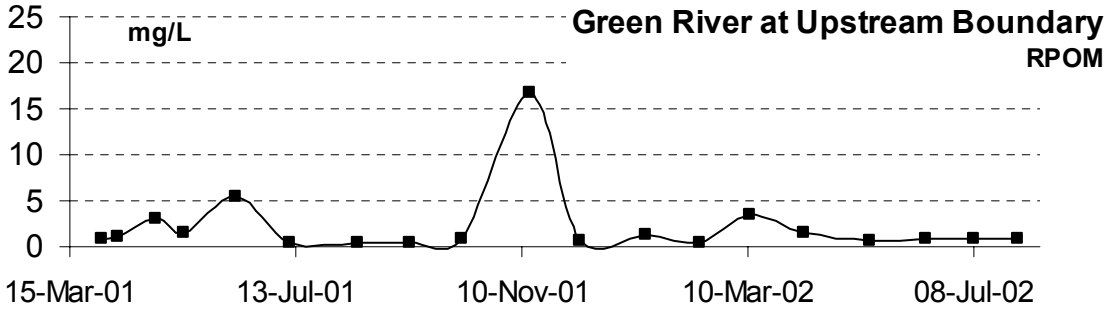

Figure 45: RPOM at Upstream Boundary: Apr 2001 - July 2002

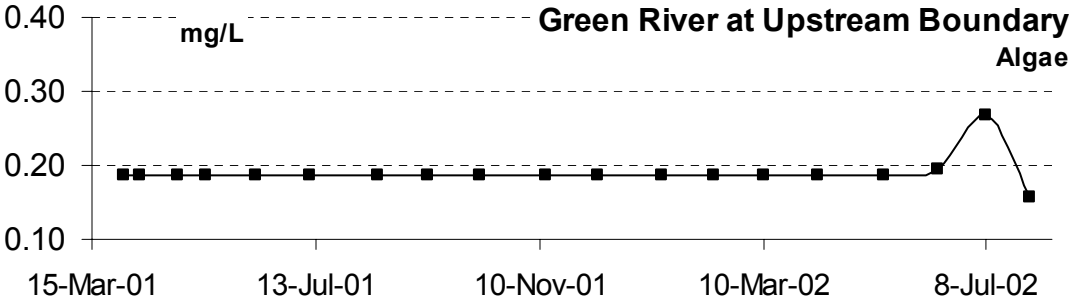

Figure 46: Algae at Upstream Boundary: Apr 2001 – July 2002

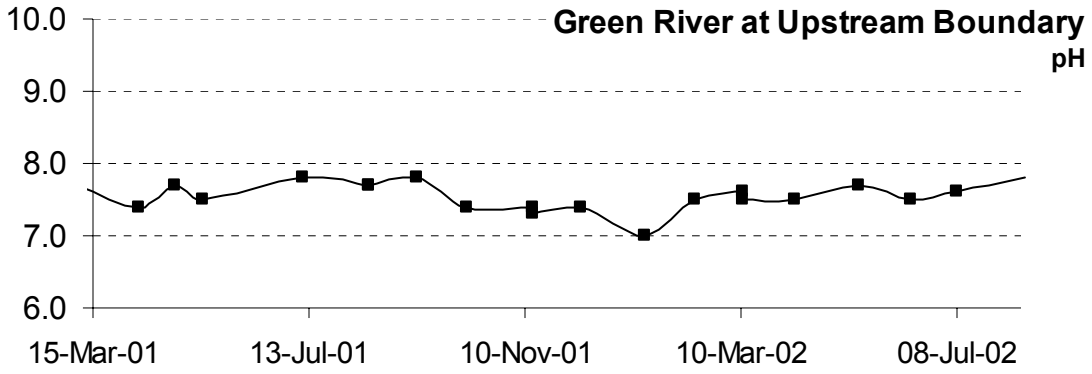

Figure 47: pH at Upstream Boundary: Apr 2001 - July 2002

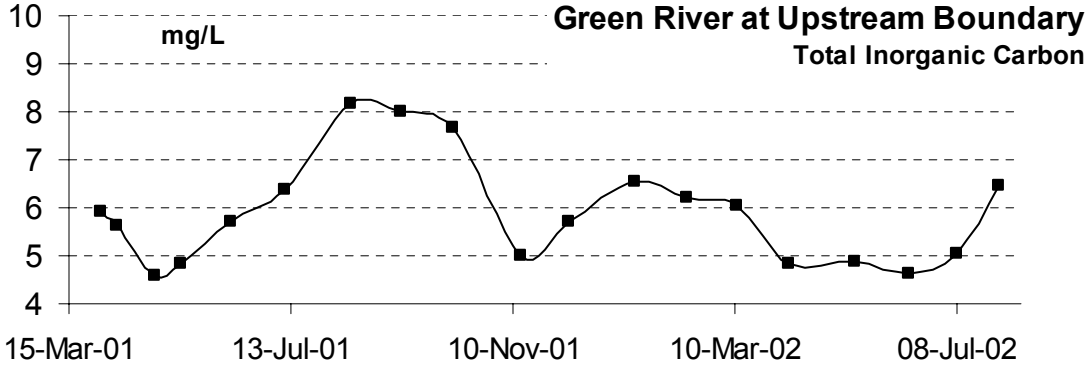

Figure 48: TIC at Upstream Boundary: Apr 2001 – July 2002

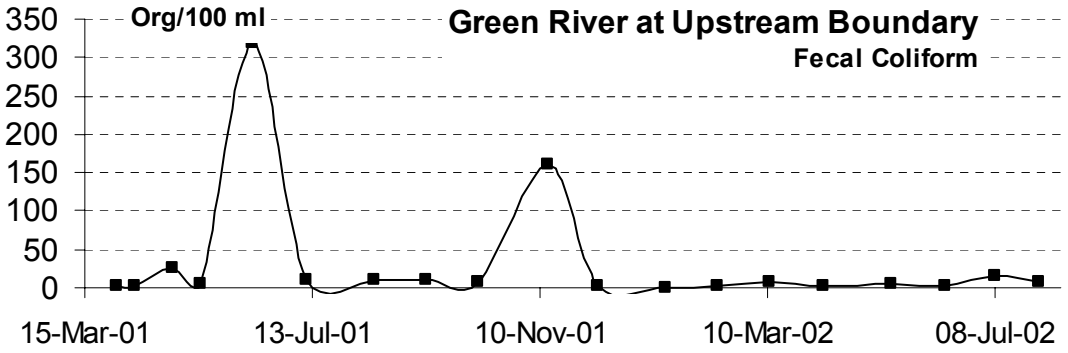

Figure 49: Fecal Coliform at Upstream Boundary: Apr 2001 - July 2002

2.4.2 Downstream Boundary

The downstream boundary is at Fort Dent, in Tukwila at River Mile 11.2, where the Green River enters the Duwamish River. The boundary condition is characterized by water surface elevation, temperature, and water quality. This section of the river is tidally influenced, and flow data were recorded at this location until 1987. A review of this data indicates that the tide does not reverse flow in the river, but may influence flow velocities. A graph of flow from 1960 to 1987 is included in Appendix A.

May 25, 1995 – November 1996

Stage

Hourly stage data were obtained from the USGS gage (12113350) at Fort Dent and used for the external downstream boundary condition. This gage has bad or missing data from May 24, 1995 to May 8, 1996. A good correlation with data from another source has not been found. Stage data from May 24, 1997 to May 8 1998 was used in the model. Figure 50 shows the stage data for the model calibration period.

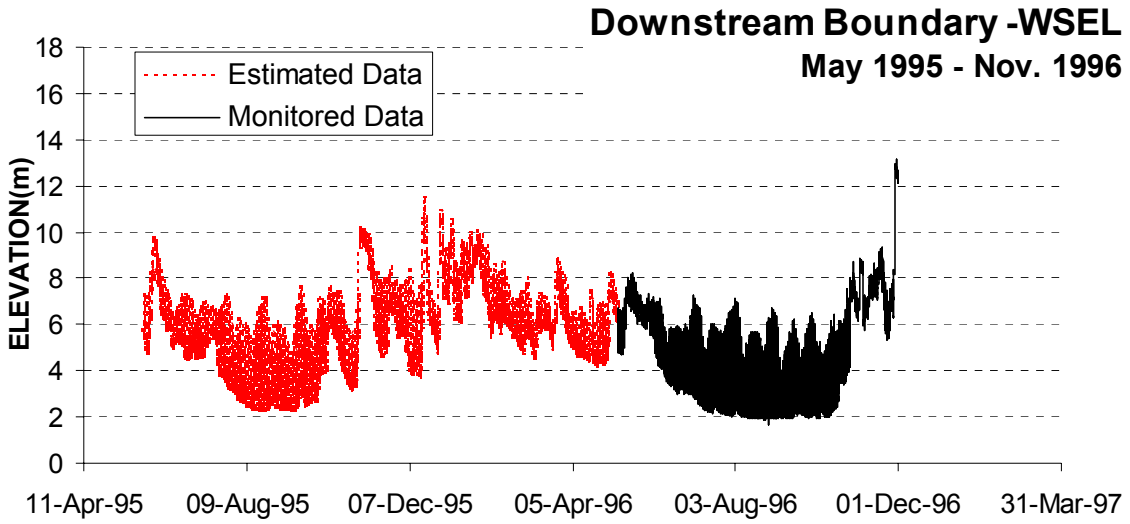

Figure 50: Stage at downstream boundary, May 25, 1995 - Nov 1996

Temperature

King County conducted a temperature study in 1995-1996 which monitored temperature approximately 2.0 km upstream of the downstream boundary location at Station BIC. There is missing data from April 30, 1996 to June 7, 1996. Data from a temperature station on Big Soos Creek (Station 54a) were correlated with data from Station BIC to fill this gap. The equation is:

$$BIC = 1.3147(\text{Big Soos Temp}) - 0.9051$$

Figure 51 shows the temperature correlation for the two stations, Figure 52 shows correlated values and monitored data for the correlation period, and Figure 53 shows the completed temperature record for the model calibration period with correlated values included.

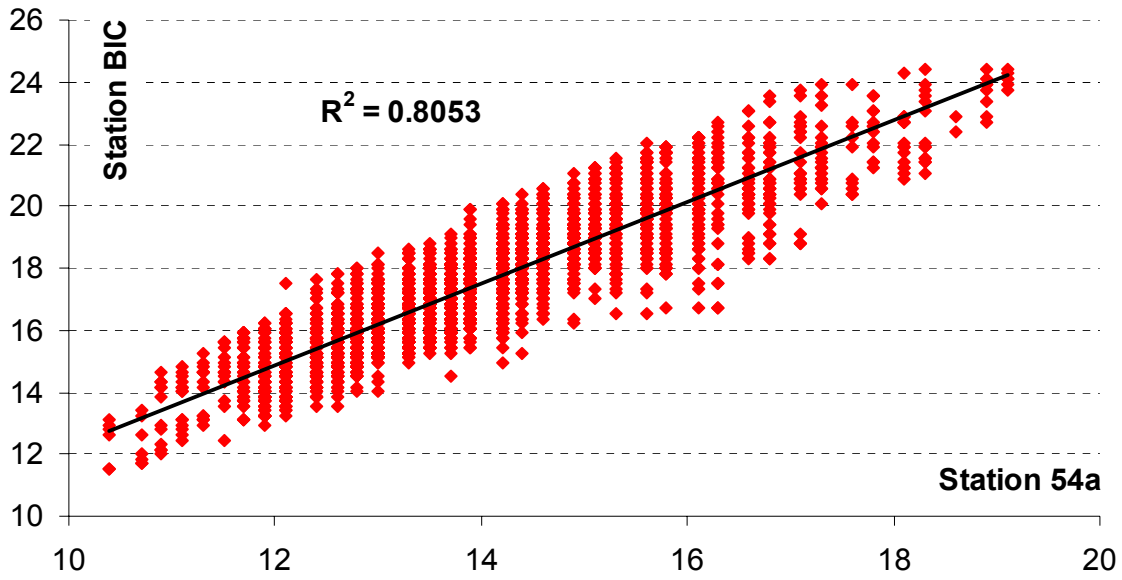

Figure 51: Correlation between Big Soos Temperature and D/S boundary station

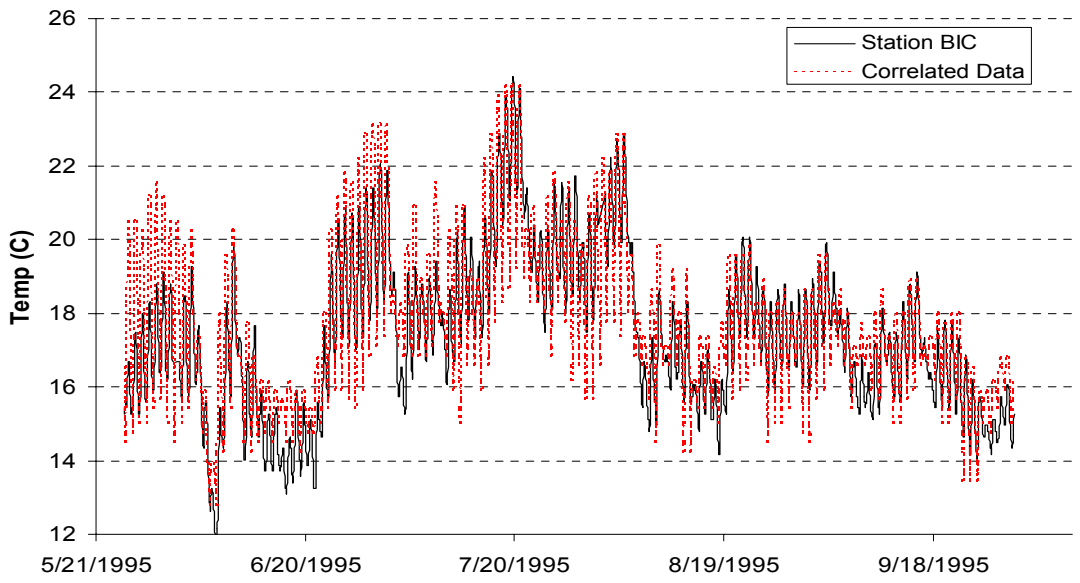

Figure 52: Downstream Boundary: Station versus correlated data, 1995-1996

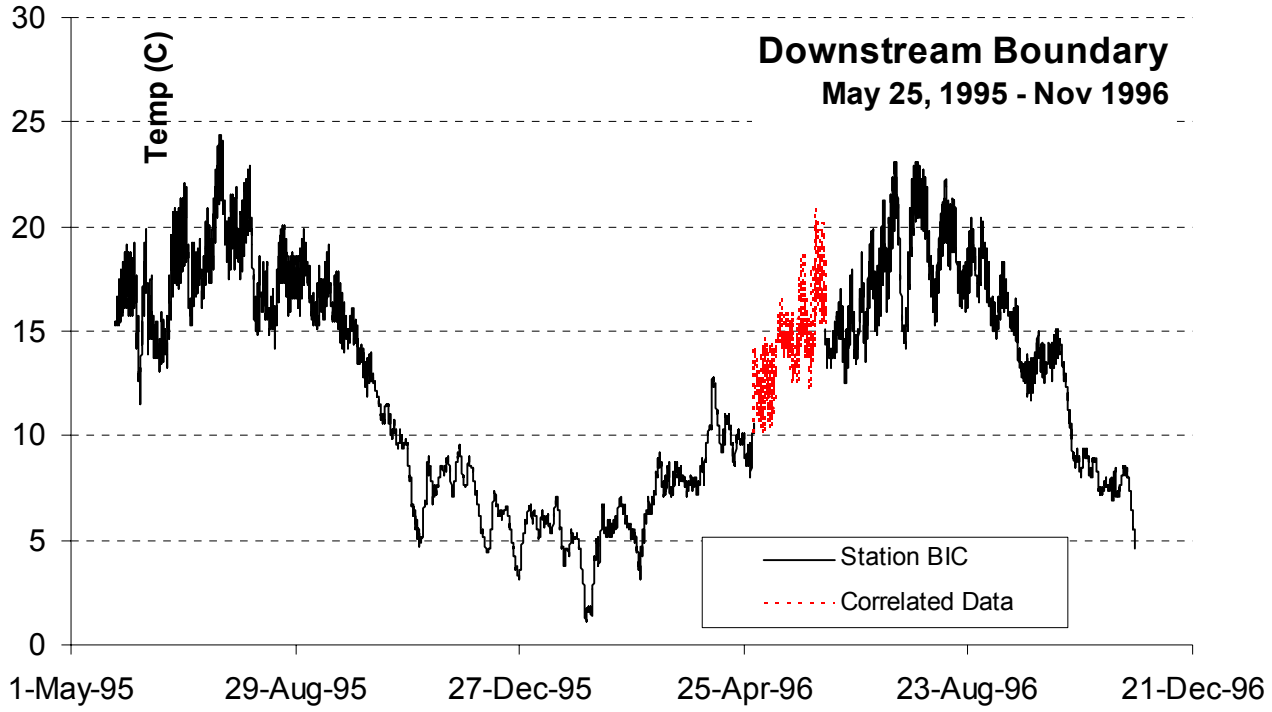

Figure 53: Green River Temperature at Downstream Boundary: May 25, 1995 – Nov 1996

Water Quality

King County collects water quality at Monitoring Station 3106 which is located at the downstream boundary. Data are available for all constituents except chlorophyll a and alkalinity for the model calibration period. Figure 54 through Figure 68 shows the constituent data for the model calibration period. See Appendix D for procedures used in developing the downstream water quality boundary condition, including filling data gaps.

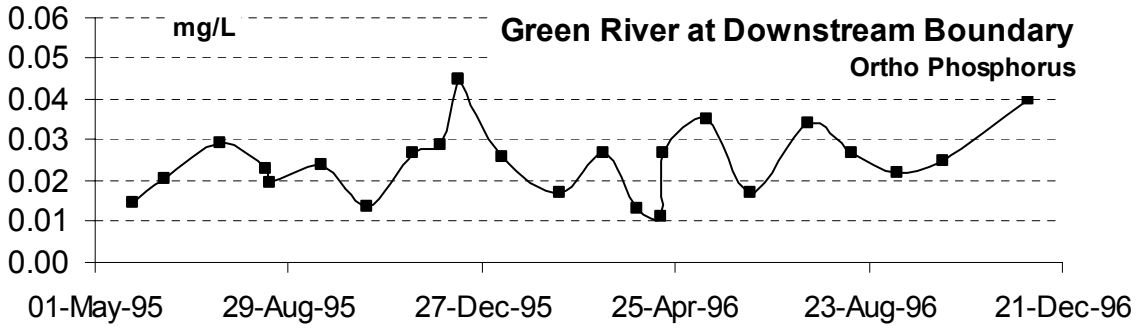

Figure 54: Ortho phosphorus at Downstream Boundary: May 1995 to November 1996

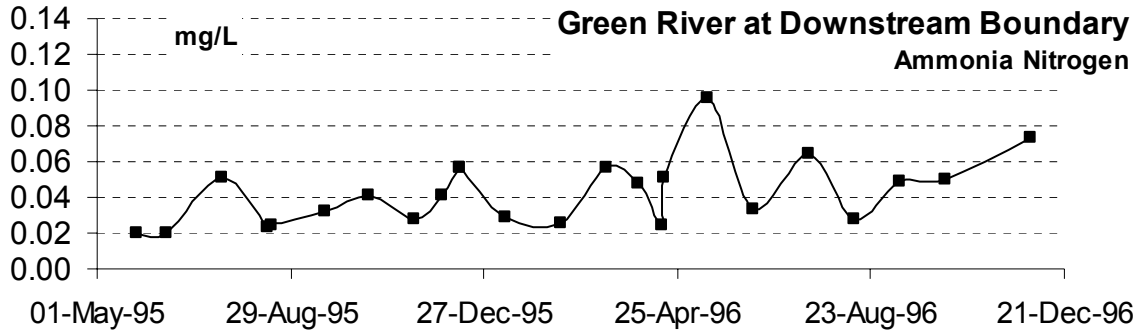

Figure 55: Ammonia at Downstream Boundary: May 1995 to November 1996

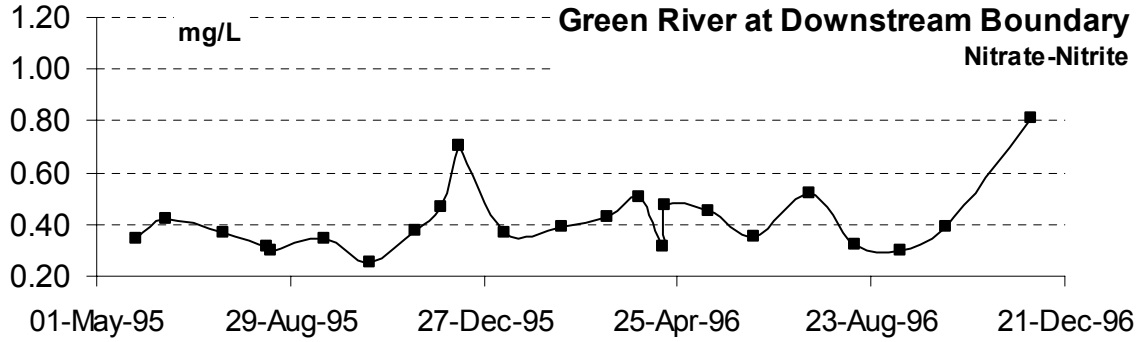

Figure 56: Nitrate-Nitrite at Downstream Boundary: May 1995 to November 1996

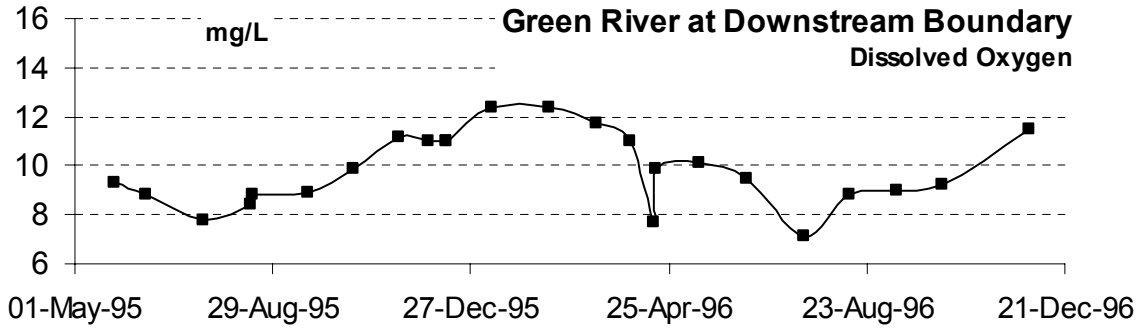

Figure 57: DO at Downstream Boundary: May 1995 to November 1996

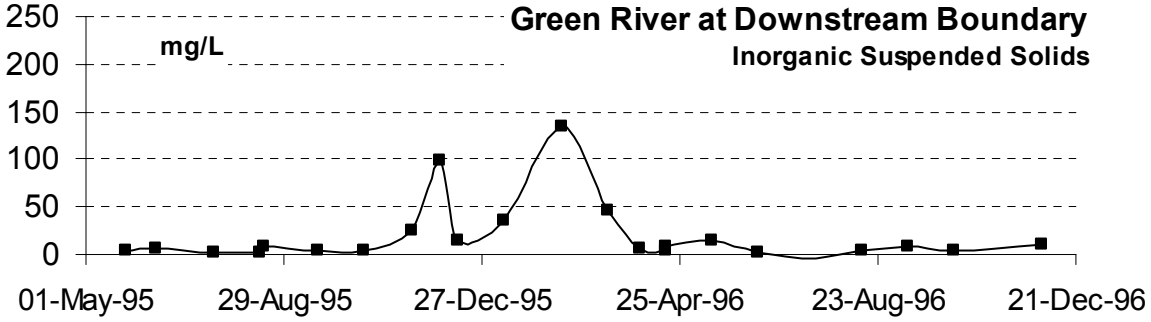

Figure 58: ISS at Downstream Boundary: May 1995 to November 1996

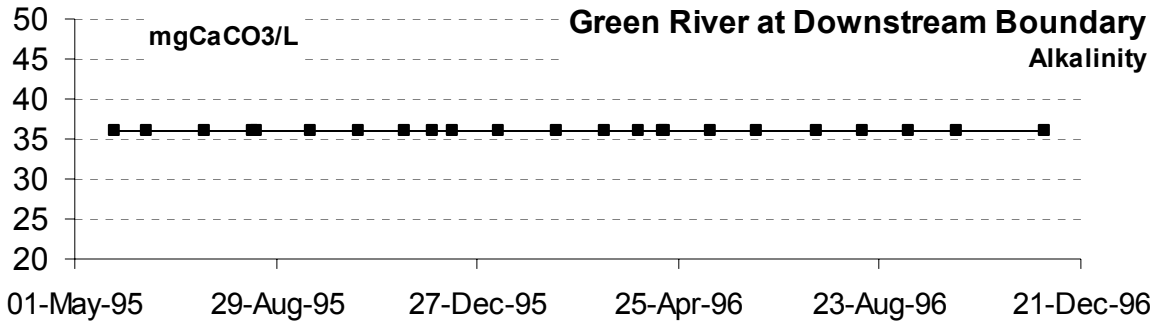

Figure 59: Alkalinity at Downstream Boundary: May 1995 to November 1996

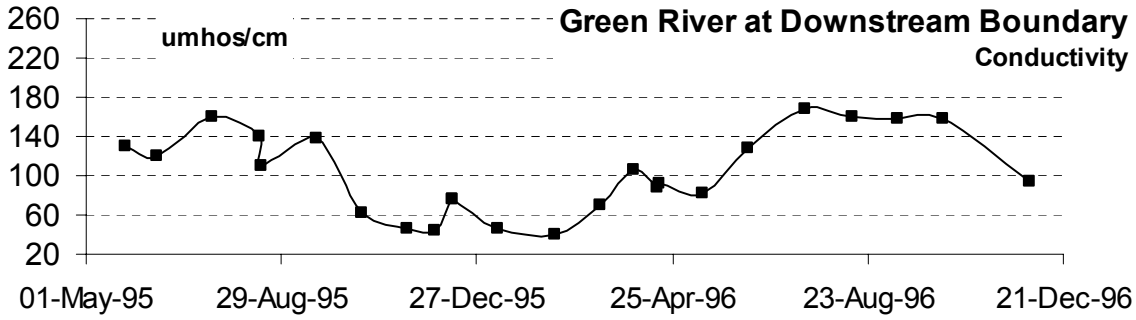

Figure 60: Conductivity at Downstream Boundary: May 1995 to November 1996

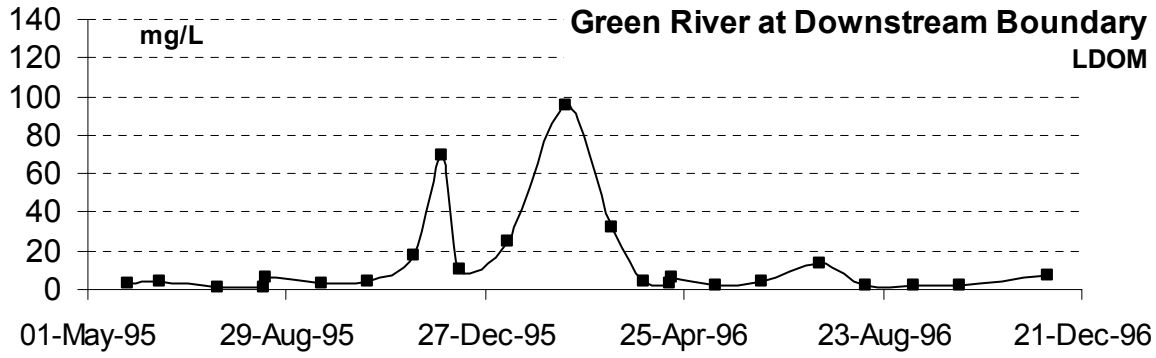

Figure 61: LDOM at Downstream Boundary: May 1995 to November 1996

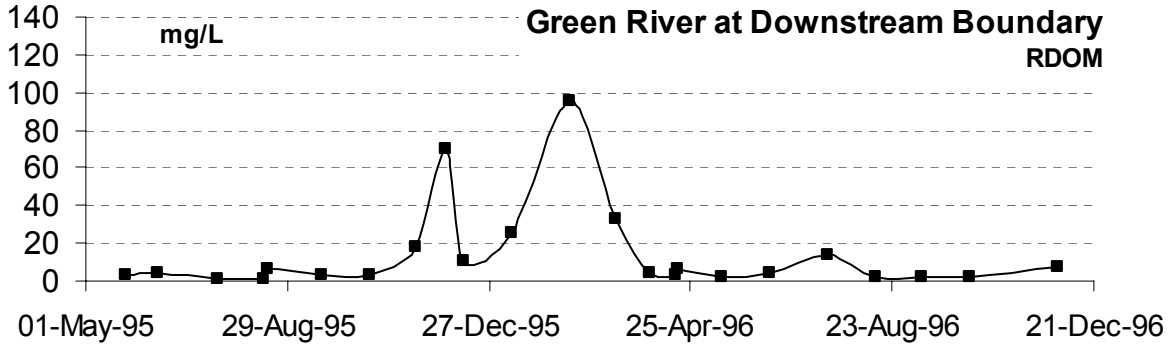

Figure 62: RDOM at Downstream Boundary: May 1995 to November 1996

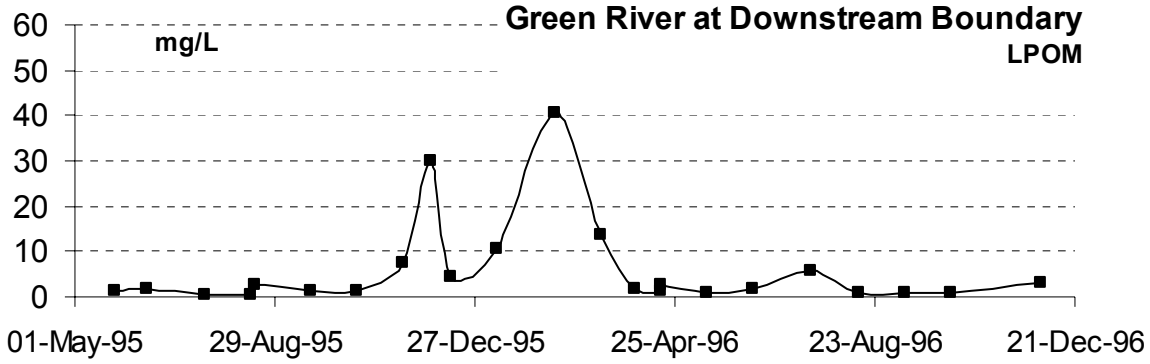

Figure 63: LPOM at Downstream Boundary: May 1995 to November 1996

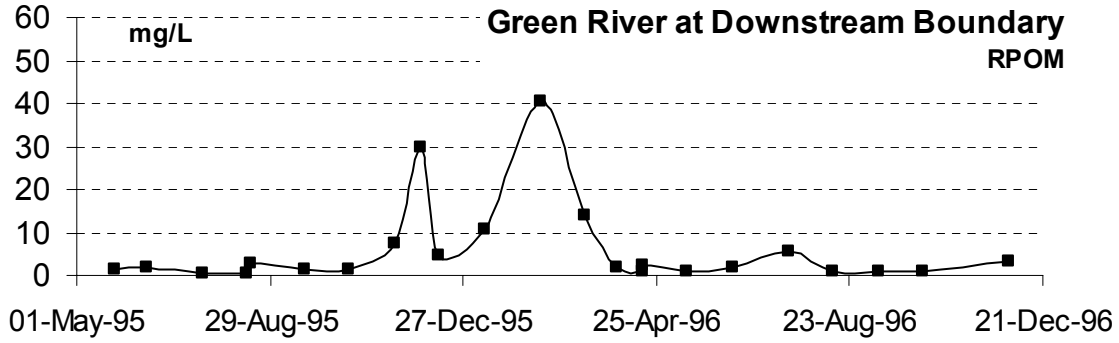

Figure 64: RPOM at Downstream Boundary: May 1995 to November 1996

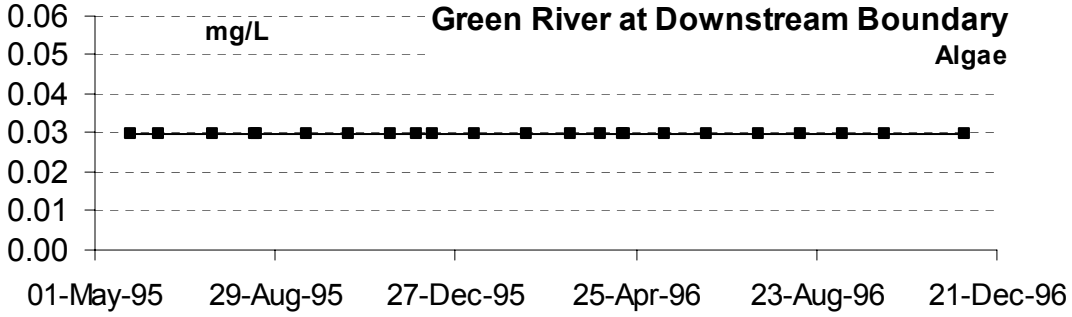

Figure 65: Algae at Downstream Boundary: May 1995 to November 1996

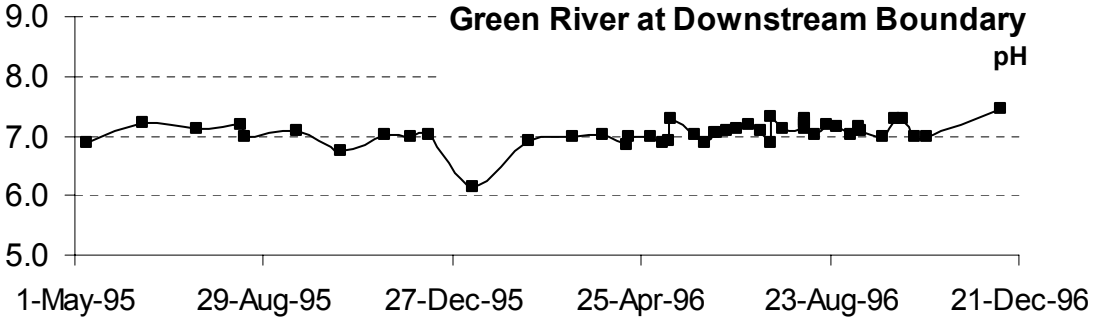

Figure 66: pH at Downstream Boundary: May 1995 - November 1996

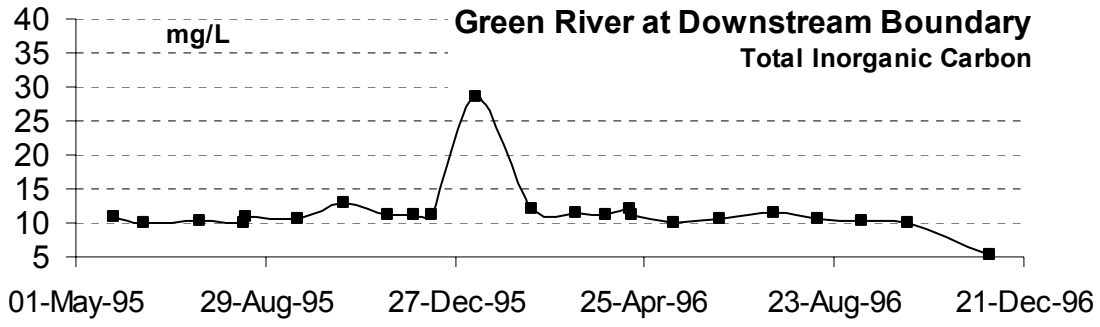

Figure 67: TIC at Downstream Boundary: May 1995 to November 1996

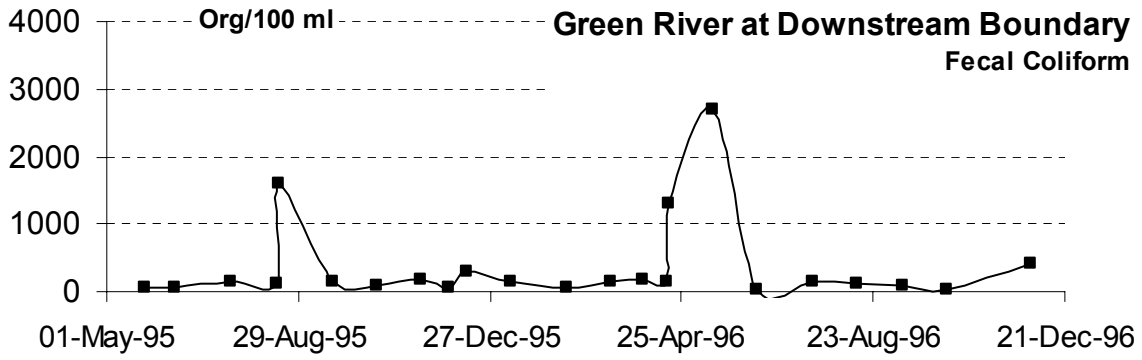

Figure 68: Fecal Coliform at Downstream Boundary: May 1995 to November 1996

April 2001 – July 2002

Stage

Downstream stage data from USGS Gage 13113500 was available from April 2001 to June 18, 2002. To complete the data set through the end of July 2002, an average of the data from 1996 to 2001 for the same time period were used. The gage at Fort Dent was also missing data for two days in February 2002. Data from other years for the same two day time period were used to fill in the missing time period. Figure 69 shows the stage data for the model period. A graph of stage data from this gage from 1995 through June 18, 2002 is included in Appendix A.

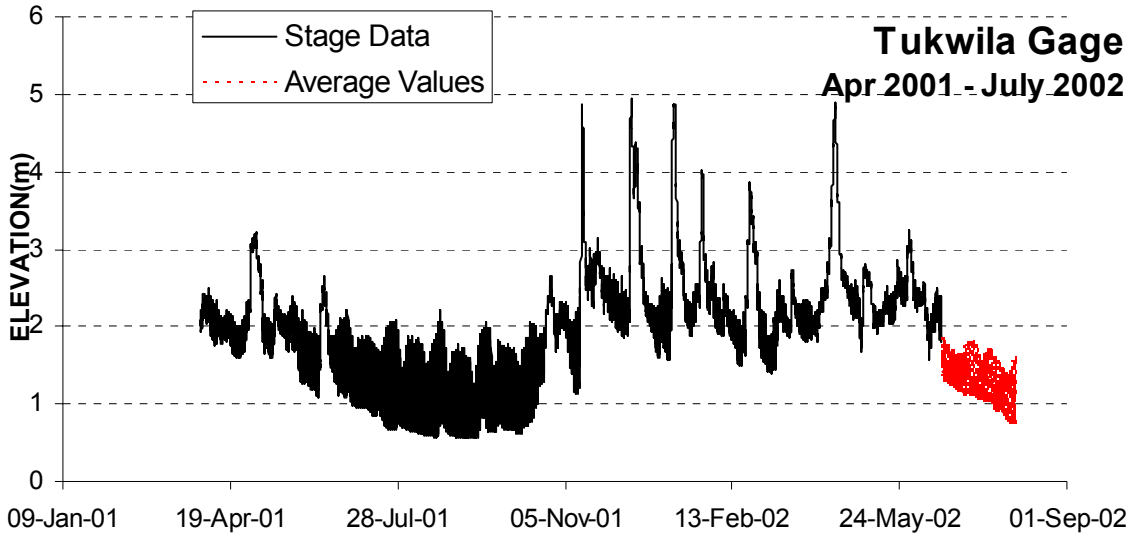

Figure 69: Green River Stage at Downstream Boundary: Apr 2001 – July 2002

Temperature

King County began monitoring water temperature at this location in July 2002, and data were provided through September 2002 (Station GRT18). To develop temperatures for April 2001 to July 2002, a correlation was developed with temperature data monitored by the University of Washington approximately 20 km upstream (Station GR1). The correlation period was between July 9, 2002 and September 12, 2002. The equation used to fill the data is as follows:

$$\text{D/S Bdy. Temp} = 0.8632(\text{GR1}) + 3.5519$$

Figure 70 shows the temperature correlation for the two stations, Figure 71 shows a graph of data from GRT18 and correlated values, and Figure 72 shows the data used for the model calibration period.

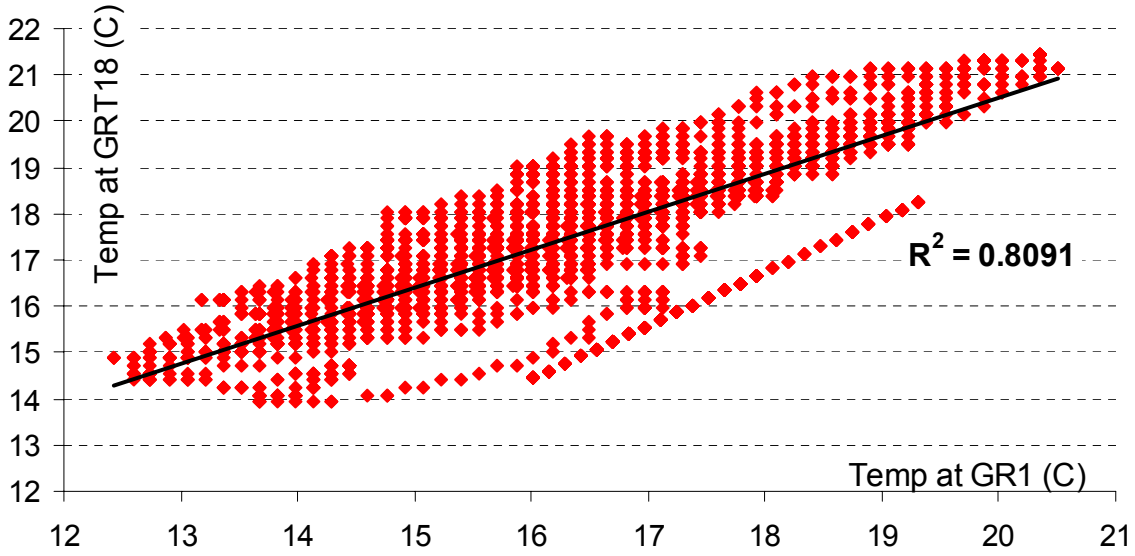

Figure 70: Correlation between Station GR1 and D/S boundary station GRT18

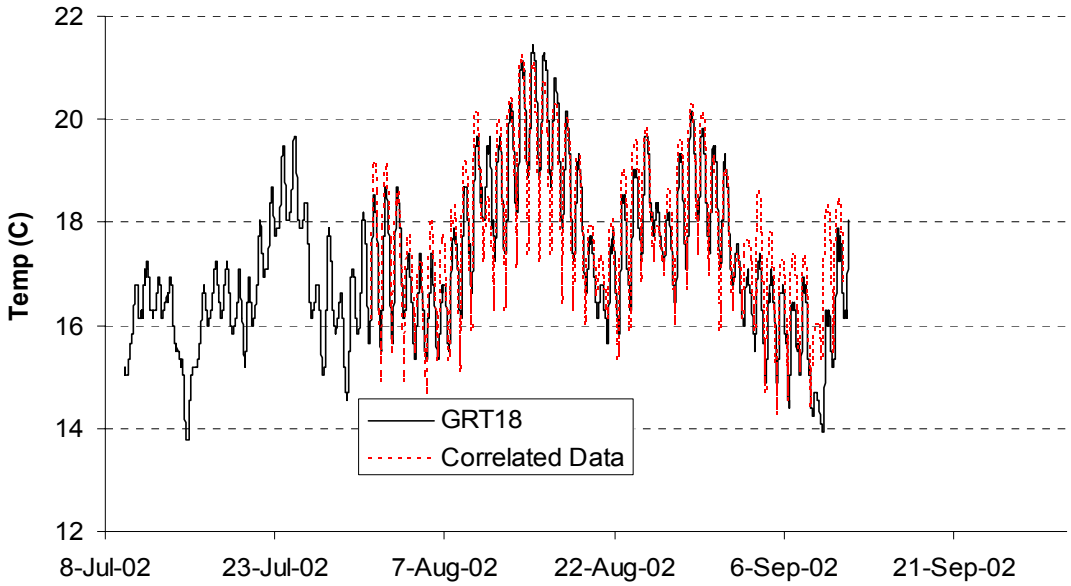

Figure 71: Downstream Boundary: Station versus correlated data, 2001-2002

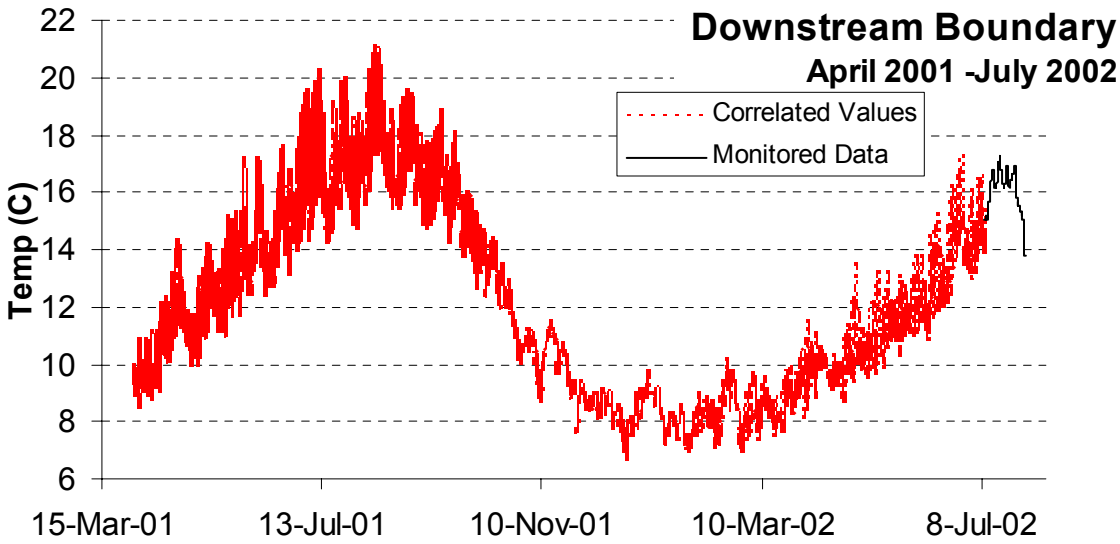

Figure 72: Green River Temperature at Downstream Boundary: Apr 2001 – July 2002

Water Quality

Water quality was monitored at the downstream boundary (Site 3106) for all constituents, but with only minimal data available for chlorophyll a. These data are shown in Figure 73 through Figure 87. See Appendix D for procedures used in developing the water quality boundary condition.

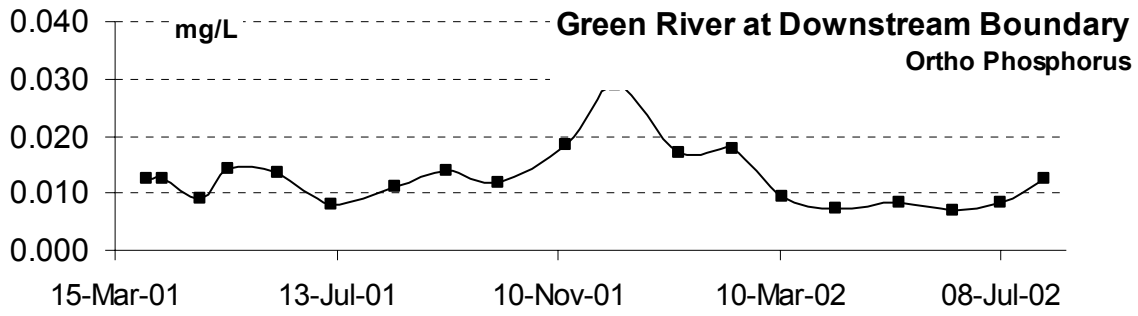

Figure 73: Ortho phosphorus at Downstream Boundary: Apr 2001 – July 2002

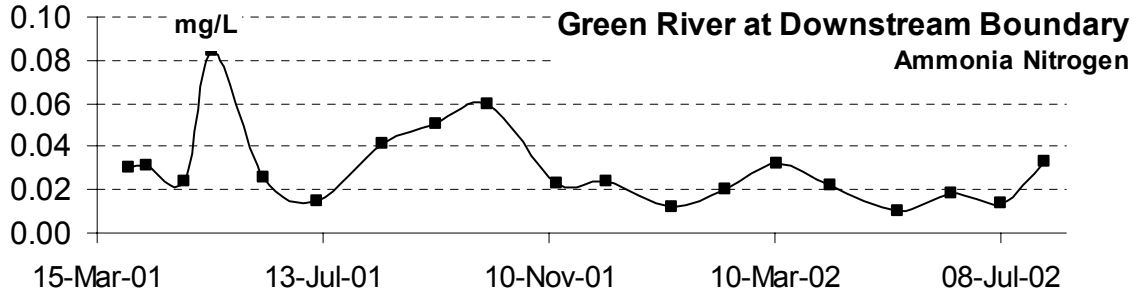

Figure 74: Ammonia at Downstream Boundary: Apr 2001 – July 2002

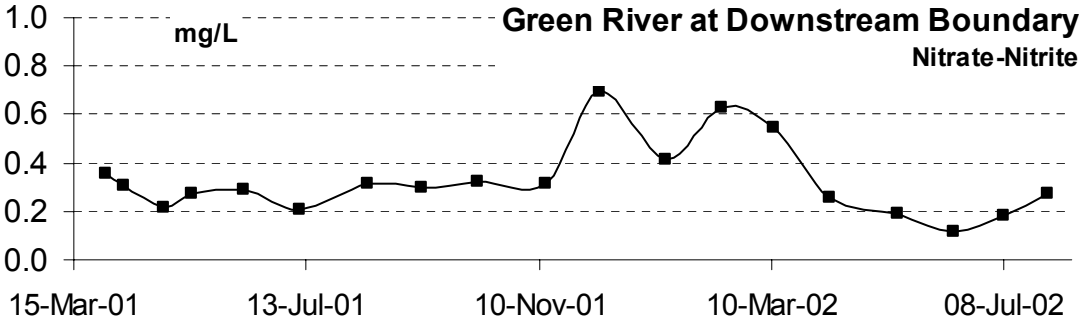

Figure 75: Nitrate-Nitrite at Downstream Boundary: Apr 2001 – July 2002

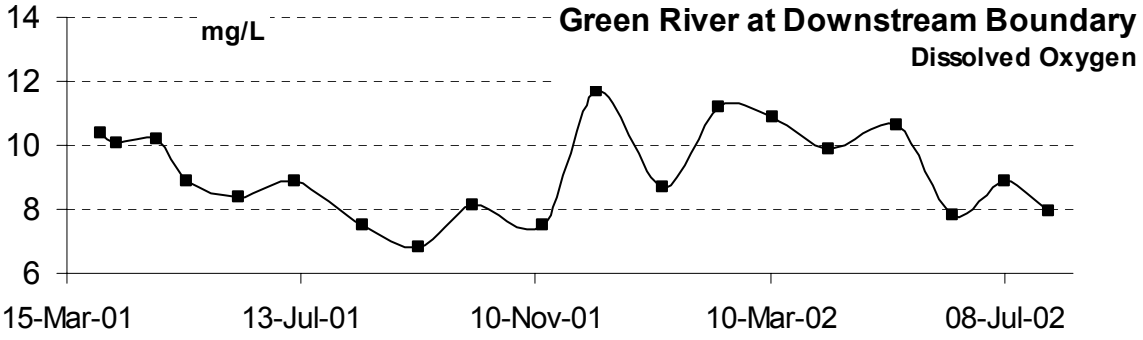

Figure 76: DO at Downstream Boundary: Apr 2001 – July 2002

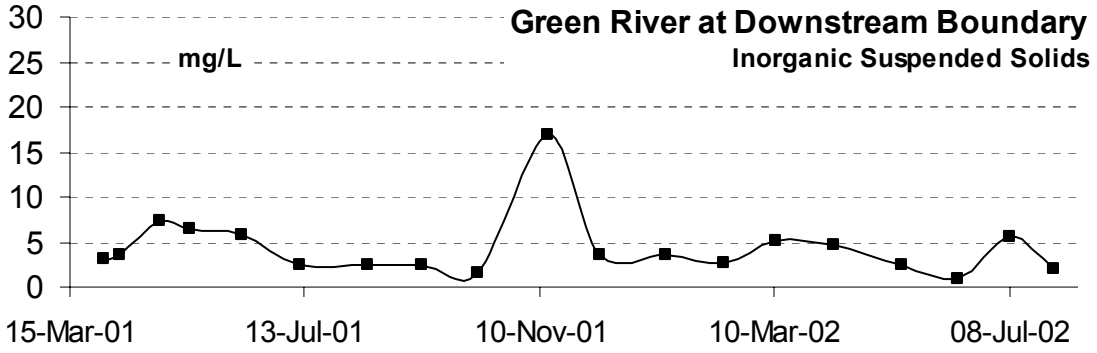

Figure 77: ISS at Downstream Boundary: Apr 2001 – July 2002

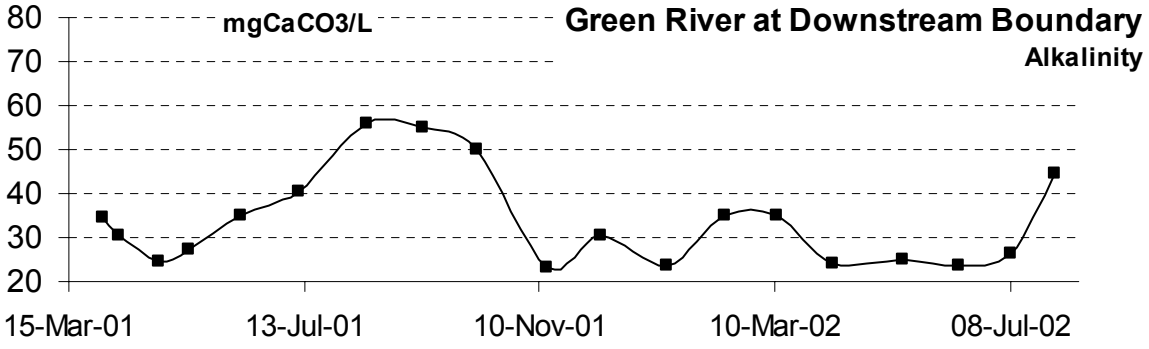

Figure 78: Alkalinity at Downstream Boundary: Apr 2001 – July 2002

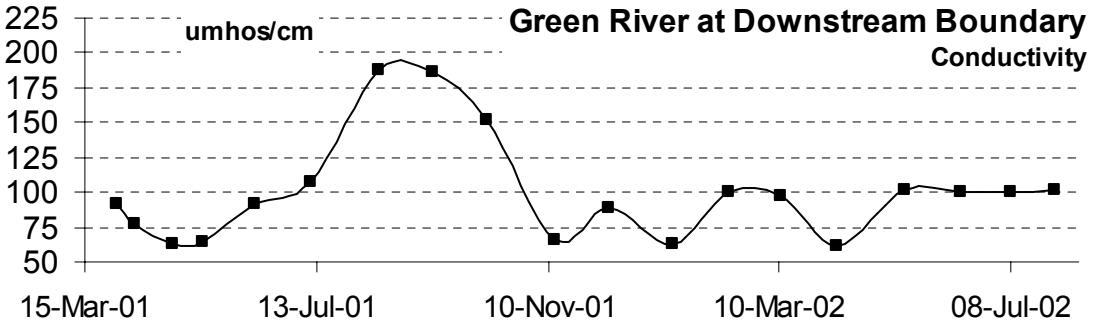

Figure 79: Conductivity at Downstream Boundary: Apr 2001 – July 2002

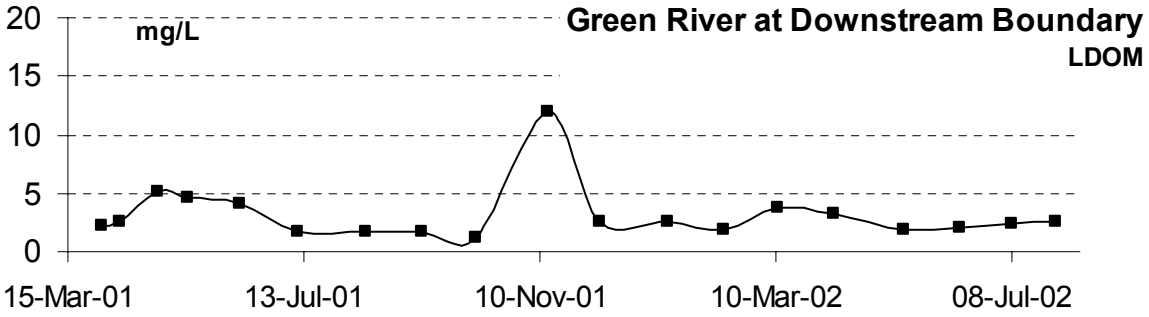

Figure 80: LDOM at Downstream Boundary: Apr 2001 – July 2002

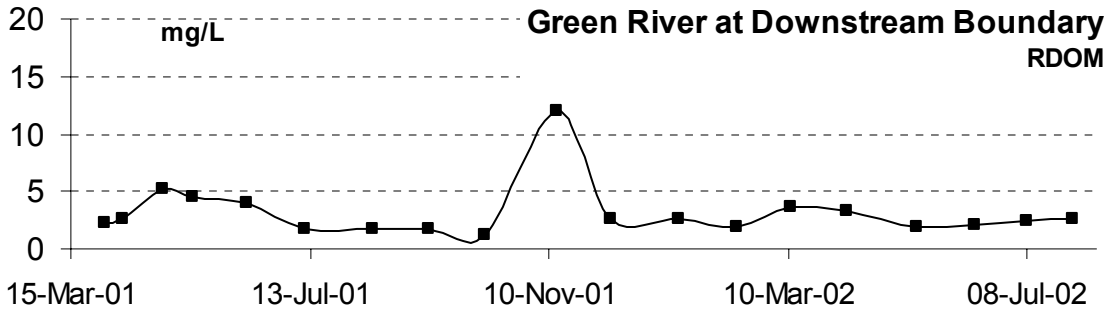

Figure 81: RDOM at Downstream Boundary: Apr 2001 – July 2002

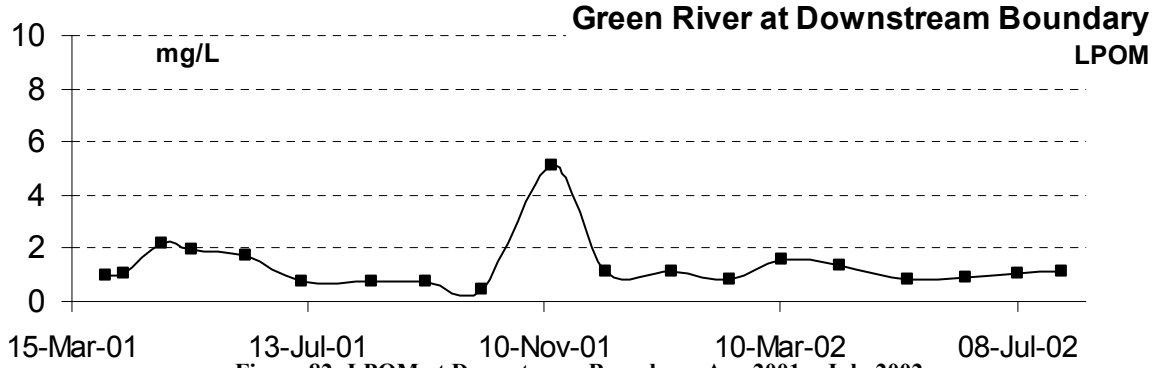

Figure 82: LPOM at Downstream Boundary: Apr 2001 – July 2002

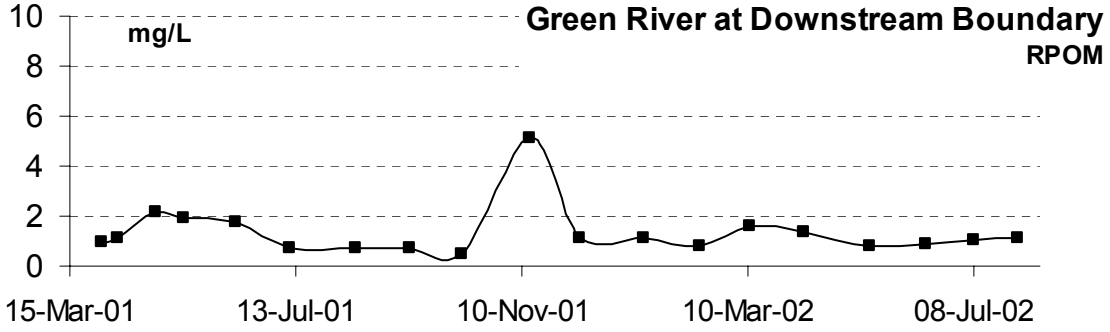

Figure 83: RPOM at Downstream Boundary: Apr 2001 – July 2002

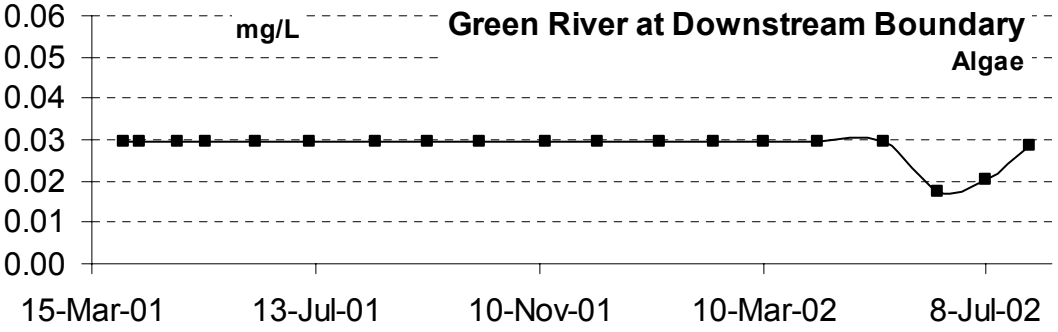

Figure 84: Algae at Downstream Boundary: Apr 2001 – July 2002

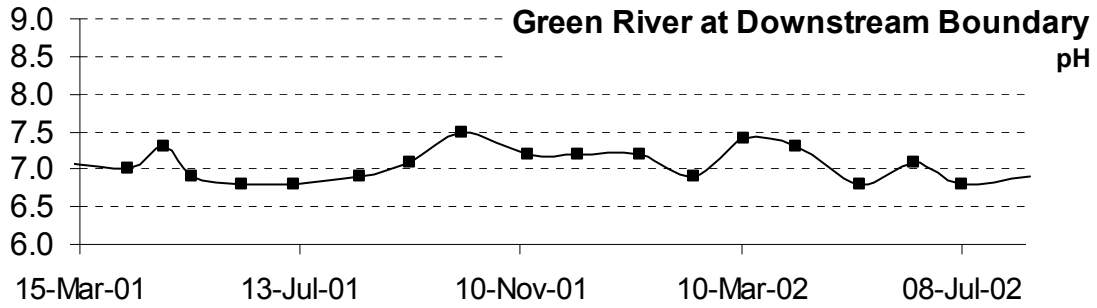

Figure 85: pH at Downstream Boundary: Apr 2001 - July 2002

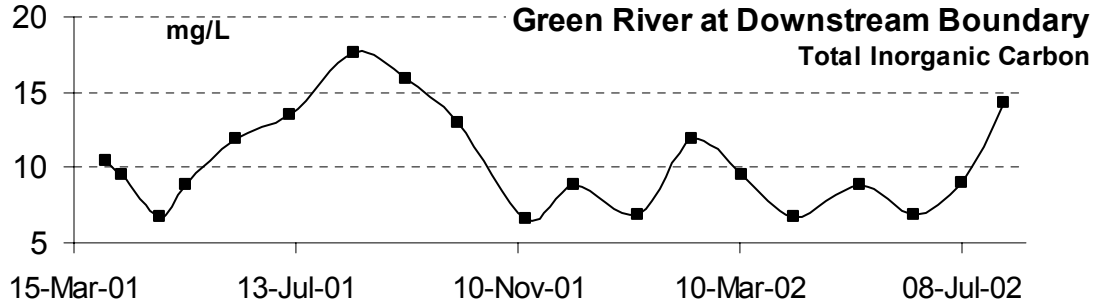

Figure 86: TIC at Downstream Boundary: Apr 2001 – July 2002

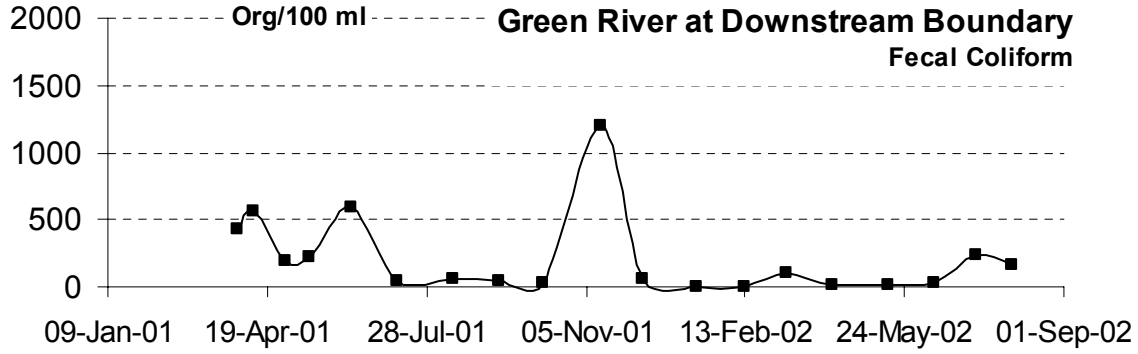

Figure 87: Fecal Coliform at Downstream Boundary: Apr 2001 - July 2002

2.5 Tributaries

There are seven tributaries to be included in this model: Newaukum Creek, Crisp Creek, Big Soos Creek, Auburn Creek, Mill Creek, Mullen Slough, and Midway Creek.

Figure 88 shows the location of these tributaries in the Green River basin, and Table 7 lists the river mile and model segment number for each tributary.

Each tributary was characterized by flow, temperature, and water quality. The larger tributaries (Big Soos, Newaukum, Crisp, Mill) have some gaged or sampled data available. The three smaller tributaries (Midway, Mullen Slough, Auburn) have no gaged or sampled data available.