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Lower Willamette River Model: Boundary Conditions and Model Setup

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Lower Willamette River Model: Boundary Conditions and Model Setup



by

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Technical Report EWR-1-01

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Table of Contents

<i>Table of Contents</i>	<i>i</i>
<i>List of Figures</i>	<i>ii</i>
<i>List of Tables</i>	<i>iv</i>
<i>Acknowledgements</i>	<i>i</i>
<i>Introduction</i>	<i>1</i>
Background Studies	2
Modeling Approach	4
Water Quality Data	5
Willamette River	6
Lateral analysis.....	12
Vertical Profiles.....	15
Columbia River	17
Model Boundary Conditions	17
Columbia River	18
Columbia River Water Level at Beaver Army Terminal.....	18
Columbia River Flow at Bonneville Dam	21
Water Quality	22
Willamette River	31
Flow data	31
Water Quality	38
Meteorological Data	43
Tributary Inflows	47
Willamette River.....	48
Columbia River	62
Point Sources	75
Oregon.....	76
Washington.....	80
Lower Willamette and Columbia Databases	82
Model Geometry	82
Bathymetry Data	82
Model Grid Development	87
Summary	101
References	102
Appendix A: Willamette River Hydrolab data	105
Appendix B: Willamette River Longitudinal Profiles (monthly averages)	113
Appendix C: Willamette River Grab Samples across the river	122
Appendix D: Willamette River Grab Samples across the river - Standard Deviations	126

<i>Appendix E: Willamette River Temperature Profiles, summer 2000.....</i>	<i>130</i>
<i>Appendix F: Willamette River Dissolved Oxygen Profiles, summer 2000.....</i>	<i>136</i>
<i>Appendix G: Willamette River Conductivity Profiles, summer 2000.....</i>	<i>142</i>
<i>Appendix H: Willamette River pH Profiles, summer 2000.....</i>	<i>148</i>
<i>Appendix I: Willamette River Project Databases.....</i>	<i>154</i>
Flow and Water Level Databases.....	154
Water Quality Database.....	156
Point Source Database	170
Meteorological Database.....	176
<i>Appendix J: Water Quality file development procedures</i>	<i>177</i>
Water Quality Constituent Procedure for Boundary Conditions.....	177
Water Quality Constituent Procedure for Tributaries.....	179
Water Quality Constituent Procedure for Point Sources	181

List of Figures

Figure 1. Lower Willamette River Basin Region.....	2
Figure 2. Conceptual Layout of the Lower Willamette River System Model (Points Represent Model Segments)	5
Figure 3. BES sample locations in the Willamette River.....	7
Figure 4. Water Quality in the Willamette River at RM 6.8, 1997-2000.....	8
Figure 5. Water Quality in the Willamette River at RM 17.9, 1997-2000.....	9
Figure 6. Water Quality Longitudinal Profiles in the Willamette River.....	10
Figure 7. TSS, TDS and TS Longitudinal profiles, Summer Averages, 1992-2000.....	11
Figure 8. Dissolved Oxygen profiles across the Willamette River, 1992-2000.....	13
Figure 9. Standard deviation for Dissolved Oxygen, 1992-2000.....	14
Figure 10. Temperature profiles in the middle of the Willamette River at Waverly Country Club, RM 17.9.....	16
Figure 11. Dissolved Oxygen profiles in the middle of the Willamette River at Waverly Country Club, RM 17.9.....	16
Figure 12. Columbia River water quality sampling locations.....	17
Figure 13. Model Boundaries on the Columbia and Willamette Rivers.....	18
Figure 14. Columbia River Water Level Elevation at Beaver Army Terminal, m NGVD, RM 53.8	20
Figure 15. Columbia River Flow measured below the Bonneville Dam, m ³ /s, RM 144.5.....	21
Figure 16. Columbia River at Beaver Army Terminal (RM 53.8) water temperature, °C.....	23
Figure 17. Columbia River at Bonneville Dam (RM 144.5) water temperature, °C.....	24
Figure 18. Columbia River at Beaver Army Terminal Boundary Condition, RM 54.....	26
Figure 19. Columbia River at Beaver Army Terminal Boundary Condition, RM 54 (Part 2)	27
Figure 20. Columbia River at Beaver Army Terminal Boundary Condition, RM 54 (Part 3)	28
Figure 21. Columbia River at Bonneville Dam Boundary Condition, RM 145.....	29
Figure 22. Columbia River at Bonneville Dam Boundary Condition, RM 145 (Part 2)	30
Figure 23. Columbia River at Bonneville Dam Boundary Condition, RM 145 (Part 3)	31

Figure 24. Willamette River Flow at Portland comparison between data, the USGS model and the USACOE model	33
Figure 25. Flow difference between data and routing models in Willamette River at Portland.....	34
Figure 26. Willamette River at Canby Ferry flow comparison, Summer 1993	36
Figure 27. Willamette River flow near Canby Ferry (RM 35), m ³ /s	37
Figure 28. Willamette River at Canby Ferry water temperature, °C.....	39
Figure 29. Willamette River at Canby Ferry Boundary Condition, RM 35.....	41
Figure 30. Willamette River at Canby Ferry Boundary Condition, RM 35 (Part 2).....	42
Figure 31. Willamette River at Canby Ferry Boundary Condition, RM 35 (Part 3).....	43
Figure 32. Location of several met stations in the model region	44
Figure 33. Air Temperature, °C, 10 day moving average at the Portland International Airport 1992-2000	45
Figure 34. Dew Point Temperature, °C, 10 day moving average at the Portland International Airport 1992-2000.....	45
Figure 35. Wind Speed, m/s, 10 day moving average at the Portland International Airport, 1992-2000.....	46
Figure 36. Wind Direction, degrees, 10 day moving average at the Portland International Airport, 1992-2000	46
Figure 37. Cloud Cover 10 day moving average at the Portland International Airport, 1992-2000.....	47
Figure 38. Columbia and Willamette River tributary inflows, shaded basins have no flow data.....	48
Figure 39. USGS gage stations in the Willamette River Basin.....	49
Figure 40. Columbia Slough flow, m ³ /s.....	50
Figure 41. Johnson Creek flow, m ³ /s	51
Figure 42. Tualatin River flow, m ³ /s.....	52
Figure 43. Clackamas River near Clackamas and Clackamas River at Estacada Flow Correlation, Year 1962 to 1983	53
Figure 44. Clackamas River flow, m ³ /s.....	54
Figure 45. Johnson Creek water temperature, °C.....	56
Figure 46. Tualatin River water temperature, °C	57
Figure 47. Clackamas River water temperature, °C.....	58
Figure 48. Columbia Slough Water Temperature Correlation.....	59
Figure 49. Columbia Slough water temperature, °C	60
Figure 50. Columbia River Tributary gage stations.....	63
Figure 51. Washington basins considered in the model.....	64
Figure 52. Grays-Elokoman Basin and Kalama River flows, m ³ /s.....	65
Figure 53. Cowlitz River flow, m ³ /s	66
Figure 54. Lewis River flow, m ³ /s	67
Figure 55. Lewis and Washougal River Basin.....	68
Figure 56. East Fork of Lewis River and Washougal River correlation, Year 1944 to 1981	69
Figure 57. East Fork of Lewis River and Little Washougal River correlation, Year 1951 to 1955	69
Figure 58. Washougal River flow, m ³ /s	70
Figure 59. Sandy River flow, m ³ /s	72
Figure 60. Washington Tributary water temperatures, °C	74
Figure 61. Oregon Point Source locations	79
Figure 62. Washington Point Source locations	81
Figure 63. Columbia and Willamette River cross-section locations	83
Figure 64. Willamette River cross-sections RM 18 and 23	84
Figure 65. Willamette River Bathymetry RM 24 to 26.8.....	85
Figure 66. Willamette River cross-sections locations from PGE.....	86
Figure 67. Willamette River cross-section RM 29.6.....	86

Figure 68. Clackamas River and Cove Bathymetry	87
Figure 69. Model Grid Layout	88
Figure 70. Model segment numbers along Willamette River and Clackamas River.	90
Figure 71. Model segment numbers along the Willamette River in vicinity of Lake Oswego and Ross Island.	91
Figure 72. Model segment numbers in the vicinity of downtown Portland and Swan Island.	92
Figure 73. Model segment numbers at confluence of Willamette River and Columbia River.	93
Figure 74. Model segment numbers along Columbia River near Bonneville Dam.	94
Figure 75. Model segment numbers along Columbia River near Sandy River.	94
Figure 76. Model segment numbers along the Columbia River near Sauvie Island and Vancouver Lake.	95
Figure 77. Model segment numbers along Columbia River near the Lewis River.	96
Figure 78. Model segment numbers along Columbia River near Kalama River.	97
Figure 79. Model segments along the Columbia River near Cowlitz River and Beaver Army Terminal.	98
Figure 80. Vertical grid resolution along the Willamette River model domain (note variable longitudinal segment spacing and vertical grid resolution).	99
Figure 81. Vertical grid resolution along the Columbia River model domain.	100

List of Tables

Table 1. Bureau of Environmental Services monitoring stations.....	6
Table 2. BES profiles sample locations	15
Table 3. Water Quality parameters available for the Columbia River Boundary Conditions	25
Table 4. USACOE correlations to estimate flow at Willamette River at Portland	32
Table 5. Flow Routing Model Comparison with data Statistics	34
Table 6. USGS gage stations used in developing the boundary condition and the extent of their data... ..	35
Table 7. Water Quality parameters available for the Willamette River Boundary Condition	40
Table 8. Willamette River Tributary gage stations	48
Table 9. Water Quality parameters available for the Willamette River tributaries.....	61
Table 10. Columbia River Tributary gage stations	62
Table 11. Water Quality parameter available for the Columbia River tributaries	75
Table 12. Tetra Tech Phase II Point Source Inputs.....	76
Table 13. 1995 vs. Current Point Source Designations.....	77
Table 14. Oregon Point Sources for the Model.....	78
Table 15. West Linn Storm Water Management Model Results	80
Table 16. Washington Point Sources for the Model	82
Table 17. Model Grid Layout Specifications	89

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Introduction

The Willamette River system is a 11,500 mi² 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

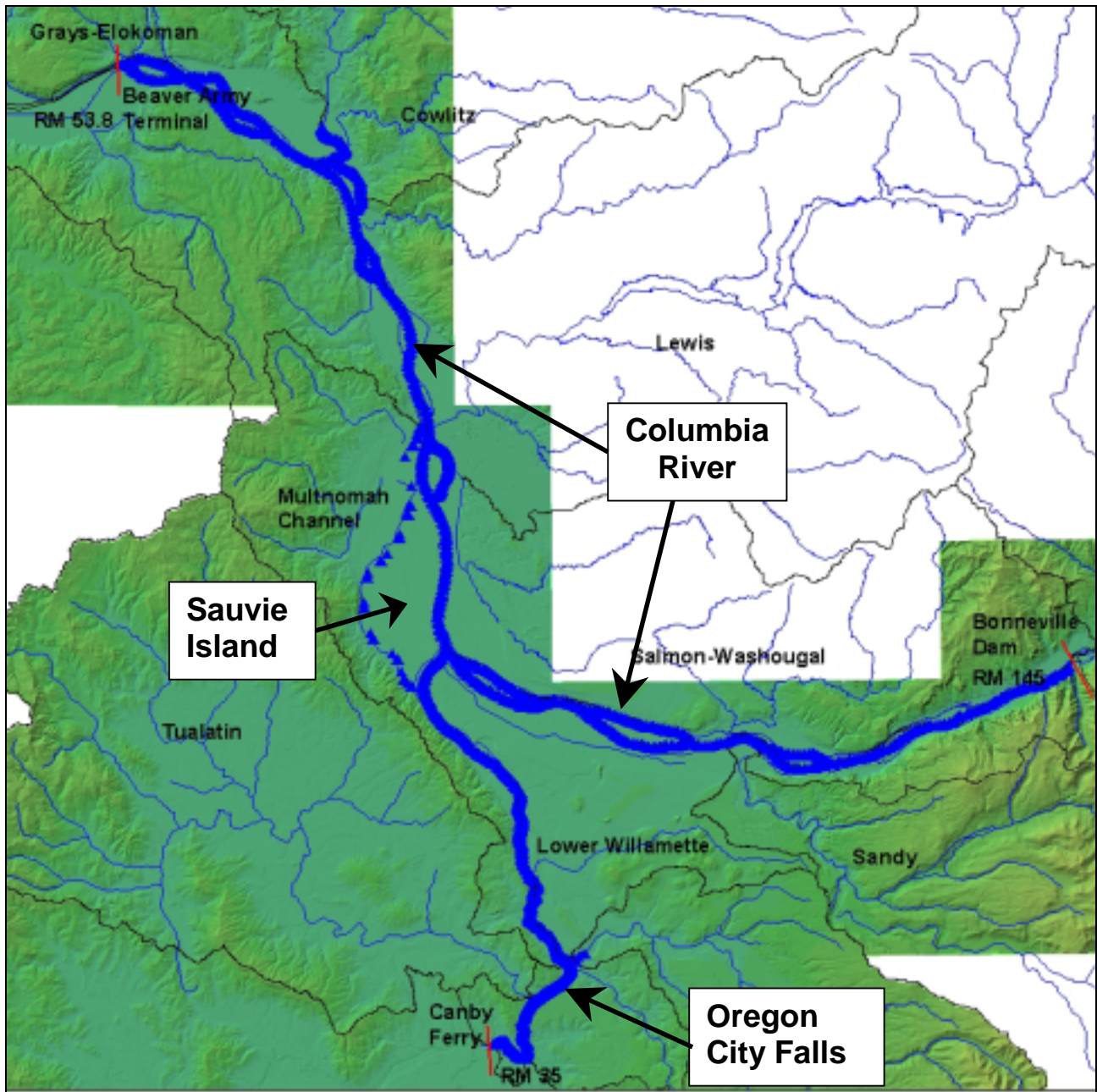


Figure 1. Lower Willamette River Basin Region

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 1st to October 1st, 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 PO₄, 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

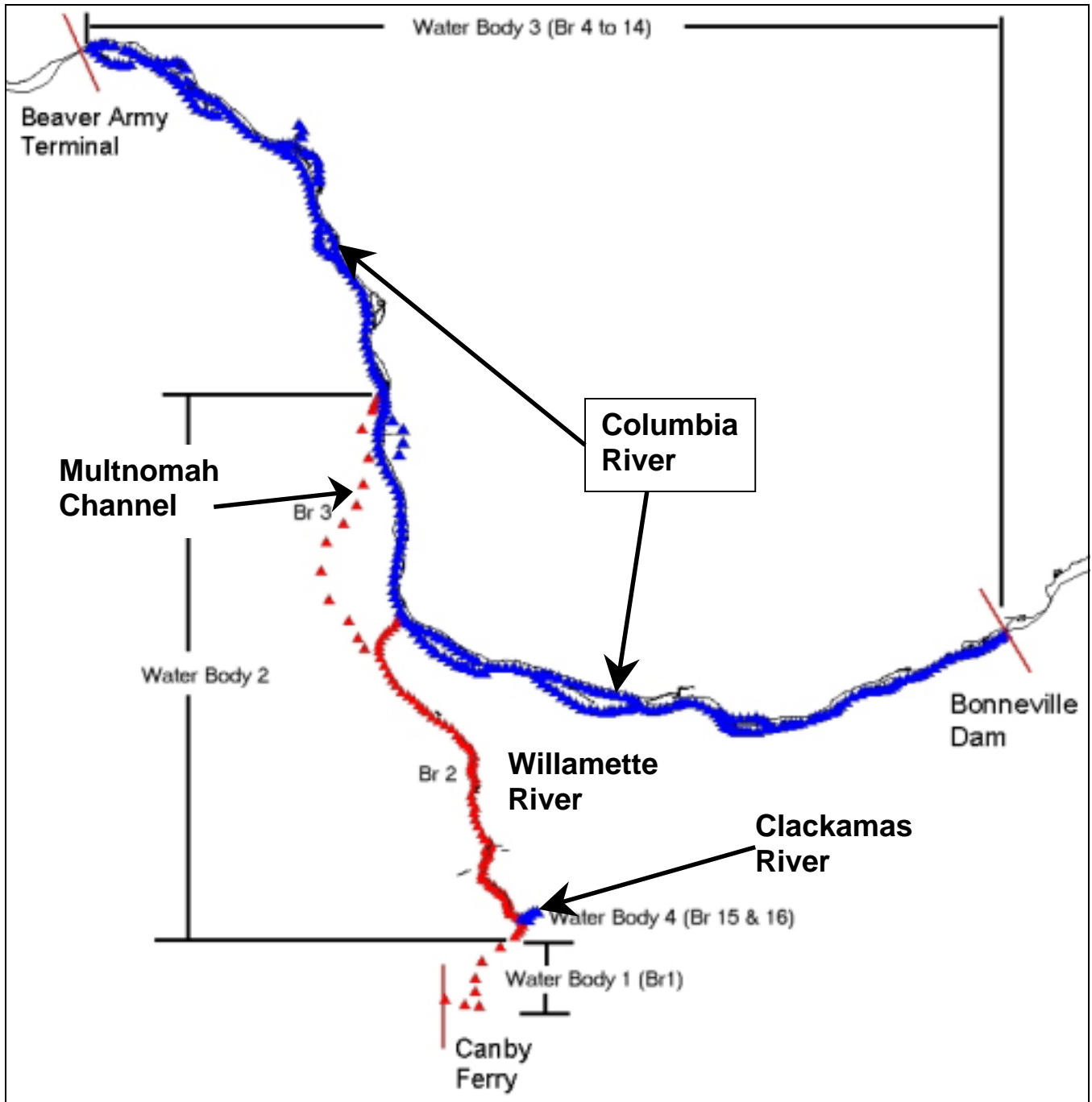


Figure 2. Conceptual Layout of the Lower Willamette River System Model (Points Represent Model Segments)

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

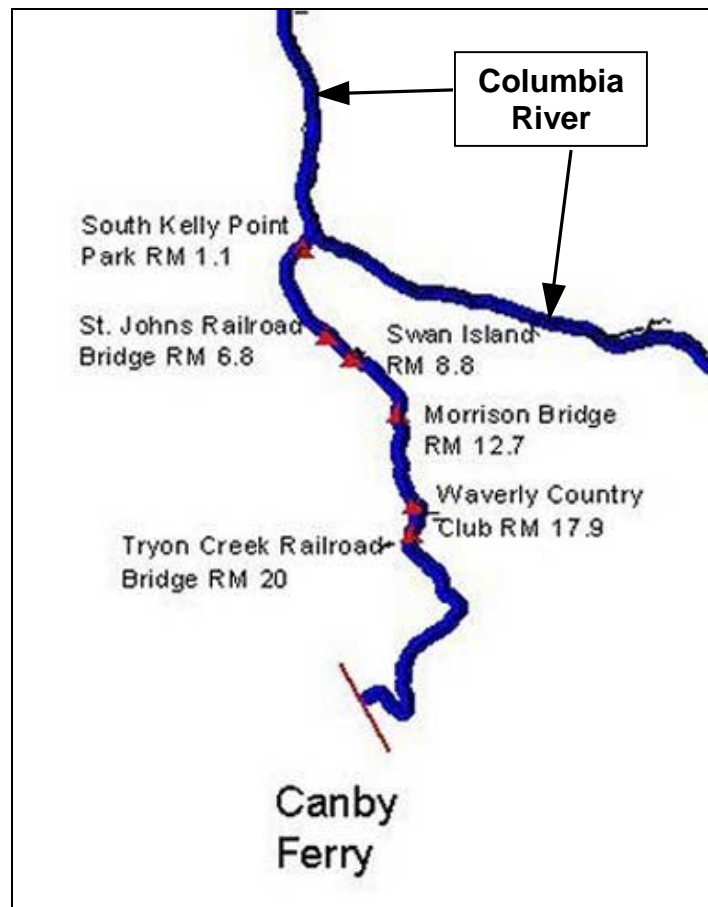


Figure 3. BES sample locations in the Willamette River

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-PO₄, BOD₅, 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 1st to September 30th 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.

Hydrolab Data at St. Johns Railroad Bridge. RM 6.8

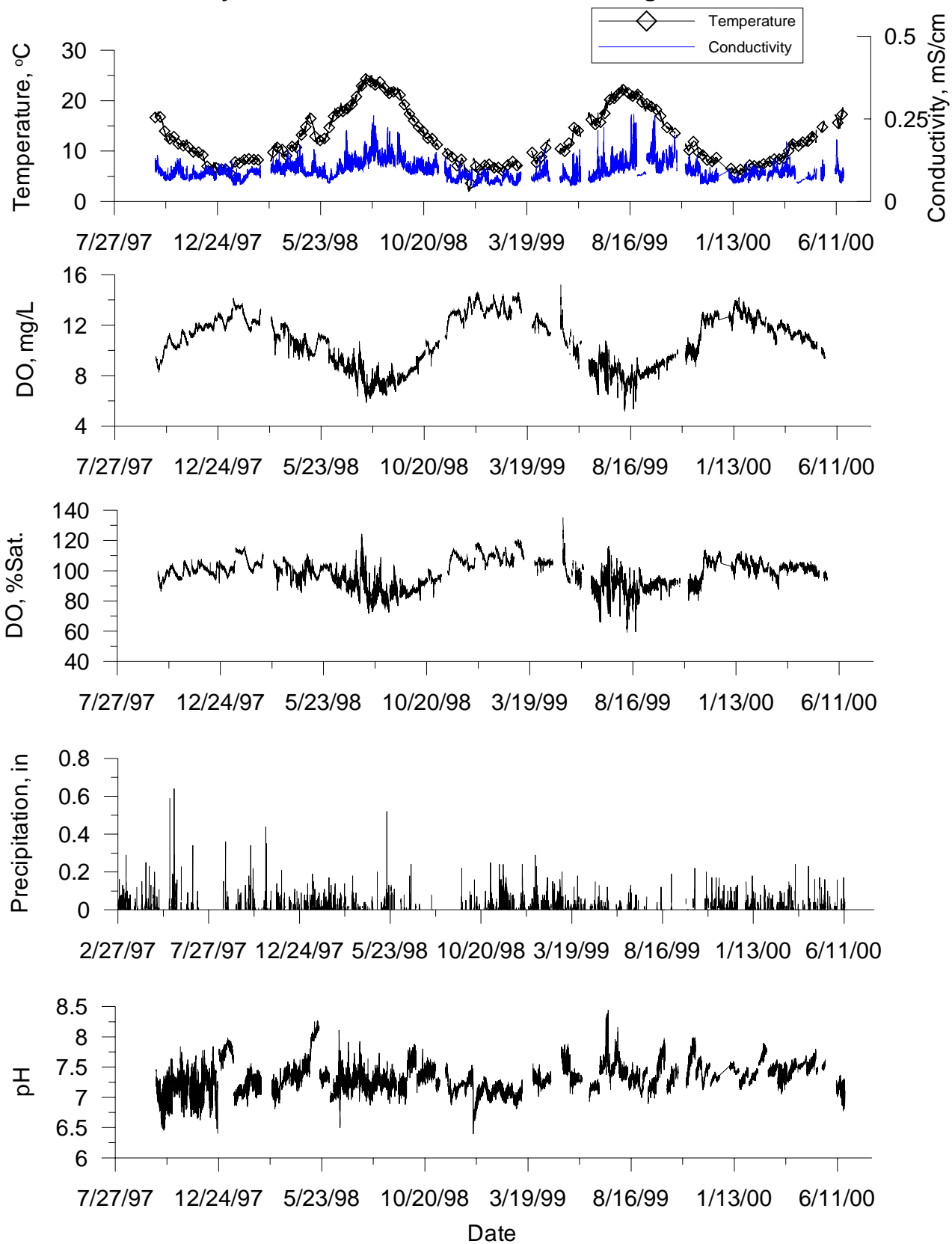


Figure 4. Water Quality in the Willamette River at RM 6.8, 1997-2000

Hydrolab Data at Waverly Country Club. RM 17.9

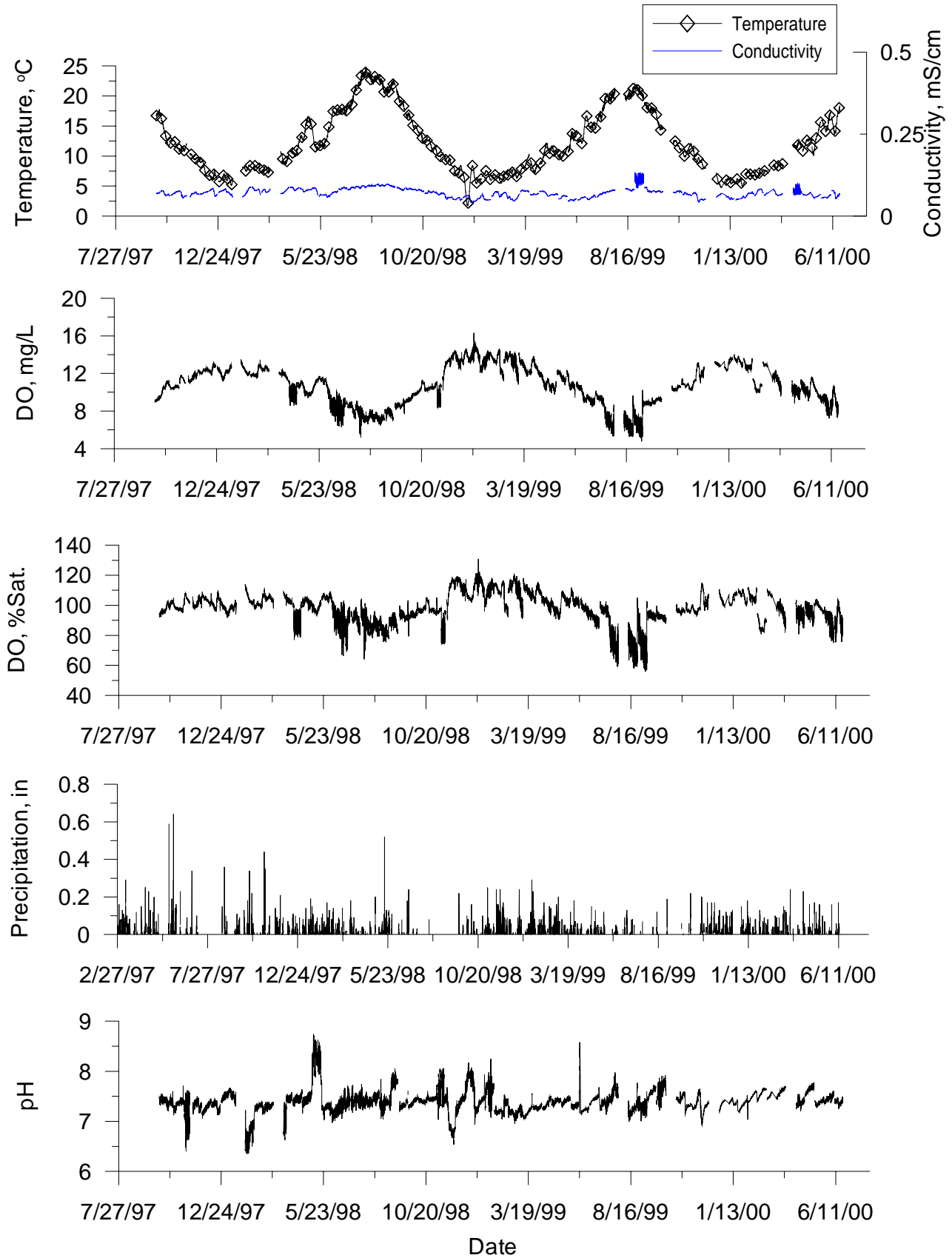


Figure 5. Water Quality in the Willamette River at RM 17.9, 1997-2000

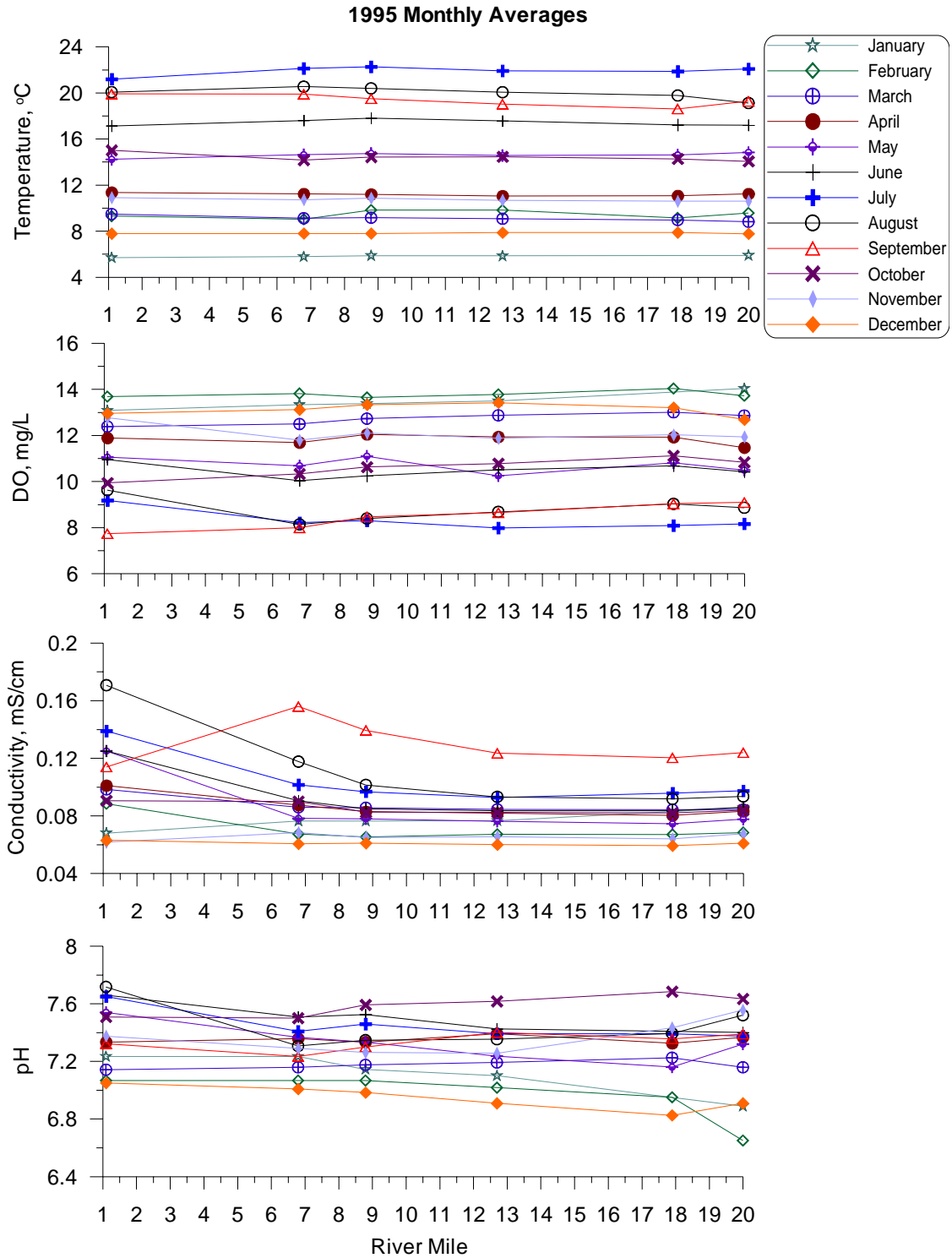


Figure 6. Water Quality Longitudinal Profiles in the Willamette River

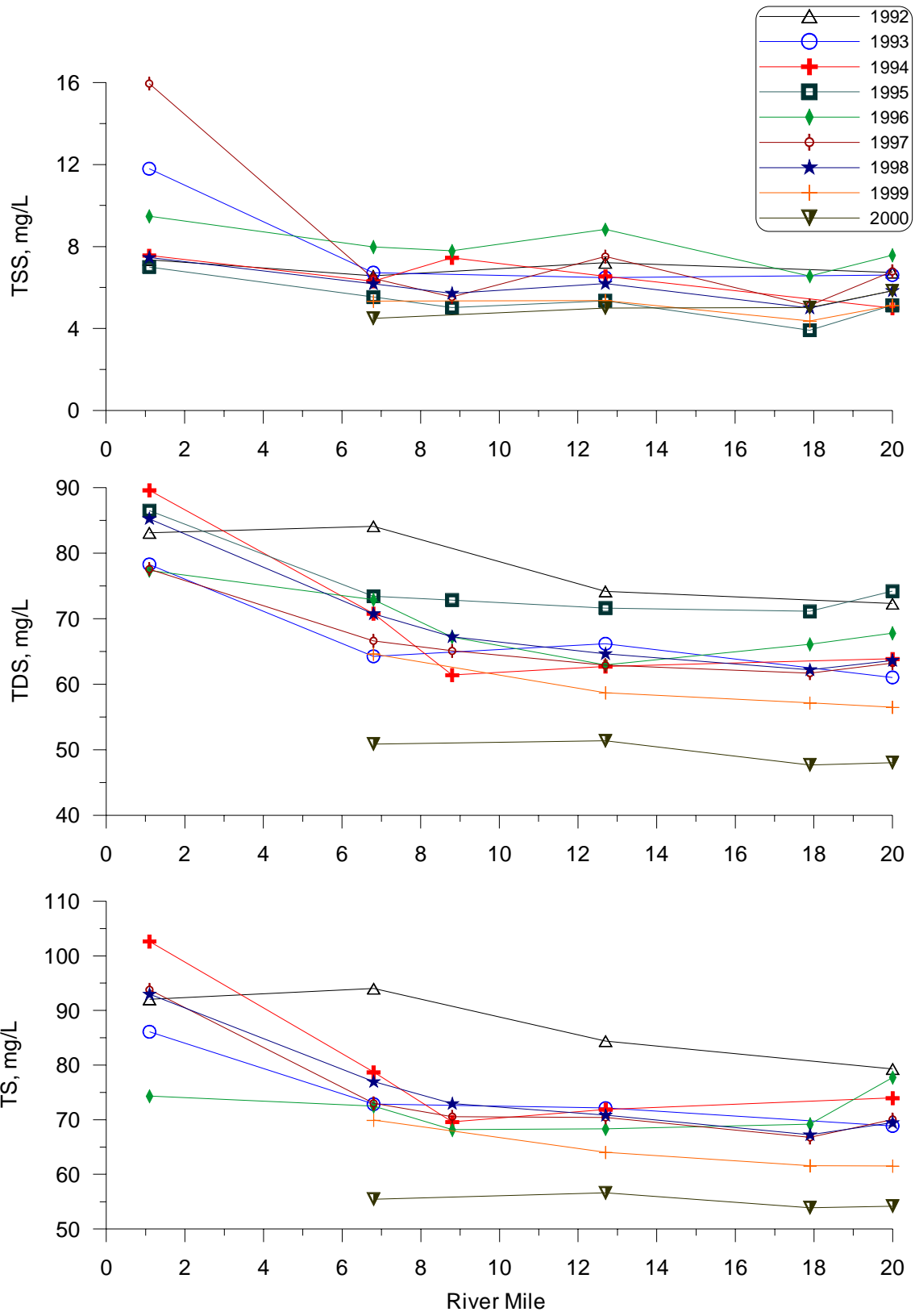


Figure 7. TSS, TDS and TS Longitudinal profiles, Summer Averages, 1992-2000

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.

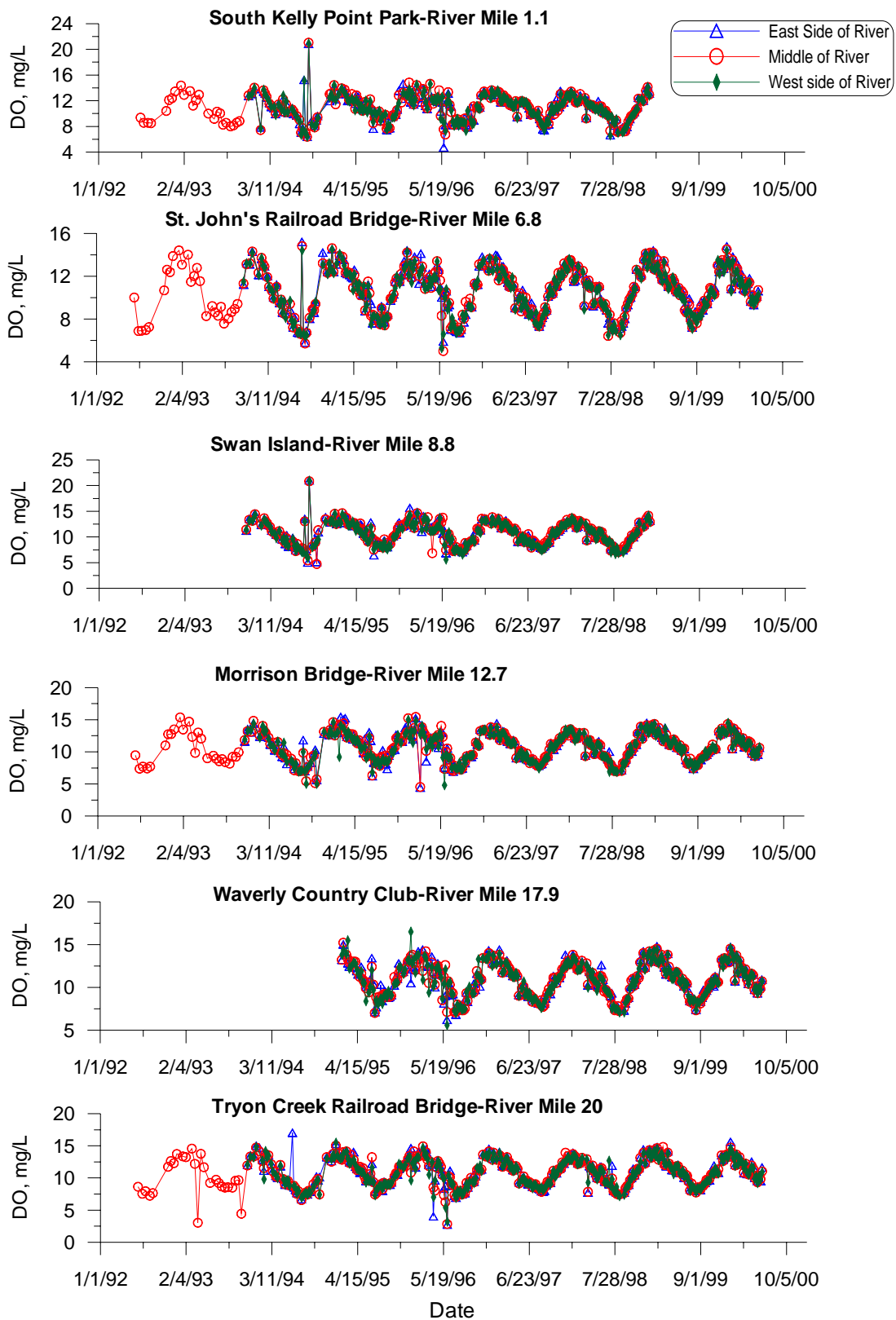


Figure 8. Dissolved Oxygen profiles across the Willamette River, 1992-2000

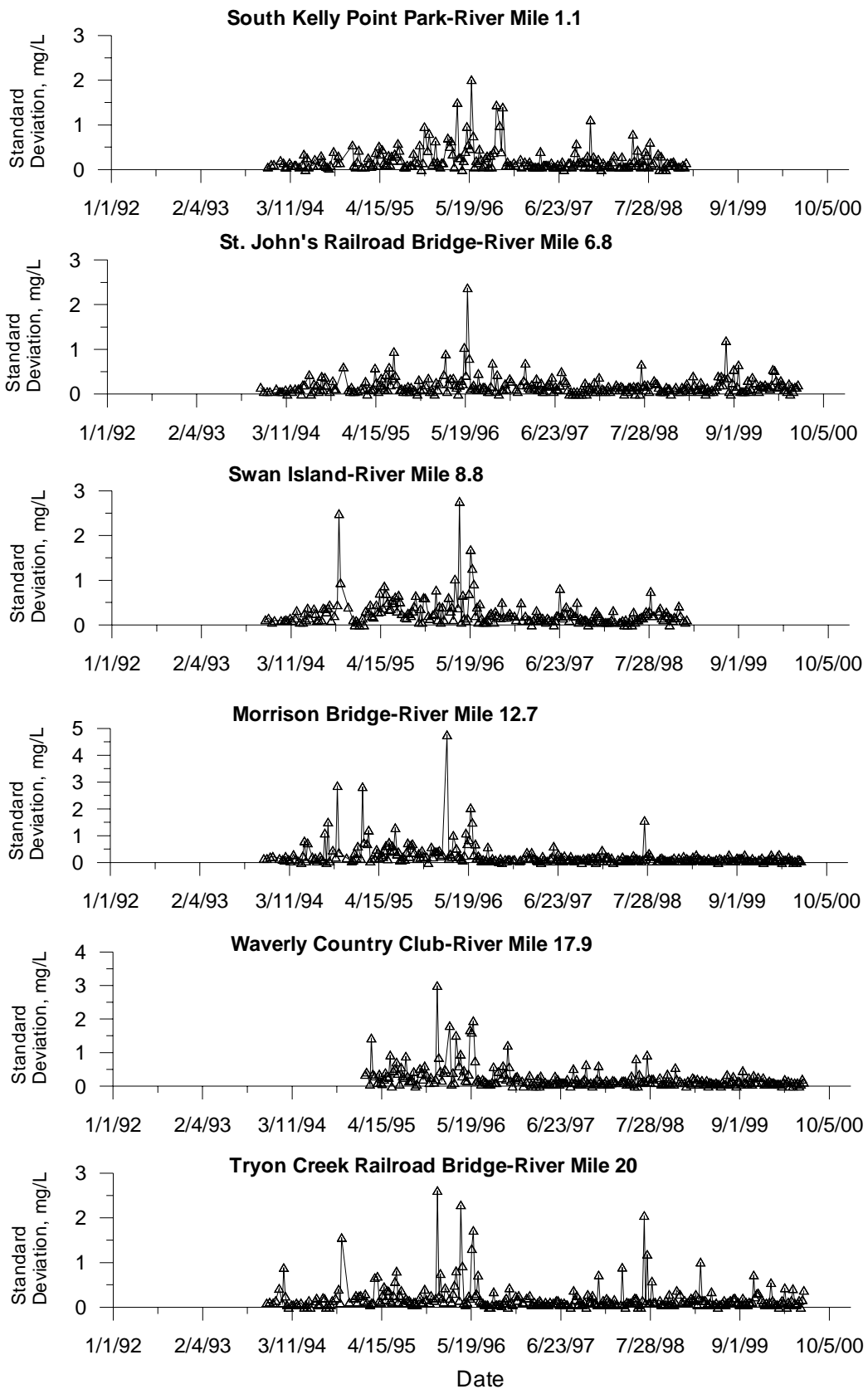


Figure 9. Standard deviation for Dissolved Oxygen, 1992-2000

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 the 10-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 the 10-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

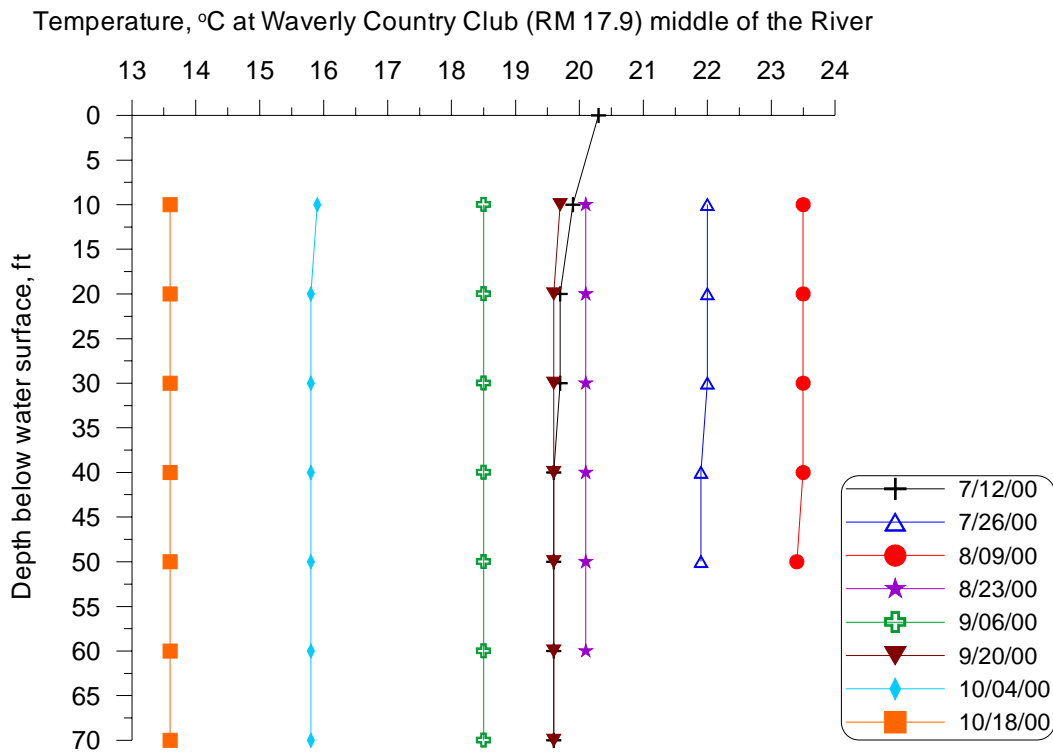


Figure 10. Temperature profiles in the middle of the Willamette River at Waverly Country Club, RM 17.9

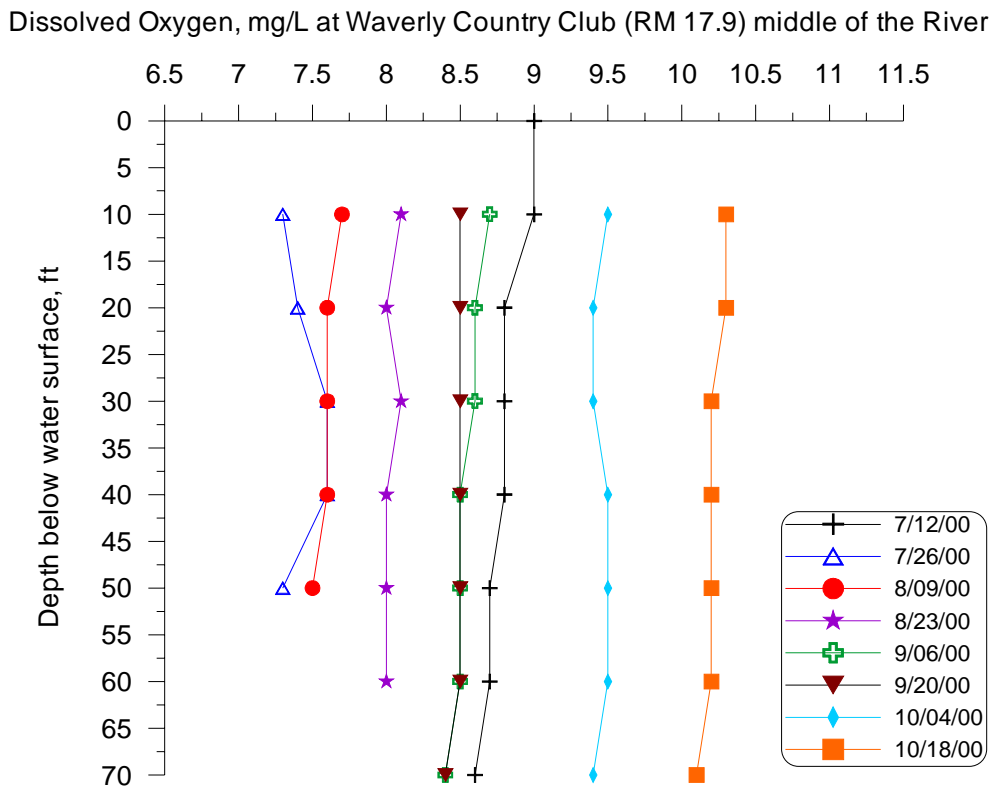


Figure 11. Dissolved Oxygen profiles in the middle of the Willamette River at Waverly Country Club, RM 17.9

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.

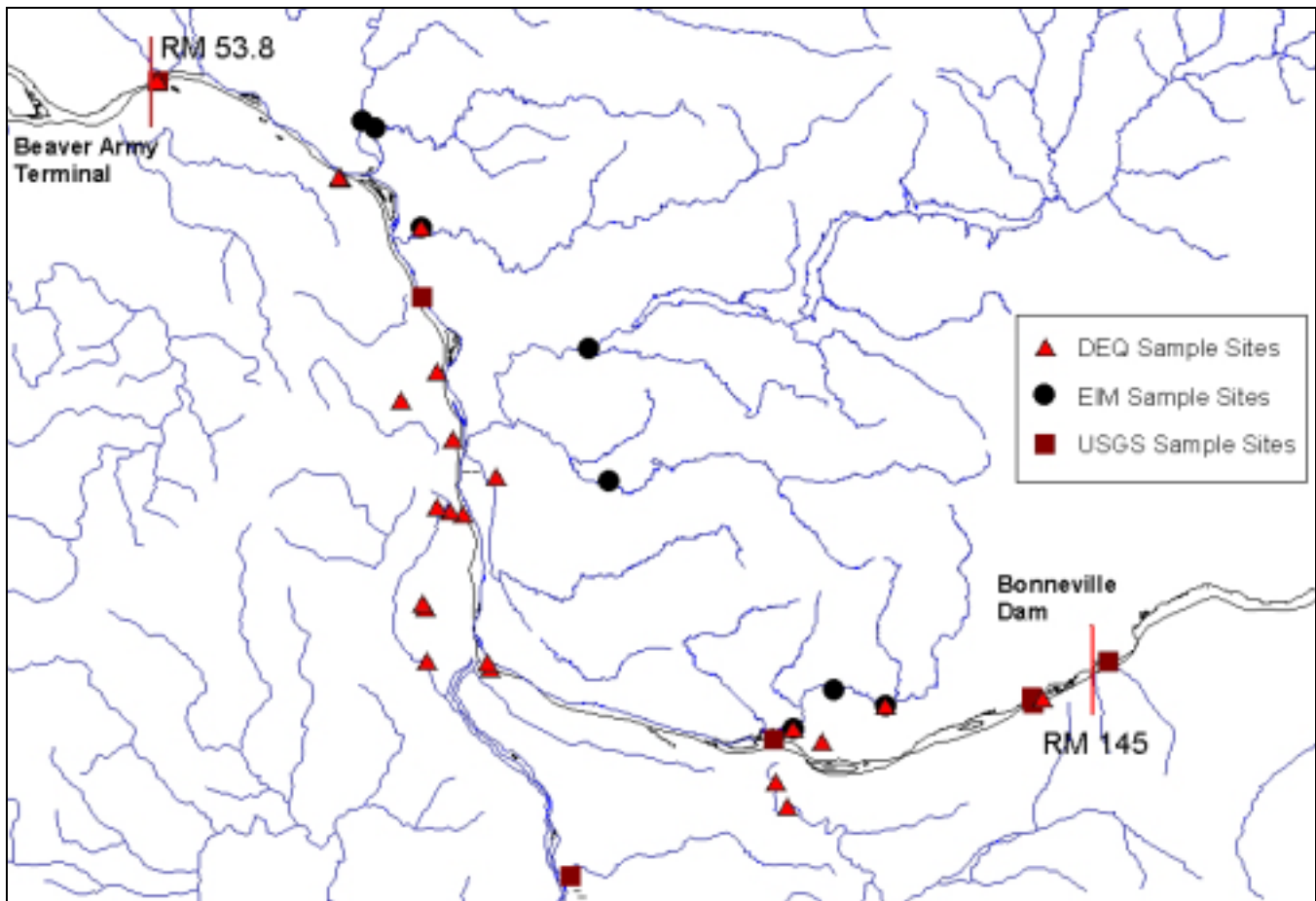


Figure 12. Columbia River water quality sampling locations

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.

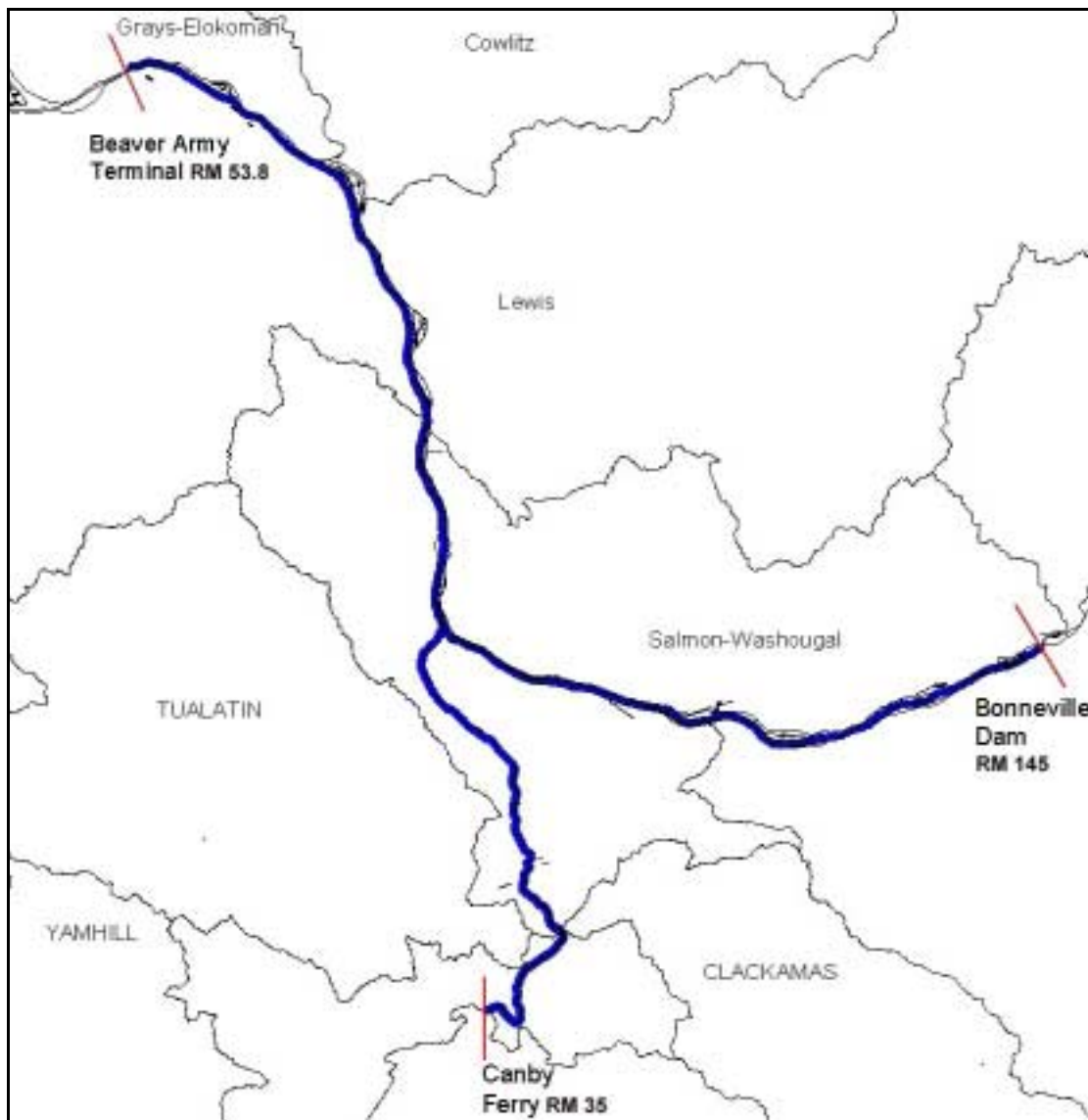


Figure 13. Model Boundaries on the Columbia and Willamette Rivers

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:

$$\begin{aligned} \text{BeaverArmyTerminalWLElev}_m &= 0.0143(\text{Hourly}) + 0.0109(\text{Daily}) - 0.0062(\text{Monthly}) + \\ & 0.0054(\text{Annually}) - 0.2922(\text{VancouverWLElev}_m) + 1.1156(\text{LongviewWLElev}_m) + \\ & 0.0389(\text{BonnevilleWLElev}_m) - 0.1942 \end{aligned}$$

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.

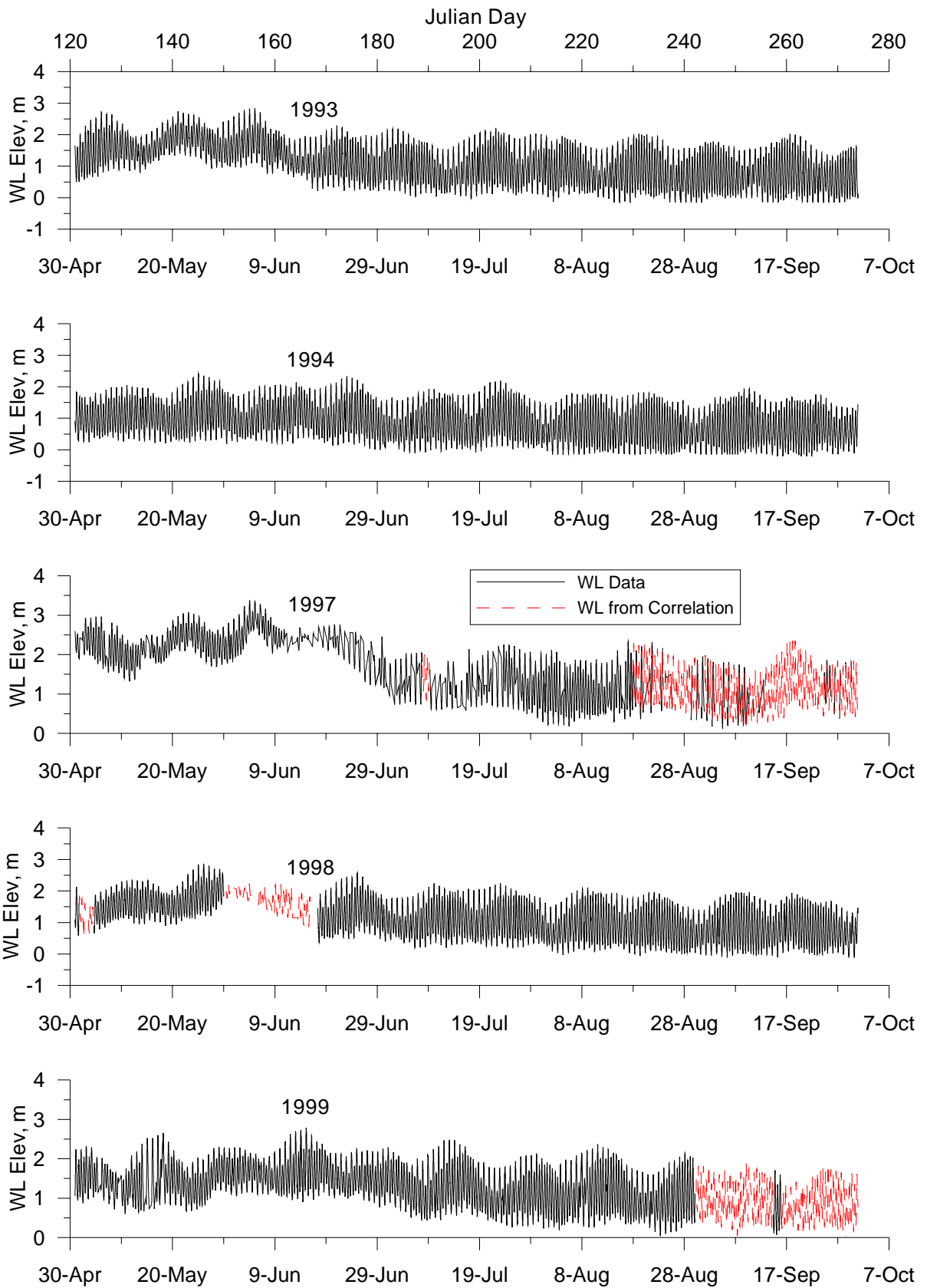


Figure 14. Columbia River Water Level Elevation at Beaver Army Terminal, m NGVD, RM 53.8

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.

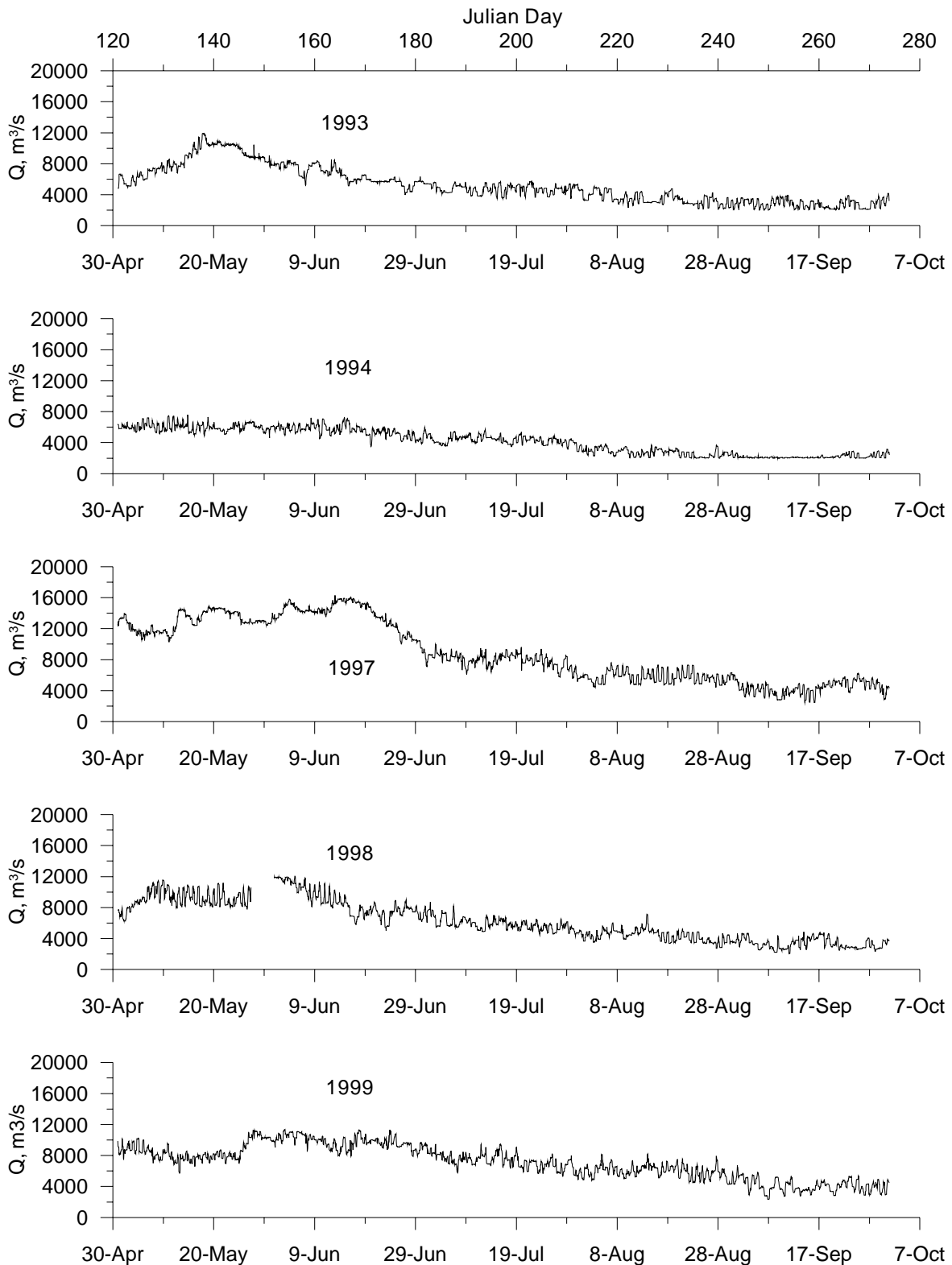


Figure 15. Columbia River Flow measured below the Bonneville Dam, m³/s, RM 144.5

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.

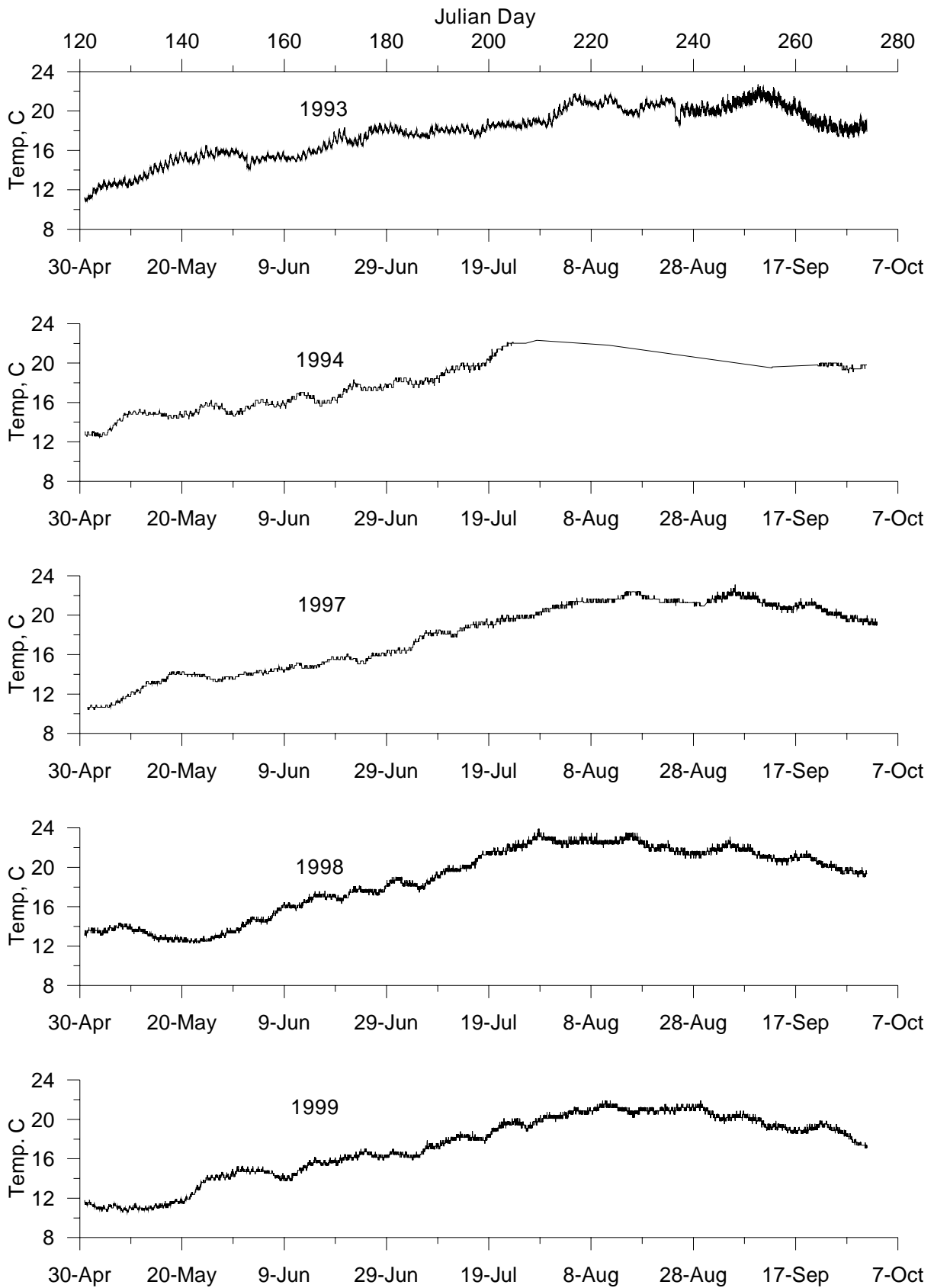


Figure 16. Columbia River at Beaver Army Terminal (RM 53.8) water temperature, °C

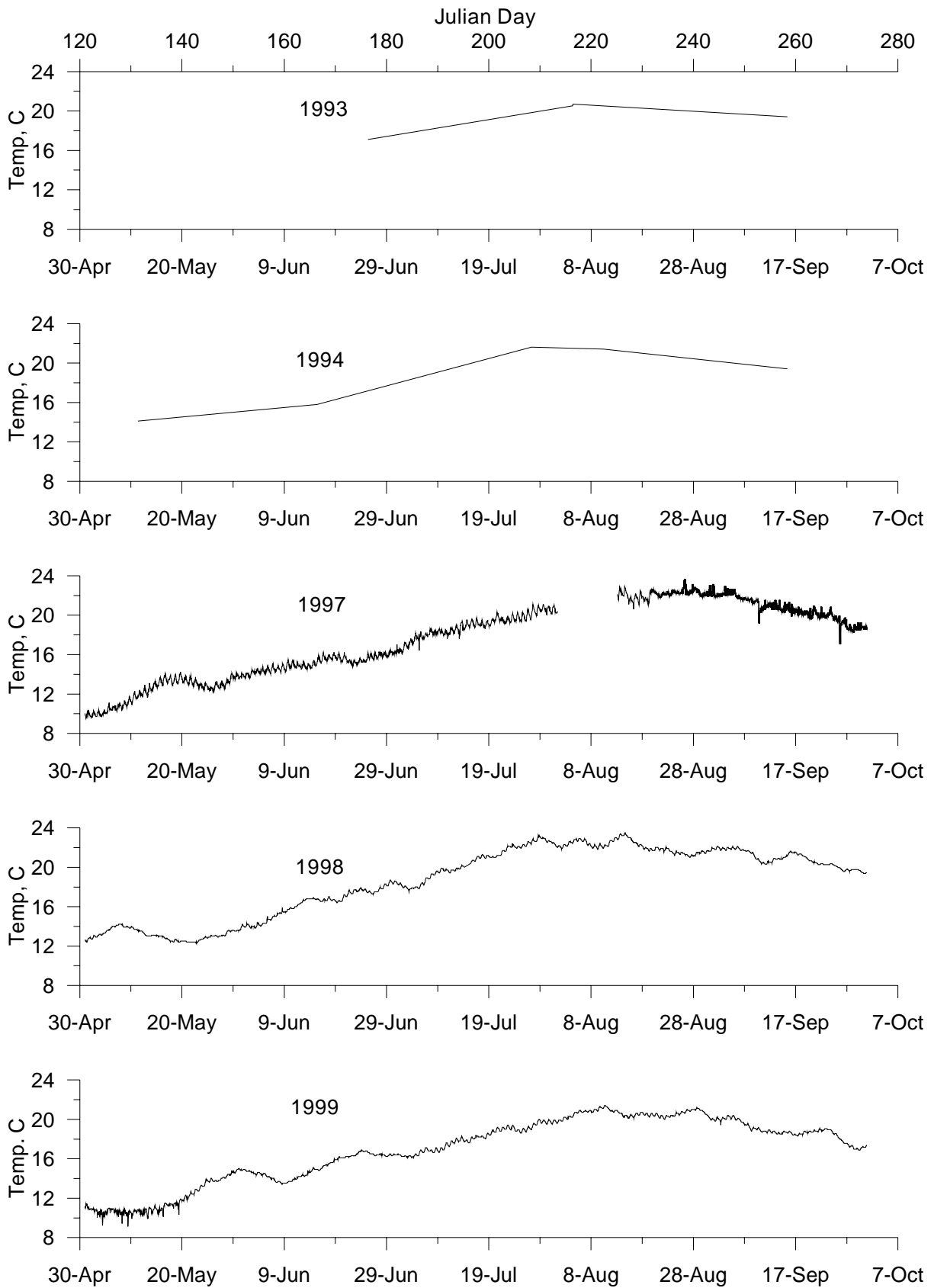


Figure 17. Columbia River at Bonneville Dam (RM 144.5) water temperature, °C

Parameters	Columbia River at Bonneville Dam	Columbia River at Beaver Army Terminal
ALKALIN AS CaCO3	X	X
Alkalinity	X	X
Calcium Hardness	X	X
CHLOROPHYL A	X	X
Conductivity, mS/cm	X	X
D ORG C C	X	X
Dissolved Oxygen	X	X
D.O Saturation	X	X
ENTOCOCCI	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

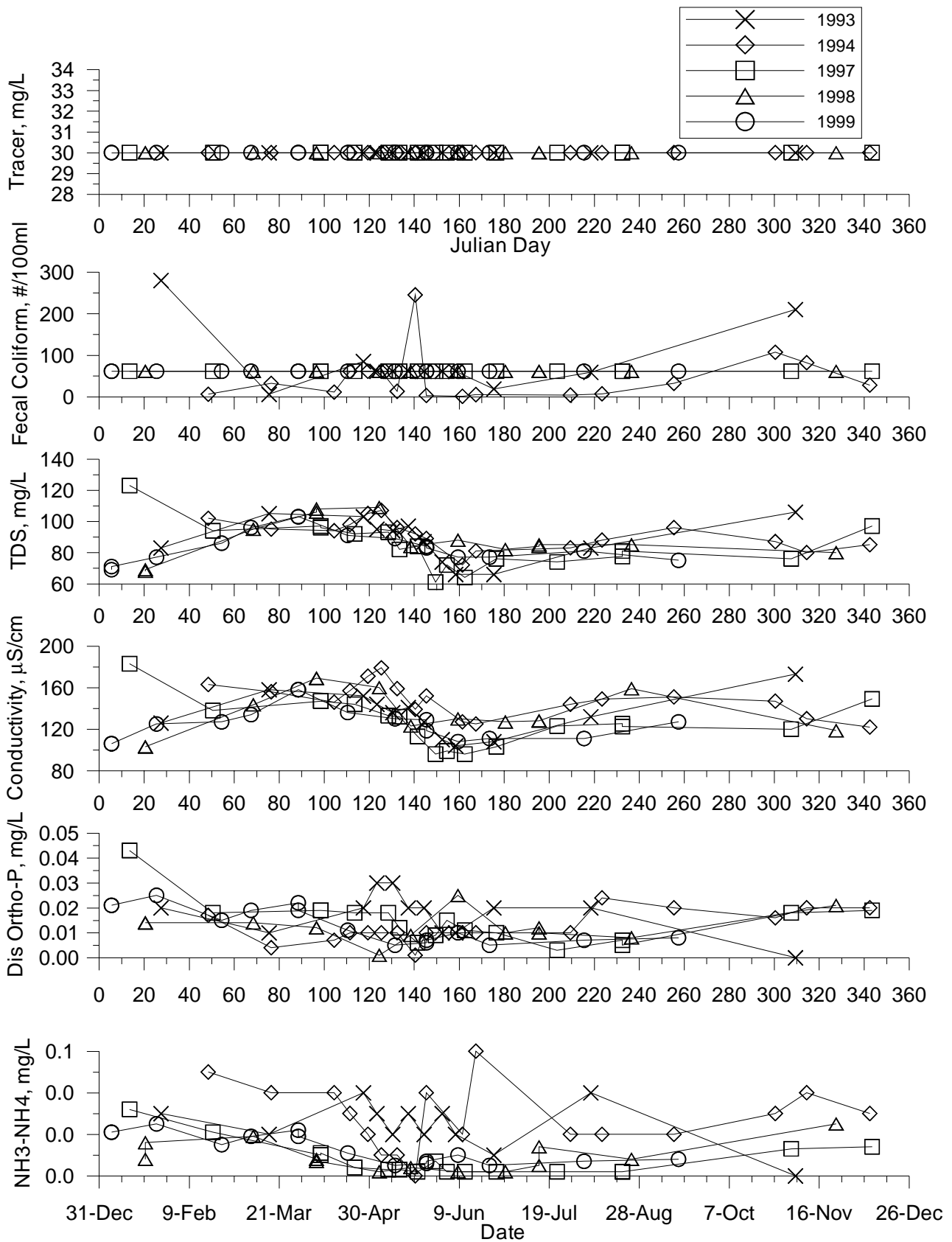


Figure 18. Columbia River at Beaver Army Terminal Boundary Condition, RM 54

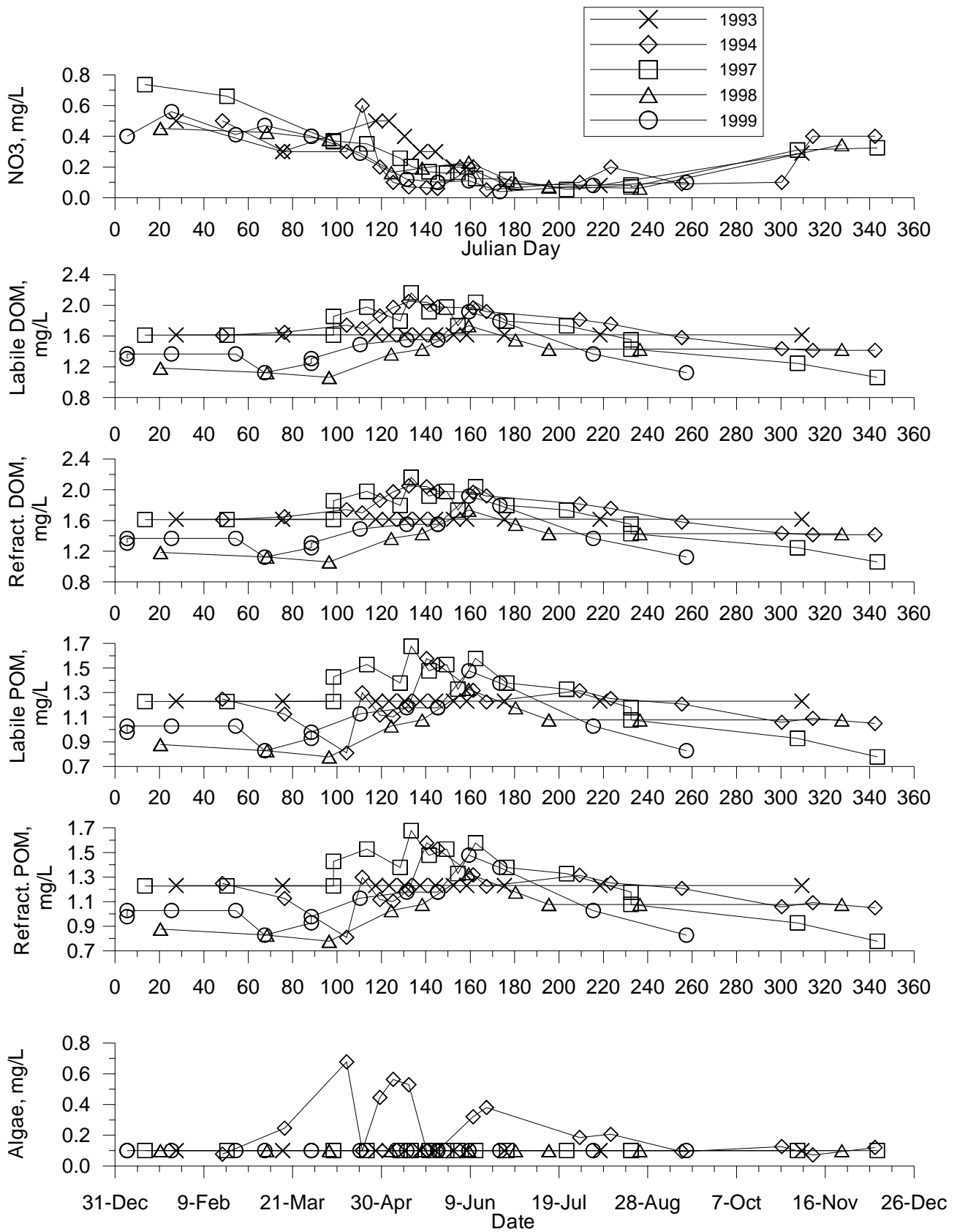


Figure 19. Columbia River at Beaver Army Terminal Boundary Condition, RM 54 (Part 2)

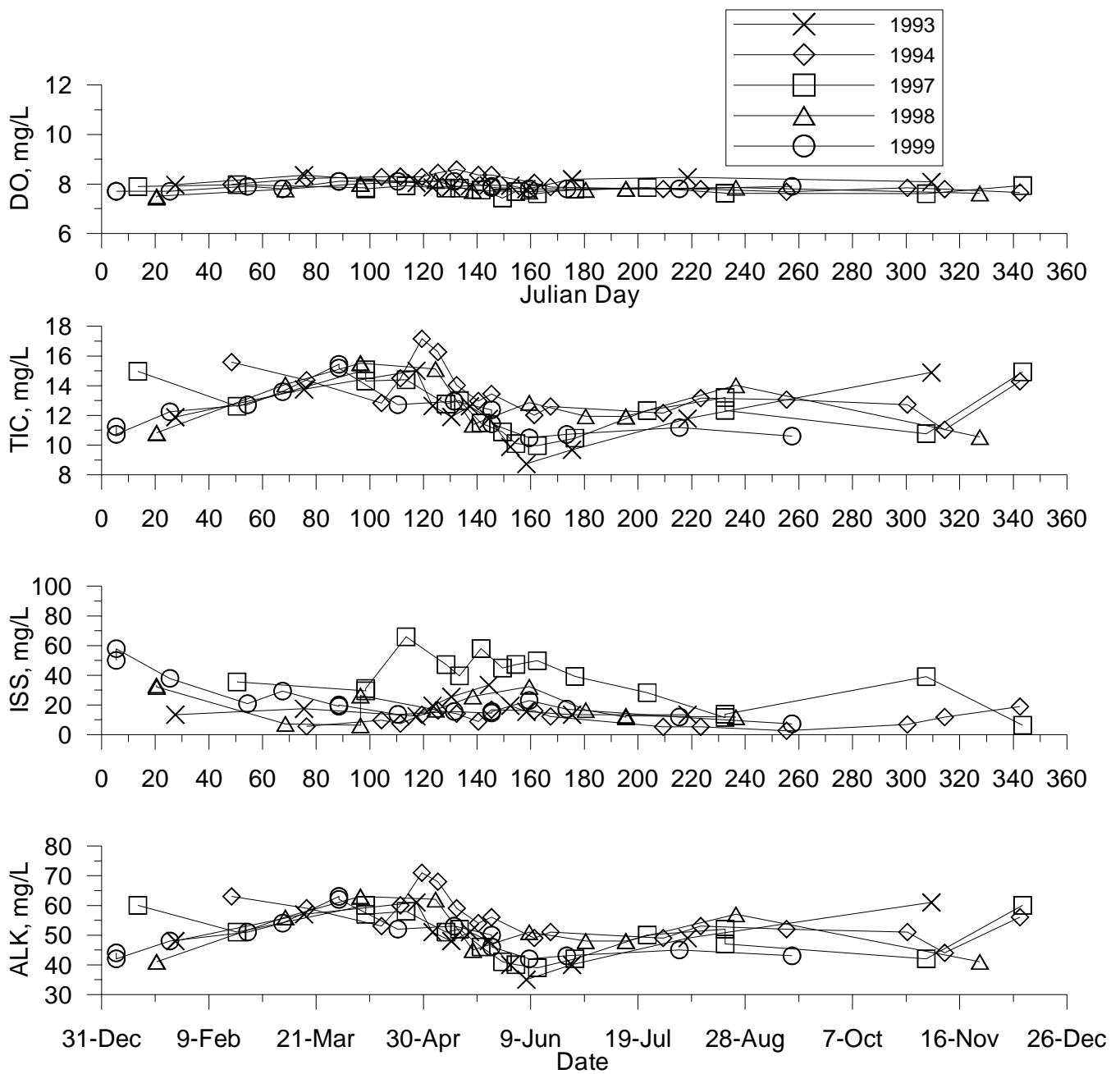


Figure 20. Columbia River at Beaver Army Terminal Boundary Condition, RM 54 (Part 3)

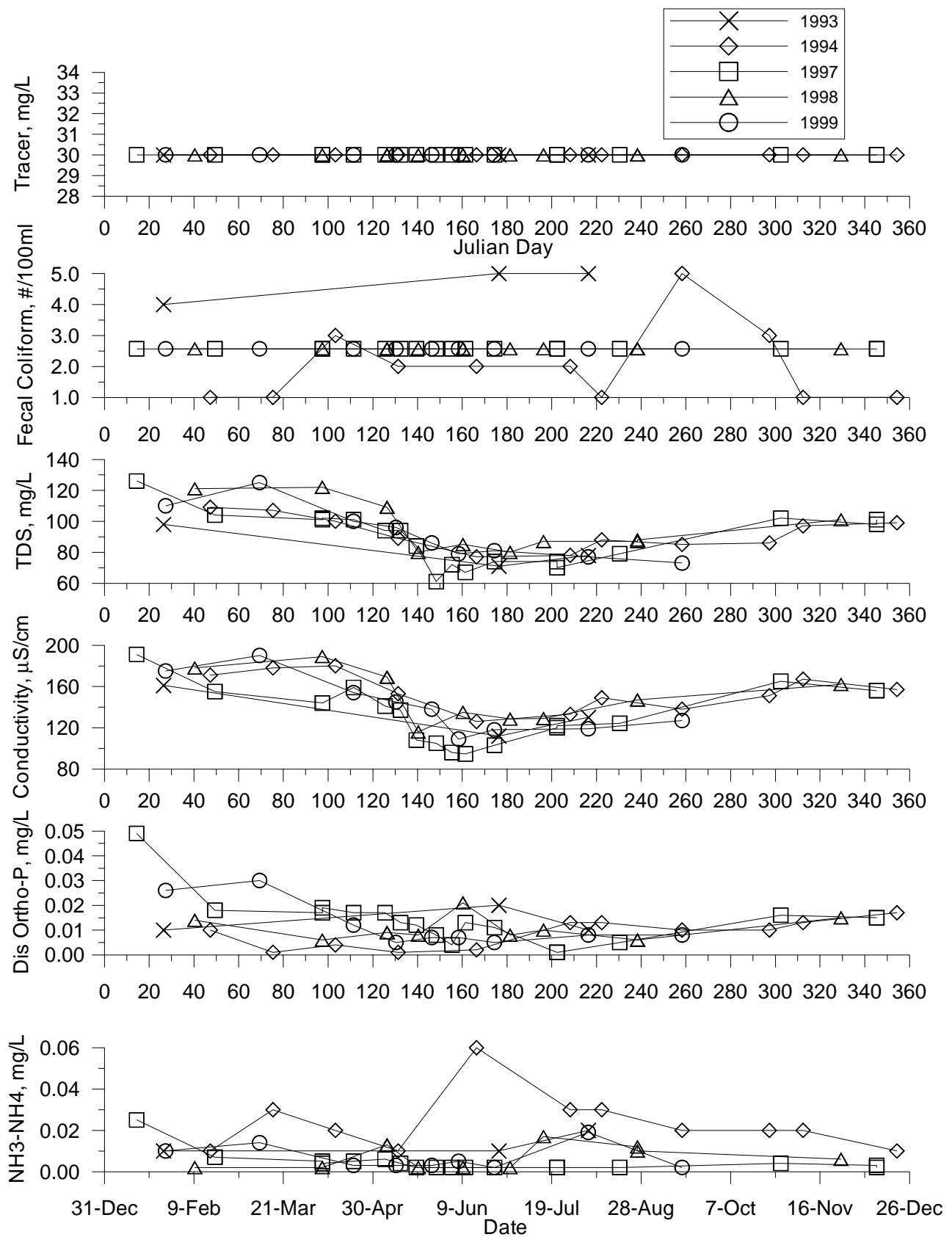


Figure 21. Columbia River at Bonneville Dam Boundary Condition, RM 145

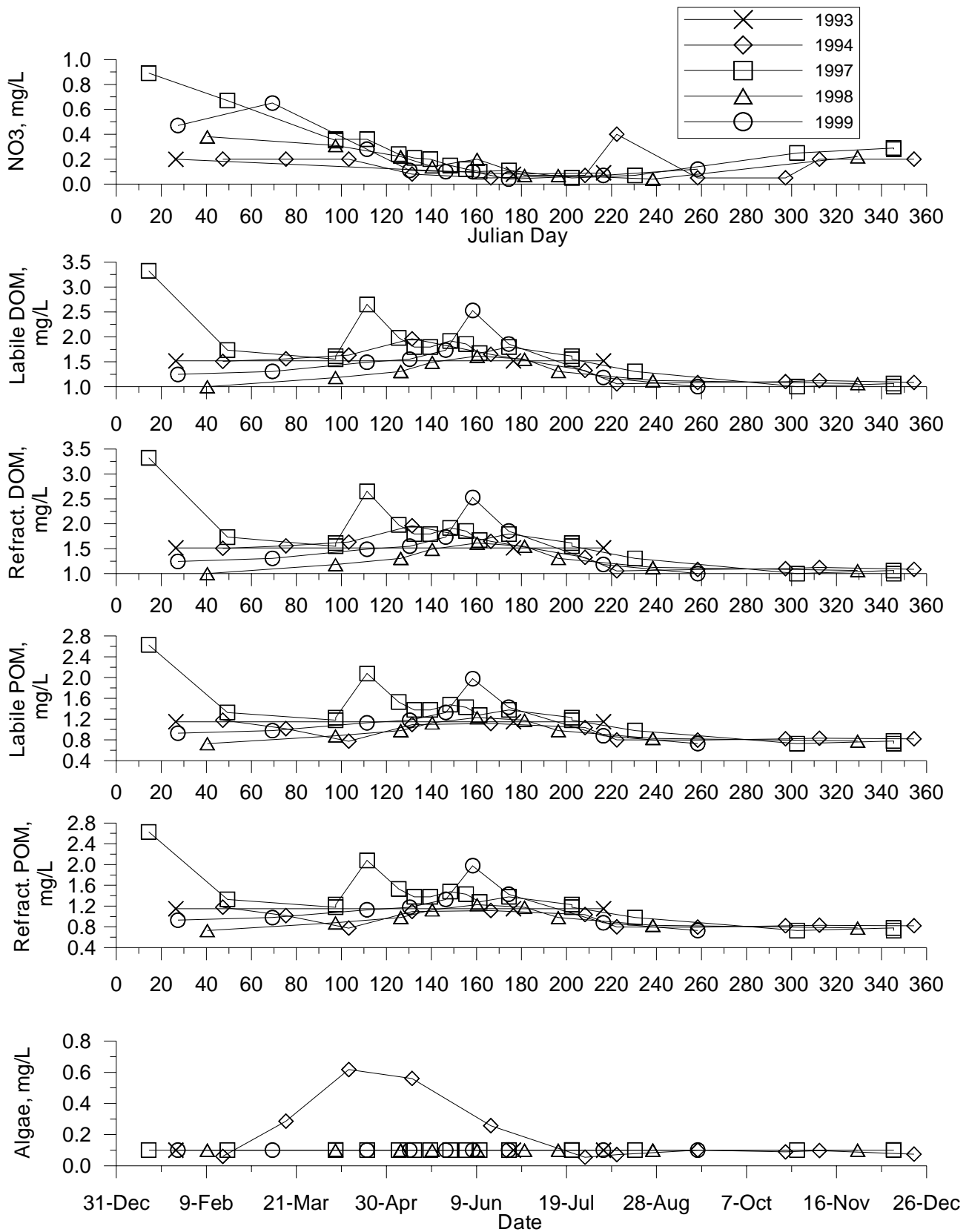


Figure 22. Columbia River at Bonneville Dam Boundary Condition, RM 145 (Part 2)

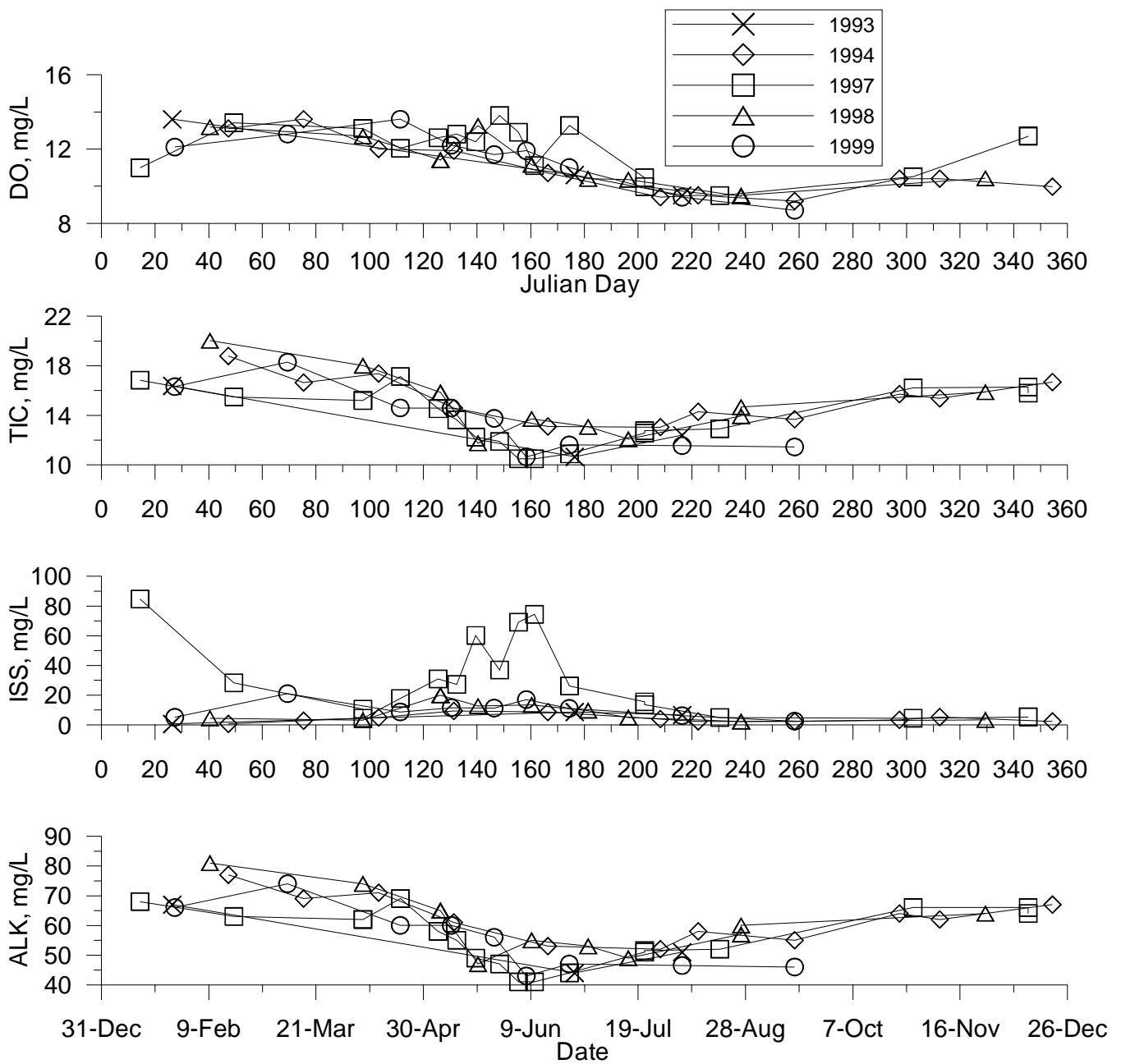


Figure 23. Columbia River at Bonneville Dam Boundary Condition, RM 145 (Part 3)

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

$$\begin{aligned}
&+ \text{ (Mean daily Q at South Yamhill) } \times 2 \text{ with 1 day lag} \\
&+ \text{ (Mean daily Q at Pudding near Woodburn) } \times 2 \text{ with 1 day lag} \\
&+ \text{ (Mean daily Q at Tualatin River-West Linn) } \times 1.5 \\
&+ \text{ (Mean daily Q at Clackamas River-Estacada) } \times 1.5 \\
&+ \text{ Mean daily Q at Johnson Creek-Milwaukie} \\
\hline
&= \text{ Mean daily Q at Willamette River-Portland}
\end{aligned}$$

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 unengaged 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:

$$\begin{aligned}
&\text{Mean daily Q at Molalla River-Canby} \\
&+ \text{ Mean daily Q at South Yamhill-Whiteson} \\
&+ \text{ Mean daily Q at Pudding-Aurora} \\
&+ \text{ Mean daily Q at Tualatin River-West Linn} \\
&+ \text{ Mean daily Q at Clackamas River-Estacada} \\
&+ \text{ Mean daily Q at W.R at Salem} \\
&+ \text{ Mean daily Q at Johnson Creek-Sycamore} \\
&+ \text{ Mean daily Q Ungaged between Salem and Oregon City} \\
\hline
&= \text{ Mean daily Q at Willamette River-Portland}
\end{aligned}$$

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.

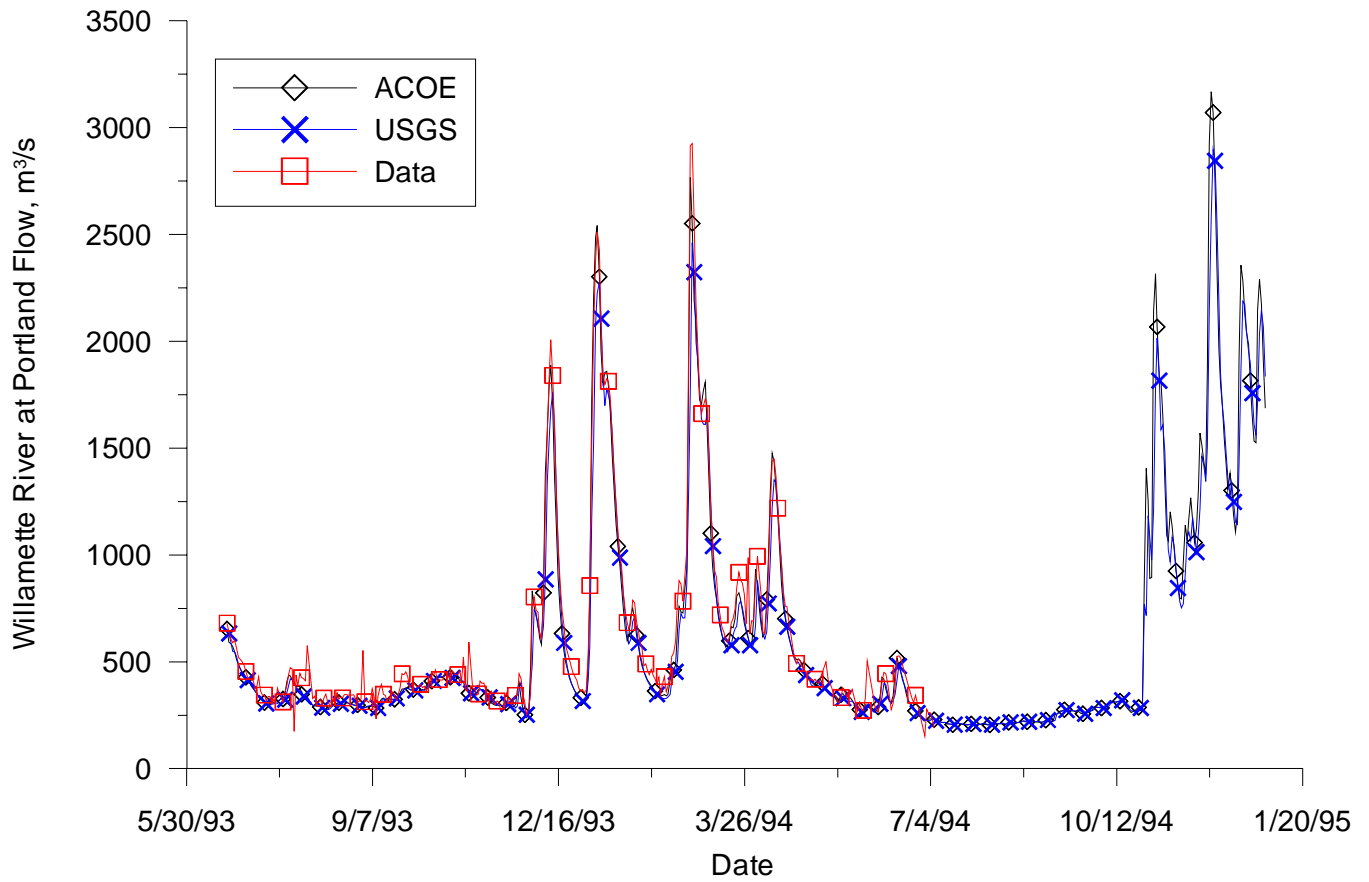


Figure 24. Willamette River Flow at Portland comparison between data, the USGS model and the USACOE model

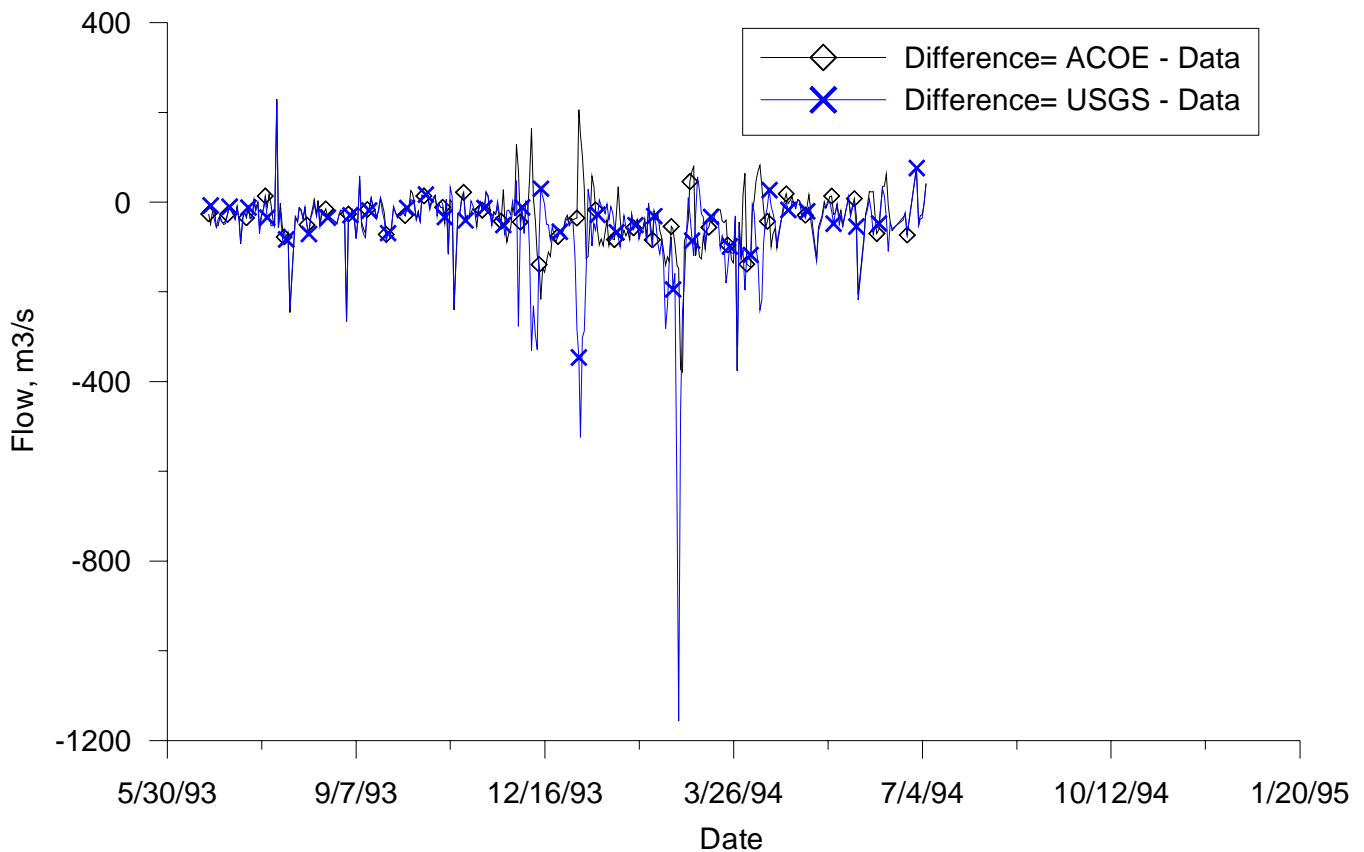


Figure 25. Flow difference between data and routing models in Willamette River at Portland

Model comparison	Number of Days	Std Deviation (m³/s)	AME (m³/s)	RMS (m³/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:

$$\begin{aligned}
 & \text{Mean daily Q at Molalla River-Canby} \\
 + & \text{ Mean daily Q at South Yamhill} \\
 + & \text{ Mean daily Q at Pudding-Aurora} \\
 + & \text{ Mean daily Q at W.R at Salem} \\
 + & \text{ Mean daily Q Ungaged between Salem and Oregon City} \\
 \hline
 = & \text{ Mean daily Q near Canby Ferry}
 \end{aligned}$$

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 mi ²	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 McMinnville 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 $0.3926(Q, \text{South Yamhill near Willamina, cfs})=Q$,

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: $1.8986(\text{South Yamhill below Willamina})=\text{South Yamhill at Whiteson}$ ($R^2=0.8078$). 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.

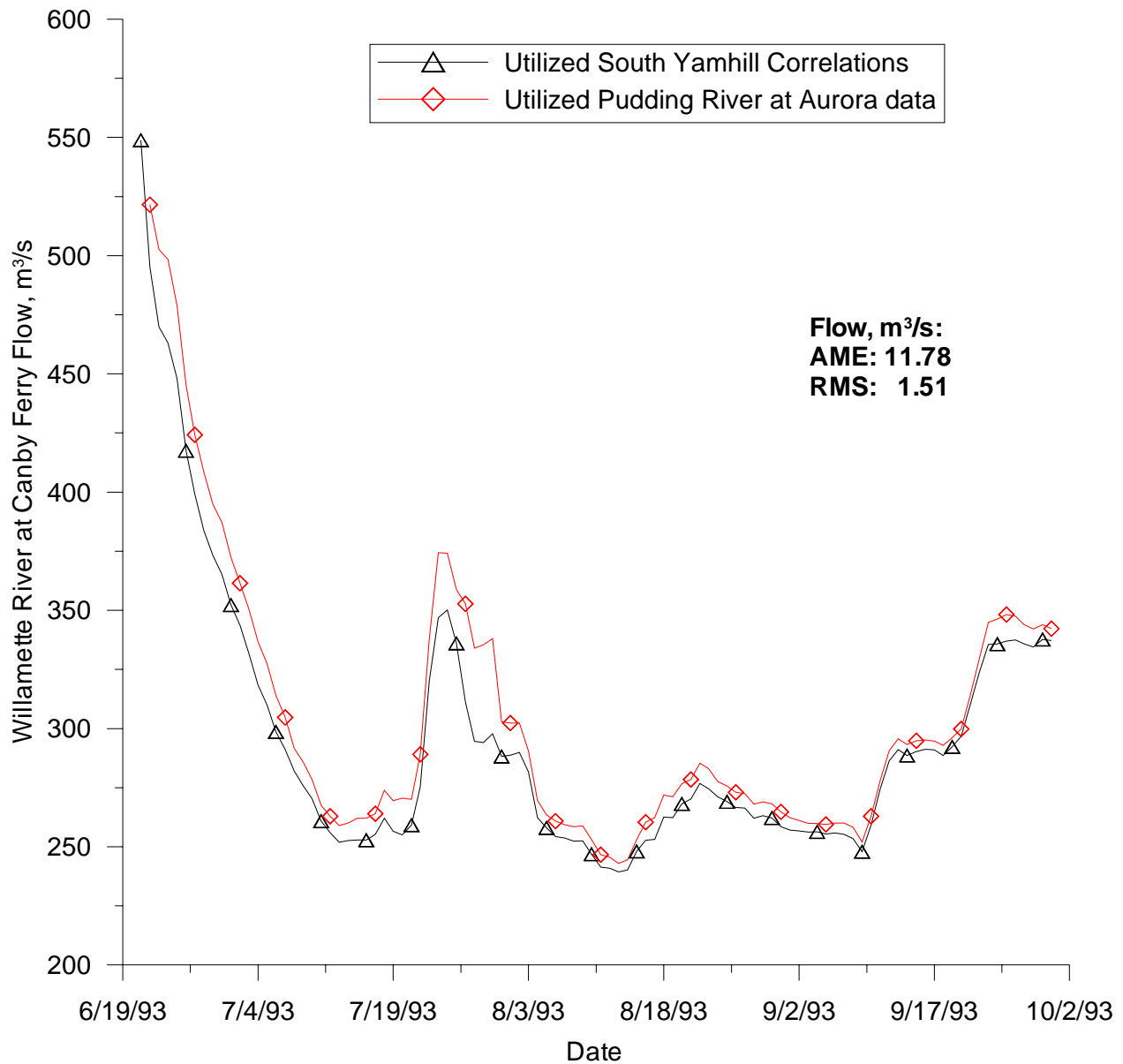


Figure 26. Willamette River at Canby Ferry flow comparison, Summer 1993

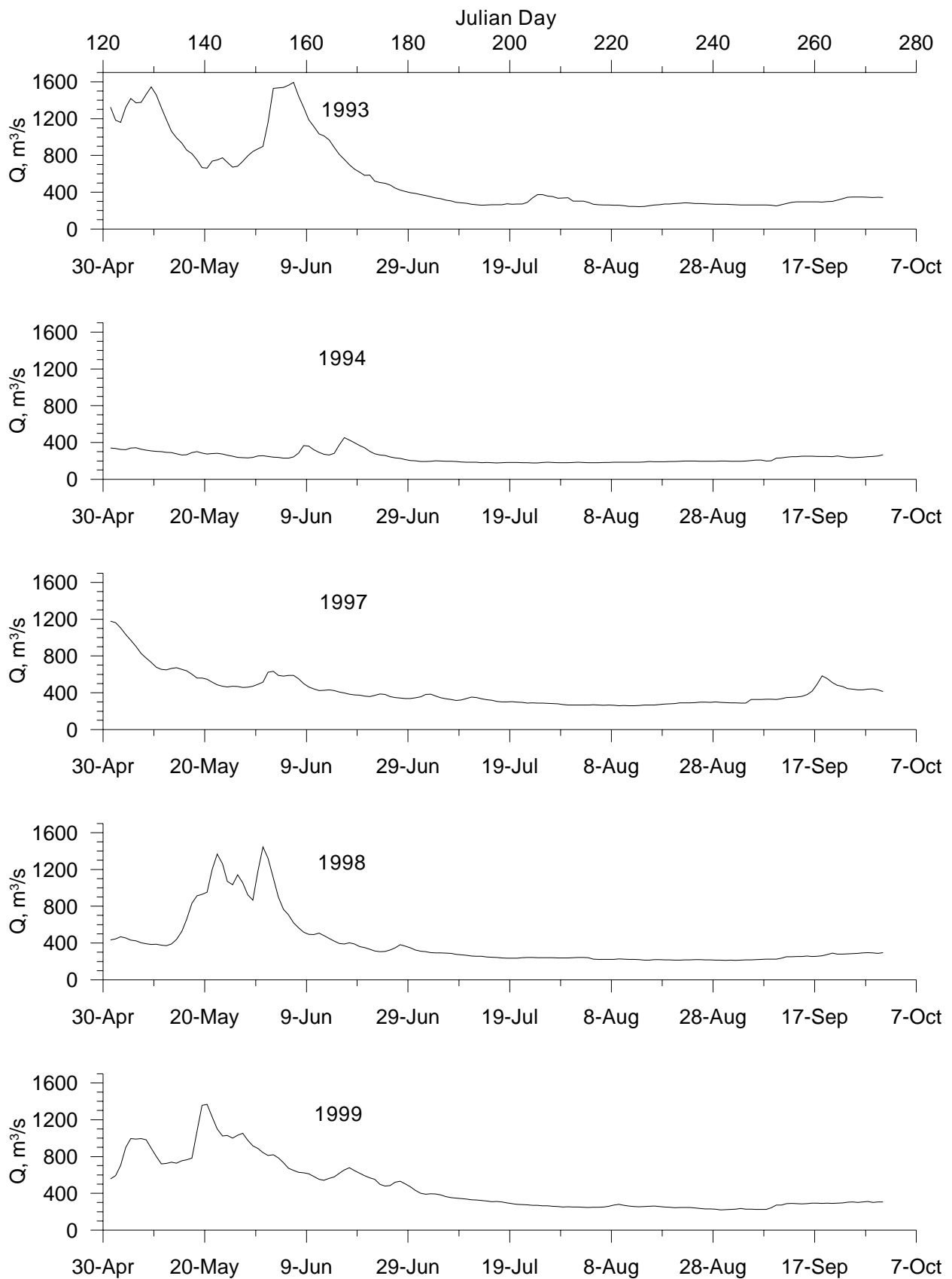


Figure 27. Willamette River flow near Canby Ferry (RM 35), m^3/s

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.

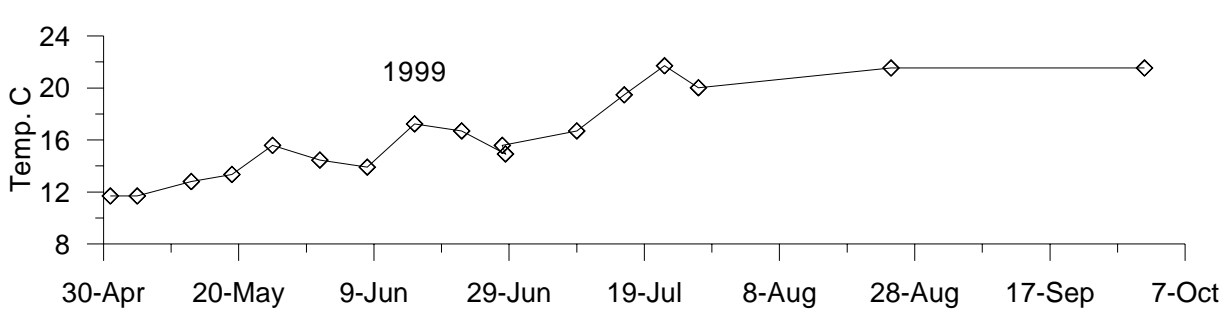
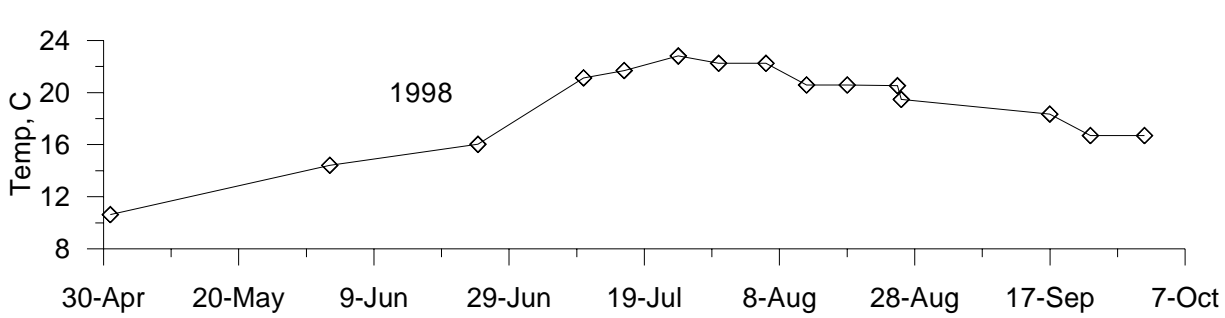
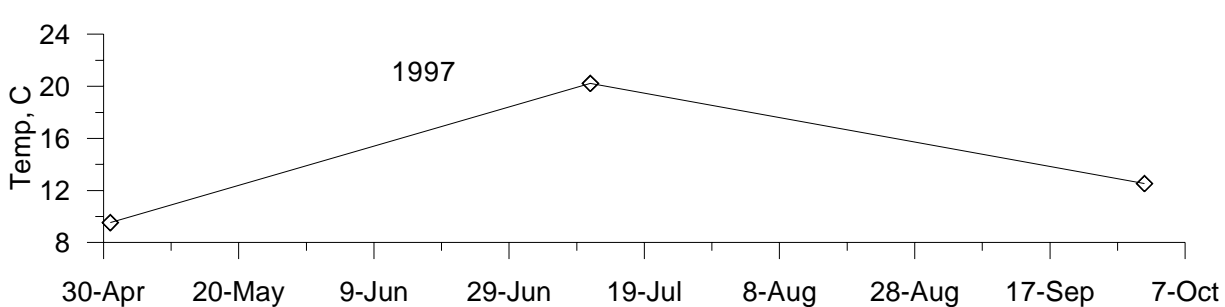
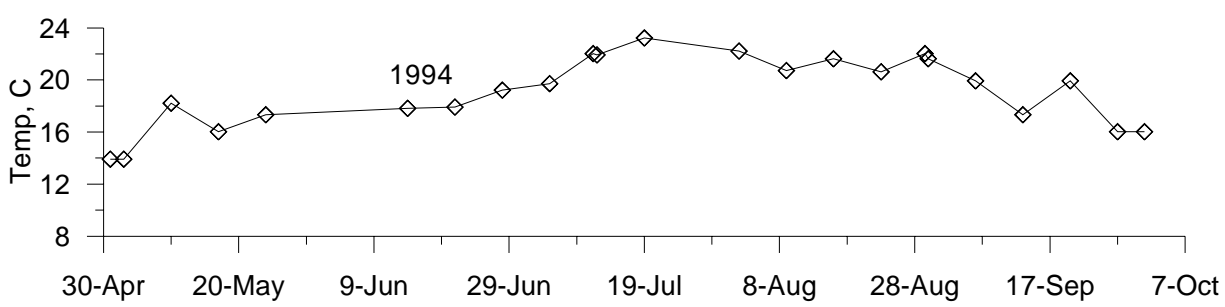
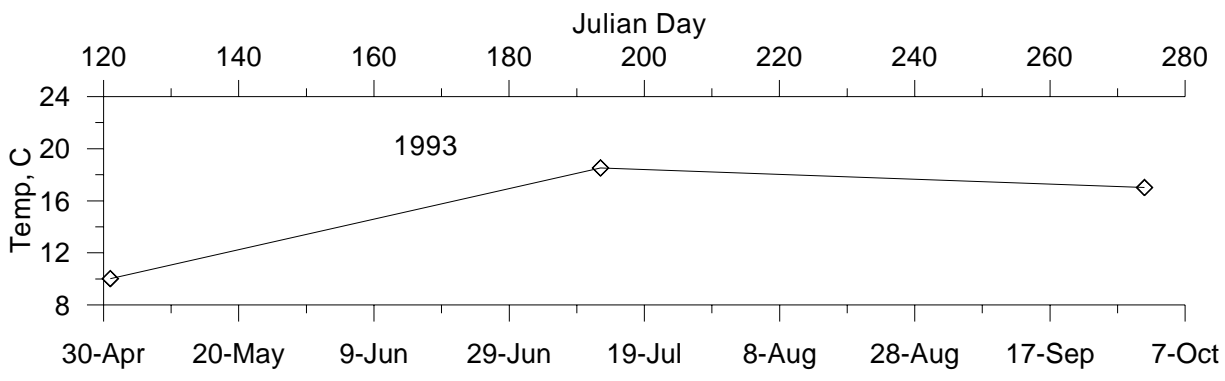


Figure 28. Willamette River at Canby Ferry water temperature, °C

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

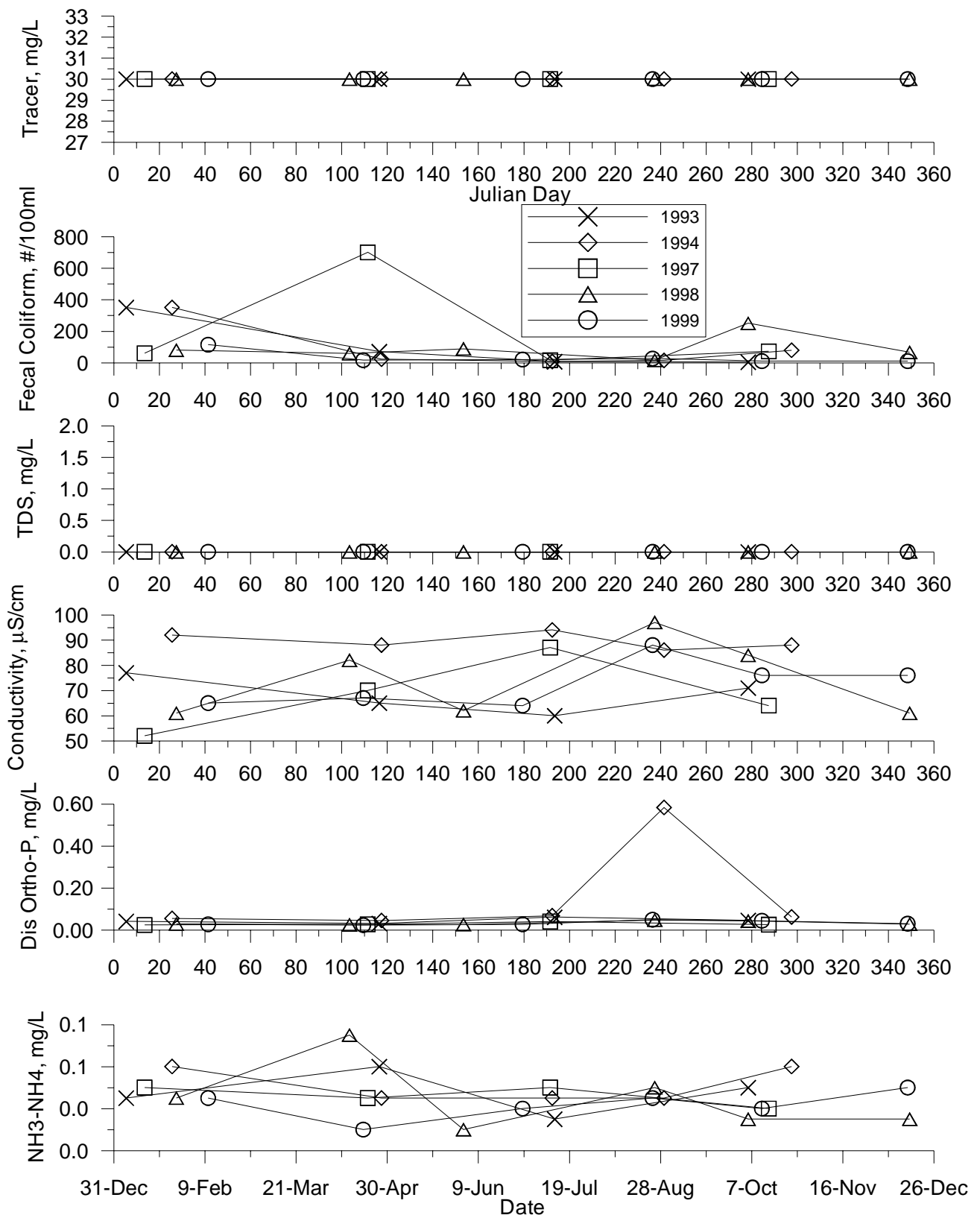


Figure 29. Willamette River at Canby Ferry Boundary Condition, RM 35

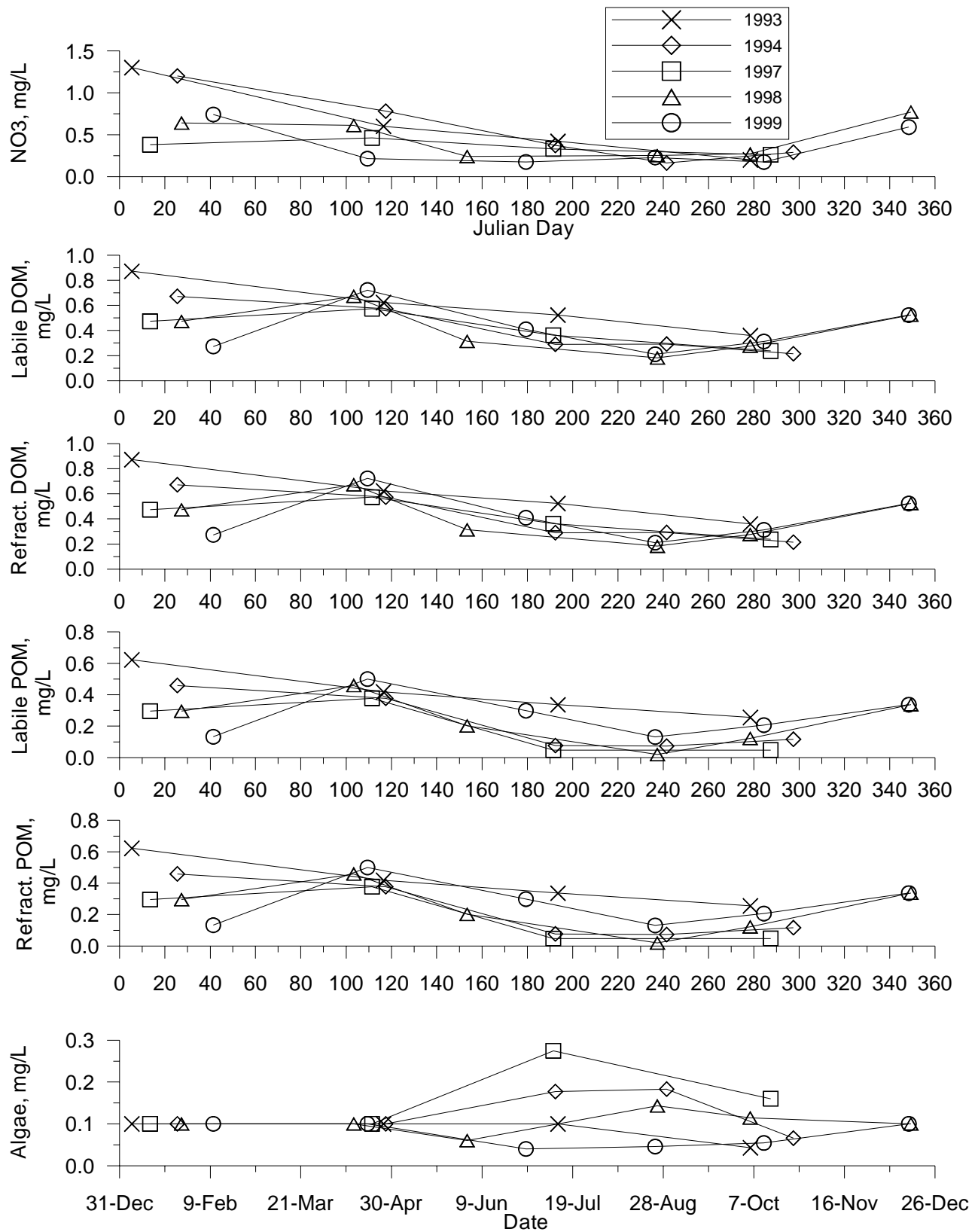


Figure 30. Willamette River at Canby Ferry Boundary Condition, RM 35 (Part 2)

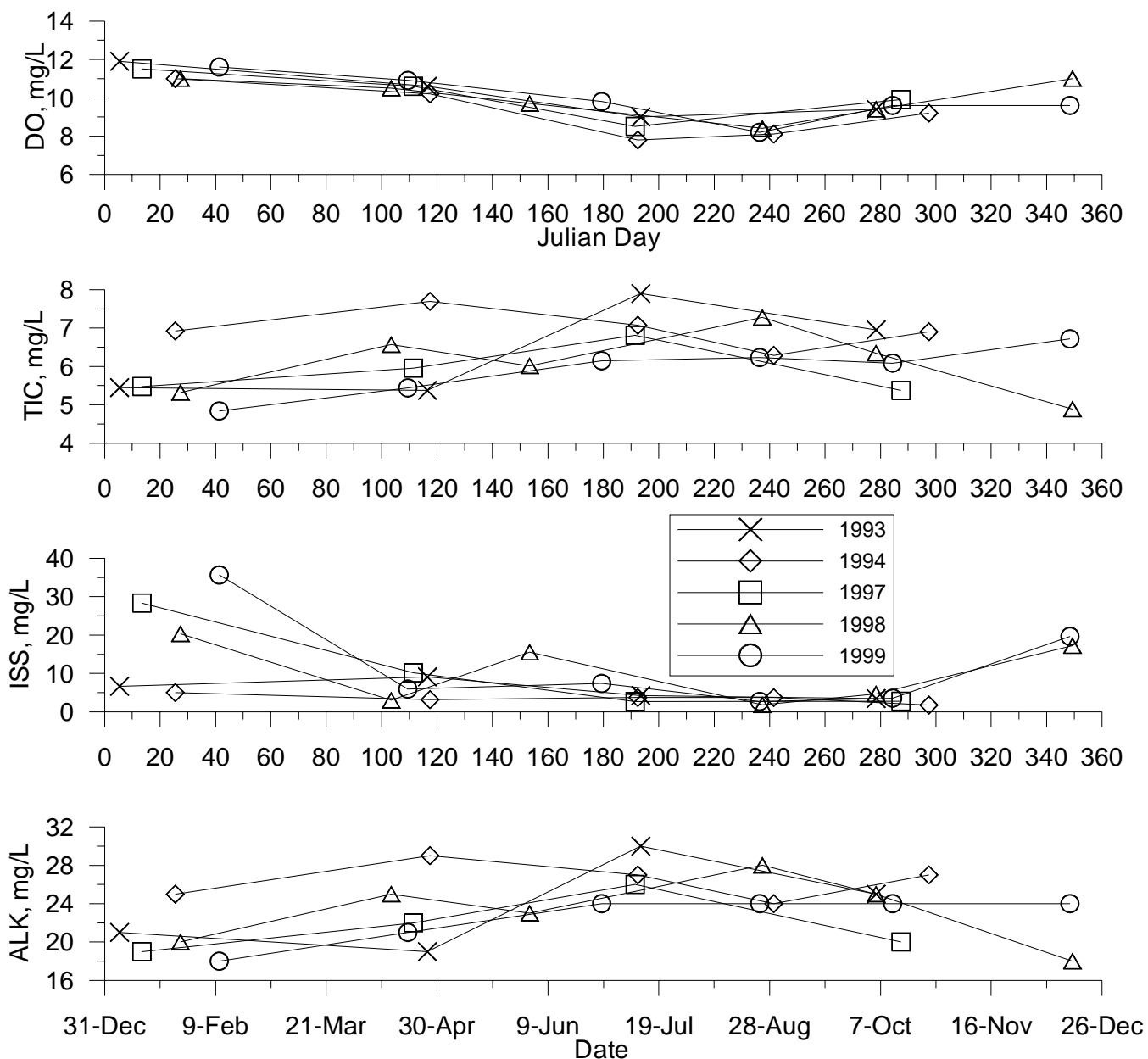


Figure 31. Willamette River at Canby Ferry Boundary Condition, RM 35 (Part 3)

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

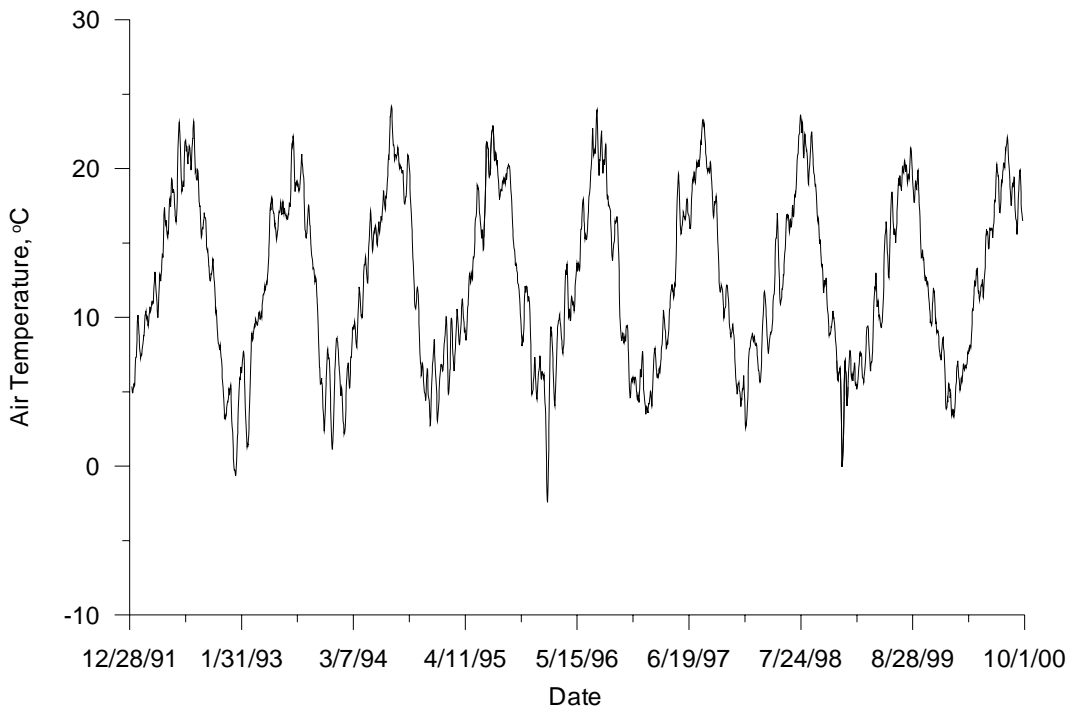


Figure 33. Air Temperature, °C, 10 day moving average at the Portland International Airport 1992-2000

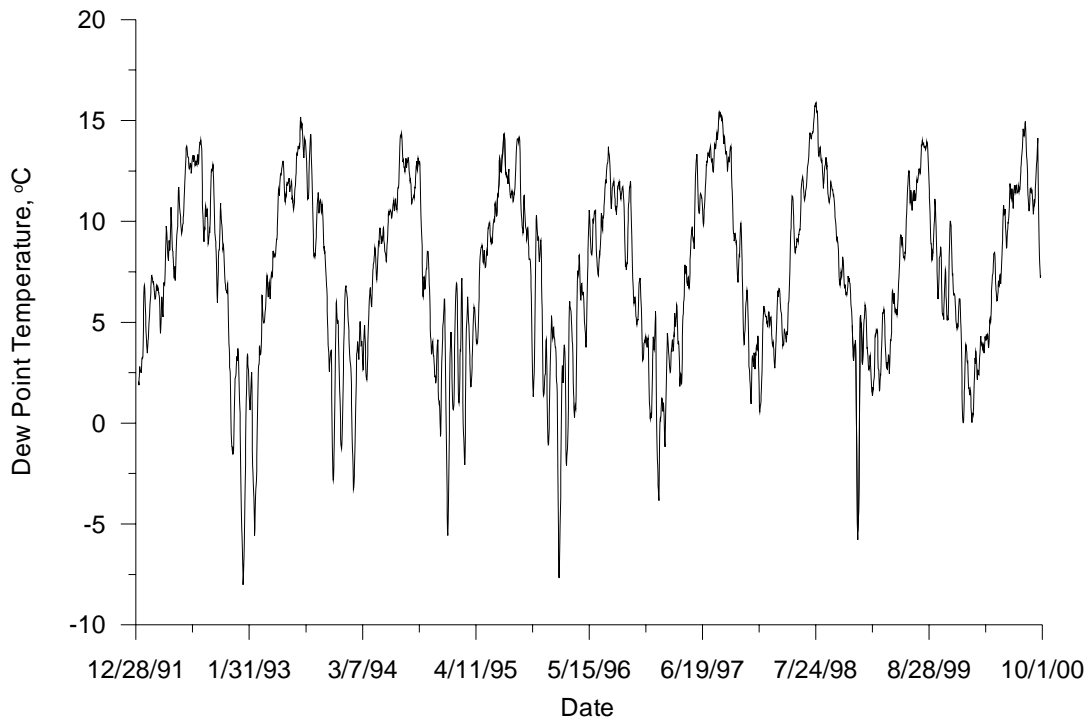


Figure 34. Dew Point Temperature, °C, 10 day moving average at the Portland International Airport 1992-2000

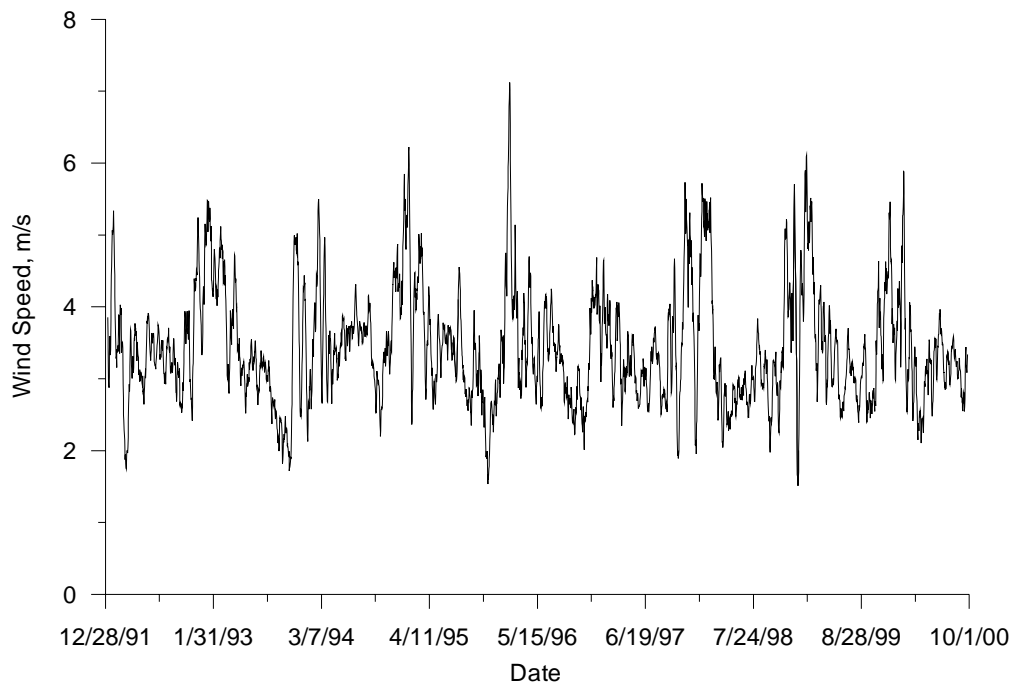


Figure 35. Wind Speed, m/s, 10 day moving average at the Portland International Airport, 1992-2000

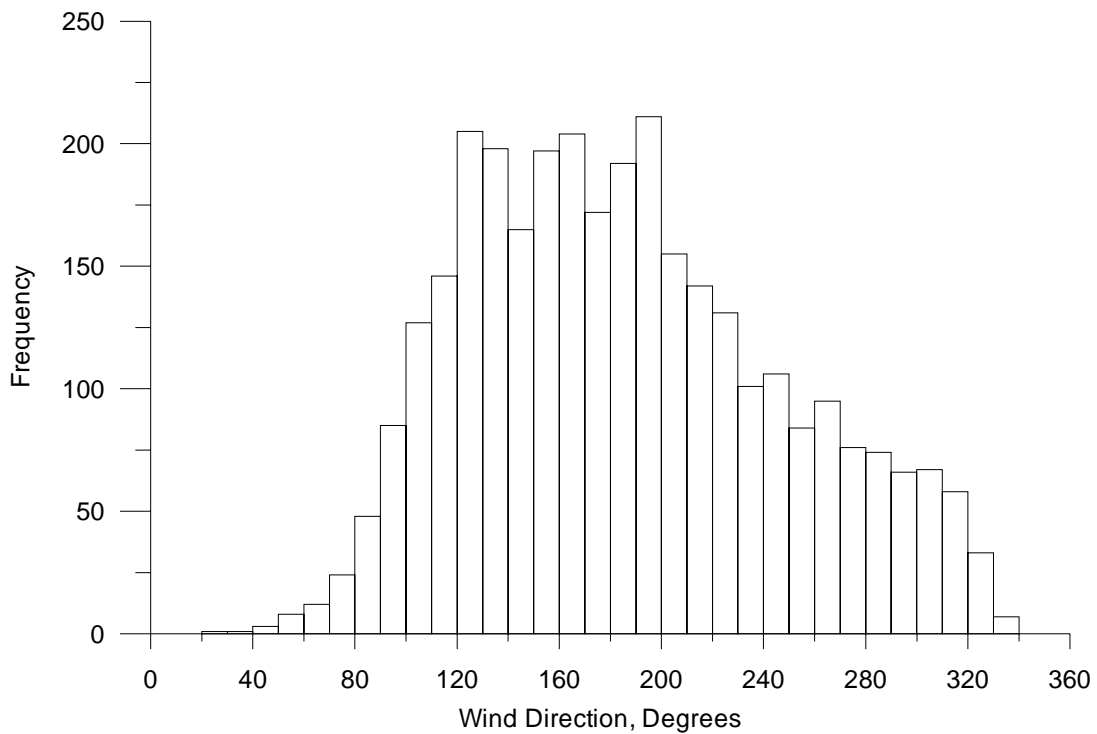


Figure 36. Wind Direction, degrees, 10 day moving average at the Portland International Airport, 1992-2000

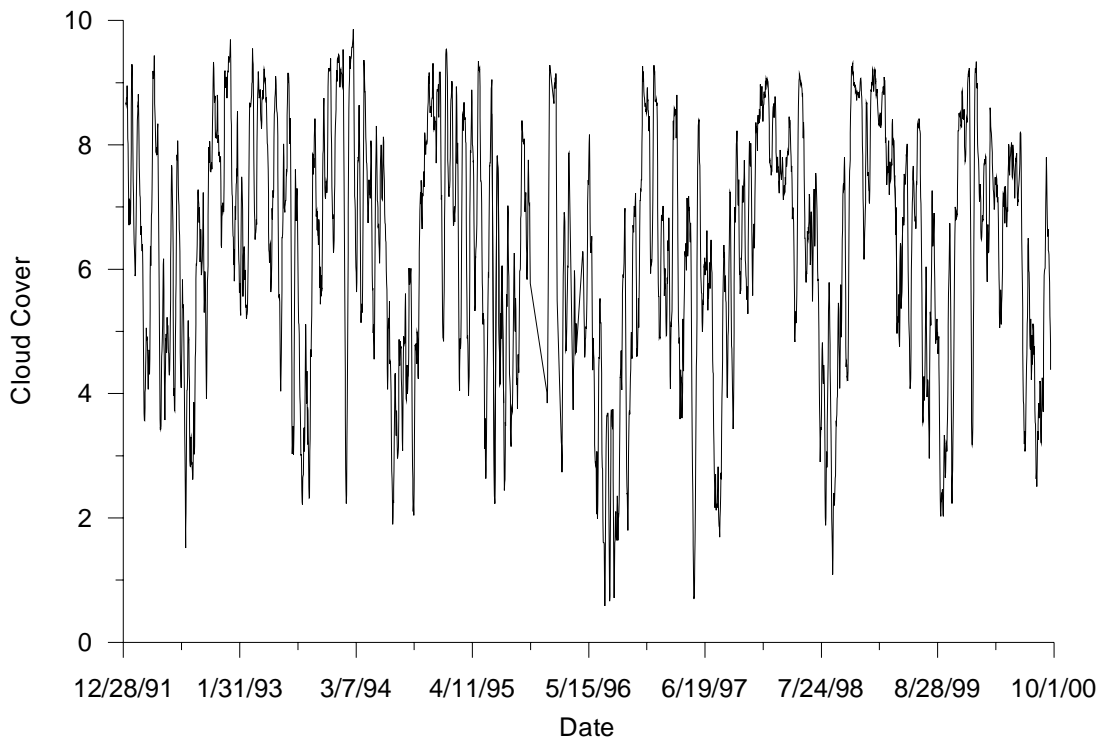


Figure 37. Cloud Cover 10 day moving average at the Portland International Airport, 1992-2000

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.

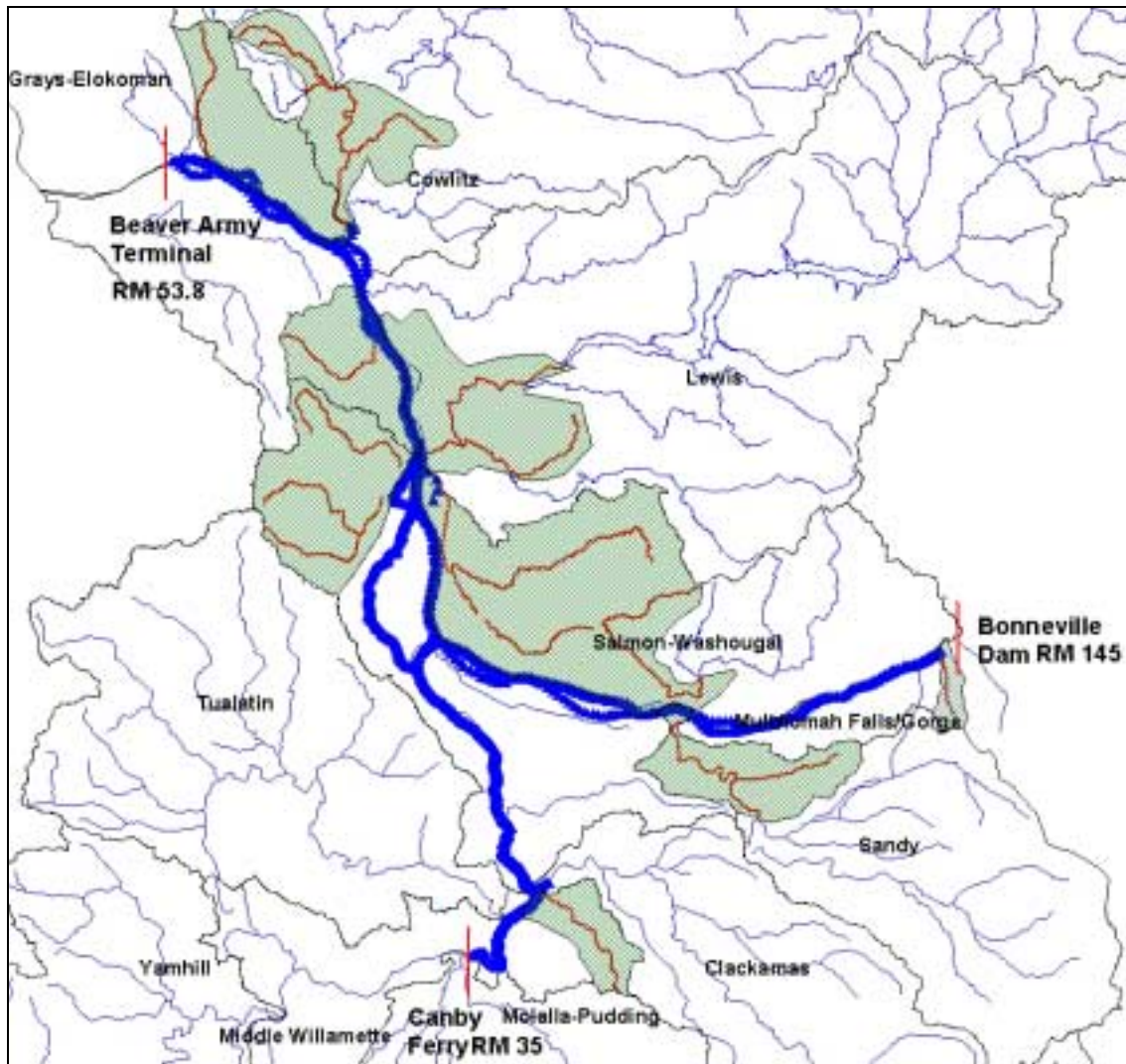


Figure 38. Columbia and Willamette River tributary inflows, shaded basins have no flow data

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

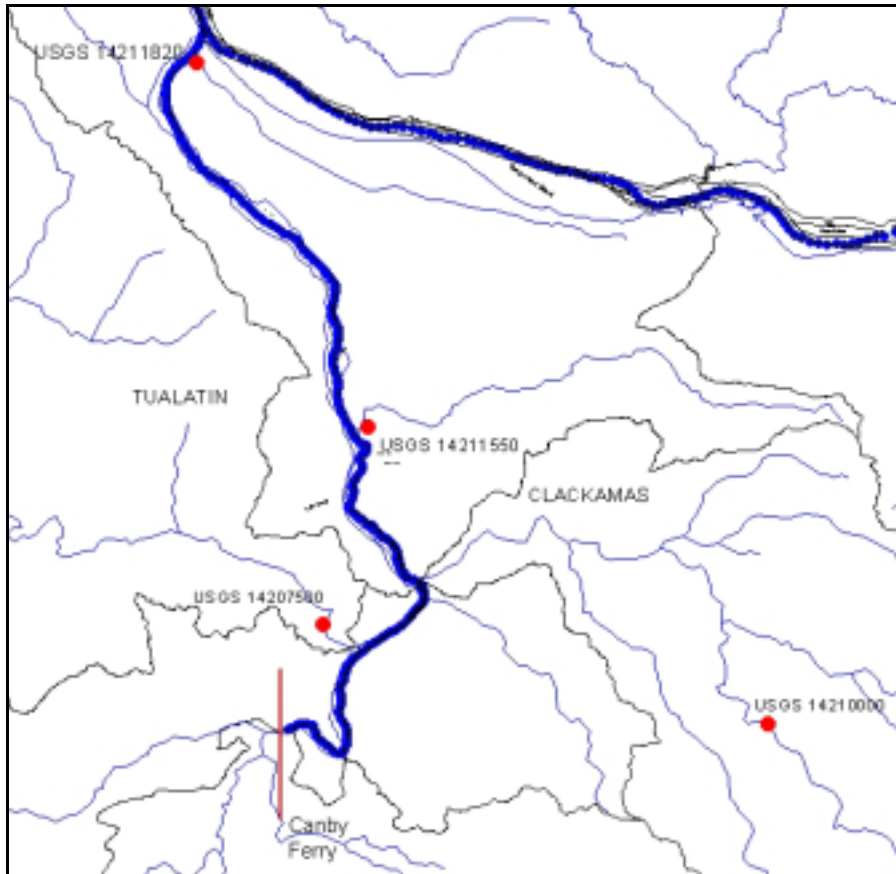


Figure 39. USGS gage stations in the Willamette River Basin

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.

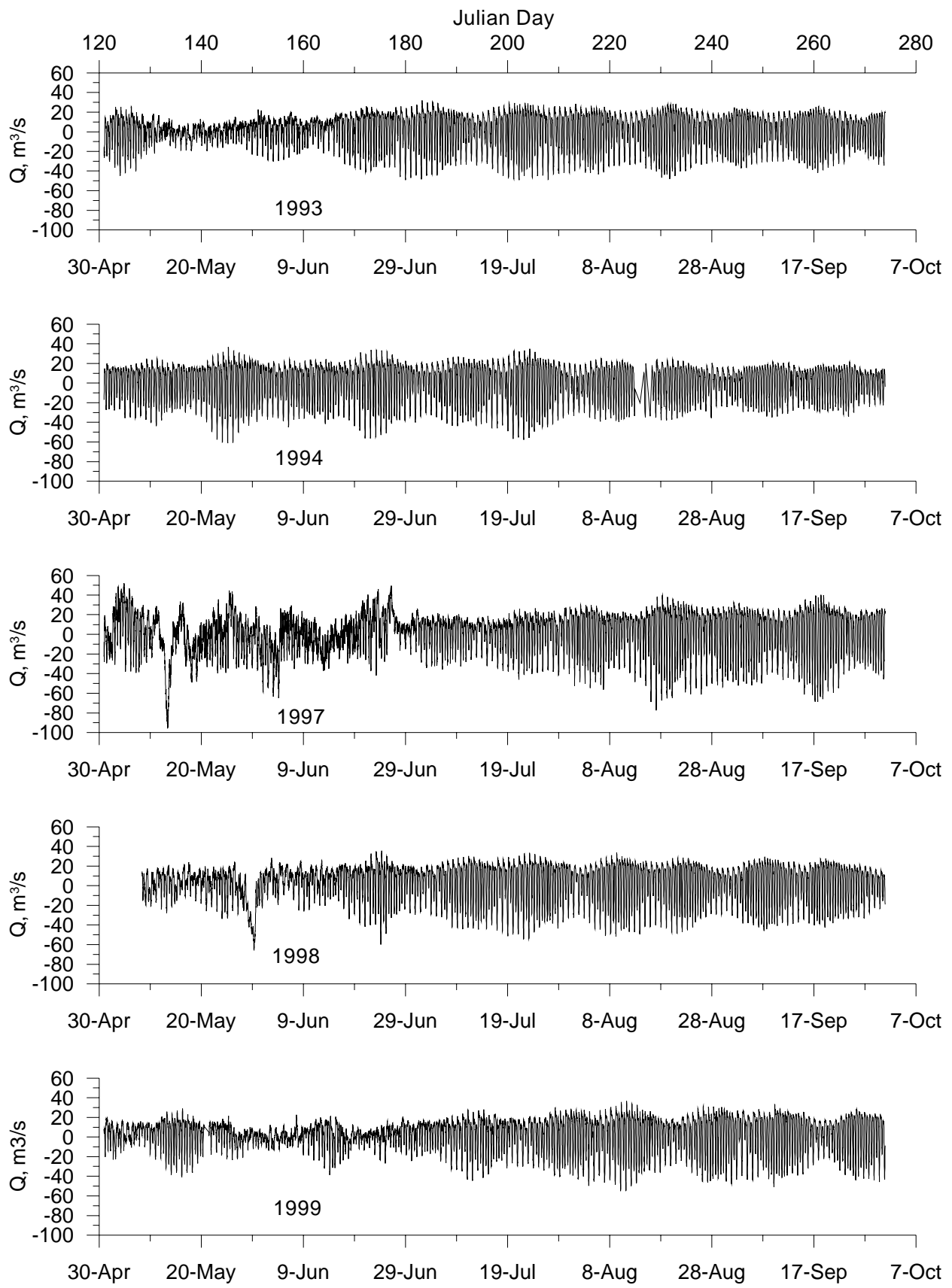


Figure 40. Columbia Slough flow, m^3/s

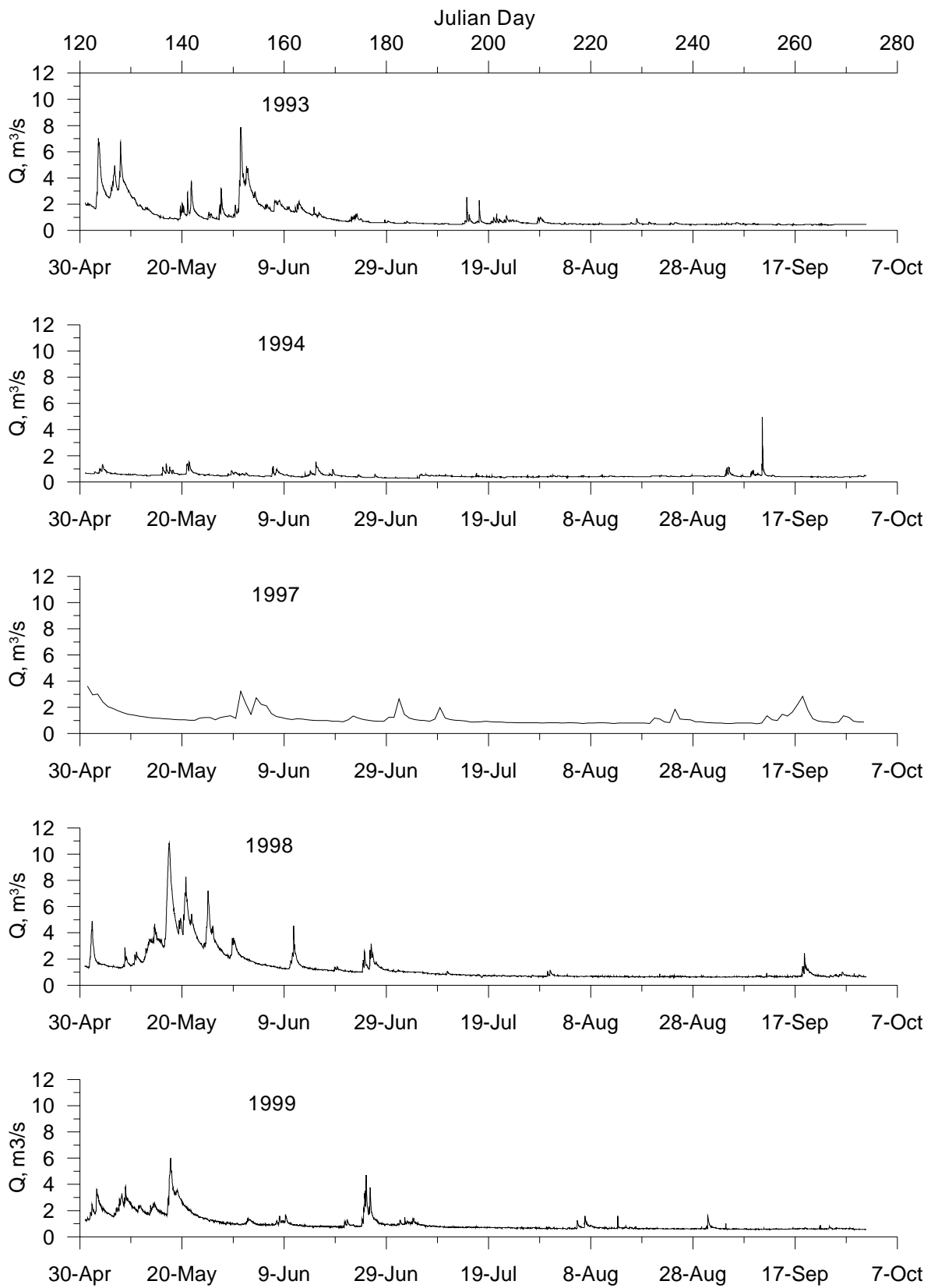


Figure 41. Johnson Creek flow, m³/s

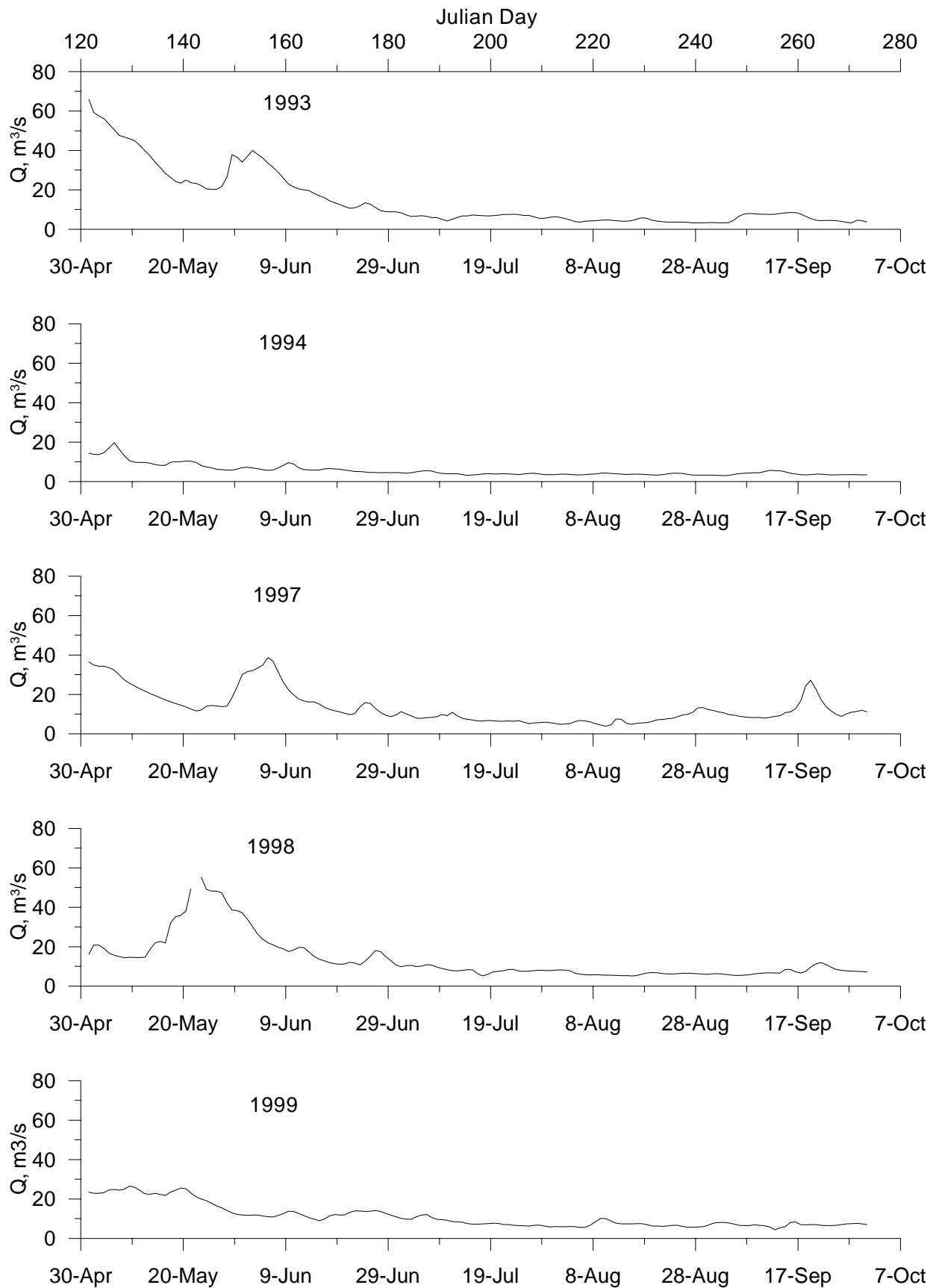


Figure 42. Tualatin River flow, m³/s

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.

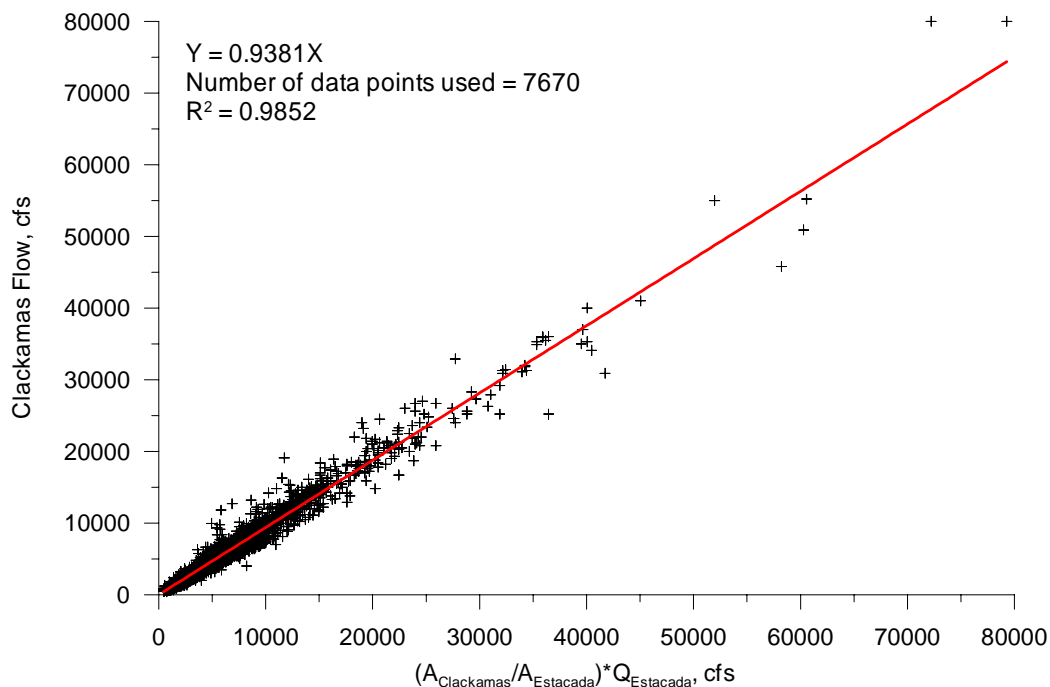


Figure 43. Clackamas River near Clackamas and Clackamas River at Estacada Flow Correlation, Year 1962 to 1983

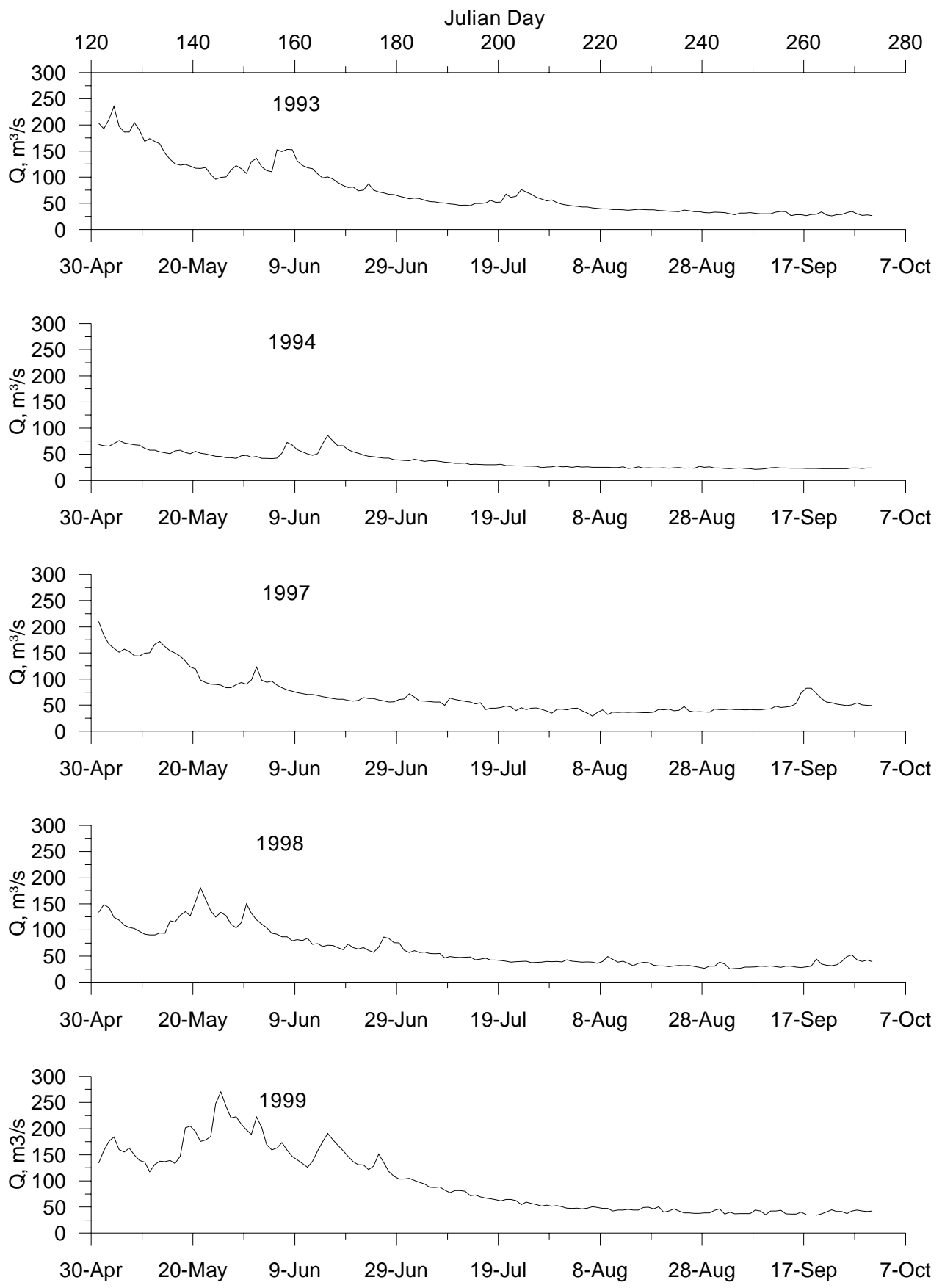


Figure 44. Clackamas River flow, m³/s

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: $LOM\ Temp(C^{\circ}) = 0.9118(SJB\ Temp(C^{\circ})) + 0.6183$ ($R^2 = 0.9584$). 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.

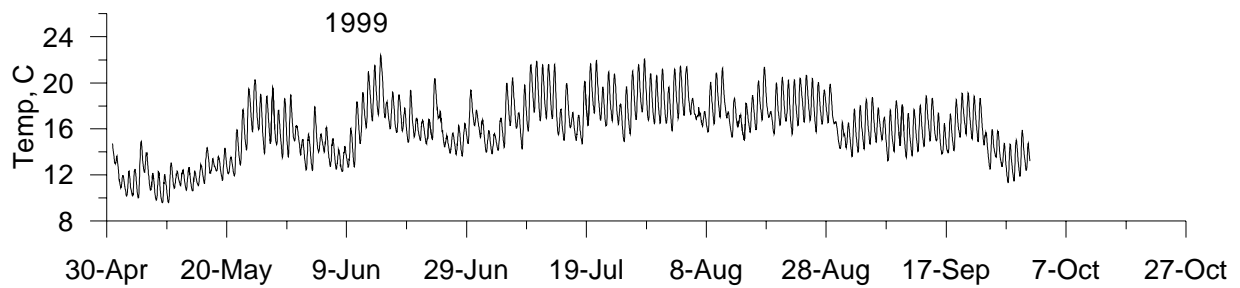
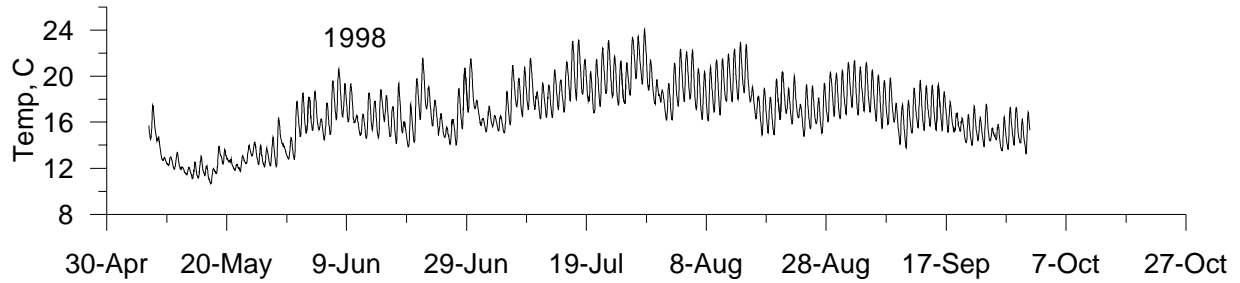
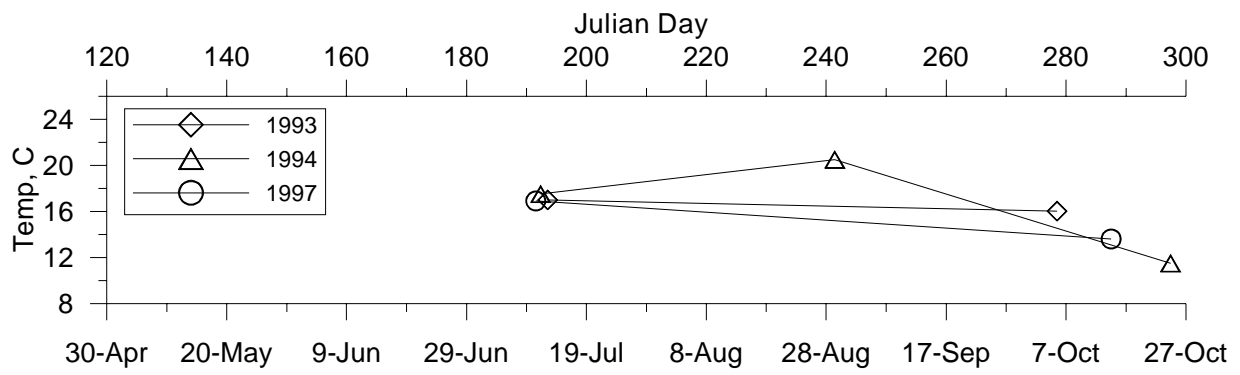


Figure 45. Johnson Creek water temperature, °C

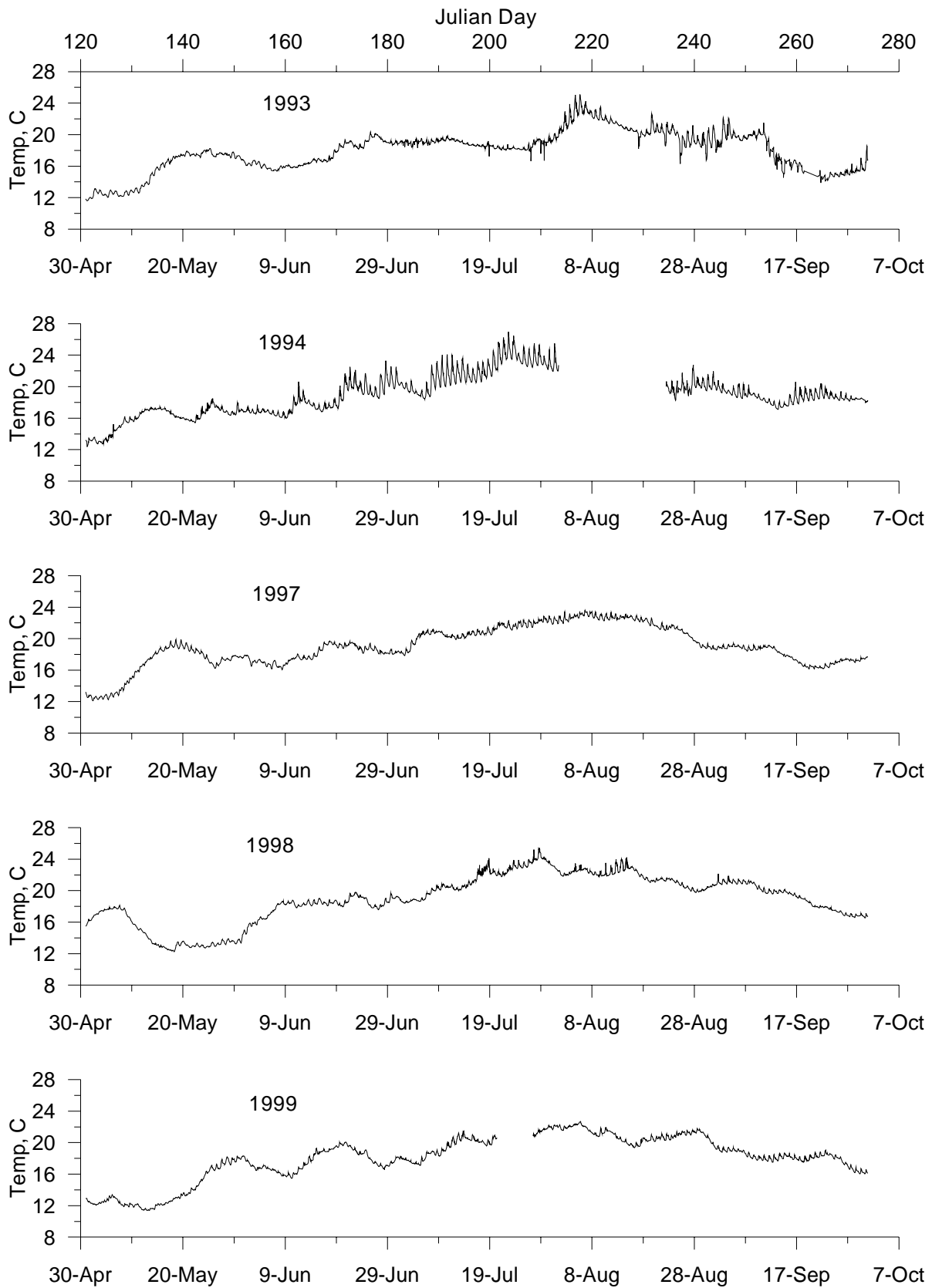


Figure 46. Tualatin River water temperature, °C

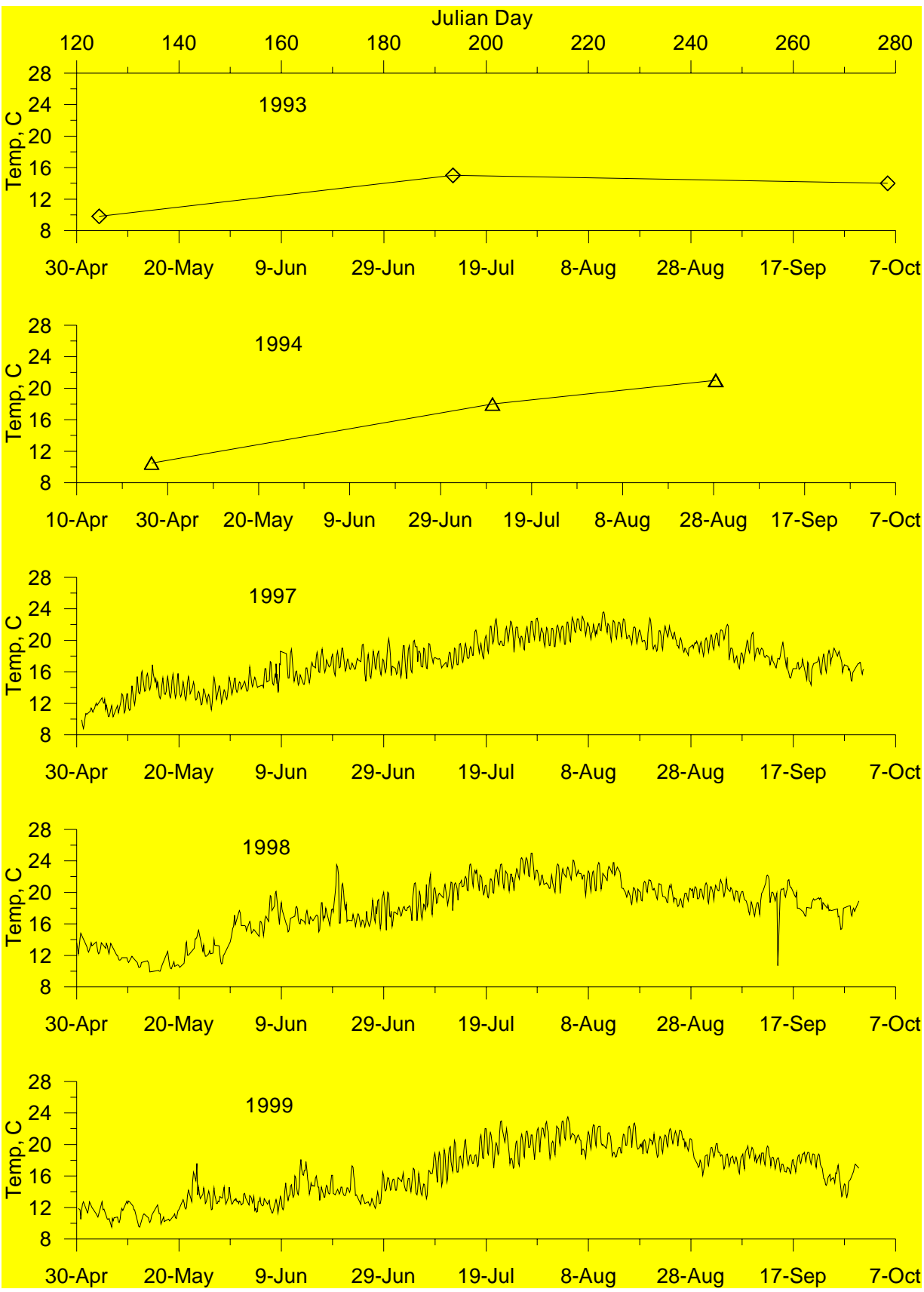


Figure 47. Clackamas River water temperature, °C

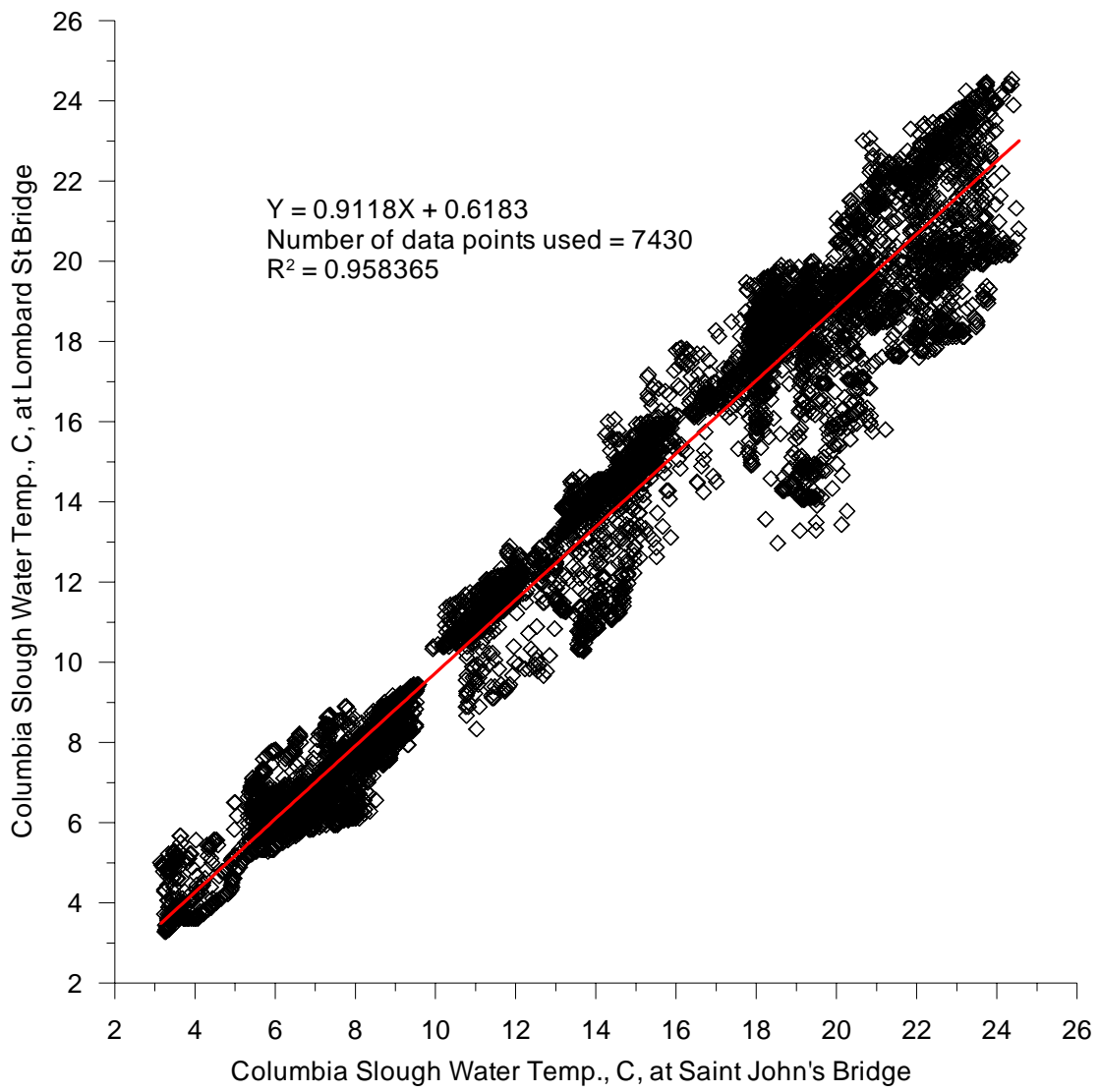


Figure 48. Columbia Slough Water Temperature Correlation

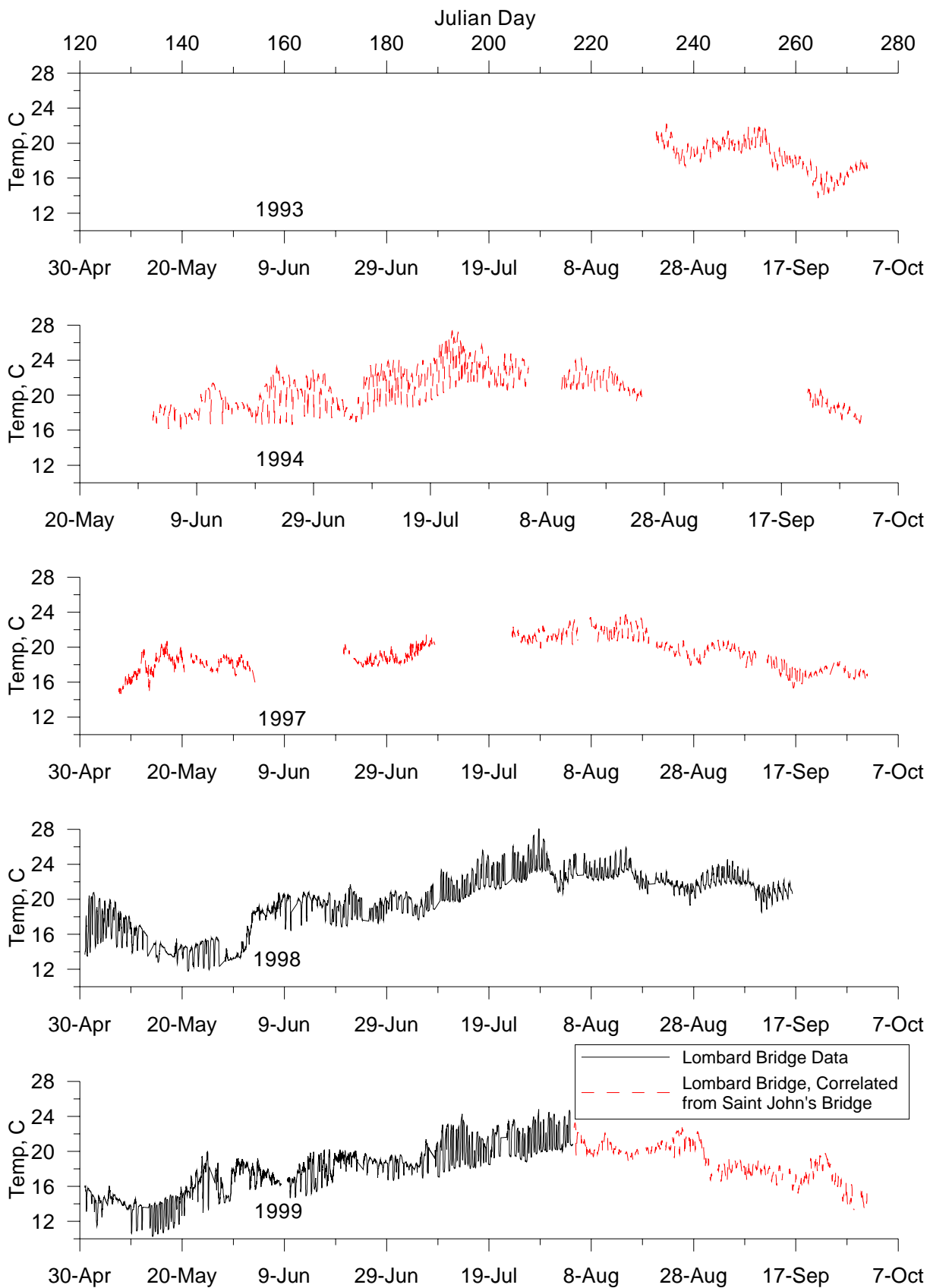


Figure 49. Columbia Slough water temperature, °C

Parameter	Clackamas River	Johnson Creek	Tualatin River	Columbia Slough
ALKALINITY 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.

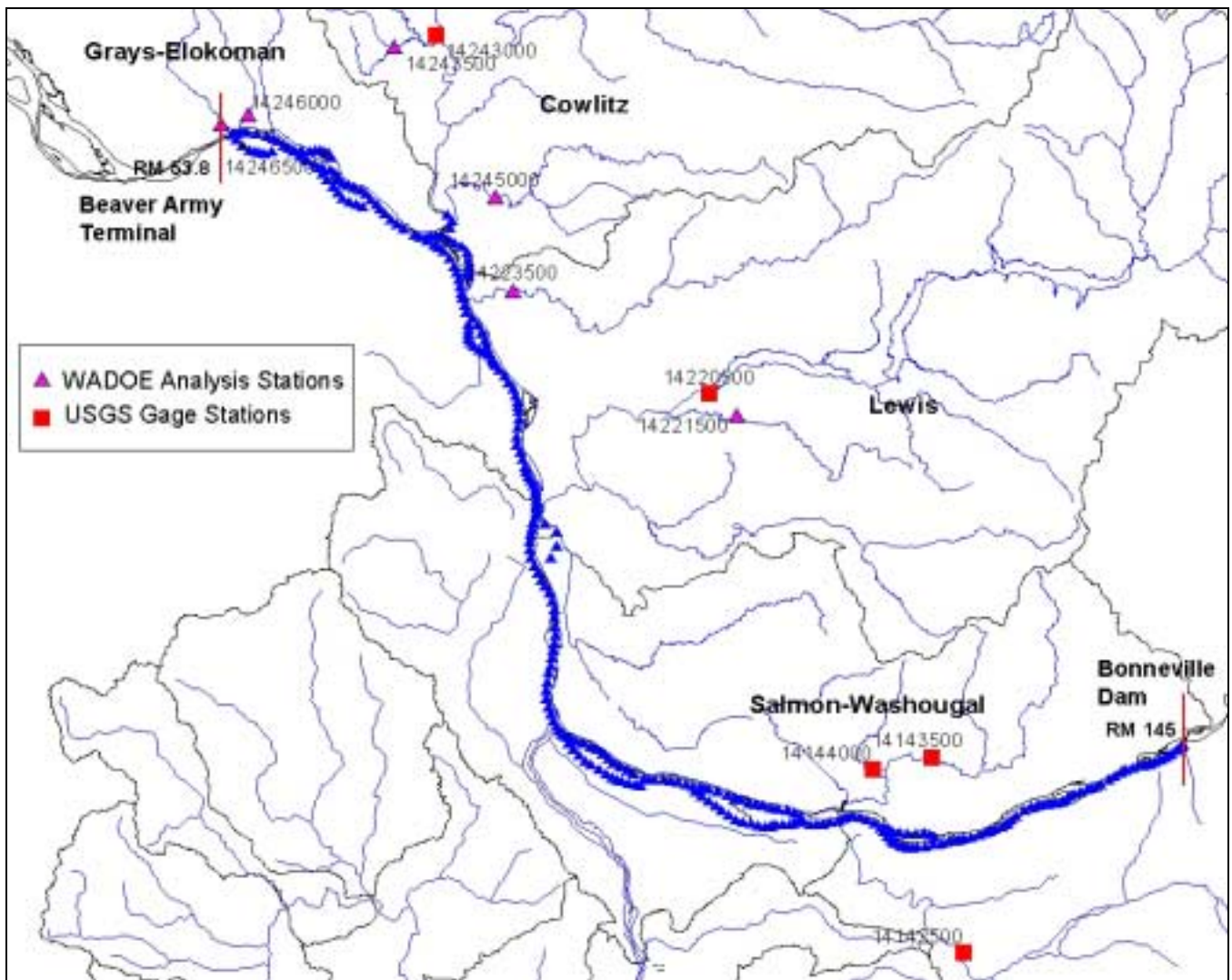


Figure 50. Columbia River Tributary gage stations



Figure 51. Washington basins considered in the model

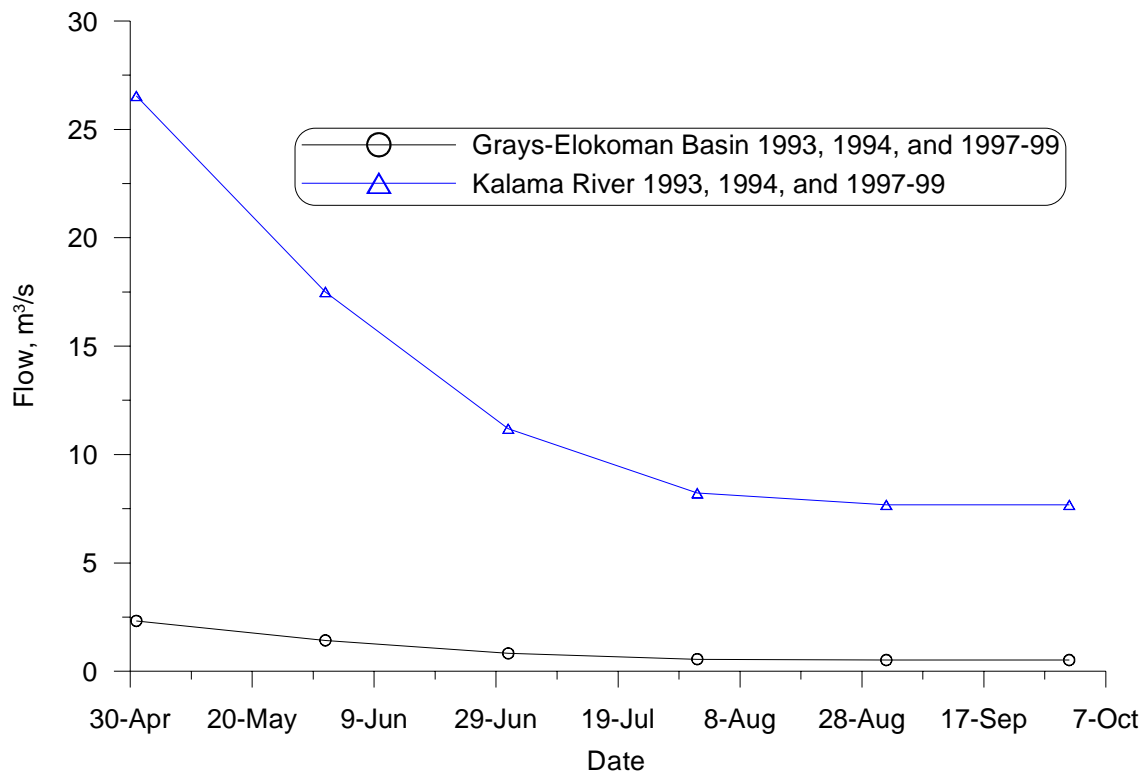


Figure 52. Grays-Elokoman Basin and Kalama River flows, m³/s

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.

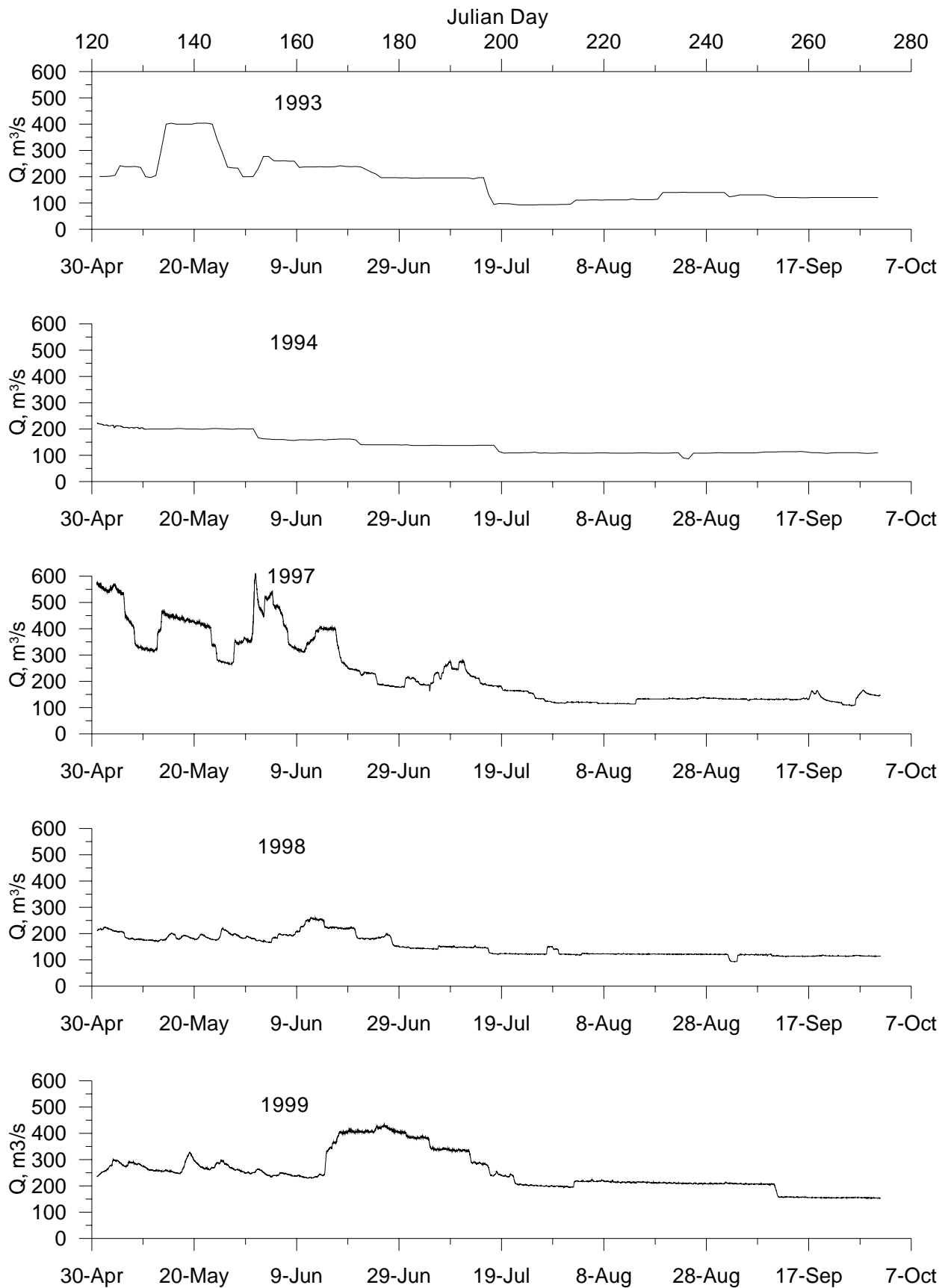


Figure 53. Cowlitz River flow, m³/s

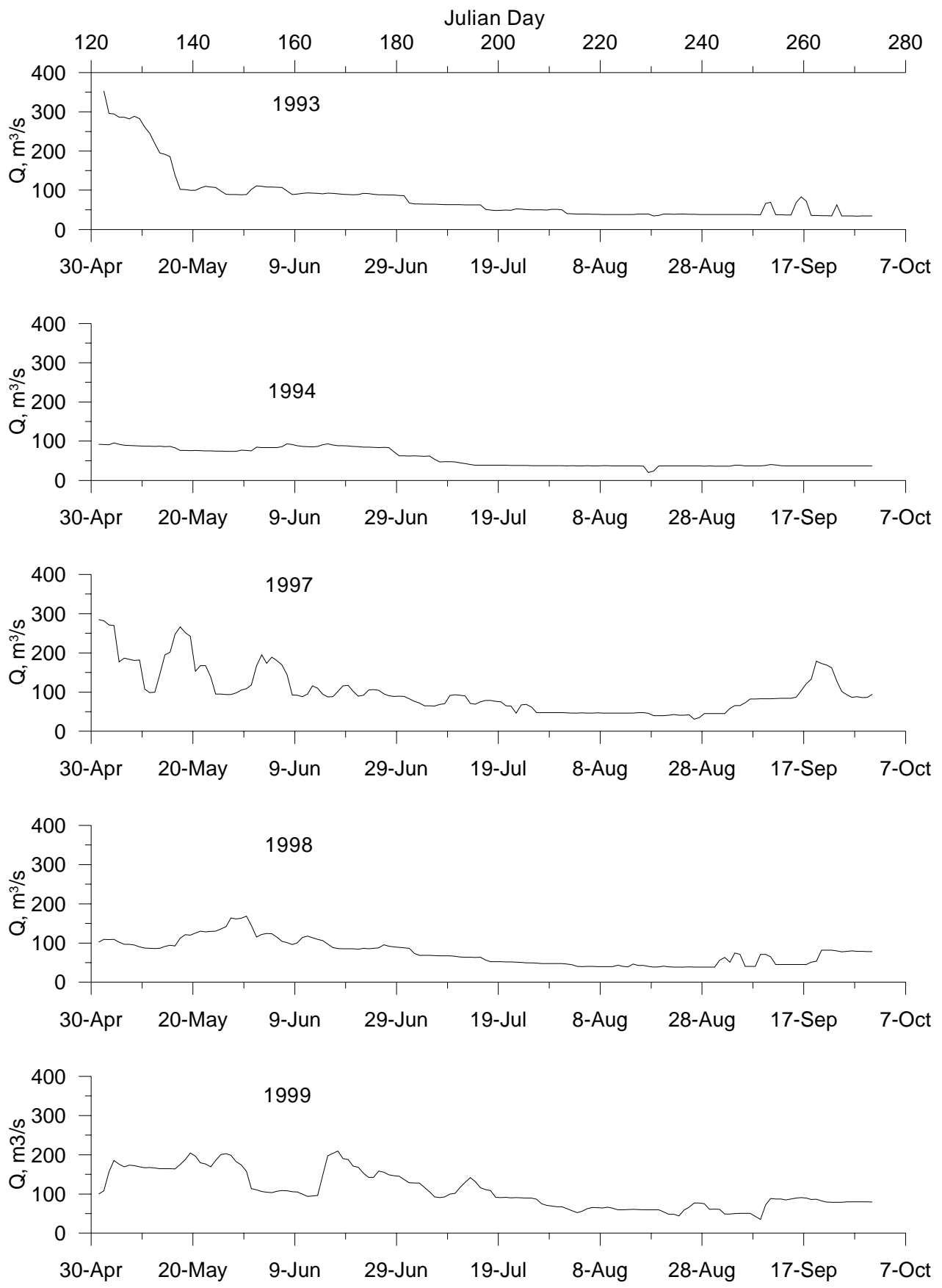


Figure 54. Lewis River flow, m^3/s

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 ($R^2 = 0.9744$).

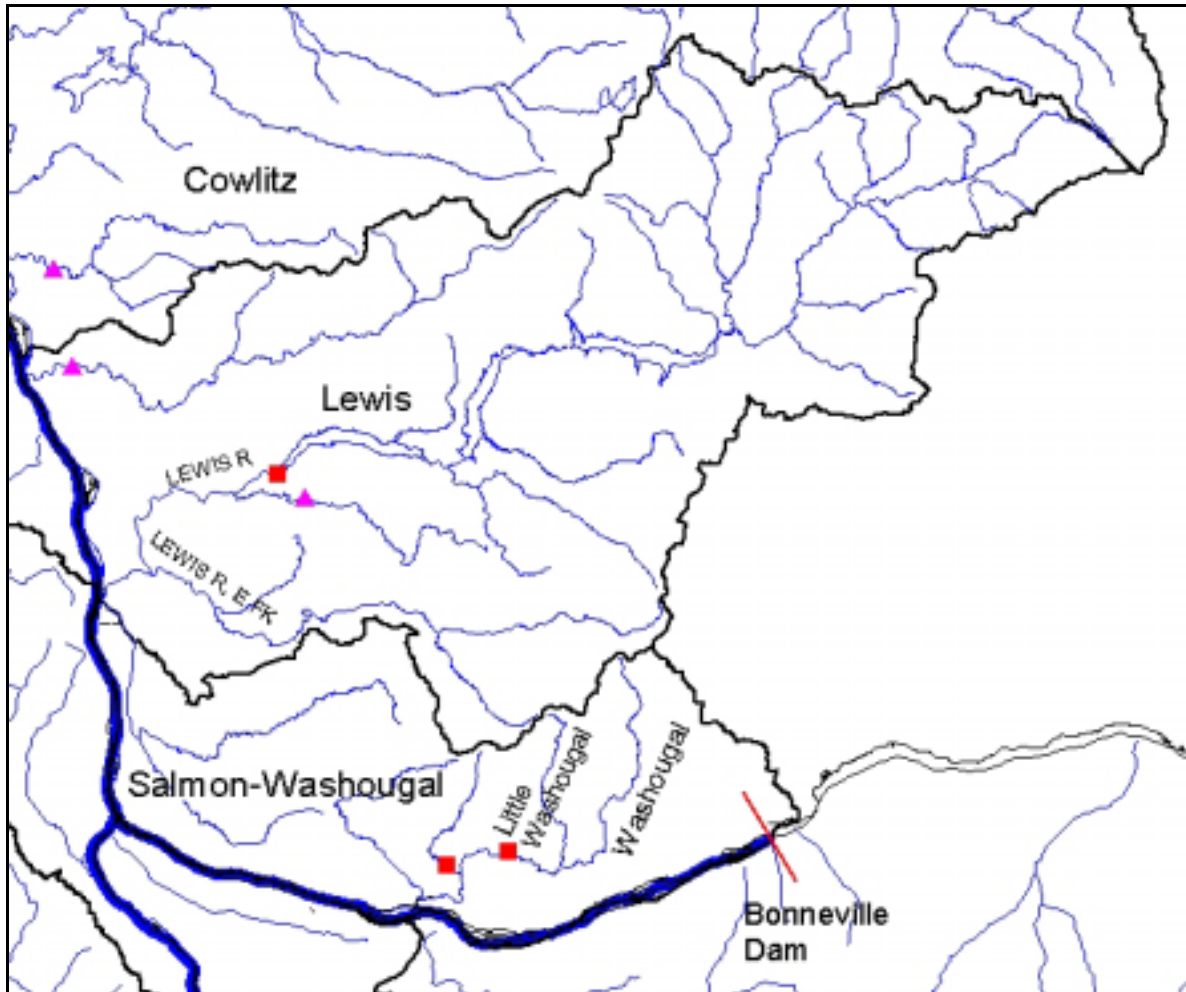


Figure 55. Lewis and Washougal River Basin

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.

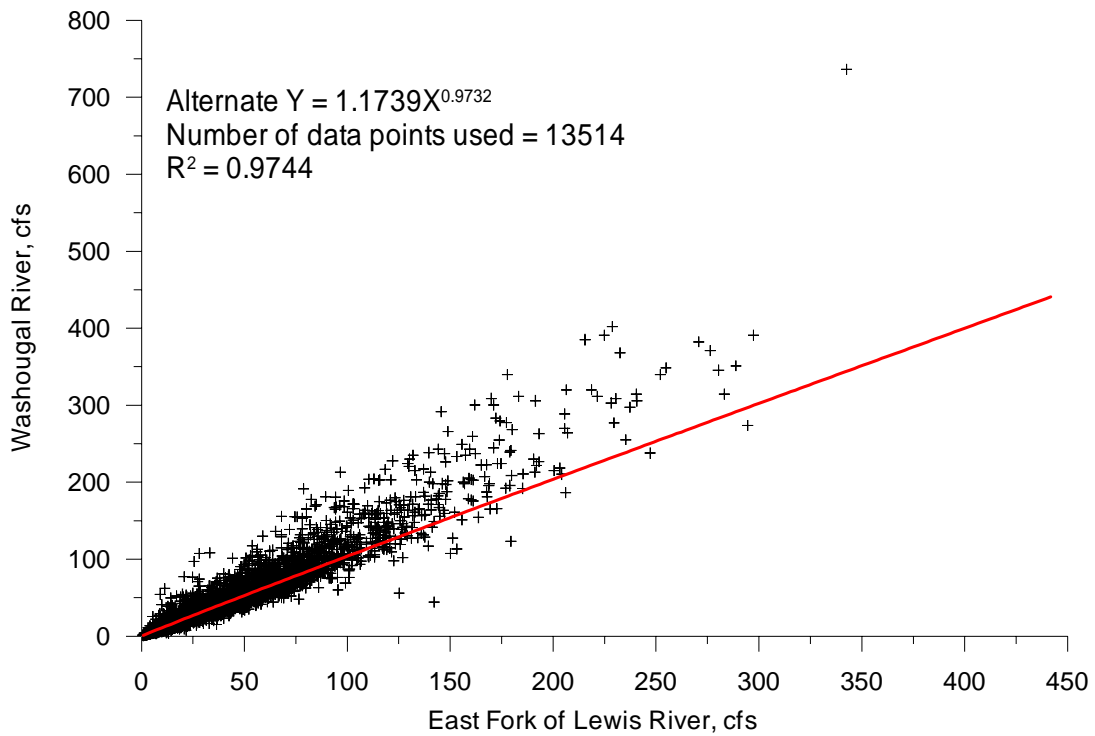


Figure 56. East Fork of Lewis River and Washougal River correlation, Year 1944 to 1981

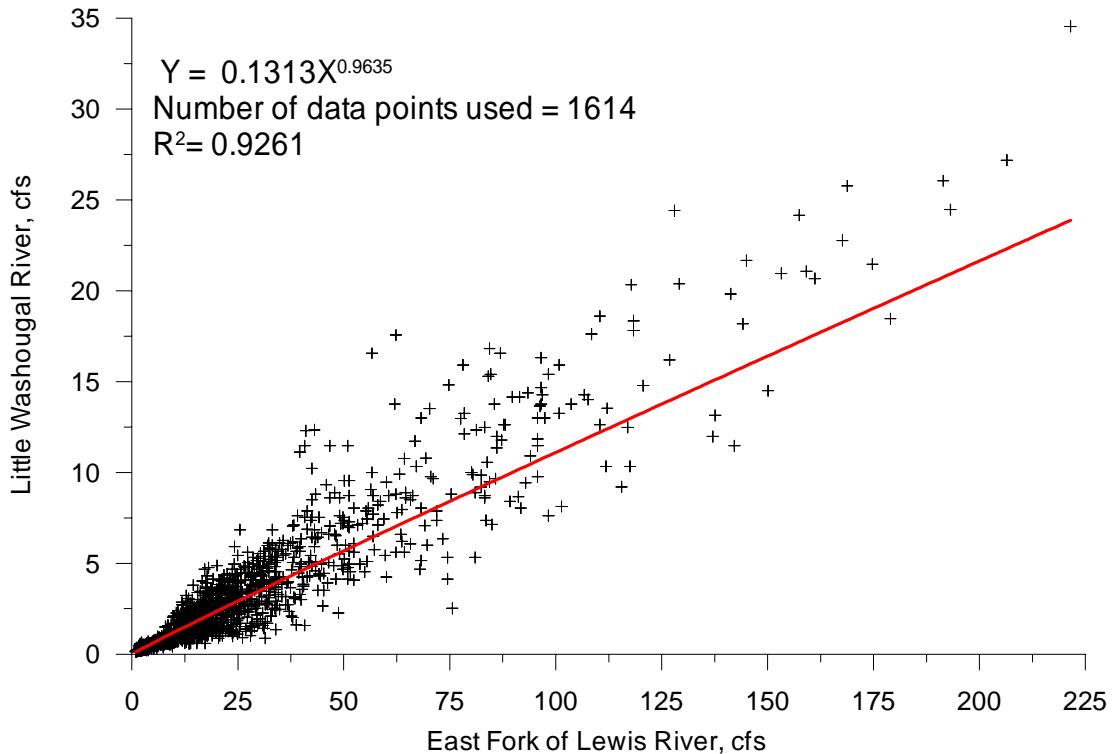


Figure 57. East Fork of Lewis River and Little Washougal River correlation, Year 1951 to 1955

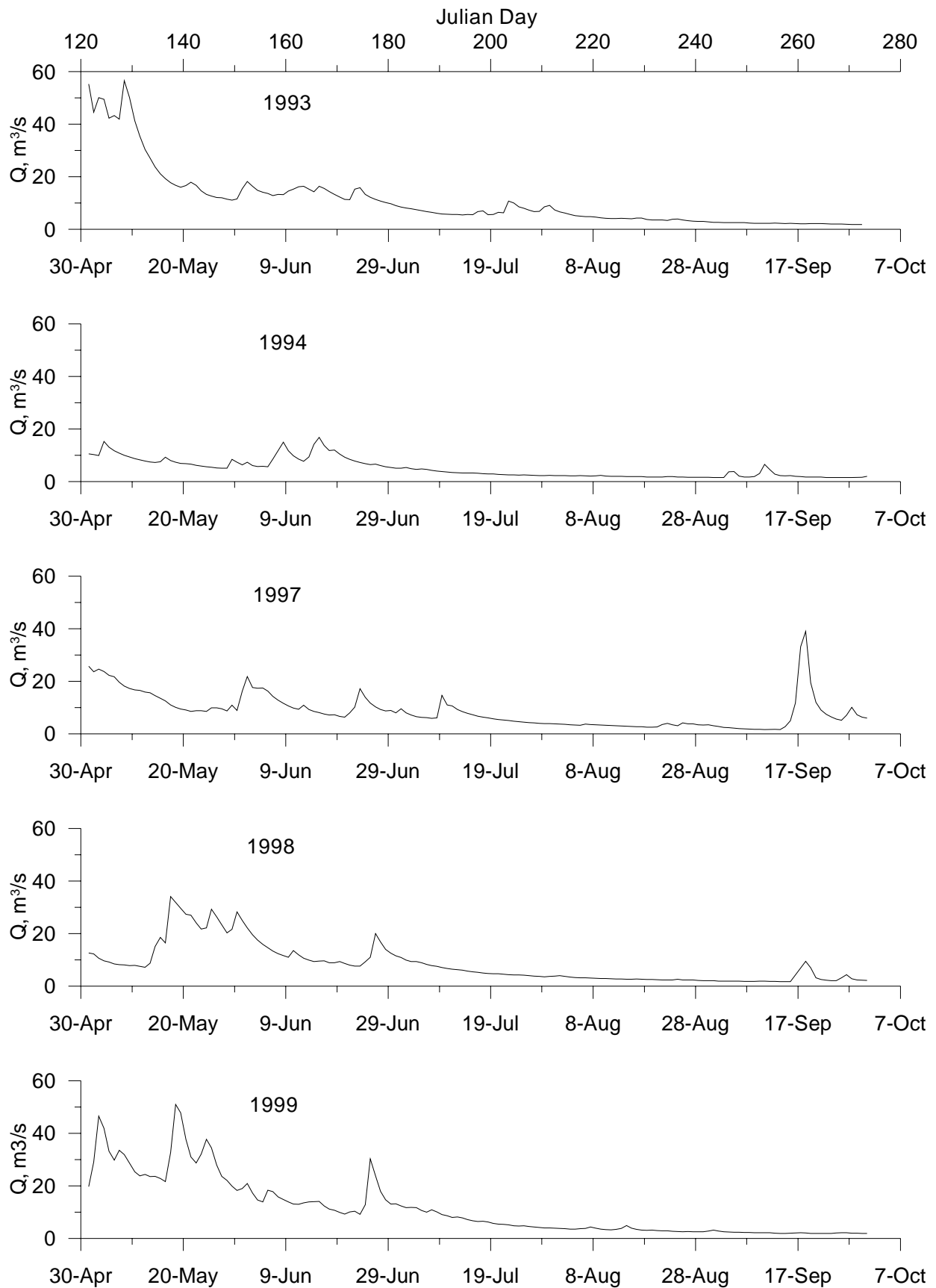


Figure 58. Washougal River flow, m³/s

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.

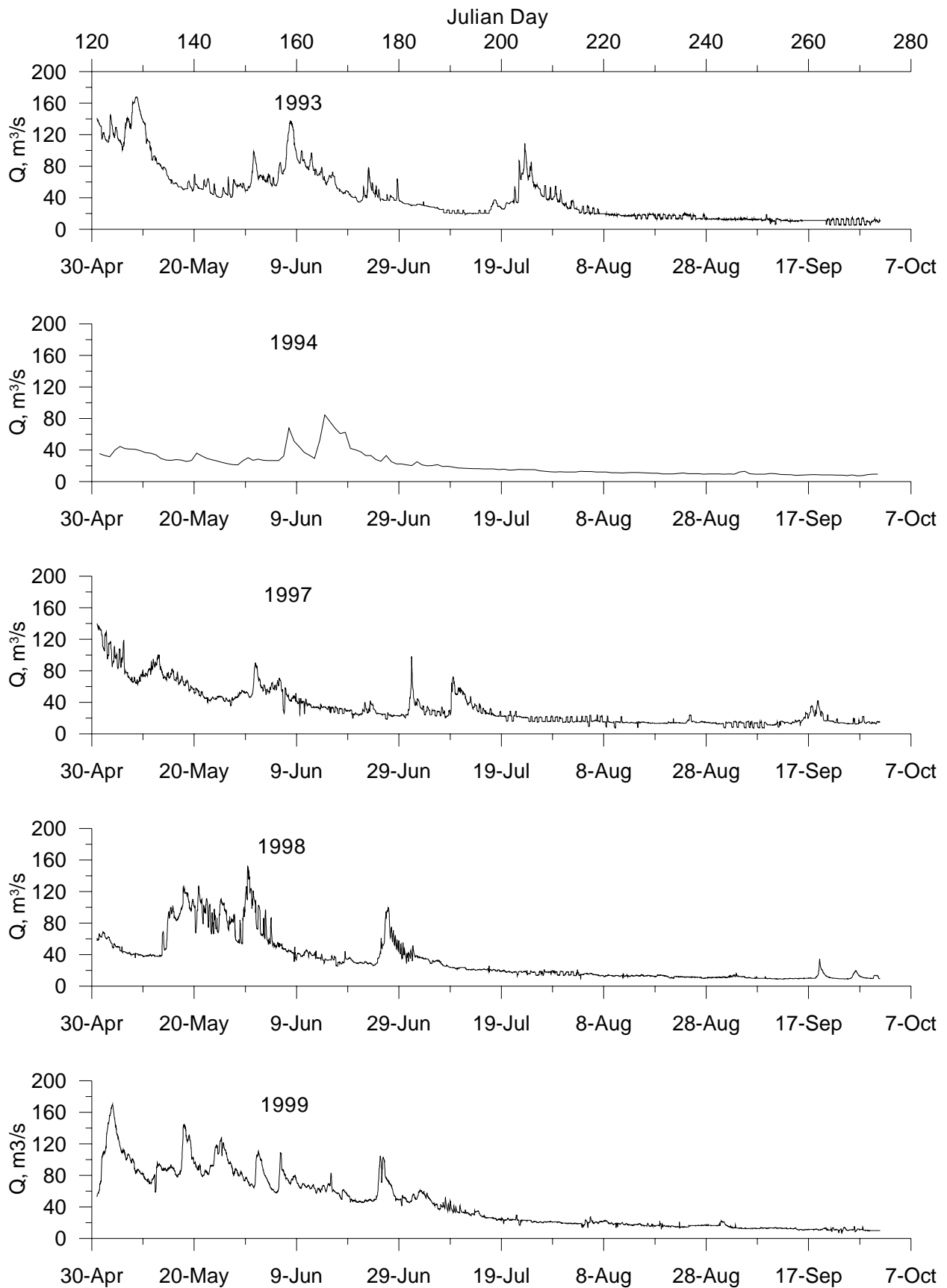


Figure 59. Sandy River flow, m^3/s

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.

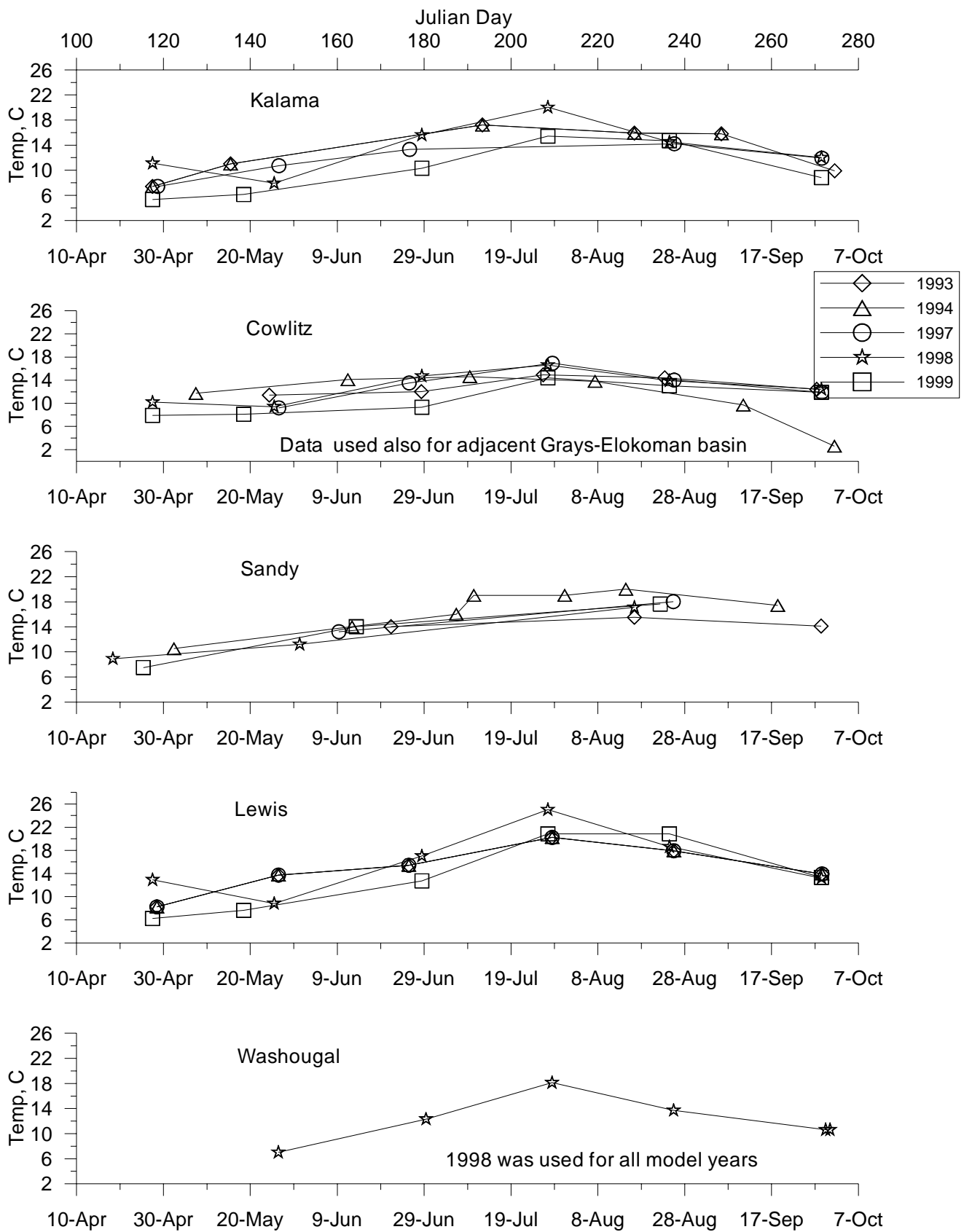


Figure 60. Washington Tributary water temperatures, °C

Parameter	Cowlitz River	Kalama River	EF Lewis River	Washougal River	Sandy River
ALKALINITY 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 is 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

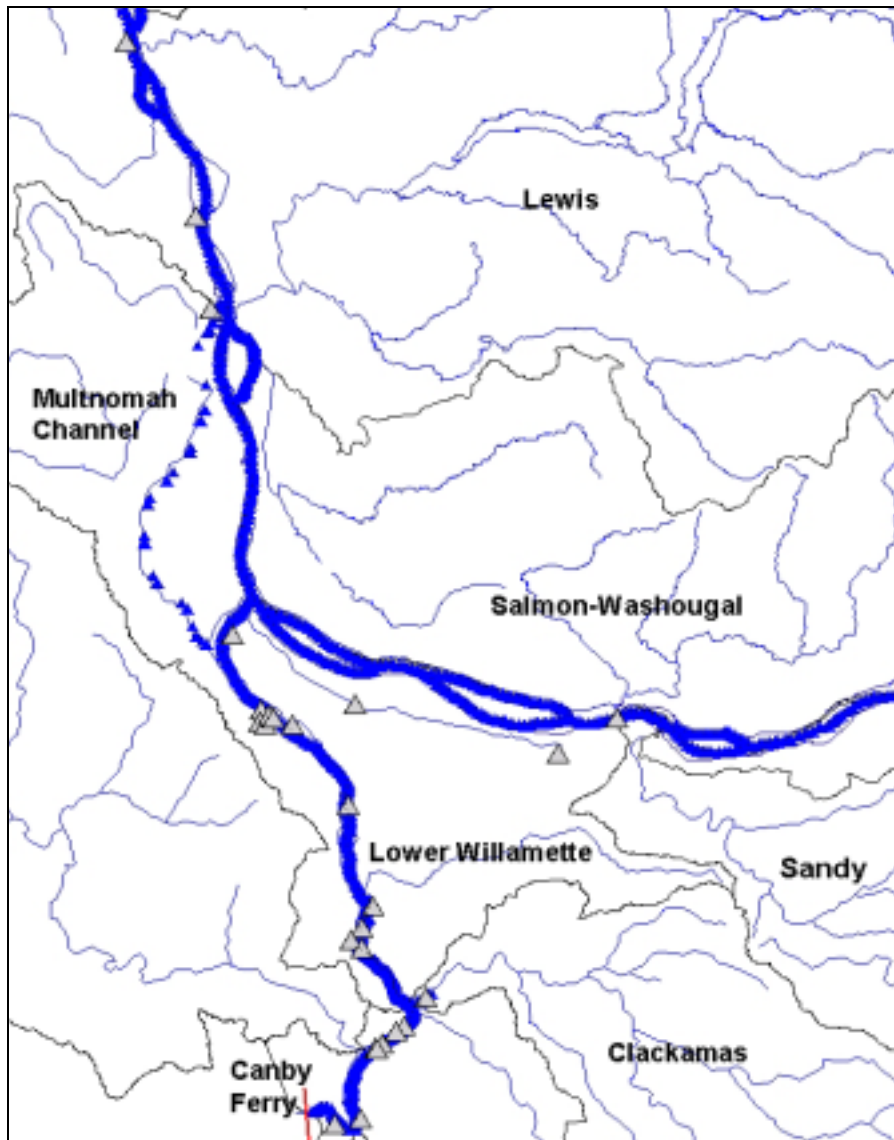


Figure 61. Oregon Point Source locations

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.

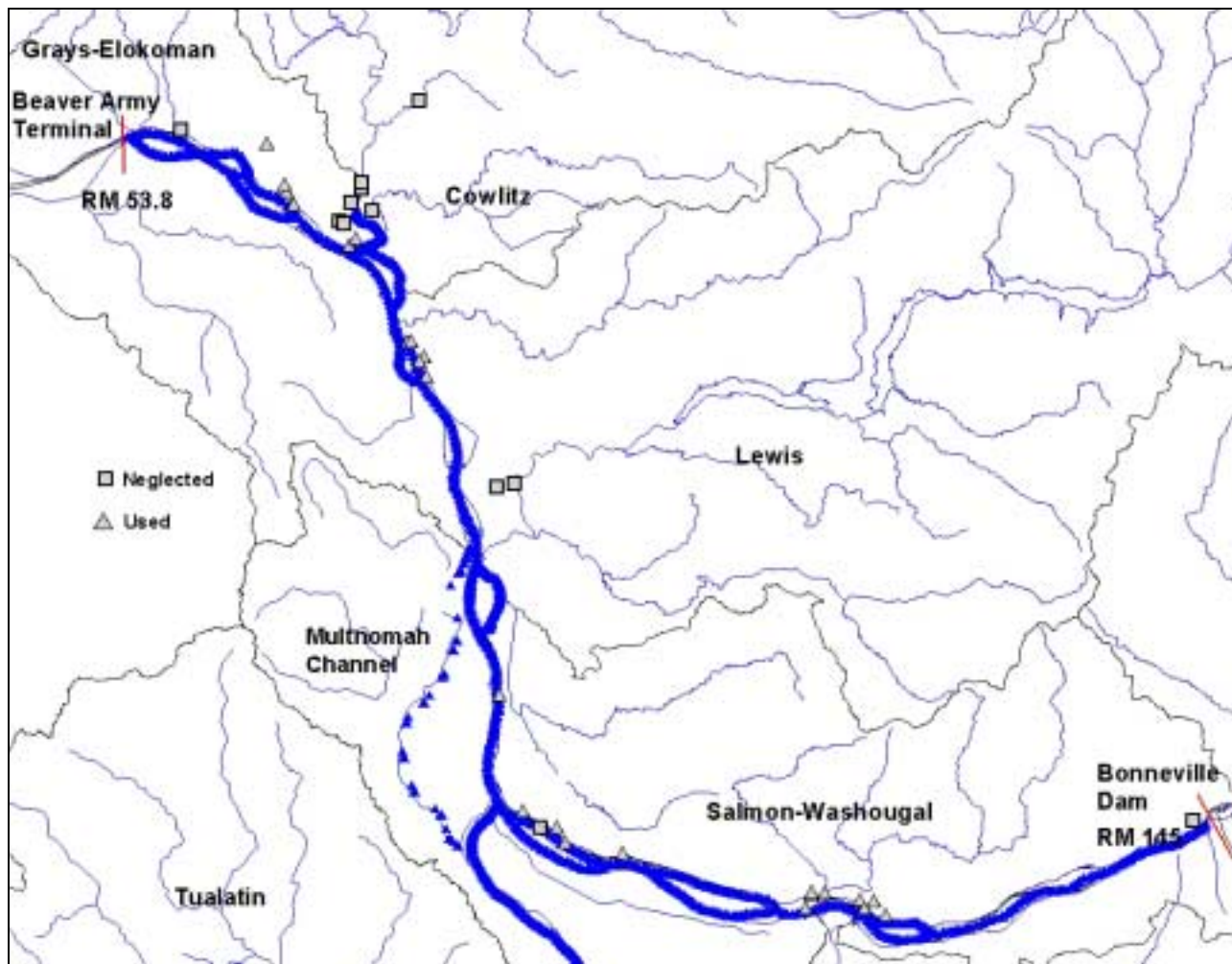


Figure 62. Washington Point Source locations

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.

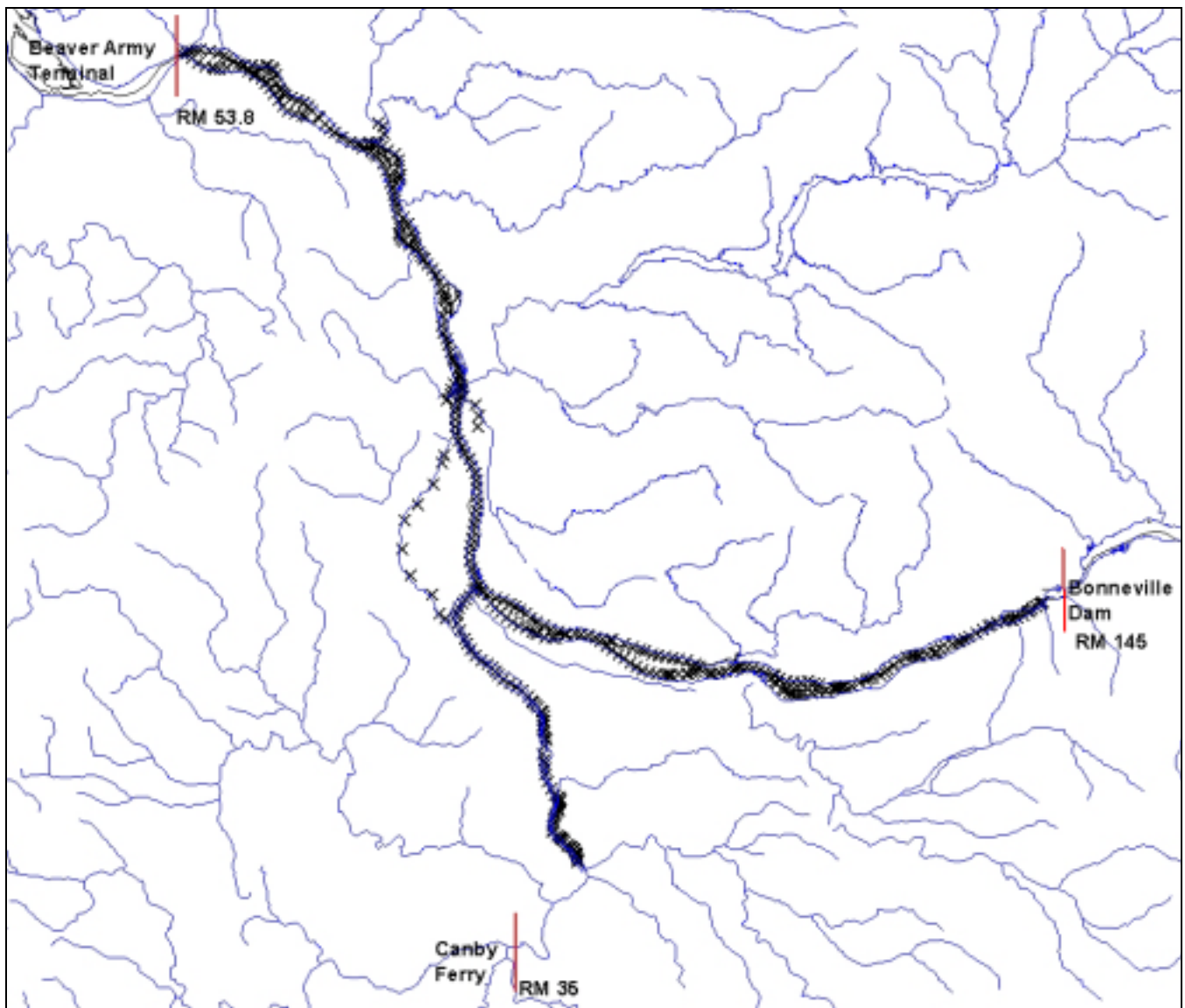


Figure 63. Columbia and Willamette River cross-section locations

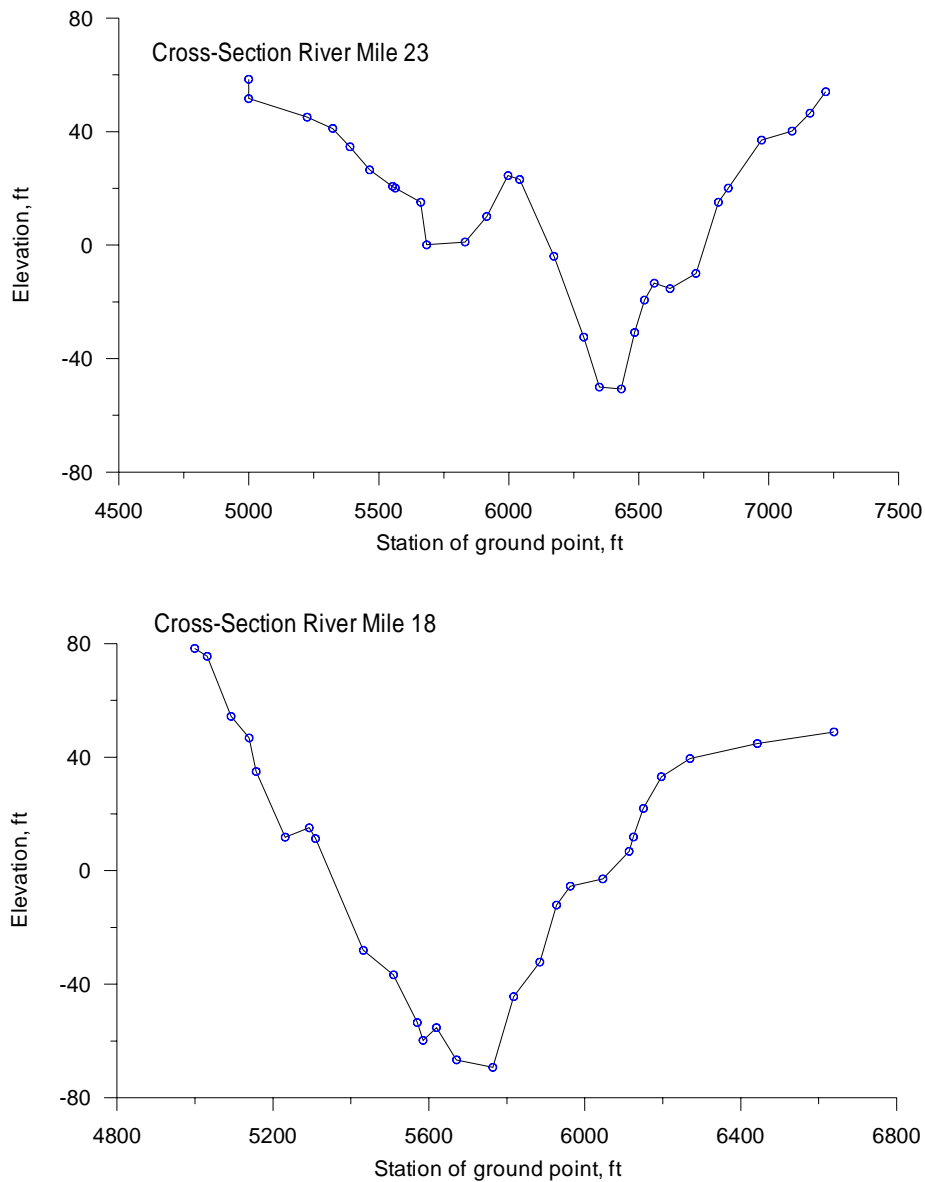


Figure 64. Willamette River cross-sections RM 18 and 23

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.

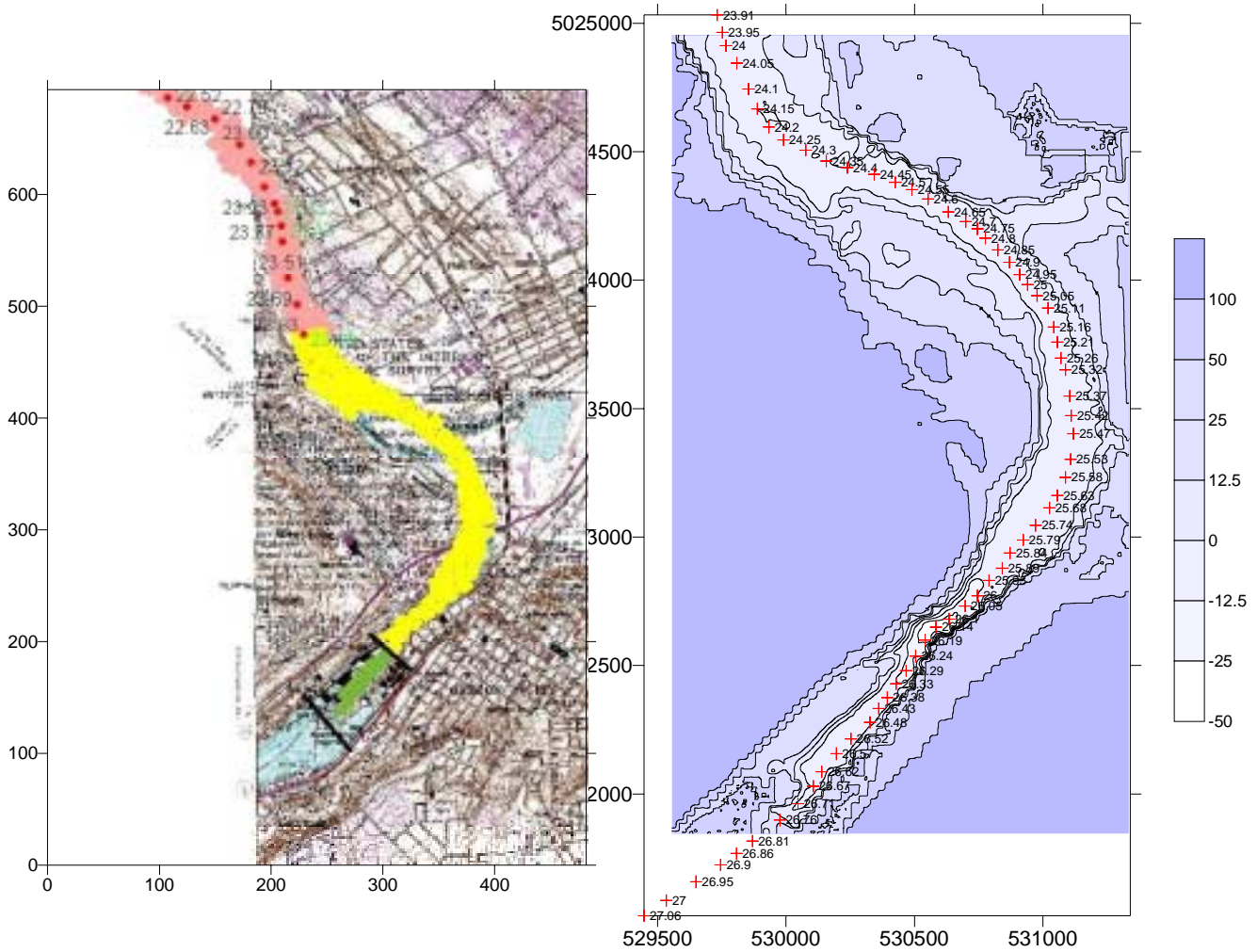


Figure 65. Willamette River Bathymetry RM 24 to 26.8

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.

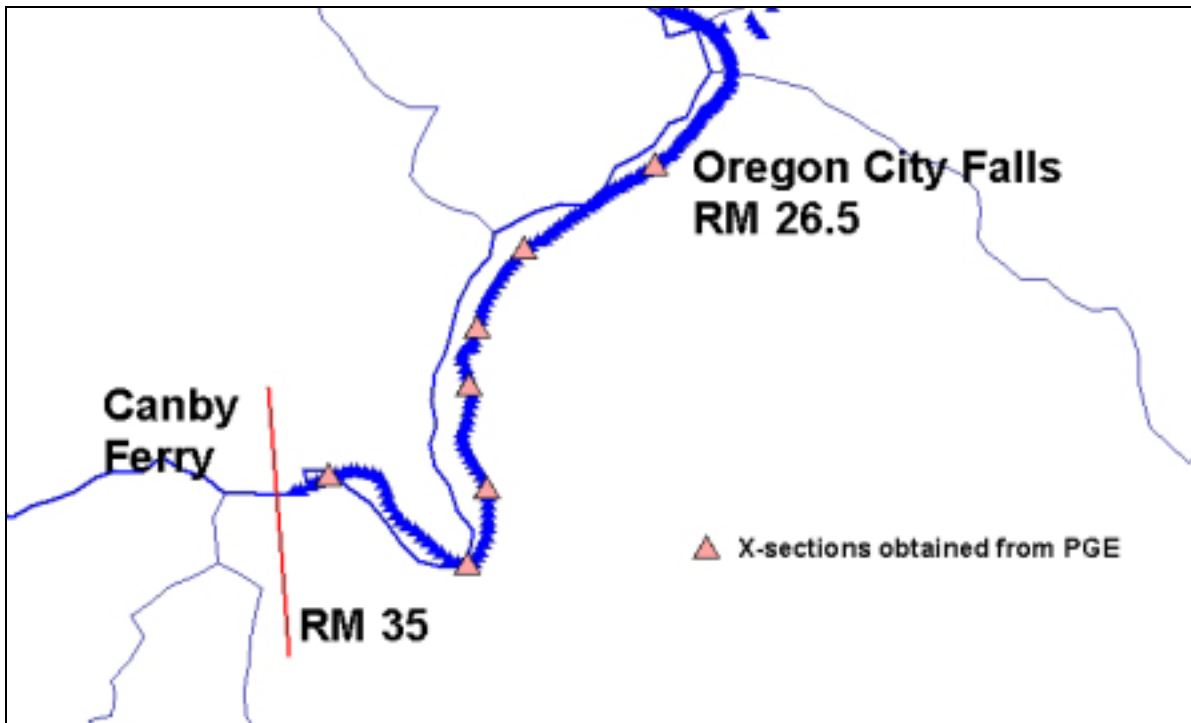


Figure 66. Willamette River cross-sections locations from PGE

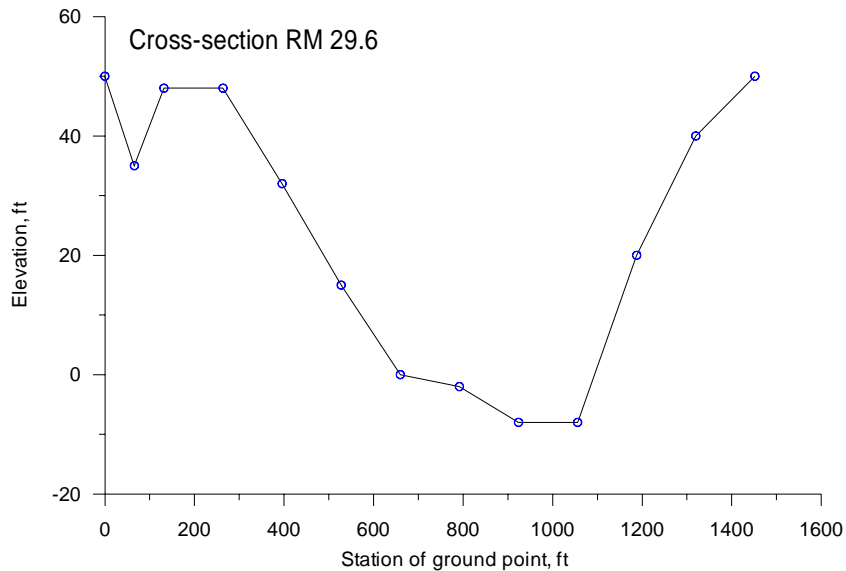


Figure 67. Willamette River cross-section RM 29.6

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.

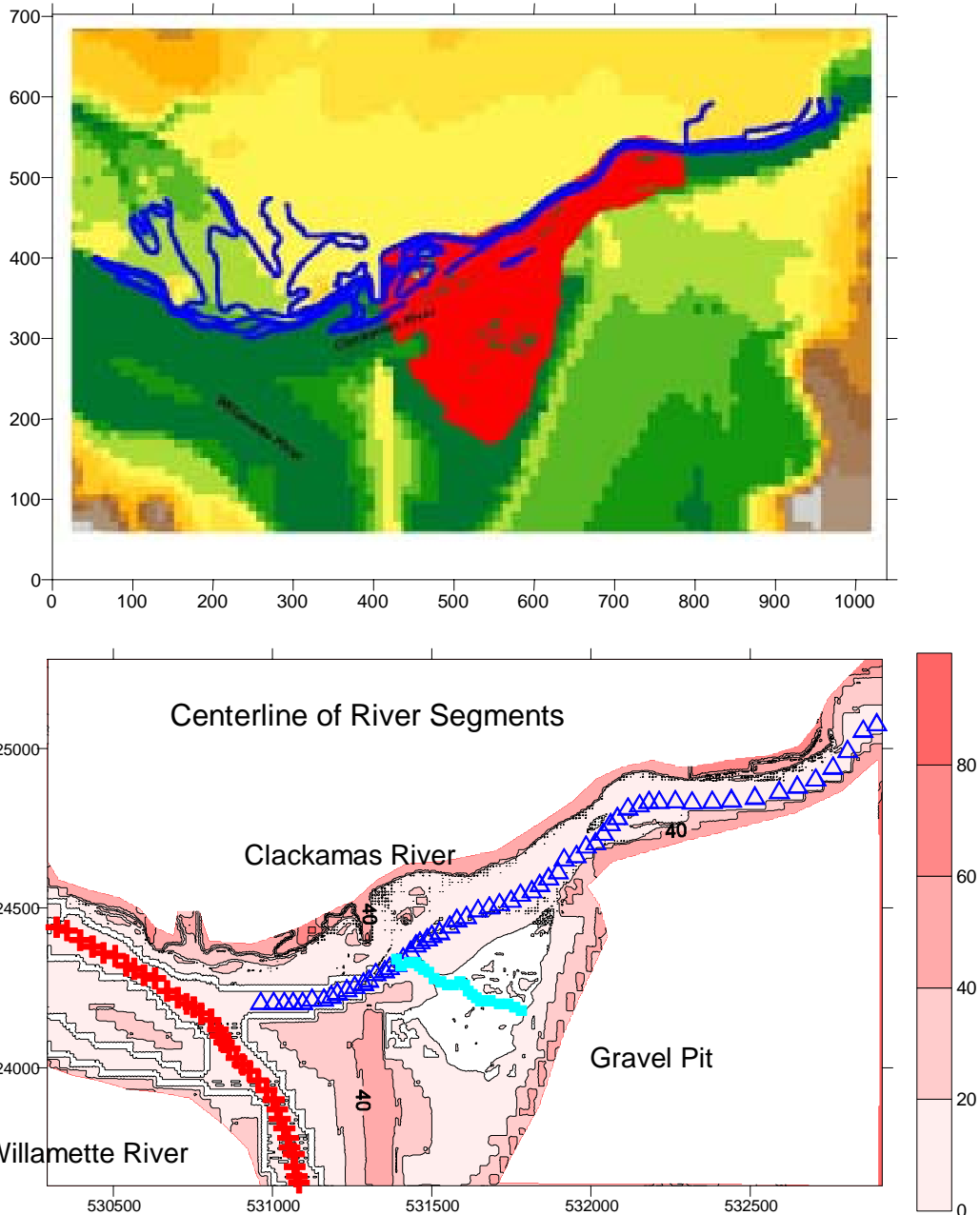


Figure 68. Clackamas River and Cove Bathymetry

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.

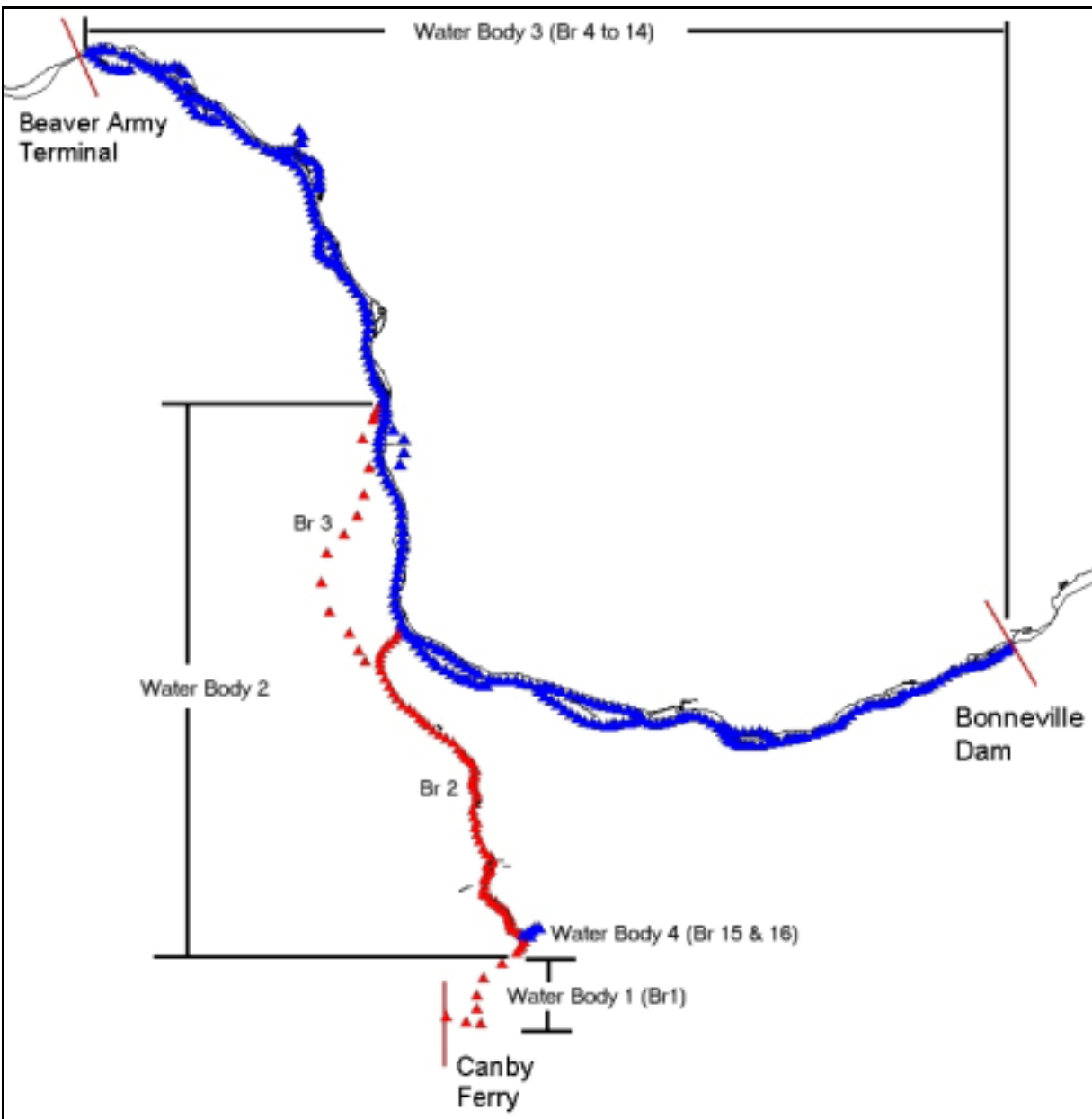


Figure 69. Model Grid Layout

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	Carrolls 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.

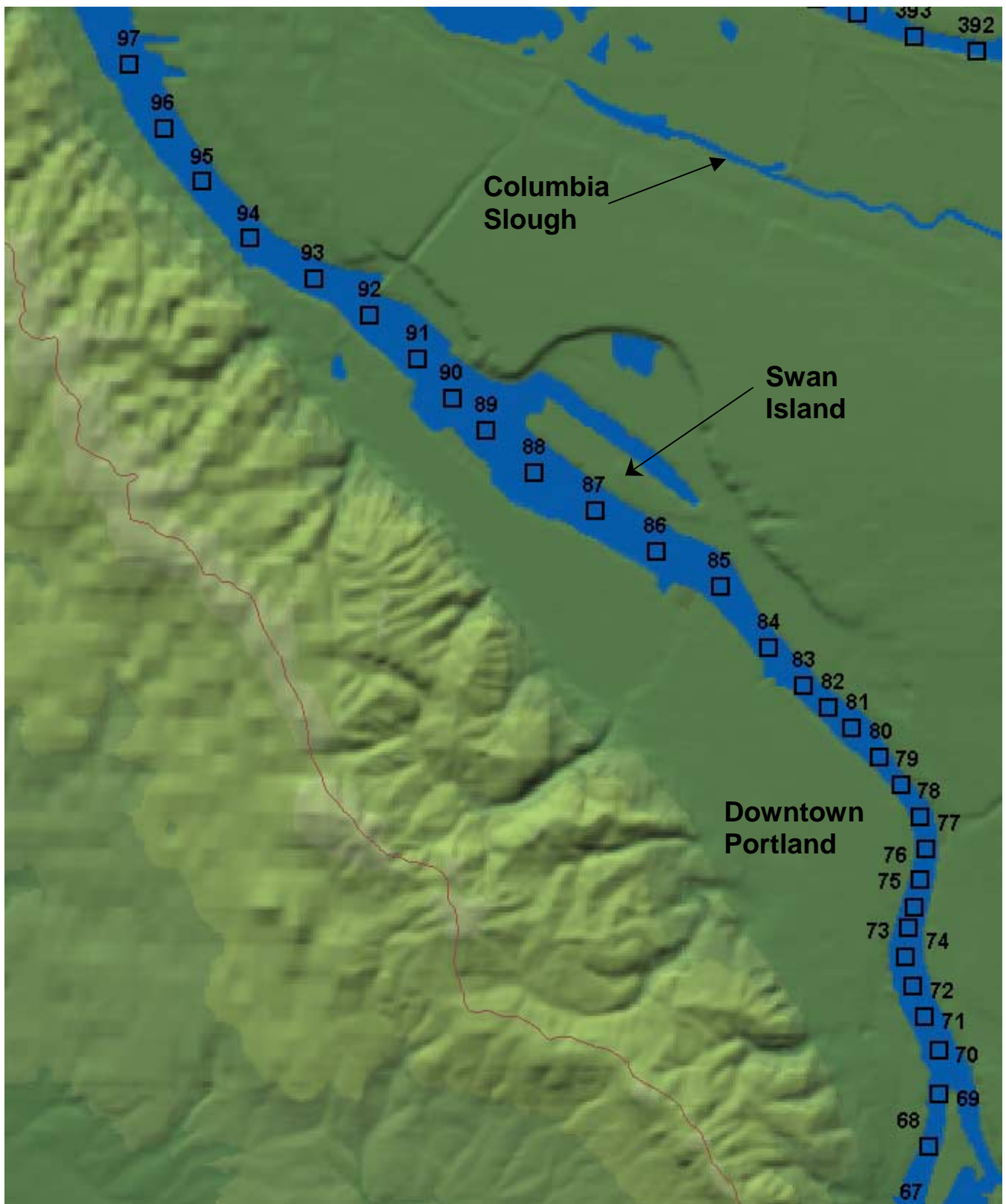


Figure 72. Model segment numbers in the vicinity of downtown Portland and Swan Island.



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



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

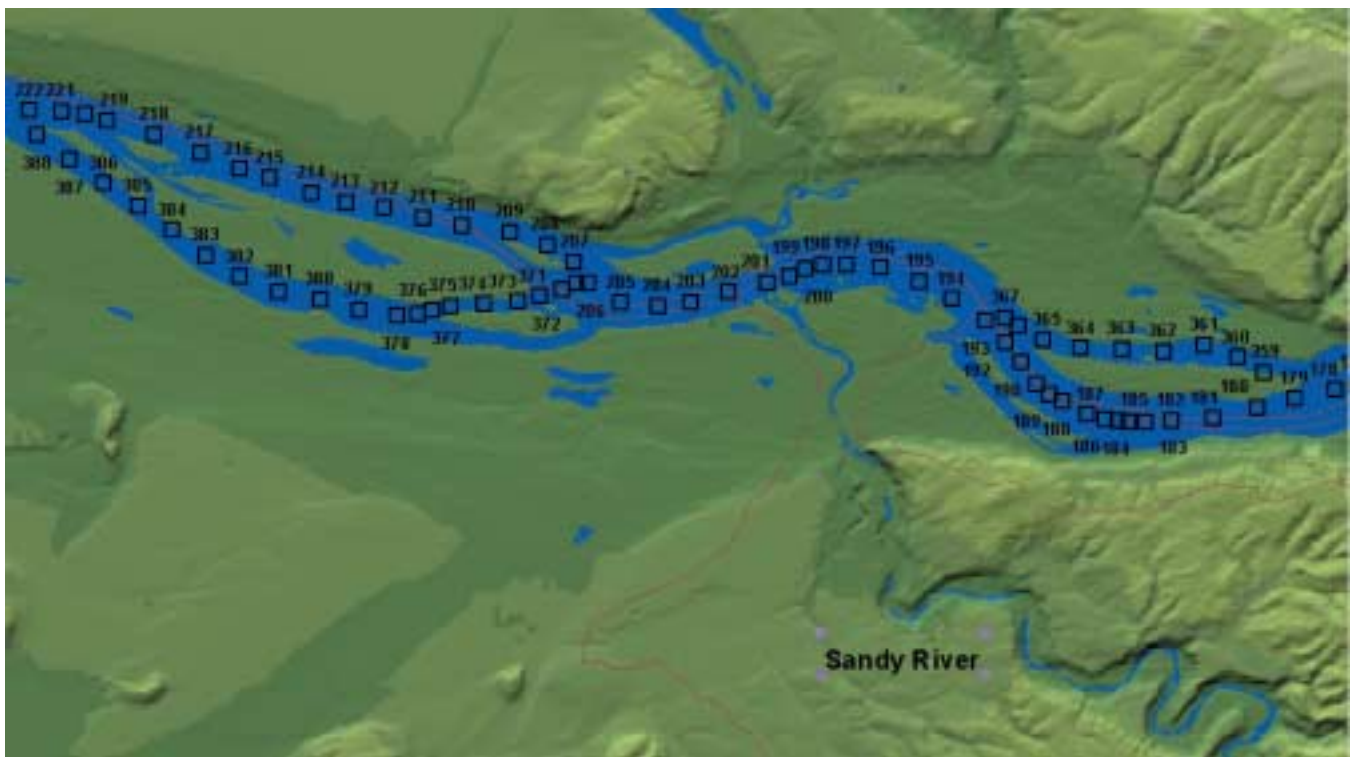


Figure 75. Model segment numbers along Columbia River near Sandy River.



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

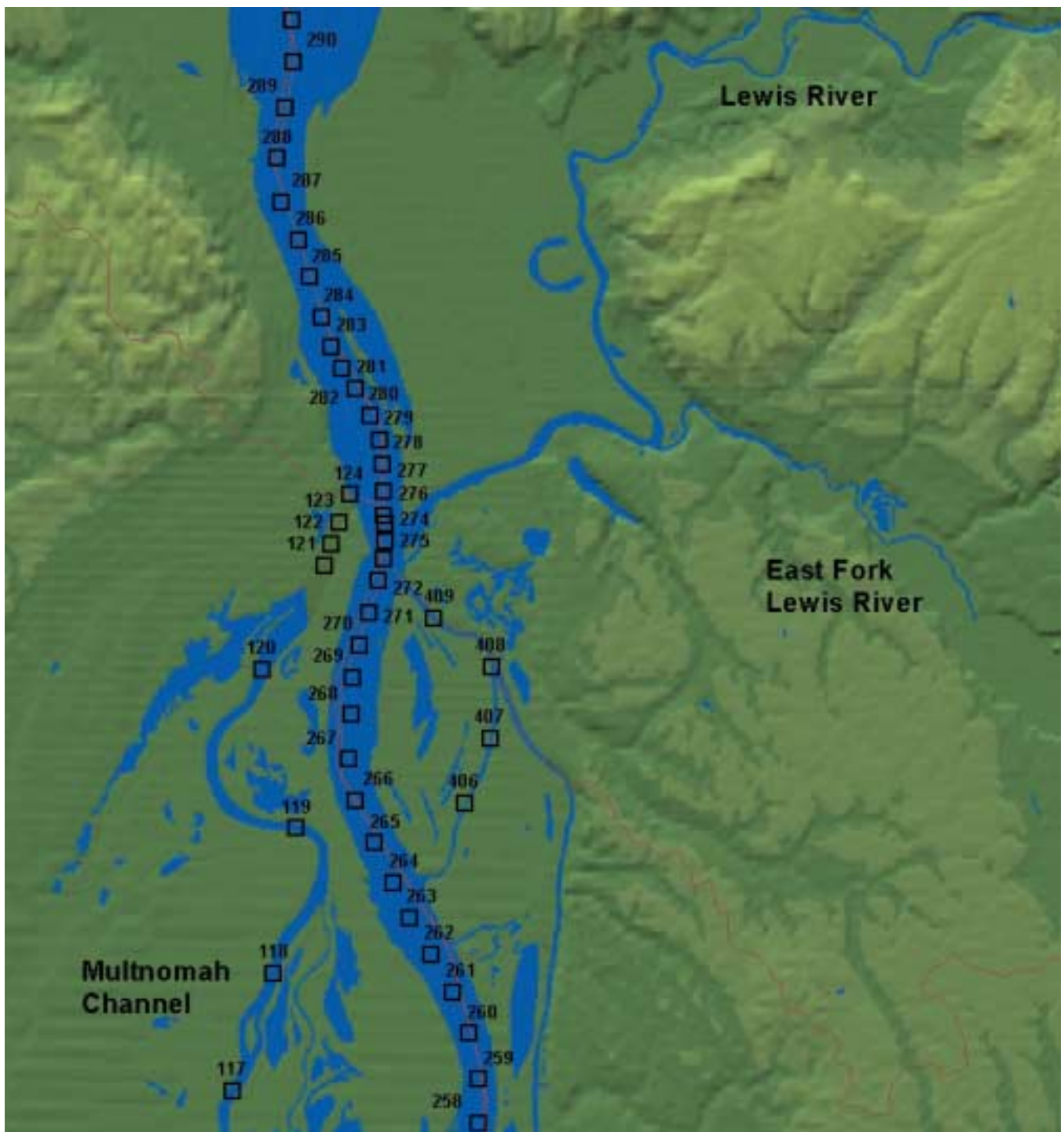


Figure 77. Model segment numbers along Columbia River near the Lewis River.

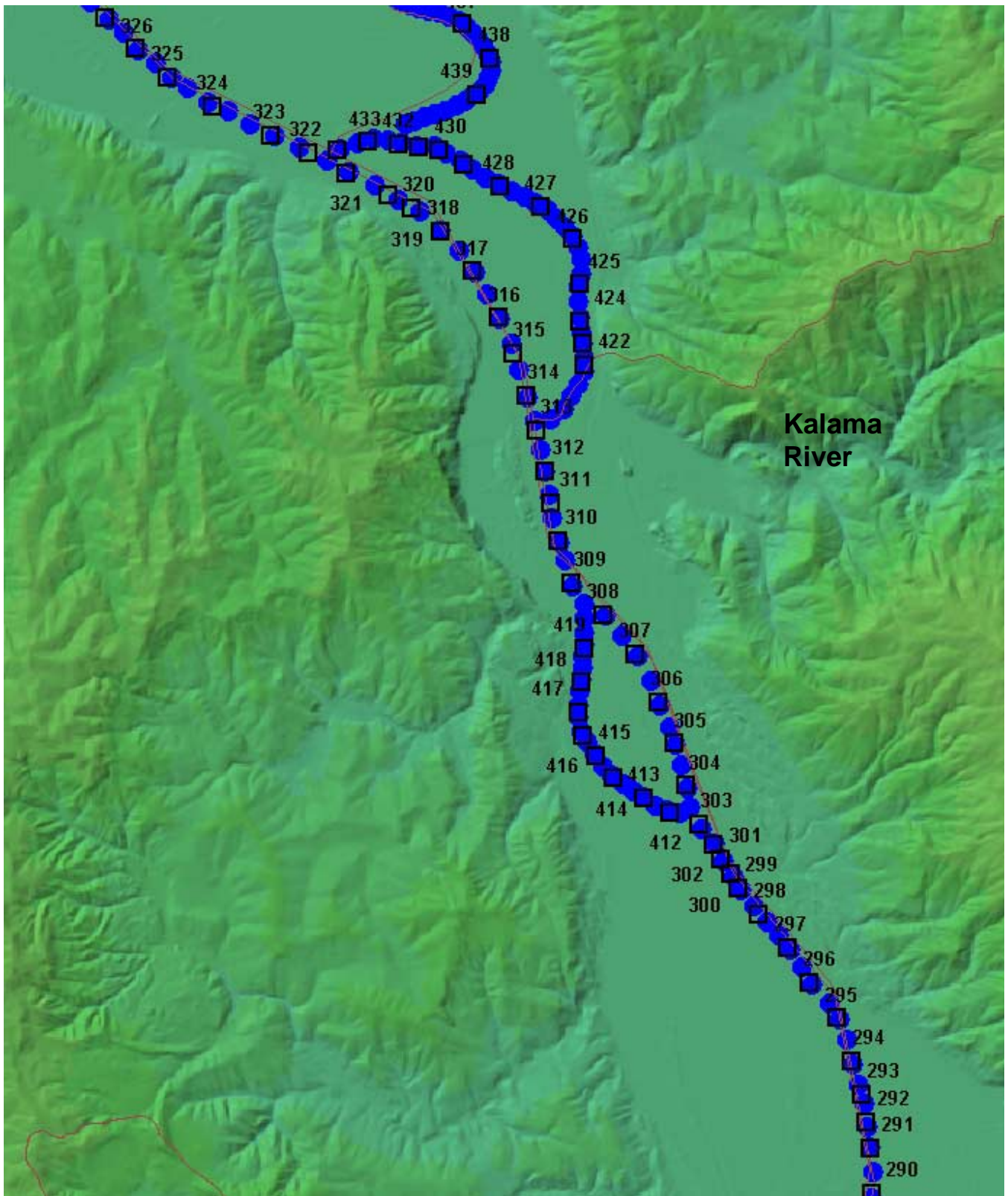


Figure 78. Model segment numbers along Columbia River near Kalama River.



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

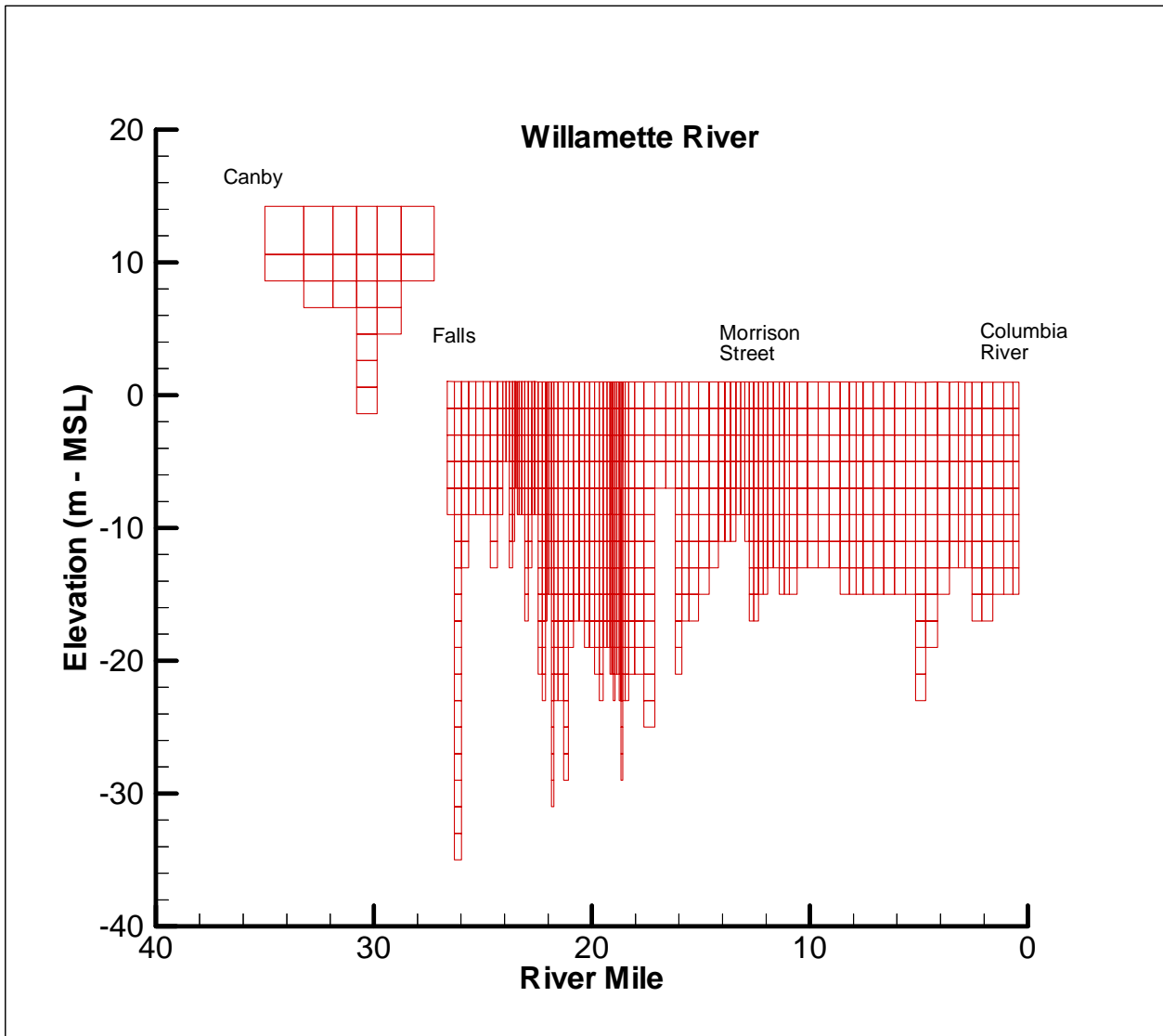


Figure 80. Vertical grid resolution along the Willamette River model domain (note variable longitudinal segment spacing and vertical grid resolution).

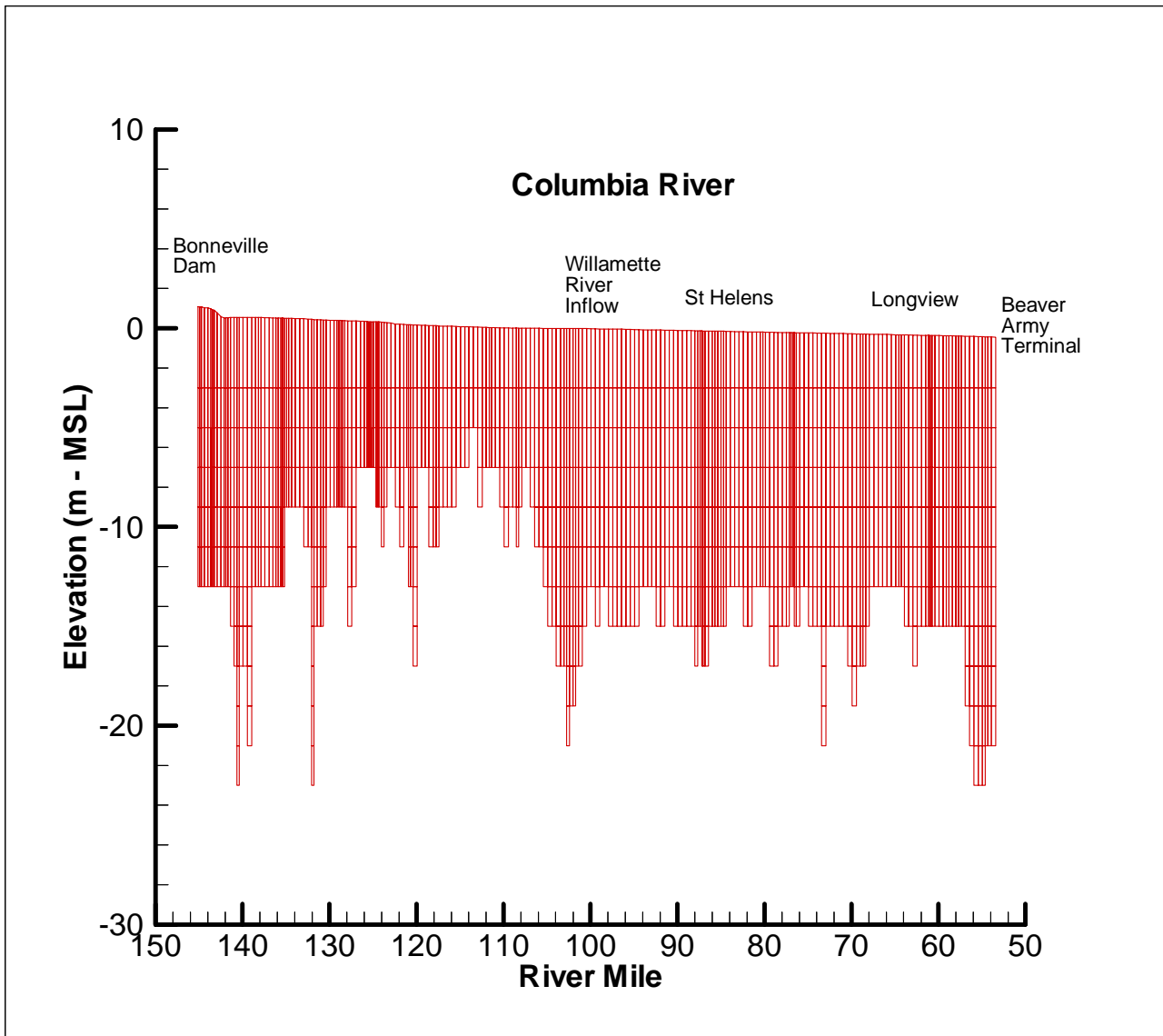


Figure 81. Vertical grid resolution along the Columbia River model domain.

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 PO₄, 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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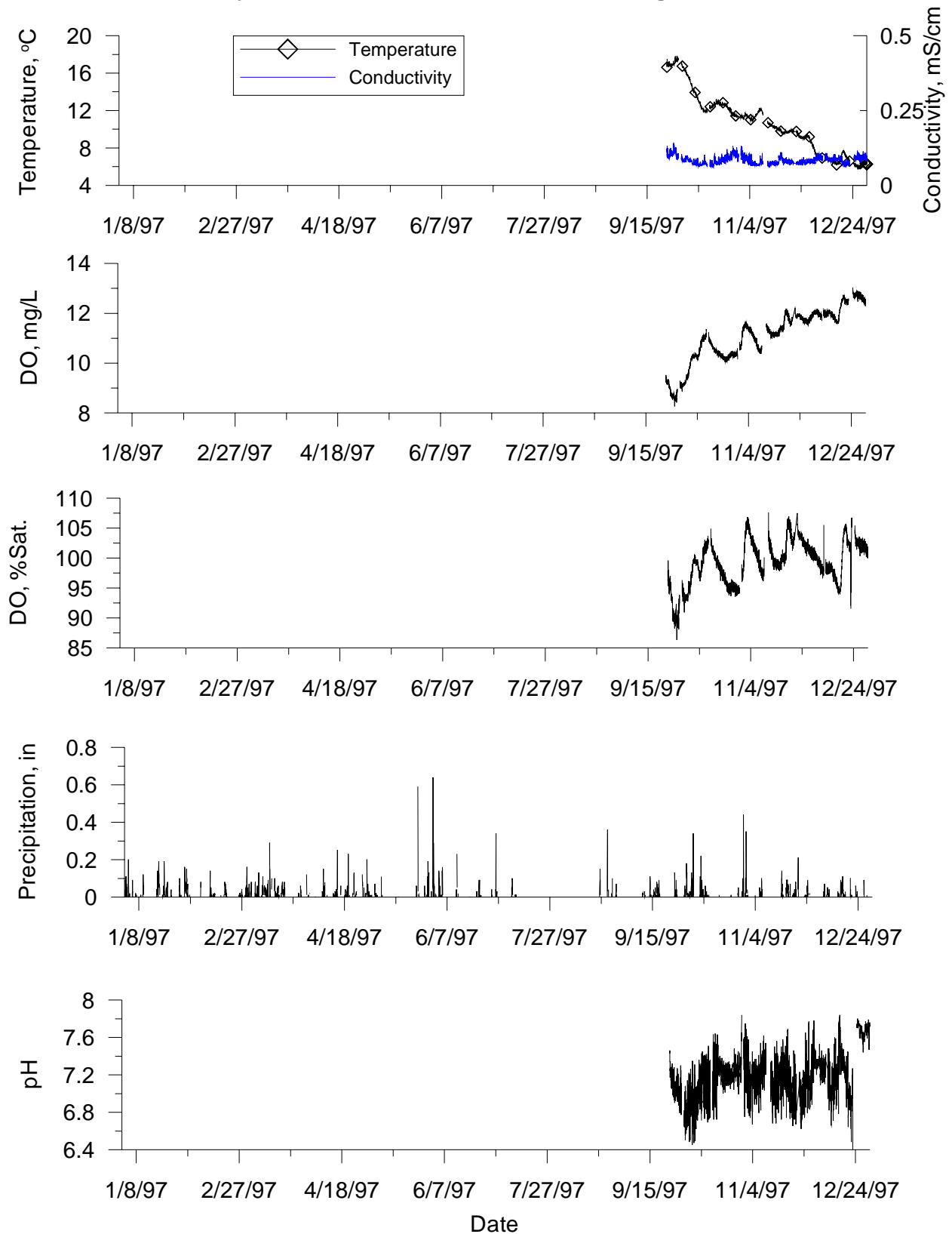
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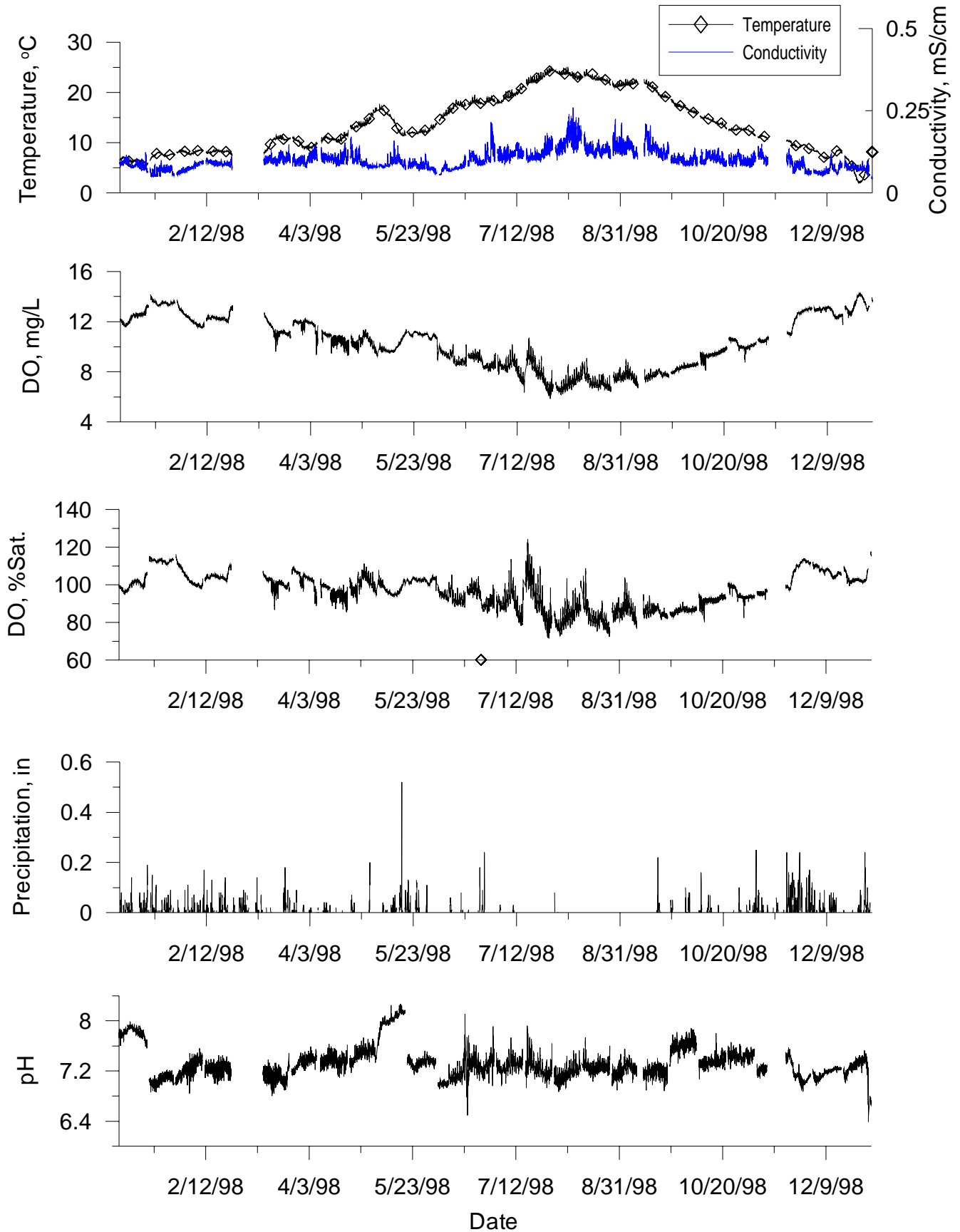
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Appendix A: Willamette River Hydrolab data

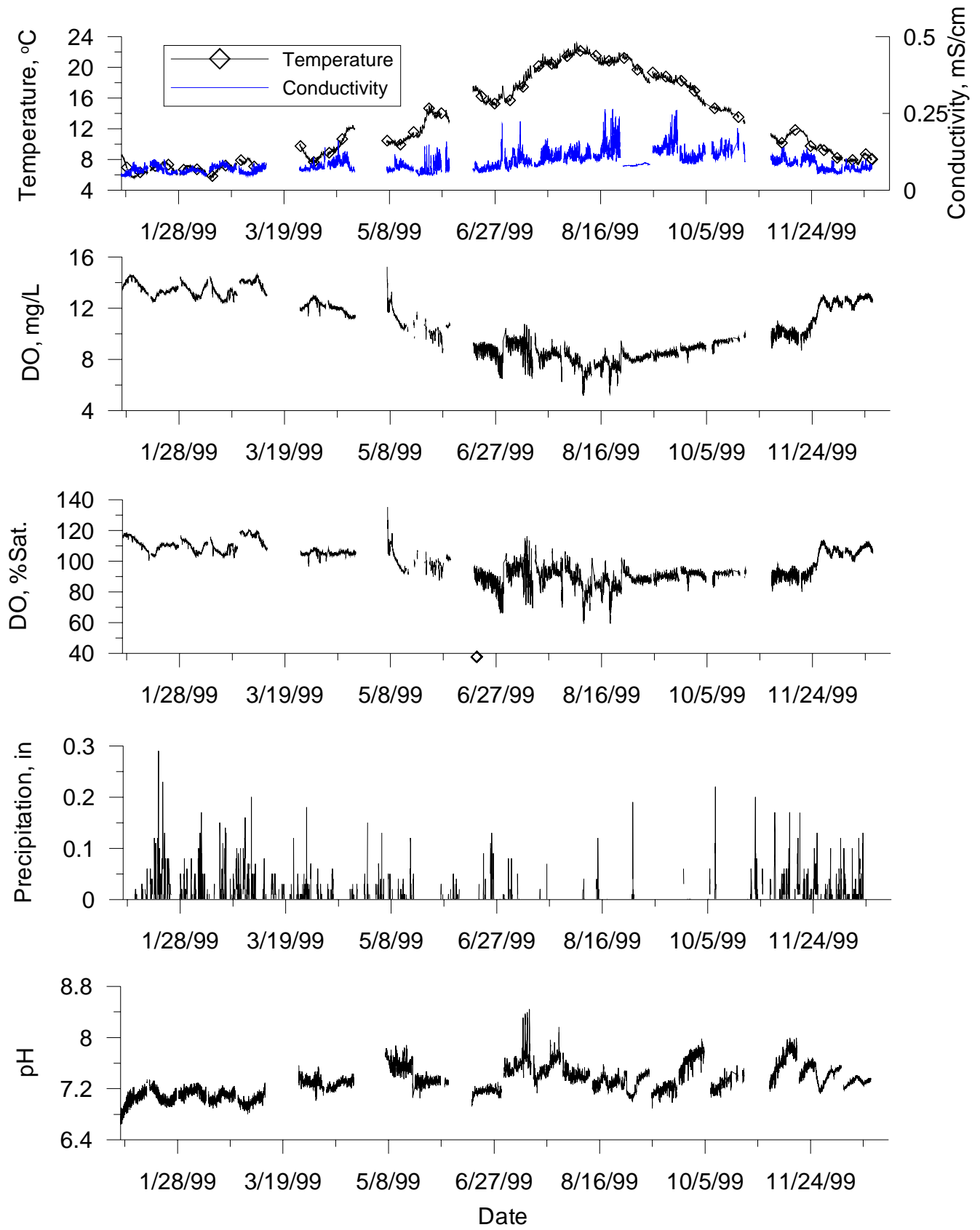
1997 Hydrolab Data at St. Johns Railroad Bridge. RM 6.8



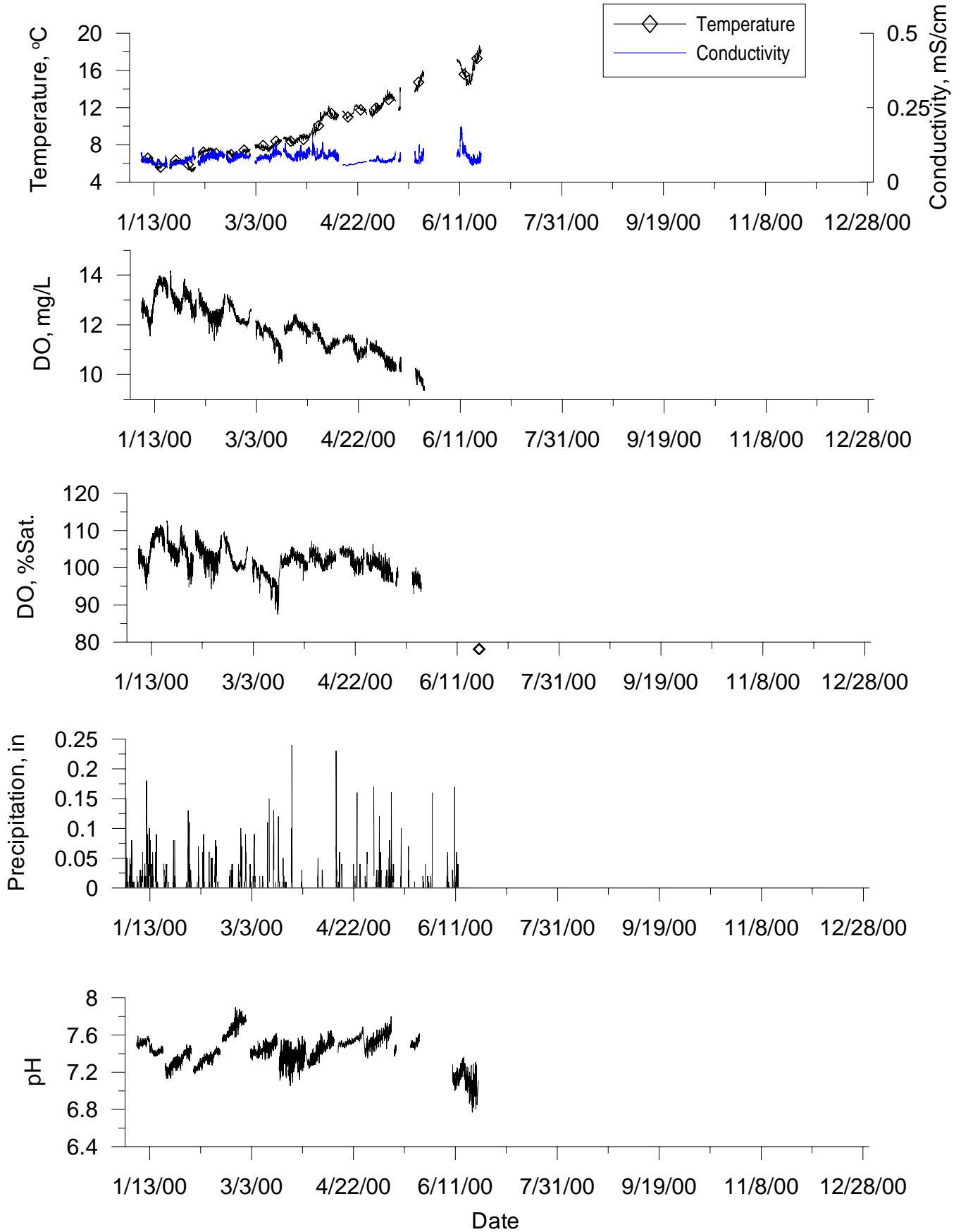
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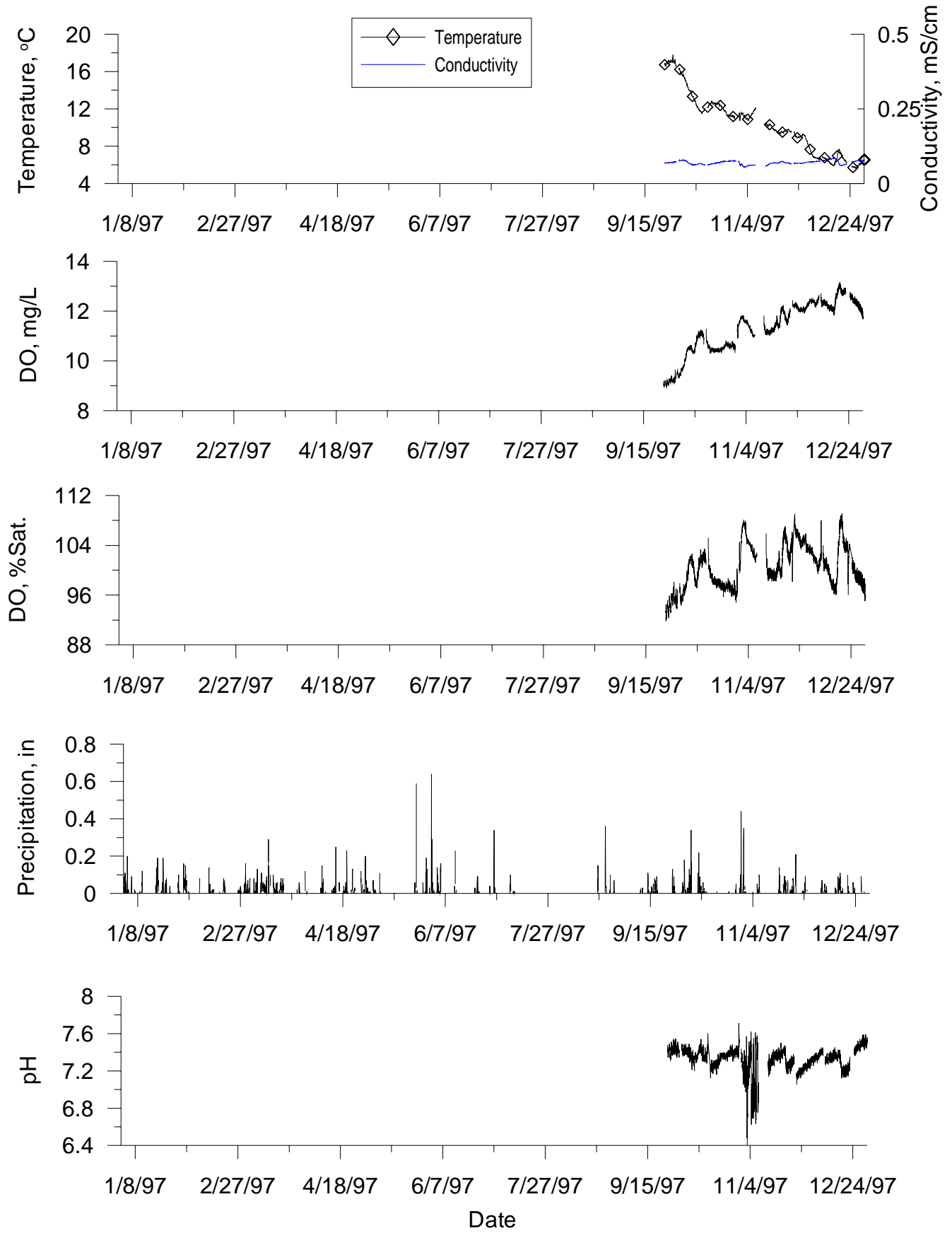
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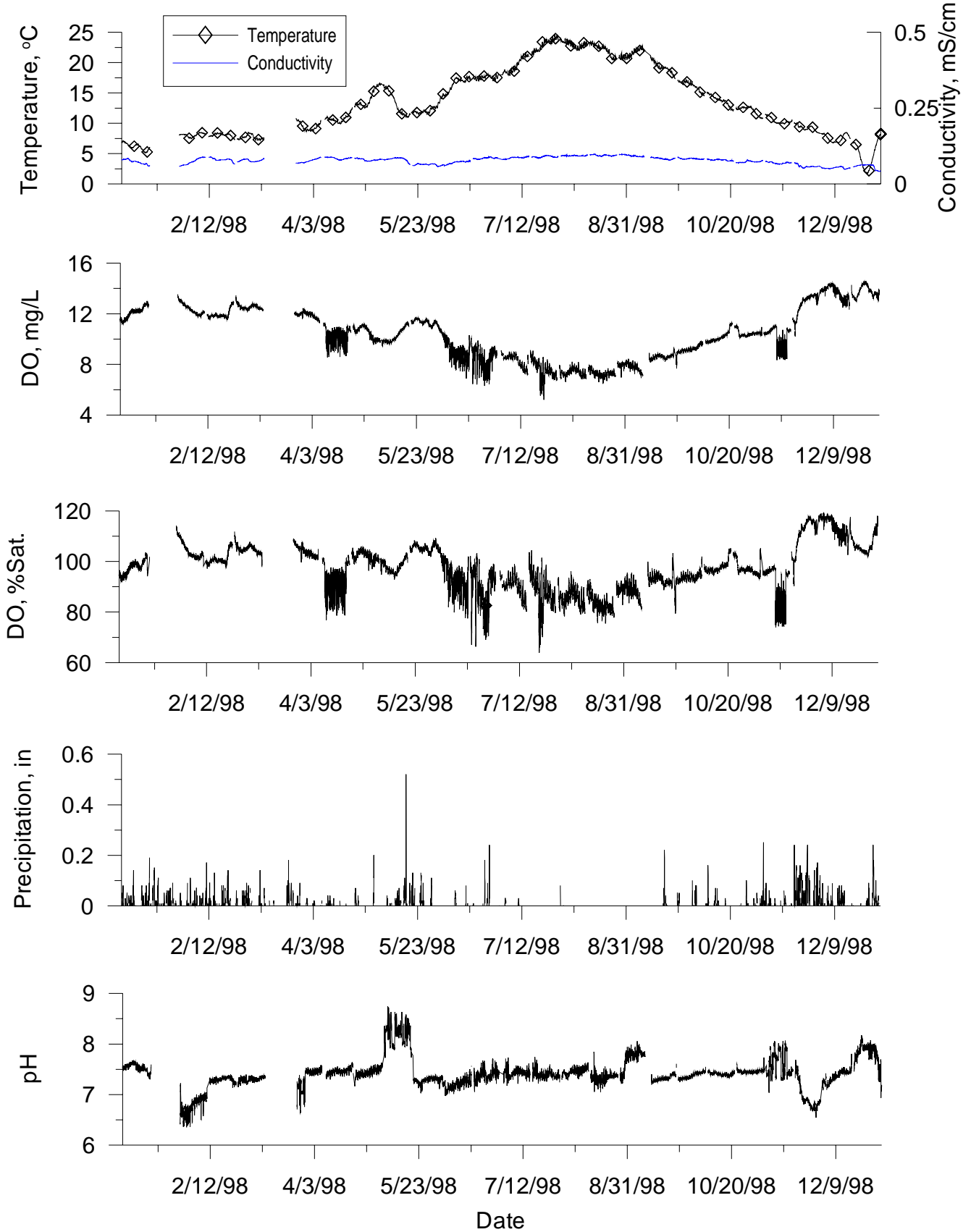
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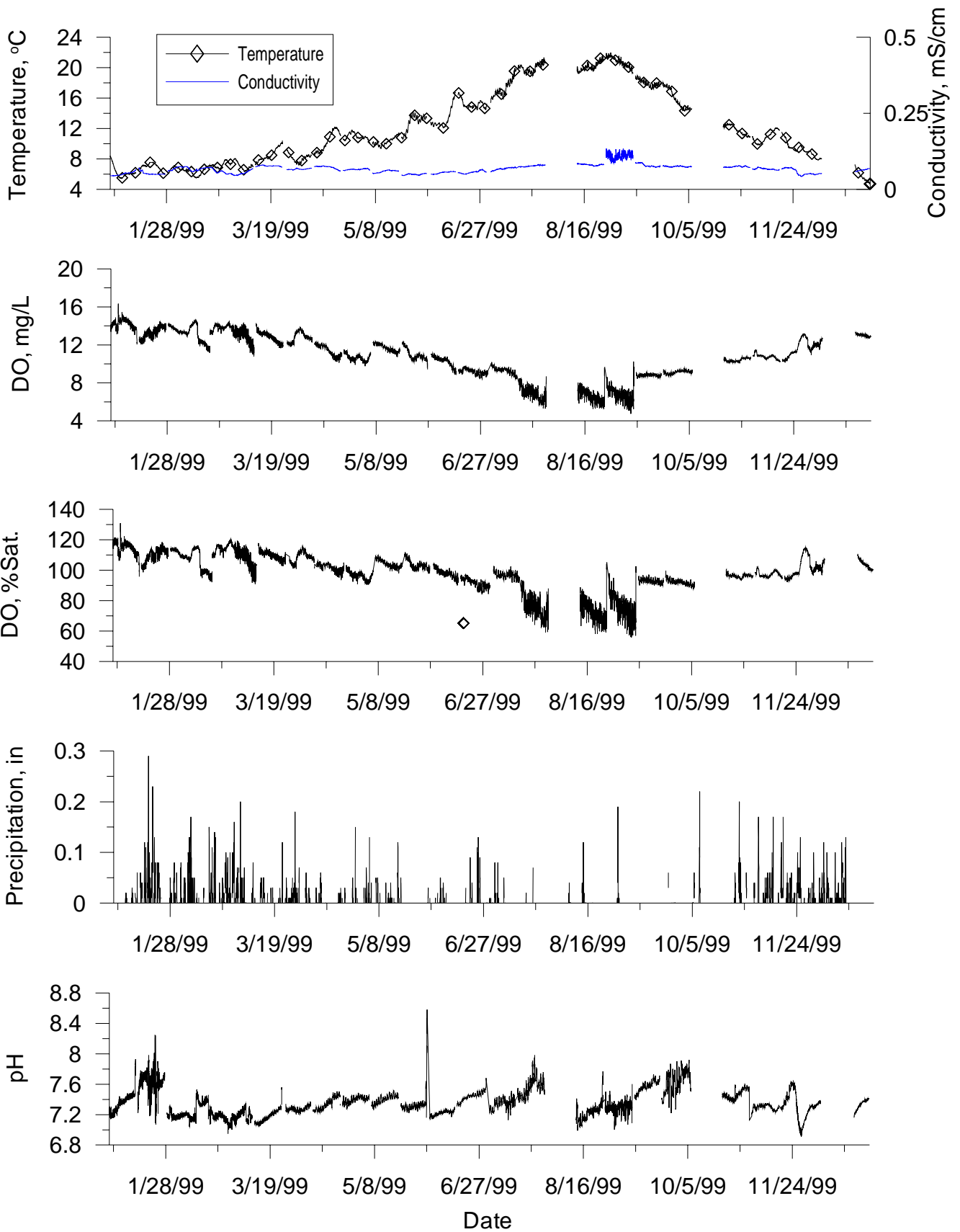
1997 Hydrolab Data at Waverly Country Club. RM 17.9



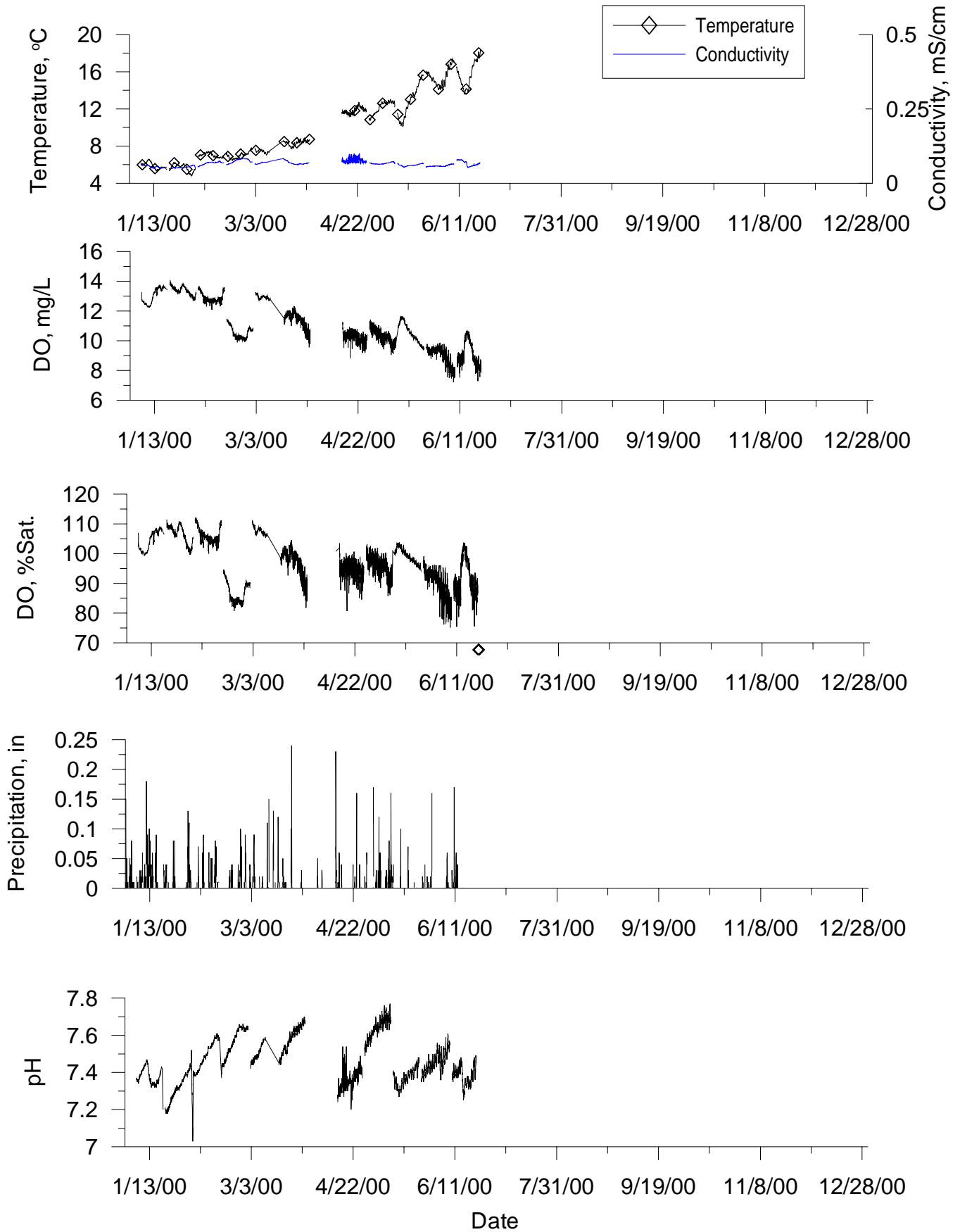
1998 Hydrolab Data at Waverly Country Club. RM 17.9



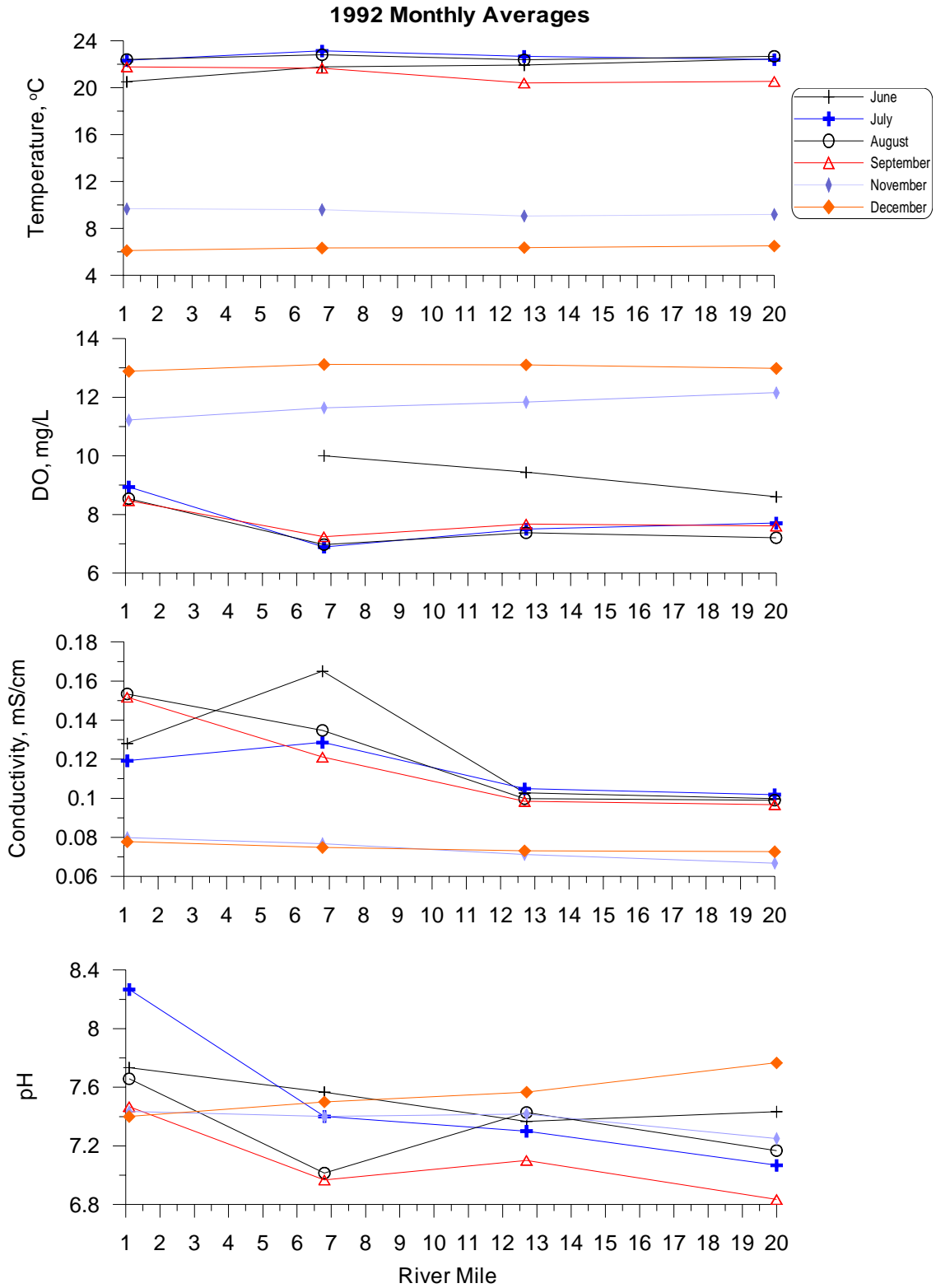
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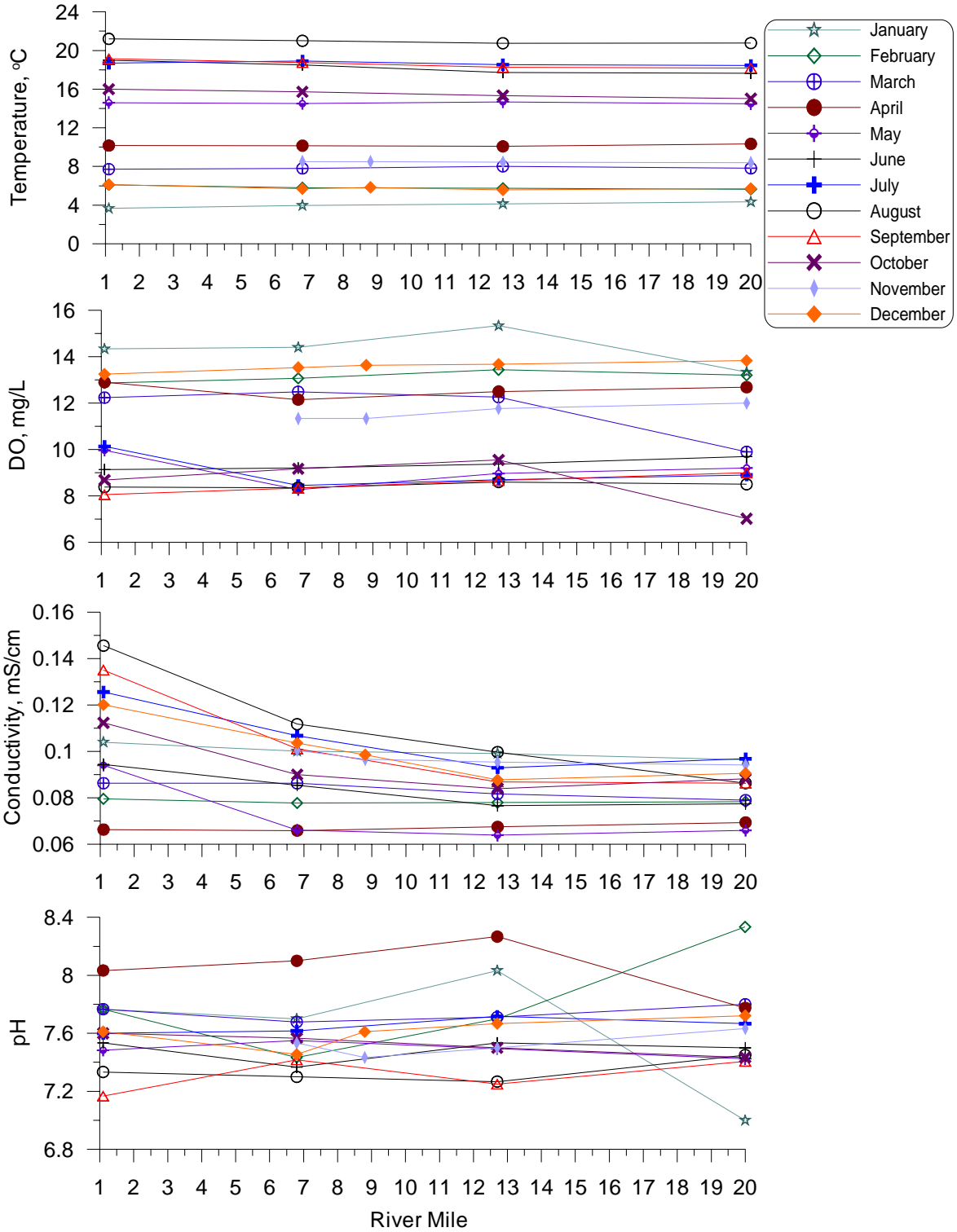
2000 Hydrolab Data at Waverly Country Club. RM 17.9



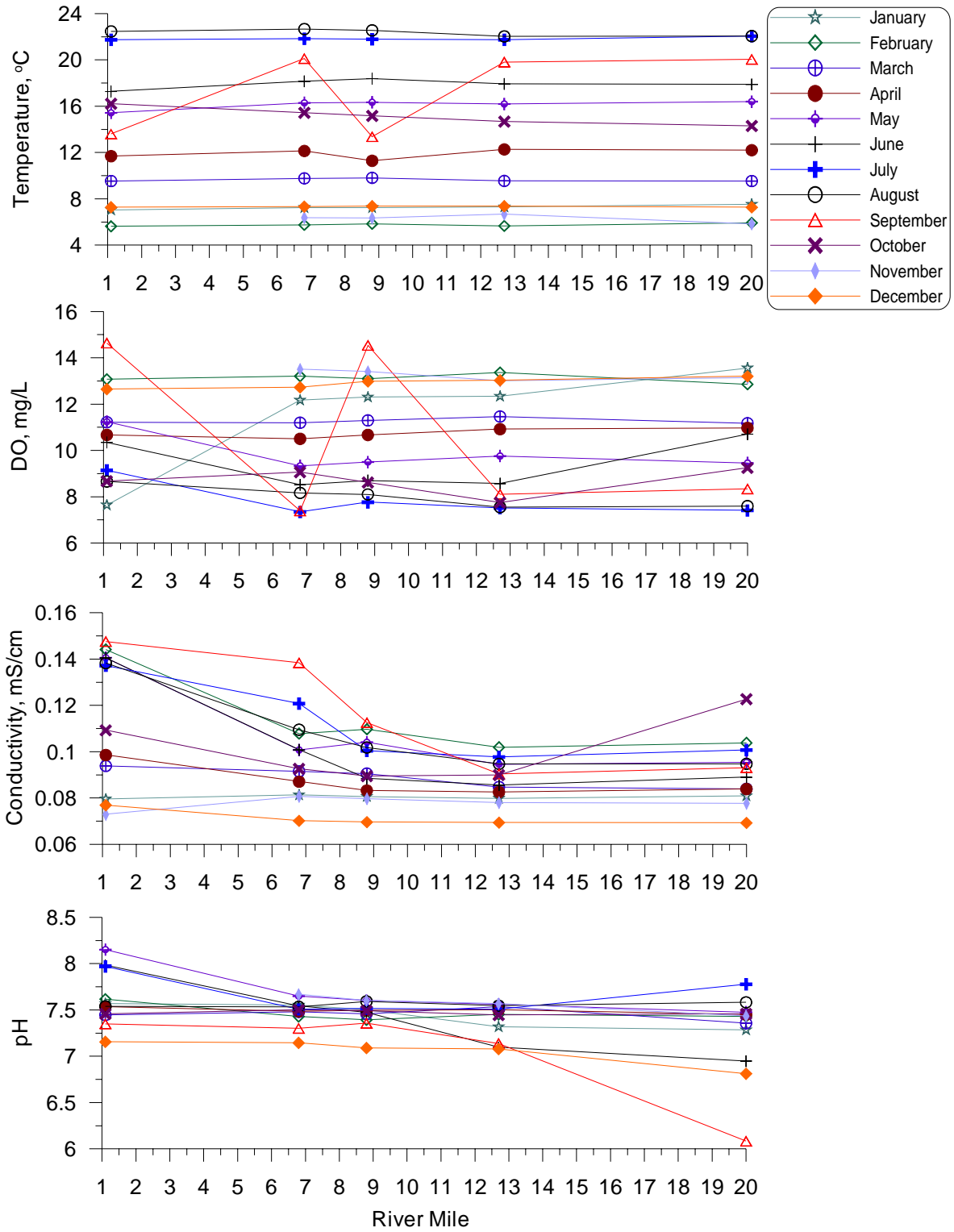
Appendix B: Willamette River Longitudinal Profiles (monthly averages)



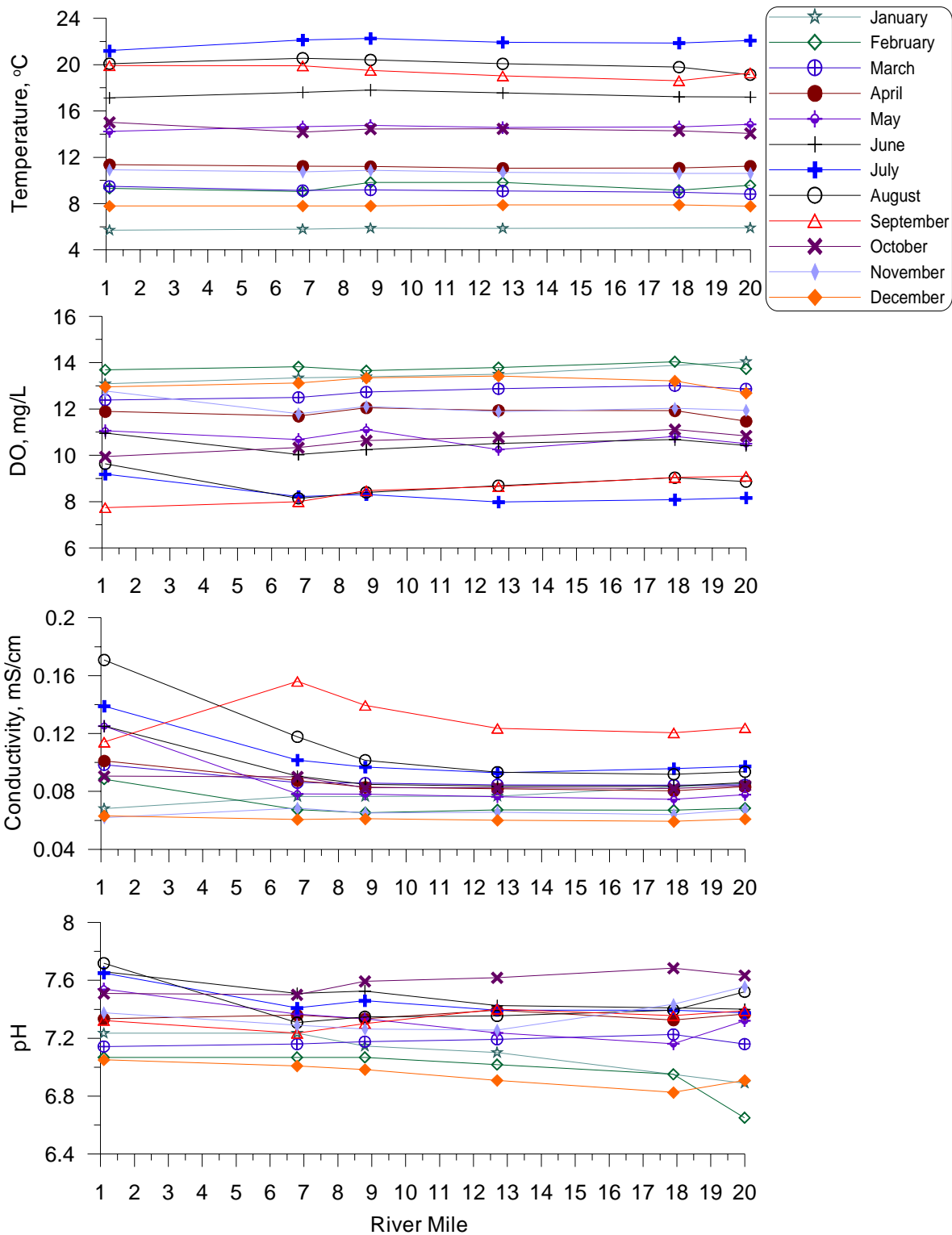
1993 Monthly Averages



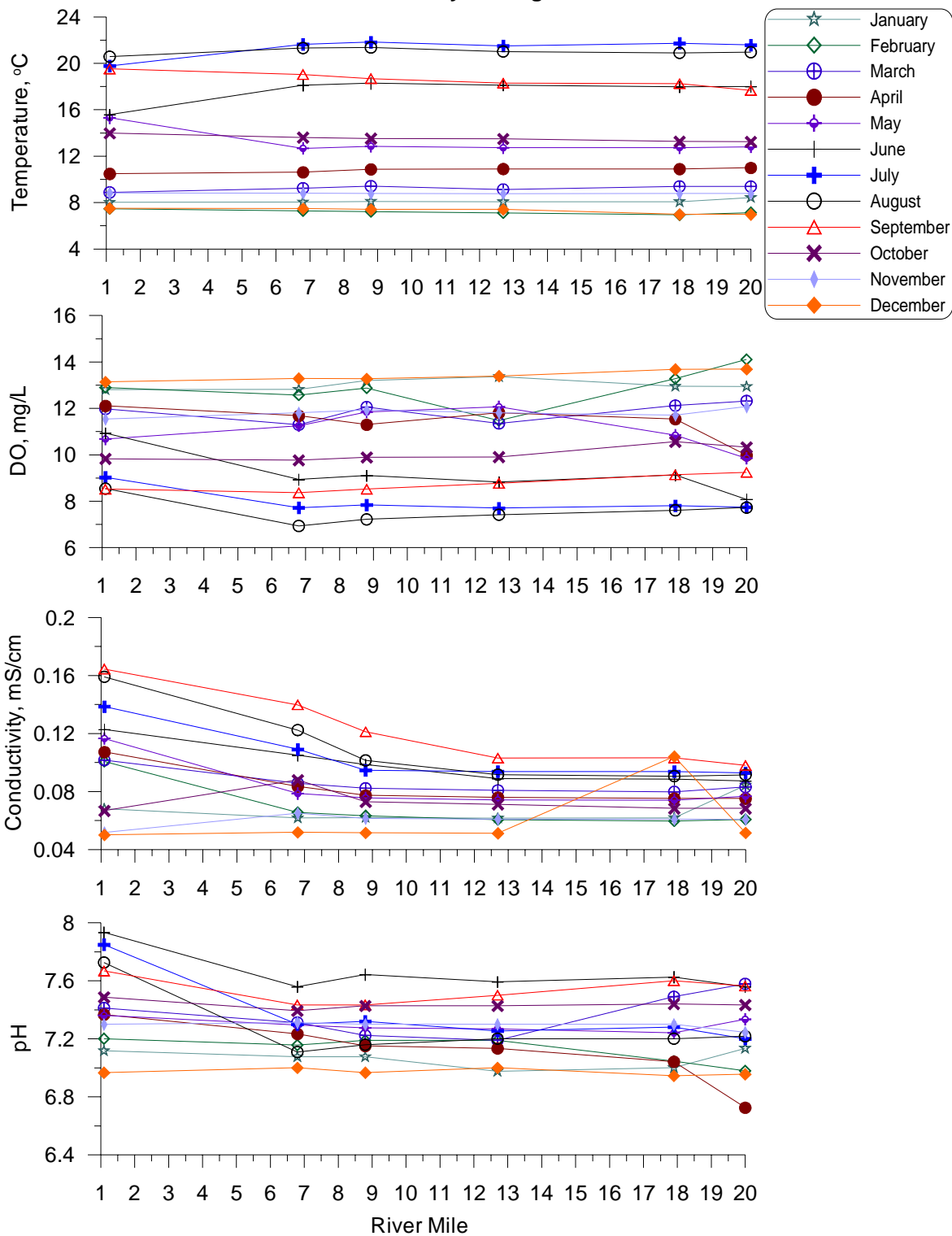
1994 Monthly Averages



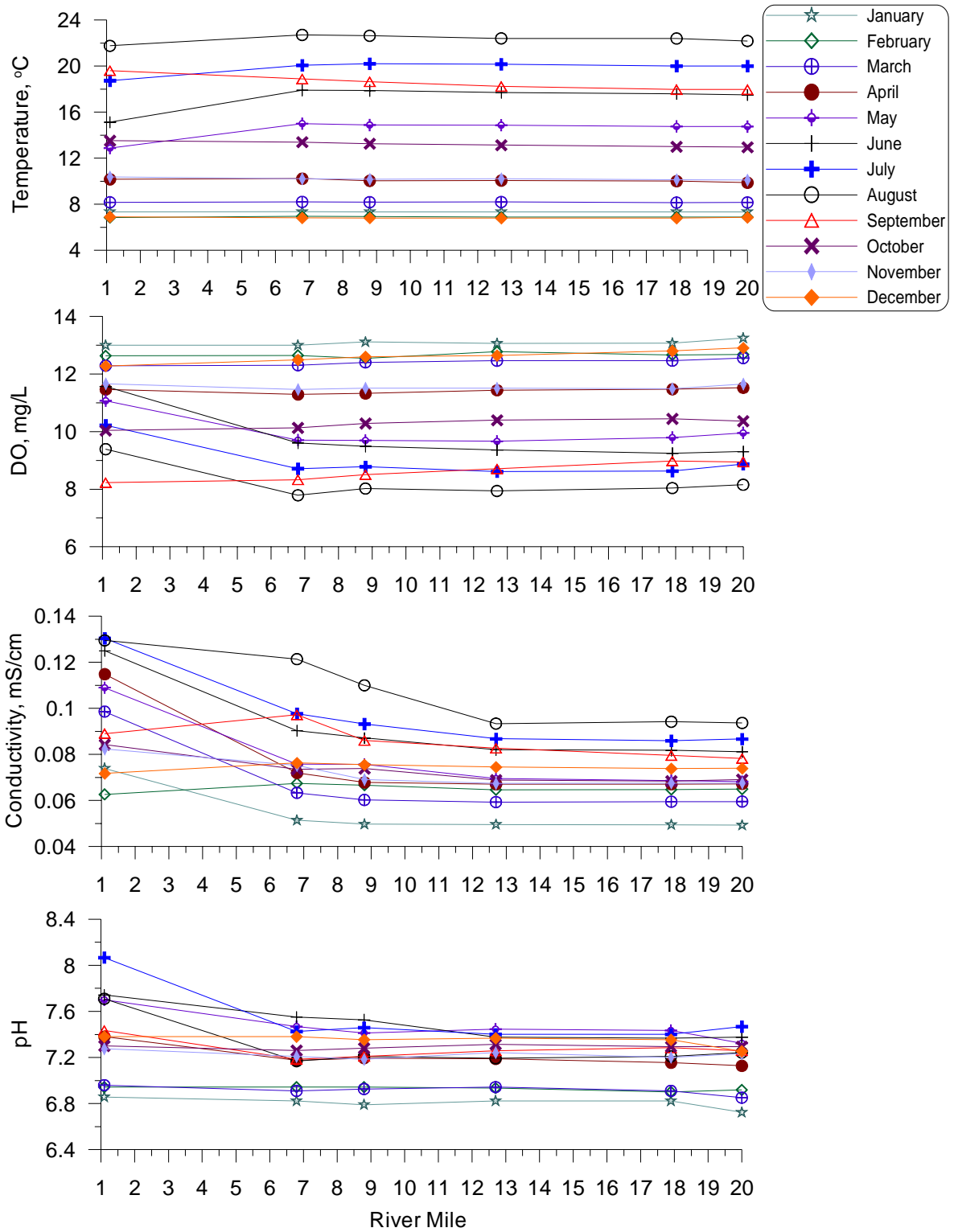
1995 Monthly Averages



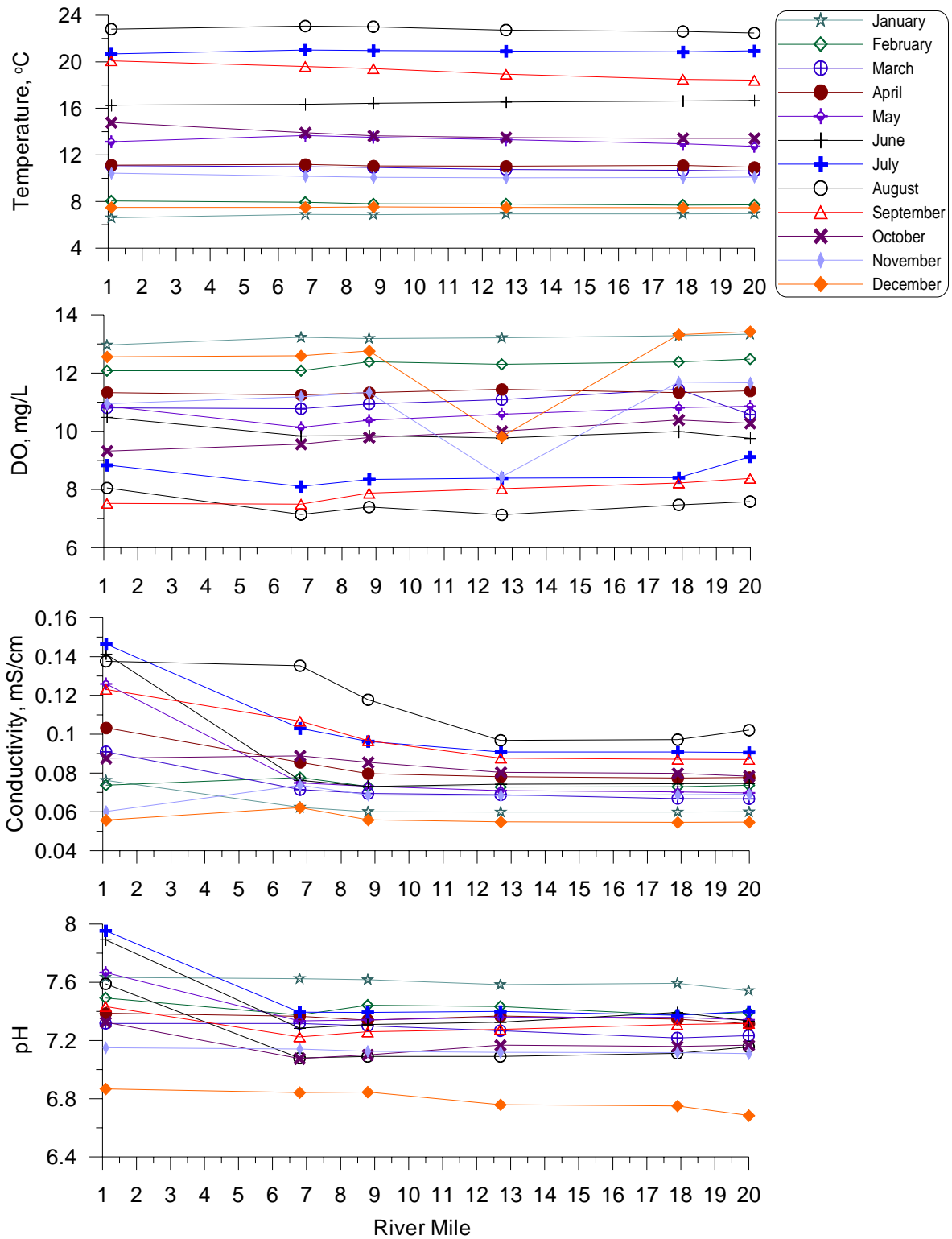
1996 Monthly Averages



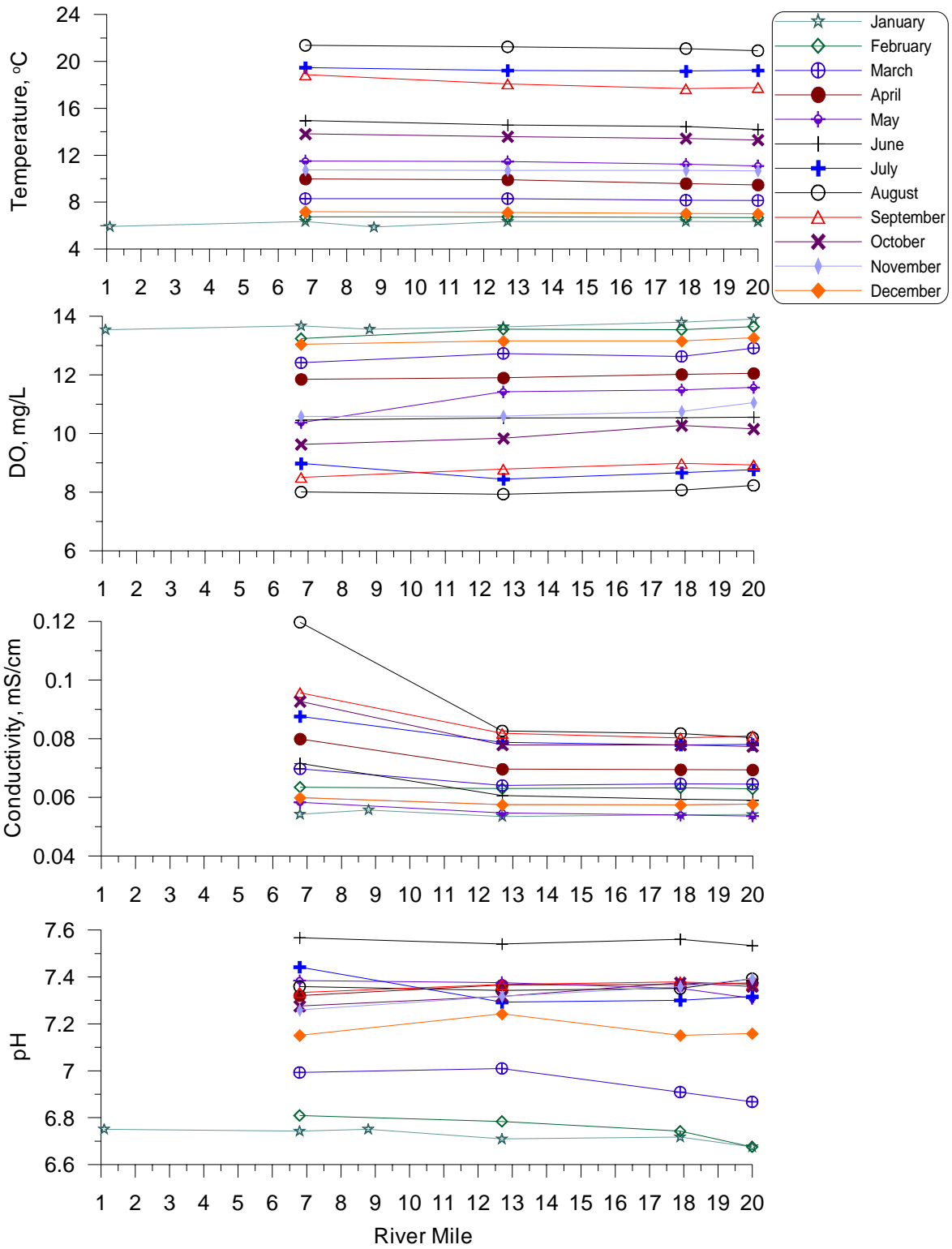
1997 Monthly Averages



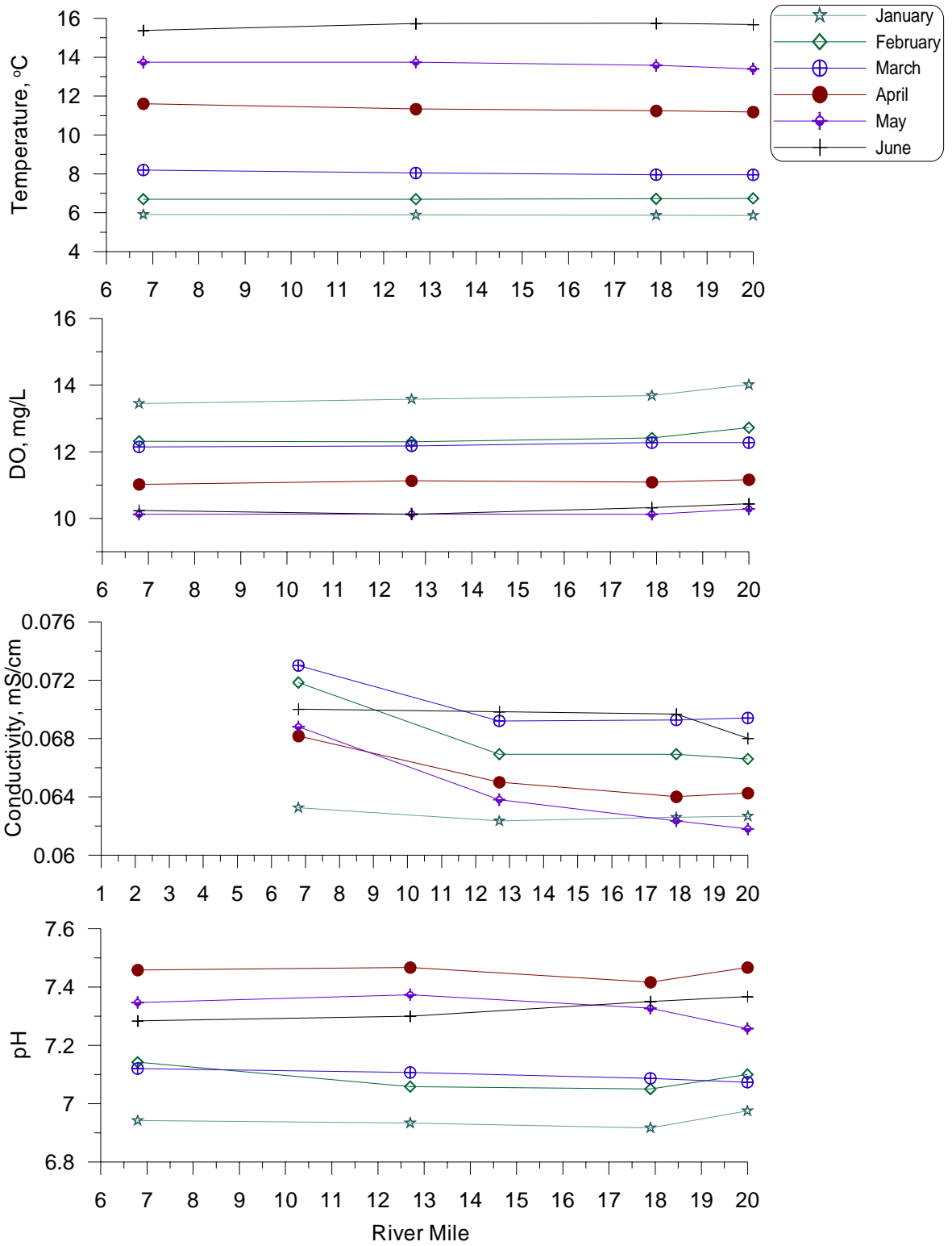
1998 Monthly Averages



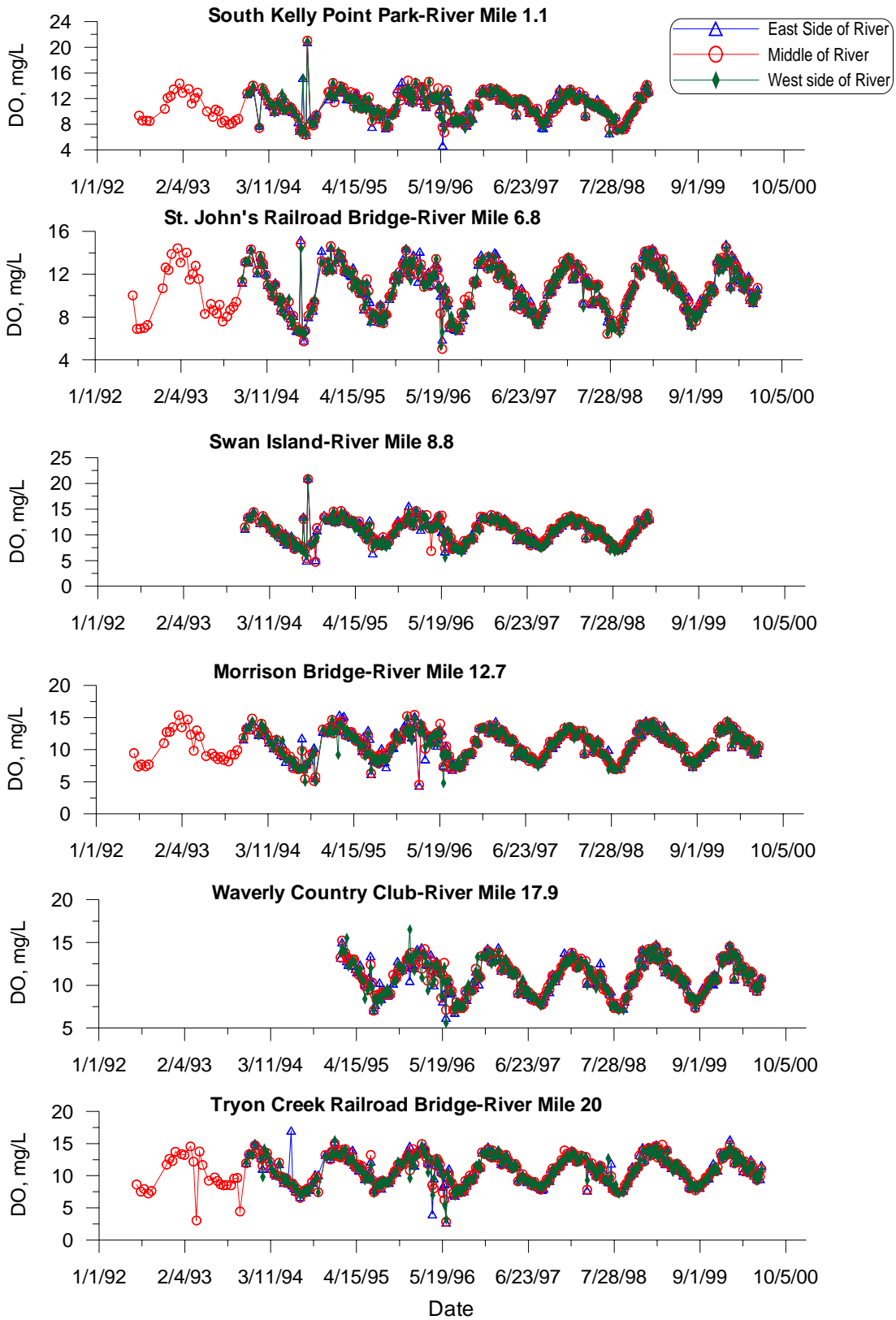
1999 Monthly Averages



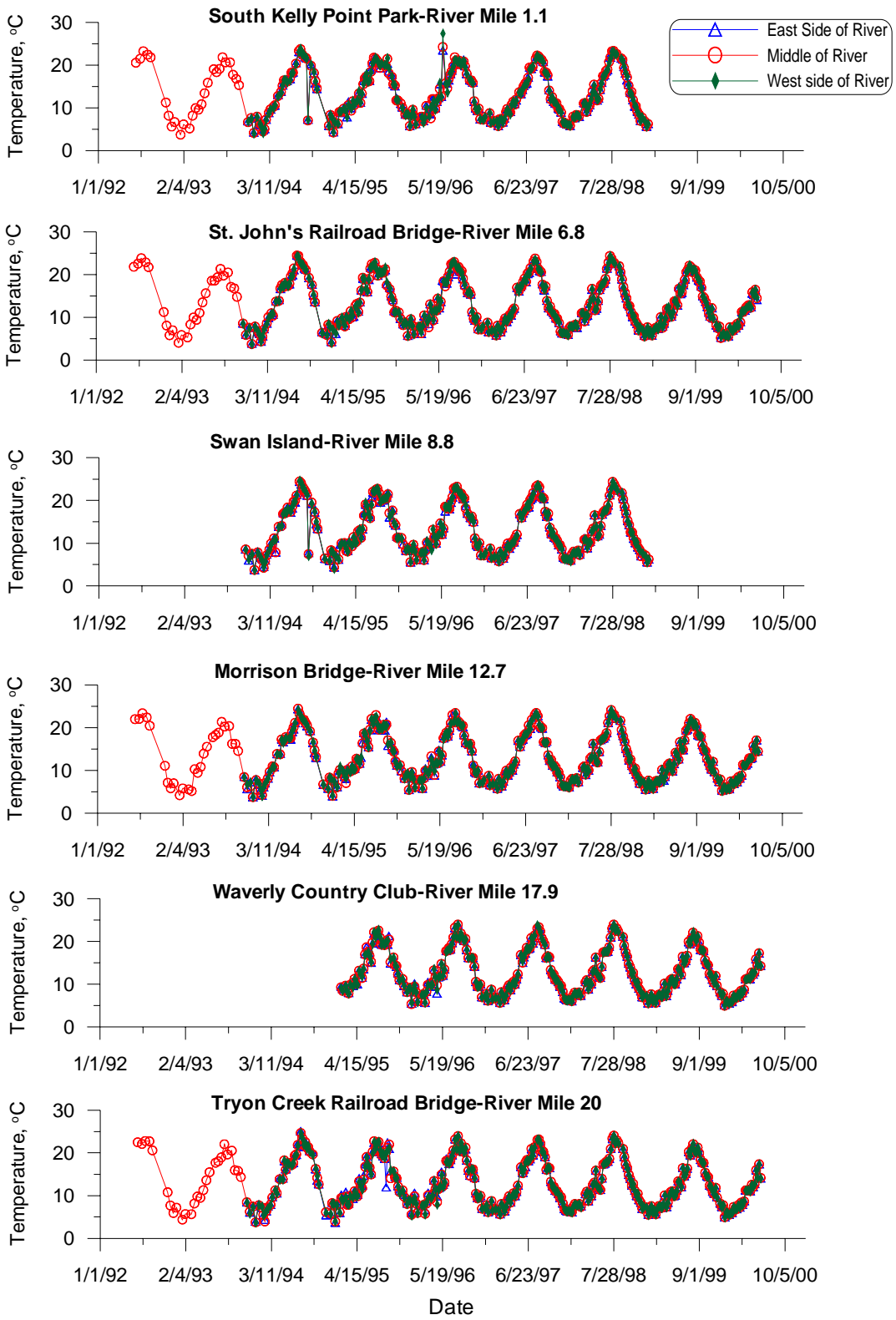
2000 Monthly Averages



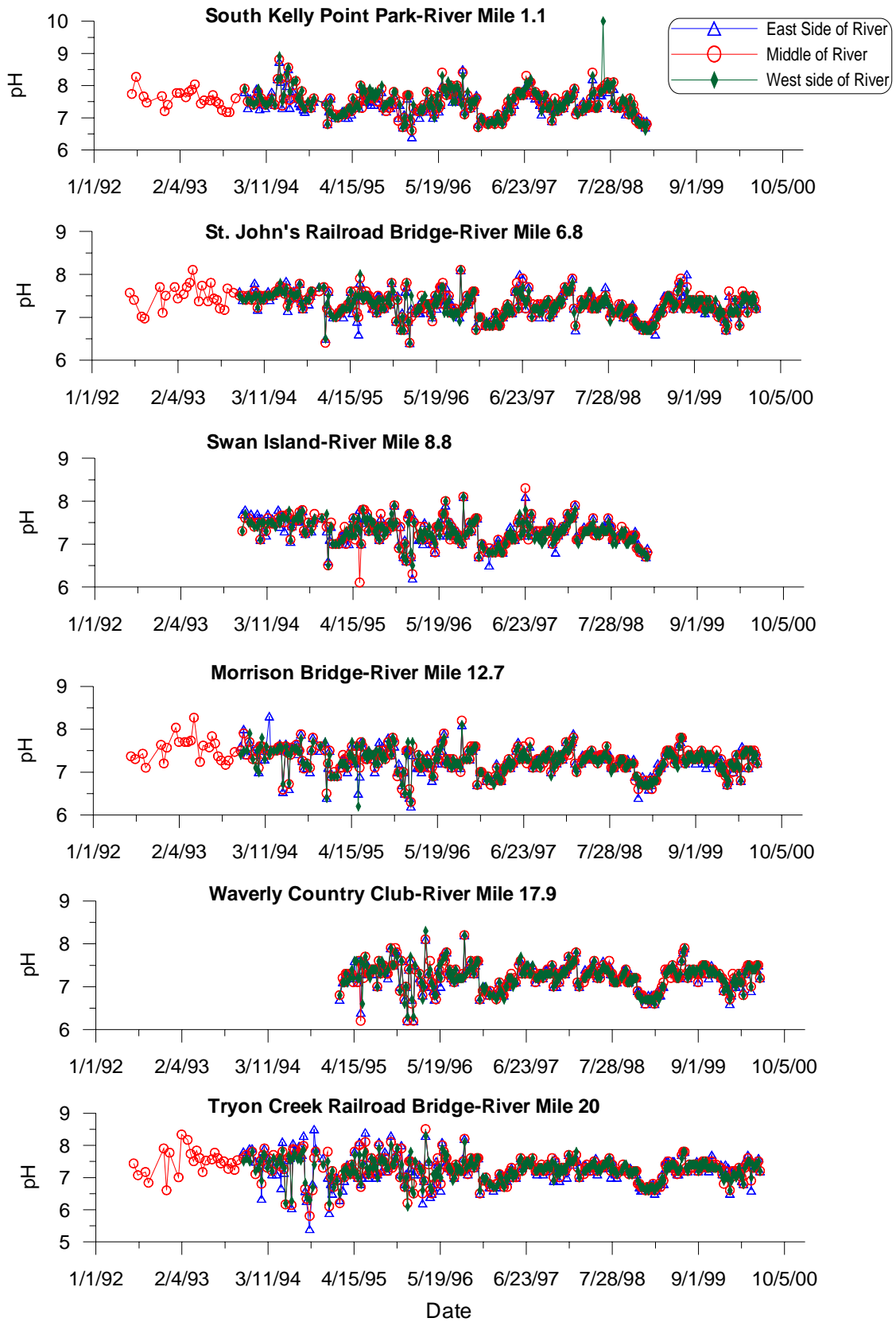
Appendix C: Willamette River Grab Samples across the river Dissolved Oxygen



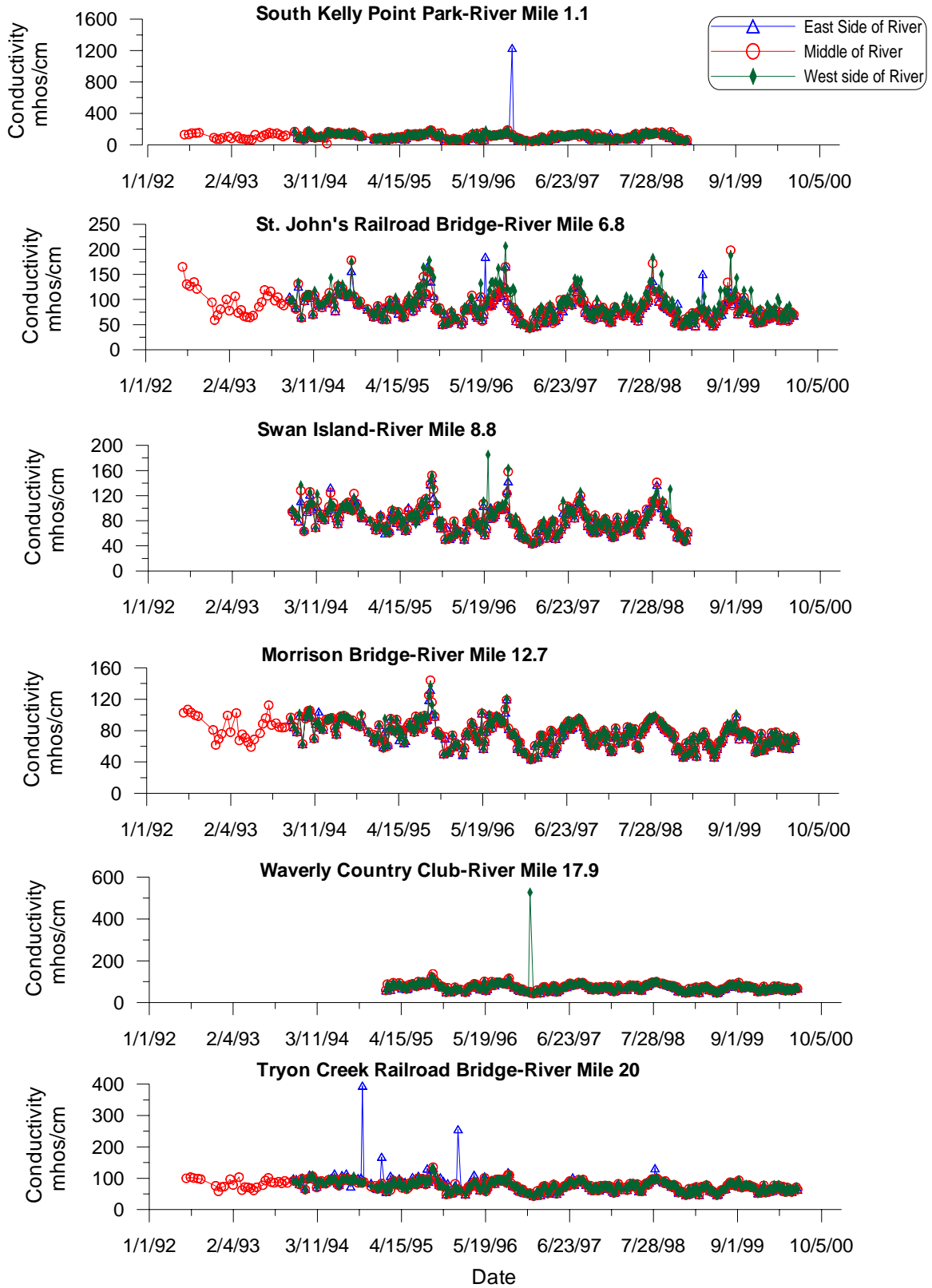
Temperature



pH

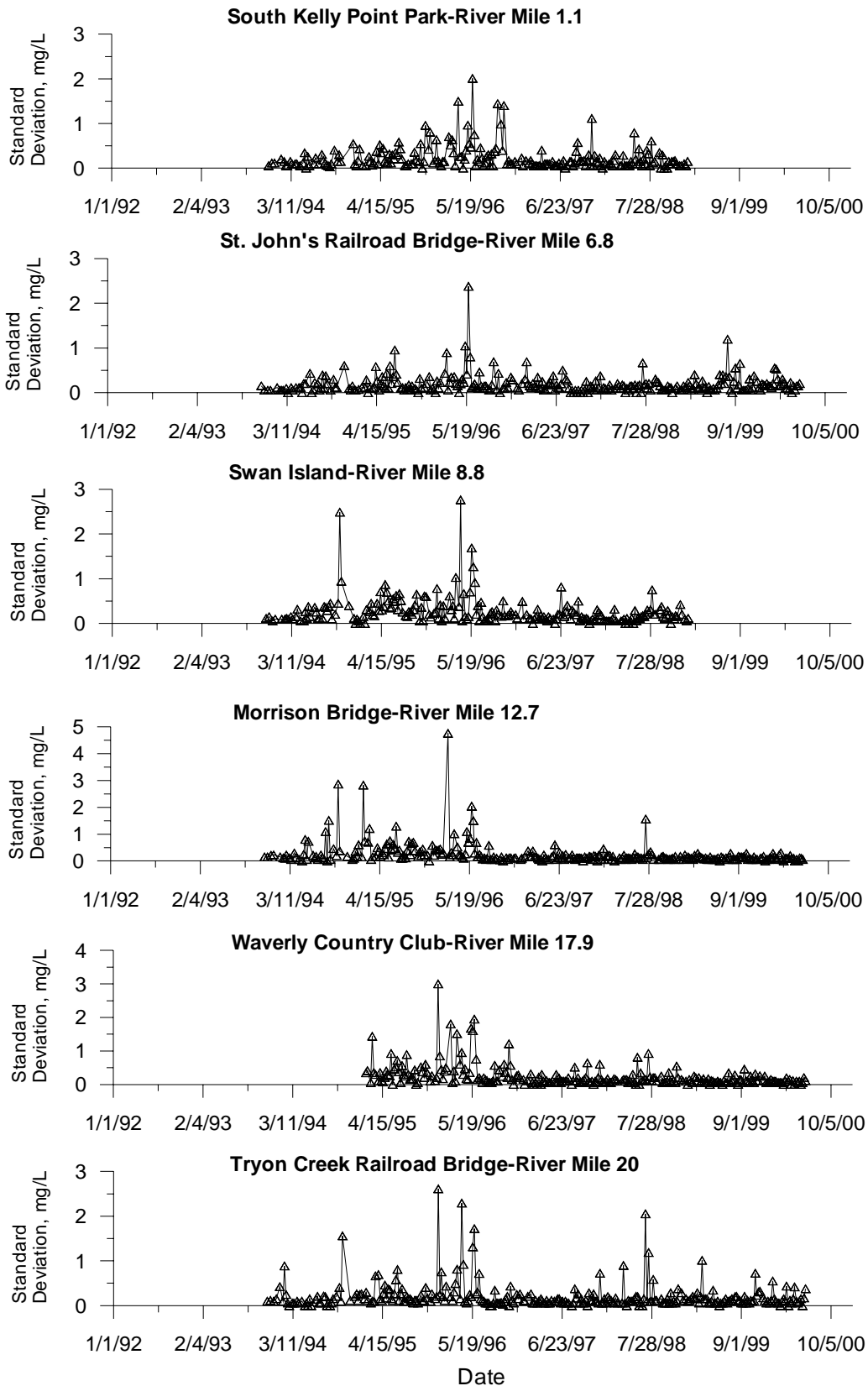


Conductivity

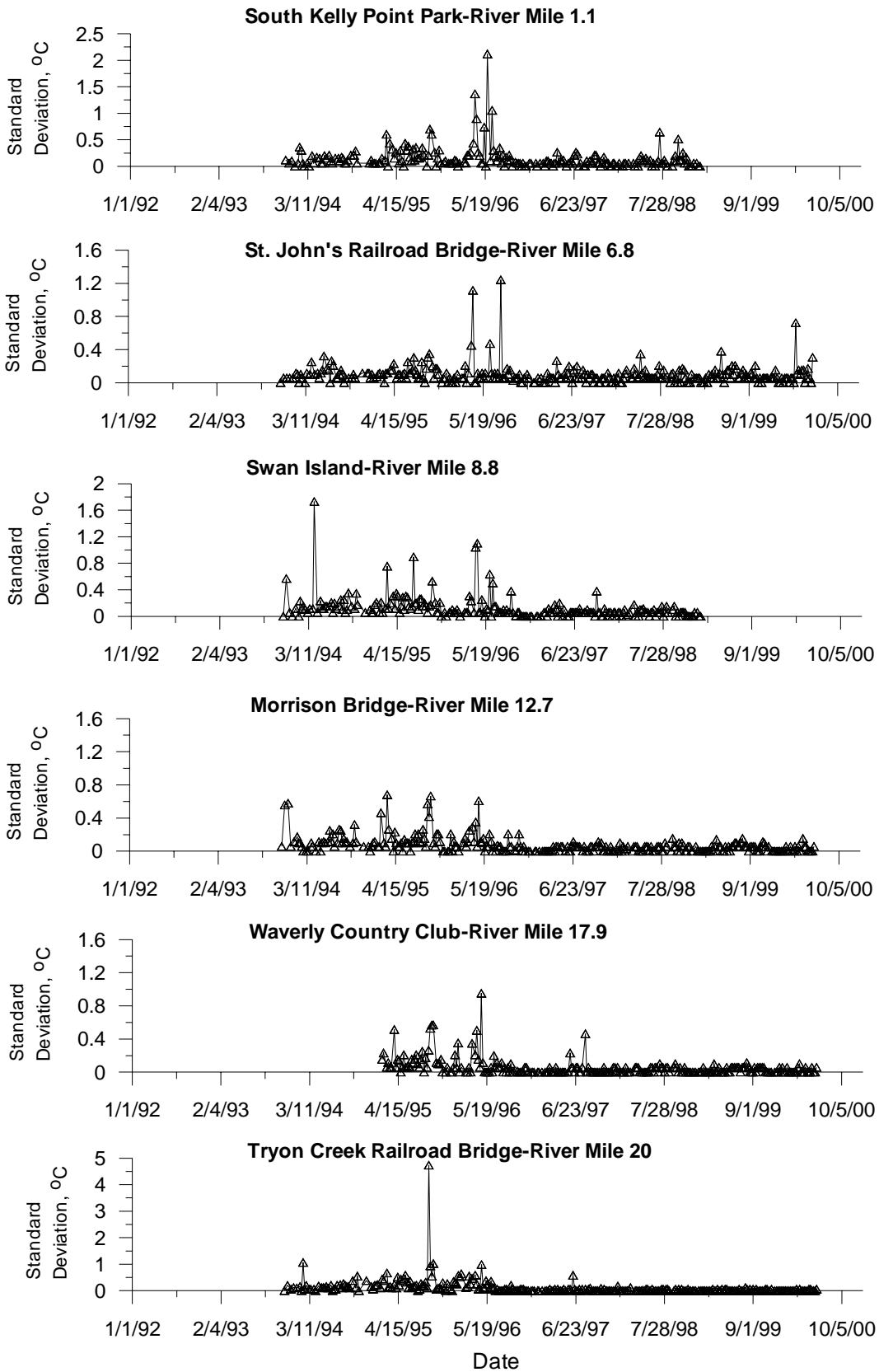


Appendix D: Willamette River Grab Samples across the river - Standard Deviations

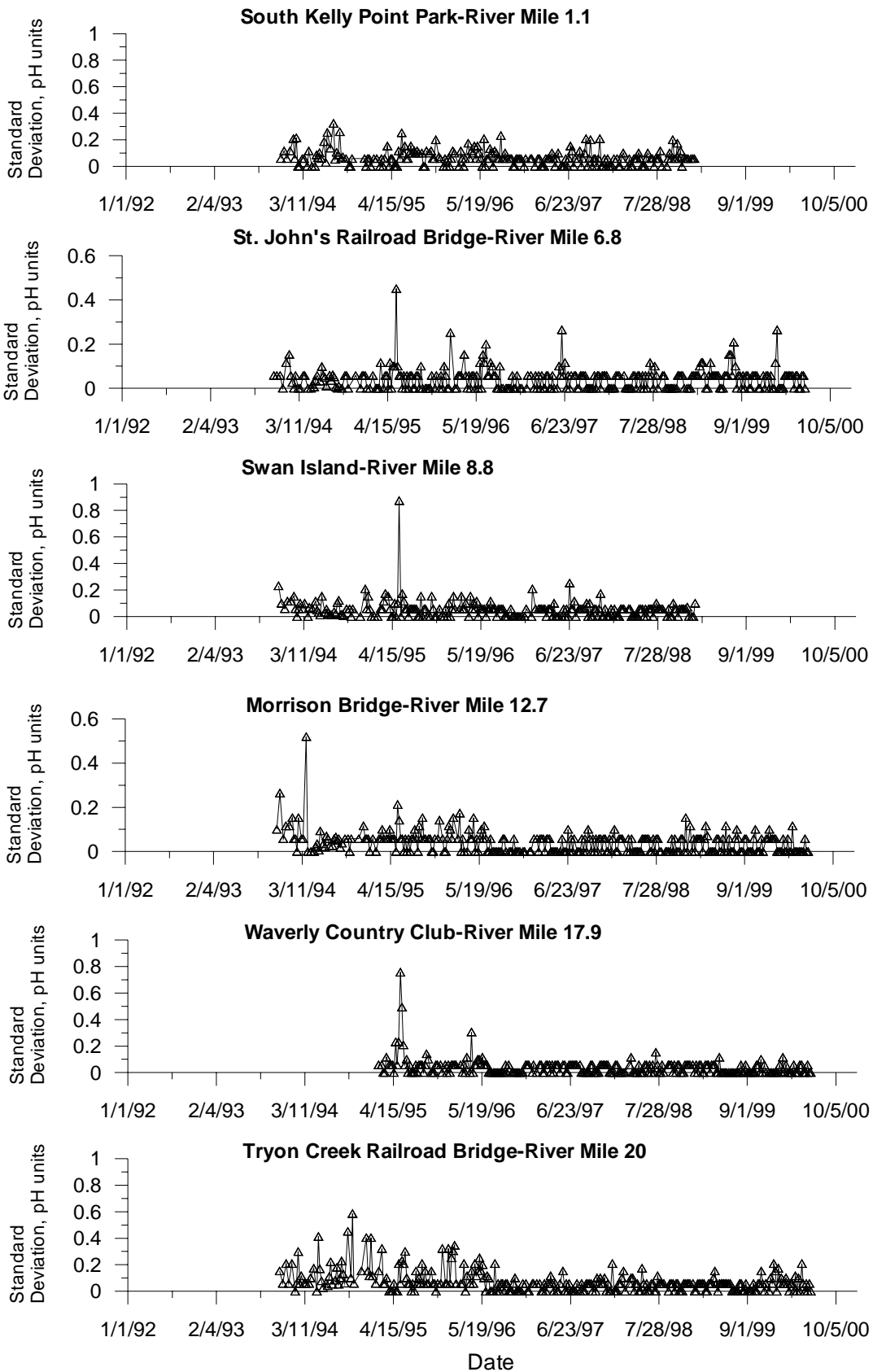
Dissolved Oxygen



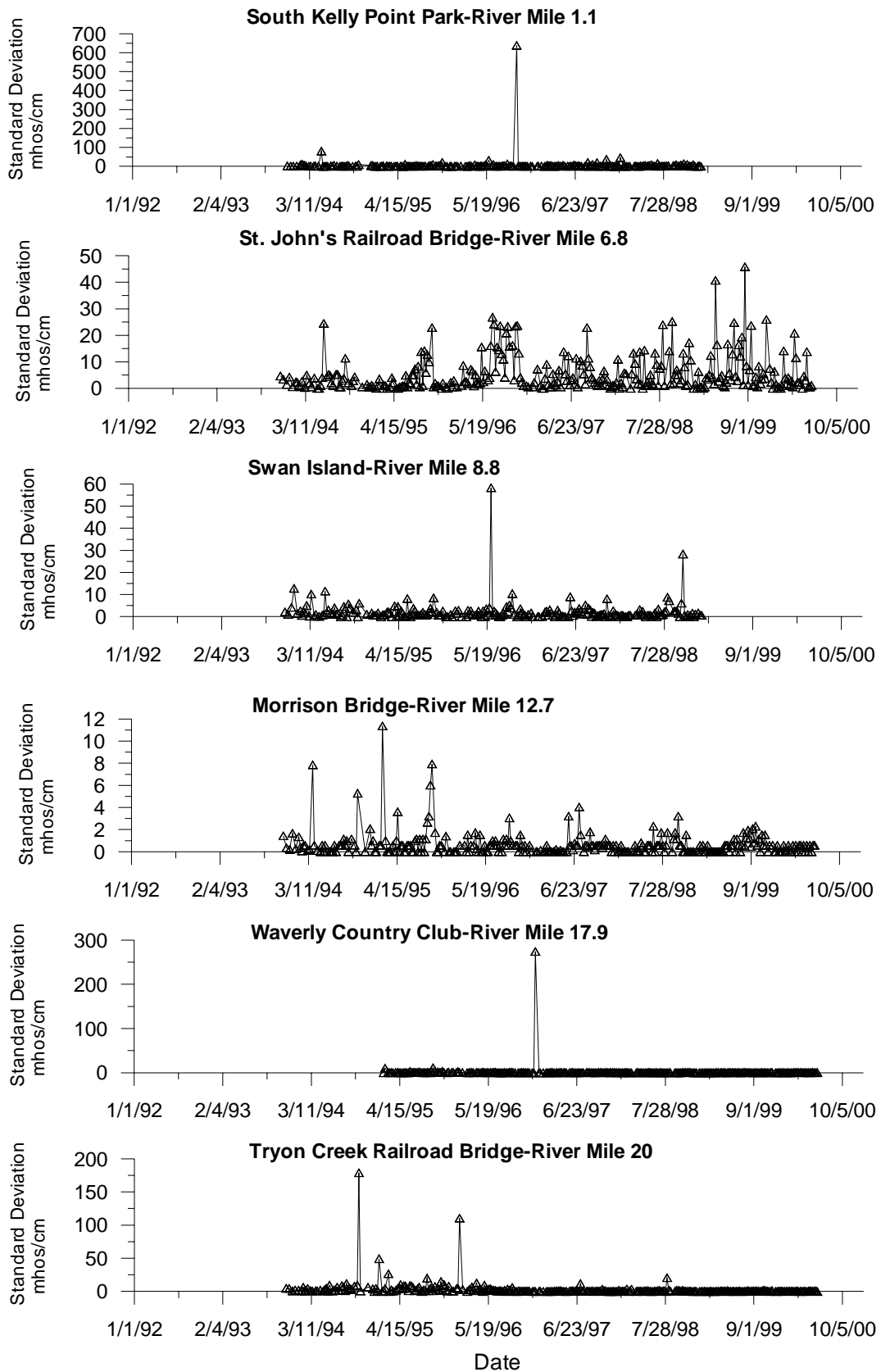
Temperature



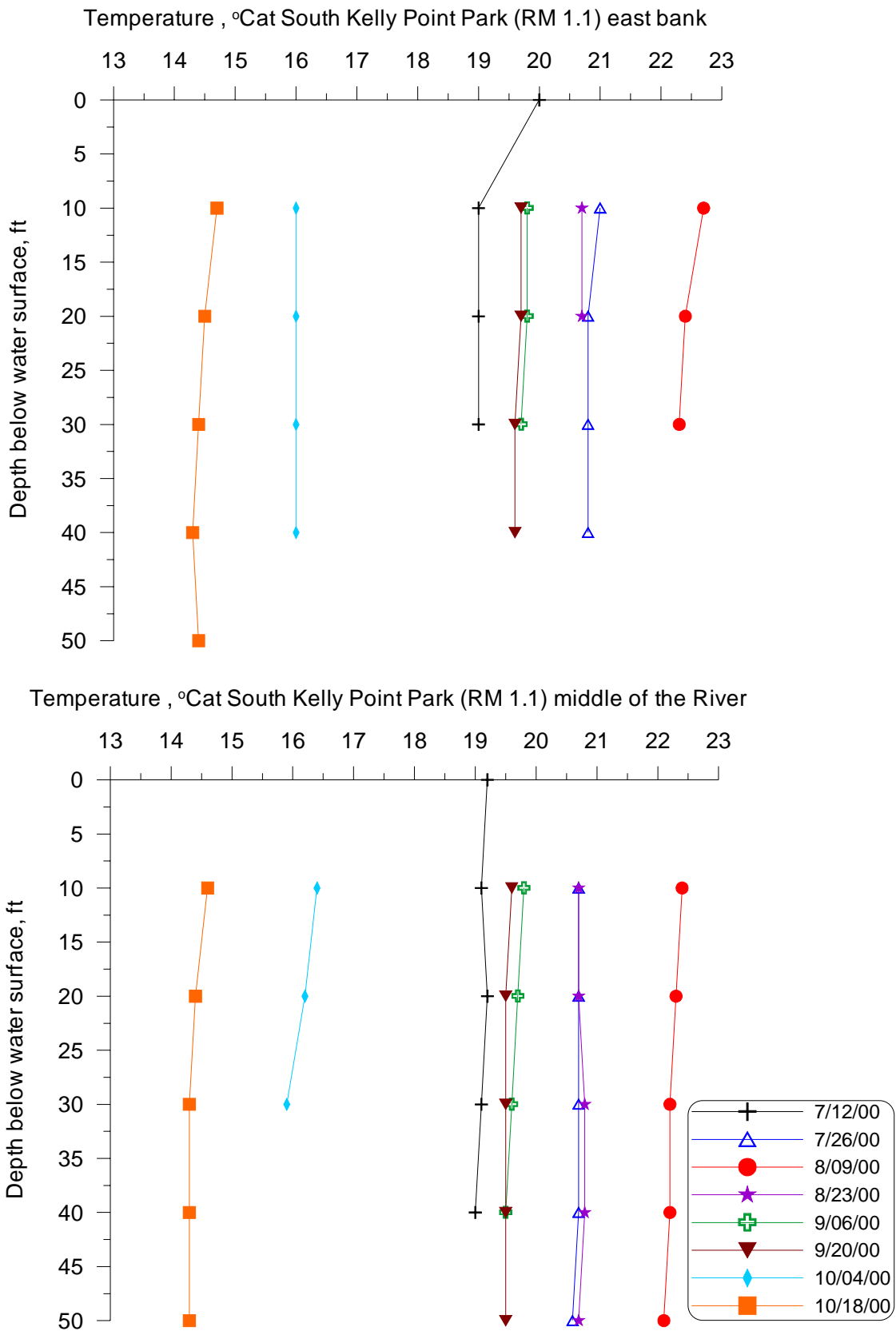
pH



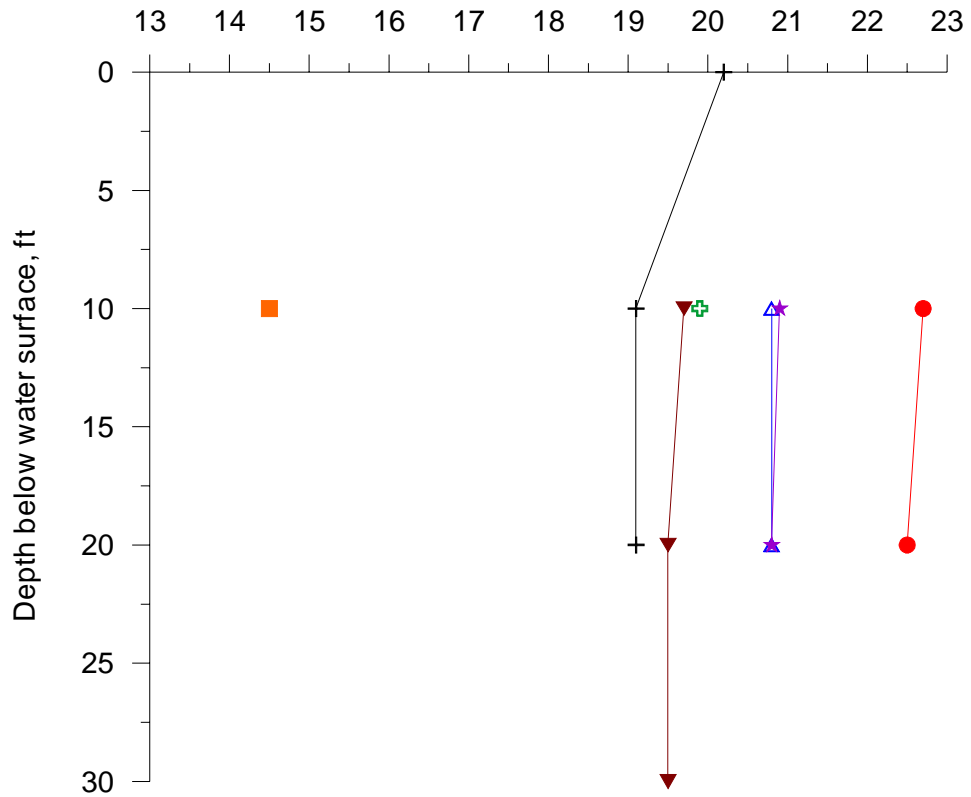
Conductivity



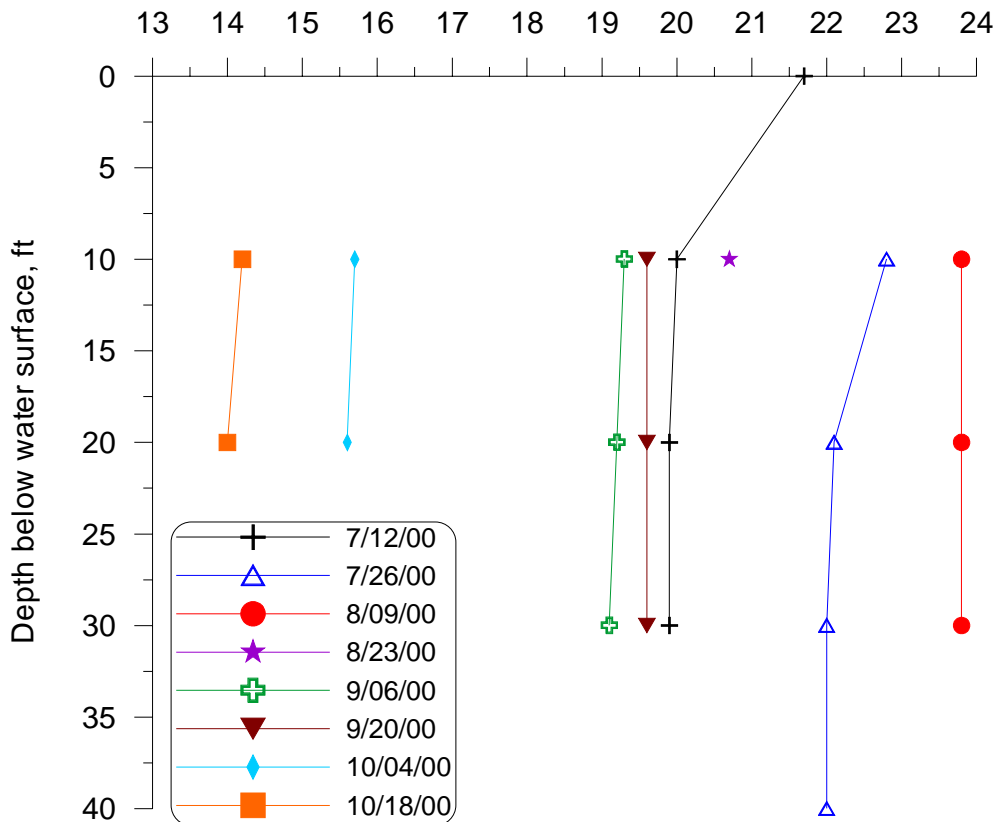
Appendix E: Willamette River Temperature Profiles, summer 2000



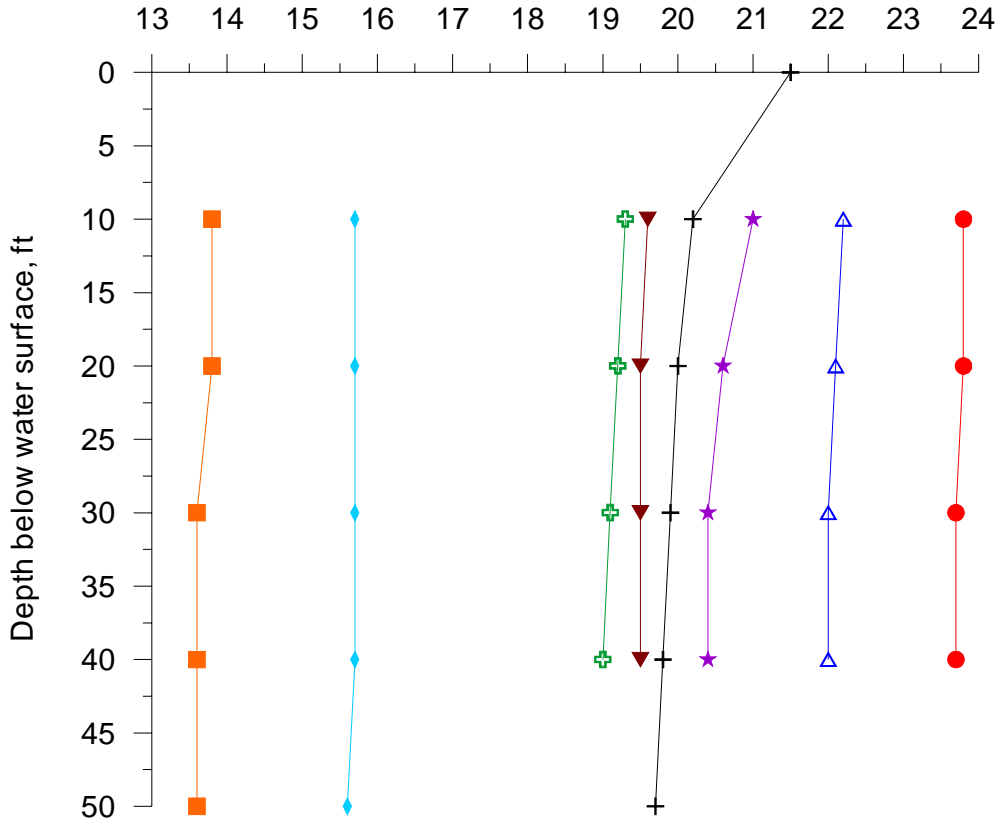
Temperature , °Cat South Kelly Point Park (RM 1.1) west bank



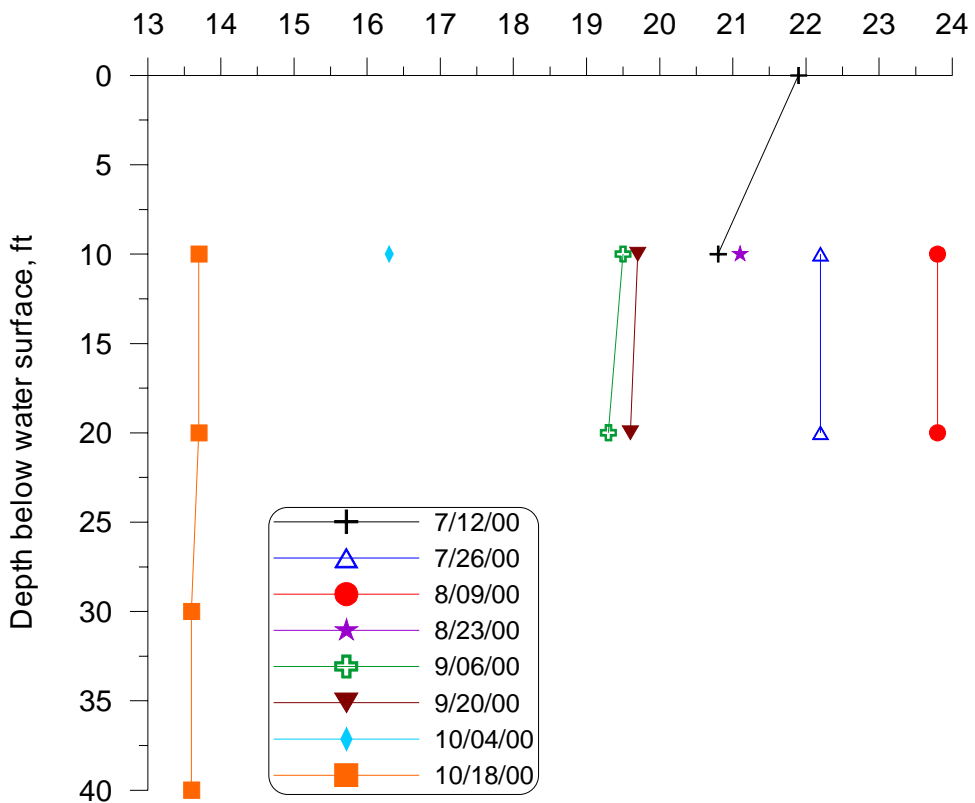
Temperature , °Cat St. Johns Railroad Bridge (RM 6.8) east bank

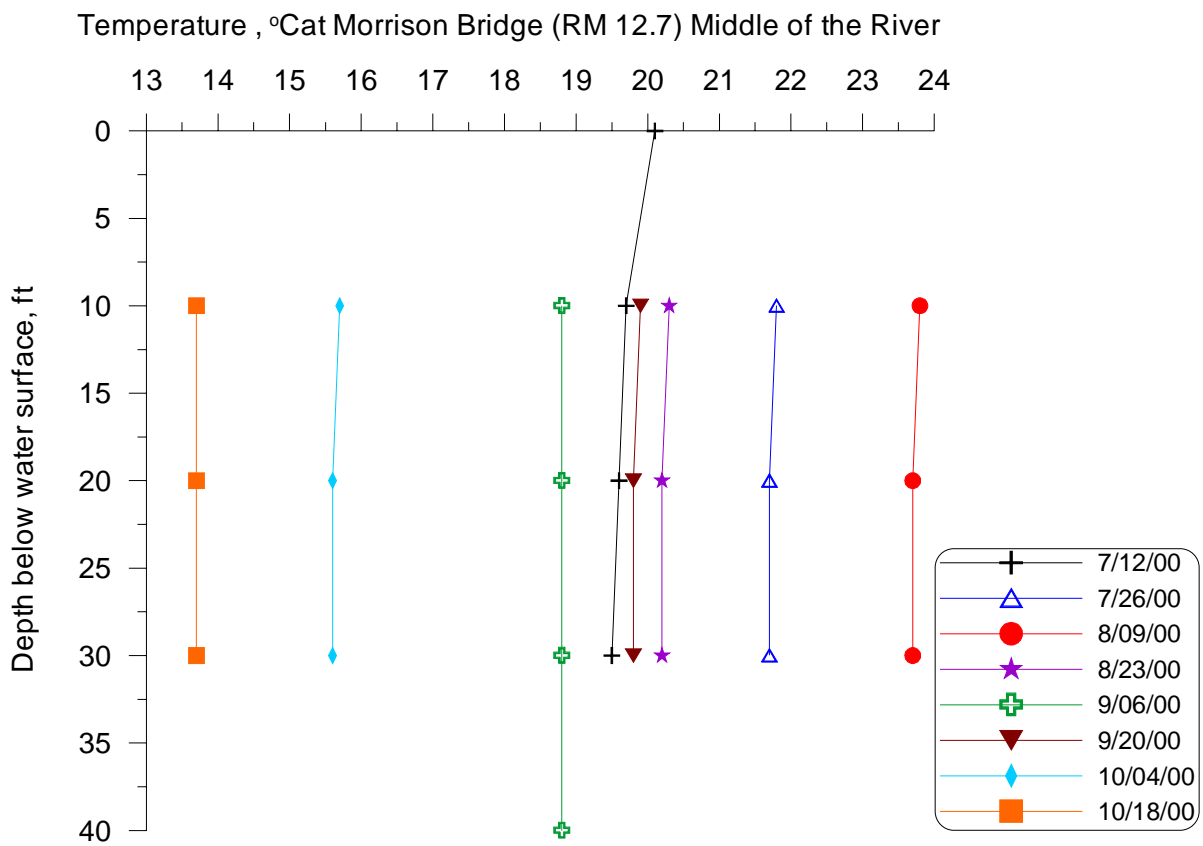
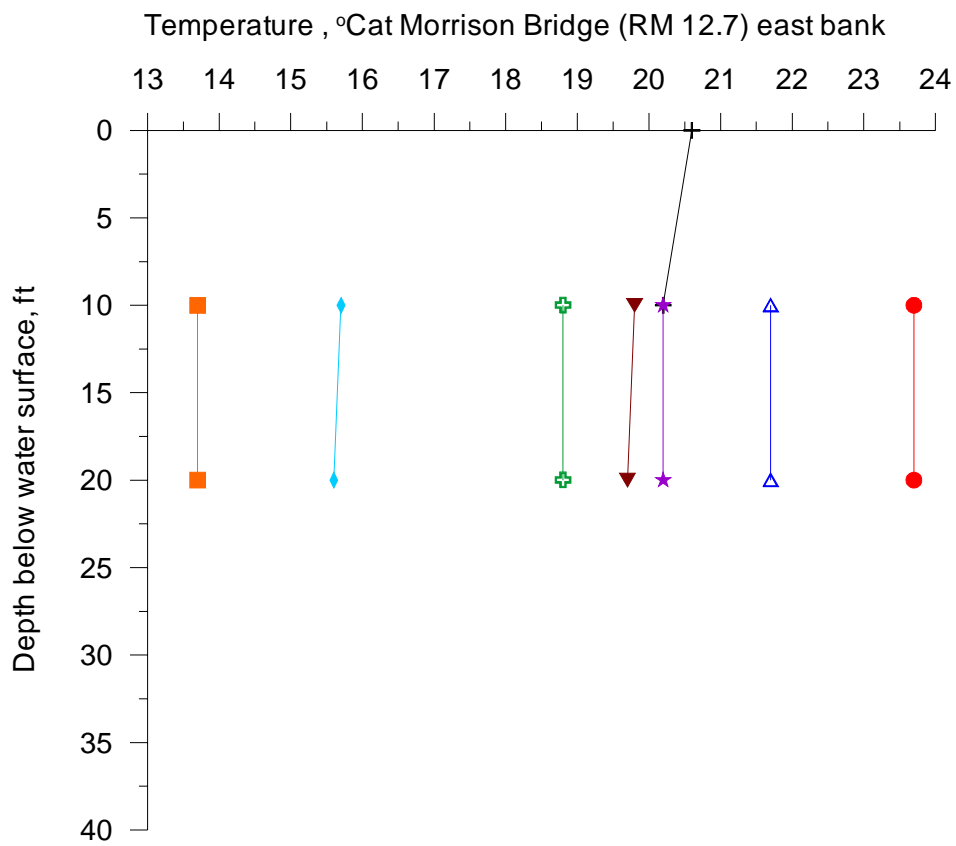


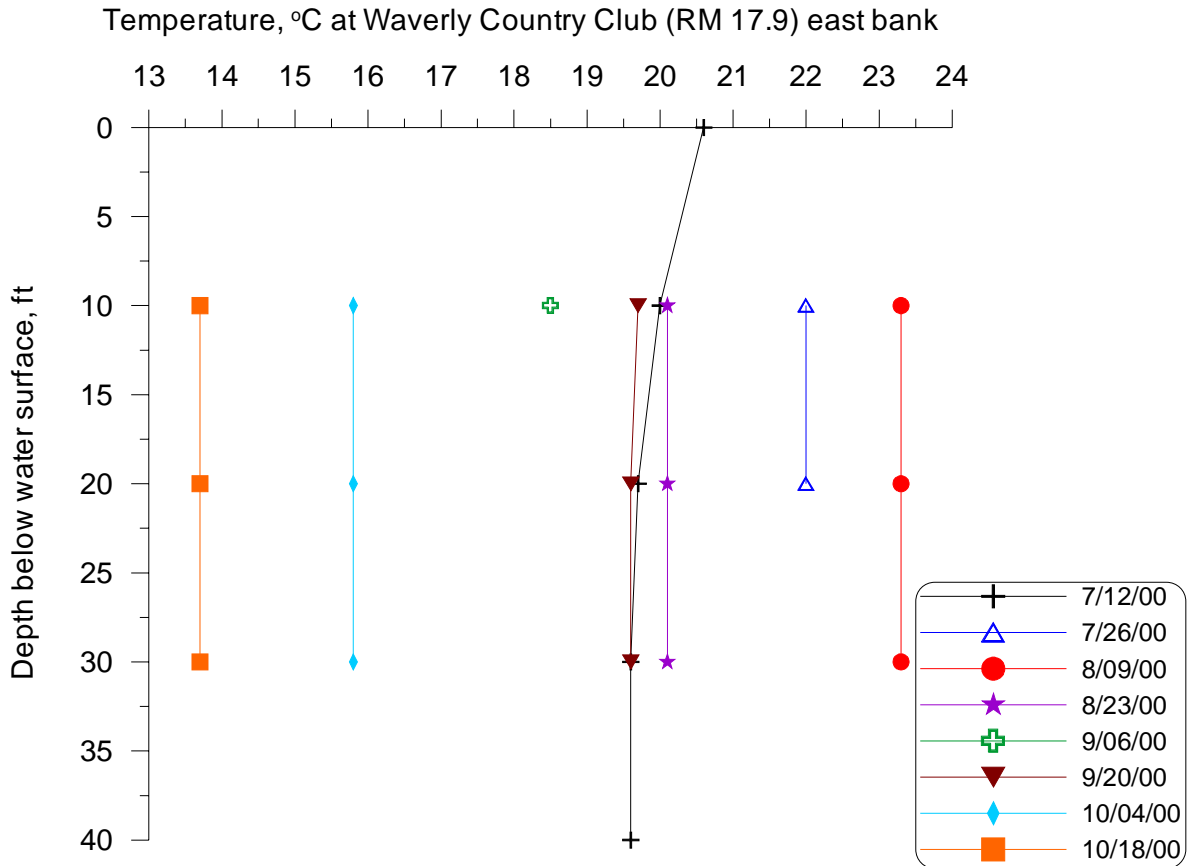
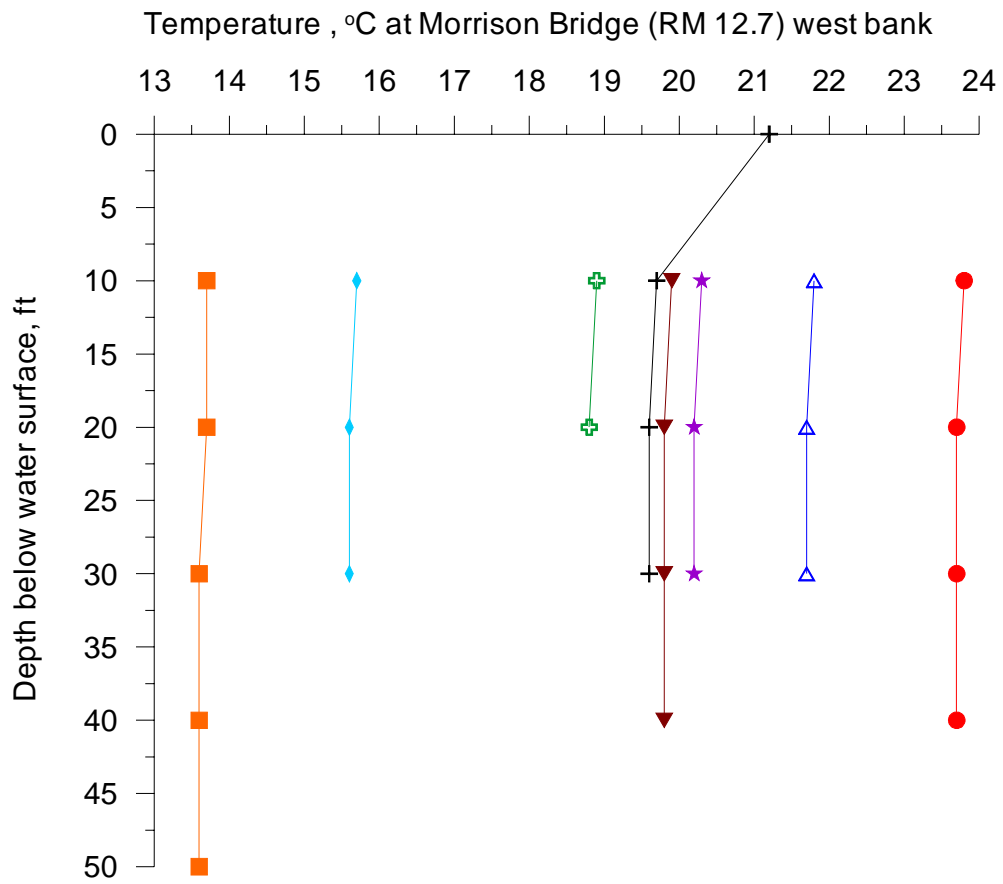
Temperature , °Cat St. Johns Railroad Bridge (RM 6.8) middle of the River



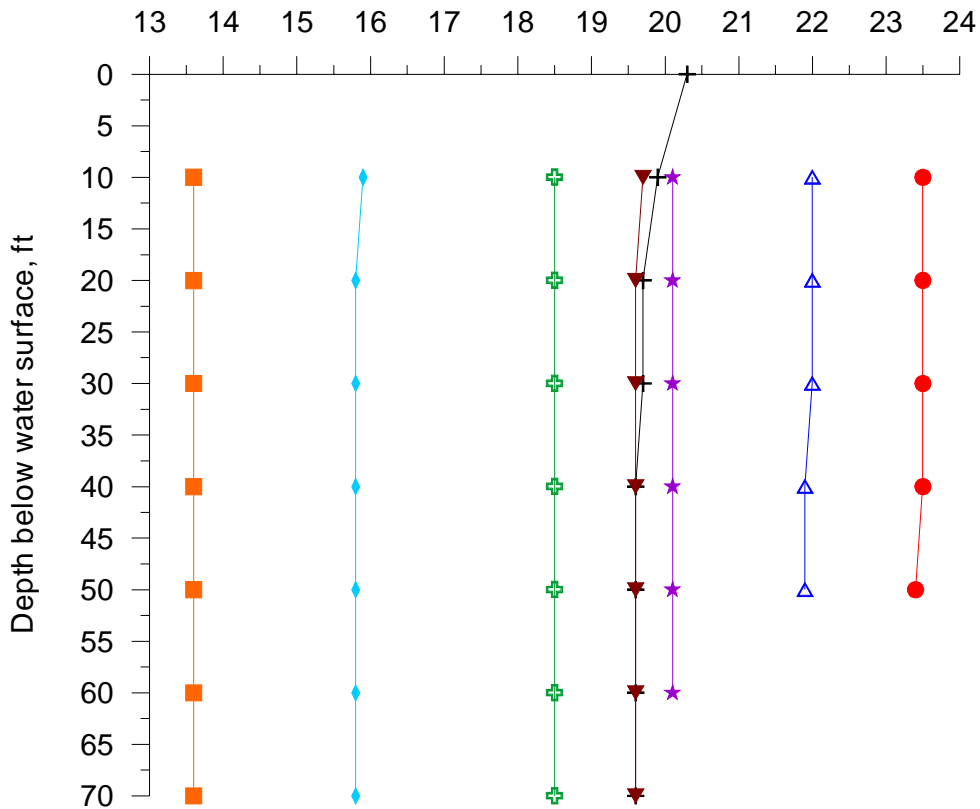
Temperature , °Cat St. Johns Railroad Bridge (RM 6.8) west bank



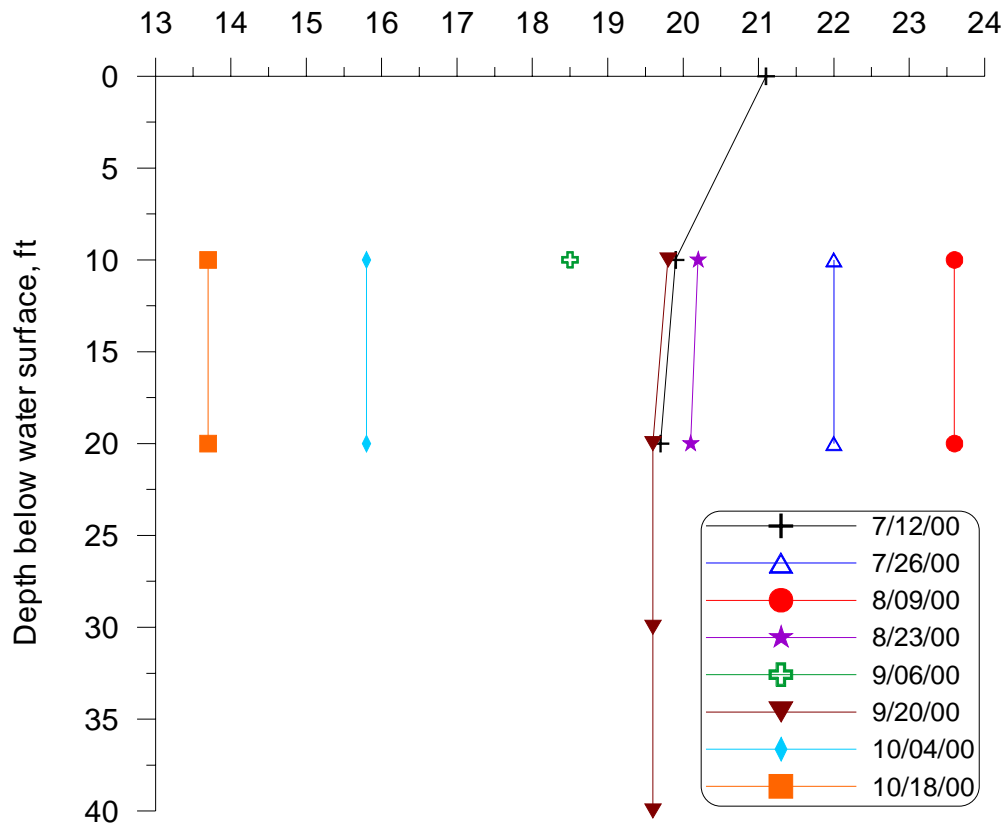




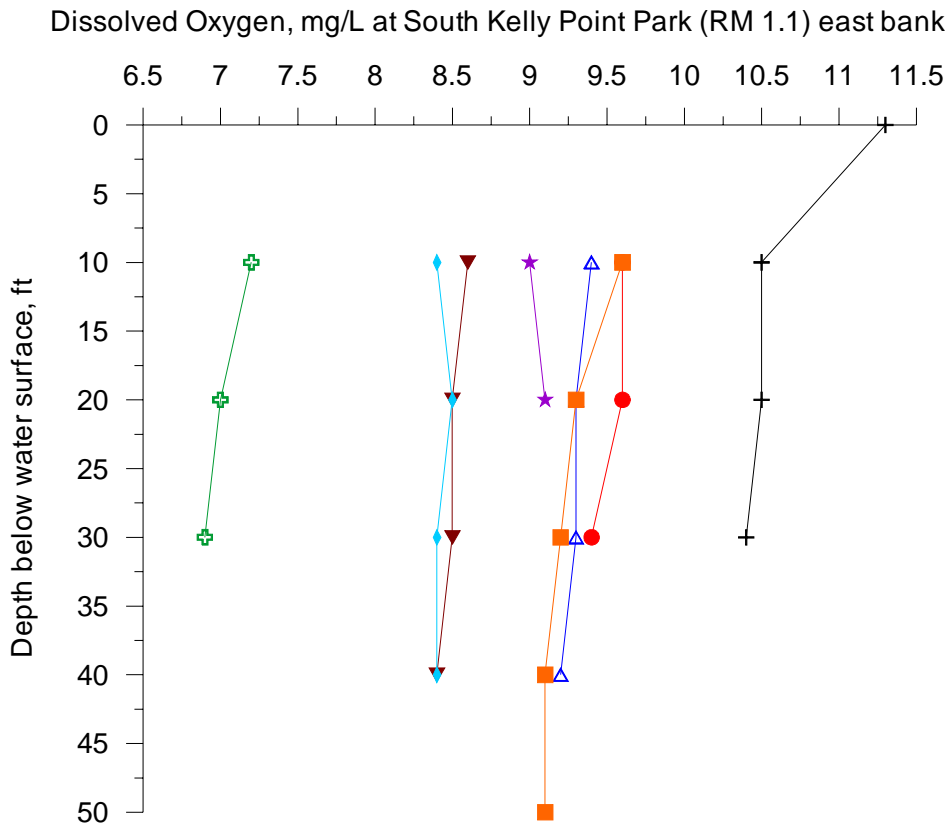
Temperature, °C at Waverly Country Club (RM 17.9) middle of the River



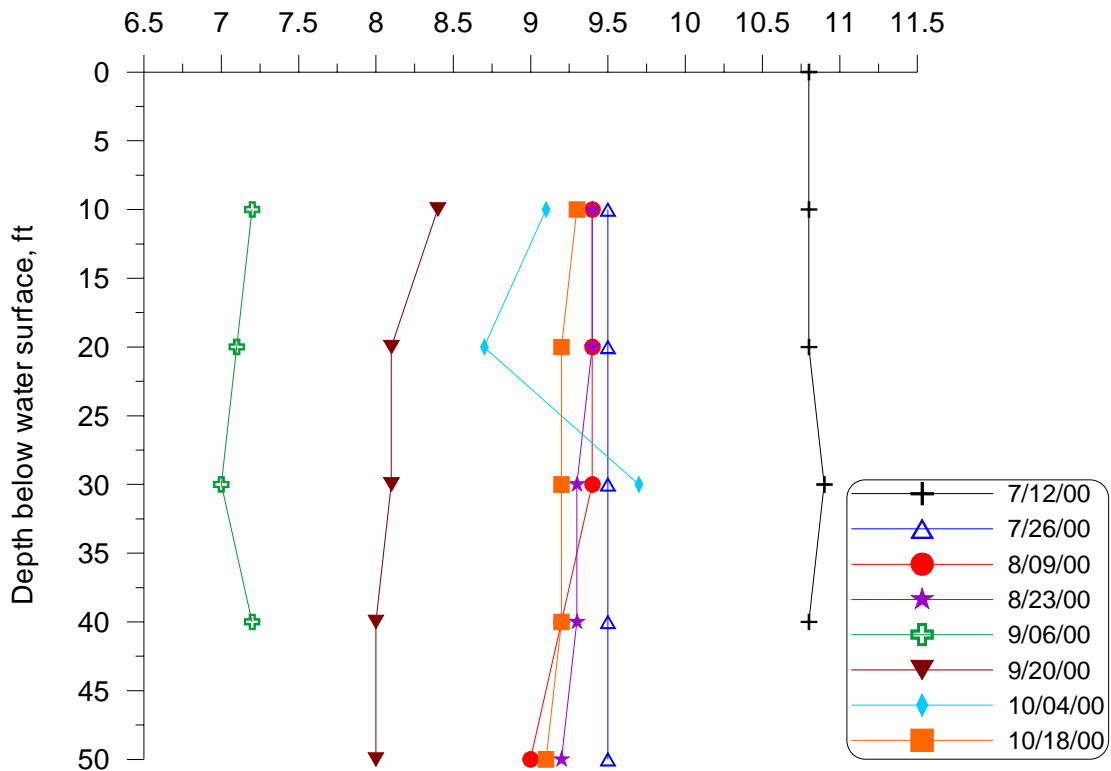
Temperature, °C at Waverly Country Club (RM 17.9) west bank



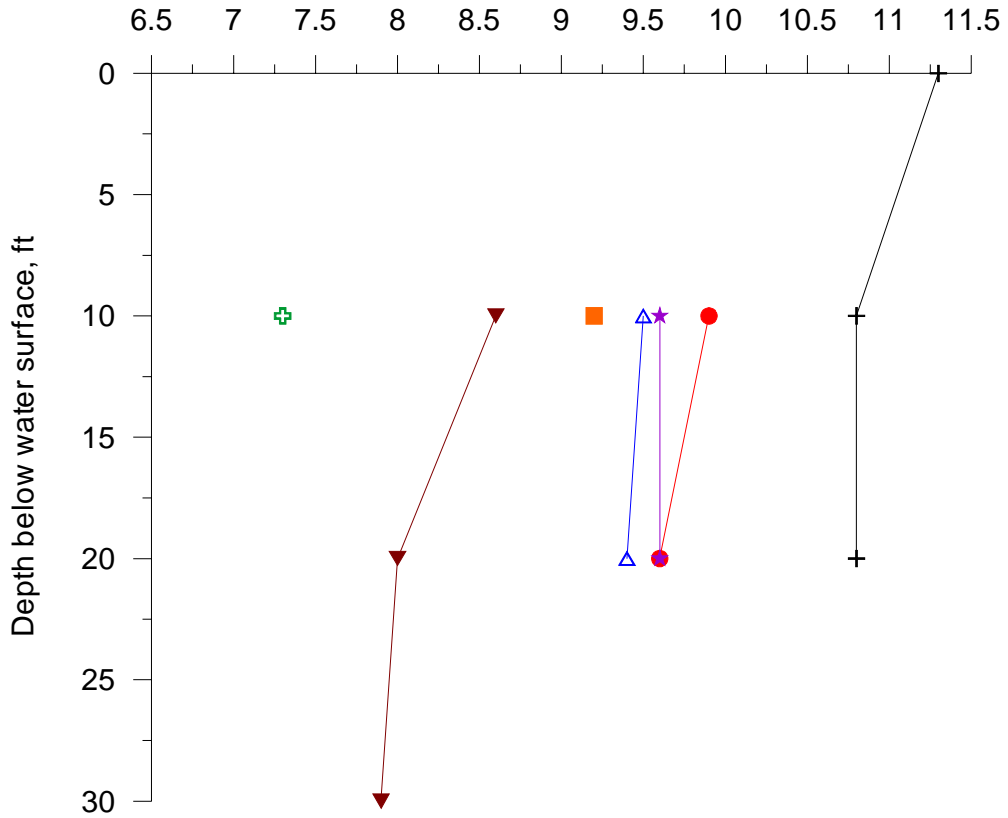
Appendix F: Willamette River Dissolved Oxygen Profiles, summer 2000



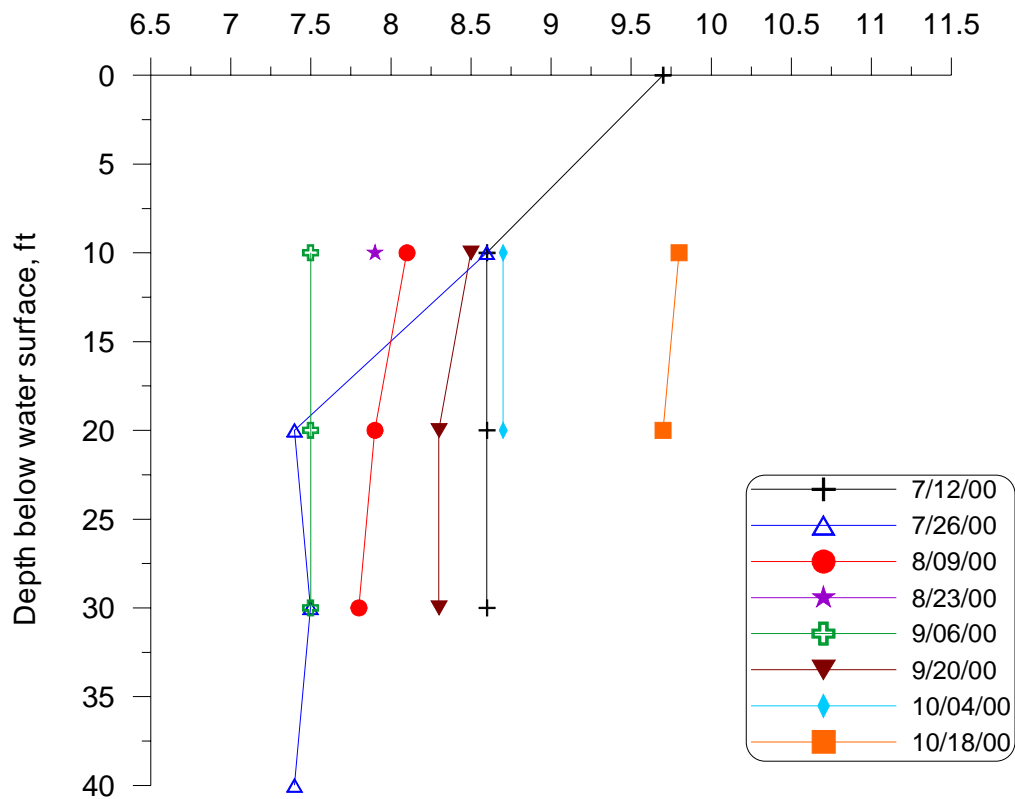
Dissolved Oxygen, mg/L at South Kelly Point Park (RM 1.1) middle of the River



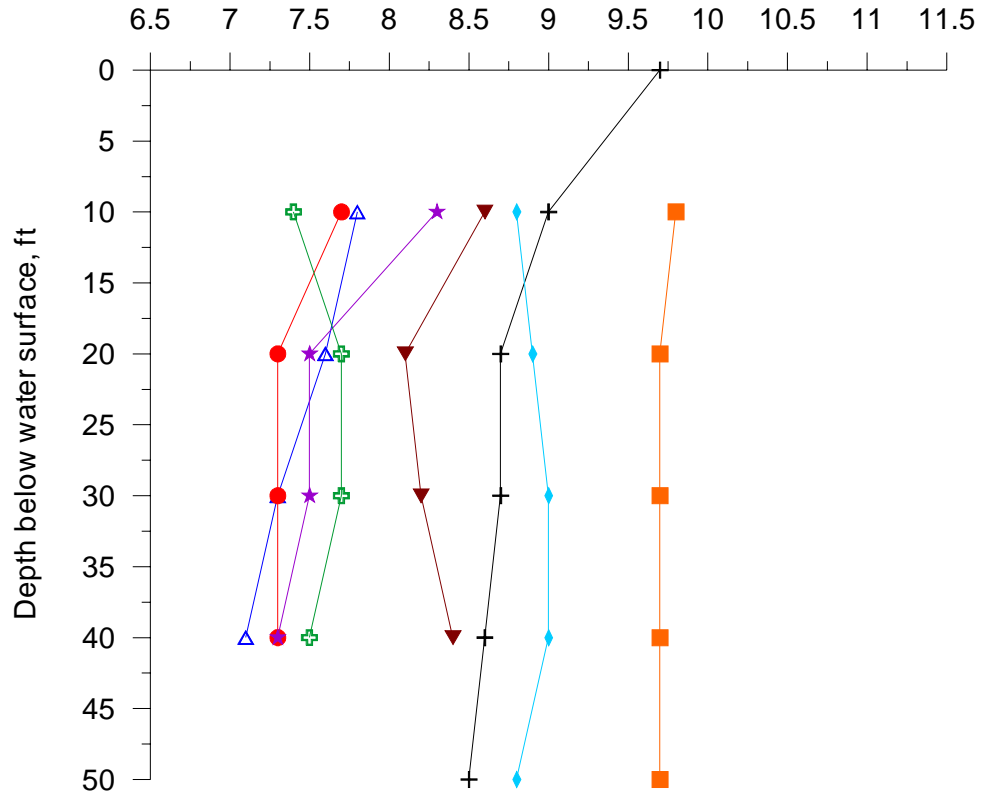
Dissolved Oxygen, mg/L at South Kelly Point Park (RM 1.1) west bank



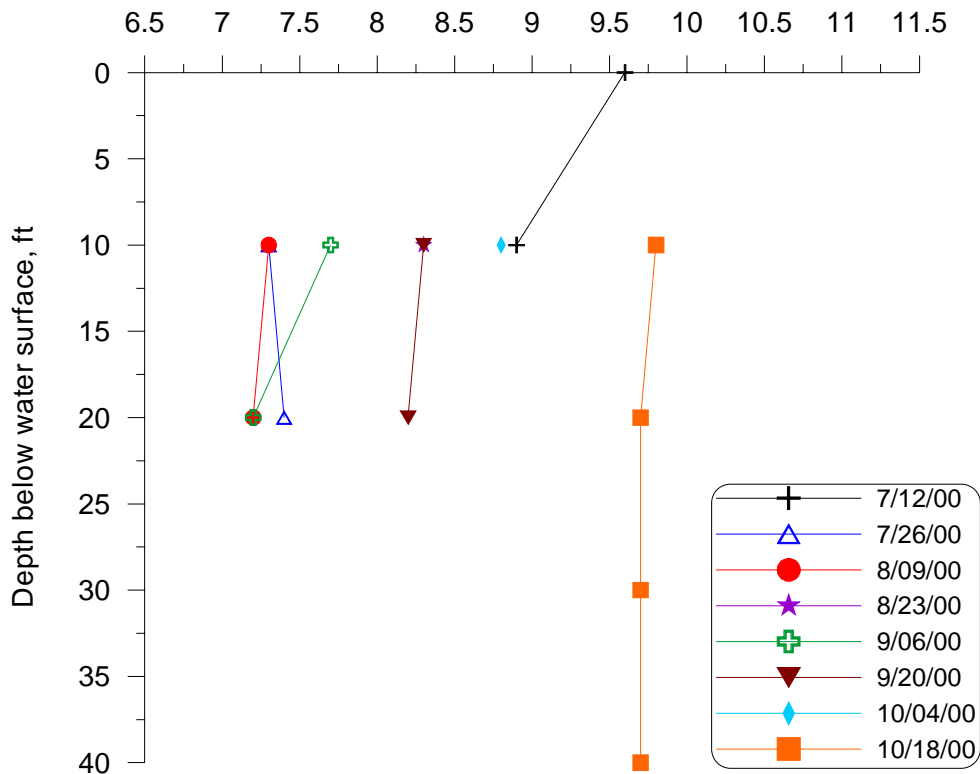
Dissolved Oxygen, mg/L at St. John's Railroad Bridge (RM 6.8) east bank



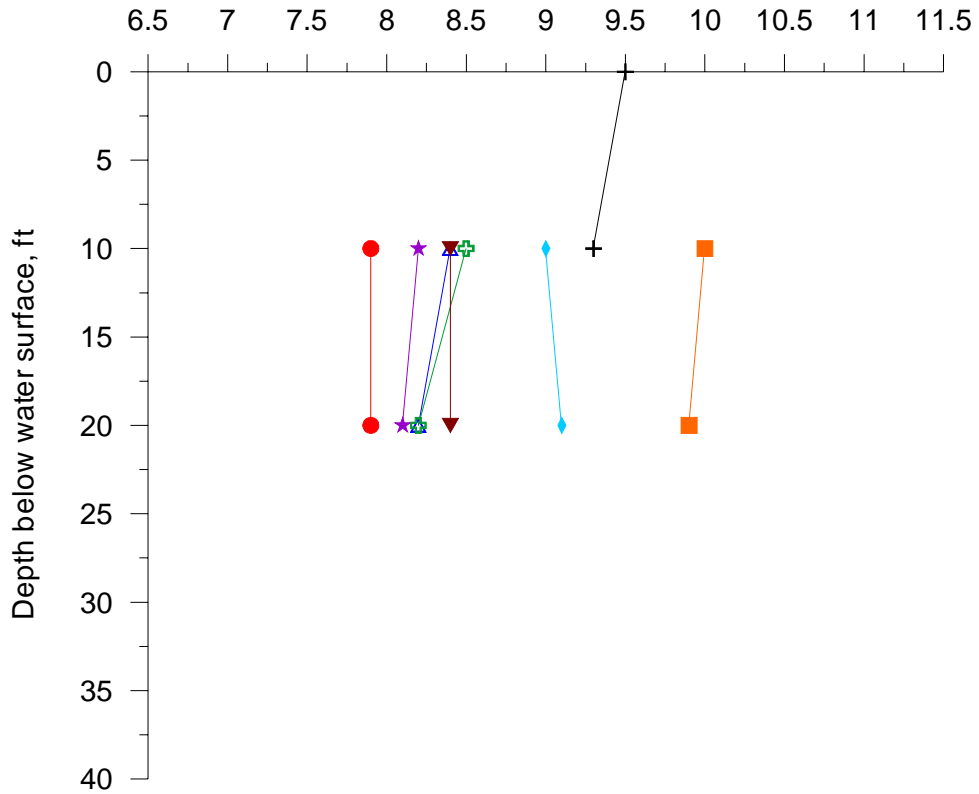
Dissolved Oxygen, mg/L at St. John's Railroad Bridge (RM 6.8) middle of the River



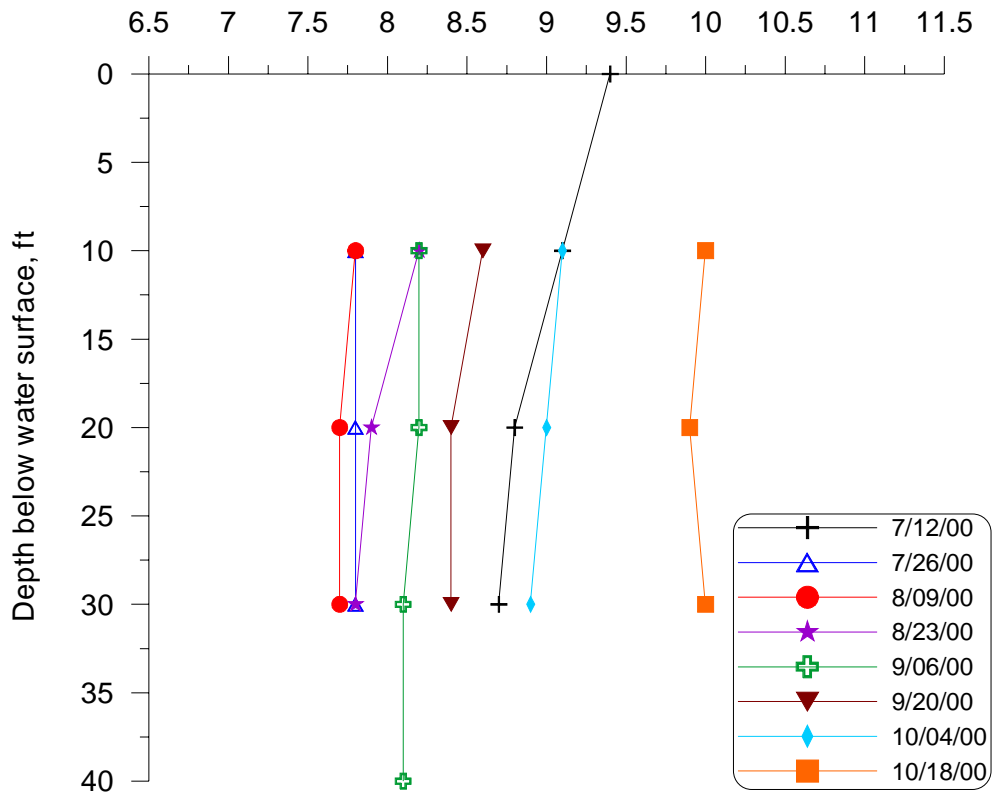
Dissolved Oxygen, mg/L at St. John's Railroad Bridge (RM 6.8) west bank



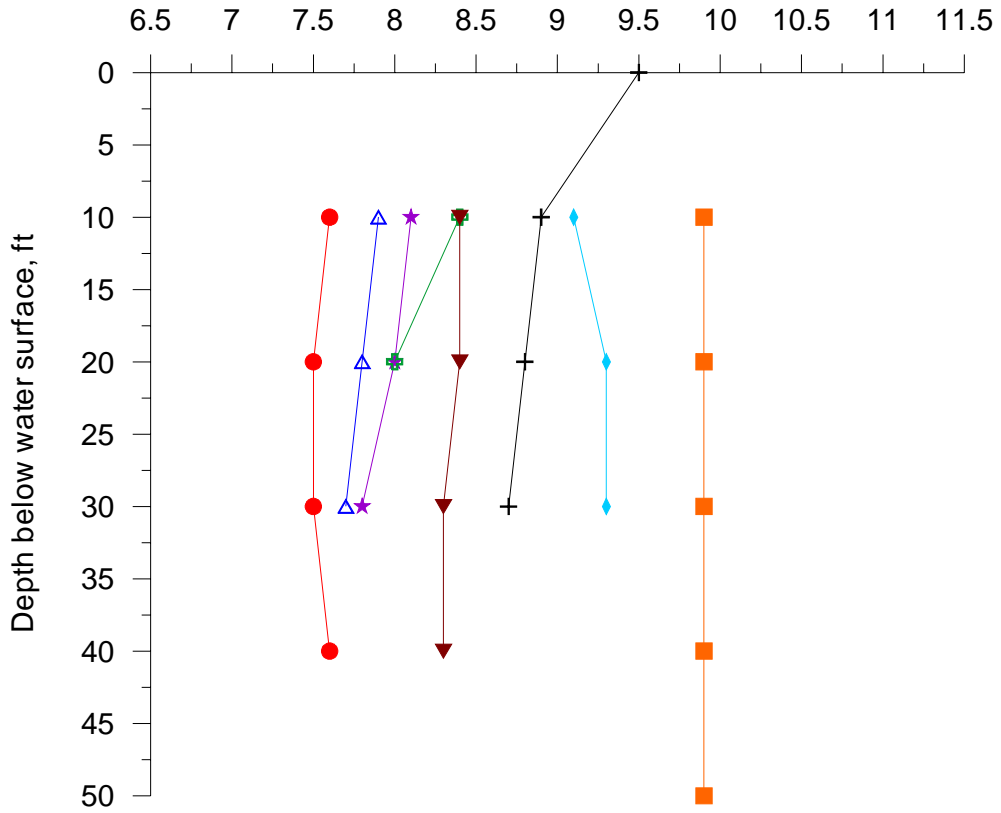
Dissolved Oxygen, mg/L at Morrison Bridge (RM 12.7) east bank



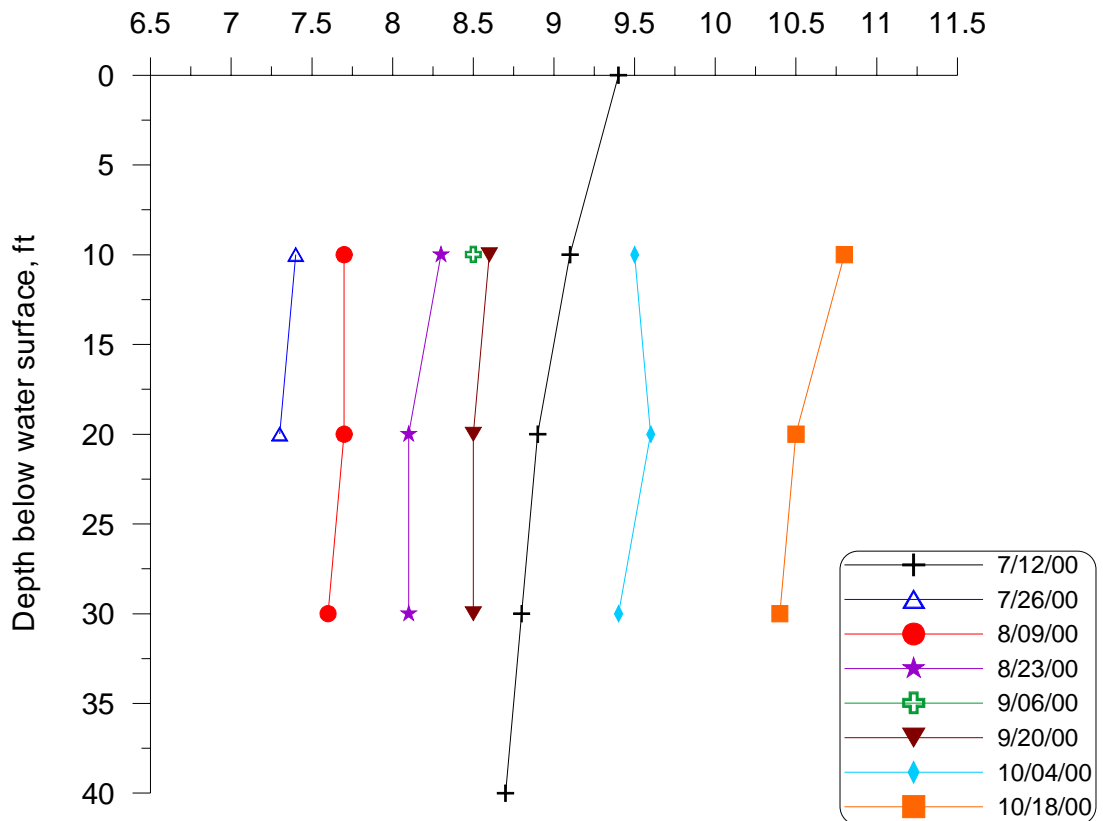
Dissolved Oxygen, mg/L at Morrison Bridge (RM 12.7) middle of the River



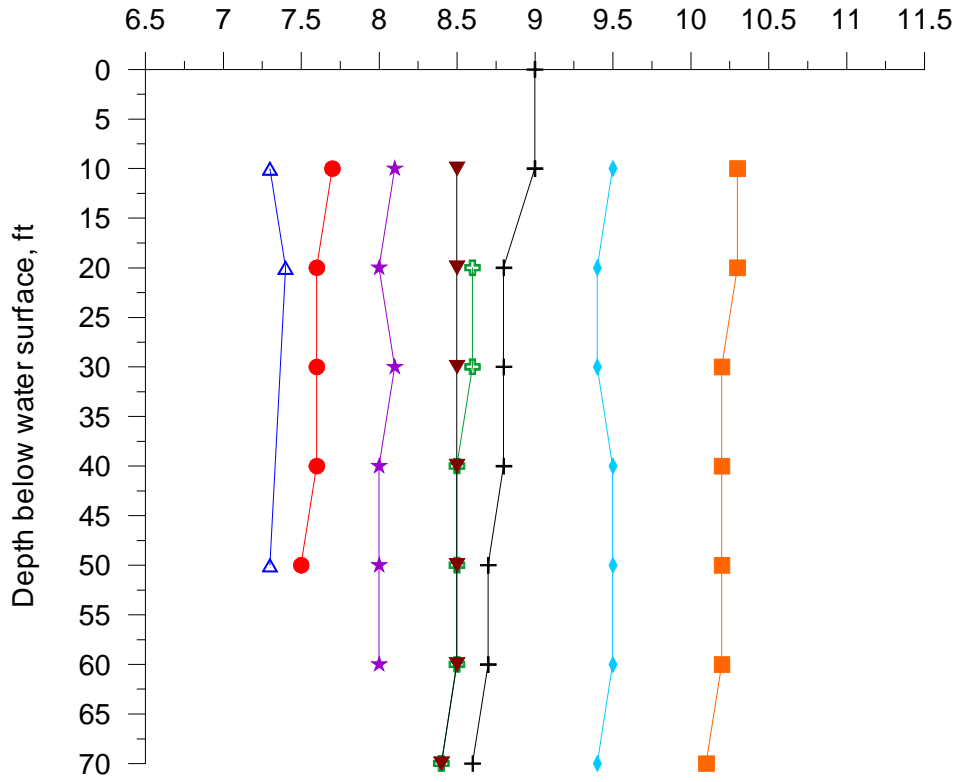
Dissolved Oxygen, mg/L at Morrison Bridge (RM 12.7) west bank



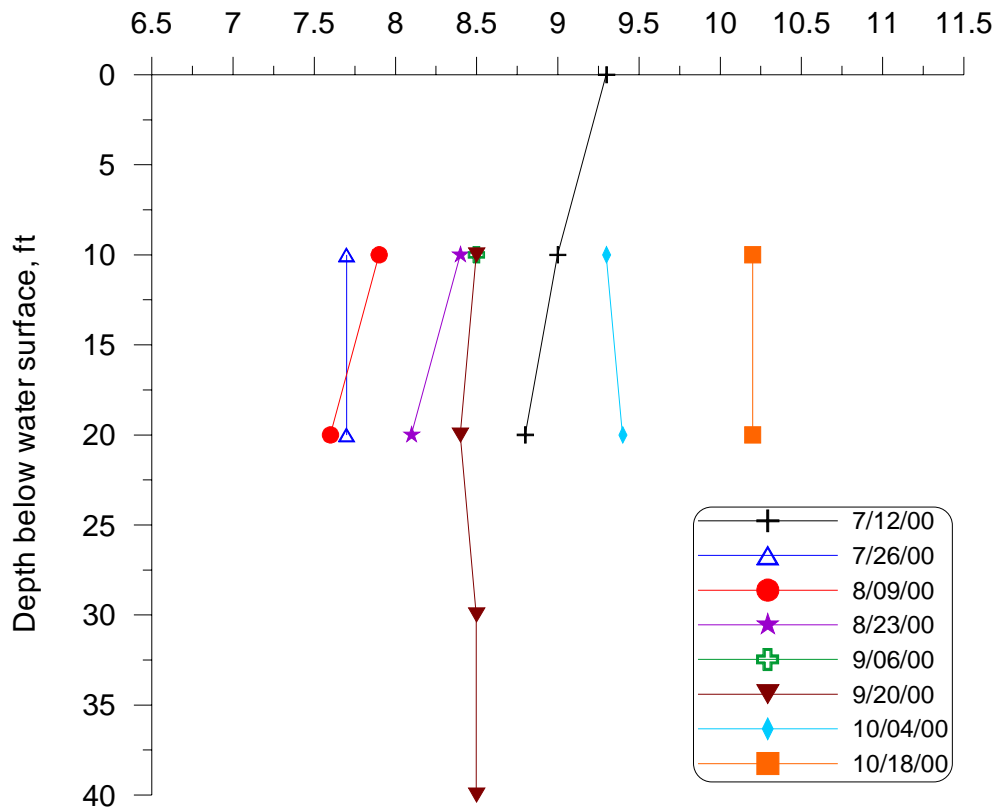
Dissolved Oxygen, mg/L at Waverly Country Club (RM 17.9) east bank



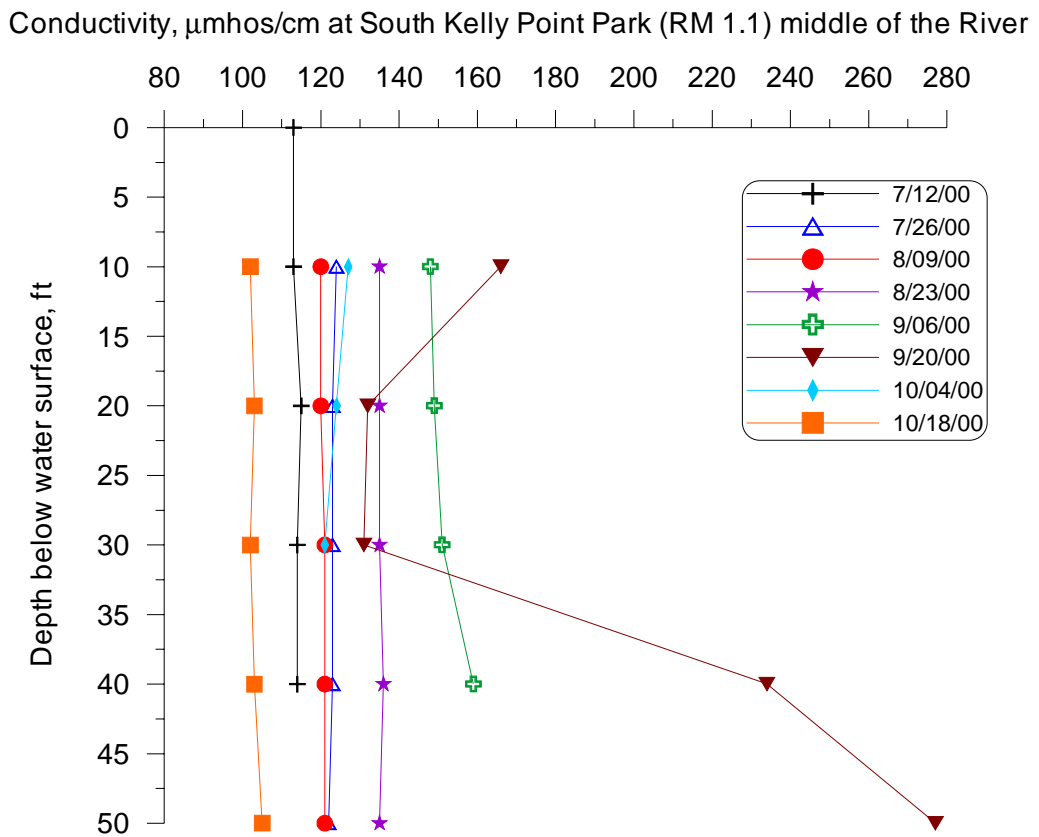
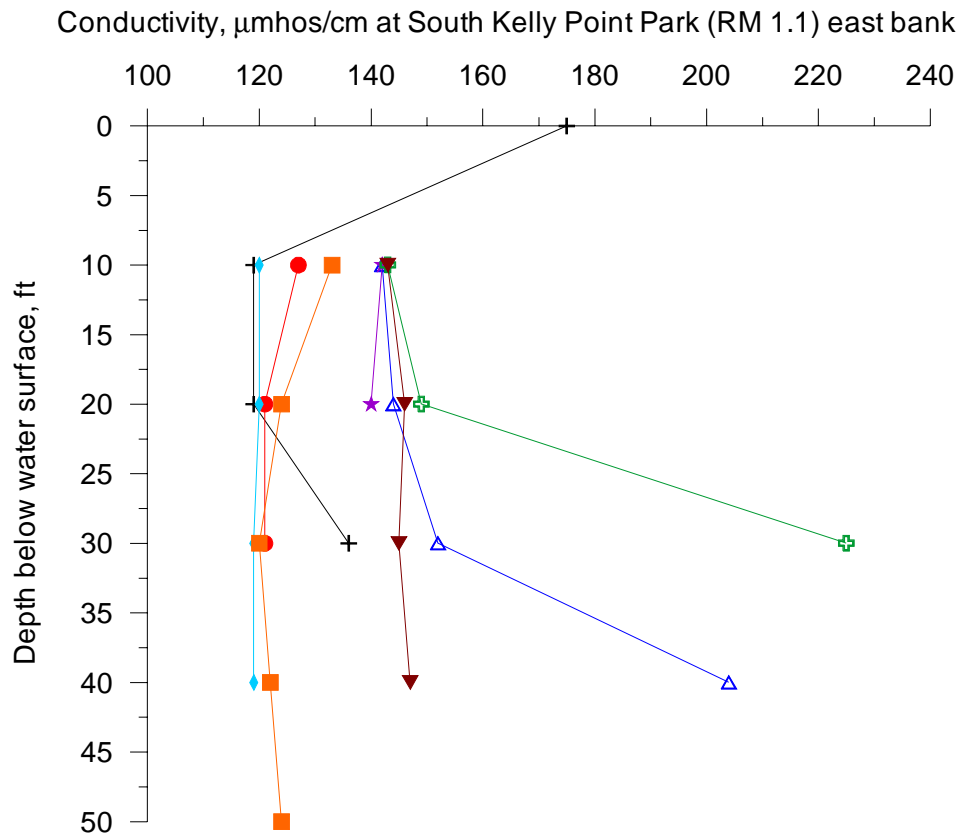
Dissolved Oxygen, mg/L at Waverly Country Club (RM 17.9) middle of the River



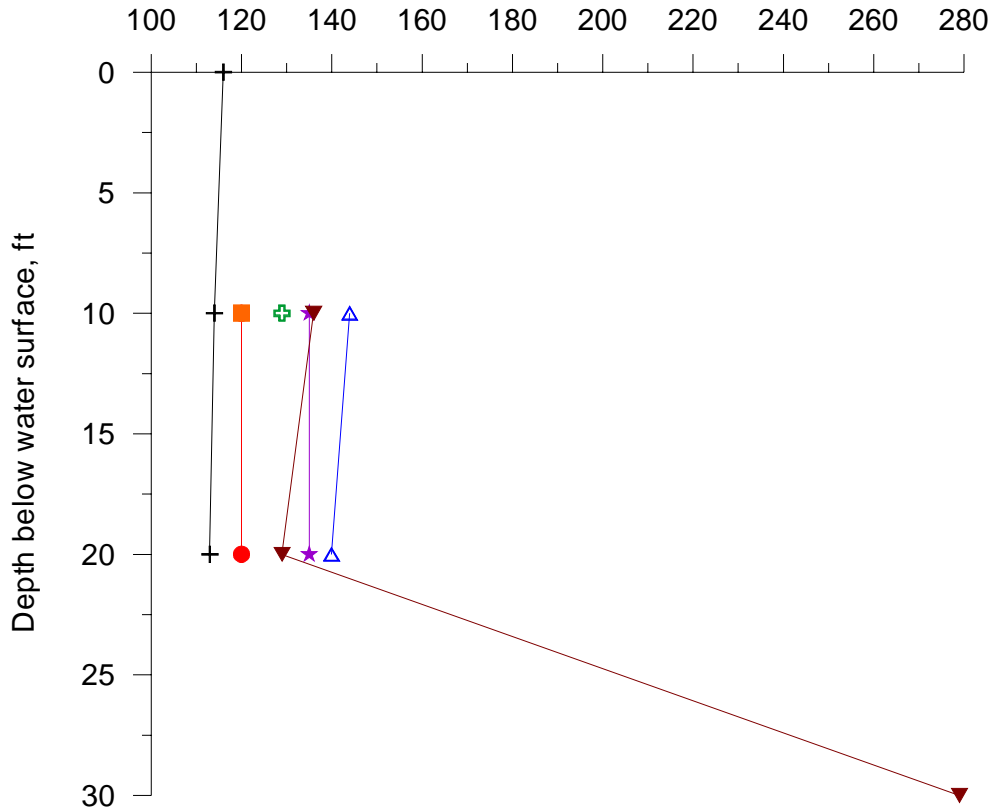
Dissolved Oxygen, mg/L at Waverly Country Club (RM 17.9) west bank



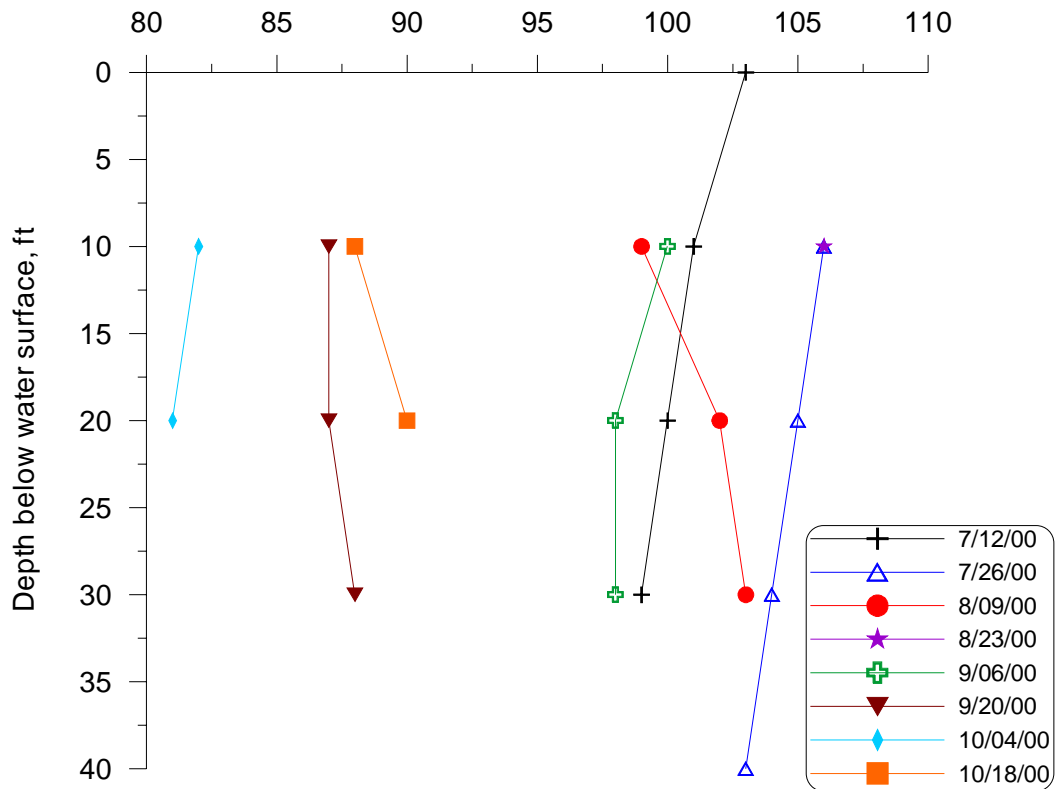
Appendix G: Willamette River Conductivity Profiles, summer 2000



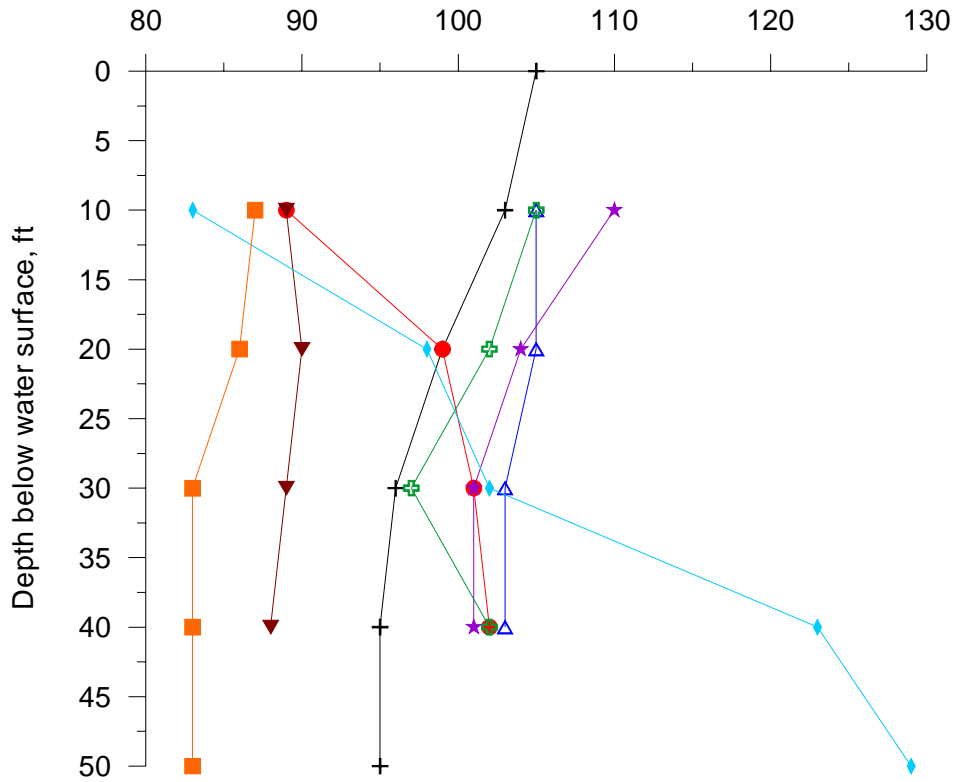
Conductivity, $\mu\text{mhos/cm}$ at South Kelly Point Park (RM 1.1) west bank



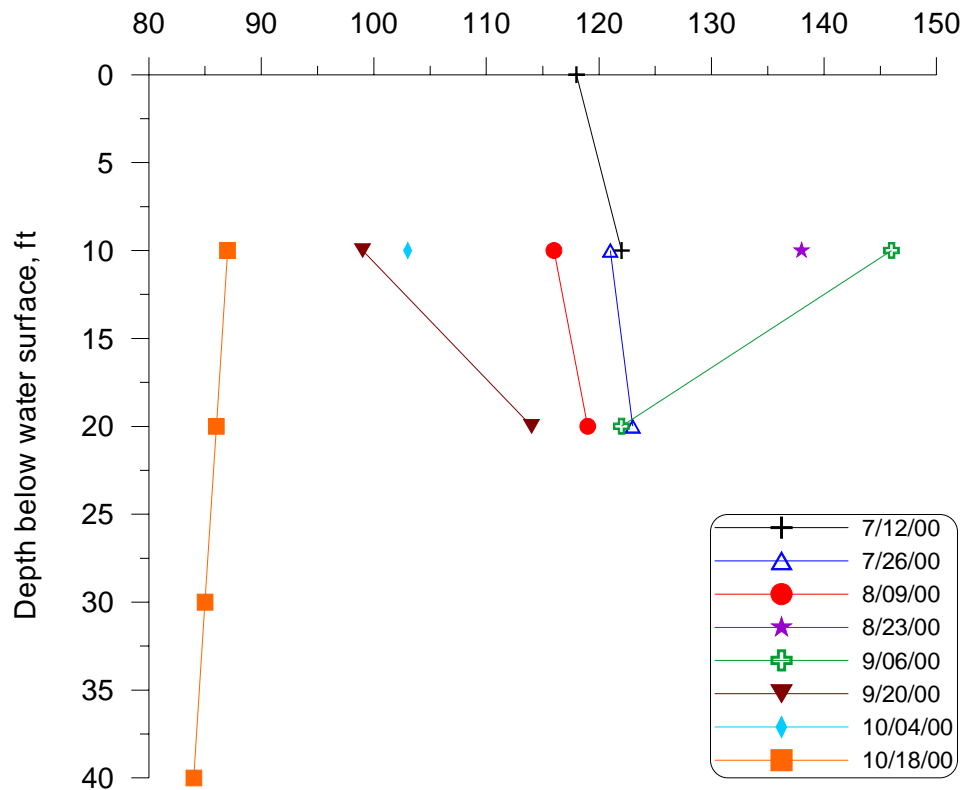
Conductivity, $\mu\text{mhos/cm}$ at St. John's Railroad Bridge (RM 6.8) east bank



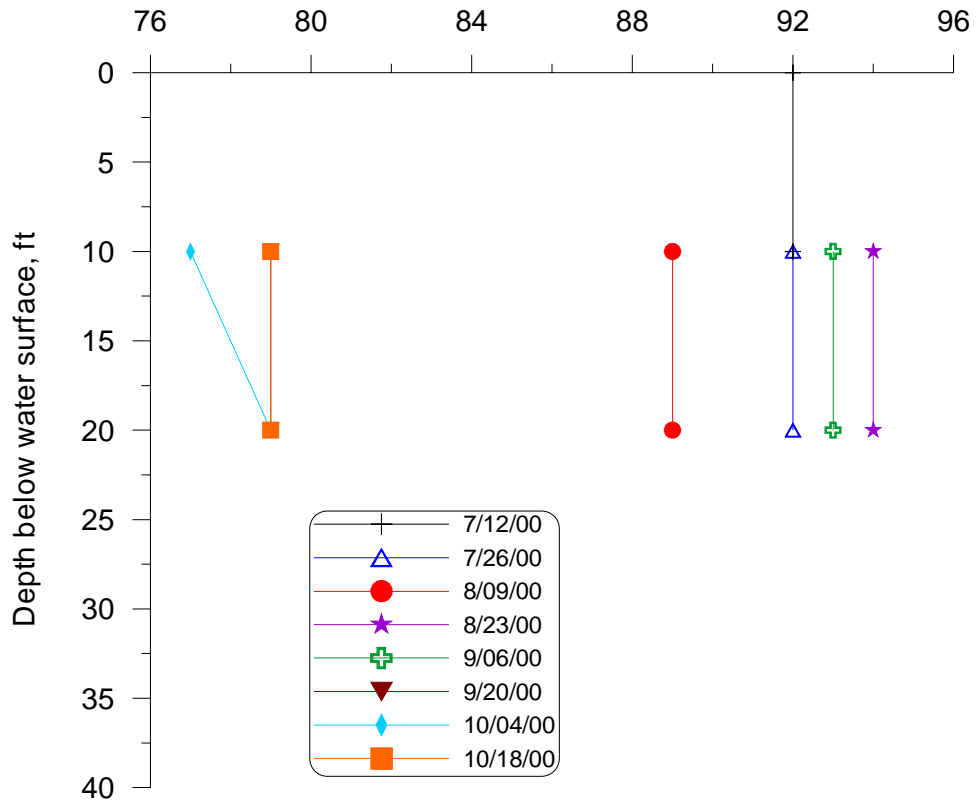
Conductivity, $\mu\text{mhos/cm}$ at St. John's Railroad Bridge (RM 6.8) middle of the River



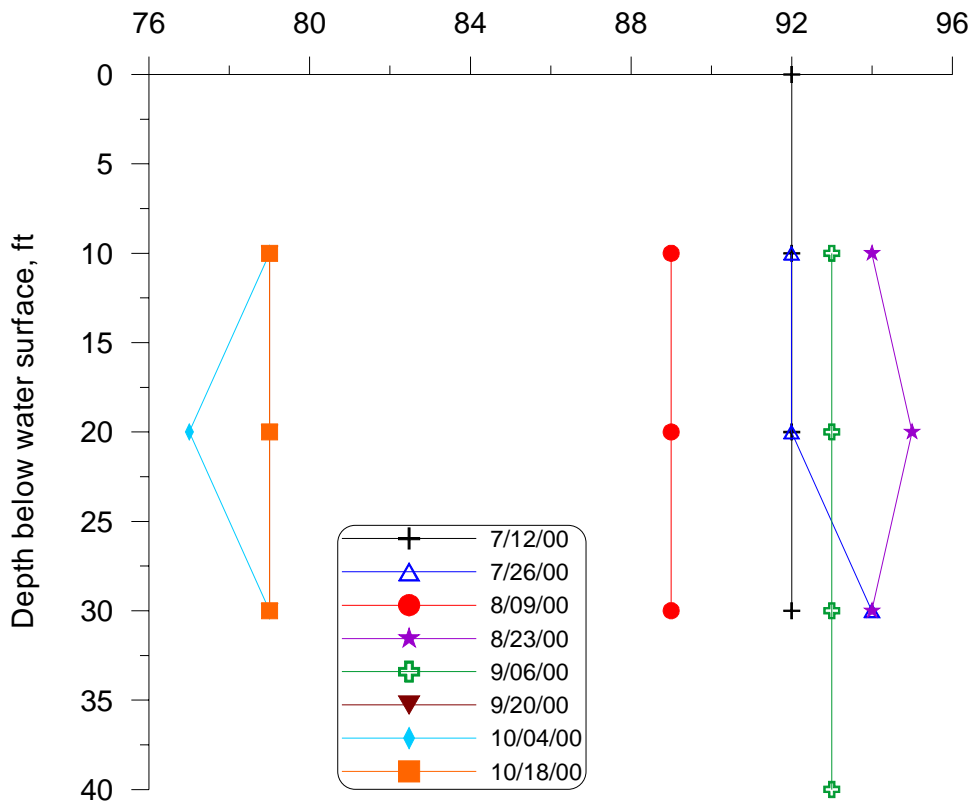
Conductivity, $\mu\text{mhos/cm}$ at St. John's Railroad Bridge (RM 6.8) west bank



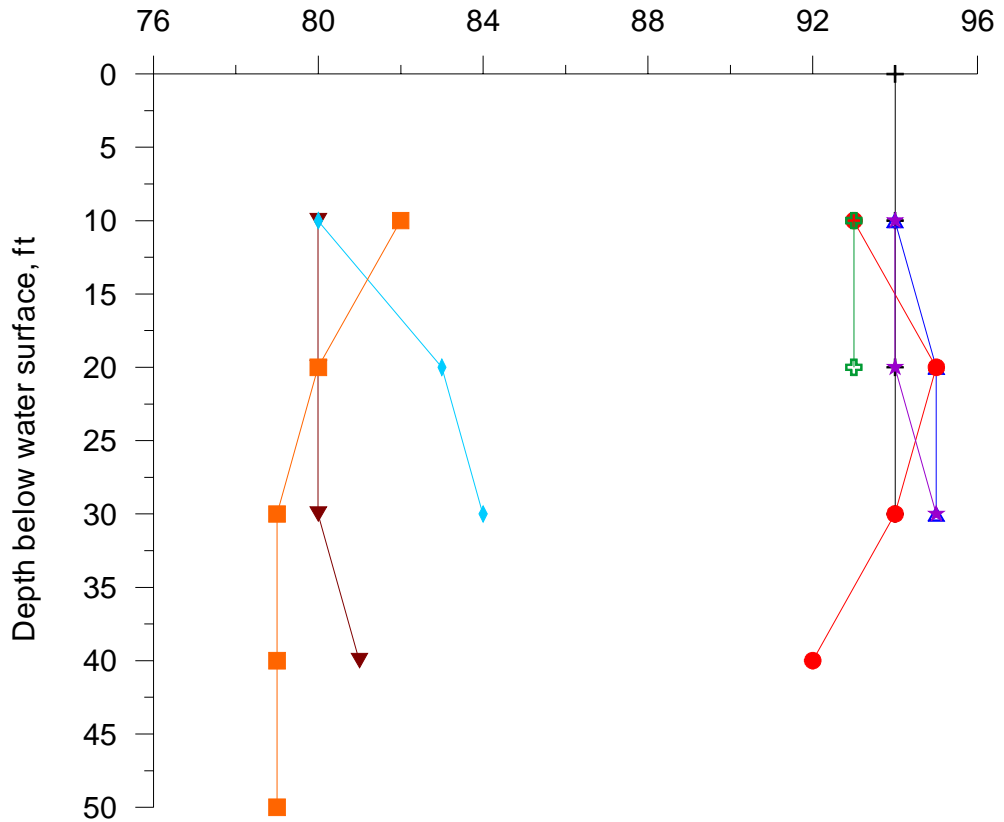
Conductivity, $\mu\text{mhos/cm}$ at Morrison Bridge (RM 12.7) east bank



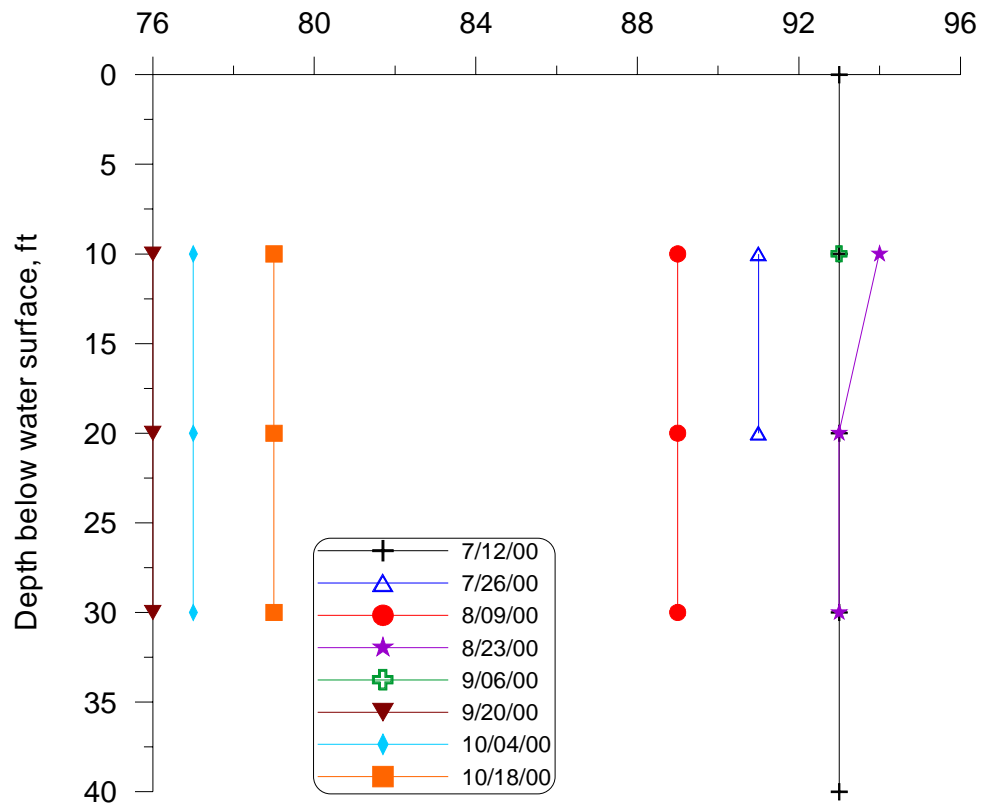
Conductivity, $\mu\text{mhos/cm}$ at Morrison Bridge (RM 12.7) middle of the River



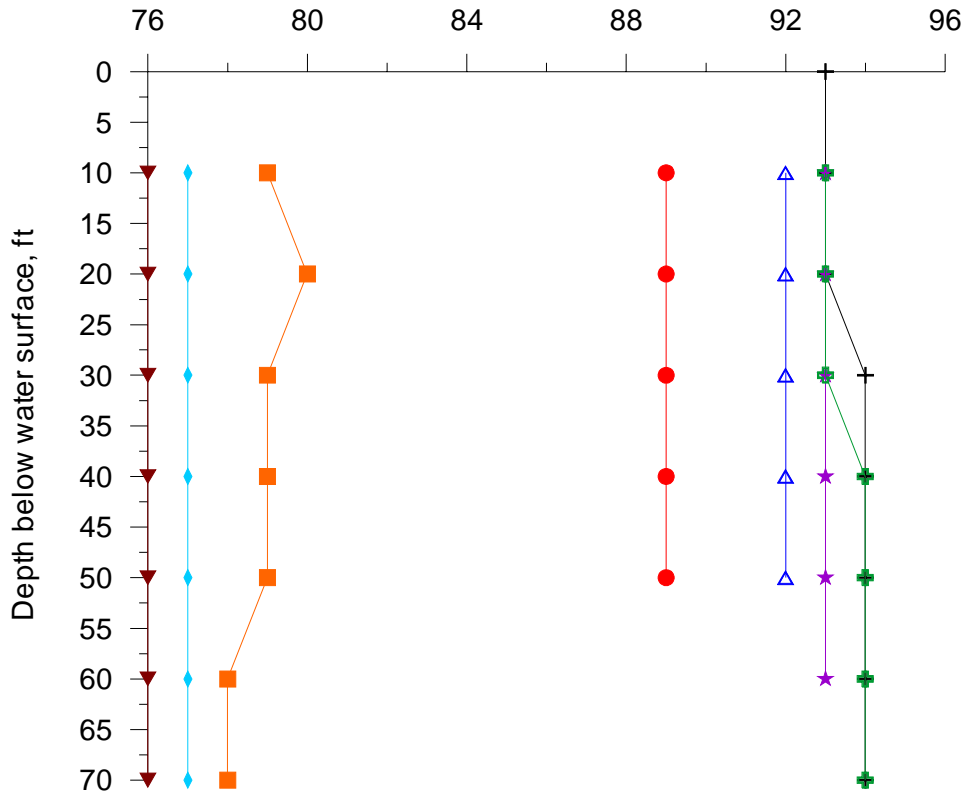
Conductivity, $\mu\text{hos/cm}$ at Morrison Bridge (RM 12.7) west bank



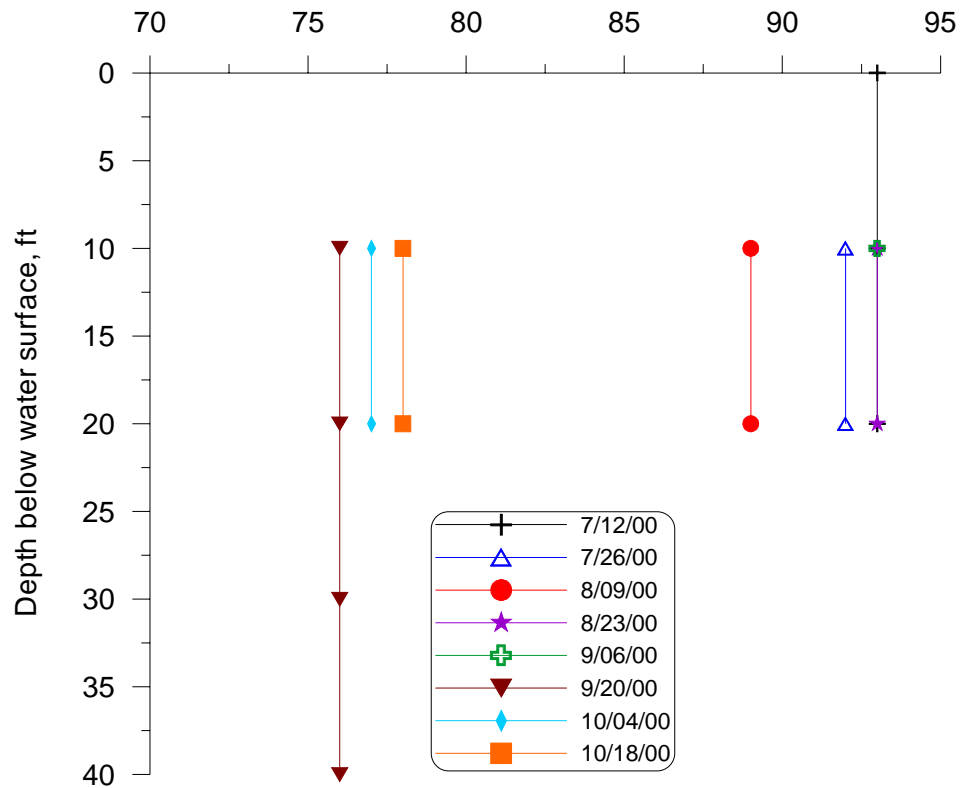
Conductivity, $\mu\text{hos/cm}$ at Waverly Country Club (RM 17.9) east bank



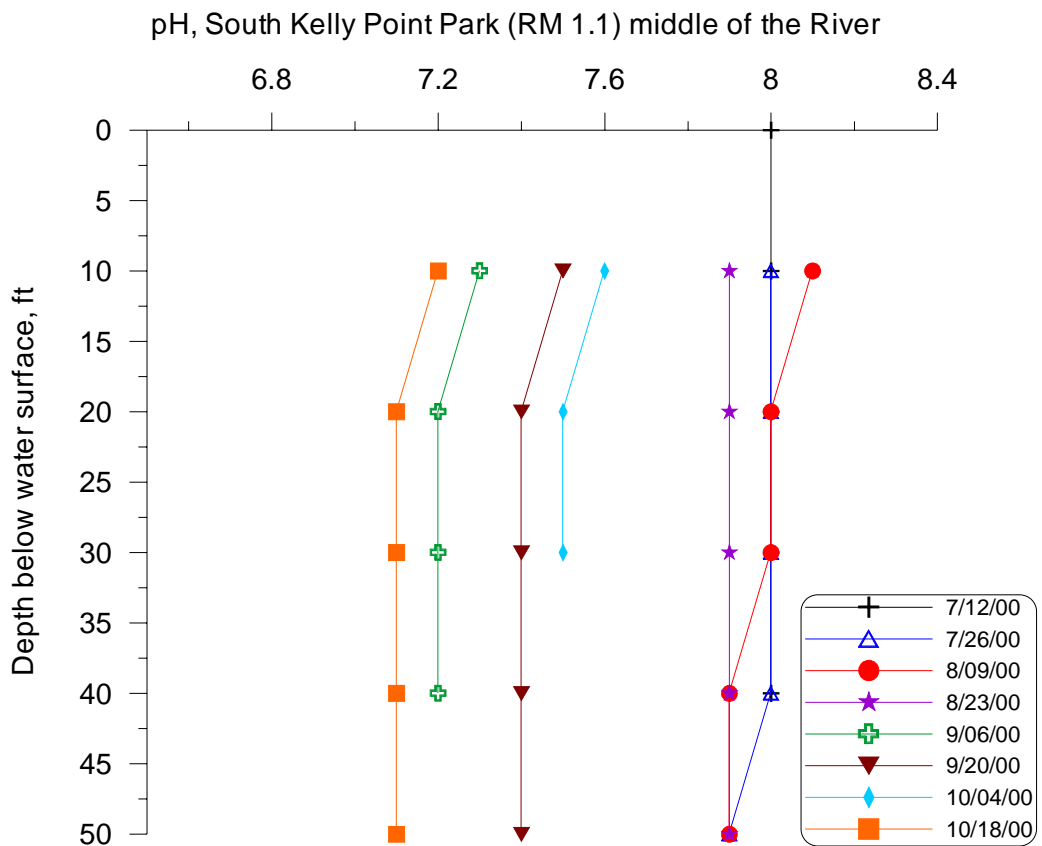
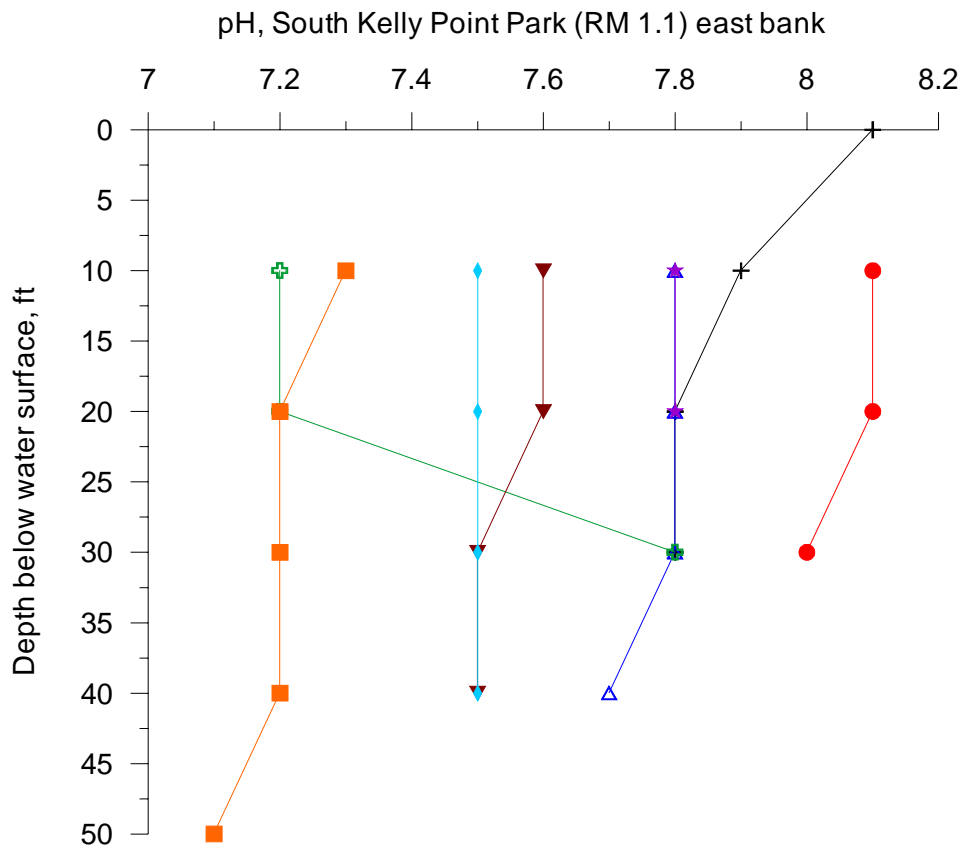
Conductivity, $\mu\text{mhos/cm}$ at Waverly Country Club (RM 17.9) middle of the River

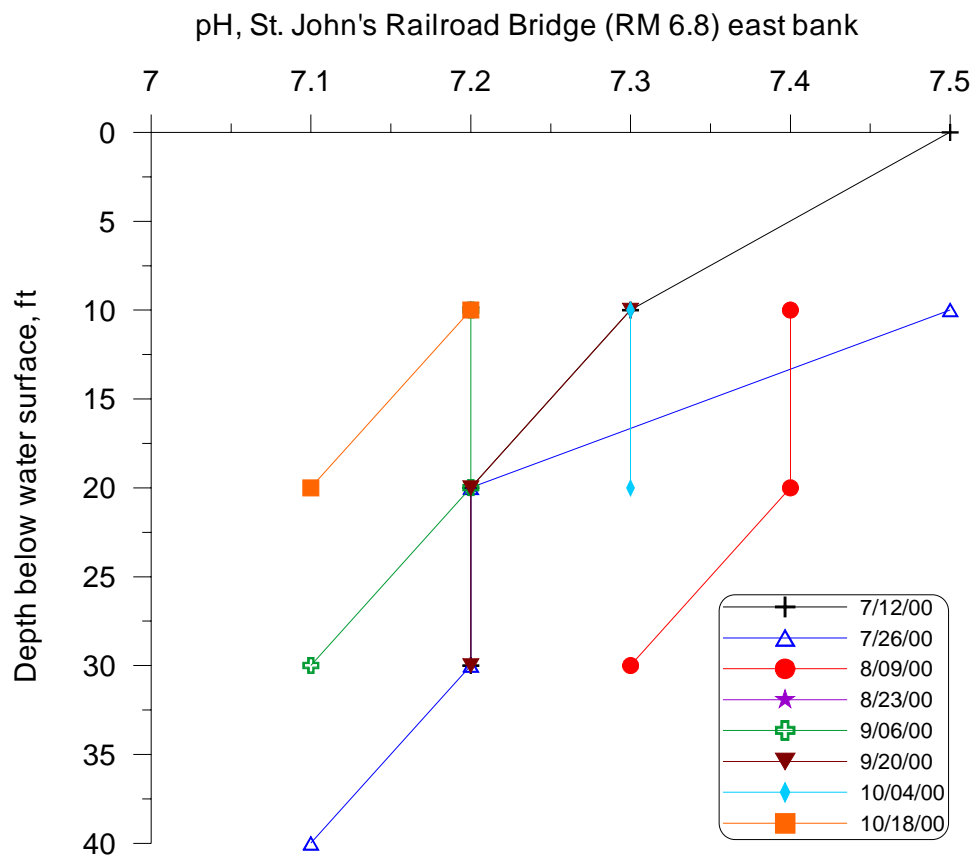
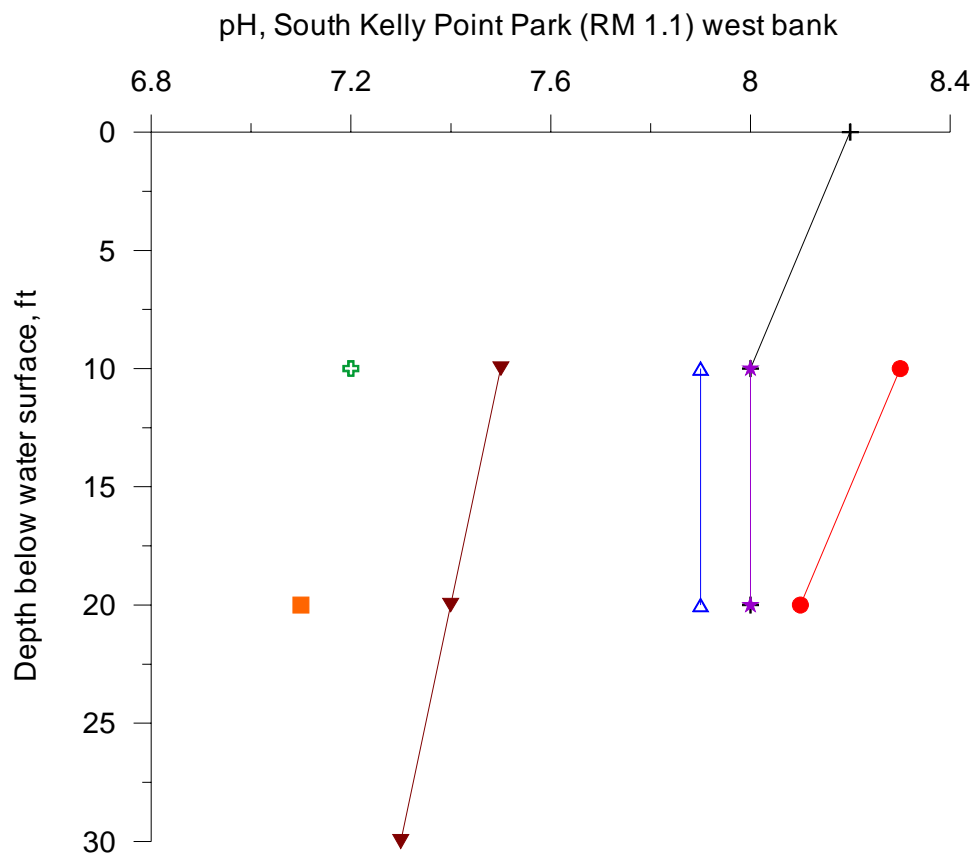


Conductivity, $\mu\text{mhos/cm}$ at Waverly Country Club (RM 17.9) west bank

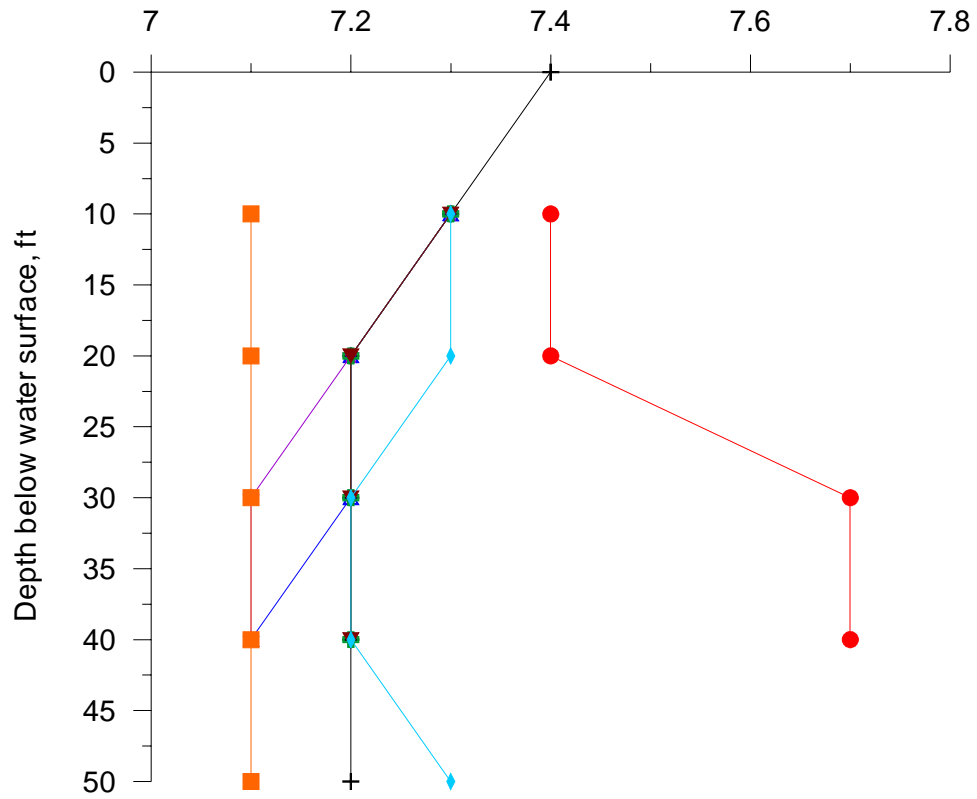


Appendix H: Willamette River pH Profiles, summer 2000

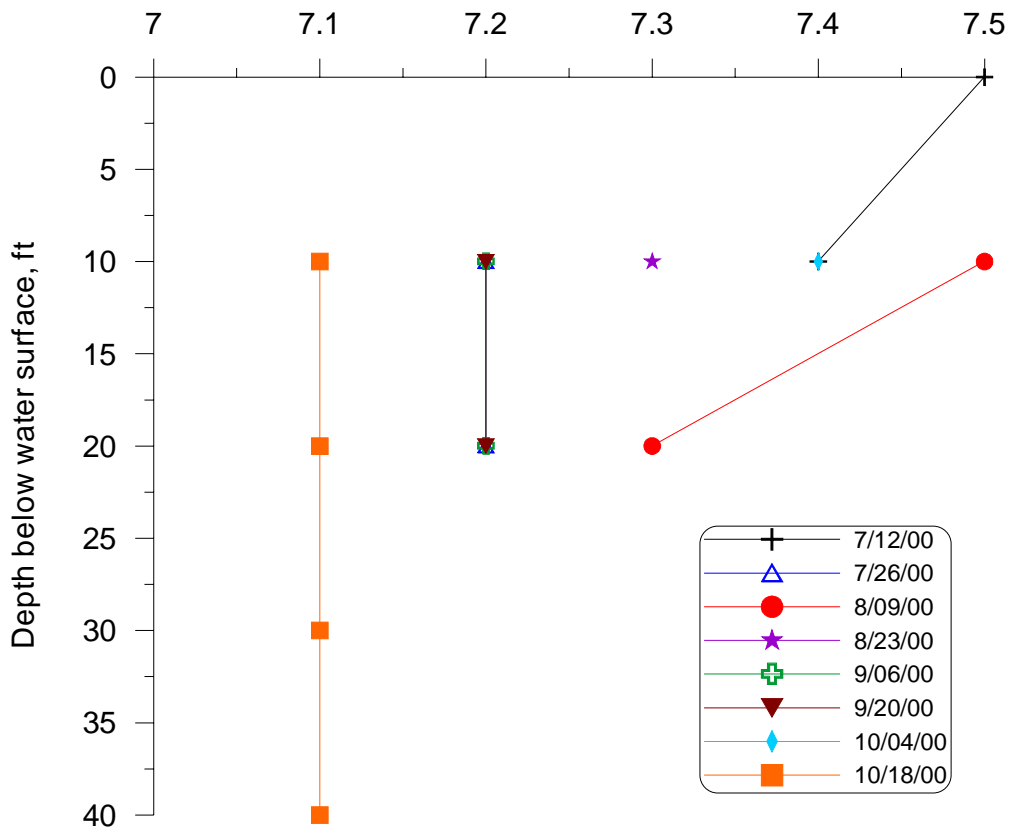




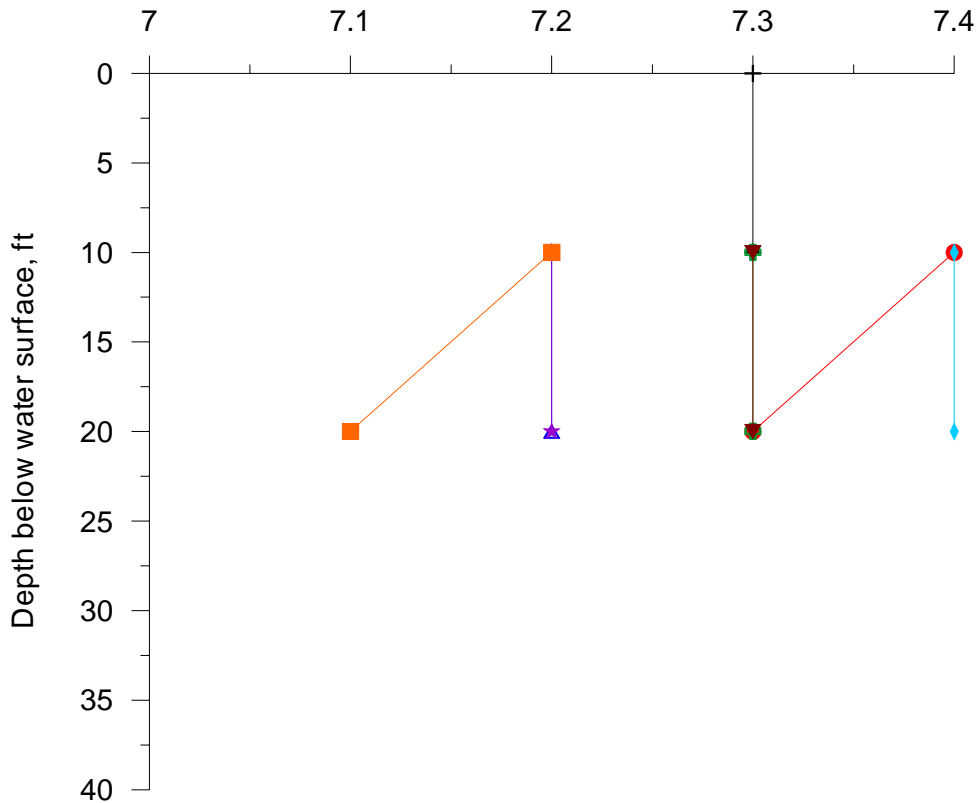
pH, St. John's Railroad Bridge (RM 6.8) middle of the River



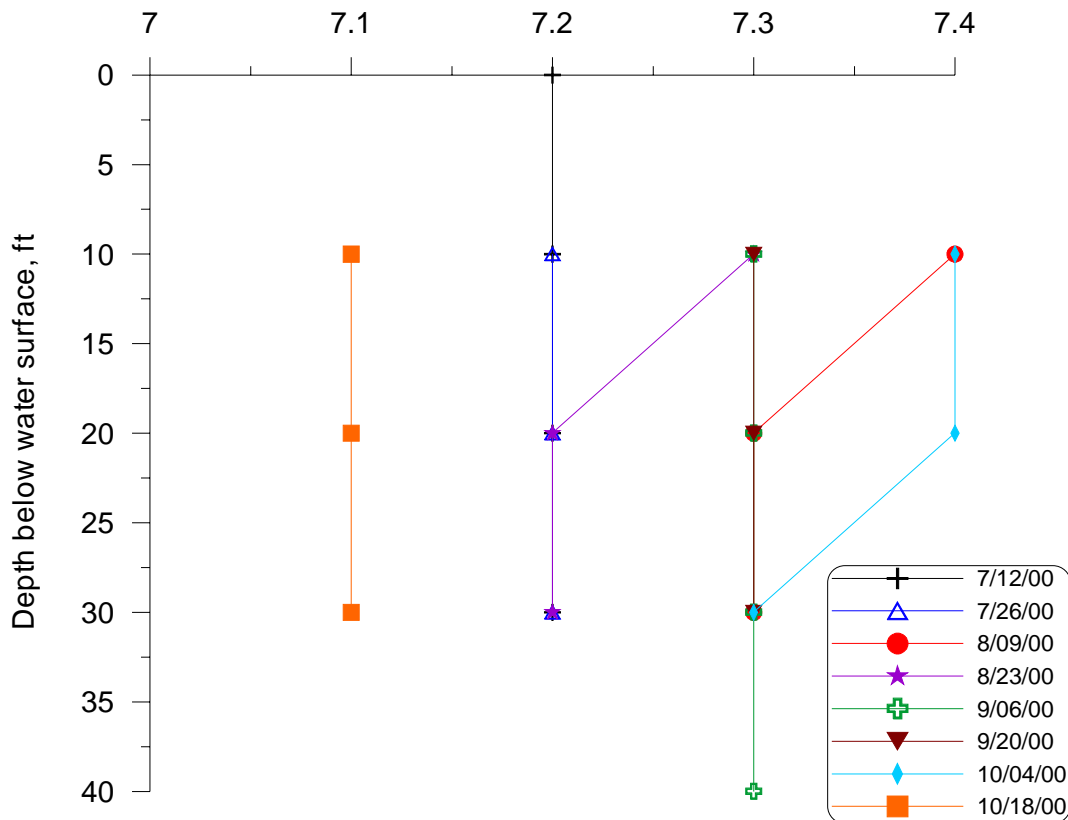
pH, St. John's Railroad Bridge (RM 6.8) west bank



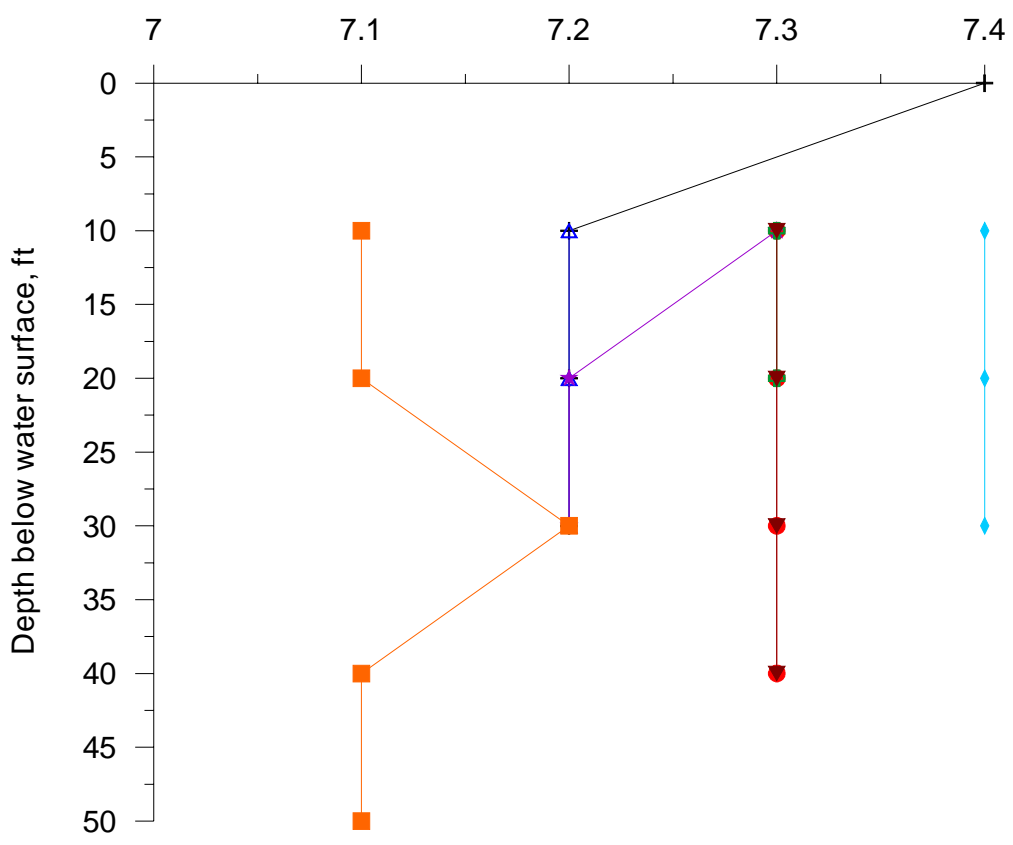
pH, Morrison Bridge (RM 12.7) east bank



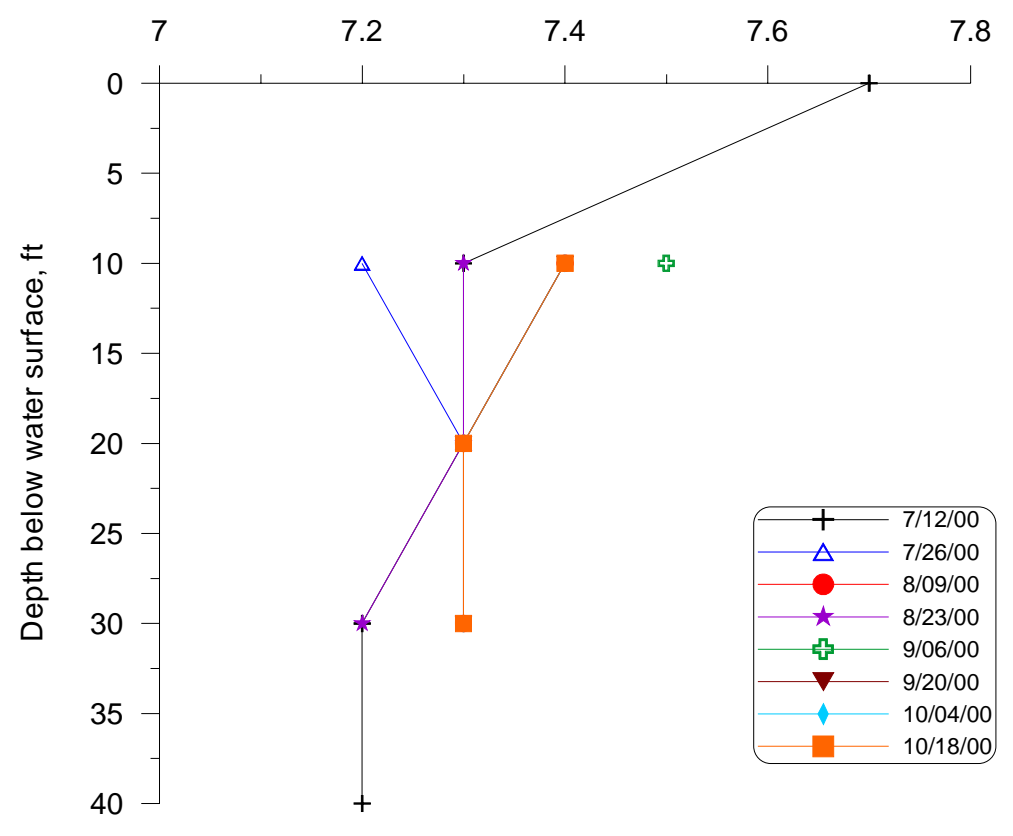
pH, Morrison Bridge (RM 12.7) middle of the River



pH, Morrison Bridge (RM 12.7) west bank

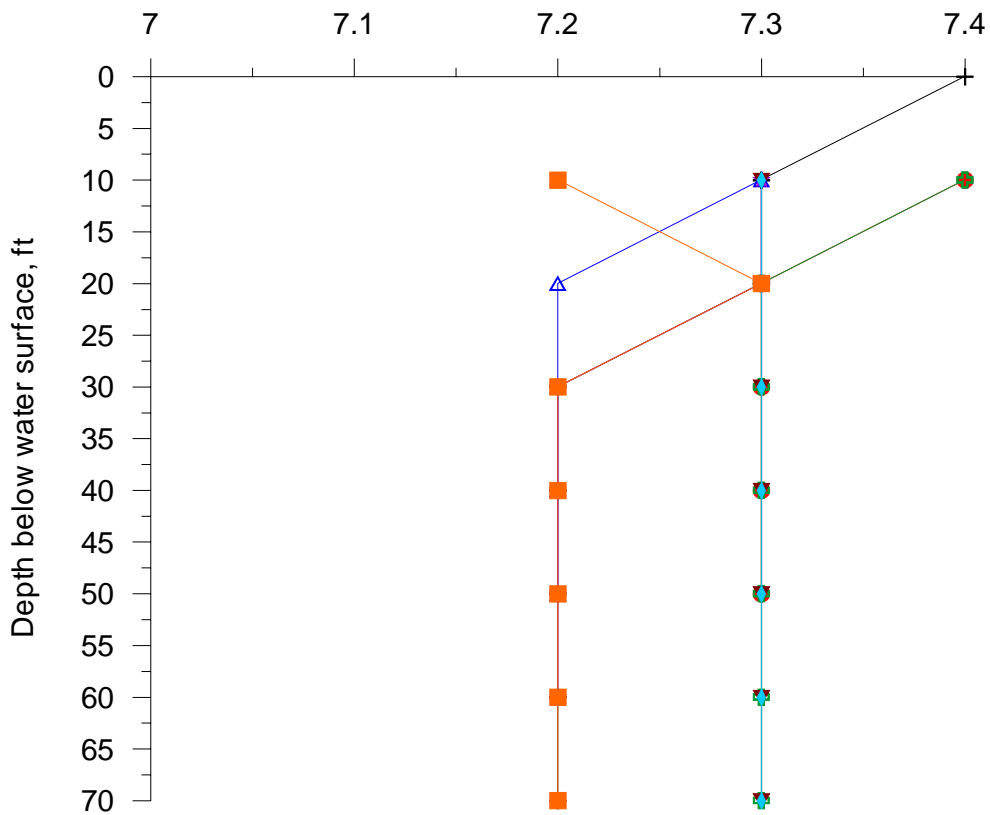


pH, Waverly Country Club (RM 17.9) east bank

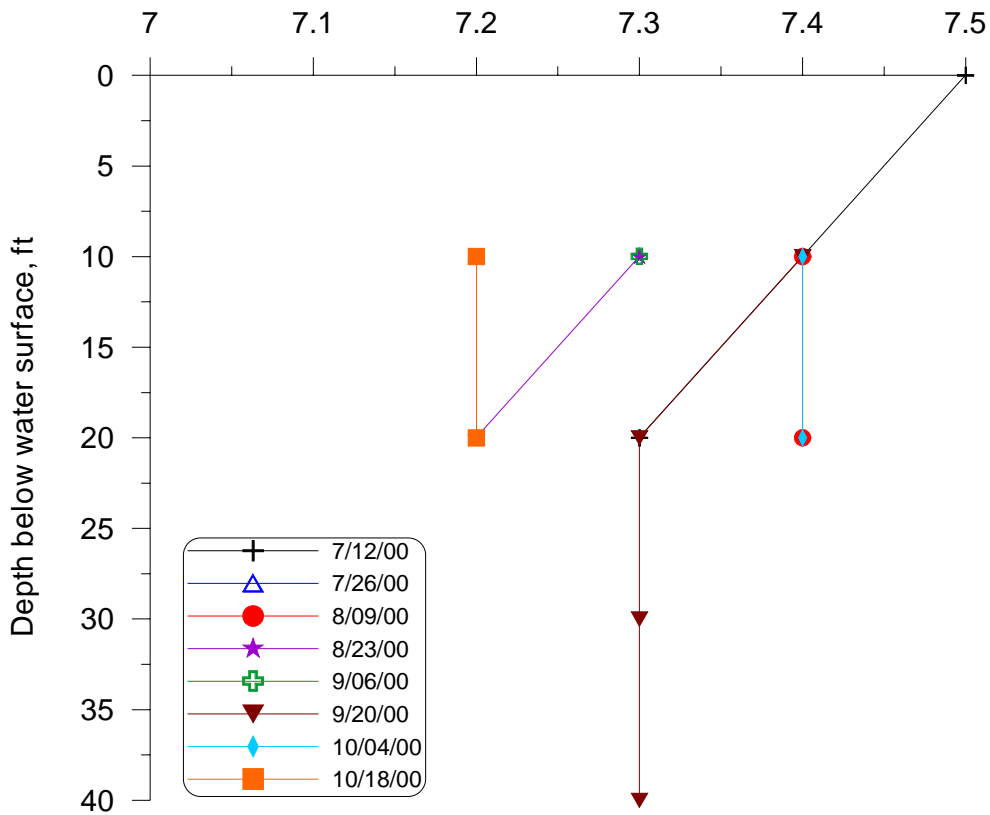


- 7/12/00
- 7/26/00
- 8/09/00
- 8/23/00
- 9/06/00
- 9/20/00
- 10/04/00
- 10/18/00

pH, Waverly Country Club (RM 17.9) middle of the River



pH, Waverly Country Club (RM 17.9) west bank



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

Site ID	Flow Date		Flow # of Records	Water Elevation Date		Water Elev. # of Records
	Min	Max		Min	Max	
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

Site ID	Flow Date		Flow # of Records
	Min	Max	
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 (°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

Site ID	Temperature Date		Temperature # of Records
	Min	Max	
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

Site ID	Flow Date		BOD	pH	DO Sat.	Temp	Chlrphyl A	Conduct.	DO	T. Phosp	NO2&NO3 N-Diss
	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
Willamette 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 of 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

Site ID	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
	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
Willamette 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 of 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

Site ID	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
	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							
Willamette 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 of 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
CONDIVITY	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
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)
TURBIDITY

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:

$$\sum \Phi_{algae} = \Phi_{algae(total)} = \frac{\Phi_{Chl_a(total)}}{Chla_to_Algae_ratio} \quad (1)$$

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

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

Where $k=0.1$, if $BOD_5=0$ then BOD_5 is set to 3

Total Organic Matter

$$\Phi_{TOM} = \frac{BOD_u}{\delta_o} - \sum \Phi_{algae} \quad (3)$$

$$\delta_o = 1.4$$

Detritus:

$$\Phi_{POM} = fraction(\Phi_{TOM}) - \sum \Phi_{algae} \quad (4)$$

Where fraction = 0.45

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

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:

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

Dissolved Organic Matter (DOM)

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

Labile DOM

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

$$f_{LDOM} = 0.50$$

Refractory DOM

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

Labile POM

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

$$f_{LPOM} = 0.5$$

Refractory POM

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

Total Organic Phosphorus

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

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

Nitrogen

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

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

Dissolved Organic Carbon (if data does not exist)

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

$\Phi_{coliform} = \Phi_{fecal_coliform} = data$, 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.

$$\Phi_{TOM} = \frac{\Phi_{TOC}}{\delta_C} - \sum \Phi_{algae} \quad (15)$$

Water Quality Constituent Procedure for Tributaries

Algae:

$$\sum \Phi_{algae} = \Phi_{algae(total)} = \frac{\Phi_{Chl_a(total)}}{Chla_to_Algae_ratio} \quad (16)$$

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

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

Where $k=0.1$, if $BOD_5=0$ then BOD_u is set to 3

Total Organic Matter

$$\Phi_{TOM} = \frac{BOD_u}{\delta_o} - \sum \Phi_{algae} \quad (18)$$

$$\delta_o = 1.4$$

Detritus:

$$\Phi_{POM} = fraction(\Phi_{TOM}) - \sum \Phi_{algae} \quad (19)$$

Where fraction = 0.45

$$f = \frac{\Phi_{POM} + \sum \Phi_{algae}}{\Phi_{TSS}} \quad (20)$$

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:

$$\Phi_{ISS} = (\Phi_{TSS} - \sum \Phi_{algae} - \Phi_{POM}) \text{ or } \Phi_{ISS} = (1 - f)(\Phi_{TSS}) \quad (21)$$

Dissolved Organic Matter (DOM)

$$\Phi_{DOM} = \Phi_{TOM} - \Phi_{POM} \quad (22)$$

If $DOM < 0.0$ then it was set to 0.10

Labile DOM

$$\Phi_{LDOM} = f_{LDOM} \Phi_{DOM} \quad (23)$$

$$f_{LDOM} = 0.50$$

Refractory DOM

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

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

$Tracer = ArbitraryTracer = 30\text{ mg/L}$

$\Phi_{TDS} = \Phi_{Salinity} = 0$, 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.

$$\Phi_{POM} = f(\Phi_{TSS}) - \sum \Phi_{algae} = \Phi_{TSS} - \Phi_{ISS} - \sum \Phi_{algae} \quad (30)$$

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

$$\Phi_{TOM} = \frac{\Phi_{TOC}}{\delta_C} - \sum \Phi_{algae} \quad (31)$$

If TOM < 0 then its set 1.0

Water Quality Constituent Procedure for Point Sources

Algae:

$$\sum \Phi_{algae} = \Phi_{algae(total)} = 0 \quad (32)$$

BOD ultimate

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

Where k=0.1. If no BOD5 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

$$\Phi_{TOM} = \frac{BOD_u}{\delta_o} \quad (34)$$

$$\delta_o = 1.4$$

Detritus:

$$\Phi_{POM} = fraction(\Phi_{TOM}) \quad (35)$$

Where fraction = 0.45

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

ISS:

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

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

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

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

Nitrogen

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

$\delta_N = 0.08$ 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 then 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)

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

$\text{Tracer} = \text{ArbitraryTracer} = 0 \text{ mg/L}$

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

$\Phi_{\text{NO}_3+\text{NO}_2} = \text{data}$, 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.