# Lower Willamette River Model: Boundary Conditions and Model Setup


by

Hernan G. Rodriguez, M.S.

Robert L. Annear Jr., M.S.,

Scott A. Wells, Ph.D., P.E.

and

Chris Berger, Ph.D.



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School of Engineering & Applied Science
Department of Civil Engineering
Portland State University
Portland, Oregon 97207-0751



Prepared for Water Environment Services, Inc. on behalf of Richwine Environmental Inc.
Project Managers: Dale Richwine and Ted Kyle

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# Introduction

The Willamette River system is a 11,500 $mi^2$ watershed and drains through the Lower Willamette River from RM 0 to RM 35 (Canby Ferry), Figure 1. The river passes through the Portland metropolitan area before its confluence with the Columbia River at Columbia RM 106. The Columbia River is tidally influenced from the Pacific Ocean to the tailrace of the Bonneville Dam at RM 145. The Lower Willamette River is also tidally influenced from RM 0 (confluence with the Columbia) to the Oregon City Falls at RM 26.8

Water Environment Services of Clackamas County is in the process of planning upgrades on several of its sewage treatment plants which discharge into the Lower Willamette River. The goals of the modeling effort are to:

- Gather data to construct a computer simulation model of the Lower Willamette River system including part of the Lower Columbia River and the Willamette River above the Oregon City Falls; Because of the tidal influence in the Lower Willamette River, portions of the Columbia River that might affect the Lower Willamette River water quality were also modeled. Also, a section of the Willamette River above the head of tide, the Oregon City Falls, was modeled because of the lack of good boundary condition data at the Falls.
- Ensure that the model accurately represents the system physics and chemistry (flow, temperature, dissolved oxygen and nutrient dynamics);
- Use the model to evaluate how to meet various future discharge scenarios for the sewage district.

A hydrodynamic and water quality model, CE-QUAL-W2 Version 3 (Wells, 1997), is being applied to model the Willamette-Columbia system. CE-QUAL-W2 is a two dimensional (longitudinal-vertical), laterally averaged, hydrodynamic and water quality model that has been under development by the Corps of Engineers Waterways Experiments Station (Cole and Wells, 2000).

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

- Willamette and Columbia River flow, water level and water quality data
- Tributary inflows and water quality
- Meteorological conditions
- Bathymetry of the Columbia and Willamette Rivers and several side channels
- Point source inflows and water quality characteristics

Many local, state and federal agencies have been collecting data in the Lower Willamette and Columbia Rivers. This report summarizes data used in the modeling effort.

Information provided in this report was organized in the following sections:

- Previous data gathering and modeling studies in the Lower Willamette River system
- Rationale for using CE-QUAL-W2 Version 3
- Columbia and Willamette River water quality data
- Columbia and Willamette River flow and water level data

- Meteorological data
- Model geometry for the Columbia and Willamette Rivers
- Point Source flow and water quality data
- Tributary inflow and water quality data

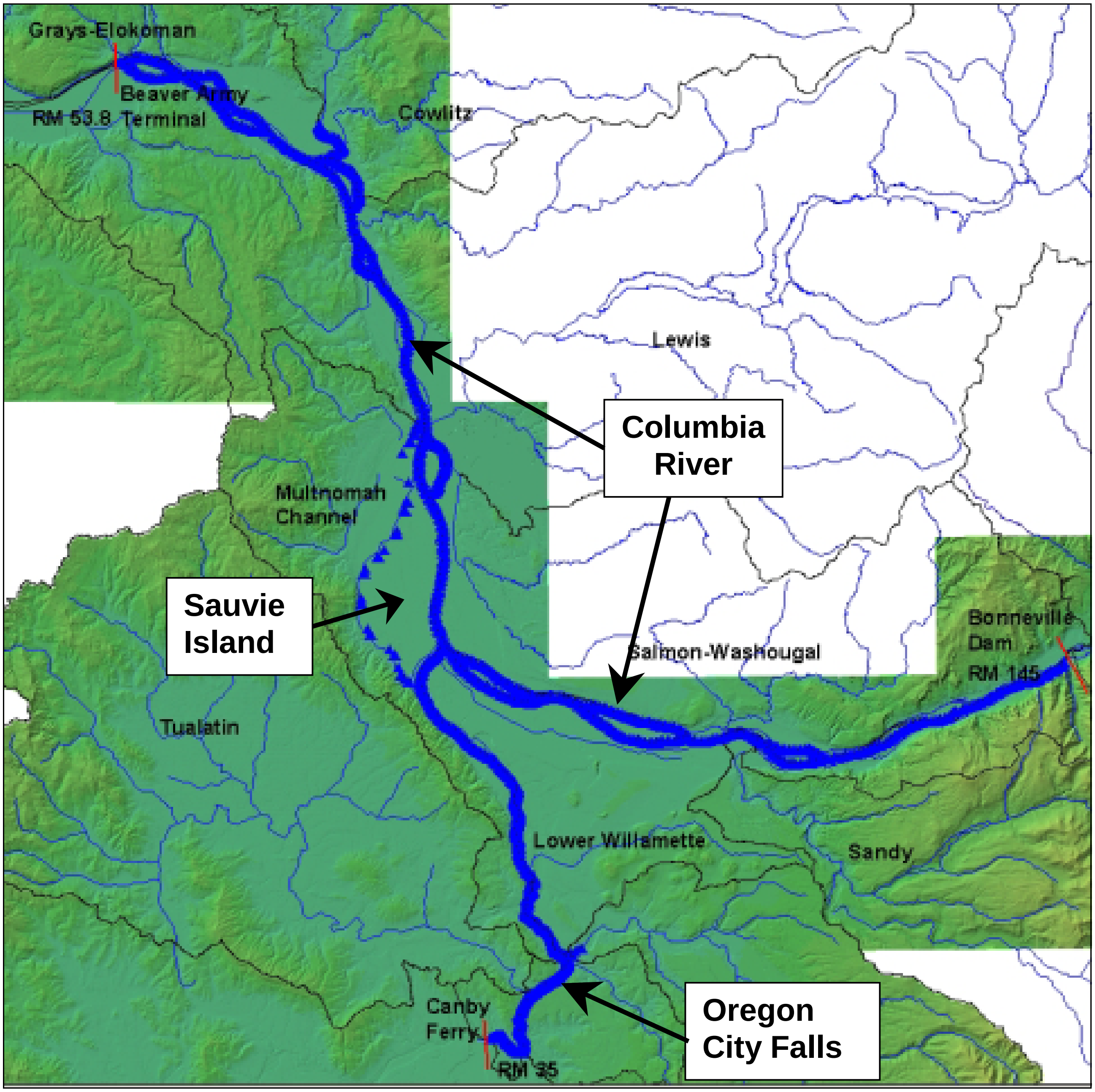



**Figure 1. Lower Willamette River Basin Region**

**Background Studies**

The Lower Willamette River has been studied extensively by several agencies. Some of the prior studies include:

- A water quality model of the Willamette River mainstem (RM 0 to 187) was developed by Tetra Tech, Inc. (Tetra Tech, Inc., 1995) using QUAL2EU for the Oregon Department of Environmental Quality. QUAL2EU (Brown and Barnwell, 1987) is a one-dimensional, steady state, hydraulic and water quality model.
- The Army Corps of Engineers (USACOE), Portland District, developed a flow routing model for the Willamette River and Columbia River using UNET (HEC, 1997). This model is being used to predict water levels and flow characteristics in the Columbia and Willamette system. The UNET model is a hydraulic, one-dimensional, unsteady flow model. The UNET cross-sectional data for both rivers were used in the current modeling effort with CE-QUAL-W2.
- An investigation of the Lower Willamette and the tidal influence on the combined sewer overflow (CSO) area was conducted by Limno-Tech, Inc. using DYNHYD for the City of Portland, Bureau of Environmental Services (Limno-Tech, Inc., 1997). DYNHYD (Ambrose et al. 1988) is a one-dimensional, unsteady hydraulic model with no water quality modeling capabilities. This study also investigated the magnitude of flows through Multnomah Channel. Unfortunately, in order to calibrate the flow model, the location of the Oregon City Falls was moved 75 miles upstream and the location of the Bonneville Dam was also moved 39 miles upstream. Moving the head of tide for both the Willamette and Columbia Rivers, even though they improved model-data agreement, was not appropriate and reflected more serious errors in the model set-up, probably in the DYNHYD model bathymetry.
- Montgomery Watson, Inc. conducted two water quality studies for the City of Tigard (Montgomery Watson, 1999) and the Tualatin Valley Water District (Montgomery Watson, 1997) to investigate the feasibility of using the Willamette River as a drinking water source. Data collected from these studies were valuable in establishing the upstream boundary condition for the Willamette River.
- A bathymetric review was conducted of the Willamette River upstream of the Oregon City Falls for Portland General Electric as part of their re-licensing effort for facilities at the falls. This review provided bathymetric data for developing the model grid above the Oregon City Falls.

Some of these studies provide valuable information for estimating boundary conditions for the development of the model. The studies also provided general information to understand the river system.

The Oregon Department of Environmental Quality (DEQ) is concerned about Oregon water quality standards being exceeded in the Willamette River as a result of untreated sewage and stormwater discharges into the river (Bloom, 1997). The Federal Clean Water Act and the Endangered Species Act require DEQ to develop Total Maximum Daily Loads (TMDLs) for the Willamette River Basin in order to meet water quality standards during all seasons. There are 1,436 miles of streams in the Willamette River Basin listed in the Oregon 303(d) list that do not meet water quality standards. Most of the river miles listed are due to temperature and bacteria violations. DEQ has to develop TMDLs for the Willamette River mainstem by the end of 2003 (Bloom, 2000).

The initial process for the development of TMDLs in the Willamette River Basin included the analysis of five water quality modeling options proposed by DEQ. These modeling options have been analyzed according to the time and resources necessary to develop them. The options proposed by DEQ included available models, enhancement of available models, and development of new models for the Willamette River Basin. DEQ is considering using a dynamic water quality model for the Willamette River because it is tidally influenced up to the Willamette Falls (RM 26.5). The water quality model selected should also be capable of modeling other water quality constituents in the future. Two phases are considered during the development of the TMDLs with the intention of meeting the 2003 TMDLs deadline. Phase I will consider modeling existing temperature and bacteria listings by the end of 2002. This phase is also considering modeling the major reservoirs in order to reduce the margins of safety for the TMDL development. Phase II will address other water quality constituents that are not listed in the 303(d) list such as dissolved oxygen, pH, and algae.

**Modeling Approach**

A previous report by Wells (2000) discussed the background of various water quality and hydrodynamic models and why the CE-QUAL-W2 Version 3 model was chosen for the Willamette-Columbia system. CE-QUAL-W2 Version 3 was proposed as the most appropriate model for the Lower Willamette system primarily because it contained the following elements:

- Two-dimensional, dynamic hydrodynamics and water quality capable of replicating the density stratified environment of the tidally influenced river sections as well as the sloping river channel sections. This is especially important when there are deep "holes" where a 1-D model would predict erroneously flow through the entire cross-section of the "hole".
- River-estuary and hydrodynamic-water quality linkage is transparent for the Model User.
- The model can handle two-dimensional branches added on to the main stem of the Willamette River such as the lower reach of the Clackamas River as well as flow around islands.
- The CE-QUAL-W2 Version 3 code has many state-of-the-art model refinements that reduce numerical errors and improve the accuracy of model simulations.

This model has been under development for many years and is a public-domain code maintained by the Corps of Engineers, Waterways Experiments Station (WES), located in Vicksburg, Mississippi. The earlier version, Version 2 (Cole and Buchak, 1995), has been superceded by Version 3 developed by WES and Wells (1997). Version 3 has undergone rigorous testing (Wells, 1998) and has been successfully applied to the Lower Snake River system (Wells and Berger, 1998).

The model time period consists of simulating the summers, May 1$^{st}$ to October 1$^{st}$, for the years, 1993, 1994, 1997, 1998 and 1999. Model results from 1993 will be compared with results obtained from the DYNHYD model developed by Limno-Tech, Inc. for the City of Portland. Model results from 1994 will be compared with the QUAL2E model results produced by Tetra Tech, Inc. In addition to modeling the hydrodynamics and temperature, the Willamette River model will also simulate: dissolved and particulate non-living organic matter (both refractory and labile components), ammonia, nitrate, dissolved $PO_4$, algae, TDS, pH, dissolved oxygen, and bacteria.

Conceptually the model elements, shown in Figure 2, are:

- Willamette River above the Oregon City Falls
- Willamette River below the Oregon City Falls
- Columbia River with side channels

- Multnomah Channel
- Lower Clackamas River and adjacent gravel pit

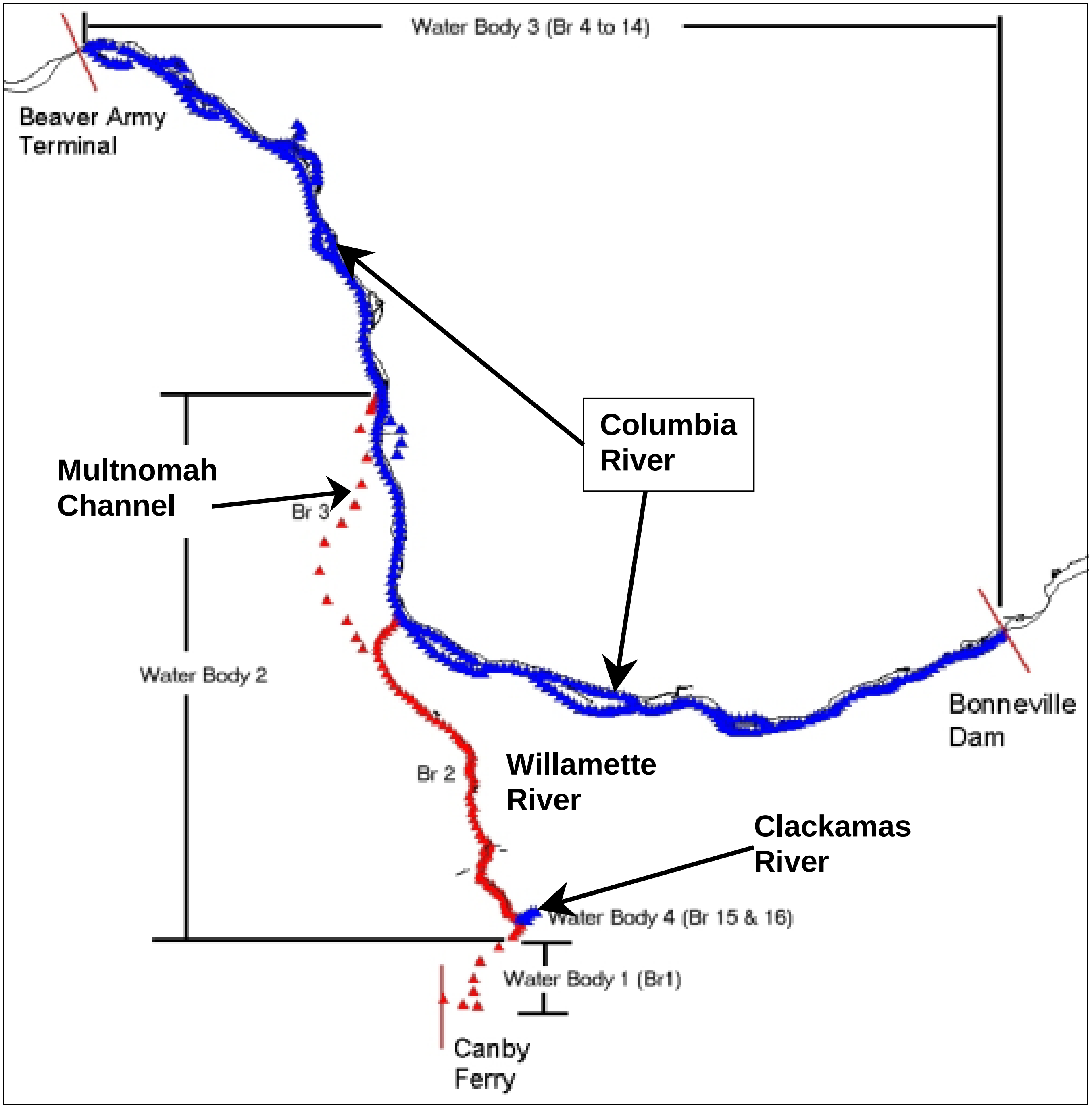



**Figure 2. Conceptual Layout of the Lower Willamette River System Model (Points Represent Model Segments)**

## Water Quality Data

**Willamette River**
The Oregon Department of Environmental Quality (DEQ) held the Willamette River basin Water Quality Data Summit (Corvallis, 2000) with the objectives of increasing awareness about the current conditions of the Willamette River Basin, exchanging information about water quality monitoring in the Basin, and addressing and explaining the TMDL development process.

Presentations on physical and chemical data were made by McKenzie Watershed Council, EPA, City of Salem, National Council Air & Stream Improvement, NRCS, ODEQ, and USGS. Presentations on water quantity were made by USGS and OWRD. Riparian vegetation and aquatic habitat were covered by EPA, OSU – Pacific NW Ecosystem Research Consortium, BLM, USFS, and ODFW. Much of the data presented were concerned with regions outside of the model's boundary conditions discussed in this report, namely upstream of Salem and in the headwaters controlled by the USFS and BLM.

The DEQ Water Quality Division presented the Willamette River Technical Advisory Steering Committee (WRTASC) studies of dioxin and furan concentration & effects in Willamette River fish as well as distribution of dissolved pesticides in the Willamette River basin. These studies led to a 1999 study initiated to investigate the risk to human health from the consumption of fish from the Newberg Pool area, the level of bacteria contamination in and upstream of the Newberg Pool, and evaluate the in-situ fish embryo bioassay. These reports can be downloaded from http://waterquality.deq.state.or.us/wq/Willamet/reports2000.htm

The Willamette River is listed in the 303(d) list for temperature because it exceeds water quality standards. DEQ held the water quality summit to involve different agencies collecting water quality data in the Willamette River so they can evaluate who has water quality data and what kind of data is available for developing the TMDLs.

The City of Portland, Bureau of Environmental Services (BES) has been collecting water quality data in the Willamette River during the last 8 years. BES collects data at 6 monitoring stations along the Willamette River as shown in Table 1 and Figure 3. Grab samples are taken weekly for the period 1992-2000 and 2 Hydrolabs took continuous measurements from 1997-2000. Both the grab samples and the Hydrolab measurements are made at a 10-foot depth. Figure 4 and Figure 5 are examples of the Hydrolab time series data at St. John's Railroad Bridge (RM 6.8) and the Waverly Country Club (RM 17.9) for the period 1992-2000. Annual continuous Hydrolab data plots for both sites can be found in Appendix A.

| RM | Location | Sample Type |
|---|---|---|
| 1.1 | South Kelly point Park | Grab |
| 6.8 | St. John's Railroad Bridge | Grab, Hydrolab |
| 8.8 | Swan Island | Grab |
| 12.7 | Morrison Bridge | Grab |
| 17.9 | Waverly Country Club | Grab, Hydrolab |
| 20 | Tryon Creek Railroad Bridge | Grab |

**Table 1. Bureau of Environmental Services monitoring stations**

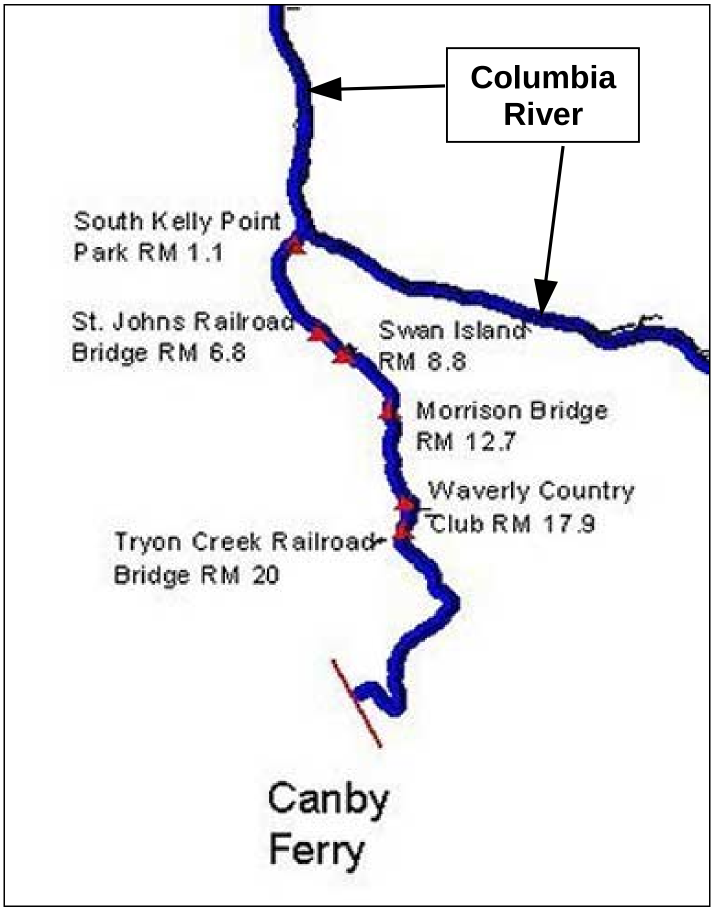



**Figure 3. BES sample locations in the Willamette River**

Low concentrations of dissolved oxygen can be observed in Figure 4 and Figure 5 during the summers of 1998 and 1999.

Longitudinal profiles for temperature, dissolved oxygen, conductivity and pH were also plotted using the grab samples provided by BES. Figure 6 shows monthly averages for the year 1995. The monthly average for the parameters plotted seem to be constant along the Willamette River except for conductivity which increases slightly near the confluence with the Columbia River. Other parameters such as ammonia-nitrogen, nitrate-nitrogen, nitrite-nitrogen, O-$PO_4$, $BOD_5$, fecal coliform, E. coli, enterococcus, TSS, TDS and TS were also plotted against river mile. These data were plotted for the period 1992-2000 using summer averages from May 1$^{st}$ to September 30$^{th}$ for available data as shown in Appendix B. Figure 7 shows a comparison between TSS, TDS and TS where an increase in these parameters can be observed near the confluence with the Columbia River.

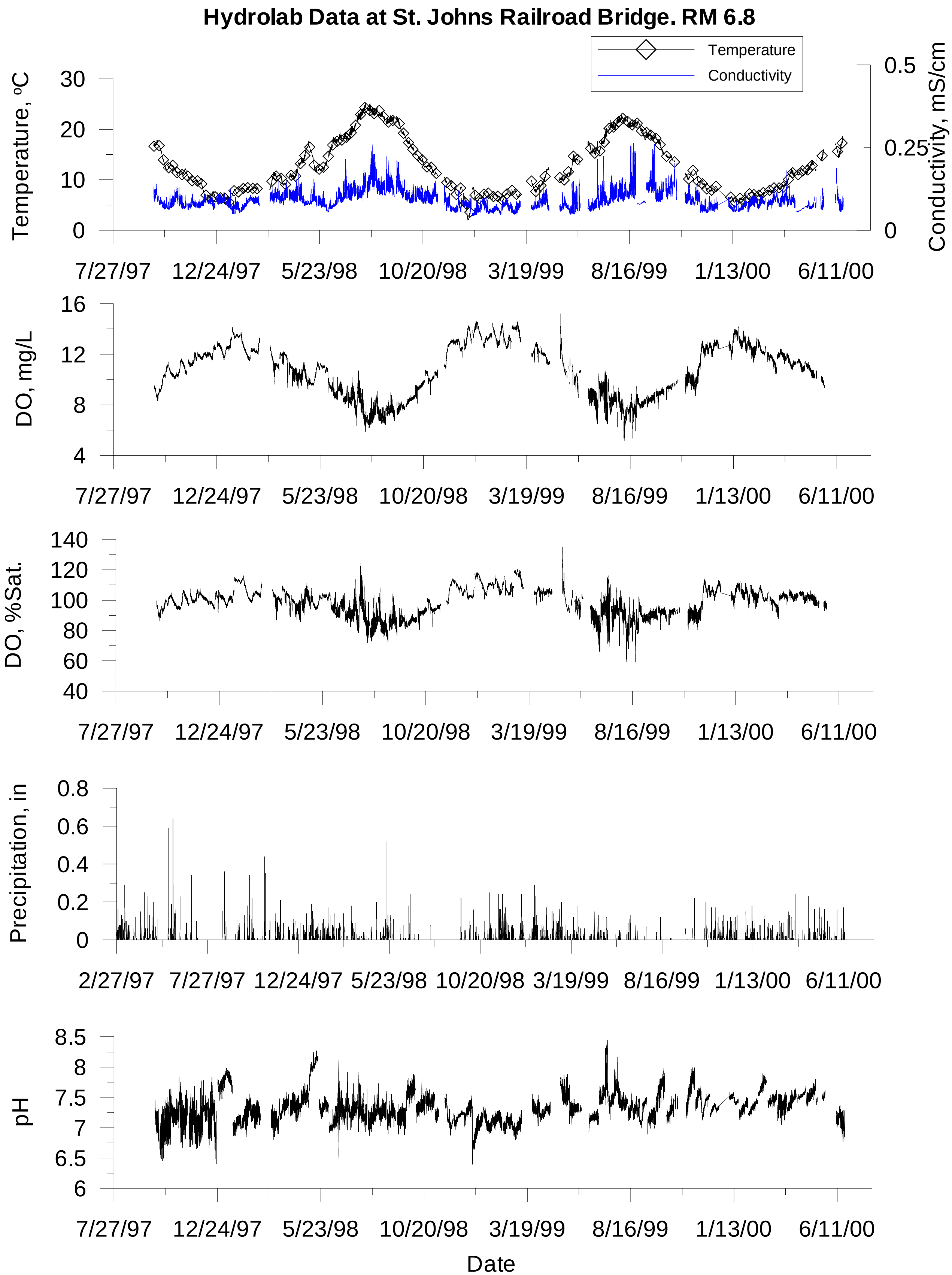



**Figure 4. Water Quality in the Willamette River at RM 6.8, 1997-2000**

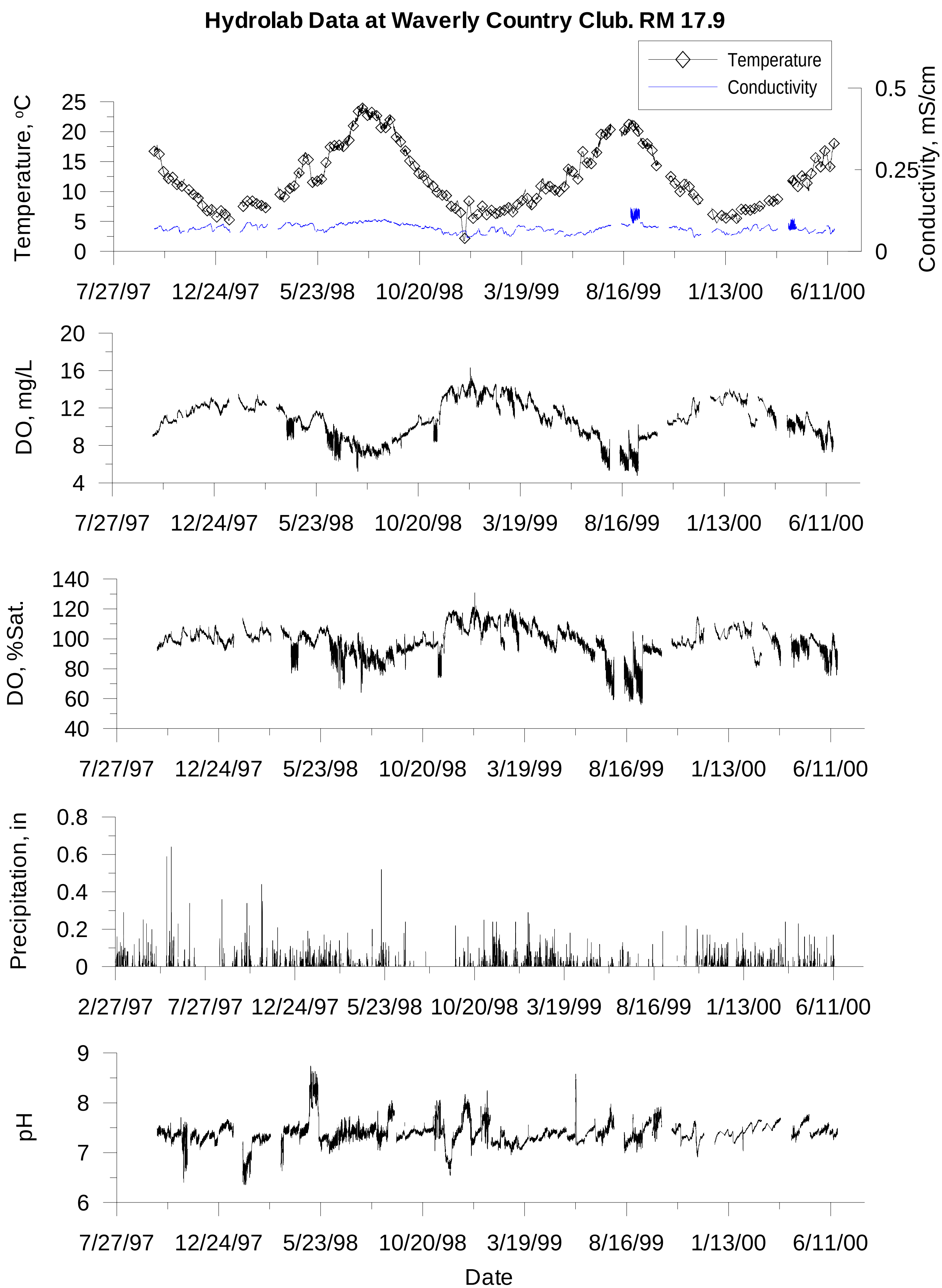



**Figure 5. Water Quality in the Willamette River at RM 17.9, 1997-2000**

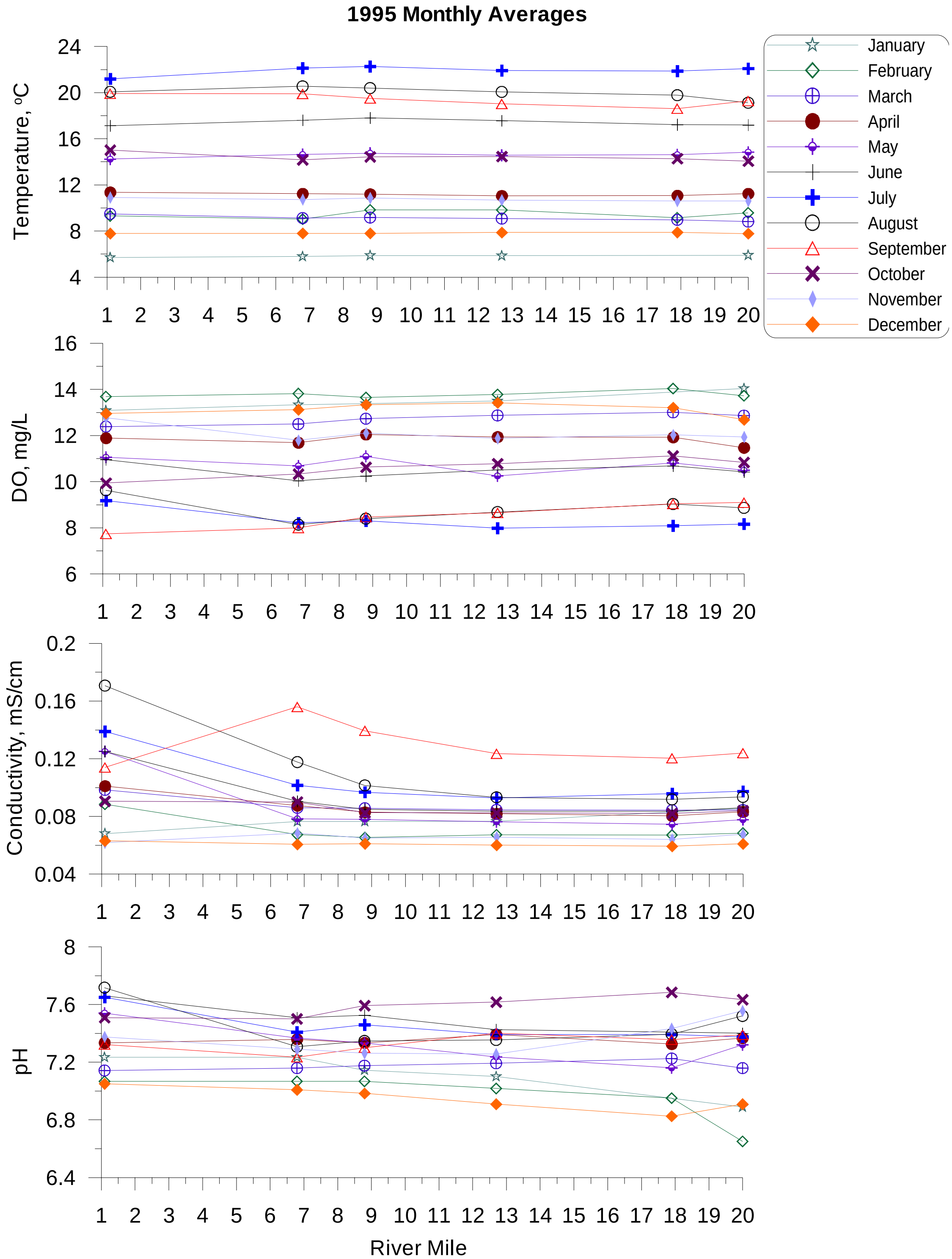



**Figure 6. Water Quality Longitudinal Profiles in the Willamette River**

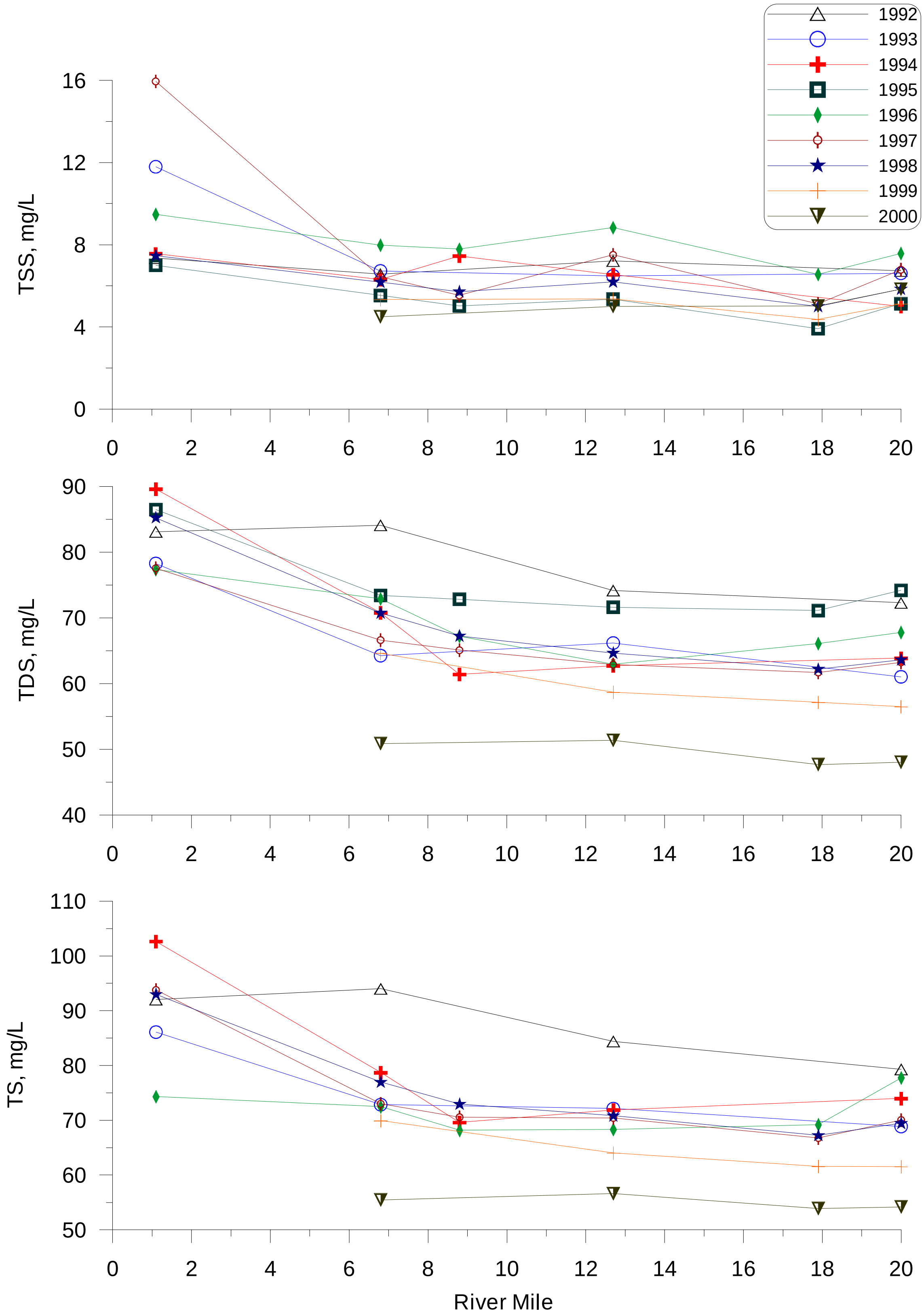



**Figure 7. TSS, TDS and TS Longitudinal profiles, Summer Averages, 1992-2000**

Lateral analysis

The Grab samples collected by BES include weekly data from 1992 to 2000 on the east and west banks and from the middle of the river for several locations These data were used to verify if a laterally averaged model would be appropriate for the Willamette River. Data from 1992 to 2000 were used to create time series plots for each sample location as shown in Figure 8 for dissolved oxygen. The standard deviation was estimated using the east, middle and west measurements at each location. Figure 9 shows the standard deviation for dissolved oxygen at each of the monitoring stations. The results obtained from this analysis show small variations in the dissolved oxygen across the river channel. However, these results are affected by sampling errors as can be observed in Figure 8 as spikes. The same analysis for other parameters such as pH, conductivity and temperature show similar results and can be found in Appendix C and D.

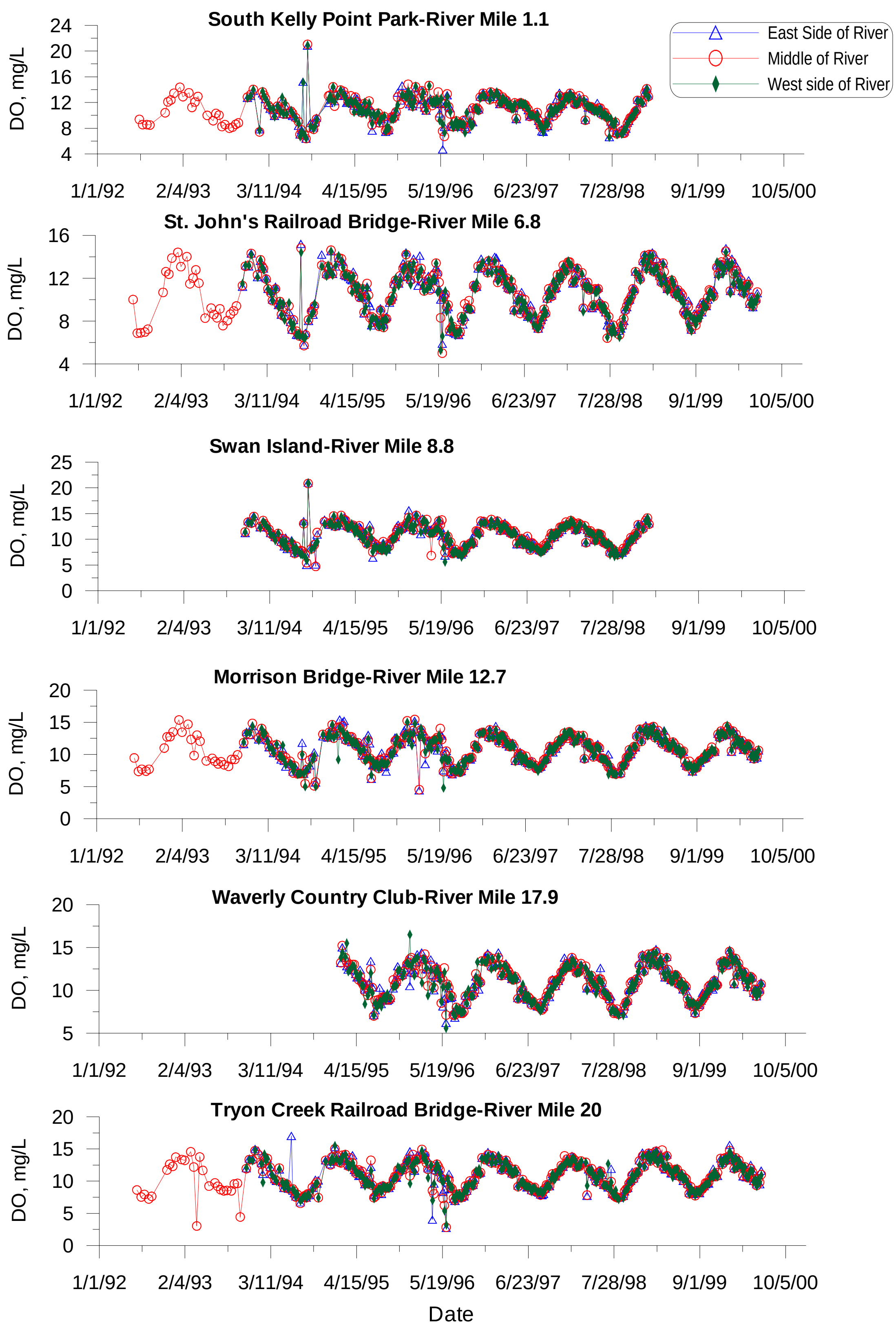



**Figure 8. Dissolved Oxygen profiles across the Willamette River, 1992-2000**

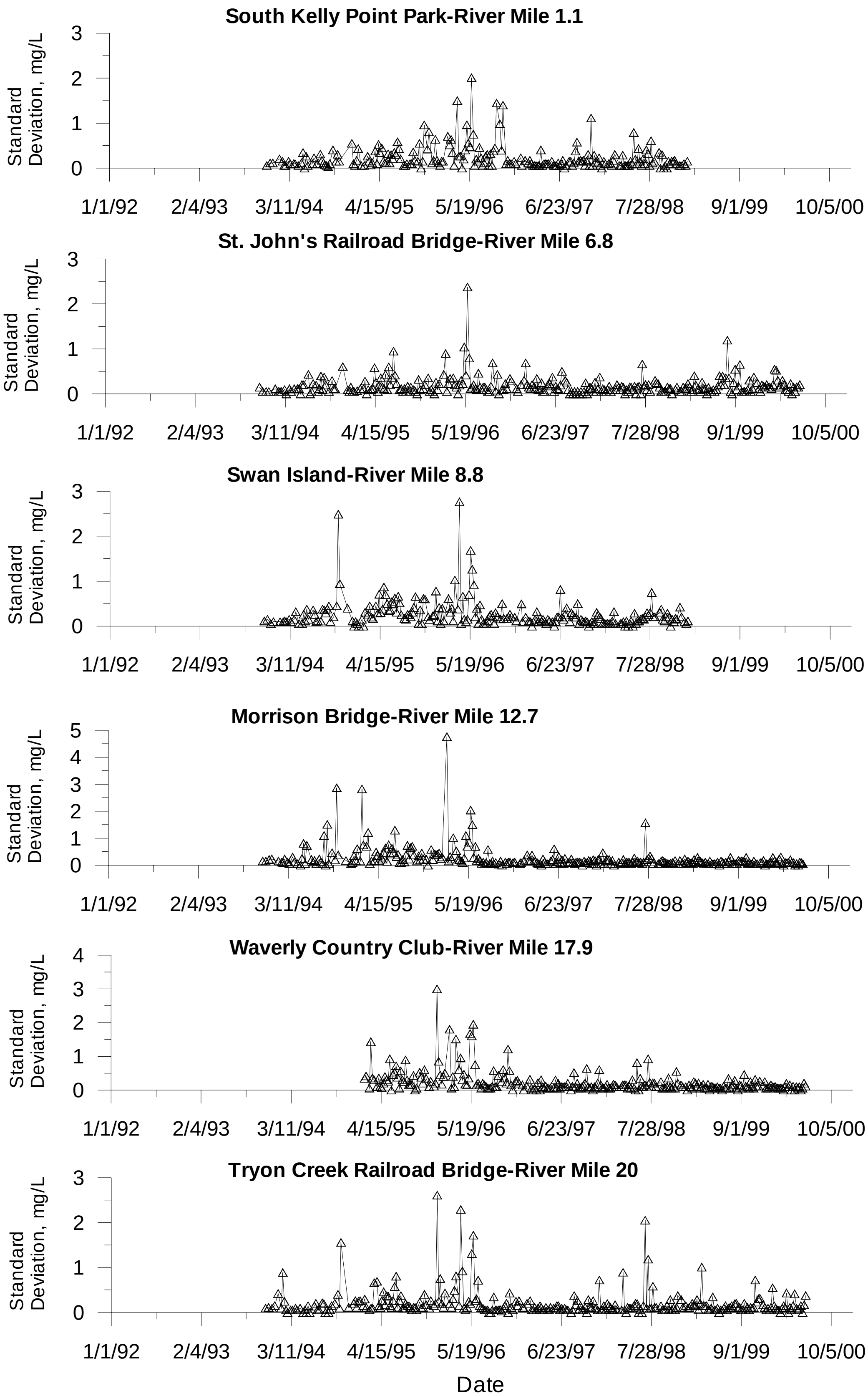



**Figure 9. Standard deviation for Dissolved Oxygen, 1992-2000**

Vertical Profiles

The City of Portland Bureau of Environmental Services started a new monitoring program in the Willamette River in the summer of 2000 with a sample frequency of two weeks from July to October. Temperature, conductivity, pH, and dissolved oxygen samples were taken every 10 feet at four locations, Table 2. Vertical profiles were taken from the east and west banks and from the middle of the river for each location. Figure 10 shows temperature profiles for the summer 2000 in the middle of the river at Waverly Country Club. Figure 11 shows dissolved oxygen profiles for the same location and time period. Profiles for the other locations are in Appendices E through H.

Temperature and dissolved oxygen measurements collected by BES in the Willamette River (RM 1.1 to RM 17.9) do not show significant stratification during the summer 2000 below the10-ft depth (Figure 10 and Figure 11). Unfortunately, the sampling program did not measure the near surface temperature and dissolved oxygen above the 10-ft depth except on the first day of the monitoring program (July 12, 2000). In Figure 10 and Figure 11, slight stratification seems to exist in the top 10-ft of the river. Additional vertical profiles for temperature and dissolved oxygen are shown in Appendix E and F. Conductivity and pH show small variations below the10-ft depth. Data for the top 10-ft is also missing for all days except 7/12/2000. Conductivity and pH profiles can be found in Appendix G and H.

Temperature stratification in the Willamette River (RM 1.1 to RM 17.9) could be a consequence of higher water level elevations in the Columbia River than in the Willamette River. This occurs at the end of spring and beginning of the summer. The difference in water levels produces a Columbia River water intrusion in the Willamette River moving upstream creating a bottom wedge of Columbia River water (Bloom, 2000).

| RM | Location |
|---|---|
| 1.1 | South Kelly point Park |
| 6.8 | St. John’s Railroad Bridge |
| 12.7 | Morrison Bridge |
| 17.9 | Waverly Country Club |

**Table 2. BES profiles sample locations**

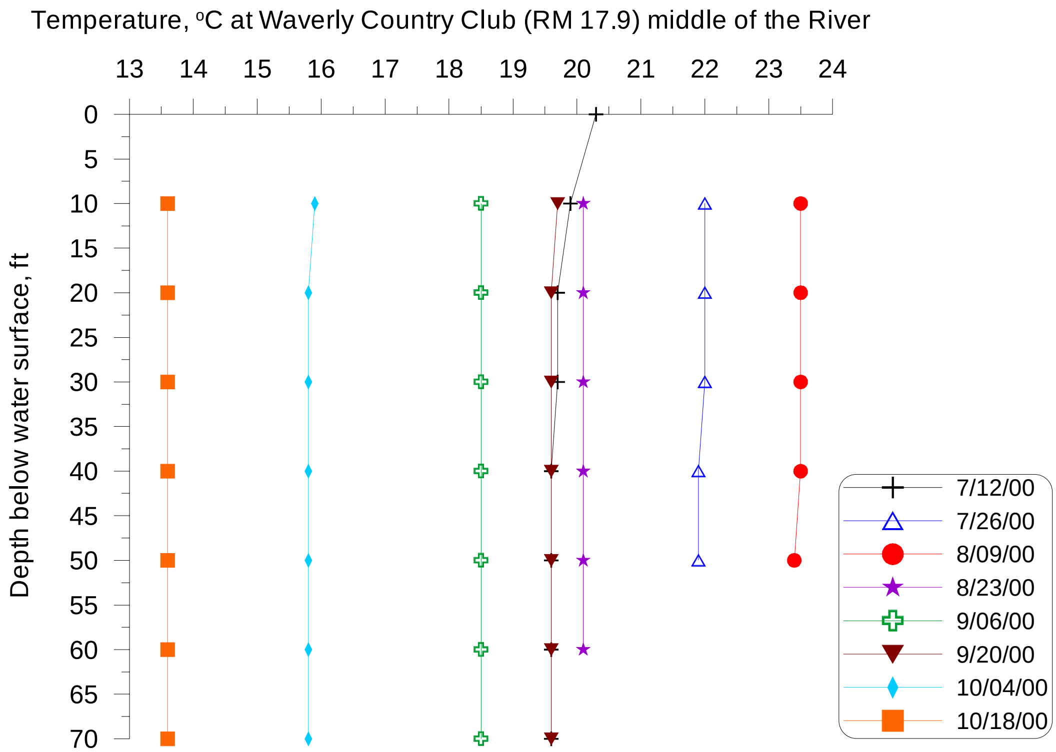



**Figure 10. Temperature profiles in the middle of the Willamette River at Waverly Country Club, RM 17.9**

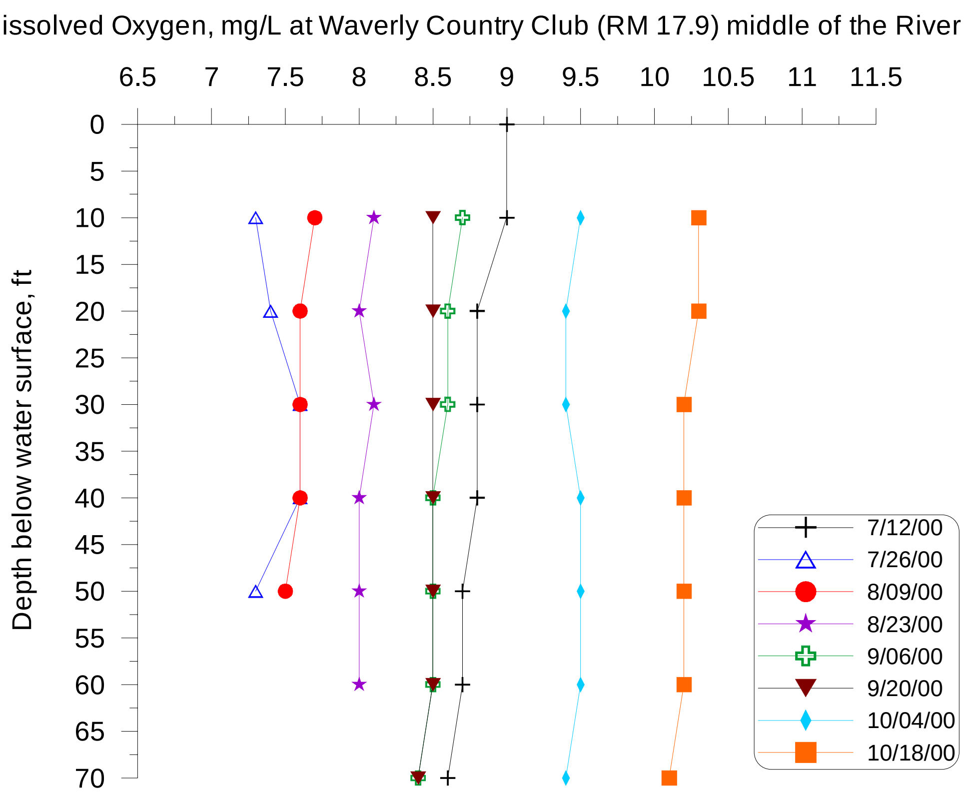



**Figure 11. Dissolved Oxygen profiles in the middle of the Willamette River at Waverly Country Club, RM 17.9**

### Columbia River

The Oregon Department of Environmental Quality (DEQ) and Washington Department of Ecology (Environmental Information Monitoring) collected data for the EPA STORET Program at different locations in the Columbia River and its tributaries. The U.S Geological Survey (USGS) also collected water quality data in the Columbia River as part of a dissolved gas study done in conjunction with the USACOE (Richmond, 2000). The water quality sampling locations are shown in Figure 12. Since the model will simulate the summers (May 1 to October 1) for the years 1993, 1994 and 1997 to 1999 data were obtained from 1993 to present where possible. The extent of the water quality data collected for the Columbia River can be found in Appendix I.

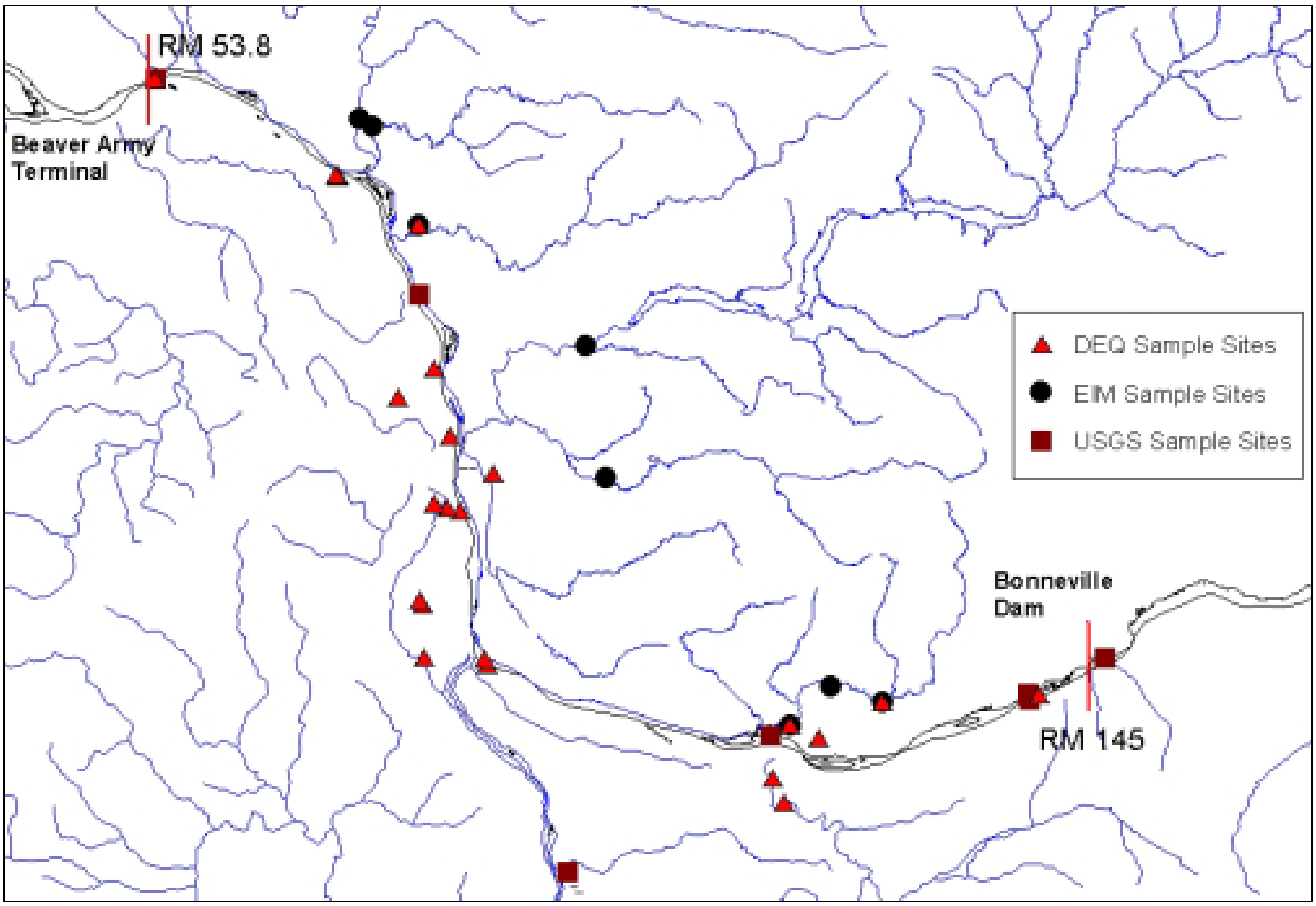



**Figure 12. Columbia River water quality sampling locations**

## Model Boundary Conditions

The boundaries for the Willamette River modeling project are Bonneville Dam (RM 145) and Beaver Army Terminal (RM 54) on the Columbia River and river mile 35 (near Canby Ferry) on the Willamette River. Figure 13 shows the location of the boundaries and some large scale basins in the region.

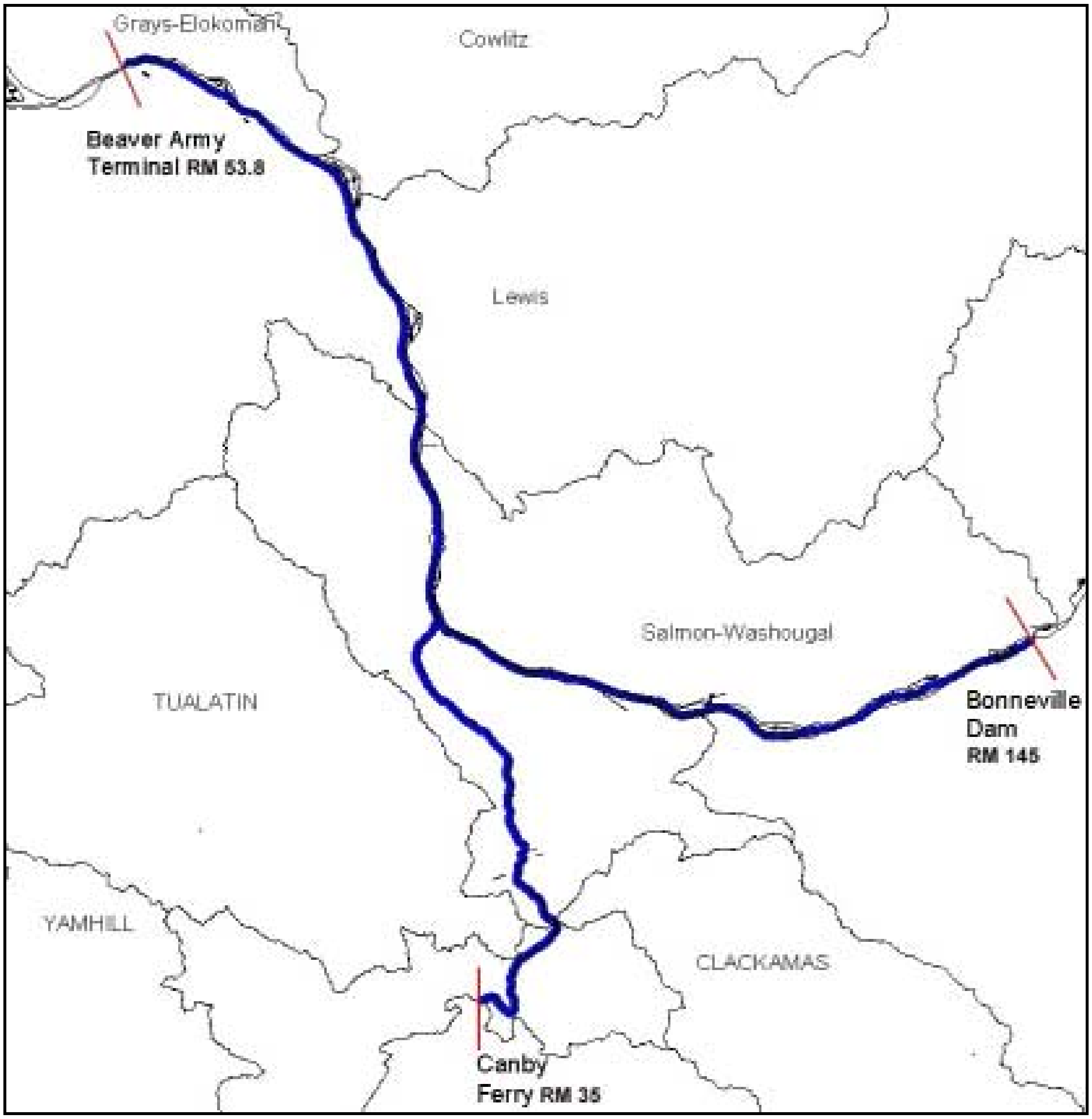



**Figure 13. Model Boundaries on the Columbia and Willamette Rivers**

## Columbia River

Columbia River Water Level at Beaver Army Terminal

The Beaver Army Terminal station (USGS: 14246900) has been recording continuous water level data from October 1991 to present. In 1997, 1998 and 1999 there were several gaps in the data. To fill those gaps a correlation was developed between the Beaver Army Terminal site, the Vancouver, WA site (USGS: 14144700), the Longview, WA site (USACOE: LOP), the site below the Bonneville Dam (USGS: 14128870) and the tidal influences on the Columbia River. The correlation used ($R^2$=0.8301) is:

$$BeaverArmyTer\min alWLElev\_m = 0.0143(Hourly) + 0.0109(Daily) - 0.0062(Monthly) + 0.0054(Annually) - 0.2922(VancouverWLElev\_m) + 1.1156(LongviewWLElev\_m) + 0.0389(BonnevilleWLElev\_m) - 0.1942$$

Where:

Hourly is the tidal influence from 12.4 hour tidal cycle as: $Hourly = \sin\left(\frac{2\pi(JulianDay)}{12.4hours/24hours}\right)$

Daily is the daily tidal cycle estimated as: $Daily = \sin(2\pi(JulianDay))$

Monthly is the monthly tidal cycle estimated as: $Monthly = \sin\left(\frac{2\pi(JulianDay)}{30days}\right)$

Annually is the influence of any annual tidal fluctuations as: $Annually = \sin\left(\frac{2\pi(JulianDay)}{365days}\right)$

The water level elevation at Beaver Army Terminal for the summers modeled is shown in Figure 14. Although the coefficient of determination was 0.83 the correlated water level information fit well with the existing data for the station.

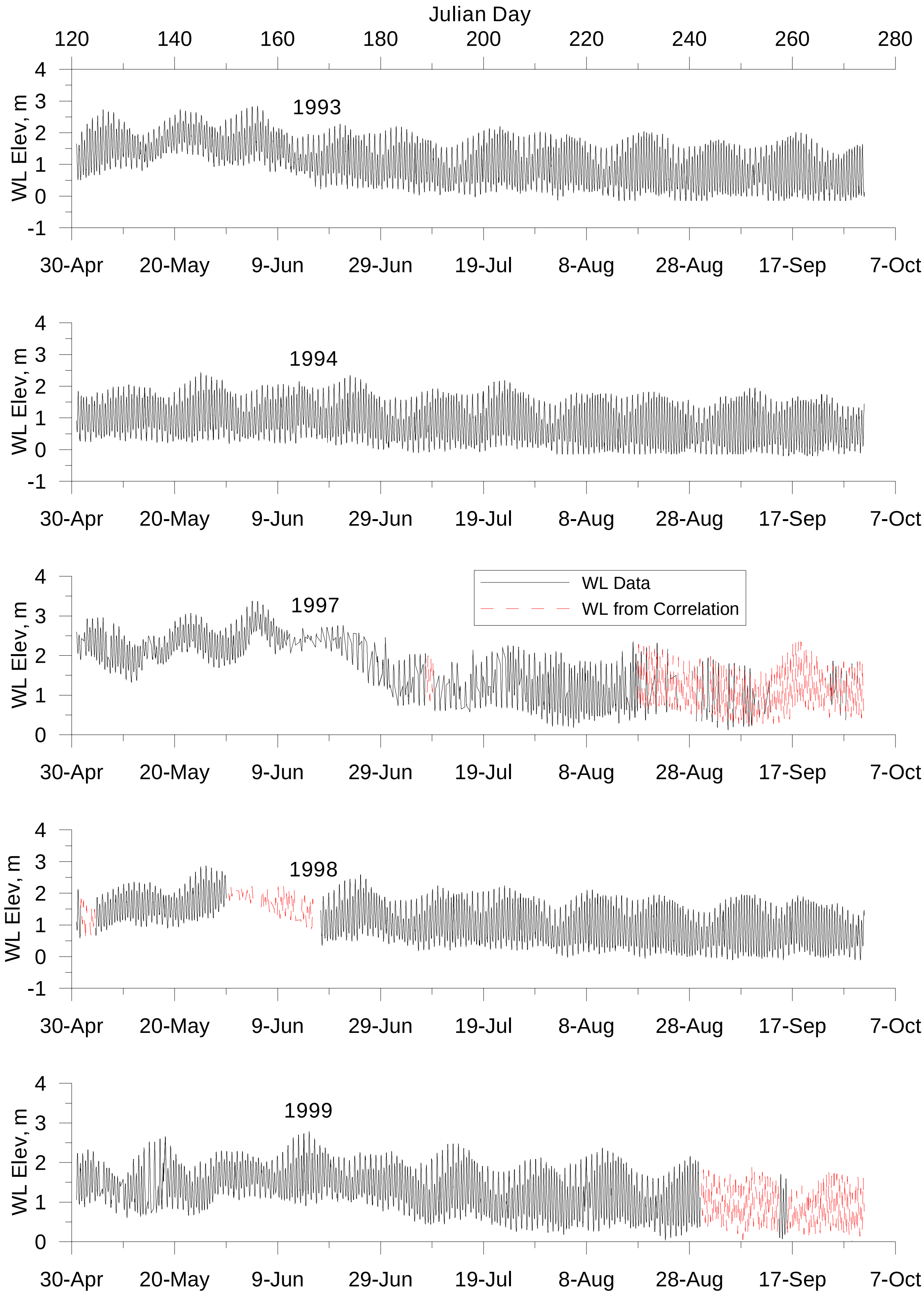



**Figure 14. Columbia River Water Level Elevation at Beaver Army Terminal, m NGVD, RM 53.8**

Columbia River Flow at Bonneville Dam

Flows at Bonneville Dam were obtained from the USACOE from January 1993 to 2000. A plot showing flow data below the Bonneville Dam for all modeled summers is shown in Figure 15.

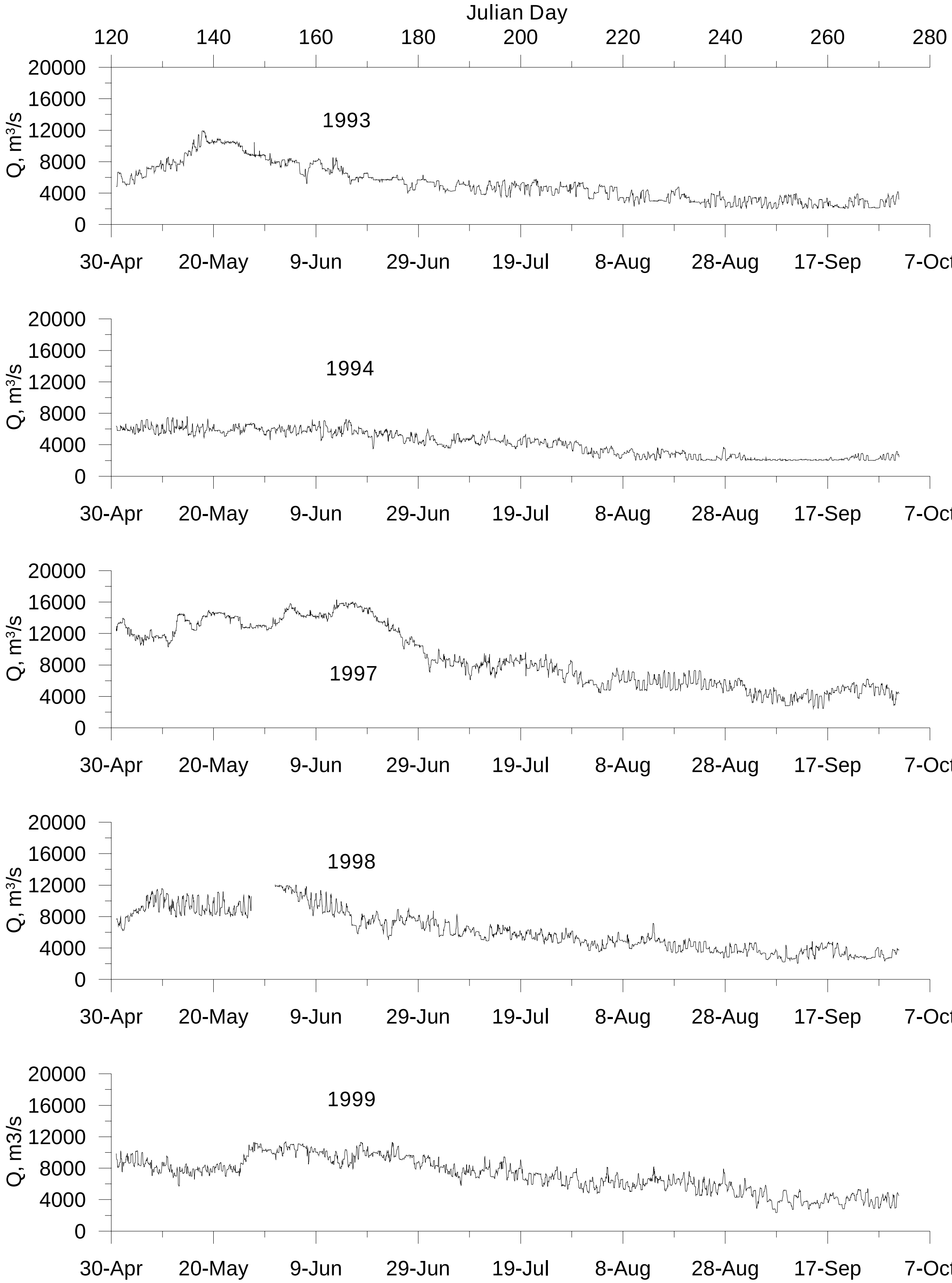



**Figure 15. Columbia River Flow measured below the Bonneville Dam, $m^3/s$, RM 144.5**

Water Quality

Water Quality monitoring in the Columbia River is predominately conducted by DEQ. However, USGS has monitored temperature and some water quality parameters such as conductivity, dissolved oxygen, and pH hourly. Continuous temperature data from 1997 to 2000 were obtained from a dissolved gas study carried out by USGS and the USACOE.  DEQ (STORET) data is collected at a frequency of monthly to a few times a year.

Temperature data in the Columbia River at Bonneville dam and at Beaver Army Terminal were taken from USGS monitoring and STORET grab samples.   Water quality data in the Columbia River at the Bonneville Dam were obtained from grab samples taken by DEQ (STORET) at Warrendale, Oregon because data at the Bonneville Dam were not available.  Water quality input files for the model at the Beaver Army Terminal were generated by combining DEQ (STORET) data and continuous USGS data. Figure 16 and Figure 17 show temperature in the Columbia River at Beaver Army Terminal (RM 53.8) and at Bonneville Dam (RM 144.5) respectively. Table 3 shows a list of water quality parameters available for the Columbia River at Bonneville Dam and Beaver Army Terminal.

Figure 18 through Figure 20 shows plots of the water quality constituents used for the downstream boundary condition at Beaver Army Terminal.  Figure 21 through Figure 23 show similar water quality plots for the Columbia River at the Bonneville Dam.  The procedure used for developing the water quality files from data can be found in Appendix J:  Water Quality file development procedures.

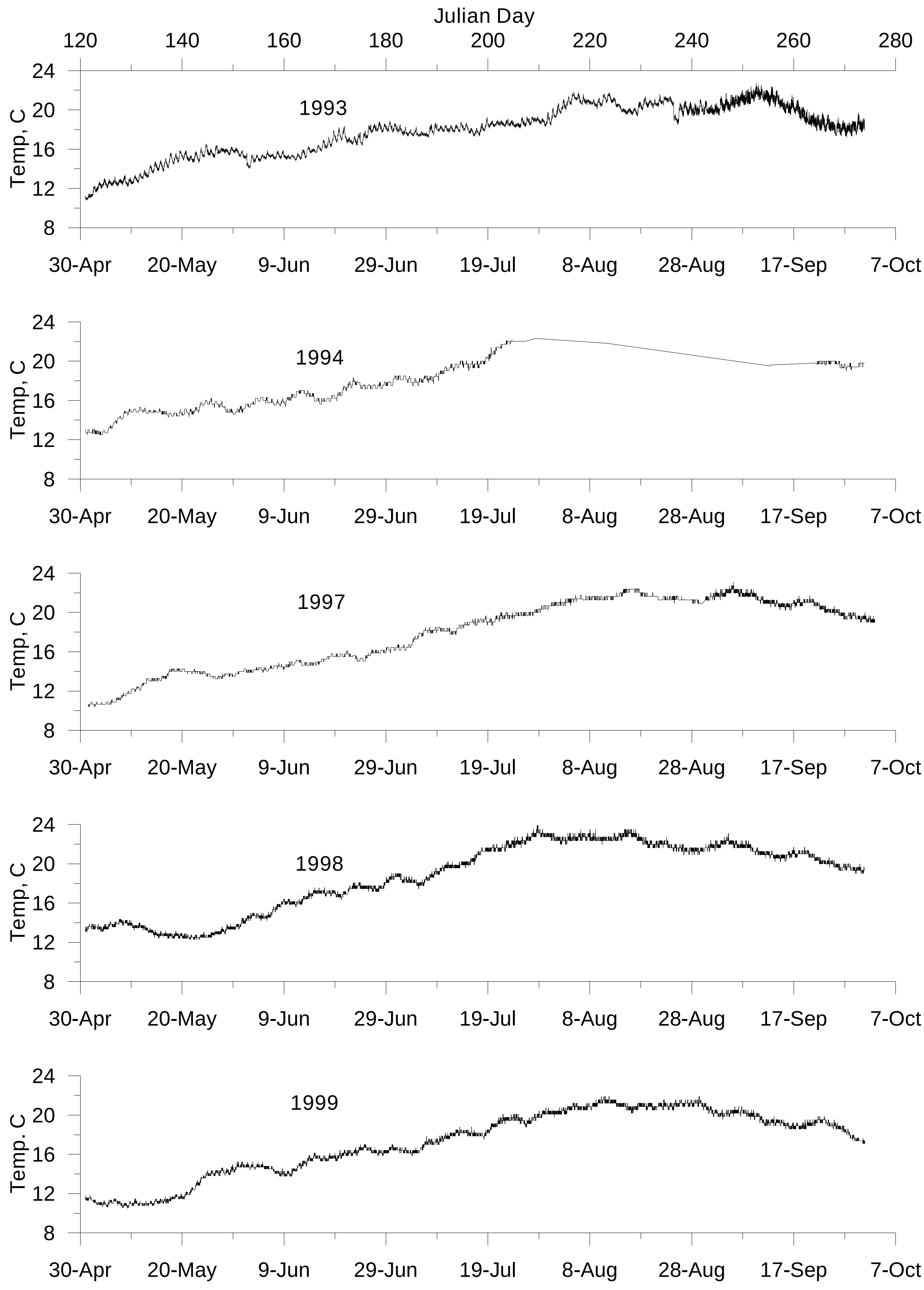



**Figure 16. Columbia River at Beaver Army Terminal (RM 53.8) water temperature, $^{o}C$**

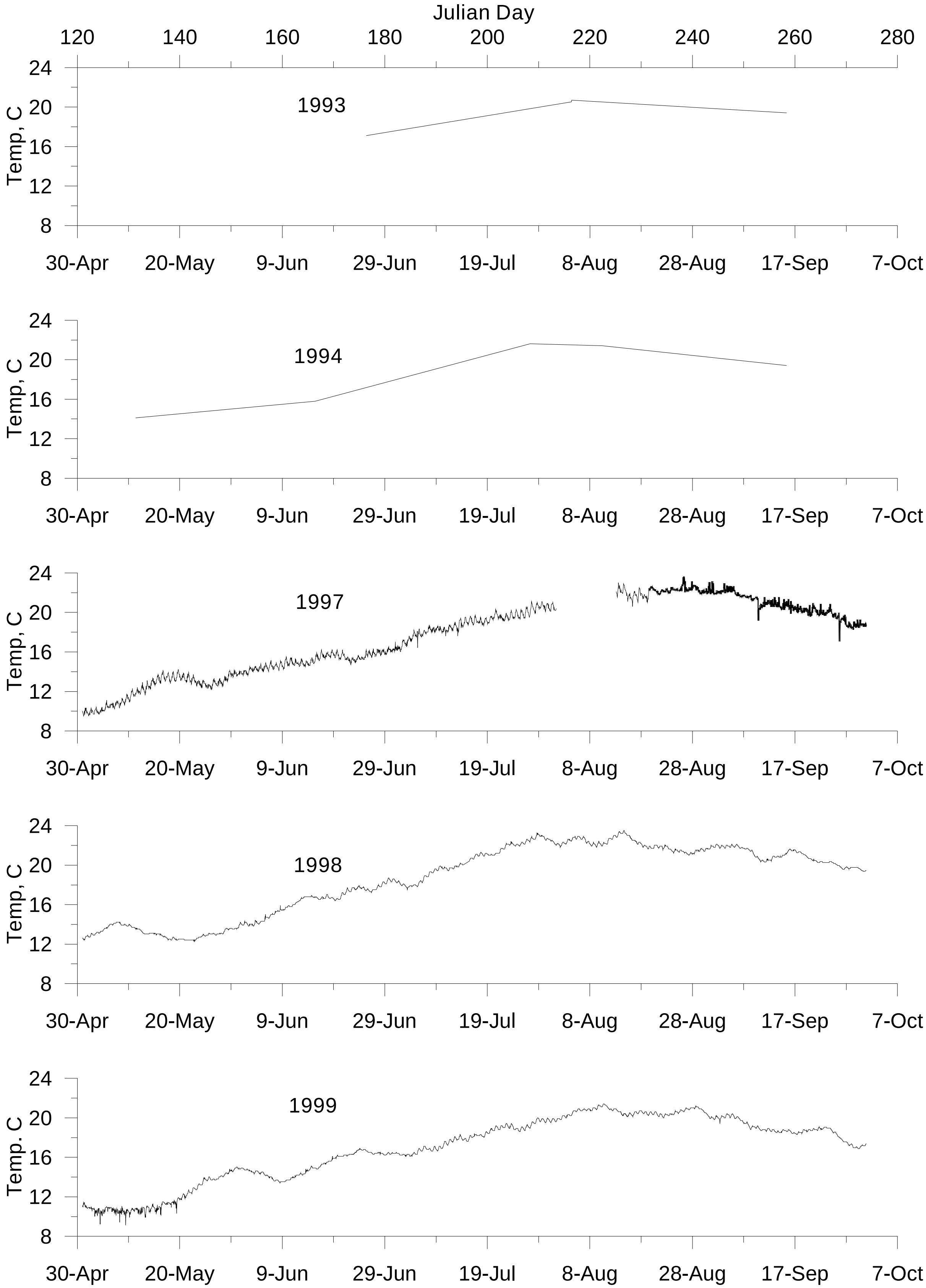



**Figure 17. Columbia River at Bonneville Dam (RM 144.5) water temperature, °C**

| Parameters | Columbia River at Bonneville Dam | Columbia River at Beaver Army Terminal |
|---|---|---|
| ALKALIN AS CACO3 | X | X |
| Alkalinity | X | X |
| Calcium Hardness | X | X |
| CHLRPHYL A | X | X |
| Conductivity, mS/cm | X | X |
| D ORG C C | X | X |
| Dissolved Oxygen | X | X |
| D.O Saturation | X | X |
| ENTCOCCI | X | X |
| Fecal Coliforms ./100 mL | X | X |
| NH3+NH4- N DISS | X | X |
| NH3+NH4- N TOTAL | X | X |
| NO2&NO3 N-DISS | X | X |
| NO2&NO3 N-TOTAL | X | X |
| NO2-N DISS | X | X |
| NO2-N TOTAL | X | X |
| PH | X | X |
| PHOS-DIS | X | |
| PHOS-DIS ORTHO | X | X |
| PHOSPHOR SED,SUSP | X | X |
| PHOS-T ORTHO | X | X |
| PHOS-TOT | X | X |
| S ORG C C | X | X |
| SUSP SED CONC | X | X |
| SUSP SED DISCHARG | | X |
| SUSP SED PARTSIZE | X | X |
| T ALK CACO3 | X | X |
| Temperature | X | X |
| Turbidity | X | X |
| UN-IONZD NH3-N | X | X |
| UN-IONZD NH3-NH3 | X | X |

**Table 3. Water Quality parameters available for the Columbia River Boundary Conditions**

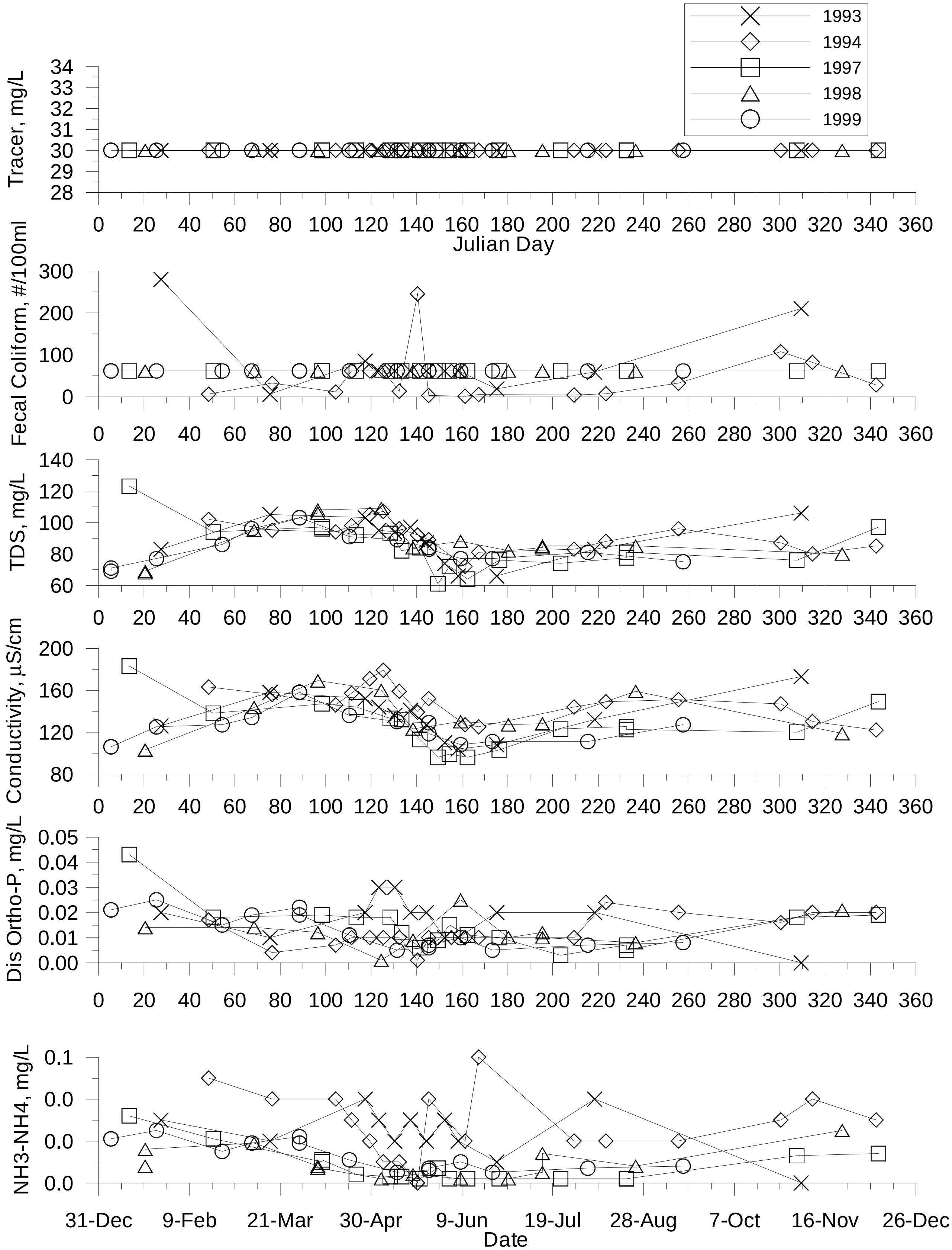



**Figure 18. Columbia River at Beaver Army Terminal Boundary Condition, RM 54**

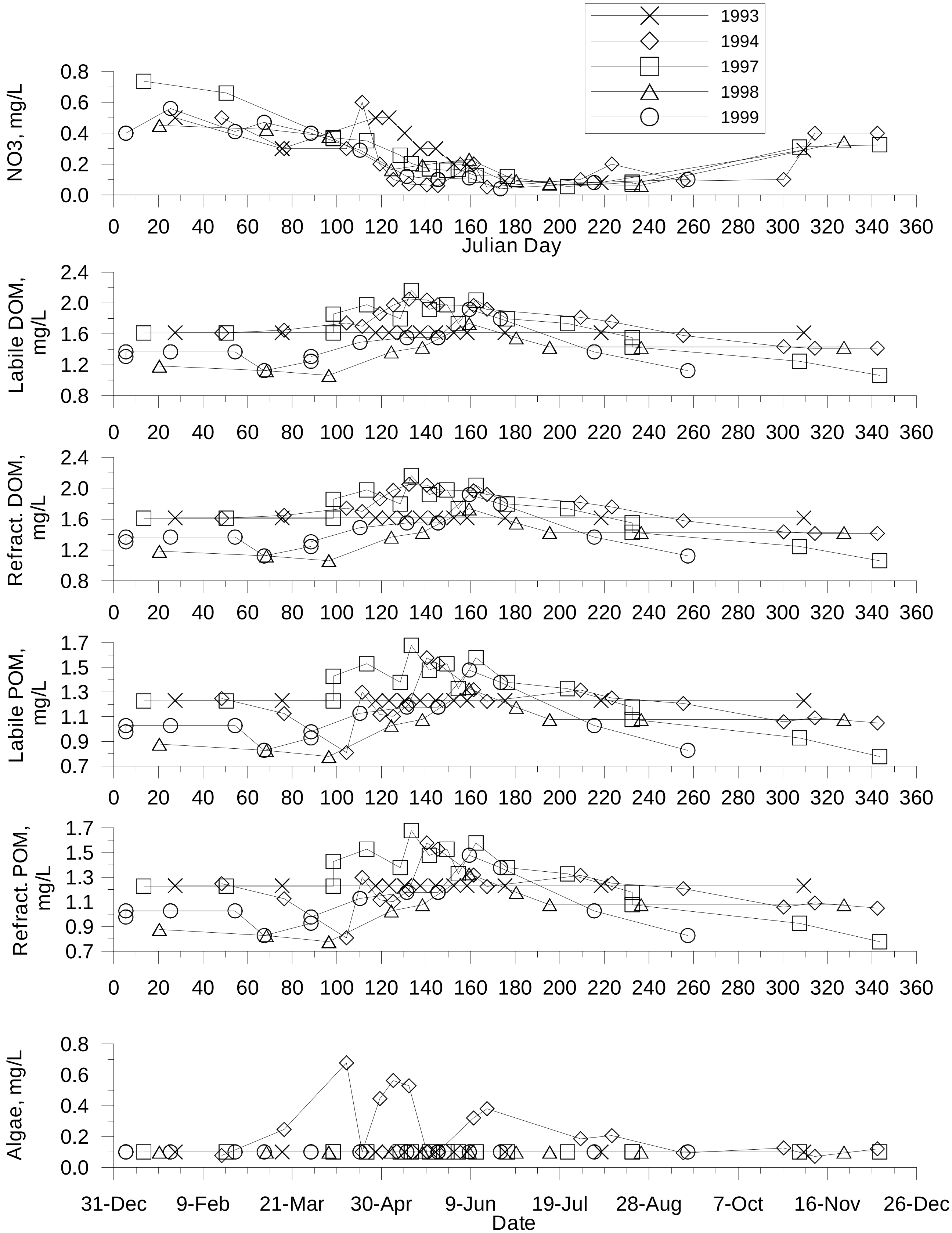



**Figure 19. Columbia River at Beaver Army Terminal Boundary Condition, RM 54 (Part 2)**

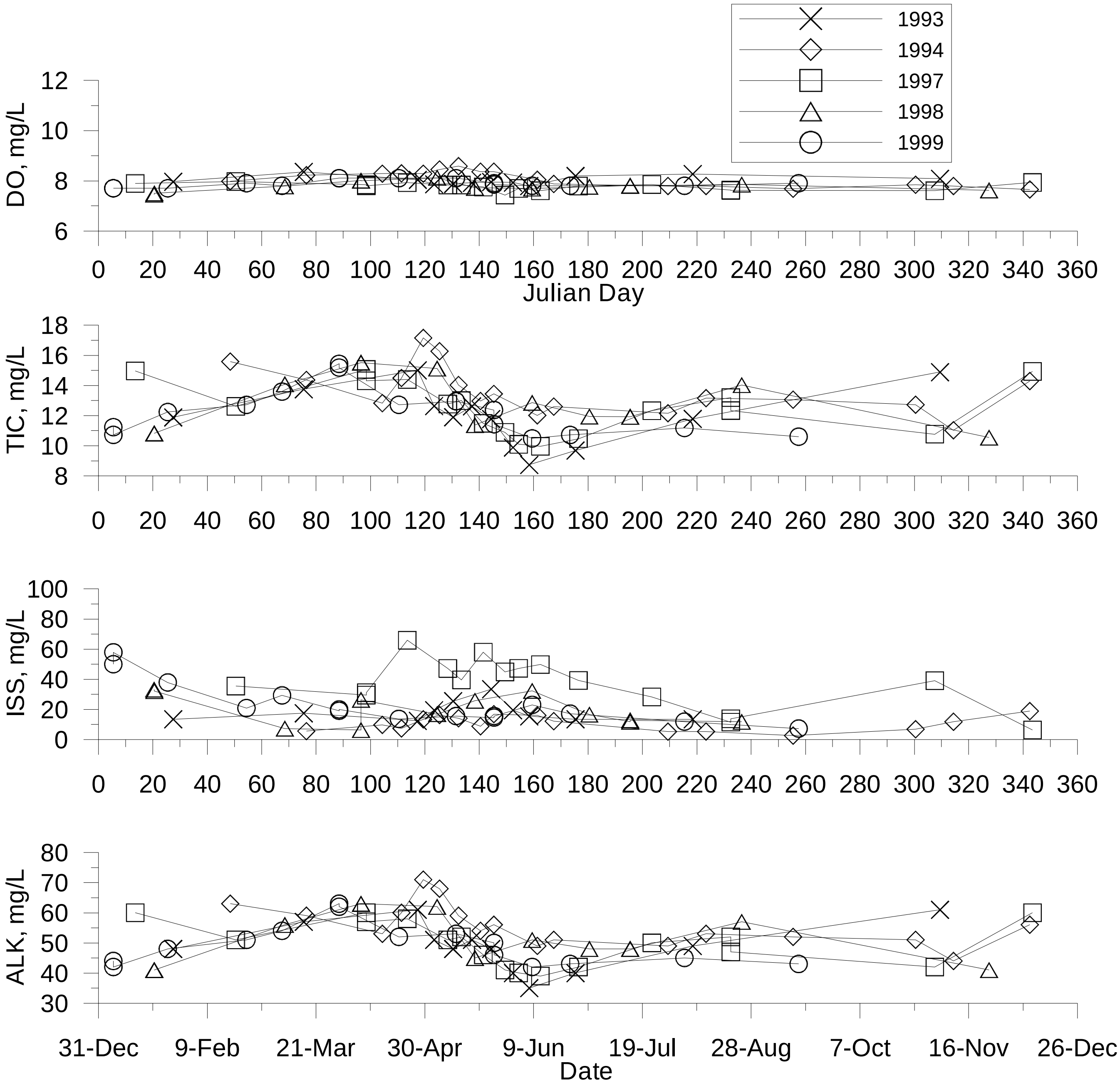



**Figure 20. Columbia River at Beaver Army Terminal Boundary Condition, RM 54 (Part 3)**

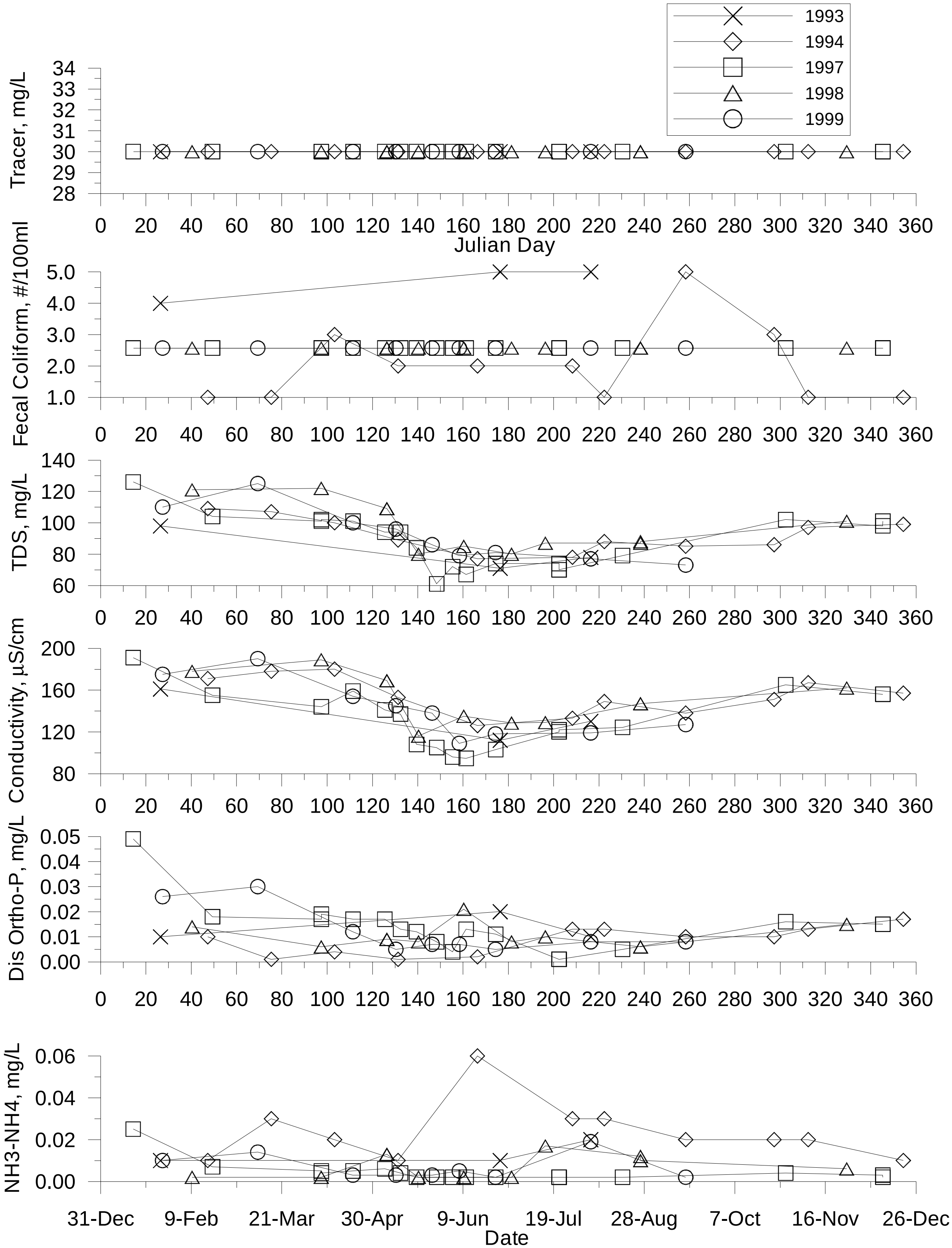



**Figure 21. Columbia River at Bonneville Dam Boundary Condition, RM 145**

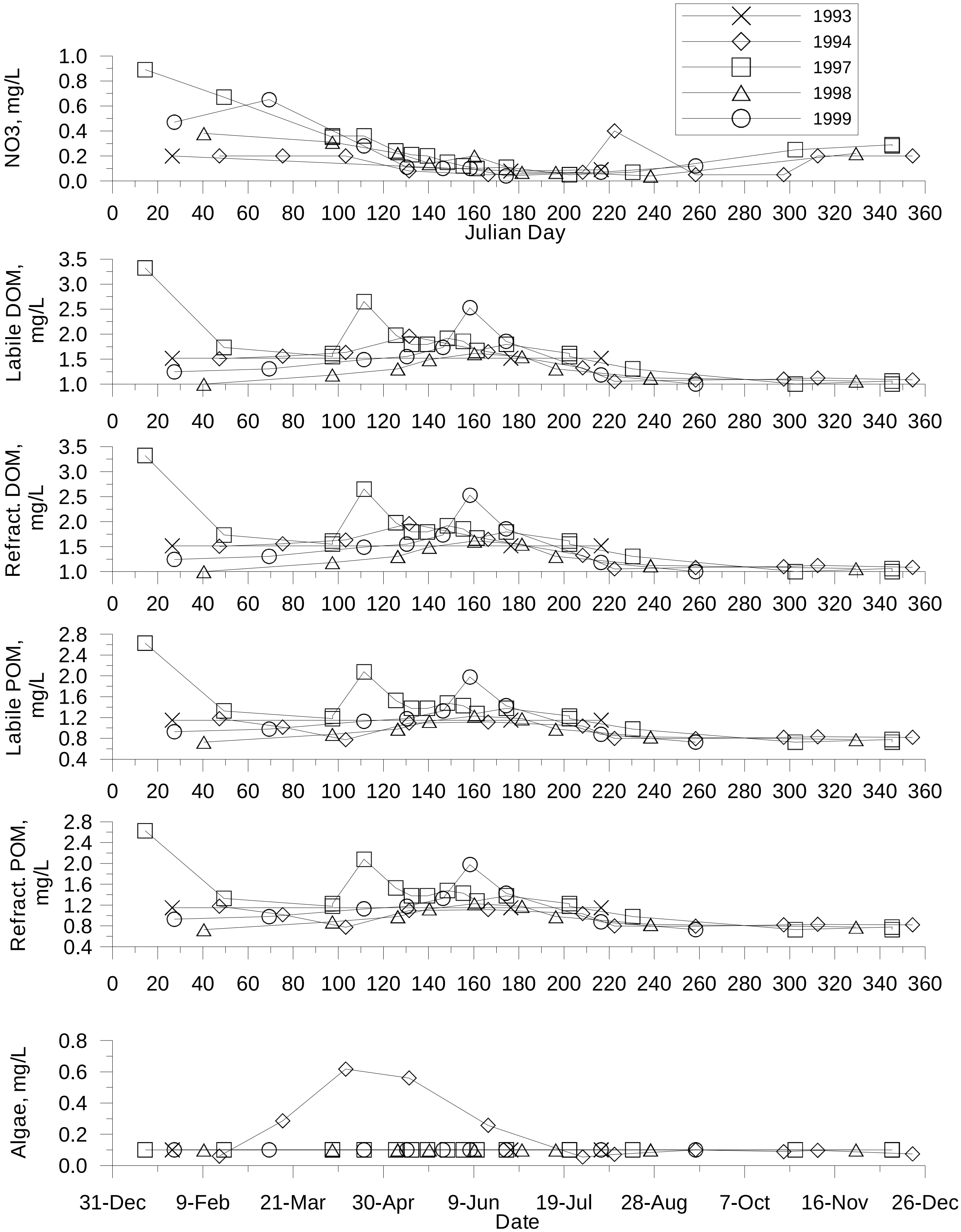



**Figure 22. Columbia River at Bonneville Dam Boundary Condition, RM 145 (Part 2)**

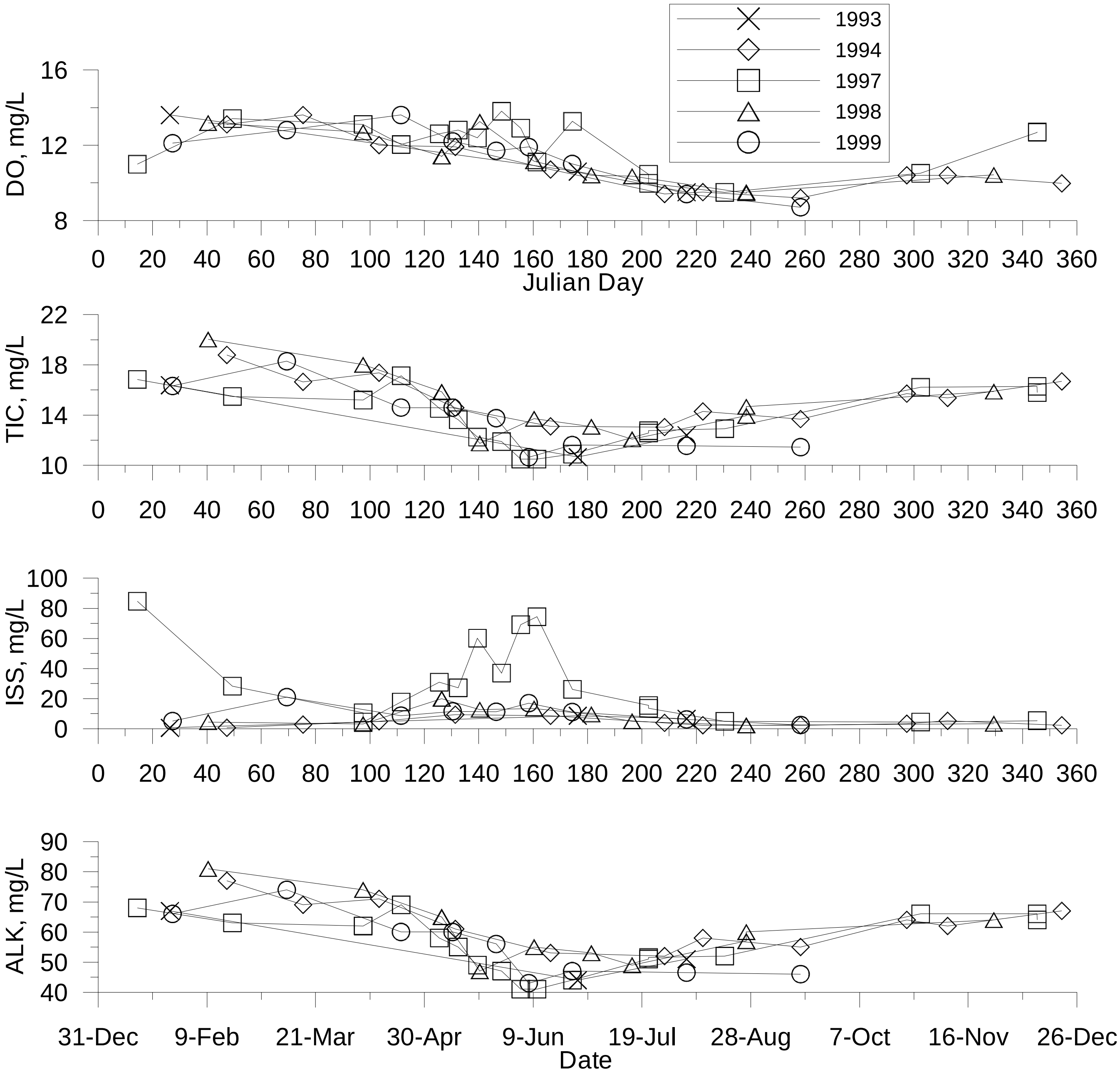



**Figure 23. Columbia River at Bonneville Dam Boundary Condition, RM 145 (Part 3)**

**Willamette River**

Flow data

There is currently no gage station on the Willamette River at Canby Ferry so flow routing models were investigated to develop the flow at Canby Ferry to serve as the upstream boundary condition. USGS developed a flow routing model to estimate daily flows in the Willamette River at Portland. This approach is based on measured daily flows upstream of the Portland gage station (USGS: 14211720). The equation used to estimate flows is:

Mean daily Q at Willamette River at Salem with 1 day lag

+ (Mean daily Q at South Yamhill) x 2 with 1 day lag
+ (Mean daily Q at Pudding near Woodburn) x 2 with 1 day lag
+ (Mean daily Q at Tualatin River-West Linn ) x 1.5
+ (Mean daily Q at Clackamas River-Estacada) x 1.5
+ Mean daily Q at Johnson Creek-Milwaukie
= Mean daily Q at Willamette River-Portland

The most upstream sites are lagged by one day to account for travel time and some of the lower sites are increased by a factor to account for ungaged flows. The flows from these stations were added together to obtain daily flows in the Willamette River at the Portland gage station (USGS: 14211720).

The U.S Army Corps of Engineers also developed the Lower Columbia River UNET Model (Knutson, 2000), a routing method to estimate daily flows in the Willamette River at Portland. The flow in the Willamette River at Portland was obtained using the following equation:

Mean daily Q at Molalla River-Canby
+ Mean daily Q at South Yamhill-Whiteson
+ Mean daily Q at Pudding-Aurora
+ Mean daily Q at Tualatin River-West Linn
+ Mean daily Q at Clackamas River-Estacada
+ Mean daily Q at W.R at Salem
+ Mean daily Q at Johnson Creek-Sycamore
+ Mean daily Q Ungaged between Salem and Oregon City
= Mean daily Q at Willamette River-Portland

In order to utilize this flow routing equation for a larger period of time the USACOE developed several flow correlations between stations in the Willamette basin to fill gaps found in the data. These correlations are shown in Table 4.

| Correlation Number | Correlation | Time Period |
|---|---|---|
| 1 | Molalla River at Canby = 0.48 * Clackamas at Estacada | prior 1929, 1959-1964, 1978-to present |
| 2 | Pudding River at Aurora = 0.60 * Yamhill at Whiteson | prior 1929, 1964-1993 |
| 3 | South Yamhill at Whiteson = 1.7 * Pudding River at Aurora | prior 1940, 1991-1994 |
| 4 | Johnson Creek at Sycamore = 0.024 * Clackamas at Estacada | prior 1940 |
| 5 | Ungaged Flow = (ungaged drainage area/Aurora Creek drainage area)*Pudding River at Aurora | |

**Table 4. USACOE correlations to estimate flow at Willamette River at Portland**

In order to determine which flow routing model was more appropriate for developing the boundary condition the flow in the Willamette River at Portland was estimated using both models for 1993 and 1994. The results were compared as shown in Figure 24, with daily data measured at the Willamette River at Portland gage station (USGS: 14211720) before it was discontinued in 1994. The difference between the estimated flows and the data were plotted in Figure 25. Error statistics were calculated, as shown in Table 5, to determine which approach gives a better representation of the flows at Portland. Based on the AME and RMS errors listed in the table the USACOE flow routing model provided a better approximation of the flow and was therefore used in developing the model boundary condition.

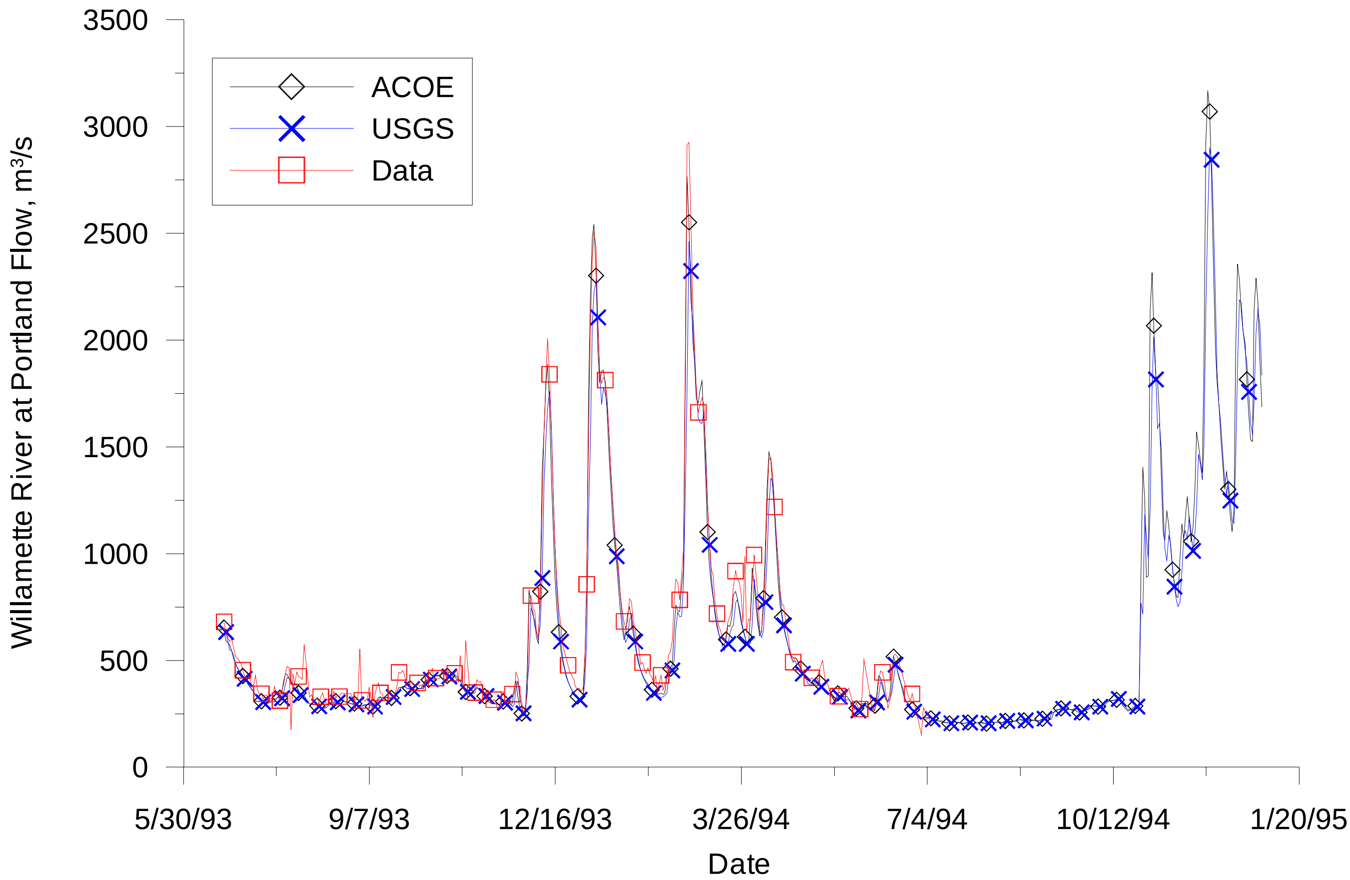



**Figure 24. Willamette River Flow at Portland comparison between data, the USGS model and the USACOE model**

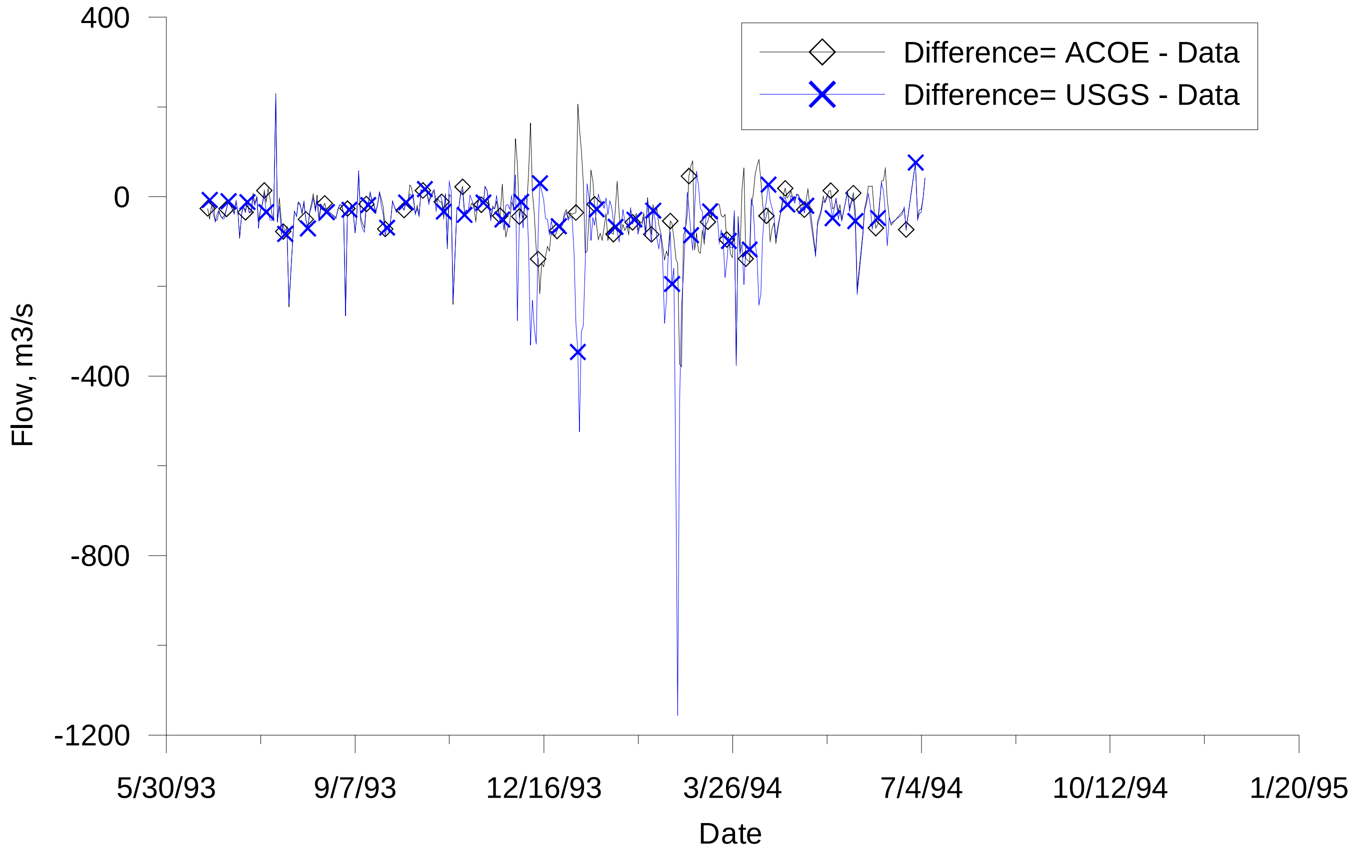



**Figure 25. Flow difference between data and routing models in Willamette River at Portland**

| Model comparison | Number of Days | Std Deviation ($m^3/s$) | AME ($m^3/s$) | RMS ($m^3/s$) |
|---|---|---|---|---|
| USACOE vs. Data | 356 | -37 | 52 | 75 |
| USGS vs. Data | 357 | -58 | 64 | 120 |

**Table 5. Flow Routing Model Comparison with data Statistics**

Willamette River flow near Canby Ferry was obtained using part of the USACOE flow routing model described above. The flow approximation was used:

Mean daily Q at Molalla River-Canby
\+ Mean daily Q at South Yamhill
\+ Mean daily Q at Pudding-Aurora
\+ Mean daily Q at W.R at Salem
\+ Mean daily Q Ungaged between Salem and Oregon City
= Mean daily Q near Canby Ferry

Table 6 shows the gage station used in developing the flow boundary condition at Canby Ferry and the extent of the data at each station.

| Site ID | Address | RM | Drainage Area mi2 | Datum ft NGVD | Min Date | Max Date | Flow Count |
|---|---|---|---|---|---|---|---|
| USGS14191000 | Willamette River at Salem | 84.2 | 7280 | 106 | 01/01/1948 | 09/13/2000 | 19248 |
| USGS14192500 | South Yamhill River near Willamina | | 133 | 236 | 05/01/1934 | 09/30/1993 | 21338 |
| USGS14193000 | Willamina Creek near Willamina | | 64.7 | 315 | 06/01/1934 | 09/30/1991 | 20941 |
| USGS14194000 | South Yamhill River near Whiteson | | 502 | 82 | 10/01/1940 | 09/30/1991 | 18627 |
| USGS14194150 | South Yamhill River at McMinnville | 5.6 | 528 | 50 | 10/01/1994 | 09/12/2000 | 2174 |
| USGS14201340 | Pudding River near Woodburn | | 314 | 130 | 10/01/1997 | 09/12/2000 | 1075 |
| USGS14202000 | Pudding River at Aurora | | 479 | 72 | 06/21/1993 | 09/30/1997 | 1563 |
| USGS14210000 | Clackamas River at Estacada | 23.1 | 671 | 287 | 11/28/1992 | 09/30/1999 | 2498 |
| USGS14211720 | Willamette River at Portland | 12.8 | 11100 | 2 | 07/06/1994 | 09/30/1999 | 1548 |

**Table 6. USGS gage stations used in developing the boundary condition and the extent of their data**

Due to data gaps at some of the gage stations correlations were developed between stations where data existed and the correlations in Table 4 were utilized to fill these gaps for the summers of 1993, 1994 and 1997 through 1999. The equation for developing the boundary condition flow at Canby Ferry used the daily flow data from the USGS gage station on the Willamette River at Salem for all five summers. The Molalla River flow was calculated using correlation 1 in Table 4 and the daily flow data from the Clackamas River at Estacada gage station.

For the summers of 1993 and 1994 the Pudding River flow was obtained from the Pudding River at Aurora gage station and for the summers of 1997 through 1999 the Pudding River at Woodburn gage station was used since the Aurora gage station was no longer operational. A correlation could not be developed between the two gages on the Pudding River because none of the data overlapped in time. The South Yamhill River flow at Whiteson was calculated using correlation 3 in Table 4 and the Pudding River flow at Aurora for 1993 and 1994. The South Yamhill River at McMinneville flow data was used for the flow at Whiteson for the summers of 1997 through 1999 since the stations were close together. The ungaged flow to the Willamette River between Salem and Oregon City was calculated using correlation 5 in Table 4 and the Pudding River flow (Aurora or Woodburn gage station data).

The remaining gap that existed in the data was from 05/01/1993 to 06/21/1993 at the Pudding River at Aurora gage station. Because of this gap the South Yamhill River flow and the ungaged basin flow could not be calculated. In order to fill the gap flow data from the South Yamhill basin was utilized. The goal of the analysis was to develop a daily flow time series for the South Yamhill River at Whiteson for 05/01/1993 to 06/21/1993. The first step in the analysis was to combine data upstream on the South Yamhill. Willamina Creek near Willamina (USGS: 14193000) has flow data from 1934 to 1991 and the South Yamhill near Willamina (USGS: 14192500) had flow data from 1934 to 1993. Table 6 lists the stations utilized in this analysis and the extent of the data at each station. A correlation was developed between these two gages station to complete the flow record at Willamina Creek for 1991 to 1993. The flow relationship used was 0.3926(Q, South Yamhill near Willamina, cfs)=Q, Willamina Creek near Willamina, cfs ($R^2$=0.9459). The correlation was then used to complete the data set for Willamina Creek and then the flows from the two gage stations were added together. The flow below Willamina was then correlated with the South Yamhill River flow at Whiteson (USGS: 14194000). The correlation developed was: 1.8986(South Yamhill below Willamina)=South Yamhill at Whiteson ($R^2$=0.8078). This correlation was then used to extend the flow record at Whiteson through June 21, 1993. The extended flow record at Whiteson was then used with correlation 2 in Table 4 to calculate the flow in the Pudding River at Aurora. Correlation 5 in Table 4 was then used to calculate the ungaged basin flow. Since several correlations were used to develop the necessary flows on the South Yamhill River a comparison was made between the Willamette River at Canby Ferry flow with the South Yamhill Correlations developed above and with using the Pudding River at Aurora data when it was available. Figure 26 shows the comparison plot with flow difference statistics. Figure 27 shows the Willamette River flows at Canby Ferry for the summer periods modeled.

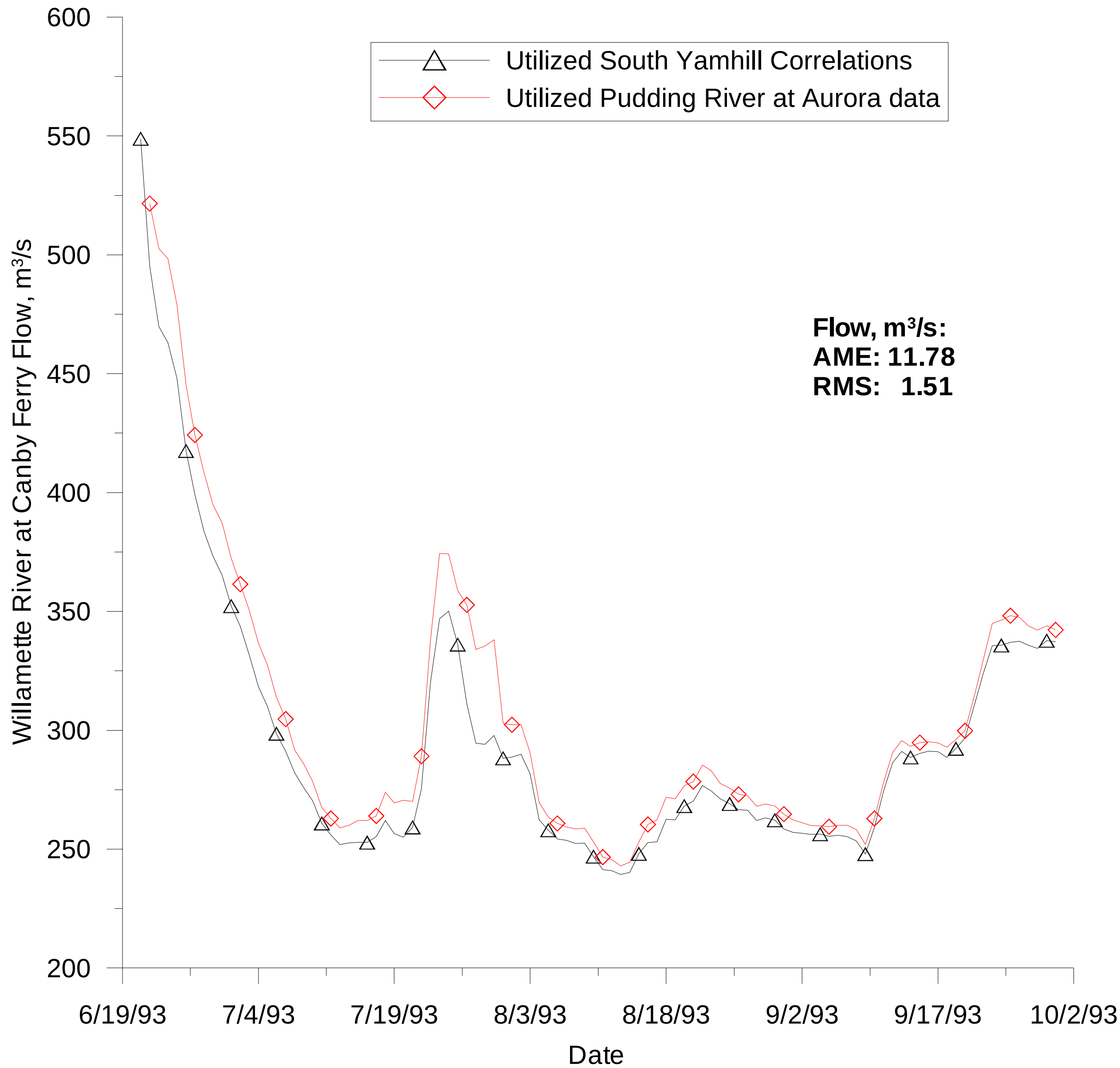



**Figure 26. Willamette River at Canby Ferry flow comparison, Summer 1993**

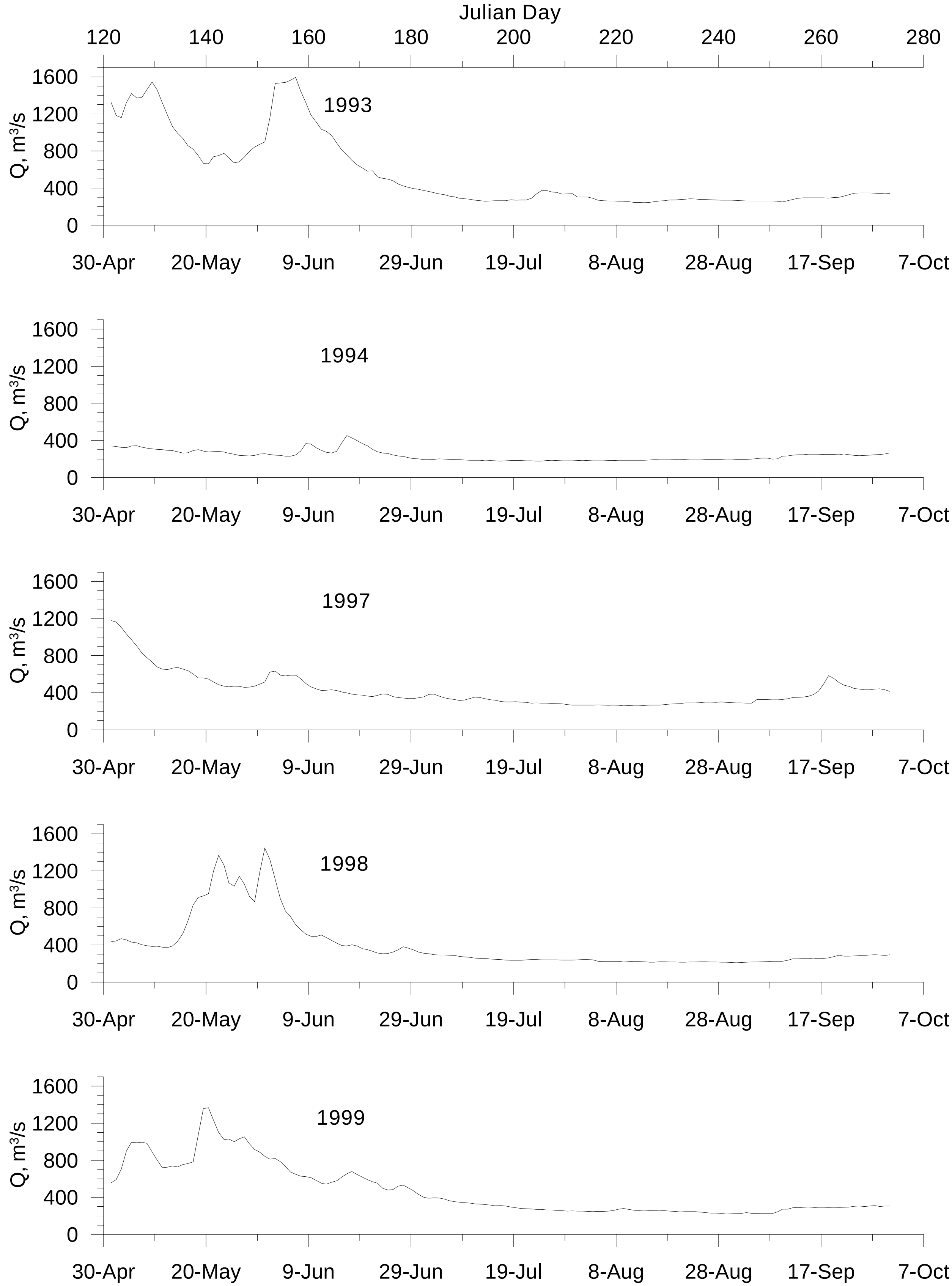



**Figure 27. Willamette River flow near Canby Ferry (RM 35), $m^3/s$**

### Water Quality

Temperature and water quality data at Canby Ferry were obtained from DEQ (STORET data) and from two monitoring studies conducted by Montgomery Watson (1997 and 1999) for the City of Tigard and the Tualatin Valley Water District. These monitoring studies measured temperature and water quality parameters in the Willamette River at Wilsonville (RM 41). DEQ STORET water quality data consists of grab samples taken once a month to a couple of times a year. Water quality data monitored by Montgomery Watson were taken about once a week from 1994 to 1999.

Water quality data measured at Wilsonville and DEQ data measured at Canby Ferry were combined to generate the input files for the model. Figure 28 shows water temperature in the Willamette River at Canby Ferry for the period modeled. Table 7 shows a list of water quality parameters available for the Willamette River at Canby Ferry. Figure 29 through Figure 31 show the water quality constituents used for the boundary condition in the model. The procedure used for developing the water quality files from data can be found in Appendix J: Water Quality file development procedures. Further discussion of the water quality boundary conditions is found in Berger et al. (2001) during model calibration.

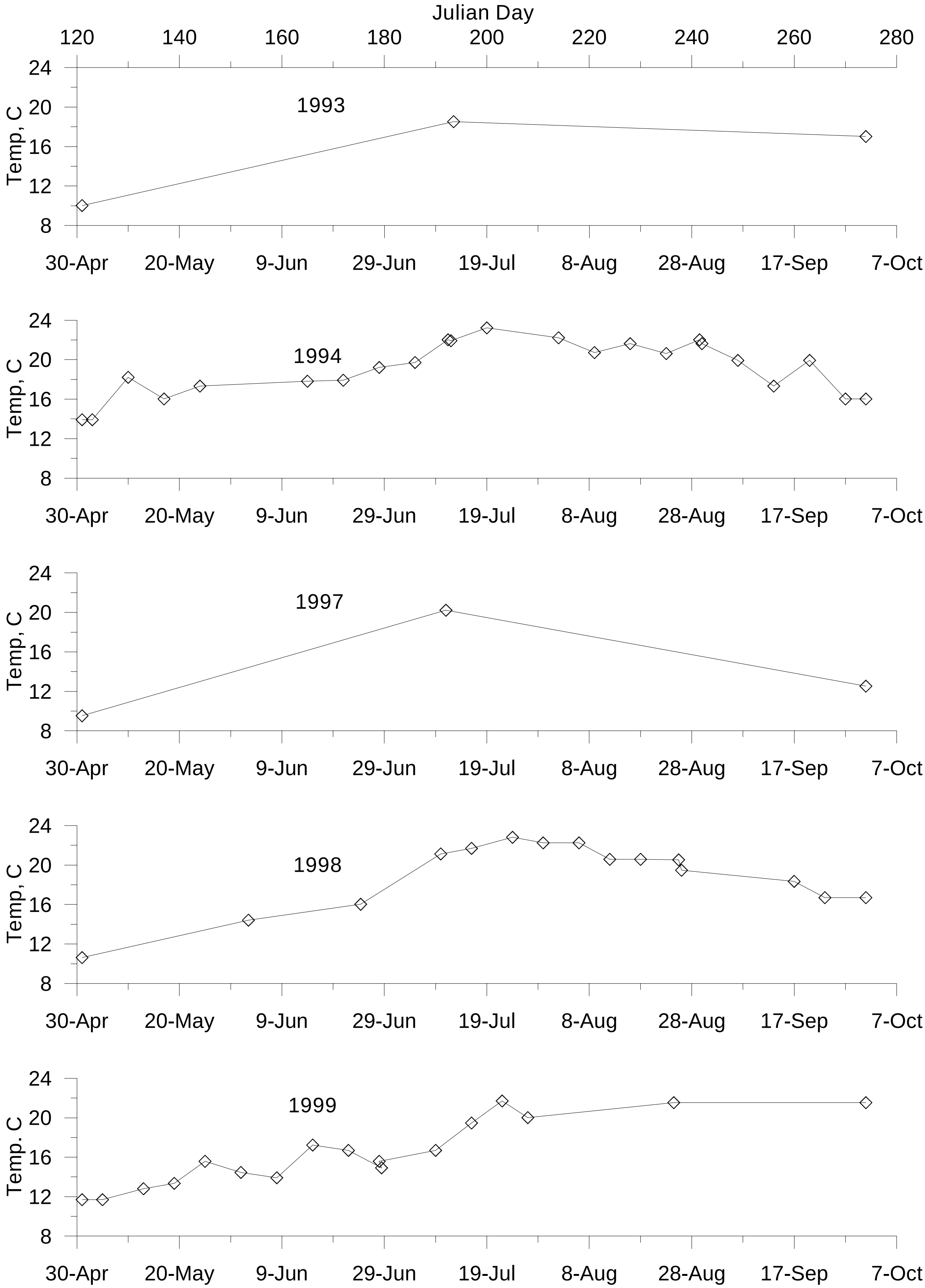



**Figure 28. Willamette River at Canby Ferry water temperature, $^oC$**

| Parameters | Willamette River at Canby Ferry |
| --- | --- |
| Alkalinity | X |
| Ammonia-Nitrogen mg/L | X |
| BOD 5 DAY | X |
| Calcium Hardness | X |
| CHLRPHYL A | X |
| COLOR PT-CO | X |
| Conductivity, mS/cm | X |
| D ORG C C | X |
| Dissolved Oxygen | X |
| D.O Saturation | X |
| E.COLI | X |
| ENTCOCCI | X |
| Fecal Coliforms ./100 mL | X |
| NH3+NH4- N TOTAL | X |
| Nitrate-N mg/L | X |
| NO2&NO3 N-DISS | X |
| NO2&NO3 N-TOTAL | X |
| PH | X |
| PHOS-DIS ORTHO | X |
| PHOS-TOT | X |
| SUSP SED CONC | X |
| T ALK CACO3 | X |
| T ORG C C | X |
| Temperature | X |
| Total Coliform | X |
| Total Hardness | X |
| Turbidity | X |
| UN-IONZD NH3-N | X |
| UN-IONZD NH3-NH3 | X |

**Table 7. Water Quality parameters available for the Willamette River Boundary Condition**

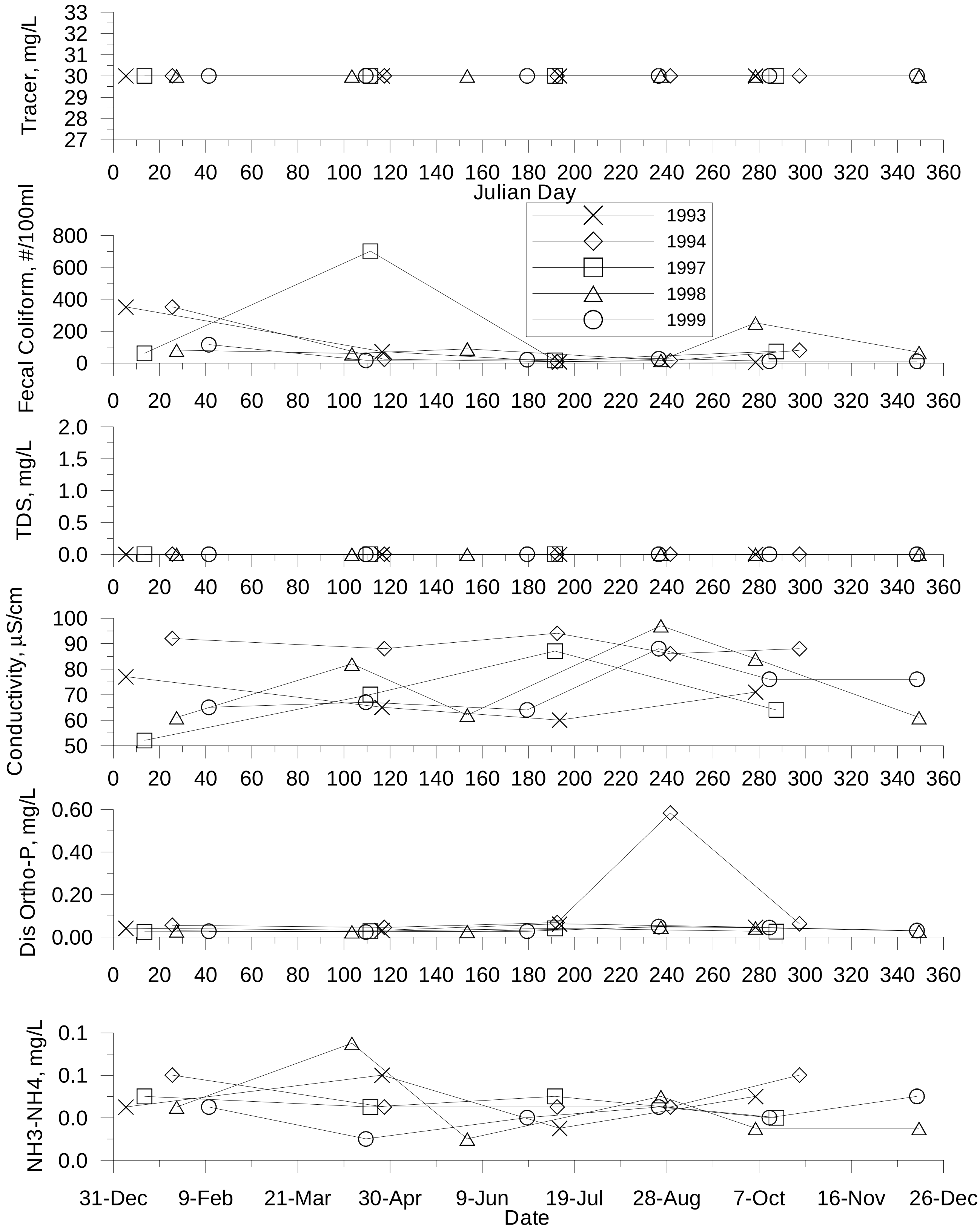



**Figure 29. Willamette River at Canby Ferry Boundary Condition, RM 35**

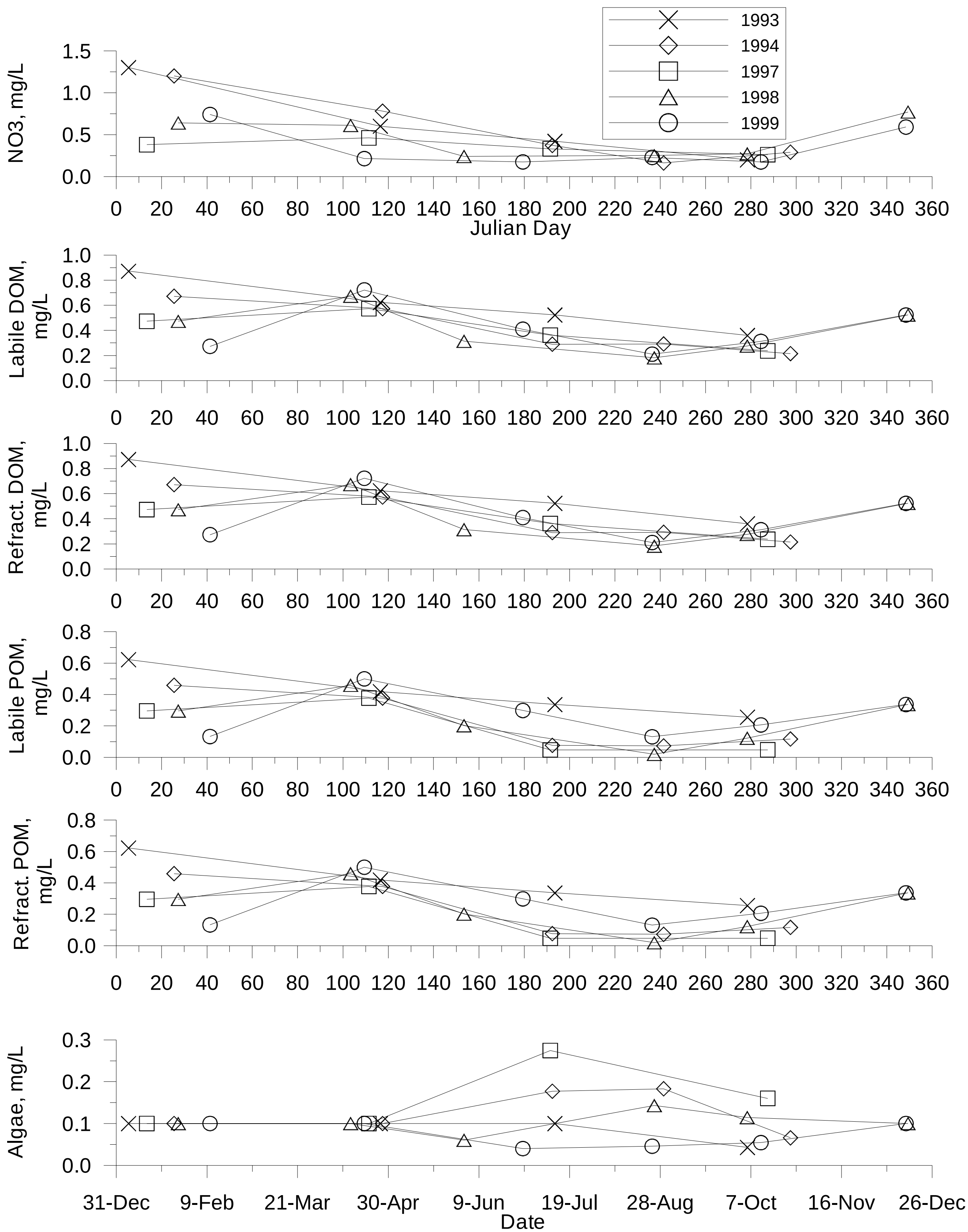



**Figure 30. Willamette River at Canby Ferry Boundary Condition, RM 35 (Part 2)**

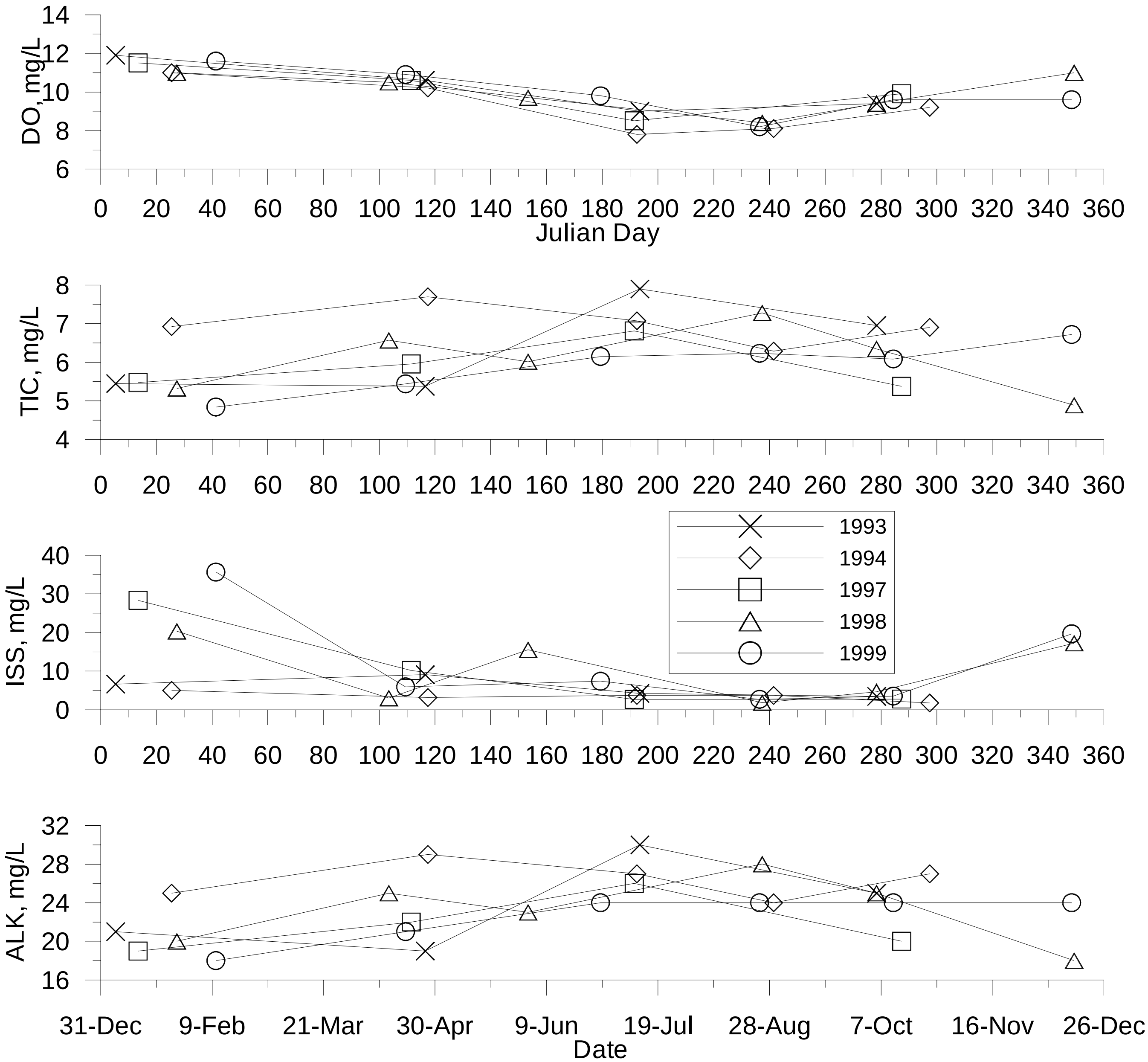



**Figure 31. Willamette River at Canby Ferry Boundary Condition, RM 35 (Part 3)**

## Meteorological Data

Meteorological data were collected at Portland International Airport and include air temperature, wind speed, wind direction, dew point, and cloud cover. Figure 32 shows the location of the Portland International Airport and several other meteorological stations in the model region. The Portland International Airport was selected because it contained the longest historical record of data and fairly represents the meteorological conditions in the model domain. Future work could investigate the feasibility of using additional meteorological stations such as the Aurora Airport. Figure 33 through Figure 37 show the meteorological data at the Portland International Airport from January 1992 to September 2000. In Figure 37 cloud cover varies on a scale of 0 to 10 with zero representing no cloud cover and ten representing full cloud cover. In July 1996 the method for measuring cloud changed to a scale of 1 to 4 resulting in less approximate conditions.   The scale was converted to a 1 to 10 scale to be compatible with historical data.

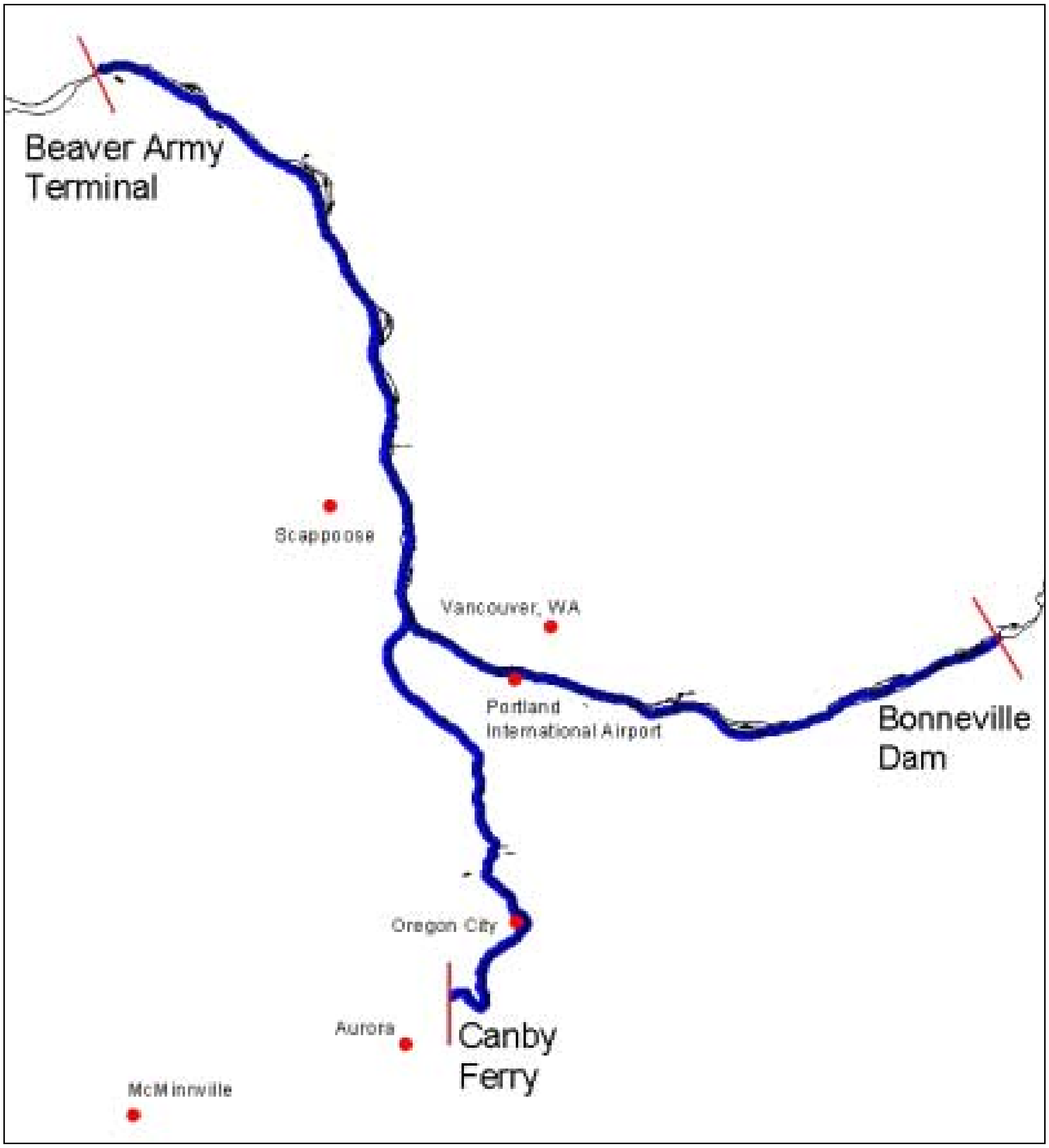



**Figure 32.  Location of several met stations in the model region**

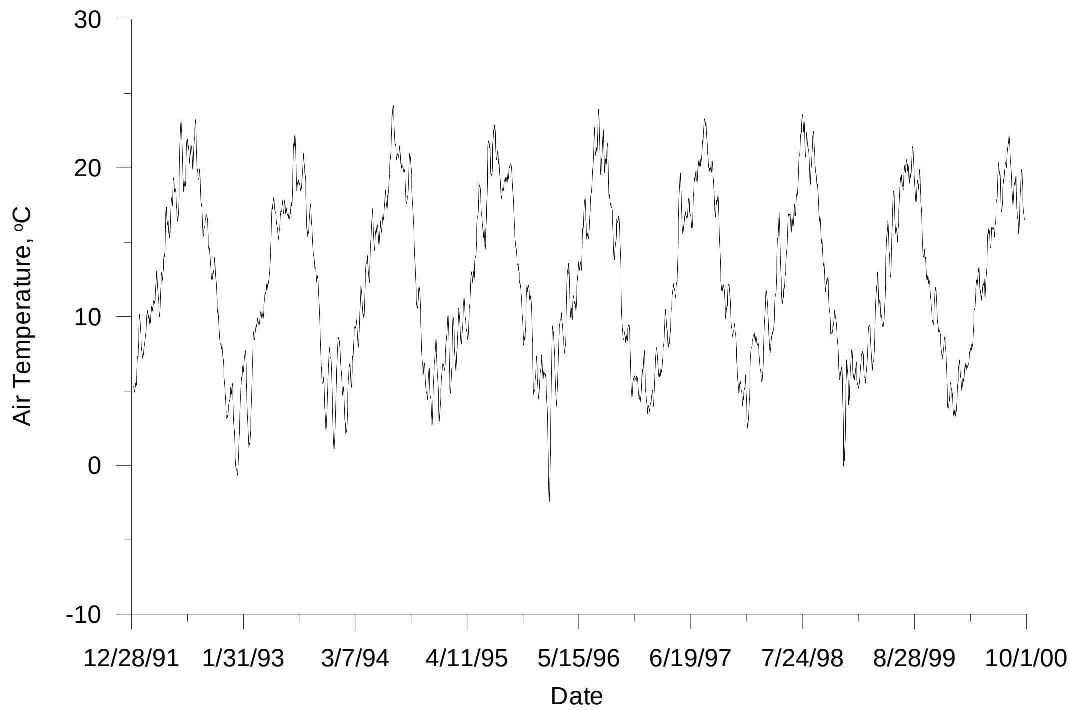



**Figure 33. Air Temperature, °C, 10 day moving average at the Portland International Airport 1992-2000**

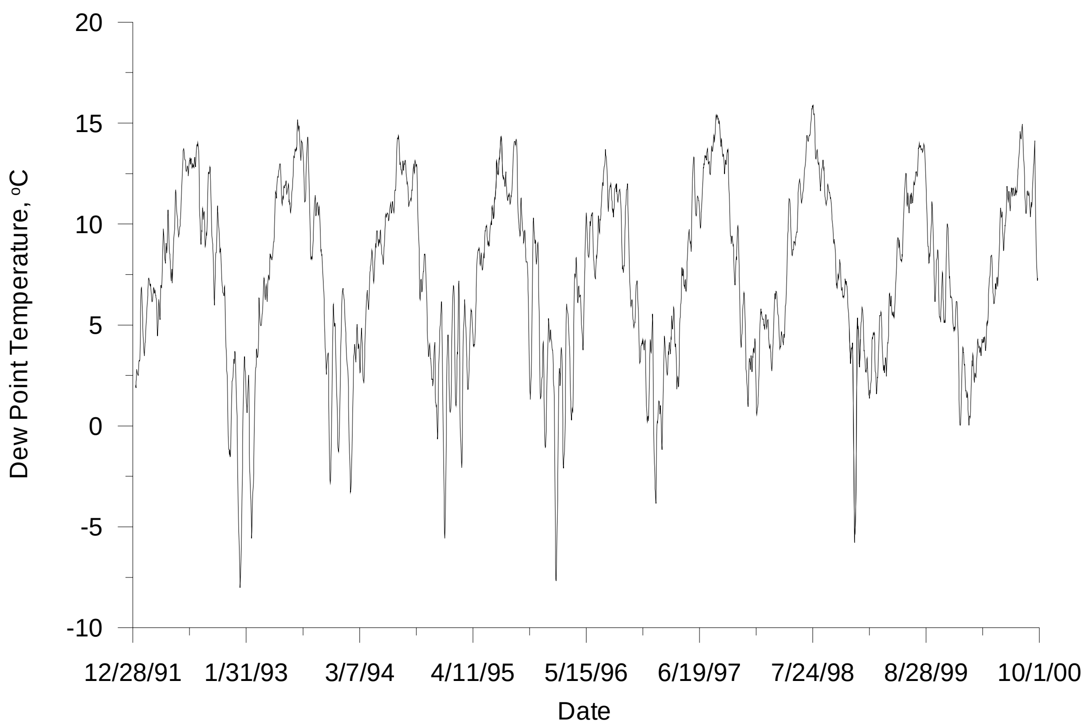



**Figure 34. Dew Point Temperature, °C, 10 day moving average at the Portland International Airport 1992-2000**

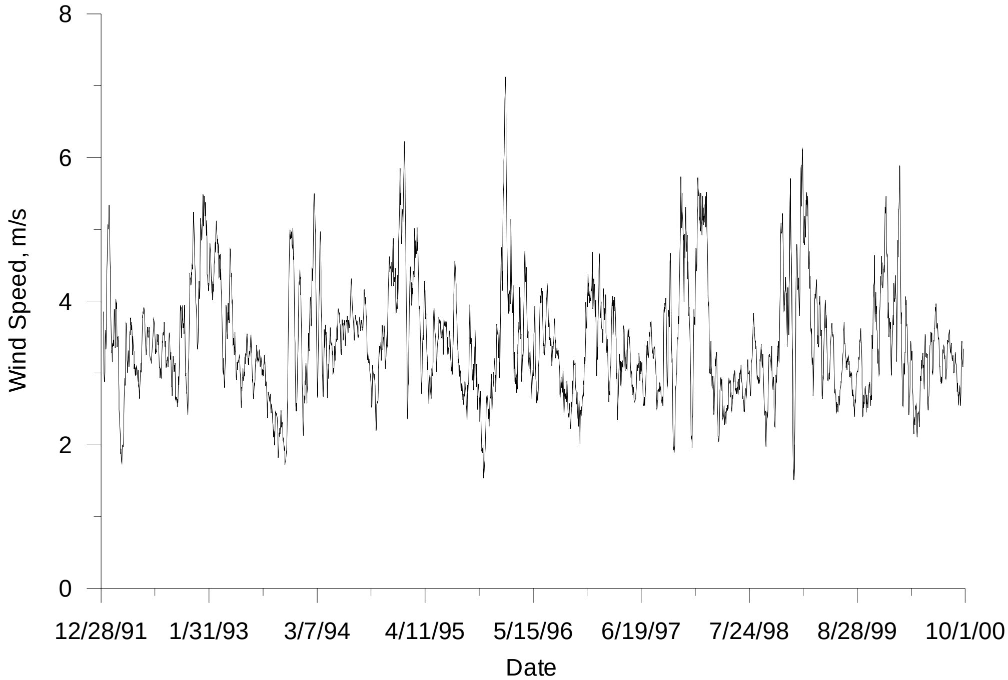



**Figure 35. Wind Speed, m/s, 10 day moving average at the Portland International Airport, 1992-2000**

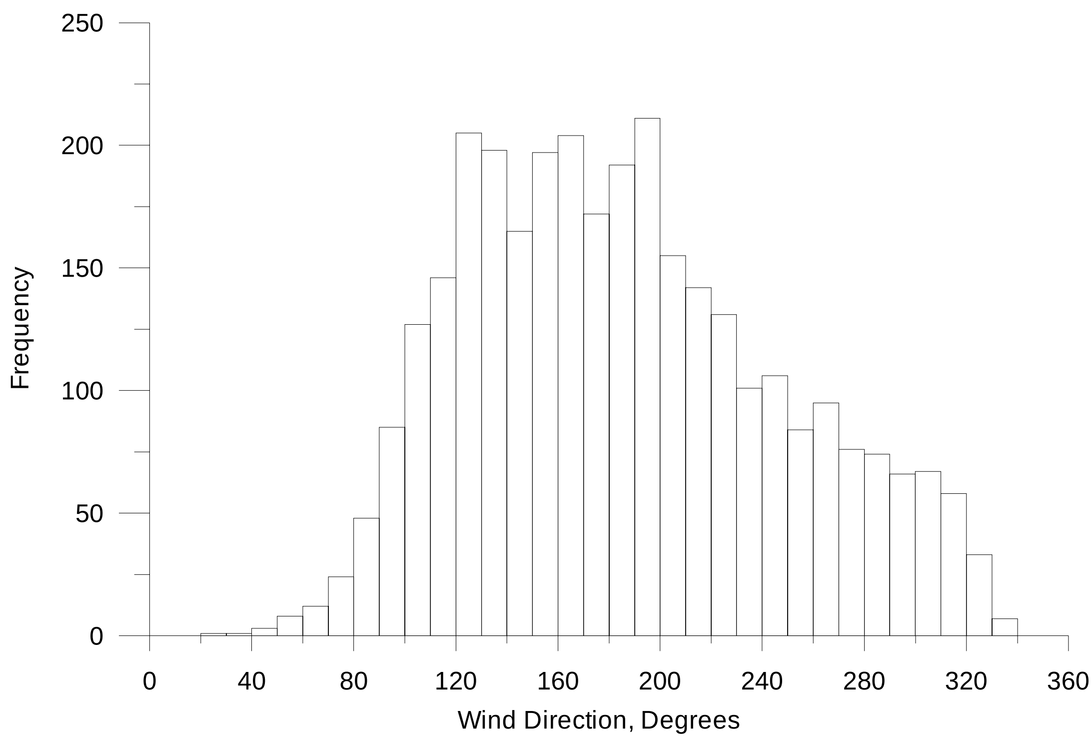



**Figure 36. Wind Direction, degrees, 10 day moving average at the Portland International Airport, 1992-2000**

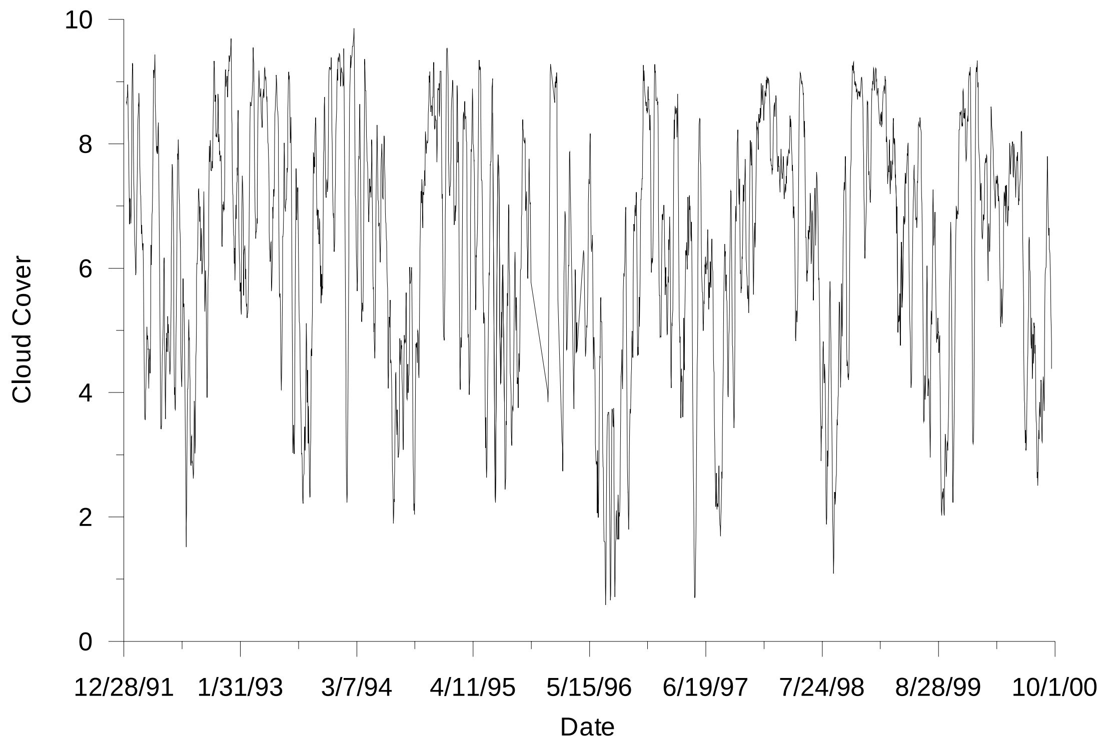



**Figure 37. Cloud Cover 10 day moving average at the Portland International Airport, 1992-2000**

## Tributary Inflows

The majority of the tributary inflows to the Columbia and Willamette River were considered in the model. Nevertheless, a small number of these tributaries were not characterized because flow information was not available. Figure 38 shows the shaded basins where the tributary inflows were not considered explicitly in the model. An analysis was conducted using a Geographic Information System, which determined the total drainage area not considered in the model was about 0.34%. The analysis considers the entire Columbia River basin above Bonneville Dam and the entire Willamette Basin above Canby Ferry which are not shown in Figure 38.

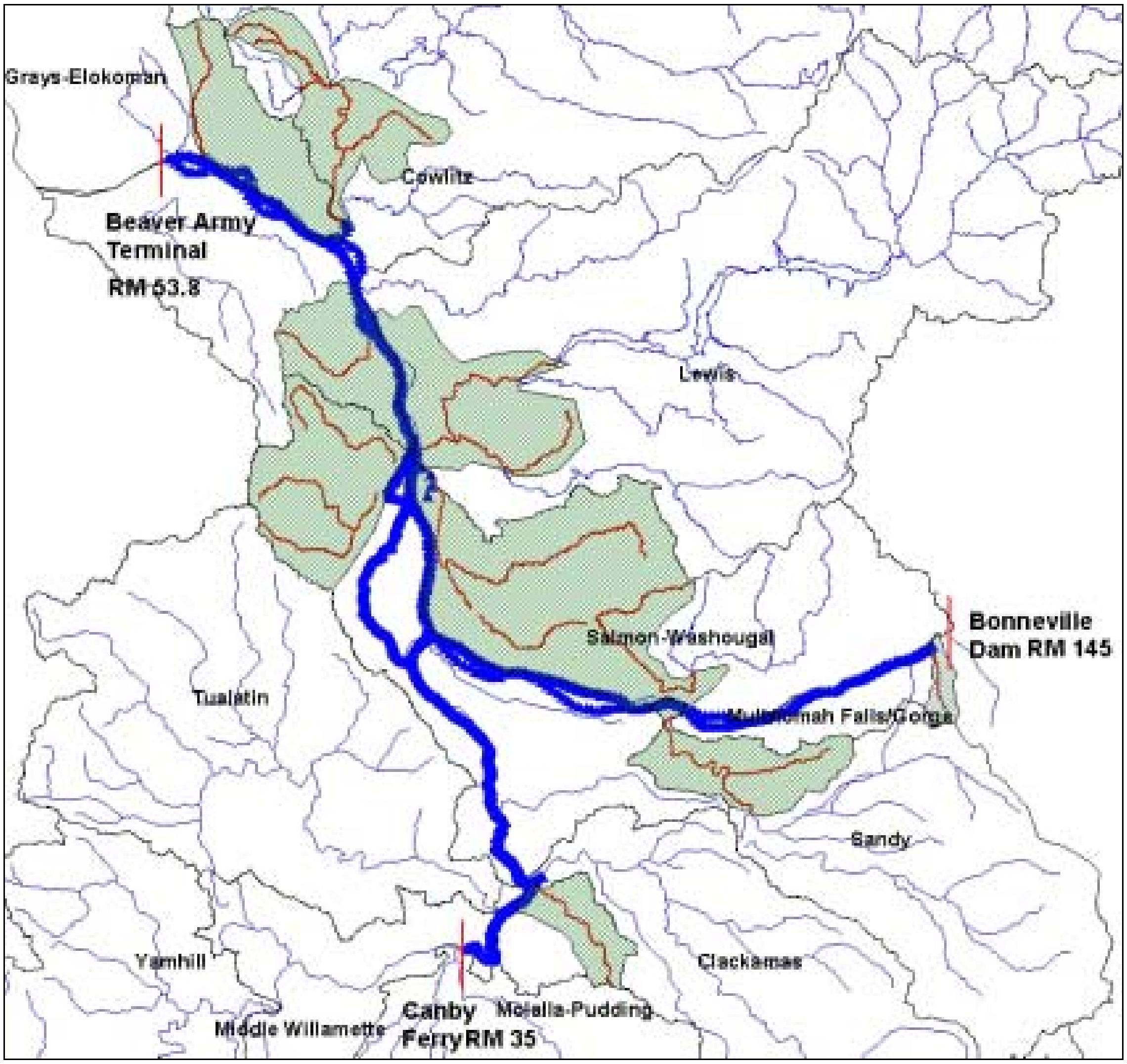



**Figure 38. Columbia and Willamette River tributary inflows, shaded basins have no flow data**

Willamette River

*Flow*

The data set for the Willamette River tributaries was obtained from the USGS gage stations shown in Table 8 and their locations are shown in Figure 39. The extent of the data can be found in Appendix I. Input files for the model were developed using continuous and daily data; however, correlations were also developed using nearby stations to fill data gaps when they existed.

| Site ID | Tributary |
|---|---|
| USGS14211820 | Columbia Slough |
| USGS14211550 | Johnson Creek At Milwaukie |
| USGS14210000 | Clackamas River at Estacada |
| USGS14207500 | Tualatin River at West Linn |

**Table 8. Willamette River Tributary gage stations**

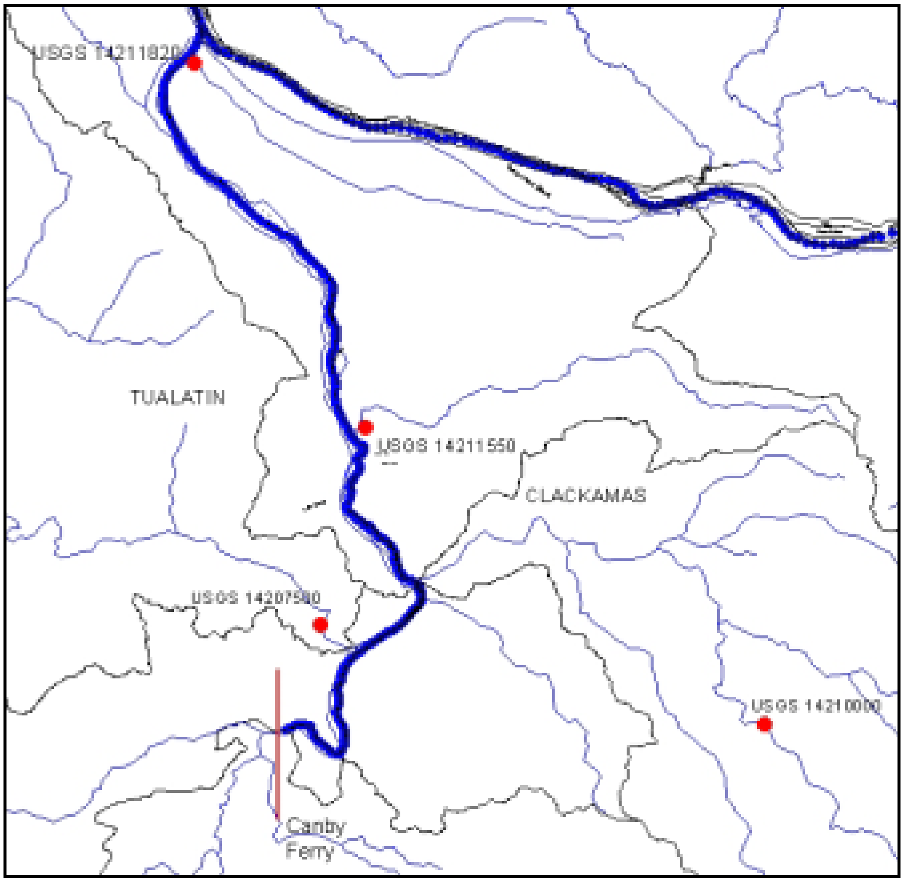



**Figure 39. USGS gage stations in the Willamette River Basin**

Columbia Slough flow data at the Lombard station (USGS: 14211820) and Johnson Creek flow data at Milwaukie (USGS: 14211820) are recorded continuously. The input files for CE-QUAL-W2 were created using the continuous data for the summers (May 1 to September 30) of 1993,1994, 1997,1998, and 1999. For the Johnson Creek station continuous data for the year 1997 was missing consequently daily data was used to fill in gaps for the model input file. Daily flow data for the Tualatin River gage station located at West Linn was also used to create input files for CE-QUAL-W2. Figure 40 through Figure 42 show flows in the Columbia Slough, Johnson Creek, and Tualatin River for the summer periods modeled.

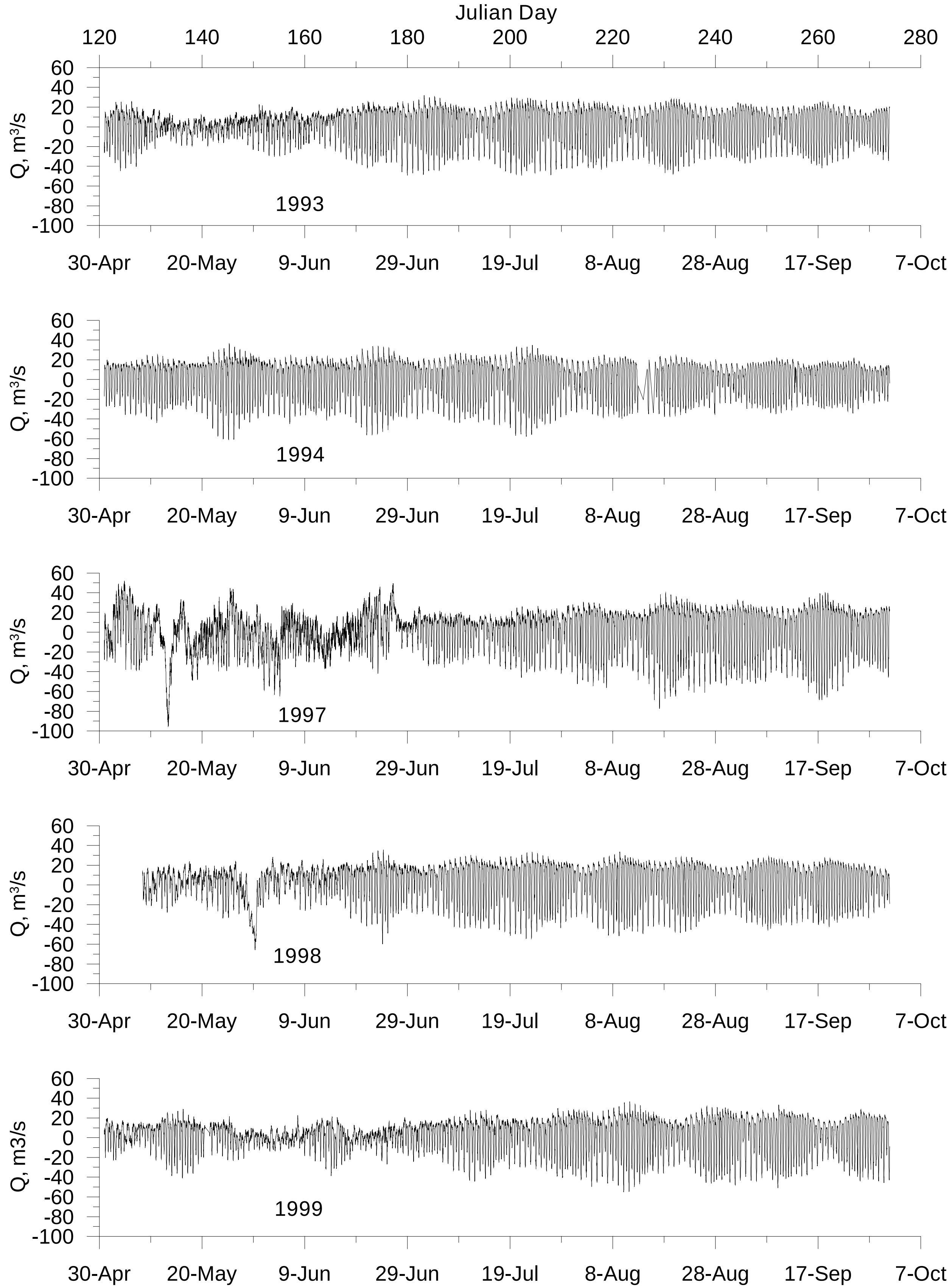



**Figure 40. Columbia Slough flow, $m^3/s$**

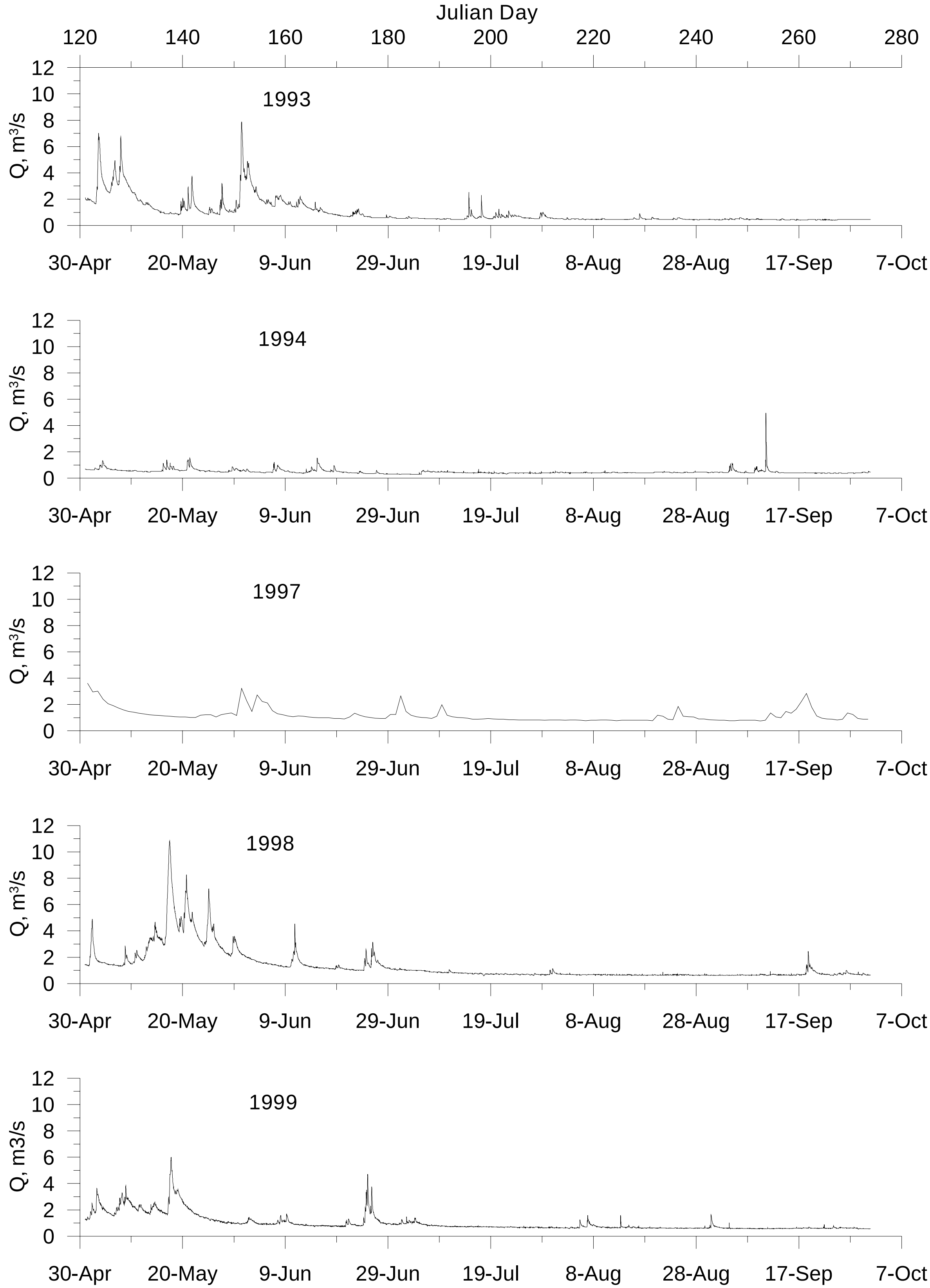



**Figure 41. Johnson Creek flow, m$^3$/s**

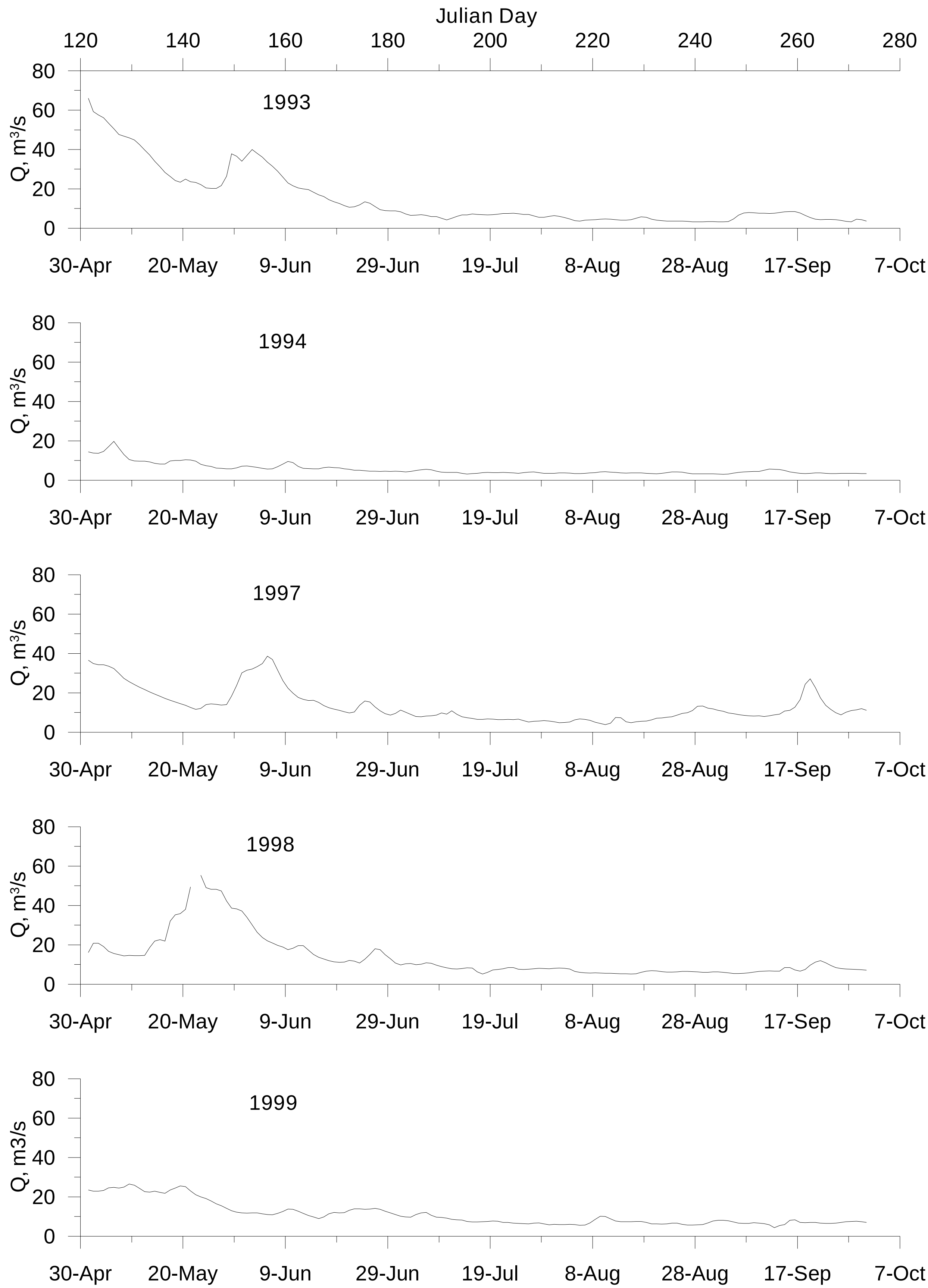



**Figure 42. Tualatin River flow, $m^3/s$**

The USGS gage station on the Clackamas River at Estacada (USGS: 14210000, RM 25.5) has recorded continuous flow data for the time periods modeled. A correlation was developed to obtain flows near the mouth of the Clackamas River using daily flow data from the Clackamas River station near Clackamas (USGS: 14211000) and daily data for the Clackamas station at Estacada from 10/01/1962 to 09/30/1983. The correlation relates daily flows between the two stations using the drainage areas as follows ($R^2$ = 0.9852):

$$Q_1 = \alpha\left(\frac{Area_1}{Area_2}\right)Q_2$$

Figure 43 shows the correlation between the Clackamas River station at Clackamas and the Clackamas River station at Estacada. Figure 44 shows the flows for the Clackamas River at Clackamas, OR, using the correlation, for the summers modeled.

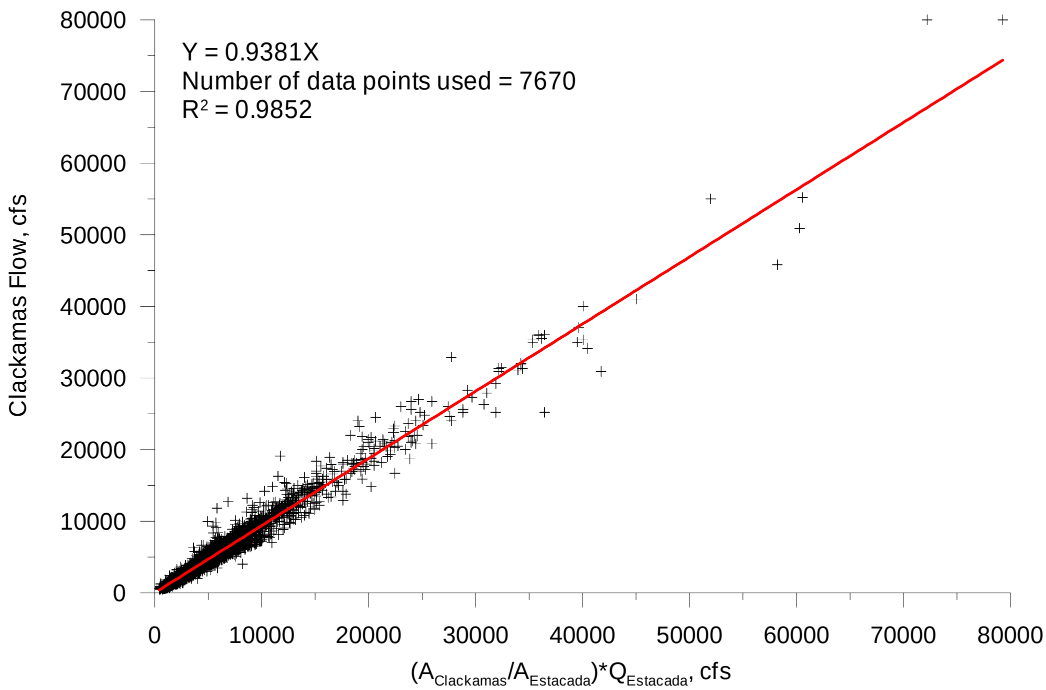



**Figure 43. Clackamas River near Clackamas and Clackamas River at Estacada Flow Correlation, Year 1962 to 1983**

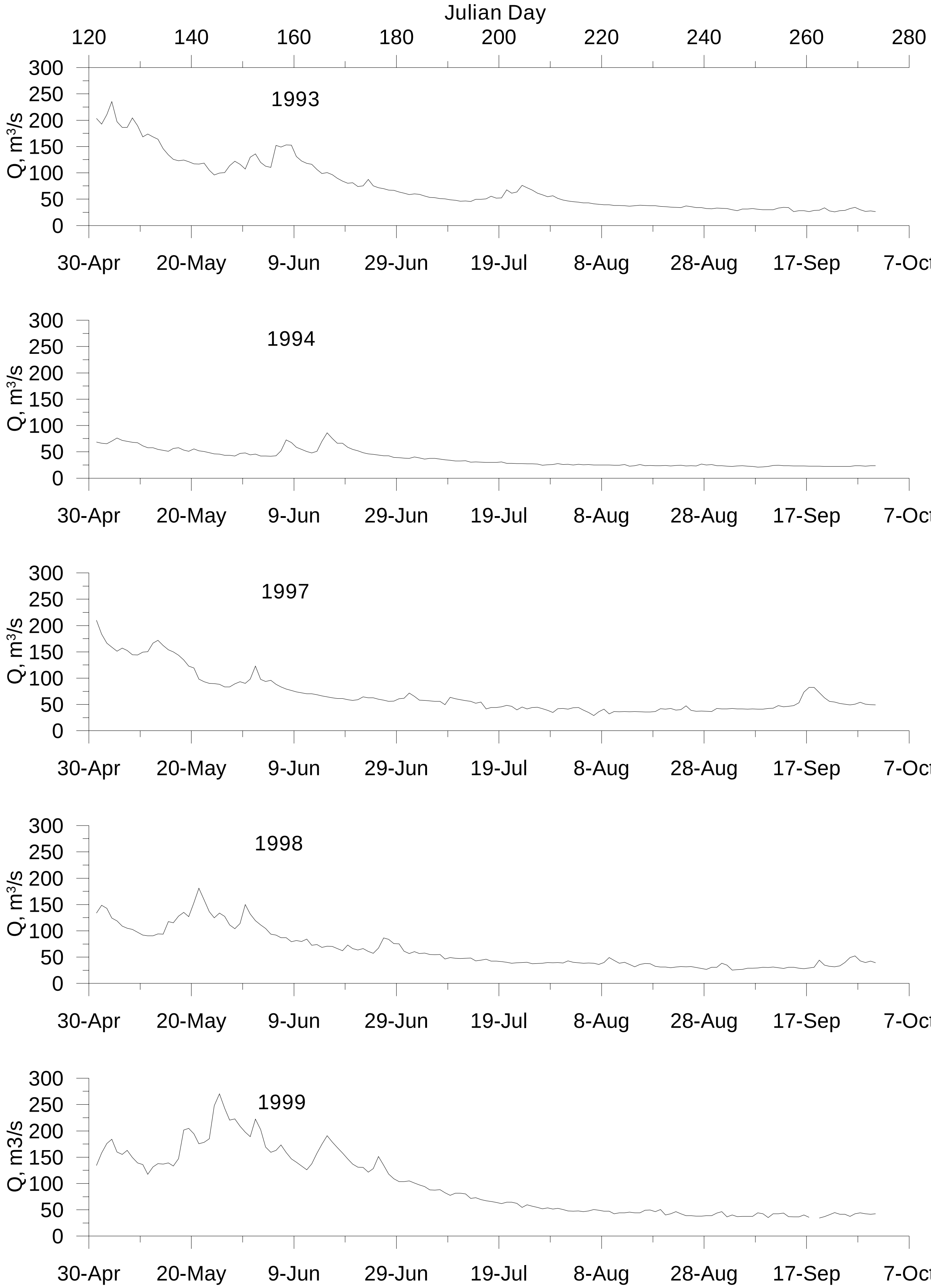



**Figure 44. Clackamas River flow, m$^3$/s**

*Water Quality*

Temperature and water quality data for the Willamette River tributaries were obtained from the Oregon Department of Environmental Quality (DEQ), US Geological Survey (USGS), the City of Lake Oswego, and the Metro Regional Government (Metro). DEQ water quality data consist of grab samples taken at a frequency of monthly to twice a year. USGS measures continuous temperature in Johnson Creek at Milwaukie and continuous temperature, conductivity, dissolved oxygen, and pH in the Tualatin River near West Linn. The City of Lake Oswego collects water quality data in the Clackamas River (RM 0.3) every 4 hours. Some of the constituents measured are temperature, pH, alkalinity, conductivity, color, and turbidity. Metro has a continuous Hydrolab in the Columbia Slough that measures temperature, dissolved oxygen, dissolved oxygen saturation, conductivity, and pH.

Data provided by these agencies were combined to generate input files for the model. Figure 45 through Figure 47 and Figure 49 show water temperature for the Willamette River tributaries. In the Columbia Slough there was a lack of temperature data at Lombard St. Bridge (LOM, RM 0.45) so a correlation was developed with temperature measurements at Saint John's Landfill Bridge (SJB, RM 2.9). The correlation is shown in Figure 48 and resulted in the correlation equation: LOM Temp($C^o$)=0.9118(SJB Temp($C^o$) + 0.6183 ($R^2$=0.9584). Figure 49 shows the LOM temperature data and temperatures obtained from the correlation. Table 9 shows a list of water quality parameters available for the Willamette River tributaries. The procedure used for developing the water quality files from data can be found in Appendix J: Water Quality file development procedures.

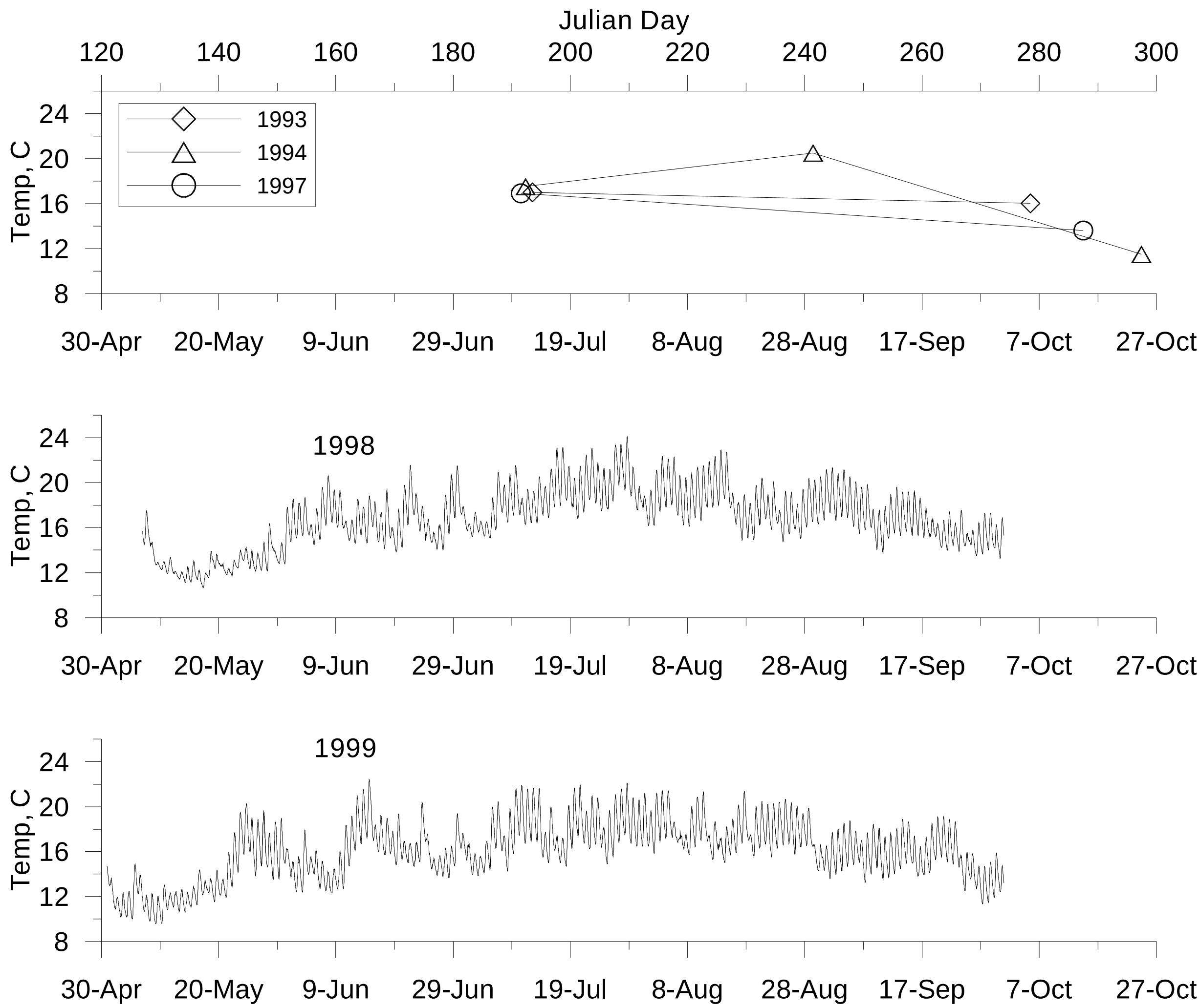



**Figure 45. Johnson Creek water temperature, $^oC$**

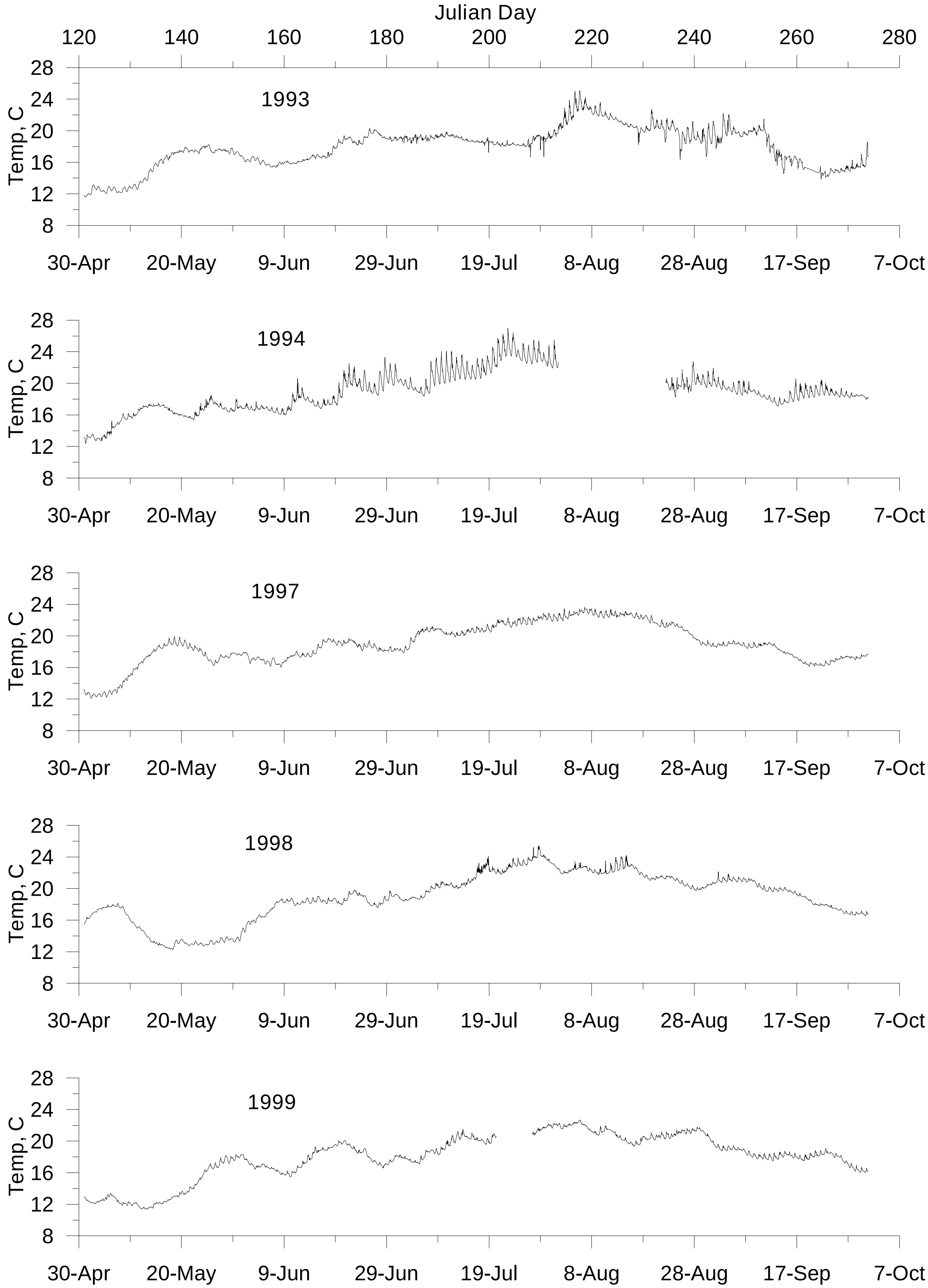



**Figure 46. Tualatin River water temperature, $^{o}C$**

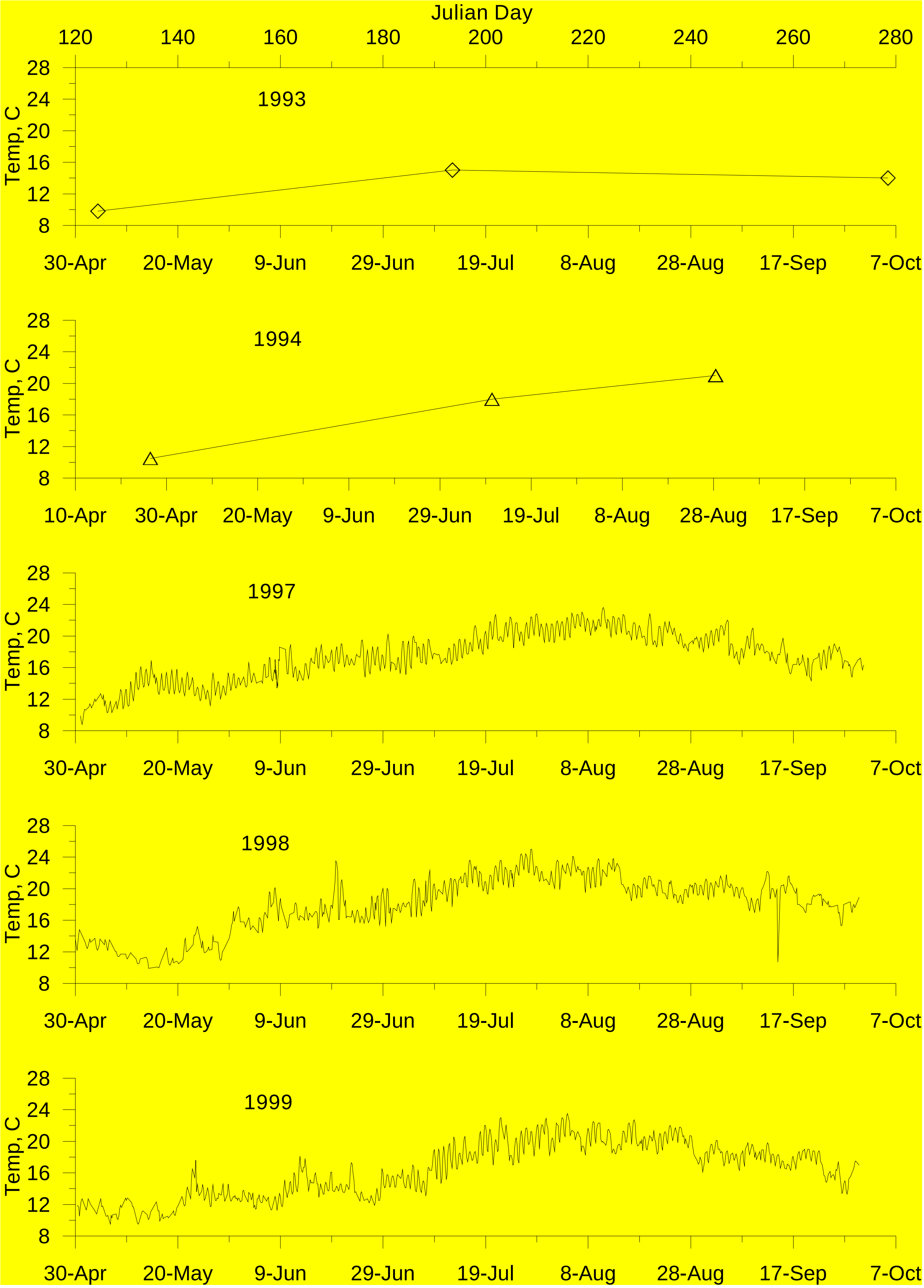



**Figure 47. Clackamas River water temperature, $^oC$**

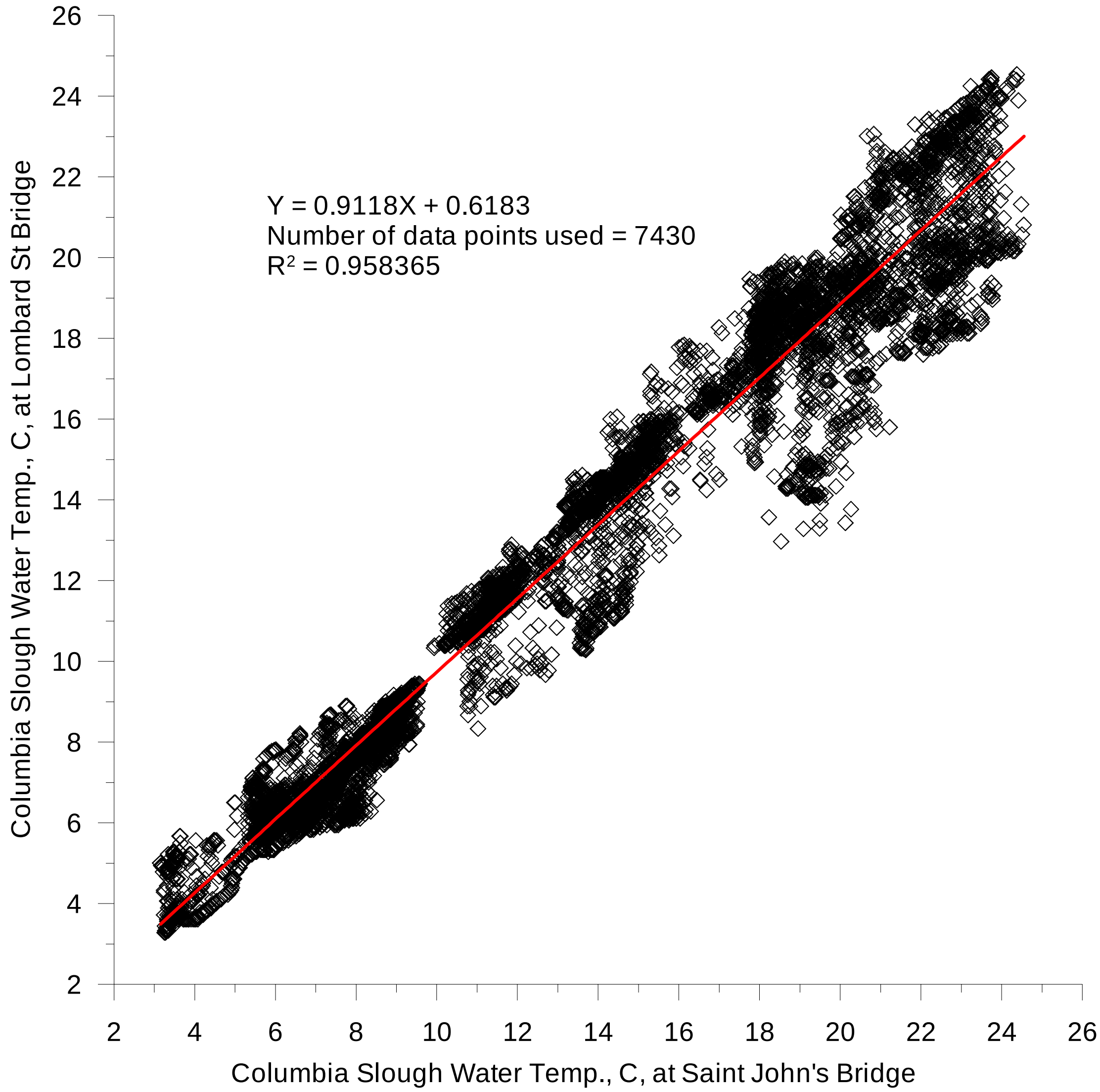



**Figure 48. Columbia Slough Water Temperature Correlation**

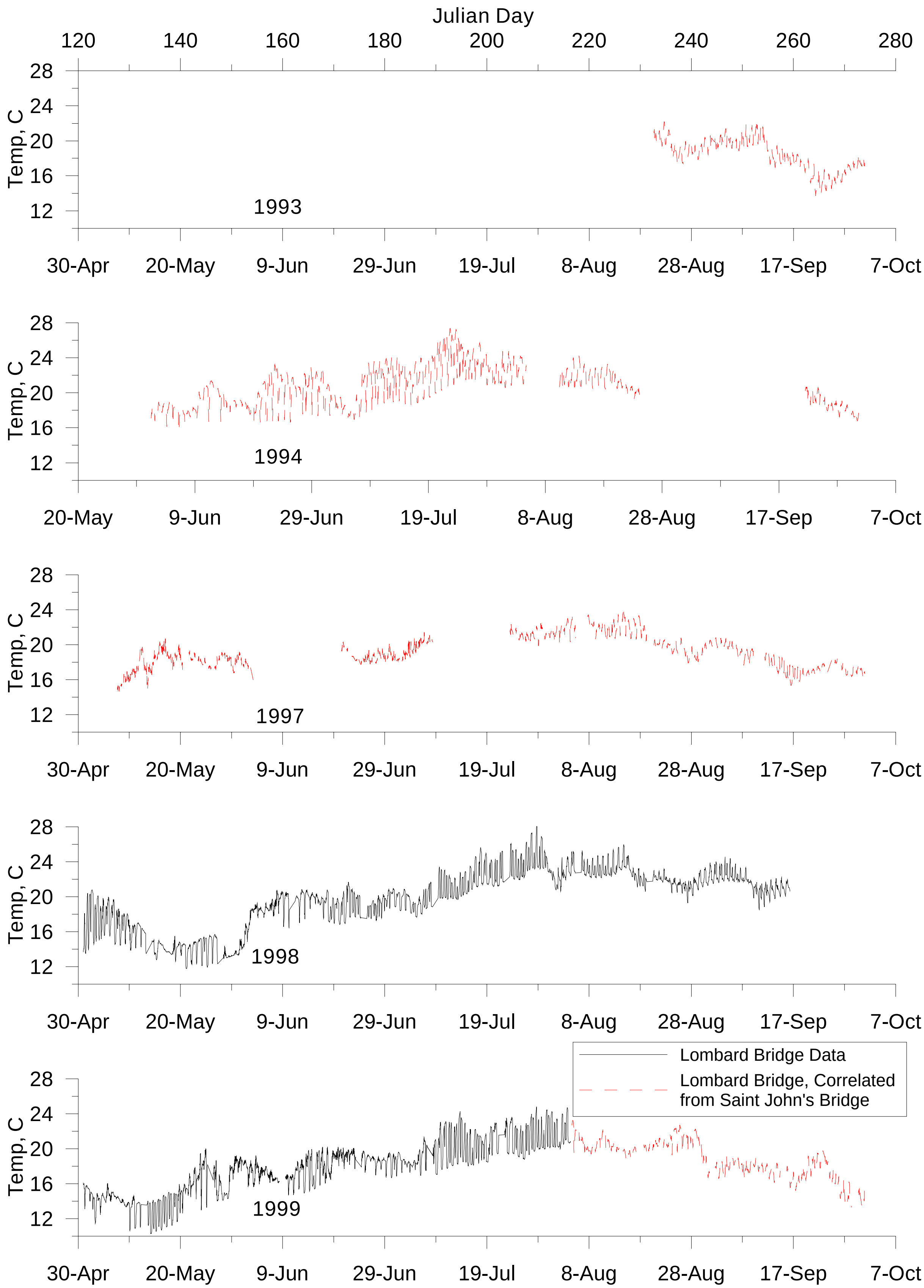



**Figure 49. Columbia Slough water temperature, $^{o}C$**

| Parameter | Clackamas River | Johnson Creek | Tualatin River | Columbia Slough |
|---|---|---|---|---|
| ALKLNITY WTR DISS | X | | | |
| BOD | X | X | X | X |
| CAL HARD CA MG | | X | X | X |
| CHLRPHYL A | X | X | X | X |
| COLOR | X | X | X | |
| Conductivity | X | X | X | X |
| D ORG C C | | X | | |
| DO, % sat | X | X | X | X |
| DO, mg/L | X | X | X | X |
| E.COLI | X | X | X | X |
| ENTCOCCI | X | X | X | X |
| Fecal Coliform | X | X | X | X |
| HARDNESS | X | X | | X |
| NH3 | | | | X |
| NH3+NH4- N DISS | | X | X | |
| NH3+NH4- N TOTAL | X | X | X | X |
| NH3-N | | | | X |
| NH4 | | | | X |
| NO2&NO3 N-DISS | X | X | X | X |
| NO2&NO3 N-TOTAL | X | X | X | X |
| NO2-N DISS | | X | X | |
| NO3 | | | | X |
| NO3-N | | | | X |
| NO3-N TOTAL | | | X | |
| OPO4 | | | | X |
| PH | X | X | X | X |
| PHOS-DIS | | X | | |
| PHOS-DIS ORTHO | X | X | | X |
| PHOS-T ORTHO | | | X | |
| PO4-P | | | | X |
| S ORG C C | | X | | |
| SUSP SED CONC | X | X | X | |
| SUSP SED PARTSIZE | X | | | |
| T ALK CACO3 | X | X | X | X |
| T ORG C C | X | X | X | X |
| TDS | | | | X |
| Temperature | X | X | X | X |
| TOC | | | | X |
| TOT HARD CACO3 | | | X | |
| Total Phosphorus | X | X | X | X |
| T-PO4 | | | | X |
| TSS | | | | X |
| Turbidity | X | X | X | X |
| UN-IONZD NH3-N | X | X | X | X |
| UN-IONZD NH3-NH3 | X | X | X | X |

**Table 9. Water Quality parameters available for the Willamette River tributaries**

Columbia River

*Flow*

The major tributaries to the Columbia River, excluding the Willamette itself, are identified in Table 10. Flow data for these tributaries was obtained from USGS gage stations and from the Washington State Department of Ecology (WADOE). Figure 50 shows the locations of the USGS and WADOE stations used to develop the input files for CE-QUAL-W2. Figure 51 shows the watersheds included in the model. The extent of the data can be found in Appendix I.

The Washington State Department of Ecology conducted a study to characterize baseflows for rivers and streams in Washington (Sinclair and Pitz, 1999). Table 10 has six stations where recent flow measurements were not available but the State of Washington estimated monthly baseflows. These stations were used to develop input flows for the model.

| | |
|---|---|
| USGS14142500 | Sandy River Below Bull Run River, OR |
| USGS14143500 | Washougal River Near Washougal, WA |
| USGS14144000 | Little Washougal River Near Washougal, WA |
| USGS14220500 | Lewis River at Ariel, WA |
| USGS14243000 | Cowlitz River at Castle Rock, WA. |
| WSDE14246000 | Abernathy Creek near Longview, WA |
| WSDE14246500 | Mill Creek near Cathlamet, WA. |
| WSDE14243500 | Delameter Creek near Castle Rock, WA. |
| WSDE14245000 | Coweman River near Kelso, WA. |
| WSDE14223500 | Kalama River below Italian Creek near Kalama, WA. |
| WSDE14221500 | Cedar Creek near Ariel, WA. |

**Table 10. Columbia River Tributary gage stations**

The inflow to the Columbia River from the Grays-Elokoman basin was characterized by adding baseflows for the Abernathy Creek near Longview and Mill Creek near Cathlamet as shown in Figure 50. Figure 51 also shows the portion of the Grays-Elokoman basin that contributes to the model domain. The input file for the model was created using monthly averaged baseflows for the summer months modeled since no other data were available.

Kalama River flows were also characterized using monthly baseflows estimated at the Kalama River near Kalama as shown in Figure 50, since the basin was lacking flow data. Figure 51 shows the size of the Kalama basin. Figure 52 shows the flows for the Grays-Elokoman basin and the Kalama River for the summers modeled.

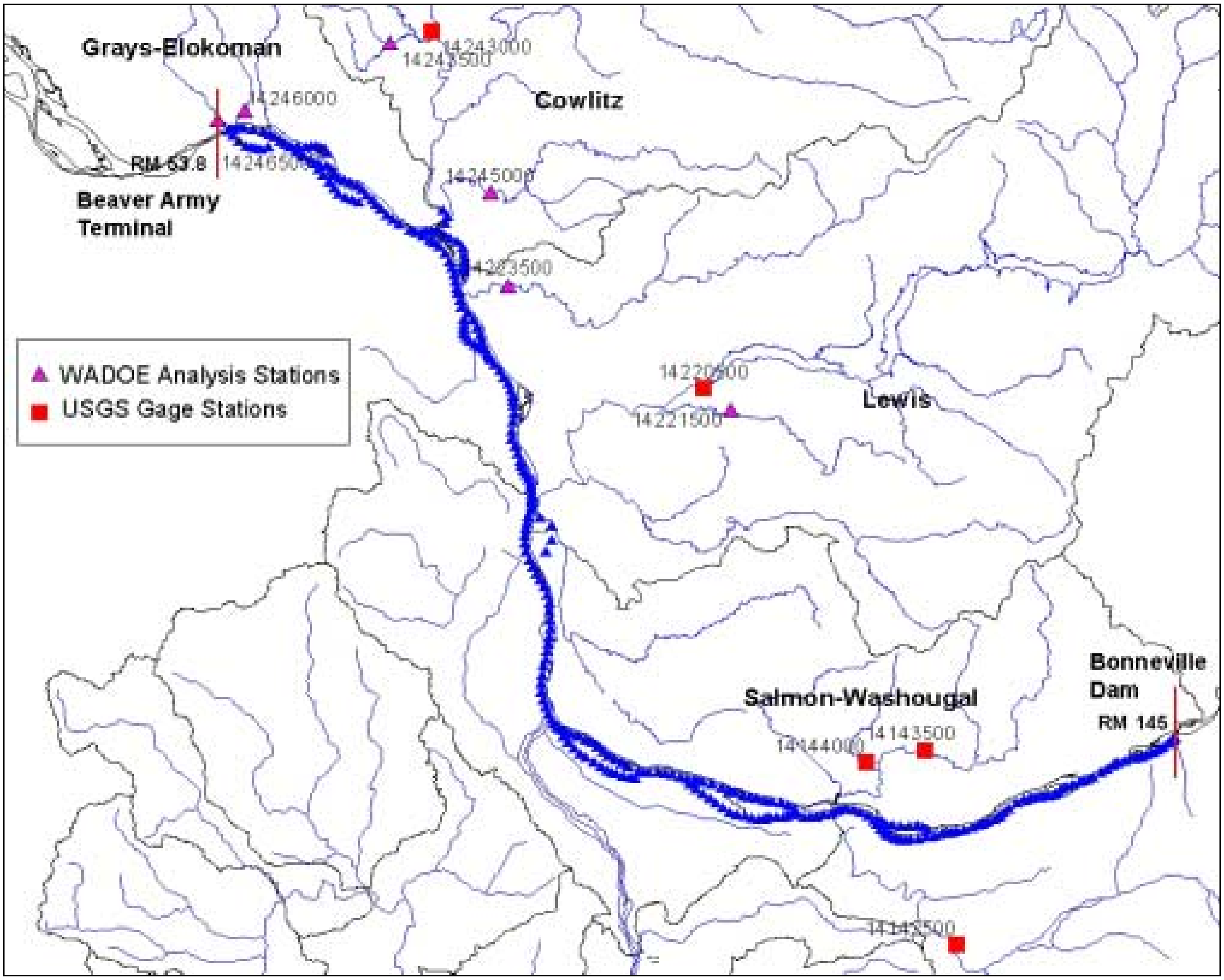



**Figure 50. Columbia River Tributary gage stations**


**Figure 51. Washington basins considered in the model**

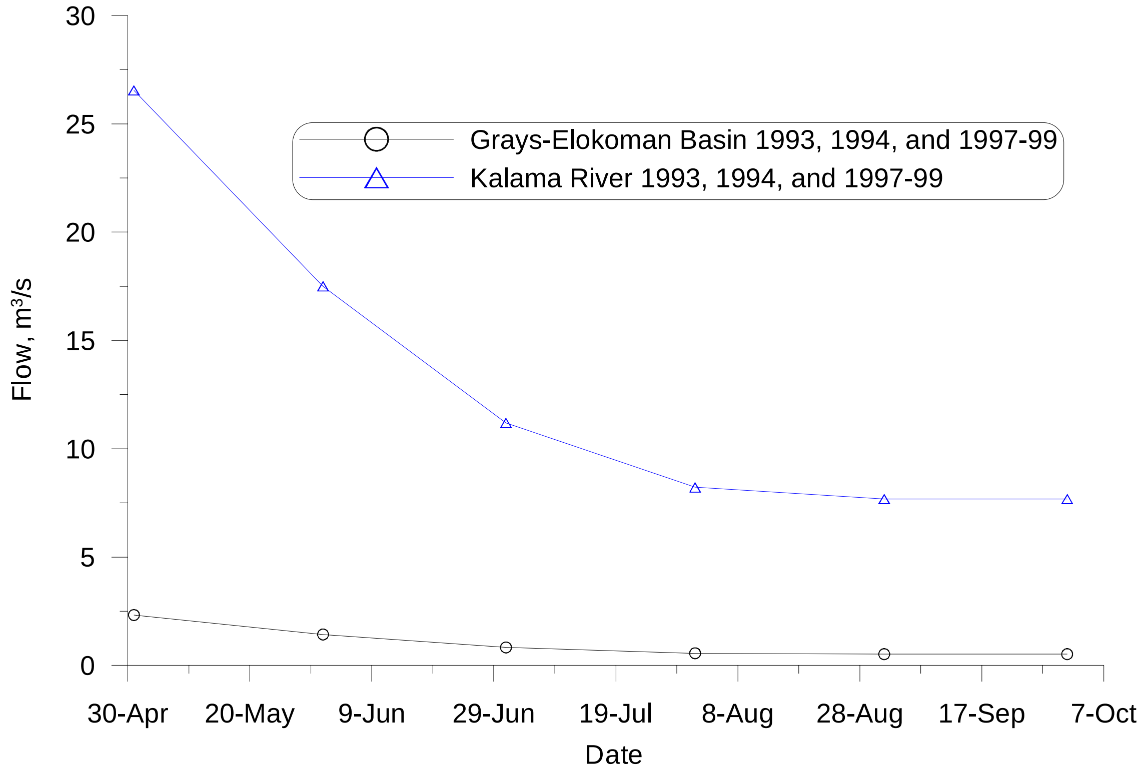



**Figure 52. Grays-Elokoman Basin and Kalama River flows, $m^3/s$**

The Cowlitz basin was characterized using continuous data for the Cowlitz River station at Castle Rock (USGS: 14243000) for the summers of 1994, and 1997 to 1999 and daily data for 1993 since there was a gap in the continuous data. Figure 51 shows the Cowlitz basin and its tributaries. The data from this station were added to the baseflows estimated at the Delameter Creek station near Castle Rock and the Coweman River station near Kelso to obtain the total Cowlitz basin inflow. Figure 53 shows flows for the Cowlitz River for the modeled summer periods.

Lewis basin flows were calculated by adding daily average flows for the Lewis River station at Ariel and the East Fork of the Lewis River. Figure 51 shows the Lewis River Basin and its tributaries. Additionally, the baseflows from Cedar Creek were incorporated to generate the total inflow from the Lewis River Basin. Lewis River inflow to the Columbia River for the modeled periods are shown in Figure 54.

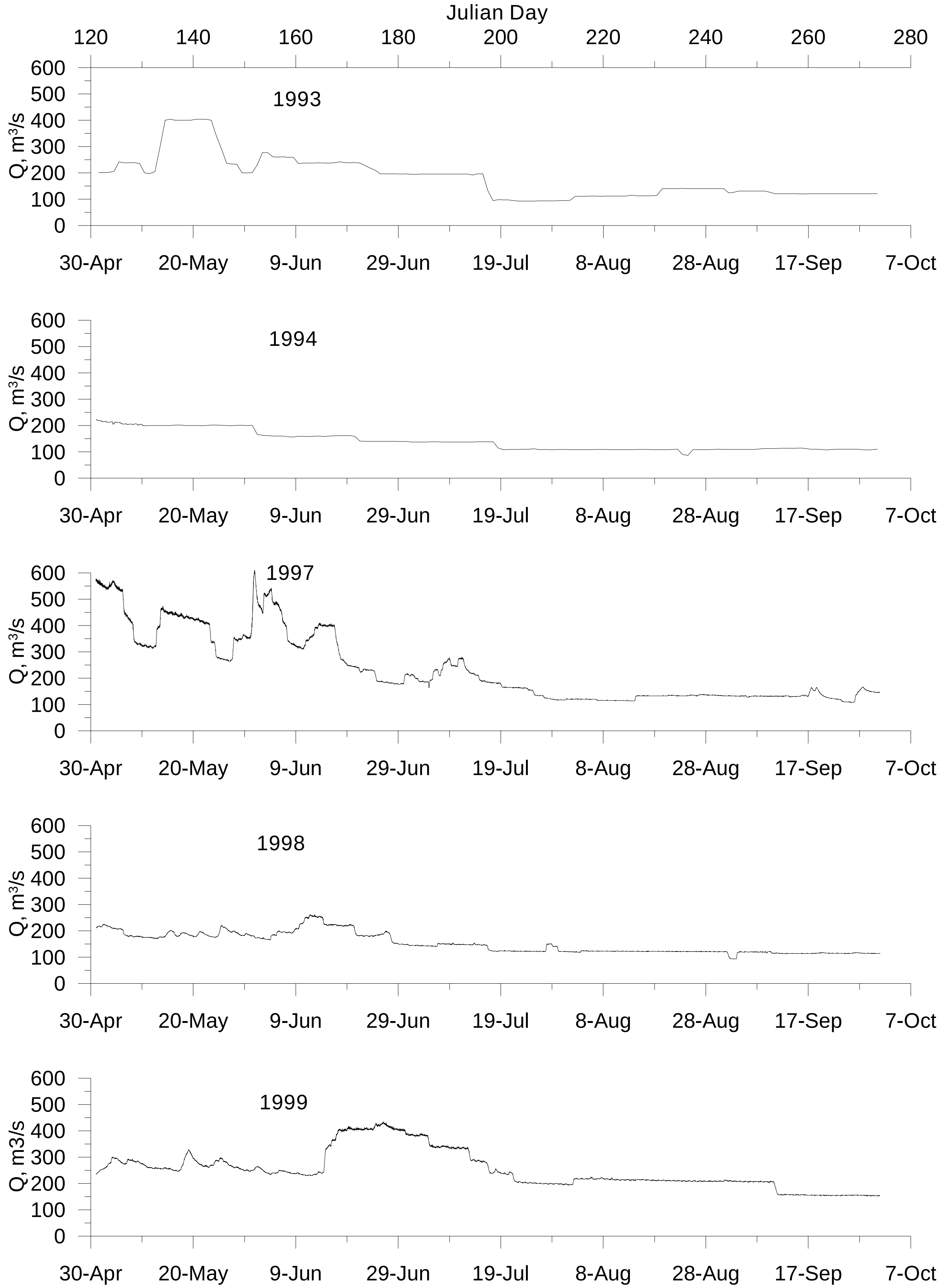



**Figure 53. Cowlitz River flow, m$^3$/s**

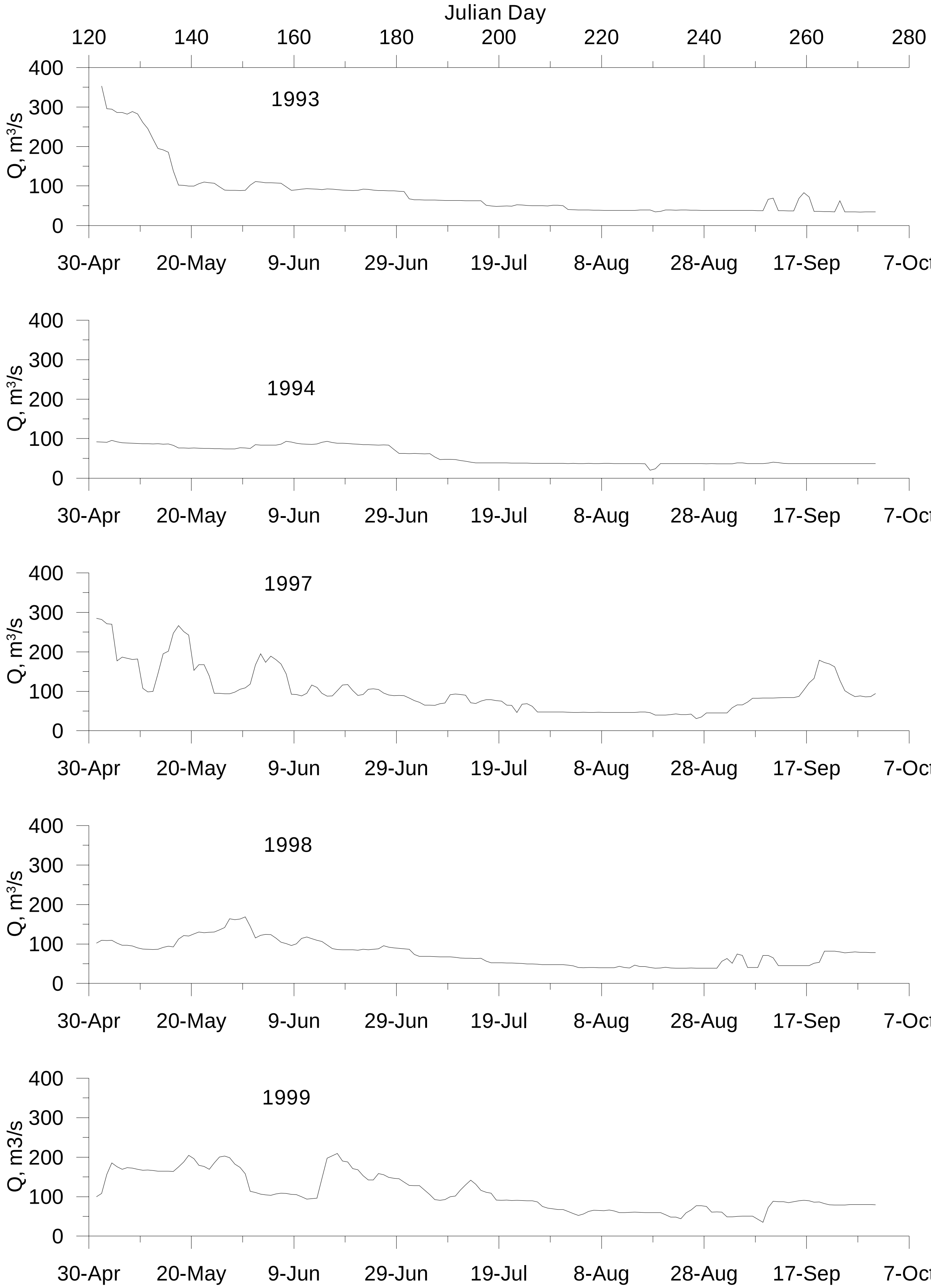



**Figure 54. Lewis River flow, m$^3$/s**

The flow for the Washougal River was estimated based on correlations between the East Fork of the Lewis River and the Washougal River and the Little Washougal River. First, a correlation relating daily flows in the East Fork of the Lewis River with daily flows in the Washougal River was developed from the period 10/01/1944 to 9/30/1981. Figure 55 shows the Washougal and East Fork Lewis River Basins. The East Fork of the Lewis River was selected for the correlation because it is an adjacent basin to the Washougal River. This correlation is shown in Figure 56 ($R^2$ = 0.9744).

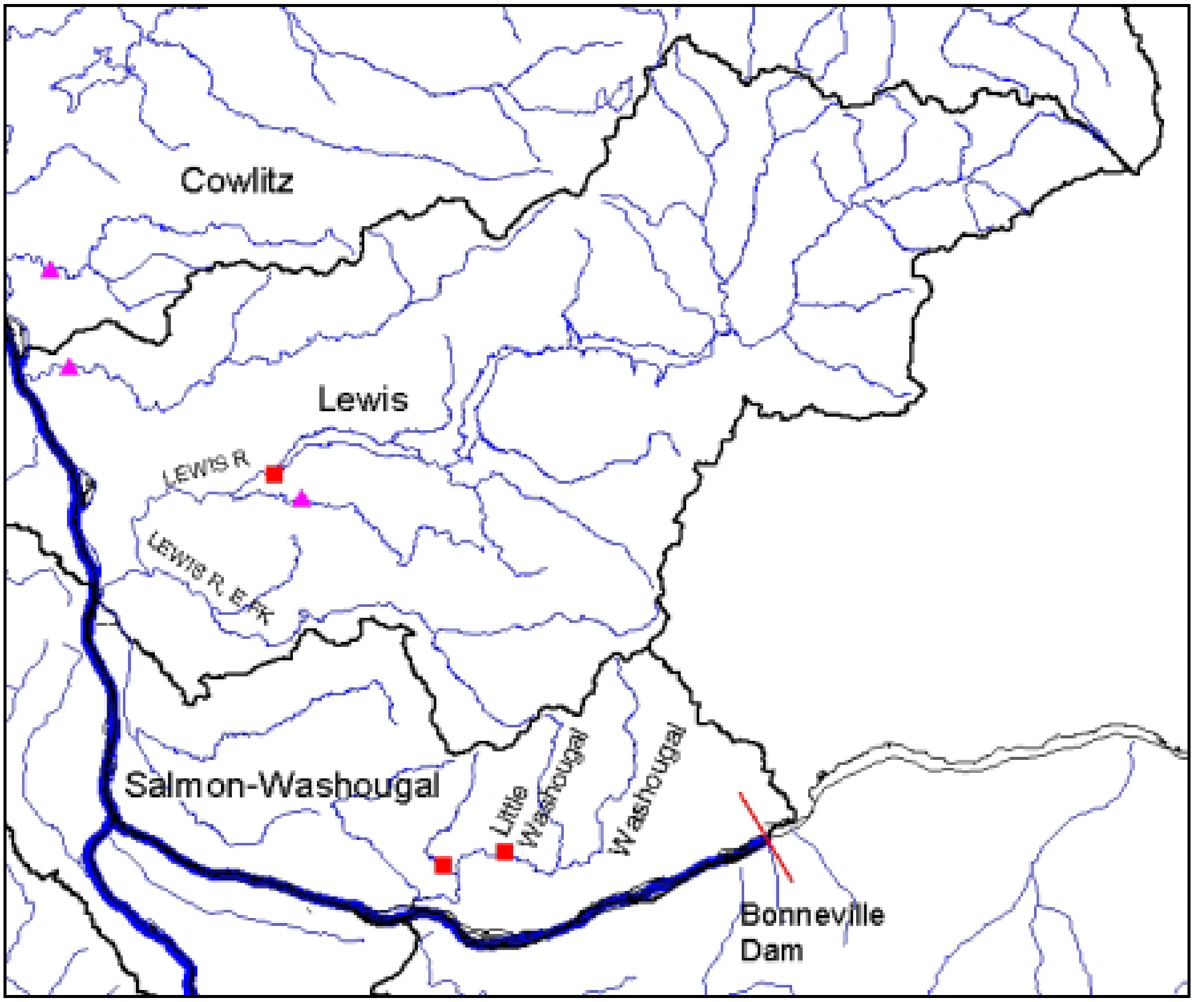



**Figure 55. Lewis and Washougal River Basin**

The second correlation relates daily flows in the East Fork of the Lewis River with daily flows in the Little Washougal River. This correlation was developed for the period 7/01/1951 to 11/10/1955 and is shown in Figure 57 ($R^2$ = 0.9261). The daily flows for the Washougal River and the Little Washougal were calculated based on these correlations and added together to create the tributary inflow for the model. Figure 58 show the Washougal River flow for the modeled time periods.

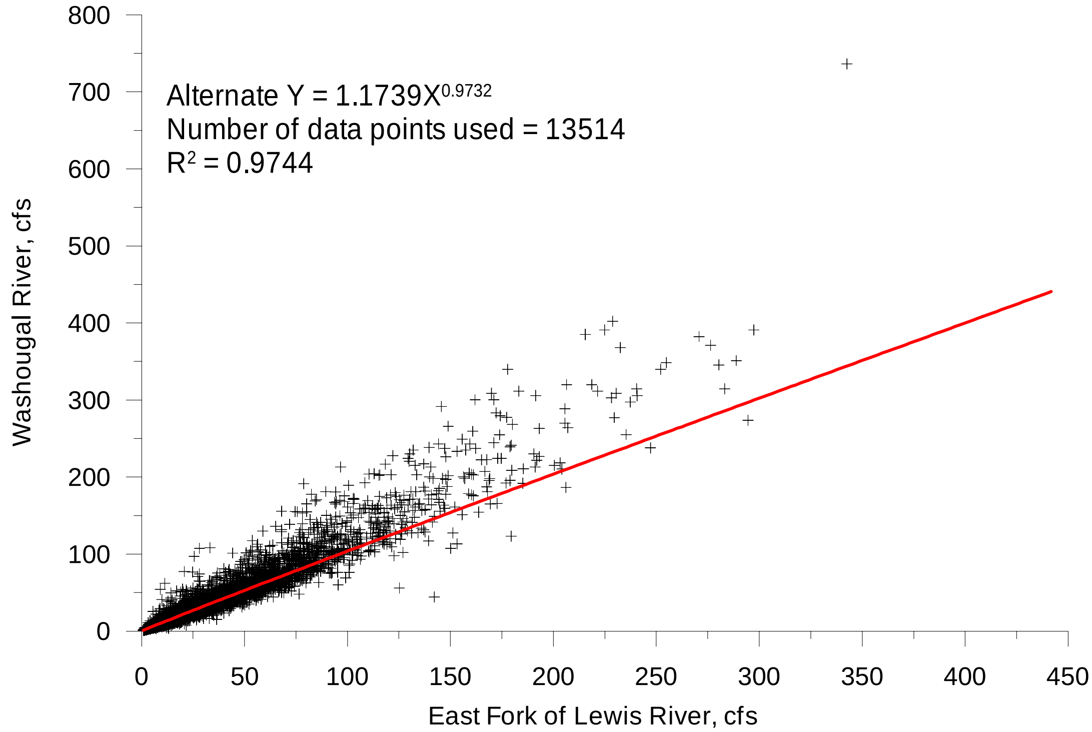



**Figure 56. East Fork of Lewis River and Washougal River correlation, Year 1944 to 1981**

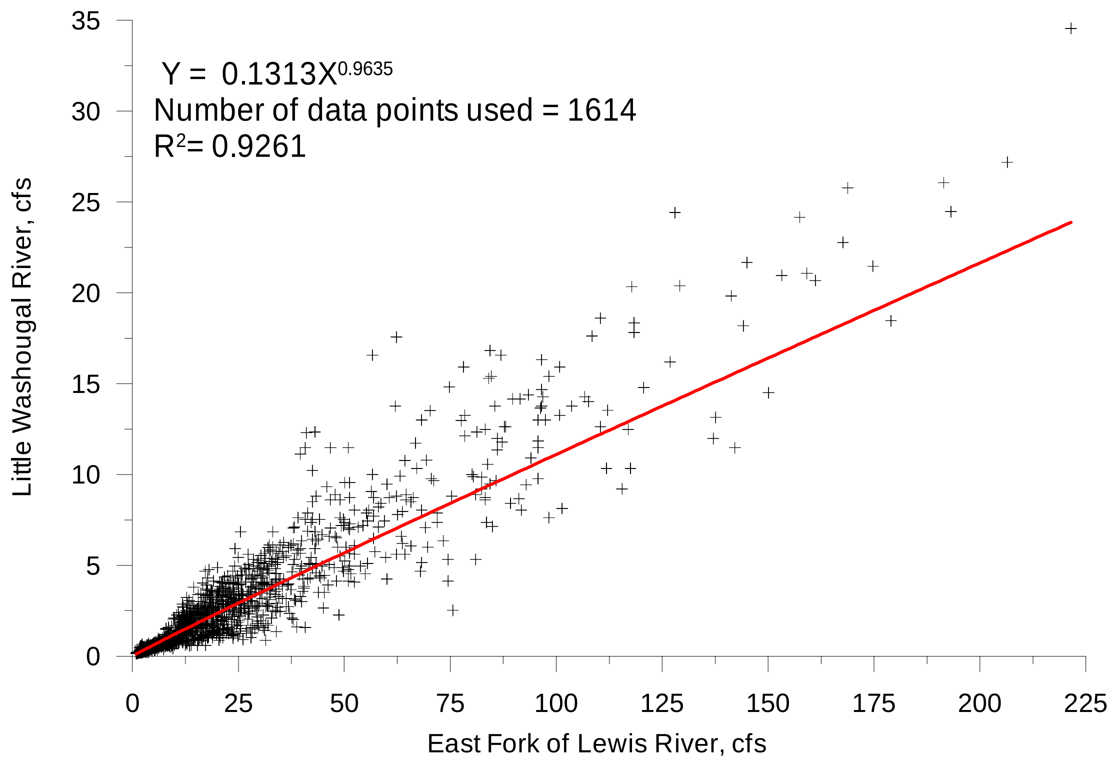



**Figure 57. East Fork of Lewis River and Little Washougal River correlation, Year 1951 to 1955**

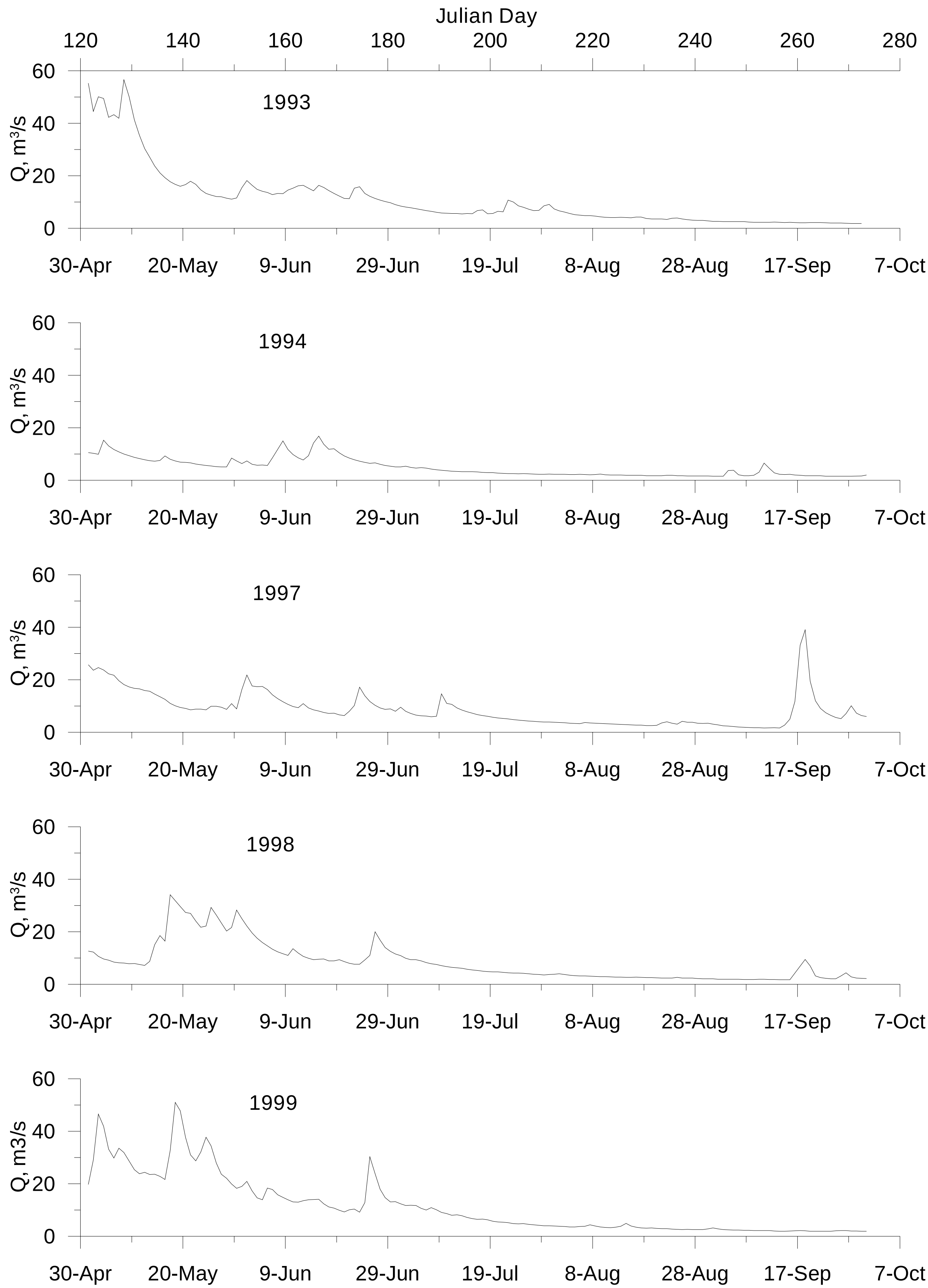



**Figure 58. Washougal River flow, $m^3/s$**

Sandy River flows were characterized based on the USGS gage station located below the confluence with the Bull Run River (USGS: 14142500). Continuous flow data for the summers of 1993 and 1997 to 1999 were used to generate the inflow files for the model. However for 1994 daily data were used because there was a gap in the continuous data record. Sandy River flows for the summers modeled are shown in Figure 59.

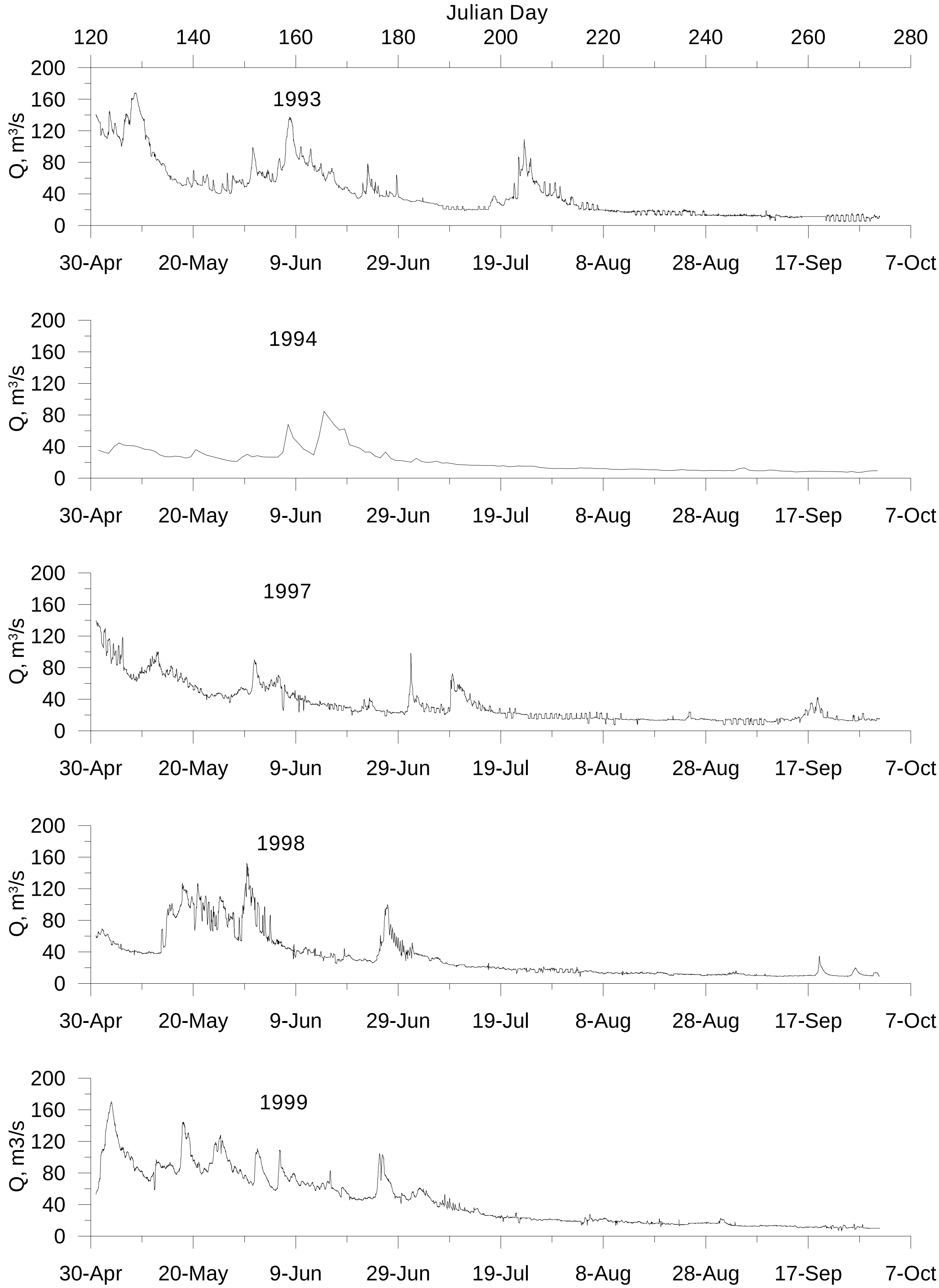



**Figure 59. Sandy River flow, $m^3/s$**

*Water Quality*

The Oregon Department of Environmental Quality (DEQ) and the Washington Department of Ecology (WADOE) collect data on some of the tributaries to the Columbia River. DEQ (EPA STORET Program) water quality data consists of grab samples that are taken at a frequency of monthly to twice a year. Water quality data from WADOE (Environmental Information Monitoring) are taken on a monthly basis.

Water quality data from DEQ and WADOE were combined to generate the input files for the model. Figure 60 shows the inflow temperature for the Columbia River tributaries. In some cases no data were available for a given year on a tributary so data from the year before or after was used. In the case of the Grays-Elokoman basin, no temperature data was available at all, so temperature data was used from the adjacent Cowlitz River basin. Table 11 shows a list of water quality parameters for which data are available for the tributaries. Since no water quality data was available for the Gray-Elokoman basin the Cowlitz River basin data was used since they are adjacent basins. The procedure used for developing the water quality files from data can be found in Appendix J: Water Quality file development procedures.

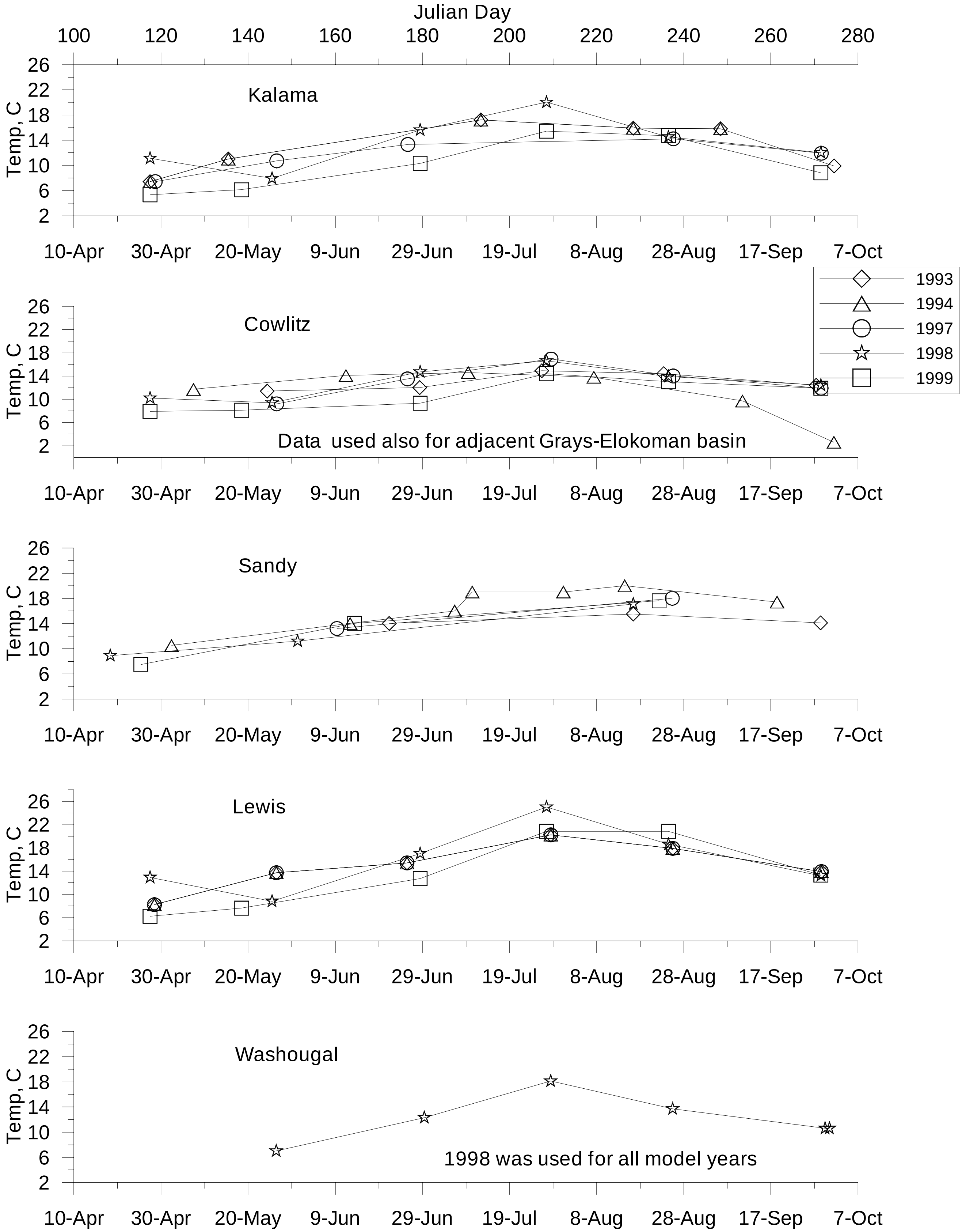



**Figure 60. Washington Tributary water temperatures, $^{o}$C**

| Parameter | Cowlitz River | Kalama River | EF Lewis River | Washougal River | Sandy River |
|---|---|---|---|---|---|
| ALKLNITY WTR DISS | | X | | | |
| Ammonia-Nitrogen | X | X | X | X | |
| BOD | | | | | X |
| CAL HARD CA MG | | X | | | X |
| CHLRPHYL A | | X | | | X |
| COLOR | | | | | |
| Conductivity | X | X | X | X | X |
| D ORG C C | | X | | | |
| Dissolved Nitrite | X | | | | |
| Dissolved Soluble | X | X | X | X | |
| DO, % sat | X | X | X | X | X |
| DO, mg/L | X | X | | X | X |
| E.COLI | | | | | X |
| ENTCOCCI | | X | | | X |
| Fecal Coliform | X | X | X | X | X |
| NH3+NH4- N DISS | | X | | | X |
| NH3+NH4- N TOTAL | X | X | | X | X |
| Nitrate-Nitrite | X | X | X | X | |
| NO2&NO3 N-DISS | | X | | X | X |
| NO2&NO3 N-TOTAL | X | X | | X | X |
| NO2-N DISS | X | X | | X | X |
| PH | X | X | X | X | X |
| PHOS-DIS | | X | | | X |
| PHOS-DIS ORTHO | X | X | | X | X |
| SUSP SED CONC | | | | | X |
| Suspended Solids | X | X | X | X | |
| T ALK CACO3 | | | | | X |
| T ORG C C | | | | | X |
| Temperature | X | X | X | X | X |
| TOT HARD CACO3 | X | X | | | |
| Tot Persulfate Nitrogen | X | X | X | | |
| TOTAL N N | X | | | X | |
| Total Phosphorus | X | X | X | X | X |
| Turbidity | X | X | X | X | X |
| UN-IONZD NH3-N | | X | | X | X |
| UN-IONZD NH3-NH3 | | X | | X | X |

**Table 11. Water Quality parameter available for the Columbia River tributaries**

### Point Sources

Point sources data for the Columbia and Willamette Rivers were collected from the Discharge Monitoring Reports (DMR) provided by Oregon Department of Environmental Quality (DEQ) and Washington Department of Ecology (WADOE). The Clean Water Act requires that any discharge “pollutants” through a point source into a water body in the United States should have a National Pollution Discharge Elimination System (NPDES) permit. The NPDES permit may define minimum or maximum limits of discharge constituents and may require periodic monitoring and reporting of the discharge. This reporting is submitted to the local branches of the EPA (Permit Compliance System) and DEQ/WADOE in the form of a Discharge Monitoring Report (DMR).

Oregon

The 1995 QUAL2E model employed in Tetra Tech Inc.'s Willamette River Basin Water Quality Study utilized steady state point source inputs. This differs from the CE-QUAL-W2 Version 3 model, which allows for dynamic point source inputs. This dynamic ability is a significant improvement when considering point sources can have high variability in discharge rates and constituents that are not seasonally related.

The QUAL2E model used the point sources shown in Table 12 for the Lower Willamette River. The flow and water quality constituents were derived from the DMRs.

| Point Load | Flow | Temp | DO | BOD-ult | Chl a | Org N | NH3-N | NO2-N | NO3-N | Org P | Diss P | Location |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | cfs | F | mg/L | mg/L | ug/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | River Mile |
| Ameron | 290.1 | 70.0 | 5 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.0 |
| Port Portland #2 | 1.14 | 70.0 | 5 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.5 |
| OR Steel Mill | 3.56 | 70.0 | 5 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.7 |
| Ash Grove | 0 | 70.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3.1 |
| Linnton Ply | 0 | 70.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4.9 |
| Union Oil | 0 | 70.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5.7 |
| Wacker Silt | 0.585 | 70.0 | 5 | 10.3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6.3 |
| Koppers | 0.005 | 70.0 | 5 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6.4 |
| Port Port #1 | 0.797 | 70.0 | 5 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6.5 |
| R-P/Cannonie | 0.006 | 78.8 | 5 | 26.2 | 0 | 3.2 | 3 | 0.2 | 6.1 | 0.9 | 3.2 | 7.0 |
| Elf Autochemical | 41 | 80.0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7.5 |
| Chevron USA | 0 | 70.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8.0 |
| Chiloquin | 0.167 | 70.0 | 6 | 15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 11.5 |
| OMSI | 2.924 | 70.0 | 5 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 13.5 |
| Lone Star NW | 0 | 70.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 13.8 |
| Ross Island S&G | 0 | 70.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 14.9 |
| Clackamas STP | 9.7 | 69.8 | 7.8 | 12.4 | 0 | 2.6 | 6.9 | 0.75 | 24.15 | 0.32 | 0.68 | 18.4 |
| Oak Lodge STP | 4.1 | 69.8 | 3.6 | 44.9 | 0 | 2.9 | 24.1 | 0.01 | 0.38 | 1.25 | 2.65 | 20.2 |
| Port WWTP | 8.7 | 69.8 | 6.3 | 18.3 | 0 | 3.52 | 17.7 | 0.06 | 1.8 | 1 | 2.08 | 20.3 |
| Tri-City STP | 7.3 | 69.8 | 6 | 16.5 | 0 | 1.2 | 3 | 0.11 | 3.49 | 8.95 | 14 | 25.3 |
| Simpson Paper | 14.3 | 80.0 | 5 | 61.4 | 0 | 1.52 | 1.98 | 0.13 | 2.67 | 0.2 | 1.9 | 26.4 |
| Smurf. ORCity | 17.2 | 86.0 | 1.9 | 183.7 | 0 | 1.52 | 1.98 | 0.13 | 2.67 | 0.2 | 1.9 | 27.5 |
| JR Lawrence | 0.007 | 70.0 | 6 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 29.0 |
| Caffall Bros | 0 | 70.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 30.0 |
| GS Gradow | 0.033 | 70.0 | 6 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 31.6 |
| Canby WWTP | 1.2 | 69.8 | 6 | 7.5 | 0 | 3.2 | 3 | 0.2 | 6.1 | 0.9 | 3.2 | 33.0 |

**Table 12. Tetra Tech Phase II Point Source Inputs**

Several of these point sources have changed ownership or name or have stopped discharging since 1995 when Tetra Tech collected the data. Table 13 shows a list of facilities which have changed their name or ownership.

| 1995 Facility Name | Current Facility Name |
|---|---|
| Port of Portland #2 | Kinder Morgan Bulk Terminals, Inc. |

| 1995 Facility Name | Current Facility Name |
|---|---|
| Port of Portland #1 | Cascade General, Inc. |
| Elf Autochemical | Atofina Chemicals |
| Simpson Paper Co. | West Linn Paper Co. |
| Smurfit Newsprint Corp. | Blue Heron Paper Co. |
| JR Lawrence | Forest Park Mobile Village |
| GS Gradow | Canby Regency Mobile Home Park |

**Table 13. 1995 vs. Current Point Source Designations**

In the case of Union oil, Chevron USA, Lone Star NW, Ross Island Sand & Gravel, and Caffall Bros. (Table 12), no quantitative discharge data were available in order to characterize discharge flows or water quality. The Tetra Tech point source labeled Chiloquin is an error. The City of Chiloquin in located in Kalamath County in Southern Oregon on the Williamson River, RM 11.5.

Table 14 identifies the point sources to the Willamette and Columbia Rivers from Oregon that were used in the CE-QUAL-W2 model. Most of the point sources from the Tetra Tech work were included, except the following: Kinder Morgan (Port of Portland #2); Koppers Industries, Inc; Linnton Plywood Association; and Ash Grove Cement Co. because their flows were either zero or negligible. Additional dischargers to the Willamette River that were considered "major" dischargers by DEQ and that had discharge data were also considered. In some cases a company had more than one discharge on the same property or more than one property with a discharge. The locations of these point sources are shown in Figure 61. Data from the point sources was found to be limited. Many water quality constituents, such as nutrients, were not monitored in the point sources. Data was collected on a monthly basis or less frequent.

| Model Seg. | Outfall ID | Facility Name | Receiving Water | River Mile |
|---|---|---|---|---|
| 3 | 13691/A | CANBY STP | Willamette | 33.0 |
| 4 | 97612/B | CANBY REGENCY MOBILE HOME PARK | Willamette | 31.6 |
| 8 | 21489/C-001 | WEST LINN PAPER COMPANY | Willamette | 27.7 |
| 8 | 72634/B-001 | BLUE HERON PAPER COMPANY | Willamette | 27.5 |
| 8 | 30554/B | FOREST PARK MOBILE VILLAGE | Willamette | 28.2 |
| 11 | 72634/B-002 | BLUE HERON PAPER COMPANY | Willamette | 27.5 |
| 11 | 72634/B-003 | BLUE HERON PAPER COMPANY | Willamette | 27.5 |
| 11 | 21489/C-002 | WEST LINN PAPER COMPANY | Willamette | 27.7 |
| 15 | 89700/A | TRI CITY REGIONAL STP | Willamette | 25.5 |
| 41 | LOPOWER | LAKE OSWEGO | Willamette | 21.0 |
| 42 | 70735/A | TRYON CREEK WWTP | Willamette | 20.2 |
| 45 | 62795/A | OAK LODGE STP | Willamette | 20.1 |
| 57 | 16590/A | KELLOGG CREEK STP | Willamette | 18.5 |
| 72 | 106060/A | OMSI | Willamette | 13.5 |
| 88 | 70596/B-001/7 | CASCADE GENERAL, INC. | Willamette | 6.5 |
| 88 | 70596/B-001/8 | CASCADE GENERAL, INC. | Willamette | 6.5 |
| 88 | 70596/B-002 | CASCADE GENERAL, INC. | Willamette | 6.5 |
| 88 | 70596/B-003 | CASCADE GENERAL, INC. | Willamette | 6.5 |
| 91 | 68471/A-003 | ATOFINA CHEMICALS, INC. | Willamette | 7.4 |
| 91 | 74995/A-002 | RHONE-POULENC AG | Willamette | 7.0 |
| 91 | 74995/A-003 | RHONE-POULENC AG | Willamette | 7.0 |
| 91 | 68471/A-001 | ATOFINA CHEMICALS, INC. | Willamette | 7.4 |

| Model Seg. | Outfall ID | Facility Name | Receiving Water | River Mile |
|---|---|---|---|---|
| 91 | 68471/A-002 | ATOFINA CHEMICALS, INC. | Willamette | 7.4 |
| 91 | 74995/A-001 | RHONE-POULENC AG | Willamette | 7.0 |
| 91 | 68471/A-004 | ATOFINA CHEMICALS, INC. | Willamette | 7.4 |
| 92 | 93450/A-MV1 | WACKER SILTRONIC CORPORATION | Willamette | 6.3 |
| 92 | 93450/A-MV3 | WACKER SILTRONIC CORPORATION | Willamette | 6.3 |
| 102 | 64905/A-002 | PORTLAND STEELWORKS - RIVERGATE | Willamette | 2.7 |
| 102 | 64905/A-001 | PORTLAND STEELWORKS - RIVERGATE | Willamette | 2.7 |
| 124 | 84069/A-001 | ST HELENS STP | Columbia | 86.0 |
| 201 | 74860/A-002 | REYNOLDS ALUMINUM | Columbia | 120 |
| 201 | 74860/A-001 | REYNOLDS ALUMINUM | Columbia | 120 |
| 288 | 74470/C | COASTAL ST. HELENS CHEMICAL | Columbia | 82.0 |
| 311 | 70825/A-001 | PGE - TROJAN NUCLEAR POWER PLANT | Columbia | 72.5 |
| 311 | 70825/A-002 | PGE - TROJAN NUCLEAR POWER PLANT | Columbia | 72.5 |
| 372 | 35173/A | GRESHAM  STP (SEE FILE NO. 110254) | Columbia | 117.5 |
| 391 | Ameron/SW | AMERON | Columbia | 108 |
| 391 | Ameron/CB | AMERON | Columbia | 108 |
| 391 | Ameron/PWW | AMERON | Columbia | 108 |
| 391 | Ameron/BBD | AMERON | Columbia | 108 |

**Table 14.  Oregon Point Sources for the Model**

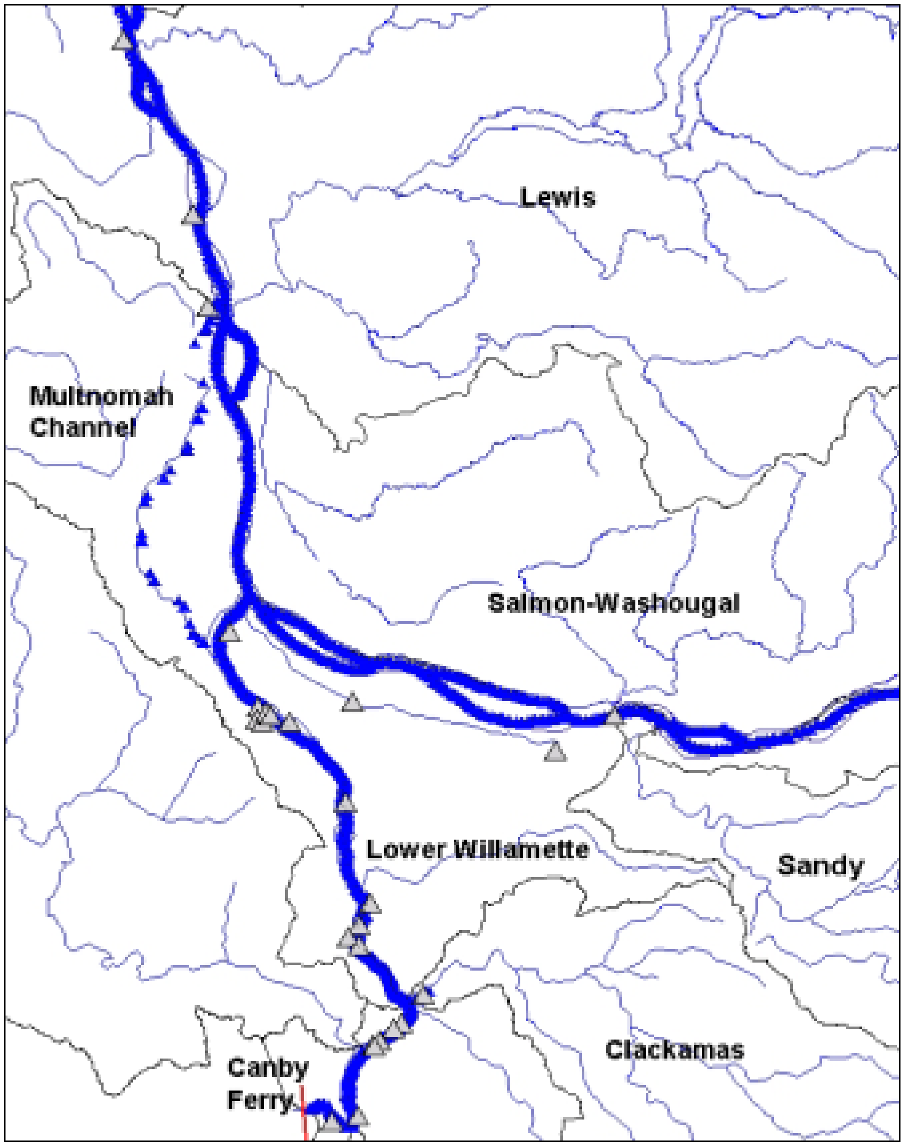



**Figure 61. Oregon Point Source locations**

*Storm and Combination Sewers*

Other point sources in the Willamette Basin include the storm sewer and combined sewer outlets in Portland and upstream districts. The locations of these outlets were acquired from the individual districts. Most of the data however is not in a digital format. The contributing land surface area to each outlet is typically less understood. The City of Portland provided AutoCAD drawings for each of their Storm and Combined Sewers, as well as aerial photos of the outlets. Little data though exists for flow rates from each of these discharges even though the City of Portland has a computer model of their sanitary and storm water system using the EPA Storm Water Management Model (SWMM).

One study underway by the City of Portland examines the Swan Island area. A rational method analysis was performed on a storm sewer collection system on Swan Island with water quality measured by the City of Portland, BES at selected manholes. The study estimated flow into the Willamette River and associated water quality for a few winter storms. The study is ongoing and with an expanded scope could provide valuable data for winter modeling.

The City of West Linn utilized the EPA SWMM model to evaluate all existing major basins in West Linn for 10 and 25 year storm events. This model was constructed to provide a Drainage System Capacity Evaluation component to the City of West Linn Master Storm Drain plan. Woodward Clyde Consultants, Inc. performed this study in 1996. Assumptions used to generate the model included:

1. The maximum 24-hour rainfall in the city as derived from the applicable regional NOAA Atlas
2. The standard 10 year return frequency 24-hour maximum rainfall in the city is 3.3 inches. The distribution of rainfall within the 24-hour period is based on the SCS Type 1A rainfall distribution.

| Basin # | Estimated Peak 10 Year Flow (cfs)* | Diameter (in) | Oregon North State Plane | |
|---|---|---|---|---|
| 1 | 73.50 | 60 | 7651475.99 | 639237.99 |
| 2 | 100.00 | 60 | 7653271.22 | 637859.64 |
| 3 | 25.60 | 24 | 7654273.33 | 636929.76 |
| 4 | 72.10 | 24 | 7656426.00 | 632352.24 |
| 5 | 45.20 | 24 | 7657311.15 | 630128.64 |
| 6 | 66.80 | 30 | 7658578.52 | 628778.54 |
| 7 | 5.20 | 24 | 7659087.68 | 628281.73 |
| 8 | 30.10 | 30 | 7661059.10 | 626984.79 |
| 9 | 82.00 | 36 | 7660352.73 | 625399.65 |
| 10 | 28.90 | 18 | 7657884.93 | 622881.00 |
| 11 | 146.00 | 60 | 7655229.74 | 620436.84 |
| 12 | 97.00 | 30 | 7652926.83 | 619260.13 |

**Table 15. West Linn Storm Water Management Model Results**

Due to the lack of consistent water quality and flow data and the focus on summer low-water conditions in the Lower Willamette River modeling, stormwater and CSO inflows were not considered as point sources in the model.

Washington

In Washington the State Department of Ecology was contacted and a list identified for all major point sources contributing to the Columbia River in the model domain. The locations of these sites are shown in Figure 62. Some of the point sources identified discharged into tributaries of the Columbia River downstream of where gaging stations were used to characterize the tributary flows. Eleven sites were neglected from inclusion in the model since their flow was not significant and would not have much influence on water quality in the Lower Willamette as shown in Figure 62. There were 47 point sources considered in the model, and these are listed in Table 16. Some of these point sources were combined if they discharged to the same model segment. Similar to the point sources identified in Oregon, the extent of the data was found to be limited. Many water quality constituents, such as nutrients, were not monitored. Data were collected on a monthly basis or less frequent.

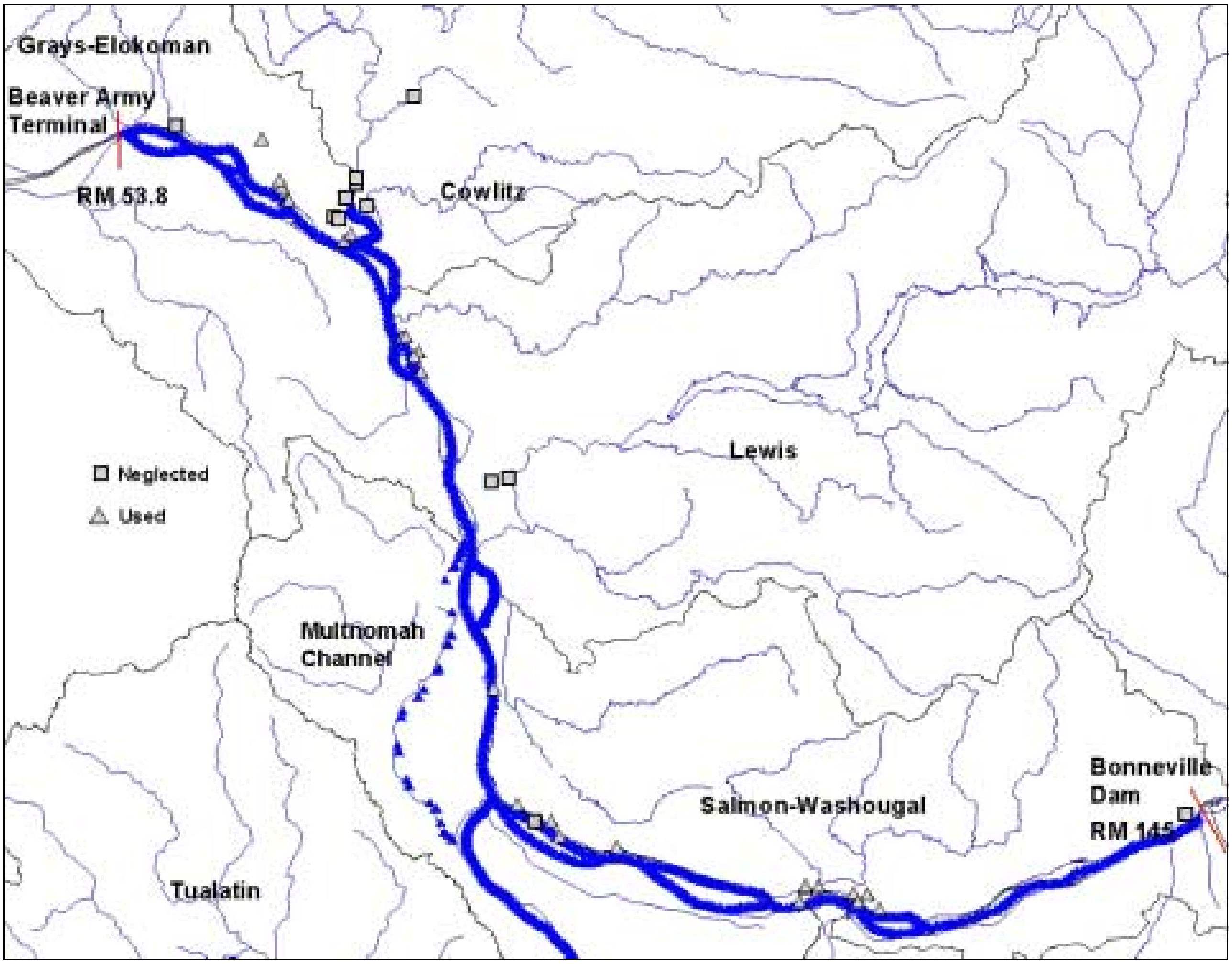



**Figure 62. Washington Point Source locations**

| Model Seg. | Outfall ID | Facility Name | Receiving Water | River Mile |
|---|---|---|---|---|
| 194 | 1 | ALLWEATHER WOOD TREATERS | Columbia | 122.9 |
| 194 | 2 | ALLWEATHER WOOD TREATERS | Columbia | 122.9 |
| 308 | 001C | BFGOODRICH | Columbia | 74.0 |
| 308 | 002C | BFGOODRICH | Columbia | 74.0 |
| 308 | 1 | BFGOODRICH | Columbia | 74.0 |
| 308 | 2 | BFGOODRICH | Columbia | 74.0 |
| 233 | 1 | BOISE CASCADE VANCOUVER | Columbia | 106.0 |
| 199 | 1 | CAMAS STP | Columbia | 121.1 |
| 304 | 1 | CLARIANT CORP | Columbia | 76.1 |
| 202 | 1 | FORT JAMES CAMAS | Columbia | 120.0 |
| 201 | 2 | FORT JAMES CAMAS | Columbia | 120.3 |
| 201 | S | FORT JAMES CAMAS | Columbia | 120.3 |
| 306 | 1 | KALAMA STP | Columbia | 75.0 |
| 434 | 1 | LONGVIEW FIBRE LONGVIEW | Columbia | 67.5 |
| 433 | S | LONGVIEW FIBRE LONGVIEW | Columbia | 68.0 |
| 339 | 1 | LONGVIEW STP | Columbia | 60.4 |
| 225 | 1 | MARINE PARK WATER RECLAMATION FACIL | Columbia | 109.5 |

| Model Seg. | Outfall ID | Facility Name | Receiving Water | River Mile |
|---|---|---|---|---|
| 306 | 1 | PORT OF KALAMA | Columbia | 75.2 |
| 332 | 002A | REYNOLDS METALS LONGVIEW | Columbia | 63.2 |
| 332 | 002B | REYNOLDS METALS LONGVIEW | Columbia | 63.2 |
| 332 | 1 | REYNOLDS METALS LONGVIEW | Columbia | 63.2 |
| 332 | 3 | REYNOLDS METALS LONGVIEW | Columbia | 62.8 |
| 256 | 1 | SALMON CREEK STP | Columbia | 95.3 |
| 239 | 1 | VANALCO | Columbia | 103.0 |
| 239 | 2 | VANALCO | Columbia | 103.0 |
| 235 | 1 | VANCOUVER WEST STP | Columbia | 105.0 |
| 193 | 1 | WASHOUGAL STP | Columbia | 123.2 |
| 330 | 00C | WEYERHAEUSER LONGVIEW | Columbia | 63.9 |
| 330 | 1 | WEYERHAEUSER LONGVIEW | Columbia | 63.9 |
| 330 | 2 | WEYERHAEUSER LONGVIEW | Columbia | 63.9 |
| 330 | 3 | WEYERHAEUSER LONGVIEW | Columbia | 63.9 |
| 330 | 4 | WEYERHAEUSER LONGVIEW | Columbia | 63.9 |
| 330 | OCL | WEYERHAEUSER LONGVIEW | Columbia | 63.9 |
| 330 | OWP | WEYERHAEUSER LONGVIEW | Columbia | 63.9 |
| 330 | 5 | WEYERHAEUSER LONGVIEW | Columbia | 64.0 |

**Table 16. Washington Point Sources for the Model**

## Lower Willamette and Columbia Databases

Five Databases for the Lower Willamette River modeling project were created using Microsoft Access. The databases contain flow, water level elevation, water quality, point source quality and flow, and meteorological data for the Columbia River, Willamette River, and their tributaries. The extent of data for each database can be found in Appendix I.

## Model Geometry

### Bathymetry Data

The model grid was developed based on detailed cross sections for the Columbia River and the Willamette River provided by the USACOE (Knutson, 2000). The model grid was developed using cross sections from RM 145 (Bonneville Dam) to RM 53.8 (Beaver Army Terminal) in the Columbia River and from RM 0 to RM 24 (Oregon City Falls) in the Willamette River, as shown in Figure 63. Figure 64 shows two example cross sections in the Willamette River provided by USACOE.

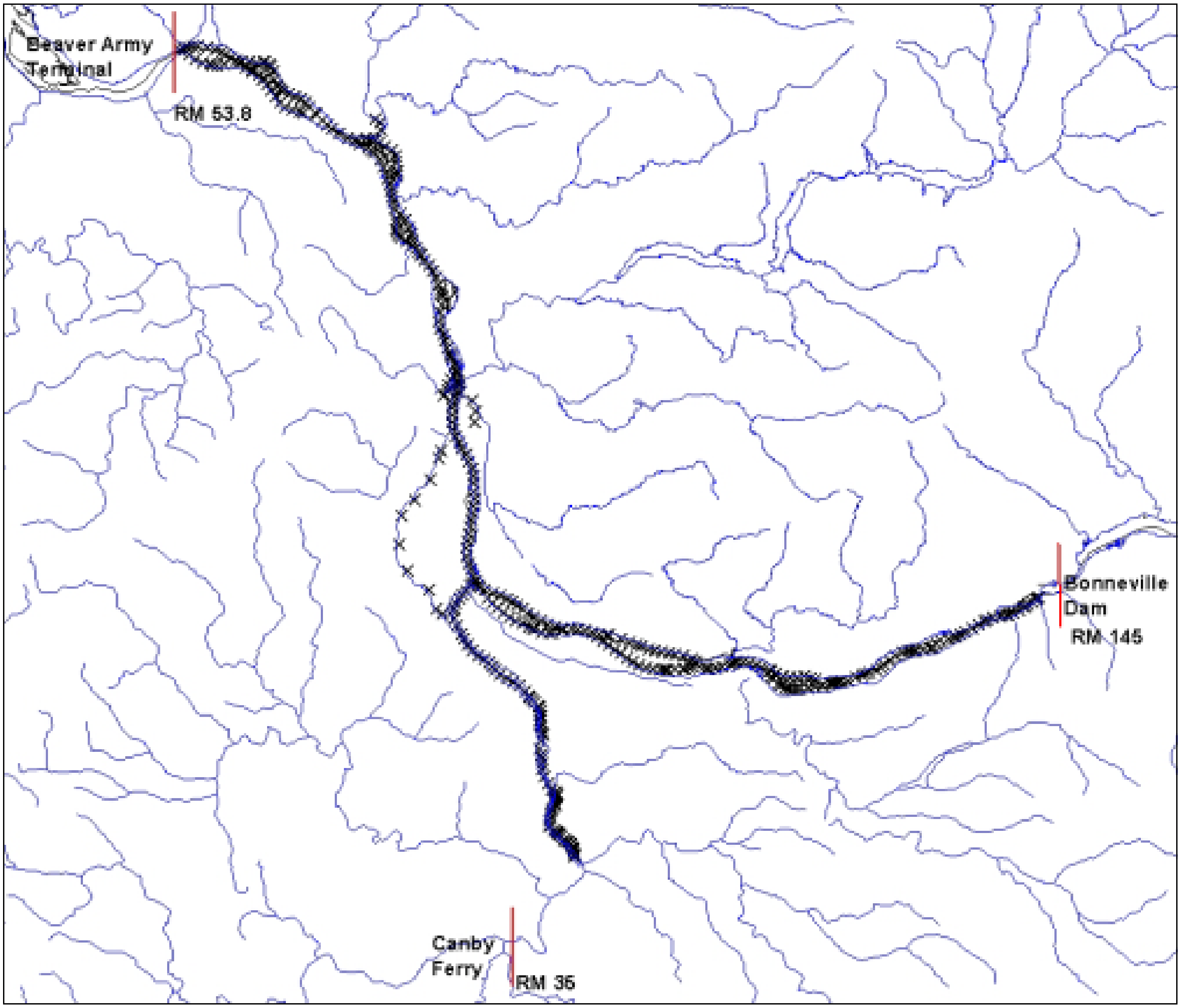
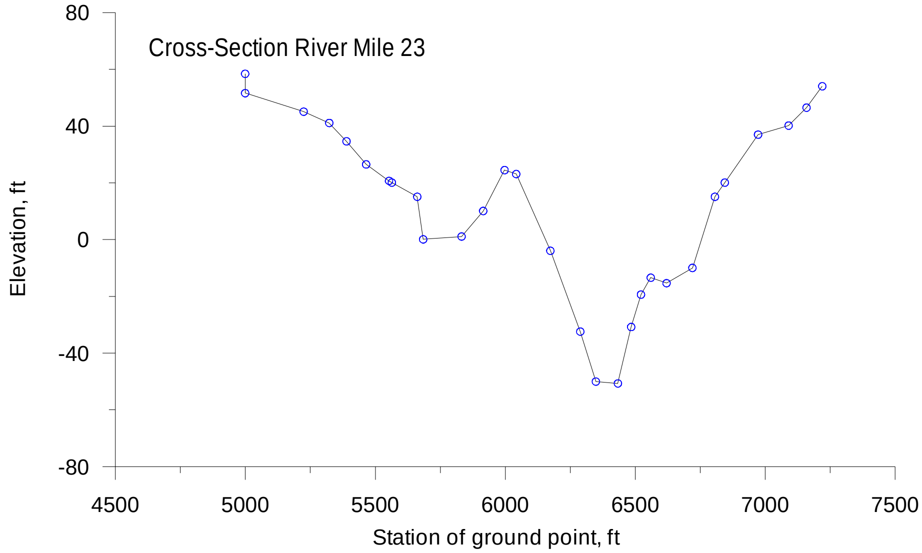



**Figure 63. Columbia and Willamette River cross-section locations**



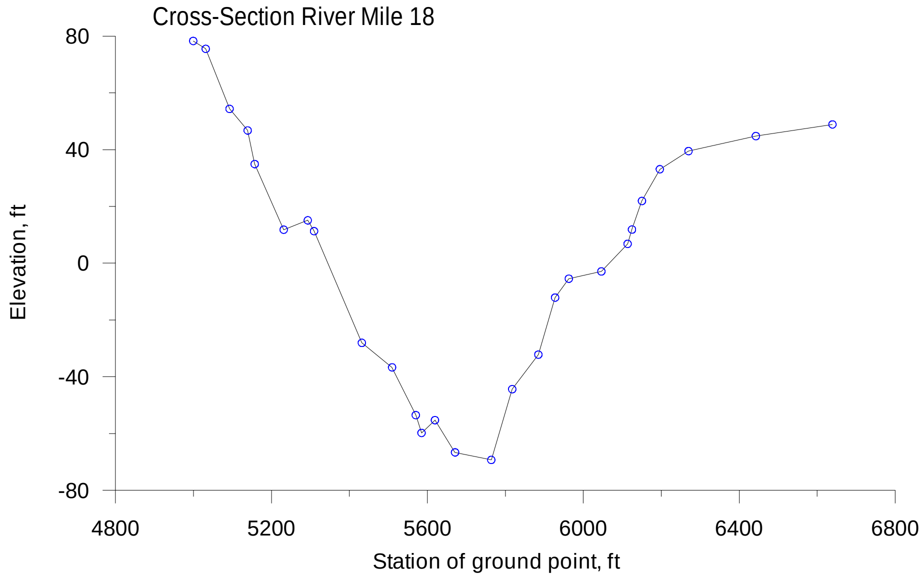




**Figure 64. Willamette River cross-sections RM 18 and 23**

Bathymetry data in the Willamette River between RM 24 and just below the Oregon City Falls (RM 26.5) were obtained from a survey work done in 1999 by the USACOE using a sound transponder and Global Positioning System (GPS). The bathymetry data for the last 0.3 miles between the USACOE data set and the Oregon City Falls were obtained by digitizing bathymetric estimates on the USGS quadrangle map. The data sets provided x, y, and z coordinates that were combined and used in SURFER, a 3-D mapping program, to develop the model grid between RM 24 and the Oregon City Falls. Figure 65 shows the location of the data provided by the USACOE and the USGS map.

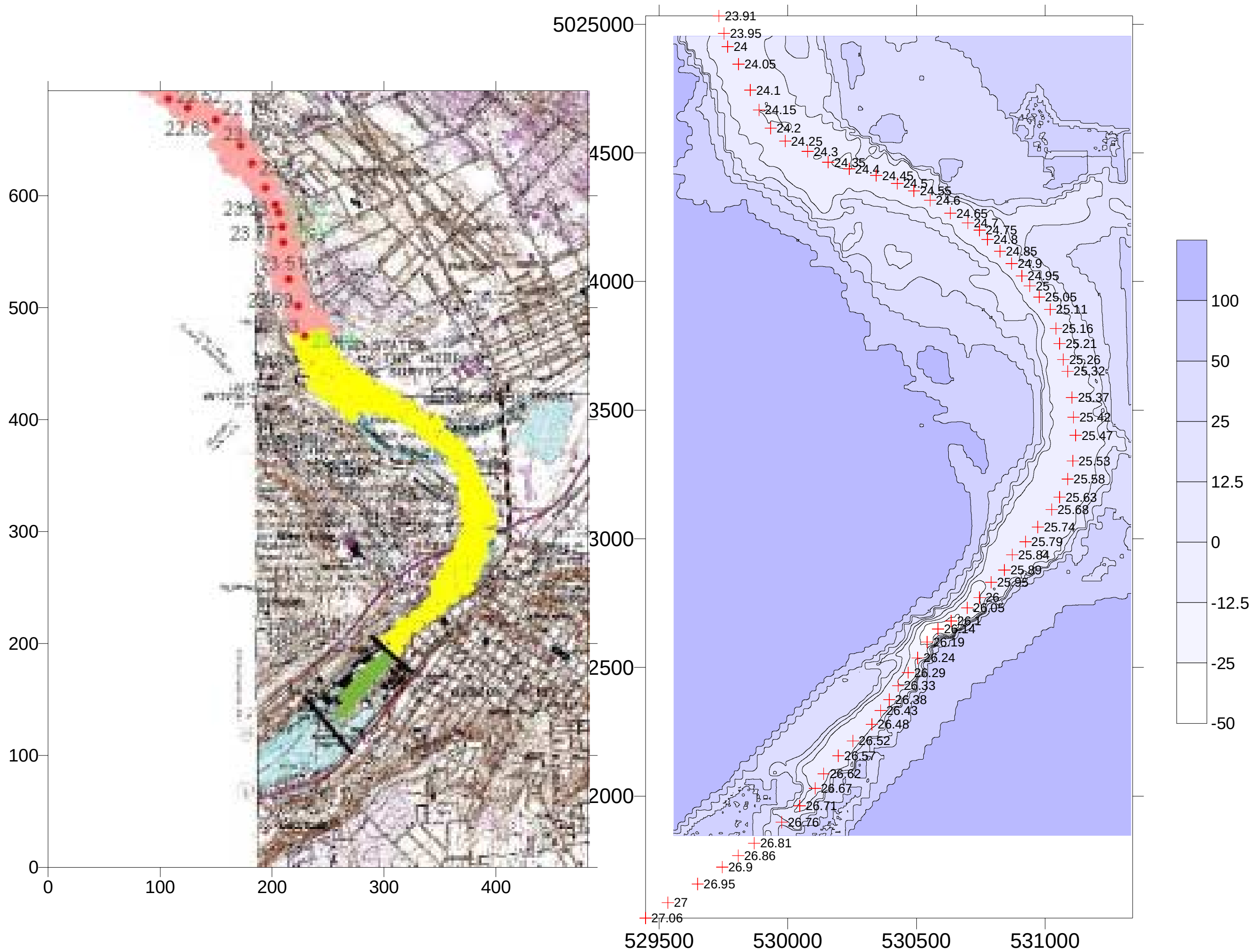



**Figure 65. Willamette River Bathymetry RM 24 to 26.8**

Cross-sections of the Willamette River between the Oregon City Falls (RM 26.8) and Canby Ferry (RM 35) were provided by Portland General Electric (PGE, 1998). The cross-sections were based on a survey done by the National Oceanic and Atmospheric Administration (NOAA) in October 25, 1997. Figure 66 shows the extent of the cross sections available for this reach of the river. Figure 67 shows a sample cross-section at RM 29.6.

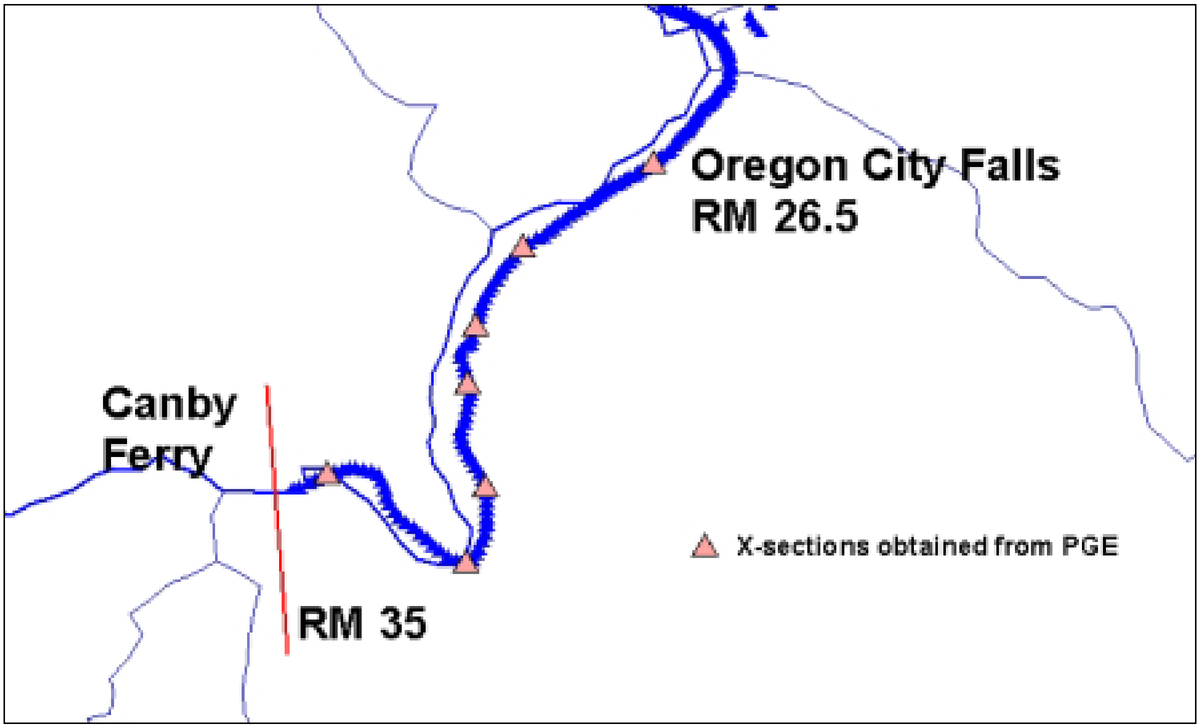



**Figure 66. Willamette River cross-sections locations from PGE**

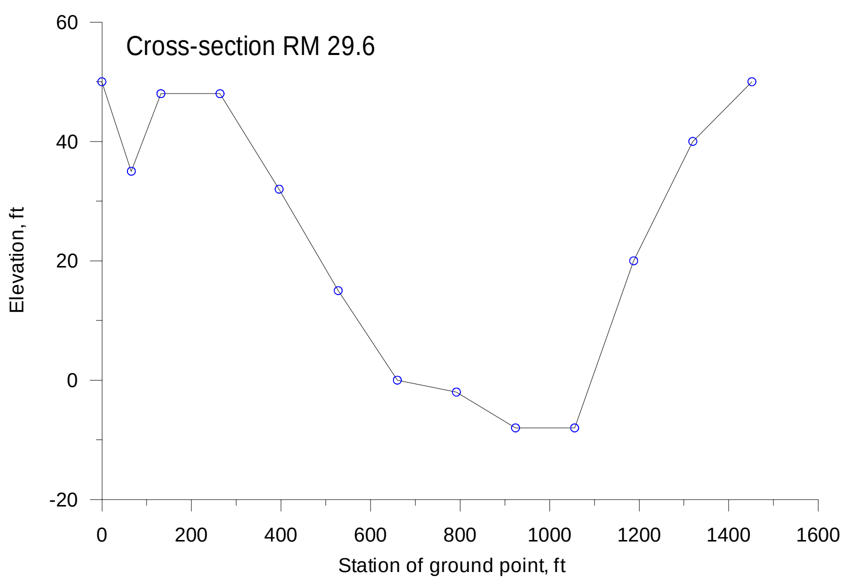



**Figure 67. Willamette River cross-section RM 29.6**

Bathymetry data from RM 0.0 to RM 1.2 in the Clackamas River and the cove (an abandoned gravel pit) connected to the Clackamas River was obtained from survey work conducted by Pacific Water Resources (Savage, 2000). One mile of the Clackamas River and the cove were incorporated in the model since both are tidally influenced. The head of tide in the Clackamas River ends above the entrance of the cove (Kyle, 2000). The bathymetry data were combined with elevation data from the USGS Digital Elevation Model to extract model cross-sections for CE-QUAL-W2. Figure 68 shows contour plots of the data used to generate the grid for the model.

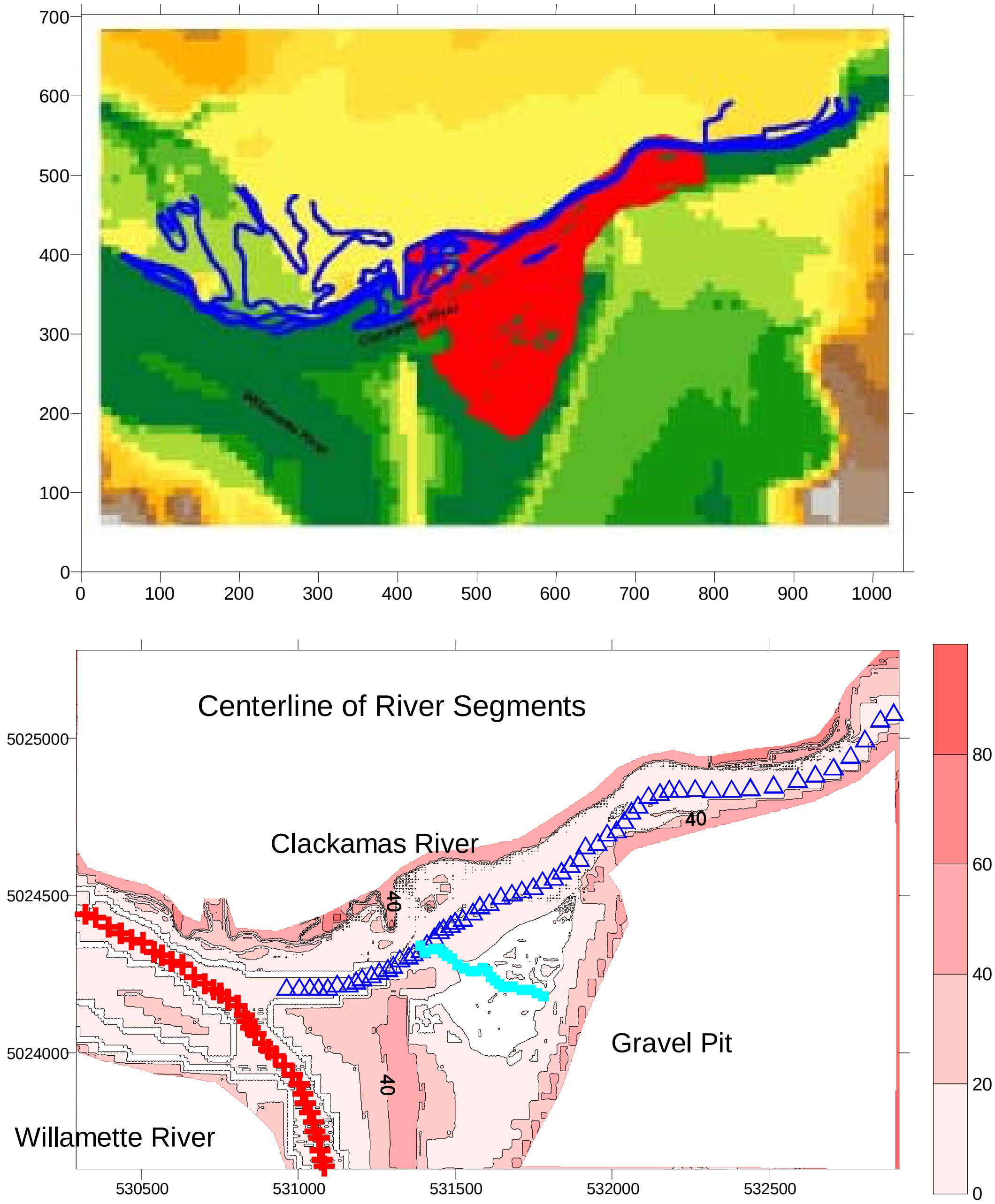



**Figure 68. Clackamas River and Cove Bathymetry**

## Model Grid Development

Using the river cross-sections and the bathymetric contour plots discussed above, the model grid was developed for 4 water bodies. Figure 69 shows a layout of the model grid. A total of 16 branches make up the 4 water bodies in the model. The Willamette River above the Oregon City Falls is modeled as one branch within a waterbody. The second Waterbody consists of two branches, the first is the mainstem of the Willamette River and the second is Multnomah Channel. The Columbia River represents a third waterbody with 11 branches. The first branch is the main channel of the Columbia River and the remaining 10 branches are at tributary inflows or side channels around islands in the river. The fourth waterbody represents the lowest reach of the Clackamas River and a gravel pit cove on the side.  Segment size was based on the spacing of the cross-sections in the bathymetry data.  Layer thickness in the model is 2 meters throughout.  Table 17 provides the model grid specifications and boundary conditions for each branch. A detailed layout of each model segment is shown in the following Figures: Figure 70, Figure 71, Figure 72, and Figure 73 for the Willamette River segments and Figure 74, Figure 75, Figure 76, Figure 77, Figure 78, and Figure 79 for the Columbia River segments.

The model vertical resolution is shown in Figure 80 and Figure 81 for the Willamette model branches and for the Columbia branch, respectively. The model has a vertical grid resolution of 2 m.

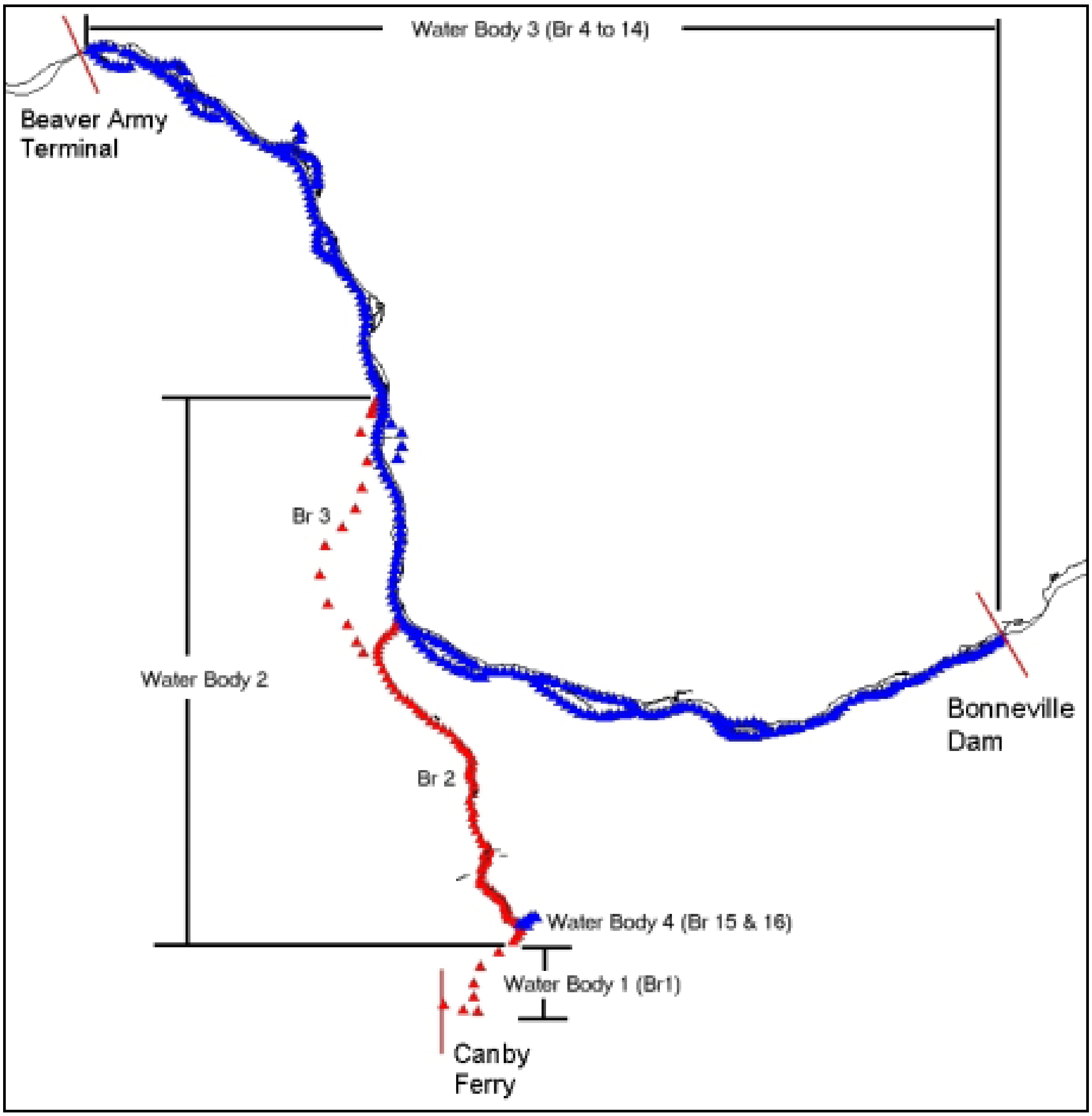



**Figure 69.  Model Grid Layout**

| Water Body | Branch | Description | Segment Start | Segment End | Number of Segments | Upstream BC | Downstream BC | Segment Length, m | Layer Thickness, m |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | Canby to Falls | 1 | 9 | 9 | flow | | 1642 - 3331 | 2 |
| 2 | 2 | Falls to Columbia River | 10 | 108 | 99 | | internal | 80 - 925 | 2 |
| | 3 | Multnomah Channel | 109 | 125 | 17 | internal | internal | 370 - 4361 | 2 |
| 3 | 4 | Columbia River, Bonneville to Beaver Terminal | 126 | 357 | 232 | flow | wl | 169 - 805 | 2 |
| | 5 | Reed Island Channel | 358 | 368 | 11 | internal | internal | 241 - 805 | 2 |
| | 6 | Government Island | 369 | 389 | 21 | internal | internal | 201 - 805 | 2 |
| | 7 | Oregon Slough | 390 | 404 | 15 | internal | internal | 394 - 805 | 2 |
| | 8 | Bachelor Island | 405 | 410 | 6 | internal | internal | 1287 - 1609 | 2 |
| | 9 | Sandy Island | 411 | 420 | 10 | internal | internal | 370 - 708 | 2 |
| | 10 | Carrols Channel | 421 | 435 | 15 | internal | internal | 306 - 805 | 2 |
| | 11 | Cowlitz River | 436 | 440 | 5 | flow | internal | 644 - 805 | 2 |
| | 12 | Lord Island | 441 | 451 | 11 | internal | internal | 499 - 805 | 2 |
| | 13 | Fisher Island | 452 | 461 | 10 | internal | internal | 402 - 805 | 2 |
| | 14 | Bradbury Slough | 462 | 471 | 10 | internal | internal | 402 - 805 | 2 |
| 4 | 15 | Clackamas River | 472 | 478 | 7 | flow | internal | 436 | 2 |
| | 16 | Clackamas River Gravel Pit | 479 | 483 | 5 | flow | internal | 111 | 2 |

**Table 17. Model Grid Layout Specifications**


**Figure 70. Model segment numbers along Willamette River and Clackamas River.**


**Figure 71. Model segment numbers along the Willamette River in vicinity of Lake Oswego and Ross Island.**

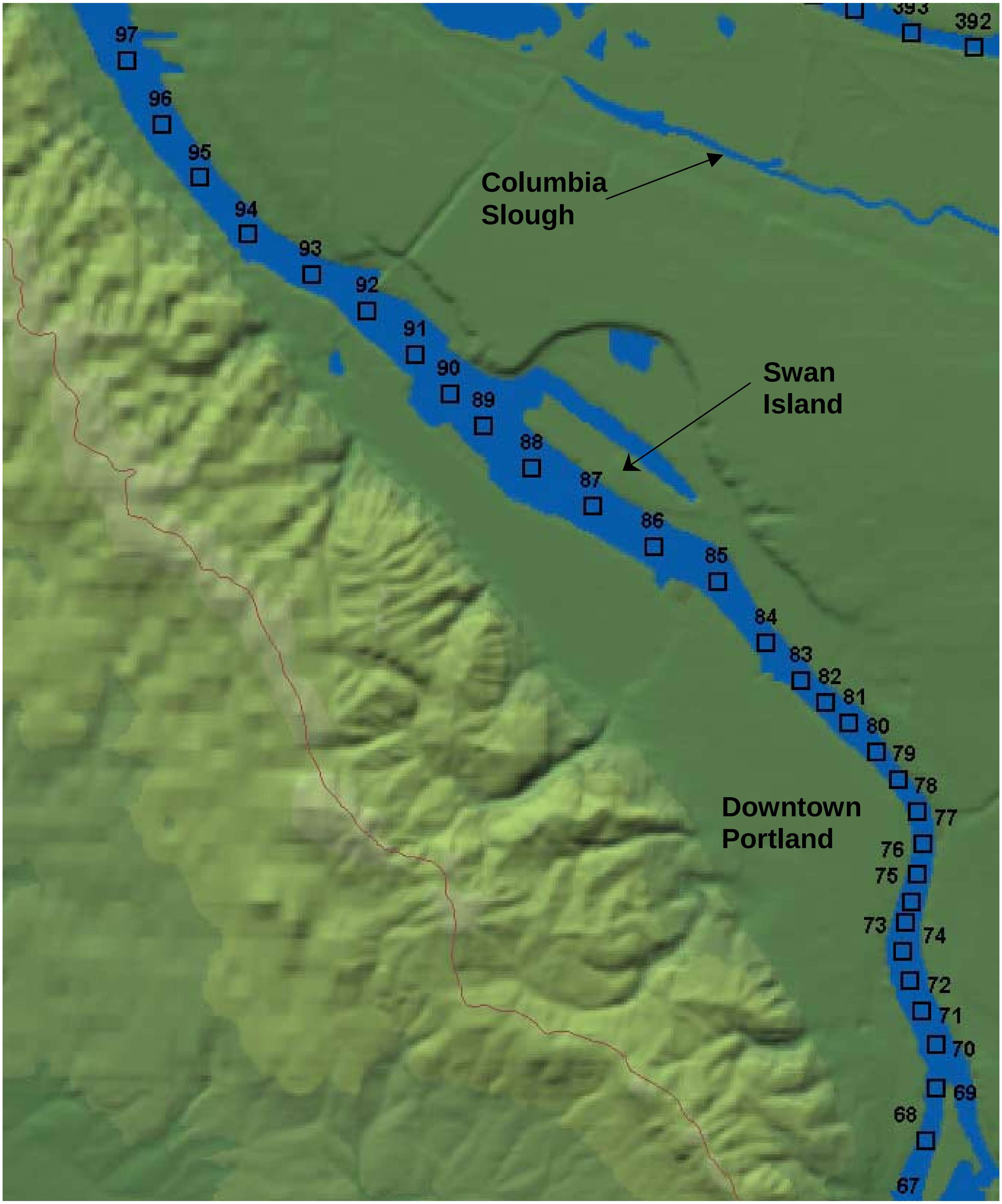



**Figure 72. Model segment numbers in the vicinity of downtown Portland and Swan Island.**

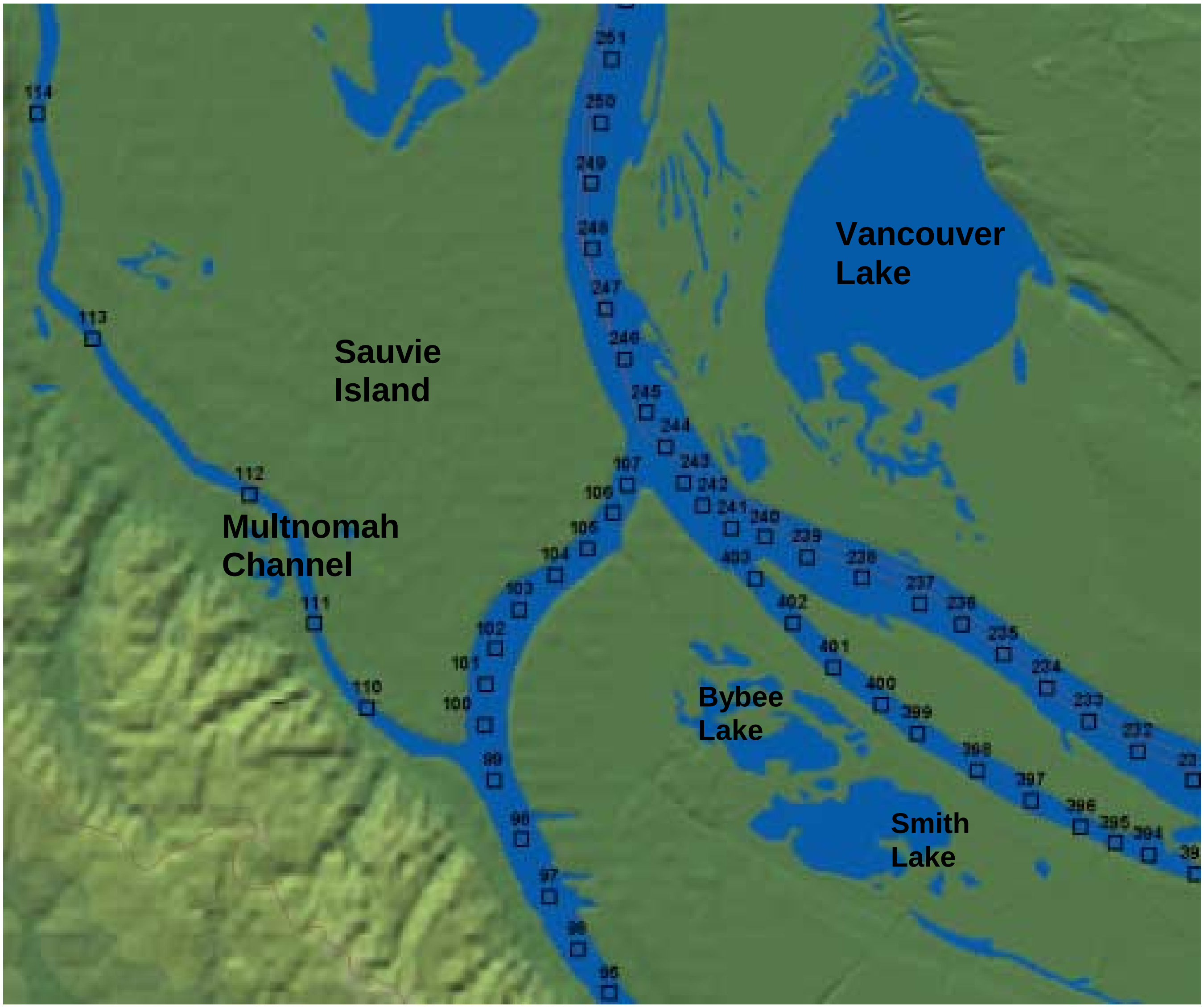



**Figure 73. Model segment numbers at confluence of Willamette River and Columbia River.**

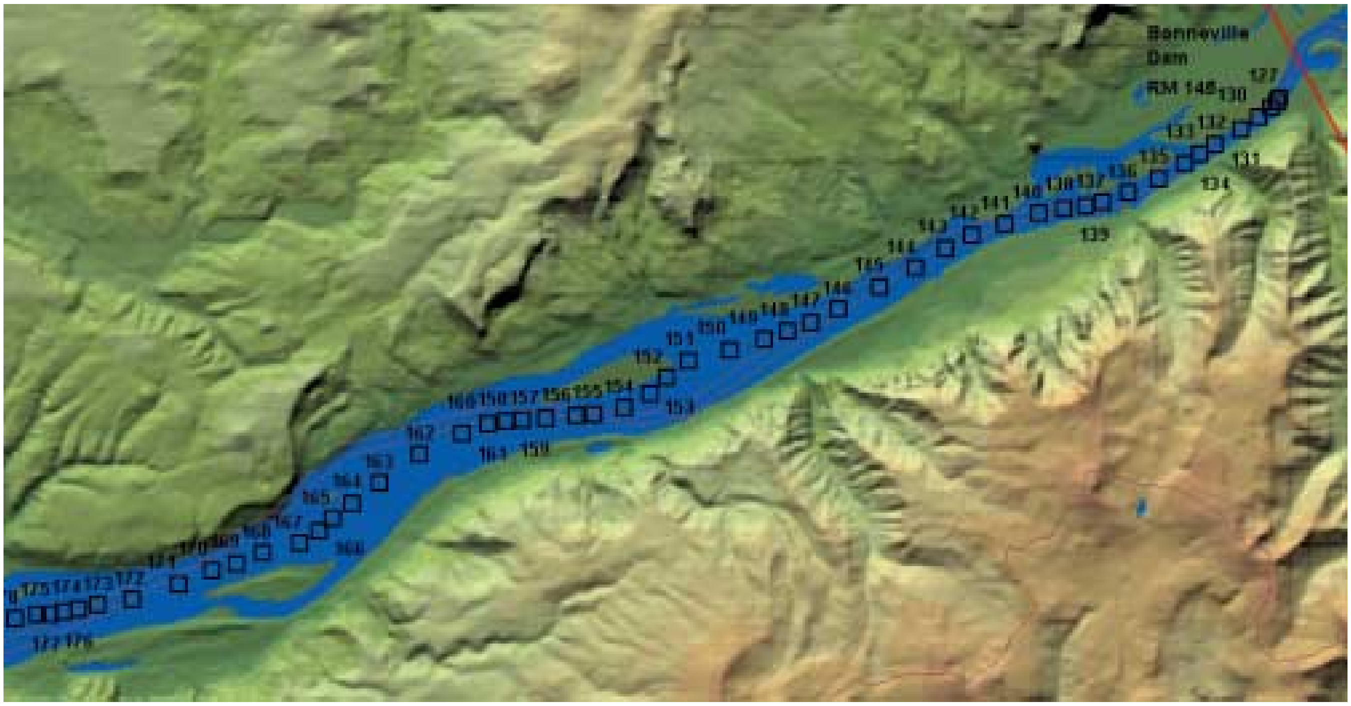



**Figure 74. Model segment numbers along Columbia River near Bonneville Dam.**

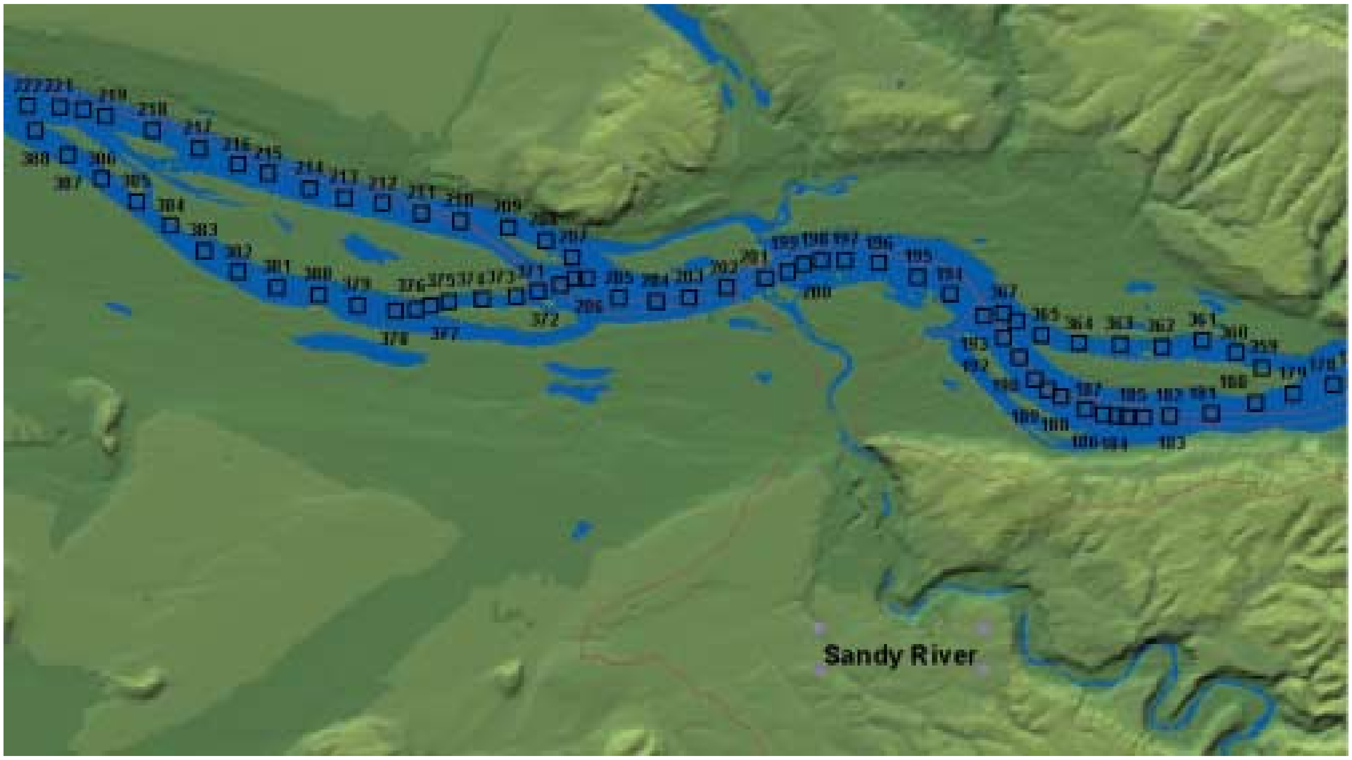



**Figure 75. Model segment numbers along Columbia River near Sandy River.**

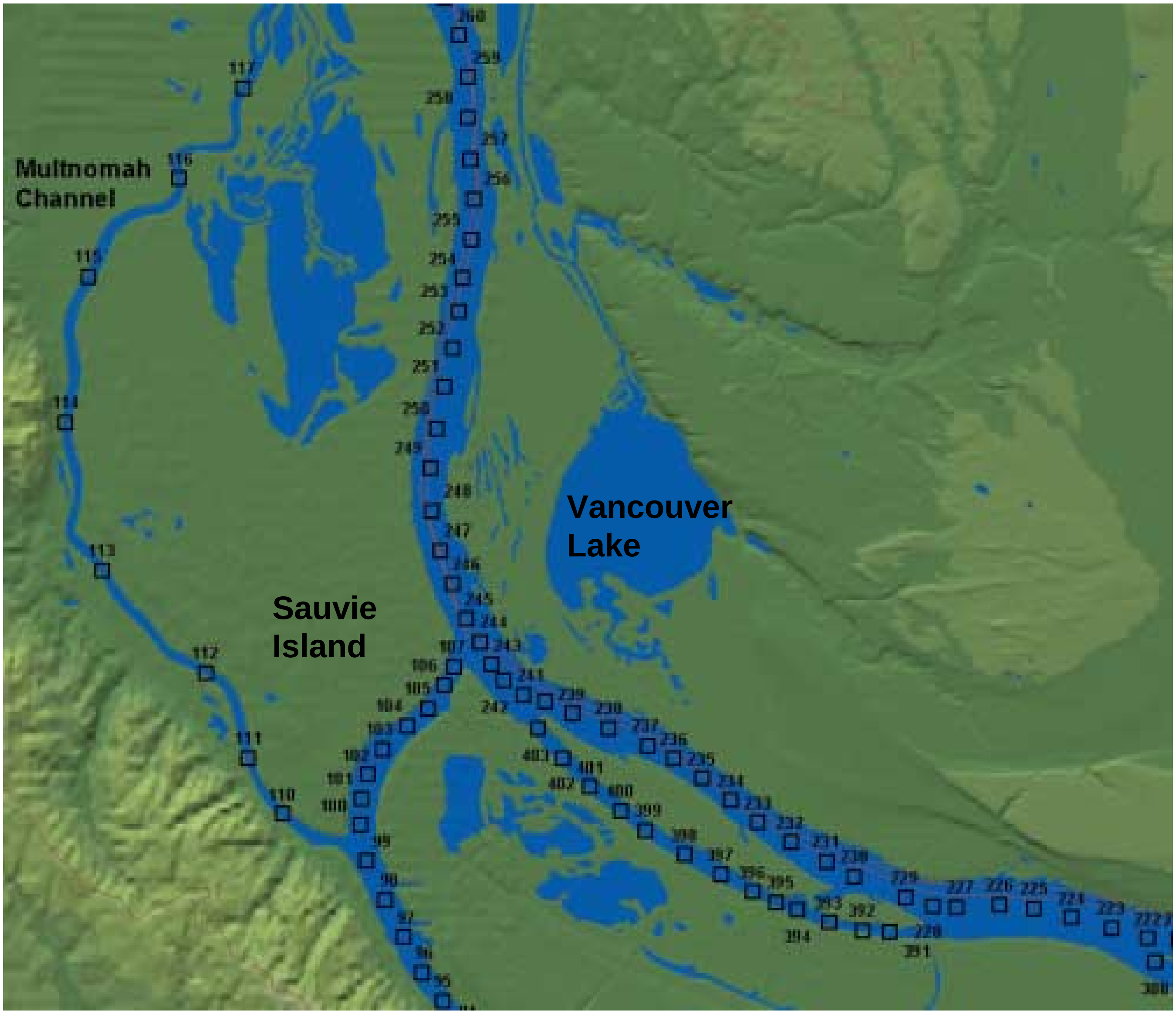



**Figure 76. Model segment numbers along the Columbia River near Sauvie Island and Vancouver Lake.**

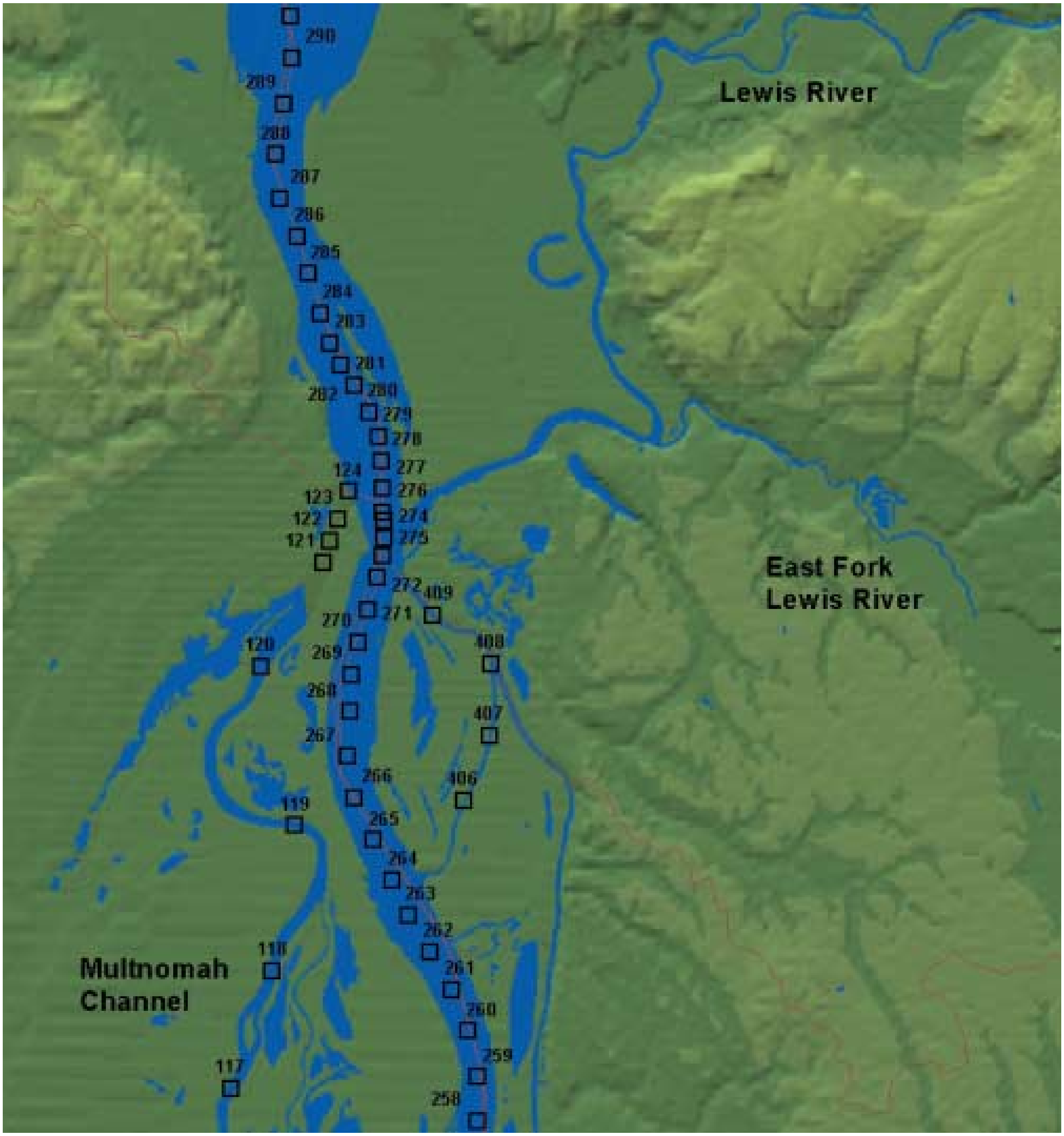



**Figure 77. Model segment numbers along Columbia River near the Lewis River.**

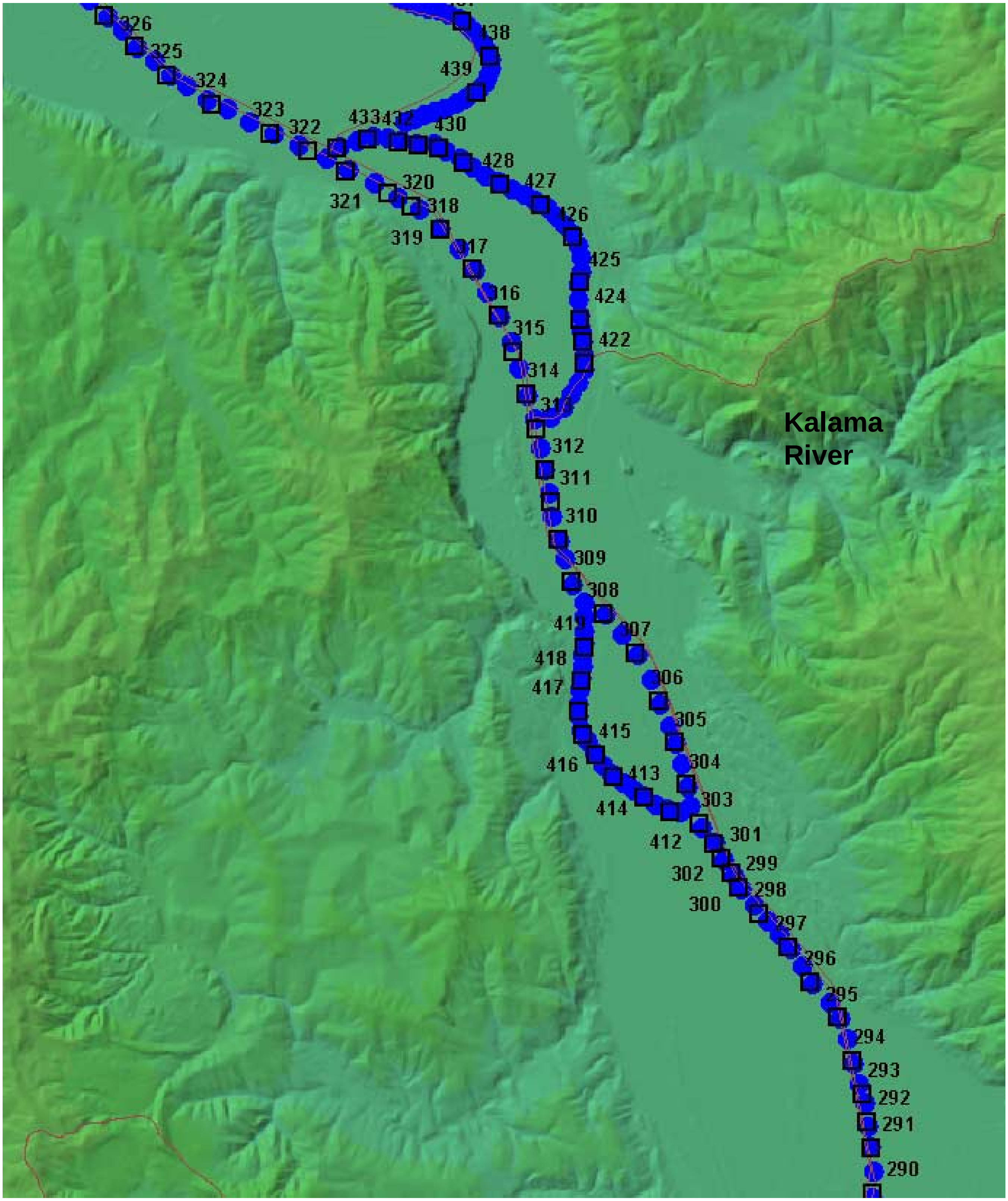



Figure 78. Model segment numbers along Columbia River near Kalama River.

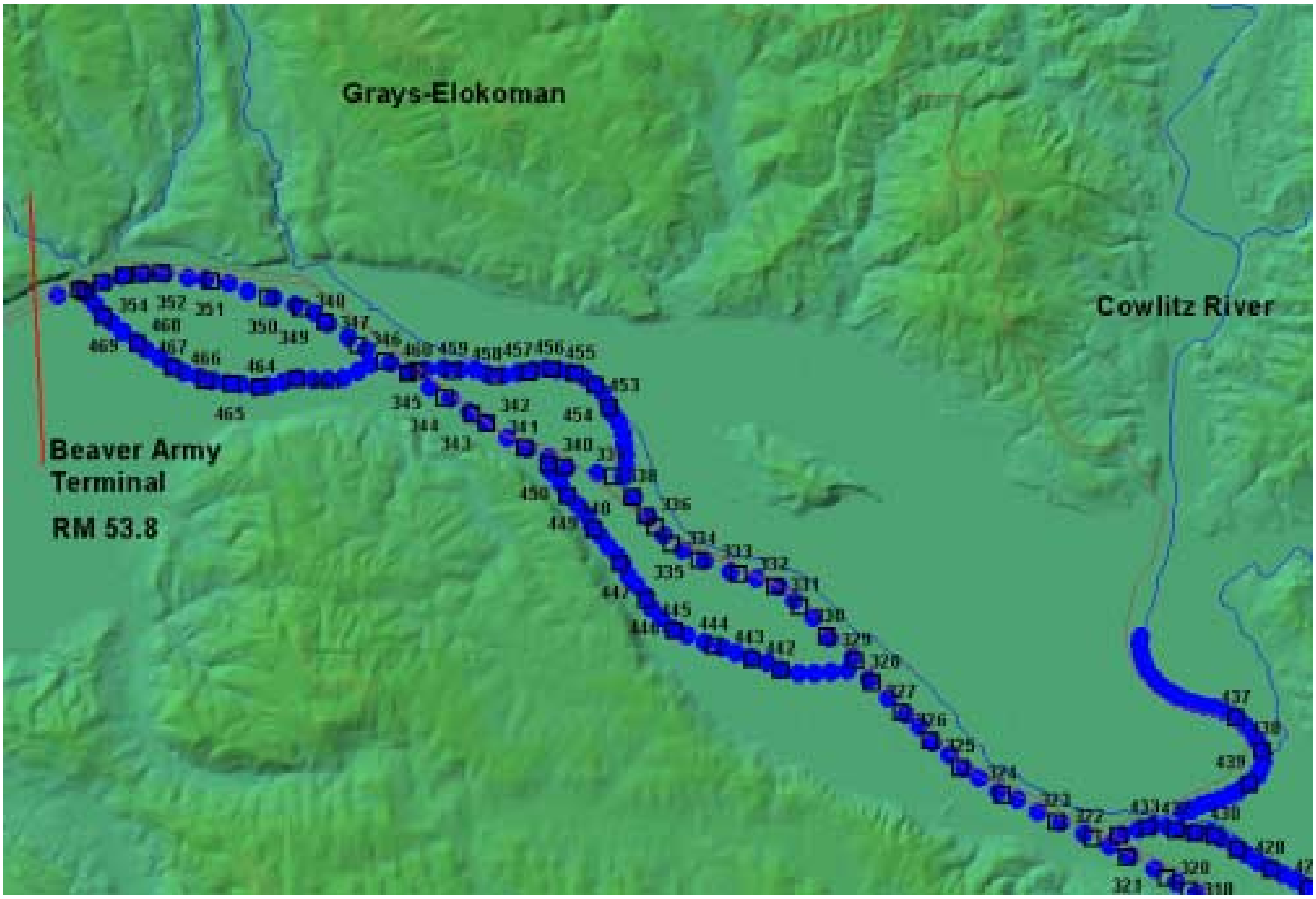



**Figure 79. Model segments along the Columbia River near Cowlitz River and Beaver Army Terminal.**

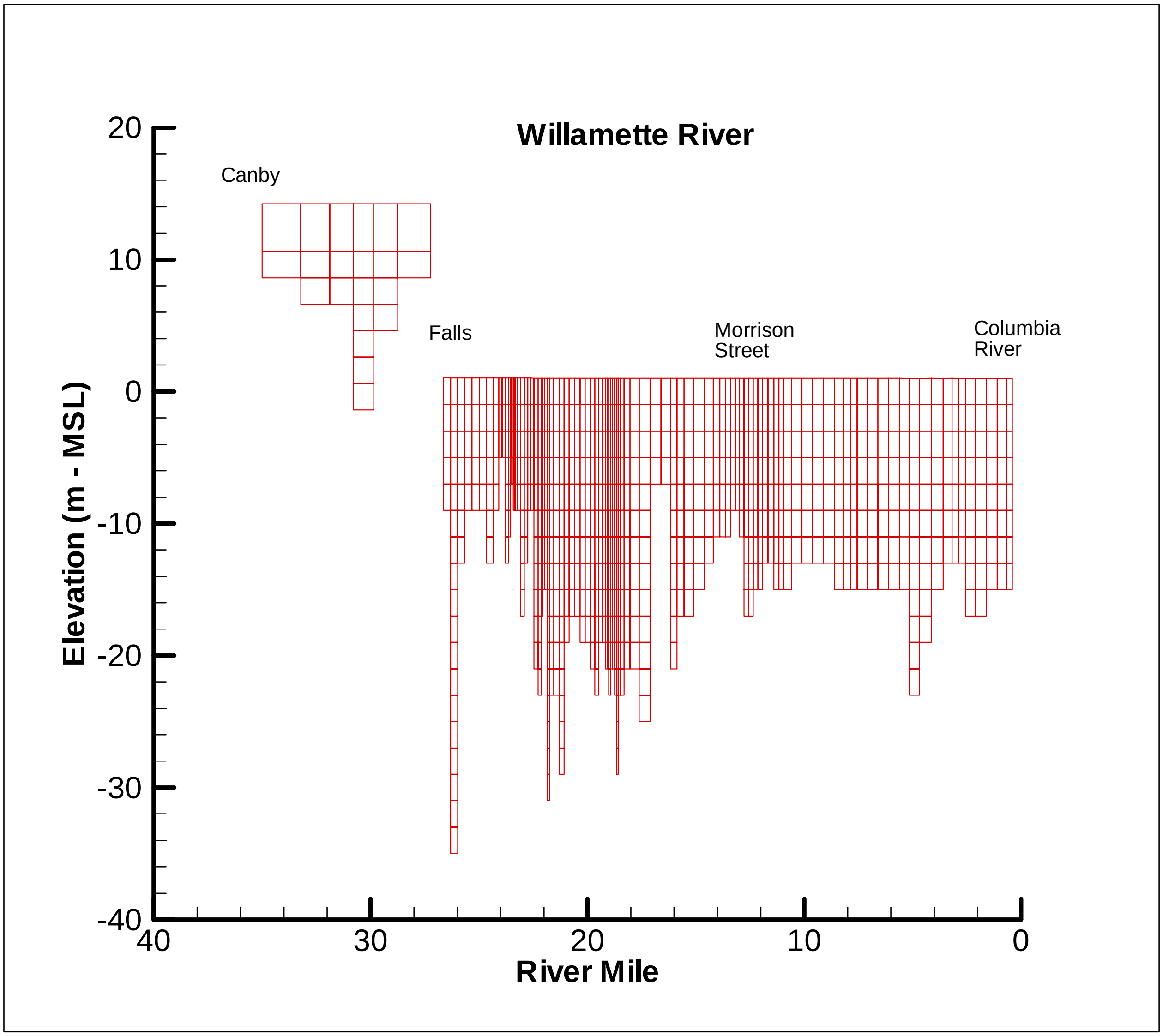



**Figure 80. Vertical grid resolution along the Willamette River model domain (note variable longitudinal segment spacing and vertical grid resolution).**

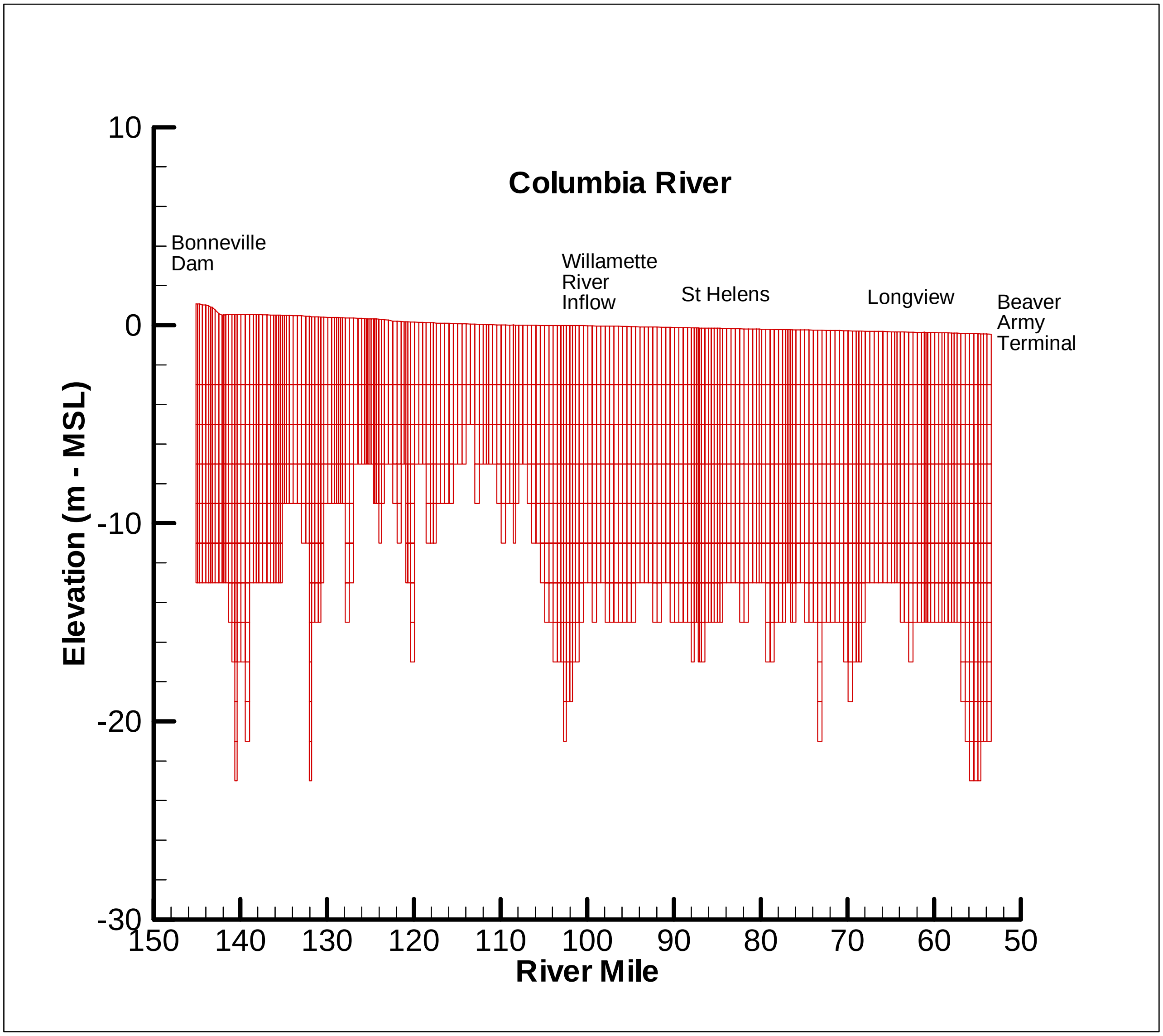



**Figure 81. Vertical grid resolution along the Columbia River model domain.**

## Summary

A model has been set-up for the Lower Willamette River and the Columbia River between the head of tide at Bonneville Dam and the Beaver Terminal. The focus of this study is the water quality of the Lower Willamette during summer periods. There is interest in understanding the cause of water quality limited conditions and explore the use of a mathematical model to evaluate different discharge options for Water Environment Services, Clackamas County.

The Corps of Engineers model CE-QUAL-W2 Version 3 (Cole and Wells, 2000) was chosen for the Willamette-Columbia system. This is a two-dimensional (vertical-longitudinal) hydrodynamic and water quality model that can model the parameters of interest in this project: dissolved and particulate non-living organic matter (both refractory and labile components), ammonia, nitrate, dissolved $PO_4$, algae, TDS, pH, dissolved oxygen, and bacteria.

Because of the tidal influence in the Lower Willamette River, portions of the Columbia River that might affect the Lower Willamette River water quality were also modeled. Also, a section of the Willamette River above the head of tide, the Oregon City Falls, was modeled because of the lack of good boundary condition data at the Falls.

Data developed in this report for the model included:

- Meteorological data
- Bathymetry data
- Inflow temperatures, water quality and flows
- Tributary and point source temperatures, water quality and flows
- Tidal conditions at Beaver Terminal

In many cases, boundary condition data were estimated using data correlations to fill in missing measurements for the period of the model simulation. The model simulation is focused on the summers (May 1- October 1) of 1993, 1994, 1997, 1998, and 1999.

Some point sources were not accounted for in the model such as storm water and CSO discharge points in the Lower Willamette since the focus was on summer, low-flow events in the Lower Willamette.

The model grid consists of 4 water bodies and 16 branches and a total of 483 segments with segment lengths ranging from 80 m to 3000 m. The vertical grid resolution was 2 m. The model river mile extent is about 35 miles of the Willamette River and 91 miles of the Columbia River (not counting side channels).

A companion report will be developed detailing the model calibration and management strategies.

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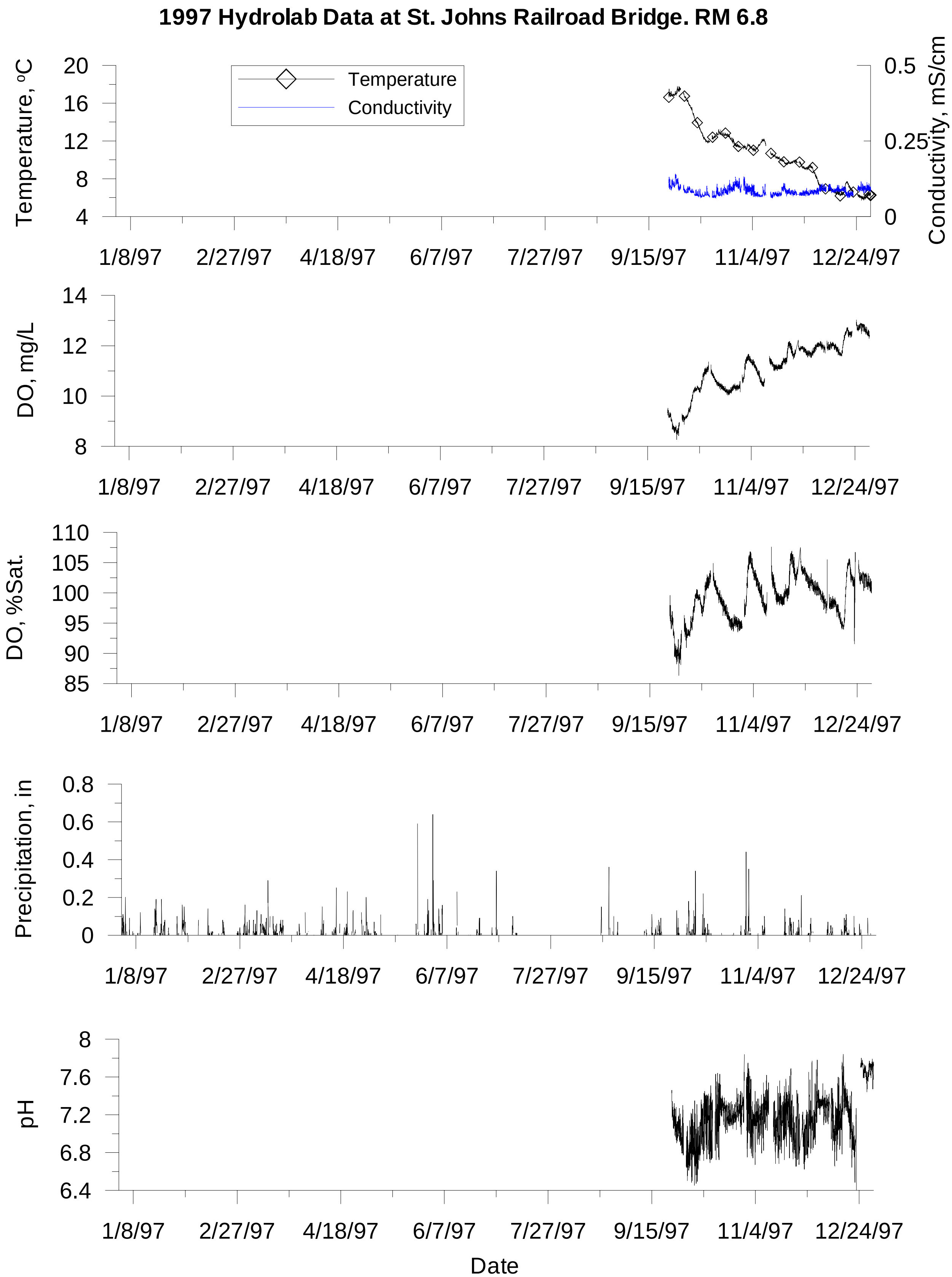
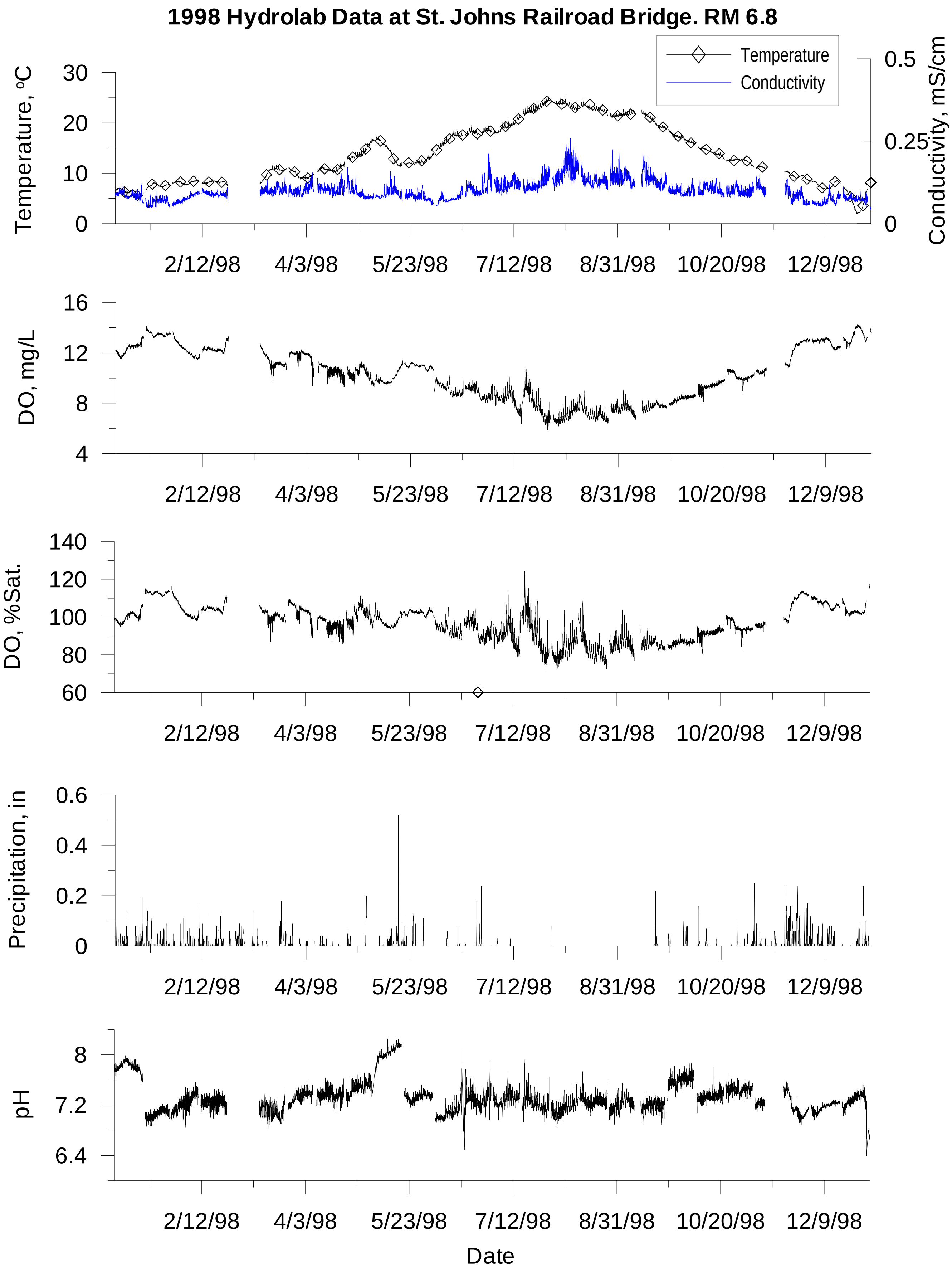
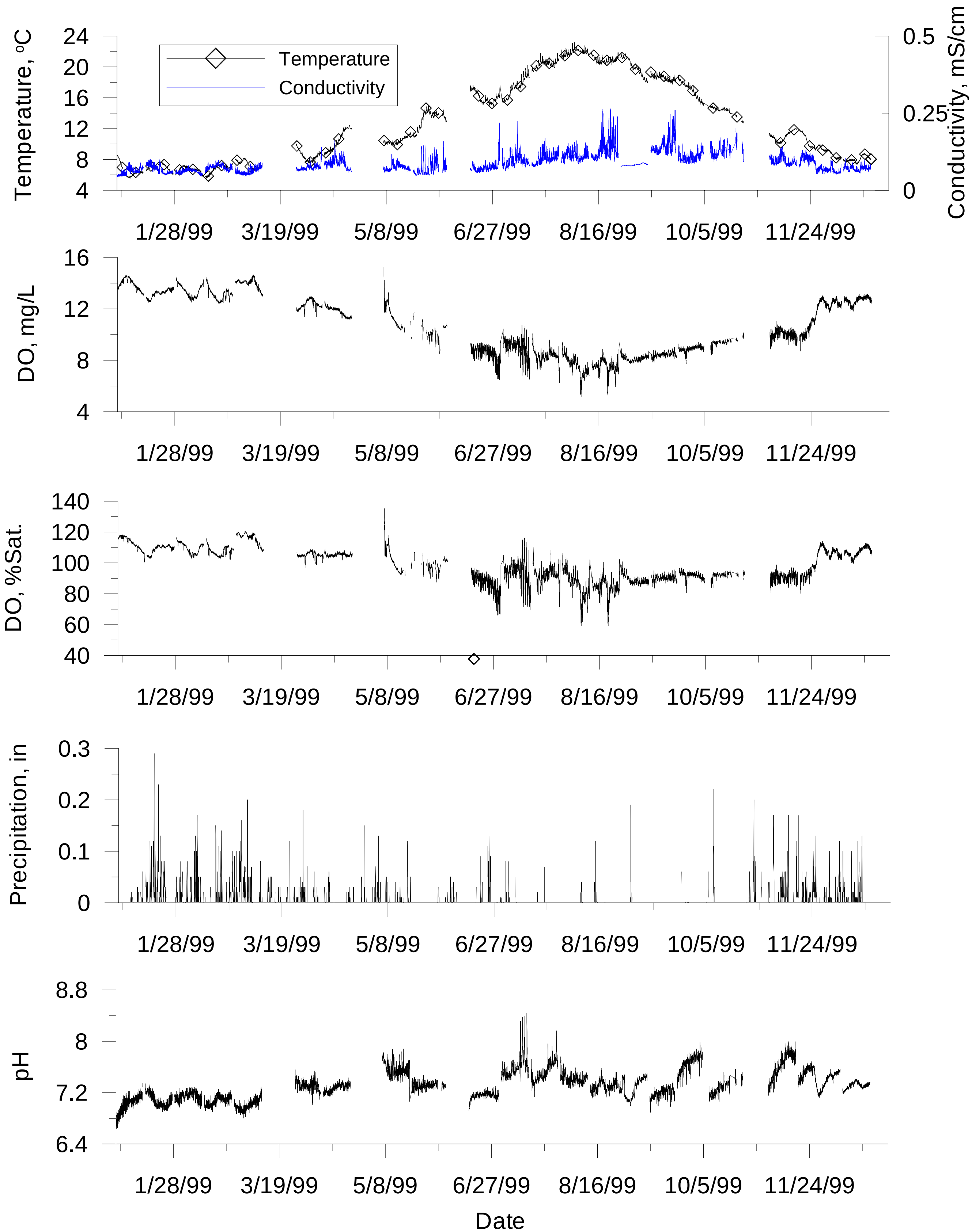
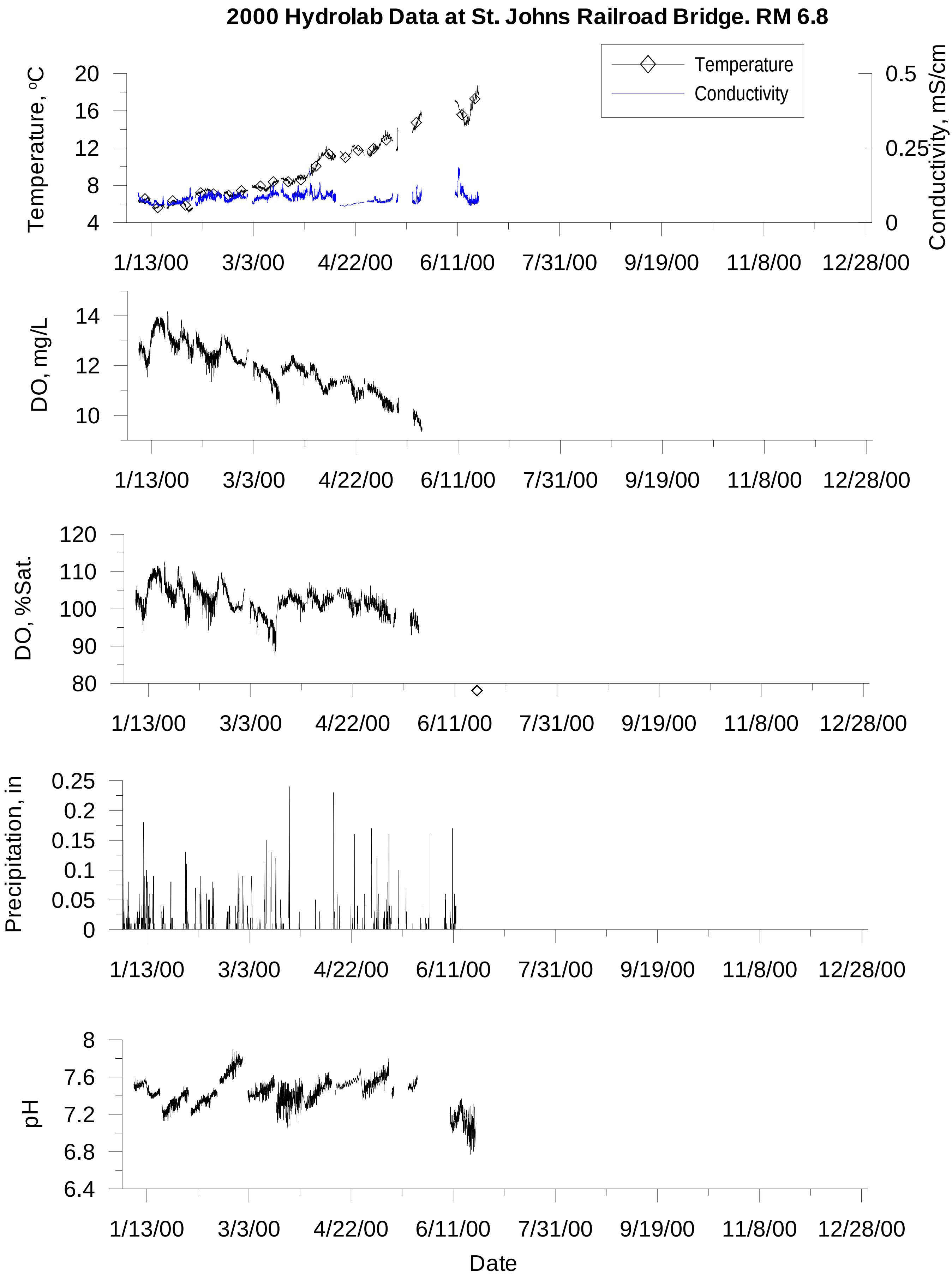
## Appendix A:  Willamette River Hydrolab data




1998 Hydrolab Data at St. Johns Railroad Bridge. RM 6.8
Temperature
Conductivity
Temperature, °C
Conductivity, mS/cm
DO, mg/L
DO, %Sat.
Precipitation, in
pH
2/12/98
4/3/98
5/23/98
7/12/98
8/31/98
10/20/98
12/9/98
Date

## 1999 Hydrolab Data at St. Johns Railroad Bridge. RM 6.8




2000 Hydrolab Data at St. Johns Railroad Bridge. RM 6.8
Temperature
Conductivity
Temperature, °C
Conductivity, mS/cm
20
16
12
8
4
0.5
0.25
0
DO, mg/L
14
12
10
DO, %Sat.
120
110
100
90
80
Precipitation, in
0.25
0.2
0.15
0.1
0.05
0
pH
8
7.6
7.2
6.8
6.4
1/13/00
3/3/00
4/22/00
6/11/00
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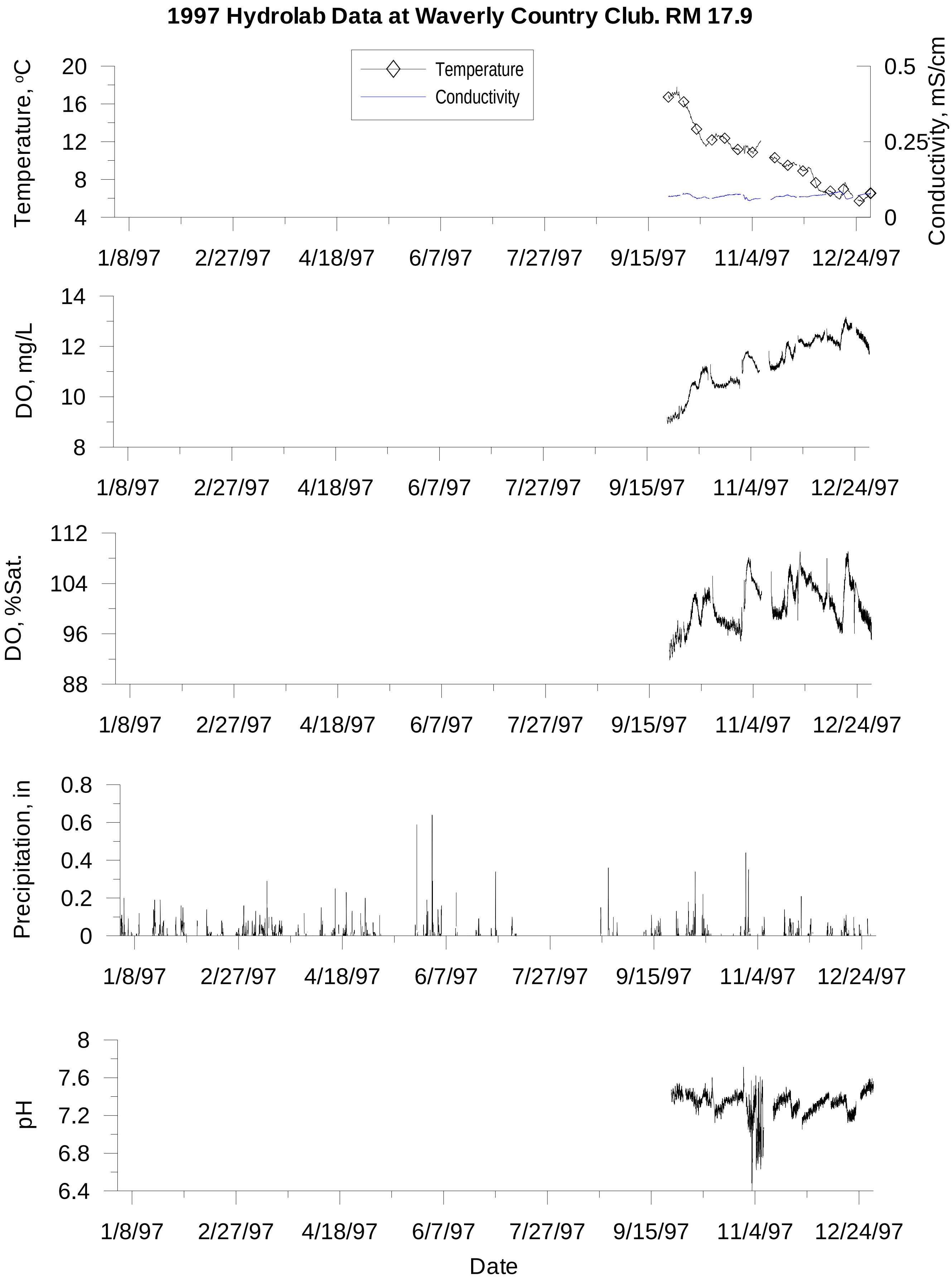
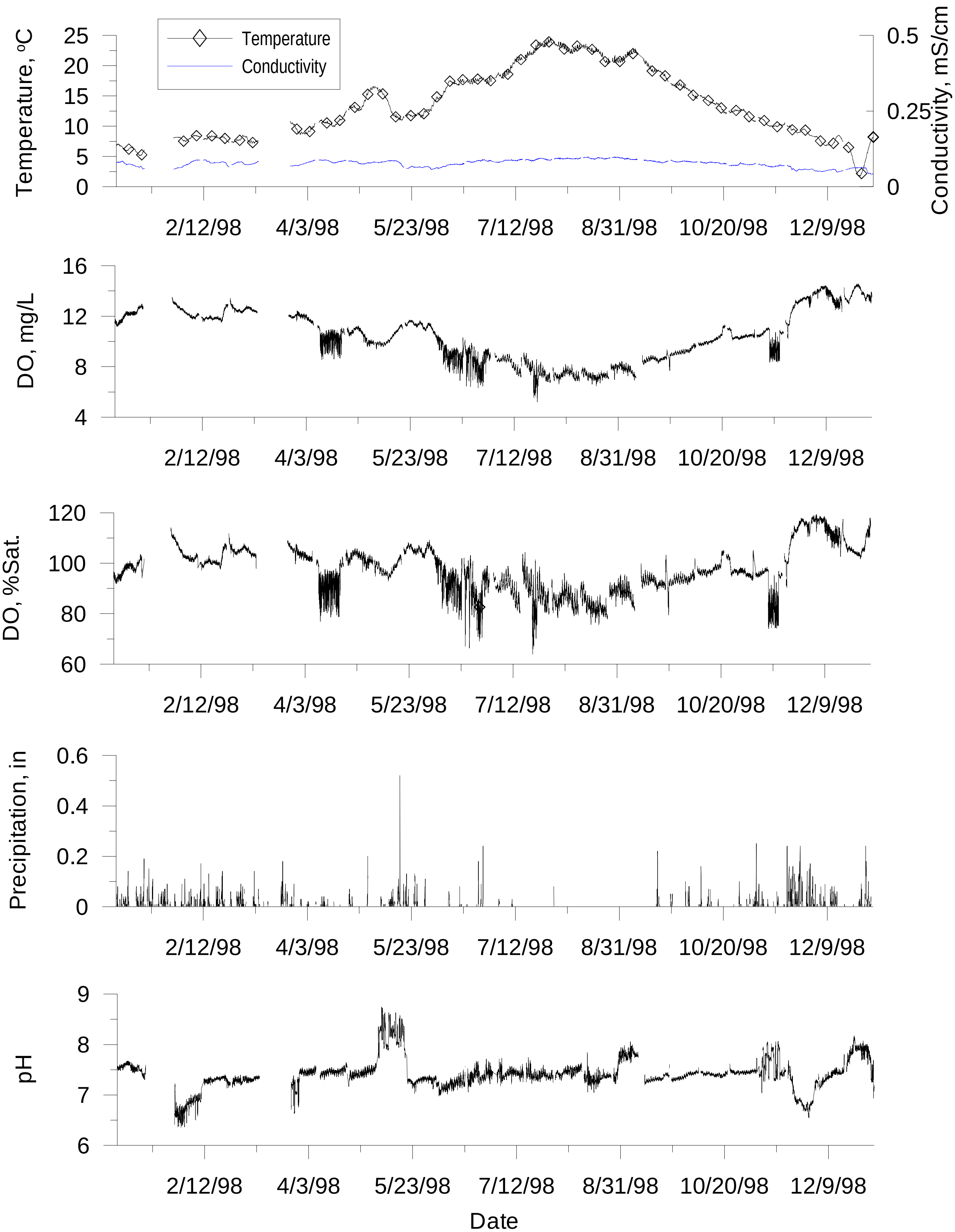
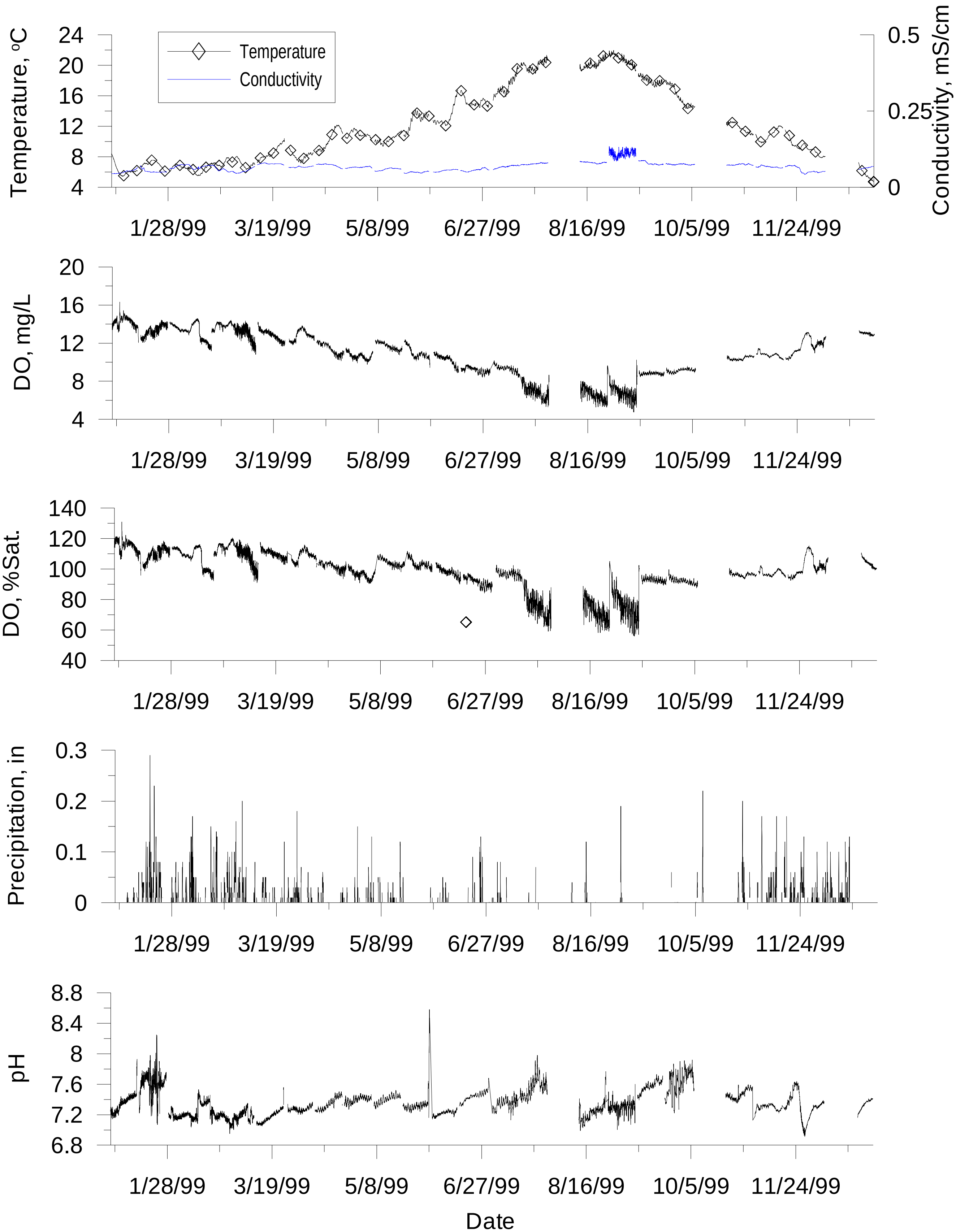
11/8/00
12/28/00
Date


1997 Hydrolab Data at Waverly Country Club. RM 17.9
Temperature
Conductivity
Temperature, °C
Conductivity, mS/cm
20
16
12
8
4
0.5
0.25
0
1/8/97
2/27/97
4/18/97
6/7/97
7/27/97
9/15/97
11/4/97
12/24/97
DO, mg/L
14
12
10
8
DO, %Sat.
112
104
96
88
Precipitation, in
0.8
0.6
0.4
0.2
0
pH
8
7.6
7.2
6.8
6.4
Date

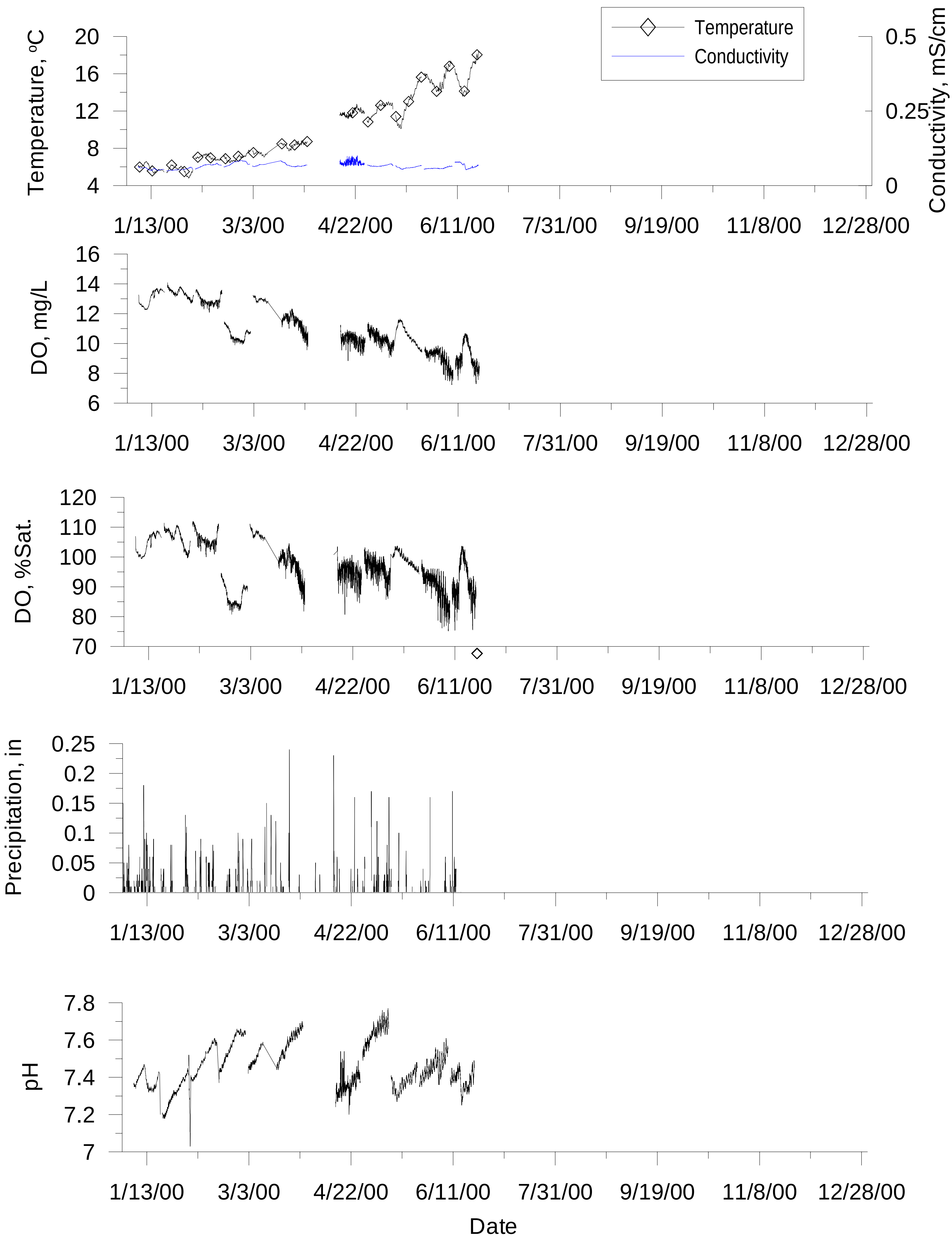
## 1998 Hydrolab Data at Waverly Country Club. RM 17.9



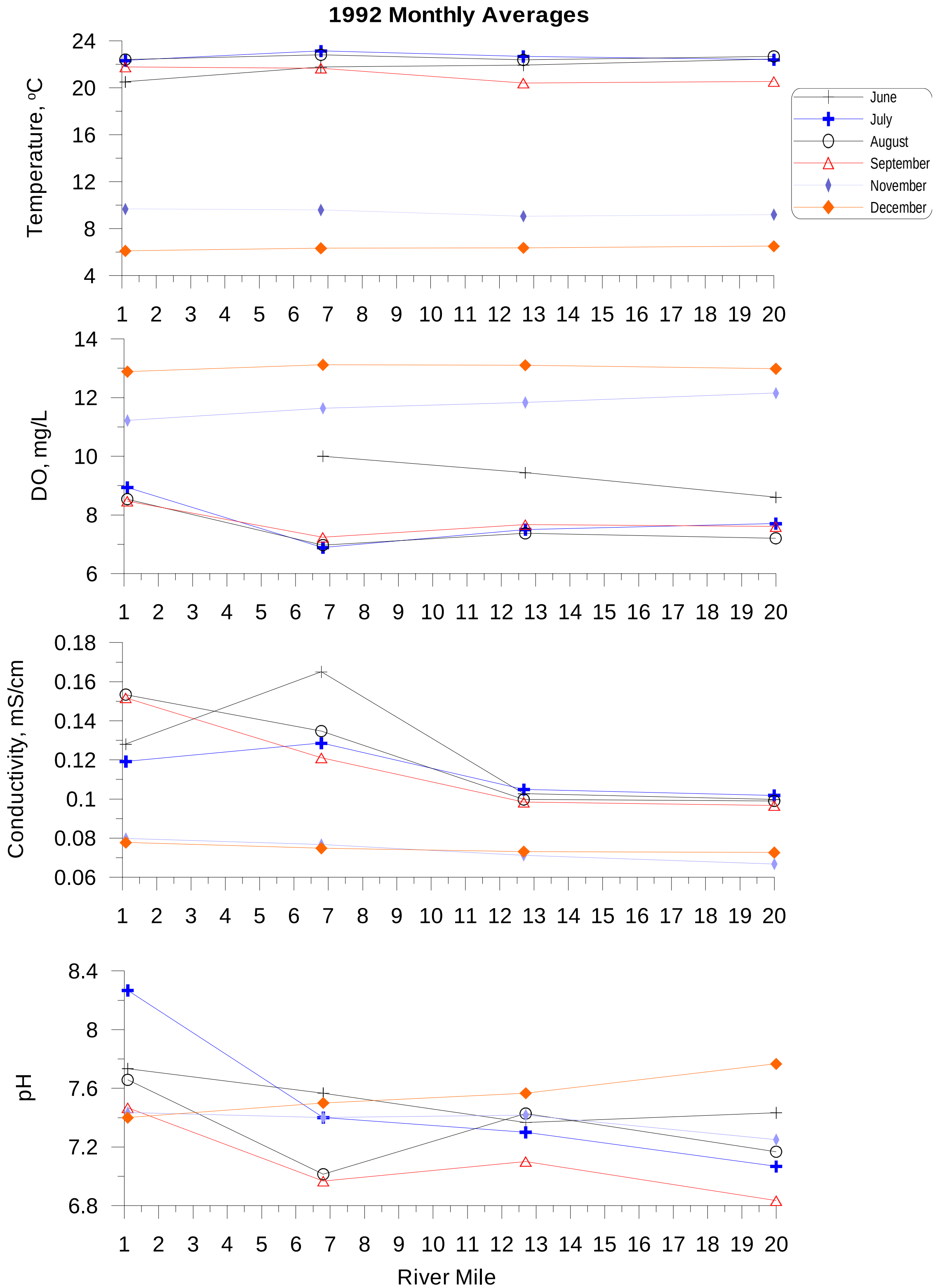
## 1999 Hydrolab Data at Waverly Country Club. RM 17.9

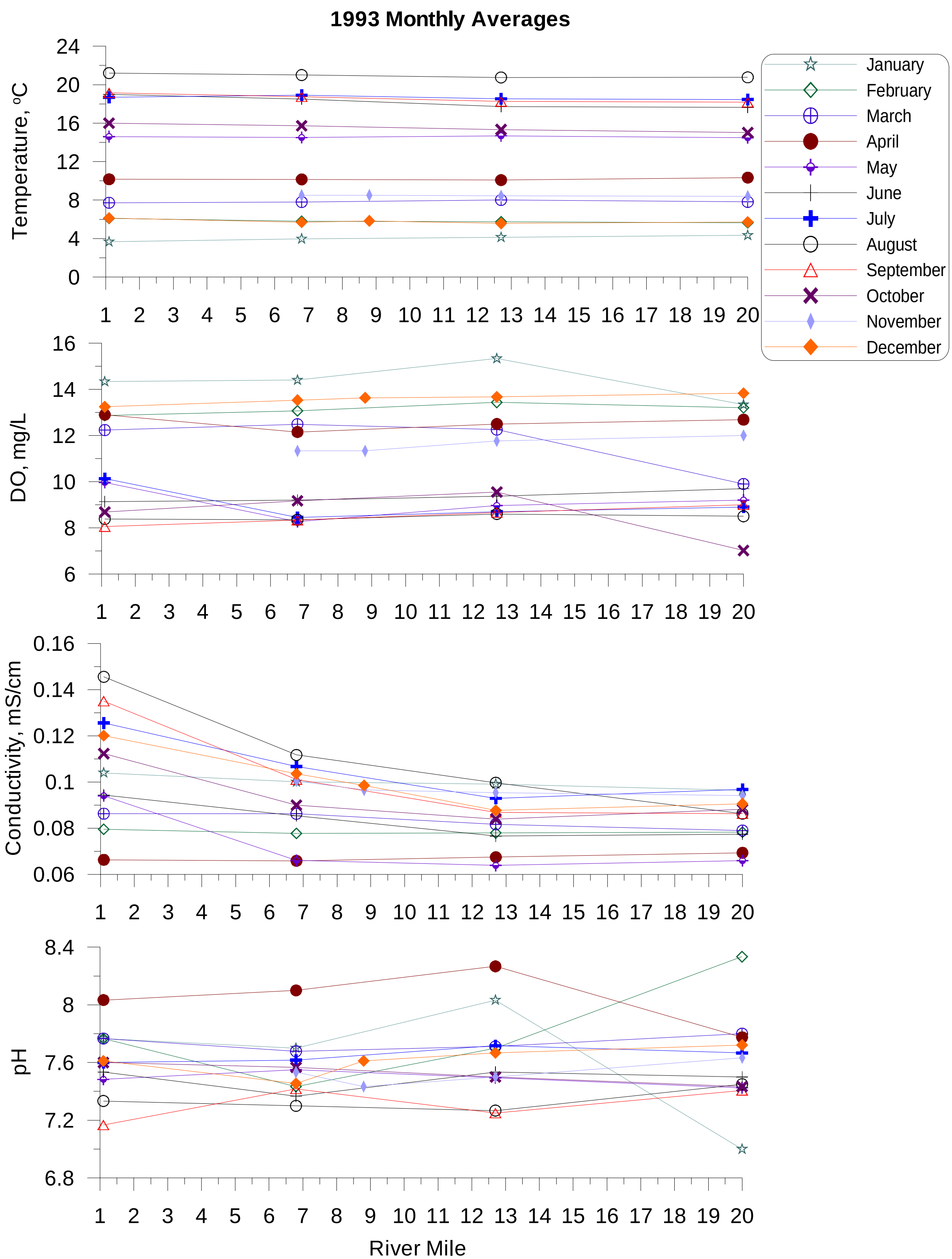


## 2000 Hydrolab Data at Waverly Country Club. RM 17.9

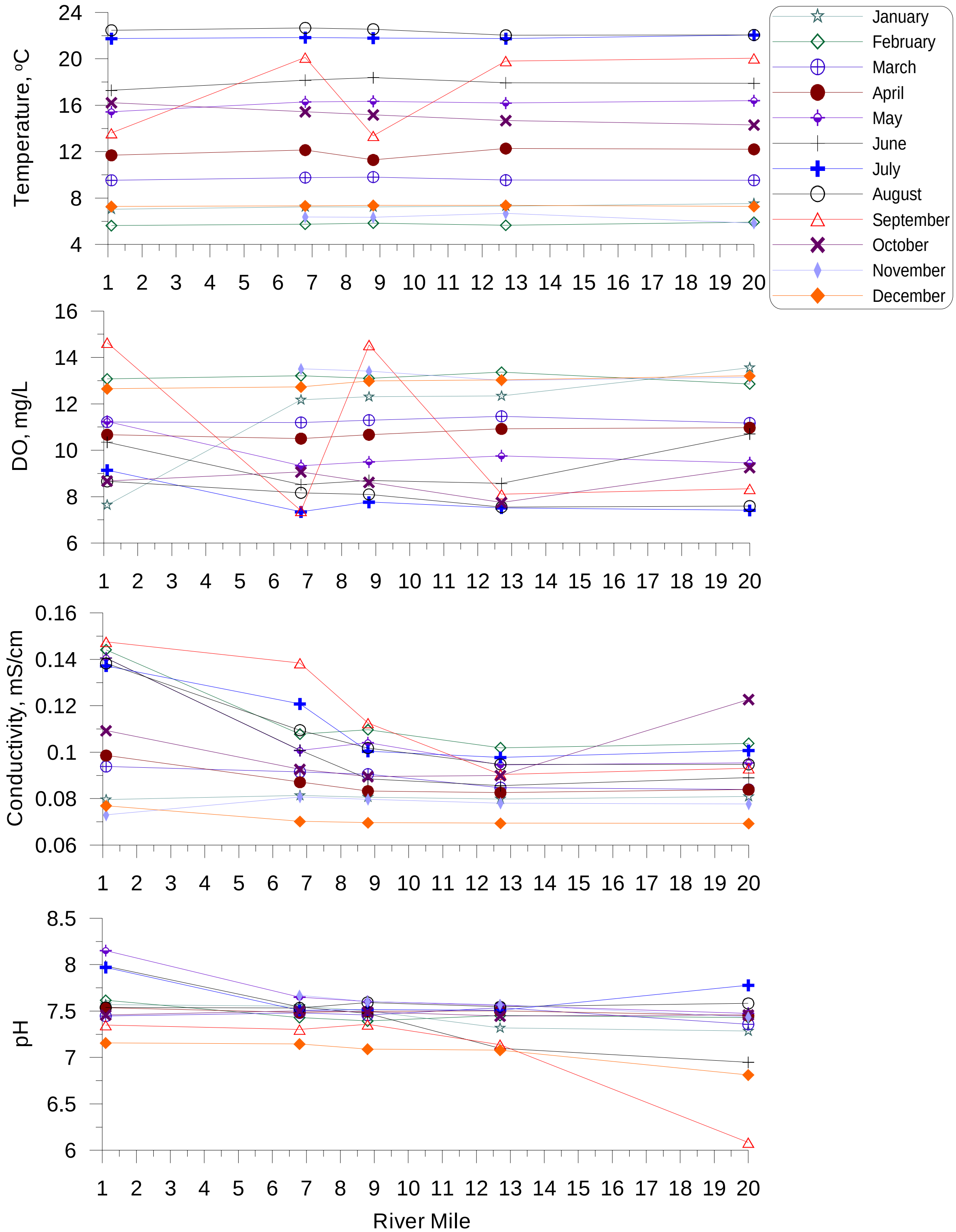


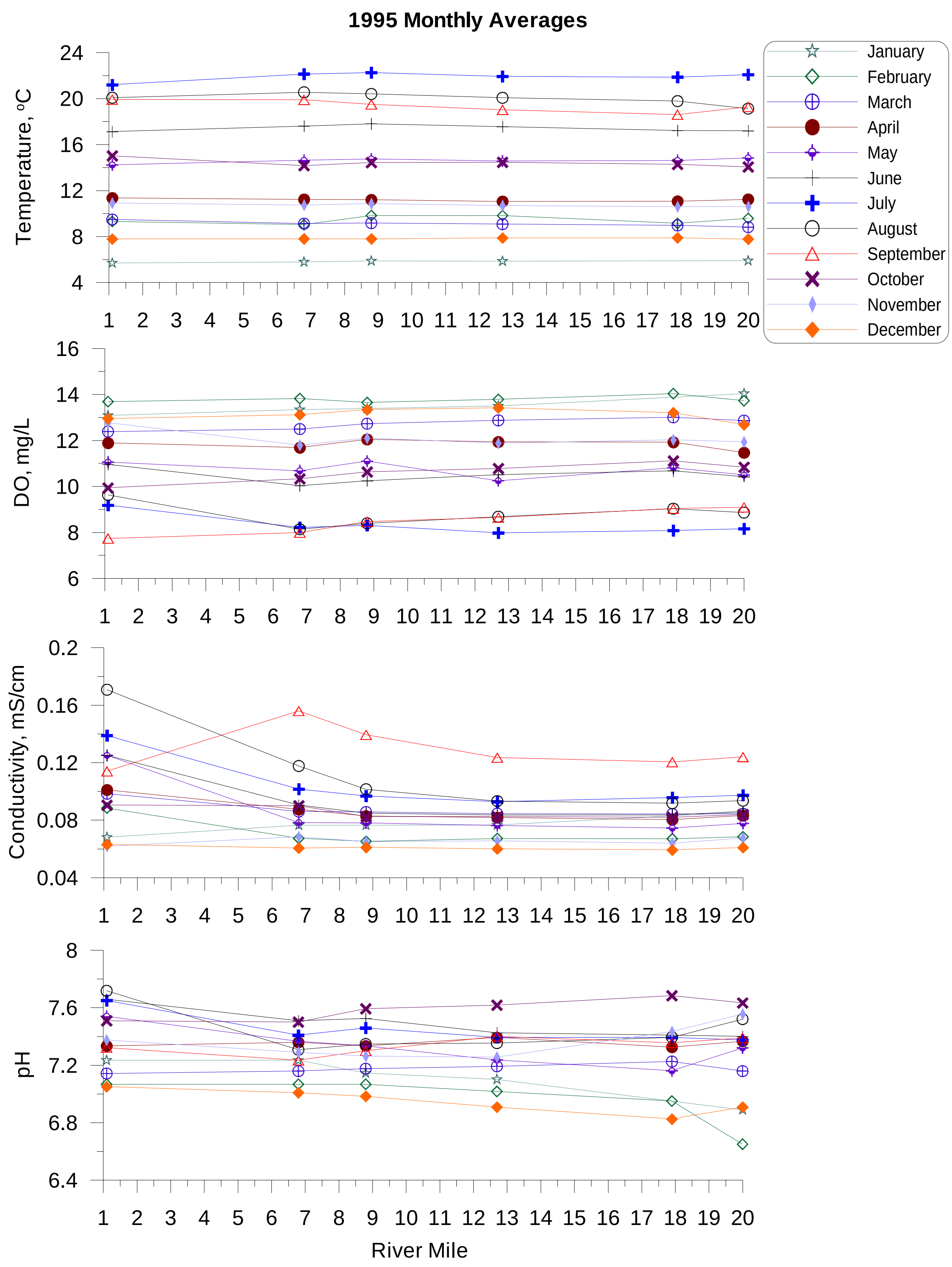
# Appendix B:  Willamette River Longitudinal Profiles (monthly averages)

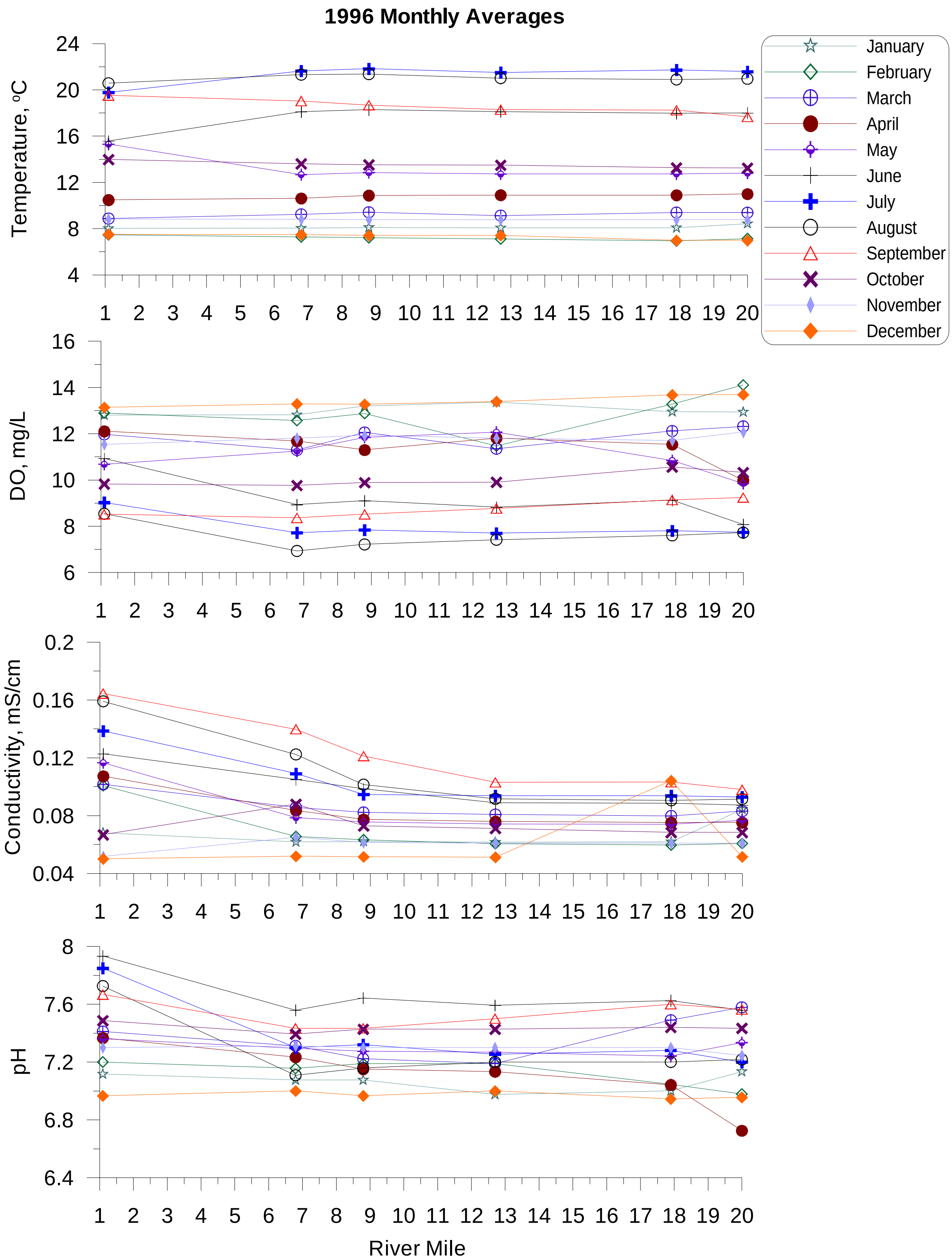


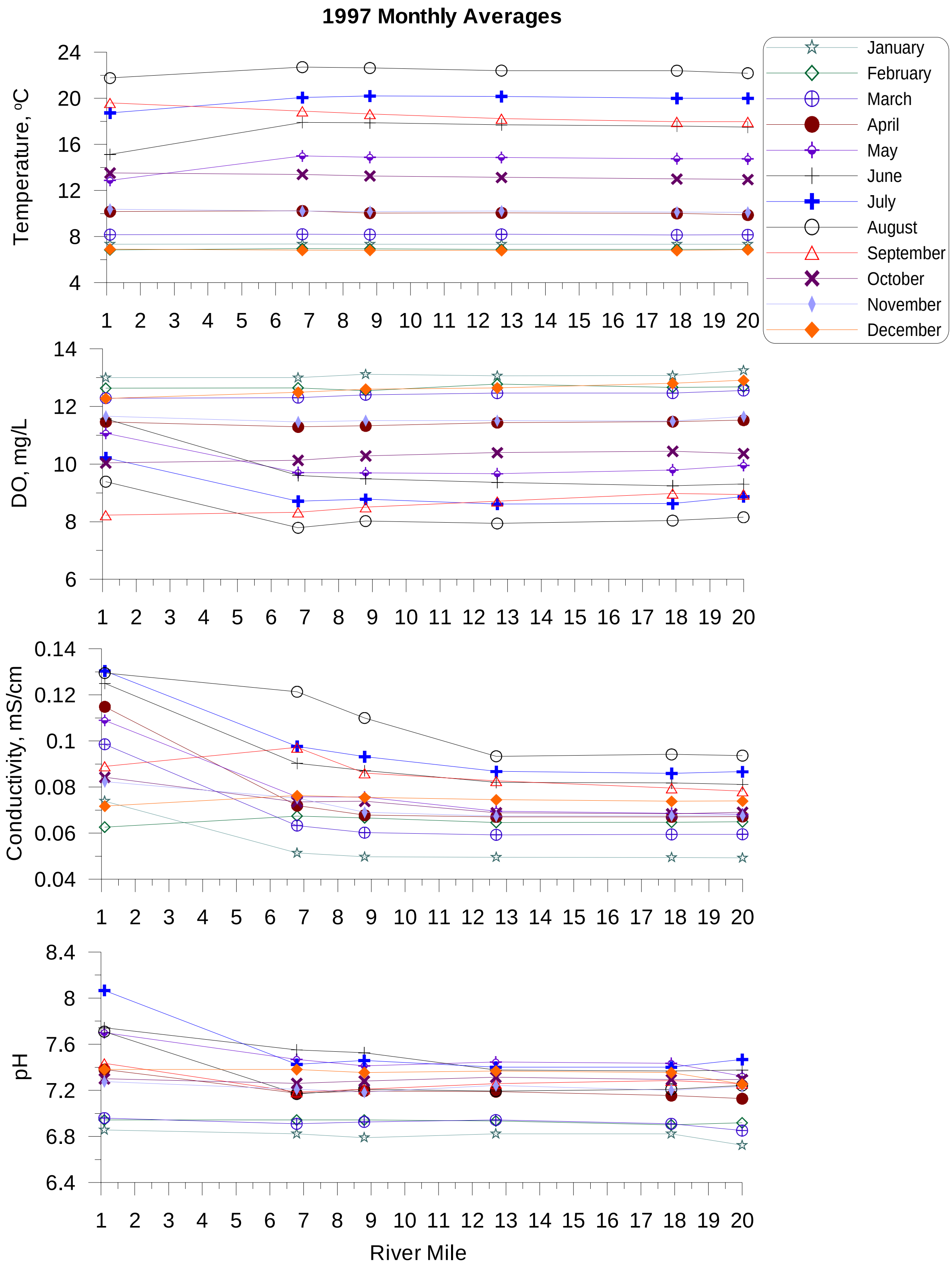

1993 Monthly Averages
Temperature, °C
DO, mg/L
Conductivity, mS/cm
pH
River Mile
January
February
March
April
May
June
July
August
September
October
November
December

## 1994 Monthly Averages

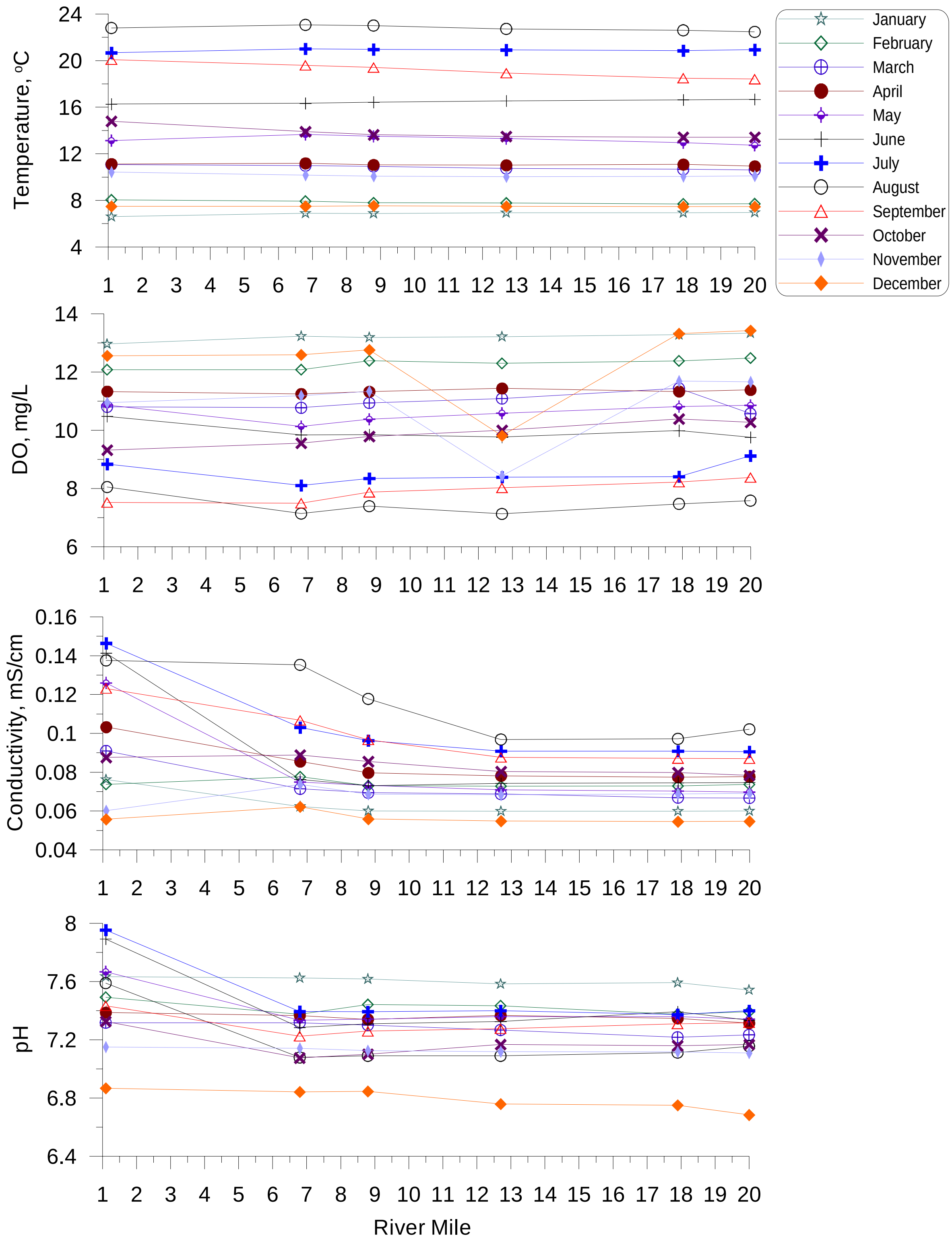


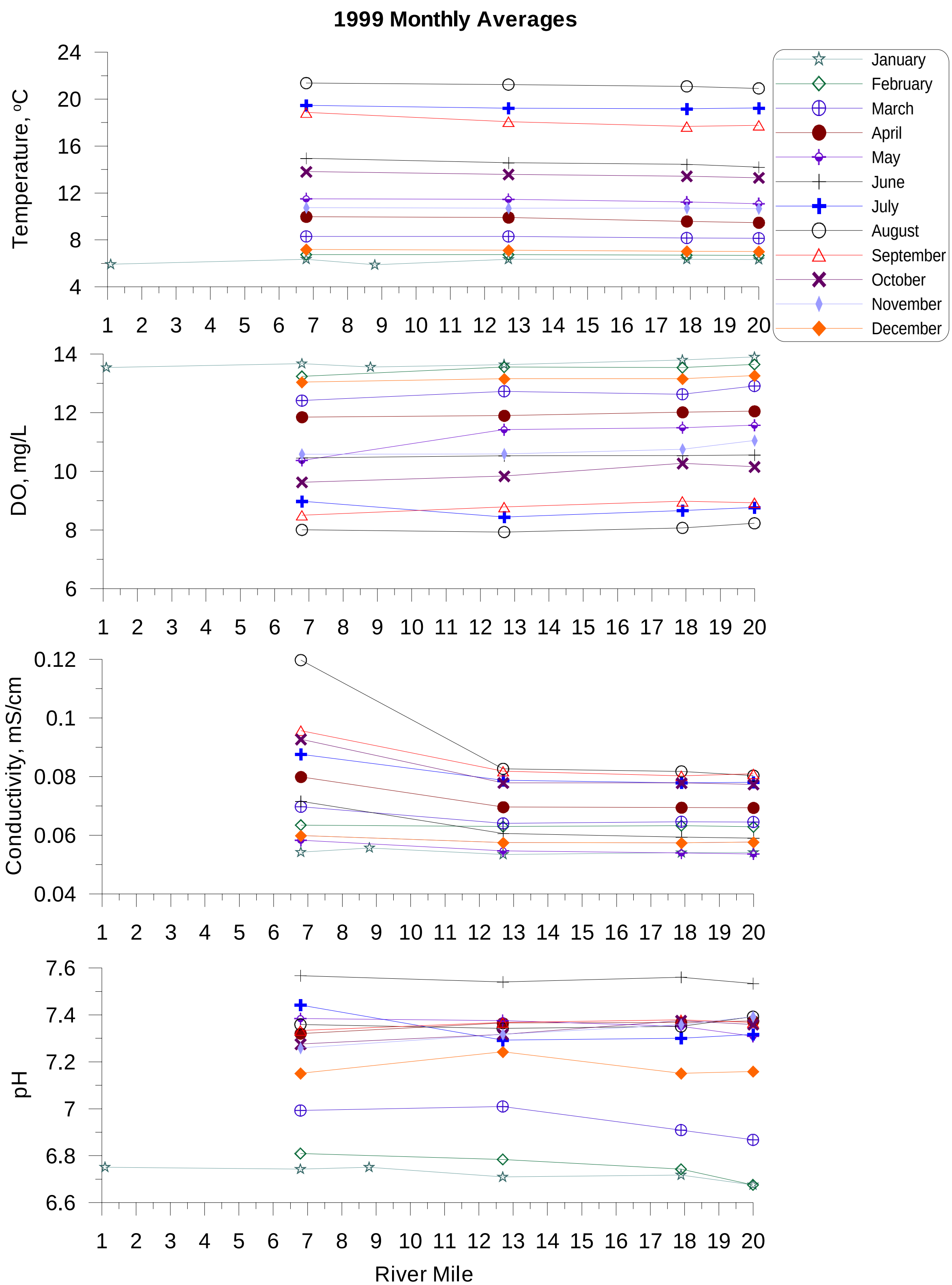

1995 Monthly Averages
Temperature, oC
DO, mg/L
Conductivity, mS/cm
pH
River Mile
January
February
March
April
May
June
July
August
September
October
November
December

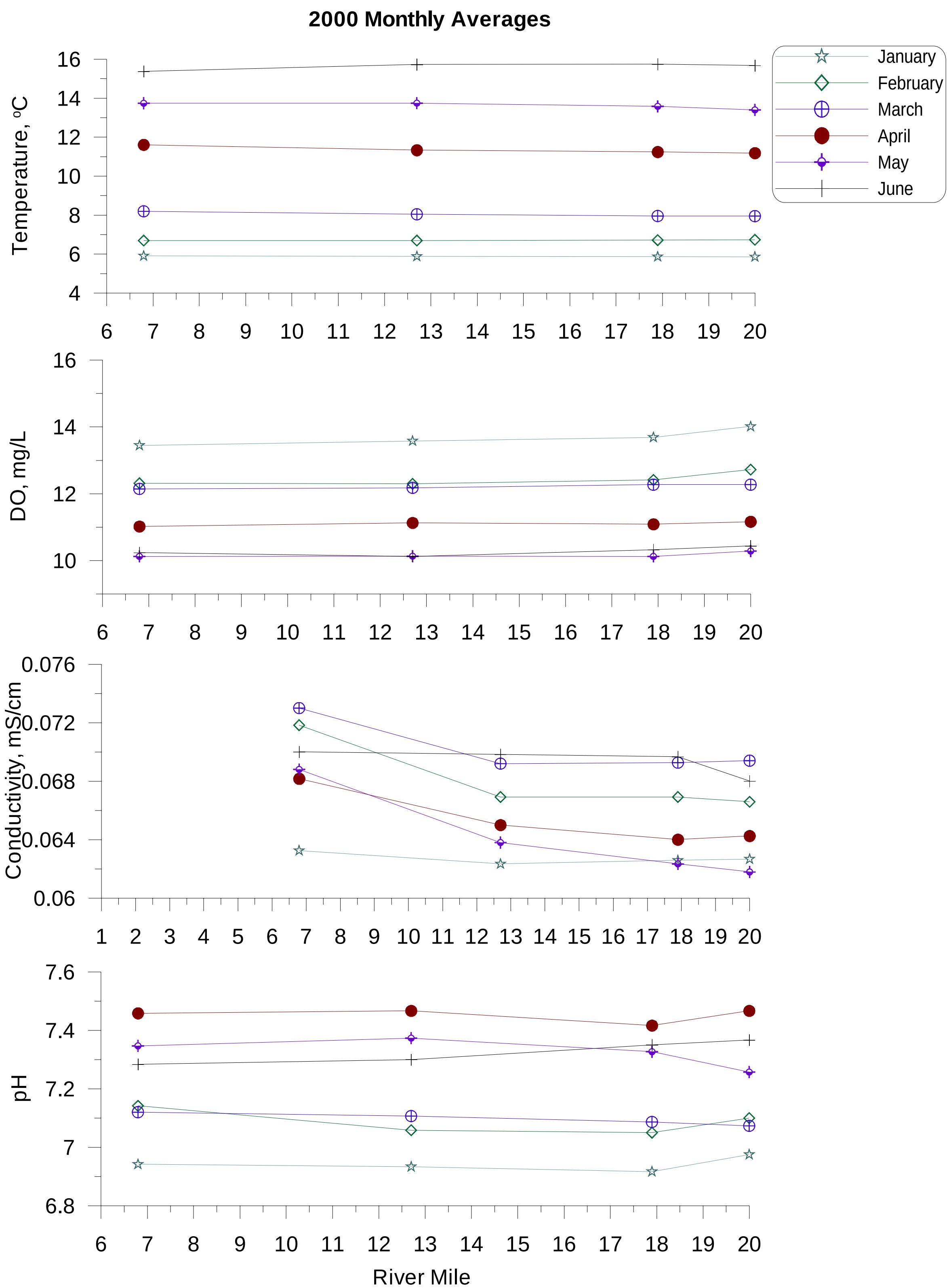

1996 Monthly Averages
Temperature, °C
DO, mg/L
Conductivity, mS/cm
pH
River Mile
January
February
March
April
May
June
July
August
September
October
November
December


1997 Monthly Averages
January
February
March
April
May
June
July
August
September
October
November
December
Temperature, °C
DO, mg/L
Conductivity, mS/cm
pH
River Mile
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

## 1998 Monthly Averages

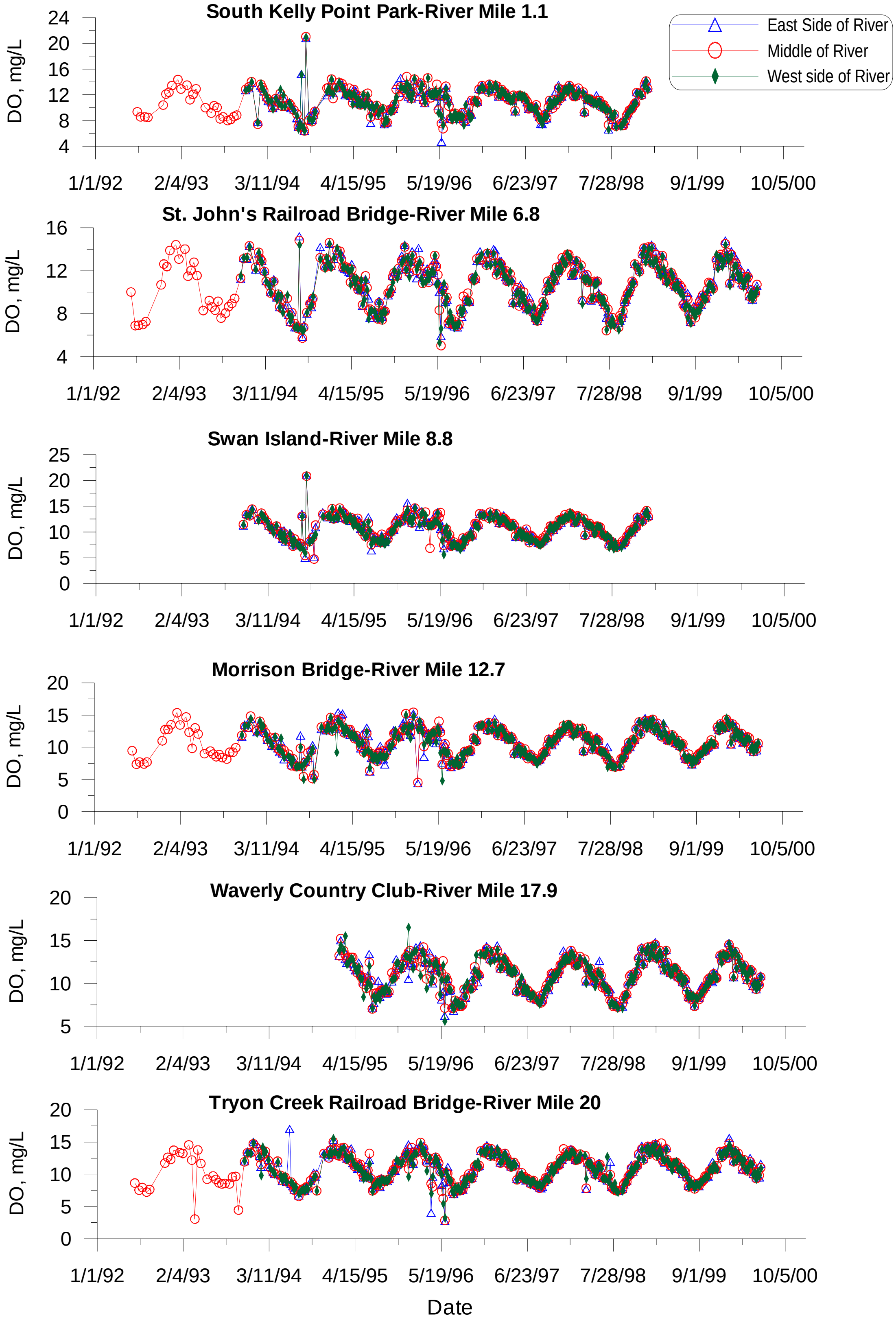



1999 Monthly Averages
Temperature, oC
DO, mg/L
Conductivity, mS/cm
pH
River Mile
January
February
March
April
May
June
July
August
September
October
November
December

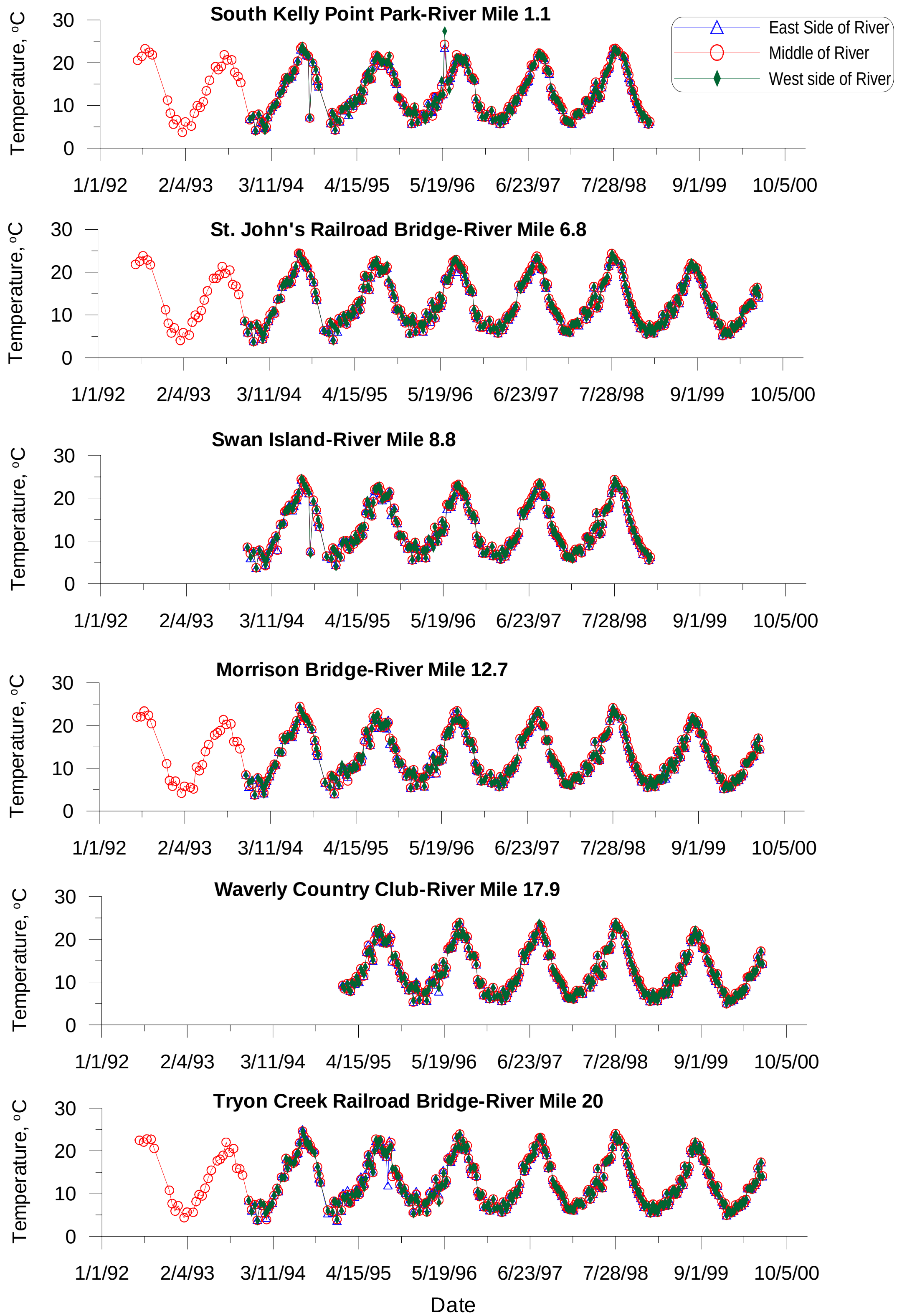

2000 Monthly Averages
January
February
March
April
May
June
Temperature, oC
DO, mg/L
Conductivity, mS/cm
pH
River Mile

# Appendix C:  Willamette River Grab Samples across the river

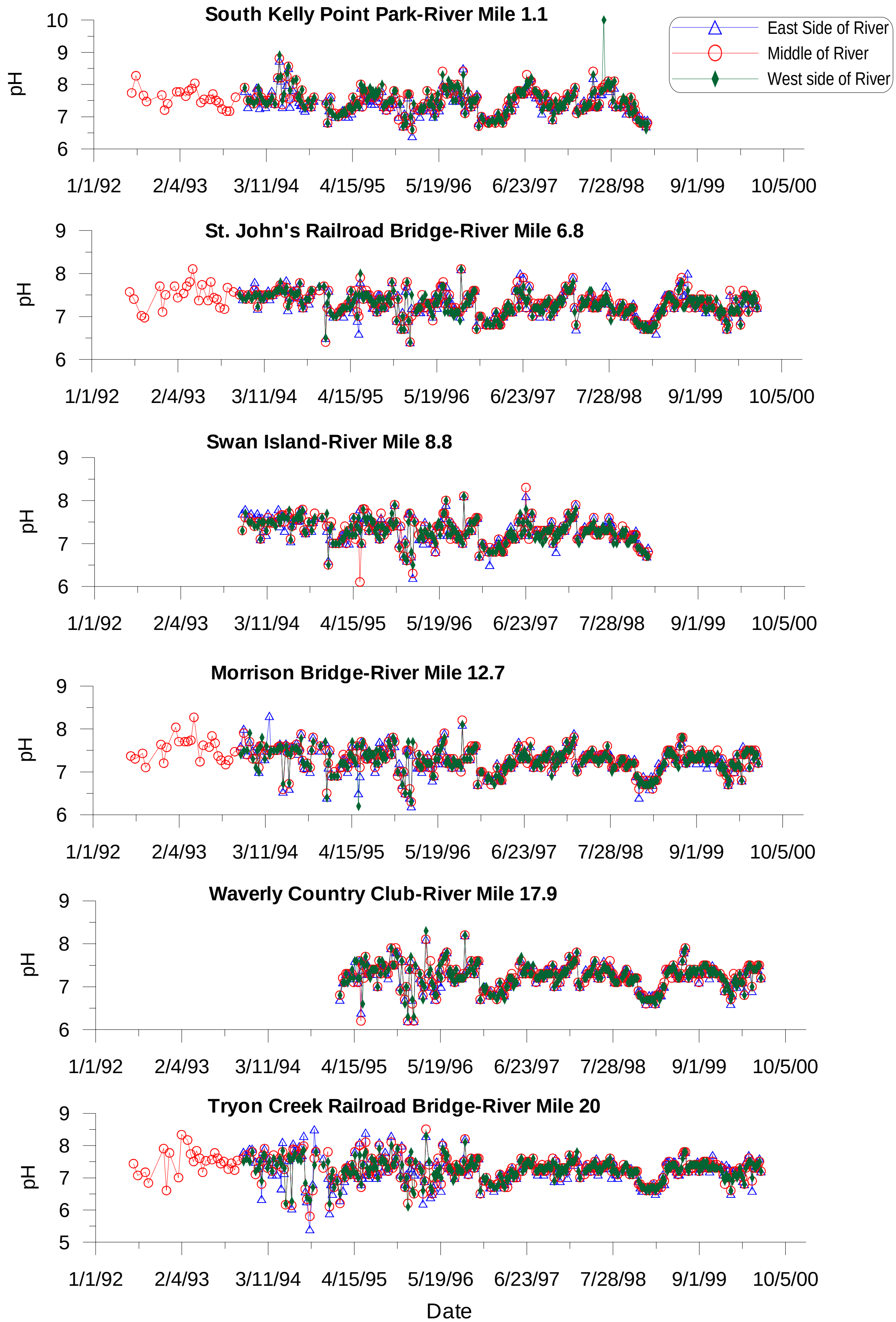
## Dissolved Oxygen



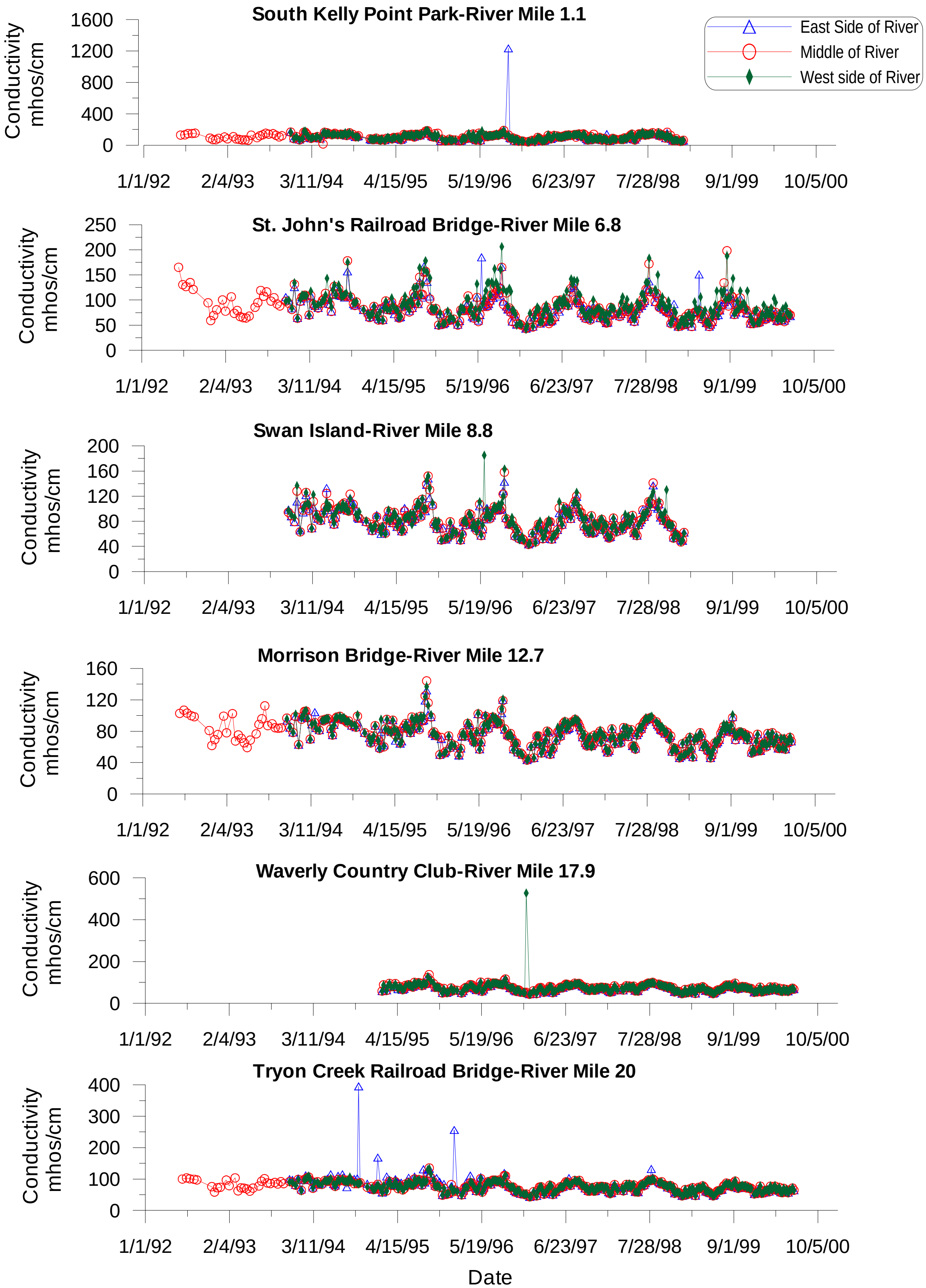
# Temperature



# pH

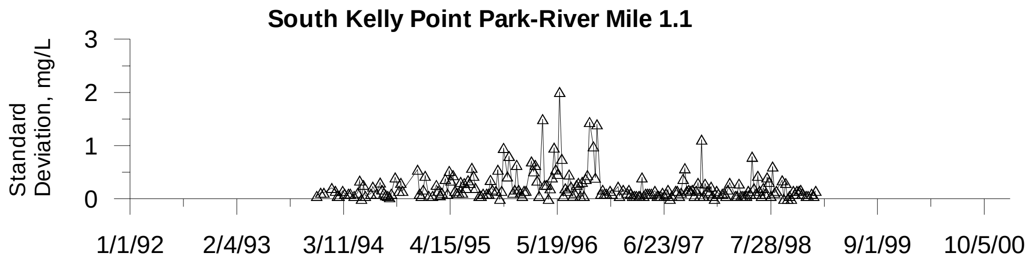

South Kelly Point Park-River Mile 1.1
St. John's Railroad Bridge-River Mile 6.8
Swan Island-River Mile 8.8
Morrison Bridge-River Mile 12.7
Waverly Country Club-River Mile 17.9
Tryon Creek Railroad Bridge-River Mile 20
East Side of River
Middle of River
West side of River
pH
Date
1/1/92
2/4/93
3/11/94
4/15/95
5/19/96
6/23/97
7/28/98
9/1/99
10/5/00

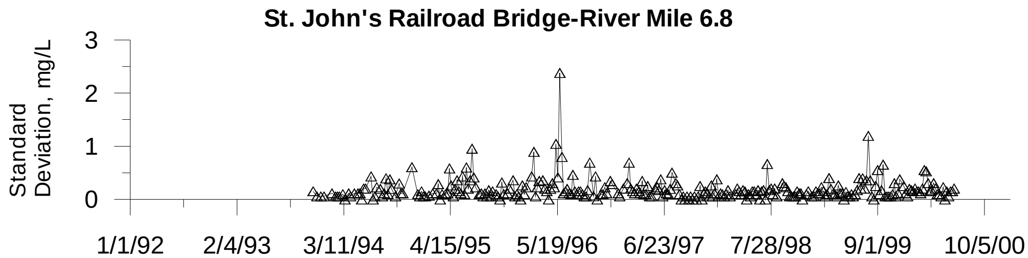
# Conductivity

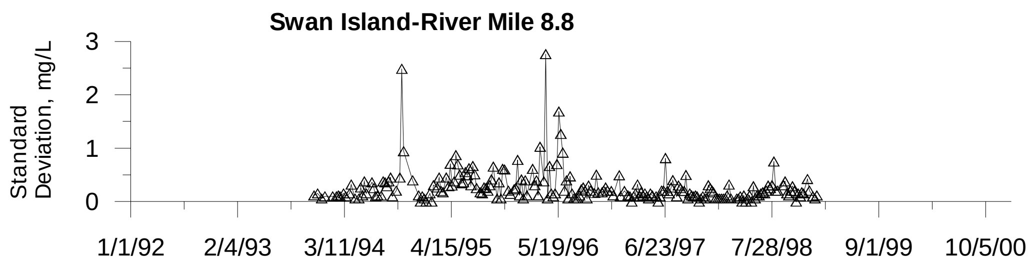


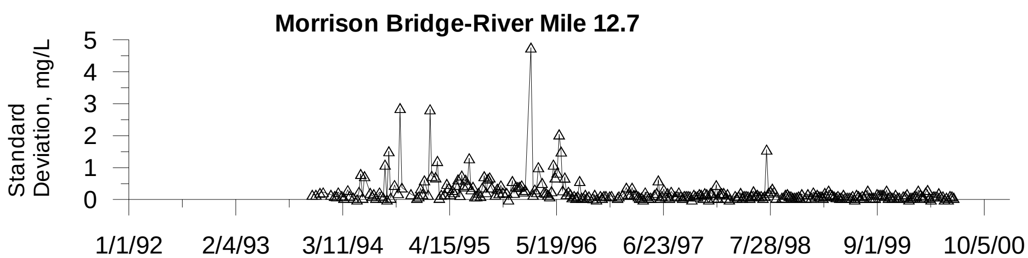
# Appendix D: Willamette River Grab Samples across the river - Standard Deviations

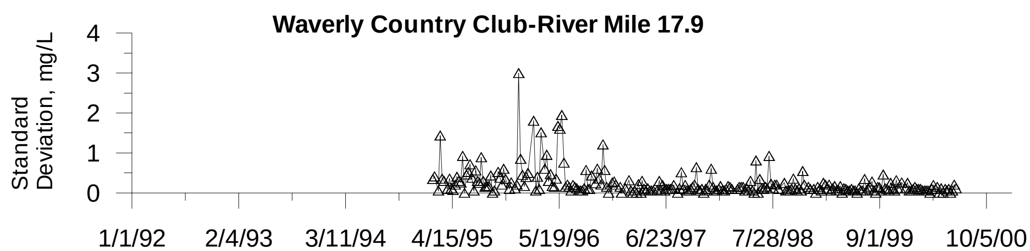
## Dissolved Oxygen

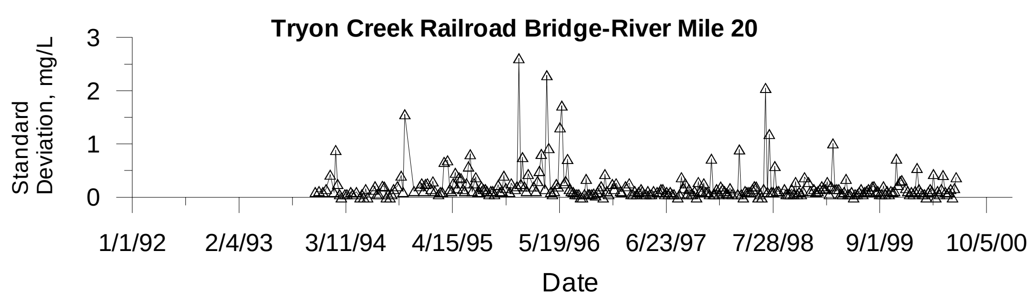


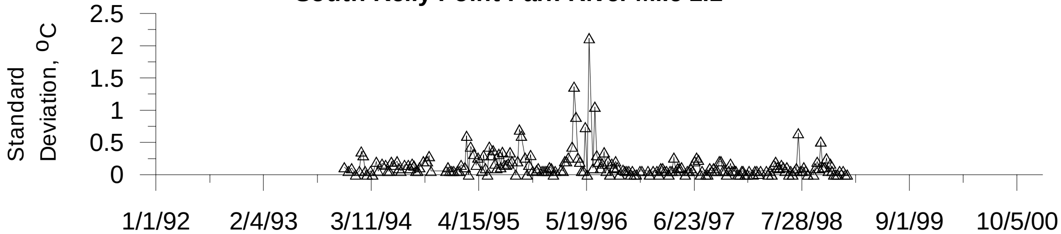



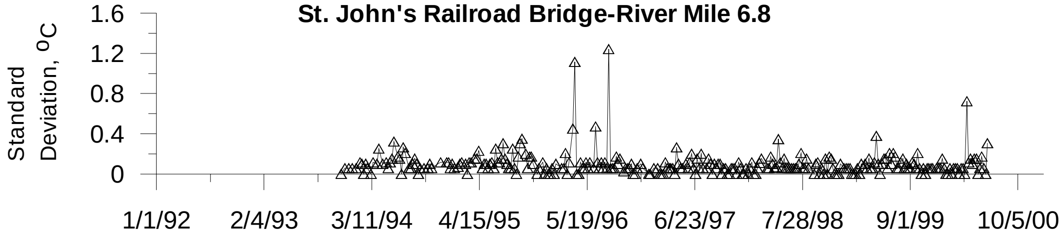



# Temperature

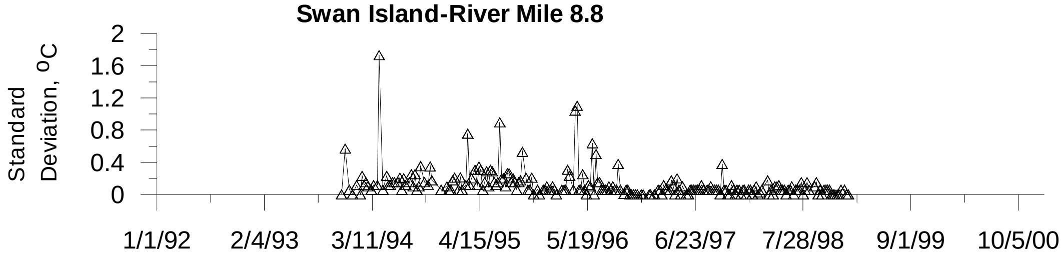
South Kelly Point Park-River Mile 1.1



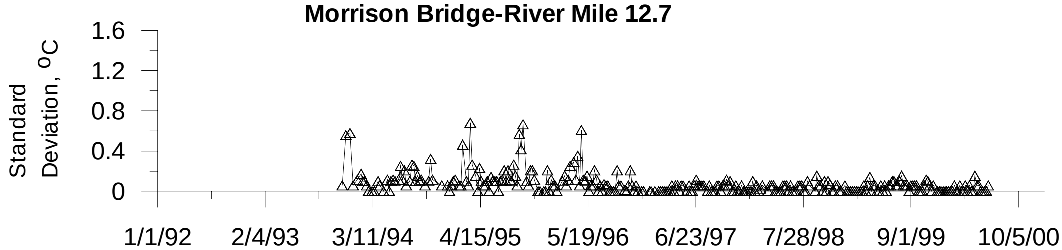

St. John's Railroad Bridge-River Mile 6.8



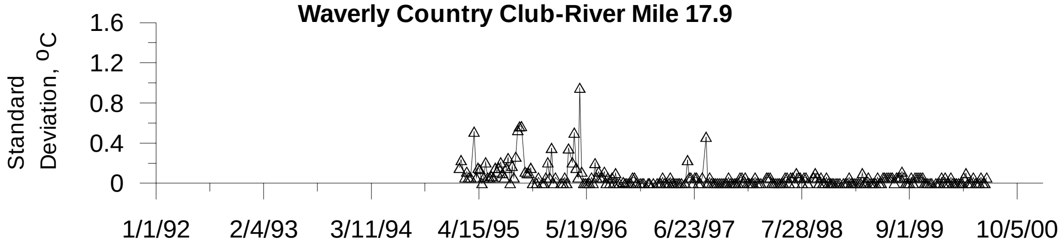

Swan Island-River Mile 8.8



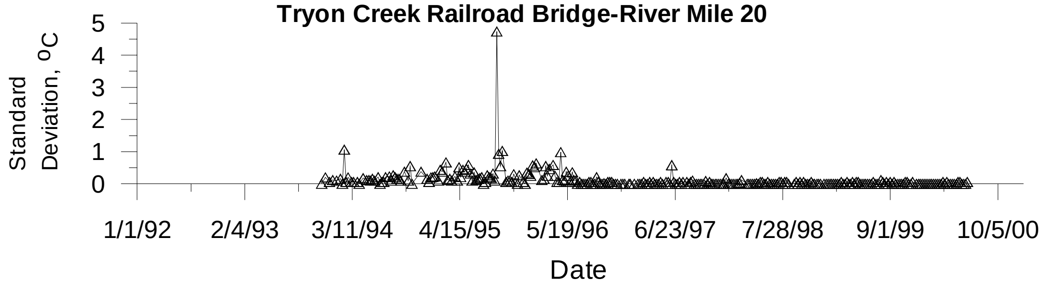

Morrison Bridge-River Mile 12.7



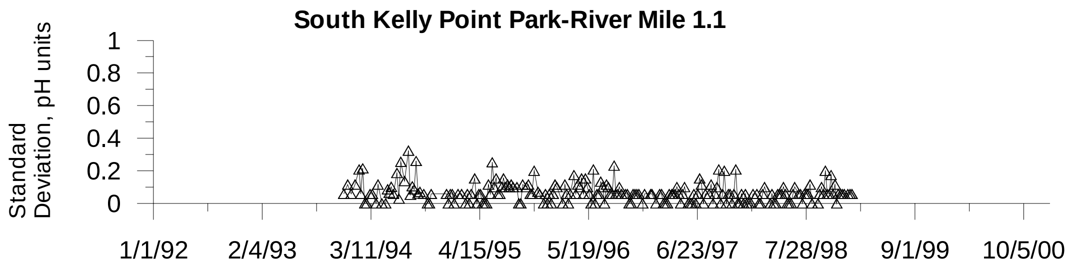

Waverly Country Club-River Mile 17.9

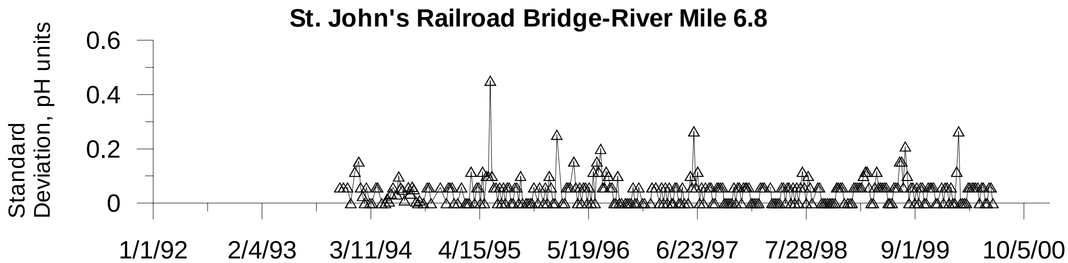


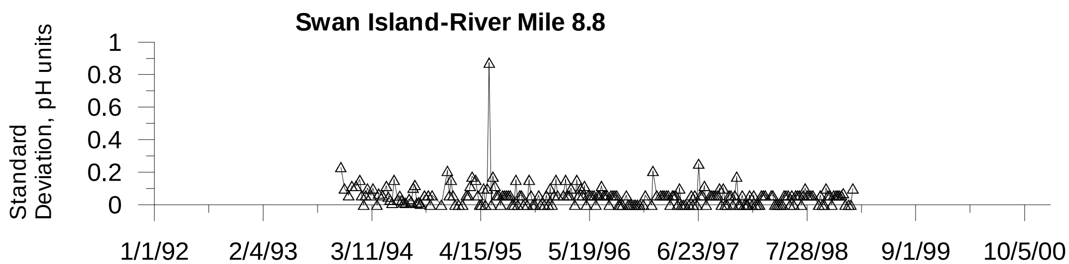

Tryon Creek Railroad Bridge-River Mile 20

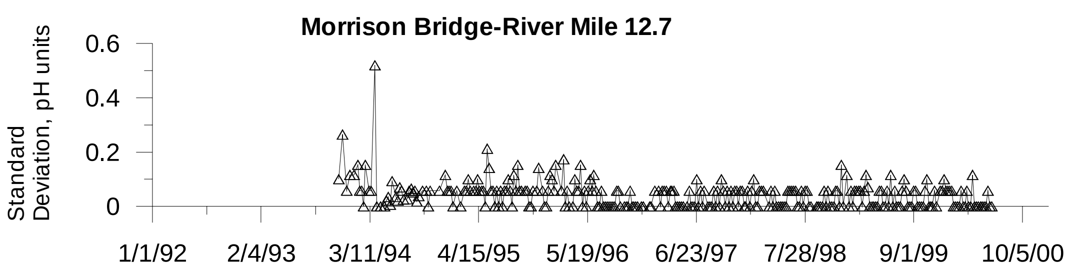


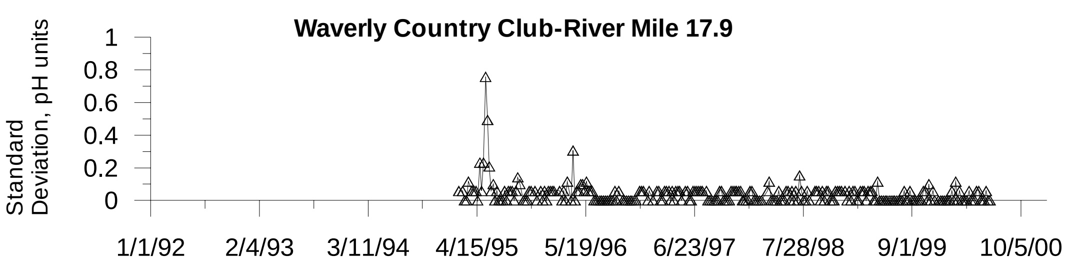
# pH

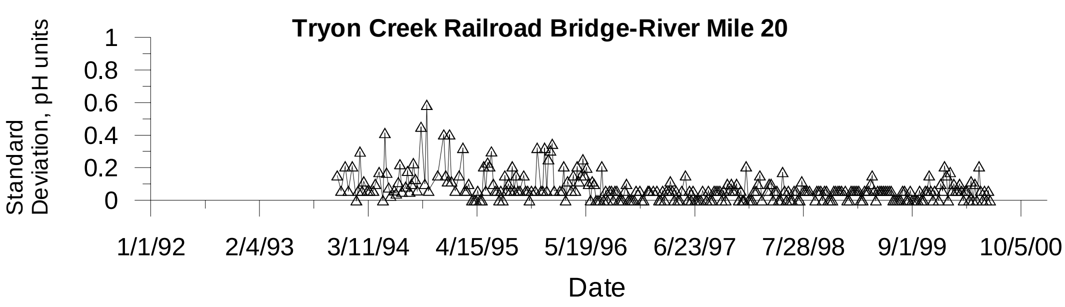

South Kelly Point Park-River Mile 1.1
Standard Deviation, pH units
1
0.8
0.6
0.4
0.2
0
1/1/92
2/4/93
3/11/94
4/15/95
5/19/96
6/23/97
7/28/98
9/1/99
10/5/00


St. John's Railroad Bridge-River Mile 6.8
Standard Deviation, pH units
0.6
0.4
0.2
0
1/1/92
2/4/93
3/11/94
4/15/95
5/19/96
6/23/97
7/28/98
9/1/99
10/5/00

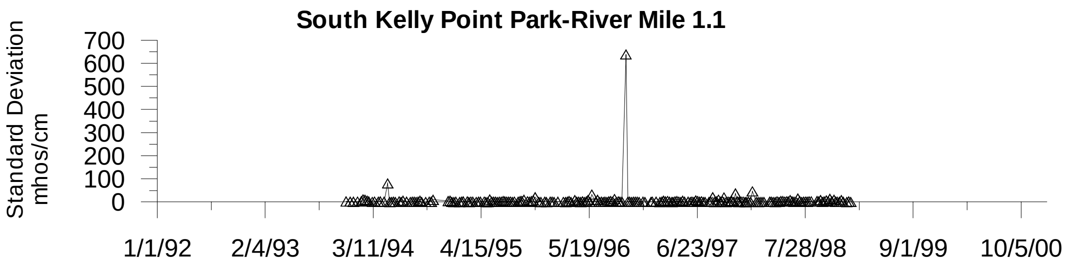

Swan Island-River Mile 8.8
Standard Deviation, pH units
1
0.8
0.6
0.4
0.2
0
1/1/92
2/4/93
3/11/94
4/15/95
5/19/96
6/23/97
7/28/98
9/1/99
10/5/00

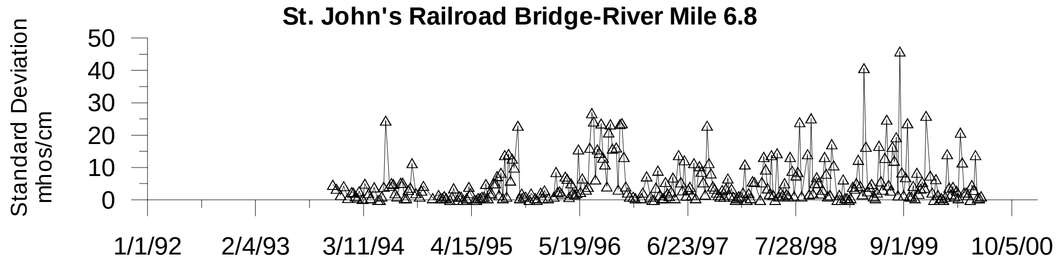

Morrison Bridge-River Mile 12.7
Standard Deviation, pH units
0.6
0.4
0.2
0
1/1/92
2/4/93
3/11/94
4/15/95
5/19/96
6/23/97
7/28/98
9/1/99
10/5/00

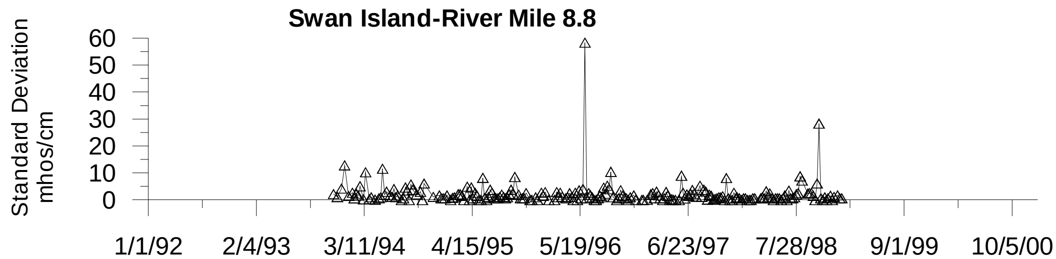

Waverly Country Club-River Mile 17.9
Standard Deviation, pH units
1
0.8
0.6
0.4
0.2
0
1/1/92
2/4/93
3/11/94
4/15/95
5/19/96
6/23/97
7/28/98
9/1/99
10/5/00

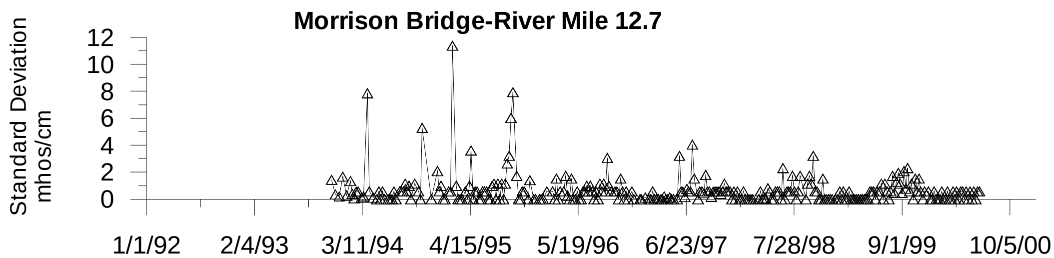

Tryon Creek Railroad Bridge-River Mile 20
Standard Deviation, pH units
1
0.8
0.6
0.4
0.2
0
1/1/92
2/4/93
3/11/94
4/15/95
5/19/96
6/23/97
7/28/98
9/1/99
10/5/00
Date

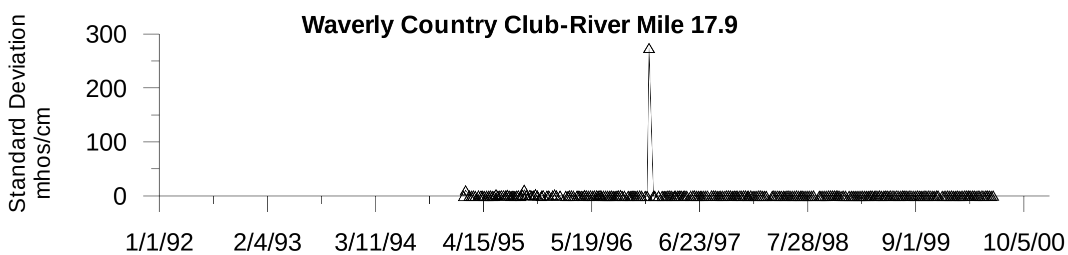
# Conductivity

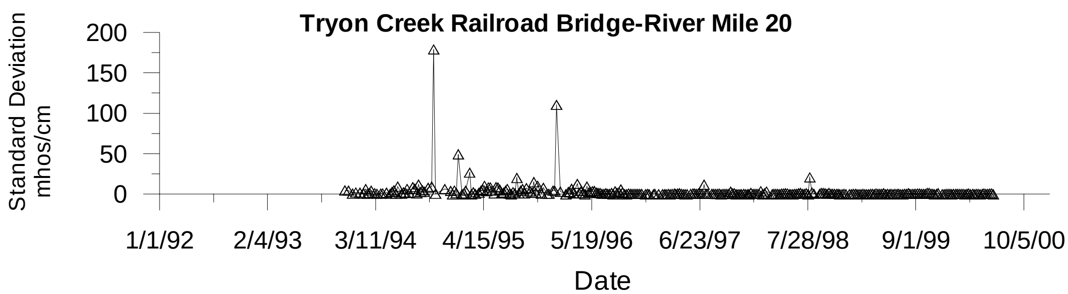


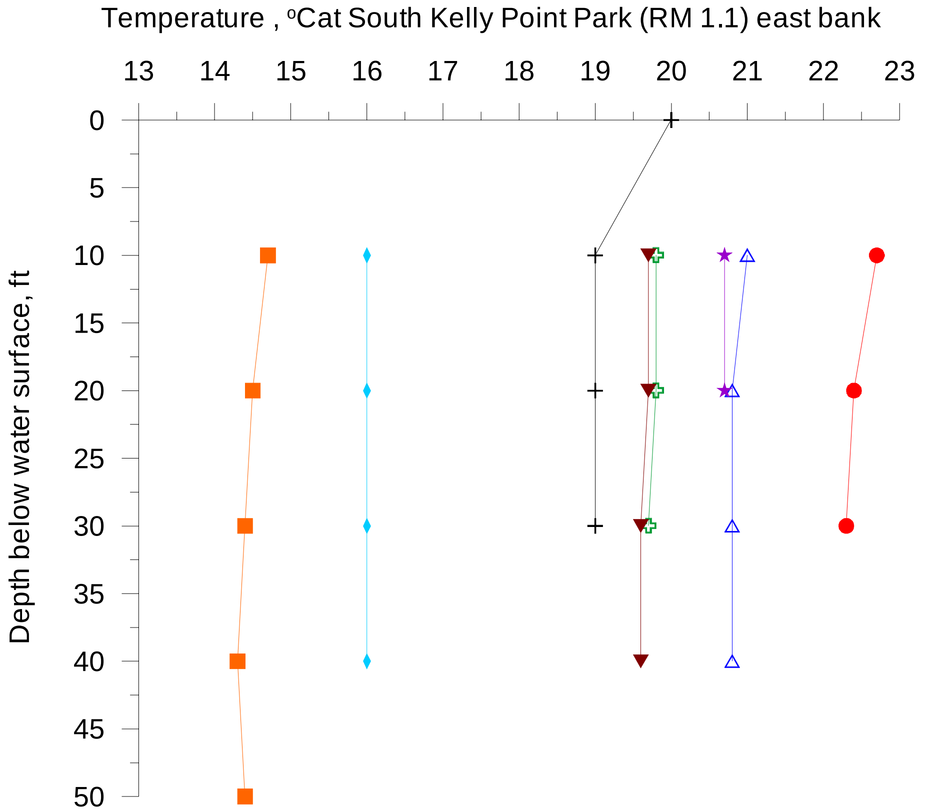



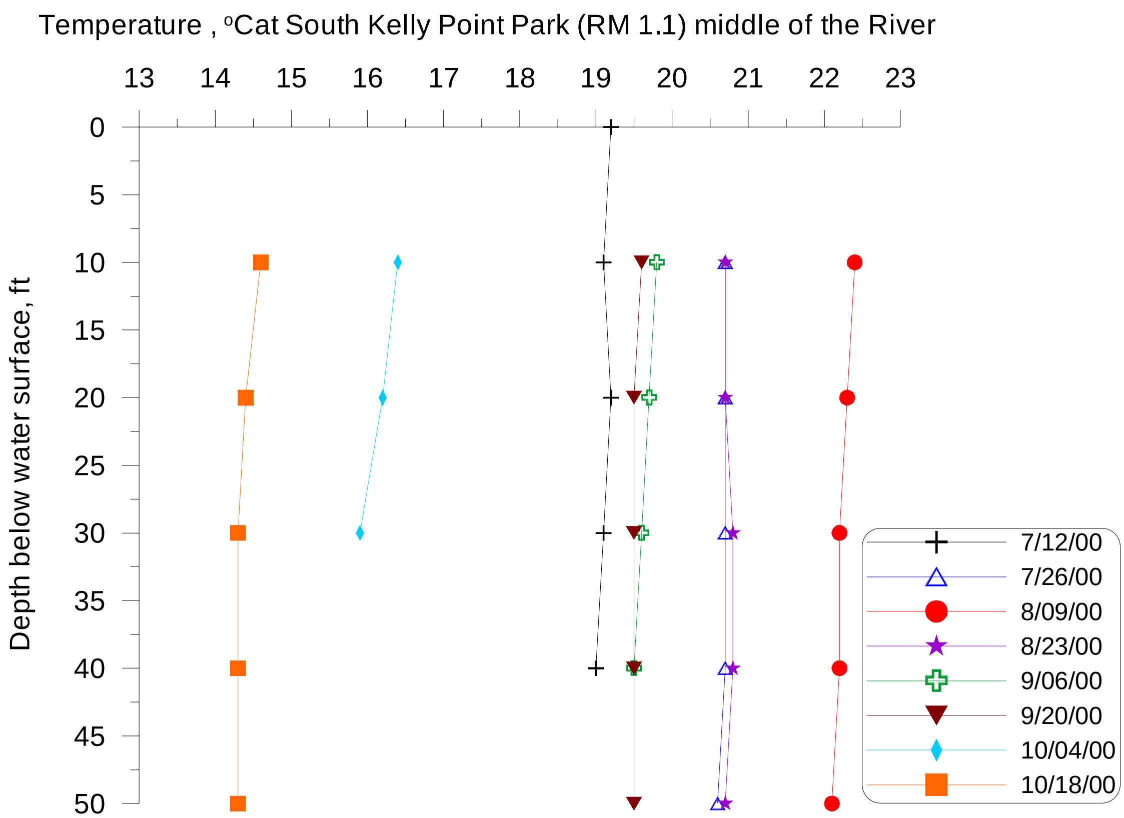



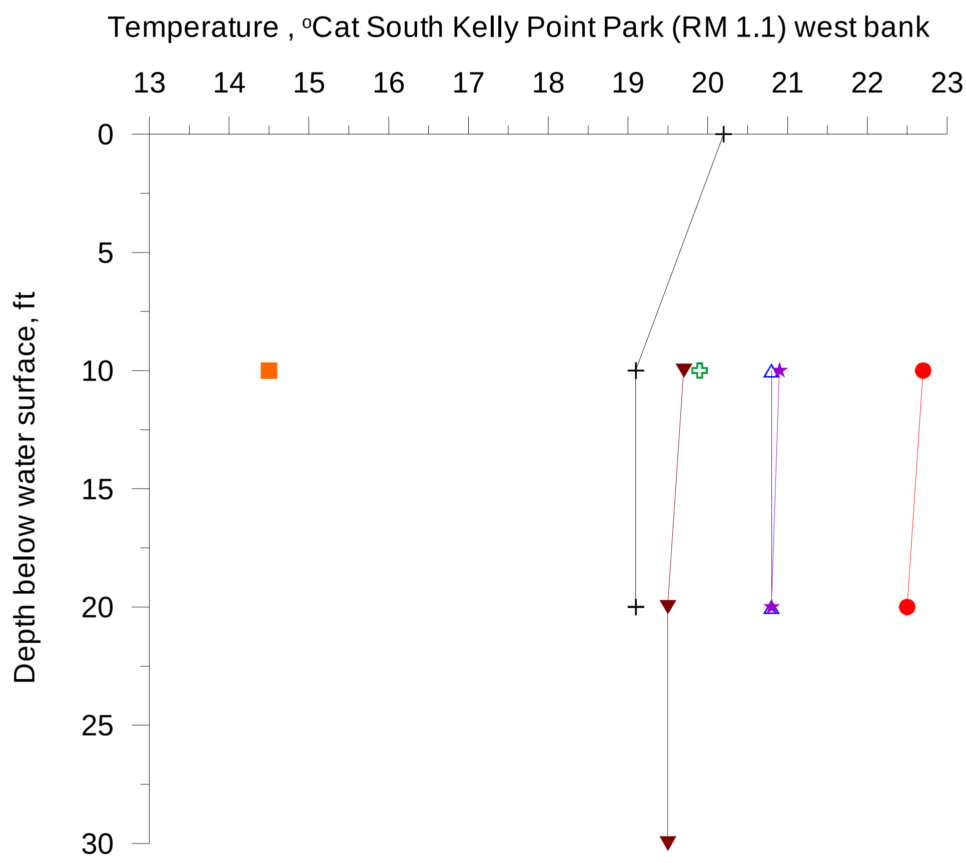



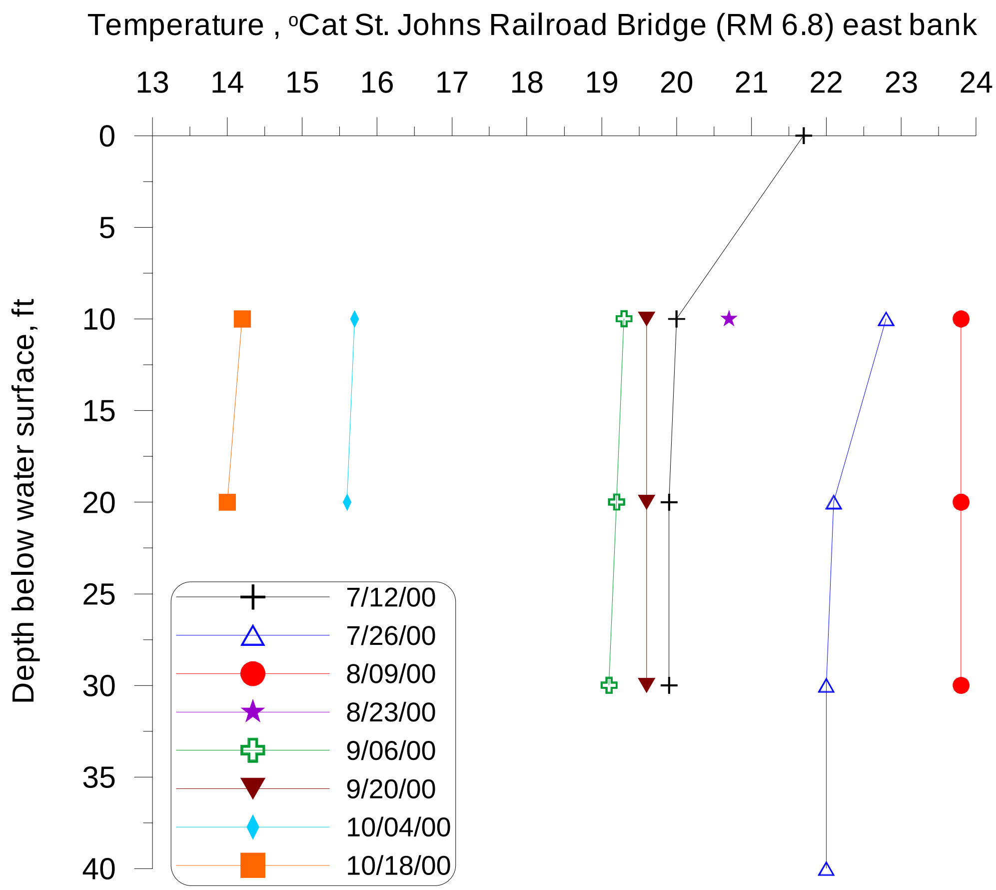



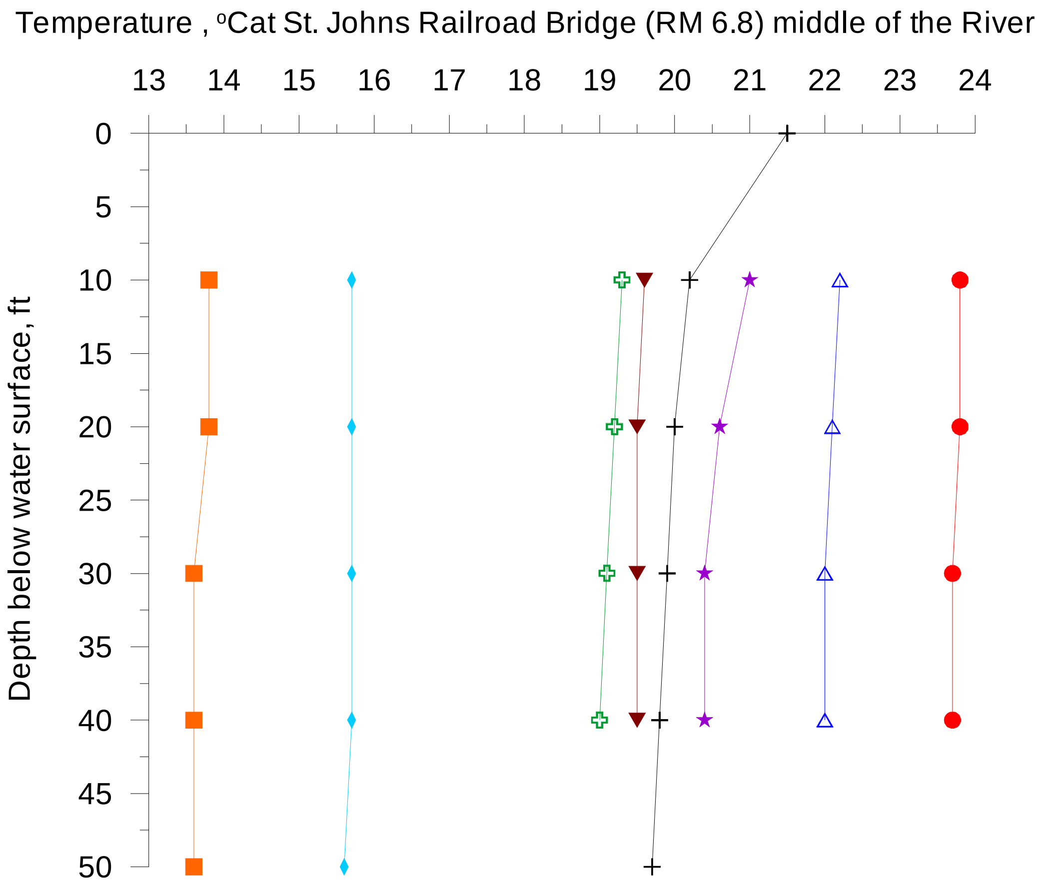
## Appendix E: Willamette River Temperature Profiles, summer 2000

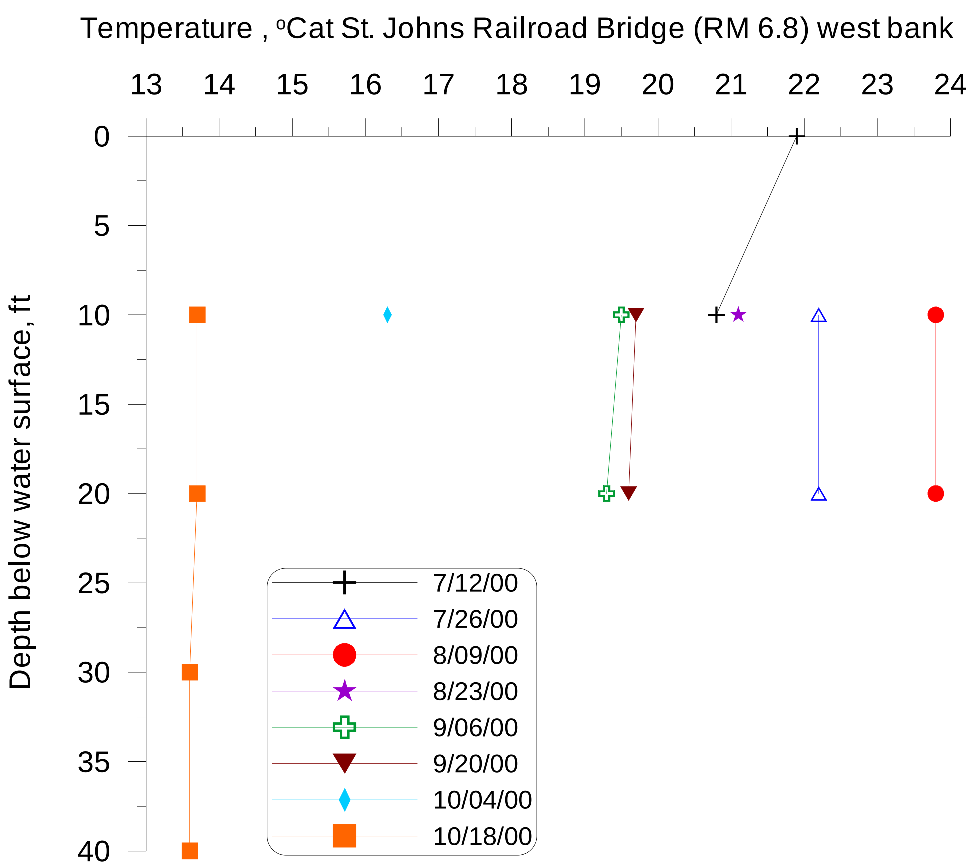


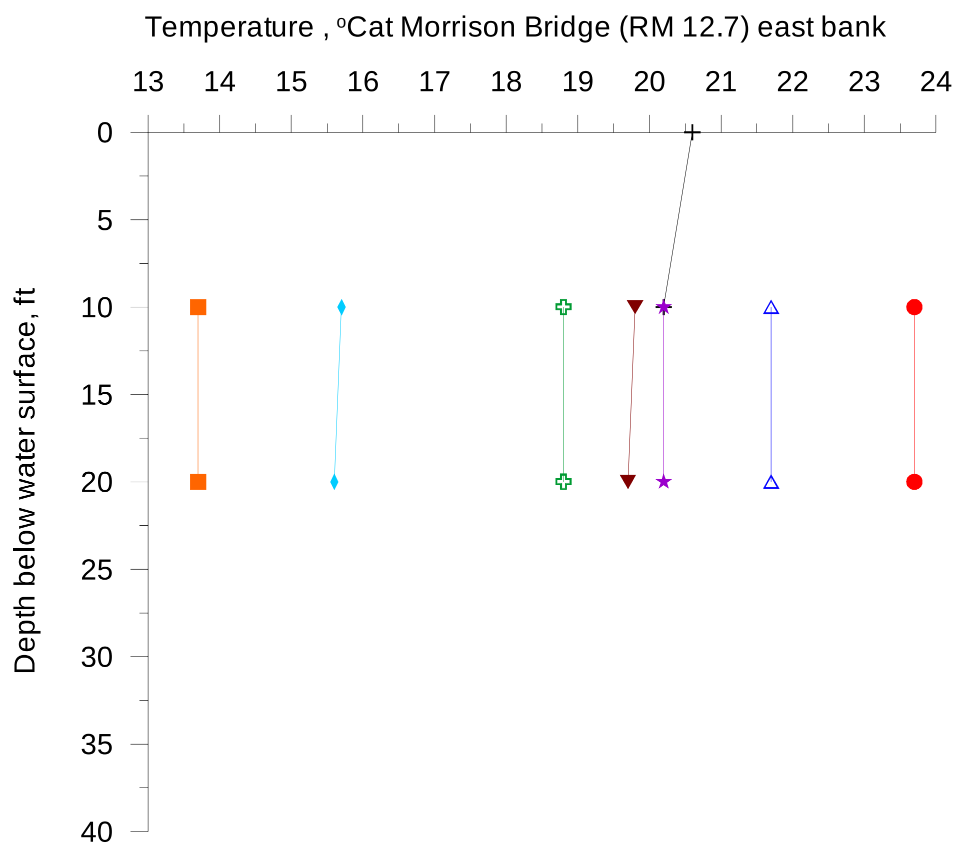



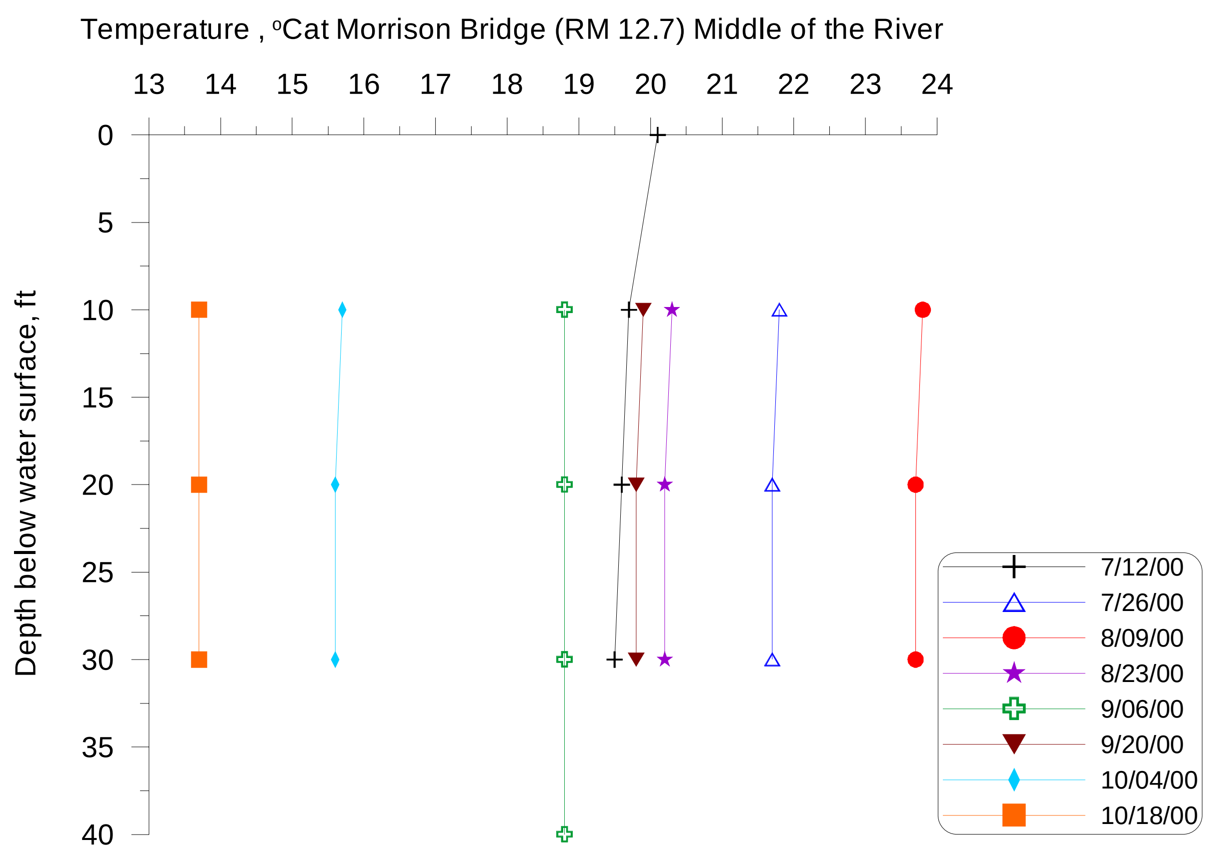

Temperature , °Cat South Kelly Point Park (RM 1.1) west bank
13
14
15
16
17
18
19
20
21
22
23
0
5
10
15
20
25
30
Depth below water surface, ft

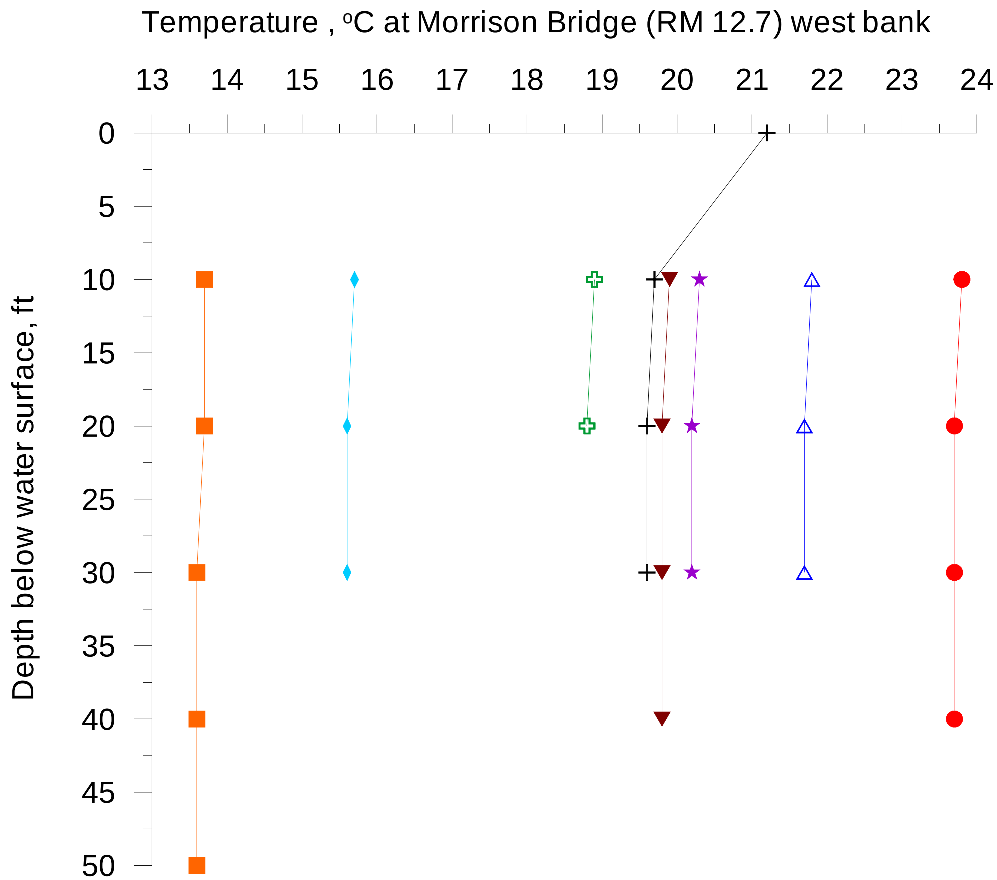

Temperature , °Cat St. Johns Railroad Bridge (RM 6.8) east bank
13
14
15
16
17
18
19
20
21
22
23
24
0
5
10
15
20
25
30
35
40
Depth below water surface, ft
7/12/00
7/26/00
8/09/00
8/23/00
9/06/00
9/20/00
10/04/00
10/18/00

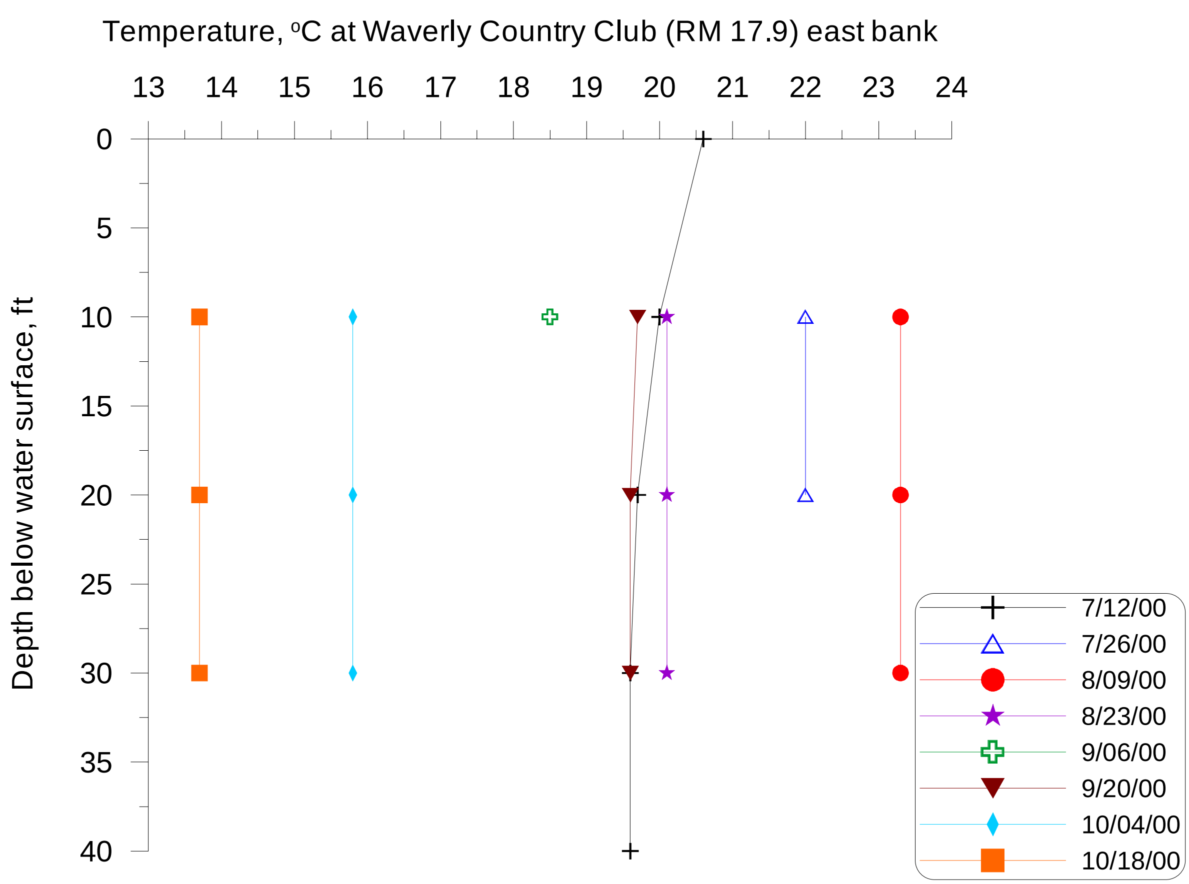

Temperature , ºCat St. Johns Railroad Bridge (RM 6.8) middle of the River
13 14 15 16 17 18 19 20 21 22 23 24
0 5 10 15 20 25 30 35 40 45 50
Depth below water surface, ft

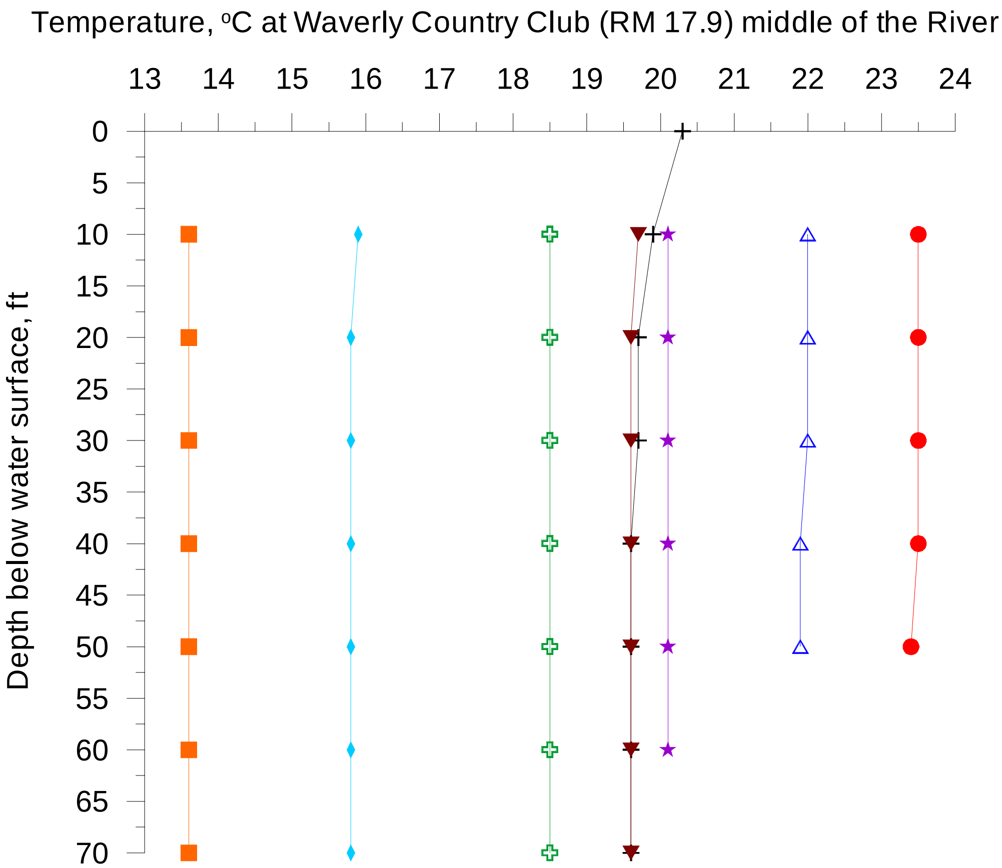

Temperature , ºCat St. Johns Railroad Bridge (RM 6.8) west bank
13 14 15 16 17 18 19 20 21 22 23 24
0 5 10 15 20 25 30 35 40
Depth below water surface, ft
7/12/00
7/26/00
8/09/00
8/23/00
9/06/00
9/20/00
10/04/00
10/18/00

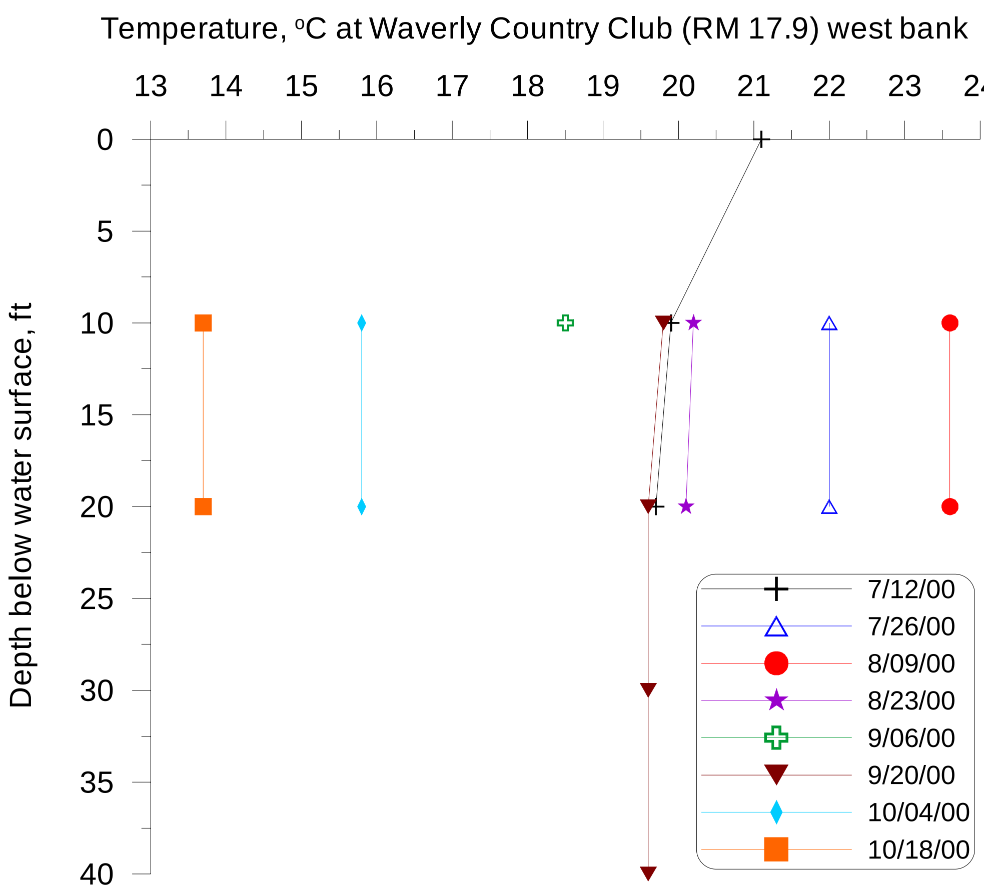

Temperature , ºCat Morrison Bridge (RM 12.7) east bank
13
14
15
16
17
18
19
20
21
22
23
24
Depth below water surface, ft
0
5
10
15
20
25
30
35
40


Temperature , ºCat Morrison Bridge (RM 12.7) Middle of the River
13
14
15
16
17
18
19
20
21
22
23
24
Depth below water surface, ft
0
5
10
15
20
25
30
35
40
7/12/00
7/26/00
8/09/00
8/23/00
9/06/00
9/20/00
10/04/00
10/18/00

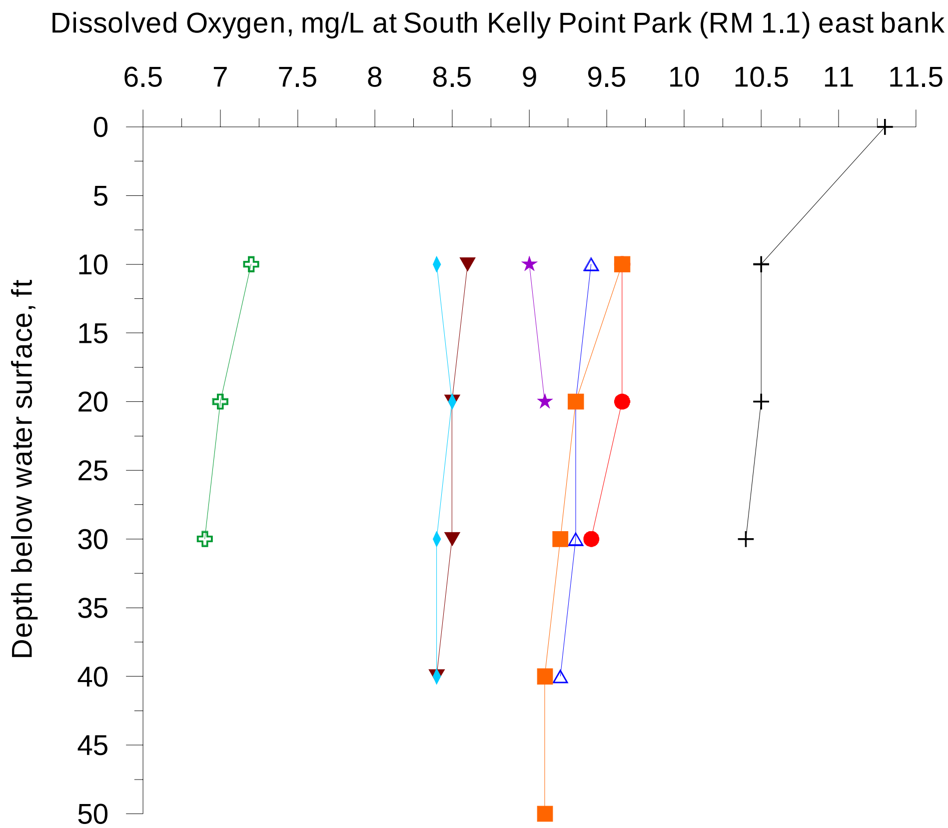

Temperature , °C at Morrison Bridge (RM 12.7) west bank
13 14 15 16 17 18 19 20 21 22 23 24
0 5 10 15 20 25 30 35 40 45 50
Depth below water surface, ft

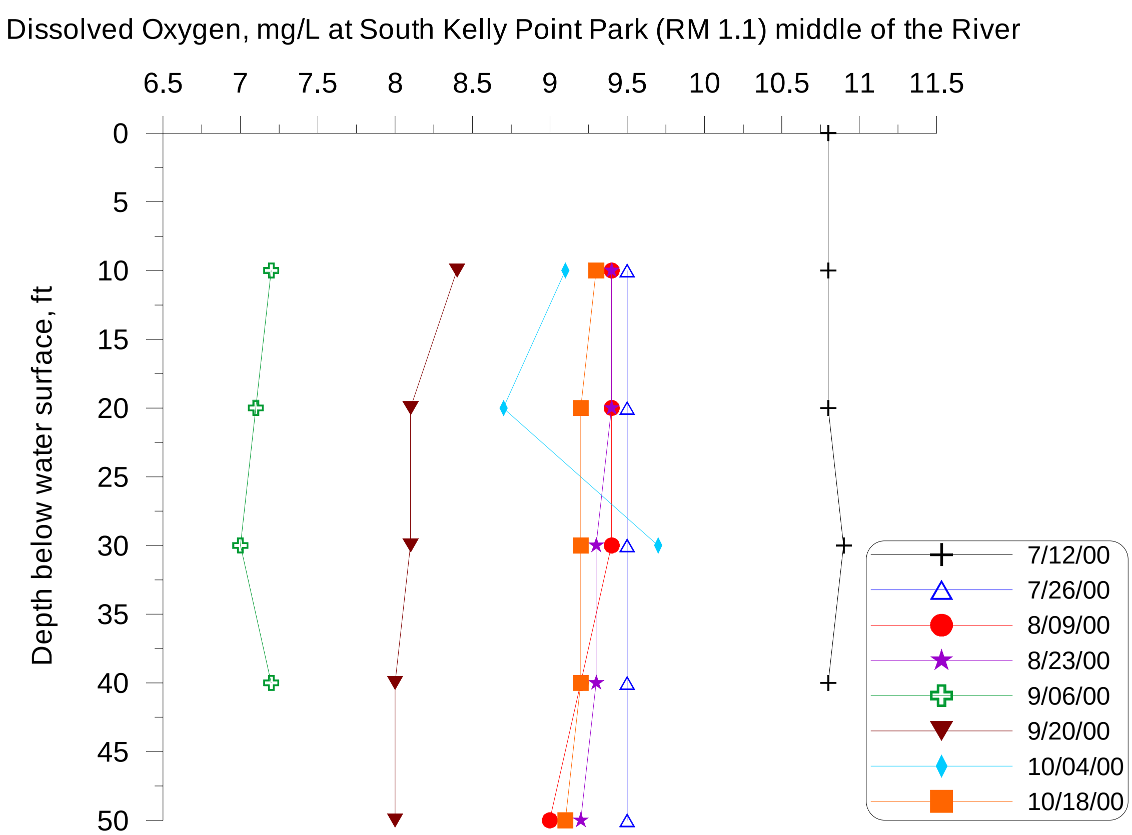

Temperature, °C at Waverly Country Club (RM 17.9) east bank
13 14 15 16 17 18 19 20 21 22 23 24
0 5 10 15 20 25 30 35 40
Depth below water surface, ft
7/12/00
7/26/00
8/09/00
8/23/00
9/06/00
9/20/00
10/04/00
10/18/00

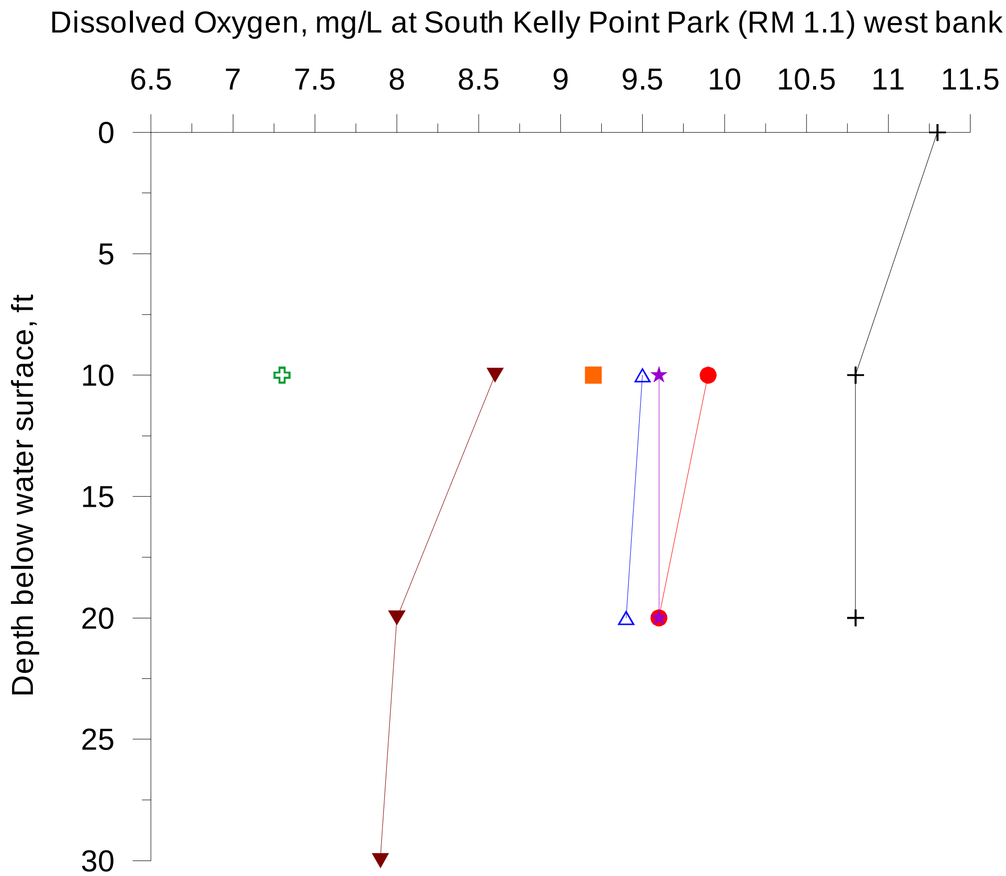

Temperature, °C at Waverly Country Club (RM 17.9) middle of the River
Depth below water surface, ft

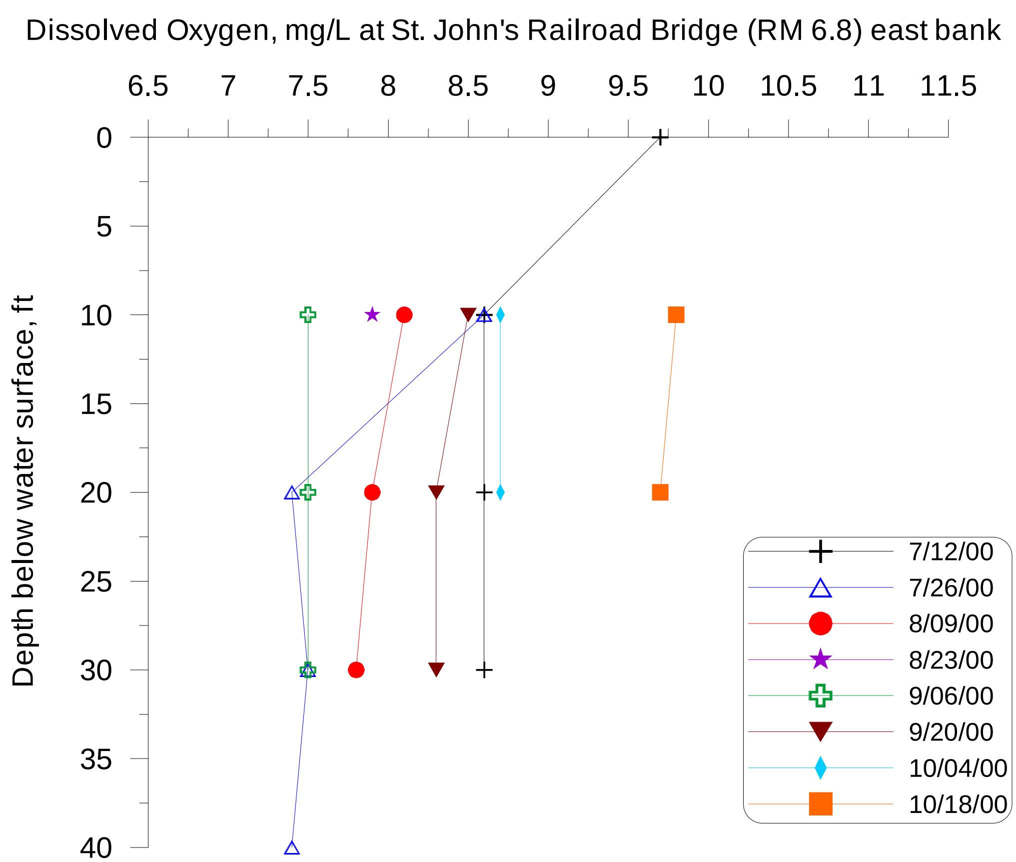

Temperature, °C at Waverly Country Club (RM 17.9) west bank
Depth below water surface, ft
7/12/00
7/26/00
8/09/00
8/23/00
9/06/00
9/20/00
10/04/00
10/18/00

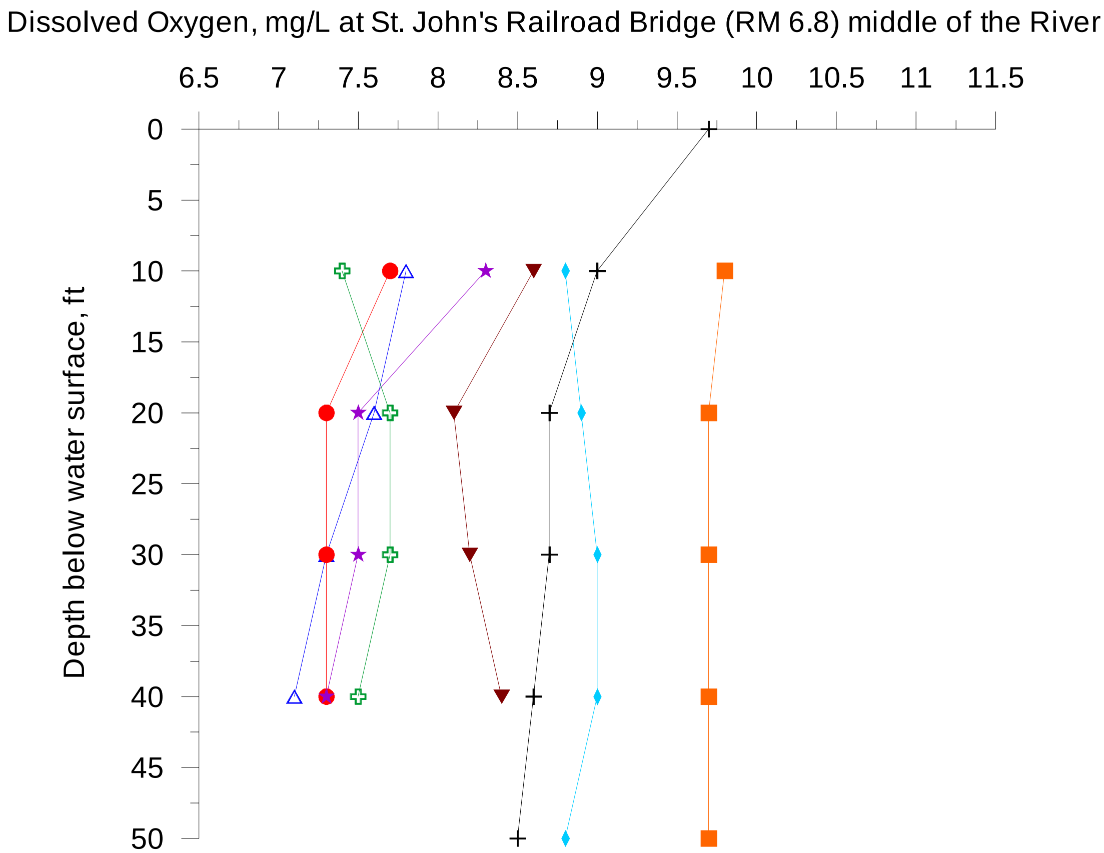
## Appendix F: Willamette River Dissolved Oxygen Profiles, summer 2000

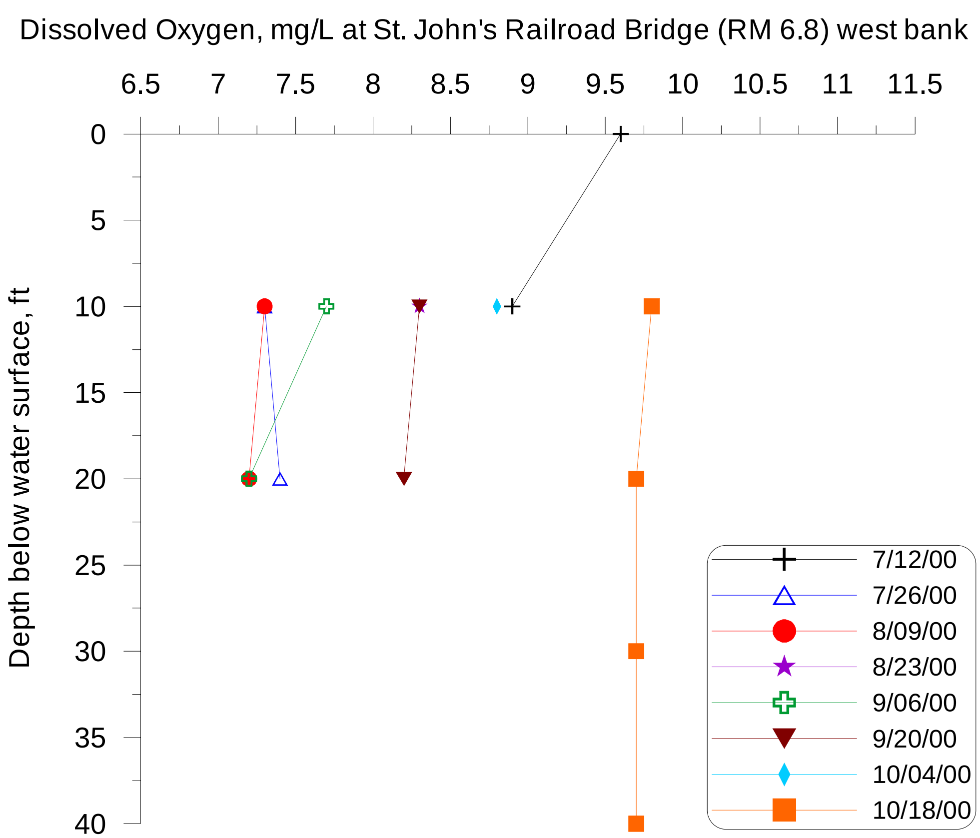


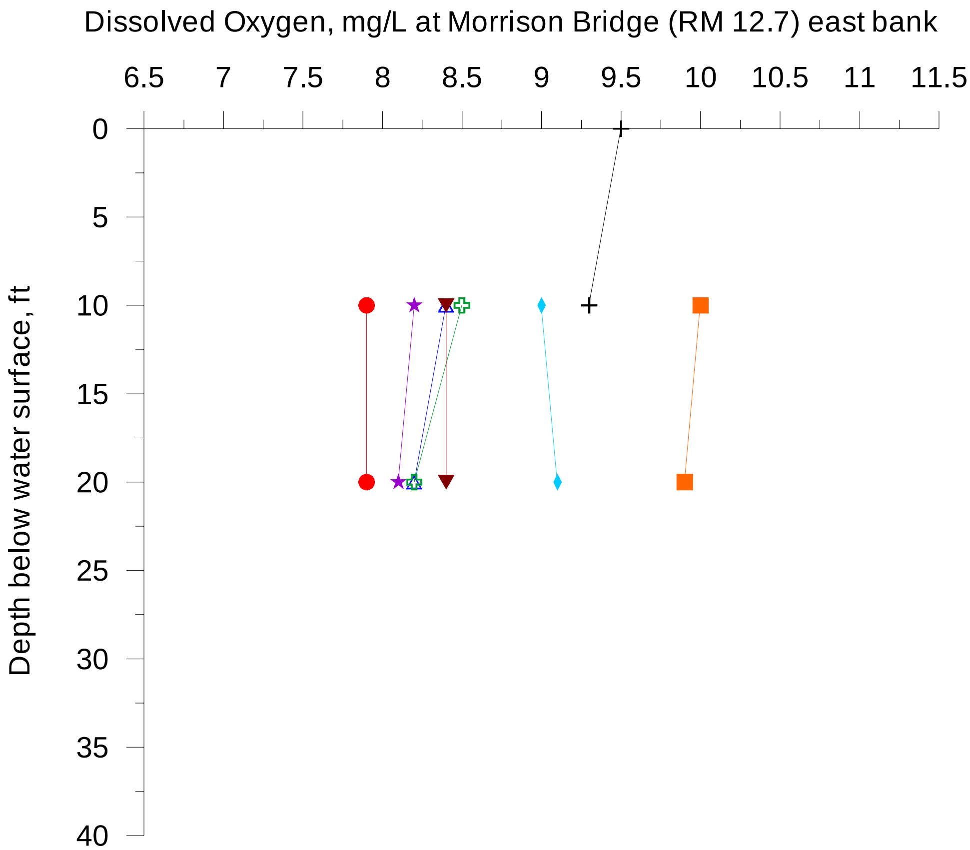



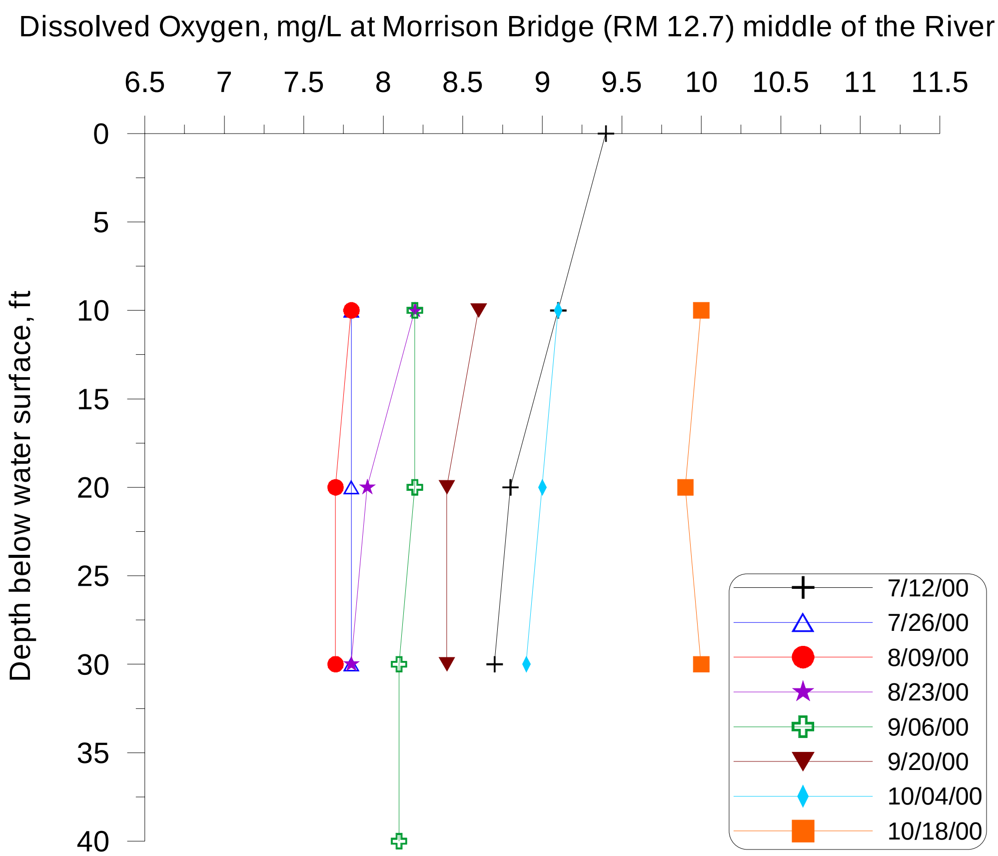

Dissolved Oxygen, mg/L at South Kelly Point Park (RM 1.1) west bank
6.5
7
7.5
8
8.5
9
9.5
10
10.5
11
11.5
0
5
10
15
20
25
30
Depth below water surface, ft

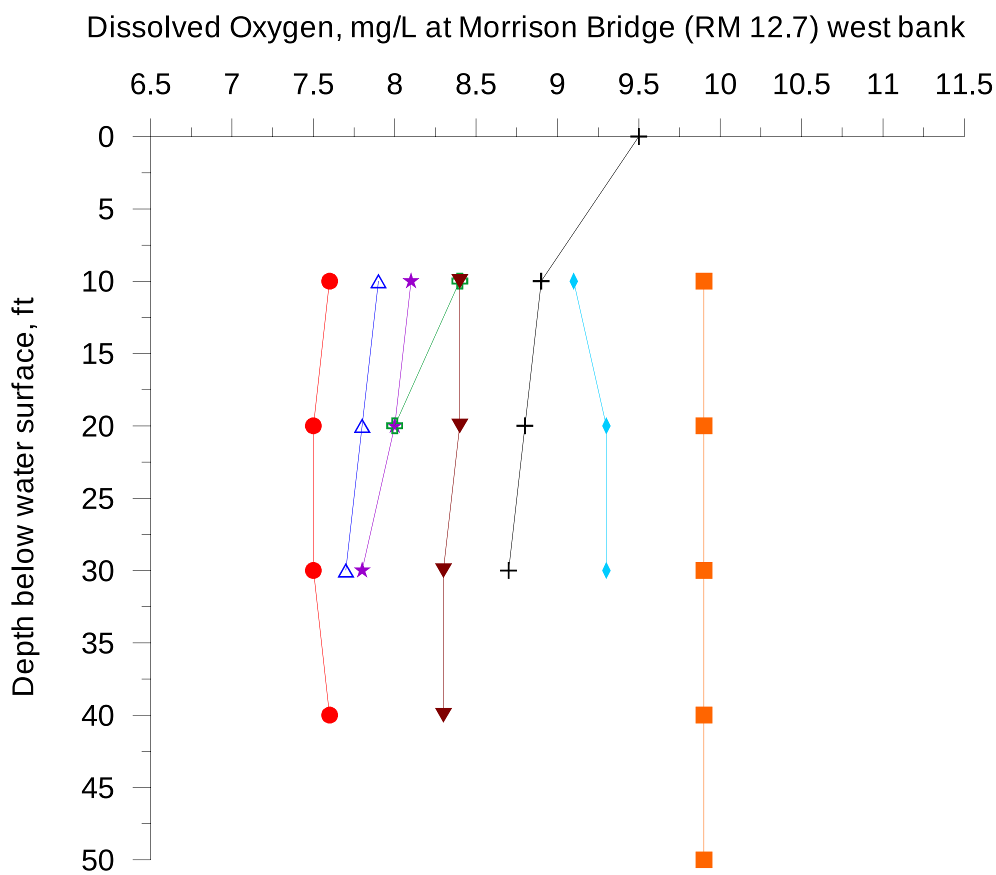

Dissolved Oxygen, mg/L at St. John's Railroad Bridge (RM 6.8) east bank
6.5
7
7.5
8
8.5
9
9.5
10
10.5
11
11.5
0
5
10
15
20
25
30
35
40
Depth below water surface, ft
7/12/00
7/26/00
8/09/00
8/23/00
9/06/00
9/20/00
10/04/00
10/18/00

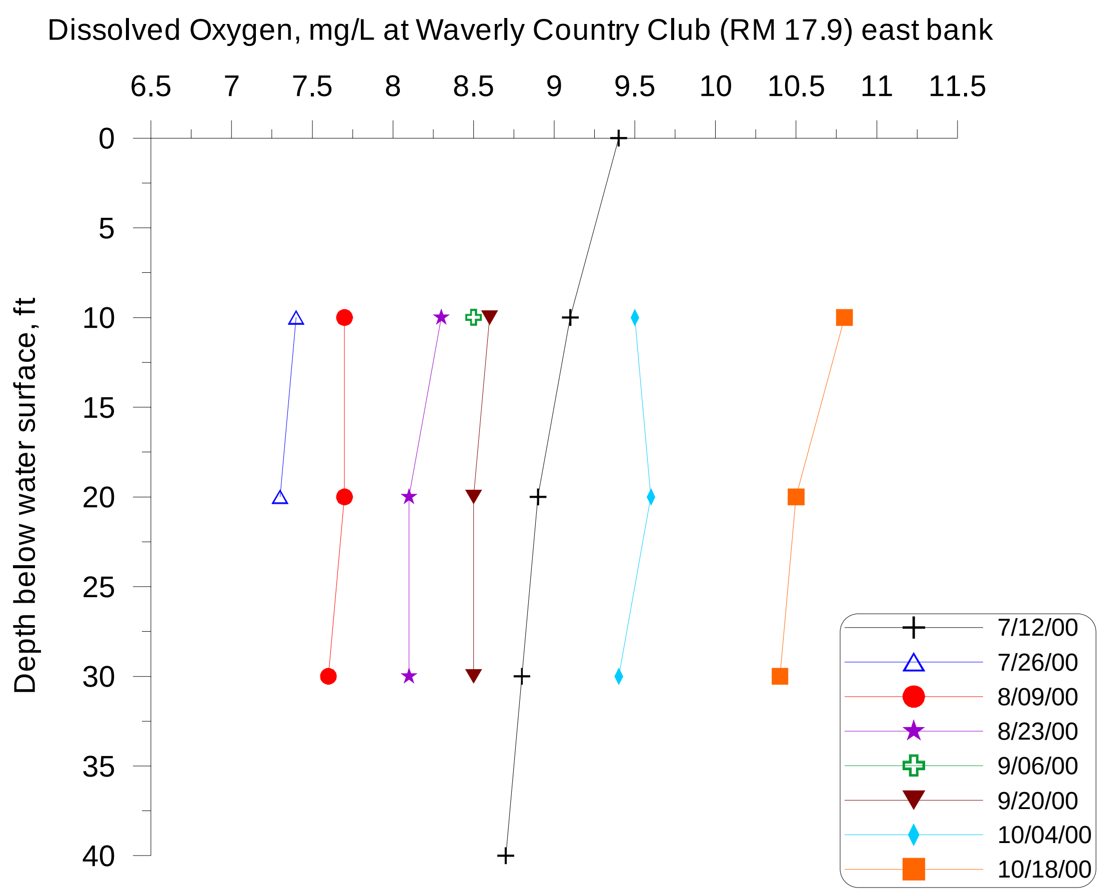

Dissolved Oxygen, mg/L at St. John's Railroad Bridge (RM 6.8) middle of the River
6.5
7
7.5
8
8.5
9
9.5
10
10.5
11
11.5
0
5
10
15
20
25
30
35
40
45
50
Depth below water surface, ft

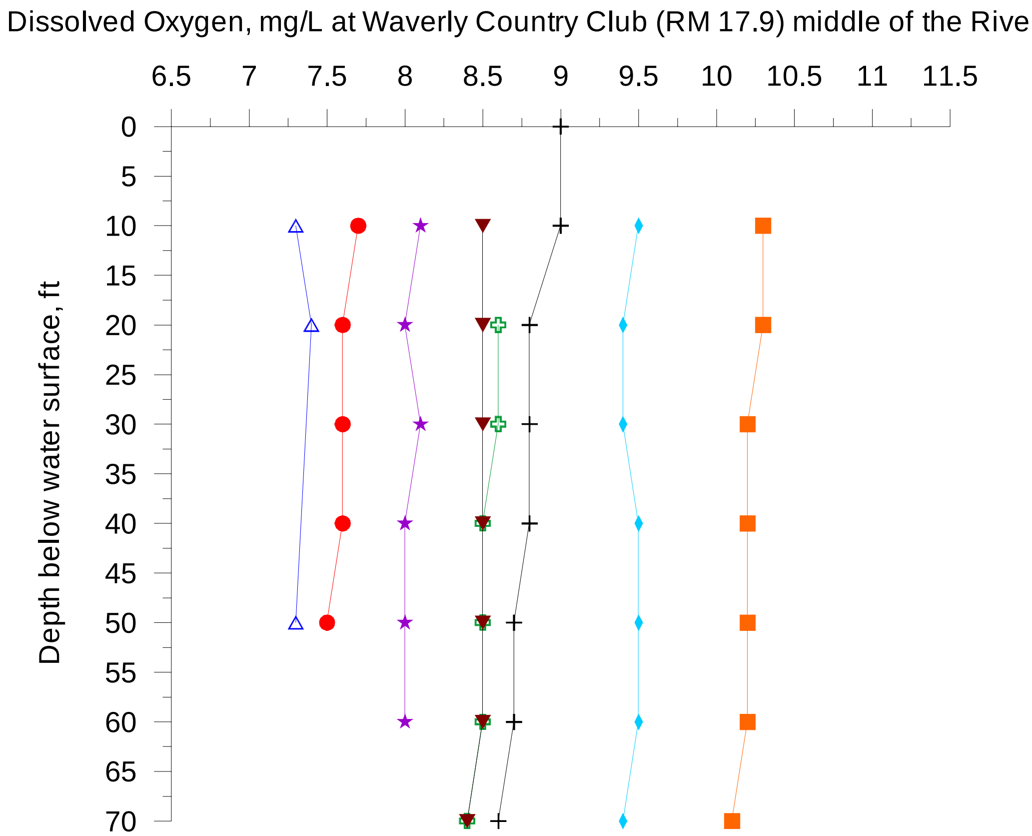

Dissolved Oxygen, mg/L at St. John's Railroad Bridge (RM 6.8) west bank
6.5
7
7.5
8
8.5
9
9.5
10
10.5
11
11.5
0
5
10
15
20
25
30
35
40
Depth below water surface, ft
7/12/00
7/26/00
8/09/00
8/23/00
9/06/00
9/20/00
10/04/00
10/18/00

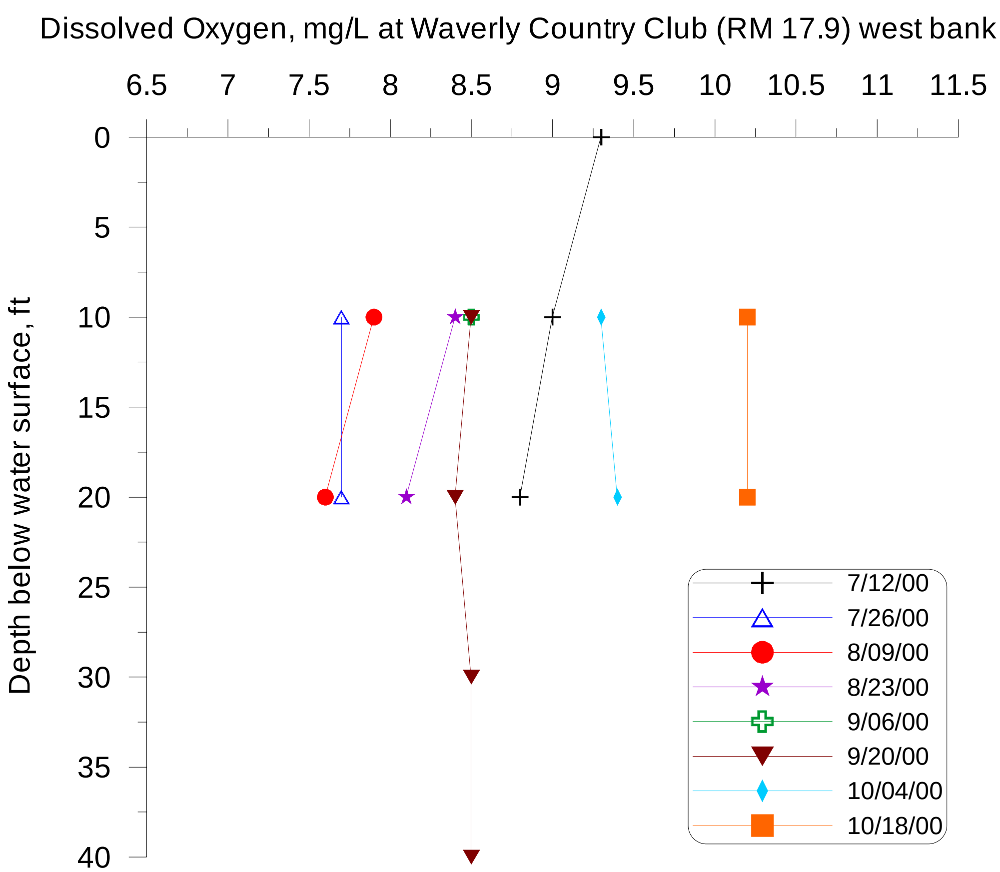

Dissolved Oxygen, mg/L at Morrison Bridge (RM 12.7) east bank
6.5
7
7.5
8
8.5
9
9.5
10
10.5
11
11.5
0
5
10
15
20
25
30
35
40
Depth below water surface, ft


Dissolved Oxygen, mg/L at Morrison Bridge (RM 12.7) middle of the River
6.5
7
7.5
8
8.5
9
9.5
10
10.5
11
11.5
0
5
10
15
20
25
30
35
40
Depth below water surface, ft
7/12/00
7/26/00
8/09/00
8/23/00
9/06/00
9/20/00
10/04/00
10/18/00

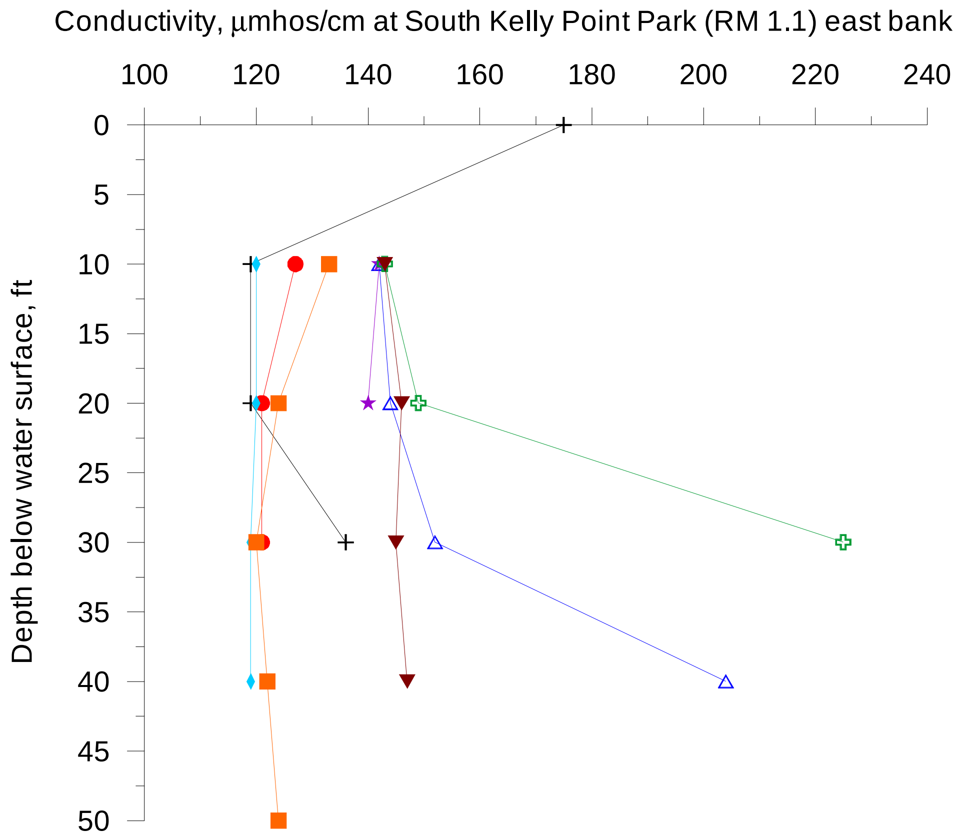

Dissolved Oxygen, mg/L at Morrison Bridge (RM 12.7) west bank
6.5
7
7.5
8
8.5
9
9.5
10
10.5
11
11.5
Depth below water surface, ft
0
5
10
15
20
25
30
35
40
45
50

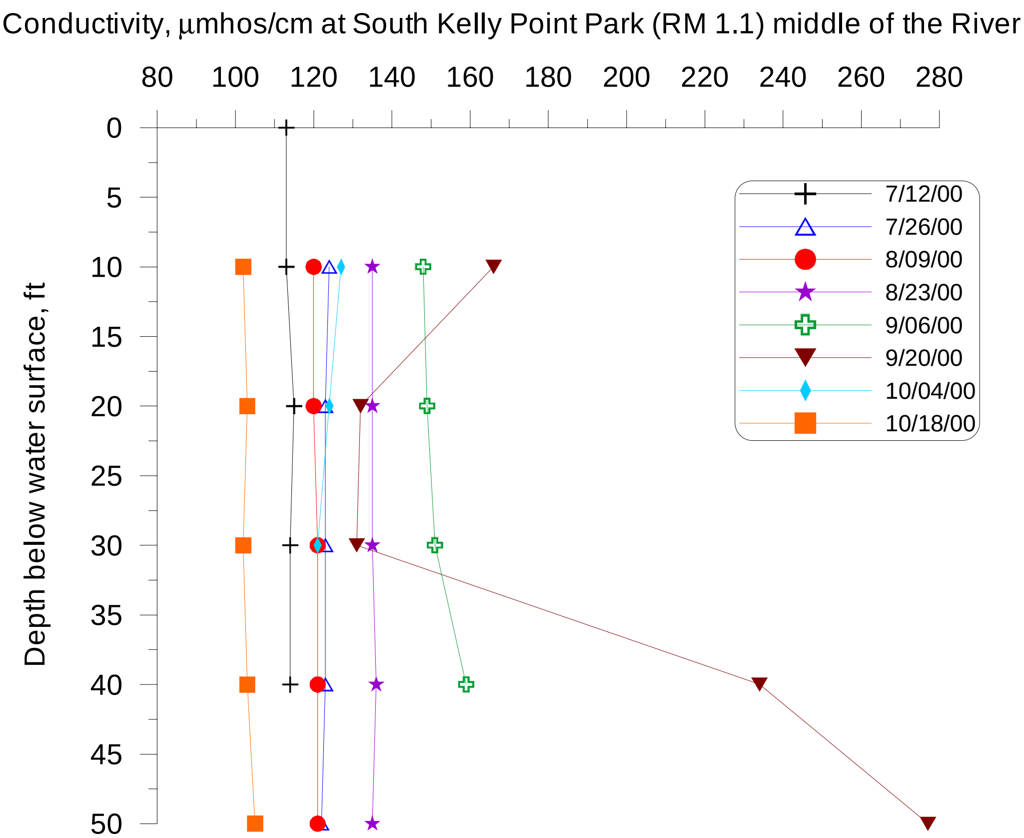

Dissolved Oxygen, mg/L at Waverly Country Club (RM 17.9) east bank
6.5
7
7.5
8
8.5
9
9.5
10
10.5
11
11.5
Depth below water surface, ft
0
5
10
15
20
25
30
35
40
7/12/00
7/26/00
8/09/00
8/23/00
9/06/00
9/20/00
10/04/00
10/18/00

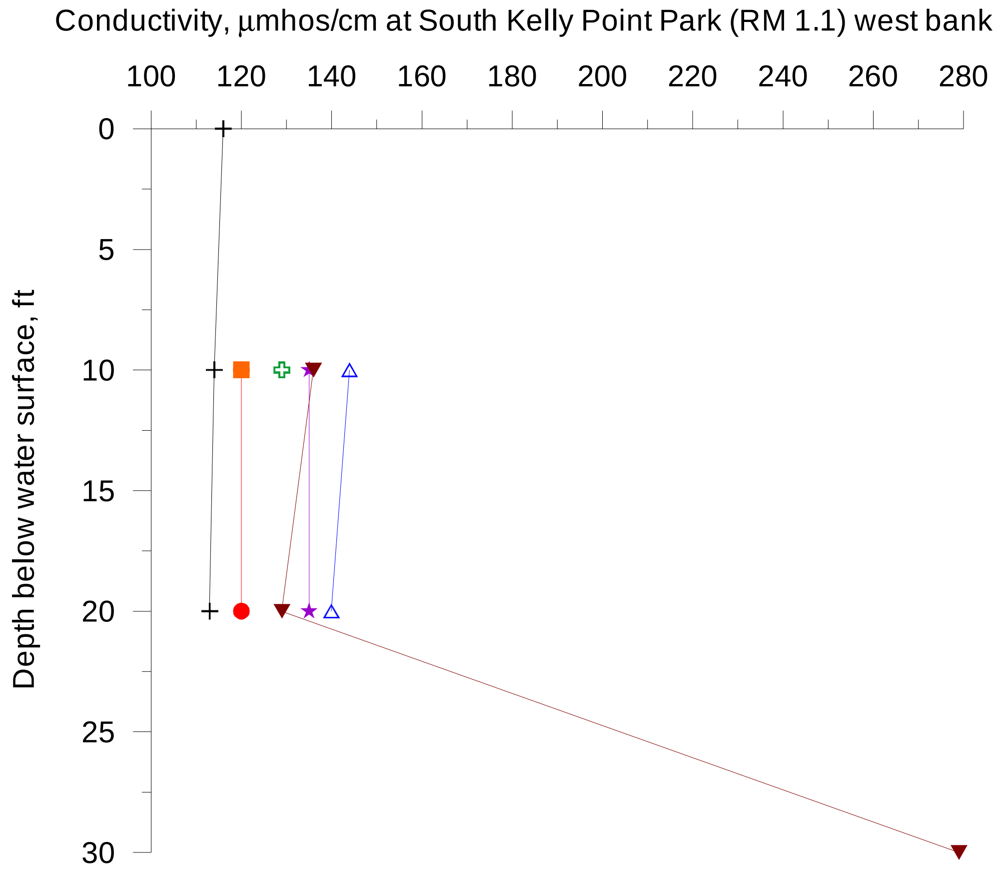

Dissolved Oxygen, mg/L at Waverly Country Club (RM 17.9) middle of the River
6.5
7
7.5
8
8.5
9
9.5
10
10.5
11
11.5
Depth below water surface, ft
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70

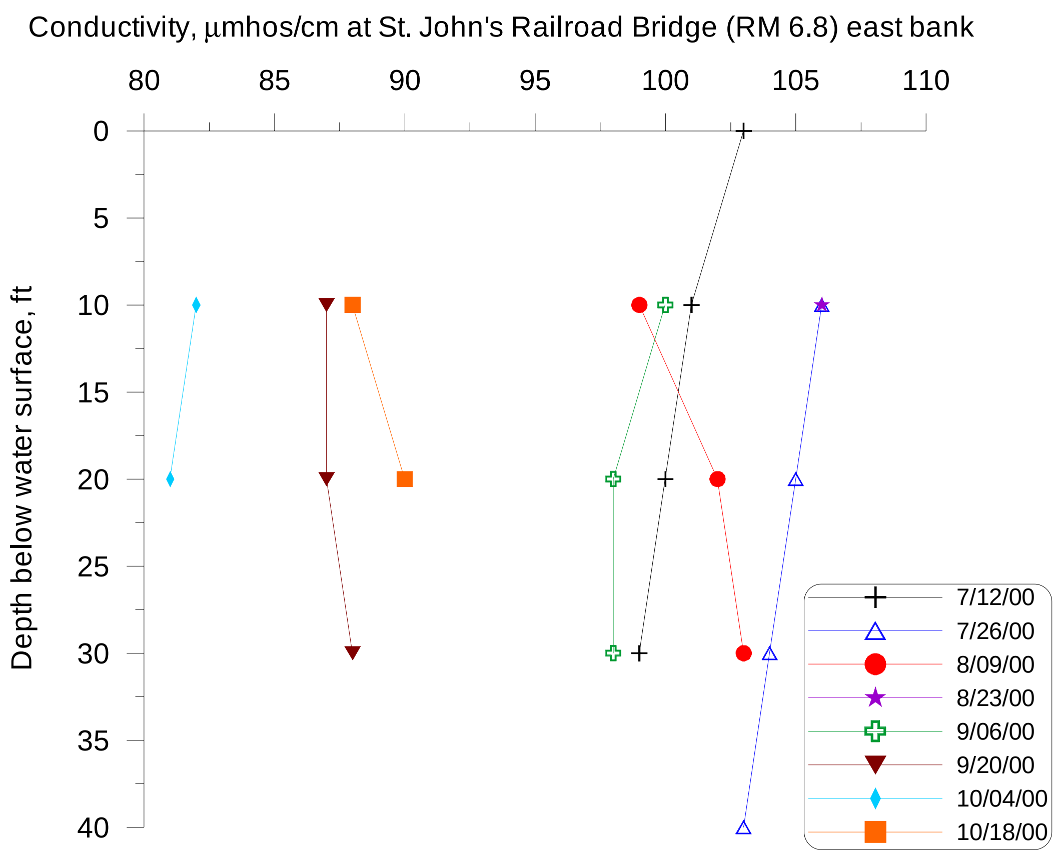

Dissolved Oxygen, mg/L at Waverly Country Club (RM 17.9) west bank
6.5
7
7.5
8
8.5
9
9.5
10
10.5
11
11.5
Depth below water surface, ft
0
5
10
15
20
25
30
35
40
7/12/00
7/26/00
8/09/00
8/23/00
9/06/00
9/20/00
10/04/00
10/18/00

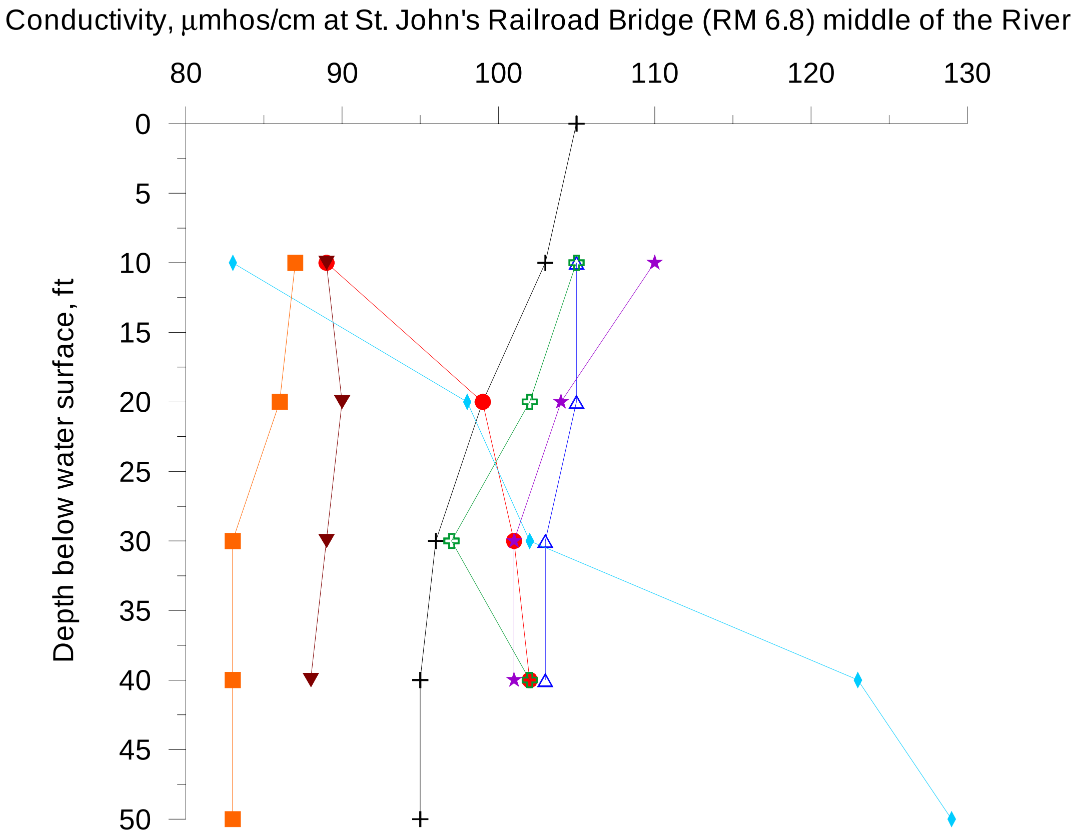
## Appendix G:  Willamette River Conductivity Profiles, summer 2000

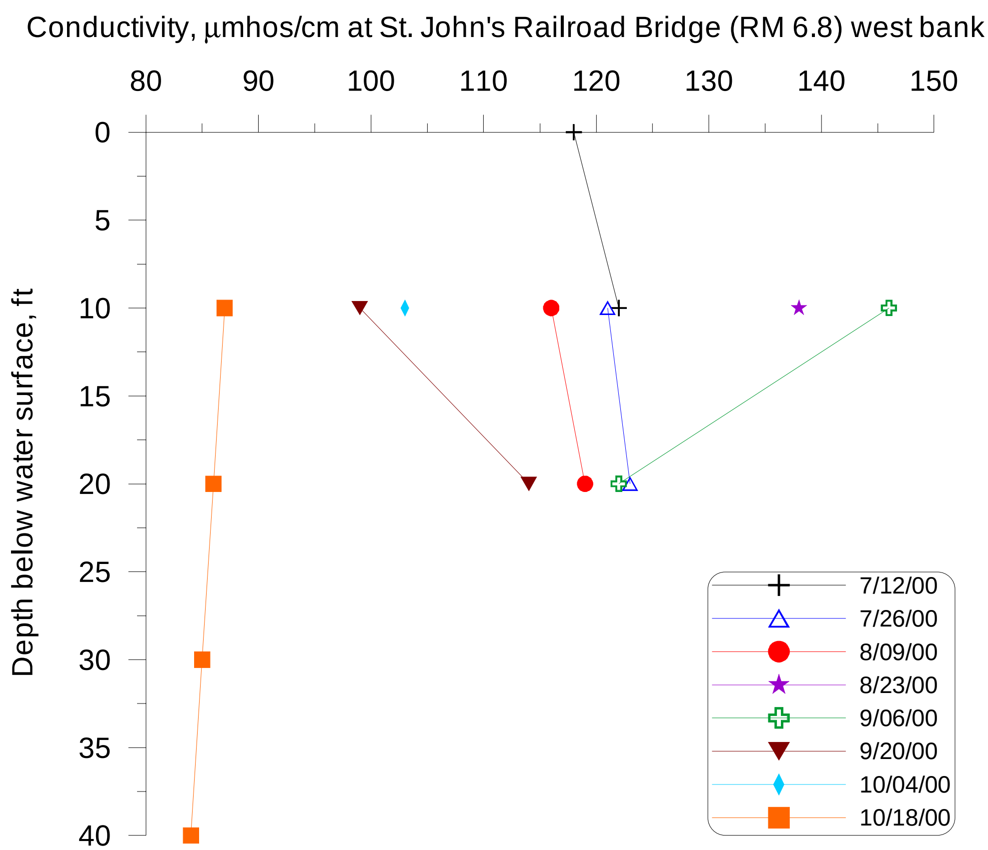


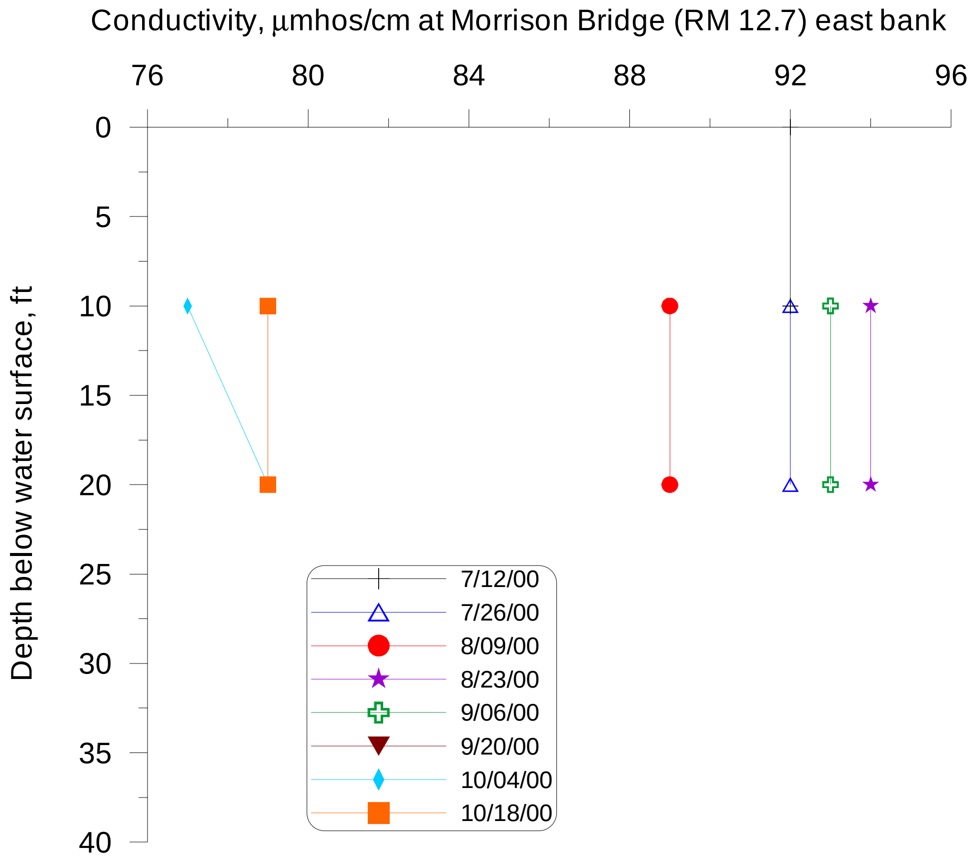



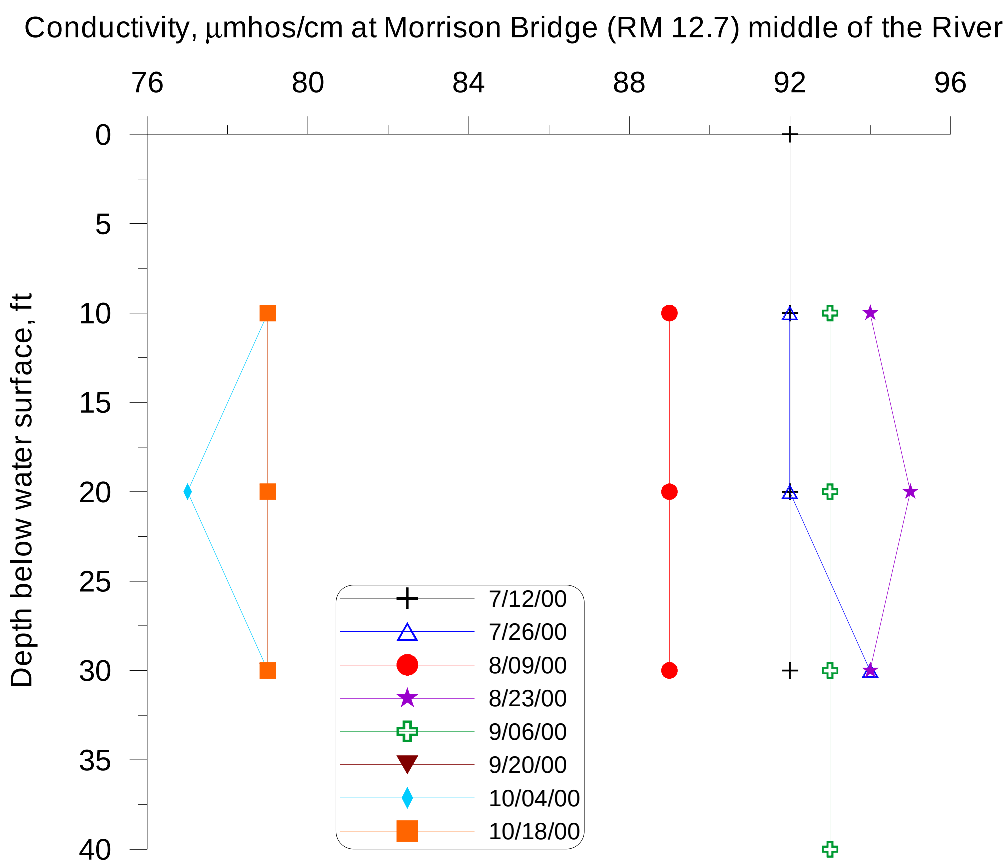

Conductivity, µmhos/cm at South Kelly Point Park (RM 1.1) west bank
100
120
140
160
180
200
220
240
260
280
Depth below water surface, ft
0
5
10
15
20
25
30

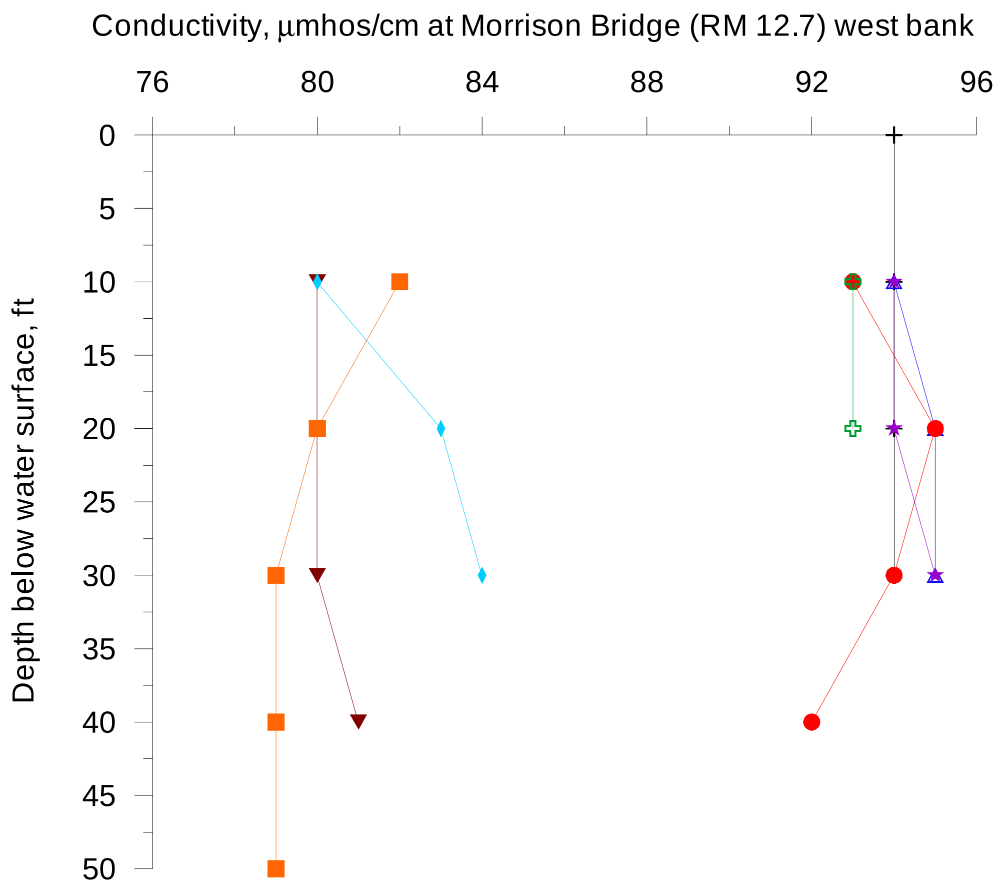

Conductivity, µmhos/cm at St. John's Railroad Bridge (RM 6.8) east bank
80
85
90
95
100
105
110
Depth below water surface, ft
0
5
10
15
20
25
30
35
40
7/12/00
7/26/00
8/09/00
8/23/00
9/06/00
9/20/00
10/04/00
10/18/00

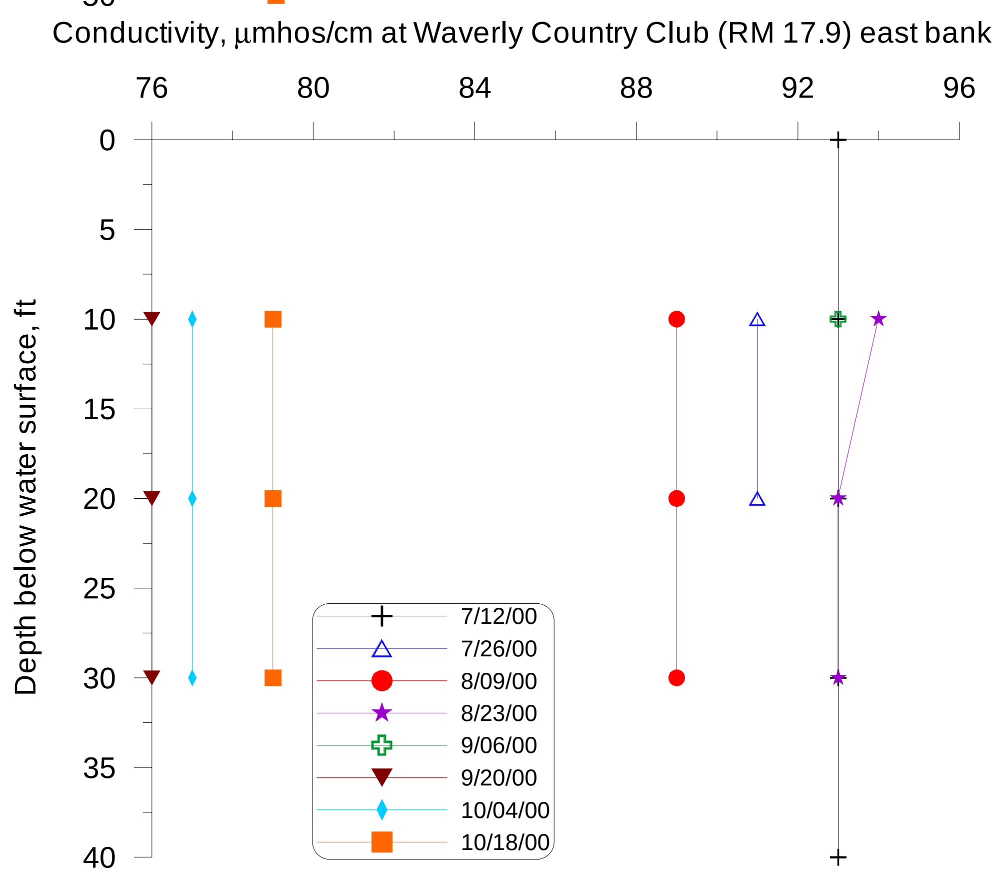

Conductivity, µmhos/cm at St. John's Railroad Bridge (RM 6.8) middle of the River
80
90
100
110
120
130
0
5
10
15
20
25
30
35
40
45
50
Depth below water surface, ft

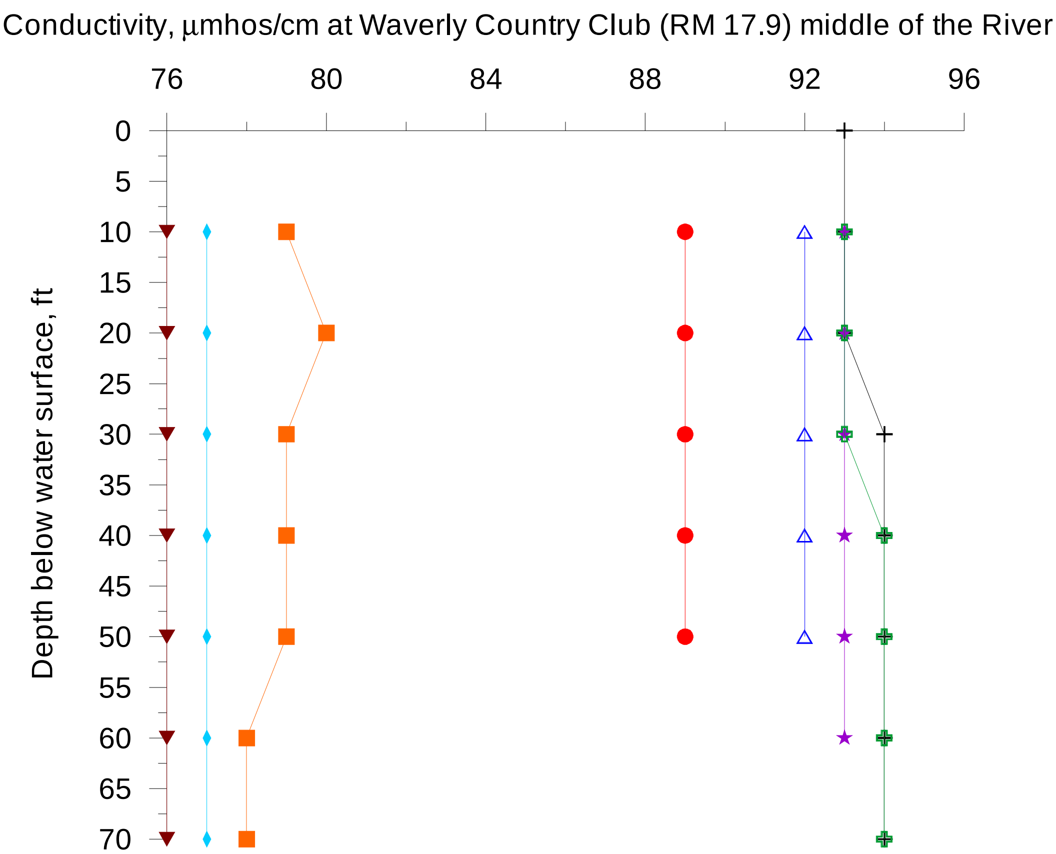

Conductivity, µmhos/cm at St. John's Railroad Bridge (RM 6.8) west bank
80
90
100
110
120
130
140
150
0
5
10
15
20
25
30
35
40
Depth below water surface, ft
7/12/00
7/26/00
8/09/00
8/23/00
9/06/00
9/20/00
10/04/00
10/18/00


Conductivity, µmhos/cm at Morrison Bridge (RM 12.7) east bank
76
80
84
88
92
96
0
5
10
15
20
25
30
35
40
Depth below water surface, ft
7/12/00
7/26/00
8/09/00
8/23/00
9/06/00
9/20/00
10/04/00
10/18/00

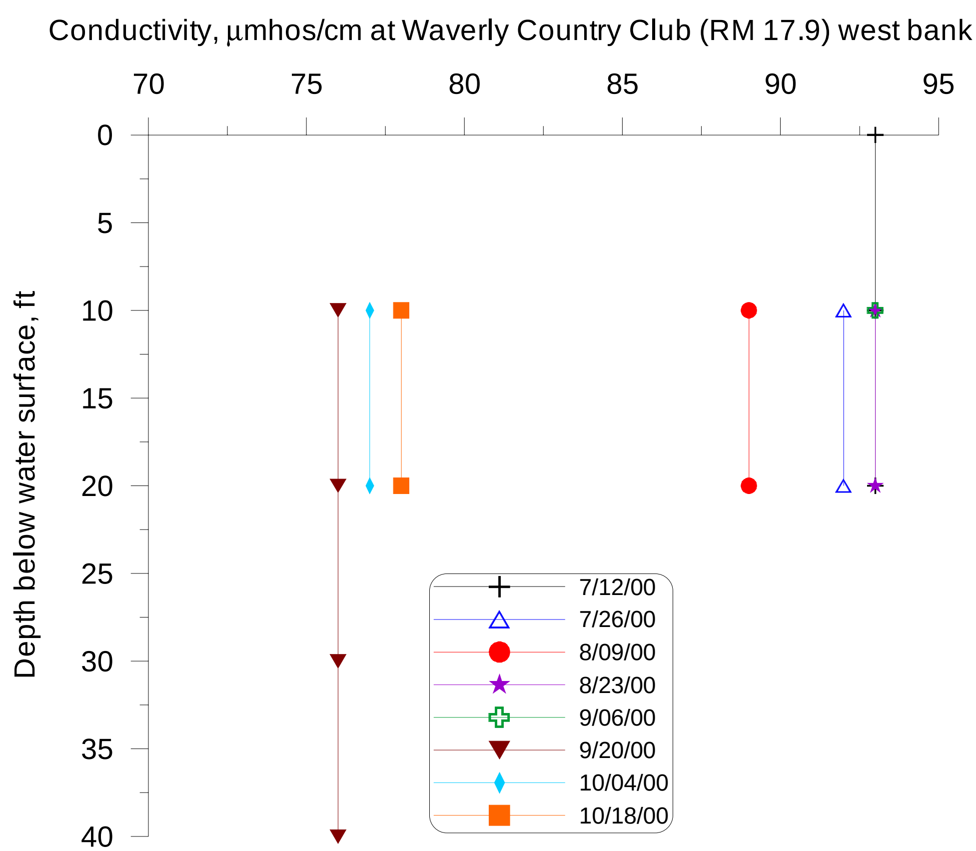

Conductivity, µmhos/cm at Morrison Bridge (RM 12.7) middle of the River
76
80
84
88
92
96
0
5
10
15
20
25
30
35
40
Depth below water surface, ft
7/12/00
7/26/00
8/09/00
8/23/00
9/06/00
9/20/00
10/04/00
10/18/00


Conductivity, µmhos/cm at Morrison Bridge (RM 12.7) west bank
76
80
84
88
92
96
0
5
10
15
20
25
30
35
40
45
50
Depth below water surface, ft


Conductivity, µmhos/cm at Waverly Country Club (RM 17.9) east bank
76
80
84
88
92
96
0
5
10
15
20
25
30
35
40
Depth below water surface, ft
7/12/00
7/26/00
8/09/00
8/23/00
9/06/00
9/20/00
10/04/00
10/18/00

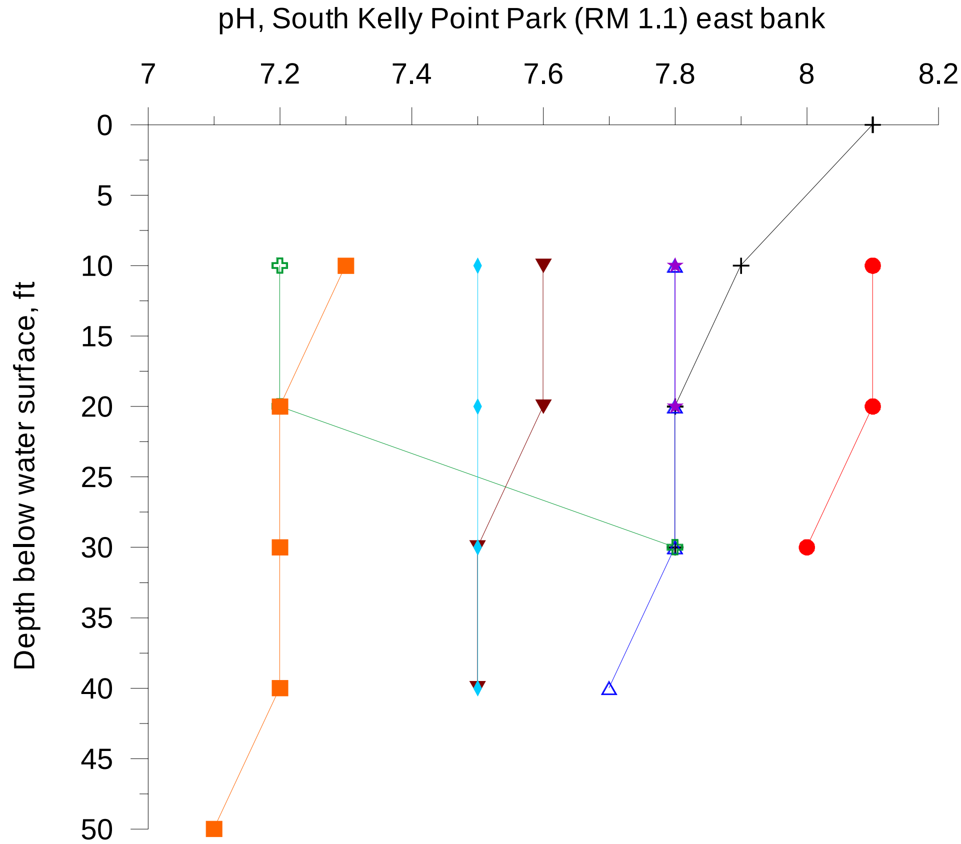


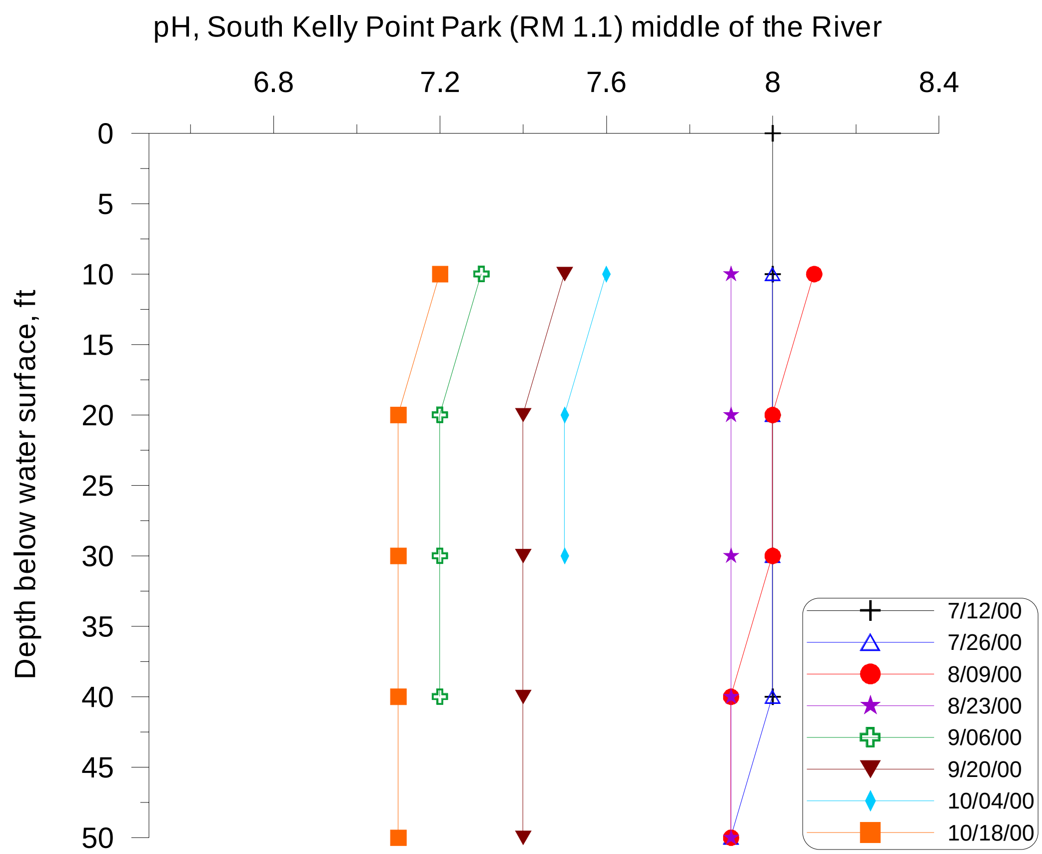
Conductivity, µmhos/cm at Waverly Country Club (RM 17.9) middle of the River
76
80
84
88
92
96
Depth below water surface, ft
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70

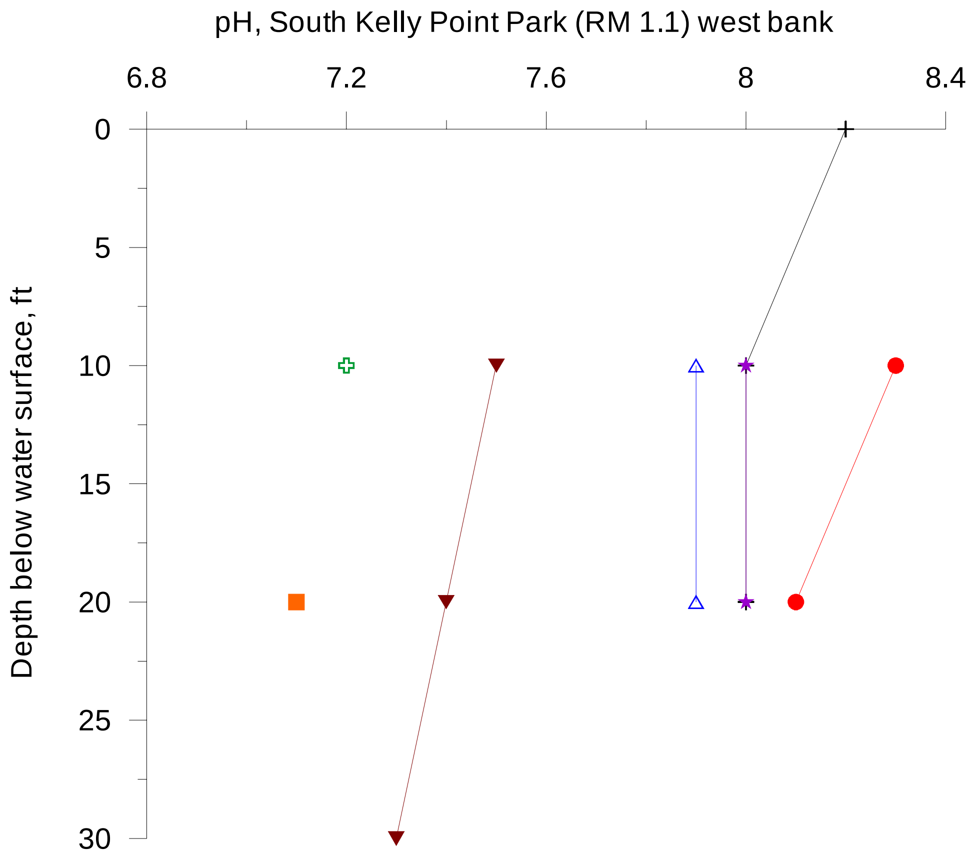



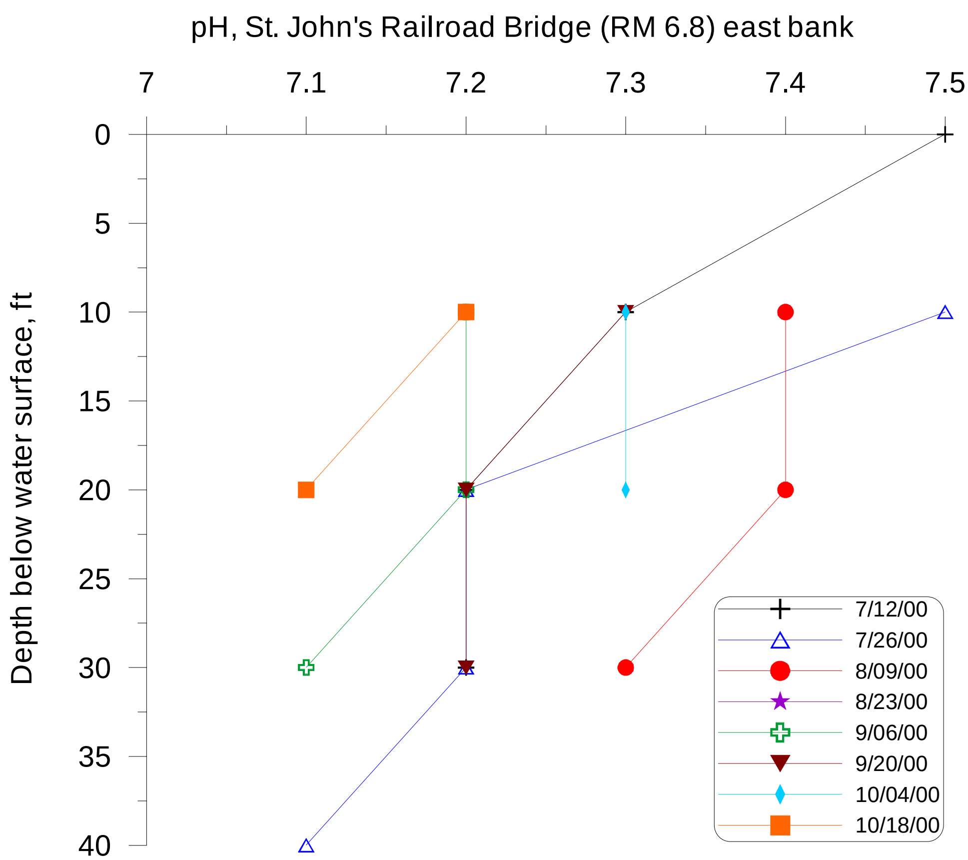
Conductivity, µmhos/cm at Waverly Country Club (RM 17.9) west bank
70
75
80
85
90
95
Depth below water surface, ft
0
5
10
15
20
25
30
35
40
7/12/00
7/26/00
8/09/00
8/23/00
9/06/00
9/20/00
10/04/00
10/18/00

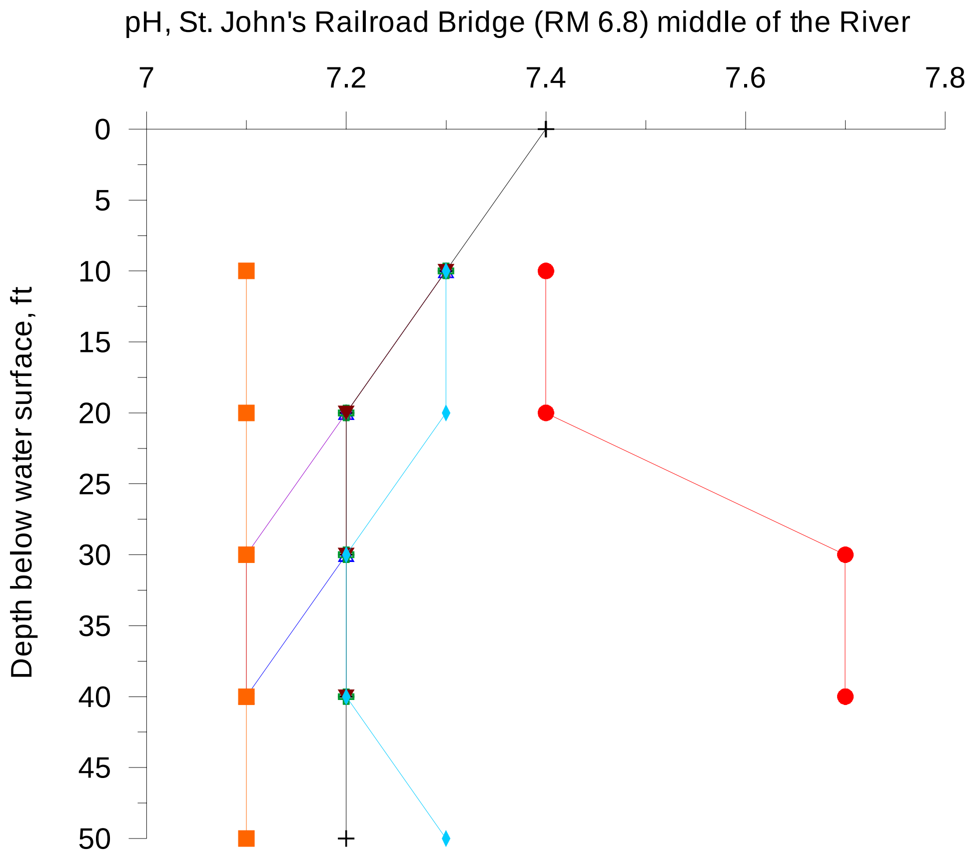
## Appendix H: Willamette River pH Profiles, summer 2000

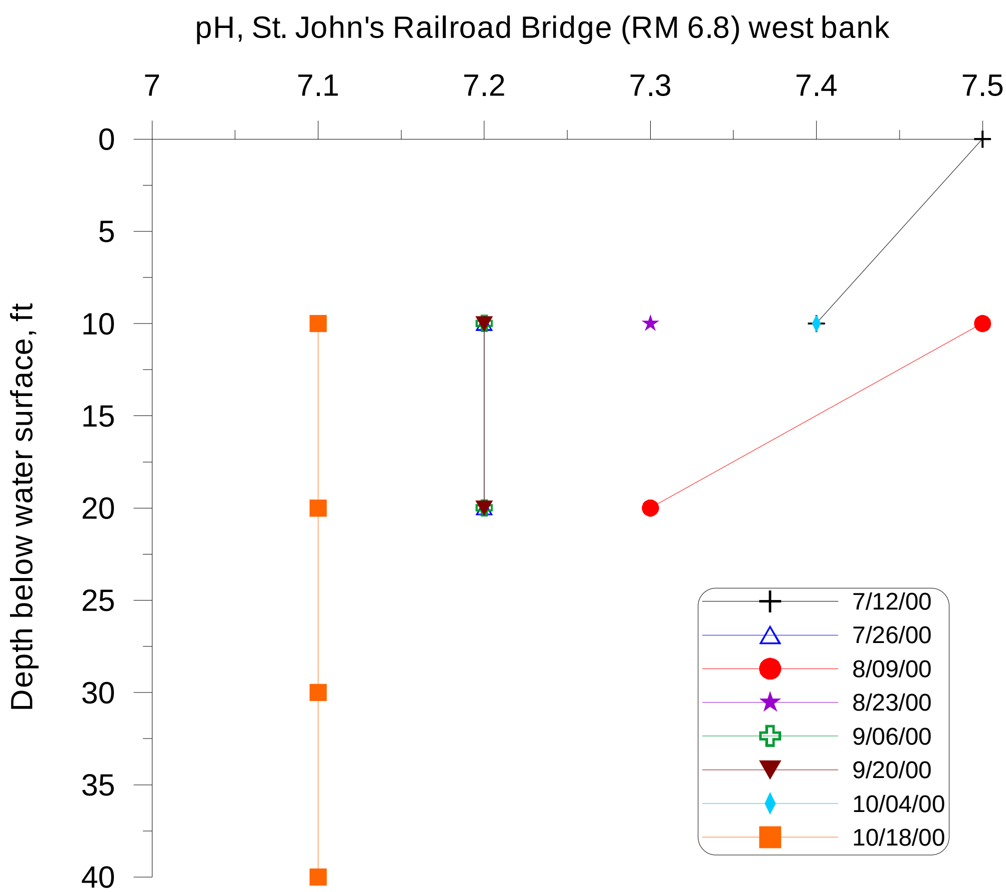


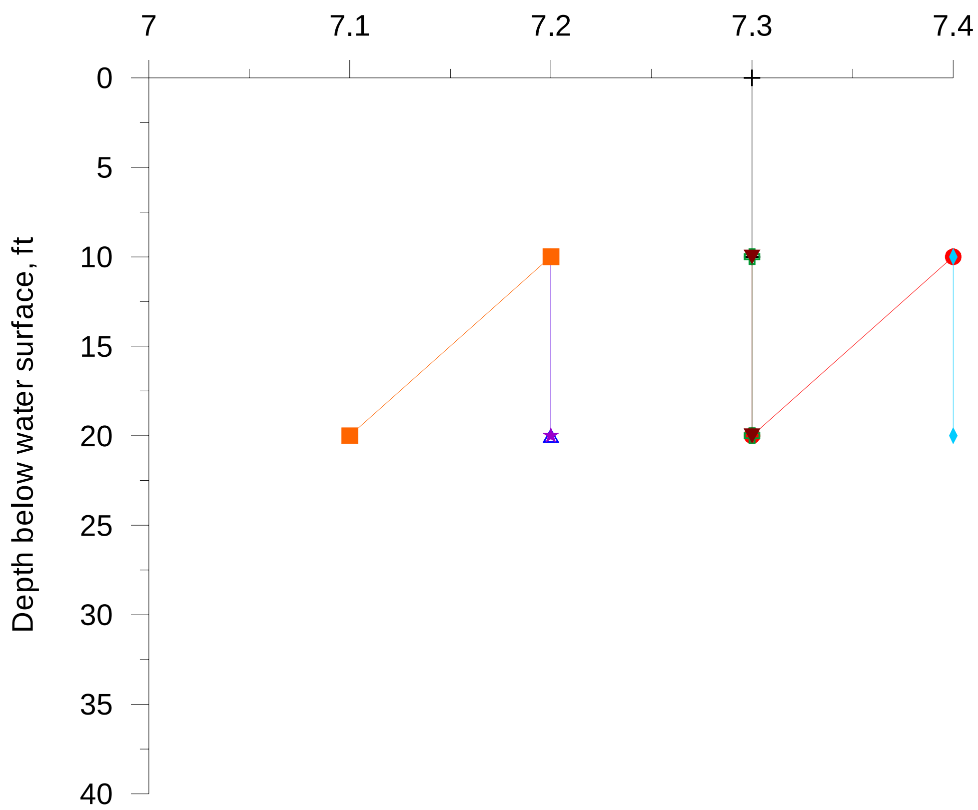

pH, South Kelly Point Park (RM 1.1) west bank
6.8
7.2
7.6
8
8.4
0
5
10
15
20
25
30
Depth below water surface, ft


pH, St. John's Railroad Bridge (RM 6.8) east bank
7
7.1
7.2
7.3
7.4
7.5
0
5
10
15
20
25
30
35
40
Depth below water surface, ft
7/12/00
7/26/00
8/09/00
8/23/00
9/06/00
9/20/00
10/04/00
10/18/00

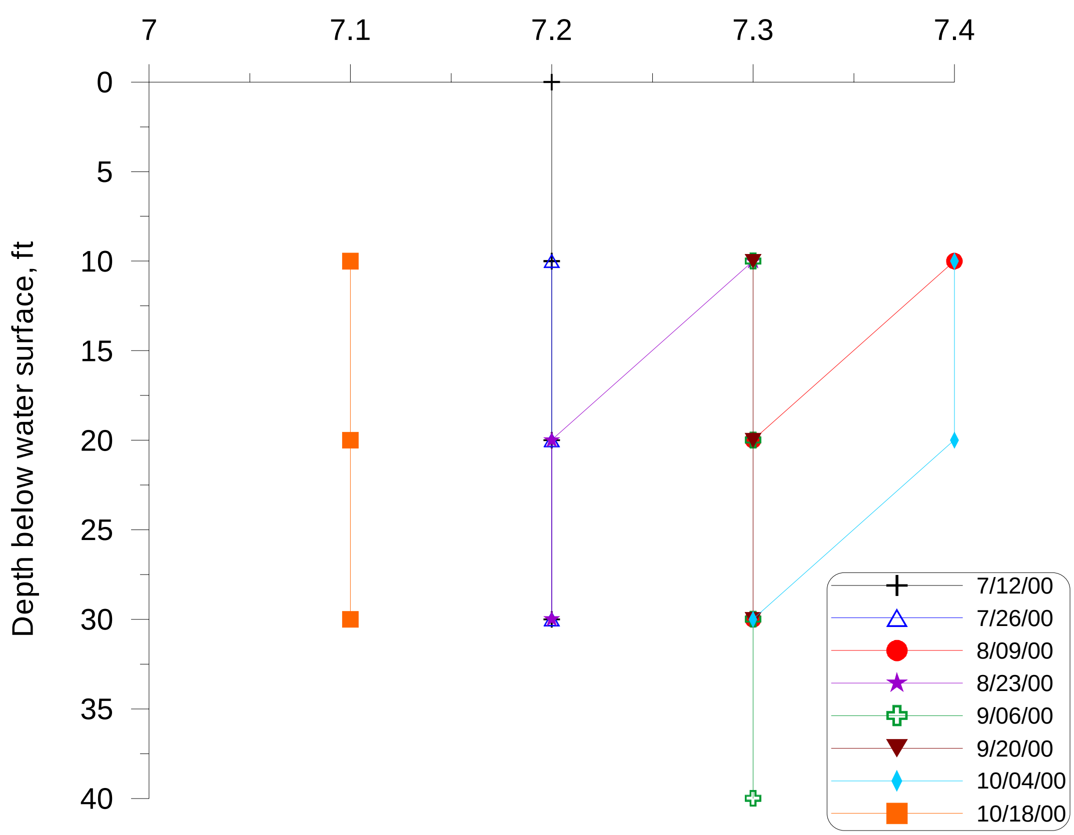

pH, St. John's Railroad Bridge (RM 6.8) middle of the River
7
7.2
7.4
7.6
7.8
0
5
10
15
20
25
30
35
40
45
50
Depth below water surface, ft

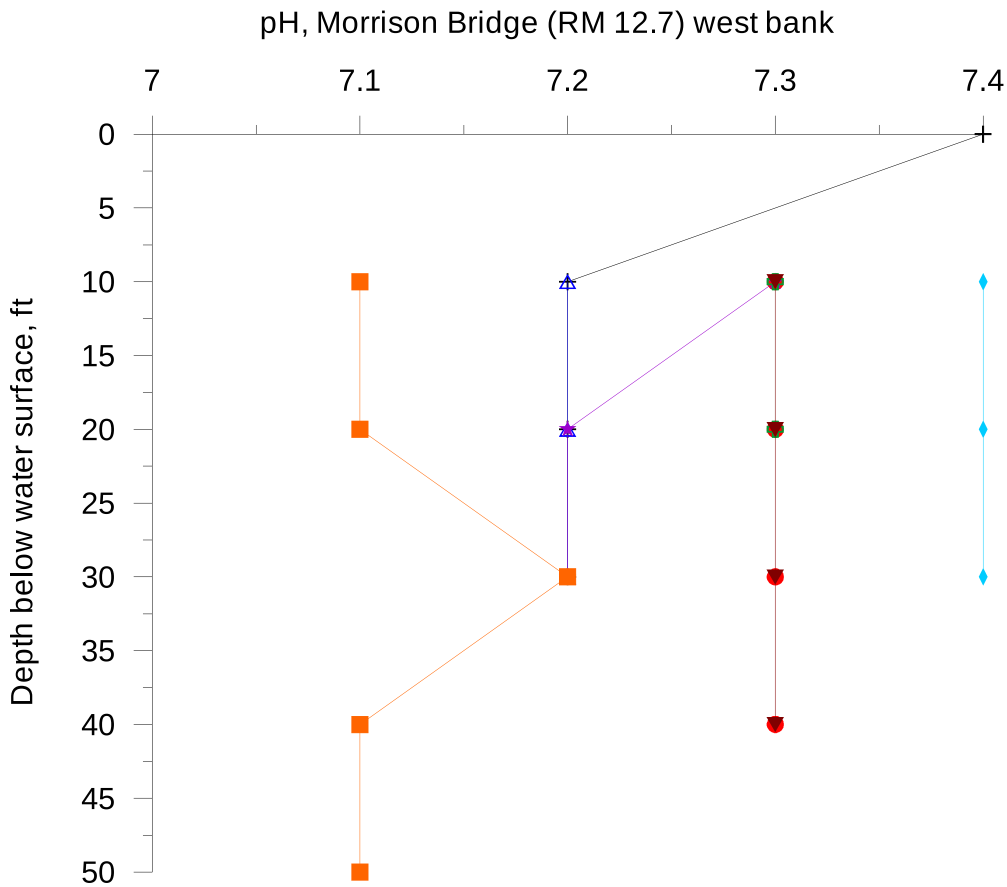

pH, St. John's Railroad Bridge (RM 6.8) west bank
7
7.1
7.2
7.3
7.4
7.5
0
5
10
15
20
25
30
35
40
Depth below water surface, ft
7/12/00
7/26/00
8/09/00
8/23/00
9/06/00
9/20/00
10/04/00
10/18/00

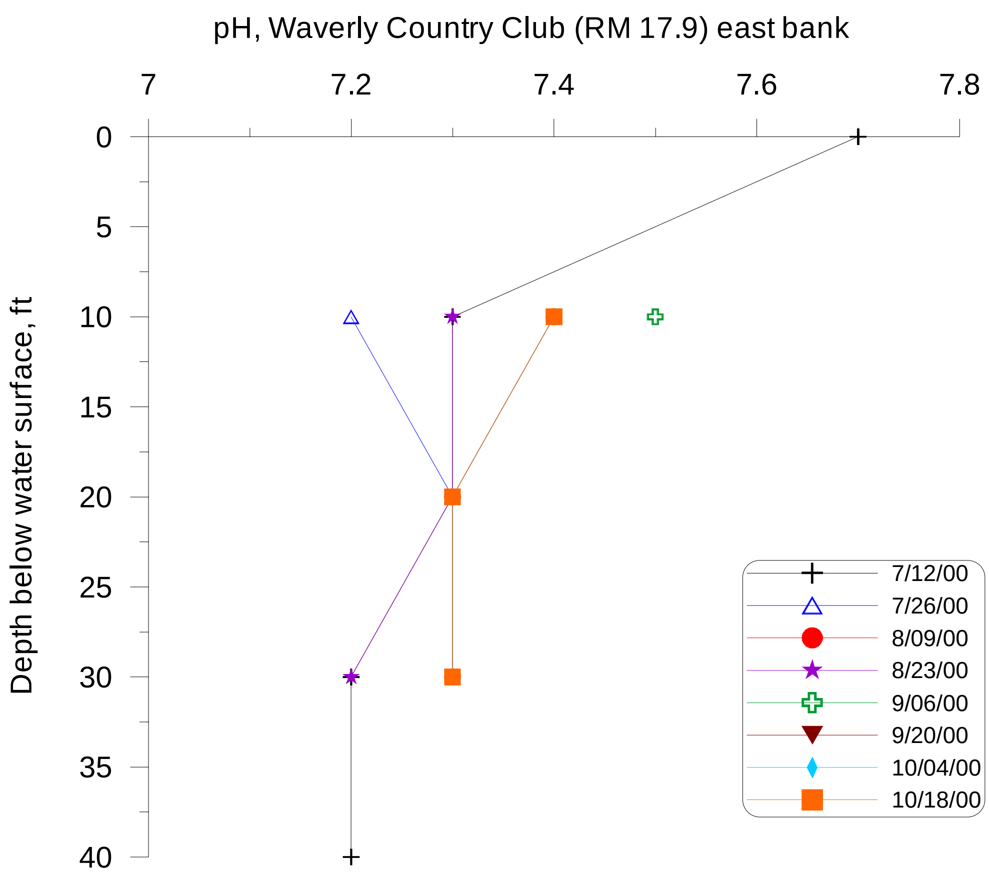
pH, Morrison Bridge (RM 12.7) east bank

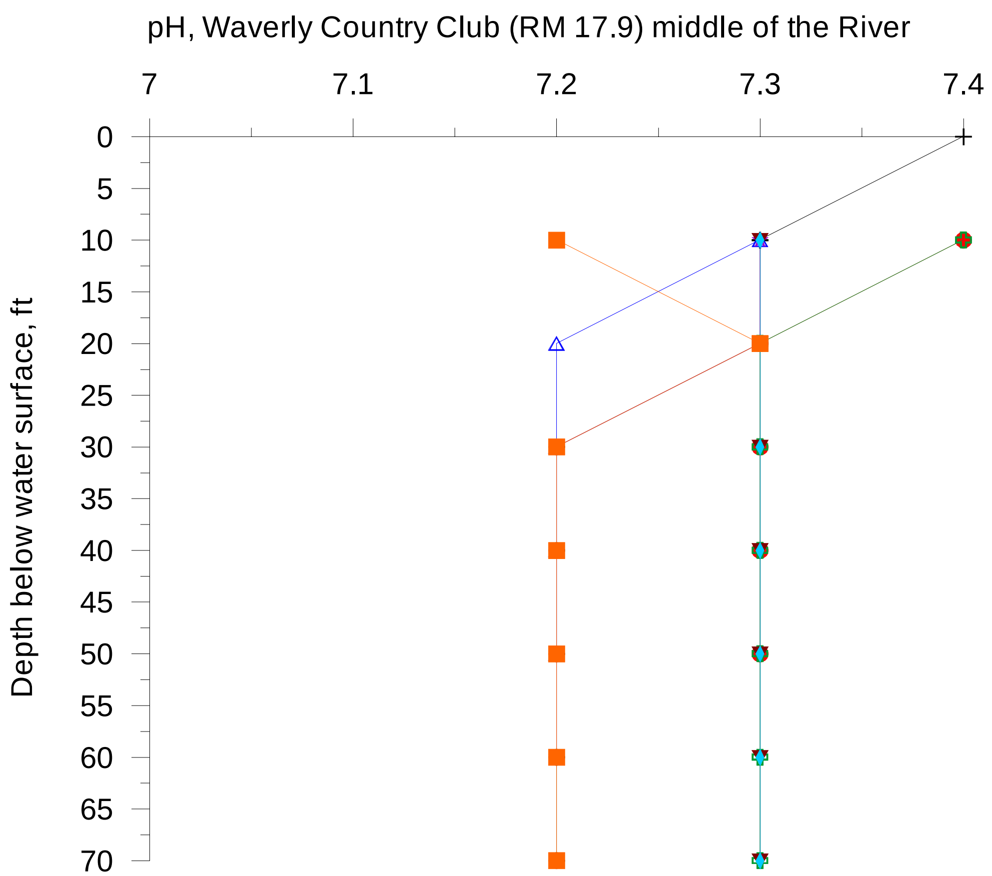


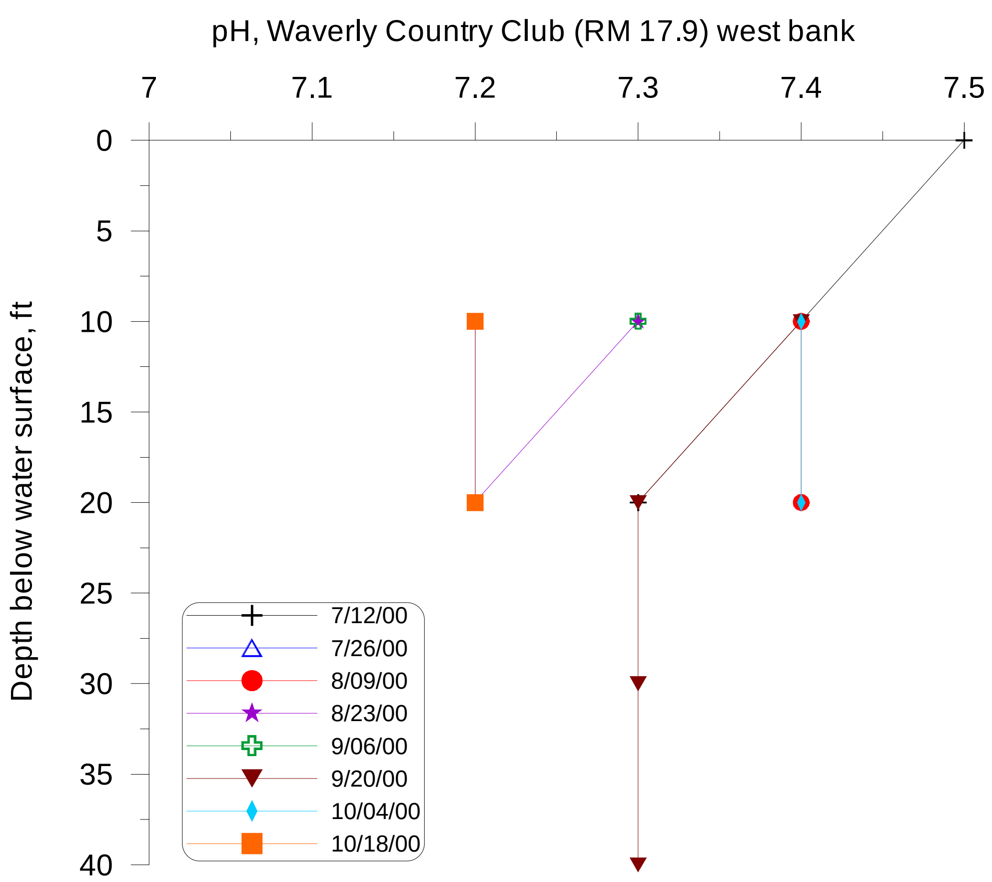

pH, Morrison Bridge (RM 12.7) middle of the River




pH, Morrison Bridge (RM 12.7) west bank
7
7.1
7.2
7.3
7.4
0
5
10
15
20
25
30
35
40
45
50
Depth below water surface, ft


pH, Waverly Country Club (RM 17.9) east bank
7
7.2
7.4
7.6
7.8
0
5
10
15
20
25
30
35
40
Depth below water surface, ft
7/12/00
7/26/00
8/09/00
8/23/00
9/06/00
9/20/00
10/04/00
10/18/00


pH, Waverly Country Club (RM 17.9) middle of the River
7
7.1
7.2
7.3
7.4
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
Depth below water surface, ft


pH, Waverly Country Club (RM 17.9) west bank
7
7.1
7.2
7.3
7.4
7.5
0
5
10
15
20
25
30
35
40
Depth below water surface, ft
7/12/00
7/26/00
8/09/00
8/23/00
9/06/00
9/20/00
10/04/00
10/18/00

# Appendix I: Willamette River Project Databases

## Flow and Water Level Databases

Flow gage stations

| Site ID | Site Name |
|---|---|
| USGS14142500 | Sandy River Below Bull Run River |
| USGS14143500 | Washougal River Near Washougal, WA |
| USGS14144000 | Little Washougal River Near Washougal, WA |
| USGS14191000 | Willamette River at Salem |
| USGS14194150 | South Yamhill River at McMinnville, OR |
| USGS14197000 | North Yamhill |
| USGS14198000 | Willamette River at Wilsonville |
| USGS14201340 | Pudding River near Woodburn, OR |
| USGS14202000 | Pudding River at Aurora, OR |
| USGS14207500 | Tualatin River at West Linn, Or |
| USGS14210000 | Clackamas River at Estacada, OR |
| USGS14211550 | Johnson Creek At Milwaukie, OR |
| USGS14211720 | Willamette River at Portland |
| USGS14211820 | Columbia Slough |
| USGS14220500 | Lewis R. Ariel |
| USGS14222500 | East Fork of the Lewis River Near Heisson, WA |
| USGS14238000 | Cowlitz River below Mayfield Dam |
| USGS14243000 | Cowlitz River at Castle Rock, WA. |
| USGS14246900 | Columbia River at Beaver Army Terminal Near Quincy, OR |
| ACEBONN | Columbia River at Bonneville Dam |
| WRR | Willamette River at Mouth of Slough |

Water Elevation gage stations

| Site ID | Site Name |
|---|---|
| USGS14128870 | Columbia River Below Bonneville Dam |
| USGS14142500 | Sandy River Below Bull Run River |
| USGS14144700 | Columbia River at Vancouver, WA |
| USGS14207770 | Willamette River Below OC Falls |
| USGS14210000 | Clackamas River at Estacada |
| USGS14211550 | Johnson Creek at Milwaukie |
| USGS14211720 | Willamette River at Portland |
| USGS14211820 | Columbia Slough |
| USGS14220500 | Lewis R. Ariel |
| USGS14246900 | Columbia River at Beaver Army Terminal Near Quincy, OR |
| ACELW | Columbia River at Longview |
| ACESTHEL | Columbia River at St. Helens |
| ACEVAN | Columbia River at Vancouver |
| CRR | Columbia River at MCDD#4 (outfall from Slough), US6 |
| LOM | Columbia Slough |

Continuous Flow and Water Level Data

| | Flow Date | | Flow | Water Elevation Date | | Water Elev. |
|---|---|---|---|---|---|---|
| Site ID | Min | Max | # of Records | Min | Max | # of Records |
| USGS14128870 | | | | 10/01/91 | 06/16/00 | 296137 |
| USGS14142500 | 10/01/91 | 08/31/00 | 135516 | 10/01/91 | 08/31/00 | 118513 |
| USGS14144700 | | | | 02/04/98 | 06/16/00 | 80148 |
| USGS14207770 | | | | 10/01/91 | 08/31/00 | 146362 |
| USGS14210000 | 10/01/91 | 06/16/00 | 128780 | | | |
| USGS14211550 | 10/01/91 | 06/15/00 | 133035 | 10/01/91 | 06/15/00 | 133288 |
| USGS14211720 | 10/01/91 | 07/06/94 | 80214 | 10/01/91 | 06/16/00 | 175401 |
| USGS14211820 | 07/01/89 | 08/31/00 | 329381 | 10/01/91 | 06/30/00 | 245038 |
| USGS14220500 | 10/01/92 | 06/04/00 | 198845 | 10/01/91 | 06/16/00 | 235013 |
| USGS14243000 | 11/01/91 | 06/16/00 | 235975 | | | |
| USGS14246900 | 10/01/97 | 07/12/00 | 64787 | 10/01/97 | 07/17/00 | 71517 |
| ACEVAN | | | | 01/01/82 | 10/01/97 | 81663 |
| ACELW | | | | 01/01/93 | 10/11/00 | 140961 |
| ACESTHEL | | | | 10/01/95 | 10/10/00 | 119596 |
| ACEBONN | 08/01/94 | 10/12/00 | 54301 | | | |
| CRR | | | | 11/20/87 | 10/30/98 | 751 |
| LOM | | | | 12/09/88 | 09/29/91 | 24620 |
| WRR | 10/01/94 | 07/28/96 | 445 | | | |

Daily Flow Data

| | Flow Date | | Flow |
|---|---|---|---|
| Site ID | Min | Max | # of Records |
| USGS14142500 | 10/01/93 | 09/30/94 | 365 |
| USGS14143500 | 10/01/44 | 09/30/81 | 13514 |
| USGS14144000 | 07/01/51 | 11/30/55 | 1614 |
| USGS14191000 | 01/01/48 | 09/13/00 | 19248 |
| USGS14194150 | 10/01/94 | 09/12/00 | 2174 |
| USGS14197000 | 10/01/48 | 09/30/73 | 9131 |
| USGS14198000 | 10/01/48 | 09/30/93 | 9801 |
| USGS14201340 | 10/01/97 | 09/12/00 | 1075 |
| USGS14202000 | 06/21/93 | 09/30/97 | 1563 |
| USGS14207500 | 01/01/48 | 09/12/00 | 19247 |
| USGS14210000 | 11/28/92 | 09/30/99 | 2498 |
| USGS14211550 | 10/01/92 | 09/30/99 | 2556 |
| USGS14211720 | 07/06/94 | 09/30/99 | 1548 |
| USGS14220500 | 10/01/95 | 09/30/97 | 731 |
| USGS14222500 | 10/01/29 | 09/30/99 | 25567 |
| USGS14238000 | 10/01/87 | 09/30/99 | 4383 |

**Water Quality Database**

Bureau of Environmental Services Willamette River sampling locations

| Site ID | Site Name | RM |
|---|---|---|
| D | South Kelly Point Park | 1.1 |
| DE | South Kelly Point Park - East Bank | 1.1 |
| DM | South Kelly Point Park - Middle | 1.1 |
| DW | South Kelly Point Park - West Bank | 1.1 |
| C | St. John's Railroad Bridge | 6.8 |
| CE | St. John's Railroad Bridge - East Bank | 6.8 |
| CM | St. John's Railroad Bridge - Middle | 6.8 |
| CW | St. John's Railroad Bridge - West Bank | 6.8 |
| E | Swan Island | 8.8 |
| EE | Swan Island - East Bank | 8.8 |
| EM | Swan Island - Middle | 8.8 |
| EW | Swan Island - West Bank | 8.8 |
| B | Morrison Bridge | 12.7 |
| BE | Morrison Bridge - East Bank | 12.7 |
| BM | Morrison Bridge - Middle | 12.7 |
| BW | Morrison Bridge - West Bank | 12.7 |
| F | Waverly Country Club | 17.9 |
| FE | Waverly Country Club - East Bank | 17.9 |
| FM | Waverly Country Club - Middle | 17.9 |
| FW | Waverly Country Club - West Bank | 17.9 |
| A | Tryon Creek Railroad Bridge | 20.0 |
| AE | Tryon Creek Railroad Bridge - East Bank | 20.0 |
| AM | Tryon Creek Railroad Bridge - Middle | 20.0 |
| AW | Tryon Creek Railroad Bridge - West Bank | 20.0 |
| SJRB | St. John's Railroad Bridge | 6.8 |
| WCC | Waverly Country Club | 17.9 |

Water Quality Data at South Kelly Point Park RM 1.1

| **Site ID** | **D** | **DE** | **DM** | **DM1** | **DM2** | **DM3** | **DW** |
|---|---|---|---|---|---|---|---|
| **Min Date** | 12/01/93 | 12/01/93 | 12/01/93 | 02/05/92 | 02/05/92 | 02/05/92 | 12/01/93 |
| **Max Date** | 01/13/99 | 01/13/99 | 01/13/99 | 10/20/93 | 10/20/93 | 10/20/93 | 01/13/99 |
| **Parameter** | **Number of Records** | | | | | | |
| Alkalinity | | | | 35 | 35 | 34 | |
| Ammonia-Nitrogen | | | | 34 | 34 | 34 | |
| BOD5 | | | | 33 | 33 | 32 | |
| Conductivity | | 228 | 224 | 27 | 28 | 27 | 225 |
| Dissolved Oxygen | | 224 | 220 | 24 | 24 | 24 | 221 |
| E. Coli | | 150 | 149 | | | | 148 |
| Enterococcus | 10 | 63 | 60 | 24 | | | 62 |
| Fecal Coliform | 11 | 219 | 215 | 26 | | | 216 |
| Hardness | 227 | 1 | | 34 | 35 | 35 | |
| Nitrate-Nitrogen | | | | 35 | 35 | 34 | |
| Nitrite-Nitrogen | | | | 30 | 30 | 28 | |
| O-PO4-P | | | | 32 | 32 | 32 | |
| pH | | 228 | 224 | 23 | 23 | 23 | 225 |
| Temperature | | 228 | 224 | 27 | 27 | 27 | 225 |
| Total Dissolved Solids | 226 | | | 19 | 19 | 19 | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Total Phosphorus | | | | 10 | 10 | 9 | |
| Total Solids | 136 | | | 37 | 37 | 36 | |
| Total Suspended Solids | 227 | | | 36 | 36 | 36 | |
| Total O&G | | | | 2 | | | |

Water Quality Data at St. John's Railroad Bridge RM 6.8

| **Site ID** | **C** | **CE** | **CM** | **CM1** | **CM2** | **CM3** | **CW** |
|---|---|---|---|---|---|---|---|
| **Min Date** | 11/17/93 | 11/17/93 | 11/17/93 | 02/05/92 | 02/05/92 | 02/05/92 | 11/17/93 |
| **Max Date** | 06/14/00 | 06/14/00 | 06/14/00 | 10/20/93 | 10/20/93 | 10/20/93 | 06/14/00 |
| **Parameter** | **Number of Records** | | | | | | |
| Alkalinity | | | | 35 | 35 | 34 | |
| Ammonia-Nitrogen | | | | 34 | 34 | 33 | |
| BOD5 | | | | 33 | 33 | 32 | |
| Conductivity | | 305 | 303 | 27 | 27 | 27 | 305 |
| Dissolved Oxygen | | 300 | 299 | 26 | 25 | 25 | 301 |
| E. Coli | | 223 | 223 | | | | 223 |
| Enterococcus | 11 | 64 | 64 | 24 | | | 66 |
| Fecal Coliform | 12 | 293 | 293 | 26 | | | 295 |
| Hardness | 310 | | | 35 | 35 | 34 | |
| Nitrate-Nitrogen | | | | 35 | 35 | 34 | |
| Nitrite-Nitrogen | | | | 30 | 30 | 30 | |
| O-PO4-P | | | | 32 | 32 | 31 | |
| pH | | 304 | 303 | 23 | 23 | 23 | 305 |
| Temperature | | 305 | 303 | 27 | 27 | 27 | 305 |
| Total Dissolved Solids | 309 | | | 20 | 19 | 19 | |
| Total Phosphorus | | | | 10 | 10 | 9 | |
| Total Solids | 212 | | | 36 | 36 | 35 | |
| Total Suspended Solids | 310 | | | 36 | 36 | 35 | |

Water Quality Data at Swan Island RM 8.8

| **Site ID** | **E** | **EE** | **EM** | **EW** |
|---|---|---|---|---|
| **Min Date** | 11/17/93 | 11/17/93 | 11/17/93 | 11/17/93 |
| **Max Date** | 01/13/99 | 01/13/99 | 01/13/99 | 01/13/99 |
| **Parameter** | **Number of Records** | | | |
| Conductivity | | 232 | 231 | 231 |
| Dissolved Oxygen | | 228 | 227 | 227 |
| E. Coli | | 150 | 150 | 149 |
| Enterococcus | 11 | 65 | 64 | 65 |
| Fecal Coliform | 12 | 219 | 219 | 219 |
| Hardness | 233 | | | |
| pH | | 231 | 231 | 230 |
| Temperature | | 232 | 231 | 231 |
| Total Dissolved Solids | 231 | | | |
| Total Solids | 139 | | | |
| Total Suspended Solids | 233 | | | |
| Turbidity | 1 | | | |

Water Quality Data at Morrison Bridge RM 12.7

| **Site ID** | **B** | **BE** | **BM** | **BM1** | **BM2** | **BM3** | **BW** |
|---|---|---|---|---|---|---|---|
| **Min Date** | 11/17/93 | 11/17/93 | 11/17/93 | 02/05/92 | 02/05/92 | 02/05/92 | 11/17/93 |
| **Max Date** | 06/14/00 | 06/14/00 | 06/14/00 | 10/20/93 | 10/20/93 | 10/20/93 | 06/14/00 |

| Parameter | Number of Records | | | | | | |
|---|---|---|---|---|---|---|---|
| Alkalinity | | | | 35 | 35 | 35 | |
| Ammonia-Nitrogen | | | | 34 | 34 | 34 | |
| BOD5 | | | | 35 | 33 | 35 | |
| Conductivity | | 307 | 303 | 26 | 27 | 25 | 301 |
| Dissolved Oxygen | | 304 | 300 | 26 | 26 | 26 | 298 |
| E. Coli | | 224 | 221 | | | | 221 |
| Enterococcus | 11 | 66 | 65 | 24 | | | 63 |
| Fecal Coliform | 12 | 295 | 290 | 26 | | | 289 |
| Hardness | 302 | | | 34 | 35 | 35 | |
| Nitrate-Nitrogen | | | | 34 | 35 | 35 | |
| Nitrite-Nitrogen | | | | 30 | 30 | 30 | |
| O-PO4-P | | | | 33 | 32 | 32 | |
| pH | 306 | | 302 | 23 | 23 | 23 | 300 |
| Temperature | | 306 | 303 | 27 | 27 | 27 | 301 |
| Total Dissolved Solids | 301 | | | 19 | 19 | 21 | |
| Total Phosphorus | | | | 10 | 10 | 10 | |
| Total Solids | 212 | | | 36 | 36 | 36 | |
| Total Suspended Solids | 303 | | | 36 | 36 | 36 | |

Water Quality Data at Waverly Country Club RM 17.9

| **Site ID** | **F** | **FE** | **FM** | **FW** |
|---|---|---|---|---|
| **Min Date** | 02/01/95 | 02/01/95 | 02/01/95 | 02/01/95 |
| **Max Date** | 06/14/00 | 06/14/00 | 06/14/00 | 06/14/00 |
| **Parameter** | **Number of Records** | | | |
| Conductivity | | 264 | 261 | 260 |
| Dissolved Oxygen | | 264 | 261 | 260 |
| E. Coli | | 223 | 223 | 222 |
| Enterococcus | | 41 | 38 | 38 |
| Fecal Coliform | | 264 | 261 | 260 |
| Hardness | 262 | | | |
| pH | | 263 | 260 | 259 |
| Temperature | | 264 | 261 | 260 |
| Total Dissolved Solids | 262 | | | |
| Total Solids | 185 | | | |
| Total Suspended Solids | 262 | | | |

Water Quality Data at Tryon Creek Railroad Bridge RM 20

| **Site ID** | **A** | **AE** | **AM** | **AM1** | **AM2** | **AM3** | **AW** |
|---|---|---|---|---|---|---|---|
| **Min Date** | 11/17/93 | 11/17/93 | 11/17/93 | 2/5/92 | 2/5/92 | 2/5/92 | 11/17/93 |
| **Max Date** | 06/14/00 | 06/14/00 | 06/14/00 | 10/20/93 | 10/20/93 | 10/20/93 | 06/14/00 |
| **Parameter** | **Number of Records** | | | | | | |
| Alkalinity | | | | 36 | 35 | 35 | |
| Ammonia-Nitrogen | | | | 36 | 34 | 34 | |
| BOD5 | | | | 33 | 33 | 33 | |
| Conductivity | | 304 | 306 | 27 | 27 | 27 | 305 |
| Dissolved Oxygen | 1 | 304 | 305 | 26 | 26 | 26 | 304 |
| E. Coli | | 221 | 223 | | | | 223 |
| Enterococcus | 12 | 65 | 66 | 24 | | | 65 |
| Fecal Coliform | 13 | 292 | 293 | 26 | | | 292 |
| Hardness | 307 | | | 36 | 35 | 35 | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Nitrate-Nitrogen | | | | 35 | 35 | 36 | |
| Nitrite-Nitrogen | | | | 31 | 30 | 30 | |
| O-PO4-P | | | | 33 | 31 | 33 | |
| pH | | 302 | 304 | 25 | 24 | 24 | 304 |
| Temperature | | 304 | 306 | 27 | 27 | 27 | 305 |
| Total Dissolved Solids | 306 | | | 19 | 19 | 20 | |
| Total Phosphorus | | | | 10 | 10 | 10 | |
| Total Solids | 212 | | | 38 | 38 | 36 | |
| Total Suspended Solids | 307 | | | 38 | 36 | 36 | |

Hydrolab Water Quality Data Sampling Locations

| Site ID | Site Name |
|---|---|
| CRR | Columbia River at MCDD#4 (outfall from Slough),CRR |
| LOM | Columbia Slough, Lombard St. Bridge, L2, CS RM 0.45, 14211820 |
| SJB | St. Johns Landfill Bridge (Main Channel), L3, Downstream |
| SJRB | St. John's Railroad Bridge |
| US-6 | Columbia River at MCDD#4 (outfall from Slough) |
| WCC | Waverly Country Club |
| WRR | Willamette River at Mouth of Slough (Main Channel), L1 |

Continuous Hydrolab Water Quality Data

| Sited ID | SJRB | WCC | LOM | SJB |
|---|---|---|---|---|
| **Min Date** | 09/24/97 | 09/24/97 | 10/16/97 | 07/28/92 |
| **Max Date** | 06/22/00 | 06/21/00 | 01/12/00 | 03/31/98 |
| **Parameter** | **Number of Records** | | | |
| Temp ($^{o}$C) | 38490 | 39555 | 26641 | 50467 |
| pH | 38224 | 39548 | 26649 | 50467 |
| Sp. Cond (mS/cm) | 37338 | 39464 | 26644 | 50467 |
| DO (%Sat) | 37195 | 39549 | 26643 | 49705 |
| DO (mg/L) | 37200 | 39576 | 26017 | 49705 |
| Turbidity (NTU) | 37374 | 37470 | 0 | 613 |

Grab Samples

| Site ID | LOM | US-6 | WRR | CRR |
|---|---|---|---|---|
| **Min Date** | 11/16/90 | 07/29/92 | 11/16/90 | 11/16/90 |
| **Max Date** | 12/03/93 | 12/02/93 | 10/07/97 | 03/02/91 |
| **Parameter** | **Number of Records** | | | |
| Alkalinity | 0 | 0 | 36 | 0 |
| Ammonia-Nitrogen | 13 | 0 | 4 | 2 |
| BOD | 10 | 10 | 30 | 0 |
| BOD5 | 18 | 20 | 56 | 2 |
| Conductivity | 2 | 0 | 14 | 2 |
| Dissolved Oxygen | 0 | 0 | 12 | 0 |
| E. Coli | 0 | 0 | 33 | 0 |
| Fecal Coliform | 20 | 30 | 88 | 0 |
| Hardness | 13 | 0 | 51 | 2 |
| Nitrate-Nitrogen | 20 | 26 | 81 | 2 |
| O-PO4-P | 10 | 16 | 26 | 2 |
| pH | 0 | 0 | 6 | 0 |
| Temperature | 0 | 0 | 6 | 0 |

| | | | | |
|---|---|---|---|---|
| Total Phosphorus | 35 | 26 | 68 | 2 |
| Total Solids | 0 | 0 | 10 | 0 |
| Total Suspended Solids | 2 | 0 | 56 | 2 |
| Turbidity | 2 | 0 | 56 | 2 |
| Chlorophyll A | 29 | 23 | 74 | 2 |

USGS Water Quality in the Columbia River Sampling Locations

| Site ID | Site Name |
|---|---|
| 453439122223900 | COLUMBIA RIVER,RIGHT BANK,AT WASHOUGAL, WA |
| 453630122021400 | COLUMBIA RIVER,LEFT BANK, NR DODSON, OR |
| 453651122022200 | COLUMBIA RIVER,RIGHT BANK, NR SKAMANIA, WA |
| 453845121562000 | COLUMBIA R AT BONNEVILLE DAM FOREBAY |
| 455903122500000 | COLUMBIA RIVER,RIGHT BANK,NR KALAMA,WA |
| 460923123235800 | COLUMBIA RIVER LEFT BANK AT WAUNA |

| Location | Min | Max | Temp |
|---|---|---|---|
| 453439122223900 | 03/08/96 | 08/16/00 | 22215 |
| 453630122021400 | 03/07/96 | 08/16/00 | 33571 |
| 453651122022200 | 05/03/96 | 08/16/00 | 20970 |
| 453845121562000 | 03/04/96 | 08/16/00 | 39532 |
| 455903122500000 | 05/29/96 | 09/16/98 | 11006 |
| 460923123235800 | 03/06/96 | 09/16/98 | 11427 |

USGS Continuous and Daily Water Quality Sampling Locations

| Site ID | Site Name |
|---|---|
| 14207200 | Tualatin River at Oswego Dam, Near West Linn, OR |
| 14211550 | Johnson Creek at Milwaukie OR |
| 14246900 | Columbia River at Beaver Army Terminal, Near Quincy, OR |

USGS Continuous Water Quality

| **Site ID** | **14207200** | **14211550** | **14246900** |
|---|---|---|---|
| **Min Date** | 10/01/92 | 05/07/98 | 10/01/92 |
| **Max Date** | 10/26/00 | 10/27/00 | 10/24/00 |
| **Parameter** | **Number of Records** | | |
| Temp | 66249 | 42773 | 121269 |
| Conductivity | 64531 | 0 | 105421 |
| DO | 64834 | 0 | 0 |
| pH | 65383 | 0 | 0 |

USGS Daily Water Quality

| **Site ID** | **14207200** | **14211550** | **14246900** |
|---|---|---|---|
| **Min Date** | 10/01/92 | 05/07/98 | 10/01/92 |
| **Max Date** | 10/26/00 | 10/27/00 | 10/24/00 |
| **Parameter** | **Number of Records** | | |
| Max Temp | 2741 | 878 | 2576 |
| Max Conductivity | 2664 | 0 | 2559 |
| Max DO | 2684 | 0 | 0 |
| Max pH | 2709 | 0 | 0 |
| Min Temp | 2741 | 878 | 2577 |
| Min Conductivity | 2664 | 0 | 2561 |

| | | | |
|---|---|---|---|
| Min DO | 2684 | 0 | 0 |
| Min pH | 2709 | 0 | 0 |
| Mean Temp | 2743 | 878 | 2701 |
| Mean DO | 2684 | 0 | 0 |
| Mean pH | 2709 | 0 | 0 |
| Mean Conductivity | 2664 | 0 | 2556 |

Hydrolab Scout Water Quality Sampling Locations

| Site ID | Site Name |
|---|---|
| CRC | Columbia River between RR Bridge and I5 Bridge |
| CRR | Columbia River at MCDD#4 (outfall from Slough),CRR |
| LOM | Columbia Slough, Lombard St. Bridge, L2, CS RM 0.45, 14211820 |
| OSC | Columbia River, Between 3rd and 4th supports of RR bridge from the South |
| SJB | ST JOHNS LANDFILL BRIDGE (MAIN CHANNEL), L3, Downstream |
| US6 | Columbia River at MCDD#4 (outfall from Slough) |
| WRR | WILLAMETTE RIVER @ MOUTH OF SLOUGH (MAIN CHANNEL), L1 |

Hydrolab Scout Water Quality

| Site ID | CRC | CRR | LOM | OSC | SJB | US6 | WRR |
|---|---|---|---|---|---|---|---|
| Min Date | 09/25/96 | 08/16/90 | 08/08/90 | 09/25/96 | 08/16/90 | 05/31/94 | 08/08/90 |
| Max Date | 10/15/96 | 07/18/91 | 12/03/92 | 10/15/96 | 09/09/97 | 12/13/94 | 09/09/97 |
| Parameter | Number of Records | | | | | | |
| Temperature | 53 | 201 | 897 | 44 | 1344 | 17 | 2921 |
| pH | 53 | 201 | 897 | 44 | 1344 | 17 | 2921 |
| Conductivity | 53 | 201 | 897 | 44 | 1344 | 17 | 2921 |
| DO sat % | 53 | 201 | 897 | 44 | 1344 | 17 | 2921 |
| DO | 53 | 201 | 897 | 44 | 1344 | 17 | 2921 |
| Turbidity | 53 | 0 | 0 | 44 | 0 | 0 | 0 |

Environmental Information Monitoring (EIM) Water Quality Sampling Locations

| Station | Site Name |
|---|---|
| 26B070 | Cowlitz R @ Kelso |
| 26C070 | Coweeman R @ Kelso |
| 27B070 | Kalama R nr Kalama |
| 27D090 | EF Lewis R nr Dollar Corner |
| 27E070 | Cedar Cr nr Etna |
| 28B070 | Washougal R nr Washougal |
| 28B090 | Washougal R blw Canyon Ck |
| 28B110 | Salmon Washougal |

EIM Water Quality

| Site ID | 26B070 | 26C070 | 27B070 | 27D090 | 27E070 | 28B070 | 28B090 | 28B110 |
|---|---|---|---|---|---|---|---|---|
| Min Date | 10/29/91 | 10/29/91 | 10/29/91 | 10/25/94 | 10/25/94 | 10/29/91 | 08/30/00 | 10/25/94 |
| Max Date | 09/27/00 | 09/29/98 | 09/26/00 | 09/26/00 | 09/27/95 | 06/23/92 | 09/27/00 | 07/26/00 |
| Parameter | Number of Records | | | | | | | |
| Ammonia-Nitrogen | 102 | 24 | 79 | 69 | 12 | 9 | 0 | 33 |
| Conductivity | 107 | 24 | 84 | 72 | 12 | 9 | 2 | 34 |
| Dissolved Nitrite | 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Dissolved Soluble | 101 | 24 | 79 | 69 | 12 | 9 | 0 | 33 |
| Fecal Coliforms | 102 | 24 | 79 | 68 | 12 | 9 | 0 | 33 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Nitrate-Nitrite | 98 | 22 | 76 | 69 | 12 | 9 | 0 | 33 |
| Dissolved Oxygen | 107 | 24 | 84 | 72 | 12 | 9 | 2 | 34 |
| Dissolved Oxygen Sat % | 15 | 12 | 12 | 0 | 0 | 9 | 0 | 0 |
| pH | 107 | 24 | 84 | 72 | 12 | 9 | 2 | 34 |
| Suspended Solids | 102 | 24 | 79 | 68 | 12 | 9 | 0 | 33 |
| Temperature | 107 | 24 | 84 | 72 | 12 | 9 | 2 | 34 |
| Tot Persulfate Nitrogen | 78 | 12 | 67 | 69 | 12 | 0 | 0 | 33 |
| Total Phosphorus | 102 | 24 | 79 | 69 | 12 | 9 | 0 | 33 |
| Turbidity | 102 | 24 | 79 | 68 | 12 | 9 | 0 | 33 |

PGE Water Quality Sampling Locations

| Site ID | Site Name |
|---|---|
| 57 | Canby A |
| 58 | Canby B |
| 60 | Buoy 9A |
| 61 | Buoy 9B |
| 62 | Dock A |
| 63 | Dock B |
| 64 | Marina A |
| 65 | Marina B |
| 66 | Boat house A |
| 67 | Boat house B |
| 68 | log Boom A |
| 78 | log Boom B |
| 79 | Forebay A |
| 80 | Forebay B |
| 81 | Tailrace A |
| 82 | Tailrace B |
| 83 | Lower (lower Will below falls) |
| CR_Mouth | Clackamas River at Mouth |
| PGEClack | Clackamas River at RM 2.5, PGE study |

PGE Water Quality

| | Temperature Date | | Temperature |
|---|---|---|---|
| **Site ID** | **Min** | **Max** | **# of Records** |
| 57 | 06/10/2000 | 11/07/2000 | 3233 |
| 58 | 06/10/2000 | 11/07/2000 | 3593 |
| 60 | 06/10/2000 | 11/07/2000 | 3593 |
| 61 | 06/10/2000 | 11/07/2000 | 3254 |
| 62 | 06/10/2000 | 11/07/2000 | 3591 |
| 63 | 06/10/2000 | 11/07/2000 | 3591 |
| 64 | 06/10/2000 | 11/07/2000 | 3591 |
| 65 | 06/10/2000 | 11/07/2000 | 3591 |
| 66 | 06/10/2000 | 11/07/2000 | 3589 |
| 67 | 06/10/2000 | 11/07/2000 | 3589 |
| 68 | 06/10/2000 | 11/07/2000 | 3587 |
| 78 | 06/10/2000 | 11/07/2000 | 3588 |
| 79 | 06/10/2000 | 10/24/2000 | 2898 |
| 80 | 06/10/2000 | 10/24/2000 | 3253 |
| 81 | 06/10/2000 | 11/07/2000 | 3558 |

| | | | |
|---|---|---|---|
| 82 | 06/10/2000 | 11/07/2000 | 3557 |
| 83 | 06/10/2000 | 11/07/2000 | 3549 |
| CR_Mouth | 06/23/1999 | 09/06/1999 | 1800 |
| PGEClack | 08/31/2000 | 11/09/2000 | 1685 |

Water Quality in the Willamette River at Wilsonville

| **Site ID** | **Willamette River at Wilsonville** |
|---|---|
| **Min Date** | 04/19/94 |
| **Max Date** | 07/27/99 |
| **Parameter** | **# of Records** |
| Turbidity | 157 |
| pH | 160 |
| Temperature | 158 |
| Alkalinity | 160 |
| Calcium Hardness | 158 |
| total Hardness | 159 |
| TOC | 156 |
| DOC | 138 |
| Total Coliform | 137 |
| Fecal Coliforms | 146 |
| Ammonia-Nitrogen | 40 |
| Nitrate-N | 8 |

Water Quality from the City of Lake Oswego

| **Site ID** | **Lake Oswego** |
|---|---|
| **Min Date** | 07/27/99 |
| **Max Date** | 09/12/00 |
| **Parameter** | **# of Records** |
| Temperature | 352 |
| SpCOND | 352 |
| Conductivity | 352 |
| DO (%) | 352 |
| DO | 352 |
| DO CHARGE | 352 |
| pH | 352 |

STORET data

| | Flow Date | | BOD | pH | DO Sat. | Temp | Chlrphyl A | Conduct. | DO | T. Phosp | NO2&NO3 N-Diss |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Site ID | Min | Max | # of Records | | | | | | | | |
| Beaver Creek Near Troutdale, OR | 08/22/91 | 08/05/94 | | 5 | 3 | 8 | | 4 | 3 | 3 | 3 |
| Clackamas River and High Rocks (Old HWY 213) | 01/23/90 | 02/07/00 | 147 | 274 | 270 | 3122 | 35 | 274 | 269 | 78 | 78 |
| Clackamas River Near Clackamas, Oreg. | 11/21/91 | 06/08/93 | | | | 34 | | | | | |
| Clatskanie River @ HWY 30 (Clatskanie) | 10/12/92 | 03/29/00 | 71 | 48 | 38 | 70 | 18 | 45 | 33 | 39 | 38 |
| Columbia R at Beaver Army Terminal NR Quincy, OR | 11/20/90 | 04/23/97 | | 348 | 212 | 424 | 13 | 189 | 211 | 66 | 78 |
| Columbia River @ Walton Beach (Reeder Road) | 07/16/90 | 03/23/93 | 22 | 21 | 12 | 24 | 8 | 13 | 12 | 12 | 12 |
| Columbia River 100 ft. u/s Ranier STP Outfall | 08/25/97 | 08/25/97 | 2 | 2 | 1 | 2 | | 1 | 1 | 1 | 1 |
| Columbia River 50 ft. d/s Ranier STP Outfall | 08/25/97 | 08/25/97 | 2 | 2 | 1 | 2 | | 1 | 1 | 1 | 1 |
| Columbia River at Marker #47 (u/s Willamette) | 02/20/91 | 12/15/98 | 94 | 66 | 47 | 94 | 17 | 54 | 47 | 47 | 48 |
| Columbia River at Ranier STP Outfall | 08/25/97 | 08/25/97 | 2 | 2 | 1 | 2 | | 2 | 1 | 1 | 1 |
| Columbia River at Warrendale, Oreg. | 03/06/90 | 06/04/97 | | 165 | 109 | 218 | 10 | 109 | 109 | 26 | 33 |
| Columbia River NR Columbia City, Oreg. | 01/19/94 | 12/07/94 | | 36 | 12 | 24 | 10 | 12 | 12 | 12 | 12 |
| Columbia River, RM 102 DS of Hayden Island, OR | 01/18/94 | 12/05/94 | | 40 | 14 | 28 | 12 | 14 | 14 | 13 | 13 |
| Columbia Slough at Landfill Road | 10/09/91 | 12/15/98 | 76 | 249 | 228 | 454 | 19 | 232 | 227 | 39 | 39 |
| Cowlitz R at Kelso | 10/29/91 | 09/27/00 | | 98 | | 122 | | 122 | 122 | 118 | |
| Dart Creek at RM 3.7 | 07/18/94 | 03/06/97 | 12 | 6 | 6 | 16 | | 8 | 6 | 6 | 10 |
| Gee Cr @ Ridgefield | 10/25/94 | 09/27/95 | | 12 | 12 | 24 | | 12 | 12 | 12 | 12 |
| Gibbons Creek Near Washougal | 10/29/91 | 09/29/92 | | 12 | 12 | 24 | | 12 | 12 | 12 | 12 |
| Gilbert River Near Multnomah Channel | 07/16/90 | 03/23/93 | 36 | 35 | 17 | 34 | 12 | 27 | 19 | 17 | 18 |
| Johnson Creek Above Mouth | 01/25/90 | 01/26/90 | | 6 | | | | 2 | | 3 | 3 |
| Johnson Creek at SE 17th Ave. (Portland) | 08/11/90 | 04/11/00 | 72 | 95 | 71 | 137 | 32 | 95 | 71 | 73 | 9 |
| Kalama River Above Spencer Creek, NR Kalama, WA. | 05/16/94 | 09/06/94 | | 12 | 4 | 8 | 4 | 4 | 4 | 4 | 4 |
| Kalama River Near Kalama | 01/30/90 | 09/28/97 | | 69 | 68 | 138 | | 69 | 68 | 67 | 67 |
| Multnomah Channel @ Sauvies Is. Moorage STP | 08/05/97 | 08/05/97 | 4 | 6 | 2 | 4 | | 3 | 2 | 2 | 2 |
| Multnomah Channel 150 ft. d/s Sauvies Is. STP | 08/05/97 | 08/05/97 | 2 | 1 | 1 | 2 | | 1 | 1 | 1 | 1 |
| Multnomah Channel 20 ft. d/s Sauvies Is. STP | 08/05/97 | 08/05/97 | 2 | 1 | 1 | 2 | | 1 | 1 | 1 | 1 |
| Multnomah Channel 25 ft. u/s Sauvies Is. STP | 08/05/97 | 08/05/97 | 2 | 1 | 1 | 2 | | 1 | 1 | 1 | 1 |
| Multnomah Channel 400 ft. d/s Sauvies Is. STP | 08/05/97 | 08/05/97 | 2 | 1 | 1 | 2 | | 1 | 1 | 1 | 1 |
| Multnomah Channel Near Mouth, at St Helens, OR | 02/15/94 | 12/07/94 | 22 | 34 | 12 | 24 | 10 | 12 | 12 | 12 | 12 |
| Multnomah Channel Near the Gilbert River | 07/16/90 | 03/23/93 | | 21 | 11 | 22 | 8 | 13 | 12 | 12 | 12 |
| QA Tualatin River @ Scholls | 04/11/00 | 04/11/00 | | | 1 | | | | | | |
| Sandy River at Troutdale Bridge | 06/04/90 | 04/24/00 | 158 | 100 | 84 | 163 | 39 | 93 | 84 | 84 | 85 |
| Sandy River Near Troutdale, OR | 07/06/92 | 09/19/94 | | 14 | 6 | 12 | 4 | 6 | 6 | 4 | 4 |
| Swan Island at Boat Ramp | 09/27/91 | 09/27/91 | 2 | 3 | 1 | 2 | | 1 | 1 | | |
| Swan Island Channel Opp Cenex Tower | 02/20/91 | 12/15/98 | 96 | 70 | 49 | 98 | 18 | 58 | 49 | 49 | 50 |
| TUALATIN RIVER @ WEISS BRIDGE | 01/02/90 | 12/21/98 | 31 | 691 | 349 | 354 | 443 | 358 | 348 | 352 | 87 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Tualatin River At Boones Ferry Road | 01/09/95 | 04/11/00 | 50 | 49 | 6 | 48 | 22 | 48 | 48 | 50 | 50 |
| Tualatin River At Elsner Road | 01/09/95 | 04/11/00 | 47 | 48 | 6 | 48 | 21 | 47 | 48 | 49 | 49 |
| Tualatin River At Hwy 210 (Scholls) | 01/09/95 | 04/11/00 | 48 | 49 | 5 | 48 | 22 | 48 | 48 | 49 | 49 |
| Tualatin River At Rood Road | 01/09/95 | 04/11/00 | 49 | 48 | 6 | 48 | 22 | 47 | 48 | 49 | 49 |
| Washougal R Blw Canyon Ck | 10/25/94 | 09/27/95 | | 12 | 12 | 24 | | 12 | 12 | 12 | 12 |
| Washougal River at Washougal | 10/29/91 | 06/23/92 | | 9 | 9 | 18 | | 9 | 9 | 9 | 9 |
| Wilamette River at McCormick & Baxter Cove | 08/23/90 | 08/23/90 | | | | | | | | | |
| Willamette R ab St Johns Br at Portland, Oreg. | 05/23/94 | 05/13/96 | | 18 | 5 | 14 | | 6 | 5 | 7 | 7 |
| Willamette R. Ea.Side D/S Oak Lodge @ R BR.FTG | 06/07/96 | 06/07/96 | | 1 | 1 | 2 | | 1 | 1 | 1 | 1 |
| Willamette Rive @ 1st Doc U/S Willamette Pk. | 09/02/98 | 09/03/98 | 2 | | | | | | | | |
| Willamette River @ Meldrum Bar Boat Ramp | 07/15/98 | 07/22/98 | | | | | | | | | |
| Willamette River @ Milwaukie Boat Ramp | 07/15/98 | 07/22/98 | | | | | | | | | |
| Willamette River @ Oaks Park | 07/15/98 | 07/22/98 | | | | | | | | | |
| Willamette River @ Willamette Park | 09/02/98 | 09/03/98 | | | | | | | | | |
| Willamette River 100 Yds D/S Oswego Cr. Mouth | 07/27/98 | 07/28/98 | | | | | | | | | |
| Willamette River 200 yds. U/S of Oak Lodge ZID | 06/07/96 | 06/07/96 | 2 | 1 | 1 | 2 | | 1 | 1 | 1 | 1 |
| Willamette River at Canby Ferry | 01/23/90 | 04/11/00 | 124 | 81 | 61 | 130 | 27 | 74 | 66 | 66 | 66 |
| Willamette River at East Side of SP&S Bridge | 08/23/90 | 08/23/90 | | | | | | | | | |
| Willamette River at Hawthorne Bridge | 01/23/90 | 12/15/98 | 242 | 151 | 123 | 246 | 50 | 138 | 123 | 120 | 121 |
| Willamette River at Hwy 219 (New Newberg Br) | 02/21/90 | 04/11/00 | 226 | 123 | 116 | 223 | 49 | 119 | 116 | 122 | 122 |
| Willamette River at Linnton, OR | 04/18/92 | 10/26/92 | | 1 | 1 | 2 | | 1 | 1 | | |
| Willamette River at Oregon City Marina | 06/24/98 | 06/24/98 | | | | 2 | | | | | |
| Willamette River at Portland, Oreg. | 01/18/90 | 06/02/97 | | 288 | 163 | 332 | 11 | 165 | 163 | 58 | 71 |
| Willamette River at Sellwood Park Boat Dock | 07/22/98 | 07/22/98 | | | | | | | | | |
| Willamette River at SP&S Bridge (Portland) | 01/23/90 | 12/15/98 | 116 | 76 | 61 | 122 | 26 | 66 | 61 | 58 | 59 |
| Willamette River at Wheatland Ferry | 01/23/90 | 04/11/00 | 119 | 79 | 67 | 121 | 25 | 70 | 64 | 64 | 65 |
| Willamette River D/S of SP&S Bridge at East Cove | 08/23/90 | 08/23/90 | | | | | | | | | |
| Willamette River East Side ot Oak Lodge ZID | 06/07/96 | 06/07/96 | 2 | 1 | 1 | 2 | | 1 | 1 | 1 | 1 |
| Willamette River West Side D/S of Tryon Creek | 06/07/96 | 06/07/96 | 2 | 1 | 1 | 2 | | 1 | 1 | 1 | 1 |

| | **Flow Date** | | **NO2&NO3 N-Total** | **NO2-N DISS** | **E.COLI** | **Fecal Coliform** | **Turbidi t** | **NH3+NH4 N TOTAL** | **PHOS-DIS ORTHO** | **T ORG C C** | **UN-IONZD NH3-NH3** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Site ID** | **Min** | **Max** | | | | | | | | | |
| Beaver Creek Near Troutdale, OR | 08/22/91 | 08/05/94 | | 3 | | | | | 3 | | 3 |
| Clackamas River and High Rocks (Old HWY 213) | 01/23/90 | 02/07/00 | 69 | | 30 | 71 | 76 | 78 | 78 | 66 | 69 |
| Clackamas River Near Clackamas, Oreg. | 11/21/91 | 06/08/93 | | | | | | | | | |
| Clatskanie River @ HWY 30 (Clatskanie) | 10/12/92 | 03/29/00 | 31 | | 20 | 37 | 41 | 39 | 39 | 39 | 32 |
| Columbia R at Beaver Army Terminal NR Quincy, OR | 11/20/90 | 04/23/97 | 21 | 87 | | 40 | 65 | 21 | 67 | | 66 |
| Columbia River @ Walton Beach (Reeder Road) | 07/16/90 | 03/23/93 | 12 | | | 11 | 12 | 12 | 12 | 12 | 12 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Columbia River 100 ft. u/s Ranier STP Outfall | 08/25/97 | 08/25/97 | 1 | | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Columbia River 50 ft. d/s Ranier STP Outfall | 08/25/97 | 08/25/97 | 1 | | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Columbia River at Marker #47 (u/s Willamette) | 02/20/91 | 12/15/98 | 45 | | 20 | 46 | 48 | 47 | 47 | 47 | 47 |
| Columbia River at Ranier STP Outfall | 08/25/97 | 08/25/97 | 1 | | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Columbia River at Warrendale, Oreg. | 03/06/90 | 06/04/97 | 9 | 35 | | 26 | 17 | 12 | 26 | | 26 |
| Columbia River NR Columbia City, Oreg. | 01/19/94 | 12/07/94 | | 12 | | 11 | | | 12 | | 12 |
| Columbia River, RM 102 DS of Hayden Island, OR | 01/18/94 | 12/05/94 | | 13 | | 13 | | | 13 | | 13 |
| Columbia Slough at Landfill Road | 10/09/91 | 12/15/98 | 37 | | 20 | 35 | 40 | 39 | 39 | 38 | 39 |
| Cowlitz R at Kelso | 10/29/91 | 09/27/00 | 118 | 48 | | 118 | 118 | 118 | 117 | | |
| Dart Creek at RM 3.7 | 07/18/94 | 03/06/97 | 6 | | | | 8 | 6 | 6 | 6 | 6 |
| Gee Cr @ Ridgefield | 10/25/94 | 09/27/95 | 12 | | | 12 | 12 | 12 | 12 | | 12 |
| Gibbons Creek Near Washougal | 10/29/91 | 09/29/92 | 12 | 12 | | 12 | 12 | 12 | 12 | | 12 |
| Gilbert River Near Multnomah Channel | 07/16/90 | 03/23/93 | 17 | | | 18 | 19 | 17 | 19 | 17 | 16 |
| Johnson Creek Above Mouth | 01/25/90 | 01/26/90 | | 3 | | | 1 | 3 | 3 | | |
| Johnson Creek at SE 17th Ave. (Portland) | 08/11/90 | 04/11/00 | 63 | | 25 | 68 | 74 | 73 | 73 | 73 | 64 |
| Kalama River Above Spencer Creek, NR Kalama, WA. | 05/16/94 | 09/06/94 | | 4 | | 4 | | | 4 | | 4 |
| Kalama River Near Kalama | 01/30/90 | 09/28/97 | 67 | 32 | | 66 | 66 | 67 | 66 | | 67 |
| Multnomah Channel @ Sauvies Is. Moorage STP | 08/05/97 | 08/05/97 | 2 | | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Multnomah Channel 150 ft. d/s Sauvies Is. STP | 08/05/97 | 08/05/97 | 1 | | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Multnomah Channel 20 ft. d/s Sauvies Is. STP | 08/05/97 | 08/05/97 | 1 | | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Multnomah Channel 25 ft. u/s Sauvies Is. STP | 08/05/97 | 08/05/97 | 1 | | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Multnomah Channel 400 ft. d/s Sauvies Is. STP | 08/05/97 | 08/05/97 | 1 | | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Multnomah Channel Near Mouth, at St Helens, OR | 02/15/94 | 12/07/94 | | 12 | | 12 | | | 12 | | 12 |
| Multnomah Channel Near the Gilbert River | 07/16/90 | 03/23/93 | 12 | | | 10 | 12 | 12 | 12 | 12 | 11 |
| QA Tualatin River @ Scholls | 04/11/00 | 04/11/00 | | | | | | | | | |
| Sandy River at Troutdale Bridge | 06/04/90 | 04/24/00 | 77 | 4 | 23 | 77 | 84 | 79 | 84 | 85 | 79 |
| Sandy River Near Troutdale, OR | 07/06/92 | 09/19/94 | | | | 4 | | | 4 | | 4 |
| Swan Island at Boat Ramp | 09/27/91 | 09/27/91 | | | | | | | | | |
| Swan Island Channel Opp Cenex Tower | 02/20/91 | 12/15/98 | 47 | | 17 | 49 | 50 | 49 | 49 | 49 | 49 |
| TUALATIN RIVER @ WEISS BRIDGE | 01/02/90 | 12/21/98 | 267 | 173 | 167 | 158 | 298 | 263 | 343 | | 352 |
| Tualatin River At Boones Ferry Road | 01/09/95 | 04/11/00 | | | 37 | 49 | 58 | | 50 | 50 | |
| Tualatin River At Elsner Road | 01/09/95 | 04/11/00 | | | 36 | 49 | 56 | | 49 | 49 | |
| Tualatin River At Hwy 210 (Scholls) | 01/09/95 | 04/11/00 | | | 37 | 49 | 58 | | 49 | 49 | |
| Tualatin River At Rood Road | 01/09/95 | 04/11/00 | | | 36 | 49 | 57 | | 49 | 49 | |
| Washougal R Blw Canyon Ck | 10/25/94 | 09/27/95 | 12 | | | 12 | 12 | 12 | 12 | | 12 |
| Washougal River at Washougal | 10/29/91 | 06/23/92 | 9 | 9 | | 9 | 9 | 9 | 9 | | 9 |
| Wilamette River at McCormick & Baxter Cove | 08/23/90 | 08/23/90 | | | | | | | | 1 | |
| Willamette R ab St Johns Br at Portland, Oreg. | 05/23/94 | 05/13/96 | | 7 | | | 6 | | 7 | | 7 |
| Willamette R. Ea.Side D/S Oak Lodge @ R BR.FTG | 06/07/96 | 06/07/96 | 1 | | 1 | 1 | 1 | 1 | | 1 | 1 |
| Willamette Rive @ 1st Doc U/S Willamette Pk. | 09/02/98 | 09/03/98 | | | 4 | 4 | | | | | |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Willamette River @ Meldrum Bar Boat Ramp | 07/15/98 | 07/22/98 | | | 5 | 5 | | | | | |
| Willamette River @ Milwaukie Boat Ramp | 07/15/98 | 07/22/98 | | | 3 | 3 | | | | | |
| Willamette River @ Oaks Park | 07/15/98 | 07/22/98 | | | 3 | 3 | | | | | |
| Willamette River @ Willamette Park | 09/02/98 | 09/03/98 | | | 5 | 5 | | | | | |
| Willamette River 100 Yds D/S Oswego Cr. Mouth | 07/27/98 | 07/28/98 | | | 5 | 5 | | | | | |
| Willamette River 200 yds. U/S of Oak Lodge ZID | 06/07/96 | 06/07/96 | 1 | | 1 | 1 | 1 | 1 | | 1 | 1 |
| Willamette River at Canby Ferry | 01/23/90 | 04/11/00 | 58 | | 18 | 63 | 64 | 66 | 66 | 51 | 58 |
| Willamette River at East Side of SP&S Bridge | 08/23/90 | 08/23/90 | | | | | | | | 1 | |
| Willamette River at Hawthorne Bridge | 01/23/90 | 12/15/98 | 120 | | 43 | 116 | 120 | 119 | 117 | 109 | 119 |
| Willamette River at Hwy 219 (New Newberg Br) | 02/21/90 | 04/11/00 | 106 | | 47 | 112 | 113 | 122 | 120 | 112 | 105 |
| Willamette River at Linnton, OR | 04/18/92 | 10/26/92 | | | | | | | | | |
| Willamette River at Oregon City Marina | 06/24/98 | 06/24/98 | 13 | | | | | | | | |
| Willamette River at Portland, Oreg. | 01/18/90 | 06/02/97 | | 71 | | 44 | 47 | 18 | 59 | | 58 |
| Willamette River at Sellwood Park Boat Dock | 07/22/98 | 07/22/98 | | | 1 | 1 | | | | | |
| Willamette River at SP&S Bridge (Portland) | 01/23/90 | 12/15/98 | 55 | | 16 | 58 | 58 | 58 | 58 | 48 | 58 |
| Willamette River at Wheatland Ferry | 01/23/90 | 04/11/00 | 55 | | 22 | 59 | 63 | 65 | 64 | 53 | 55 |
| Willamette River D/S of SP&S Bridge at East Cove | 08/23/90 | 08/23/90 | | | | | | | | 1 | |
| Willamette River East Side ot Oak Lodge ZID | 06/07/96 | 06/07/96 | 1 | | 1 | 1 | 1 | 1 | | 1 | 1 |
| Willamette River West Side D/S of Tryon Creek | 06/07/96 | 06/07/96 | 1 | | 1 | 1 | 1 | 1 | | 1 | 1 |

| | Flow Date | | UN-IONZD NH3-N | T. Alkalinity | D ORG C C | ENTCOCCI | Hardness T. Diss | SUSP SED CONC | NH3+NH4-N DISS | PHOS-DIS |
|---|---|---|---|---|---|---|---|---|---|---|
| **Site ID** | **Min** | **Max** | | | | | | | | |
| Beaver Creek Near Troutdale, OR | 08/22/91 | 08/05/94 | 3 | | 2 | | | 1 | 3 | 3 |
| Clackamas River and High Rocks (Old HWY 213) | 01/23/90 | 02/07/00 | 69 | 77 | | 43 | 46 | 9 | | |
| Clackamas River Near Clackamas, Oreg. | 11/21/91 | 06/08/93 | | | | | | 20 | | |
| Clatskanie River @ HWY 30 (Clatskanie) | 10/12/92 | 03/29/00 | 32 | 44 | | 16 | | 7 | | |
| Columbia R at Beaver Army Terminal NR Quincy, OR | 11/20/90 | 04/23/97 | 66 | 2 | 17 | 14 | | 52 | 66 | 66 |
| Columbia River @ Walton Beach (Reeder Road) | 07/16/90 | 03/23/93 | 12 | 11 | | 11 | | | | |
| Columbia River 100 ft. u/s Ranier STP Outfall | 08/25/97 | 08/25/97 | 1 | | | | 1 | | | |
| Columbia River 50 ft. d/s Ranier STP Outfall | 08/25/97 | 08/25/97 | 1 | | | | 1 | | | |
| Columbia River at Marker #47 (u/s Willamette) | 02/20/91 | 12/15/98 | 47 | 51 | | 27 | 40 | | | |
| Columbia River at Ranier STP Outfall | 08/25/97 | 08/25/97 | 1 | | | | 1 | | | |
| Columbia River at Warrendale, Oreg. | 03/06/90 | 06/04/97 | 26 | 4 | 4 | 10 | | 25 | 26 | 26 |
| Columbia River NR Columbia City, Oreg. | 01/19/94 | 12/07/94 | 12 | | 4 | 11 | | 11 | 12 | 12 |
| Columbia River, RM 102 DS of Hayden Island, OR | 01/18/94 | 12/05/94 | 13 | | 4 | 13 | | 13 | 13 | 13 |
| Columbia Slough at Landfill Road | 10/09/91 | 12/15/98 | 39 | 44 | | 14 | 38 | | | |
| Cowlitz R at Kelso | 10/29/91 | 09/27/00 | | | | | | | | |
| Dart Creek at RM 3.7 | 07/18/94 | 03/06/97 | 6 | 4 | 3 | | 4 | | | |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Gee Cr @ Ridgefield | 10/25/94 | 09/27/95 | 12 | | | | | | | |
| Gibbons Creek Near Washougal | 10/29/91 | 09/29/92 | 12 | | | | | | | |
| Gilbert River Near Multnomah Channel | 07/16/90 | 03/23/93 | 16 | 18 | | 17 | | | | |
| Johnson Creek Above Mouth | 01/25/90 | 01/26/90 | | | 3 | | | | 3 | 3 |
| Johnson Creek at SE 17th Ave. (Portland) | 08/11/90 | 04/11/00 | 64 | 93 | | 42 | 47 | 9 | | |
| Kalama River Above Spencer Creek, NR Kalama, WA. | 05/16/94 | 09/06/94 | 4 | | 4 | 4 | | 4 | 4 | 4 |
| Kalama River Near Kalama | 01/30/90 | 09/28/97 | 67 | | | | | | | |
| Multnomah Channel @ Sauvies Is. Moorage STP | 08/05/97 | 08/05/97 | 2 | 1 | | | | | | |
| Multnomah Channel 150 ft. d/s Sauvies Is. STP | 08/05/97 | 08/05/97 | 1 | | | | | | | |
| Multnomah Channel 20 ft. d/s Sauvies Is. STP | 08/05/97 | 08/05/97 | 1 | | | | | | | |
| Multnomah Channel 25 ft. u/s Sauvies Is. STP | 08/05/97 | 08/05/97 | 1 | | | | | | | |
| Multnomah Channel 400 ft. d/s Sauvies Is. STP | 08/05/97 | 08/05/97 | 1 | | | | | | | |
| Multnomah Channel Near Mouth, at St Helens, OR | 02/15/94 | 12/07/94 | 12 | | 4 | 12 | | 11 | 12 | 12 |
| Multnomah Channel Near the Gilbert River | 07/16/90 | 03/23/93 | 11 | 11 | | 10 | | | | |
| QA Tualatin River @ Scholls | 04/11/00 | 04/11/00 | | | | | | | | |
| Sandy River at Troutdale Bridge | 06/04/90 | 04/24/00 | 79 | 94 | | 55 | | 8 | 8 | 4 |
| Sandy River Near Troutdale, OR | 07/06/92 | 09/19/94 | 4 | | 4 | 4 | | 4 | 4 | |
| Swan Island at Boat Ramp | 09/27/91 | 09/27/91 | | | | | | | | |
| Swan Island Channel Opp Cenex Tower | 02/20/91 | 12/15/98 | 49 | 55 | | 32 | 40 | | | |
| TUALATIN RIVER @ WEISS BRIDGE | 01/02/90 | 12/21/98 | 343 | 231 | | 212 | | | 90 | |
| Tualatin River At Boones Ferry Road | 01/09/95 | 04/11/00 | | 49 | | | | 50 | 50 | |
| Tualatin River At Elsner Road | 01/09/95 | 04/11/00 | | 48 | | | | 49 | 49 | |
| Tualatin River At Hwy 210 (Scholls) | 01/09/95 | 04/11/00 | | 48 | | | | 49 | 49 | |
| Tualatin River At Rood Road | 01/09/95 | 04/11/00 | | 48 | | | | 49 | 49 | |
| Washougal R Blw Canyon Ck | 10/25/94 | 09/27/95 | 12 | | | | | | | |
| Washougal River at Washougal | 10/29/91 | 06/23/92 | 9 | | | | | | | |
| Wilamette River at McCormick & Baxter Cove | 08/23/90 | 08/23/90 | | | | | | | | |
| Willamette R ab St Johns Br at Portland, Oreg. | 05/23/94 | 05/13/96 | 7 | | 7 | | | 1 | 7 | 7 |
| Willamette R. Ea.Side D/S Oak Lodge @ R BR.FTG | 06/07/96 | 06/07/96 | 1 | | | | | | | |
| Willamette Rive @ 1st Doc U/S Willamette Pk. | 09/02/98 | 09/03/98 | | | | | | | | |
| Willamette River @ Meldrum Bar Boat Ramp | 07/15/98 | 07/22/98 | | | | | | | | |
| Willamette River @ Milwaukie Boat Ramp | 07/15/98 | 07/22/98 | | | | | | | | |
| Willamette River @ Oaks Park | 07/15/98 | 07/22/98 | | | | | | | | |
| Willamette River @ Willamette Park | 09/02/98 | 09/03/98 | | | | | | | | |
| Willamette River 100 Yds D/S Oswego Cr. Mouth | 07/27/98 | 07/28/98 | | | | | | | | |
| Willamette River 200 yds. U/S of Oak Lodge ZID | 06/07/96 | 06/07/96 | 1 | | | | | | | |
| Willamette River at Canby Ferry | 01/23/90 | 04/11/00 | 58 | 82 | | 45 | 33 | 8 | | |
| Willamette River at East Side of SP&S Bridge | 08/23/90 | 08/23/90 | | | | | | | | |
| Willamette River at Hawthorne Bridge | 01/23/90 | 12/15/98 | 119 | 130 | | 71 | 95 | | | |
| Willamette River at Hwy 219 (New Newberg Br) | 02/21/90 | 04/11/00 | 105 | 113 | | 63 | 83 | 16 | | |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Willamette River at Linnton, OR | 04/18/92 | 10/26/92 | | | 3 | | | 2 | | |
| Willamette River at Oregon City Marina | 06/24/98 | 06/24/98 | | | | | | | | |
| Willamette River at Portland, Oreg. | 01/18/90 | 06/02/97 | 58 | 6 | | 13 | | 55 | 58 | 58 |
| Willamette River at Sellwood Park Boat Dock | 07/22/98 | 07/22/98 | | | | | | | | |
| Willamette River at SP&S Bridge (Portland) | 01/23/90 | 12/15/98 | 58 | 60 | 39 | 42 | 38 | | | |
| Willamette River at Wheatland Ferry | 01/23/90 | 04/11/00 | 55 | 68 | | 38 | 36 | 8 | | |
| Willamette River D/S of SP&S Bridge at East Cove | 08/23/90 | 08/23/90 | | | | | | | | |
| Willamette River East Side ot Oak Lodge ZID | 06/07/96 | 06/07/96 | 1 | | | | | | | |
| Willamette River West Side D/S of Tryon Creek | 06/07/96 | 06/07/96 | 1 | | | | | | | |

**Point Source Database**

City of Lake Oswego Water Quality

| **Site ID** | **City of Lake Oswego** |
|---|---|
| **Min Date** | 01/01/97 |
| **Max Date** | 12/08/00 |
| **Parameter** | **# of Records** |
| 2nd % | 1026 |
| 2nd coag /SPM | 1268 |
| 2nd MG/L | 353 |
| AL A % | 2572 |
| AL A GPH | 2523 |
| ALUM A | 2791 |
| ALUM MG/L | 1128 |
| ALUM_FEED | 2517 |
| BASIN CL2 | 5848 |
| BASIN PH | 5853 |
| BLOWD CW | 2354 |
| BLOWD FM | 134 |
| BLOWDN % | 2 |
| C FM | 72 |
| CL2_FEED_B | 2518 |
| CL2_FEEDCW | 1597 |
| CO2 APPLPT | 3267 |
| CONDTIVITY | 2466 |
| CW ALK | 1620 |
| CW CL2 | 3334 |
| CW COLOR | 994 |
| CW NTU | 3333 |
| CW PH | 5847 |
| CW TEMP | 3334 |
| DRYFEED | 2513 |
| EFF_ALK | 935 |
| EFF_CL2 | 2516 |
| EFF_COLOR | 735 |
| EFF_TEMP | 2515 |
| EFF_TURB | 2517 |
| EFFL PH | 3260 |
| FILTER/POLY/SEC/%/LBS | 3325 |
| HEADER_PH | 353 |
| HY A % | 3030 |
| HY A GPH | 3110 |
| HY B % | 1198 |
| HY B GPH | 1169 |
| HYPO A | 3327 |
| HYPO B | 1288 |
| INFL GPM | 3327 |
| LIME CW 1 | 340 |
| LIME CW 2 | 2186 |
| LIME FM | 421 |
| LIME POLY | 2320 |

| | |
|---|---|
| LIME PUMP | 2366 |
| LIME SETPT | 2357 |
| LIME UNIT | 3239 |
| PLC | 2606 |
| POLY_FEED | 2531 |
| RAW ALK | 2897 |
| RAW COLOR | 2598 |
| RAW COND | 3318 |
| RAW NTU | 3326 |
| RAW PH | 5845 |
| RAW TEMP, C | 5844 |
| RAW TURB | 2517 |
| SATUR ALK | 1114 |
| SATUR NTU | 814 |
| SOLIDS % | 1856 |

Tri-City STP Water Quality

| **Site ID** | **Tri-City STP** |
|---|---|
| **Min Date** | 01/01/93 |
| **Max Date** | 07/07/99 |
| **Parameter** | **# of Records** |
| Precipitation | 1997 |
| Flow | 2408 |
| TSS | 1683 |
| BOD | 1331 |
| CBOD | 1340 |
| Cl2 Res | 2041 |
| Fecal Coliform | 796 |
| pH | 2001 |

## Oregon Point Sources

| | RHONE-POULENC AG | | | OMSI | CANBY STP | EVERGREEN MILL - WEST LINN PAPER COMPANY | | GRESHAM STP | CASCADE GENERAL, INC. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Min Date** | 05/01/93 | 11/01/99 | 12/01/99 | 11/28/92 | 06/30/94 | 09/30/92 | 04/30/93 | 01/31/93 | 10/01/96 | 10/01/96 | 02/01/97 | 09/01/96 |
| **Max Date** | 03/01/00 | 11/01/99 | 12/01/99 | 04/15/00 | 06/30/00 | 09/30/00 | 09/30/00 | 04/30/00 | 06/01/00 | 06/01/00 | 06/01/00 | 06/01/00 |
| **Discharge #** | #001 | #002 | #003 | | | #001 | #002 | | #001/7 | #001/8 | #002 | #003 |
| **Parameter** | | | | | | | | | | | | |
| Ammonia as Total N, Average | | | | | | | | 87 | | | | |
| BOD, Average | | | | | 28 | 87 | | 87 | | | | |
| BOD, Maximum | 1 | | | | 28 | 87 | | 87 | | | | |
| BOD, Minimum | 1 | | | | | | | | | | | |
| CBOD | | | | | | | | | | | | |
| Chloroform | | | | | | | | | | | | |
| Cl2 Residual, Maximum | | | | | | | | 73 | | | | |
| Cl2, Residual Average | | | | | 2 | | | 41 | | | | |
| Conductivity, Average | | | | | | | | | | | | |
| DO | | | | | | | | | | | | |
| Fecal Coliform, Average | | | | | | | | 88 | | | | |
| Fecal Coliform, Maximum | | | | | | | | 87 | | | | |
| Flow Excluding Supplemental Dilution | | | | | | | | | | | 35 | |
| Flow Excluding Supplemental Dilution, Max | | | | | | | | | | | 22 | |
| Flow Supplemental Dilution | | | | | | | | | | | 20 | |
| Flow Supplemental Dilution, Maximum | | | | | | | | | | | 16 | |
| Flow, Average | 55 | 1 | 1 | 1 | 73 | 94 | 96 | 88 | 1 | 2 | | 7 |
| Flow, Maximum | | | | 88 | | | | | 36 | 25 | 21 | 8 |
| NO3+NO2-N | | | | | | | | | | | | |
| Oil & Grease, Average | | | | | | | | | 4 | 1 | 22 | |
| Oil & Grease, Maximum | | | | | | | | | 22 | 18 | 16 | 1 |
| pH, Average | 18 | 1 | | 87 | | | | | 9 | 8 | 1 | |
| pH, Maximum | 54 | 1 | 1 | | 73 | 93 | 84 | 87 | 19 | 18 | 22 | 1 |
| pH, Minimum | 52 | | 1 | | 73 | 93 | 84 | 87 | 10 | 7 | 25 | |
| Phenols, Average | | | | | | | | | | | | |
| SS, Average | 54 | | | | | | | | | | | |
| SS, Maximum | 53 | 1 | 1 | | | | | | | | | |
| SS, Minimum | 7 | | | | | | | | | | | |
| TDS, Average | | | | | | | | | | | | |
| TDS, Maximum | | | | | | | | | | | | |
| TDS, Minimum | | | | | | | | | | | | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Temperature, Average | 8 | | | 1 | | | | | | | | 7 |
| Temperature, Maximum | 55 | | | 87 | | | | | | | | |
| Temperature, Minimum | 7 | | | | | | | | | | | |
| TOC, Average | 52 | | | | | | | | | | | |
| TOC, Maximum | 52 | | | | | | | | | | | |
| TOC, Minimum | 6 | | | | | | | | | | | |
| TSS, Average | | | | | 73 | 94 | | 87 | 13 | 7 | 23 | |
| TSS, Maximum | | | | | 72 | 94 | | 87 | 22 | 18 | 23 | 1 |
| TSS, Minimum | | | | | | | | | 3 | | 10 | |
| Turbidity, Average | | | | | | | | | | | | |
| Turbidity, Maximum | | | | | | | | | | | | |
| Turbidity, Minimum | | | | | | | | | | | | |
| VSS | | | | | | | | | | | | |

| | ATOFINA CHEMICALS, INC. | | | | PORTLAND STEELWORKS - RIVERGATE | | OAK LODGE STP | KOPPERS | ASH GROVE CEMENT | FOREST PARK MOBILE VILLAGE | KELLOGG CREEK STP | WILLAMETTE OAKS BUILDING (ABN) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Min Date** | 05/31/91 | 05/31/91 | 05/31/91 | 05/31/91 | 02/01/96 | 02/01/96 | 01/01/93 | 01/01/92 | 11/28/94 | 01/03/93 | 01/01/96 | 01/01/98 |
| **Max Date** | 06/30/00 | 06/30/00 | 06/30/00 | 06/30/00 | 05/01/00 | 03/01/00 | 08/28/00 | 06/01/00 | 07/01/00 | 07/30/00 | 12/31/99 | 07/01/00 |
| **Discharge #** | #001 | #002 | #003 | #004 | #001 | #002 | | | | | | |
| **Parameter** | | | | | | | | | | | | |
| Ammonia as Total N, Average | | | | | | | | | | 31 | | |
| BOD, Average | | | | | | | 2039 | | | 34 | 530 | |
| BOD, Maximum | | | | | | | | | | | | |
| BOD, Minimum | | | | | | | | | | | | |
| CBOD | | | | | | | 2034 | | | | 536 | |
| Chloroform | | | | | | | | | | | | 30 |
| Cl2 Residual, Maximum | | | | | | | | | | | | |
| Cl2, Residual Average | 110 | 110 | 110 | 110 | | | 2778 | | | 387 | 891 | |
| Conductivity, Average | 110 | | 110 | 110 | | | | | | | | |
| DO | | | | | | | 2702 | | | | | |
| Fecal Coliform, Average | | | | | | | 1207 | | | 31 | 412 | |
| Fecal Coliform, Maximum | | | | | | | | | | | | |
| Flow Excluding Supplemental Dilution | | | | | | | | | | | | |
| Flow Excluding Supplemental Dilution,Max | | | | | | | | | | | | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Flow Supplemental Dilution | | | | | | | | | | | | |
| Flow Supplemental Dilution, Maximum | | | | | | | | | | | | |
| Flow, Average | 111 | 109 | 110 | 108 | 51 | 45 | 2796 | | 4 | 386 | 1230 | 30 |
| Flow, Maximum | | | | | 51 | 45 | | | 3 | | | |
| NO3+NO2-N | | | | | | | | | | 31 | | |
| Oil & Grease, Average | | | | | | | | 61 | | | | |
| Oil & Grease, Maximum | | | | | | | | | | | | |
| pH, Average | | | | | 22 | | 2786 | 84 | 3 | 388 | 942 | 30 |
| pH, Maximum | | | | | 51 | | | 84 | 3 | | | |
| pH, Minimum | | | | | 51 | | | 84 | | | | |
| Phenols, Average | | | | | | | | 61 | | | | |
| SS, Average | | | | | | | 2180 | | 4 | | | |
| SS, Maximum | | | | | | | | | 3 | | | |
| SS, Minimum | | | | | | | | | | | | |
| TDS, Average | | | | | 51 | | | | | | | |
| TDS, Maximum | | | | | 51 | | | | | | | |
| TDS, Minimum | | | | | 51 | | | | | | | |
| Temperature, Average | 110 | 110 | 110 | 110 | 51 | | | 84 | | | 849 | |
| Temperature, Maximum | | | | | 51 | | | 84 | | | | |
| Temperature, Minimum | | | | | 51 | | | 84 | | | | |
| TOC, Average | | | | | | | | | | | | |
| TOC, Maximum | | | | | | | | | | | | |
| TOC, Minimum | | | | | | | | | | | | |
| TSS, Average | 110 | 110 | 110 | 110 | 51 | | | | | 32 | 842 | |
| TSS, Maximum | | | | | 51 | | | | | | | |
| TSS, Minimum | | | | | | | | | | | | |
| Turbidity, Average | | | | | 51 | | 2790 | | 1 | | | |
| Turbidity, Maximum | | | | | 51 | | | | | | | |
| Turbidity, Minimum | | | | | 51 | | | | | | | |
| VSS | | | | | | | | | | | 803 | |

Washington Point Sources

| Facilities Discharging into the Columbia River | Date | | # Discharges |
|---|---|---|---|
| | Min | Max | |
| ALLWEATHER WOOD TREATERS | 01/01/93 | 10/01/00 | 2 |
| BBA NONWOVENS WASHOUGAL | 09/21/94 | 07/01/00 | 2 |
| BFGOODRICH | 01/01/93 | 01/01/00 | 4 |
| BOISE CASCADE VANCOUVER | 01/01/93 | 10/01/00 | 1 |
| CAMAS STP | 01/01/93 | 10/01/00 | 1 |
| CLARIANT CORP | 01/01/93 | 10/01/00 | 1 |
| COLUMBIA RIVER CARBONATES | 01/01/93 | 06/01/98 | 1 |
| COWLITZ CNTY HALL OF JUSTICE | 02/15/93 | 02/28/97 | 1 |
| CYTEC INDUSTRIES | 01/01/93 | 10/01/00 | 3 |
| FORT JAMES CAMAS | 01/01/93 | 10/01/00 | 3 |
| FOSTER FARMS KELSO | 09/01/98 | 10/01/00 | 1 |
| KALAMA STP | 01/01/93 | 10/01/00 | 1 |
| VANALCO | 01/01/93 | 10/01/00 | 2 |
| MARINE PARK WATER RECLAMATION FACIL | 01/01/93 | 10/01/00 | 3 |
| VANCOUVER WEST STP | 01/01/93 | 10/01/00 | 2 |
| WASHOUGAL STP | 01/01/93 | 10/01/00 | 2 |
| WOODLAND STP | 01/01/93 | 10/01/00 | 1 |
| WOODBROOK STP | 01/01/93 | 10/01/00 | 1 |
| LONGVIEW FIBRE LONGVIEW | 01/01/93 | 10/01/00 | 2 |
| LONGVIEW STP | 03/01/93 | 10/01/00 | 1 |
| NORTH BONNEVILLE STP | 01/01/93 | 10/01/00 | 1 |
| PENDLETON WOOLEN MILLS | 01/01/93 | 09/01/00 | 5 |
| REYNOLDS METALS LONGVIEW | 01/01/93 | 10/01/00 | 4 |
| SALMON CREEK STP | 01/01/93 | 10/01/00 | 1 |
| PORT OF KALAMA | 05/01/97 | 10/01/00 | 1 |
| STELLA STP | 04/01/93 | 10/01/00 | 1 |
| SUPPORT TERMINAL SERVICES | 01/01/93 | 09/01/00 | 2 |
| WEYERHAEUSER LONGVIEW | 01/01/93 | 09/01/00 | 8 |
| ROSS SIMMONS HARDWOOD LUMBER CO | 08/01/97 | 07/01/00 | 1 |
| HOUGHTON INTERNATIONAL | 03/15/93 | 12/16/96 | 1 |
| PENDLETON WOOLEN MILLS | 01/01/93 | 08/01/00 | 1 |

Data Available for the Washington Point Sources

| Parameter |
|---|
| BOD, 5-DAY (20 DEG. C) |
| BOD, 5-DAY PERCENT REMOVAL |
| BOD, 5-DAY, DISSOLVED |
| BOD, CARBONACEOUS, % REMOVAL |
| BOD, CARBONACEOUS, 5-DAY (20 DEG C) |
| BOD, SOLUBLE, 5-DAY (20 DEG. C) |
| COD (CHEMICAL OXYGEN DEMAND) |
| COLIFORM, FECAL |

| |
|---|
| FLOW |
| FLOW, RATE |
| FLOW, IN CONDUIT OR THRU TREATMENT PLANT |
| HARDNESS, TOTAL (AS CACO3) |
| MAGNESIUM, TOTAL (AS MG) |
| NITROGEN, AMMONIA (AS N) & UNIONIZED AMMONIA |
| NITROGEN, AMMONIA TOTAL (AS N) |
| NITROGEN, AMMONIA TOTAL (AS NH4) |
| NITROGEN, AMMONIA, UNIONIZED |
| OIL & GREASE |
| OXYGEN, DISSOLVED (DO) |
| PH AVG |
| PHOSPHORUS, TOTAL (AS P) |
| SOLIDS, SETTLEABLE AVG |
| SOLIDS, SUSPENDED, % REMOVAL |
| SOLIDS, TOTAL AVD |
| SOLIDS, TOTAL SUSPENDED |
| TEMPERATURE , WATER (DEG C) |
| TURDIDITY |

**Meteorological Database**

| **Site ID** | **Portland International Airport** |
|---|---|
| **Min Date** | 01/01/1948 |
| **Max Date** | 09/30/2000 |
| **Parameter** | **# of Records** |
| Air Temp (C) | 414791 |
| Dew Pt Temp (C) | 414789 |
| Wind Speed (m/s) | 274749 |
| Wind Direction (rad) | 274749 |
| Cloud Cover | 413311 |

# Appendix J: Water Quality file development procedures

### Water Quality Constituent Procedure for Boundary Conditions

Algae:

$$\sum \Phi_{algae} = \Phi_{algae(total)} = \Phi_{Chl\_a(total)} \Big/ Chla\_to\_Algae\_ratio \qquad (1)$$

Chla_to_Algae_Ratio = 35 and $\Phi_{Chl\_a(total)} = data$ if no data then $\Phi_{algae(total)} = 0.1$. In this case it is assumed there is only one algae species.

BOD ultimate

$$BOD_u = \frac{BOD_5}{(1-\exp(-5k))} \qquad (2)$$

Where k=0.1, if BOD5=0 then BOD5 is set to 3

Total Organic Matter

$$\Phi_{TOM} = \frac{BOD_u}{\delta_O} - \sum \Phi_{algae} \qquad (3)$$

$\delta_O = 1.4$

Detritus:

$$\Phi_{POM} = fration(\Phi_{TOM}) - \sum \Phi_{algae} \qquad (4)$$

Where fraction = 0.45

$$f = \frac{\Phi_{POM} + \sum \Phi_{algae}}{\Phi_{TSS}} \qquad (5)$$

Average f = 0.06 for this data set. $\Phi_{TSS} = data$ if no data then . In the case of 1999 estimates were made based on monthly averaged data RM 35 and RM 48.

ISS:

$$\Phi_{ISS} = \left(\Phi_{TSS} - \sum \Phi_{algae} - \Phi_{POM}\right) \text{ or } \Phi_{ISS} = (1-f)(\Phi_{TSS}) \qquad (6)$$

Dissolved Organic Matter (DOM)

$$\Phi_{DOM} = \Phi_{TOM} - \Phi_{POM} \qquad (7)$$

Labile DOM

$$\Phi_{LDOM} = f_{LDOM} \Phi_{DOM} \qquad (8)$$

$f_{LDOM} = 0.50$

Refractory DOM

$$\Phi_{RDOM} = (1 - f_{LDOM}) \Phi_{DOM} \qquad (9)$$

Labile POM

$$\Phi_{LPOM} = f_{LPOM}\Phi_{POM} \qquad (10)$$

$f_{LPOM} = 0.5$

Refractory POM

$$\Phi_{RPOM} = (1 - f_{LPOM})\Phi_{POM} \qquad (11)$$

Total Organic Phosphorus

$$\Phi_{PO4-P} = \Phi_{PO4} \qquad (12)$$

If no data then $\Phi_{PO4} = \dfrac{\sum_{j=1}^{n}\Phi_{PO4-data}}{n}$ for all n data points

Nitrogen

$$\Phi_{TKN} = \Phi_{NH4} \qquad (13)$$

If no data exists for that time then $\Phi_{NH4} = \dfrac{\sum_{j=1}^{n}\Phi_{NH4-data}}{n}$ for all n data points.

Dissolved Organic Carbon (if data does not exist)

$$\Phi_{DOC} = \Phi_{DOM}\delta_C \qquad (14)$$

$\Phi_{coliform} = \Phi_{fecal\_coliform} = data$ , if missing take average of all remaining data and use average

$\Phi_{TIC} = function(\Phi_{alk} + pH + Temp)$ as per Fortran code

$\Phi_{alk} = data$ , if missing interpolate with nearest two points

$\Phi_{DO} = data$ , if missing interpolate with nearest two points

$\Phi_{arbitray\_constituent} = Conductivity = data$ , if missing interpolate with nearest two points

$Tracer = ArbitraryTracer = 30\, mg/L$

$\Phi_{TDS} = \Phi_{Salinity}$ , if missing interpolate with nearest two points

$\Phi_{NO3+NO2} = data$ , if missing interpolate with nearest two points

If no BOD5 data was available then TOC data was used in Eq. 15. The procedure above was then used.

$$\Phi_{TOM} = \frac{\Phi_{TOC}}{\delta_C} - \sum \Phi_{a\lg ae} \qquad (15)$$

**Water Quality Constituent Procedure for Tributaries**

Algae:

$$\sum \Phi_{a\lg ae} = \Phi_{a\lg ae(total)} = \Phi_{Chl\_a(total)} \big/ Chla\_to\_A\lg ae\_ratio \tag{16}$$

Chla_to_Algae_Ratio = 35 and $\Phi_{Chl\_a(total)} = data$ if no data then $\Phi_{a\lg ae(total)} = 0.1$. In this case it is assumed there is only one algae species.

BOD ultimate

$$BOD_u = \frac{BOD_5}{(1-\exp(-5k))} \tag{17}$$

Where k=0.1, if BOD5=0 then BOD5 is set to 3

Total Organic Matter

$$\Phi_{TOM} = \frac{BOD_u}{\delta_O} - \sum \Phi_{a\lg ae} \tag{18}$$

$\delta_O = 1.4$

Detritus:

$$\Phi_{POM} = fration(\Phi_{TOM}) - \sum \Phi_{a\lg ae} \tag{19}$$

Where fraction = 0.45

$$f = \frac{\Phi_{POM} + \sum \Phi_{a\lg ae}}{\Phi_{TSS}} \tag{20}$$

Average f = 0.06 for this data set. $\Phi_{TSS} = data$ if no data then . In the case of 1999 estimates were made based on monthly averaged data RM 35 and RM 48.

ISS:

$$\Phi_{ISS} = \left(\Phi_{TSS} - \sum \Phi_{a\lg ae} - \Phi_{POM}\right) \text{ or } \Phi_{ISS} = (1-f)(\Phi_{TSS}) \tag{21}$$

Dissolved Organic Matter (DOM)

$$\Phi_{DOM} = \Phi_{TOM} - \Phi_{POM} \tag{22}$$

If DOM<0.0 thenit was set to 0.10

Labile DOM

$$\Phi_{LDOM} = f_{LDOM} \Phi_{DOM} \tag{23}$$

$f_{LDOM} = 0.50$

Refractory DOM

$$\Phi_{RDOM} = (1 - f_{LDOM})\Phi_{DOM} \tag{24}$$

Labile POM

$$\Phi_{LPOM} = f_{LPOM}\Phi_{POM} \quad (25)$$

$f_{LPOM} = 0.5$

Refractory POM

$$\Phi_{RPOM} = (1 - f_{LPOM})\Phi_{POM} \quad (26)$$

Total Organic Phosphorus

$$\Phi_{PO4-P} = \Phi_{PO4} \quad (27)$$

If no data then $\Phi_{PO4} = \frac{\sum_{j=1}^{n}\Phi_{PO4-data}}{n}$ for all n data points. PO4 represented Dissolved Ortho Phosphorus. If not available then Ortho Phosphorus.

Nitrogen

$$\Phi_{TKN} = \Phi_{NH4} \quad (28)$$

If no data exists for that time then $\Phi_{NH4} = \frac{\sum_{j=1}^{n}\Phi_{NH4-data}}{n}$ for all n data points. NH4 represents NH3-N Dissolved, if available, if not then NH3-N total.

Dissolved Organic Carbon (if data does not exist)

$$\Phi_{DOC} = \Phi_{DOM}\delta_C \quad (29)$$

$\Phi_{coliform} = \Phi_{fecal\_coliform} = data$ , if missing take average of all remaining data and use average
$\Phi_{TIC} = function(\Phi_{alk} + pH + Temp)$ as per Fortran code

$\Phi_{alk} = data$ , if missing interpolate with nearest two points. If no data at all set to 20 mg/L CACO3.

$\Phi_{DO} = data$ , if missing interpolate with nearest two points

$\Phi_{arbitray\_constituent} = Conductivity = data$ , if missing interpolate with nearest two points

$Tracer = ArbitraryTracer = 30\, mg/L$

$\Phi_{TDS} = \Phi_{Salinity} = 0$, unless otherwise stated by data. If missing interpolate with nearest two points
$\Phi_{NO3+NO2} = data$ , if missing interpolate with nearest two points

An alternative method was used to calculate POM for cases where Eq 4 resulted in a negative POM value. The fraction in Eq 4 was set at 0.45 for all dates. Eq 5 above was used to calculate f even though POM was negative (algae is large) then the average f was calculated from all dates. The equation below was then used to calculate POM for only those dates with a negative POM from Eq 4.

$$\Phi_{POM} = f(\Phi_{TSS}) - \sum \Phi_{a\lg ae} = \Phi_{TSS} - \Phi_{ISS} - \sum \Phi_{a\lg ae} \qquad (30)$$

If no BOD5 data was available then TOC data was used in Eq. 16. The procedure above was then used.

$$\Phi_{TOM} = \frac{\Phi_{TOC}}{\delta_C} - \sum \Phi_{a\lg ae} \qquad (31)$$

If TOM<0 then its set 1.0

**Water Quality Constituent Procedure for Point Sources**

Algae:

$$\sum \Phi_{a\lg ae} = \Phi_{a\lg ae(total)} = 0 \qquad (32)$$

BOD ultimate

$$BOD_u = \frac{BOD_5}{(1 - \exp(-5k))} \qquad (33)$$

Where k=0.1. If no NOD5 data exists but TSS data exists then f in Eq 5 below is set to 0.1 and used to get at TOM and BODu. If there is no BOD5 or TSS data then BOD5 is set to 3.

Total Organic Matter

$$\Phi_{TOM} = \frac{BOD_u}{\delta_O} \qquad (34)$$

$\delta_O = 1.4$

Detritus:

$$\Phi_{POM} = fration(\Phi_{TOM}) \qquad (35)$$

Where fraction = 0.45

$$f = \frac{\Phi_{POM}}{\Phi_{TSS}} \qquad (36)$$

ISS:

$$\Phi_{ISS} = (\Phi_{TSS} - \Phi_{POM}) \text{ or } \Phi_{ISS} = (1 - f)(\Phi_{TSS}) \qquad (37)$$

Dissolved Organic Matter (DOM)

$$\Phi_{DOM} = \Phi_{TOM} - \Phi_{POM} \quad (38)$$

Labile DOM

$$\Phi_{LDOM} = f_{LDOM}\Phi_{DOM} \quad (39)$$

$f_{LDOM} = 0.50$

Refractory DOM

$$\Phi_{RDOM} = (1 - f_{LDOM})\Phi_{DOM} \quad (40)$$

Labile POM

$$\Phi_{LPOM} = f_{LPOM}\Phi_{POM} \quad (41)$$

$f_{LPOM} = 0.5$

Refractory POM

$$\Phi_{RPOM} = (1 - f_{LPOM})\Phi_{POM} \quad (42)$$

Total Organic Phosphorus

$$\Phi_{PO4-P} = \delta_P\left(\Phi_{LDOM} + \Phi_{RDOM} + \Phi_{POM}\right) + \Phi_{PO4} \quad (43)$$

$\delta_P = 0.011$ and if no data then $\Phi_{PO4} = 0$ PO4 represented Dissolved Ortho Phosphorus. If not available then Ortho Phosphorus.

Nitrogen

$$\Phi_{TKN} = \delta_N\left(\Phi_{LDOM} + \Phi_{RDOM} + \Phi_{POM}\right) + \Phi_{NH4} \quad (44)$$

$\delta_N = 0.08$ and if no data exists for that time then $\Phi_{NH4} = 0$ NH4 represents NH3-N Dissolved, if available, if not then NH3-N total.

Dissolved Organic Carbon (if data does not exist)

$$\Phi_{DOC} = \Phi_{DOM}\delta_C \quad (45)$$

$\Phi_{coliform} = \Phi_{fecal\_coliform} = data$, if missing take average of all remaining data and use average. If no data at all then set to zero.

$\Phi_{TIC} = function(\Phi_{alk} + pH + Temp)$ as per Fortran code. If no Temp data exists or no pH and Temp data exists them TIC was set to 3 mg/L.

$\Phi_{alk} = data$, if missing interpolate with nearest two points. If no data at all set to 10 mg/L CACO3.

$\Phi_{DO} = data$, if missing interpolate with nearest two points. If no data at all then set to 6.4 mg/L for non-STP facilities. (assessed by looking at two non-STP facilities that had monitored DO)

$\Phi_{arbitray\_constituent} = Conductivity = data$ , if missing interpolate with nearest two points. If no data at all then set to 0.

$Tracer = ArbitraryTracer = 0\, mg/L$

$\Phi_{TDS} = \Phi_{Salinity} = 0$ unless otherwise stated by data. If missing interpolate with nearest two points

$\Phi_{NO3+NO2} = data$ , if missing interpolate with nearest two points. If no data at all then for:
STPs set 2mg/L of Total N aside for it (Rest of any Total N would be for NH3-N).
If STP measures Total NH3 rather than total N and then NO3 is set to zero.. If non-STP set to 0.