Element 5 - South Delta Water Quality Monitoring (2010)

Introduction

The Department of Water Resources (DWR) has been monitoring water quality as part of the South Delta Temporary Barriers Project since 1991 to investigate the water quality conditions that may be affected by temporary barrier installations and operations. In 2010, DWR continued its South Delta water quality sampling program, which consisted of 2 components: (1) bimonthly discrete sampling; and (2) continuous sampling. The information collected by this program is required for compliance with a 401 Water Quality Certification issued by the Central Valley Regional Water Quality Control Board. For detailed information on the South Delta Improvements Program and the Temporary Barriers Project, please visit DWR's Bay-Delta Office Web site at http://baydeltaoffice.water.ca.gov/sdb/.

Historically, DWR conducted discrete sampling on a weekly basis at 10 locations to monitor physical and biological constituents, as well as nutrients. The objective of this discrete program was and still is to monitor the effects of barrier operations on water quality. To ensure that adequate data were collected before, after, and during the operational period of the barrier, DWR started discrete sampling 2 weeks before the barriers were installed and did not conclude until 2 weeks after all the barriers were removed. Staff conducted sampling every Tuesday morning to target the time when dissolved oxygen concentrations tend to be lowest.

In 1998, the Central District[1] (now referred to as NCRO—see footnote) initiated a pilot program to test the viability of establishing permanent multiparameter water quality stations in the South Delta to continuously monitor water temperature, pH, dissolved oxygen, specific conductance, and turbidity. NCRO established this program to better understand barrier installations in accordance with the following: (1) to determine the feasibility of collecting reliable time-series water quality data; (2) to develop an understanding of dynamic water quality conditions in a tidally influenced system; and (3) to establish and maintain long-term continuous data records in the South Delta for analysis.

This continuous water quality monitoring program began with 2 stations: Old River at Tracy Wildlife Association and Middle River at Howard Road. NCRO staff determined that the time-series data generated from these 2 sites were reliable, accurate, and precise when compared to calibration standards and field data. The success of the pilot program resulted in the decision to expand the continuous monitoring program. DWR designed this expansion to complement the existing discrete stations. As a result, NCRO staff installed continuous monitoring stations at each of the 10 discrete monitoring locations between 2000 and 2006. After the installation of multiparameter instruments at the discrete locations was complete, the weekly dissolved oxygen sampling was terminated, and monitoring of biological constituents and nutrients was changed from weekly to bi-monthly.

In 2005, DWR drafted a monitoring proposal for the South Delta Permanent Barriers Project that included the implementation of 3 new continuous multiparameter water quality stations. The proposed station locations were Grant Line Canal near Old River, Victoria Canal, and Doughty Cut above Grant Line Canal. The water quality instruments at Grant Line Canal near Old River and Victoria Canal were co-located with an acoustic doppler current profiler instrument, which provides time-series water quality data that can be correlated with time-series flow data. The purpose of the Doughty Cut station was to document possible improvements to water quality based on permanent barrier operation. In addition, all

[1] As of 2010, the Central District is now named North Central Region Office (NCRO) due to DWR reorganization.

3 of these stations provide water quality information for the calibration and validation of the DSM2 model for the South Delta. NCRO staff installed multiparameter water quality stations at Doughty Cut above Grant Line Canal in 2006 and at Victoria Canal and Grant Line Canal near Old River in 2007. The data collected at these 3 sites are included in this chapter for data evaluation and analysis purposes.

In addition to satisfying the monitoring and reporting requirements mandated by the 401 Water Quality Certification for the Temporary Barriers Project, DWR staff will address the following questions in this chapter:

1) How do the water quality data collected at all of the sites compare to established water quality standards specifically for pH and dissolved oxygen?
2) Are the dissolved oxygen concentrations significantly different at the sites closest to the temporary barriers compared to the sites farther upstream and/or downstream in the same water body?
3) For the above 2 questions, do the analyses differ among seasons?

Materials and Methods

Discrete Monitoring

Sample Collection

The discrete monitoring program consists of 10 permanent sampling sites shown in Figure 6-1. The locations include one on the downstream side of each barrier, one on the upstream side of each barrier, excluding the Old River at Head barrier. Also, additional sites are located farther upstream on each of the main river channels (Old River, Middle River, and Grant Line Canal). NCRO staff conducted bimonthly sampling from May 26 through November 17, 2010, between 5 a.m. and 9 a.m. at each of these 10 stations. Staff collected samples for the following water quality constituents:

- chlorophyll *a* (µg/L)
- pheophytin *a* (µg/L)
- dissolved ammonia (mg/L as Nitrogen)
- dissolved nitrite+nitrate (mg/L as Nitrogen)
- dissolved organic nitrogen (mg/L as Nitrogen)
- dissolved orthophosphate (mg/L as Phosphorous)

Staff collected samples for all of the constituents listed above from the top of the water column using a stainless steel container. Water from the container was used to fill 2 plastic quart bottles at each site. One of the containers was used for analysis of chlorophyll *a* and pheophytin *a*, and the other container was used for the analysis of ammonia, nitrite+nitrate, organic nitrogen, and orthophosphate. All sample bottles were stored in a cooler that contained ice to preserve the samples at 4 ºC and to keep them out of the sunlight.

Immediately after the samples were collected, staff transported them to a site in Stockton for filtration. For the chlorophyll *a* and pheophytin *a* samples, approximately 500 mL of sample water was passed through a 47 mm diameter glass fiber filter with a 1.0 µm pore size at a pressure of 10 inches of mercury. After filtration, the filters were immediately frozen to preserve them for future analysis. The ammonia, nitrite+nitrate, organic nitrogen, and orthophosphate samples were filtered through a 0.45 µm pore size membrane filter into a half-pint polyethylene bottle. The filtered aqueous samples were temporarily stored in a cooler with ice to preserve them. The filtered aqueous samples and frozen filters were then transported to DWR's Bryte Laboratory for analysis. A summary of the lab methods for the nutrients measured are shown in Table 6-1.

Site #	Location
1	Old River at Head
2	Old River at Tracy Blvd
3	Old River upstream of the ORT barrier
4	Old River downstream of the ORT barrier
5	Middle River at Undine Road
6	Middle River at Tracy Blvd
7	Middle River at Union Point
8	Doughty Cut above Grant Line Canal
9	Grant Line Canal above the GLC barrier
10	Grant Line Canal at Tracy Blvd

Figure 6-1. Discrete Monitoring Locations for the South Delta Temporary Barriers Project

Table 6-1. Summary of Lab Methods for the Water Quality Constituents Measured at Each of the 10 Discrete Water Quality Sampling Sites

Constituent	Lab method
Dissolved ammonia	EPA 350.1
Dissolved nitrite+nitrite [(a)]	Modified Standard Method 4500-NO3-F
Dissolved organic nitrogen	EPA 351.2
Dissolved orthophosphate [(a)]	Modified EPA 365.1
Chlorophyll *a*	Standard Method 10200 H, Spectrometric Determination of Chlorophyll
Pheophytin *a*	Standard Method 10200 H, Spectrometric Determination of Chlorophyll

[a] Dissolved nitrite + nitrate and dissolved orthophosphate lab methods have been modified by DWR-Bryte Lab

Data Analysis

Staff used descriptive statistics, including mean, median, maximum, and minimum to summarize and compare the data for each constituent shown in Table 6-1 at all 10 discrete stations. In addition, staff used the Kruskal-Wallis test, a nonparametric hypothesis test used to analyze differences among 3 or more groups of data, to compare the data collected at the discrete sites[2]. Staff grouped the sites located along the same waterway and then used the hypothesis test to compare the sites within the same group to each other in order to determine if there were significant differences between them. The sites were placed into the Grant Line Canal, Middle River, or Old River group. This procedure was done for each constituent collected at the discrete sites except for chlorophyll *a*, which was more thoroughly analyzed in the continuous data set.

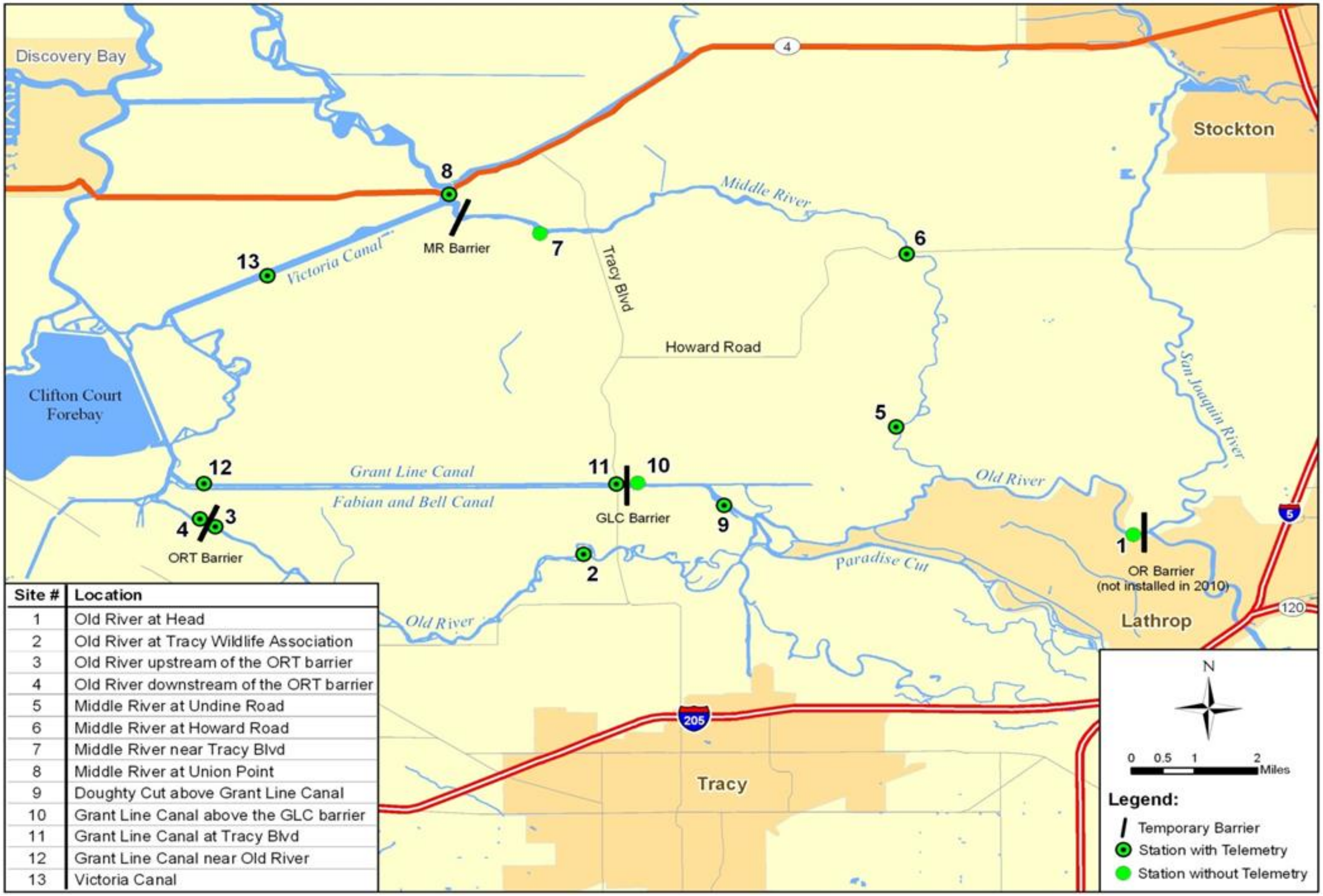
Continuous Monitoring

Station Locations

DWR collects continuous water quality data at 13 monitoring stations in the South Delta: 4 in Middle River, 4 in Old River, 4 in Grant Line Canal, and one in Victoria Canal. Figure 6-2 illustrates these site locations, and Table 6-2 provides station coordinates and the date each station was established. DWR provides real-time data for 9 of the 13 South Delta stations on the DWR California Data Exchange Center (CDEC):

- Doughty Cut above Grant Line Canal
- Grant Line Canal at Tracy Blvd
- Grant Line Canal near Old River
- Middle River at Howard Road
- Middle River at Union Point
- Old River at Tracy Wildlife Association
- Old River downstream of the Old River at Tracy (ORT) barrier
- Old River upstream of the ORT barrier
- Victoria Canal

[2] Microsoft Excel was used to calculate mean, maximum, and minimum summary statistics. The Minitab statistical software was used to perform all other statistical analyses including calculating the median, nonparametric hypothesis tests, and regression analysis.



Site #	Location
1	Old River at Head
2	Old River at Tracy Wildlife Association
3	Old River upstream of the ORT barrier
4	Old River downstream of the ORT barrier
5	Middle River at Undine Road
6	Middle River at Howard Road
7	Middle River near Tracy Blvd
8	Middle River at Union Point
9	Doughty Cut above Grant Line Canal
10	Grant Line Canal above the GLC barrier
11	Grant Line Canal at Tracy Blvd
12	Grant Line Canal near Old River
13	Victoria Canal

Figure 6-2. Continuous Monitoring Locations for the South Delta Temporary Barriers Project

Table 6-2. Continuous Monitoring Station Coordinates and Date of Establishment

Station name	Latitude	Longitude	Date established	CDEC code
Doughty Cut above Grant Line Canal	37º 48' 53.0"	-121º 25' 30.8"	June 19, 2006	DGL
Grant Line Canal above the GLC barrier	37º 49' 12.7"	-121º 26' 42.1"	March 24, 2006	----
Grant Line Canal at Tracy Blvd	37º 49' 12.4"	-121º 26' 59.4"	March 6, 2006	GCT
Grant Line Canal near Old River	37º 49' 12.4"	-121º 32' 40.6"	February 2, 2007	GLC
Middle River at Howard Road	37º 52' 34.4"	-121º 22' 59.9"	October 1, 1999	MHO
Middle River at Undine Road	37º 50' 02.2"	-121º 23' 08.6"	June 4, 2002	----
Middle River at Union Point	37º 53' 26.8"	-121º 29' 18.1"	February 23, 2006	MUP
Middle River near Tracy Blvd	37º 52' 53.2"	-121º 28' 02.5"	January 1, 2003	----
Old River at Tracy Wildlife Association	37º 48' 10.1"	-121º 27' 26.7"	July 14, 1999	TWA
Old River downstream of the ORT barrier	37º 48' 39.5"	-121º 32' 39.9"	January 18, 2006	ODM
Old River near Head	37º 49' 09.8"	-121º 21' 36.4"	January 1, 2001	----
Old River upstream of the ORT barrier	37º 48' 36.9"	-121º 32' 31.9"	January 1, 2000	OAD
Victoria Canal	37º 52' 15.5"	-121º 31' 47.9"	March 30, 2007	VCU

To access data for these stations select "real-time data" from the main menu on the CDEC Web site (http://cdec4gov.water.ca.gov/), and then enter the 3-digit station identification code. Table 6-2 provides the CDEC station codes. In addition, DWR operates 3 of the 13 South Delta stations in conjunction with US Geological Survey flow stations:

- Grant Line Canal near Old River
- Old River downstream of the ORT barrier
- Victoria Canal

Instrumentation

DWR collects data for the following constituents in 15-minute intervals at a one-meter depth by deploying Yellow Spring Instrument (YSI) 6600 sondes:

- water temperature (ºC)
- dissolved oxygen (mg/L)
- pH
- specific conductance (µS/cm)
- turbidity (NTU)
- chlorophyll (µg/L)

YSI 6600 sondes are approximately 2-feet long and 3½ inches in diameter. They are completely submersible and self-contained, operating on a minimum of 9 volts of battery power from 8 C-cell alkaline batteries. Deployment data are logged in each sonde's internal memory. Sondes are capable of sampling at many different user-specified frequencies. During 2000, DWR staff used an hourly sampling frequency for all stations, which is approximately 732 samples per month. In 2001, the sampling frequency was changed to a 15-minute interval, approximately 2,920 samples per month. The change to 15-minute intervals allows for a more in-depth review of tidal factors that influence water quality. For detailed information on YSI instrumentation, visit www.ysi.com.

At each monitoring site, a sonde is vertically housed within a 4-inch diameter PVC pipe in the water column and suspended at a depth of approximately one meter. To adjust for changing tides, DWR staff installed floats to maintain the one meter depth. To discourage vandalism, the pipes are covered at the top with an end-cap and locked with master locks through two 0.5-inch diameter bolts. The installation pipes have 2.25-inch diameter holes along the length of the pipe spaced approximately 8 to 10 inches on center. Four sets of holes are arranged longitudinally at 90º angles from each other. These holes allow ambient water to adequately contact the sonde sensors to ensure accurate data collection. At each site, the sonde installation pipe is either lag-bolted into an existing float structure (wooden boat dock), steel-banded to a pump platform durable enough to withstand long-term usage, or bracketed to a US Geological Survey pile.

In addition to the YSI 6600 sondes, DWR staff use 3 other field instruments to test the validity of the sonde data:

- YSI-63 handheld unit that measures water temperature, pH, and specific conductance
- YSI Pro-ODO Luminescent Dissolved Oxygen handheld unit to check dissolved oxygen concentrations
- HACH 2100P turbidimeter to measure turbidity

Data Collection

DWR staff clean and calibrate each sonde before deployment to ensure each probe is operating correctly before being used in the field. Calibration methods for each constituent are based on YSI's Principles of Operations. In addition, the 3 handheld units are calibrated regularly according to the following schedule:

- The pH probe on the YSI-63 unit and the YSI Pro-ODO dissolved oxygen unit are calibrated before each time they are used in the field
- The specific conductance probe on the YSI-63 unit is calibrated once a month
- The HACH 2100P turbidimeter is calibrated every 3 months

During the fall and winter months, sondes are typically deployed for a 3-week period, after which staff exchange it with a clean and newly calibrated sonde. DWR staff use a 2-week rotational period during the warmer and more biologically productive spring and summer months to reduce biological growth on the probe surfaces. When visiting a station to exchange sondes, DWR staff measure water temperature, specific conductance, pH, dissolved oxygen, and turbidity data at a one-meter depth with the 3 handheld field instruments mentioned in the above section. In addition, staff collect a chlorophyll *a* sample in a plastic quart bottle at one-meter depth with a Van Dorn sampling device. The chlorophyll *a* sample and other field measurements are sampled at a one-meter depth because the YSI 6600 sondes are also sampling at this depth. During each field run, DWR staff also collect a duplicate chlorophyll *a* sample at one of the stations to test for field and lab precision and repeatability.

Immediately after the chlorophyll *a* samples are collected, DWR staff store them in a cooler that contains ice to preserve the samples at 4 ºC and to keep them out of the sunlight. DWR staff filter the chlorophyll *a* samples at the NCRO water quality lab by passing approximately 500 mL of sample water through a 47 mm diameter glass fiber filter with a 1.0 μm pore size at a pressure of 10 inches of mercury. After filtration, the filters are immediately frozen in a freezer and transported to DWR's Bryte Laboratory within 28 days for analysis. Bryte Laboratory uses Standard Method 10200 H (Spectrometric Determination of Chlorophyll) to analyze the chlorophyll *a* samples. The data from the chlorophyll *a* field samples are used to adjust the chlorophyll *a* concentrations measured by the sondes, which is described in a later section.

Post-deployment Quality Assurance

After the YSI 6600 sondes are removed from the field, DWR staff perform the following 2 procedures to check whether the sondes are still operating properly and measuring accurately:

1) A post-deployment accuracy check on the day the sondes are removed and before the instruments are cleaned
2) A comparison between the data measured by the handheld field instruments and the data collected by the sonde at the closest 15 minute time interval

The accuracy of sonde probes while deployed in the field can be negatively affected by probe malfunction, drift away from initial calibration, and/or fouling caused by biological growth on the probe reading surface. DWR staff perform the post-deployment accuracy check by the following procedure prior to cleaning the sonde probes:

1) Placing the sonde probes in fresh calibration standards with known values
2) Operating the sondes in the standards and recording the values the sondes are reading
3) Rating the values collected during the accuracy check for each constituent as excellent, good, fair, or poor based on their deviation from the calibration standard according to the US Geological Survey technical report “Guidelines and Standard Procedures for Continuous Water Quality Monitors-Station Operation, Record Computation, and Data Reporting” (Wagner et al., 2006)

The ratings obtained from the accuracy check indicate the quality, accuracy, and reliability of the data that the sonde collected while in the field.

In addition to the post-deployment accuracy check, DWR staff compare the water temperature, specific conductance, pH, dissolved oxygen, and turbidity data measured in the field by the handheld instruments (the YSI-63, YSI Pro-ODO, and HACH 2100P) to sonde data that are closest in time. While taking the field measurements, DWR staff attempt to collect the field readings at the same depth that the sonde probes are measuring at (one meter) and as close to the sonde pipe as possible. Because the field instruments are calibrated regularly, a large difference between the sonde and field readings could indicate inaccuracy of the sonde data during the deployment period. DWR staff consider these comparisons between the field and sonde readings and the ratings obtained from the post-deployment accuracy check while assessing data quality when entering the continuous data into the Hydstra database.

Data Quality Assurance/Quality Control (QA/QC)

DWR staff import the data files from the sondes into the NCRO Hydstra database where additional QA/QC procedures are performed. In addition to documenting the results of the quality assurance procedures discussed in the previous section, staff use the results of these procedures to flag any suspect or unreliable data. Also, any obvious outliers in the continuous data set due to fouling or other factors are flagged as unreliable. None of the data that was determined by DWR staff as suspect or unreliable was used in this chapter; only data that are considered reliable and of good quality were used. The reliable and good quality data in Hydstra are used to populate the Water Data Library where the data for all the continuous sites are available online at http://wdl.water.ca.gov/.

Chlorophyll *a* Estimation

Chlorophylls are complex phyto-pigment molecules found in all photosynthetic organisms, including plants and phytoplankton. There are several types of chlorophyll identified by slight differences in their molecular structure and constituents. These types include chlorophyll *a*, *b*, *c*, and *d*. Chlorophyll *a* is the principal photosynthetic pigment common to all phytoplankton and is therefore used as a measurement of the primary phytoplankton biomass.

The chlorophyll probes used on the YSI 6600 sondes emit a blue light with a peak wavelength of 470 nm. The chlorophyll within the water passing by the probe absorbs this blue light from the probe and then emits or fluoresces light with a wavelength of 650–700 nm. The amount of fluorescence from the chlorophyll is then quantified by a photodetector on the probe. Currently, YSI chlorophyll probes cannot distinguish between the slight difference in fluorescence from chlorophylls *a*, *b*, *c*, and *d*, which causes inaccuracy when attempting to quantify chlorophyll *a* concentrations.

To more accurately calculate chlorophyll *a* concentrations, DWR staff took water samples in the field for chlorophyll *a* analysis at Bryte Laboratory. Laboratory analysis is the most accurate method of measuring chlorophyll *a* concentrations. This method involves extracting chlorophyll from cells and using a spectrometer which specifically measures chlorophyll *a* without interference from other chlorophyll species (*b*, *c*, or *d*).

DWR staff used the chlorophyll *a* data from the lab to adjust the YSI sonde chlorophyll data by using an equation generated from regression analysis. This was done by first matching the lab data with the corresponding sonde chlorophyll values measured closest in time. For example, the data for a chlorophyll *a* field sample collected at 9:55 a.m. was matched with the sonde time-series value at the 15-minute time interval closest to 9:55 a.m., which would be at 10 a.m. If DWR staff happened to collect a duplicate field sample at this location, then the average of the 2 values would be used in the analysis. Staff used all of the chlorophyll data collected, including those collected during earlier years, to provide a larger data set to develop a more robust regression model.

After all of the chlorophyll data was compiled, DWR staff used the Minitab statistical software to analyze regression relationships for the matched chlorophyll data pairs. Each of the 13 continuous monitoring locations was analyzed individually because the relationship between lab and sonde data is specific to location. Each regression analysis generated an equation describing the relationship between sonde and lab chlorophyll data for the particular location. DWR staff then used these equations to adjust the chlorophyll concentrations from the sonde to more closely represent chlorophyll *a* concentrations. The regression analysis procedure is described in the following steps:

Step # 1) A simple linear regression analysis is performed with the sonde data as the explanatory variable (x-variable) and the laboratory data as the response variable (y-variable). Three assumptions of this parametric regression procedure are: the data follow a linear pattern, the underlying distribution of the data follows a normal or bell-shaped curve, and the variance of the residuals from the regression is constant. If these 3 assumptions are met, then the equation from the linear regression analysis can be used to adjust chlorophyll *a* concentrations. Next, the seasonal terms, sine and cosine, are added to the regression analysis, which is described more in step #3. If one or more of the 3 assumptions of parametric regression models are not met, move on to step #2.

Step # 2) If the data do not follow a linear pattern, the explanatory variable (sonde data) needs to be transformed so that this assumption is met. If the variance of the residuals is not constant or the underlying data is not normally distributed, then the response variable (laboratory data) needs to be transformed. A typical transformation that is effective for this data is the natural logarithm. Once the response variable is transformed, the regression equation no longer predicts the mean chlorophyll *a* concentration; it predicts the geometric mean or median. In order to correct for this, either of 2 methods can be used: the Maximum Likelihood Estimator (MLE) or Smearing. These methods are described more in step #4. If transforming the data allows for the 3 assumptions of a linear regression to be met, move on to step #3 and then step #4. If it is not possible to transform the data so that the 3 regression assumptions are satisfied, then a nonparametric regression needs to be used, which is described in step #5.

Step # 3) If the equation from either the simple linear regression (step #1) or the linear regression with transformed data (step #2) is going to be used, then the seasonal terms, sine and cosine, are added to the regression analysis to determine if they are good predictors of the seasonality of chlorophyll concentrations. If one or both of the seasonal terms are statistically significant in the analysis, then both terms are added to the regression equation in order to incorporate seasonality into the equation. If transformation was not necessary to develop the regression equation, then the model is ready to use to adjust chlorophyll *a* concentrations. However, if transformation was necessary, then the equation is ready to use with the addition of one of the bias correction methods described in step #4.

Step # 4) MLE is one of the bias correction methods used to estimate the mean concentration when using a regression equation with the response variable transformed to a natural logarithm. The MLE is calculated by the following equation:

$$\mathbf{MLE = e^{(0.5*MSE)}}$$

The MSE is the mean squared error in logarithmic units, which is a quantification of the difference between the true data and the data estimated by the regression equation. The adjusted chlorophyll *a* data generated by the regression equation with a natural logarithm transformation is then corrected by multiplying the adjusted value by the MLE. For most of the stations that had a regression equation with data transformed to natural logarithms, the MLE was used as the bias correction factor to estimate the mean chlorophyll *a* concentrations. However, for 2 of the stations, the Smearing correction factor was used, since it was the better estimator[3]. The Smearing factor is calculated by first using the natural exponent (e) to “back-transform” all of the residuals from the regression. The factor is then the average of all of the “back-transformed” residuals. Like with the MLE, the adjusted chlorophyll *a* data is multiplied by the Smearing correction factor to correct the values to the estimated mean concentrations.

Step # 5) If transforming the data doesn’t allow for the assumptions of a linear regression to be attained, then the Theil-Sen line, a nonparametric regression procedure, can be calculated. Like with the linear regression when the response variable is transformed to the natural logarithm, the Theil-Sen line equation predicts the median chlorophyll *a* concentration. However, there is no bias correction factor available to estimate the mean concentrations when using a nonparametric regression procedure. Therefore, when summarizing chlorophyll *a* concentrations adjusted with the Theil-Sen equation, statistics such as daily or monthly averages cannot be reliably calculated.

The regression procedures, equations, and bias correction factors used for all 13 continuous monitoring locations are provided in Table 6-3. After DWR staff generated the regression equations for each of the monitoring locations, each 15-minute chlorophyll value recorded by the sonde was adjusted by using the equation for the particular location. If the natural logarithm transformation was used for the response variable (y variable), then staff had to use the natural exponent (e) to “back-transform” each 15-minute value to convert to the correct units, and then multiply each value by the MLE or Smearing factor to estimate the mean adjusted concentration. Staff used these adjusted chlorophyll *a* values when calculating summary statistics or when performing other statistical analyses.

[3] The decision to use the MLE or Smearing correction factor was determined by the following procedure. The sonde chlorophyll data that was matched to the lab chlorophyll data was plugged into the regression equation and then corrected by the MLE factor to provide a predicted sonde chlorophyll concentration. These predicted values were then matched with their corresponding lab chlorophyll values, and a linear regression was performed on the matching pairs. The same procedure was used with the Smearing correction factor. The correction factor that gave a regression equation with a slope closest to one was then used.

Table 6-3. Information from Regression Analysis for the Continuous Monitoring Locations

Station name	Regression method	Regression equation [a]	MLE or smearing correction factor
Doughty Cut above Grant Line Canal	Theil-Sen Line	Adjusted Chl = 2.284*(Sonde Chl)-1.984	----
Grant Line Canal above Barrier	Linear Regression with Seasonality	ln Adjusted Chl = 0.569 - 0.0794 sin(2piT) - 0.446 cos(2piT) + 0.996 ln Sonde Chl	1.110
Grant Line Canal at Tracy Blvd	Linear Regression with Seasonality [b]	ln Adjusted Chl = - 0.113 - 0.0402 sin(2piT) - 0.257 cos(2piT) + 1.26 ln Sonde Chl	1.058 [c]
Grant Line Canal near Old River	Linear Regression with Seasonality	ln Adjusted Chl = - 0.683 - 0.317 sin(2piT) - 0.333 cos(2piT) + 1.37 ln Sonde Chl	1.155
Middle River at Howard Road	No Equation Used [d]	No equation used	
Middle River at Undine Road	Linear Regression with Seasonality	ln Adjusted Chl = 0.106 - 0.134 sin(2piT) - 0.256 cos(2piT) + 1.21 ln Sonde Chl	1.095 [c]
Middle River at Union Point	No Equation Used [e]	No equation used	----
Middle River near Tracy Blvd	Linear Regression with Seasonality	ln Adjusted Chl = 0.289 - 0.119 sin(2piT) - 0.253 cos(2piT) + 0.175 Sonde Chl	1.114
Old River at Tracy Wildlife Association	Linear Regression with Seasonality	ln Adjusted Chl = - 0.072 - 0.0987 sin(2piT) - 0.327 cos(2piT) + 1.26 ln Sonde Chl	1.073
Old River downstream DMC Barrier	Linear Regression with Seasonality	ln Adjusted Chl = - 1.36 - 0.34 sin(2piT) - 0.418 cos(2piT) + 1.77 ln Sonde Chl	1.129
Old River near Head	Linear Regression with Seasonality	ln Adjusted Chl = 0.209 - 0.134 sin(2piT) - 0.334 cos(2piT) + 1.16 ln Sonde Chl	1.068
Old River upstream DMC Barrier	Linear Regression	ln Adjusted Chl = - 0.152 + 1.16 ln Sonde Chl	1.192
Victoria Canal	No Equation Used [f]	No equation used	----

(a) "ln" signifies the natural logarithm function. When the seasonal terms, sin(2πT) and cos(2πT), are used "π" signifies the constant pi (3.141593) and "T" signifies decimal time.
(b) The residuals from the parametric regression model were not normal even after transformation. However, the Theil-Sen equation gave negative adjusted values at the lower end of the sonde chlorophyll concentrations; therefore, the linear regression equation was used to adjust chlorophyll concentrations.
(c) The Smearing correction factor was used for Grant Line Canal at Tracy Blvd and Middle River at Undine Road. The MLE was used at the remainder of the stations.
(d) No equation was used to adjust chlorophyll concentrations since there wasn't enough data in the higher concentration range to define the relationship. In addition, the residuals from the parametric regression model did not have constant variance throughout the range of x values.
(e) No equation was used to adjust chlorophyll concentrations since both the parametric and Theil-Sen equations were not statistically significant.
(f) No equation was used to adjust chlorophyll concentrations since there wasn't enough data in the higher concentration range to define the relationship. In addition, the Theil-Sen equation was not statistically significant.

Data Analysis

Staff used descriptive statistics, including monthly mean, median, maximum, minimum, and standard deviation to summarize and compare the continuous data for each constituent measured by the sondes at all 13 stations. To illustrate seasonal and annual trends, staff also calculated and graphed daily means (or medians), maximums, and minimums for each constituent at all 13 stations.

In addition to those discussed above, DWR staff performed the following analyses on the continuous data to address the preceding questions:

Question: How often did the pH and dissolved oxygen data collected at all of the stations exceed established water quality standards? Does the number of times the data exceeded the standards differ depending upon the season?

Analysis**:** To compare the data with established pH and dissolved oxygen water quality standards, staff calculated the number of sonde data points collected at each station that exceeded the particular standard. In addition, the analyses were separated by season[4] to determine if there were any seasonal trends. Staff also calculated the percent of samples exceeding a particular standard relative to the total number of samples collected at each season. The established water quality standards are 8.50 units for pH[5] and 5.0 mg/L for dissolved oxygen[6] (CVRWQCB, 2009; EPA, 1986). A dissolved oxygen sample less than 5.0 mg/L or a pH sample greater than 8.50 units exceeded the standard.

Question: Do the dissolved oxygen concentrations differ between stations located along a particular water body (Old River, Middle River, and Grant Line Canal) depending upon the season?

Analysis: Staff used Kruskal-Wallis hypothesis tests and Dunn's multiple comparison procedures[7], which are nonparametric statistical analyses, to determine if the stations located along the same water body had significant differences in their dissolved oxygen concentrations. Staff placed each station into one of 3 water body groups, then analyzed each water body group separately to determine if there were significant differences between the sites within the group. The continuous water quality stations were grouped in the following way:

- Old River: Old River at Head, Old River at Tracy Wildlife Association, Old River upstream of the ORT barrier, and Old River downstream of the ORT barrier
- Middle River: Middle River at Undine Road, Middle River at Howard Road, Middle River near Tracy Blvd, and Middle River at Union Point

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[4] Staff defined the seasons as follows: Winter (January, February, and December), Spring (March – May), Summer (June-August), Fall (September – November).

[5] The Sacramento and San Joaquin River Basin Plan states that the pH should not be above 8.50 units for all water bodies without a site-specific objective (CVRWQCB, 2009).

[6] The EPA has established National Ambient Water Quality Criteria for inorganic constituents, including dissolved oxygen, to protect freshwater aquatic life. However, there is considerable variability in dissolved oxygen tolerances among fish and other aquatic life. For a warm water system like the Delta, minimum dissolved oxygen criteria for early aquatic life stages including embryos, larvae, and less than 30-day old juveniles is 5 mg/L and 3 mg/L for other life stages including older juveniles and adults (EPA, 1986). In addition, the Sacramento and San Joaquin River Basin Plan states that within the legal boundaries of the Delta, dissolved oxygen concentrations should not be reduced below 5.0 mg/L in all water bodies except for the Sacramento River below the I Street Bridge, all waters west of the Antioch Bridge, and the San Joaquin River between Turner Cut and Stockton (these Delta water bodies have site-specific water quality objectives for dissolved oxygen; CVRWQCB, 2009).

[7] Staff used daily medians in these hypothesis tests since using the raw data collected every 15 minutes introduces very strong serial correlation among the data. Performing hypothesis test on strongly serial-correlated data causes the test results to be "too significant" or the p-values are too low. One way to minimize this is to take daily medians or means of the data and use those in the hypothesis test. Daily medians or means can still be serial-correlated, but much less so than data collected every 15 minutes. In this case, staff used daily medians for the nonparametric hypothesis tests since these tests are used to compare median concentrations. In addition, the median summary statistic is resistant to outliers in the data and provides a typical value for the time period summarized.

- Grant Line Canal: Doughty Cut above Grant Line Canal, Grant Line Canal above the GLC barrier, Grant Line Canal at Tracy Blvd, and Grant Line Canal near Old River

Furthermore, staff performed these analyses separately for the spring, summer, and fall seasons (defined the same as in the water quality standard analysis) to determine if there were any seasonal trends. The analyses were only done for these 3 seasons because they have the highest variability in dissolved oxygen concentrations.

Staff was also interested in whether the dissolved oxygen concentrations differ between stations along a particular water body depending upon whether the barrier was installed or not; however, it was too difficult to determine if differences were due to barrier operations or seasonality. Therefore, staff decided to do the seasonal differences analysis discussed directly above.

The 401 Water Quality Certification for the Temporary Barriers Project requires the statistical comparison of the dissolved oxygen concentrations measured upstream and downstream of the 3 temporary barriers. For each barrier, the upstream and downstream stations that are closest to the barrier were compared on a monthly basis. Staff used the one-sample Wilcoxon test, a nonparametric hypothesis test used to compare paired values, to compare the paired daily medians[8] of the upstream and downstream stations. Staff performed this analysis separately for each temporary barrier and for each month during 2010. The Middle River at Union Point station had 19 days without dissolved oxygen data; therefore, staff used the Mann-Whitney test, a nonparametric test used to compare nonpaired groups of data, to compare the stations upstream and downstream of the Middle River barrier.

[8] Staff used the daily medians in the hypothesis tests to minimize the effects of serial correlation. This issue is described in more detail on the previous page in footnote number 7.

Results

Discrete Monitoring

Chlorophyll *a*

Table 6-4 provides the summary statistics for chlorophyll *a* concentrations at the discrete monitoring locations. Generally, chlorophyll *a* concentrations were highest during the early summer and lowest in the fall (Figures 6-3 to 6-5 are grouped at the end of the Results section). For the 2010 discrete monitoring period, the maximum chlorophyll *a* concentration was 86.7 µg/L measured at Old River at Head on August 4, 2010; and the minimum was 0.83 µg/L measured at Middle River at Union Point on September 22, 2010. Average chlorophyll *a* concentrations were highest during the monitoring period at Old River at Head (26.7 µg/L), Old River at Tracy Blvd (15.1 µg/L), Middle River at Undine Road (20.4 µg/L), Doughty Cut above Grant Line Canal (20.1 µg/L), Grant Line Canal above the GLC barrier (15.3 µg/L), and Grant Line Canal at Tracy Blvd (14.0 µg/L). The remaining sites (Middle River at Tracy Blvd, Middle River at Union Point, Old River upstream and downstream of the ORT barrier) had average chlorophyll *a* concentrations of less than 4.0 µg/L.

Table 6-4. Chlorophyll *a* Summary Statistics for the Discrete Monitoring Locations

Location	Number of samples	Min of chlorophyll *a* (µg/L)	Max of chlorophyll *a* (µg/L)	Average of chlorophyll *a* (µg/L)
Doughty Cut above GLC	11	1.9	61.7	20.1
GLC above the GLC barrier	11	3.8	47.7	15.3
GLC at Tracy Blvd	11	1.2	41.0	14.0
MR at Tracy Blvd	11	1.0	9.9	2.6
MR at Undine Road	11	1.8	65.9	20.4
MR at Union Point	11	0.8	18.8	3.8
OR at Head	11	2.8	86.7	26.7
OR at Tracy Blvd	11	3.9	41.8	15.1
OR downstream of the ORT barrier	10	1.4	6.5	2.5
OR upstream of the ORT barrier	11	1.4	9.0	3.3

Table acronyms: GLC = Grant Line Canal, MR = Middle River; OR = Old River; ORT = Old River at Tracy

Pheophytin *a*

As phytoplankton populations decline, chlorophyll *a* degrades into byproducts. Pheophytin *a* is a degradation product of chlorophyll *a*. When phytoplankton is actively growing, the concentrations of pheophytin *a* are normally expected to be low in relation to chlorophyll *a*. After a large phytoplankton population begins to decline, the pheophytin *a* concentration increases while the chlorophyll *a* concentration decreases.

Table 6-5 provides the summary statistics for pheophytin *a* concentrations at the discrete monitoring locations. Generally, pheophytin *a* concentrations were highest during the summer and lowest in November, mirroring chlorophyll *a* concentrations (see Figures 6-3 to 6-5). For the 2010 discrete monitoring period, the maximum pheophytin *a* concentration was 47.8 µg/L measured at Middle River at Undine Road on July 22, 2010, and the minimum was 0.88 µg/L measured at Middle River at Union Point on October 21, 2010. Average pheophytin *a* concentrations were highest during the monitoring period at Old River at Head (13.0 µg/L), Old River at Tracy Blvd (12.1 µg/L), Middle River at Undine Road (14.7 µg/L), Doughty Cut above Grant Line Canal (14.8 µg/L), Grant Line Canal above the GLC barrier (14.0 µg/L), and Grant Line Canal at Tracy Blvd (13.7 µg/L), which also had the highest chlorophyll *a* concentrations discussed above. The remaining sites (Middle River near Tracy Blvd, Middle River at Union Point, Old River upstream and downstream of the ORT barrier) had average pheophytin *a* concentrations of less than 5.0 µg/L paralleling average chlorophyll *a* concentrations.

Station Comparisons by Waterway: The pheophytin *a* concentrations of the 3 discrete monitoring sites along Grant Line Canal (Doughty Cut above Grant Line Canal, Grant Line Canal above the GLC barrier, and Grant Line Canal at Tracy Blvd) were not significantly different ($p = 0.72$). However, the sites located along Middle River and Old River had significant differences. For the Middle River sites, Middle River at Undine Road had significantly higher pheophytin *a* concentrations than both the Middle River at Tracy Blvd and Middle River at Union Point locations ($p<0.0007$). For the Old River sites, both the Old River at Tracy Blvd and Old River at Head sites had significantly higher pheophytin *a* concentrations than both the Old River upstream and downstream of the ORT barrier locations ($p<0.02$). A p-value under 0.05 is considered to indicate a statistically significant difference; conversely, p-values greater than or equal to 0.05 are indicative of no significant difference between groups.

Table 6-5. Pheophytin *a* Summary Statistics for the Discrete Monitoring Locations

Location	Number of samples	Min of pheophytin *a* (µg/L)	Max of pheophytin *a* (µg/L)	Average of pheophytin *a* (µg/L)
Doughty Cut above GLC	11	2.3	45.6	14.8
GLC above the GLC barrier	11	3.7	43.4	14.0
GLC at Tracy Blvd	11	2.0	42.5	13.7
MR at Tracy Blvd	11	0.9	2.4	1.7
MR at Undine Road	11	2.4	47.8	14.7
MR at Union Point	11	0.9	1.8	1.4
OR at Head	11	3.1	35.8	13.0
OR at Tracy Blvd	11	4.0	32.7	12.1
OR downstream of the ORT barrier	10	1.8	7.5	3.6
OR upstream of the ORT barrier	11	2.0	8.5	4.3

Dissolved Ammonia

Ammonia is present naturally in surface water and wastewater. It is produced largely by deamination of organic nitrogen containing compounds and is sometimes used by wastewater treatment plants to react with chlorine (APHA, 2005). High ammonia concentrations in natural surface water may indicate contamination from effluent.

Table 6-6 provides the summary statistics for dissolved ammonia concentrations at the discrete monitoring locations. Discrete samples of dissolved ammonia concentrations in the South Delta ranged from a minimum of 0.02 mg/L to a maximum of 1.10 mg/L. Average concentrations during the monitoring period ranged from a low of 0.06 mg/L at Middle River at Union Point to a high of 0.47 mg/L at Old River at Head (see Table 6-6). Dissolved ammonia concentrations were highest during the summer months at the Grant Line Canal and Doughty Cut stations (see Figure 6-3). On Middle and Old Rivers, the concentrations of dissolved ammonia were variable without a distinct period of elevated concentrations (see Figures 6-4 and 6-5). The Old River at Head station had higher dissolved ammonia concentrations than those collected at the other Old River stations throughout the 2010 monitoring period.

Station Comparisons by Waterway: The dissolved ammonia concentrations of the 3 discrete monitoring sites along Grant Line Canal were not significantly different ($p = 0.23$). However, the sites located along Middle River and Old River had significant differences. For the Middle River sites, Middle River at Undine Road had significantly higher dissolved ammonia concentrations than Middle River at Union Point ($p<0.0006$). For the Old River sites, Old River at Head had significantly higher dissolved ammonia concentrations than the 3 other Old River stations ($p<0.04$).

Table 6-6. Dissolved Ammonia Summary Statistics for the Discrete Monitoring Locations

Location	Number of samples	Min of diss ammonia (mg/L as N)	Max of diss ammonia (mg/L as N)	Average of diss ammonia (mg/L as N)
Doughty Cut above GLC	12	0.03	0.12	0.07
GLC above the GLC barrier	12	0.03	0.18	0.09
GLC at Tracy Blvd	12	0.03	0.17	0.07
MR at Tracy Blvd	12	0.02	0.13	0.09
MR at Undine Road	12	0.04	0.27	0.13
MR at Union Point	12	0.02	0.15	0.06
OR at Head	12	0.07	1.10	0.47
OR at Tracy Blvd	12	0.03	0.21	0.08
OR downstream of the ORT barrier	12	0.04	0.11	0.08
OR upstream of the ORT barrier	12	0.06	0.15	0.11

Dissolved Nitrite + Nitrate

Total oxidized nitrogen is the sum of nitrate and nitrite nitrogen. Nitrate is an essential nutrient for many photosynthetic autotrophs (plants and algae) and can be a growth-limiting nutrient. Nitrite is an intermediate oxidation state of nitrogen, both in the oxidation of ammonia to nitrate and in the reduction of nitrate (APHA, 2005).

Table 6-7 provides the summary statistics for dissolved nitrite + nitrate concentrations at the discrete monitoring locations. Dissolved nitrite + nitrate concentrations in the South Delta ranged from a minimum of 0.02 mg/L to a maximum of 3.00 mg/L. Average concentrations during the monitoring period ranged from a low of 0.38 mg/L at Middle River at Tracy Blvd to a high of 1.71 mg/L at Old River at Head (Table 6-7). The Grant Line Canal, Doughty Cut, Old River and Middle River at Undine Road stations all had an increasing trend in dissolved nitrite + nitrate concentrations from May to October (see Figures 6-3 to 6-5). All nitrite-nitrate levels were below the California Public Health Goal of 10 mg/L (Polakoff, 1997).

Station Comparisons by Waterway: The dissolved nitrite + nitrate concentrations of the 3 discrete monitoring sites along Grant Line Canal were not significantly different ($p = 0.82$). However, the sites located along Middle River and Old River had significant differences. For the Middle River sites, Middle River at Undine Road had significantly higher dissolved nitrite + nitrate concentrations than the 2 other Middle River stations ($p<0.005$). For the Old River sites, Old River at Head had significantly higher dissolved nitrite + nitrate concentrations than both the Old River upstream and downstream of the ORT barrier locations ($p<0.009$).

Table 6-7. Dissolved NO_3 + NO_2 Summary Statistics for the Discrete Monitoring Locations

Location	Number of samples	Min of diss nitrate + nitrite (mg/L as N)	Max of diss nitrate + nitrite (mg/L as N)	Average of diss nitrate + nitrite (mg/L as N)
Doughty Cut above GLC	12	0.48	2.00	1.25
GLC above the GLC barrier	12	0.49	2.00	1.31
GLC at Tracy Blvd	12	0.47	2.10	1.32
MR at Tracy Blvd	12	0.20	0.63	0.38
MR at Undine Road	12	0.56	1.80	1.21
MR at Union Point	12	0.21	0.74	0.51
OR at Head	12	0.60	3.00	1.71
OR at Tracy Blvd	12	0.39	1.90	1.17
OR downstream of the ORT barrier	12	0.27	1.80	0.91
OR upstream of the ORT barrier	12	0.29	1.80	0.98

Dissolved Organic Nitrogen

Organic nitrogen is a component in the nitrogen cycle along with nitrite, nitrate, ammonia, and nitrogen gas, and is defined functionally as organically bound nitrogen in the trinegative oxidation state. Organic nitrogen includes such materials as proteins and peptides, nucleic acids and urea, and numerous synthetic organic materials. Organic nitrogen concentrations can range from a few hundred micrograms per liter in some lakes to more than 20 mg/L in raw sewage (APHA, 2005).

Table 6-8 provides the summary statistics for dissolved organic nitrogen concentrations at the discrete monitoring locations. Dissolved organic nitrogen concentrations in the South Delta ranged from 0.2 mg/L to 7.6 mg/L. Average concentrations during the monitoring period ranged from a low of 0.41 mg/L at Old River at Tracy Blvd to a high of 2.05 mg/L at Old River at Head (see Table 6-8). There were no discernible patterns or trends in dissolved organic nitrogen concentrations throughout the monitoring period at all of the discrete stations (see Figures 6-3 to 6-5). The Old River at Head station had 2 samples with much higher dissolved organic nitrogen concentrations (in October and November) than those collected at the other Old River stations.

Station Comparisons by Waterway: The dissolved organic nitrogen concentrations of the 3 discrete monitoring sites along Middle River were not significantly different ($p = 0.06$). However, the sites located along Grant Line Canal and Old River had significant differences. For the Grant Line Canal sites, Grant Line Canal at Tracy Blvd had significantly lower dissolved organic nitrogen concentrations than the 2 other Grant Line Canal stations ($p<0.02$). For the Old River sites, Old River at Head had significantly higher dissolved organic nitrogen concentrations than the 3 other stations located along Old River ($p<0.003$).

Table 6-8. Dissolved Organic Nitrogen Summary Statistics for the Discrete Monitoring Locations

Location	Number of samples	Min of diss organic nitrogen (mg/L as N)	Max of diss organic nitrogen (mg/L as N)	Average of Diss organic nitrogen (mg/L as N)
Doughty Cut above GLC	12	0.3	1.3	0.7
GLC above the GLC barrier	12	0.5	1.2	0.8
GLC at Tracy Blvd	12	0.3	1.0	0.5
MR at Tracy Blvd	12	0.3	0.9	0.7
MR at Undine Road	12	0.6	1.1	0.9
MR at Union Point	12	0.4	1.0	0.7
OR at Head	12	0.4	7.6	2.1
OR at Tracy Blvd	12	0.2	0.9	0.4
OR downstream of the ORT barrier	12	0.2	1.4	0.9
OR upstream of the ORT barrier	12	0.5	1.1	0.9

Dissolved Orthophosphate

Phosphorus is essential to phytoplankton growth and can be a limiting nutrient for primary productivity. In cases where phosphate is a limiting factor, the discharge of raw or treated wastewater, agricultural drainage, and/or certain industrial wastes may stimulate the growth of photosynthetic micro- and macro-organisms in nuisance quantities. Orthophosphates applied to agricultural or residential cultivated land, as fertilizers, can be carried into surface water with storm runoff (APHA, 2005).

Table 6-9 provides the summary statistics for dissolved orthophosphate concentrations at the discrete monitoring locations. Orthophosphate concentrations in the South Delta ranged from a minimum of less than the lab reporting limit of 0.01 mg/L to a maximum of 0.17 mg/L. Average concentrations during the monitoring period ranged from a low of 0.05 mg/L at Middle River at Union Point to a high of 0.11 mg/L at 4 stations (see Table 6-9). Dissolved orthophosphate concentrations were slightly higher in September at the Grant Line Canal, Doughty Cut, Old River at Tracy Blvd, and Old River upstream of the ORT barrier stations (see Figures 6-3 and 6-5). The other stations had no discernible patterns or trends in dissolved orthophosphate concentrations throughout the monitoring period (see Figures 6-4 and 6-5).

Station Comparisons by Waterway: The sites located along Old River and Grant Line Canal did not have any significant differences in their dissolved orthophosphate concentrations. The p-values for the hypothesis tests were 0.44 for the Grant Line Canal station comparisons and 0.06 for the Old River stations. However, the sites located along Middle River did have significant differences in their dissolved orthophosphate concentrations. Middle River at Undine Road had significantly higher dissolved orthophosphate concentrations than Middle River at Union Point ($p<0.0003$).

Table 6-9. Dissolved Orthophosphate Summary Statistics for the Discrete Monitoring Locations

Location	Number of samples	Min of diss ortho-phosphate (mg/L as P)	Max of diss ortho-phosphate (mg/L as P)	Average of diss ortho-phosphate (mg/L as P)
Doughty Cut above GLC	12	0.06	0.14	0.10
GLC above the GLC barrier	12	0.07	0.16	0.10
GLC at Tracy Blvd	12	0.07	0.15	0.11
MR at Tracy Blvd	12	0.03	0.11	0.06
MR at Undine Road	12	0.05	0.13	0.09
MR at Union Point	12	0.04	0.08	0.05
OR at Head	12	< 0.01 [(a)]	0.13	0.08 [(b)]
OR at Tracy Blvd	12	0.07	0.16	0.11
OR downstream of the ORT barrier	12	0.07	0.15	0.11
OR upstream of the ORT barrier	12	0.06	0.17	0.11

(a) The sample with the minimum value at Old River at Head was below the Lab Reporting Limit of 0.01 mg/L.
(b) This statistic is actually the median value, since a more sophisticated procedure is needed to calculate an average of a dataset that has one or more values below the Lab Reporting Limit.

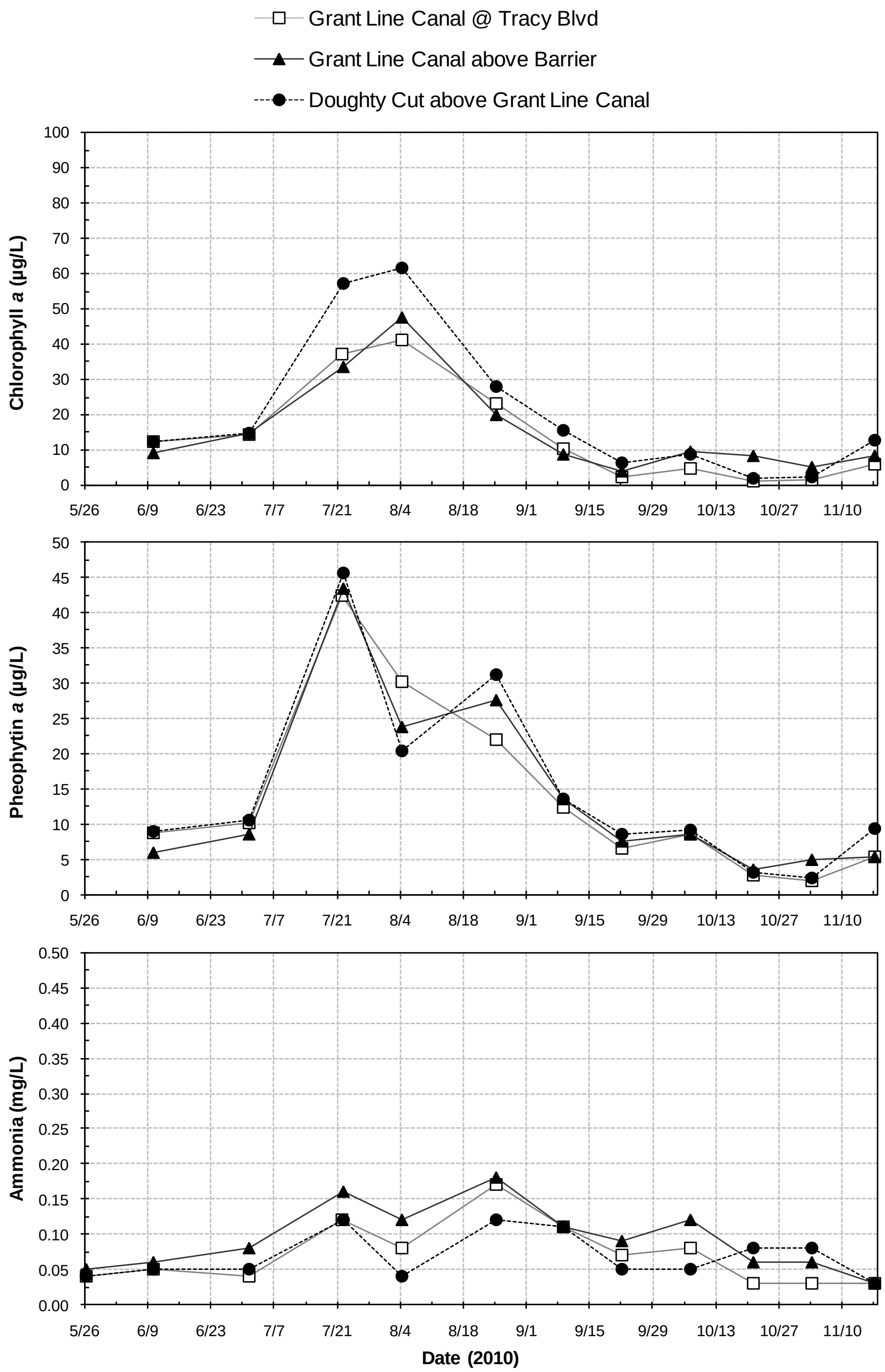


Figure 6-3. Grant Line Canal Discrete Monitoring Data for 2010

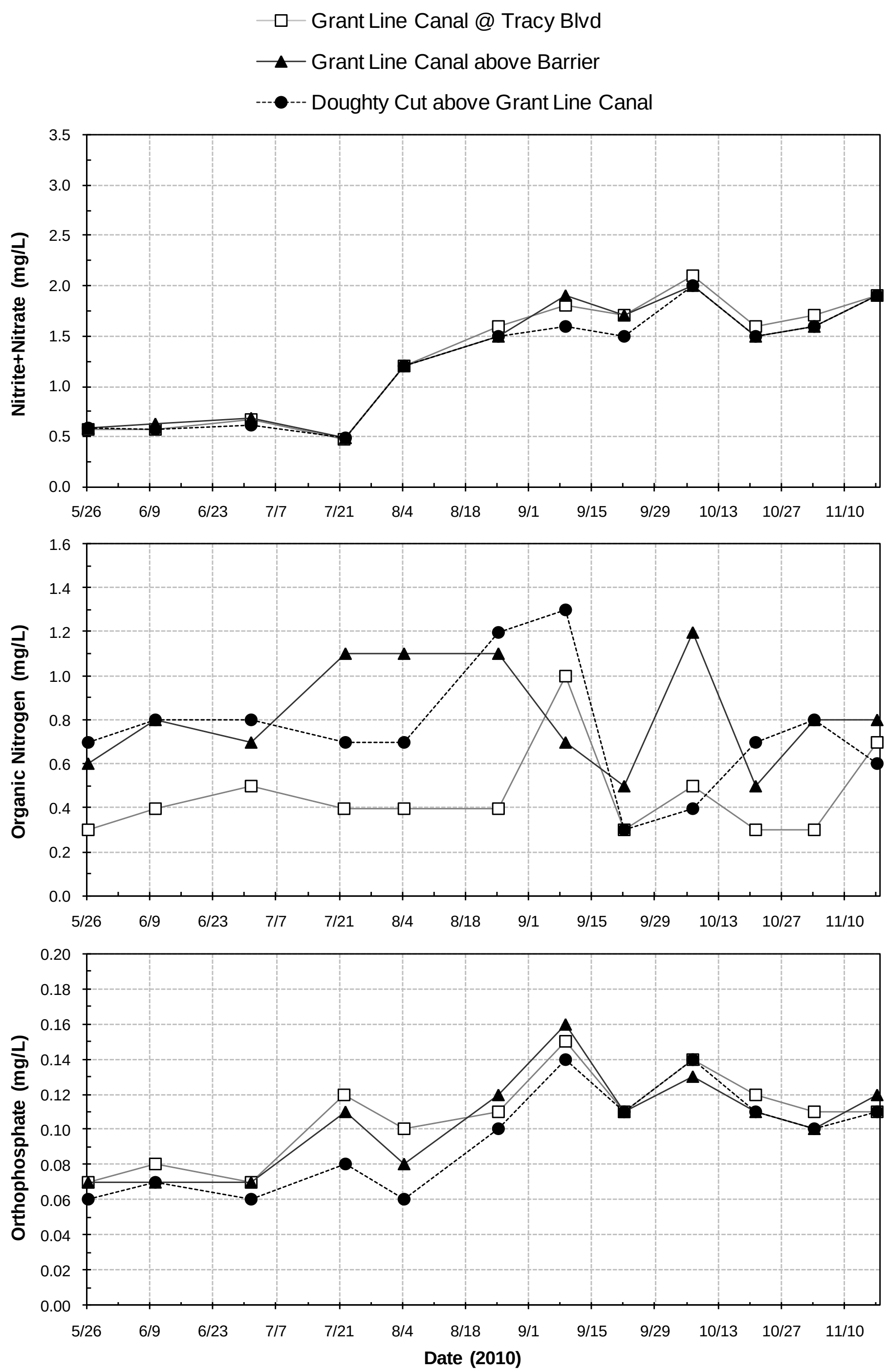


Figure 6-3 (cont.). Grant Line Canal Discrete Monitoring Data for 2010

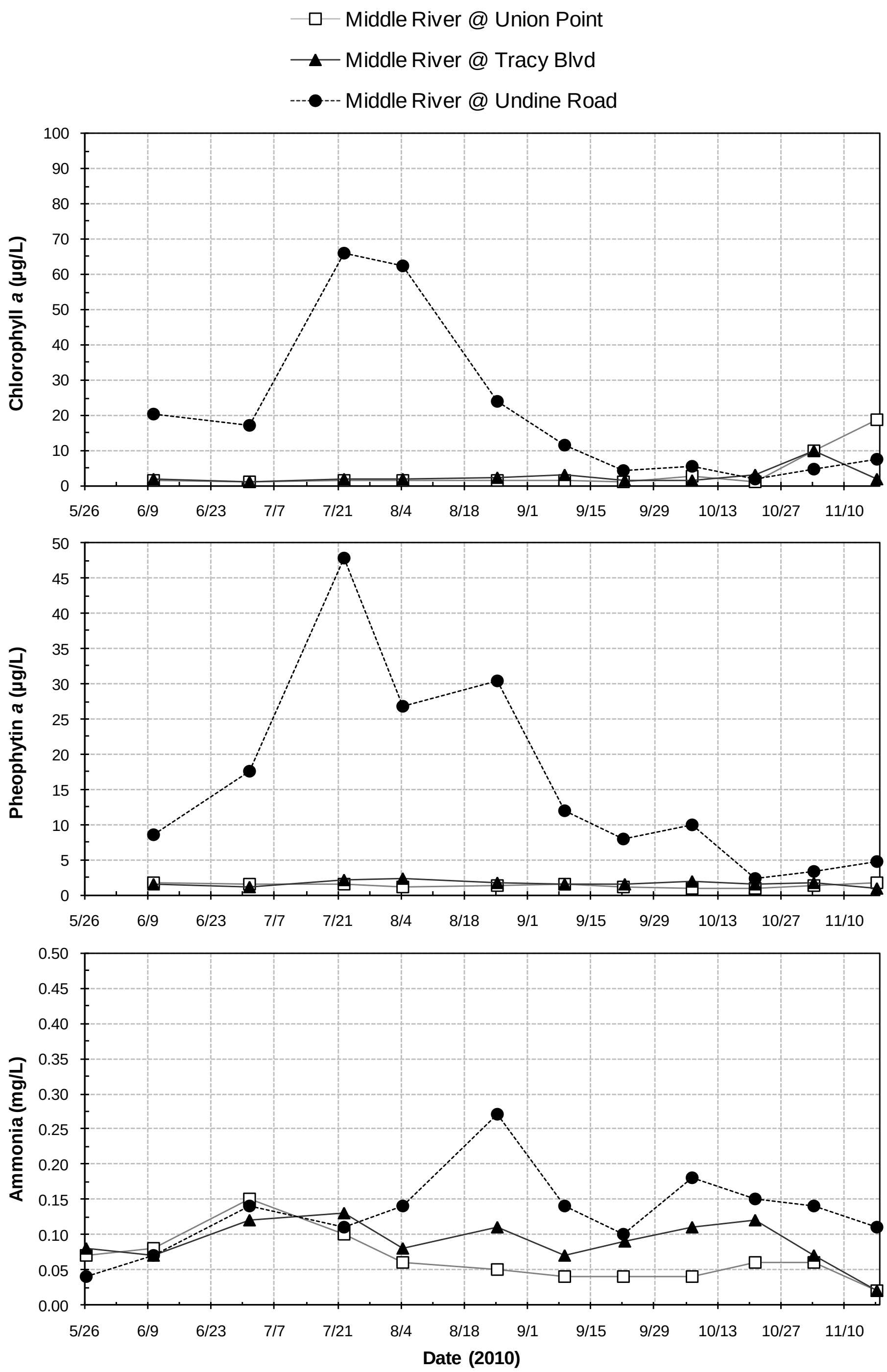


Figure 6-4. Middle River Discrete Monitoring Data for 2010

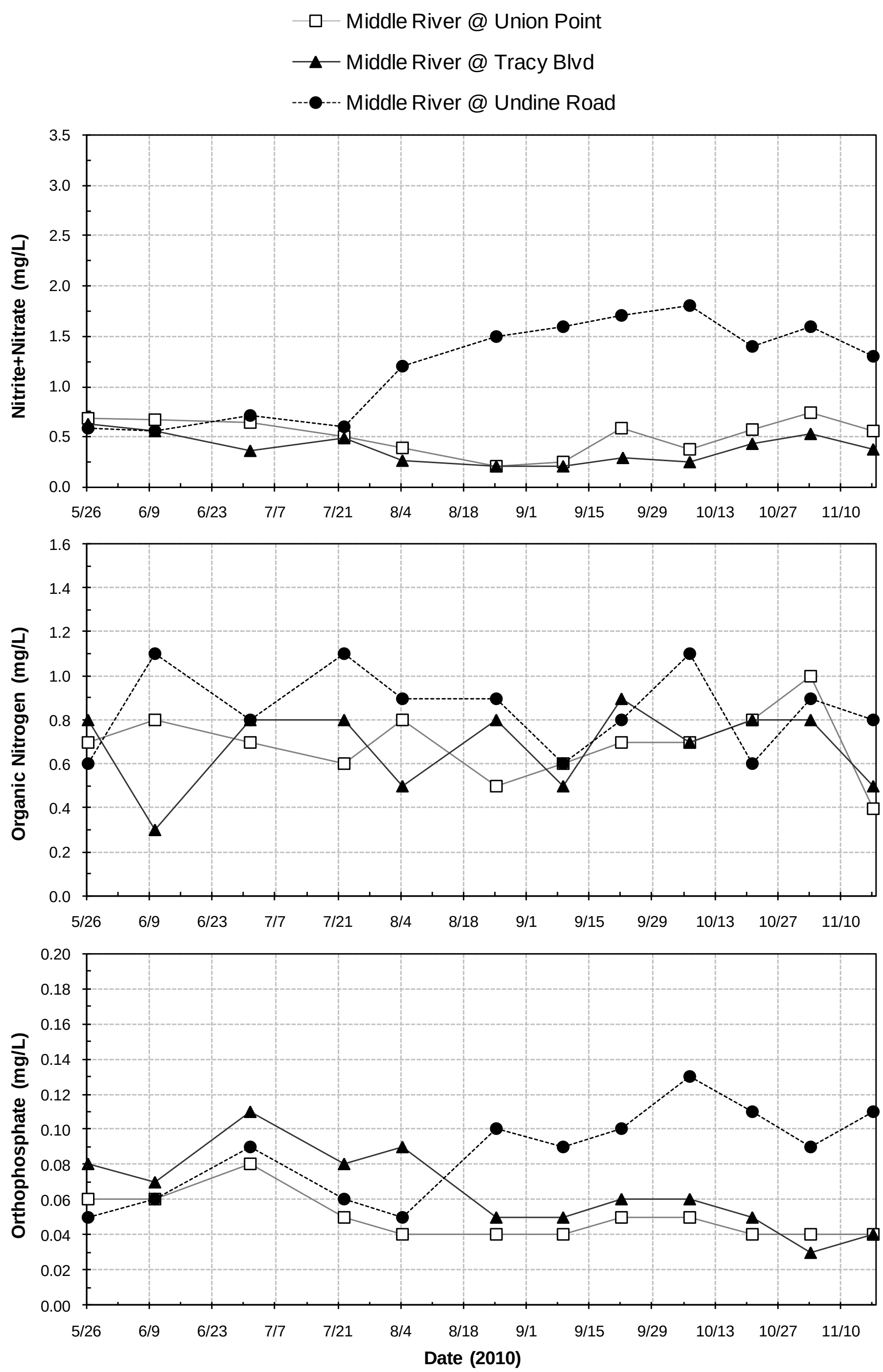


Figure 6-4 (cont.). Middle River Discrete Monitoring Data for 2010

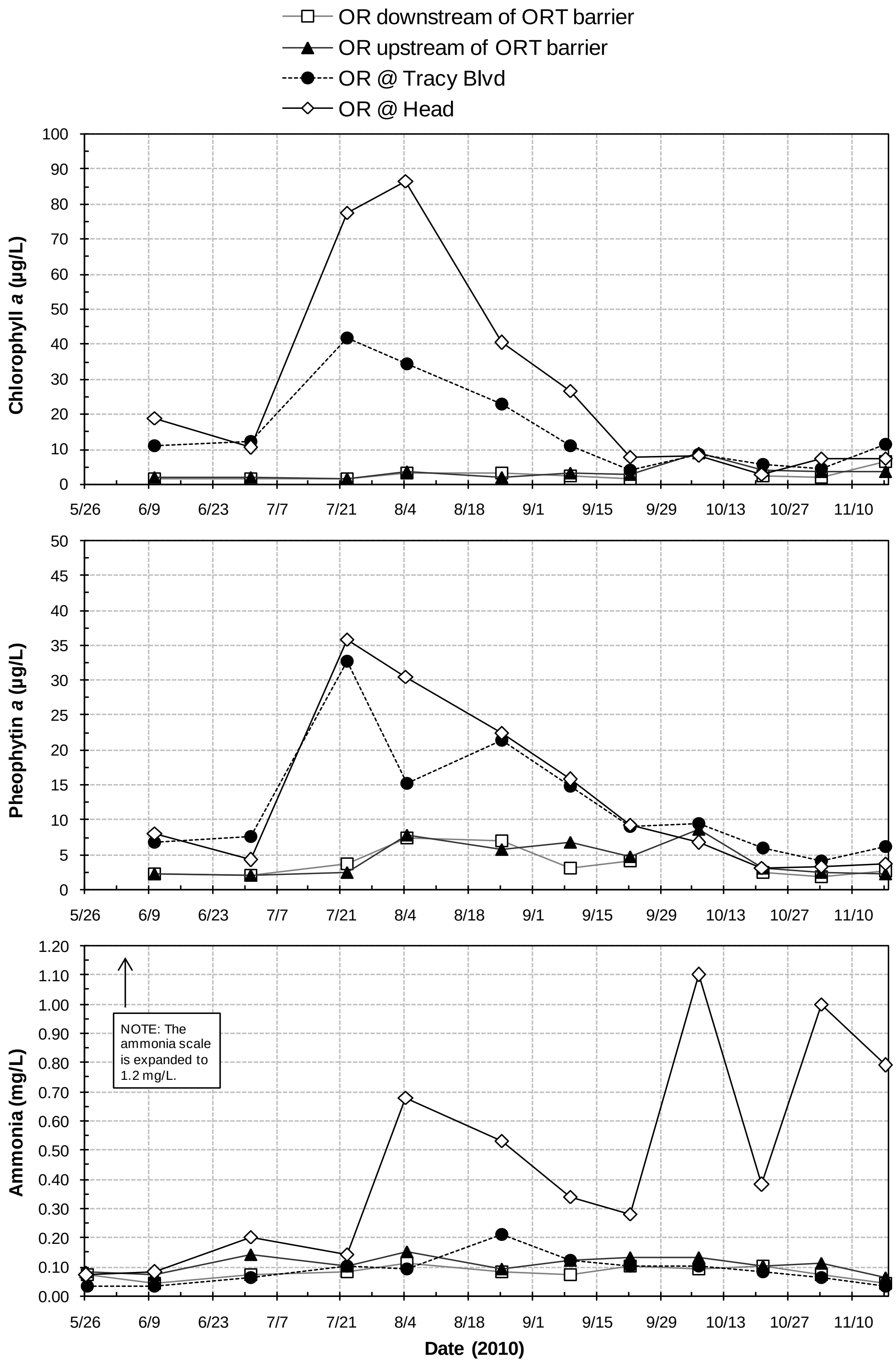


Figure 6-5. Old River Discrete Monitoring Data for 2010

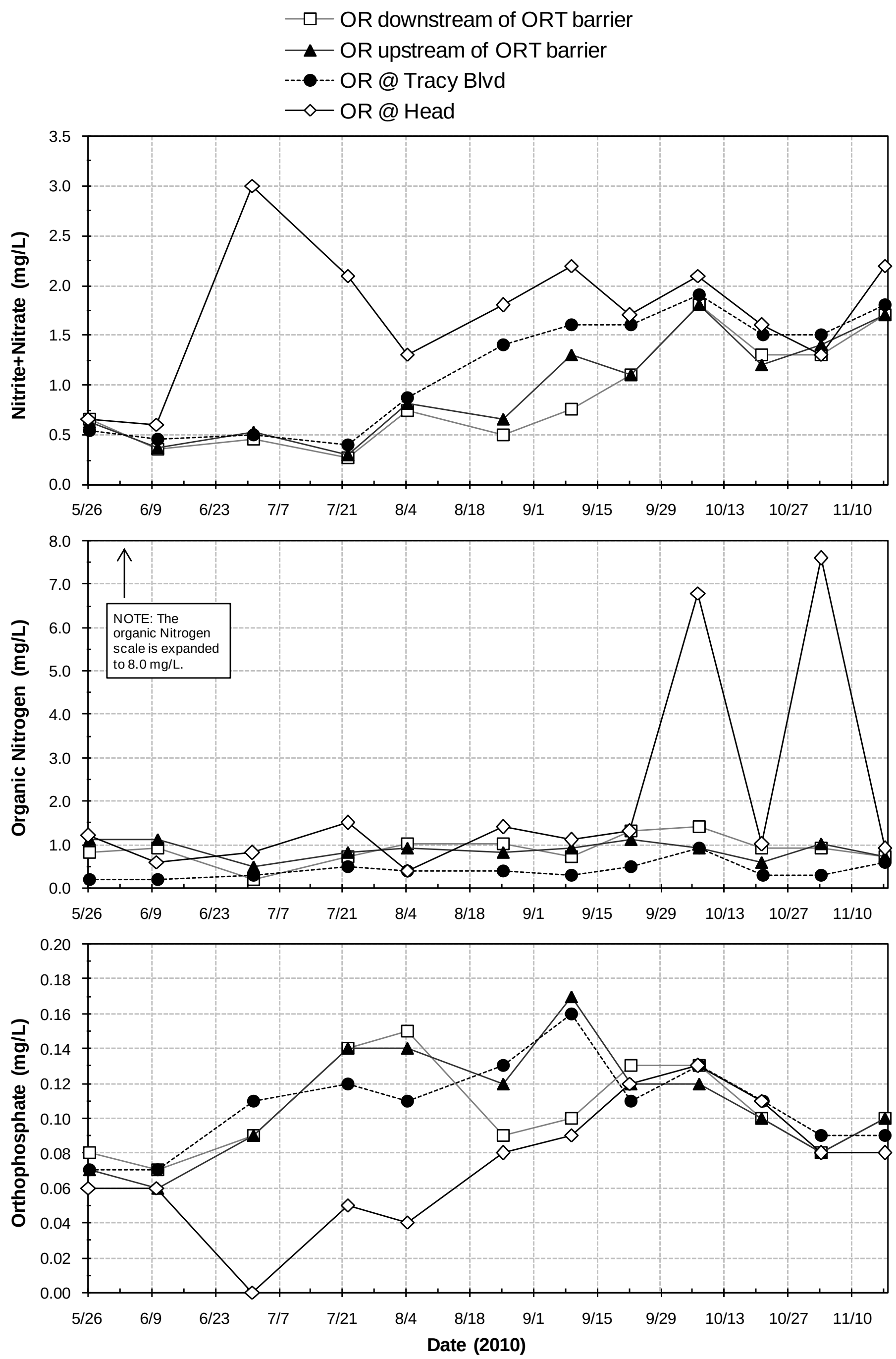


Figure 6-5 (cont.). Old River Discrete Monitoring Data for 2010

Continuous Monitoring

The results and analyses for the South Delta continuous monitoring data from 2010 are discussed below with a separate section for each constituent collected. The monthly maximums, minimums, averages, medians, and standard deviations for each constituent are summarized in Table 6-10 for the Grant Line Canal stations, Table 6-11 for the Victoria Canal station, Table 6-12 for the Middle River stations, and Table 6-13 for the Old River stations.

Water Temperature

Temperature affects pH, conductance, the solubility of constituents such as dissolved oxygen, the rate of chemical reactions, and biological activity in water (Radtke et al., 2004). It is also probably the single most important factor affecting fish distribution both between and within estuaries seasonally, although temperature effects are closely tied to the effects of other variables (Moyle and Cech, 2000).

During 2010, the highest water temperature at the South Delta continuous monitoring stations was 29.0 °C (84.2 ºF) on July 18 at Middle River at Undine Road, and the lowest was of 6.6 °C (43.9 ºF) on December 1 at Middle River at Howard Road (see Tables 6-10 to 6-13). Figures 6-6, 6-7, and 6-8 (placed following Tables 6-10 to 6-13) illustrate the daily maximums, minimums, and averages for the Grant Line and Victoria Canal, Middle River, and Old River stations, respectively. Temperature patterns followed seasonal trends, with the highest temperatures occurring in summer and the lowest in winter. Monthly mean temperatures in the summer (June – August) ranged from 20.3 ºC (68.5 ºF) in June at Old at Head to 25.5 ºC (77.9 ºF) at Middle River at Howard Road in July (see Tables 6-10 to 6-13). In the winter (January – February, and December), monthly mean temperatures ranged from 9.2 ºC (48.6 ºF) in January at both Middle River near Tracy Blvd and Victoria Canal to 12.9 ºC (55.2 ºF) in February at both Grant Line Canal at Tracy Blvd and Grant Line Canal above the GLC barrier. Water temperatures in spring and fall exhibited the steepest increases and decreases in temperature in accordance with seasonal temperature changes. Overall mean temperatures for the 2010 monitoring period ranged from 17.0 °C (62.6 ºF) at both Old River at Head and Old River upstream of the ORT barrier to 17.4 °C (63.9 ºF) at Middle River at Howard Road and Old River at Tracy Wildlife Association.

Table 6-10. Monthly Statistics for the Grant Line Canal Continuous Water Quality Monitoring Stations

	Water temperature (°C)				Dissolved oxygen (mg/L)				pH			
Month	Doughty Cut	GLC abv Barrier	GLC @ Tracy Blvd	GLC nr Old River	Doughty Cut	GLC abv Barrier	GLC @ Tracy Blvd	GLC nr Old River	Doughty Cut	GLC abv Barrier	GLC @ Tracy Blvd	GLC nr Old River
	MAXIMUMS				MAXIMUMS				MAXIMUMS			
January	11.5	11.7	11.8	11.5	10.99	10.62	11.47	10.42	8.08	8.21	8.21	8.12
February	15.0	14.6	14.7	14.6	12.25	12.52	11.90	11.63	8.39	8.16	8.20	8.27
March	18.7	18.6	18.3	17.8	15.87	14.87	14.82	12.10	8.92	8.74	8.65	8.73
April	18.8	18.6	18.6	18.6	14.18	12.89	12.76	10.95	8.89	8.69	8.55	8.72
May	20.0	20.0	19.6	19.7	9.83	9.83	9.68	9.20	7.83	7.87	8.10	7.73
June	25.5	25.1	24.9	25.2	13.40	14.40	13.52	10.36	8.87	9.00	9.02	8.27
July	28.1	28.9	27.2	27.2	18.06	19.37	15.06	11.29	9.69	9.47	9.35	8.92
August	26.8	27.7	25.9	26.6	15.23	16.12	11.52	8.30	9.24	9.26	8.87	8.15
September	26.0	26.4	24.9	25.2	9.85	11.92	8.62	9.60	8.28	8.61	8.28	7.96
October	24.1	24.8	23.8	24.1	8.98	10.02	9.05	9.49	7.81	8.09	7.97	7.96
November	17.6	17.7	17.2	17.4	11.02	10.46	10.61	11.48	8.22	7.95	7.99	7.88
December	12.8	13.0	12.9	12.9	11.07	10.54	10.73	11.66	8.15	7.71	7.88	7.96
	AVERAGES				AVERAGES				AVERAGES			
January	9.9	10.3	10.3	9.8	9.68	9.50	9.72	9.37	7.84	7.88	7.92	7.75
February	12.8	12.9	12.9	12.2	9.68	9.66	9.57	9.05	7.96	7.75	7.91	7.69
March	15.1	15.1	15.1	14.7	10.60	10.24	10.26	9.35	7.81	8.06	7.89	7.95
April	15.7	15.9	15.9	16.0	9.53	9.25	9.38	8.28	7.96	7.87	7.77	7.68
May	16.7	16.6	16.6	16.9	9.09	9.11	9.05	8.34	7.63	7.66	7.73	7.41
June	20.8	20.8	20.8	21.3	9.11	9.03	9.00	7.70	7.77	7.71	7.76	7.38
July	24.0	24.3	24.0	24.0	10.77	9.81	9.54	6.67	8.65	8.44	8.48	7.56
August	24.2	24.5	24.2	23.6	9.51	8.54	7.64	5.62	8.44	8.34	8.31	7.53
September	22.4	22.7	22.4	22.4	7.23	7.17	6.93	6.35	7.62	7.51	7.80	7.53
October	18.7	18.9	18.8	19.2	7.78	7.70	7.69	7.48	7.62	7.76	7.70	7.64
November	13.3	13.4	13.3	13.6	9.23	8.99	9.15	9.02	7.82	7.70	7.83	7.66
December	11.2	11.2	11.3	11.2	9.69	9.59	9.69	9.47	7.49	7.32	7.32	7.51
	MEDIANS				MEDIANS				MEDIANS			
January	9.9	10.3	10.3	9.7	9.79	9.65	9.80	9.44	7.86	7.98	7.97	7.79
February	12.6	12.7	12.7	12.2	9.39	9.32	9.32	8.91	7.94	7.74	7.91	7.70
March	14.5	14.4	14.2	13.7	10.50	10.43	10.53	9.17	7.94	8.18	8.10	7.97
April	15.7	15.9	15.9	15.9	9.27	8.98	9.19	8.21	7.94	7.86	7.85	7.92
May	16.5	16.5	16.5	16.6	9.11	9.12	9.07	8.35	7.63	7.65	7.70	7.43
June	20.6	20.7	20.6	21.3	8.80	8.68	8.71	7.70	7.74	7.67	7.72	7.39
July	24.4	24.7	24.4	24.2	10.52	9.67	9.52	6.92	8.97	8.77	8.78	7.52
August	24.3	24.5	24.3	23.7	9.45	8.21	7.48	5.50	8.61	8.46	8.37	7.57
September	22.1	22.4	22.2	22.2	7.14	7.01	6.87	6.28	7.64	7.62	7.83	7.55
October	19.5	19.6	19.6	20.0	7.63	7.58	7.46	7.48	7.64	7.83	7.70	7.65
November	13.6	13.8	13.7	13.9	9.19	8.96	9.12	8.94	7.80	7.71	7.87	7.66
December	11.4	11.4	11.4	11.3	9.61	9.54	9.62	9.40	7.57	7.32	7.36	7.51
	MINIMUMS				MINIMUMS				MINIMUMS			
January	8.5	8.9	9.0	8.8	8.49	8.49	8.60	7.89	7.61	7.40	7.71	7.31
February	10.9	11.2	11.3	9.3	8.30	8.40	8.43	7.19	7.78	7.55	7.59	7.32
March	12.1	12.2	12.3	12.4	8.06	8.04	7.71	6.53	7.39	7.53	7.49	7.58
April	12.8	12.7	12.9	13.2	7.90	7.70	7.98	6.36	7.67	7.63	7.39	7.24
May	15.1	14.4	14.4	14.8	8.27	8.27	8.10	6.50	7.49	7.49	7.46	7.11
June	17.5	17.5	17.6	17.4	7.69	7.00	7.08	4.95	7.44	7.28	7.39	7.07
July	19.2	19.2	19.3	20.1	3.82	2.16	2.93	1.15	7.73	7.58	7.65	7.16
August	21.4	21.5	21.6	20.8	5.88	1.04	4.01	2.00	7.48	7.59	7.89	7.19
September	20.1	20.2	20.3	19.9	4.70	4.36	5.19	3.94	7.27	7.01	7.52	7.27
October	14.3	14.4	14.4	14.6	6.25	5.83	6.18	5.40	7.37	7.42	7.53	7.41
November	7.8	8.0	8.2	8.1	7.69	7.48	8.02	7.42	7.55	7.53	7.61	7.53
December	7.8	8.2	8.2	8.2	8.92	8.78	9.07	8.70	7.21	7.11	7.12	7.35
	STANDARD DEVIATIONS				STANDARD DEVIATIONS				STANDARD DEVIATIONS			
January	0.8	0.7	0.7	0.7	0.52	0.48	0.64	0.49	0.09	0.17	0.11	0.18
February	0.8	0.8	0.8	1.1	0.79	0.86	0.70	0.71	0.14	0.13	0.11	0.21
March	1.9	1.9	1.9	1.8	1.59	1.41	1.43	1.07	0.42	0.27	0.31	0.29
April	1.4	1.4	1.3	1.3	0.93	0.87	0.82	0.63	0.24	0.21	0.24	0.36
May	1.1	1.0	1.0	1.0	0.27	0.23	0.25	0.36	0.06	0.07	0.16	0.14
June	1.7	1.7	1.7	1.6	0.98	1.15	1.02	0.67	0.32	0.38	0.36	0.17
July	1.9	2.0	1.8	1.4	2.19	2.80	2.46	1.74	0.41	0.42	0.40	0.40
August	0.9	1.1	0.8	1.0	1.33	2.08	1.11	1.29	0.28	0.32	0.24	0.15
September	1.3	1.3	1.2	1.1	0.64	1.04	0.58	0.97	0.14	0.30	0.14	0.14
October	2.6	2.7	2.6	2.6	0.58	0.66	0.66	0.89	0.08	0.16	0.09	0.09
November	2.7	2.6	2.6	2.5	0.72	0.63	0.64	0.63	0.17	0.07	0.09	0.06
December	1.1	1.1	1.1	1.1	0.39	0.30	0.35	0.38	0.24	0.14	0.16	0.13
2010 - Max.	28.1	28.9	27.2	27.2	18.06	19.37	15.06	12.10	9.69	9.47	9.35	8.92
2010 - Avg.	17.1	17.2	17.1	17.1	9.33	9.05	8.97	8.05	7.80	7.74	7.78	7.58
2010 - Med.	16.7	16.6	16.6	16.6	9.24	9.06	9.04	8.33	7.84	7.79	7.87	7.62
2010 - Min.	7.8	8.0	8.2	8.1	3.82	1.04	2.93	1.15	7.21	7.01	7.12	7.07
2010 - S.D.	5.2	5.1	4.9	5.0	1.46	1.53	1.43	1.55	0.46	0.43	0.40	0.28

Table 6-10 (cont.). Monthly Statistics for the Grant Line Canal Continuous Water Quality Monitoring Stations

	Specific conductance (µS/cm)				Turbidity (NTU)				Chlorophyll (µg/L)			
Month	Doughty Cut	GLC abv Barrier	GLC @ Tracy Blvd	GLC nr Old River	Doughty Cut	GLC abv Barrier	GLC @ Tracy Blvd	GLC nr Old River	Doughty Cut	GLC abv Barrier	GLC @ Tracy Blvd	GLC nr Old River
	MAXIMUMS				MAXIMUMS				MAXIMUMS			
January	1069	1051	1073	1069	194.9	180.6	211.3	163.8	26.6	35.7	20.9	10.8
February	1029	1021	1006	1008	64.0	59.3	45.1	40.3	48.3	30.3	38.5	16.0
March	1045	994	1011	997	65.7	83.6	63.9	62.3	153.1	122.6	163.6	75.9
April	982	951	961	963	61.9	56.1	29.4	39.0	149.4	152.2	166.3	61.8
May	406	406	386	410	67.5	56.0	43.3	38.1	38.4	35.5	25.5	4.4
June	522	480	478	477	61.2	57.6	67.1	72.9	88.7	146.0	84.9	20.4
July	655	636	633	636	67.3	71.5	52.1	69.2	224.1	215.8	279.1	90.5
August	743	750	752	753	53.0	68.3	61.2	31.1	110.8	144.2	90.7	67.3
September	669	713	707	729	54.9	79.8	39.0	25.3	43.7	106.5	28.2	22.9
October	725	690	692	696	43.2	64.5	59.8	38.4	14.7	45.8	21.7	12.7
November	885	829	830	823	57.8	177.6	49.4	34.1	67.4	29.3	7.0	13.0
December	814	788	783	799	67.7	71.6	57.9	70.9	44.8	19.9	9.7	10.4
	AVERAGES				AVERAGES				AVERAGES			
January	865	866	872	798	29.6	26.6	27.1	20.8	--	10.2	9.0	2.7
February	819	816	814	707	23.1	15.0	15.9	15.4	--	13.9	14.8	4.7
March	822	821	822	730	26.2	19.1	20.8	19.7	--	41.8	47.0	13.0
April	502	474	476	482	18.5	15.2	15.3	18.9	--	25.2	27.0	6.1
May	291	284	279	284	18.5	16.7	17.3	17.4	--	15.4	8.7	2.2
June	331	332	329	309	27.1	21.8	24.7	22.9	--	31.4	29.6	3.3
July	490	501	502	396	29.8	20.6	22.7	17.8	--	90.8	103.6	21.4
August	654	672	671	569	23.3	17.9	20.0	11.6	--	56.1	38.8	6.9
September	523	537	533	521	19.3	14.2	15.9	8.2	--	15.4	13.6	4.1
October	503	503	506	501	17.7	11.8	14.5	7.8	--	6.0	7.1	1.2
November	701	695	691	612	13.1	10.1	11.6	6.8	--	4.7	3.4	1.1
December	309	310	311	318	24.4	23.3	21.2	16.5	--	3.4	3.4	1.6
	MEDIANS				MEDIANS				MEDIANS			
January	966	970	971	796	14.7	10.0	9.9	8.3	10.8	9.9	8.1	1.9
February	806	801	803	725	22.3	13.9	15.0	14.0	16.5	12.7	10.9	3.2
March	889	891	889	727	24.7	17.3	19.7	19.0	63.6	35.1	42.2	7.7
April	480	422	422	450	17.5	14.5	14.7	18.5	18.8	15.3	14.7	3.2
May	291	284	280	288	17.8	15.6	16.8	16.7	12.9	15.3	7.9	2.2
June	317	330	326	308	26.0	21.2	23.6	20.6	15.8	22.4	26.5	2.9
July	538	559	558	374	28.9	19.8	22.1	16.3	78.4	82.1	80.4	12.3
August	655	681	677	624	22.7	16.8	19.4	11.2	42.1	52.0	36.8	5.7
September	586	613	611	529	19.1	13.9	15.7	7.7	13.3	12.3	12.8	3.9
October	484	488	493	468	17.4	11.2	13.6	6.6	6.2	4.1	5.8	1.1
November	758	760	753	666	12.3	8.9	10.6	5.6	4.4	4.7	3.3	1.0
December	276	274	276	277	21.1	19.2	18.2	12.5	4.4	2.8	2.9	0.9
	MINIMUMS				MINIMUMS				MINIMUMS			
January	453	456	461	467	6.2	3.6	2.7	2.1	2.1	4.3	2.7	0.4
February	621	614	616	377	8.1	6.2	6.1	6.1	2.4	5.6	5.2	1.1
March	526	520	523	376	13.5	4.7	8.3	5.5	0.0	10.4	7.8	2.3
April	276	278	283	283	8.7	6.7	7.3	5.1	2.1	4.7	3.6	1.5
May	238	213	217	217	9.9	8.9	9.3	7.5	7.2	7.3	3.4	0.5
June	179	184	185	190	10.6	10.0	11.5	5.6	4.9	0.0	5.6	0.0
July	234	229	248	194	17.7	5.3	12.0	6.1	13.5	11.9	12.7	0.0
August	524	542	560	212	13.5	5.5	11.2	3.2	7.6	13.6	13.7	0.9
September	276	283	277	295	8.8	6.2	9.8	2.7	4.4	3.1	6.8	0.8
October	328	329	330	332	10.7	4.8	6.0	1.8	1.9	1.4	2.5	0.1
November	360	358	359	355	7.0	3.8	4.0	1.5	0.3	0.7	1.0	0.2
December	171	174	172	172	7.2	3.8	4.3	1.4	0.0	0.5	0.8	0.1
	STANDARD DEVIATIONS				STANDARD DEVIATIONS				STANDARD DEVIATIONS			
January	184	185	186	190	31.3	34.0	35.4	29.5	4.4	3.5	4.0	2.0
February	105	104	101	168	7.1	5.3	5.5	5.2	7.4	4.2	7.4	3.1
March	160	154	154	194	6.9	7.3	7.1	7.4	39.1	30.5	34.4	10.7
April	188	185	189	178	5.1	4.0	3.8	4.8	34.6	25.2	34.9	8.2
May	28	36	36	38	4.8	4.6	3.7	4.1	2.7	3.6	3.4	0.5
June	82	75	76	67	6.7	5.7	6.7	11.4	22.3	25.2	16.3	1.9
July	110	115	109	146	5.9	6.3	4.6	7.3	48.2	45.7	72.4	20.6
August	37	42	38	162	4.3	6.0	4.6	3.7	20.0	23.3	14.5	4.9
September	120	129	129	120	3.4	4.1	2.3	3.0	5.3	9.1	3.8	1.5
October	103	105	106	100	3.2	4.0	5.4	4.1	2.1	3.9	3.7	0.6
November	128	129	126	157	4.0	6.1	4.5	4.1	2.8	1.9	1.1	0.4
December	152	153	153	149	12.1	13.2	11.3	12.3	3.3	1.6	1.6	1.2
2010 - Max.	1069	1051	1073	1069	194.9	180.6	211.3	163.8	224.1	215.8	279.1	90.5
2010 - Avg.	580	566	566	518	22.8	17.7	18.9	15.3	--	26.4	25.7	5.2
2010 - Med.	585	578	580	481	20.5	15.1	16.5	13.1	13.8	13.3	11.9	2.8
2010 - Min.	171	174	172	172	6.2	3.6	2.7	1.4	0.0	0.0	0.8	0.0
2010 - S.D.	229	234	234	221	12.3	12.6	12.9	12.0	34.6	32.3	38.0	8.4

Table 6-11. Monthly Statistics for the Victoria Canal Water Quality Monitoring Station

Month	Water temperature (°C)	Dissolved oxygen (mg/L)	pH	Specific conductance (µS/cm)	Turbidity (NTU)	Chlorophyll (µg/L)
	MAXIMUMS					
January	9.9	10.70	8.15	599	31.3	8.9
February	13.4	9.43	7.72	580	35.9	9.0
March	16.1	10.49	7.89	546	23.5	16.1
April	18.9	10.89	8.33	663	16.3	17.5
May	20.1	10.25	8.27	442	38.8	5.8
June	25.4	8.76	7.67	400	17.7	5.9
July	25.7	8.00	7.45	289	32.8	6.7
August	24.7	8.36	7.79	288	23.6	11.9
September	24.1	8.71	7.80	417	54.8	9.9
October	22.9	8.92	7.74	394	31.9	13.6
November	17.4	10.35	7.67	375	19.4	5.1
December	11.6	10.48	7.89	418	35.4	13.3
	AVERAGES					
January	9.2	9.76	7.83	530	4.1	2.9
February	11.8	8.62	7.57	432	9.6	5.9
March	13.9	9.30	7.67	434	6.1	4.2
April	16.2	9.28	7.84	501	5.6	4.2
May	17.6	8.77	7.60	328	7.6	2.3
June	21.9	7.52	7.34	278	6.5	2.5
July	23.9	7.09	7.17	216	6.4	2.9
August	23.0	7.64	7.46	229	4.9	2.3
September	22.3	7.67	7.53	351	3.2	2.1
October	19.8	7.97	7.54	347	1.9	2.3
November	14.3	9.07	7.51	316	1.7	1.8
December	10.8	9.50	7.62	339	4.6	2.6
	MEDIANS					
January	9.2	9.77	7.83	541	3.1	2.7
February	12.1	8.74	7.61	412	9.4	5.9
March	13.4	9.32	7.68	433	5.7	4.1
April	16.1	9.27	7.83	496	5.4	3.9
May	17.7	8.85	7.56	328	7.4	2.4
June	21.9	7.54	7.36	265	6.2	2.5
July	23.9	7.07	7.17	213	5.9	2.9
August	23.0	7.64	7.46	230	4.5	2.3
September	22.2	7.67	7.53	361	2.7	1.7
October	20.5	7.96	7.54	348	1.2	2.3
November	14.8	8.99	7.52	315	1.5	1.8
December	11.0	9.46	7.63	335	3.1	2.3
	MINIMUMS					
January	8.7	8.88	7.58	449	1.3	0.7
February	9.6	7.33	7.36	365	5.0	3.9
March	11.8	8.32	7.53	385	2.8	2.6
April	13.5	7.92	7.63	318	2.7	1.9
May	15.6	7.08	7.36	247	3.9	0.6
June	19.0	5.30	6.95	210	1.6	0.9
July	22.0	5.46	6.93	189	2.9	0.6
August	21.1	5.27	7.16	180	1.8	0.3
September	20.3	5.49	7.29	265	1.0	0.0
October	16.3	5.67	7.37	312	0.0	0.5
November	10.0	7.69	7.33	288	0.0	0.6
December	9.5	8.43	7.39	254	1.0	0.7
	STANDARD DEVIATIONS					
January	0.3	0.37	0.14	32	2.6	1.1
February	1.0	0.47	0.08	46	2.0	0.8
March	1.3	0.34	0.05	26	1.8	0.8
April	1.4	0.58	0.14	91	1.4	1.4
May	0.9	0.57	0.19	43	1.8	0.6
June	1.1	0.52	0.12	43	2.3	0.5
July	0.8	0.33	0.08	14	2.2	0.7
August	0.6	0.32	0.10	22	2.0	1.0
September	0.8	0.37	0.07	40	2.3	1.1
October	1.8	0.44	0.05	14	2.6	0.6
November	2.2	0.52	0.07	13	1.1	0.3
December	0.5	0.50	0.10	33	3.3	1.0
2010 - Max.	25.7	10.89	8.33	663	54.8	17.5
2010 - Avg.	17.1	8.52	7.52	358	5.2	3.0
2010 - Med.	17.1	8.58	7.57	344	5.0	2.6
2010 - Min.	8.7	5.27	6.93	180	0.0	0.0
2010 - S.D.	5.0	0.98	0.21	103	3.1	1.4

Table 6-12. Monthly Statistics for the Middle River Continuous Water Quality Monitoring Stations

	Water temperature (°C)				Dissolved oxygen (mg/L)				pH			
Month	Undine	Howard	Tracy Blvd	Union Point	Undine	Howard	Tracy Blvd	Union Point	Undine	Howard	Tracy Blvd	Union Point
	MAXIMUMS				MAXIMUMS				MAXIMUMS			
January	11.9	11.1	10.6	10.1	11.45	13.81	12.28	11.55	8.36	8.57	8.00	7.89
February	15.3	15.4	15.7	14.0	14.39	12.69	11.22	9.75	9.13	8.20	7.93	7.88
March	20.0	18.7	18.2	17.0	16.73	18.04	12.22	10.51	8.85	9.12	8.38	7.93
April	20.6	20.2	21.1	19.4	16.59	14.32	12.67	11.33	8.93	8.82	8.44	8.34
May	21.1	21.4	22.0	20.6	11.20	13.58	11.50	10.54	8.53	8.97	8.82	8.47
June	27.1	27.8	28.7	26.9	16.36	12.13	11.36	8.88	9.16	8.57	8.58	8.12
July	29.0	28.7	27.9	26.2	19.09	14.33	9.02	8.82	9.48	9.27	7.87	7.70
August	28.8	28.3	26.3	25.1	15.95	11.43	8.63	9.16	9.03	8.89	7.77	7.74
September	27.1	26.7	25.5	24.0	10.91	9.41	9.50	9.29	8.40	8.03	7.96	7.97
October	24.9	24.3	24.7	22.9	11.24	11.63	9.34	9.53	8.44	8.44	8.03	7.92
November	18.2	18.0	17.9	17.3	12.15	13.45	11.76	11.14	8.32	8.56	8.18	7.81
December	13.0	13.2	13.1	12.1	12.15	13.70	11.86	10.94	8.13	8.49	8.16	7.79
	AVERAGES				AVERAGES				AVERAGES			
January	10.1	9.5	9.2	9.3	9.72	9.79	10.40	9.98	8.00	7.74	7.67	7.44
February	12.7	12.6	12.3	11.9	9.71	9.21	9.44	8.60	8.19	7.63	7.65	7.54
March	14.9	14.6	14.4	14.1	10.53	10.99	9.92	9.21	8.06	7.79	7.81	7.58
April	15.9	16.1	16.5	16.3	9.49	8.69	9.90	9.60	7.76	7.74	7.81	7.84
May	16.8	17.9	18.2	18.0	9.40	8.28	9.01	9.10	7.73	7.46	7.75	7.81
June	20.9	22.8	22.4	22.3	9.38	5.82	7.55	7.40	7.73	7.27	7.40	7.34
July	24.1	25.5	24.6	24.1	11.51	5.18	6.41	7.14	8.38	7.22	7.30	7.29
August	24.1	24.3	23.2	23.0	9.91	4.76	6.87	7.65	8.29	7.29	7.38	7.39
September	22.4	22.5	22.3	22.3	7.60	5.34	6.51	7.66	7.67	7.31	7.38	7.62
October	18.7	19.0	19.3	19.8	8.08	7.39	6.54	7.83	7.84	7.59	7.38	7.55
November	13.0	12.8	13.6	14.2	9.48	10.58	9.00	9.09	7.88	7.98	7.52	7.58
December	11.2	11.0	10.9	10.9	9.70	9.43	9.47	9.55	7.51	7.39	7.51	7.45
	MEDIANS				MEDIANS				MEDIANS			
January	10.1	9.5	9.2	9.3	9.79	9.99	10.34	9.99	7.98	7.71	7.69	7.53
February	12.6	12.4	12.3	12.1	9.44	9.03	9.51	8.79	8.23	7.63	7.68	7.54
March	14.7	14.7	14.1	13.5	10.01	10.83	9.89	9.19	8.14	8.04	7.87	7.62
April	15.8	16.1	16.5	16.1	9.22	8.62	9.88	9.55	7.79	7.81	7.85	7.83
May	16.7	17.8	18.0	18.0	9.27	8.17	8.97	9.13	7.71	7.50	7.78	7.87
June	20.8	22.7	22.2	22.1	9.11	5.51	7.44	7.45	7.76	7.29	7.45	7.38
July	24.2	25.4	24.5	24.2	11.15	4.41	6.37	7.17	8.93	7.21	7.29	7.31
August	24.0	24.4	23.2	23.0	9.67	4.45	6.80	7.68	8.44	7.26	7.39	7.39
September	22.3	22.3	22.4	22.2	7.39	5.35	6.56	7.73	7.70	7.32	7.42	7.63
October	19.0	19.5	19.8	20.5	8.10	7.07	6.57	7.86	7.83	7.60	7.38	7.54
November	13.5	13.0	14.2	14.7	9.47	10.59	9.01	9.02	7.92	8.06	7.49	7.58
December	11.4	11.3	10.9	11.0	9.68	9.13	9.34	9.60	7.49	7.34	7.51	7.46
	MINIMUMS				MINIMUMS				MINIMUMS			
January	8.5	8.2	8.0	8.5	7.08	6.66	8.43	9.12	7.74	7.13	7.42	7.09
February	10.4	10.1	9.5	9.6	7.87	6.25	6.87	7.10	7.72	7.31	7.29	7.32
March	10.9	11.3	11.2	11.8	7.82	6.03	8.19	8.23	7.52	7.23	7.35	7.34
April	12.4	12.5	12.8	13.5	7.76	5.02	4.68	8.17	7.35	7.29	7.46	7.59
May	13.6	15.0	15.2	15.8	6.82	3.65	2.12	7.31	7.31	6.95	7.26	7.34
June	17.1	18.2	18.8	19.0	6.57	0.87	4.87	5.42	7.08	6.86	7.00	6.92
July	18.7	21.7	22.2	22.4	4.88	0.37	4.03	4.71	7.12	6.79	7.01	7.01
August	20.1	19.4	19.3	21.4	4.94	1.14	4.74	4.99	7.54	6.98	7.10	7.17
September	19.3	18.3	18.9	20.6	4.45	1.53	3.22	2.87	7.33	7.01	7.07	7.19
October	14.0	14.5	14.8	15.8	5.66	1.57	3.83	5.99	7.59	7.23	7.15	7.34
November	6.7	6.7	7.8	9.6	6.79	4.48	6.20	7.64	7.41	7.44	7.26	7.39
December	6.9	6.6	7.8	8.9	7.53	7.19	6.72	8.16	7.20	7.15	7.23	7.27
	STANDARD DEVIATIONS				STANDARD DEVIATIONS				STANDARD DEVIATIONS			
January	0.7	0.7	0.5	0.3	0.80	1.55	0.58	0.40	0.11	0.26	0.12	0.21
February	1.0	1.3	1.2	1.0	1.06	1.47	0.52	0.55	0.23	0.18	0.12	0.09
March	2.1	1.9	1.8	1.4	1.98	2.90	0.76	0.43	0.32	0.50	0.22	0.14
April	1.5	1.7	2.0	1.6	1.14	1.63	1.00	0.62	0.30	0.34	0.20	0.14
May	1.4	1.3	1.3	0.9	0.63	1.65	0.87	0.64	0.21	0.35	0.32	0.21
June	2.1	1.9	1.7	1.4	1.37	1.99	1.07	0.61	0.41	0.30	0.28	0.28
July	2.1	1.2	1.0	0.7	2.58	2.68	0.76	0.46	0.49	0.57	0.15	0.09
August	1.6	1.5	1.2	0.6	2.23	1.74	0.73	0.42	0.32	0.35	0.13	0.07
September	1.6	1.6	1.3	0.8	1.10	1.24	1.01	0.56	0.22	0.18	0.20	0.09
October	2.6	2.4	2.3	1.8	0.95	1.56	1.05	0.44	0.14	0.22	0.15	0.10
November	2.9	3.1	2.7	2.2	1.04	1.18	1.23	0.65	0.15	0.23	0.25	0.06
December	1.2	1.5	1.1	0.6	0.50	1.23	0.88	0.45	0.14	0.32	0.22	0.09
2010 - Max.	29.0	28.7	28.7	26.9	19.09	18.04	12.67	11.55	9.48	9.27	8.82	8.47
2010 - Avg.	17.1	17.4	17.3	17.2	9.55	7.95	8.41	8.58	7.85	7.47	7.51	7.51
2010 - Med.	16.6	17.1	17.3	17.2	9.35	8.08	8.67	8.65	7.93	7.55	7.57	7.55
2010 - Min.	6.7	6.6	7.8	8.5	4.45	0.37	2.12	2.87	7.08	6.79	7.00	6.92
2010 - S.D.	5.1	5.5	5.2	5.1	1.72	2.79	1.72	1.08	0.43	0.42	0.28	0.22

Table 6-12 (cont.). Monthly Statistics for the Middle River Continuous Water Quality Monitoring Stations

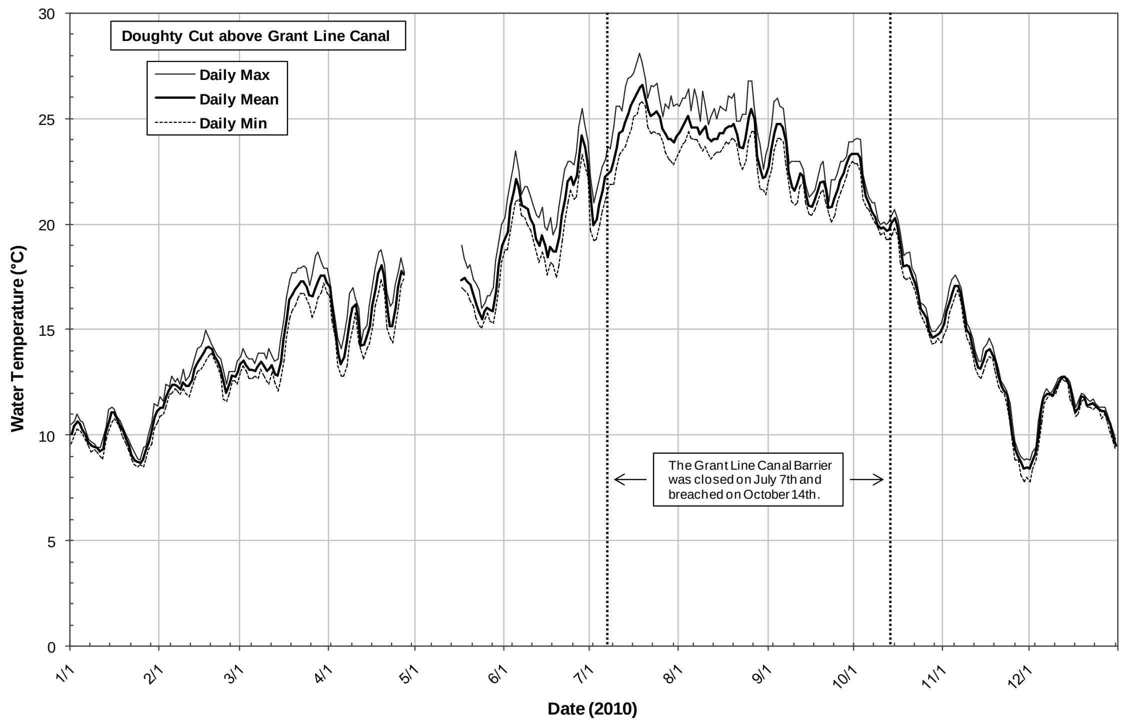
	Specific conductance (µS/cm)				Turbidity (NTU)				Chlorophyll (µg/L)			
Month	Undine	Howard	Tracy Blvd	Union Point	Undine	Howard	Tracy Blvd	Union Point	Undine	Howard	Tracy Blvd	Union Point
	MAXIMUMS				MAXIMUMS				MAXIMUMS			
January	1508	1512	1003	813	335.6	96.4	125.7	24.4	25.1	21.5	16.7	21.7
February	1522	1952	1214	751	128.9	39.1	19.8	34.4	43.0	14.3	3.3	22.5
March	1820	1783	1388	813	129.0	33.8	35.0	86.4	116.8	36.0	9.9	12.0
April	1117	1495	1250	776	49.3	35.2	40.1	17.5	119.2	31.4	8.4	11.7
May	862	767	520	463	47.4	46.0	24.4	33.3	30.8	10.8	4.2	14.8
June	639	983	509	434	337.2	48.3	35.6	27.8	155.1	19.1	8.2	8.3
July	606	999	316	247	105.8	87.6	46.3	15.3	285.4	88.4	10.0	11.3
August	771	1054	458	272	284.9	59.7	66.1	18.8	241.4	57.5	15.7	9.4
September	685	957	662	422	51.6	60.6	35.4	28.5	63.2	19.2	11.4	75.9
October	886	1119	821	510	38.0	40.6	40.5	29.1	35.4	14.8	5.9	7.3
November	1037	863	813	453	47.8	23.8	35.7	43.1	9.8	4.3	5.5	8.8
December	1119	1007	770	612	56.6	46.2	39.6	47.5	10.8	6.8	7.1	16.0
	AVERAGES				AVERAGES				AVERAGES			
January	854	905	624	539	26.5	10.8	7.6	4.3	7.7	3.5	2.0	3.7
February	817	1210	759	454	14.8	2.4	7.8	9.7	14.0	3.6	1.8	5.5
March	851	1351	833	465	19.6	3.6	6.9	5.7	35.8	5.7	3.1	5.2
April	458	624	663	530	16.3	6.3	6.9	4.0	19.0	4.5	2.8	3.7
May	269	399	391	375	16.2	11.2	6.7	5.8	11.1	2.3	2.7	3.4
June	322	493	309	270	28.9	11.4	8.1	6.0	36.4	5.0	3.9	3.4
July	477	472	242	203	29.3	13.5	9.0	5.2	120.7	13.6	3.4	3.3
August	654	523	261	219	40.6	14.6	9.3	3.7	80.4	9.4	3.2	2.7
September	517	588	434	346	19.5	16.6	6.3	2.8	18.8	5.2	3.2	2.8
October	506	675	517	345	11.9	9.5	8.5	1.7	6.8	4.8	2.8	2.2
November	687	688	465	318	9.4	2.0	3.8	2.5	3.6	1.9	1.8	2.0
December	338	413	449	344	19.5	12.1	7.5	5.4	3.2	2.2	1.7	2.9
	MEDIANS				MEDIANS				MEDIANS			
January	906	915	576	542	8.3	1.5	2.5	2.8	6.0	2.5	2.0	3.8
February	796	1190	756	427	12.3	1.2	7.6	9.4	12.2	3.4	1.8	5.4
March	888	1422	834	447	17.4	1.8	6.4	5.2	27.6	4.3	3.0	5.2
April	415	527	643	521	14.3	4.7	5.6	3.8	11.7	3.1	2.7	3.6
May	275	382	389	376	14.6	8.6	6.2	5.5	10.0	2.2	2.6	2.8
June	320	489	292	259	26.4	10.1	7.6	5.5	21.1	4.6	4.0	3.4
July	525	449	242	199	28.5	11.7	8.6	4.9	119.2	6.1	3.3	3.3
August	661	483	251	217	29.7	13.4	8.7	3.4	77.6	5.5	3.2	2.6
September	585	613	439	353	18.6	15.6	5.8	2.5	15.8	5.0	3.1	2.7
October	488	691	495	346	9.6	9.0	7.4	1.4	3.7	4.7	2.8	1.9
November	723	709	449	314	9.0	1.5	2.8	2.0	3.5	1.8	1.8	2.0
December	309	344	446	334	14.2	7.8	3.9	3.1	2.2	2.0	1.7	2.5
	MINIMUMS				MINIMUMS				MINIMUMS			
January	460	574	470	453	3.0	0.0	0.7	0.3	3.1	0.5	1.2	1.2
February	593	828	417	378	3.4	0.0	3.3	5.3	3.6	1.5	1.4	0.3
March	508	612	441	377	6.4	0.4	2.6	1.4	4.8	1.7	1.4	3.6
April	274	285	419	395	4.9	0.7	1.7	1.0	2.6	1.2	1.9	1.0
May	199	254	307	289	5.7	1.4	3.1	2.8	3.5	0.1	2.1	1.5
June	179	205	223	203	9.4	1.5	3.1	2.5	5.4	1.4	2.6	1.7
July	221	307	201	175	10.8	3.4	3.9	1.7	8.4	2.5	0.0	1.3
August	536	273	191	176	12.0	4.0	2.4	1.3	19.4	2.6	0.0	0.9
September	279	271	274	264	5.1	4.0	0.7	1.0	4.1	1.3	2.3	1.2
October	320	364	347	312	2.9	0.9	0.8	0.0	0.7	0.8	1.7	0.6
November	349	348	300	286	4.3	0.1	0.0	0.0	0.6	0.6	1.4	0.8
December	173	195	287	244	5.3	1.2	1.0	0.6	0.0	0.6	1.3	0.7
	STANDARD DEVIATIONS				STANDARD DEVIATIONS				STANDARD DEVIATIONS			
January	207	149	128	45	38.6	17.7	11.9	3.3	3.7	2.2	0.6	1.2
February	134	174	185	68	13.0	3.5	1.8	1.9	7.2	1.3	0.2	0.9
March	217	296	220	72	10.2	4.2	2.9	3.1	26.5	4.3	0.6	0.7
April	184	301	155	74	7.1	4.9	4.5	1.5	22.0	4.3	0.3	1.1
May	40	85	49	30	6.4	7.9	2.3	2.0	4.2	1.0	0.3	1.4
June	79	113	56	44	13.0	6.4	2.9	2.4	30.5	1.7	0.7	0.5
July	107	106	22	15	8.9	7.3	2.8	1.7	65.5	17.2	0.6	0.6
August	42	167	42	23	36.3	5.9	5.1	1.4	31.8	8.4	0.8	0.7
September	119	143	87	41	7.0	7.2	3.0	1.5	9.9	1.9	0.6	1.6
October	117	136	90	18	6.1	6.1	4.8	1.8	6.0	2.2	0.5	0.8
November	137	89	107	22	2.7	1.5	3.2	2.6	1.1	0.5	0.2	0.5
December	166	187	88	49	11.5	9.4	7.1	4.7	2.3	0.8	0.2	1.4
2010 - Max.	1820	1952	1388	813	337.2	96.4	125.7	86.4	285.4	88.4	16.7	75.9
2010 - Avg.	561	692	494	367	21.0	9.6	7.4	4.7	30.0	5.2	2.7	3.4
2010 - Med.	556	619	463	353	16.7	7.6	6.7	4.0	12.0	3.7	2.7	3.2
2010 - Min.	173	195	191	175	2.9	0.0	0.0	0.0	0.0	0.1	0.0	0.3
2010 - S.D.	244	342	216	116	19.3	9.1	5.3	3.2	42.9	6.8	0.8	1.4

Table 6-13. Monthly Statistics for the Old River Continuous Water Quality Monitoring Stations

	Water temperature (°C)				Dissolved oxygen (mg/L)				pH			
Month	**Head**	**TWA**	**u/s ORT**	**d/s ORT**	**Head**	**TWA**	**u/s ORT**	**d/s ORT**	**Head**	**TWA**	**u/s ORT**	**d/s ORT**
	MAXIMUMS				MAXIMUMS				MAXIMUMS			
January	12.3	11.2	11.1	11.1	11.25	10.85	10.38	10.63	7.70	7.94	7.96	7.95
February	14.4	15.0	15.1	15.2	11.69	12.71	10.70	11.16	8.47	8.58	8.28	8.17
March	17.8	18.5	17.7	17.8	12.57	19.70	17.04	17.89	8.58	9.13	9.09	9.07
April	18.0	19.0	19.5	19.5	12.71	15.07	12.13	11.92	8.60	8.92	8.77	8.79
May	19.8	20.4	20.8	20.7	10.21	9.55	9.81	9.03	8.22	7.91	8.12	7.67
June	23.6	27.7	25.8	24.8	13.32	11.07	8.91	8.55	8.94	8.47	8.24	7.94
July	28.3	28.6	26.6	26.9	17.86	18.28	10.83	9.86	9.56	9.52	8.71	8.84
August	26.9	27.3	26.3	26.3	16.65	13.93	8.57	8.05	9.23	8.81	8.56	8.15
September	25.7	26.8	24.7	24.8	11.18	8.87	9.51	8.14	8.51	7.91	8.19	7.90
October	23.7	24.0	23.8	23.6	10.09	8.60	8.63	8.94	8.12	7.91	7.90	7.78
November	17.3	17.6	17.7	17.4	11.17	10.15	10.72	10.58	8.04	8.32	8.65	7.80
December	12.9	13.1	13.0	12.9	11.09	10.46	10.92	10.64	7.91	8.31	8.17	7.95
	AVERAGES				AVERAGES				AVERAGES			
January	10.4	9.9	9.7	9.7	10.23	9.13	8.98	9.30	7.61	7.63	7.58	7.67
February	12.8	12.8	12.3	12.5	9.73	9.48	8.50	8.92	7.83	7.95	7.74	7.78
March	15.0	15.1	14.3	14.7	10.13	12.12	9.61	9.86	8.02	8.23	7.99	7.92
April	15.5	16.2	16.2	16.3	9.67	9.33	7.57	7.86	7.83	7.89	7.74	7.74
May	16.4	17.4	17.3	17.3	9.53	8.45	8.03	8.07	7.71	7.42	7.44	7.41
June	20.3	22.0	21.5	21.5	9.78	7.77	7.02	7.27	7.94	7.49	7.48	7.49
July	23.8	24.5	23.5	23.6	12.91	8.89	5.48	5.78	8.81	7.97	7.61	7.76
August	24.2	24.2	23.0	23.1	11.50	7.60	5.01	5.70	8.59	7.99	7.67	7.61
September	22.3	22.6	21.9	22.0	8.19	6.49	4.43	5.45	7.82	7.53	7.52	7.47
October	18.5	19.1	19.2	19.3	8.15	6.82	5.64	6.37	7.62	7.61	7.54	7.55
November	13.1	13.4	13.7	13.8	9.33	8.45	8.62	8.84	7.85	7.70	8.02	7.62
December	11.2	11.1	11.1	11.0	9.78	9.08	8.94	9.18	7.38	7.39	7.81	7.47
	MEDIANS				MEDIANS				MEDIANS			
January	10.4	9.9	9.6	9.6	10.38	9.05	9.13	9.46	7.61	7.64	7.57	7.70
February	12.7	12.8	12.2	12.5	9.51	9.14	8.47	8.86	7.77	7.98	7.79	7.81
March	14.4	14.6	13.3	14.0	10.28	12.31	9.21	9.37	8.11	8.45	7.97	7.90
April	15.6	16.3	16.1	16.2	9.58	9.03	7.57	7.79	7.84	7.94	7.75	7.73
May	16.3	17.4	17.2	17.2	9.53	8.47	8.04	8.08	7.83	7.39	7.43	7.42
June	20.3	21.8	21.3	21.4	9.45	7.69	7.11	7.34	7.95	7.50	7.48	7.51
July	24.4	24.6	23.5	23.6	13.02	8.53	5.58	6.10	9.07	8.47	7.62	7.75
August	24.3	24.3	23.1	23.2	11.39	7.53	5.11	5.68	8.71	8.07	7.67	7.61
September	22.0	22.4	21.8	21.8	8.03	6.46	4.40	5.35	7.81	7.56	7.52	7.48
October	19.3	20.0	20.1	20.2	8.15	6.95	5.35	6.30	7.61	7.64	7.53	7.57
November	13.4	13.7	14.1	14.3	9.19	8.44	8.68	8.86	7.89	7.61	8.15	7.62
December	11.3	11.4	11.2	11.2	9.71	9.01	8.90	9.09	7.40	7.39	7.89	7.49
	MINIMUMS				MINIMUMS				MINIMUMS			
January	8.7	9.0	8.8	8.8	8.81	7.07	6.63	7.15	7.47	7.34	7.28	7.39
February	11.1	10.4	9.8	9.7	8.87	7.66	6.36	7.16	7.59	7.53	7.40	7.43
March	12.2	12.2	11.0	12.2	8.37	6.60	7.26	7.28	7.69	7.74	7.68	7.61
April	12.4	13.2	13.5	13.6	8.67	6.26	4.52	5.98	7.60	7.52	7.43	7.44
May	13.6	14.8	15.3	15.3	8.83	6.03	6.16	6.46	7.38	7.14	7.19	7.22
June	17.1	18.4	18.2	18.4	8.36	4.24	2.99	5.39	7.53	7.02	7.21	7.11
July	18.0	20.9	21.0	21.1	5.37	1.76	0.96	1.85	7.83	6.99	7.29	7.45
August	21.2	21.2	19.5	19.5	5.83	2.31	1.04	3.22	7.84	7.42	7.37	7.34
September	20.2	19.8	18.9	19.0	5.75	4.42	1.44	3.66	7.44	7.26	7.22	7.22
October	14.1	14.5	14.7	15.0	5.61	4.44	1.92	3.26	7.40	7.43	7.34	7.34
November	8.2	8.0	8.3	8.4	7.44	6.82	4.48	7.12	7.53	7.42	7.44	7.42
December	8.4	8.0	8.1	8.1	9.25	8.09	5.55	7.80	7.09	7.05	7.35	7.01
	STANDARD DEVIATIONS				STANDARD DEVIATIONS				STANDARD DEVIATIONS			
January	0.8	0.6	0.5	0.5	0.61	0.65	0.80	0.76	0.05	0.11	0.14	0.11
February	0.8	1.0	1.0	1.1	0.57	1.03	0.69	0.67	0.24	0.22	0.18	0.16
March	1.9	1.9	2.0	1.7	1.13	2.98	1.55	1.62	0.24	0.41	0.33	0.35
April	1.4	1.4	1.3	1.3	0.61	1.43	0.92	0.93	0.18	0.34	0.25	0.28
May	1.1	1.0	1.1	1.1	0.25	0.50	0.43	0.39	0.21	0.19	0.16	0.10
June	1.6	1.7	1.5	1.5	0.97	1.09	0.75	0.56	0.35	0.18	0.12	0.16
July	2.1	1.5	0.9	0.8	1.96	3.03	1.41	1.35	0.34	0.57	0.21	0.17
August	1.0	1.1	1.2	1.1	1.83	1.36	1.37	1.07	0.26	0.29	0.19	0.15
September	1.3	1.3	1.2	1.2	0.86	0.69	1.08	0.81	0.23	0.13	0.13	0.10
October	2.6	2.6	2.4	2.3	0.57	0.88	1.34	1.27	0.09	0.10	0.08	0.08
November	2.7	2.7	2.5	2.5	0.79	0.70	0.94	0.79	0.10	0.29	0.29	0.09
December	1.1	1.2	1.2	1.1	0.40	0.42	0.71	0.63	0.22	0.35	0.19	0.17
2010 - Max.	28.3	28.6	26.6	26.9	17.86	19.70	17.04	17.89	9.56	9.52	9.09	9.07
2010 - Avg.	17.0	17.4	17.0	17.1	9.92	8.63	7.31	7.71	7.81	7.66	7.64	7.60
2010 - Med.	16.5	17.0	16.8	16.9	9.59	8.55	7.73	7.94	7.87	7.70	7.64	7.62
2010 - Min.	8.2	8.0	8.1	8.1	5.37	1.76	0.96	1.85	7.09	6.99	7.19	7.01
2010 - S.D.	4.9	5.1	4.9	4.9	1.61	2.06	2.00	1.79	0.50	0.44	0.29	0.25

Table 6-13 (cont.). Monthly Statistics for the Old River Continuous Water Quality Monitoring Stations

	Specific conductance (µS/cm)				Turbidity (NTU)				Chlorophyll (µg/L)			
Month	Head	TWA	u/s ORT	d/s ORT	Head	TWA	u/s ORT	d/s ORT	Head	TWA	u/s ORT	d/s ORT
	MAXIMUMS				MAXIMUMS				MAXIMUMS			
January	1065	1252	1287	1276	372.3	144.5	85.4	98.3	30.9	39.5	12.1	31.2
February	990	1194	1214	1229	79.6	50.1	163.1	40.8	31.5	70.4	38.7	13.9
March	980	1376	1383	1393	93.6	82.3	100.4	67.5	90.7	313.4	95.9	320.1
April	955	1088	1278	1302	77.3	82.9	97.1	41.9	86.6	180.3	49.3	176.4
May	319	565	484	548	49.0	42.7	68.2	54.3	33.6	37.9	9.5	7.2
June	446	591	580	623	46.1	41.1	83.3	30.2	178.2	80.9	10.6	10.1
July	607	775	843	831	65.8	136.4	47.4	30.1	343.3	197.5	34.2	40.2
August	741	879	950	952	86.6	69.4	48.0	62.6	258.3	103.5	31.7	126.7
September	662	886	917	930	53.1	37.5	59.5	33.2	52.9	46.9	15.7	16.9
October	697	1014	831	851	76.6	38.7	58.7	82.8	39.3	24.4	13.1	10.4
November	833	1524	1190	1185	61.9	31.0	51.5	86.0	23.4	26.5	10.6	7.2
December	736	1515	1279	1290	61.6	44.1	111.3	40.8	7.2	18.3	12.8	13.3
	AVERAGES				AVERAGES				AVERAGES			
January	855	967	896	886	37.6	27.5	11.7	14.0	9.2	12.5	4.2	2.6
February	796	939	787	773	22.7	18.9	12.6	15.5	16.0	22.4	8.0	4.1
March	807	974	829	804	30.9	19.9	13.2	17.3	47.6	73.9	12.7	23.1
April	438	564	590	588	20.7	20.6	18.0	20.4	17.5	33.7	6.3	11.6
May	258	343	340	336	20.7	18.6	16.2	18.8	17.0	11.8	3.0	2.3
June	304	448	332	320	23.5	21.8	12.2	12.3	46.2	22.2	3.7	3.4
July	487	560	544	506	18.9	29.7	10.9	9.4	150.5	81.1	6.3	3.4
August	644	722	742	717	19.9	24.1	12.0	12.0	117.2	51.3	8.4	7.2
September	511	608	693	680	16.5	16.6	10.8	9.7	24.8	16.6	3.6	2.9
October	477	623	663	645	14.4	16.1	11.7	12.0	8.5	8.2	3.0	2.7
November	697	812	677	657	13.4	14.5	7.4	7.2	8.3	9.0	3.1	1.7
December	296	427	470	466	26.5	19.3	11.8	10.8	3.5	4.4	3.4	1.6
	MEDIANS				MEDIANS				MEDIANS			
January	944	1057	905	893	12.4	18.0	8.0	10.2	7.7	10.4	3.5	1.8
February	791	931	827	792	21.9	18.3	11.2	14.3	15.1	16.8	7.9	3.7
March	882	1022	853	830	28.0	18.0	11.9	15.8	53.5	53.7	6.3	5.3
April	401	512	505	508	20.3	16.2	17.1	20.0	13.1	14.3	4.4	4.8
May	263	336	330	328	20.6	18.1	15.3	18.3	16.2	11.0	2.8	2.0
June	300	446	309	291	23.1	21.6	11.6	11.7	24.8	18.6	3.5	3.2
July	541	606	550	527	18.1	25.0	9.4	8.7	146.8	80.3	4.8	2.5
August	648	723	794	795	18.3	23.1	11.2	11.5	114.5	46.8	6.5	4.8
September	575	665	730	685	16.2	16.7	9.4	9.4	23.2	15.1	3.4	2.6
October	450	641	707	689	13.4	15.8	10.0	10.1	6.2	7.0	2.8	2.2
November	748	824	682	631	12.1	14.9	5.7	5.6	8.1	7.9	2.7	1.4
December	267	335	398	390	25.7	19.2	11.2	10.1	3.5	4.0	3.1	1.3
	MINIMUMS				MINIMUMS				MINIMUMS			
January	452	529	515	510	3.5	7.9	1.7	1.6	3.4	4.2	1.0	0.4
February	597	708	373	366	6.5	9.7	4.5	4.4	7.3	4.8	2.0	1.1
March	503	583	371	369	13.9	7.8	3.2	3.9	11.7	12.5	2.8	2.0
April	273	290	299	300	9.2	6.7	4.6	3.5	5.2	3.4	0.8	1.5
May	198	251	227	227	10.0	9.4	7.0	10.0	8.1	3.7	0.2	0.2
June	170	266	207	202	12.0	10.1	4.7	5.0	7.9	6.2	1.8	1.0
July	217	334	199	190	12.1	12.3	3.1	3.1	14.9	11.1	2.3	0.1
August	521	583	240	229	9.7	11.4	3.6	4.5	14.9	20.0	2.6	1.1
September	261	317	401	366	5.1	7.2	3.1	3.7	9.4	5.8	1.1	0.5
October	317	345	367	372	6.8	5.0	3.4	2.5	2.8	2.0	0.4	0.4
November	353	414	363	363	4.3	6.0	1.4	1.0	2.5	2.4	0.7	0.2
December	170	180	207	201	6.2	6.6	1.7	0.0	0.7	1.3	0.7	0.0
	STANDARD DEVIATIONS				STANDARD DEVIATIONS				STANDARD DEVIATIONS			
January	187	196	206	203	55.8	21.2	10.4	11.9	4.1	5.8	2.0	2.0
February	107	86	243	252	8.1	3.6	9.0	6.0	4.9	12.9	2.9	1.5
March	154	193	273	282	11.3	7.5	6.5	7.3	23.4	56.3	15.1	47.4
April	170	223	238	238	5.7	10.9	5.9	5.6	13.7	41.5	5.8	21.9
May	32	53	61	61	4.3	3.6	4.7	4.2	4.2	3.8	1.5	1.3
June	74	72	93	91	4.4	5.1	4.1	3.7	39.3	11.4	1.0	1.3
July	110	102	185	199	3.9	15.5	5.7	3.6	77.0	43.9	4.2	3.2
August	43	46	149	181	7.4	6.2	4.3	4.5	44.6	17.6	4.9	6.7
September	123	129	141	148	3.3	3.0	6.5	3.1	9.0	7.5	1.2	1.4
October	105	115	109	119	4.9	2.9	6.5	7.2	6.1	4.0	1.3	1.4
November	119	158	214	218	5.7	3.5	5.4	5.7	2.6	3.5	1.4	1.1
December	137	252	224	219	12.5	5.8	6.6	7.0	1.3	1.9	1.5	1.3
2010 - Max.	1065	1524	1383	1393	372.3	144.5	163.1	98.3	343.3	313.4	95.9	320.1
2010 - Avg.	546	664	630	614	22.2	20.7	12.4	13.3	39.2	29.0	5.5	5.5
2010 - Med.	556	658	617	588	18.8	18.3	11.3	12.0	16.5	14.7	3.9	2.8
2010 - Min.	170	180	199	190	3.5	5.0	1.4	0.0	0.7	1.3	0.2	0.0
2010 - S.D.	235	257	257	259	18.9	10.3	7.0	7.4	54.2	35.6	6.0	16.6



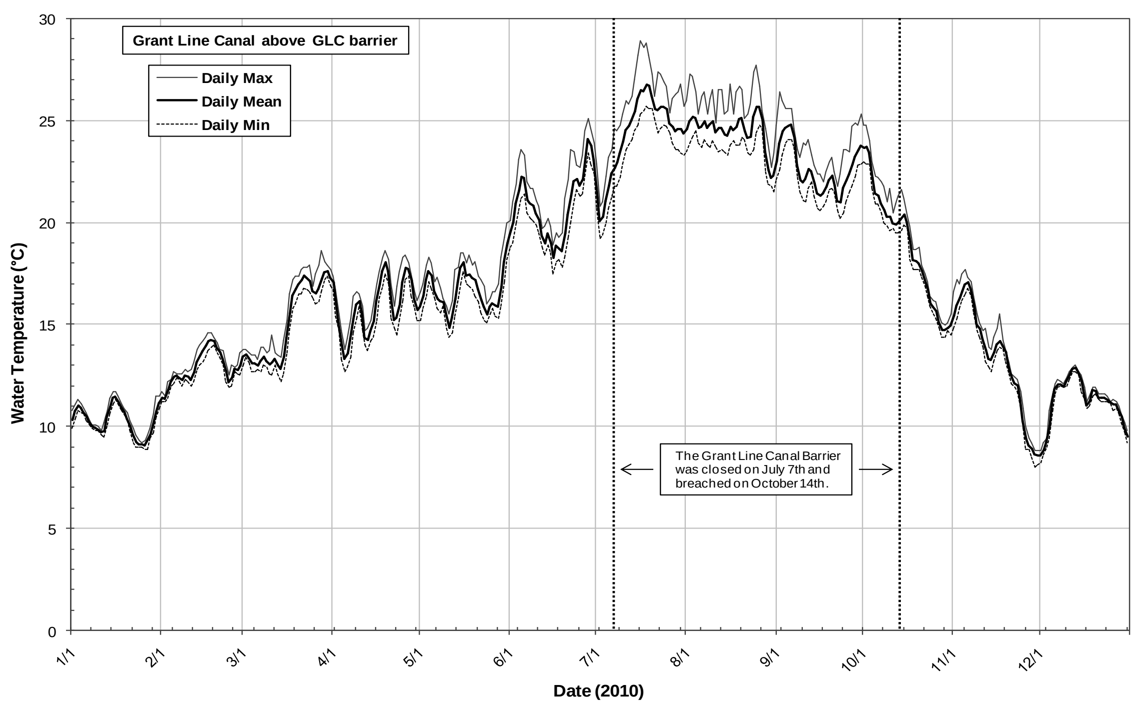
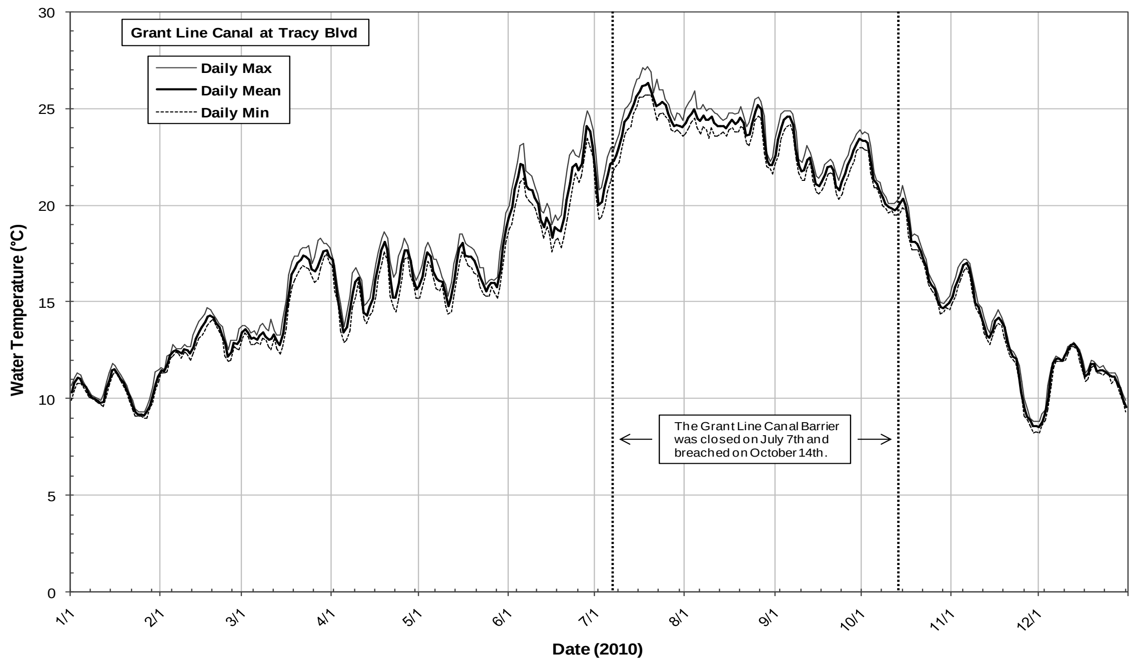


Figure 6-6. Daily Temperature Time-series Graphs for the Grant Line and Victoria Canal Stations



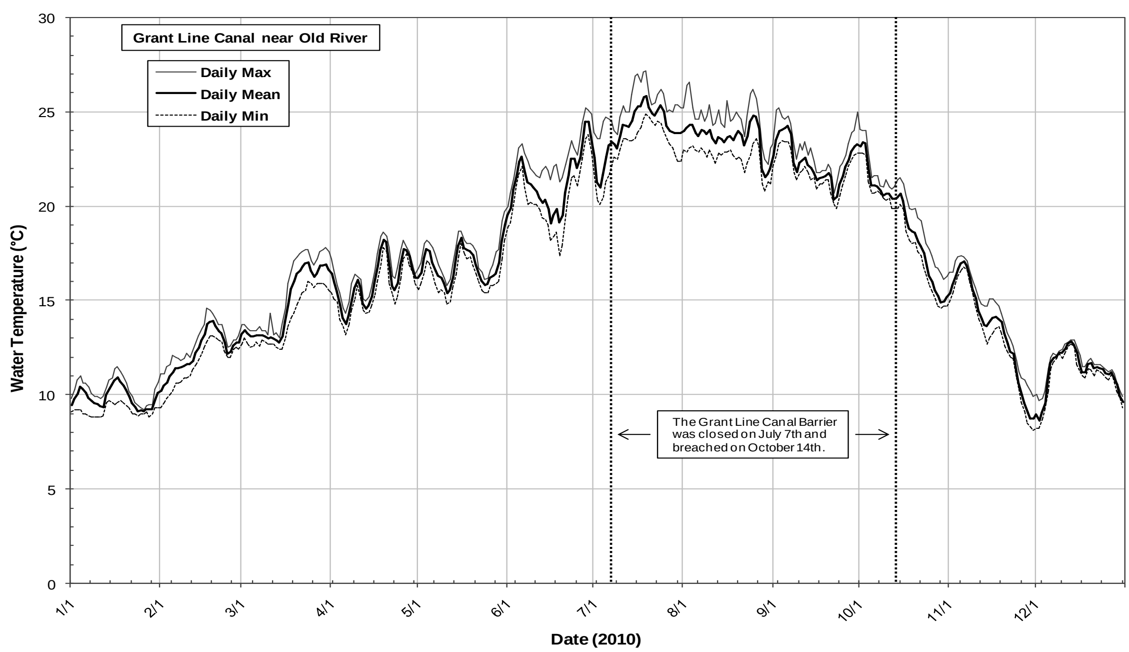


Figure 6-6 (cont.). Daily Temperature Time-series Graphs for the Grant Line and Victoria Canal Stations

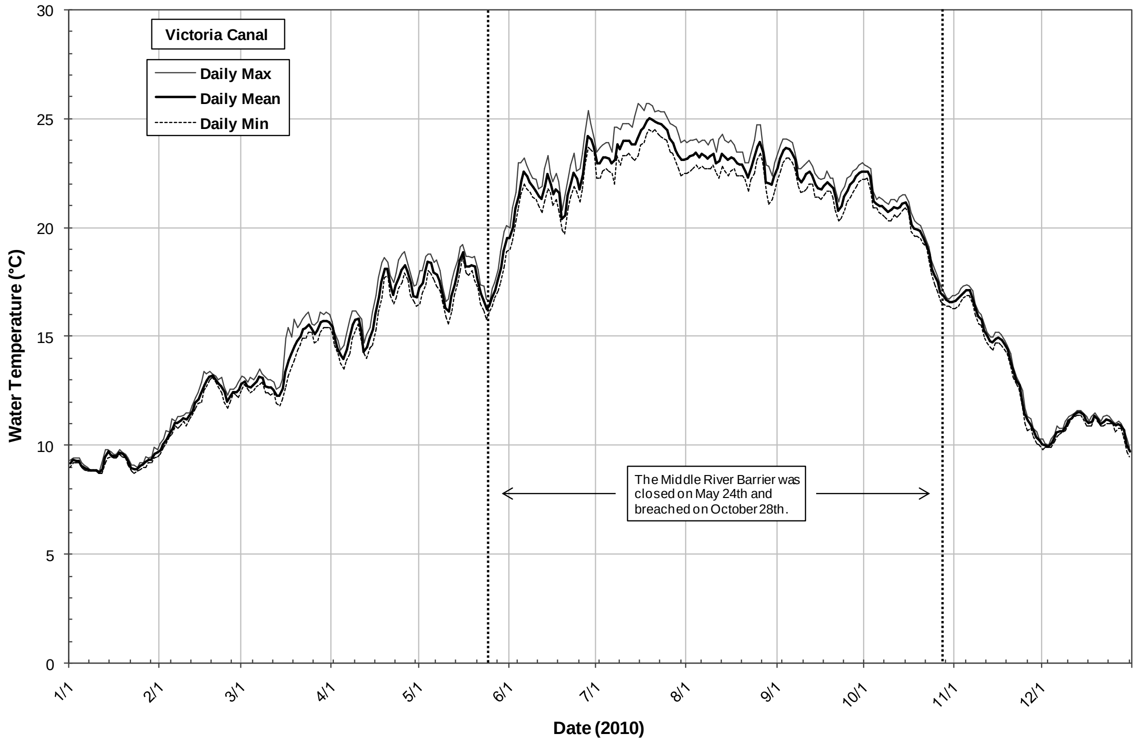
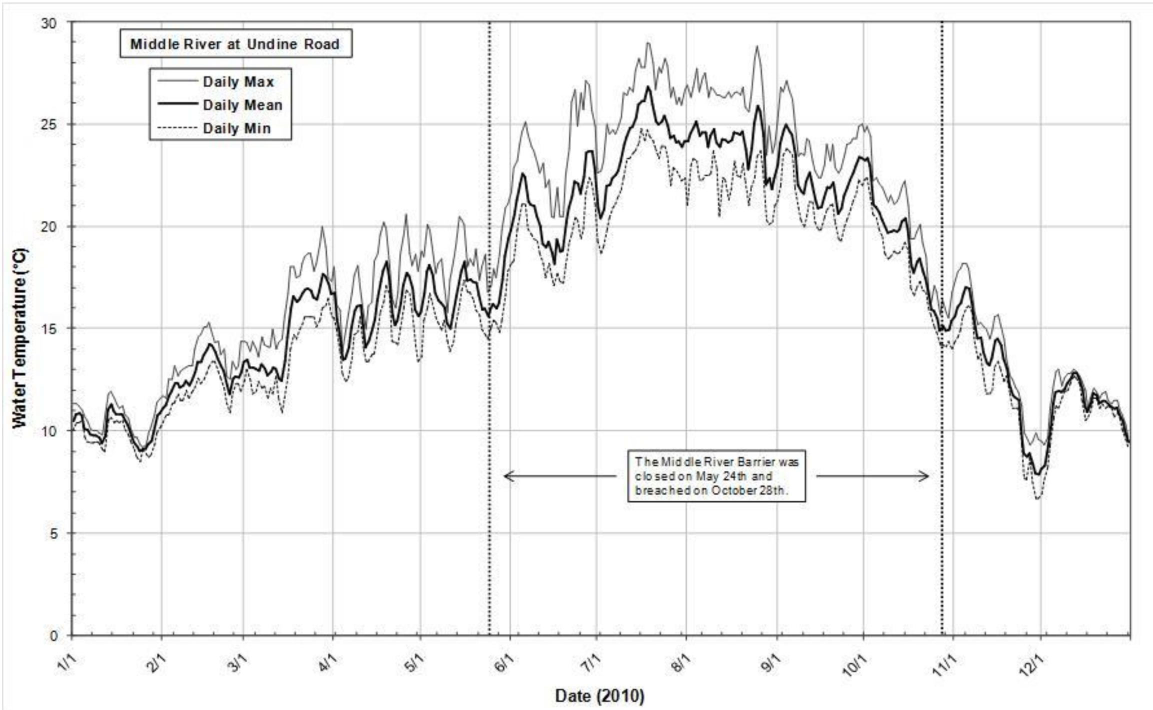


Figure 6-6 (cont.). Daily Temperature Time-series Graphs for the Grant Line and Victoria Canal Stations



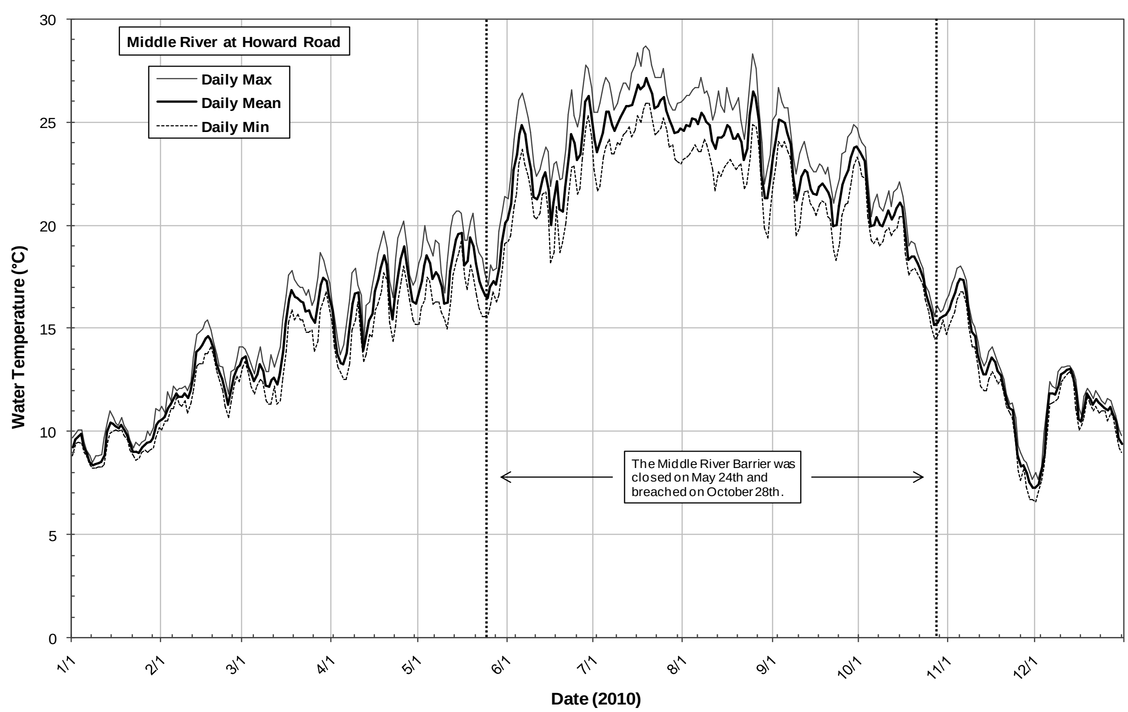
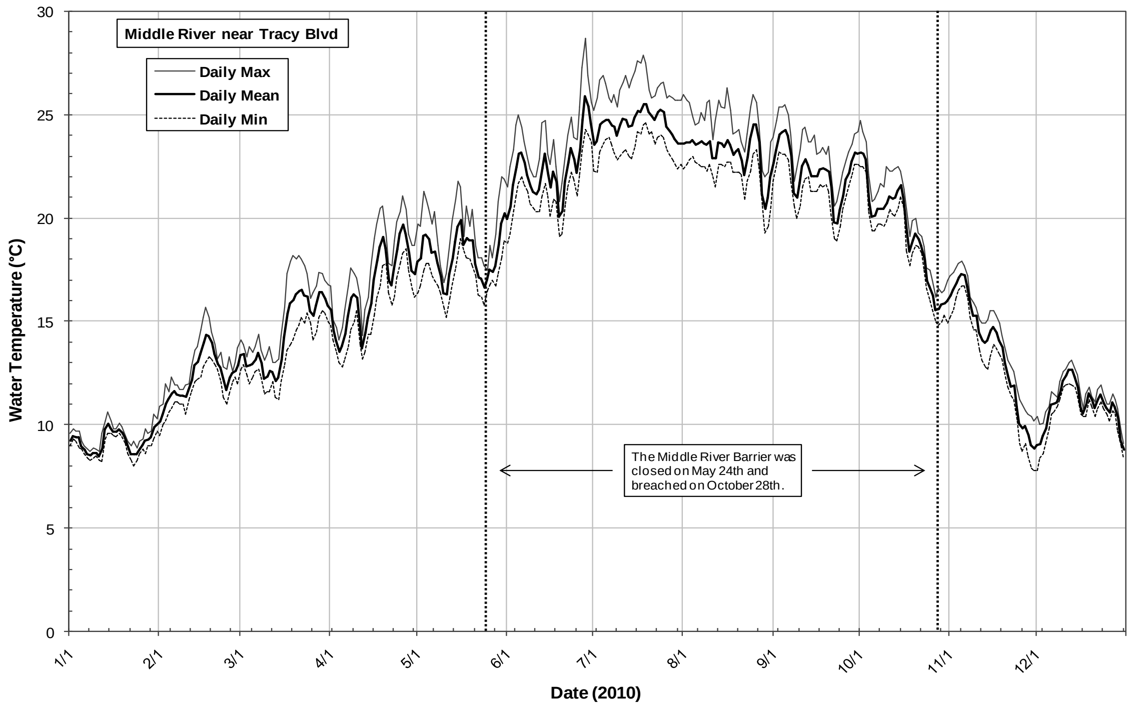


Figure 6-7. Daily Temperature Time-series Graphs for the Middle River Stations



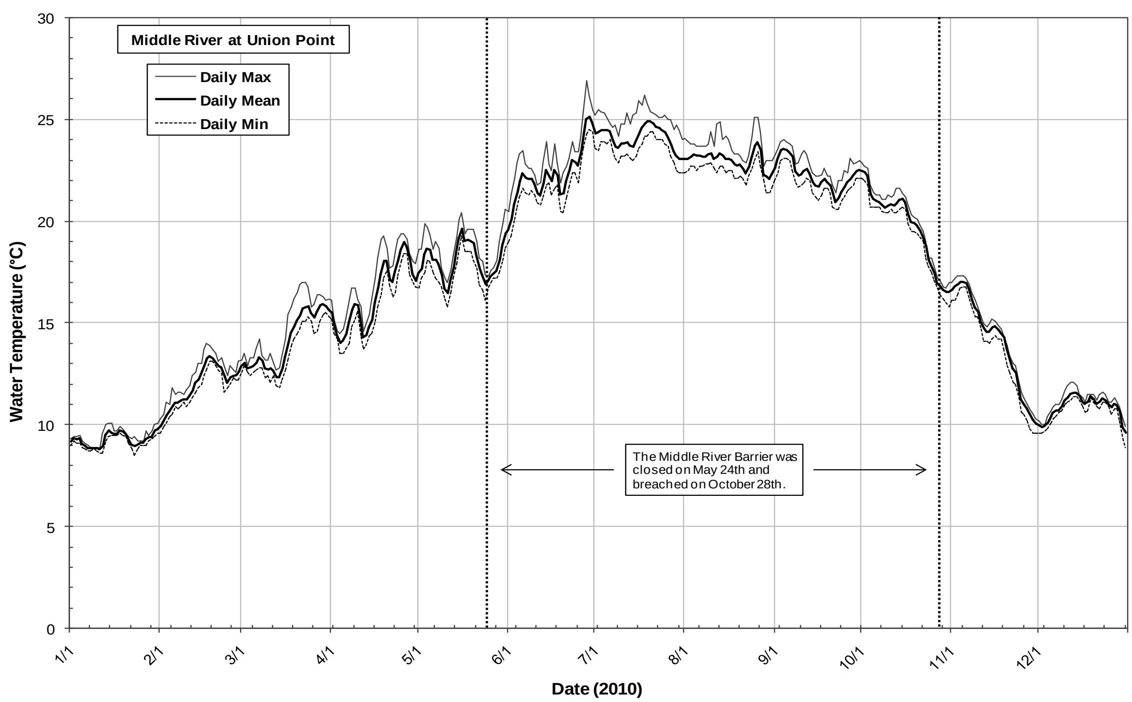
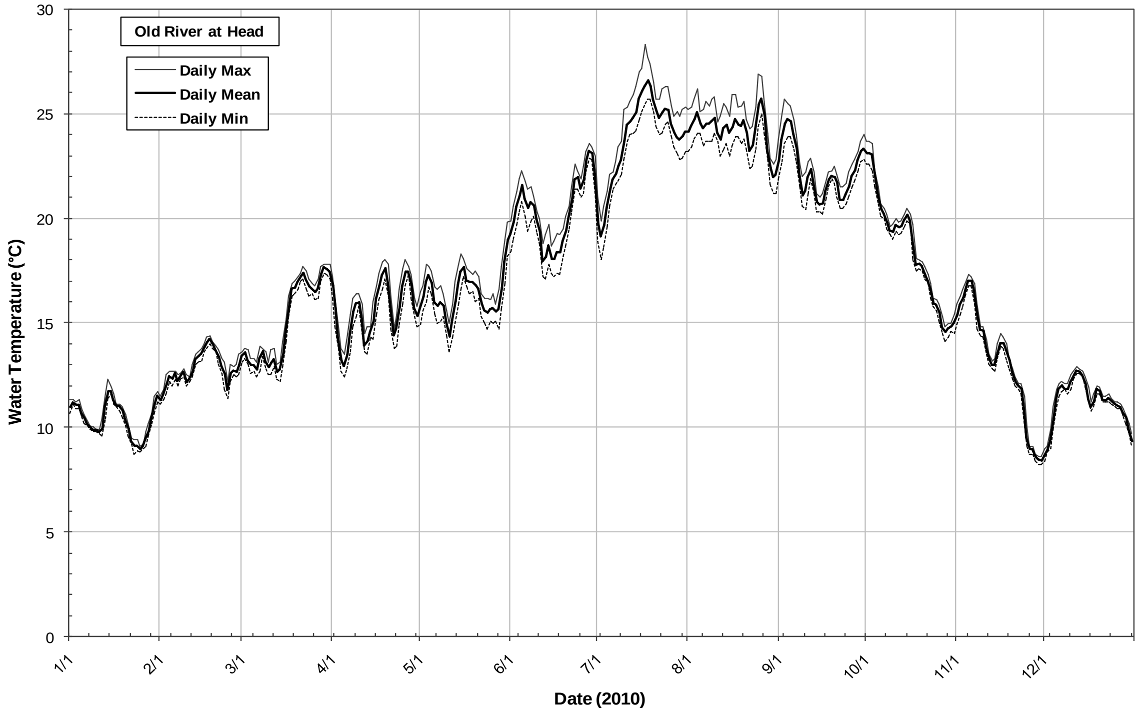


Figure 6-7 (cont.). Daily Temperature Time-series Graphs for the Middle River Stations



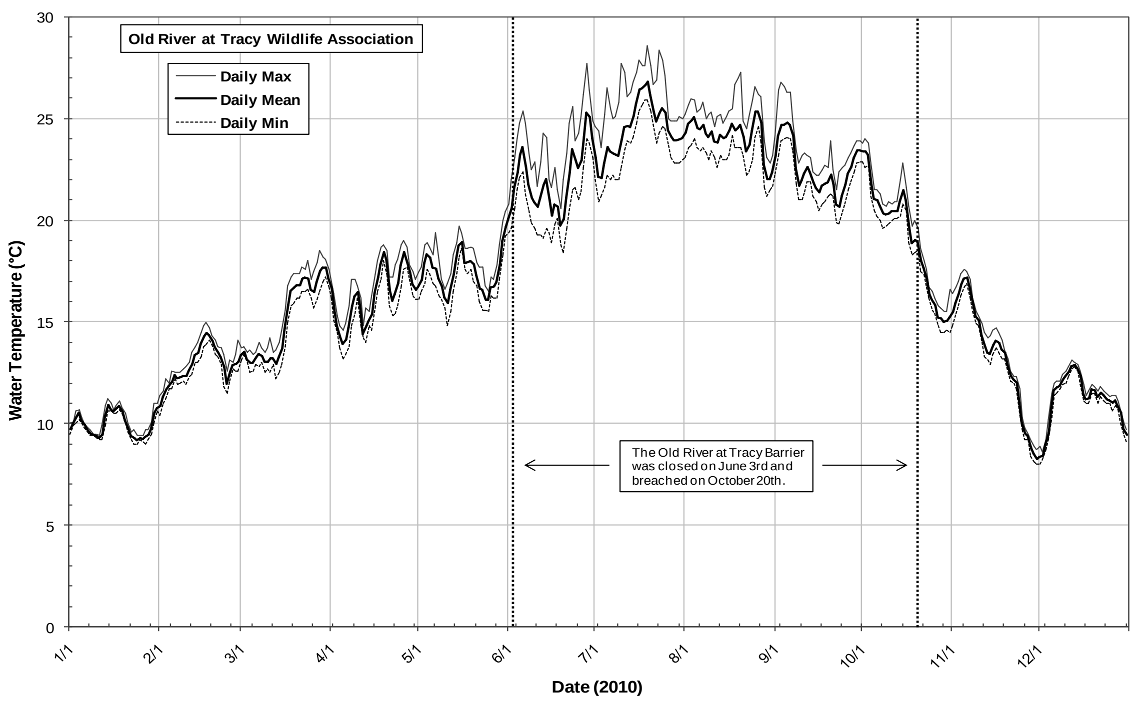
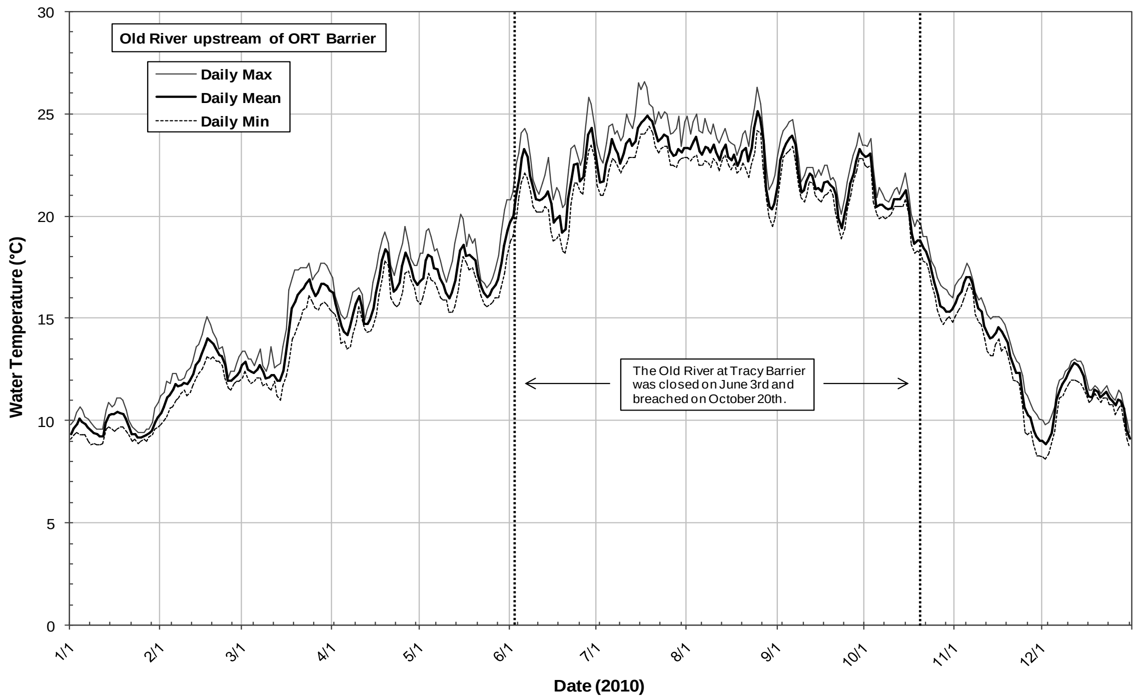


Figure 6-8. Daily Temperature Time-series Graphs for the Old River Stations



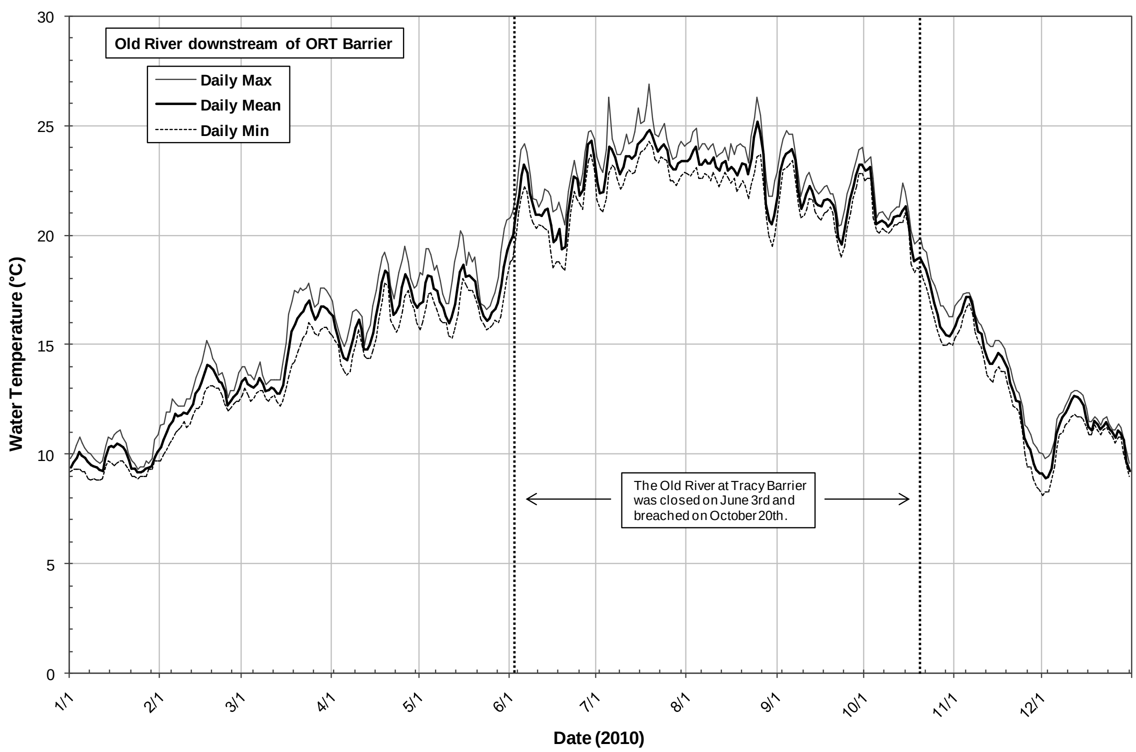


Figure 6-8 (cont.). Daily Temperature Time-series Graphs for the Old River Stations

Dissolved Oxygen

One of the most important measures of water quality is the amount of dissolved oxygen (Masters, 1997). Sources of dissolved oxygen in surface waters are primarily atmospheric reaeration and photosynthetic activity of aquatic plants (Lewis, 2005). Dissolved oxygen saturation is inversely related to water temperature (i.e., as water temperature increases, dissolved oxygen saturation decreases). Super saturated dissolved oxygen conditions can occur as a result of excess photosynthetic production of oxygen by phytoplankton and/or aquatic plants. The depletion of dissolved oxygen can occur by inorganic oxidation reactions or by biological or chemical processes that consume dissolved, suspended, or precipitated organic matter (Hem, 1989).

During the 2010 monitoring period, a maximum dissolved oxygen concentration of 19.70 mg/L was recorded on March 28 at Old River at Tracy Wildlife Association, and a minimum of 0.37 mg/L was recorded on July 16 at Middle River at Howard Road (see Tables 6-10 to 6-13). Figures 6-9, 6-10, and 6-11 (placed at end of Dissolved Oxygen section) illustrate the daily maximums, minimums, and averages for the Grant Line and Victoria Canal, Middle River, and Old River stations, respectively. Generally, dissolved oxygen concentrations were lower and more variable during the summer and early fall months, most likely due to the warmer water temperatures. Monthly average concentrations during the summer and early fall (June - September) ranged from 4.43 mg/L in September at Old River upstream of the ORT barrier to 12.91 mg/L in July at Old River at Head (see Tables 6-10 to 6-13). During the fall and winter seasons (January – February and October-December), monthly average concentrations ranged from 5.64 mg/L in October to 10.58 mg/L in November. At some of the stations, there was an obvious increase in dissolved oxygen concentrations during the spring months, most likely due to greater photosynthetic production. Monthly average concentrations during the spring season (March – May) ranged from 7.57 mg/L in April at Old River upstream of the ORT barrier to 12.12 mg/L in March at Old River at Tracy Wildlife Association.

Water Quality Standard Exceedences. As discussed in the Methods and Results section, the established dissolved oxygen criteria is 5 mg/L; therefore, staff considered any dissolved oxygen sample of reliable data quality less than 5.0 mg/L as exceeding the standard. Figures 6-12, 6-13, and 6-14 (placed at end of Dissolved Oxygen section) illustrate the number of dissolved oxygen readings with concentrations less than 5.0 mg/L for each season and the overall total for the 2010 monitoring period for the Grant Line and Victoria Canal, Middle River, and Old River stations, respectively. In addition, the figures show the percent of sonde samples exceeding the dissolved oxygen standard relative to the total number of samples collected. Figures 6-15, 6-16, and 6-17 (placed at end of Dissolved Oxygen section) provide the exceedence information in a map format allowing for the observation of geographical relationships.

The station with the most exceedences during 2010 was Middle River at Howard Road with a total of 5,998 (17.1% of the total number of samples). Most of the standard exceedences at the Howard Road station occurred in the summer (4,719; 53.4% of all samples collected in the summer). Some other stations that had large number of exceedences for the year were Old River upstream of the ORT barrier (5,692; 16.3% of the total), Old River downstream of the ORT barrier (2,972; 8.5% of the total), and Grant Line Canal near Old River (1,770; 5.1% of the total). In contrast, both the Victoria Canal and Old River at Head stations had the least number of exceedences of the dissolved oxygen standard for the year with zero. Doughty Cut above Grant Line Canal, Middle River at Union Point, and Middle River at Undine Road also had low numbers of dissolved oxygen exceedences with 5, 10, and 12, respectively. For the stations that had dissolved oxygen exceedences during 2010, most of the exceedences occurred during the summer and fall seasons.

For the stations located along Old River, the stations closest to the ORT barrier had higher total numbers of exceedences during 2010 than the stations upstream or downstream (see Figures 6-14 and

6-17). The Old River upstream and downstream of the ORT barrier stations had 5,692 and 2,972 total exceedences, respectively, compared to Old River at Tracy Wildlife Association with 394 and Old River at Head with zero. The stations located along Middle River and Grant Line Canal had no relationship between the number of dissolved oxygen exceedences and the proximity to the temporary barriers (see Figures 6-12, 6-13, 6-15, and 6-16).

Station Comparisons by Season: Grant Line Canal. The Grant Line Canal near Old River station had significantly lower dissolved oxygen concentrations than the 3 other stations along Grant Line Canal during every season analyzed (spring and summer: $p<0.00001$, fall: $p< 0.03$; Tables 6-14 to 6-16). In the summer, Doughty Cut above Grant Line Canal had significantly higher dissolved oxygen concentrations than the 3 other stations ($p<0.002$; Table 6-15).

Table 6-14. Seasonal Medians and p-Values for the Dunn's Multiple Comparison Procedure for the Grant Line Canal Stations—Spring

Station	Seasonal median DO conc (mg/L)	Pair-wise comparison p-value [a]			
		GLC near OR	GLC above barrier	GLC at Tracy Rd	Doughty Cut abv GLC
GLC near OR	8.37	--	0.00000	0.00000	0.00000
GLC above barrier	9.14	0.00000	--	NS	NS
GLC at Tracy Blvd	9.14	0.00000	NS	--	NS
Doughty Cut abv GLC	9.29	0.00000	NS	NS	--

[a] "NS" stands for "no significant difference between the two stations" in all of these tables.

Table 6-15. Seasonal Medians and p-Values for the Dunn's Multiple Comparison Procedure for the Grant Line Canal Stations—Summer

Station	Seasonal median DO conc (mg/L)	Pair-wise comparison p-value			
		GLC near OR	GLC at Tracy Blvd	GLC above barrier	Doughty Cut abv GLC
GLC near OR	6.86	--	0.00000	0.00000	0.00000
GLC at Tracy Blvd	8.55	0.00000	--	NS	0.00002
GLC above barrier	8.63	0.00000	NS	--	0.00146
Doughty Cut abv GLC	9.48	0.00000	0.00002	0.00146	--

Table 6-16. Seasonal Medians and p-Values for the Dunn's Multiple Comparison Procedure for the Grant Line Canal Stations—Fall

Station	Seasonal median DO conc (mg/L)	Pair-wise comparison p-value			
		GLC near OR	GLC at Tracy Blvd	GLC above barrier	Doughty Cut abv GLC
GLC near OR	7.31	--	0.01655	0.02427	0.00067
GLC at Tracy Blvd	7.69	0.01655	--	NS	NS
GLC above barrier	7.70	0.02427	NS	--	NS
Doughty Cut abv GLC	7.95	0.00067	NS	NS	--

Station Comparisons by Season: Middle River. Middle River at Howard Road had significantly lower dissolved oxygen concentrations than the 3 other Middle River stations during every season analyzed (spring: p<0.02, summer: p<0.00001, fall: p<0.03; Tables 6-17 to 6-19). The seasonal median dissolved oxygen concentrations at the Howard Road station were 4.53 mg/L in the summer and 6.86 mg/L in the fall. In the spring, Middle River near Tracy Blvd had significantly higher dissolved oxygen concentrations than Middle River at Union Point (p<0.03; Table 6-17). In the summer, every pair-wise comparison among the 4 Middle River stations was statistically different (p<0.0008; Table 6-18). In the fall, Middle River near Tracy Blvd had significantly lower dissolved oxygen concentrations than both the Middle River at Union Point and Middle River at Undine Road stations (p<0.00001, Table 6-19).

Table 6-17. Seasonal Medians and p-Values for the Dunn's Multiple Comparison Procedure for the Middle River Stations—Spring

Station	Seasonal median DO conc (mg/L)	Pair-wise Comparison p-value [a]			
		Middle River at Howard Rd	Middle River at Undine Rd	Middle River at Union Point	Middle River nr Tracy Blvd
Middle River at Howard Rd	8.70	--	0.00020	0.01681	0.00000
Middle River at Undine Rd	9.26	0.00020	--	NS	NS
Middle River at Union Point	9.27	0.01681	NS	--	0.02194
Middle River near Tracy Blvd	9.47	0.00000	NS	0.02194	--

[a] "NS" stands for "no significant difference between the two stations" in all of these tables.

Table 6-18. Seasonal Medians and p-Values for the Dunn's Multiple Comparison Procedure for the Middle River Stations—Summer

Station	Seasonal median DO conc (mg/L)	Pair-wise comparison p-value			
		Middle River at Howard Rd	Middle River nr Tracy Blvd	Middle River at Union Point	Middle River at Undine Rd
Middle River at Howard Rd	4.53	--	0.00000	0.00000	0.00000
Middle River near Tracy Blvd	6.79	0.00000	--	0.00072	0.00000
Middle River at Union Point	7.48	0.00000	0.00072	--	0.00000
Middle River at Undine Rd	9.57	0.00000	0.00000	0.00000	--

Table 6-19. Seasonal Medians and p-Values for the Dunn's Multiple Comparison Procedure for the Middle River Stations—Fall

Station	Seasonal median DO conc (mg/L)	Pair-wise comparison p-value			
		Middle River at Howard Rd	Middle River nr Tracy Blvd	Middle River at Union Point	Middle River at Undine Rd
Middle River at Howard Rd	6.86	--	0.02704	0.00119	0.00299
Middle River near Tracy Blvd	6.99	0.02704	--	0.00000	0.00000
Middle River at Union Point	7.94	0.00119	0.00000	--	NS
Middle River at Undine Rd	8.15	0.00299	0.00000	NS	--

Station Comparisons by Season: Old River. Old River at Head had significantly higher dissolved oxygen concentrations than the 3 other Old River stations during every season analyzed (spring: $p<0.0005$, summer and fall: $p<0.00001$; Tables 6-20 to 6-22). The 2 stations closest to the ORT barrier, Old River upstream and downstream of the barrier, had significantly lower dissolved oxygen concentrations than the 2 upstream stations during the spring and summer ($p<0.00001$; Tables 6-20 and 6-21). In the fall, just the Old River upstream of the ORT barrier station had significantly lower dissolved oxygen concentrations than the 2 upstream stations ($p<0.0009$; Table 6-22). The dissolved oxygen concentrations of the 2 stations adjacent to the ORT barrier were not significantly different during the spring, summer, and fall ($p>0.05$).

Table 6-20. Seasonal Medians and p-Values for the Dunn's Multiple Comparison Procedure for the Old River Stations—Spring

Station	Seasonal median DO conc (mg/L)	Pair-wise comparison p-value [a]			
		Old River u/s ORT barrier	Old River d/s ORT barrier	Old River at TWA	Old River at Head
Old River u/s ORT barrier	8.20	--	NS	0.00000	0.00000
Old River d/s ORT barrier	8.29	NS	--	0.00000	0.00000
Old River at TWA	8.80	0.00000	0.00000	--	0.00041
Old River at Head	9.56	0.00000	0.00000	0.00041	--

[a] "NS" stands for "no significant difference between the two stations" in all of these tables

Table 6-21. Seasonal Medians and p-Values for the Dunn's Multiple Comparison Procedure for the Old River Stations—Summer

Station	Seasonal median DO conc (mg/L)	Pair-wise comparison p-value			
		Old River u/s ORT barrier	Old River d/s ORT barrier	Old River at TWA	Old River at Head
Old River u/s ORT barrier	5.79	--	NS	0.00000	0.00000
Old River d/s ORT barrier	6.28	NS	--	0.00000	0.00000
Old River at TWA	7.62	0.00000	0.00000	--	0.00000
Old River at Head	11.27	0.00000	0.00000	0.00000	--

Table 6-22. Seasonal Medians and p-Values for the Dunn's Multiple Comparison Procedure for the Old River Stations—Fall

Station	Seasonal median DO conc (mg/L)	Pair-wise comparison p-value			
		Old River u/s ORT barrier	Old River d/s ORT barrier	Old River at TWA	Old River at Head
Old River u/s ORT barrier	5.47	--	NS	0.00081	0.00000
Old River d/s ORT barrier	6.21	NS	--	NS	0.00000
Old River at TWA	7.14	0.00081	NS	--	0.00000
Old River at Head	8.42	0.00000	0.00000	0.00000	--

Upstream/Downstream Station Comparisons: Grant Line Canal Barrier. The downstream station, Grant Line Canal at Tracy Blvd, had significantly higher dissolved oxygen concentrations than the upstream station, Grant Line Canal above the GLC barrier, during the months of January, April, November, and December 2010 (Table 6-23). Grant Line Canal above the GLC barrier had significantly higher dissolved oxygen concentrations than Grant Line Canal at Tracy Blvd during the warmer months of May, August, and October 2010.

Table 6-23. Results for the Upstream-Downstream Analysis for the Grant Line Canal Barrier

	Monthly median DO conc (mg/L) [(a)]		1-sample Wilcoxon test results [(b)]		
Month	Upstream station - GLC above the barrier	Downstream station - GLC at Tracy Blvd	p-Value	Difference between monthly medians (mg/L)	Station with significantly higher DO values [(c)]
January	9.71	9.79	<0.001	0.08	GLTR
February	9.33	9.24	NS	NS	NS
March	10.82	10.86	NS	NS	NS
April	8.91	9.14	<0.001	0.23	GLTR
May	9.13	9.09	0.003	0.04	GLAB
June	8.64	8.67	NS	NS	NS
July	9.78	9.37	NS	NS	NS
August	8.35	7.47	<0.001	0.88	GLAB
September	6.97	6.90	NS	NS	NS
October	7.43	7.42	0.046	0.01	GLAB
November	8.99	9.12	<0.001	0.13	GLTR
December	9.56	9.64	<0.001	0.07	GLTR

(a) The monthly medians are actually the medians of the daily medians for the month. For example, in this analysis the monthly median for January is the median of all of the daily medians for the month of January.
(b) “NS” stands for “no significant difference between the two stations”.
(c) “GLTR” represents the Grant Line Canal at Tracy Blvd station. “GLAB” represents the Grant Line Canal above the GLC barrier station.

Upstream/Downstream Station Comparisons: Middle River Barrier. The upstream station, Middle River near Tracy Blvd, had significantly higher dissolved oxygen concentrations than the downstream station, Middle River at Union Point, during the early and cooler months of 2010 (January – March; Table 6-24). During the warmer months (July – October 2010), Middle River at Union Point had significantly higher dissolved oxygen concentrations than Middle River near Tracy Blvd.

Table. 6-24. Results for the Upstream-Downstream Analysis for the Middle River Barrier

Month	Monthly median DO conc (mg/L) [(a)]		Mann-Whitney test results [(b)]		
	Upstream station - MR near Tracy Blvd	Downstream station - MR at Union Point	p-Value	Difference between monthly medians (mg/L)	Station with significantly higher DO values [(c)]
January	10.30	9.99	0.0008	0.31	MRNT
February	9.52	8.75	<0.0001	0.77	MRNT
March	9.83	9.16	<0.0001	0.67	MRNT
April	9.77	9.46	NS	NS	NS
May	9.12	9.30	NS	NS	NS
June	7.64	7.55	NS	NS	NS
July	6.36	7.14	<0.0001	0.78	MRUP
August	6.80	7.68	<0.0001	0.87	MRUP
September	6.40	7.73	<0.0001	1.33	MRUP
October	6.70	7.81	<0.0001	1.12	MRUP
November	8.96	9.08	NS	NS	NS
December	9.43	9.59	NS	NS	NS

(a) The monthly medians are actually the medians of the daily medians for the month. For example, in this analysis the monthly median for January is the median of all of the daily medians for the month of January.
(b) "NS" stands for "no significant difference between the two stations".
(c) "MRNT" represents the Middle River near Tracy Blvd station. "MRUP" represents the Middle River at Union Point station.

Upstream/Downstream Station Comparisons: Old River at Tracy Barrier. The downstream station, Old River downstream of the ORT barrier, had significantly higher dissolved oxygen concentrations than the upstream station, Old River upstream of the ORT barrier, during every month in 2010 (Table 6-25).

Table 6-25. Results for the Upstream-Downstream Analysis for the Old River at Tracy Barrier

Month	Monthly Median DO Conc (mg/L) [a]		1-sample Wilcoxon Test Results [b]		
	Upstream station - OR u/s ORT barrier	Downstream station - OR d/s ORT barrier	p-Value	Difference between monthly medians (mg/L)	Station with significantly higher DO values [c]
January	9.07	9.48	<0.001	0.41	ORDB
February	8.46	8.88	<0.001	0.42	ORDB
March	9.21	9.34	<0.001	0.14	ORDB
April	7.49	7.73	<0.001	0.24	ORDB
May	8.08	8.15	<0.001	0.07	ORDB
June	7.07	7.37	<0.001	0.30	ORDB
July	5.33	5.78	<0.001	0.45	ORDB
August	5.08	5.65	<0.001	0.57	ORDB
September	4.26	5.36	<0.001	1.11	ORDB
October	5.06	6.04	<0.001	0.98	ORDB
November	8.70	8.85	<0.001	0.15	ORDB
December	8.84	8.97	<0.001	0.13	ORDB

(a) The monthly medians are actually the medians of the daily medians for the month. For example, in this analysis the monthly median for January is the median of all of the daily medians for the month of January.
(b) “NS” stands for “no significant difference between the two stations”.
(c) “ORDB” represents the Old River downstream of the ORT barrier station.

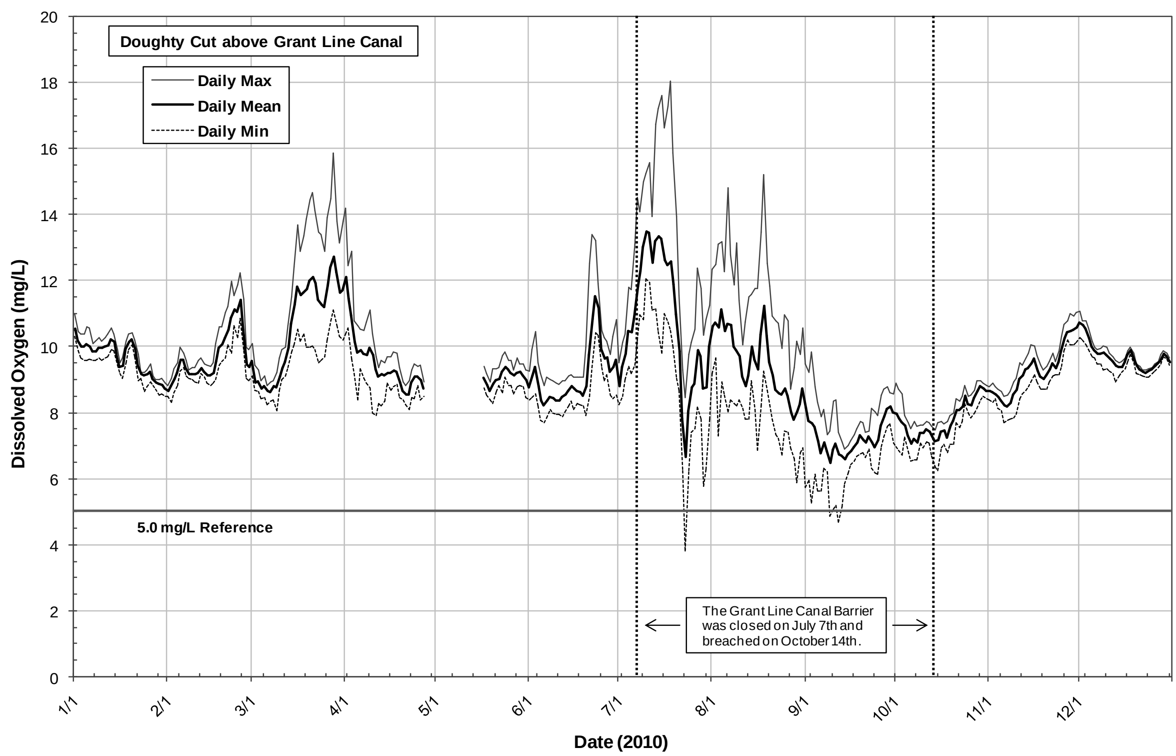
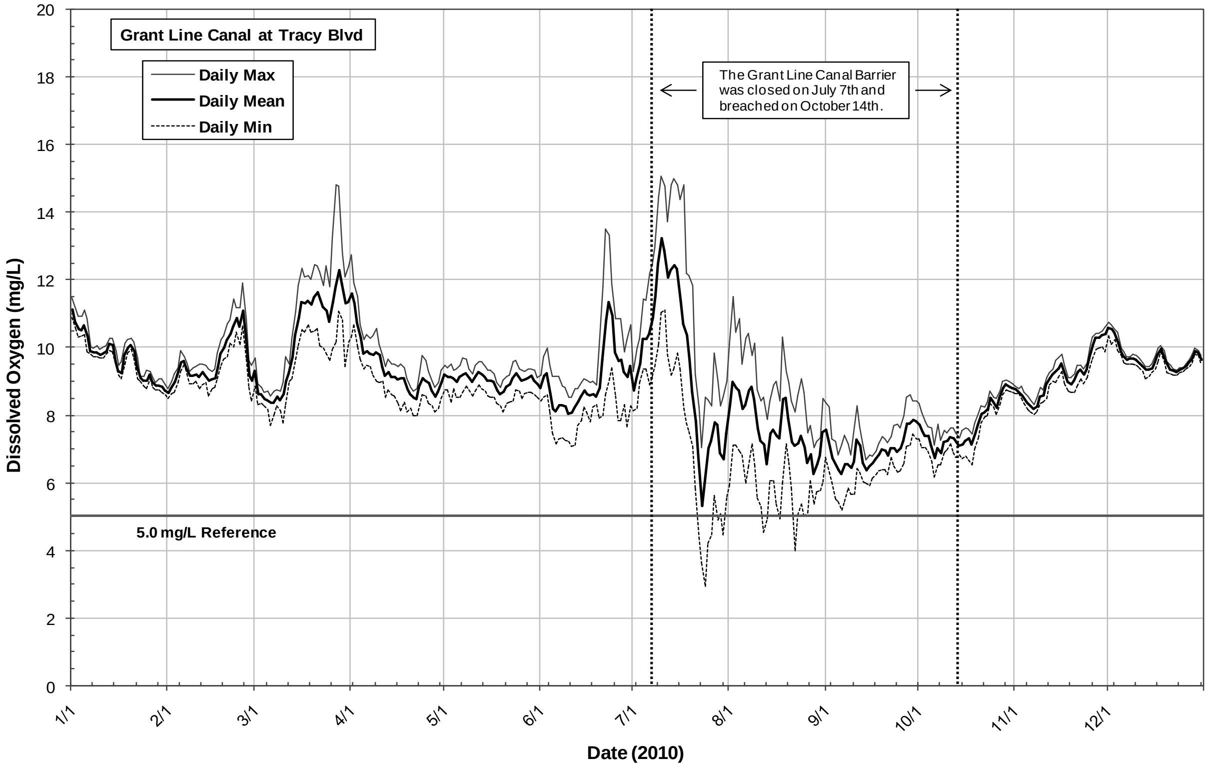


Figure 6-9. Daily Dissolved Oxygen Time-series Graphs for the Grant Line and Victoria Canal Stations



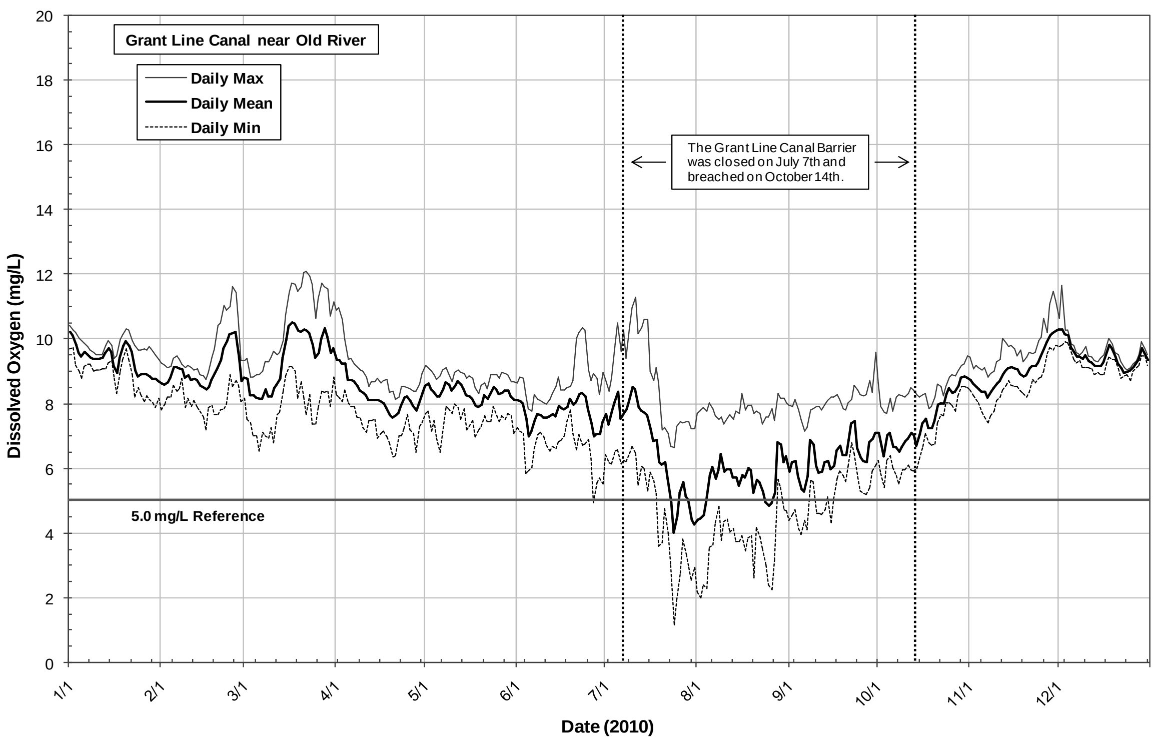


Figure 6-9 (cont.). Daily Dissolved Oxygen time-series graphs for the Grant Line and Victoria Canal stations

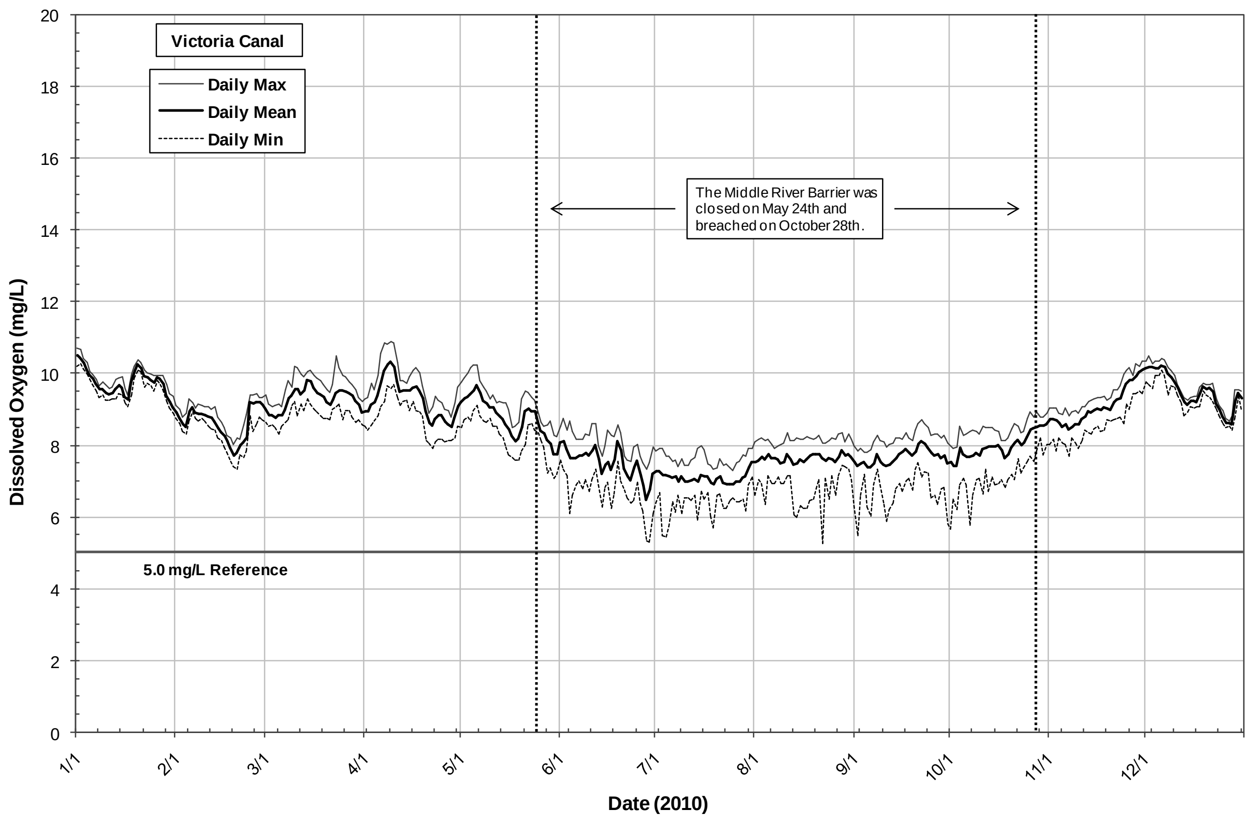
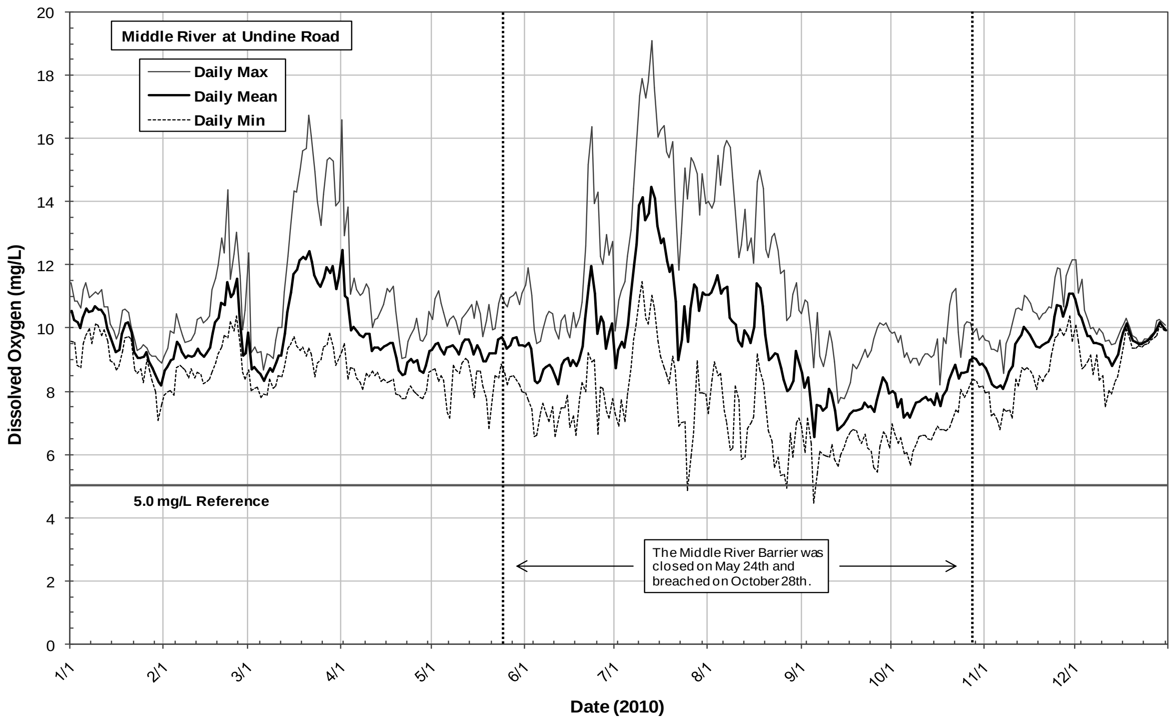


Figure 6-9 (cont.). Daily Dissolved Oxygen Time-series Graphs for the Grant Line and Victoria Canal Stations



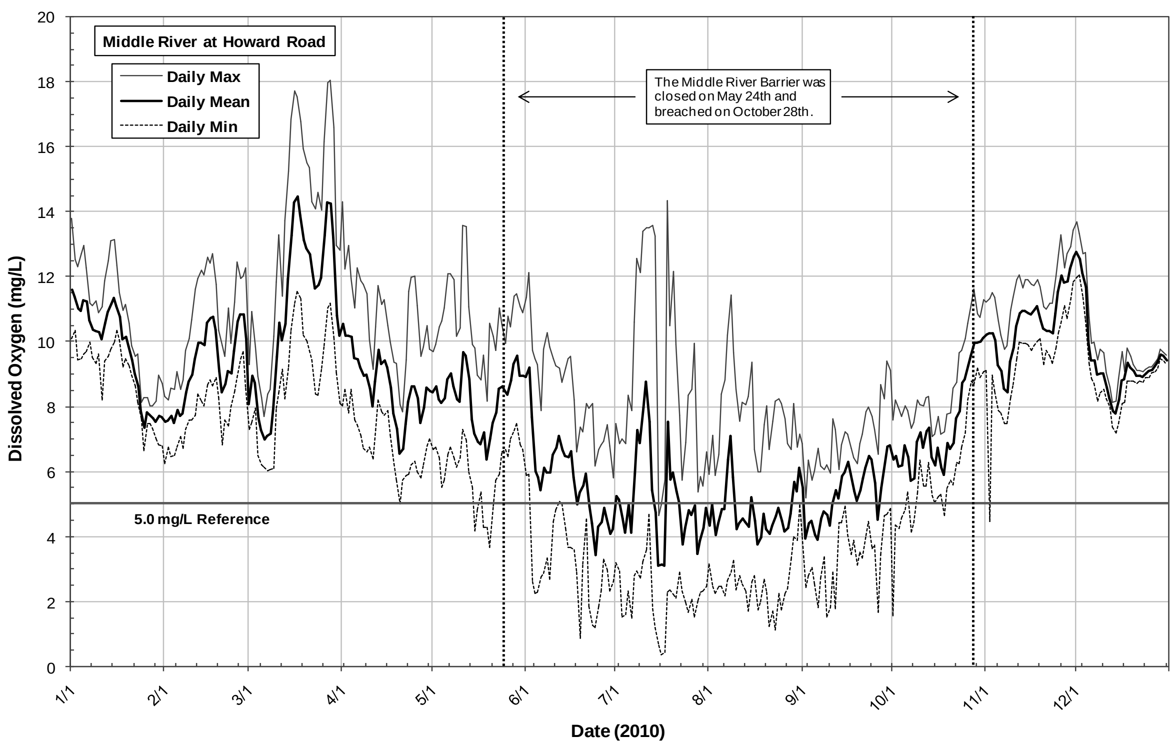
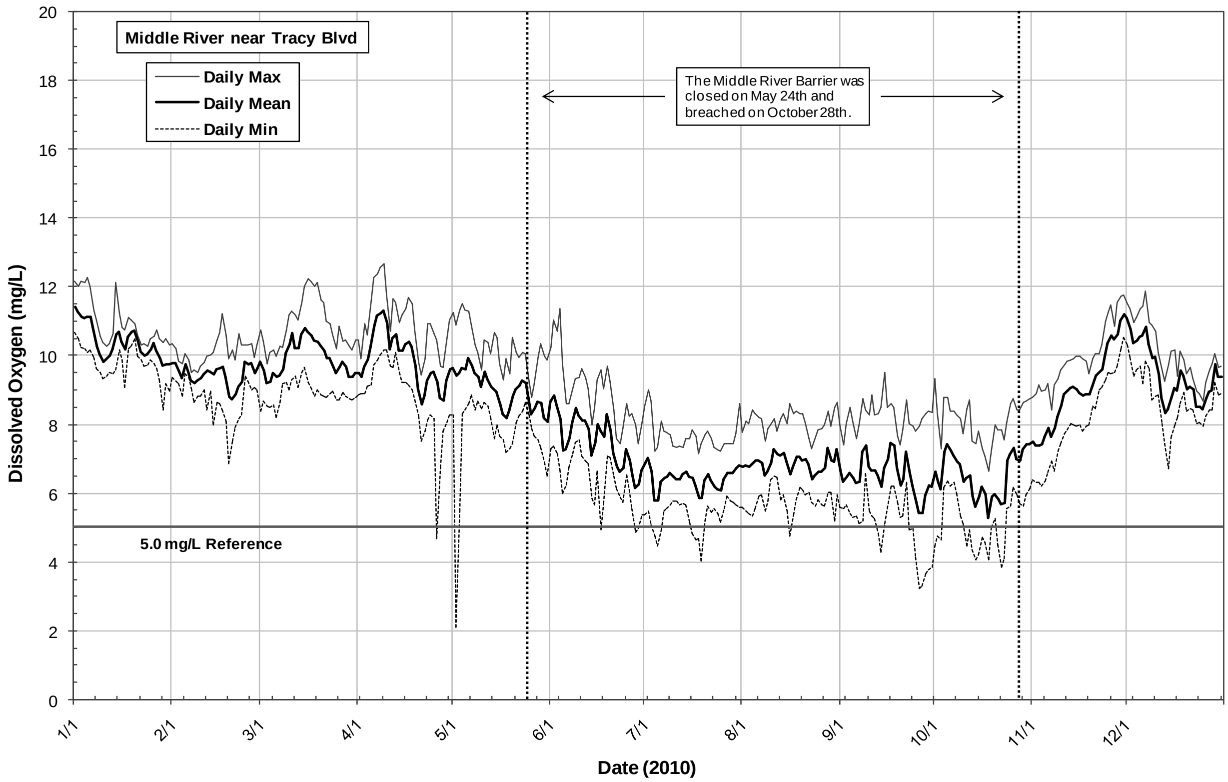


Figure 6-10. Daily Dissolved Oxygen Time-series Graphs for the Middle River Stations



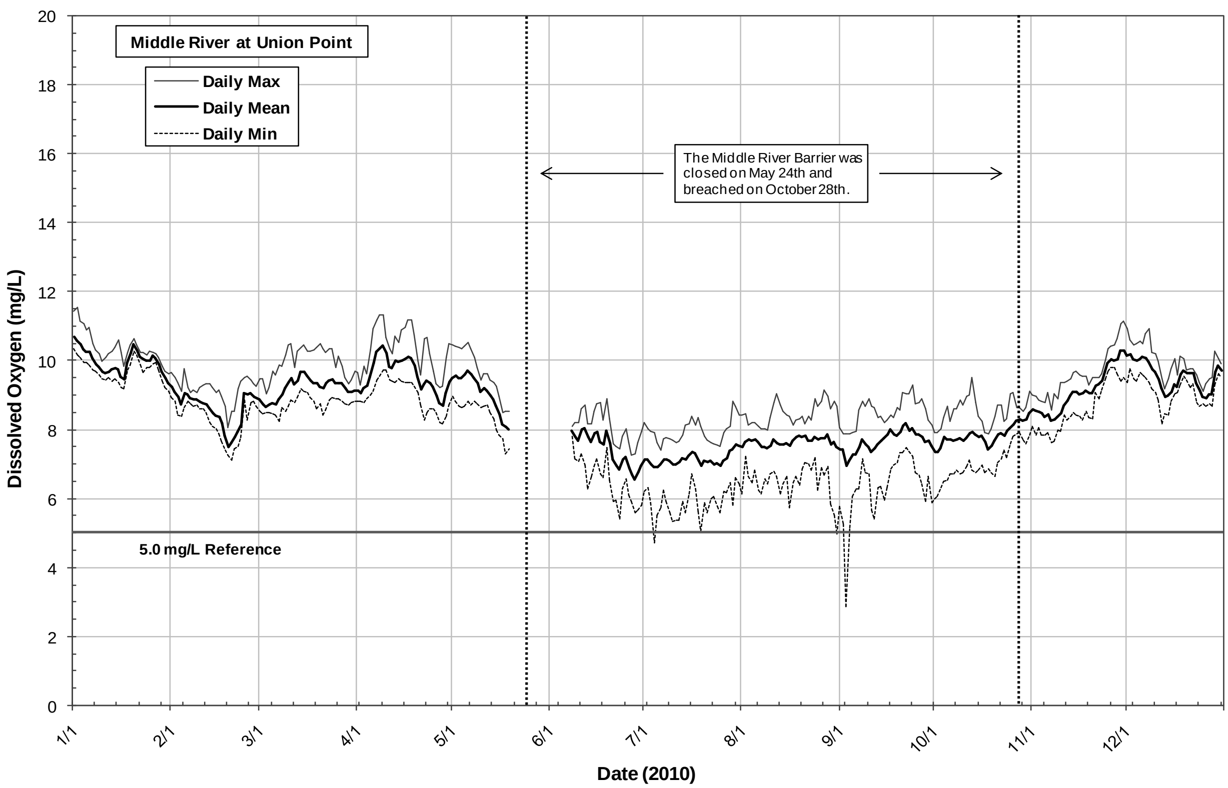
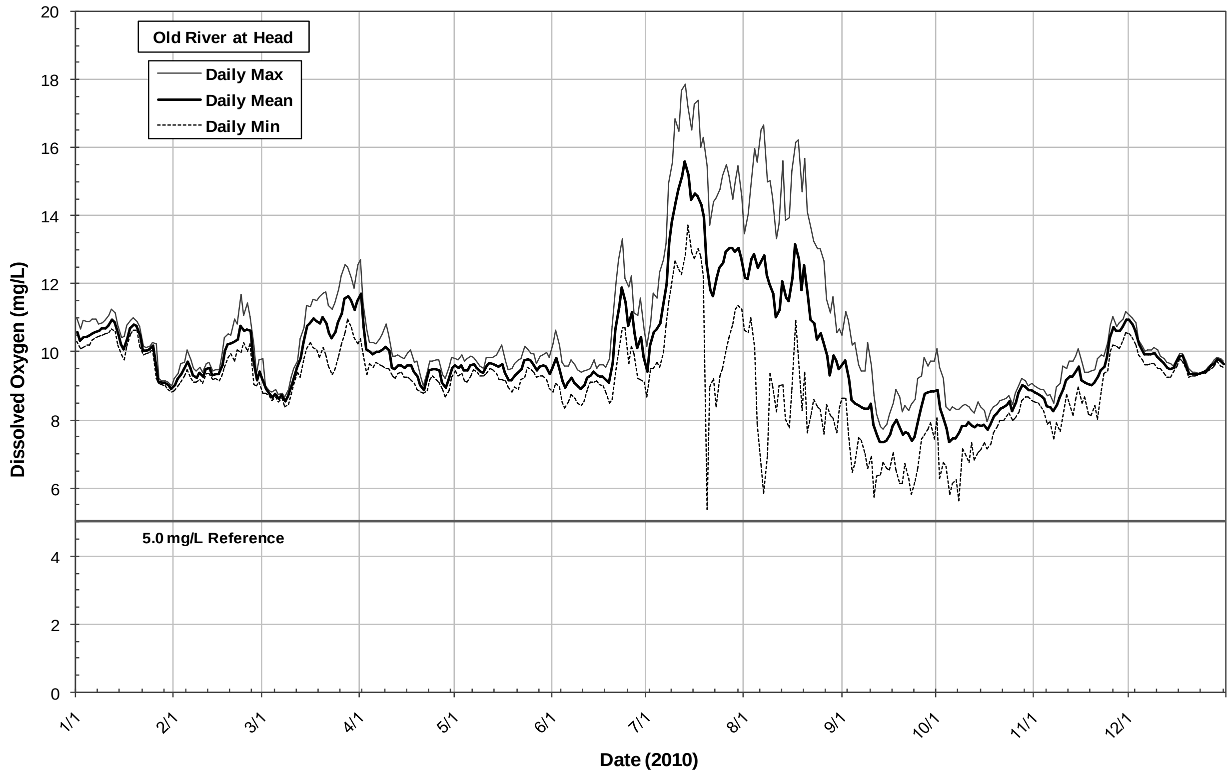


Figure 6-10 (cont.). Daily Dissolved Oxygen Time-series Graphs for the Middle River Stations



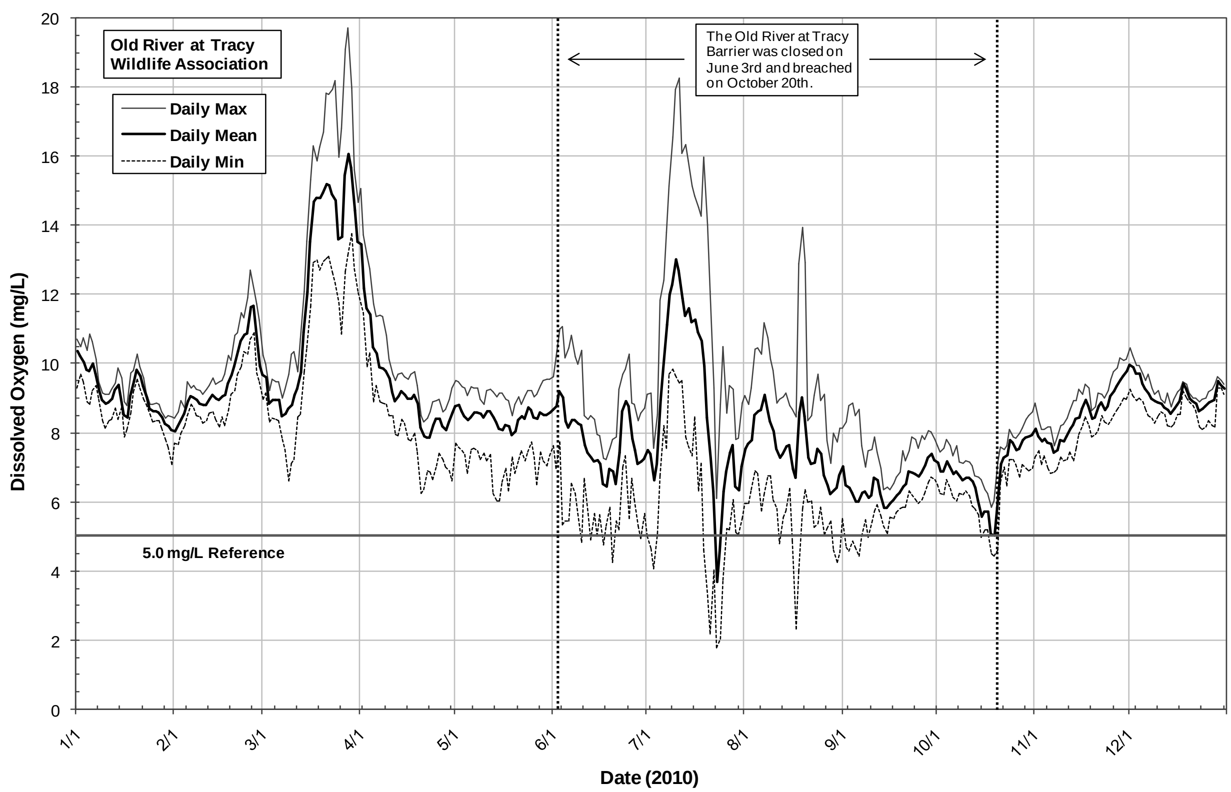
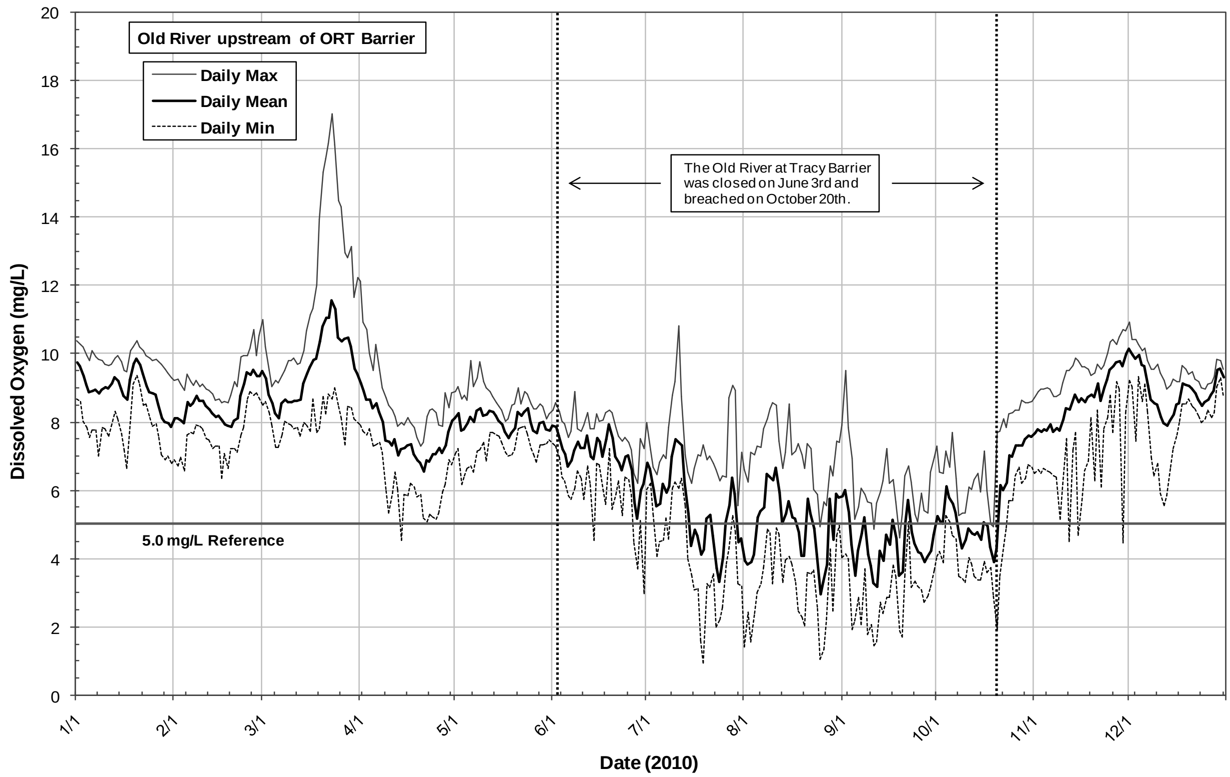


Figure 6-11. Daily Dissolved Oxygen Time-series Graphs for the Old River Stations



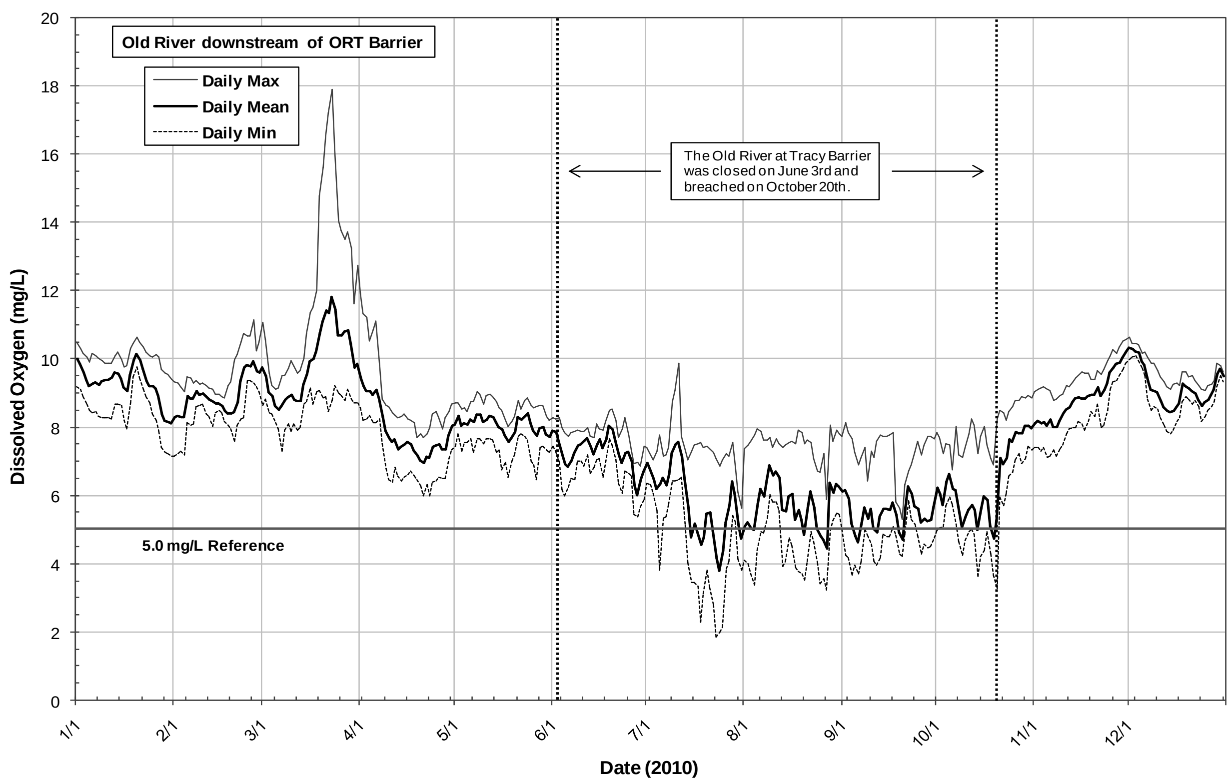
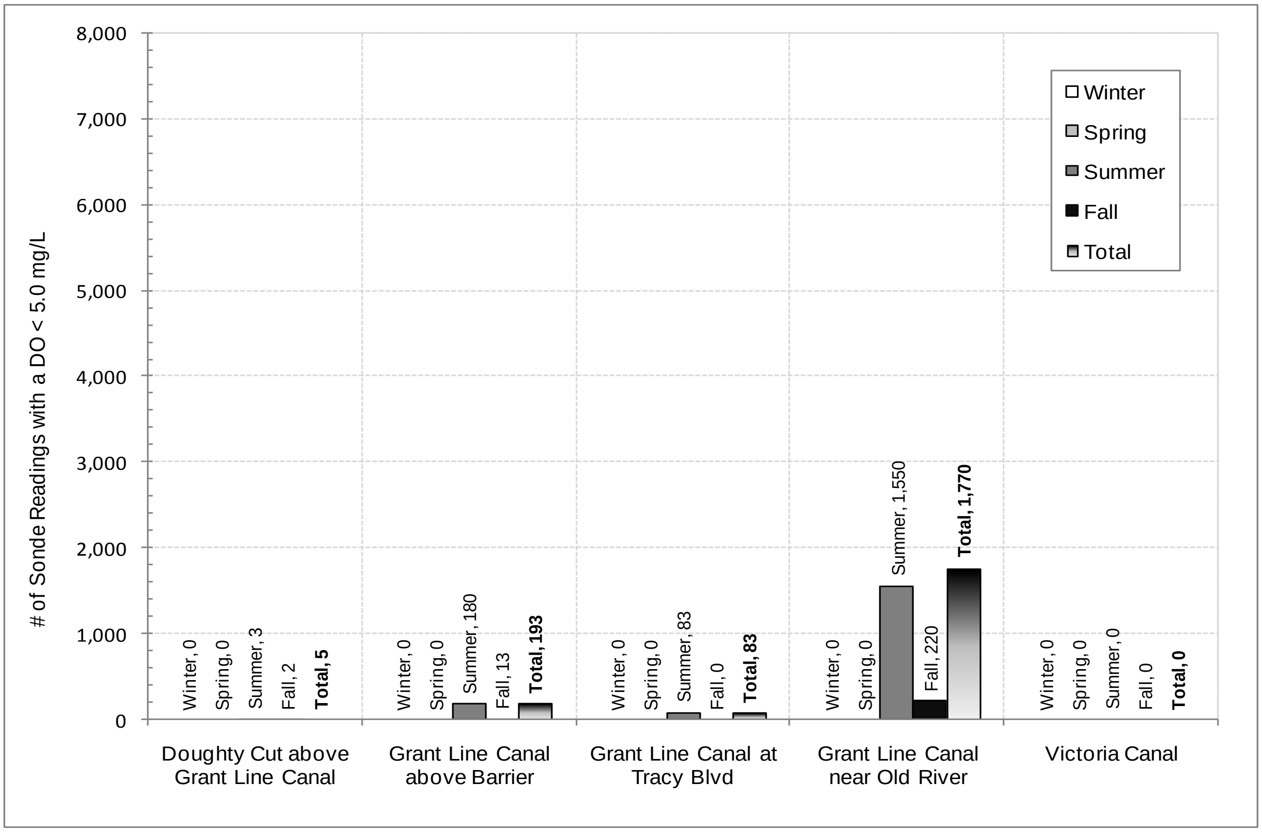


Figure 6-11 (cont.). Daily Dissolved Oxygen Time-series Graphs for the Old River Stations



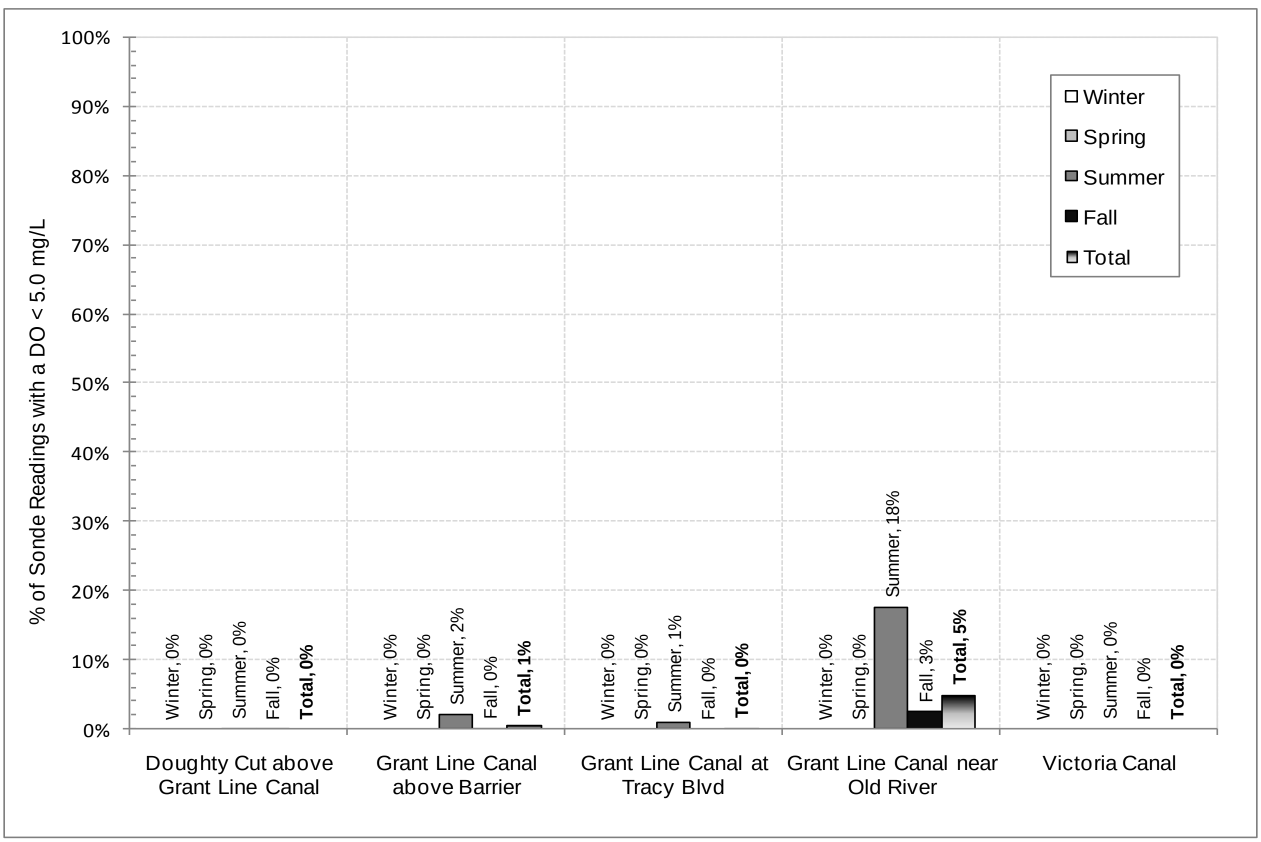
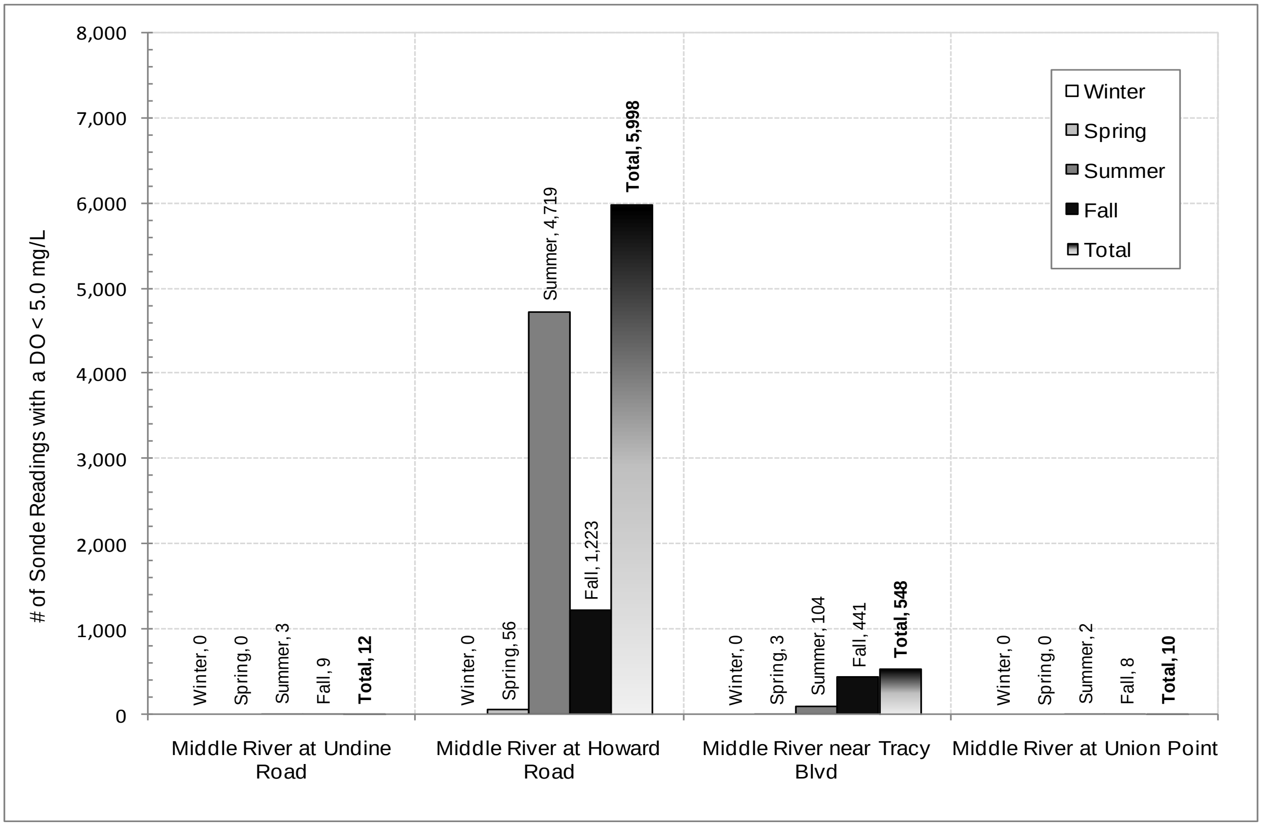


Figure 6-12. Dissolved Oxygen Standard Exceedences for the Grant Line and Victoria Canal Stations



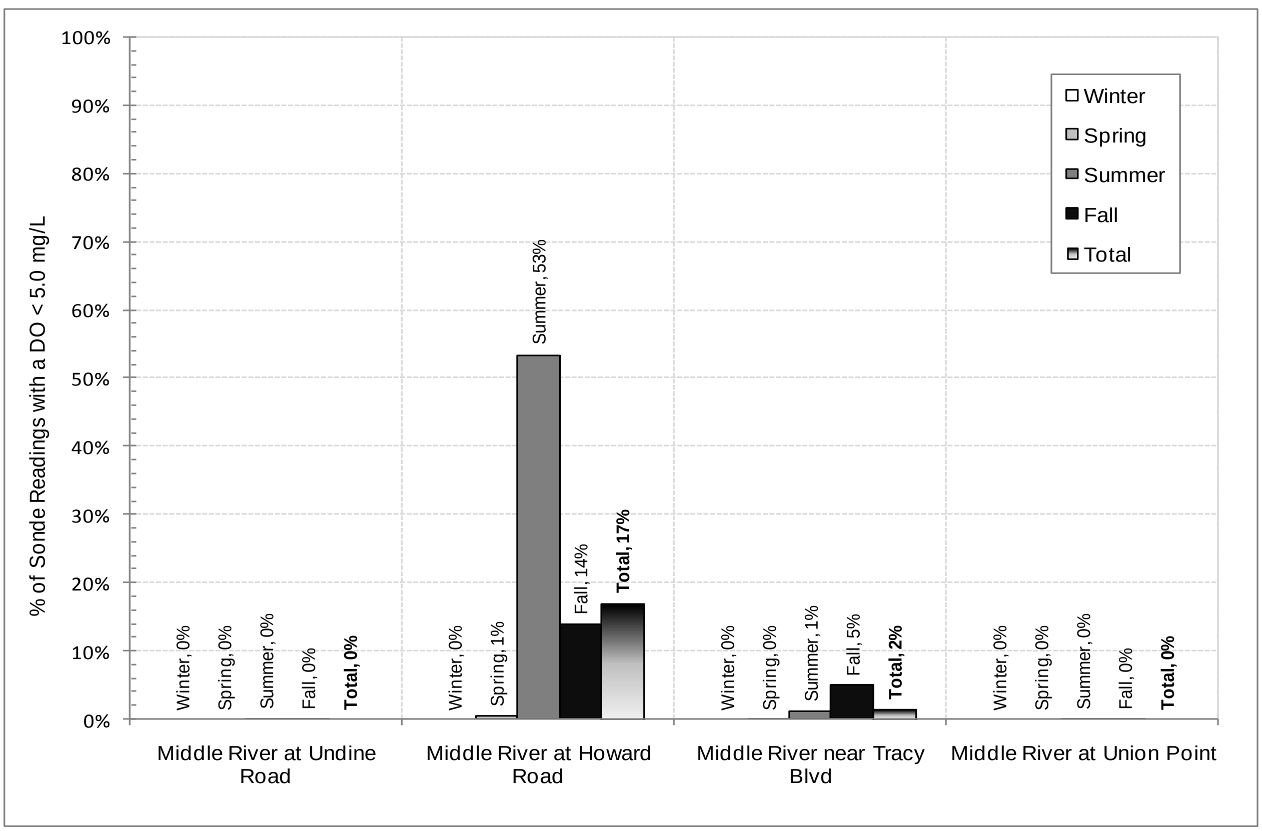
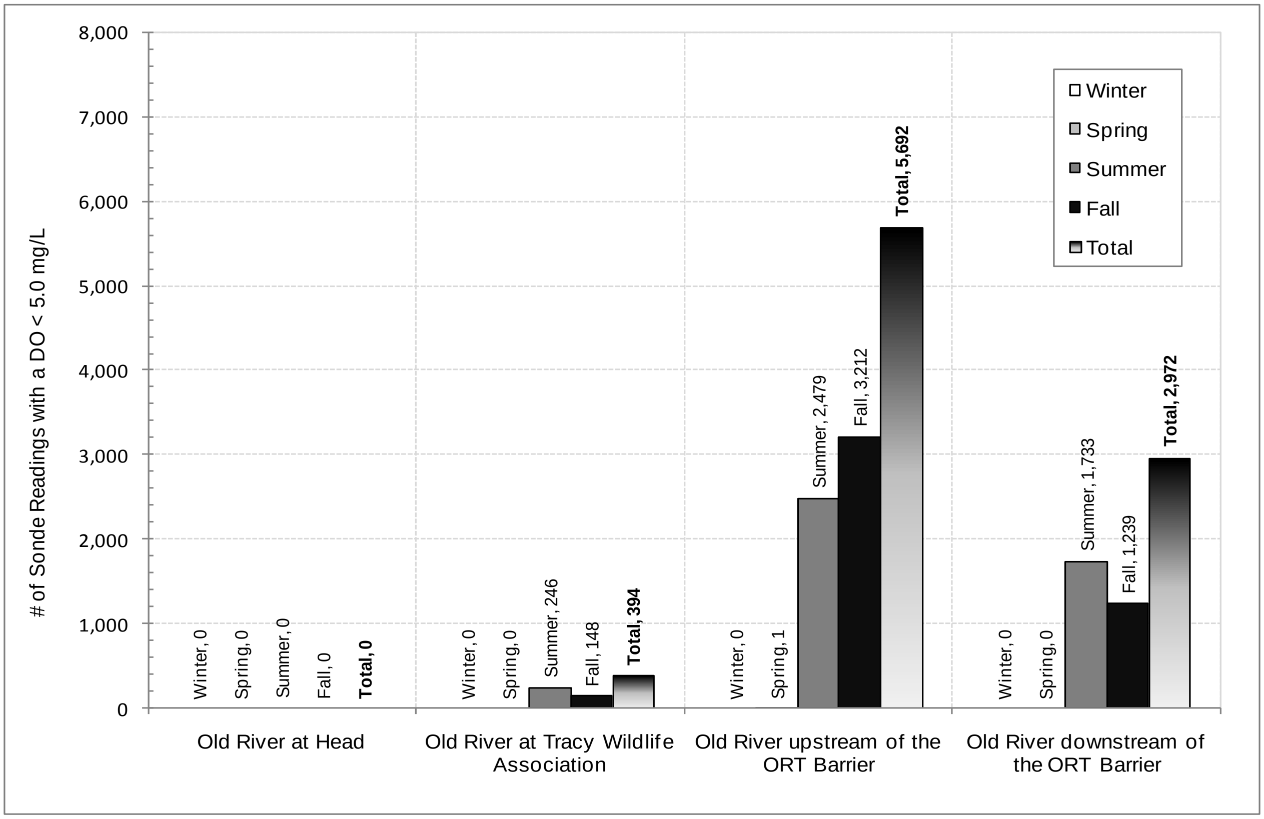


Figure 6-13. Dissolved Oxygen Standard Exceedences for the Middle River Stations



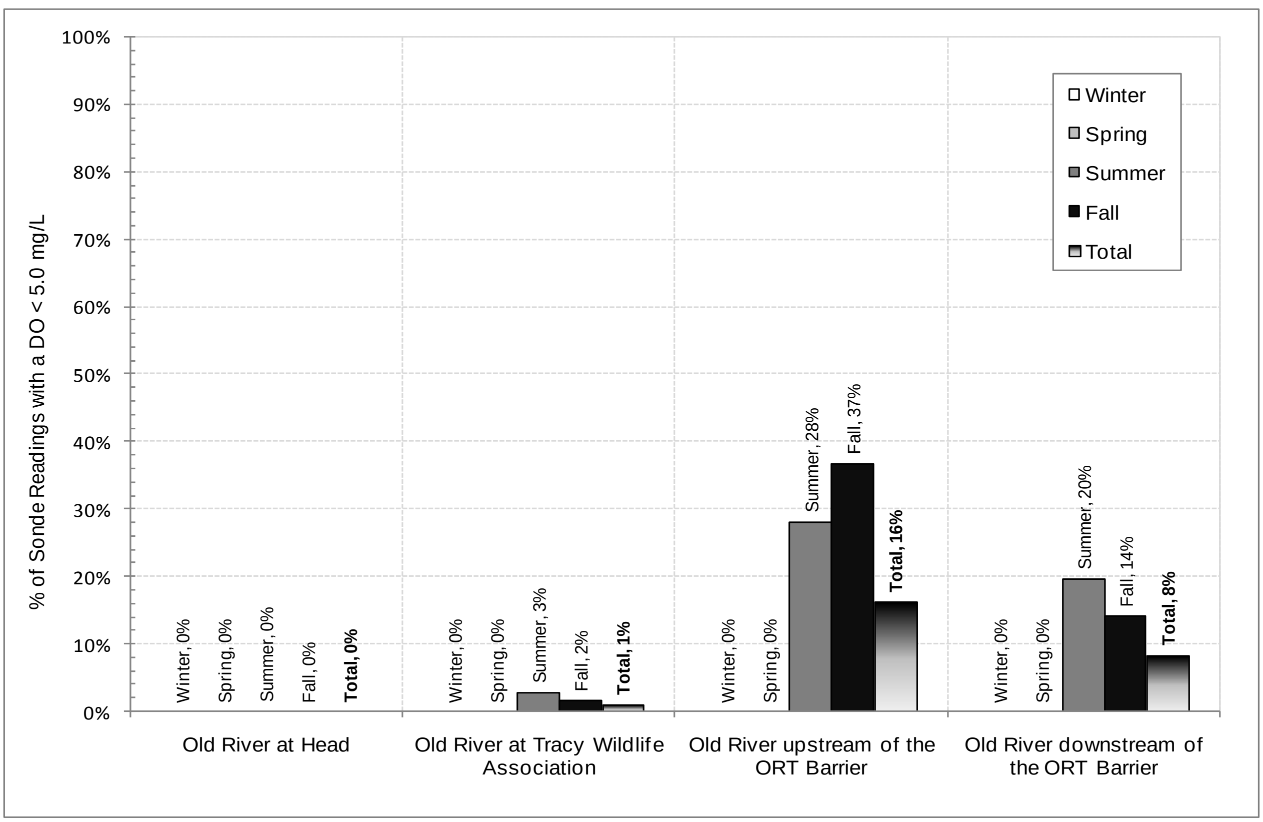


Figure 6-14. Dissolved Oxygen Standard Exceedences for the Old River Stations

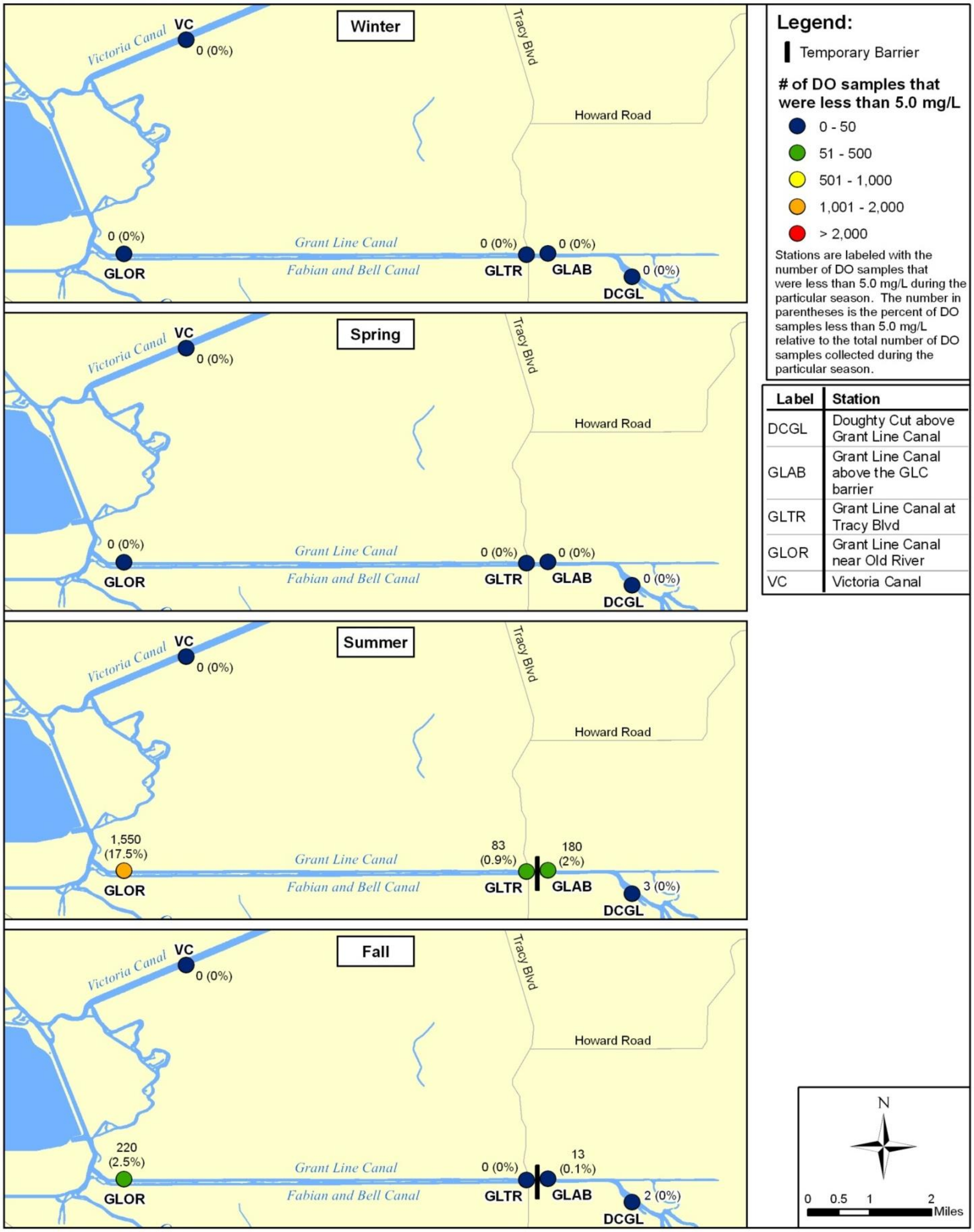


Figure 6-15. Map of Dissolved Oxygen Standard Exceedences for the Grant Line and Victoria Canal Stations

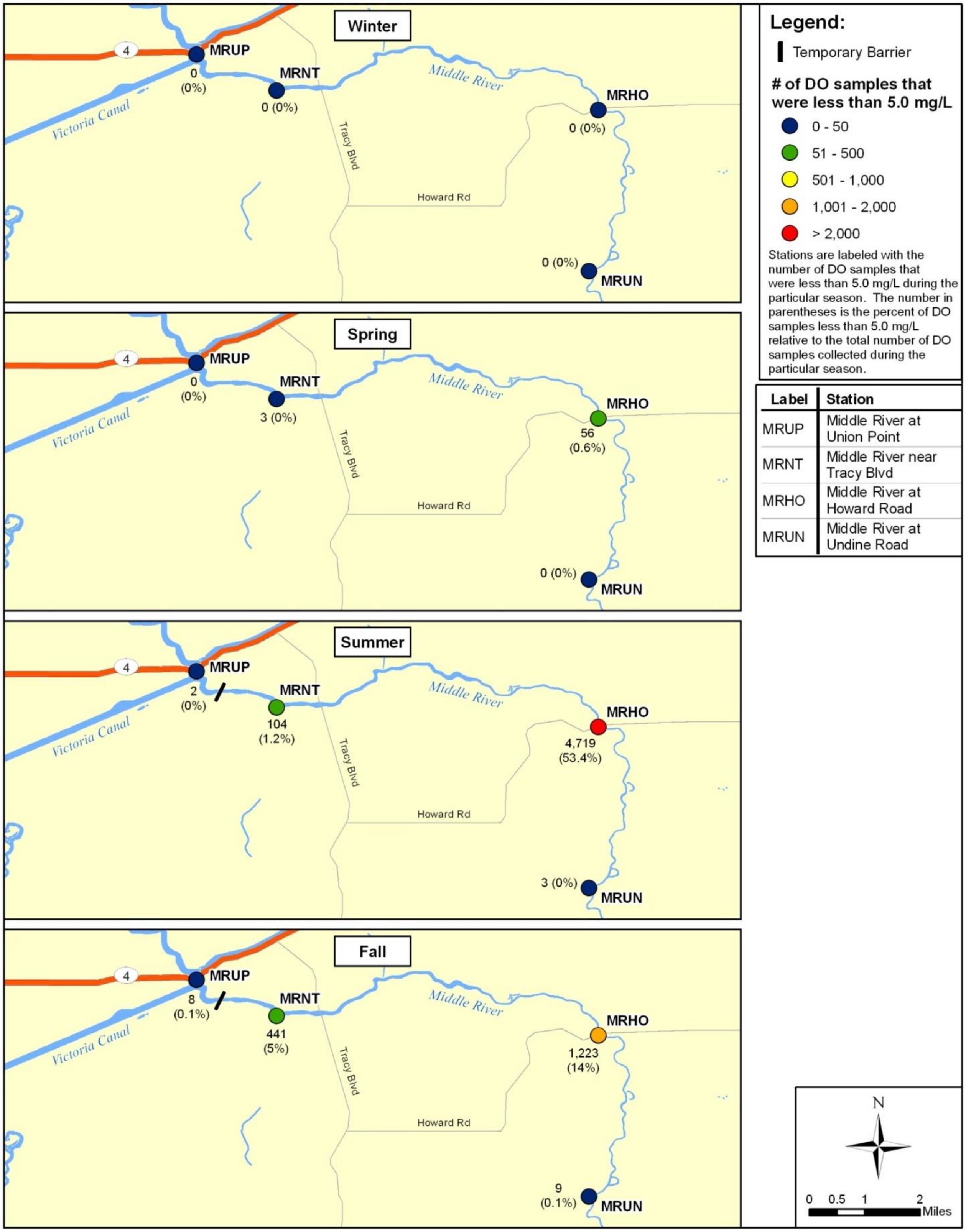


Figure 6-16. Map of Dissolved Oxygen Standard Exceedences for the Middle River Stations

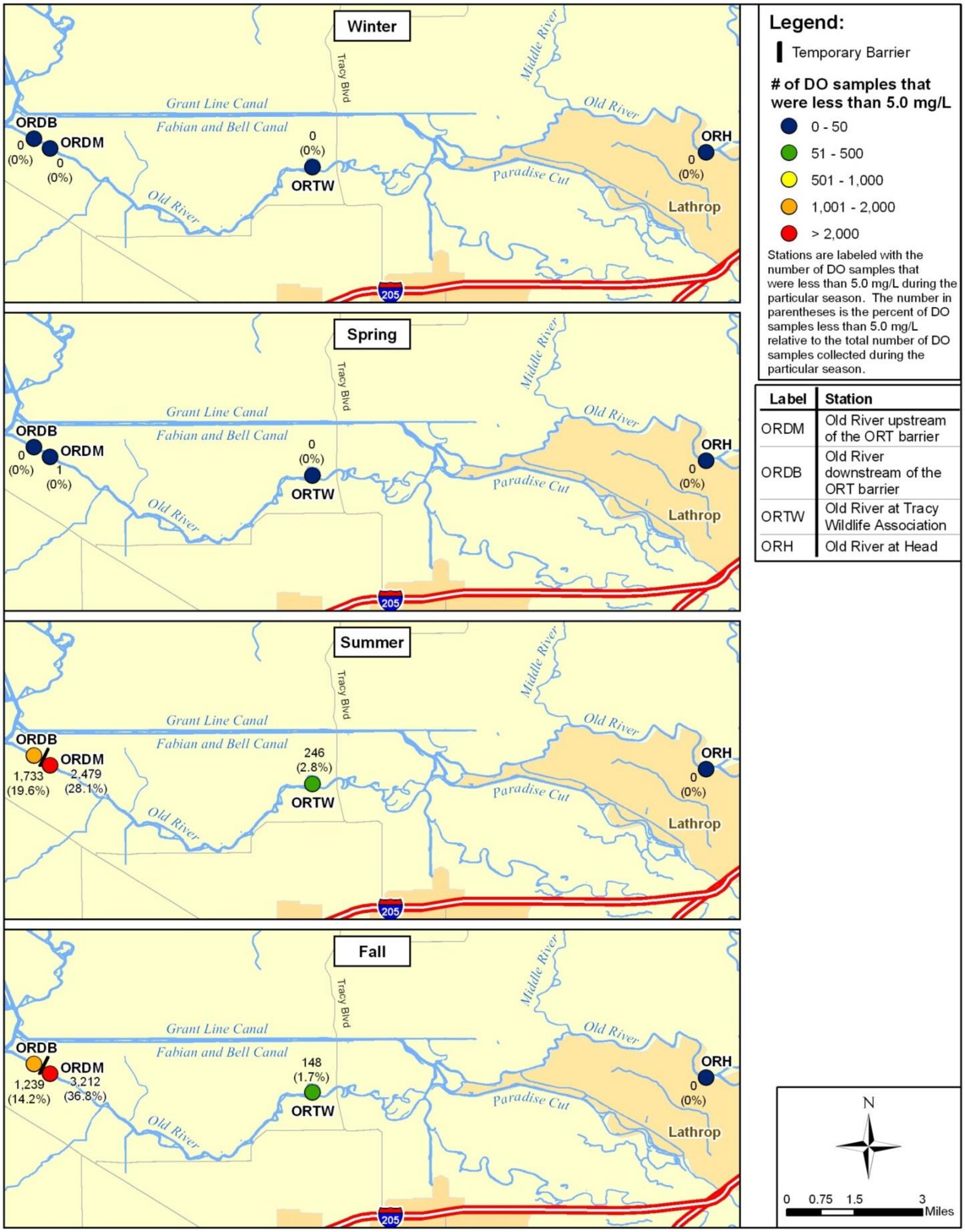


Figure 6-17. Map of Dissolved Oxygen Standard Exceedences for the Old River Stations

pH

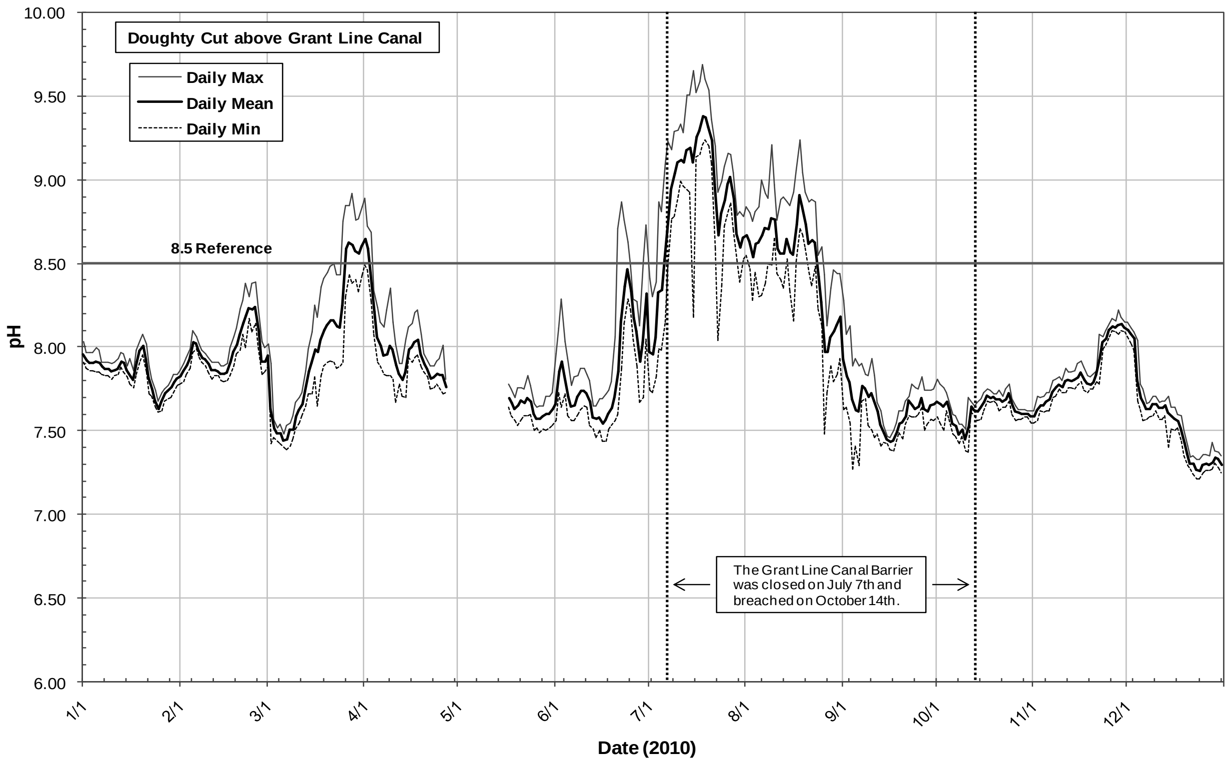
pH is a measure of the hydrogen ion concentration [H^+] of a solution. pH values range from 1 to 14, with values less than 7 considered acidic and values greater than 7 considered basic. Since the pH scale is logarithmic; a pH value of 7 is 10 times greater than a pH value of 6 and 100 times greater than a value of 5. Natural waters usually have pH values in the range of 4 to 9, and most are slightly basic (APHA, 2005). pH values can be affected by algal photosynthesis. Algae consume CO_2 from the water when photosynthesis is occurring within their cells. Less CO_2 in the water decreases carbonic acid, which makes the water more alkaline and increases the pH.

A maximum pH of 9.69 was recorded on July 18 at Doughty Cut above Grant Line Canal; a minimum of 6.79 was recorded on July 6 at Middle River at Howard Road (see Tables 6-10 to 6-13). Figures 6-18, 6-19, and 6-20 illustrate the daily maximums, minimums, and averages for the Grant Line and Victoria Canal, Middle River, and Old River stations, respectively. Generally, pH was higher and more variable from mid-June through mid-September, particularly at the stations with higher chlorophyll concentrations during this period. Monthly average pH values during the summer and early fall (June – September) ranged from 7.17 in July at Victoria Canal to 8.81 in July at Old River at Head (Tables 6-10 to 6-13). At most stations, there was a noticeable increase in pH values during mid-March to mid-April (see Figures 6-18 to 6-20). Monthly average pH values during the spring (March – May) ranged from 7.41 in May at Grant Line Canal near Old River and Old River downstream of the ORT barrier. During the fall and winter seasons, monthly average pH values ranged from 7.32 in December at Grant Line Canal above the GLC barrier and Grant Line Canal at Tracy Blvd to 8.19 in February at Middle River at Undine Road.

Water Quality Standard Exceedences: As discussed in the Methods and Results section, the established pH criteria is 8.50 units; therefore, staff considered any pH sample of reliable data quality greater than 8.50 as exceeding the standard. Figures 6-21, 6-22, and 6-23 illustrate the number of pH readings with concentrations greater than 8.50 for each season and the overall total for the 2010 monitoring period for the Grant Line and Victoria Canal, Middle River, and Old River stations, respectively. In addition, the figures show the percent of sonde samples exceeding the pH standard relative to the total number of samples collected. Figures 6-24, 6-25, and 6-26 provide the exceedence information in a map format allowing for the observation of geographical relationships.

The station with the most pH exceedences during 2010 was Old River at Head with a total of 5,459 (16.8% of the total number of samples). Most of the standard exceedences at this station occurred in the summer with 5,376 (60.9% of all samples collected in the summer). Some other stations that had large number of exceedences for the year were Doughty Cut above Grant Line Canal (5,237; 16.0% of the total), Middle River at Undine Road (4,910; 14.0% of the total), Grant Line Canal above the GLC barrier (3,978; 11.4% of the total), Old River at Tracy Wildlife Association (3,552; 10.1% of the total), and Grant Line Canal at Tracy Blvd (3,336; 9.5% of the total). In contrast, the Victoria Canal and Middle River at Union Point stations had the least number of exceedences of the pH standard for the year with zero. Middle River near Tracy Blvd also had low numbers of pH exceedences with 144. Generally, most stations had more pH exceedences during the spring and summer than during the fall and winter.

For the stations located along Middle and Old Rivers, the stations closest to the temporary barriers had lower total numbers of pH exceedences during 2010 than the stations upstream or downstream (see Figures 6-22, 6-23, 6-25, and 6-26). The Old River upstream and downstream of the ORT barrier stations had 718 and 505 total exceedences, respectively, compared to Old River at Tracy Wildlife Association with 3,552 and Old River at Head with 5,459. For the Middle River stations, Middle River at Union Point and Middle River near Tracy Blvd had 0 and 144 total exceedences, respectively; and the 2 upstream stations, Middle River at Howard Road and Middle River at Undine Road, had 1,182 and 4,910 total exceedences, respectively. The stations located along Grant Line Canal had no relationship between the number of dissolved oxygen exceedences and the proximity to the temporary barriers (see Figures 6-21 and 6-24).



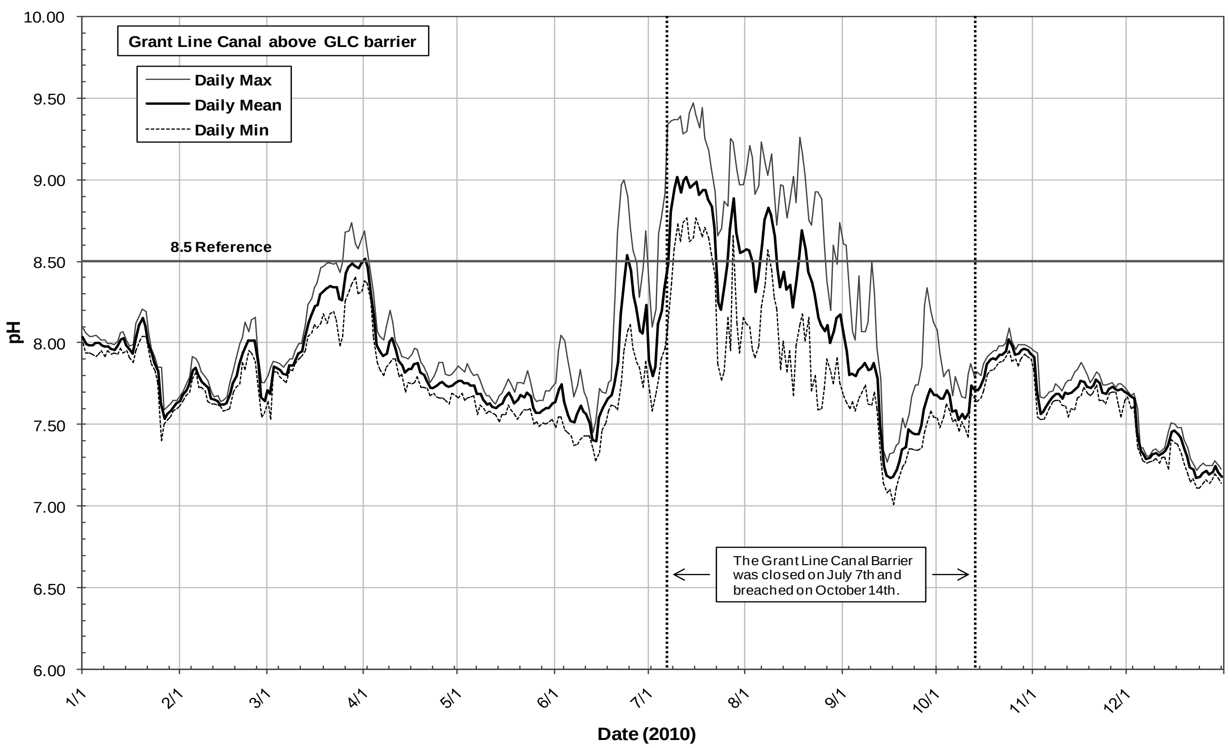
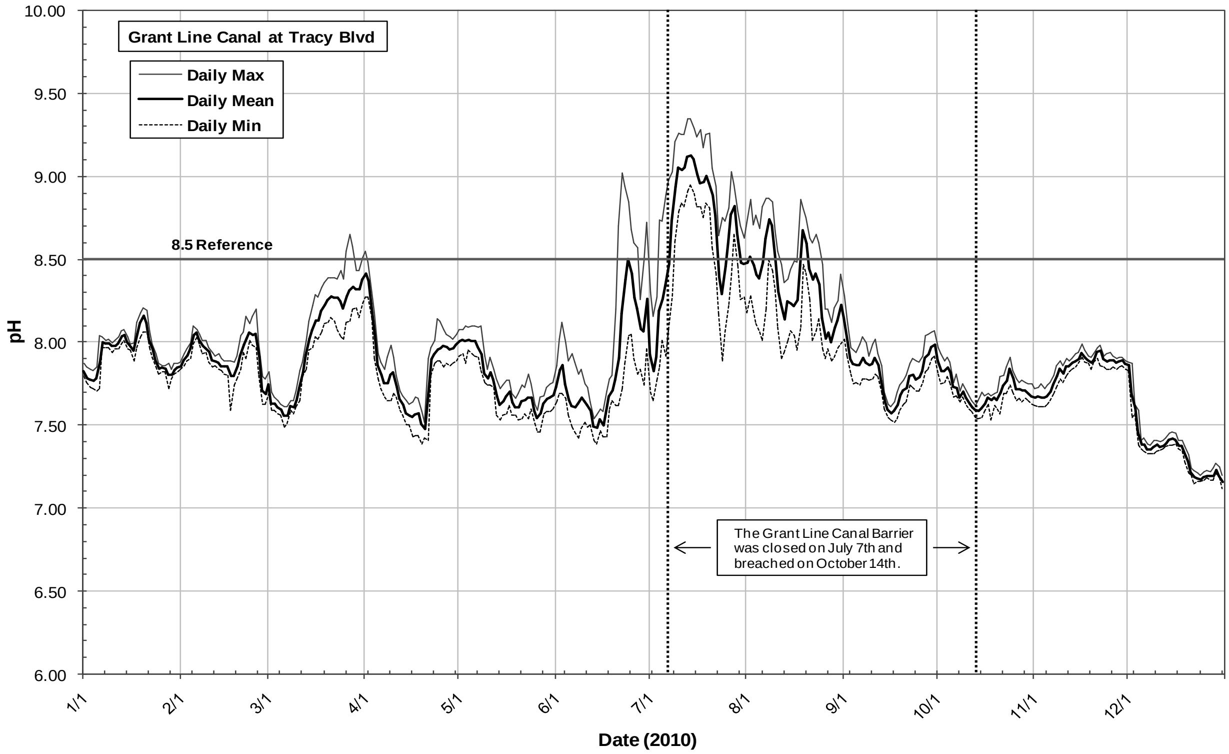


Figure 6-18. Daily pH Time-series Graphs for the Grant Line and Victoria Canal Stations



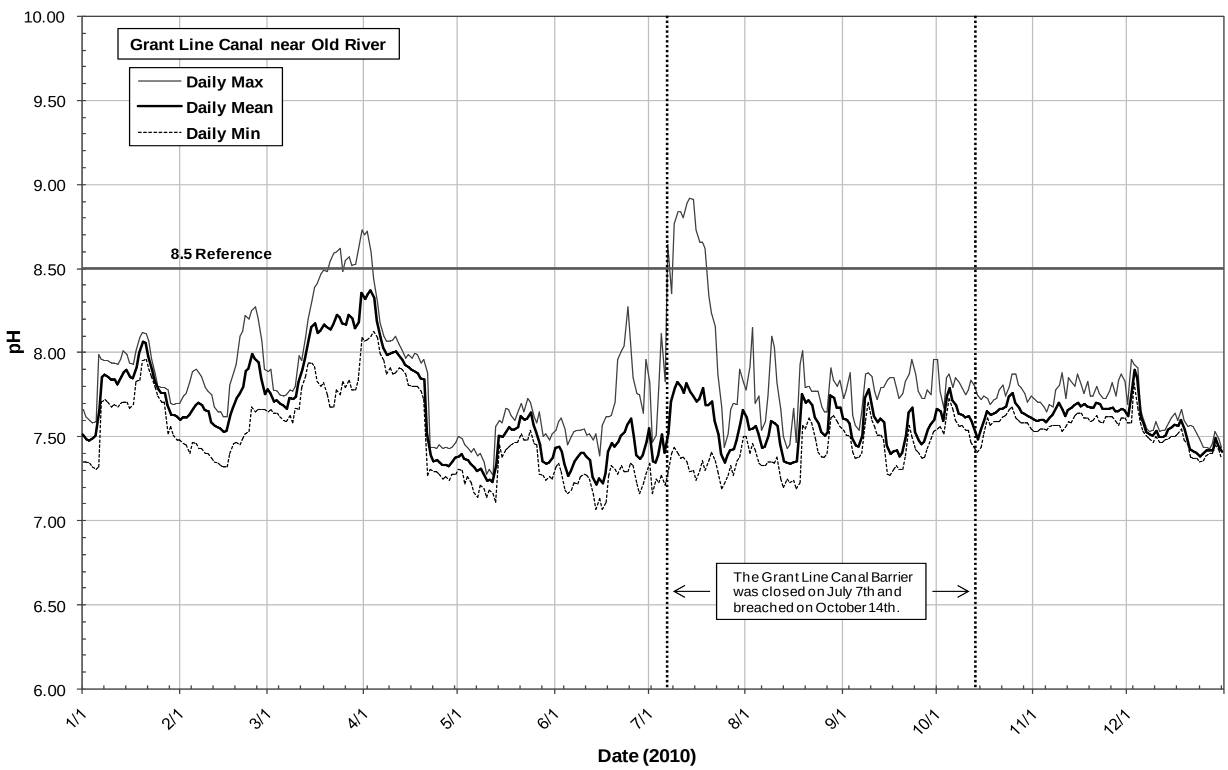


Figure 6-18 (cont.). Daily pH Time-series Graphs for the Grant Line and Victoria Canal Stations

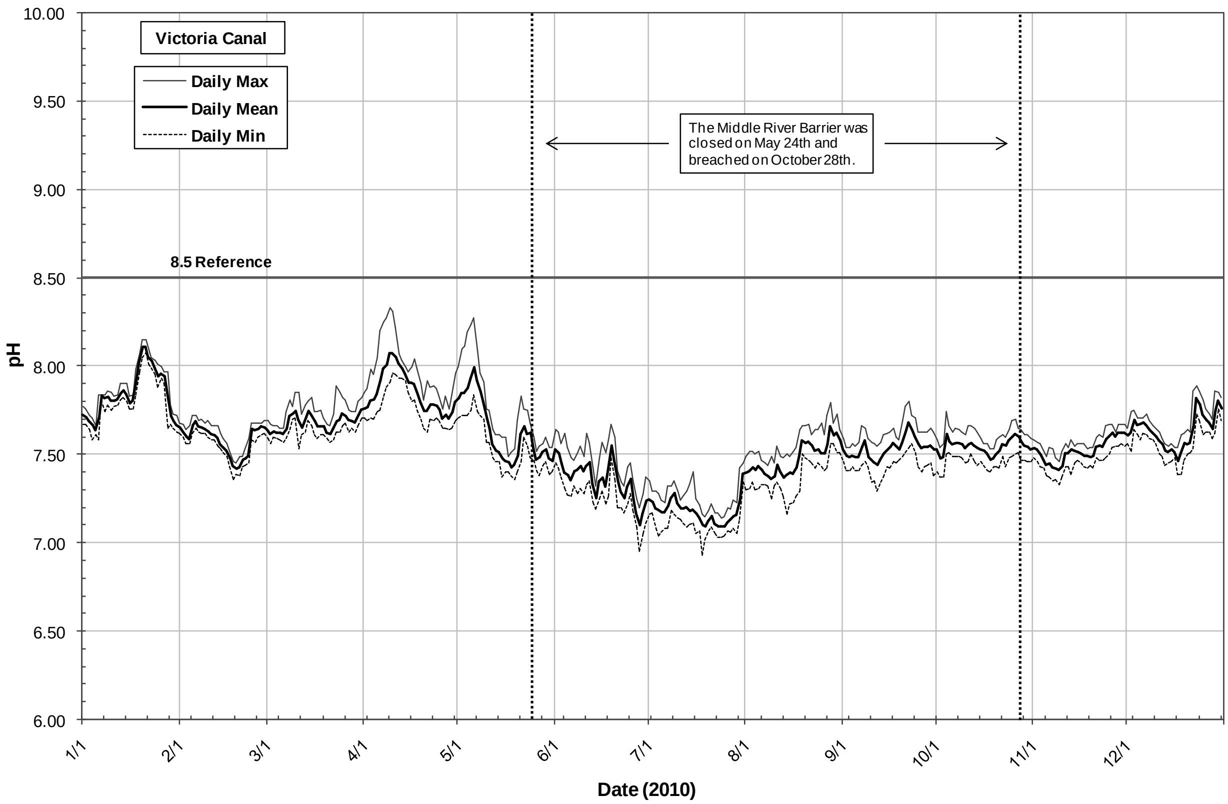
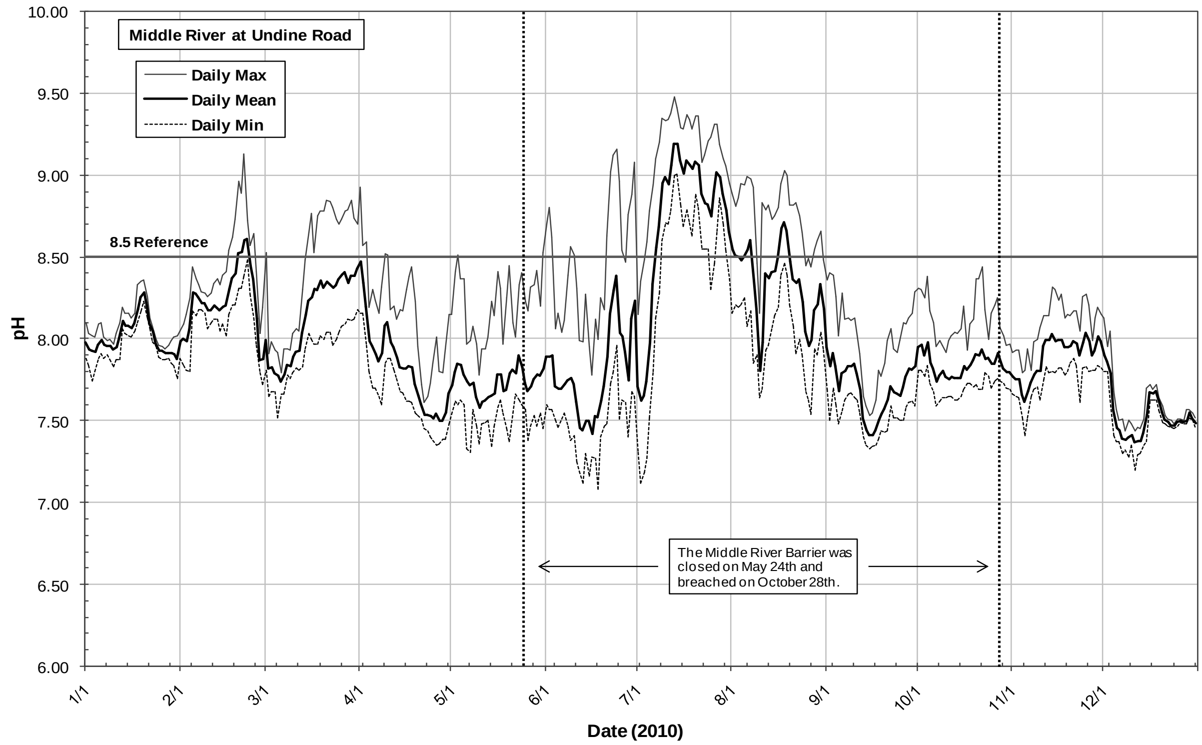


Figure 6-18 (cont.). Daily pH Time-series graphs for the Grant Line and Victoria Canal Stations



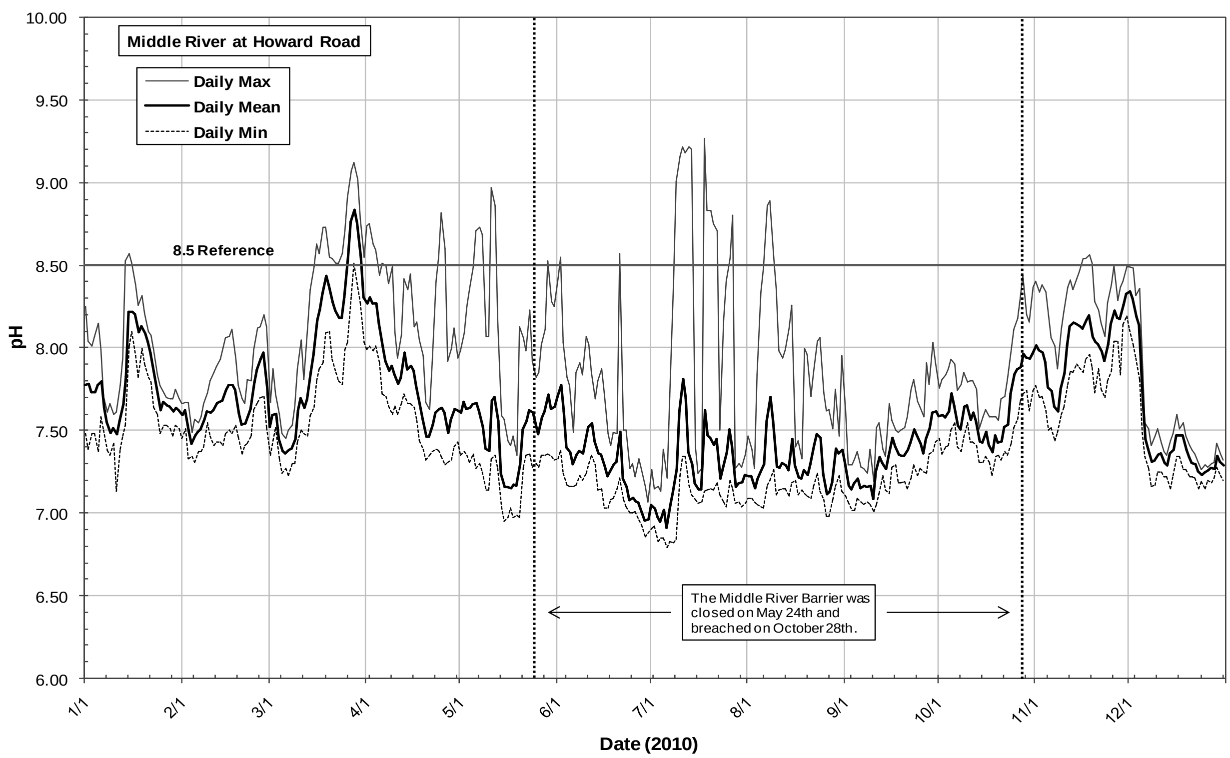
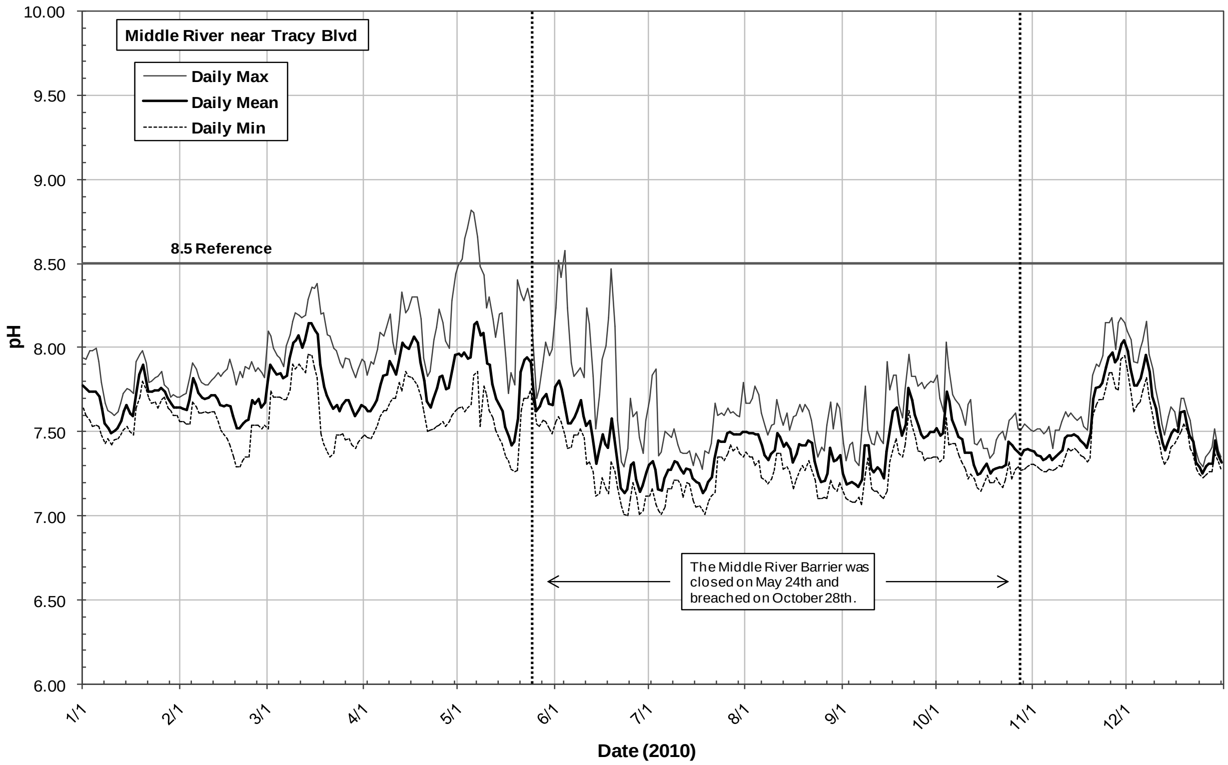


Figure 6-19. Daily pH Time-series Graphs for the Middle River Stations



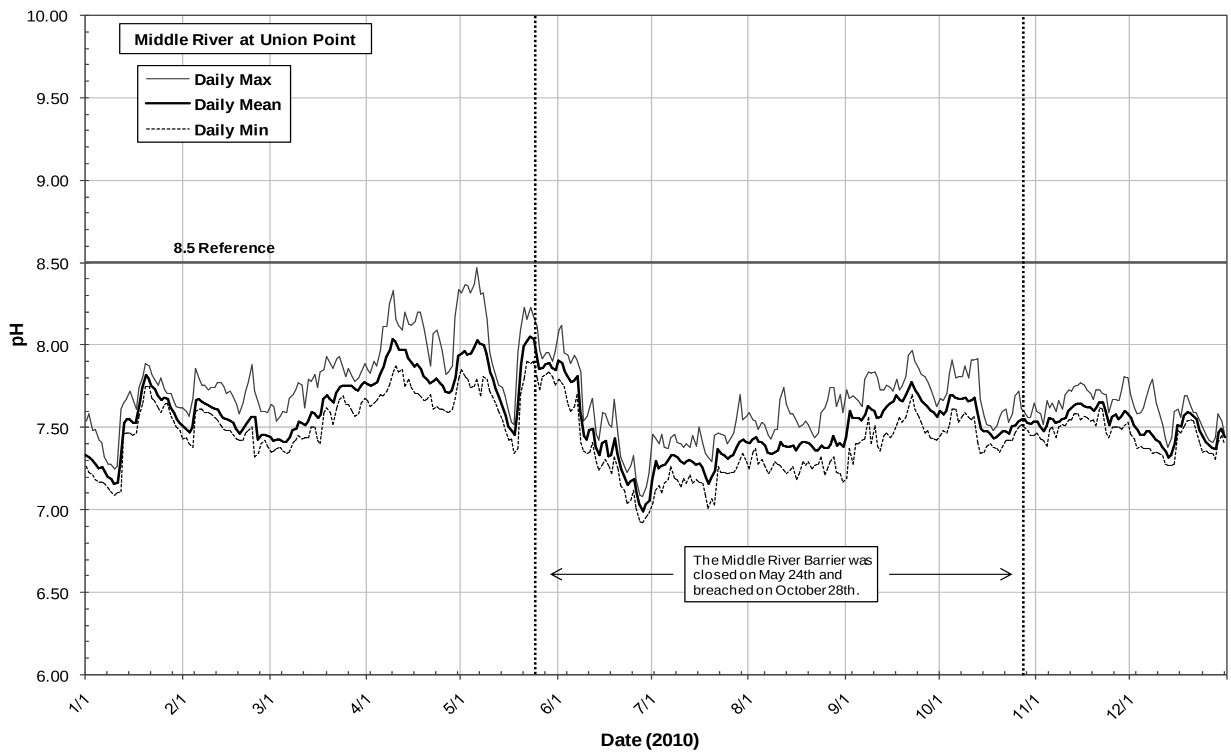
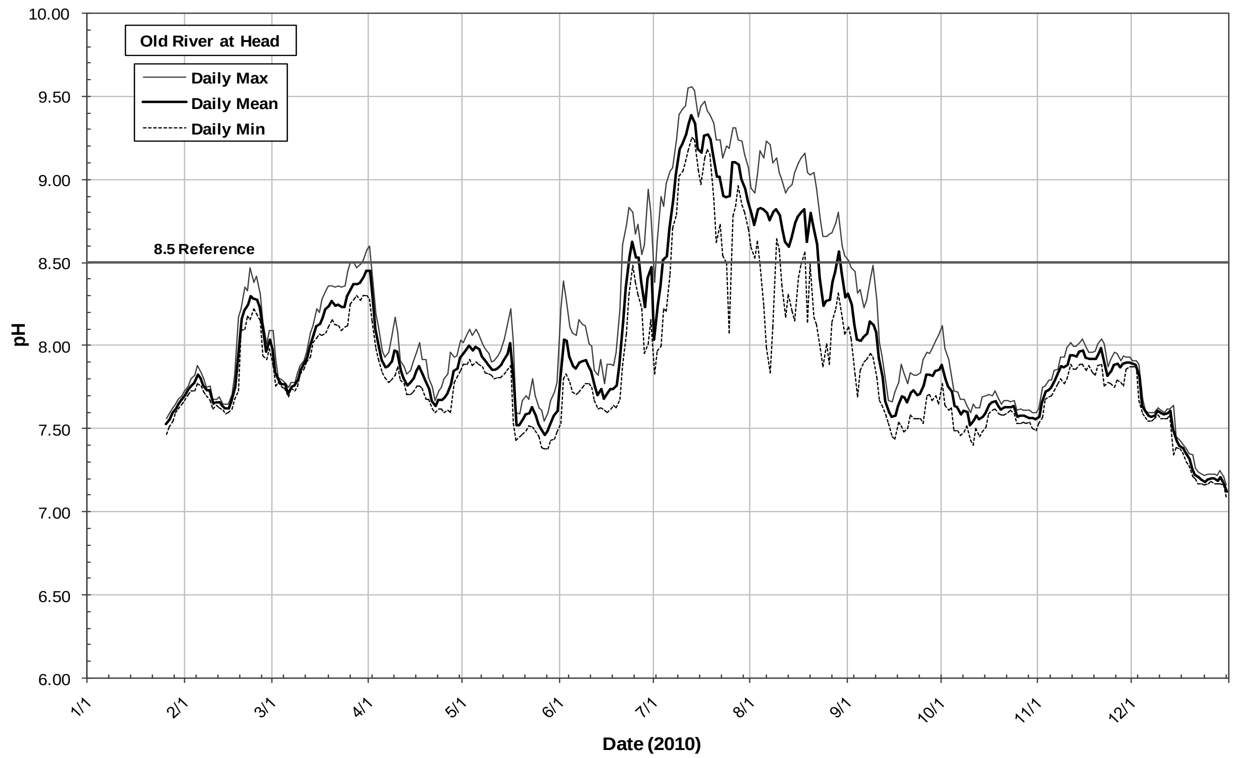


Figure 6-19 (cont.). Daily pH Time-series Graphs for the Middle River Stations



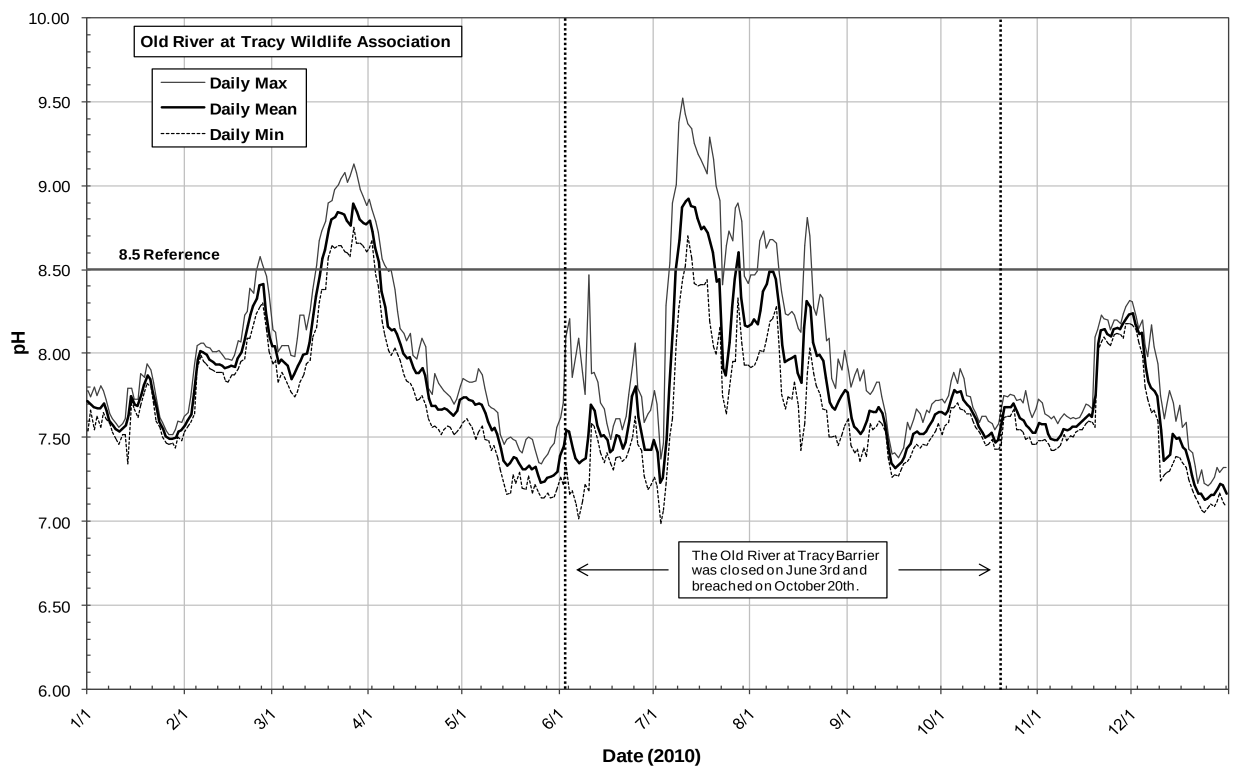
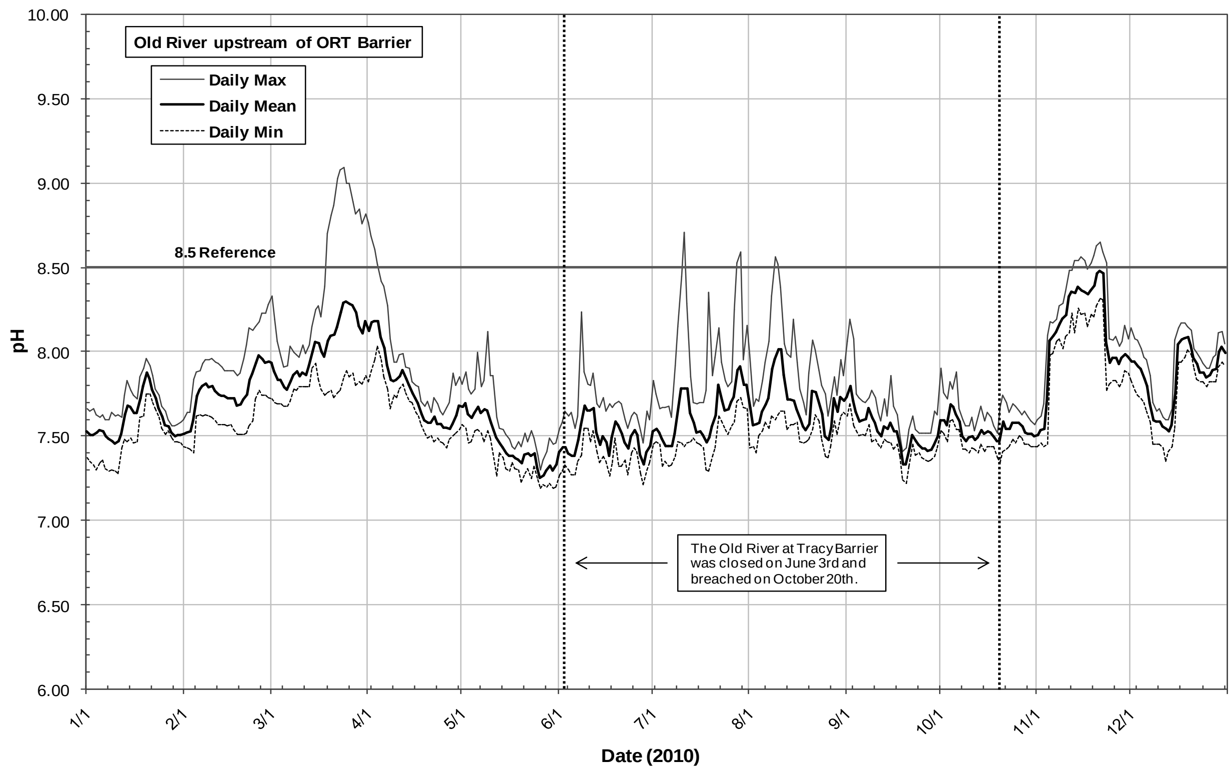


Figure 6-20. Daily pH Time-series Graphs for the Old River Stations



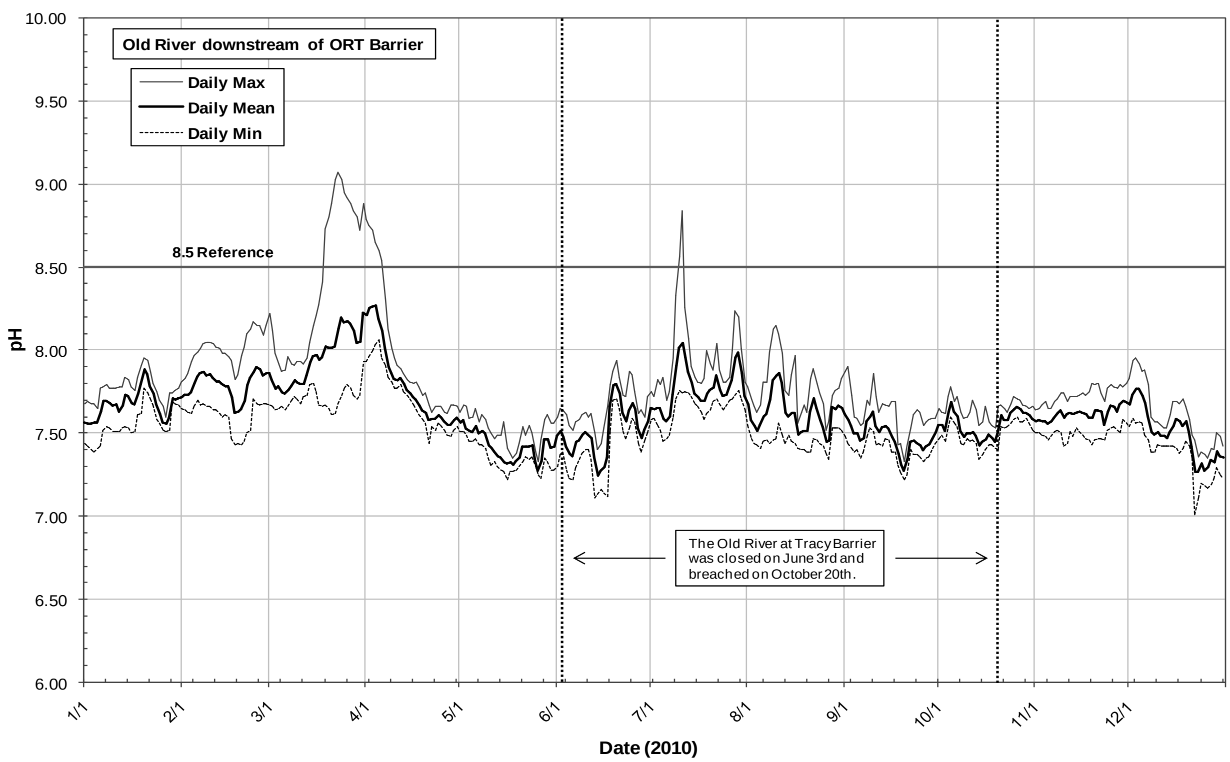
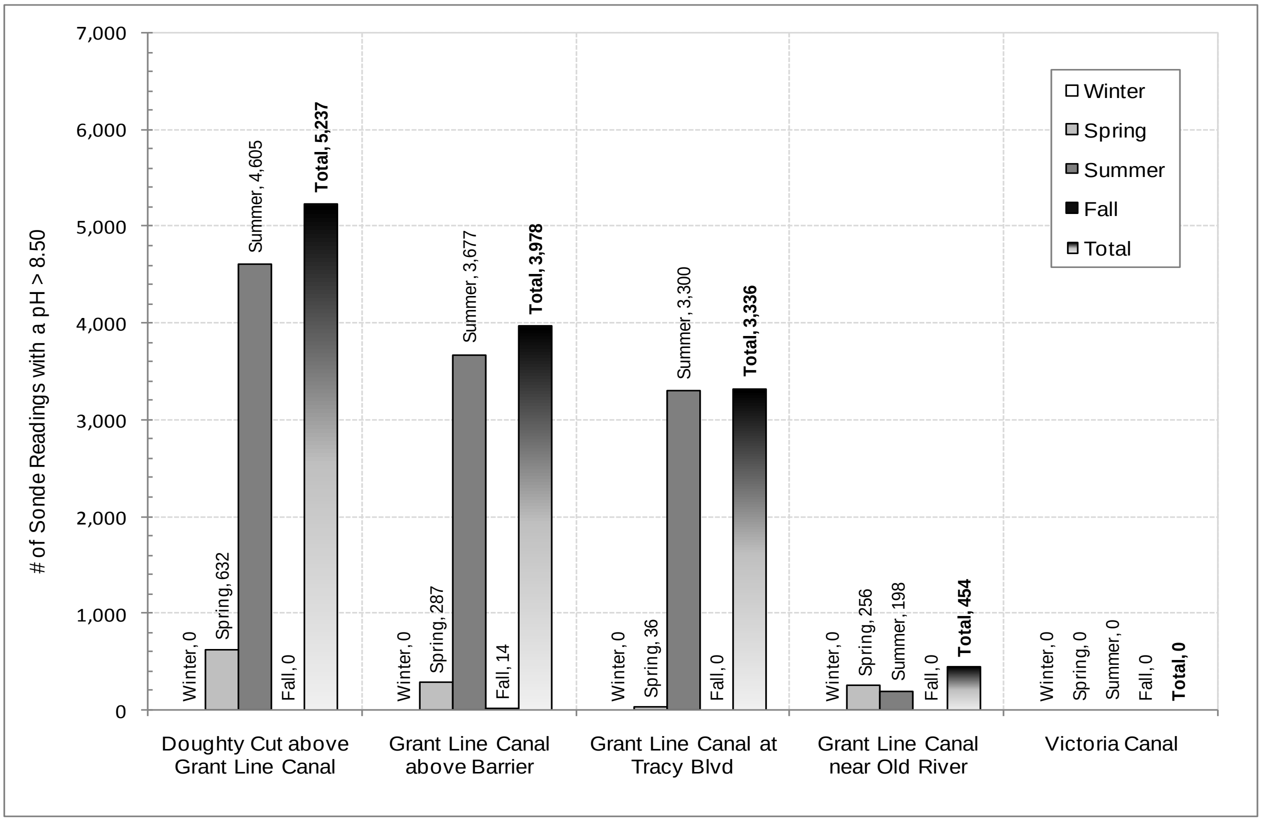


Figure 6-20 (cont.). Daily pH Time-series Graphs for the Old River Stations



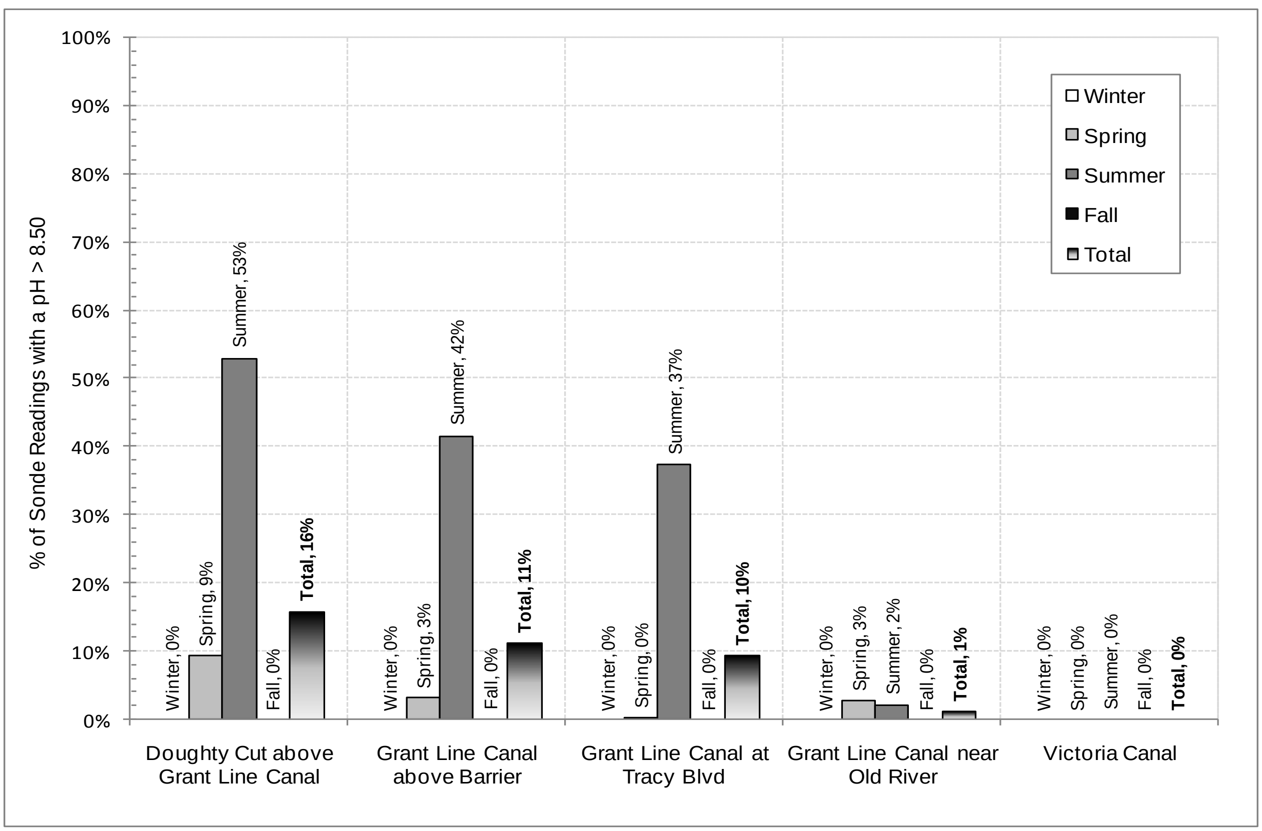


Figure 6-21. pH Standard Exceedences for the Grant Line and Victoria Canal Stations

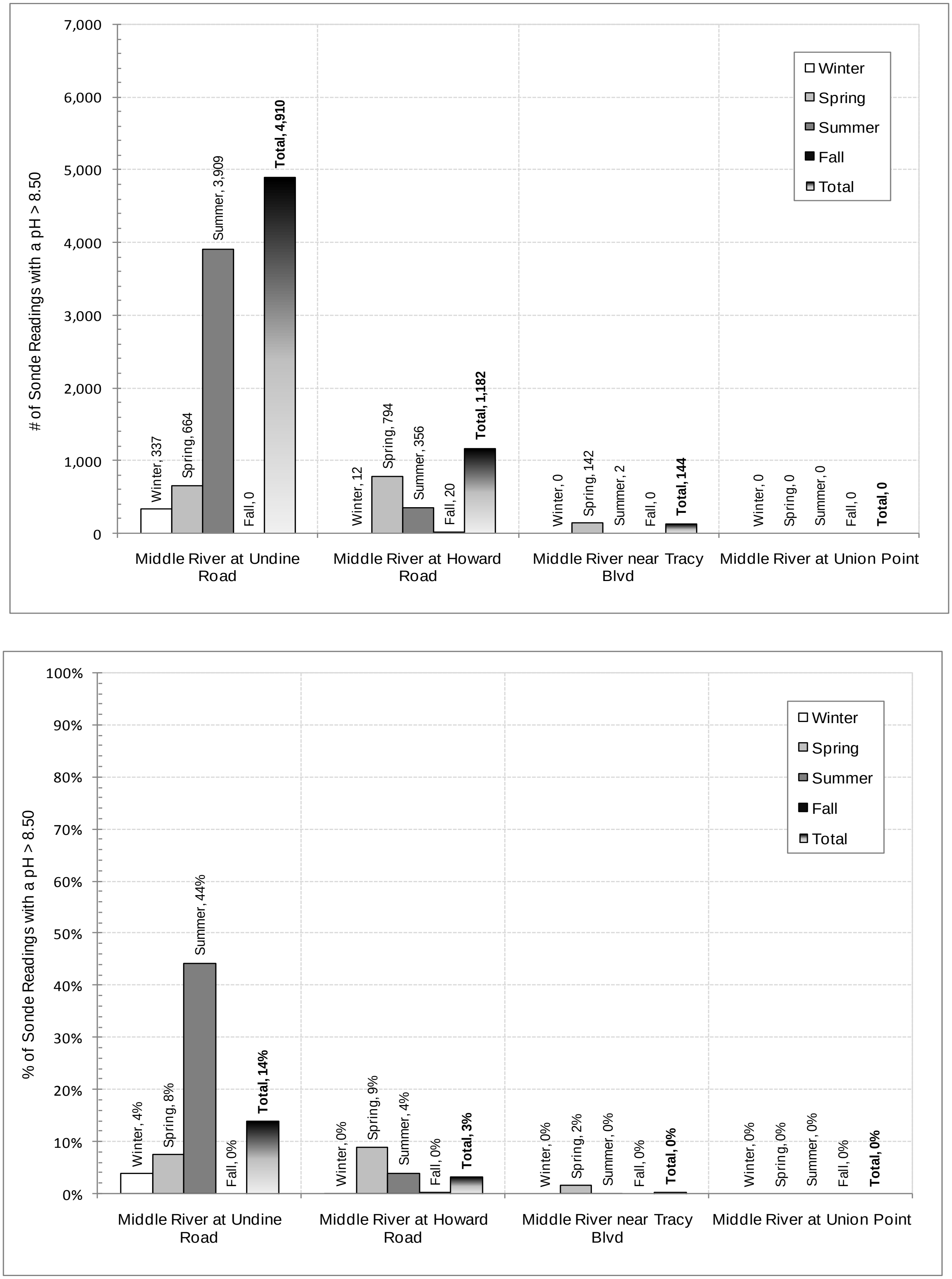
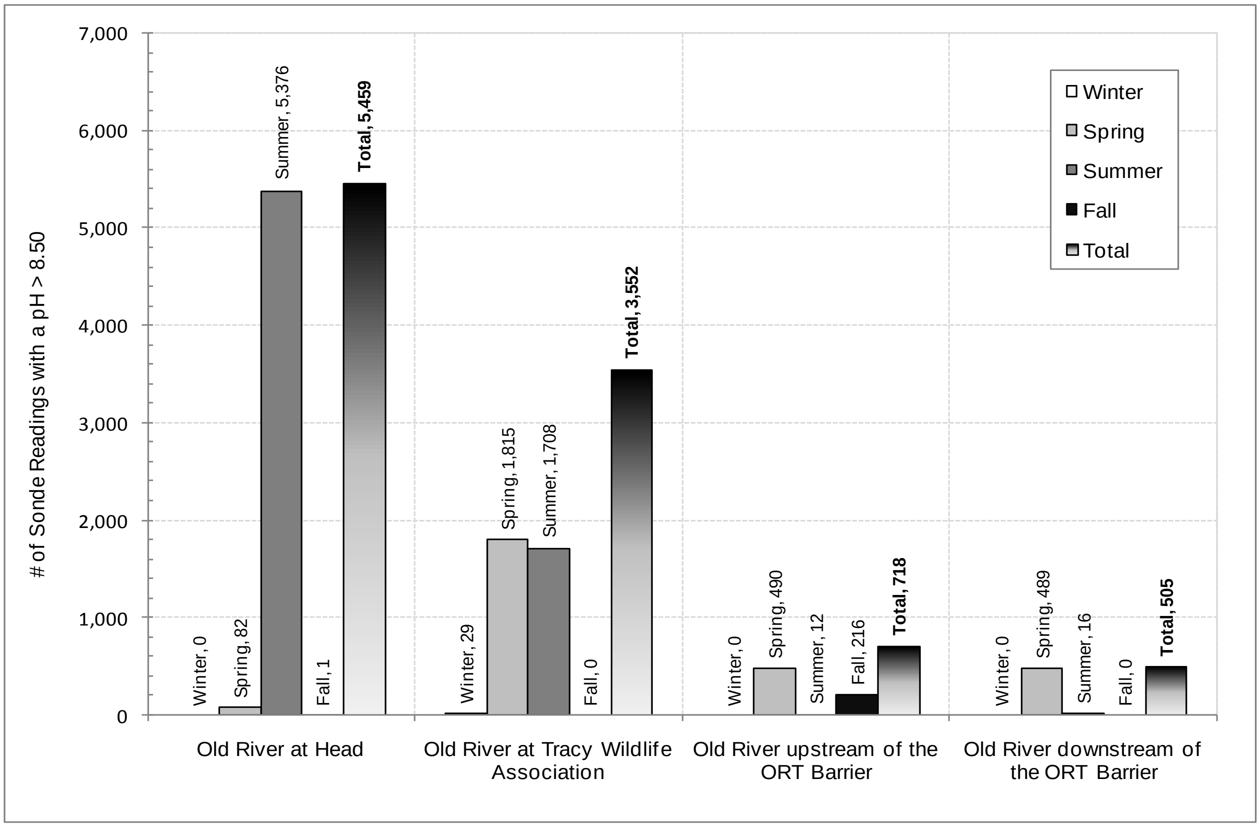


Figure 6-22. pH Standard Exceedences for the Middle River Stations



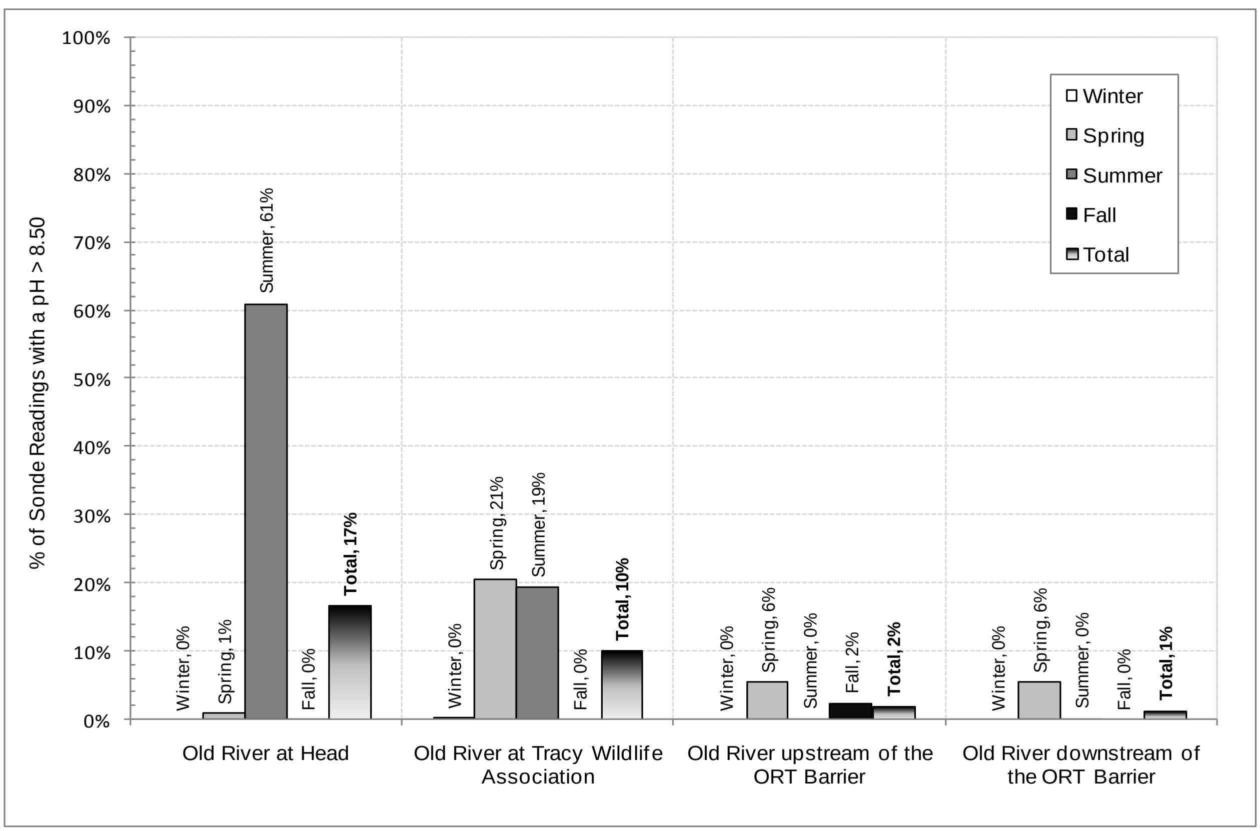


Figure 6-23. pH Standard Exceedences for the Old River Stations

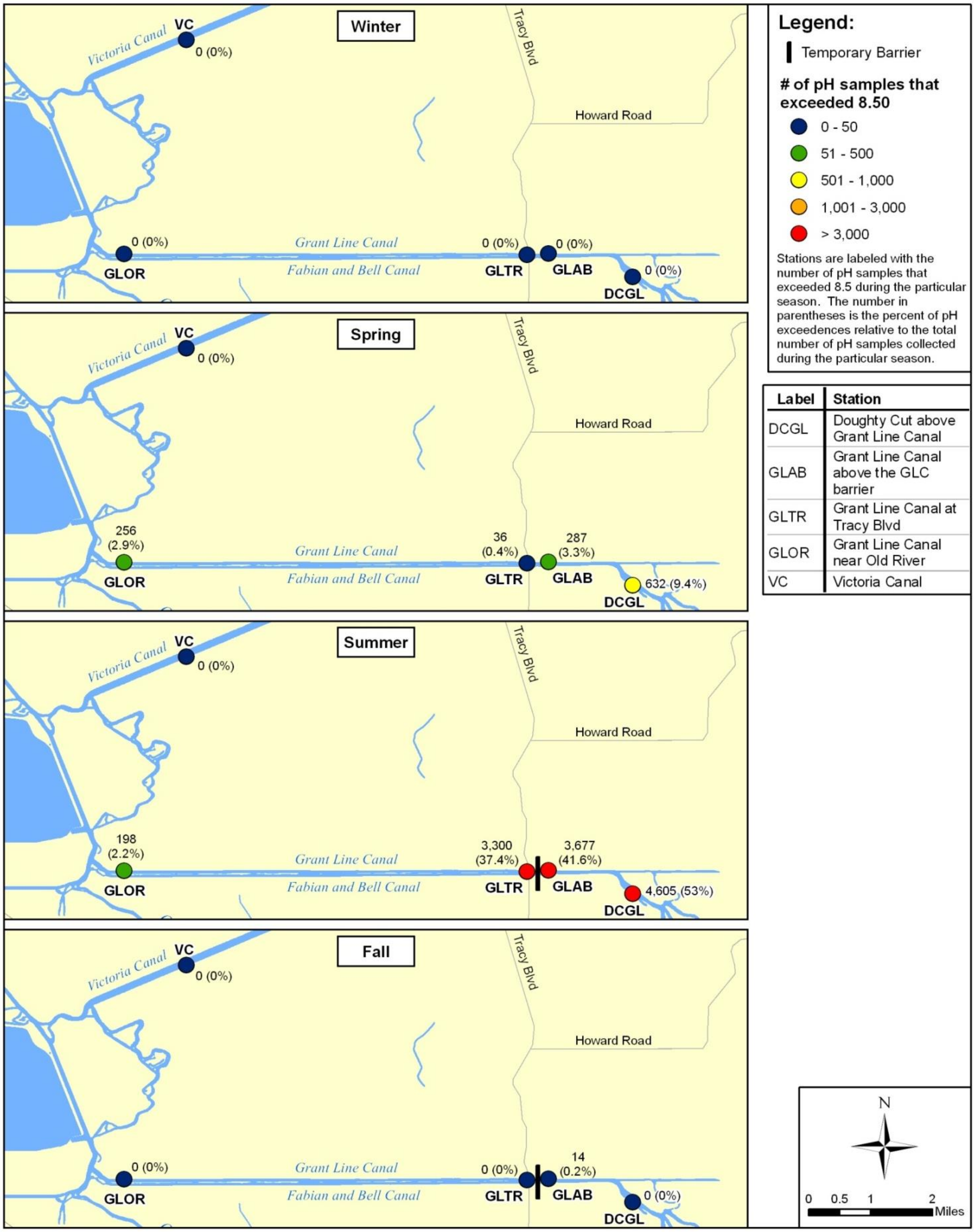


Figure 6-24. Map of pH Standard Exceedences for the Grant Line and Victoria Canal Stations

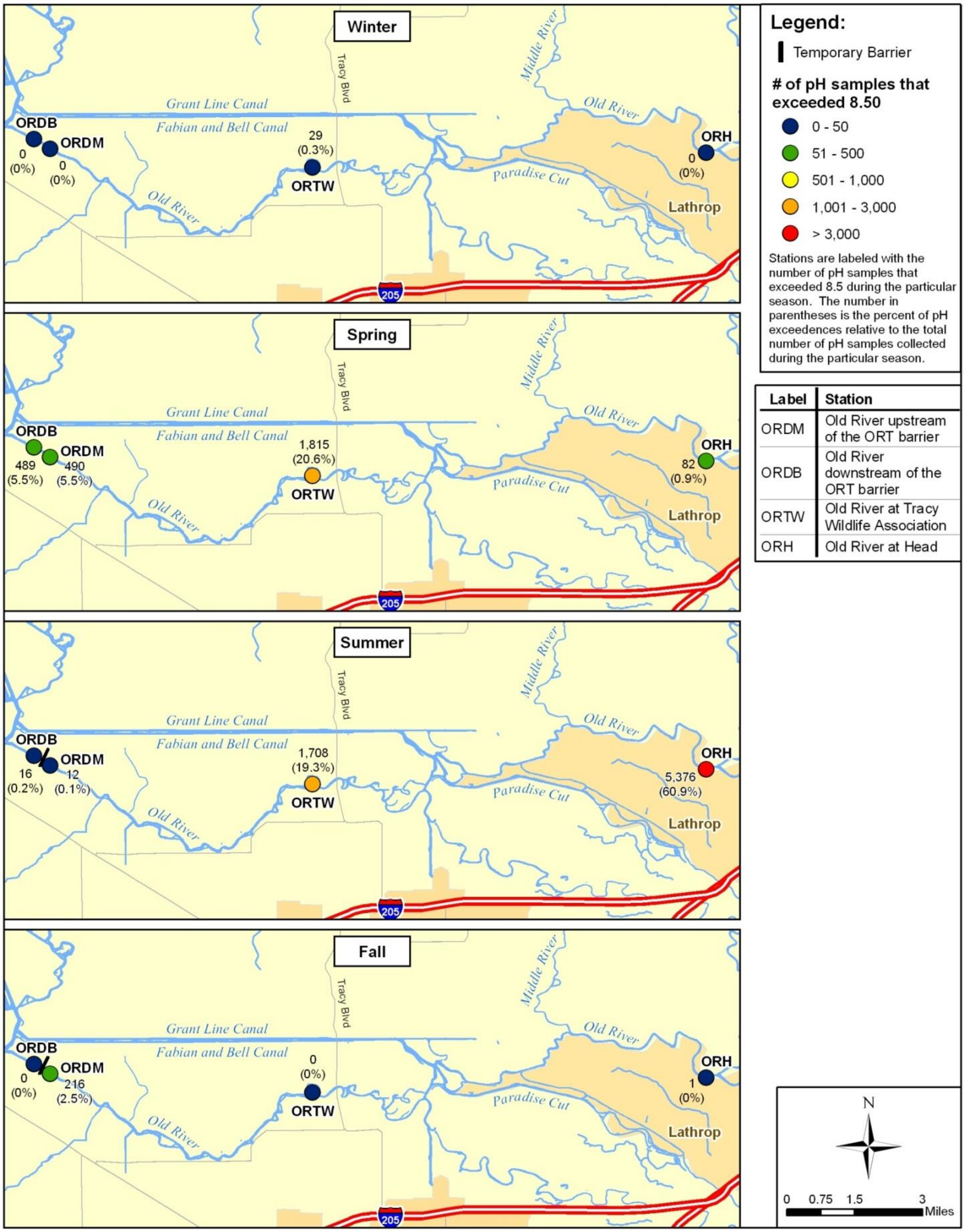


Figure 6-25. Map of pH Standard Exceedences for the Middle River Stations

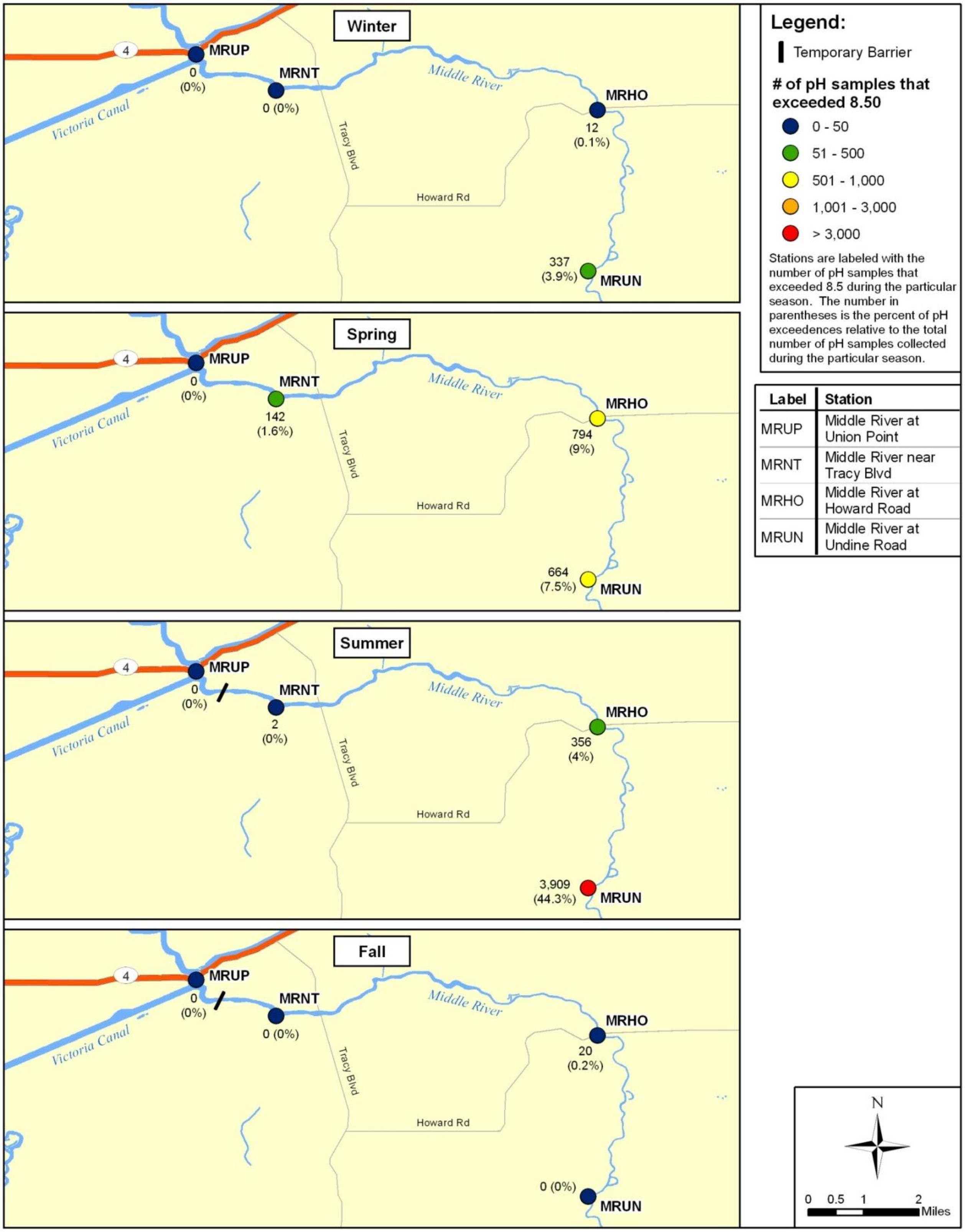


Figure 6-26. Map of pH Standard Exceedences for the Old River Stations

Specific Conductance

Conductivity is a measure of the ability of an aqueous solution to carry an electrical current (APHA, 2005). Specific conductance values are temperature compensated to 25 ºC and can be used to estimate salinity and total dissolved solids (Wagner et al., 2006). Specific conductance is of vital importance in the South Delta because the water is used for irrigation. High amounts of dissolved salts in irrigation water can result in crop damage and reduced yield. Specific conductance data measured at various locations along a particular water body can be used to determine if a major input of water with a different conductivity enters the system between the locations; a significant difference at one or more locations could indicate that the water nearby these sites comes from a different source composition.

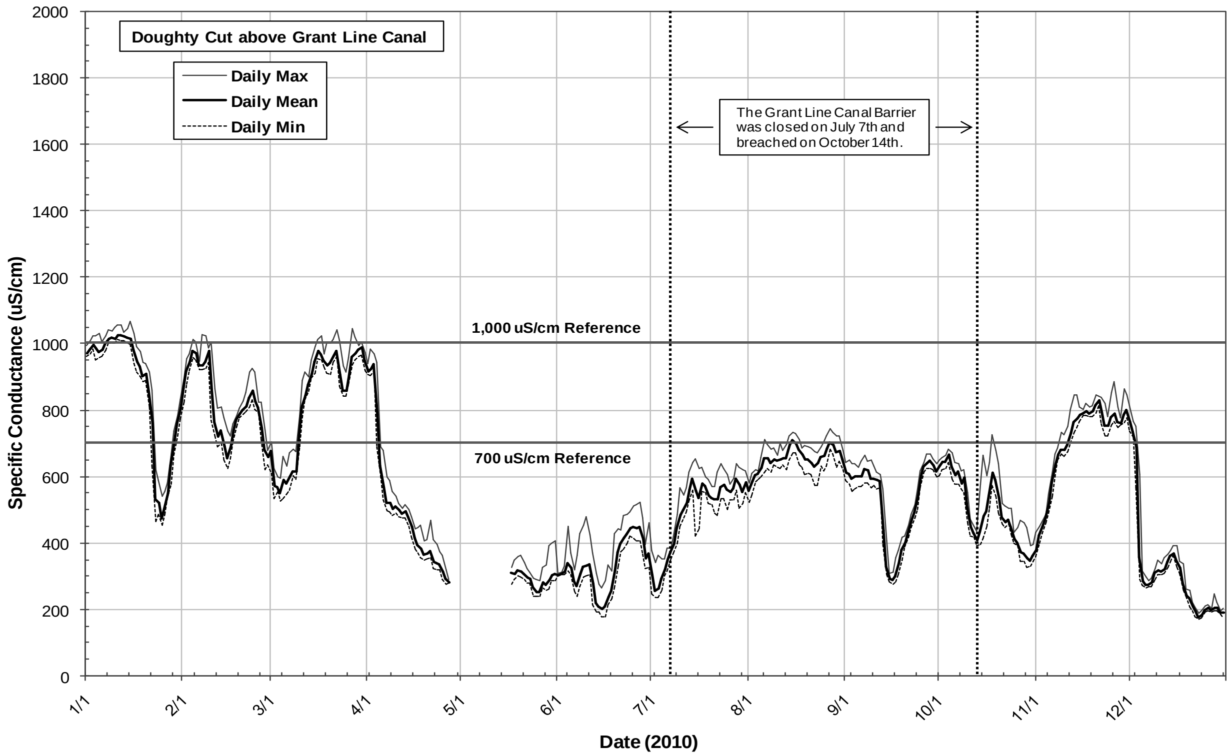
Tables 6-10, 6-11, 6-12, and 6-13 provide monthly summary statistics for the Grant Line Canal, Victoria Canal, Middle River, and Old River stations, respectively. In addition, Figures 6-27, 6-28, and 6-29 illustrate the daily maximums, minimums, and averages for the Grant Line and Victoria Canal, Middle River, and Old River stations, respectively. Generally, the specific conductance values during the 2010 monitoring period at the South Delta stations were higher in the winter and fall and lower in the spring and summer. At most of the stations, there was an obvious decrease in specific conductance values in mid-April to mid-July. This was most likely a result of greater spring and early summer snowmelt and higher flows in the lower San Joaquin River in April and May due to the Vernalis Adaptive Management Plan[9]. There was also a significant decrease in specific conductance values at most of the stations during December 2010, which was probably due to the moderate rains that occurred during late November through December.

The State Water Resources Control Board has specific conductivity objectives for 3 sites in the South Delta: San Joaquin River at Brandt Bridge, Old River near Middle River, and Old River at Tracy Road Bridge. The 30-day running average for these sites should not exceed 700 µS/cm from April 1 -August 31 and 1,000 µS/cm from September 1-March 31.

April through August 2010 – Agricultural Season. The maximum recorded specific conductance during this time period was 1,495 µS/cm on April 2 at Middle River at Howard Road; and the minimum was 170 µS/cm on June 15 at Old River at Head (see Tables 6-10 to 6-13). Monthly mean values for this period ranged from 203 µS/cm in July at Middle River at Union Point to 742 µS/cm in August at Old River upstream of the ORT barrier. Three of the 13 continuous monitoring sites, Old River at Tracy Wildlife Association and the Old River upstream and downstream of the ORT barrier stations, had one month (August) where specific conductance averaged 700 µS/cm or higher during this period.

January-March 2010 and September-December 2010. The maximum recorded specific conductance during this time period was 1,952 µS/cm on February 2 at Middle River at Howard Road, and the minimum was 170 µS/cm on December 31 at Old River at Head (see Tables 6-10 to 6-13). Monthly mean values for this period ranged from 296 µS/cm at Old River at Head to 1,351 µS/cm at Middle River at Howard Road. Only one of the 13 continuous monitoring sites, Middle River at Howard Road, had at least one month where specific conductance averaged 1,000 µS/cm or higher during this time period. Mean conductance values were greater than 1,000 µS/cm in February and March at this station. The lowest monthly mean conductance values throughout this time period were at Middle River at Union Point and Victoria Canal.

[9] The Vernalis Adaptive Management Plan (VAMP) is a long-term program designed to protect migrating juvenile Chinook salmon in the South Delta. The plan includes increasing the flow in the lower San Joaquin River from April through May by releasing more water from upstream reservoirs.



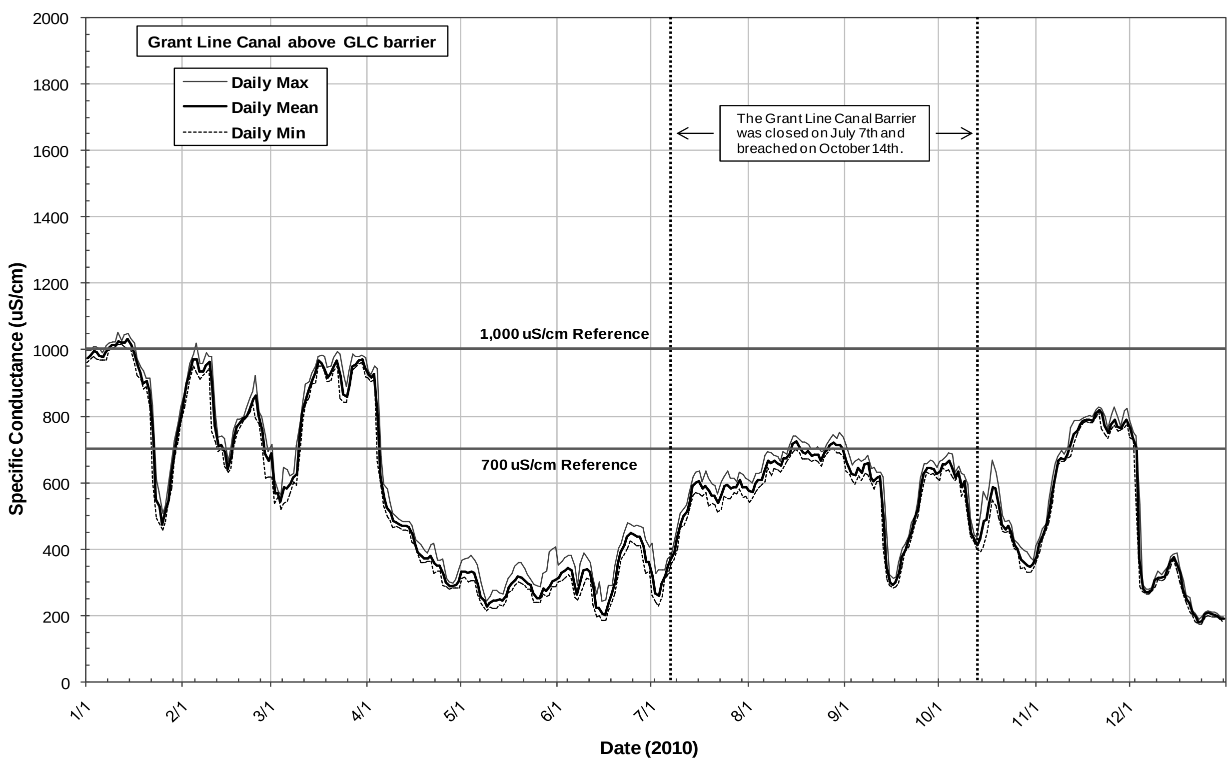
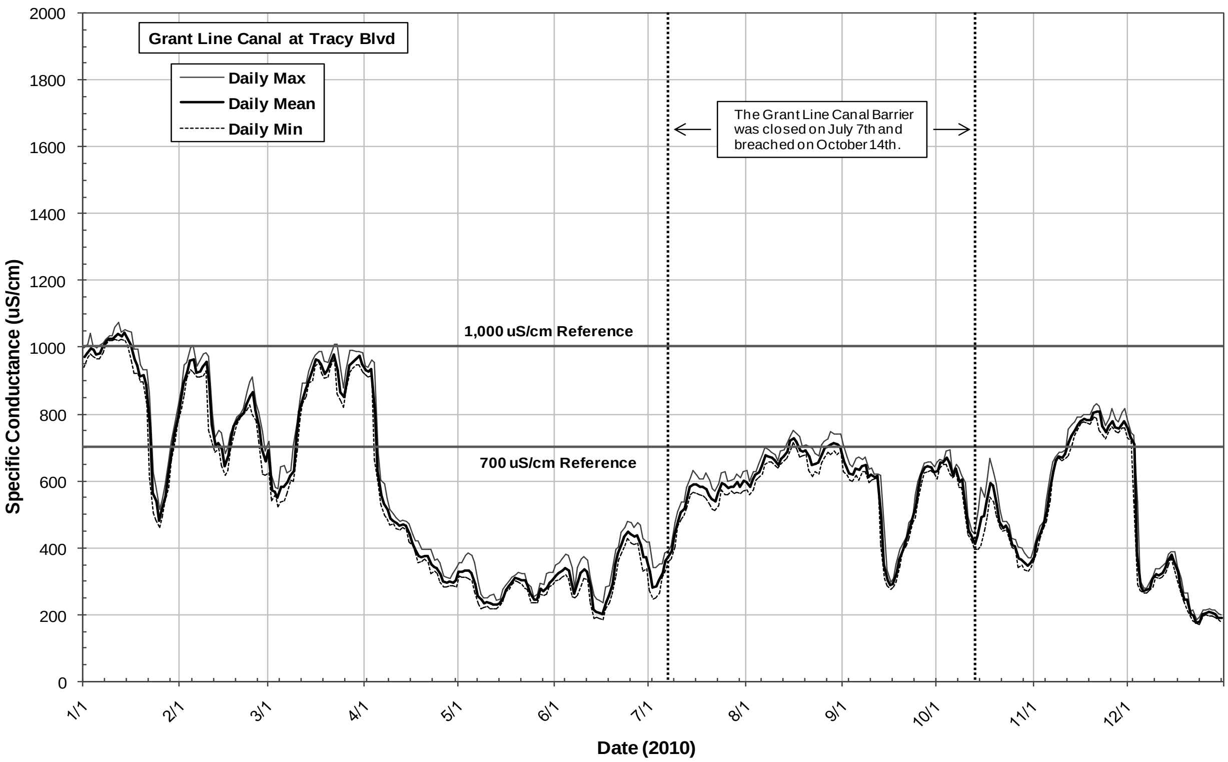


Figure 6-27. Daily Specific Conductance Time-series Graphs for the Grant Line and Victoria Canal Stations



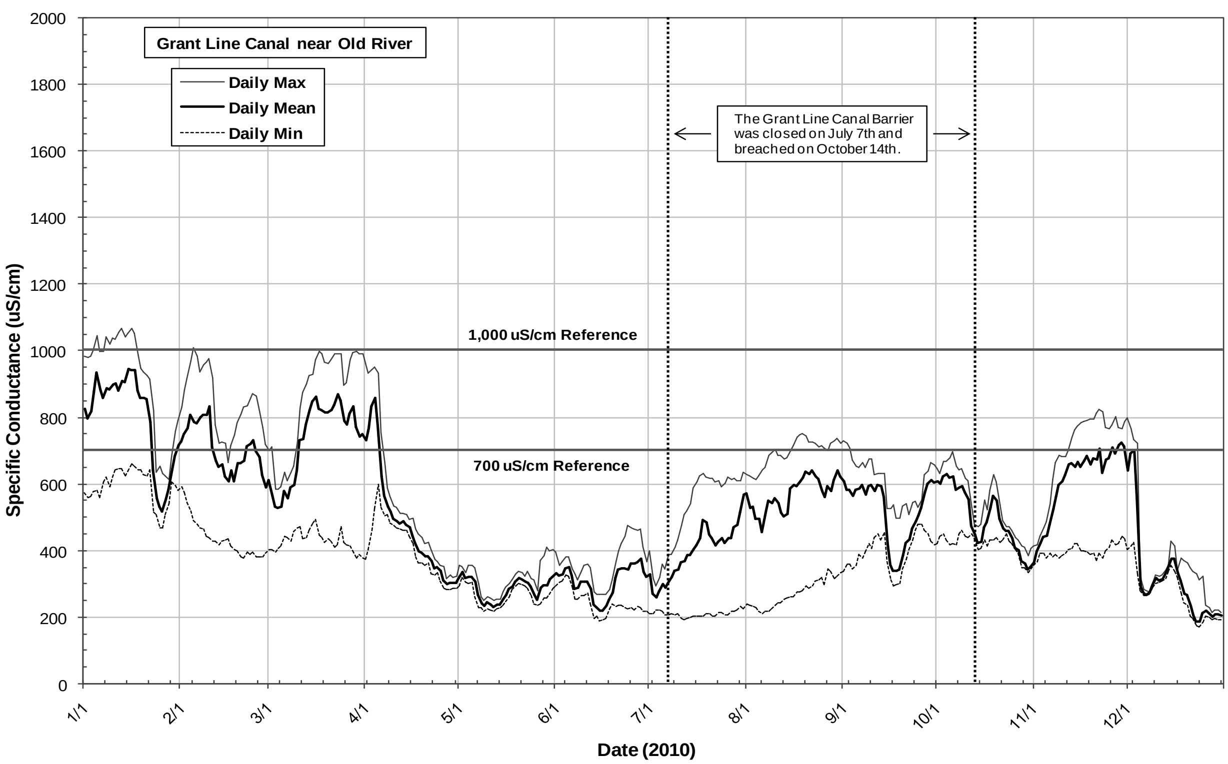


Figure 6-27 (cont.). Daily Specific Conductance Time-series Graphs for the Grant Line and Victoria Canal Stations

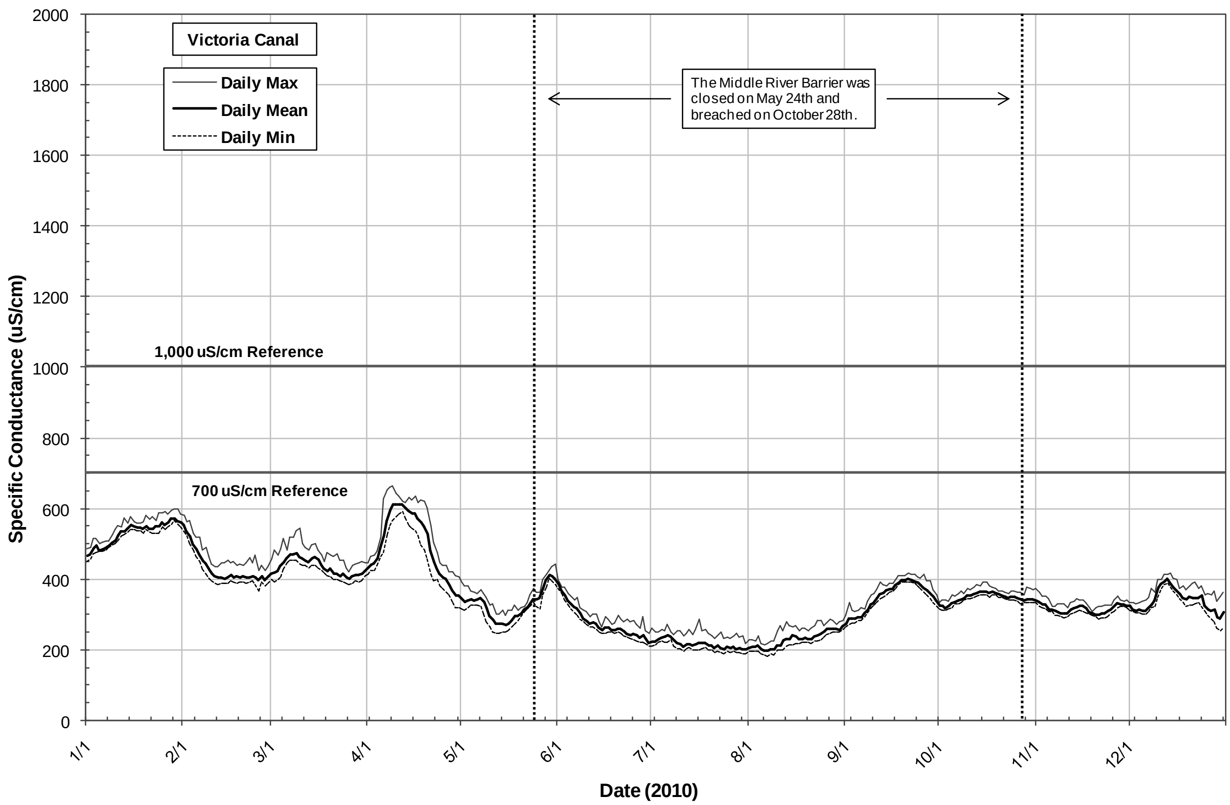
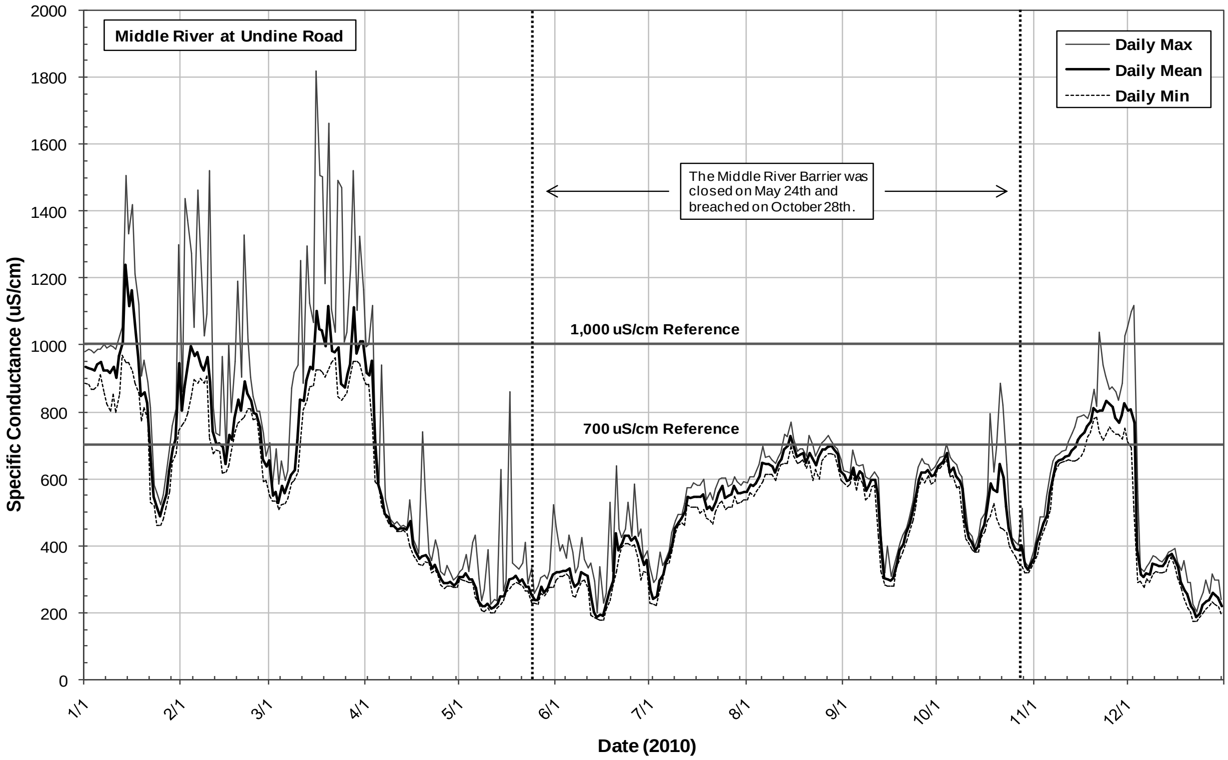


Figure 6-27 (cont.). Daily Specific Conductance Time-series Graphs for the Grant Line and Victoria Canal Stations



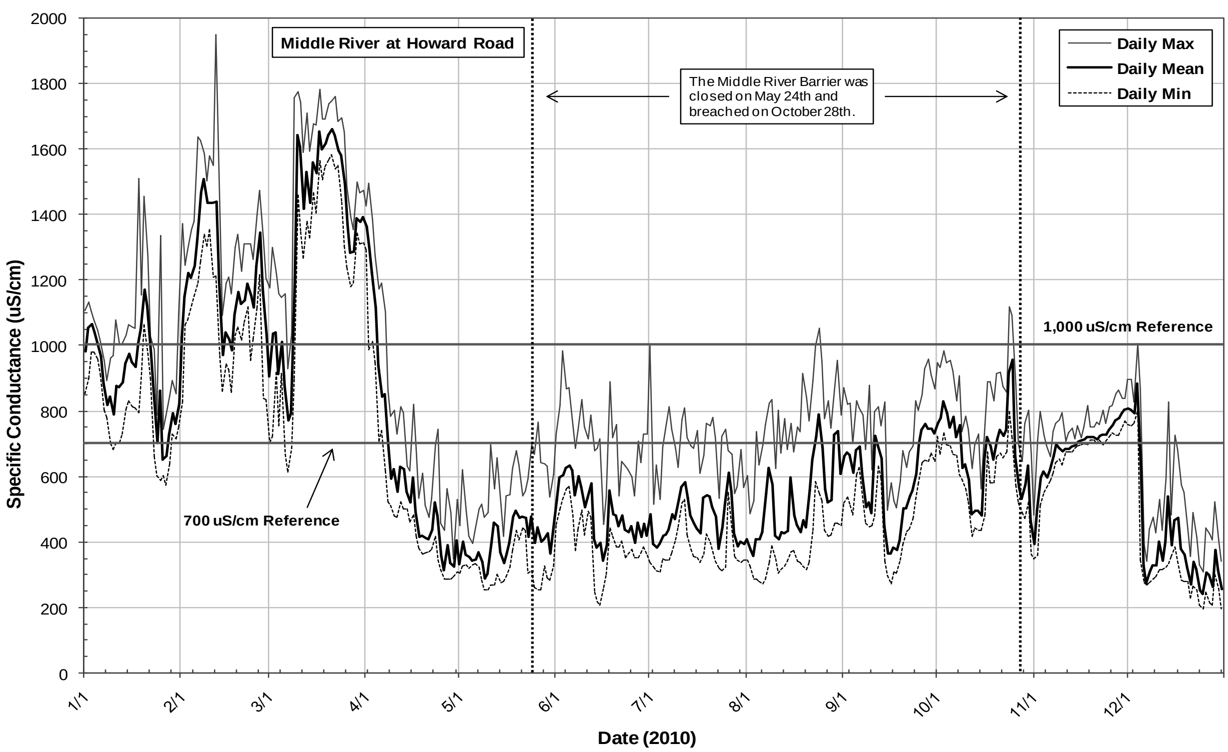
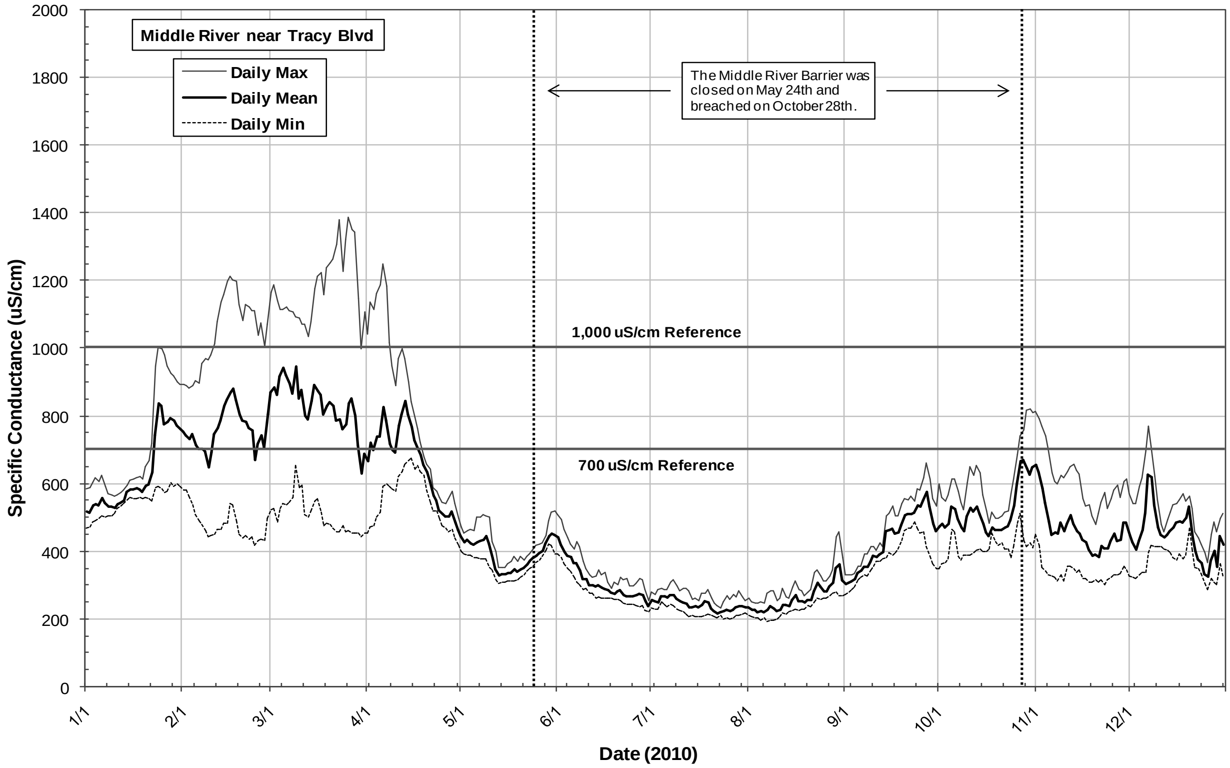


Figure 6-28. Daily Specific Conductance Time-series Graphs for the Middle River Stations



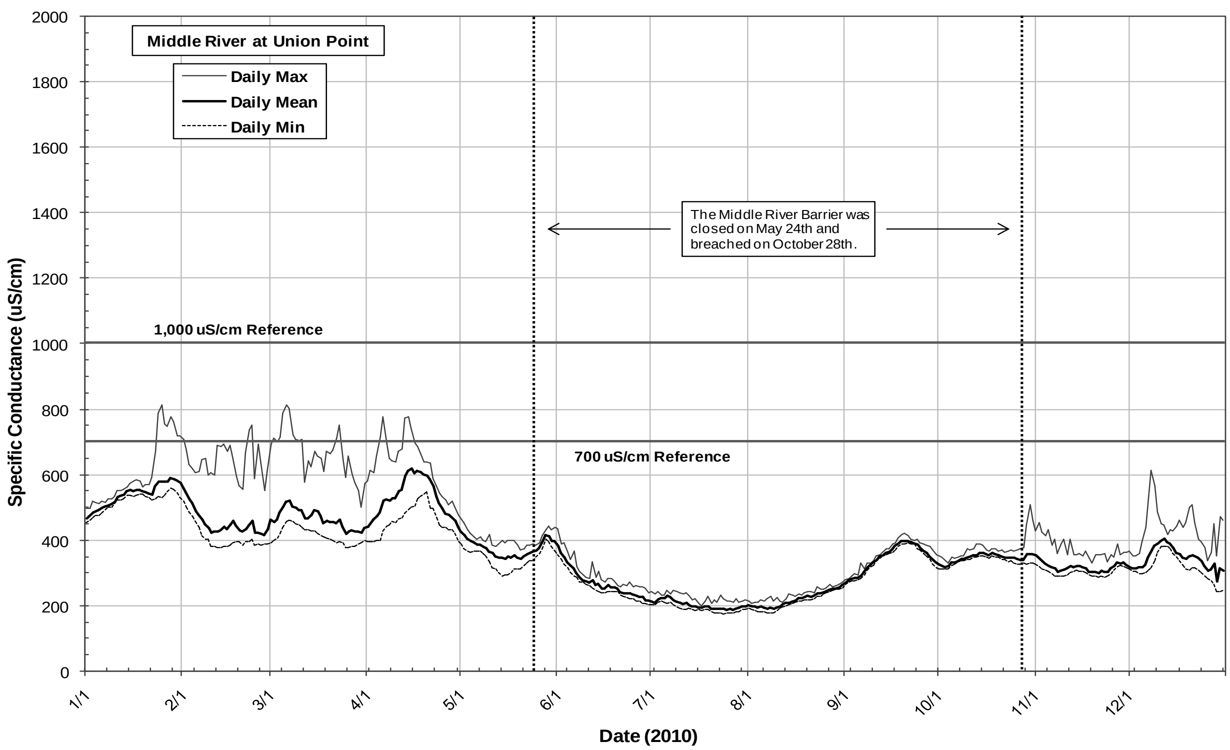
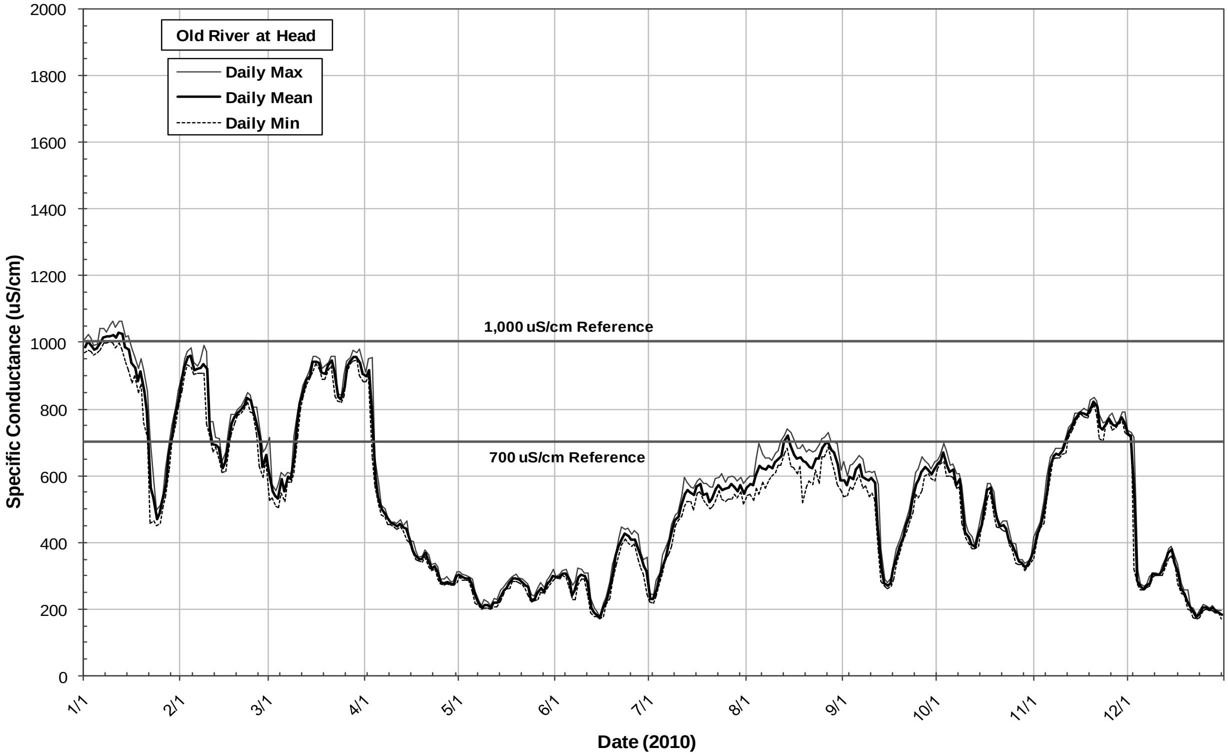


Figure 6-28 (cont.). Daily Specific Conductance Time-series Graphs for the Middle River Stations



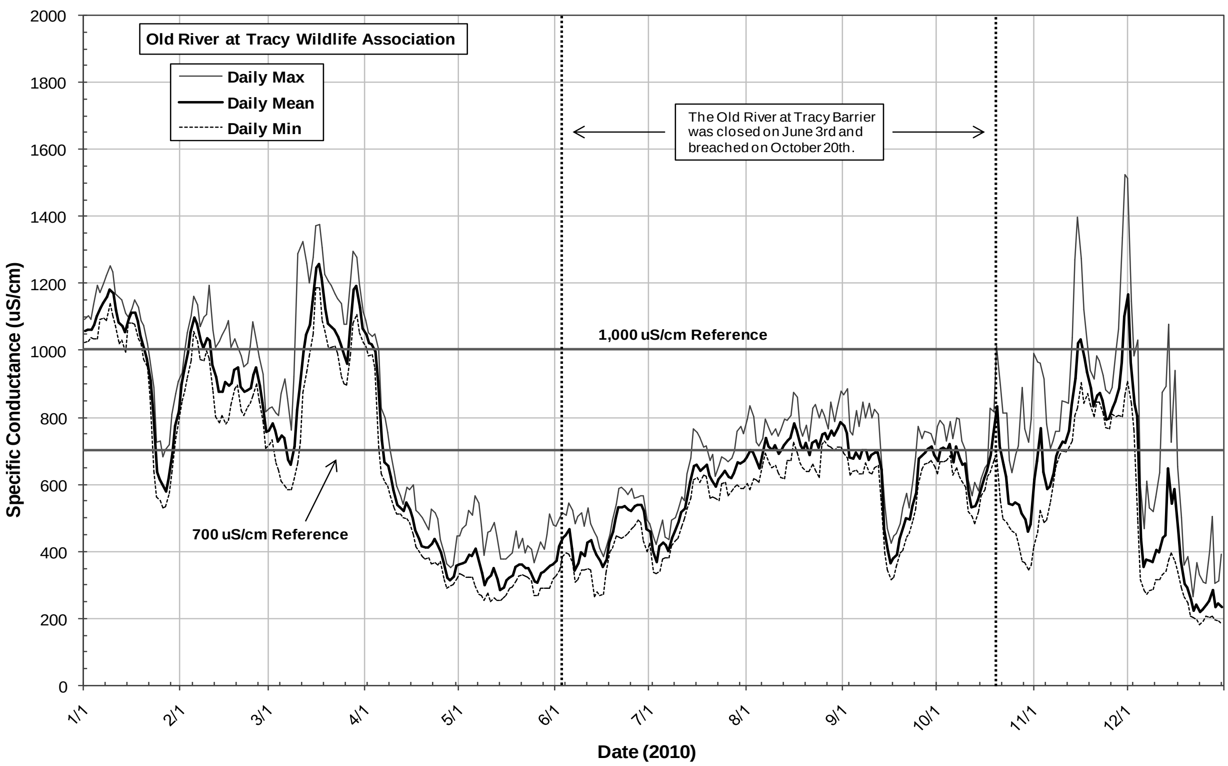
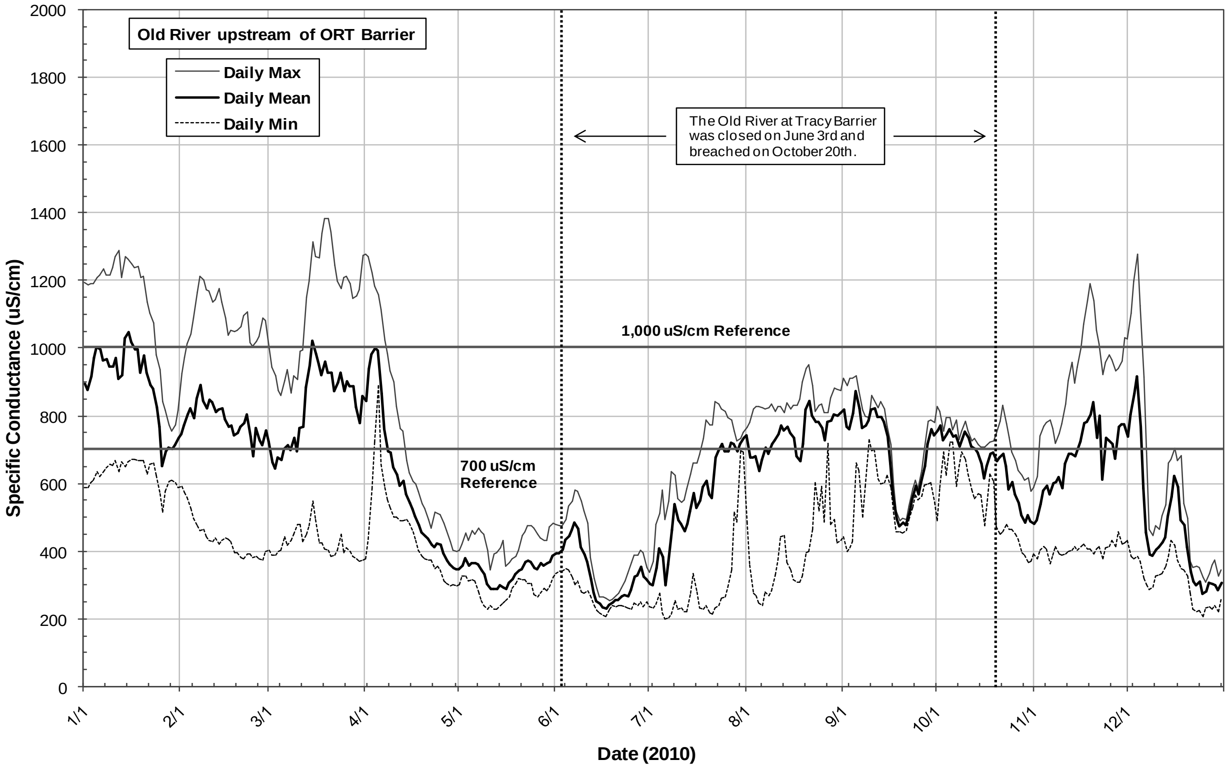


Figure 6-29. Daily Specific Conductance Time-series Graphs for the Old River Stations



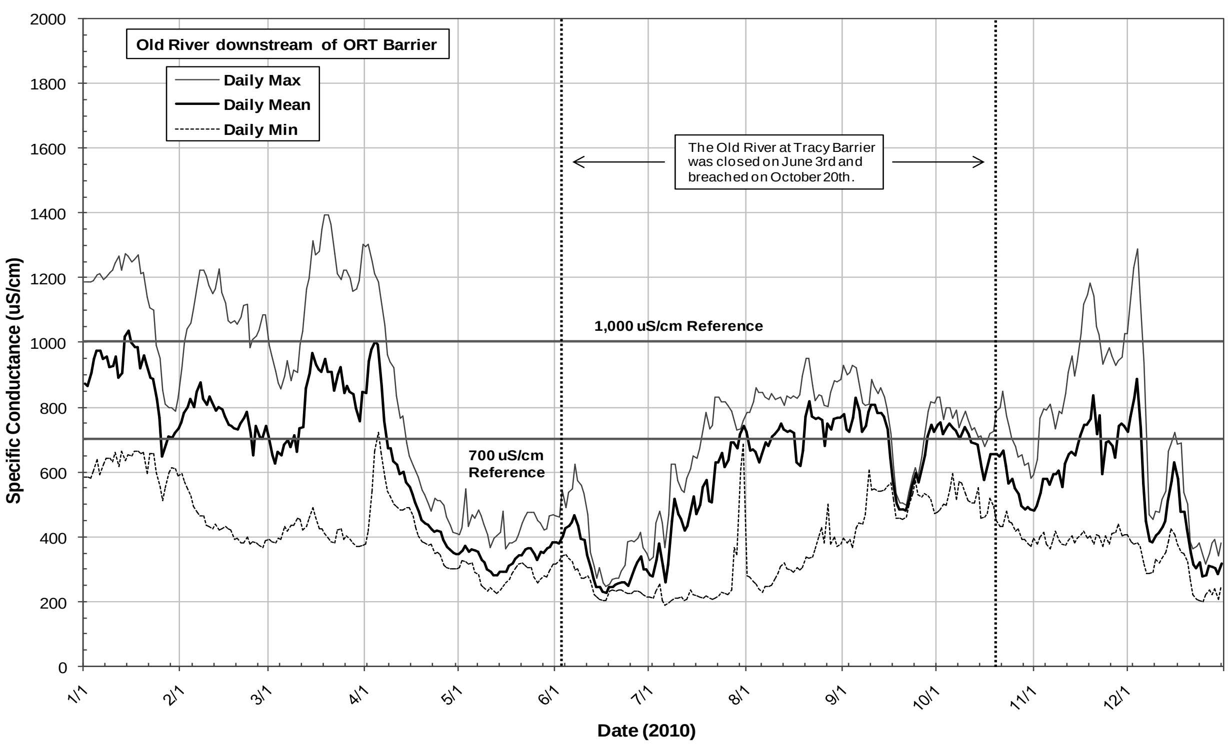
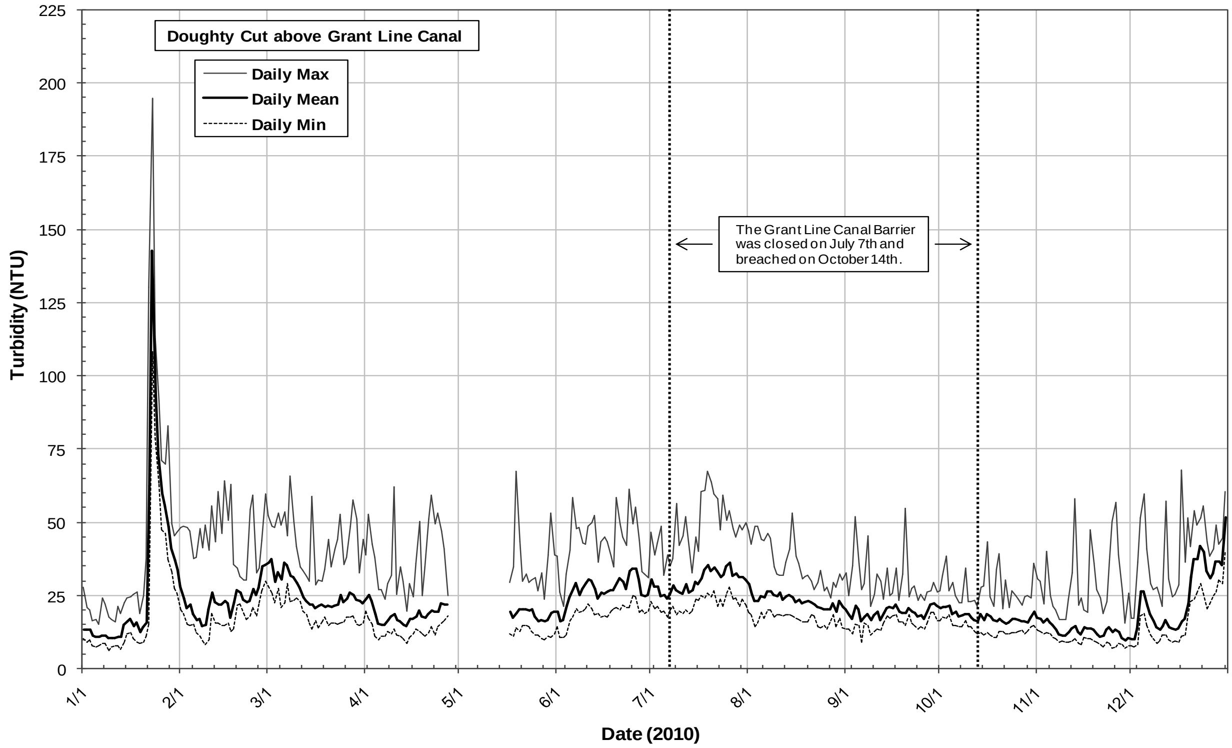


Figure 6-29 (cont.). Daily Specific Conductance Time-series Graphs for the Old River Stations

Turbidity

Turbidity in water is caused by suspended matter, such as clay, silt, organic and inorganic matter, plankton, and other microscopic organisms (APHA, 2005). Turbidity is an expression of the optical property that causes light to be scattered and absorbed rather than transmitted in straight lines through the sample (APHA, 2005). In surface waters with reduced water clarity, phytoplankton and aquatic plant growth may be adversely affected because of reduced light penetration in the water column.

Turbidity values ranged from a high of 372 NTU on January 22 at Old River at Head to a low of 0 NTU on various occasions at 5 stations (Victoria Canal, Middle River at Howard Road, Middle River near Tracy Blvd, Middle River at Union Point, and Old River downstream of the ORT barrier; see Tables 6-10 to 6-13). Figures 6-30, 6-31, and 6-32 illustrate the daily maximums, minimums, and averages for the Grant Line and Victoria Canal, Middle River, and Old River stations, respectively. Generally, single high turbidity spikes can be attributed to a foreign object, such as a leaf or fish passing before the optic sensors as the instrument is taking a reading. These anomalies are usually flagged as unreliable if a single value is greater than 200 NTU; however, there are times during the year when several continuous readings reveal a true event. At almost every South Delta station, there was a large increase in turbidity values from mid-January to the beginning of February 2010. This was most likely due to a large storm event that caused an increase in suspended sediment in these water bodies. Besides this spike in turbidity, there were no consistent seasonal trends in turbidity values during the remainder of the year at the South Delta stations. The stations with the highest turbidity values in 2010 were Doughty Cut above Grant Line Canal, Middle River at Undine Road, Old River at Head, and Old River at Tracy Wildlife Association. The stations with the lowest values in 2010 were Middle River near Tracy Blvd, Middle River at Union Point, Middle River at Howard Road, and Victoria Canal.



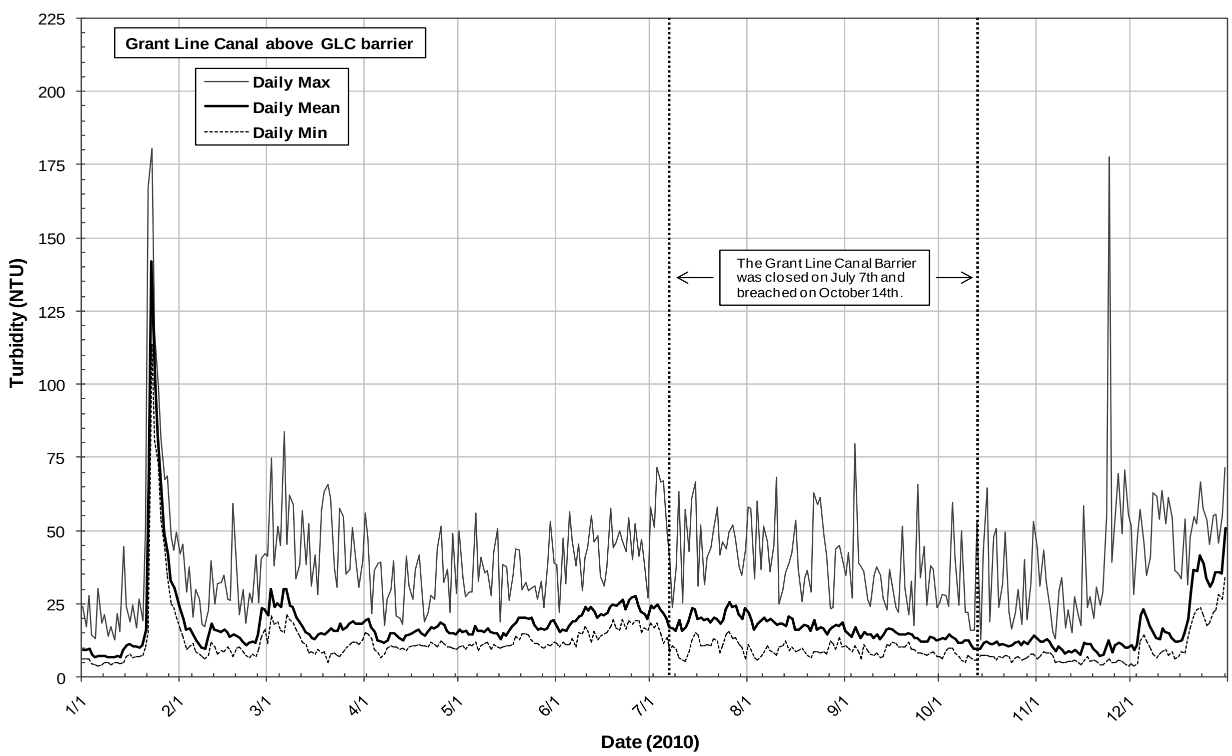
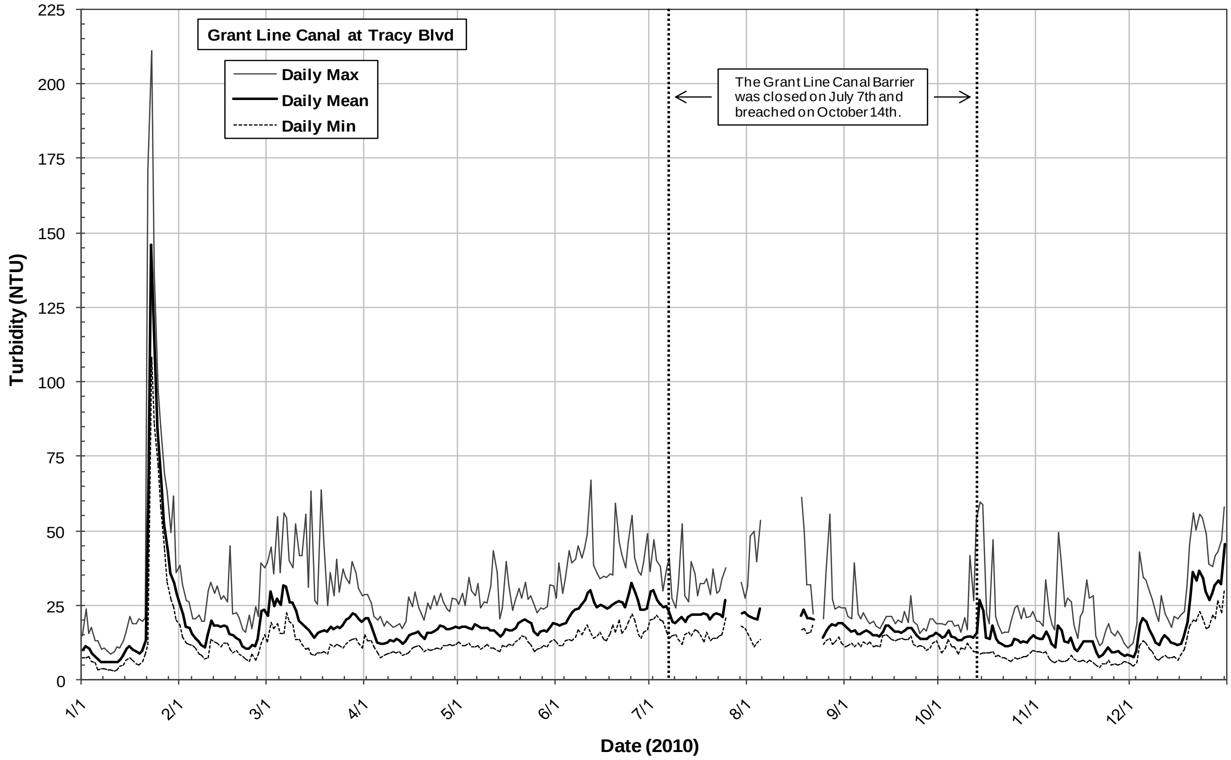


Figure 6-30. Daily Turbidity Time-series Graphs for the Grant Line and Victoria Canal Stations



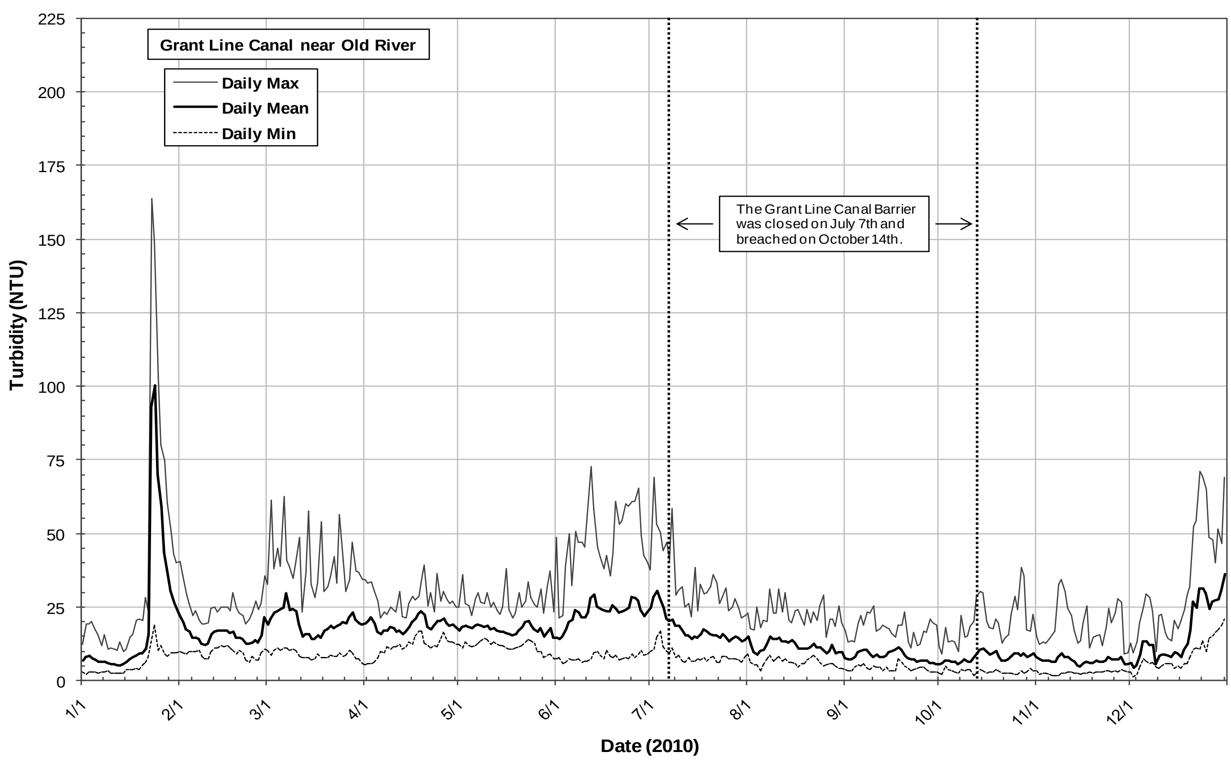


Figure 6-30 (cont.). Daily Turbidity Time-series Graphs for the Grant Line and Victoria Canal Stations

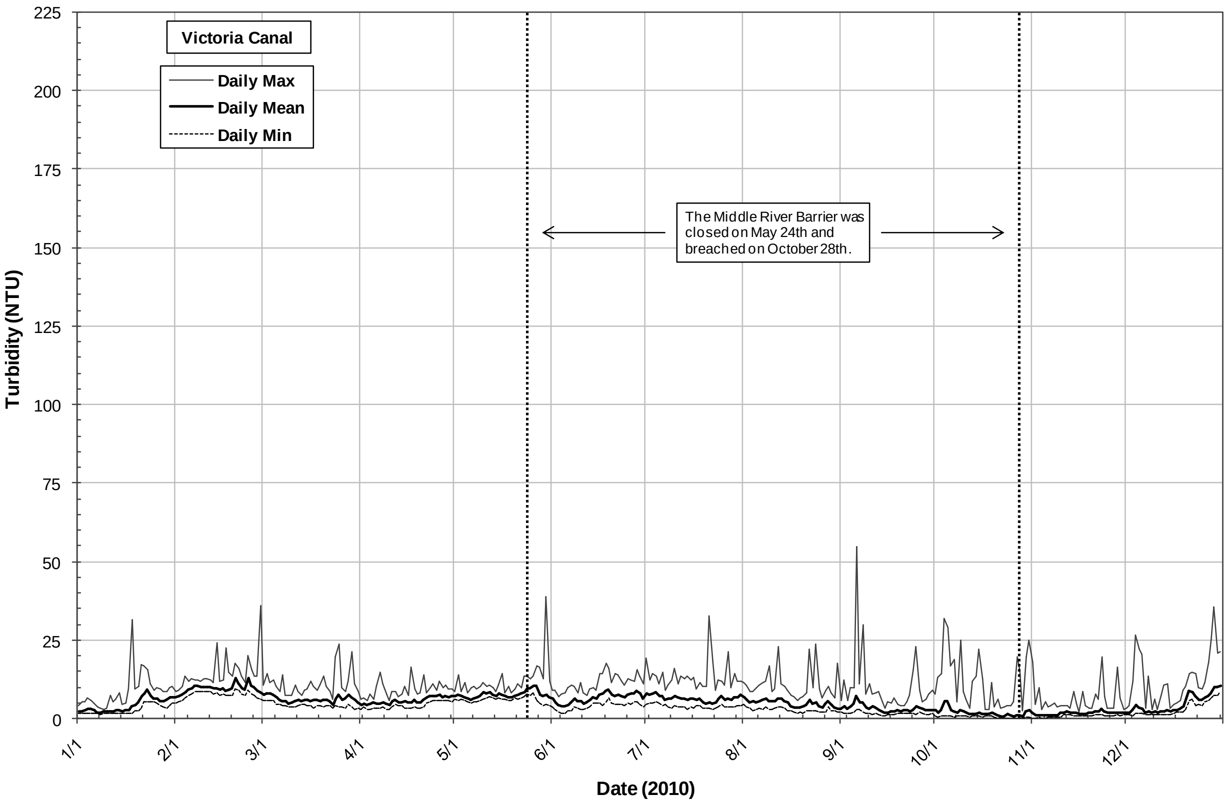
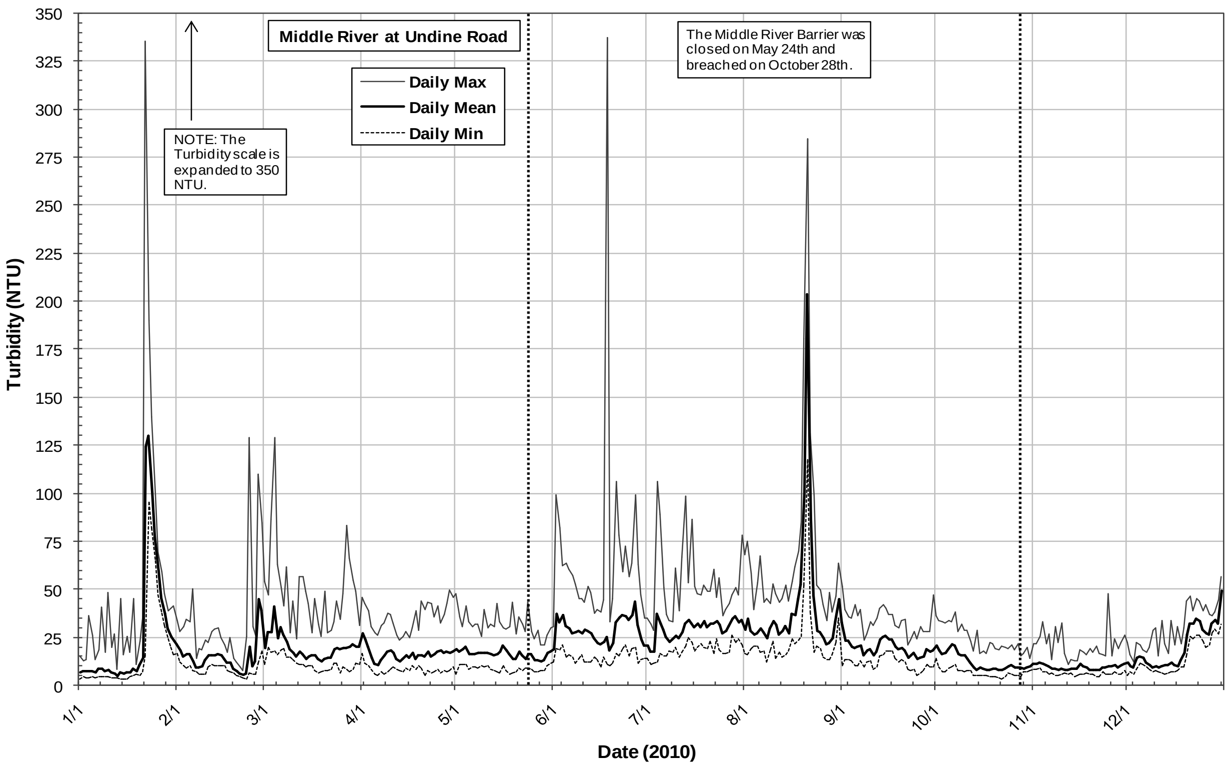


Figure 6-30 (cont.). Daily Turbidity Time-series Graphs for the Grant Line and Victoria Canal Stations



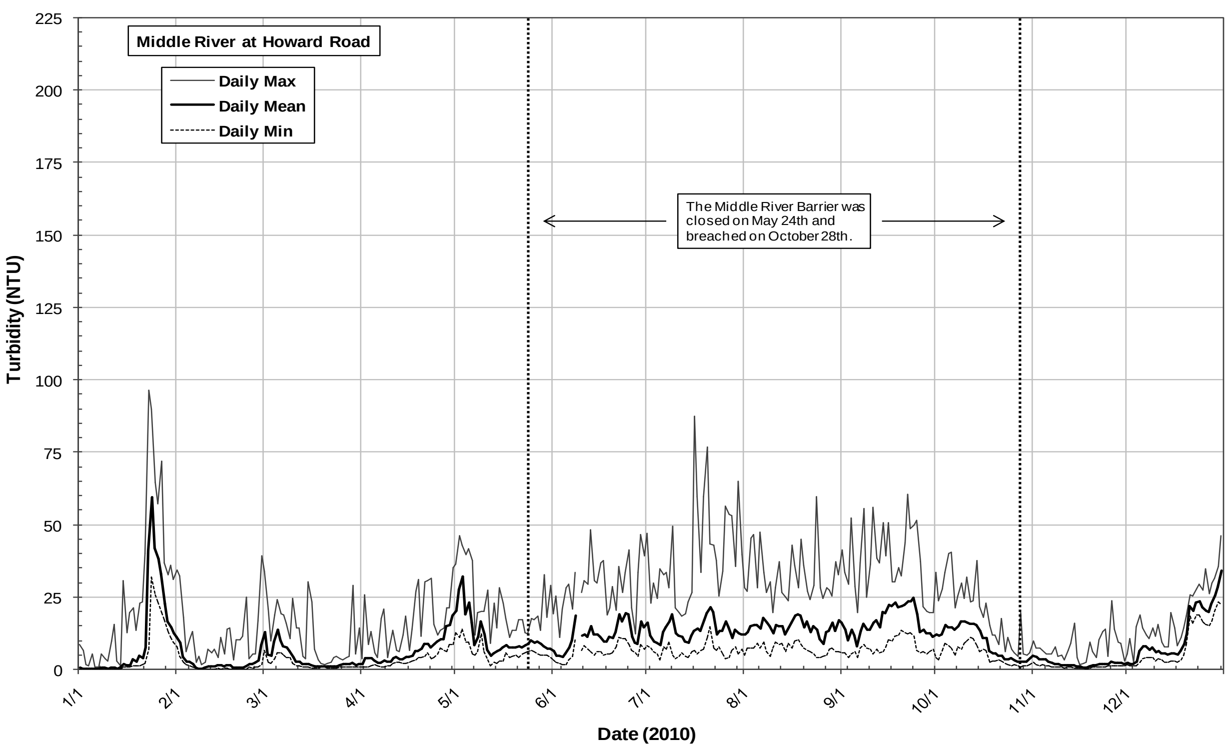
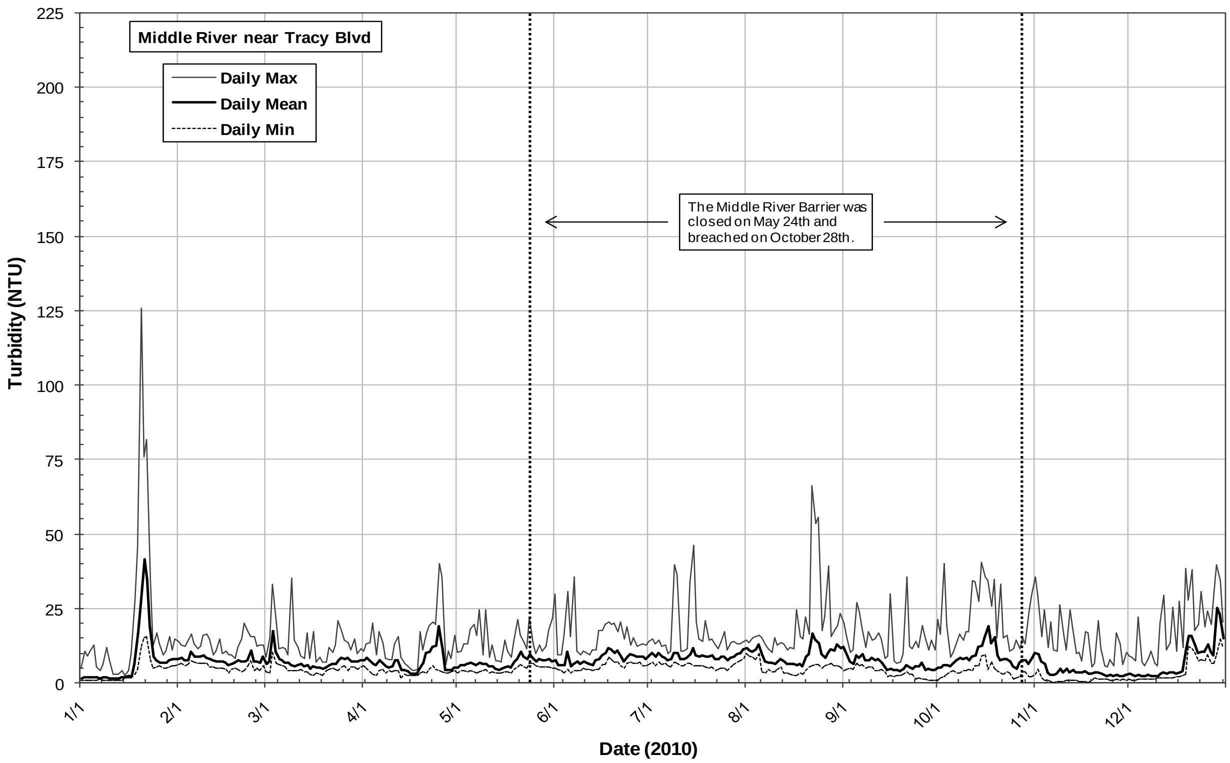


Figure 6-31. Daily Turbidity Time-series Graphs for the Middle River Stations



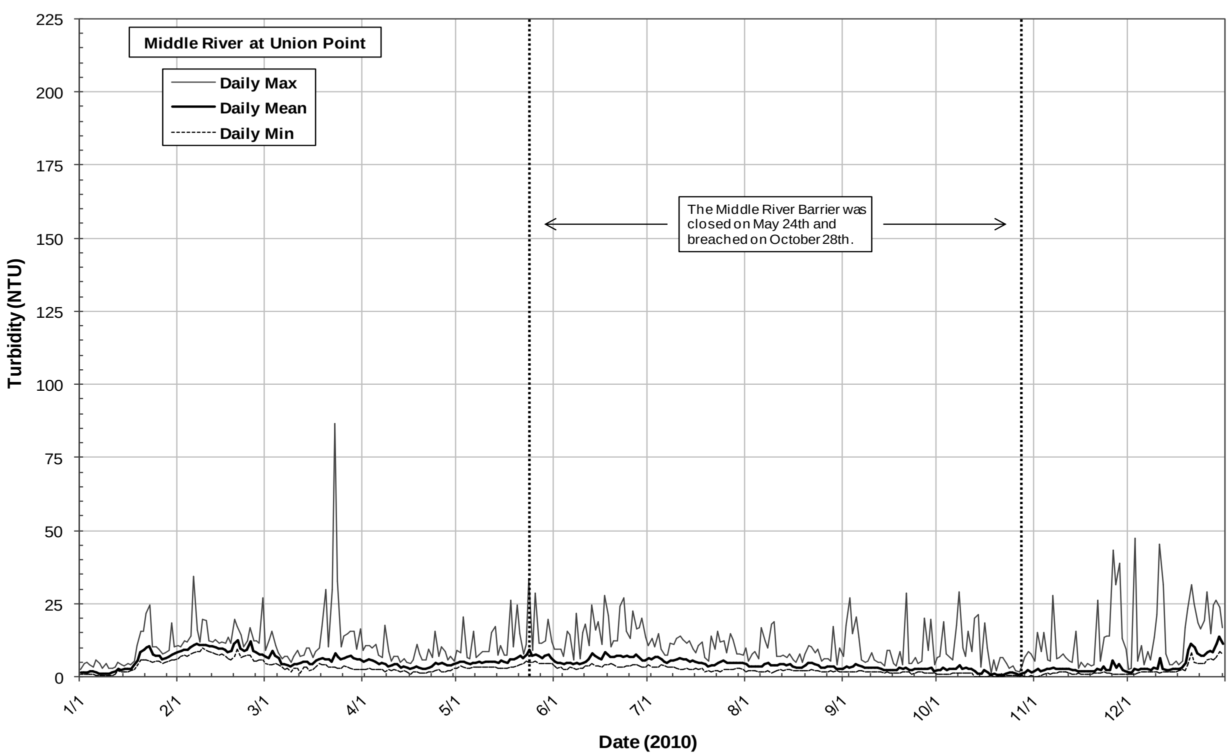
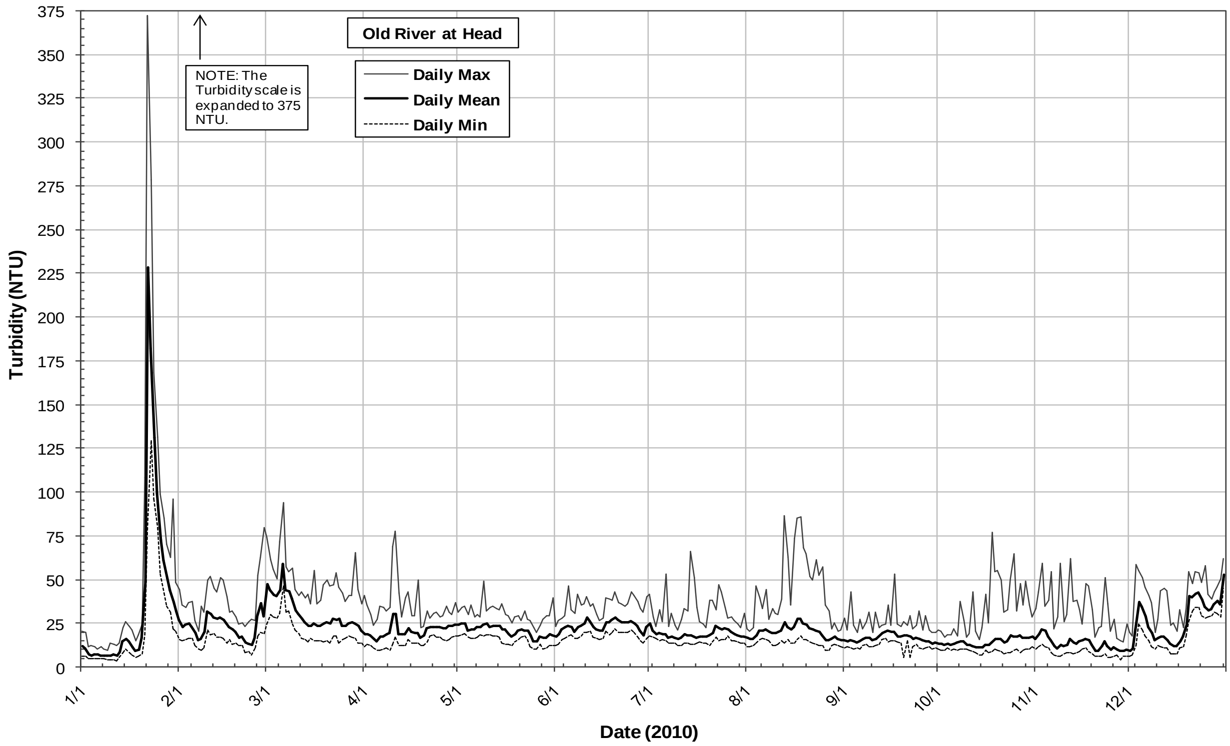


Figure 6-31 (cont.). Daily Turbidity Time-series Graphs for the Middle River Stations



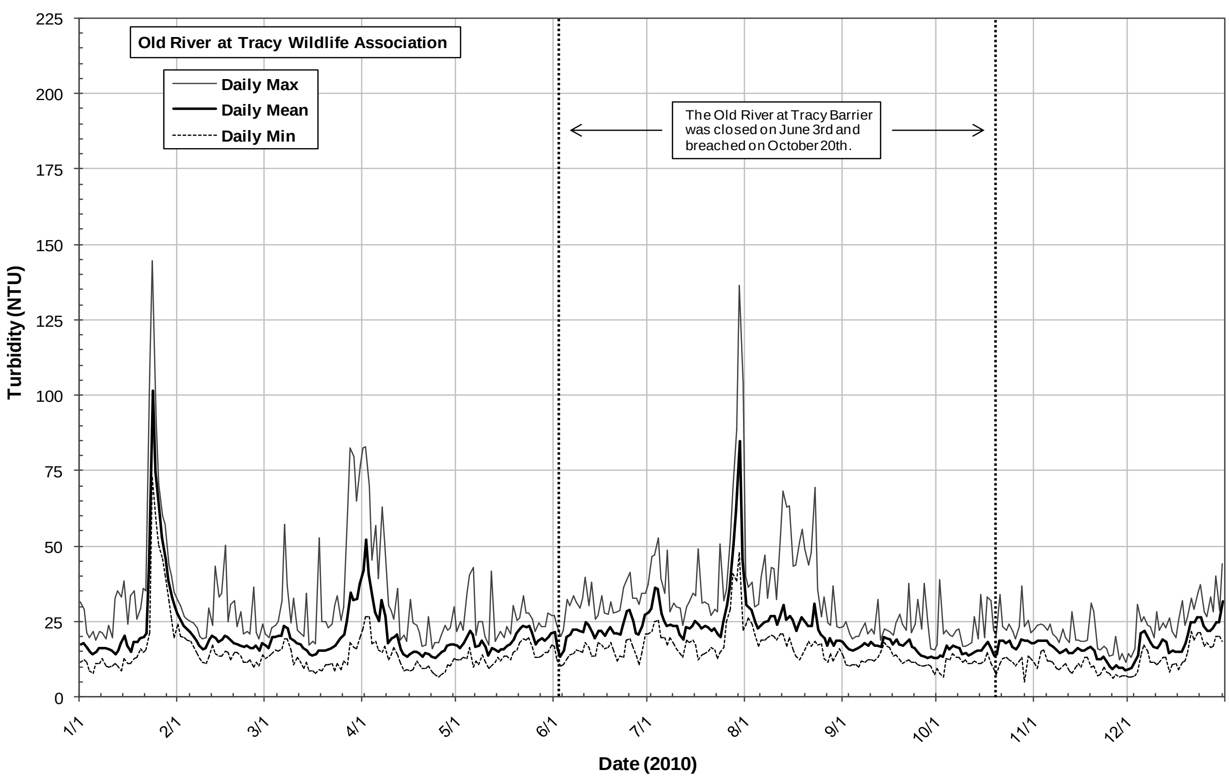
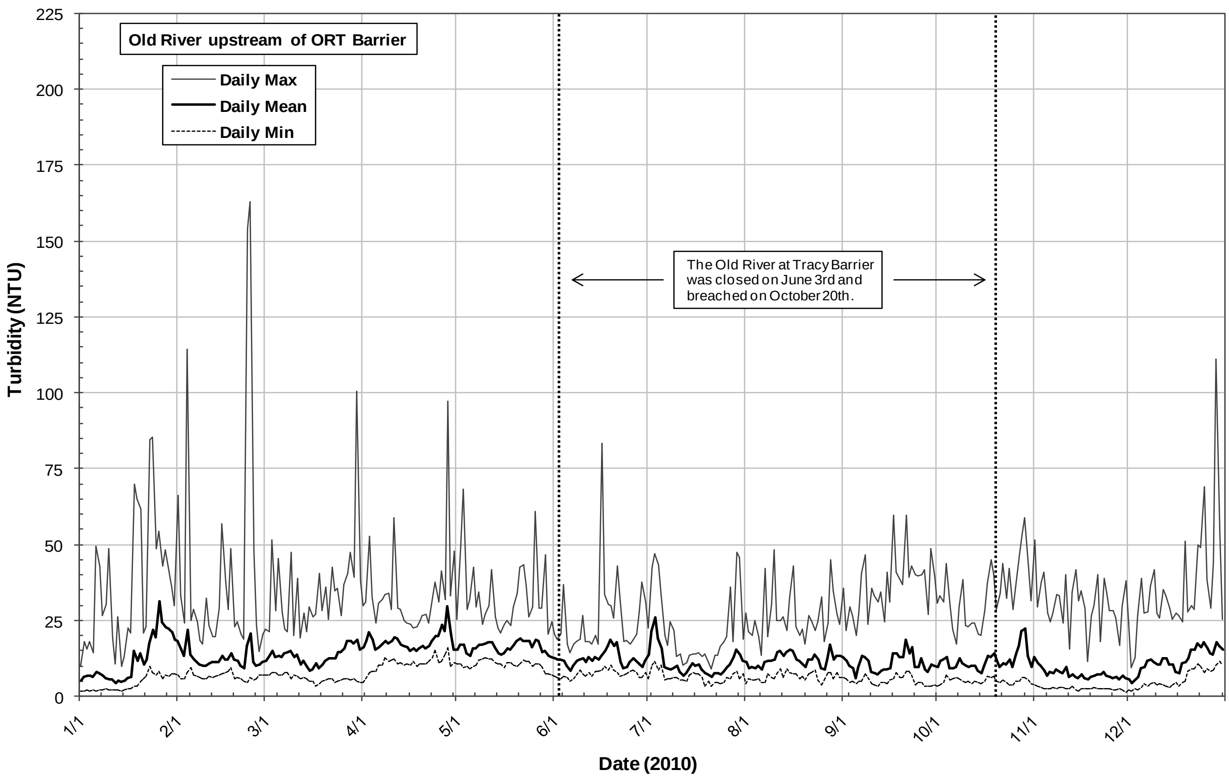


Figure 6-32. Daily Turbidity Time-series Graphs for the Old River Stations



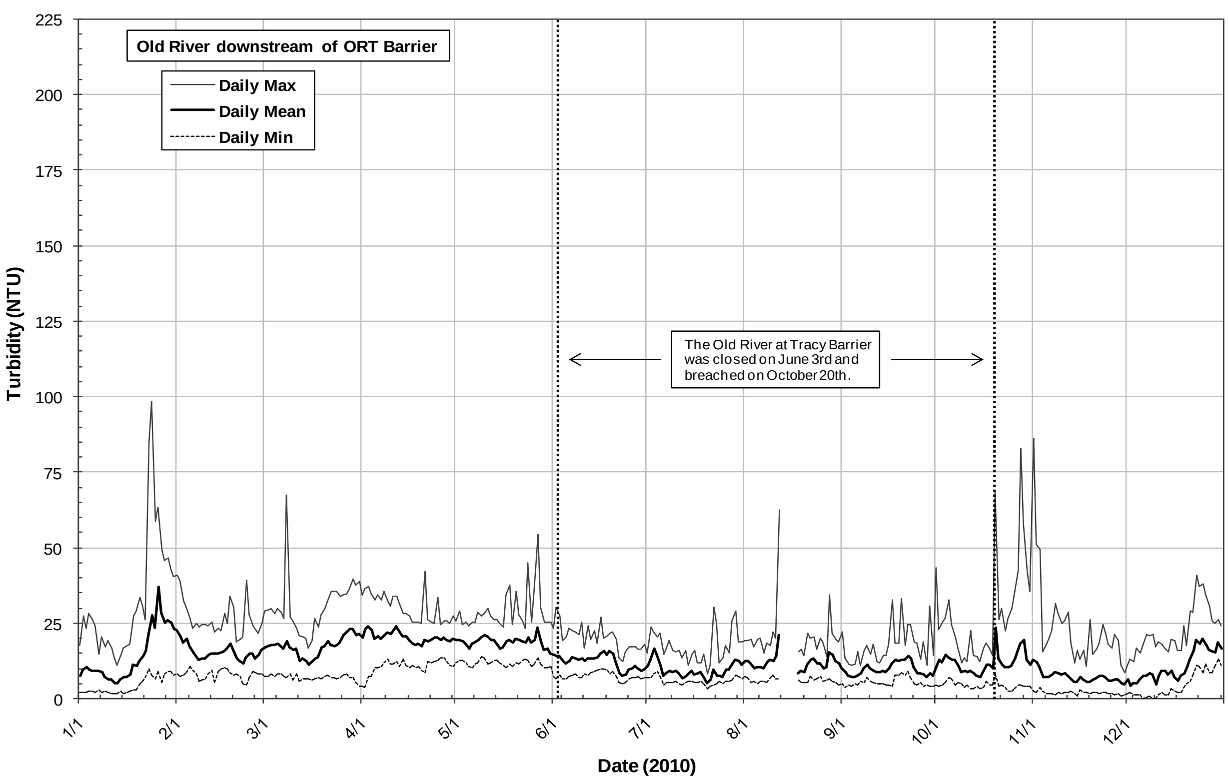


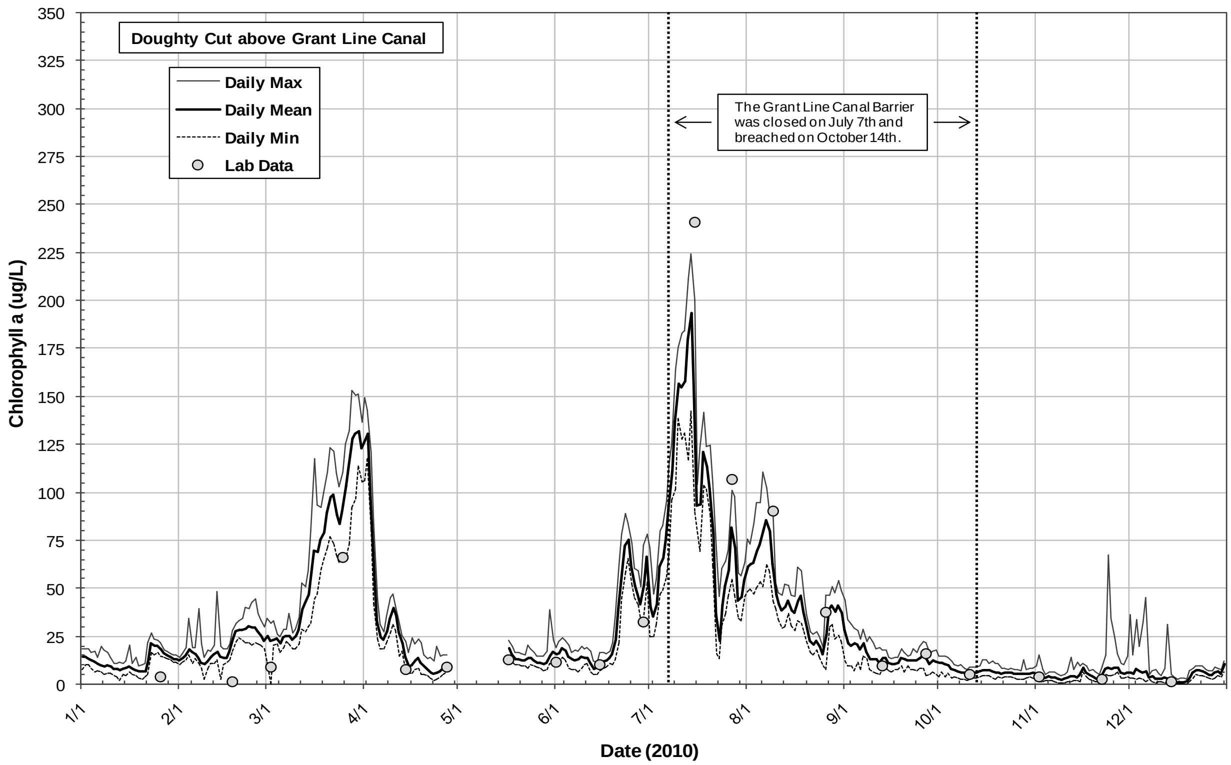
Figure 6-32 (cont.). Daily Turbidity Time-series Graphs for the Old River Stations

Chlorophyll *a*

Chlorophyll *a* concentrations can be used as an indicator of phytoplankton biomass in a water body (APHA, 2005). Phytoplankton (microscopic algae) occur as unicellular, colonial, or filamentous forms and are primarily grazed upon by zooplankton and other aquatic organisms (APHA, 2005). The species composition and/or biomass of phytoplankton may be a useful tool in assessing water quality (APHA, 2005). Algae can influence water quality by affecting pH, dissolved oxygen, turbidity, the color, taste and odor of water; and under certain conditions, some species can develop noxious blooms.

Staff adjusted the chlorophyll *a* concentrations measured by the optical probes by using the procedures discussed in the Materials and Methods section of this chapter. Adjusted chlorophyll *a* concentrations ranged from a high of 343 µg/L on July 17 at Old River at Head to a low of 0 µg/L on various occasions at 7 stations (Tables 6-10 to 6-13). Figures 6-33, 6-34, and 6-35 illustrate the daily maximums, minimums, and averages for the Grant Line and Victoria Canal, Middle River, and Old River stations, respectively.

The 4 stations along Grant Line Canal, Middle River at Undine Road, Middle River at Howard Road, and the 4 stations along Old River all displayed a similar trend in adjusted chlorophyll *a* concentrations throughout 2010. At all of these stations, adjusted chlorophyll *a* concentrations increased during 2 distinct periods: once in the spring (March to the beginning of April) and the other during the summer and fall (mid-June to the beginning of October). Average monthly chlorophyll *a* concentrations ranged from 2.2 µg/L to 73.9 µg/L in the spring and from 1.2 µg/L to 150.5 µg/L in the summer to mid-fall at these stations (Tables 6-10 to 6-13). The 2 elevated periods were most likely due to phytoplankton blooms in the water bodies near these stations. No obvious increases in adjusted chlorophyll *a* concentrations were observed at Victoria Canal, Middle River near Tracy Blvd, and Middle River at Union Point throughout the entire year. Adjusted chlorophyll *a* concentrations remained relatively constant in 2010 with an average of approximately 3 µg/L at these stations.



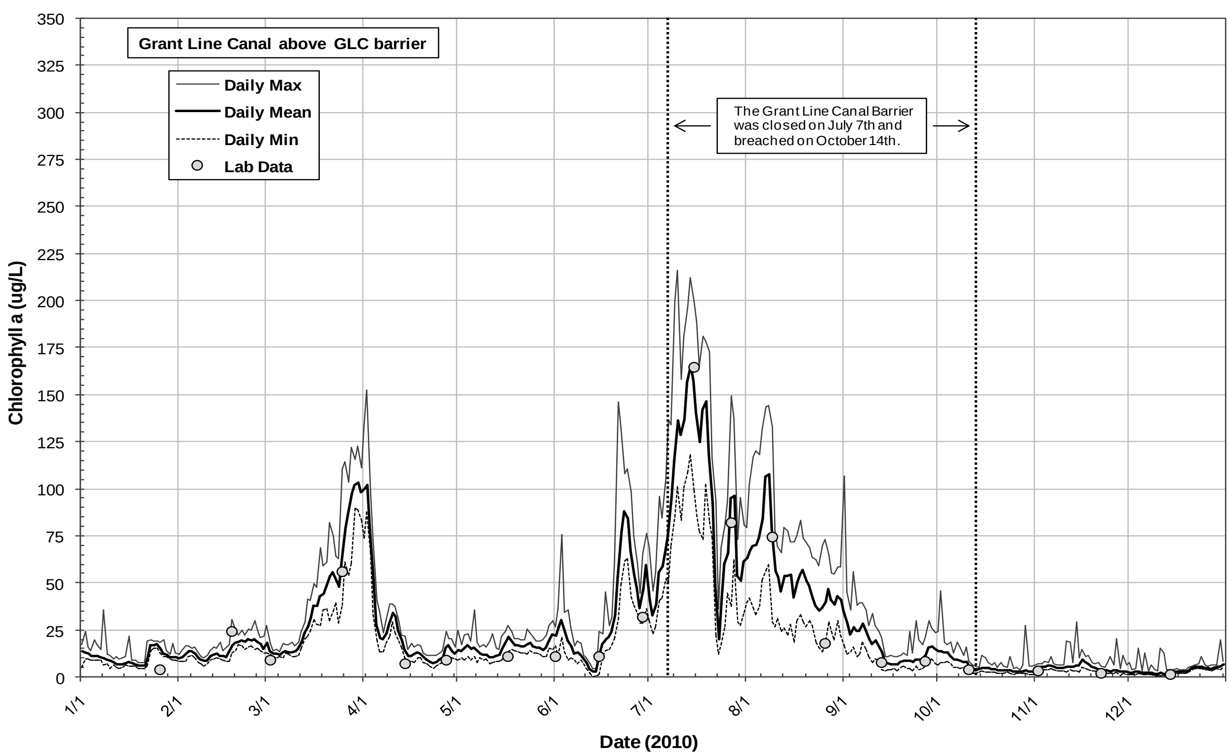
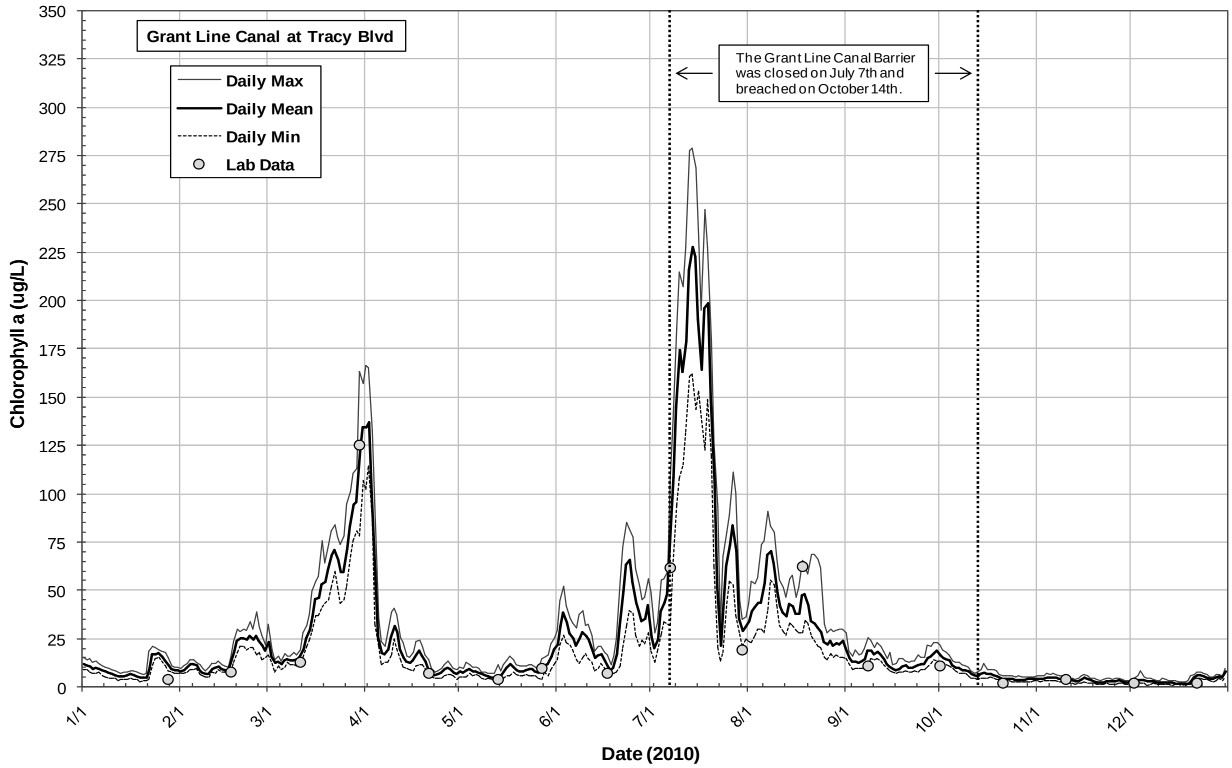


Figure 6-33. Daily Chlorophyll *a* Time-series Graphs for the Grant Line and Victoria Canal Stations



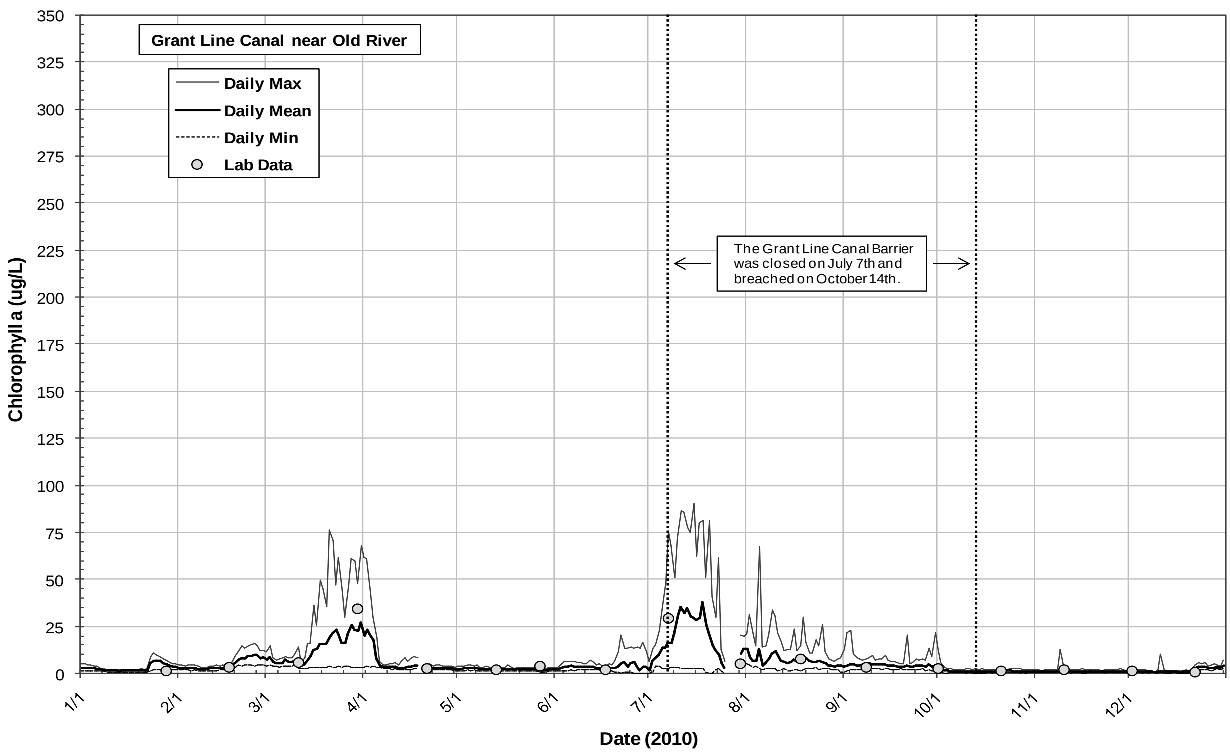


Figure 6-33 (cont.). Daily Chlorophyll *a* Time-series Graphs for the Grant Line and Victoria Canal Stations

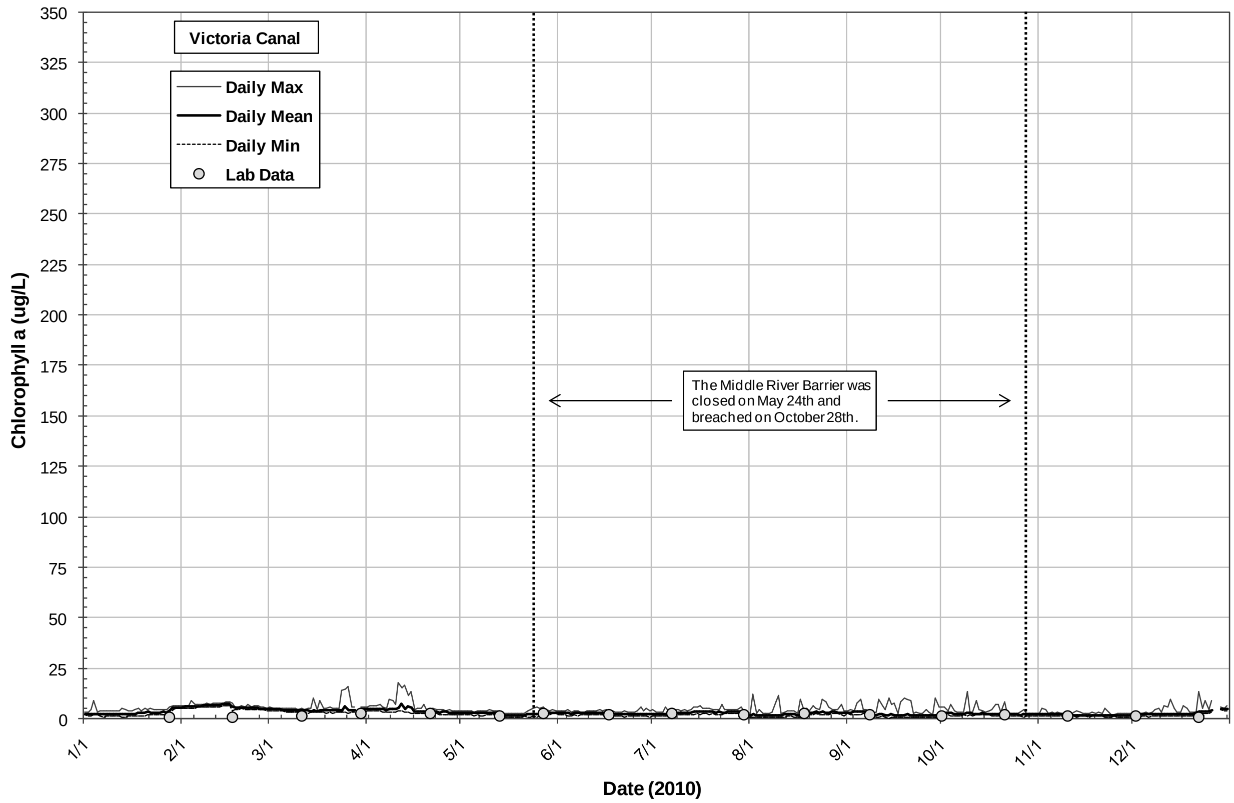
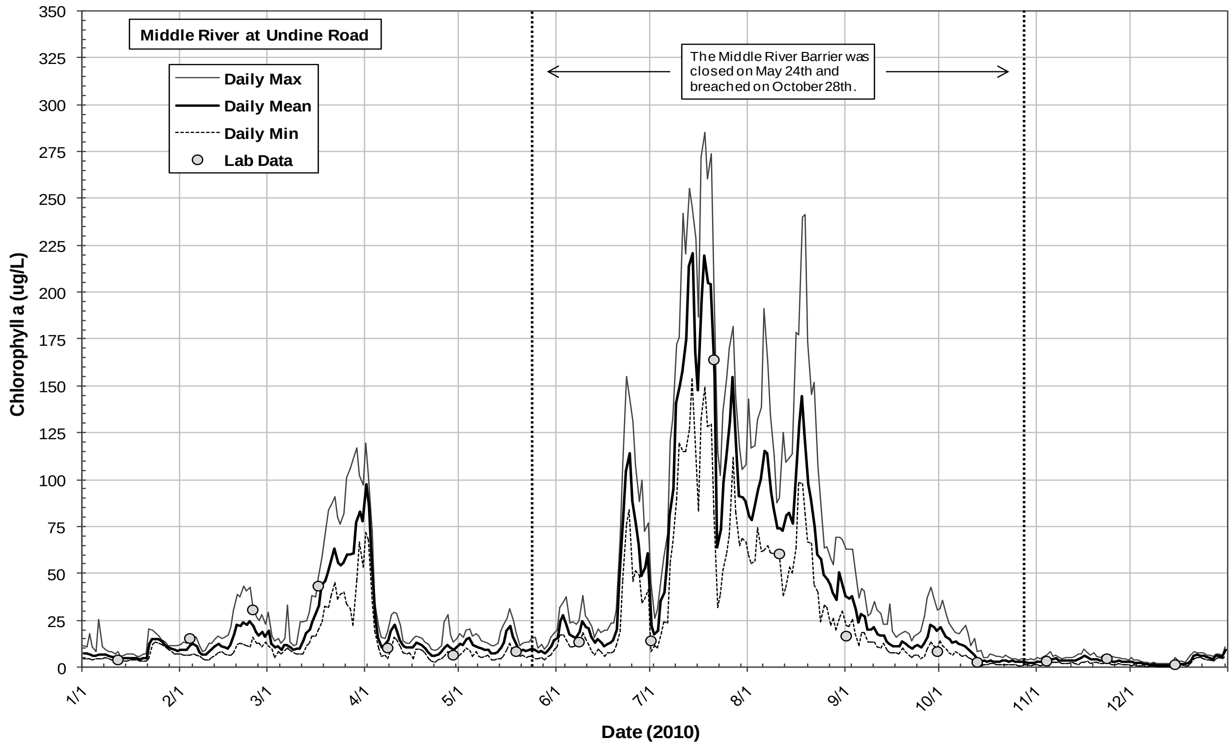


Figure 6-33 (cont.). Daily Chlorophyll *a* Time-series Graphs for the Grant Line and Victoria Canal Stations



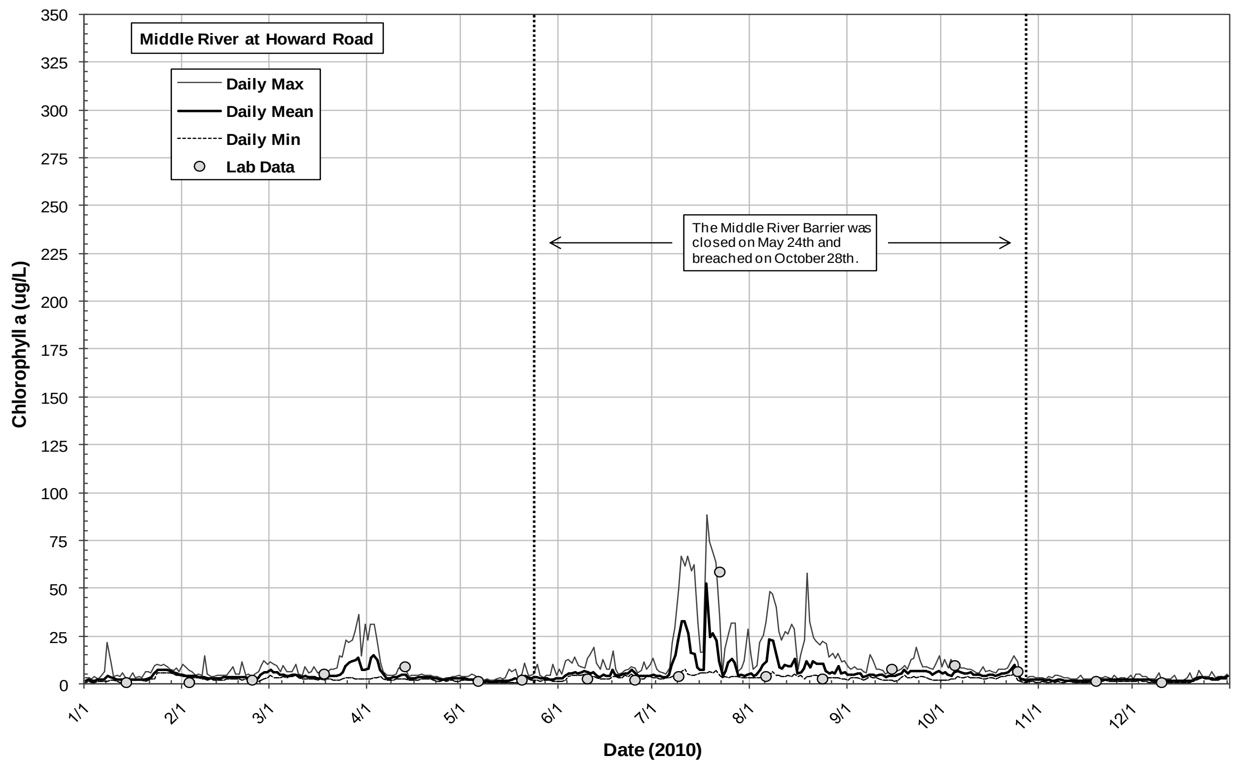
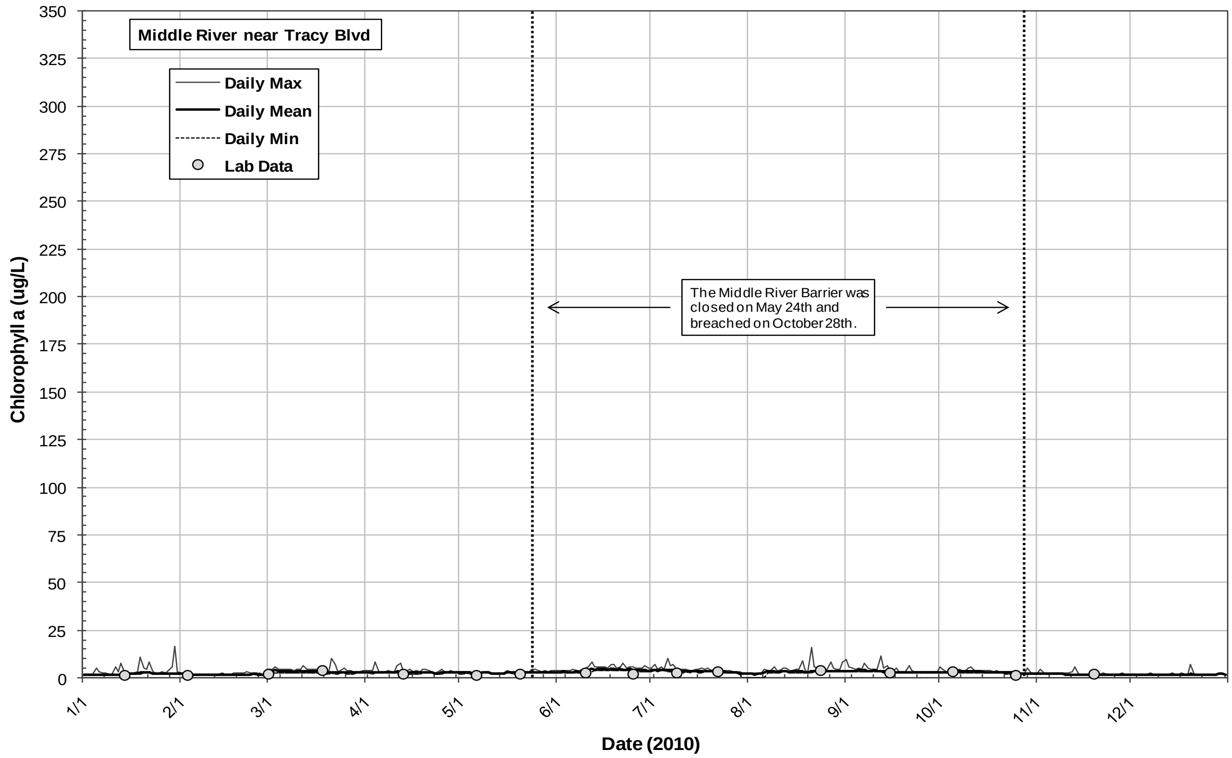


Figure 6-34. Daily Chlorophyll *a* Time-series Graphs for the Middle River Stations



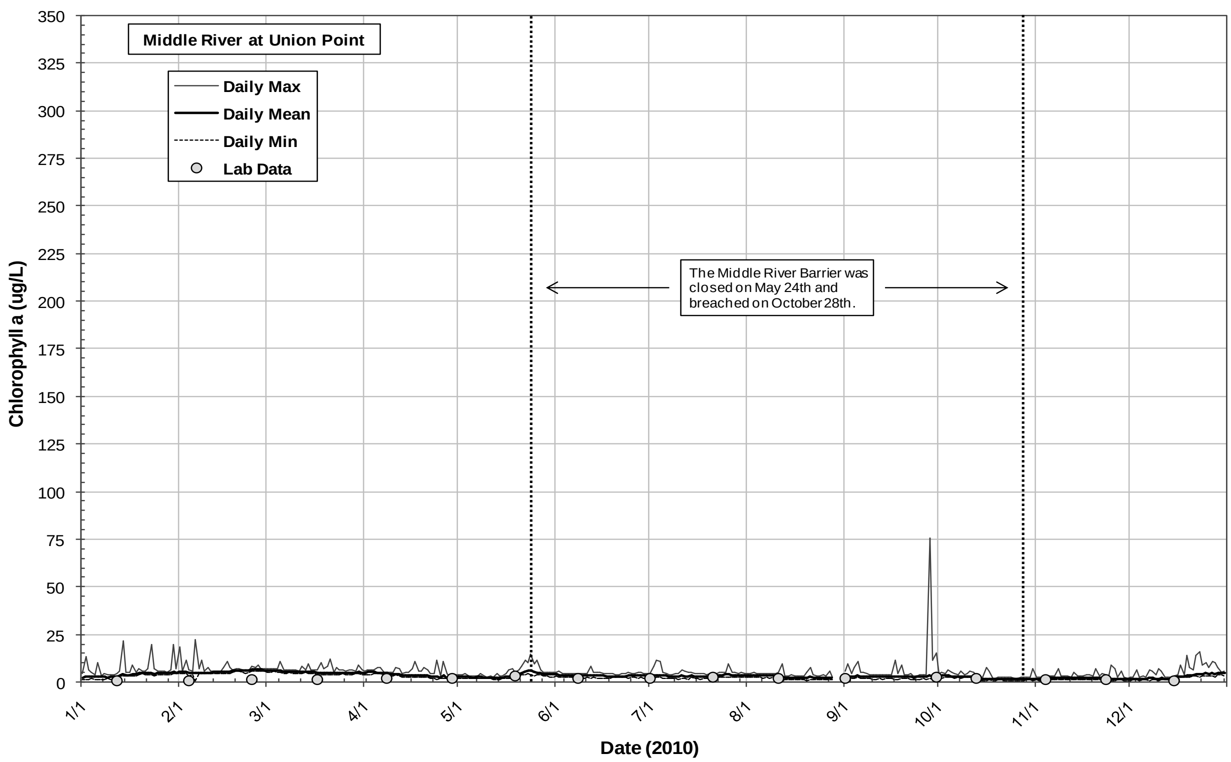
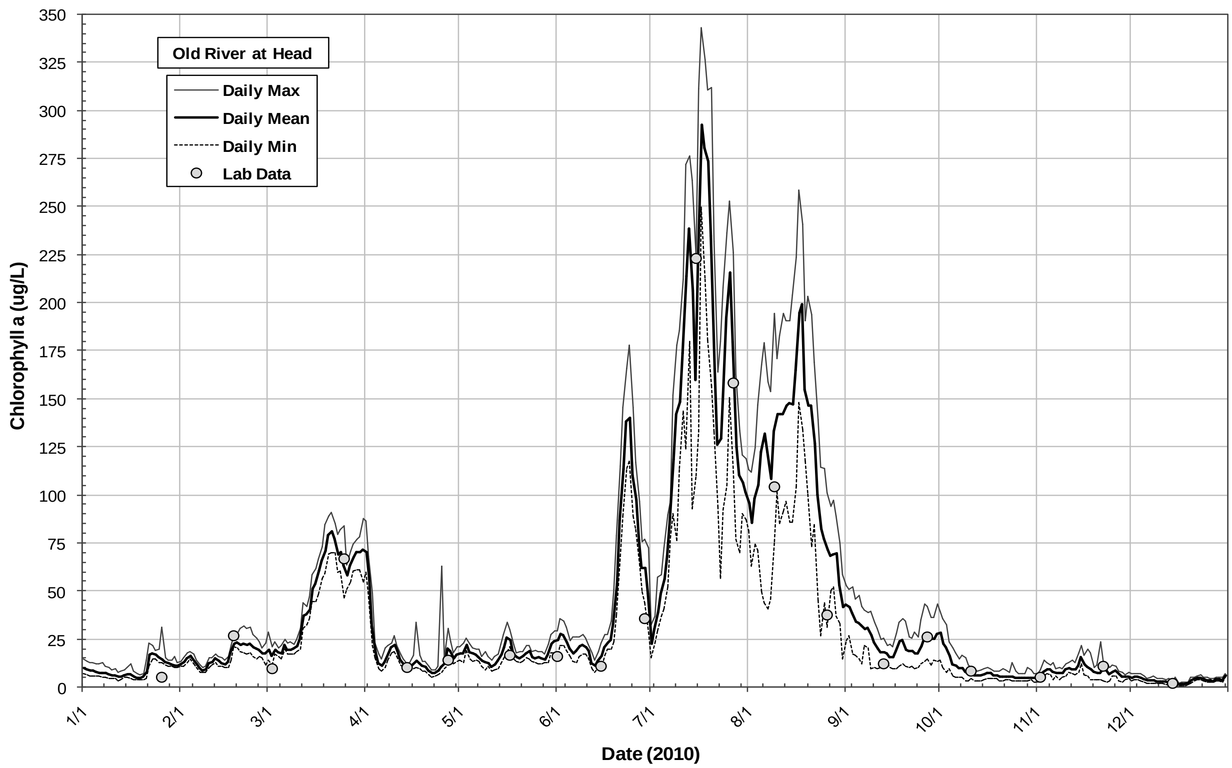


Figure 6-34 (cont.). Daily Chlorophyll *a* Time-series Graphs for the Middle River Stations



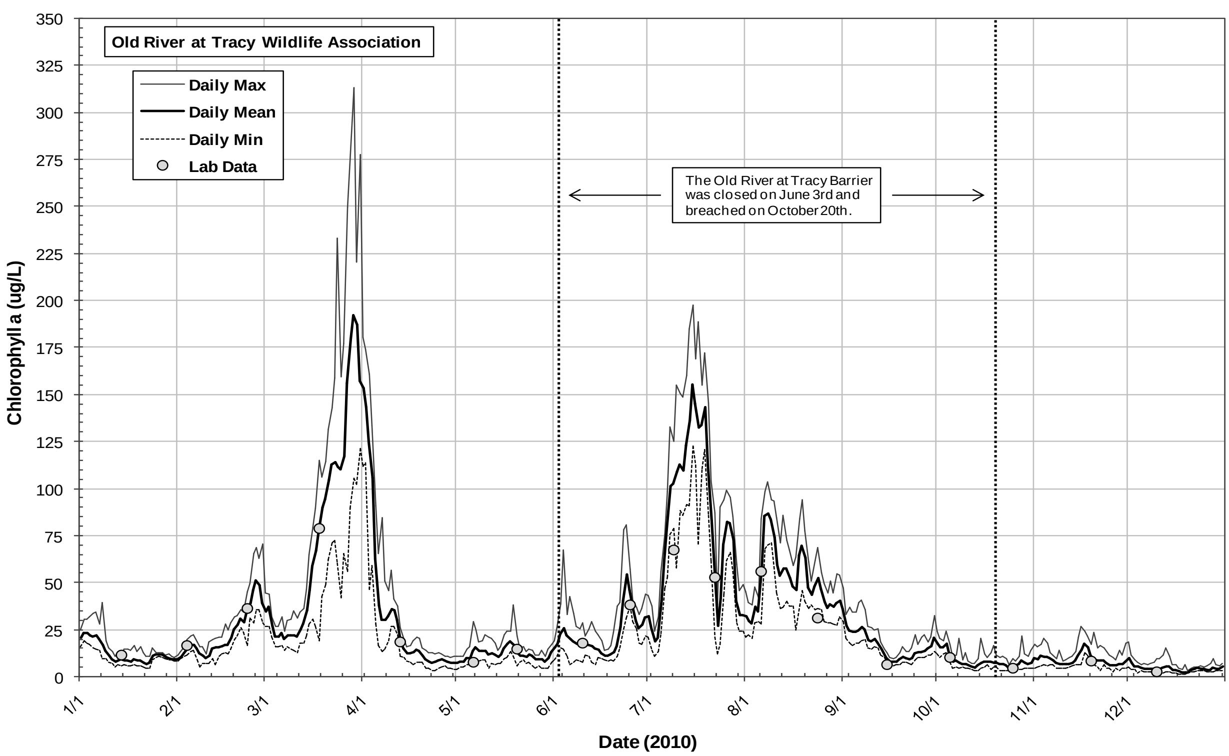
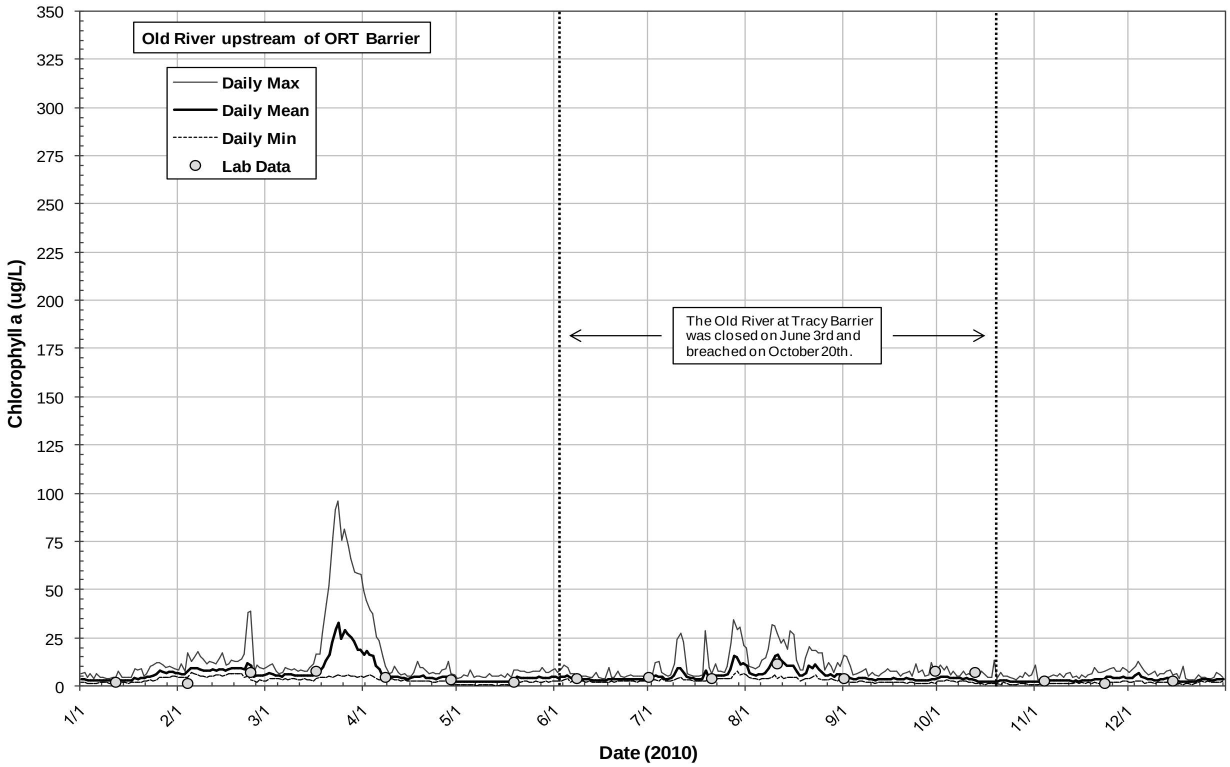


Figure 6-35. Daily Chlorophyll a Time-series Graphs for the Old River Stations



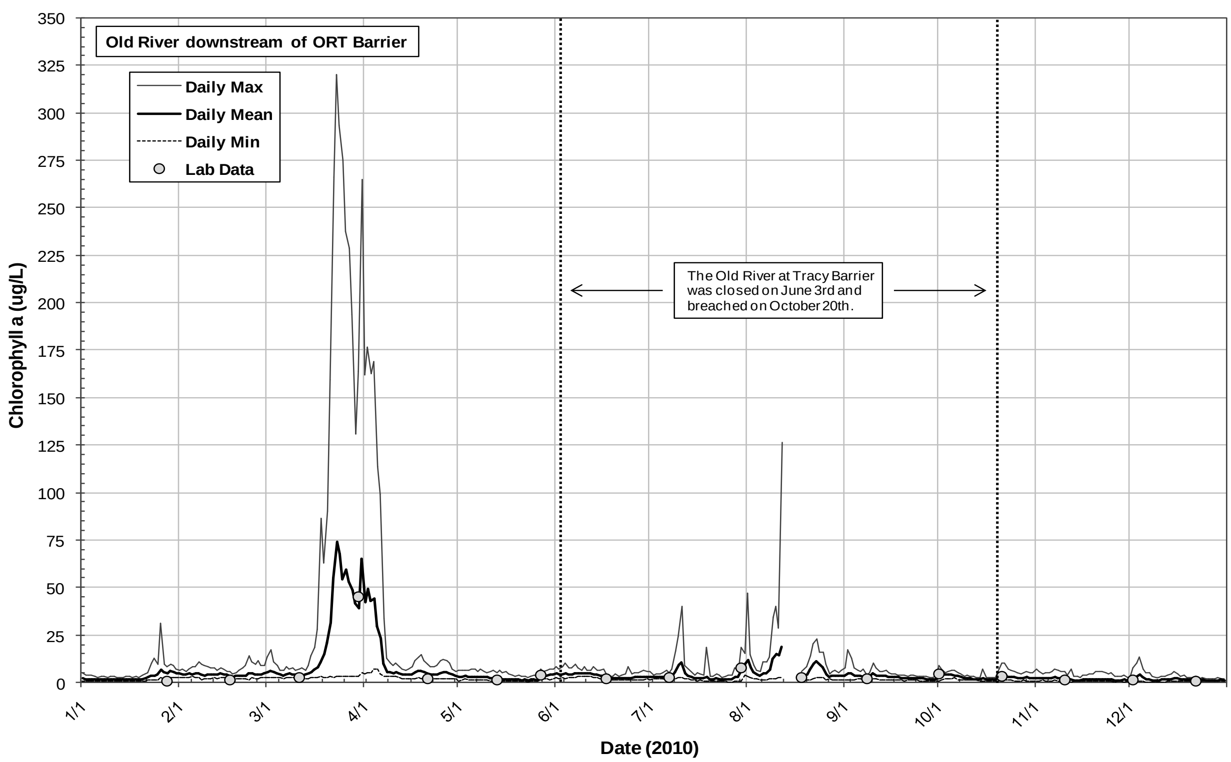


Figure 6-35 (cont.). Daily Chlorophyll *a* Time-series Graphs for the Old River Stations

Discussion

Box plots illustrating the seasonal maximums and minimums, 25th and 75th percentiles, and medians for each constituent measured at the Grant Line and Victoria Canal, Middle River, and Old River stations are shown in Figures 6-36, 6-37, and 6-38, respectively. Overall trends in the 2010 water quality data collected in the South Delta are discussed below:

- A visual comparison of the 2010 water temperature plots for the South Delta monitoring sites revealed similar trends among all of the stations. This similarity is in part attributable to a common geographic location and similar meteorological conditions. Even though the sites are close to each other, variations do occur from flow, tides, barrier operation, local discharges, and bathymetry.
- Variation observed in specific conductance was due in part to differences in source water, flow dynamics, agricultural pumping, and agricultural return flows. South Delta stations with lower conductivity values throughout the year tended to be more influenced by water from the Sacramento River.
- Chlorophyll *a* concentrations can indicate whether or not algal photosynthesis is occurring in the water nearby; higher chlorophyll *a* concentrations are indicative of higher rates of photosynthesis. Greater rates of algal photosynthesis in the water can have an effect on pH levels and dissolved oxygen concentrations. The South Delta stations with higher chlorophyll *a* values tended to have higher pH values with more variability. Dissolved oxygen concentrations were also more variable with periods of supersaturation and very low levels at the stations with higher chlorophyll *a* values.
- Turbidity values at the South Delta stations were site-specific with some stations having higher or lower turbidity along the same water body. Stations that were more influenced by the water from the Sacramento River tended to have lower turbidity values throughout the year.

A more specific discussion of the water quality trends in 2010 for each water body is presented below.

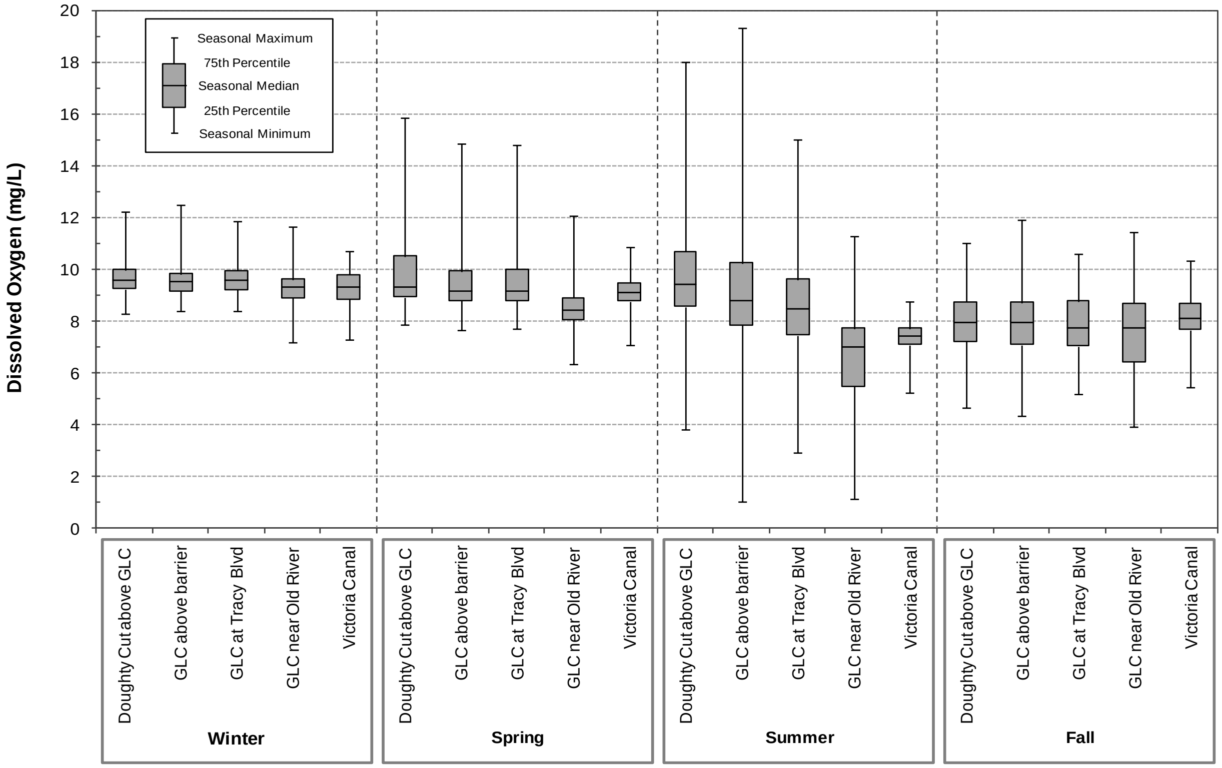
Victoria Canal

- The water quality data measured at Victoria Canal is visibly different than the data collected at most of the continuous stations located on Grant Line Canal, Middle River, and Old River (Figure 6-36 and Table 6-11). This is most likely due to Victoria Canal receiving more water from the Sacramento River.
- The median specific conductance, turbidity, and chlorophyll *a* values for all four seasons at Victoria Canal are visibly lower than those values observed at most of the other stations in the South Delta. Seasonal median specific conductance values ranged from 414 µS/cm in the spring to 232 µS/cm in the summer at Victoria Canal. The turbidity and chlorophyll *a* values were consistently low with little variability throughout 2010. Turbidity values were typically between 1 and 9 NTU throughout the year with slightly higher values in the winter and slightly lower values in the fall. Similarly, chlorophyll *a* values were usually between 2 and 5 µg/L throughout 2010.
- The observed pH and dissolved oxygen values at Victoria Canal had little variability during the entire year, which could be related to the low chlorophyll *a* values at this site. Typically, pH values ranged between 7.2 and 7.8, and dissolved oxygen concentrations were between 7.1 and

- 9.8 mg/L during 2010. Both pH and dissolved oxygen were slightly lower in the summer. Additionally, Victoria Canal did not have a single pH sample with a value greater than 8.5 mg/L, and no dissolved oxygen samples with values less than 5.0 mg/L during 2010 (Figures 6-12 and 6-21).

Grant Line Canal

- The Grant Line Canal near Old River station had slightly lower specific conductance, chlorophyll *a*, dissolved oxygen, and pH values than the other three stations located along Grant Line Canal during most of the year (Figure 6-36 and Table 6-10). This was most apparent during the spring and summer seasons. Most likely, the water from nearby Old River is mixing with the water from Grant Line Canal near this station causing the typical specific conductance values to be lower throughout most of the year. This may be partially the reason why the chlorophyll *a*, dissolved oxygen, and pH values were lower at Grant Line Canal near Old River as well.
- The Doughty Cut above Grant Line Canal, Grant Line Canal above the GLC barrier, and Grant Line Canal at Tracy Blvd stations had large increases in chlorophyll *a* concentrations during the spring and summer, indicating an increase in primary productivity and higher rates of algal photosynthesis in the water nearby these stations (Figures 6-33 and 6-36, Table 6-10). These three stations also had increased pH values and periods of supersaturated and highly variable dissolved oxygen concentrations during the summer (Figures 6-9 and 6-18). The Grant Line Canal near Old River station also had increases in chlorophyll *a* concentrations during the spring and summer, but not at the same magnitude as at the three other stations along Grant Line Canal.
- Doughty Cut above Grant Line Canal, Grant Line Canal above the GLC barrier, and Grant Line Canal at Tracy Blvd all had high numbers of pH readings with values greater than 8.5. Of these three the Doughty Cut station had the highest number with 5,237 pH standard exceedences (Figure 6-21). In contrast, Grant Line Canal near Old River had a much lower number of pH standard exceedences with a total of 454 during the year. This trend in pH standard exceedences corresponds well with the trend in chlorophyll *a* concentrations at these stations. Stations with higher chlorophyll *a* concentrations, indicating higher rates of algal photosynthesis, also had increased pH values and more pH standard exceedences.
- Most of the stations along Grant Line Canal had low numbers of dissolved oxygen standard exceedences during 2010 (Figure 6-12). Only Grant Line Canal near Old River had a moderate number of dissolved oxygen samples with concentrations less than 5.0 mg/L with 1,770 (5.1% of the total number of samples). Grant Line Canal near Old River also had significantly lower dissolved oxygen concentrations than the three other stations located along Grant Line Canal during the spring, summer, and fall ($p<0.03$; Tables 6-14 to 6-16).
- Doughty Cut above Grant Line Canal had consistently higher turbidity values by approximately 5-10 NTU than the three other stations located along Grant Line Canal (Figure 6-36). Although the differences in turbidity values were small, the consistently higher turbidity values at the Doughty Cut station throughout 2010 is noteworthy, and may be due to its site characteristics. The Doughty Cut station is situated in a shallow location with a bottom composed of silt that can be agitated into the water column by wave action.



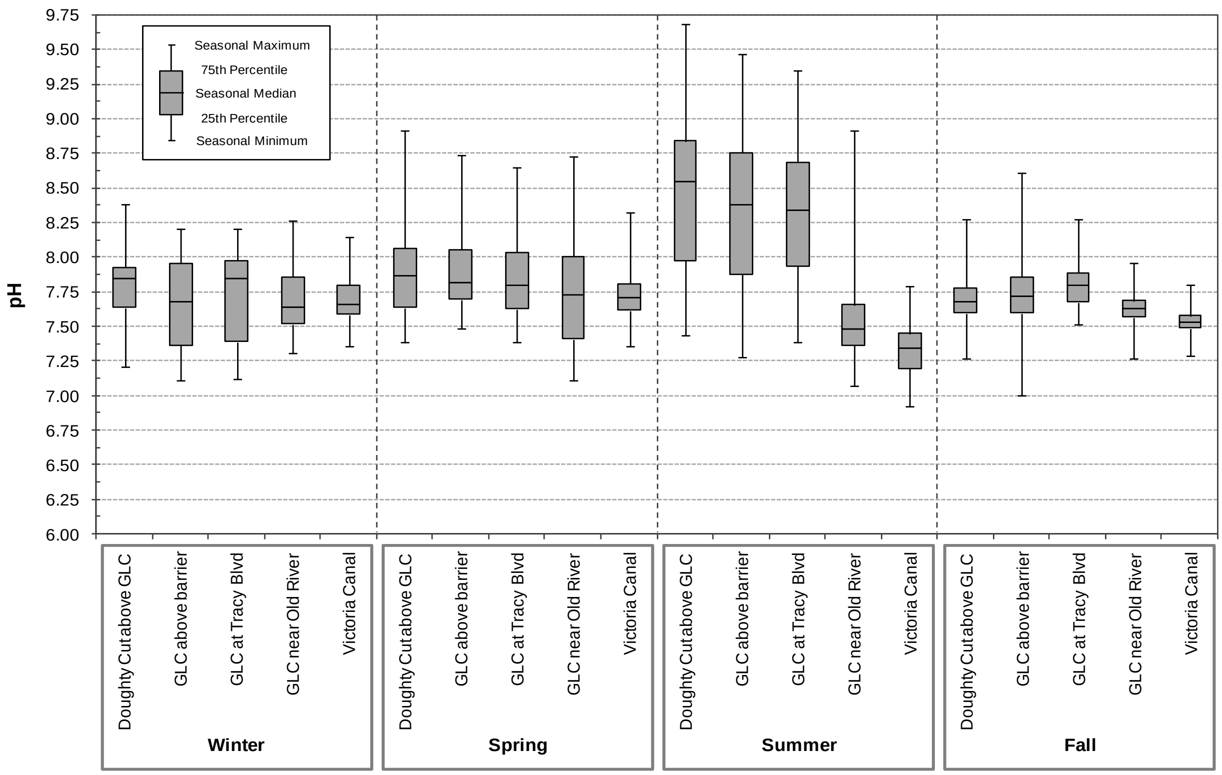
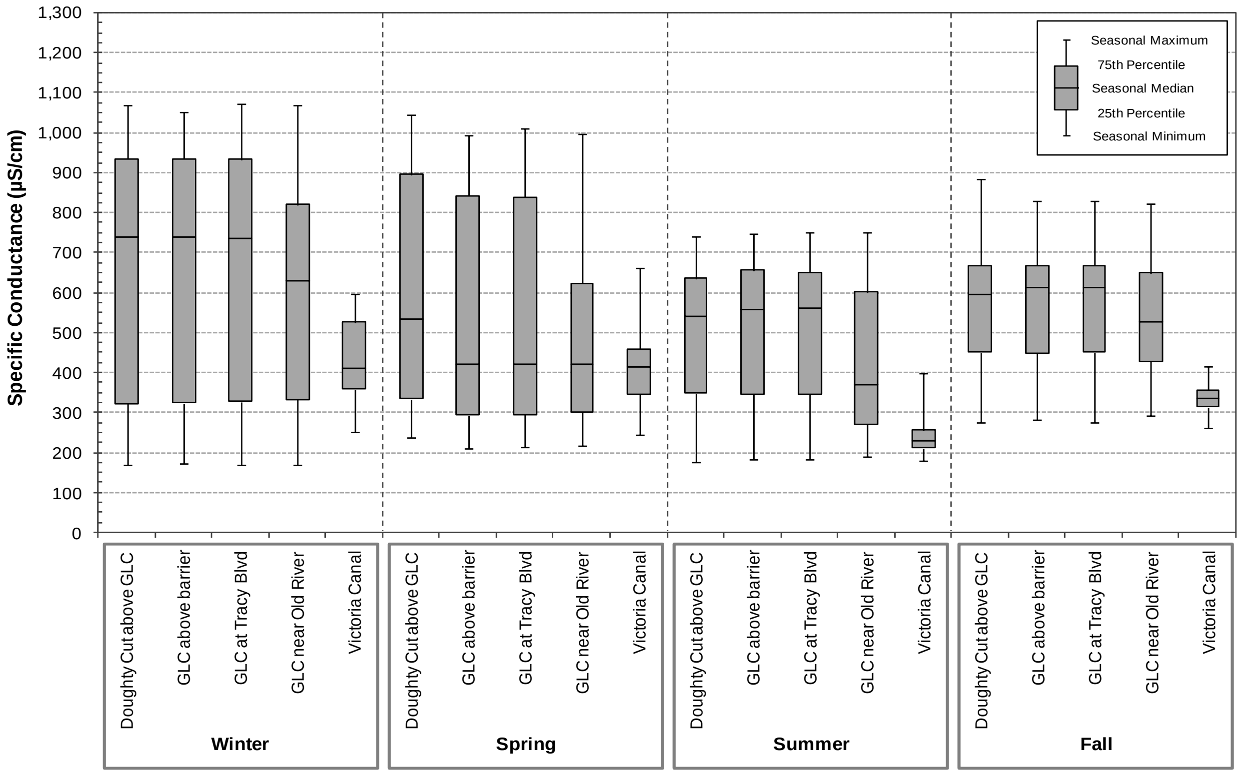


Figure 6-36. Box Plots for the Grant Line and Victoria Canal Stations



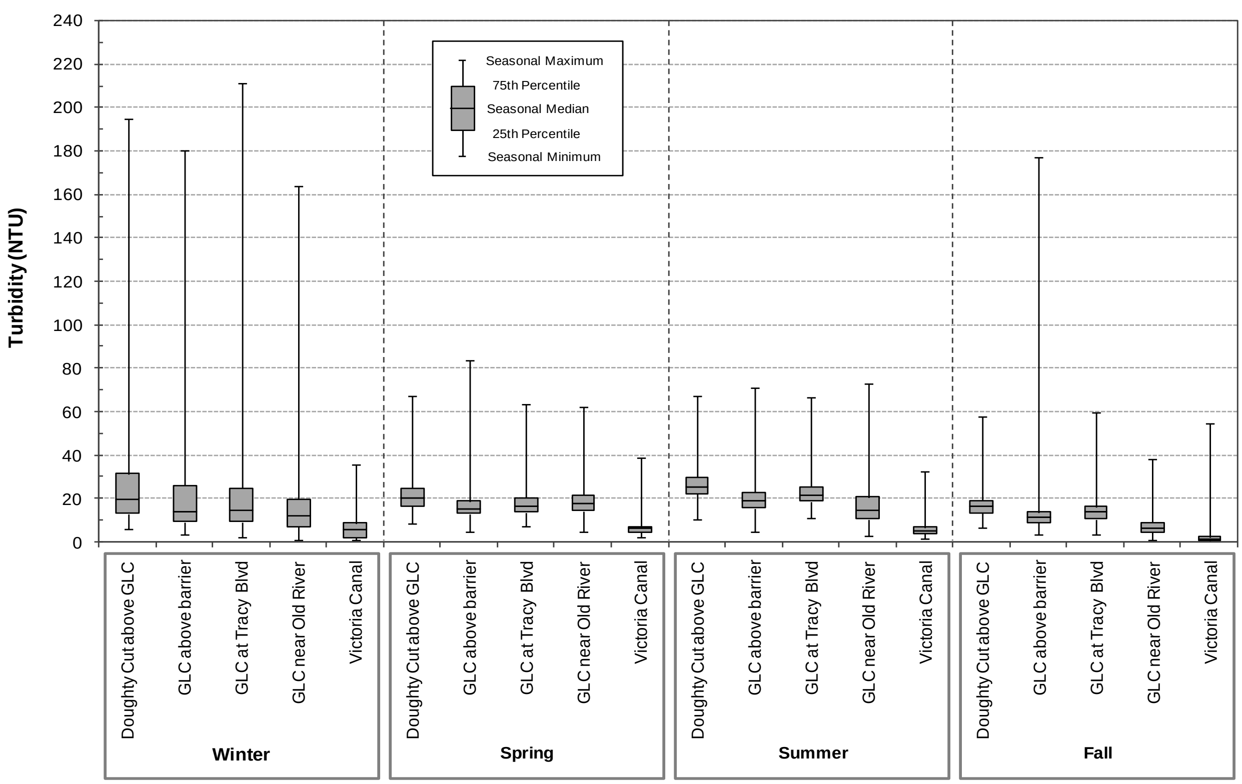


Figure 6-36 (cont.). Box Plots for the Grant Line and Victoria Canal Stations

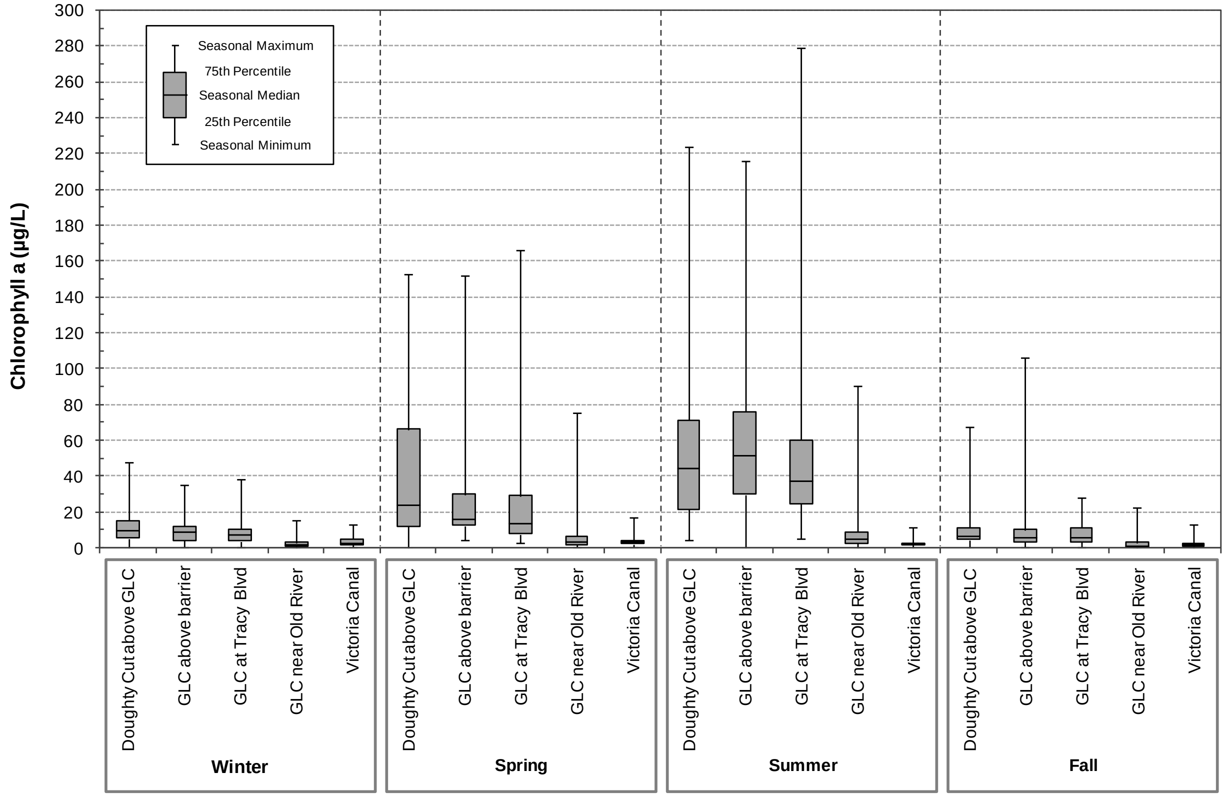
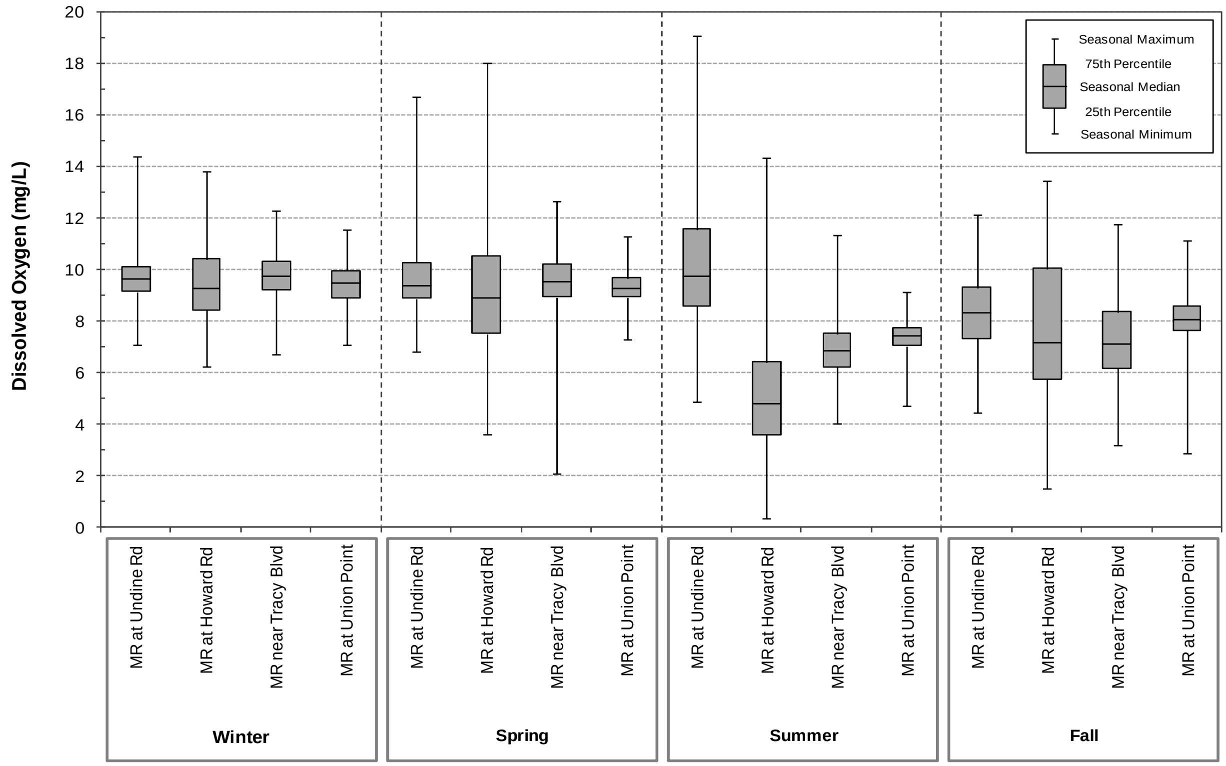


Figure 6-36 (cont.). Box Plots for the Grant Line and Victoria Canal Stations

Middle River

- Middle River at Union Point had the lowest and least variable specific conductance values of all of the stations located along Middle River throughout most of 2010 (Figure 6-37 and Table 6-12). The Middle River near Tracy Blvd station also had lower and less variable specific conductance values when compared to the Undine Road and Howard Road stations, particularly during the winter, summer, and fall. As with the Victoria Canal station, Middle River at Union Point may be more influenced by water from the Sacramento River. This may be the case, but less so, for the Middle River near Tracy Blvd station.
- Both the Howard Road and Undine Road stations had brief periods of highly elevated specific conductance values throughout much of the year (Figure 6-28). These significant spikes in specific conductance values have occurred in prior years particularly at the Howard Road station, and are likely the result of flow dynamics, agricultural pumping, and agricultural return flows.
- Middle River at Undine Road is the only station located along Middle River that had high concentrations of chlorophyll *a* particularly during the spring, summer, and early fall, indicating that photosynthetic activity was occurring near this station during these months (Figures 6-34 and 6-37). In addition to the increase in chlorophyll *a* concentrations, the Undine Road station had elevated pH values and periods of supersaturated dissolved oxygen concentrations during the same time period (Figures 6-10 and 6-19).
- Middle River at Howard Road had a slight increase in chlorophyll *a* concentrations during the spring and summer, but not at the same magnitude as at the Undine Road station. Additionally, pH values and dissolved oxygen concentrations were more variable during the spring and summer at the Howard Road station, which was probably influenced by slightly higher rates of photosynthesis occurring nearby.
- Middle River at Undine Road had a high number of pH readings with values greater than 8.5, and Howard Road had a moderate number of pH exceedences during 2010 (Figure 6-22). The Undine Road and Howard Road stations had 4,910 and 1,182 pH standard exceedences, respectively. The Undine Road station also had the highest pH values of all of the Middle River stations throughout the year (Figure 6-37 and Table 6-12).
- The Middle River at Howard Road station had significantly lower dissolved oxygen concentrations than the three other Middle River stations during the spring, summer, and fall ($p<0.03$; Figure 6-37 and Tables 6-17 to 6-19). This difference was most obvious during the summer with typical values at this station ranging between 3.6 and 6.4 mg/L with a seasonal median of 4.8 mg/L. The low dissolved oxygen concentrations observed at the Howard Road station could be due to high summer water temperatures, low flow conditions, and high biological oxygen demand as a result of the potentially large algal biomass nearby the upstream Undine Road station.
- Middle River at Howard Road also had the highest number of dissolved oxygen standard exceedences out of all of the South Delta stations. In 2010, the Howard Road station had 5,998 dissolved oxygen samples with values less than 5.0 mg/L (Figure 6-13). Most of these standard exceedences occurred in the summer with 53% of the total number of samples exceeding the standard. The three other Middle River stations had low numbers of dissolved oxygen standard exceedences (between 5 and 548 during the year).
- In addition to the highest chlorophyll *a* concentrations and pH values, Middle River at Undine Road had the highest turbidity values of all of the Middle River stations throughout the year (Figure 6-37 and Table 6-12). Turbidity values were typically 6-25 NTU higher at the Undine Road station during 2010.



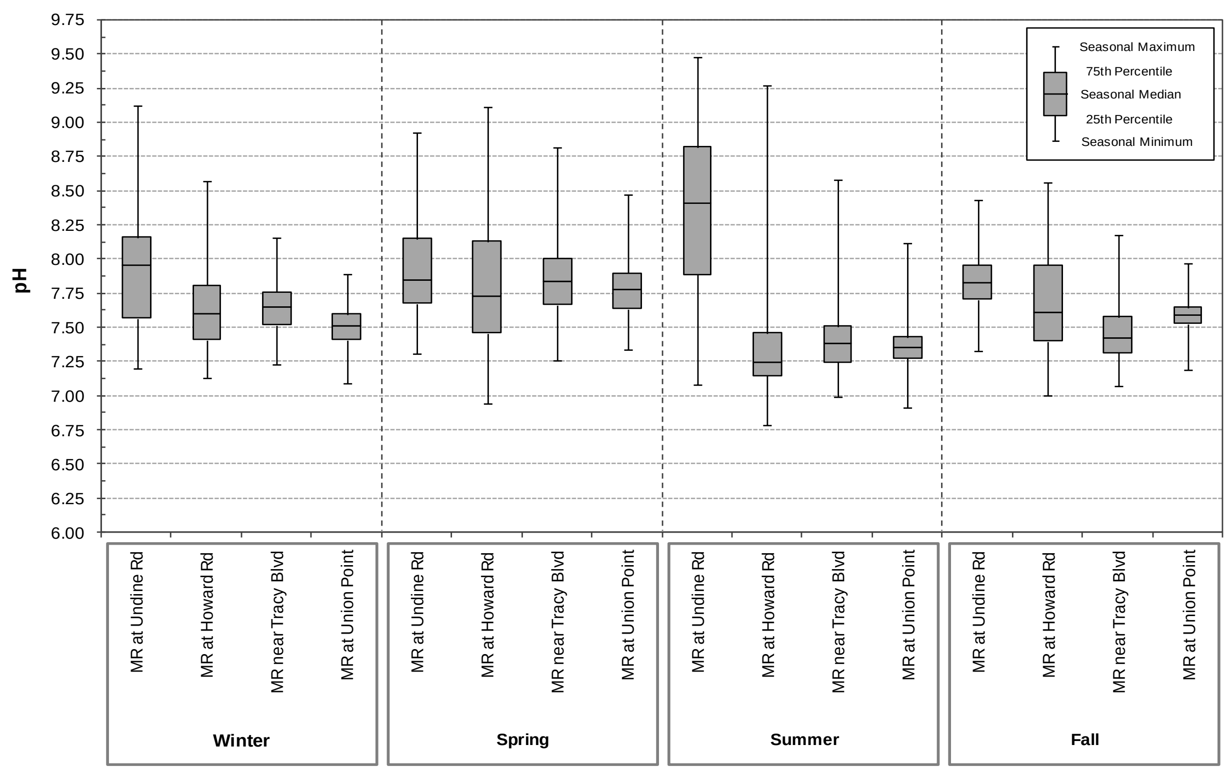
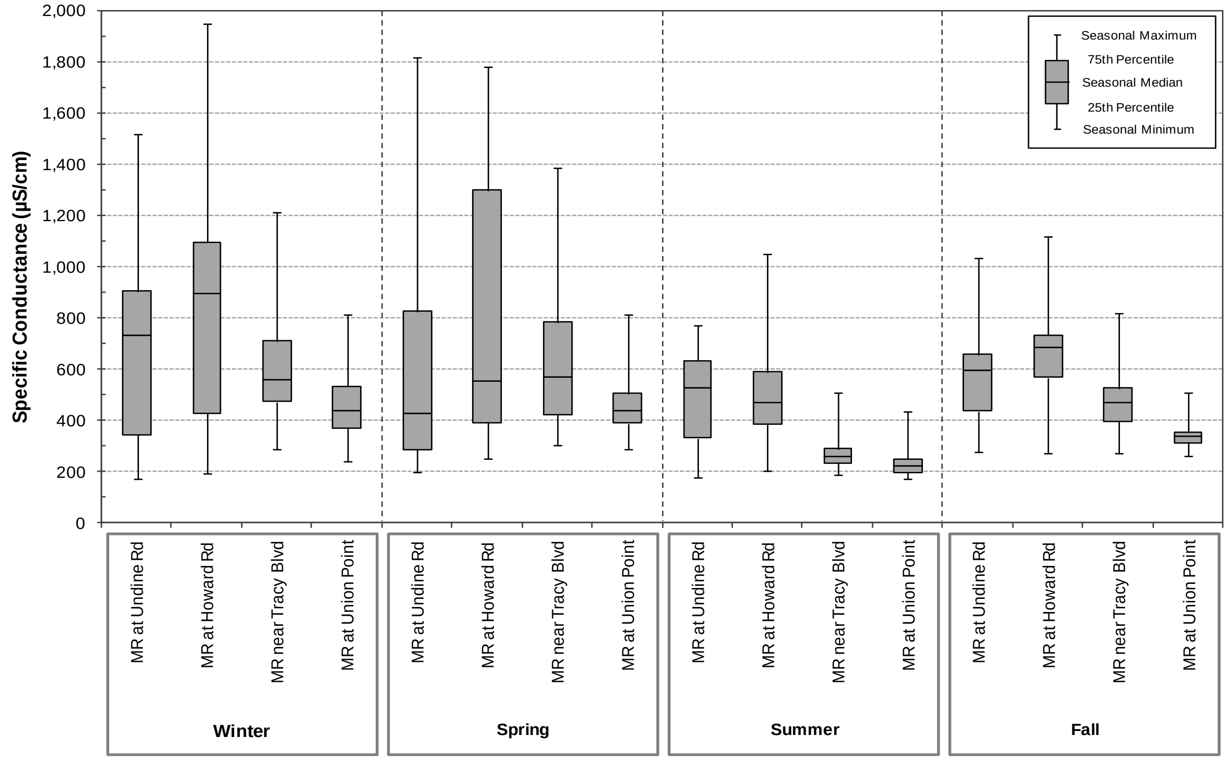


Figure 6-37. Box Plots for the Middle River Stations



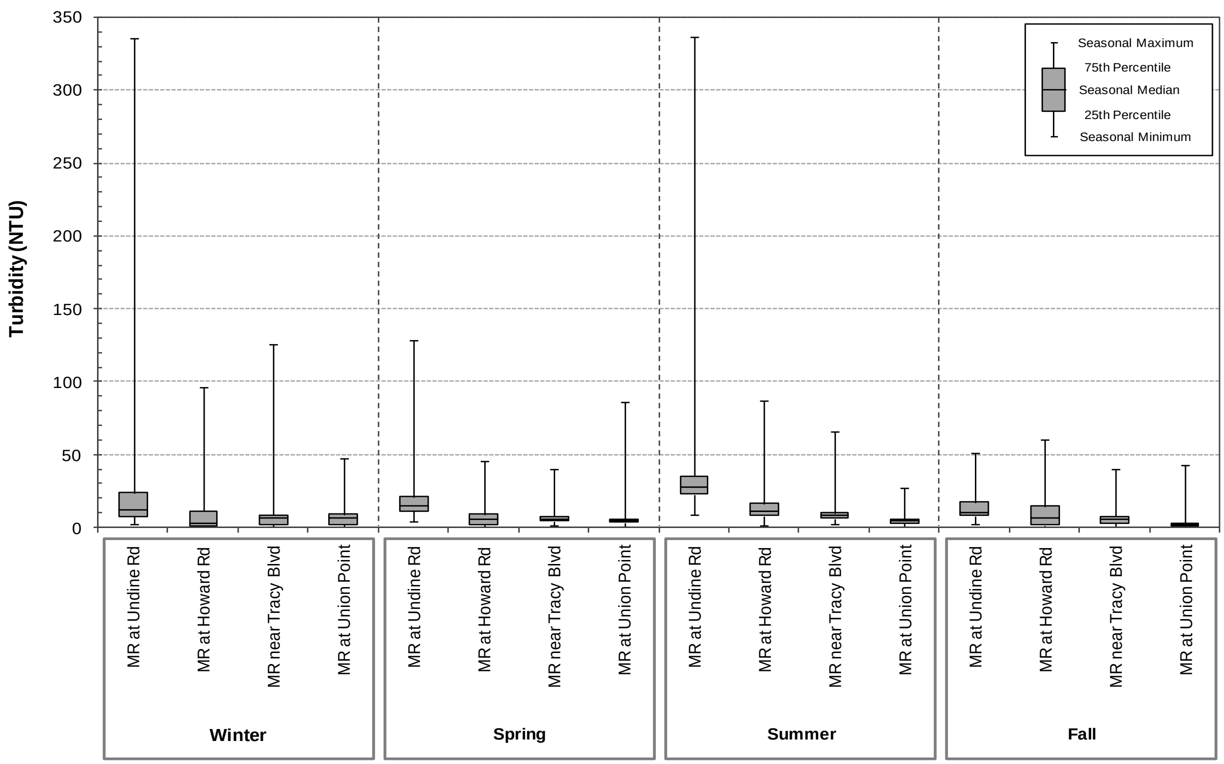


Figure 6-37 (cont.). Box Plots for the Middle River Stations

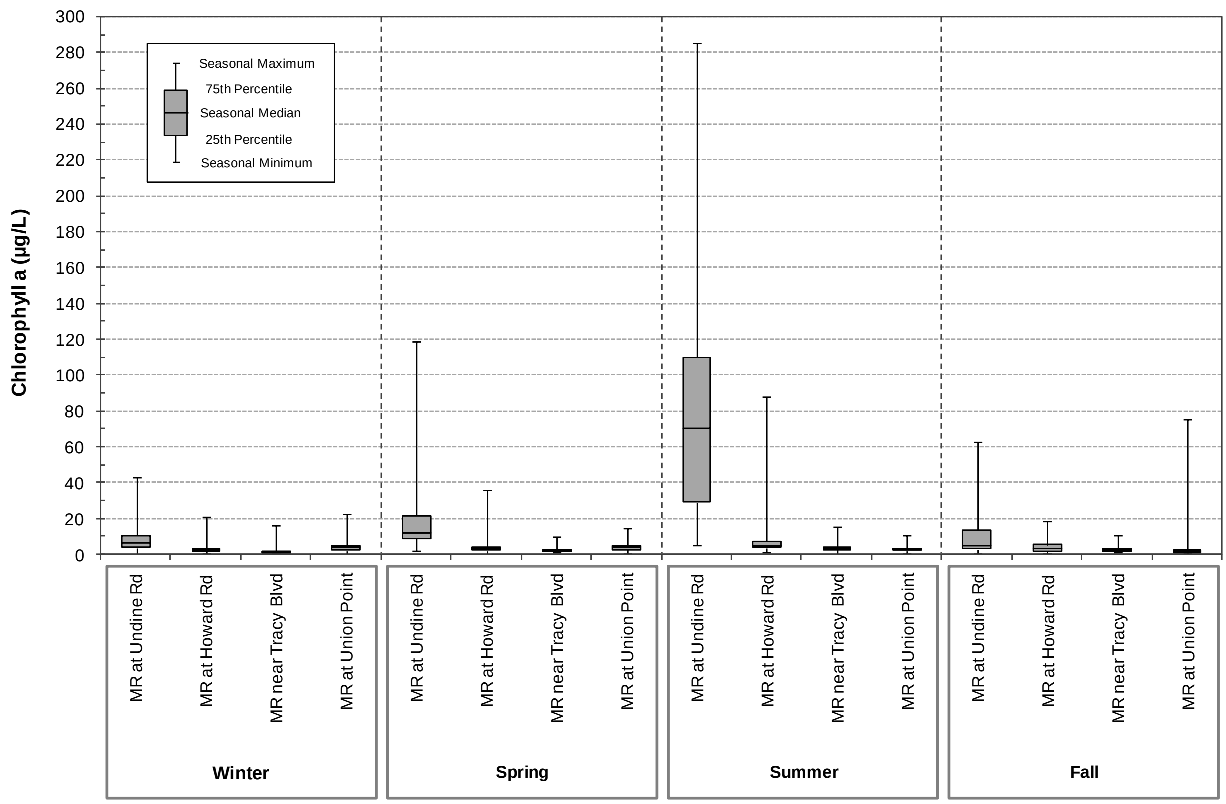
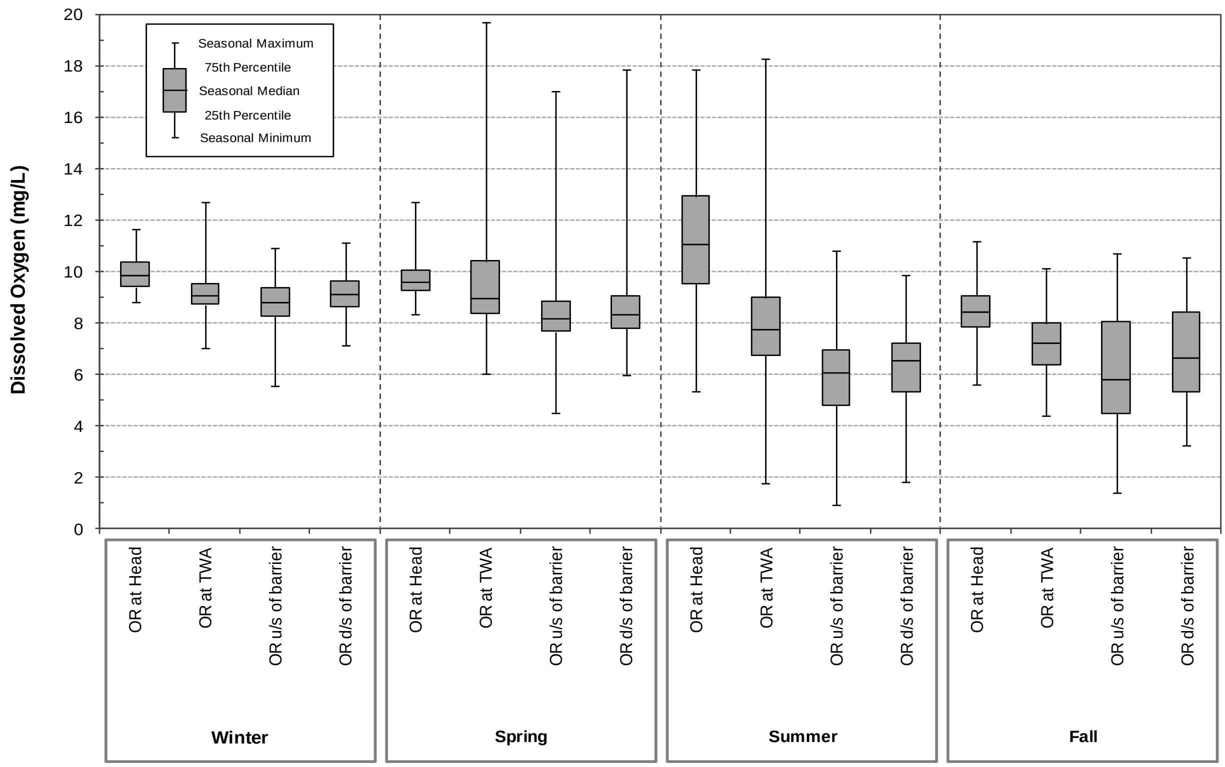


Figure 6-37 (cont.). Box Plots for the Middle River Stations

Old River

- Old River at Head and Old River at Tracy Wildlife Association had slightly higher turbidity values throughout the year and much higher chlorophyll *a* concentrations during the spring and summer than the two stations adjacent to the ORT barrier (Figure 6-38 and Table 6-13). Turbidity values were typically 2-15 NTU higher at the Head and Tracy Wildlife Association stations than the two barrier stations during 2010. Both Old River at Head and Old River at Tracy Wildlife Association had highly elevated chlorophyll *a* concentrations during the spring and summer, with the Head station having the highest concentrations in the summer (Figure 6-35). The two stations adjacent to the ORT barrier, Old River upstream of the barrier and Old River downstream of the barrier, had elevated chlorophyll *a* concentrations during the spring and summer as well, but not at the same magnitude as at the other two Old River stations.
- Along with the higher rates of photosynthesis nearby the Head and Tracy Wildlife stations, these two stations had higher pH values than the two stations closest to the ORT barrier during the spring and summer months (Figure 6-38). Old River at Head had much higher pH values than all of the other Old River stations during the summer.
- The Old River at Head station had the most pH standard exceedences out of all of the South Delta stations with a total of 5,459 during 2010 (Figure 6-23). Most of these standard exceedences occurred during the summer with 61% of the total number of samples exceeding the standard. The Tracy Wildlife station also had large numbers of pH samples with values greater than 8.5 during 2010 with 3,552. The two stations closest to the ORT barrier, Old River upstream and Old River downstream of the ORT barrier, had low numbers of pH standard exceedences during 2010 with 718 and 505, respectively.
- The two stations closest to the ORT barrier had lower dissolved oxygen concentrations than the two upstream stations, Old River at Tracy Wildlife Association and Old River at Head, during the spring, summer, and fall (Figure 6-38 and Table 6-13). These differences were statistically significant during the spring and summer ($p<0.00001$; Tables 6-20 and 6-21). The Head and Tracy Wildlife stations had periods of supersaturated dissolved oxygen concentrations particularly during the spring and summer, which could be related to their higher chlorophyll *a* values during these seasons (Figure 6-11). The Old River at Head station had significantly higher dissolved oxygen concentrations than the three other Old River stations during the spring, summer, and fall ($p<0.0005$; Tables 6-20 to 6-22).
- The two Old River stations closest to the ORT barrier had higher numbers of dissolved oxygen standard exceedences than the two upstream sites (Figure 6-14). In 2010, Old River upstream of the barrier had a total of 5,692 dissolved oxygen samples with values less than 5.0 mg/L, and the downstream of the barrier station had 2,972 exceedences. In contrast, the Old River at Head and Old River at Tracy Wildlife Association stations had zero and 394 dissolved oxygen standard exceedences, respectively.
- Old River at Tracy Wildlife Association had higher specific conductance values than the three other Old River stations particularly during the winter and spring (Figure 6-38). Typical conductance values at the Tracy Wildlife station were between 480 to 1,000 µS/cm during the winter and 350 to 970 µS/cm during the spring.



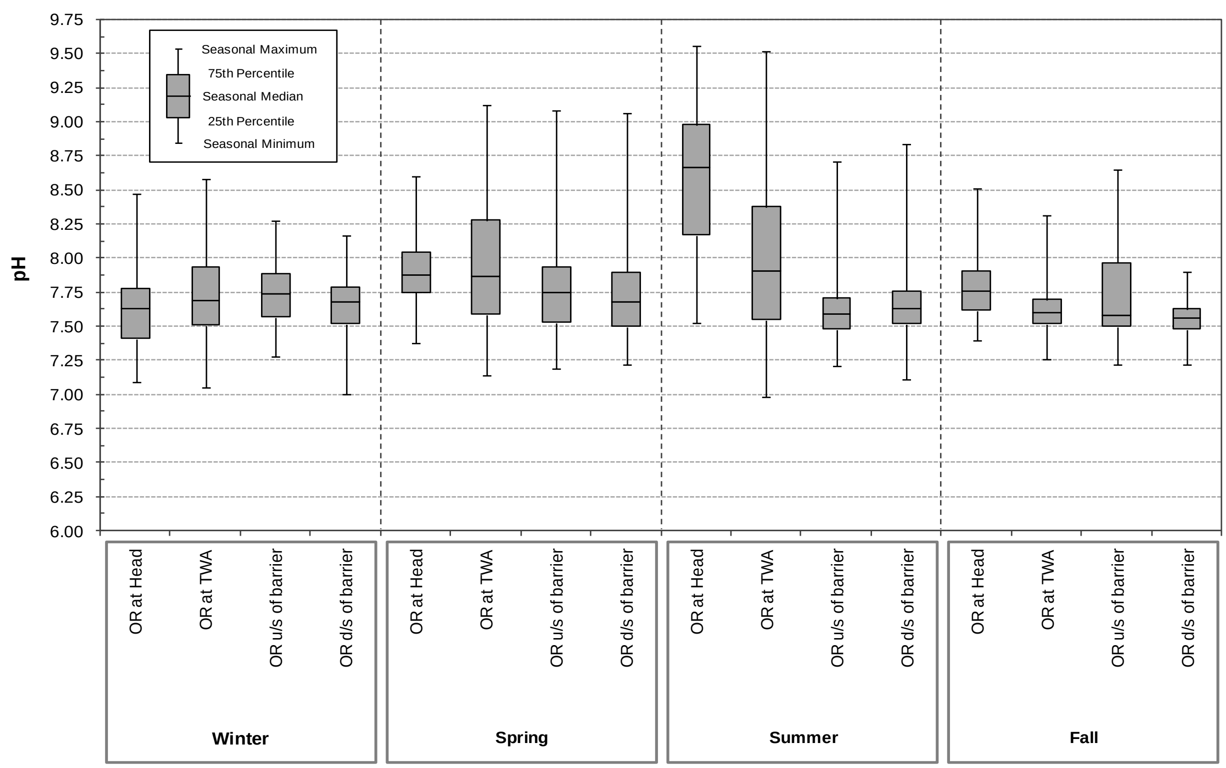
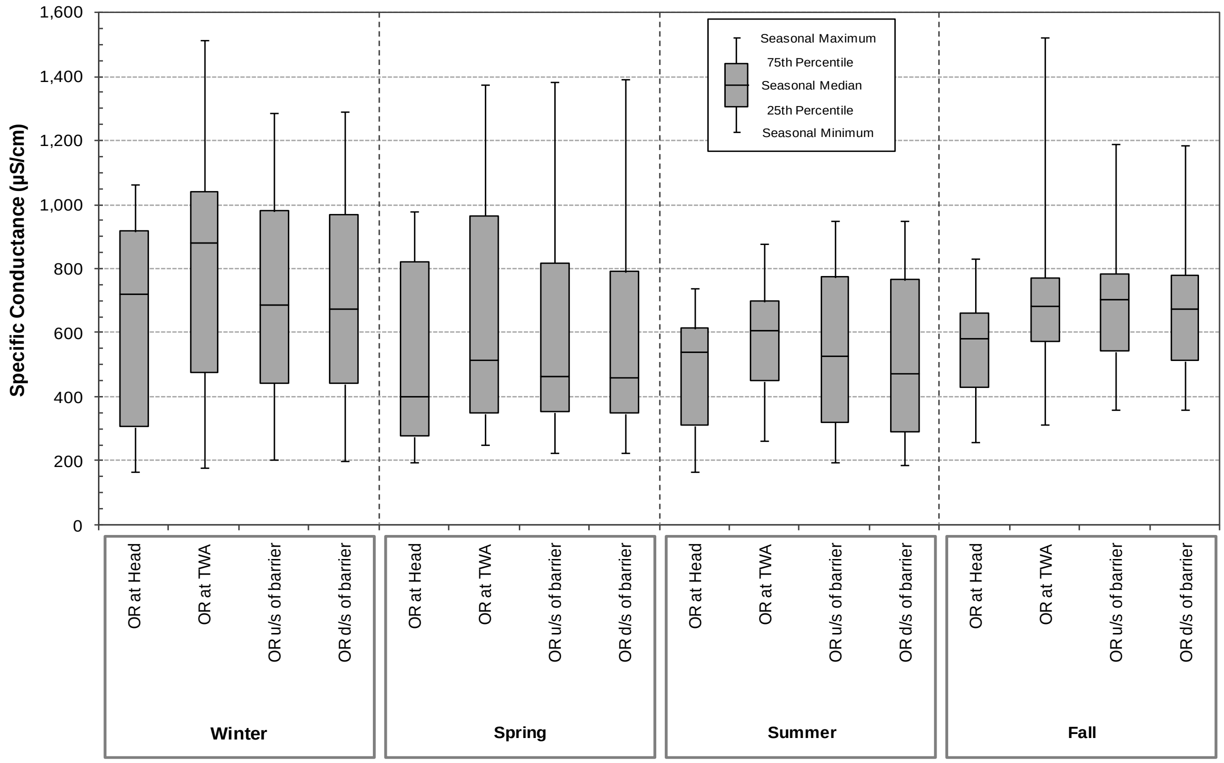


Figure 6-38. Box Plots for the Old River Stations



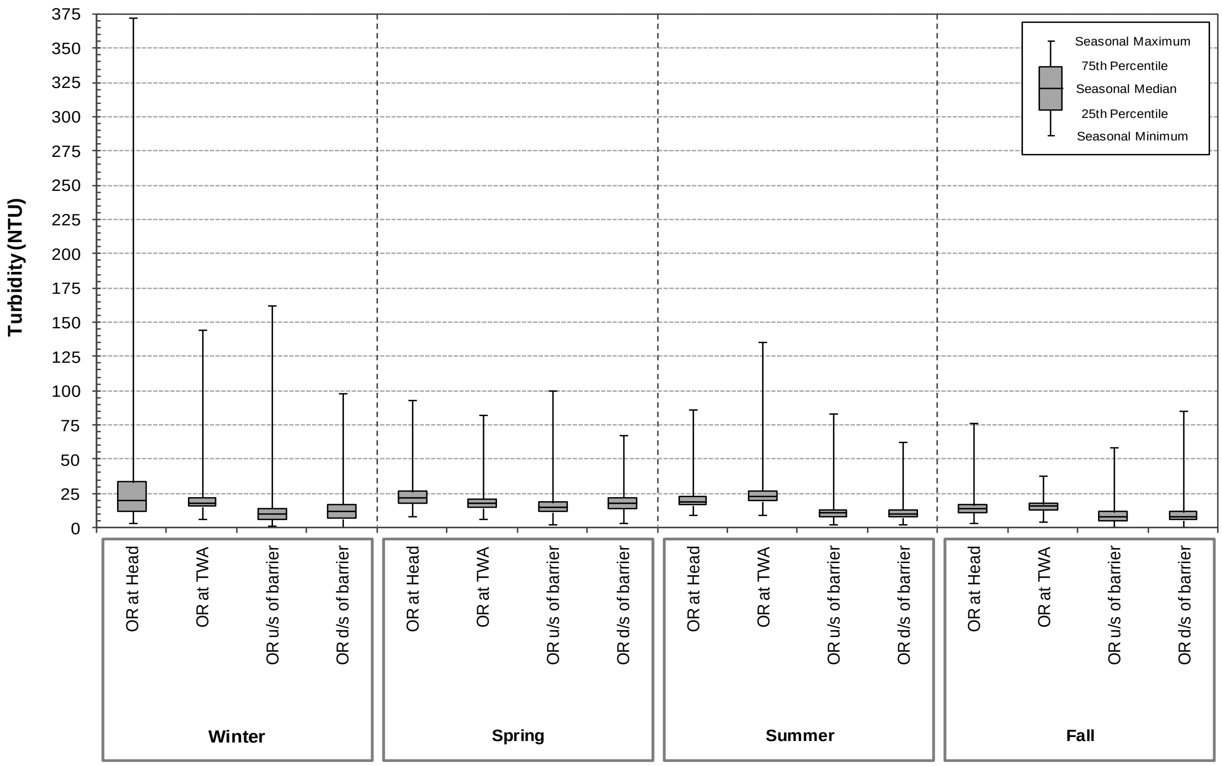


Figure 6-38 (cont.). Box Plots for the Old River Stations

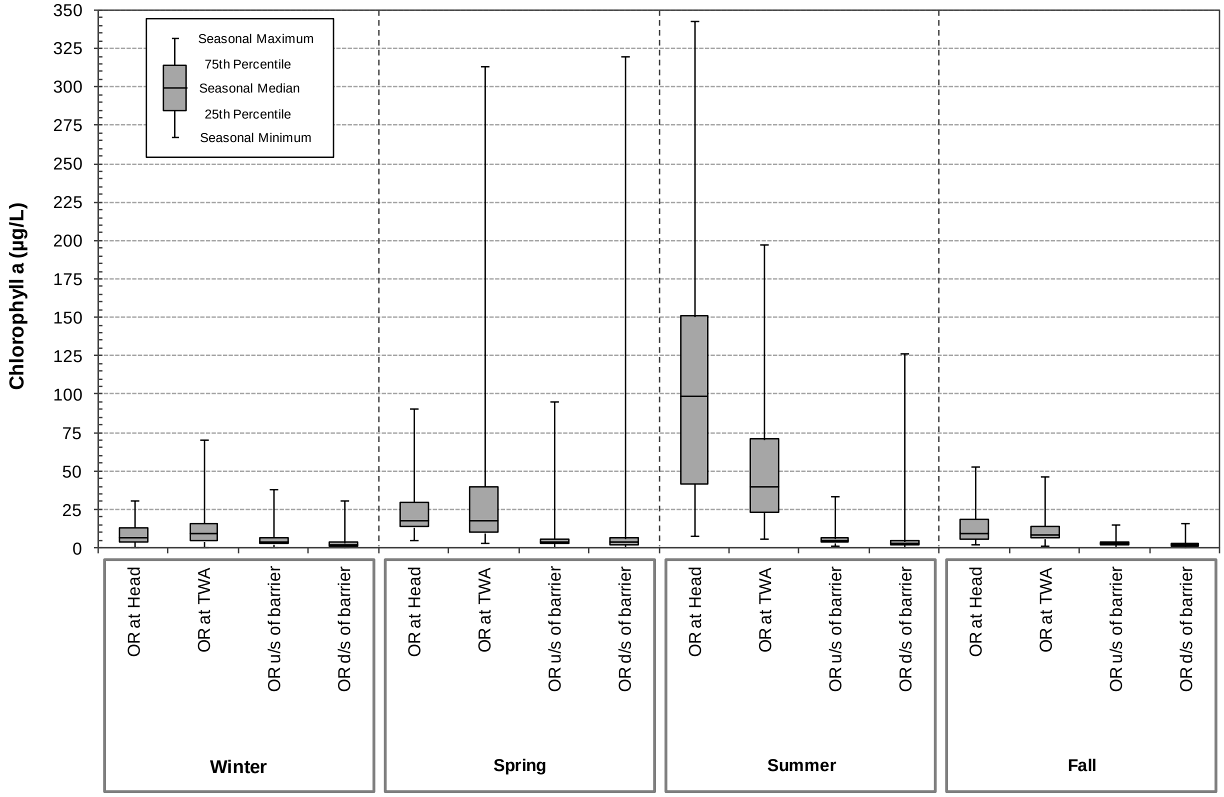


Figure 6-38 (cont.). Box Plots for the Old River Stations

Conclusions and Recommendations

Continuous data collection at the 13 South Delta monitoring locations in 2010 revealed the following overall trends:

- Middle River at Howard Road had some of the highest specific conductance values during 2010. The Howard Road station also had brief periods of highly elevated specific conductance values. Victoria Canal, Middle River at Union Point, and Middle River near Tracy Blvd had some of the lowest conductance values throughout 2010. The water at these stations may be more influenced by the Sacramento River.
- Doughty Cut, Grant Line Canal above the GLC barrier, Grant Line Canal at Tracy Blvd, Middle River at Undine, Old River at Head, and Old River at Tracy Wildlife Association all had higher turbidity values throughout 2010. Victoria Canal and Middle River at Union Point had some of the lowest turbidity values during the year.
- The stations with elevated chlorophyll *a* values in the spring, summer, and early fall were Doughty Cut, Grant Line Canal above the GLC barrier, Grant Line Canal at Tracy Blvd, Middle River at Undine, Old River at Tracy Wildlife Association, and Old River at Head. Victoria Canal, Middle River at Union Point, Middle River near Tracy Blvd, Old River upstream of the ORT barrier, and Old River downstream of the barrier all had low chlorophyll *a* values throughout 2010.
- The stations with higher chlorophyll *a* values listed above also had some of the highest pH values and supersaturated dissolved oxygen concentrations during the warmer months.
- The stations with low chlorophyll *a* values listed above had lower pH values throughout the year.
- Middle River at Howard Road, Old River upstream of the ORT barrier, and Old River downstream of the barrier all had some of the lowest dissolved oxygen concentrations in the spring, summer, and early fall. Of these three stations, Middle River at Howard Road had the lowest concentrations.

DWR staff have the following recommendations for future water quality studies in the South Delta:

- Additional studies and analyses are necessary to determine the relationships between dissolved oxygen concentrations and factors such as algal biomass, biological oxygen demand, and flow at Middle River at Howard Road and the stations nearby the ORT and GLC barriers.
- Data from the monitoring stations on Sugar and Paradise Cuts should be analyzed to help understand the influences of these water bodies on specific conductance values at Old River at Tracy Wildlife Association.
- Studies should be done to determine the sources of the brief periods of highly elevated specific conductance values at Middle River at Howard Road and Undine Road.
- DWR staff will be conducting long-term trend analyses to reveal any changes in water quality parameters at the 13 South Delta stations.

Monitoring will continue in 2011 at all 13 stations to supplement: (1) the existing time-series record, (2) provide historical data, and (3) to meet the requirements outlined in the 401 Water Quality Certification for the Temporary Barriers Project.

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