**LOXAHATCHEE RIVER DATASONDE WATER QUALITY MONITORING**

**TASK 4: FINAL REPORT**

**ASSESSMENT OF 2008-2009 LOXAHATCHEE RIVER WATER QUALITY**

**In Partial Fulfillment of Agreement No. 4600001638-A01**

**For the Period**

**October 2008 through September 2009**

**Respectfully Submitted by:**

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**Loxahatchee River District**

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## Executive Summary

This report presents water quality data collected using autonomous instruments, referred to as datasondes, in the Loxahatchee River from October 2008 through September 2009, with comparisons to previous data. The datasonde instruments collect high frequency (typically every 15 minutes) water quality data including temperature, salinity/conductivity, pH, and dissolved oxygen. The network of datasondes provides unprecedented spatial and temporal detail on water quality fluctuations throughout the Loxahatchee River. Here, these data are used to explore correlative relationships between freshwater flow at Lainhart Dam and S-46 and water quality throughout the river and estuary. Variations in water quality affect the health of a variety of ecological communities within the Loxahatchee River watershed. The modest rainfall and water flows into the Loxahatchee River during the 2008/09 reporting period resulted in daily mean salinities exceeding 2 ppt for 96 days and 134 days at Kitching Creek (KC) surface and bottom respectively. Further downstream, the range of daily salinity at the Oyster (OY) station during the reporting period averaged 16.2 ppt, with a maximum daily range of 27.2 ppt on 2 consecutive days in January 2009. At the most downstream station, North Bay (NB), the daily mean salinity averaged 33.4 ppt during the reporting period, with the minimum daily mean salinity of 22.8 ppt on October 9, 2008. The most interesting finding presented in this report is the suggestion that moderate flood control releases (i.e., <300 cfs) into the Loxahatchee River estuary through the S-46 structure can appreciably reduce daily salinity variability, which should reduce the stress and/or harm experienced by seagrasses and oyster reefs. At this time, we suggest some short duration experimental flood control releases be conducted to further evaluate this apparent relationship. Our goal is to work collaboratively to improve water management strategies to protect the valuable natural resources in the Loxahatchee River and estuary.

Additionally, during this reporting period we have consolidated nearly all of our datasonde data into a centralized database that now contains over one million data records. We continue to validate and load the remaining estimated 5-10% of our historical datasonde data into the database and plan to deliver this data by April 2010.

## Introduction

Since January 2004, the Loxahatchee River District (LRD) has partnered with the South Florida Water Management District (SFWMD) and the Loxahatchee River Preservation Initiative (LRPI) to monitor physical water quality parameters (e.g., temperature, salinity, pH, dissolved oxygen, depth) within the Loxahatchee River Watershed. We utilize autonomous instruments, generically referred to as "datasondes", to collect these data. This monitoring program has several specific goals, and they include the following: (1) establishing baseline conditions in the Loxahatchee River and Estuary, (2) establishing the relationship between the rate of freshwater discharge (i.e., flow over Lainhart Dam and/or S-46) and salinity dynamics in the estuary and the river, (3) establish a better understanding of the daily salinity variability within the estuary and river, and (4) provide observational data on a nearly continuous basis that can be used to calibrate and validate salinity models. In addition, these data are useful for interpreting changes observed in indictor organisms and communities. For example, results from previous datasonde monitoring were instrumental in understanding why seagrasses exhibited significant declines following the storms of September 2004 and the resulting freshwater discharge (Ridler et al. 2006). This ongoing water quality monitoring continues to provide valuable information towards achieving each of the goals stated above.

This report presents the data collected from October 2008 through September 2009 and includes comparisons to available historical datasonde data. Previous reports present data back to April 2004 and are available from LRD's website at www.loxhatcheeriver.org/reports.php. The intent of this report is to highlight some of the most important and relevant observations and findings that resulted from the datasonde monitoring.

One of our key goals over the past year was to begin compiling all of our datasonde data into a single, comprehensive database. While this project is still in progress, but nearly complete, we have now assembled more than 1 million datasonde water quality data records collected throughout the Loxahatchee River. An accompanying Microsoft Access Database containing all this data is available from LRD.

**Study Area**

The Loxahatchee River Estuary encompasses approximately 400 ha and drains a watershed of approximately 700 $km^2$ located in northeastern Palm Beach County and southeastern Martin County, Florida, USA. Freshwater discharges into the estuary from the North Fork, the Northwest Fork, and the Southwest Fork of the Loxahatchee River. Flood control efforts since the 1950's substantially altered the hydrology of the basin. Historically (pre-1950), most surface water runoff reaching the estuary originated in the Loxahatchee and Hungryland Sloughs and flowed gradually to the Northwest Fork. In the 1930s the Lainhart Dam, a small fixed-weir dam, was constructed in the Northwest Fork at river mile 14.5 to reduce "over" drainage of upstream reaches of the Northwest Fork during the dry season. In 1958 a major canal (C-18) and flood control structure (S-46) were constructed to divert flows from the Northwest Fork to the Southwest Fork, which increased the intensity and decreased the duration of storm-related discharge to the estuary. Furthermore, in 1947 the Jupiter inlet District began a series of jetty expansions and routine dredging at the Jupiter Inlet, the rivers eastern link to the ocean, that have resulted in increased saltwater flows through the inlet. The changes to inlet management and reduced freshwater flows from drainage modifications have resulted increased saltwater intrusion into the primarily freshwater Northwest Fork. Ongoing restoration efforts seek to increase base freshwater flows into the Northwest Fork, while not compromising the ecological integrity of downstream reaches (i.e., estuary) nor impairing valued ecosystem components of the estuary such as oysters and seagrasses (SFWMD 2006).

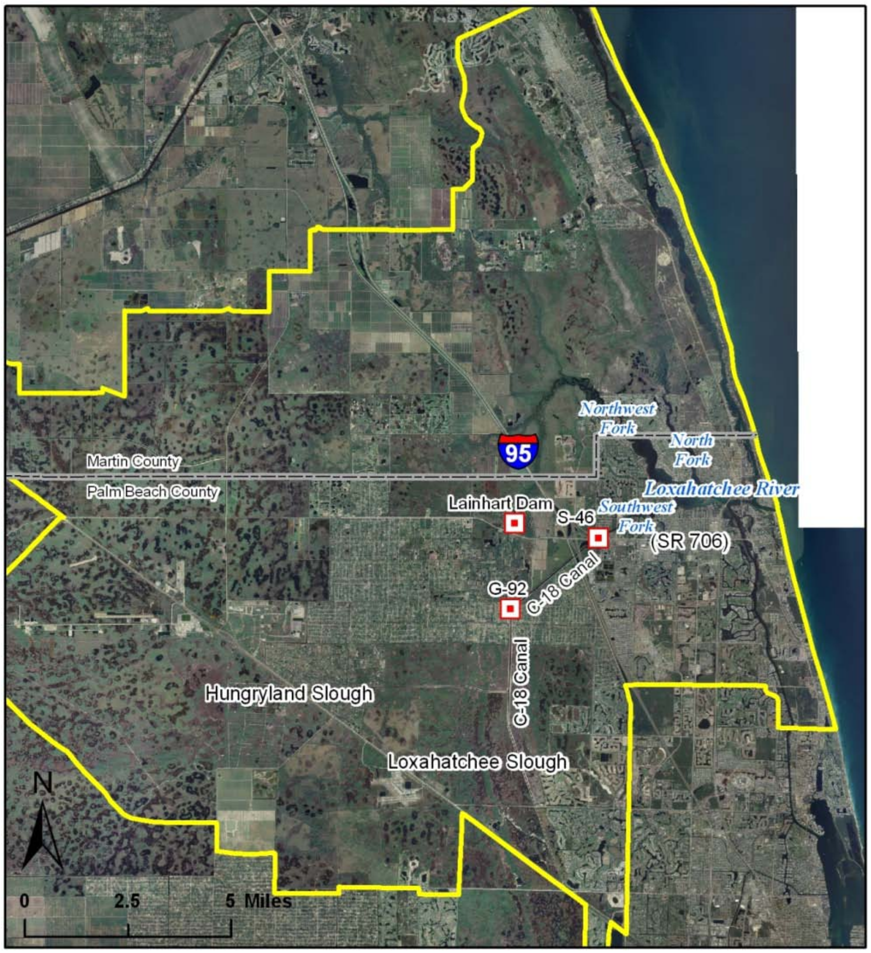


Figure 1. Loxahatchee River watershed and associated features.

During this study, we used datasondes, automatic recording, multi-parameter water quality monitoring instruments, to monitor physical water quality conditions at eight sites (Figure 2, Table 1). Water quality monitoring occurred at two stations where the LRD performed seagrass monitoring. These stations were North Bay (NB) and Pennock Point (PP). North Bay (NB) and Pennock Point (PP) were located in the central embayment of the Loxahatchee River (Figure 2). At each of these sampling locations, datasondes monitored temperature, salinity, conductivity, and water depth. Water quality monitoring also occurred at Station 69, Station 66, and Kitching Creek, all in the Wild and Scenic segment of the Northwest Fork of the Loxahatchee River. Station 69 is the most upstream sampling site, located where Indiantown Road crosses the Loxahatchee River (Figure 2). Station 66 is in the middle of the Wild & Scenic segment and was monitored during the spring of 2009 to monitor saltwater intrusion into the area. The Kitching Creek (KC) site was in the Loxahatchee River at the confluence of Kitching Creek. Note that two datasondes were deployed at Kitching Creek – one at the surface (0.5 m deep) and one in the middle of the channel approximately 20 cm above the bottom, in waters roughly 3 m deep. At each of these monitoring locations in the Wild and Scenic River, we sampled the following parameters: temperature, pH, DO, salinity, conductivity and water depth. Data collection occurred at a third station (Oyster Reef/OY) within the Northwest Fork, downsteam of the Wild and Scenic segment, in the vicinity of high densities of oysters.Additionally, datasonde monitoring occurred at Station 72 and Station 75 in the Southwest Fork of the Loxahatchee. Station 72, near the main channel of the Southwest Fork of the Loxahatchee, is influenced by freshwater discharges from the C-18 canal through the S-46 structure. Station 75 is in Jones Creek, a tributary to the Southwest Fork.

**Table 1. Locations of Datasonde water quality monitoring stations in the Loxahatchee River, Jupiter, Florida.**

| Station | Latitude | Longitude | Location | River Segment |
|---|---|---|---|---|
| 66 | 26° 59.120” | 80° 09.708” | Wild & Scenic | Wild & Scenic |
| 69 | 26° 56.239” | 80° 10.569” | Indiantown Rd. Bridge | Wild & Scenic |
| KC (surface, bottom) | 26° 59.469” | 80° 09.302” | Mouth of Kitching Creek, NW Fork | Upper region of Meso-/Oligohaline |
| OY | 26° 58.229” | 80° 07.548” | Northwest Fork | Polyhaline |
| PP | 26° 56.888” | 80° 06.650” | Pennock Point | Polyhaline |
| NB | 26° 57.055” | 80° 05.658” | North Bay, Central Embayment | Marine |
| 72 | 26° 56.598” | 80° 07.311” | Southwest Fork | Polyhaline |
| 75 | 26° 56.021” | 80° 06.788” | Jones Creek, tributary to SW Fork | |

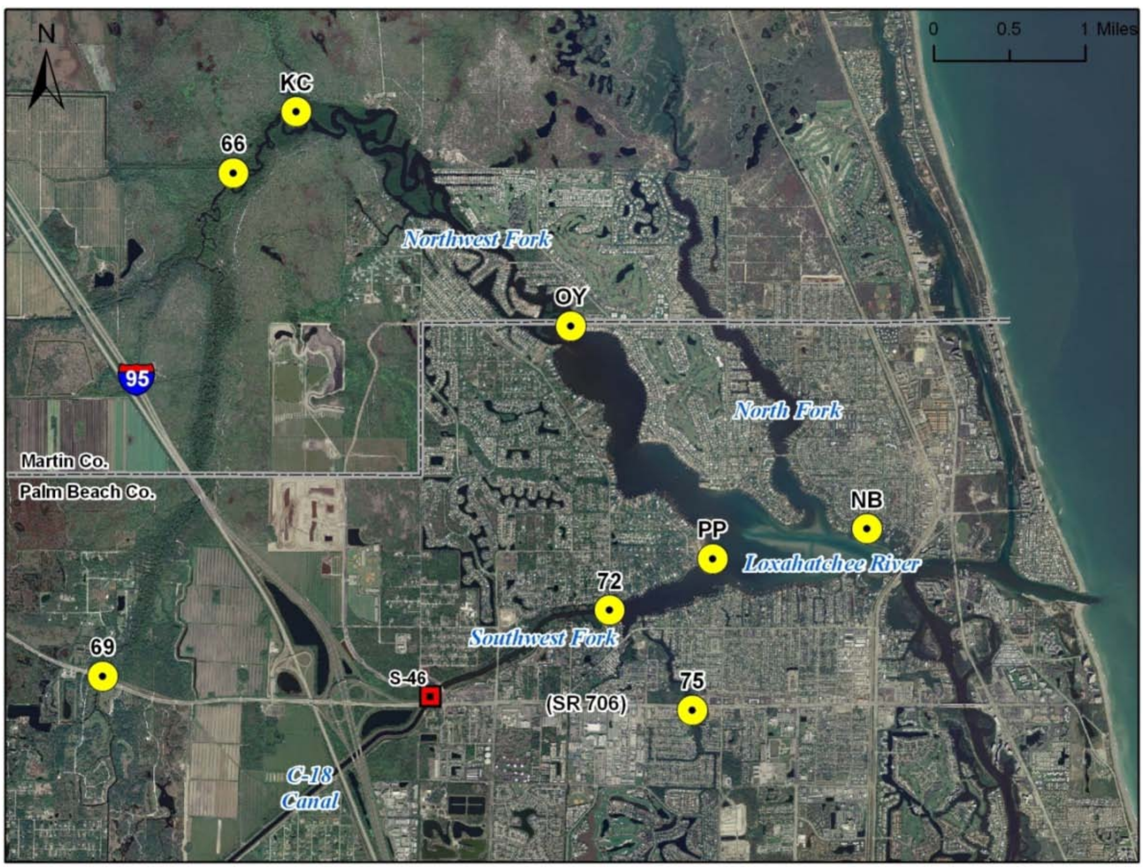


**Figure 2. Locations of Datasonde water quality monitoring stations, Loxahatchee River, Jupiter, Florida. Photo 2004.**

## Materials and Methods

At each station, LRD scientists employed a multi-parameter datasonde (a HydroTech Data Sonde 3, Data Sonde 4, or YSI 600 OMS unit) to collect physical water quality parameters. The datasondes recorded water temperature, depth, pH, conductivity/salinity and dissolved oxygen in freshwater, while only temperature, depth, and salinity were monitored in marine waters (e.g., NB). The datasondes were generally placed within 25 cm of the river bottom (see Kitching Creek surface site exception above), and observations were recorded every 15 minutes, and each hour at Station 69.

Prior to datasonde deployment, we performed an initial calibration following the protocol described in the operating manual. Subsequent to the initial calibration, we programmed the datasonde to begin collecting data at the appropriate start time and interval between readings. Datasondes were deployed in an upright position, with the probes facing down, to minimize fouling of the probes. On a weekly basis, staff traveled to each of the datasonde sites and performed an in situ QC check by collecting a comparison reading using a second, appropriately calibrated, hand-held datasonde. This permitted a comparison between results obtained from the field-deployed datasonde and the hand-held unit. Typically, we deployed datasondes for two weeks then brought the units back to the lab for cleaning, maintenance, and re-calibration. Following data collection, we perform a final calibration following the protocol described in the operating manual. In order for data to meet LRD's QA/QC acceptance criteria, weekly QC checks and final calibration data must have met the following criteria:

1. Dissolved Oxygen – difference ≤ 0.5 mg/L
2. Specific Conductance and Salinity – difference ≤ 10%
3. pH – difference ≤ 0.5 pH units
4. Temperature – difference ≤ 0.5 °C

We accepted data meeting the above criteria as valid and rejected data not meeting these criteria as unreliable. All data that did not pass QA/QC acceptance criteria were removed from the final (edited) dataset. Instrument or probe failure resulted in additional missing data for some periods at some stations.

## Results & Discussion

Results from the datasonde monitoring project clearly show the daily and seasonal variability of the various monitored parameters (e.g., salinity, dissolved oxygen) within and among the monitored locations. Table 2 presents summary statistics for each water quality parameter at each station for October 1, 2008 through September 30, 2009 (upper pane), and for all data loaded into the database at this time through September 20, 2009 (lower pane). Appendix A presents plots of the mean daily parameter values from October 1, 2008 through September 30, 2009 compared to the mean daily, minimum, and maximum values for the period of record available from the database, at each station. Note that data labeled as '2008/09' contains data from October 1, 2008 through September 30, 2009.

Appendix B provides a plot of the daily mean, minimum and maximum value for the full record of available data and parameters at each station. As we load additional historical data into the database, the historical period of record values will change.

The following is a brief summary of the data collected at each station:

Station 66 is monitored primarily during the height of the dry season (March – June) to evaluate salinity intrusion in relatively upstream reaches of the Wild & Scenic section of the river. Appendix A1 shows the limited data from 2009 indicated typical temperature and pH values, low conductivity, and a few spikes in dissolved oxygen compared to period of record (POR), or the available historical data presently loaded into our database. Appendix B1 shows the plot of all data collected at this site.

Station 69 at Indiantown Road and Riverbend County Park contained several gaps in the data due to instrument or probe failure. From January through April 2009, the data showed high conductivity and elevated pH compared to the available POR (Appendix A2 & B2). These higher conductivity and pH values were the result of discharge waters pumped into the C-18 Canal during the development of a new Floridan well for the Town of Jupiter. These saline waters in the C-18 Canal entered the Northwest Fork of the Loxahatchee through the G-92 Structure.

We collected a full season of data for Station 72 at the Loxahatchee River Road bridge over the Southwest Fork. Other than the brief period of data collected in 2006, comprehensive sampling began in April 2008. These data provides new insight into the temperatures and salinities present in the Southwest Fork during fall and winter months. Appendix A3 and B3 show the summer 2009 data did not exhibit as severe drops in salinity as those observed in 2008. These data reflect the lower rainfall and reduced freshwater discharges from the S-46 structure.

Like station 72, the data for station 75 in Jones Creek in the Southwest Fork in 2008/09 provides our first nearly complete annual record of salinity and temperature. The missing data from mid August 2008 through mid October 2008 was the result vandalism and loss of a datasonde instrument (Appendix B4). In October 2009 the instrument station was relocated slightly downstream. The few gaps in the 2008/09 data was the result of instrument sensor failure. The July through mid August 2009 data is generally similar to the data recorded for the same period in 2008 (Appendix A4). In 2007, the Jupiter Inlet District, in partnership with the Loxahatchee River Preservation Initiative, dredged portions of the Creek as part of a restoration project to remove accumulated organic sediments and improve water flow and navigability.

Sampling at Kitching Creek (KC) station in the Northwest Fork in 2008/09 provided a nearly complete year of monitoring data at the surface and bottom with the exception of a few data gaps that were the result of instrument or probe failure. Salinity data for this site is of particular interest because saline waters enter this typically freshwater segment of the river during periods when insufficient flows of freshwater pass over Lainhart Dam. The figures in Appendix A5 & B5 show the 2009 dry season daily mean salinities at the top instrument (KCT) were similar to the mean salinities for the period of record (POR) presently available in our database dating back to 2005. Daily mean salinity exceeded 2 ppt for a total of 96 days at the KCT station between October 2008 and September 2009. In contrast, the salinities measured at the instrument near the river bottom (KCB) were elevated through much of the dry season, setting new highs for mean daily salinity for some dates (A6, B6). Daily mean salinity exceeded 2 ppt for 134 days at the KCB station between October 2008 and September 2009. Mean daily dissolved oxygen levels were also notably lower than the available POR mean during the dry season at the bottom instrument. A bathymetric depression at the sampling site (at the mouth of Kitching Creek) may account for the elevated salinities and reduced dissolved oxygen levels because of the lack of mixing. Perhaps during low flows the more dense saline water may settle into the deeper bathymetric depression where it may become anoxic due to a lack of mixing. This phenomenon is apparent when comparing the 15 minute interval data for the surface and bottom instruments, where surface instrument clearly shows the tidal exchange. The persistent low water flows during the dry season may have contributed to these observations.

Sampling at the Oyster (OY) station resumed in October 2008 after the instrument was vandalized and lost in June 2008. A few gaps in the data were the result of instrument or probe failure. Salinity at this site exhibits substantial daily and seasonal variation as shown in the figures in Appendix A7 and B7. The average range of daily minimum and maximum salinities during the reporting period was 16.2 ppt, with a maximum of 27.2 ppt on January 11 and 12, 2009. Coincidently we have found this area contains the healthiest and most extensive oyster beds in the river (LRD, 2008). Salinities for the 2008/09 sampling season were generally typical for the available POR for this site dating back to 2007.

Downstream of the OY station, the Pennock Point (PP) station exhibits generally higher salinities as illustrated in the figures in Appendix A8 and B8 Daily mean salinities in 2008/09 were generally typical of the daily mean for the available POR dating back to 2004, except for the observed drop in salinities in October 2008 that were within previously observed values.

The most downstream/seaward station, North Bay (NB), contained several data gaps due to instrument or probe failure. The figures in Appendix A9 and B9 show mean daily salinities were generally similar to the daily mean salinities for the available POR dating back to 2004. Daily mean salinity averaged 33.4 ppt during the reporting period with the minimum daily mean of 22.8 ppt on October 9, 2008. The minimum salinity recorded at this site was 12.6 ppt on October 8, 2008.

**Table 2. Summary statistics for water quality parameters measured by datasonde between October 1, 2008 and September 30, 2009, Loxahatchee River, Florida.**

**October 1, 2008 - September 30, 2009**

| | Start | End | | Temperature $^{o}$C | | | Salinity (ppt) | | | Conductivity (µmho/cm) | | | pH | | | Disolved Oxygen (mg/L) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Station | Date | Date | N | Average | Min | Max | Average | Min | Max | Average | Min | Max | Average | Min | Max | Average | Min | Max |
| 66 | 3/3/2009 | 5/24/2009 | 3,840 | 22.9 | 16.4 | 28.6 | 0.6 | 0.4 | 5.4 | 1,179 | 706 | 9,624 | 7.6 | 7.3 | 7.8 | 5.6 | 3.4 | 8.6 |
| 69 | 10/1/2008 | 9/30/2009 | 5,980 | 25.5 | 14.6 | 32.6 | 0.3 | 0.2 | 0.8 | 675 | 314 | 1,553 | 7.4 | 6.9 | 7.9 | 4.4 | 1.0 | 7.7 |
| 72 | 10/1/2008 | 9/30/2009 | 34,644 | 25.7 | 13.9 | 34.9 | 27.7 | 1.1 | 34.3 | 43,018 | 2,059 | 52,303 | | | | | | |
| 75 | 10/13/2008 | 9/30/2009 | 30,695 | 24.5 | 12.4 | 33.8 | 20.9 | 0.6 | 33.7 | 33,092 | 1,133 | 51,168 | | | | | | |
| Kitching Creek Surface | 10/13/2008 | 9/30/2009 | 32,742 | 24.4 | 13.4 | 32.0 | 1.4 | 0.1 | 12.5 | 2,496 | 237 | 20,881 | 7.4 | 6.5 | 8.0 | 4.4 | 1.2 | 9.1 |
| Kitching Creek Bottom | 10/13/2008 | 9/30/2009 | 32,198 | 24.8 | 17.3 | 31.8 | 7.1 | 0.1 | 22.6 | 11,716 | 237 | 35,754 | 7.2 | 6.5 | 7.7 | 3.0 | 0.0 | 6.5 |
| NB | 10/1/2008 | 9/30/2009 | 27,172 | 25.2 | 14.7 | 34.5 | 33.4 | 12.6 | 37.0 | 50,799 | 21,153 | 55,901 | | | | | | |
| OY | 10/1/2008 | 9/30/2009 | 32,361 | 25.3 | 12.1 | 33.4 | 20.9 | 2.3 | 36.5 | 33,140 | 4,331 | 54,999 | | | | | | |
| PP | 10/1/2008 | 9/30/2009 | 34,738 | 25.2 | 14.5 | 34.3 | 32.4 | 3.0 | 37.0 | 49,440 | 5,556 | 55,693 | | | | | | |

**All Data Loaded into Database through September 30, 2009**

| | Start | End | | Temperature $^{o}$C | | | Salinity (ppt) | | | Conductivity (µmho/cm) | | | pH | | | Disolved Oxygen (mg/L) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Station | Date | Date | N | Average | Min | Max | Average | Min | Max | Average | Min | Max | Average | Min | Max | Average | Min | Max |
| 25 | 1/11/2006 | 2/29/2008 | 64,994 | 25.7 | 14.1 | 33.8 | 34.5 | 14.2 | 37.9 | 52,567 | 23,338 | 58,627 | 7.8 | 7.7 | 8.0 | 6.4 | 4.8 | 8.2 |
| 66 | 5/1/1999 | 5/24/2009 | 50,381 | 24.8 | 13.8 | 31.5 | 1.2 | 0.1 | 16.8 | 2,215 | 257 | 27,355 | 7.5 | 6.7 | 8.1 | 4.8 | 0.3 | 9.3 |
| 69 | 1/19/1995 | 9/30/2009 | 84,477 | 25.4 | 14.0 | 33.3 | 0.3 | 0.1 | 0.8 | 551 | 67 | 1,553 | 7.4 | 6.8 | 8.1 | 4.1 | 0.0 | 10.0 |
| 72 | 8/29/2006 | 9/30/2009 | 50,455 | 26.6 | 13.9 | 34.9 | 26.7 | 0.2 | 35.5 | 41,516 | 479 | 53,932 | | | | | | |
| 75 | 6/30/2008 | 9/30/2009 | 35,718 | 25.3 | 12.4 | 33.8 | 19.8 | 0.3 | 33.7 | 31,610 | 577 | 51,168 | | | | | | |
| Kitching Creek Surface | 1/1/2005 | 9/30/2009 | 141,679 | 25.0 | 13.4 | 32.8 | 1.6 | 0.0 | 23.0 | 2,840 | 48 | 36,311 | 7.3 | 6.0 | 8.0 | 4.3 | 0.2 | 9.1 |
| Kitching Creek Bottom | 1/9/2003 | 9/30/2009 | 174,617 | 25.1 | 14.6 | 32.8 | 5.7 | 0.0 | 25.1 | 9,459 | 77 | 39,351 | 7.3 | 6.3 | 8.2 | 3.5 | 0.0 | 8.9 |
| NB | 5/1/2004 | 9/30/2009 | 168,976 | 25.9 | 14.7 | 35.4 | 32.8 | 1.3 | 37.9 | 49,975 | 2,480 | 63,356 | | | | | | |
| OY | 2/13/2007 | 9/30/2009 | 74,763 | 25.6 | 12.1 | 34.0 | 19.3 | 0.1 | 36.5 | 30,733 | 250 | 54,999 | | | | | | |
| PP | 5/1/2004 | 9/30/2009 | 168,868 | 25.8 | 14.5 | 34.3 | 31.8 | 0.2 | 38.1 | 48,576 | 396 | 59,192 | | | | | | |
| | | Total: | 1,014,928 | | | | | | | | | | | | | | | |

Salinity data from the datasonde monitoring project are beneficial to understand how freshwater discharged into the Loxahatchee River Estuary (e.g., over Lainhart Dam and/or S-46) influence salinity conditions in the estuary. In particular, salinity conditions are known to affect the health of three primary valued ecosystem components (VECs) in the Loxahatchee River: cypress trees, oysters, and seagrass. It is both intuitive and immediately apparent that as freshwater flows (i.e., discharge into the system) increase, salinity values decrease. Below, we use our wealth of datasonde data to clearly describe the effect of freshwater discharges (over Lainhart Dam and/or S-46) on the minimum, mean, maximum and variability (measured by standard deviation) of the daily salinity values at each of our datasonde sampling sites. Simple Pearson correlation analysis shows strong relationships ($\rho_{xy}$>= 0.6 or 0.7; <= -0.6 or -0.7) between freshwater flows and daily mean, minimum, maximum, and standard deviation salinities, as summarized in Table 3.

**Table 3. Pearson correlation coefficient values for the relationship of daily river flows measured at Lainhart Dam, S-46 Structure, and sum versus the Mean, Min, Max and Standard Deviation of salinity (or conductivity at stations 69 and 66) at the various monitoring stations in the Loxahatchee River, Florida. Strong correlations (> 0.7 or < -0.7) are shaded green; moderate correlations (> 0.6 or < -0.6) are shaded yellow. See Figure 1 and Table 1 for station locations.**

| Flow Station | Daily Salinity Measurement | 69 | 66 | Kitching Creek Surface | Kiching Creek Bottom | OY | PP | NB | 75 | 72 |
|---|---|---|---|---|---|---|---|---|---|---|
| Lainhart | Mean | -0.737 | -0.289 | -0.528 | -0.617 | -0.703 | -0.589 | -0.768 | -0.738 | -0.59 |
| | Min | -0.749 | -0.202 | -0.431 | -0.516 | -0.778 | -0.713 | -0.789 | -0.693 | -0.668 |
| | Max | -0.697 | -0.387 | -0.617 | -0.686 | -0.346 | -0.455 | -0.607 | -0.688 | -0.442 |
| | Std Dev | 0.067 | -0.331 | -0.606 | -0.414 | 0.636 | 0.606 | 0.753 | -0.03 | 0.523 |
| S-46 | Mean | -0.406 | -0.052 | -0.257 | -0.313 | -0.518 | -0.656 | -0.773 | -0.578 | -0.639 |
| | Min | -0.421 | -0.041 | -0.217 | -0.26 | -0.478 | -0.646 | -0.729 | -0.473 | -0.652 |
| | Max | -0.375 | -0.072 | -0.314 | -0.359 | -0.319 | -0.538 | -0.646 | -0.577 | -0.442 |
| | Std Dev | 0.06 | -0.06 | -0.305 | -0.227 | 0.299 | 0.542 | 0.69 | -0.216 | 0.538 |
| Lainhart + S-46 | Mean | -0.552 | -0.125 | -0.39 | -0.458 | -0.648 | -0.671 | -0.814 | -0.733 | -0.685 |
| | Min | -0.567 | -0.091 | -0.323 | -0.382 | -0.655 | -0.706 | -0.789 | -0.643 | -0.726 |
| | Max | -0.516 | -0.169 | -0.465 | -0.517 | -0.36 | -0.541 | -0.668 | -0.708 | -0.488 |
| | Std Dev | 0.067 | -0.143 | -0.454 | -0.319 | 0.476 | 0.596 | 0.749 | -0.157 | 0.587 |

| | |
|---|---|
| (yellow) | Correlation Coefficient > 0.6 or < -0.6 |
| (green) | Correlation Coefficient > 0.7 or < -0.7 |

From a river management and restoration perspective, we need to better understand what flow conditions lead to anomalously elevated salinity conditions in regions of the river that were historically fresh. Equally important is our need to understand what freshwater flow conditions result in damagingly low salinities in the downstream reaches and central embayment of the river. Elevated salinities in the upper, traditionally freshwater, sections of the river have resulted in the loss of cypress trees and other changes to the freshwater communities. Conversely, low salinity conditions in the downstream, more saline, sections of the river have damaged oyster and seagrass communities. Figures 2 through 4 illustrate the relationships, non-linear in many cases, between freshwater discharge and salinity conditions at key sites in the river. Figure 3 shows how daily minimum and maximum salinity conditions at OY and NB sites vary as a function of freshwater flowing over Lainhart Dam. Similarly, Figures 4 shows the effect of freshwater flows over S-46 on daily minimum and maximum salinity conditions at NB, while Figure 5 shows the cumulative effect of freshwater flows from both Lainhart Dam and S-46 on minimum and maximum daily salinity conditions at NB. These plots illustrate the strong correlations shown in Table 3, though some of the relationships are obviously non-linear in nature.

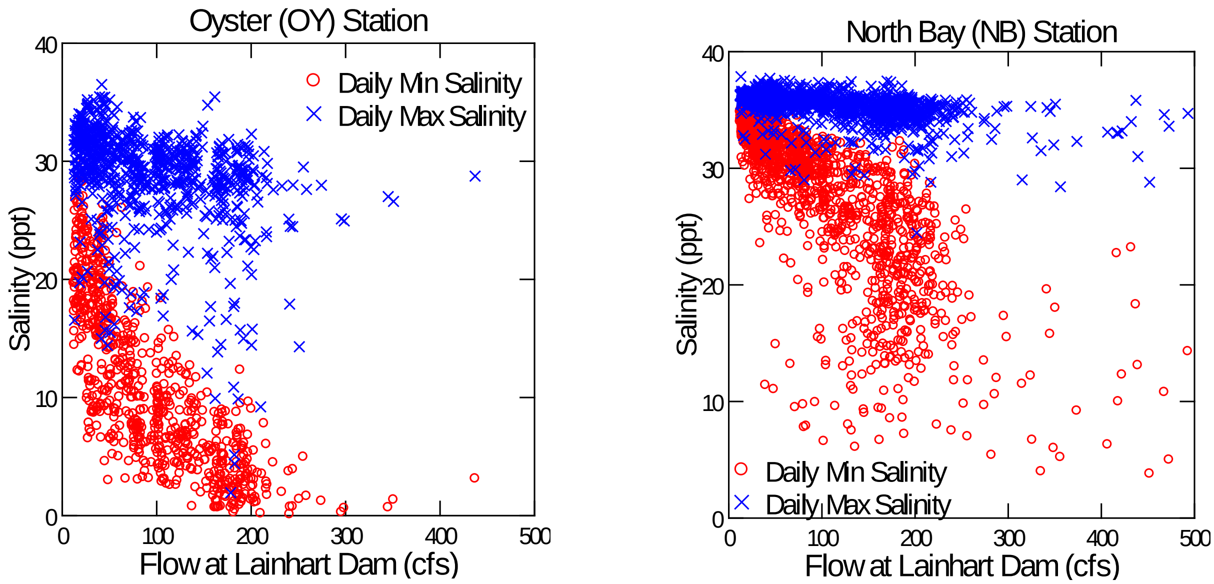


**Figure 3. Plots showing the relationship of salinity with water flow at Lainhart Dam for the Oyster (OY) and North Bay (NB) Stations, Loxahatchee River, Florida.**

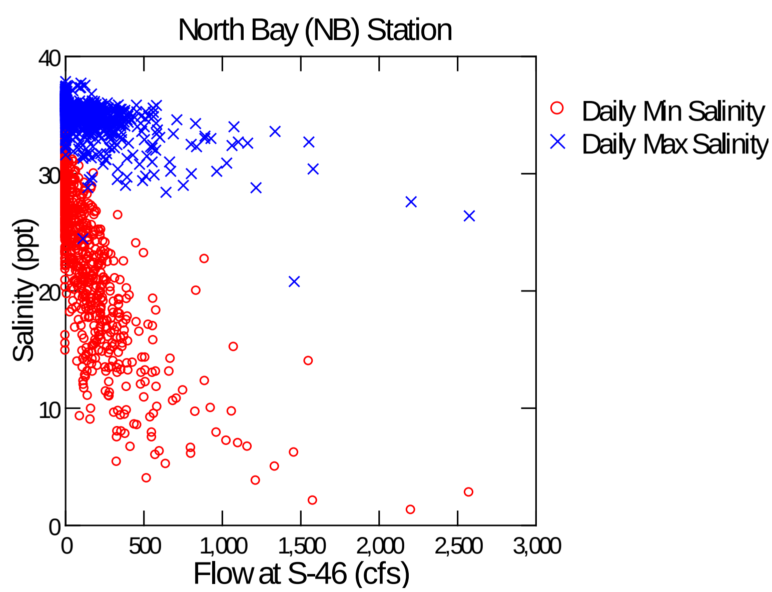


**Figure 4. Plot showing the relationship of salinity with water flow at S-46 Structure at the North Bay (NB) Station, Loxahatchee River, Florida.**

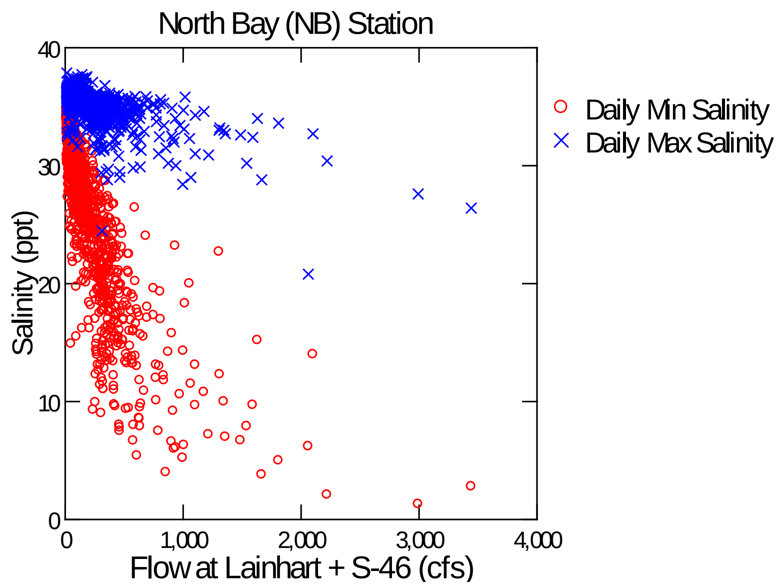


**Figure 5. Plot showing the relationship of salinity with water sum of flows at Lainhart Dam and S-46 Structure at the North Bay (NB) Station, Loxahatchee River, Florida.**

Furthering our understanding of the effect of freshwater flows on salinity conditions can provide valuable insight into the ecology of the various habitats in the Loxahatchee River. Clearly, salinity is a strong physical stressor that that likely drives the occurrence and relative health of at least three valued ecosystem components (i.e., cypress trees, oysters, and seagrasses). Figure 6 clearly shows that the healthiest oyster reefs in the Loxahatchee River occur in an area (OY) that experiences relatively high daily salinity variability even when no flood control releases occur through S-46. Also, Figure 6 shows NB, among the healthiest seagrass sites in the river, to experience relatively modest levels of daily salinity variability. Classical understanding of these habitats would support the notion that oysters live in areas that experience relatively broad swings in salinity on a daily basis, while seagrass typically proliferate in areas with relatively stable salinity conditions (e.g., nearshore areas in the Bahamas). Ridler et al. (2006) suggested that significantly large fluctuations in salinity conditions likely degraded seagrass meadows following major storms in 2004. More recently, research by Dr. Craig Layman and his graduate students has suggested oyster reef communities, including not only live oysters but also the associated crabs, shrimp, and fish, are strongly affected by salinity conditions in the Loxahatchee River..

It therefore appears that an improved understanding of how altered freshwater flow conditions affect salinity variability may be used to facilitate, to the degree possible, a renewed water management strategy for the Loxahatchee River. Figure 6 shows daily salinity variability, measured as daily standard deviation of salinity, for four sites in the river (plotted upstream (KC) to downstream (NB)) under three different flow conditions measured at S-46. These data clearly show that flood control releases, i.e., flows > 300 cfs, through the S-46 structure substantially increase salinity variability to a physiologically stressful level throughout much of the river, which was surprising. Of course, we expected flood control releases to affect salinity conditions at PP and NB – sites near or downstream of the Southwest Fork confluence, but we were surprised to see flood control releases affect daily salinity variability measured all the way up to OY (approximately x miles upstream of the outlet of the Southwest Fork). We suspect the decrease in salinity variability at KC when S-46 is flowing at more than 300 cfs is due to system-wide rainfall effects. That is, when large flood control releases are being made at S-46 we expect large, consistent freshwater flows are passing over Lainhart Dam. Finally, Figure 6 clearly shows that if flood control can be maintained through flood control releases ≤ 300 cfs then such releases are much less likely to significantly harm seagrasses and oyster reefs in the Loxahatchee River. We recognize duration is also an important component of flow, and we suggest this type of analysis deserves additional research and potentially may justify some controlled releases through the S-46 structure to better understand how consistent flood control releases of 300 cfs magnitude affect salinity conditions throughout the system.

While these relationships certainly require additional, more detailed and thorough research and analysis, we believe we have assembled an incredibly valuable collection of data that has the potential to give managers an alternative approach to flood control releases that may lessen negative impacts to valued ecosystem components, such as oyster reefs and seagrass beds, and their communities in the Loxahatchee River.

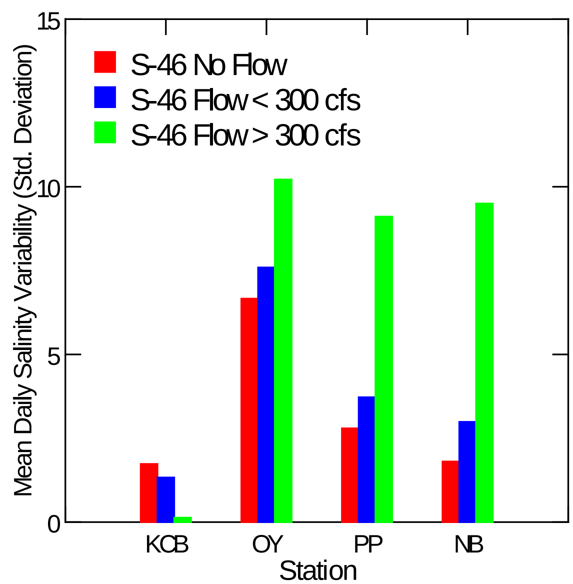


**Figure 6. Plot of salinity variability, measured as mean daily standard deviation, at four stations (upstream to downstream) under different flow conditions measured at the S-46 Structure in the Loxahatchee River, Florida.**

The goals of the datasonde monitoring project were to: (1) establish baseline conditions in the Loxahatchee River and Estuary, (2) establish the relationship between freshwater discharge and salinity dynamics in the estuary and the river, (3) establish a better understanding of the daily salinity variability within the estuary and river, and (4) provide observational data on a nearly continuous basis that can be used to calibrate and validate salinity models. Clearly, the data and figures from this report show we are accomplishing goal 1. That is, we are gaining a solid understanding of the pre-CERP physical water quality conditions in the Loxahatchee River and Estuary. These data also help to document the relationships between freshwater discharge and salinity conditions in the Loxahatchee River and Estuary (goals 2 and 3). We look forward to continuing our collaborative relationship with SFWMD staff to provide the data necessary to further our understanding of these relationships through statistical analysis and salinity models (goal 4).

In conclusion, the datasonde project has resulted in the compilation of an amazing amount of data that has a very direct relevance to ongoing research, monitoring, and restoration in the Loxahatchee River and Estuary. By continuing this datasonde project we can all expand our understanding of the wide variety of water quality and flow scenarios that occur within the river system. We look forward to continuing this cost-effective collaboration.

Recommendations for future work:

1. Continue the Datasonde monitoring program to assess long- and short-term trends in water quality in the Loxahatchee River. This data provides essential information for adaptive management of restoration activities.
2. Perform comprehensive, sophisticated analysis of the Datasonde dataset with other environmental and physical parameters to further our understanding of the relationships between the variables. Water managers can then utilize this information to best manage flows into the Loxahatchee River.
3. Perform additional controlled flood control releases at the S-46 structure. Ideally, we would like to maintain 300 cfs flow through S-46 for an extended period of 7-14 days to better understand how these protracted flows affect salinity variability and mean salinity conditions in the Loxahatchee River estuary and to understand how biological communities respond to these long-duration but low magnitude flood control releases.

Literature Cited


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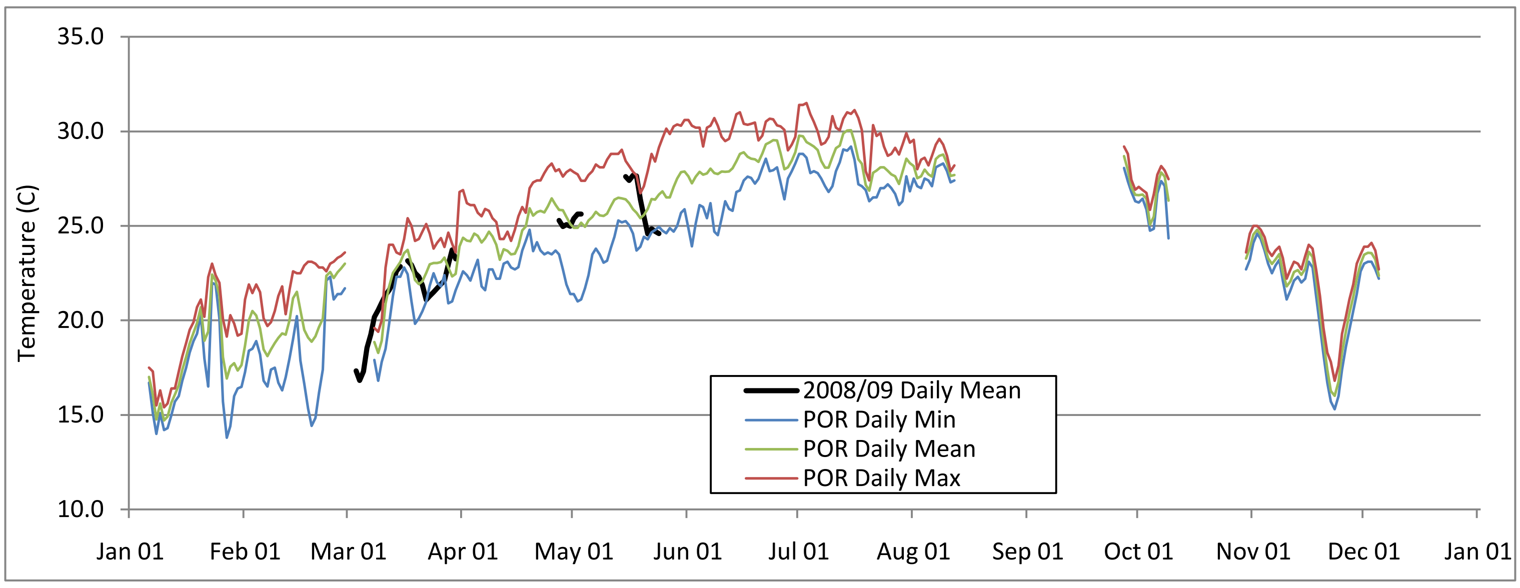
Ridler, M. S., R. C. Dent and D. A. Arrington. 2006. Effects of two hurricanes on *Syringodium filiforme*, manatee grass, within the Loxahatchee River Estuary, Southeast Florida. Estuaries and Coasts vol 29.

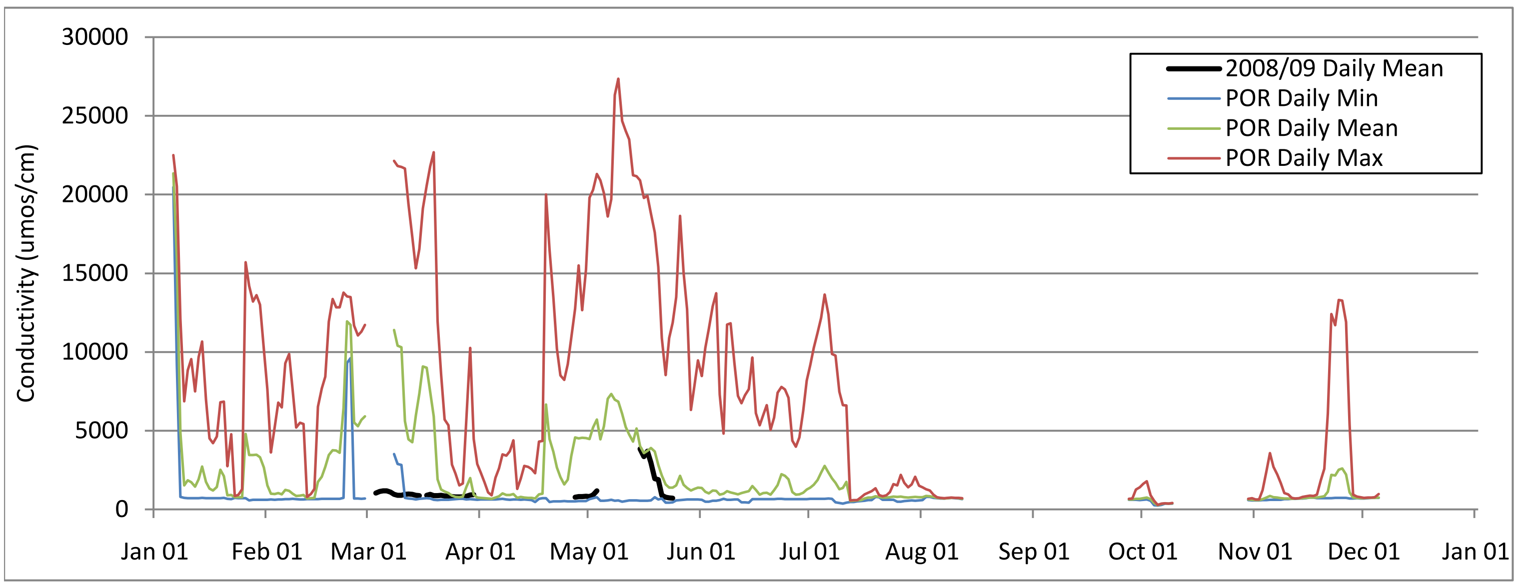
South Florida Water Management District. 2006. Restoration Plan for the Northwest Fork of the Loxahatchee River. South Florida Water Management District, Watershed Management Department, Coastal Ecosystems Division. West Palm Beach, Florida.

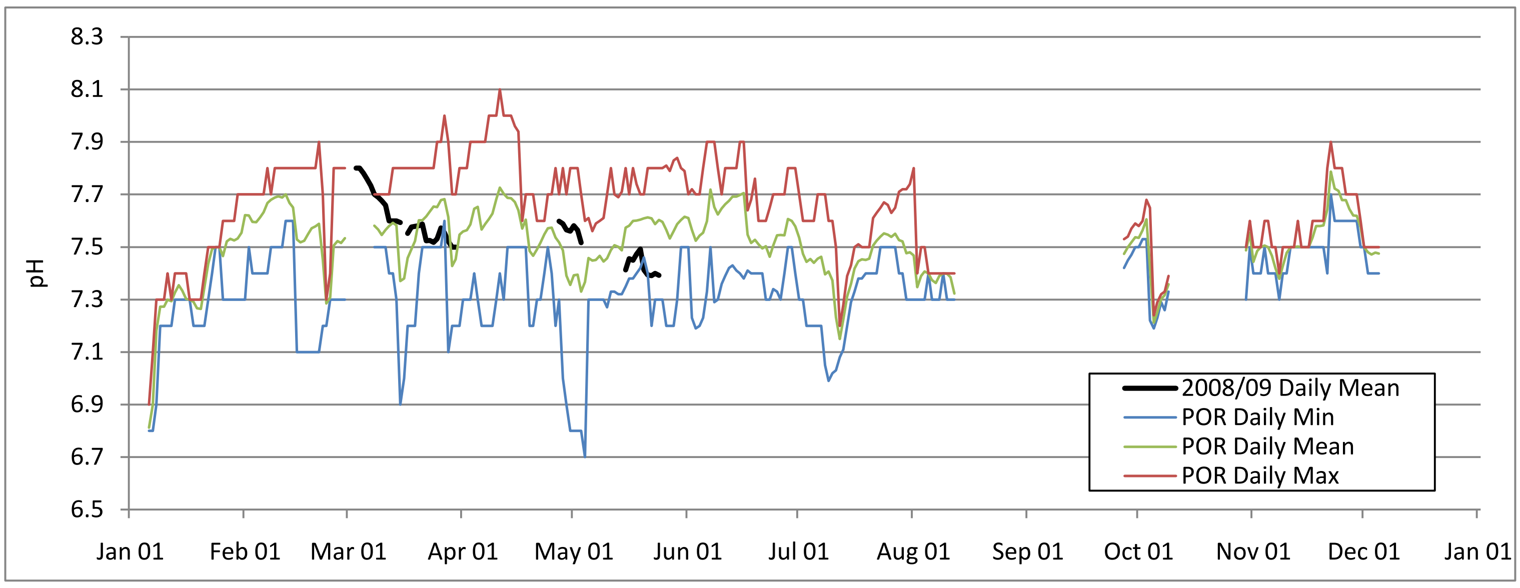
Appendix A

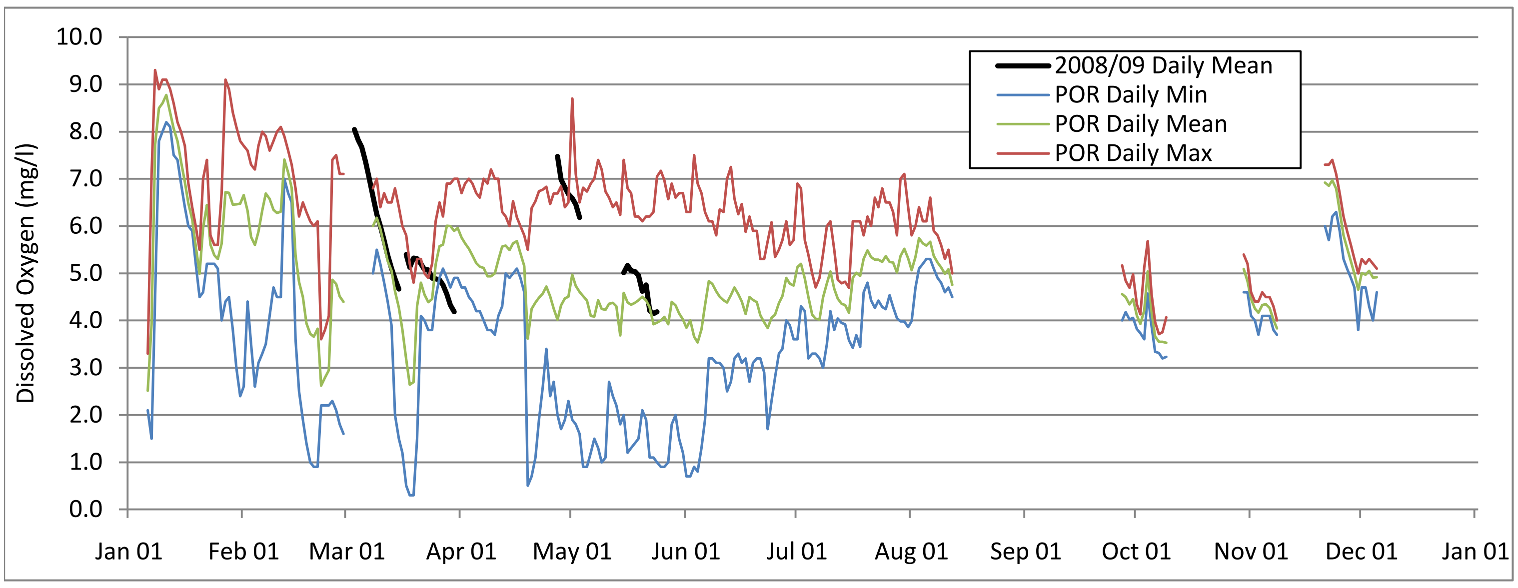
Plots of Daily Mean Water Quality Parameters versus Historical Values

**A1. Station 66**



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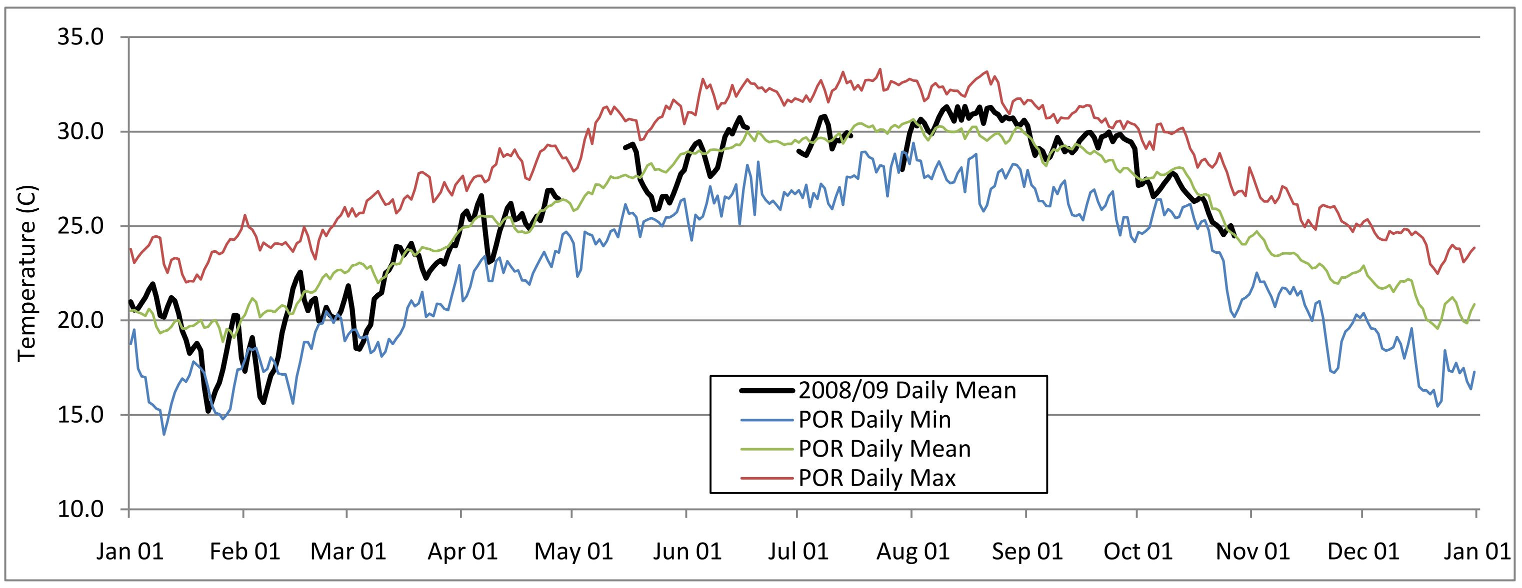


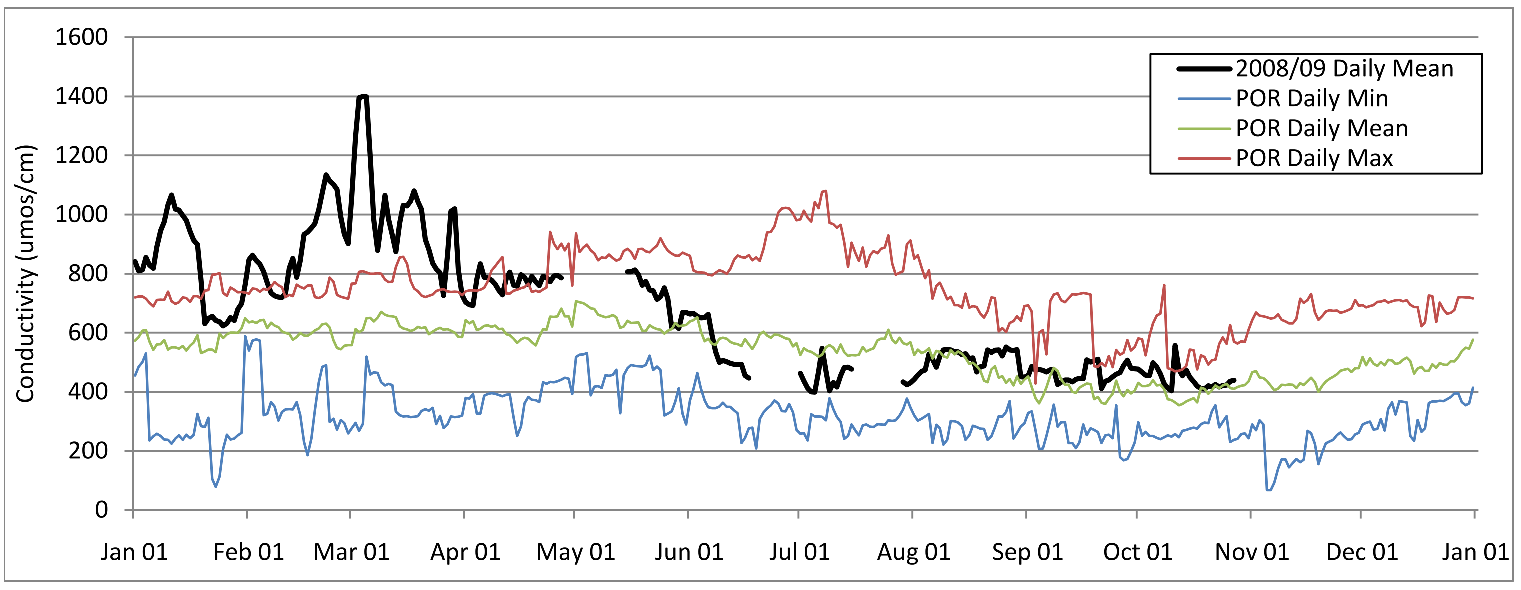


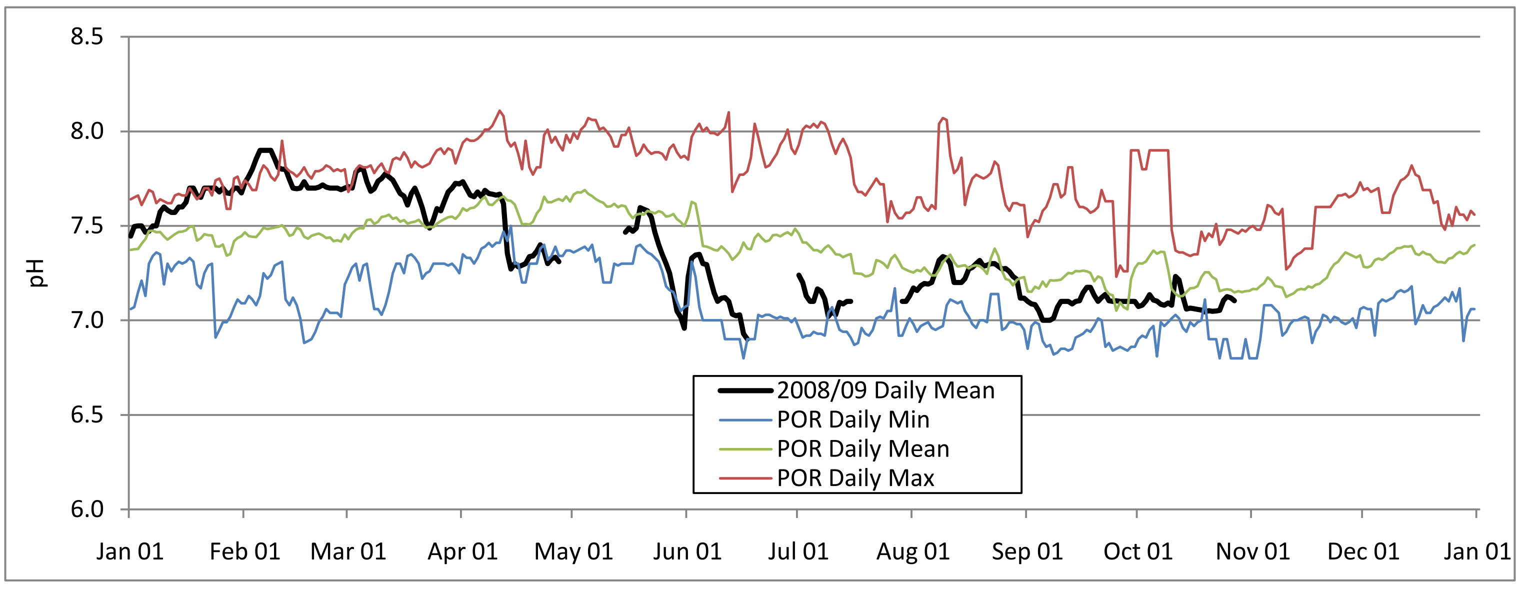


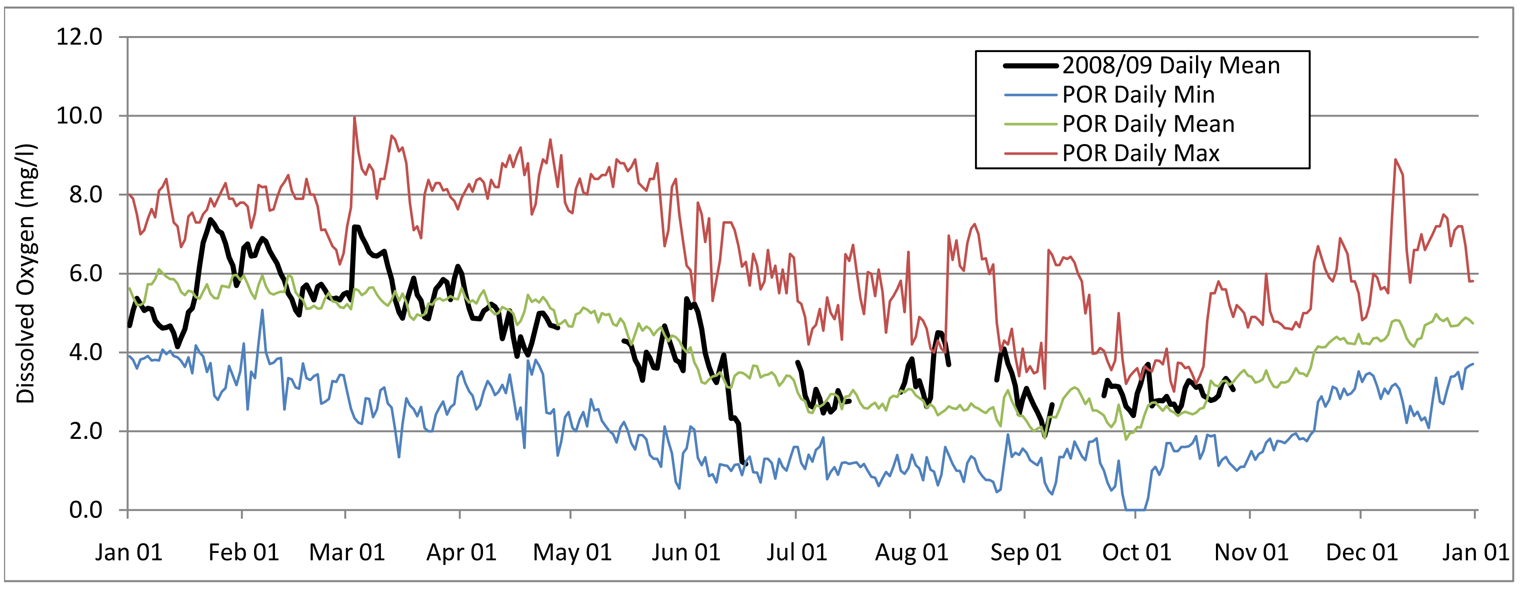

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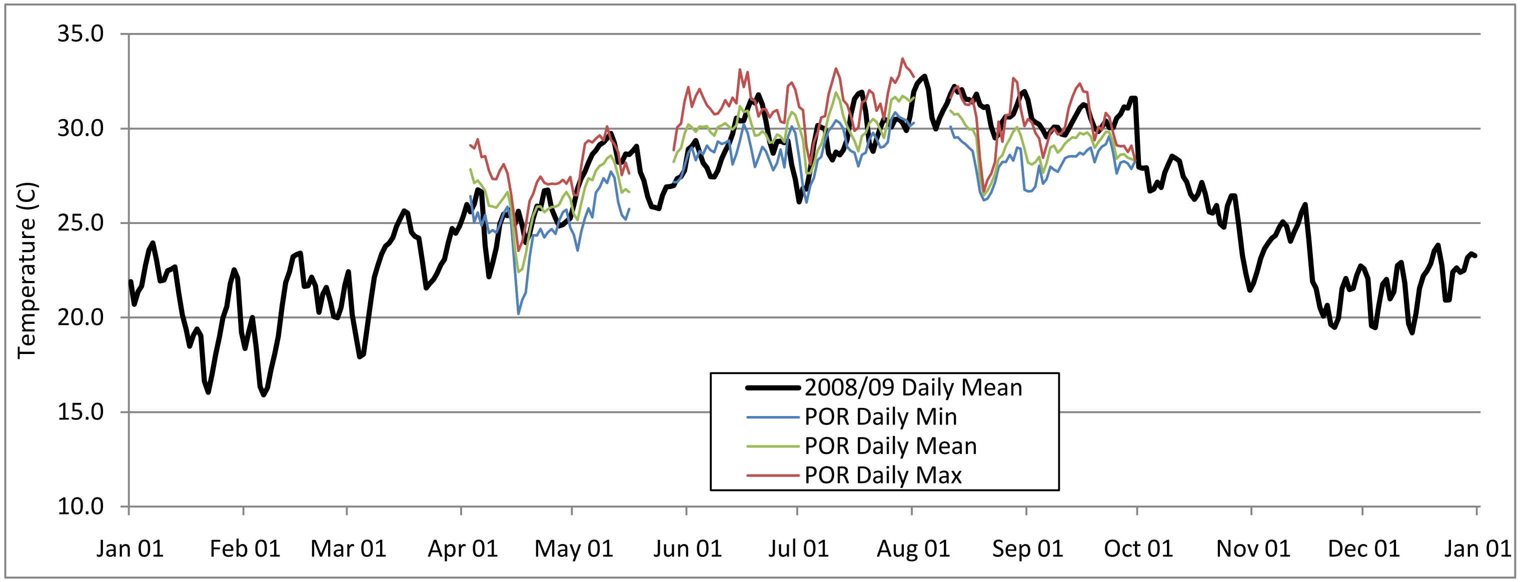


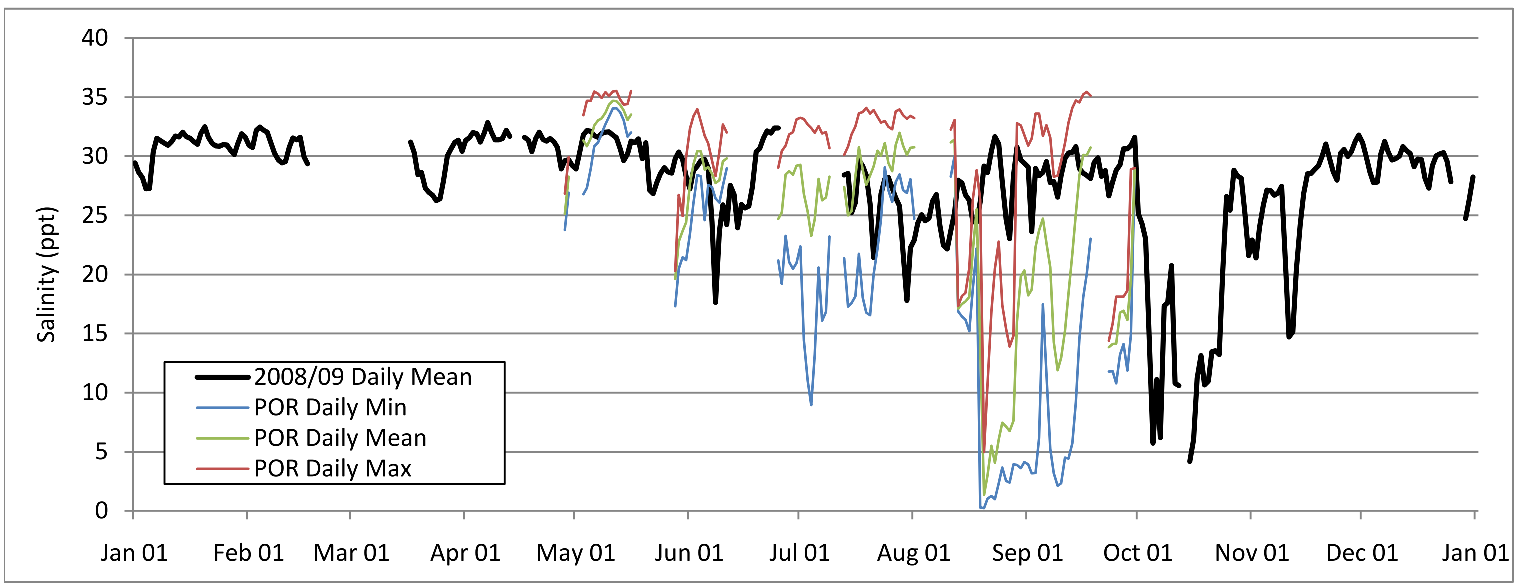

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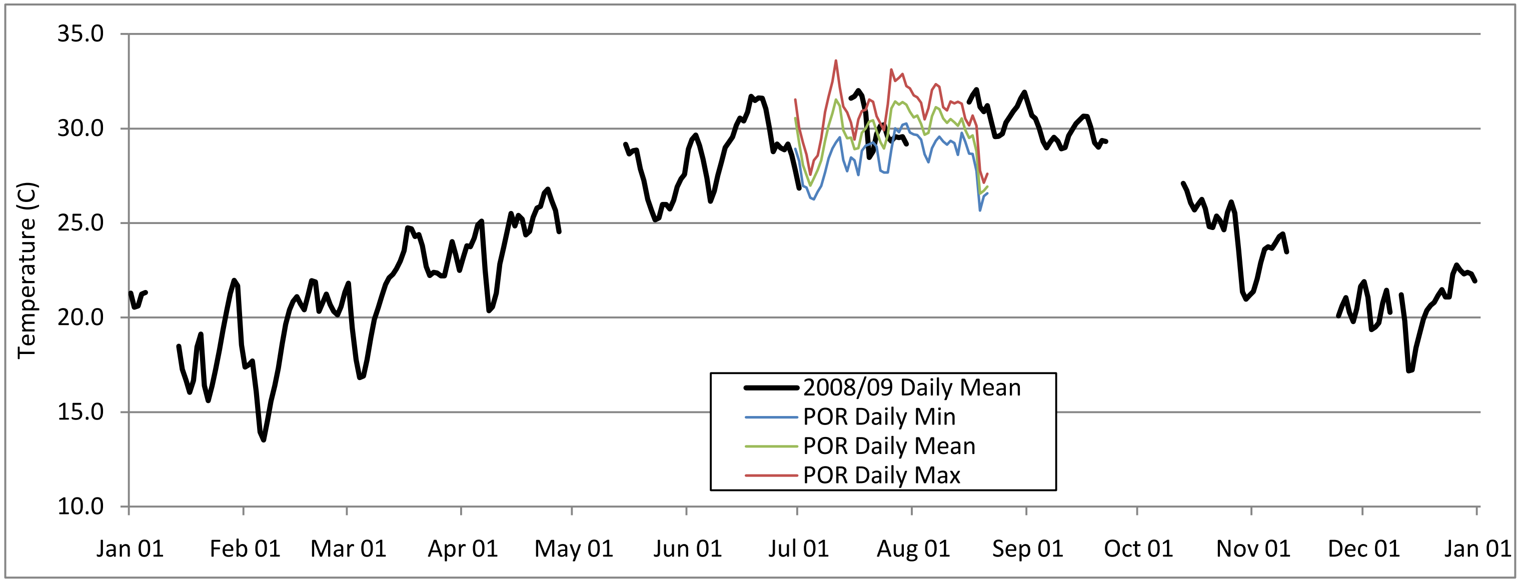
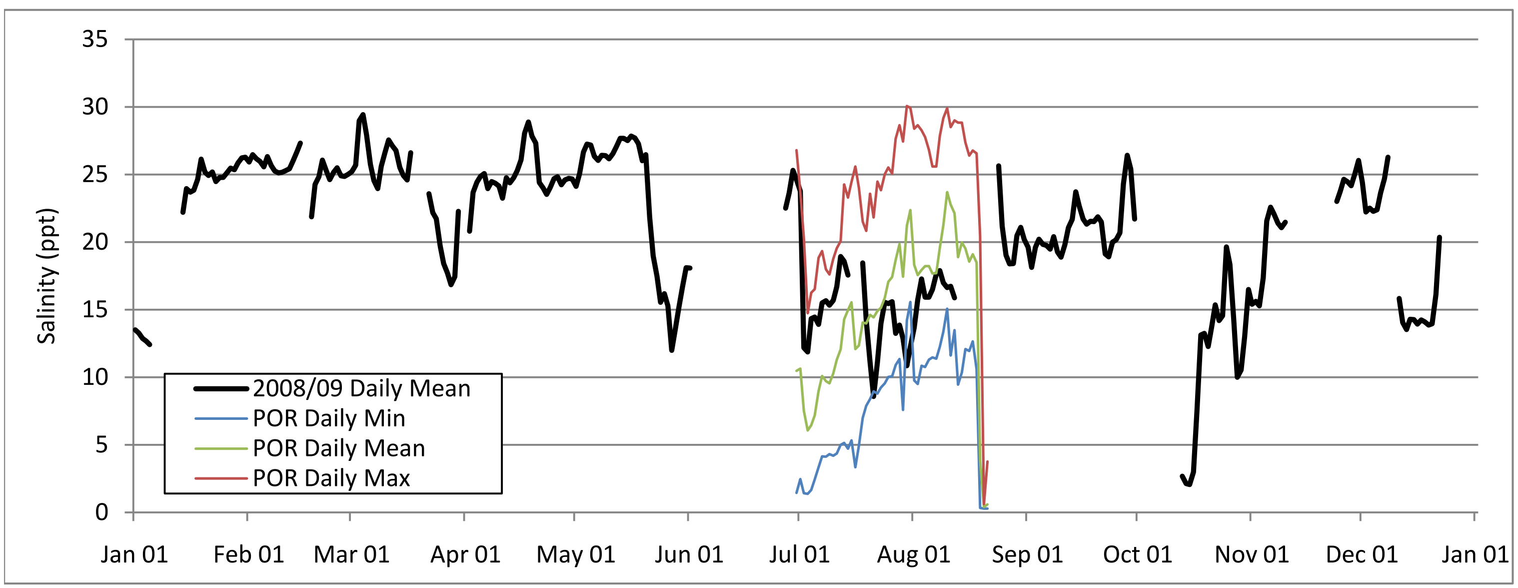
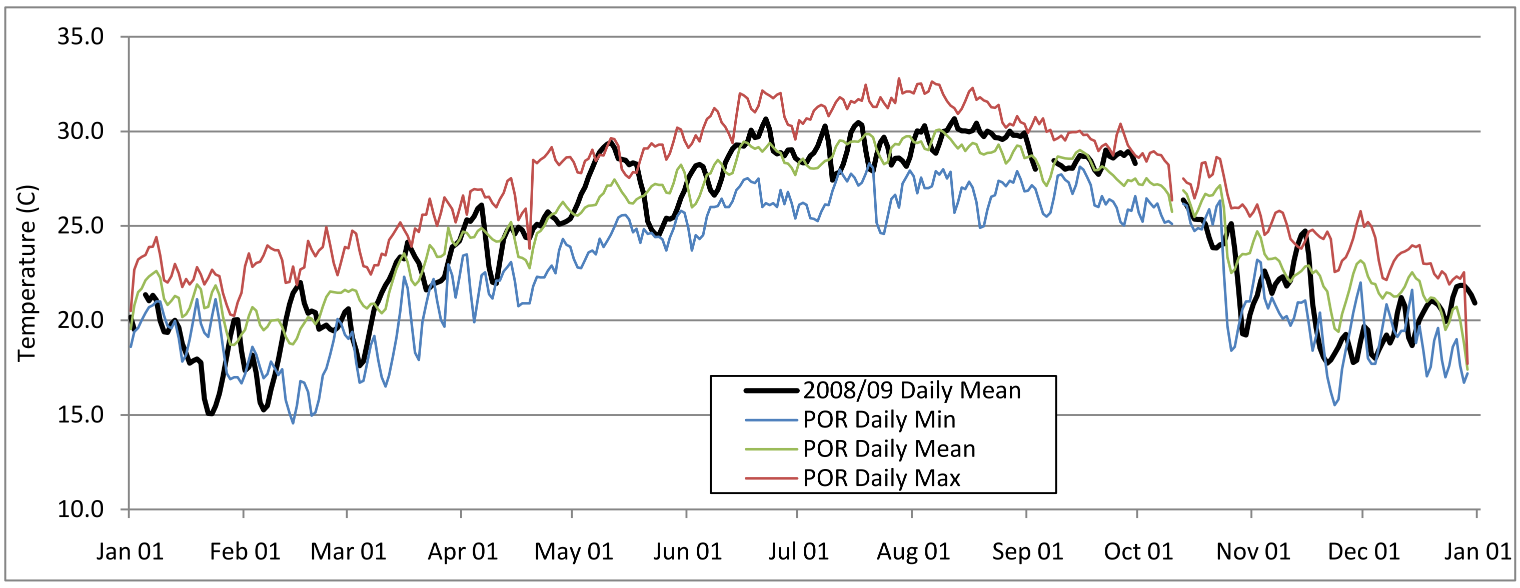
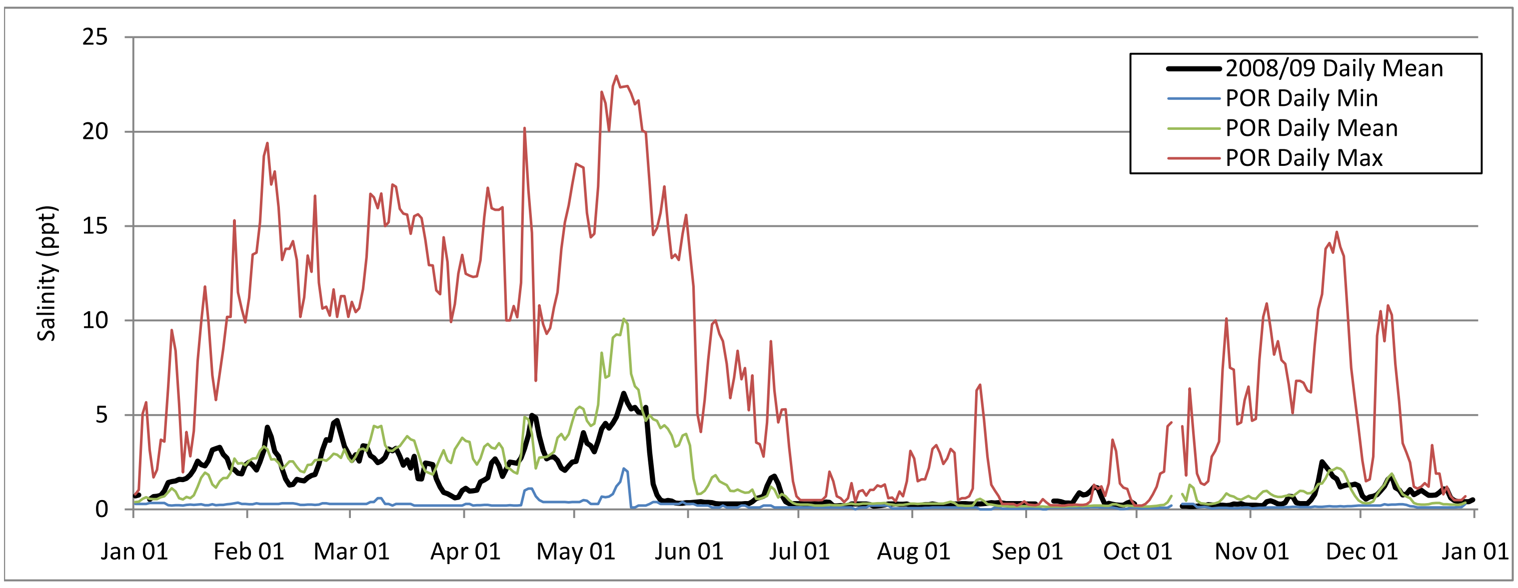
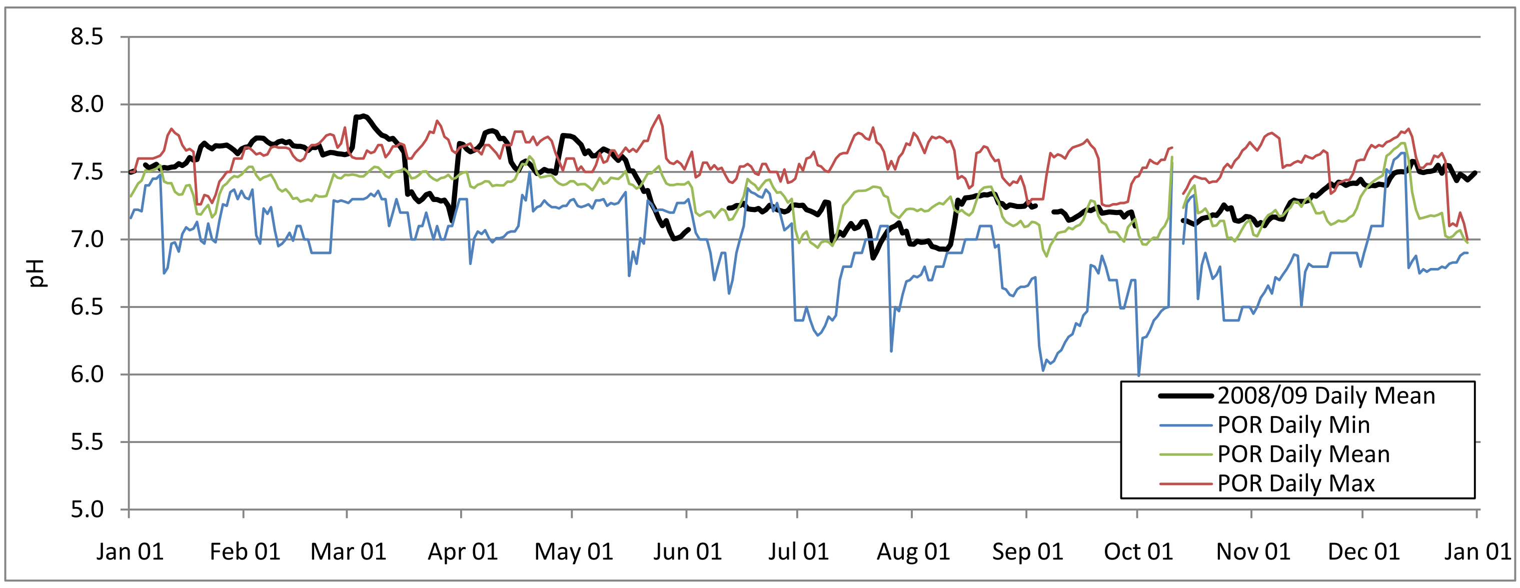


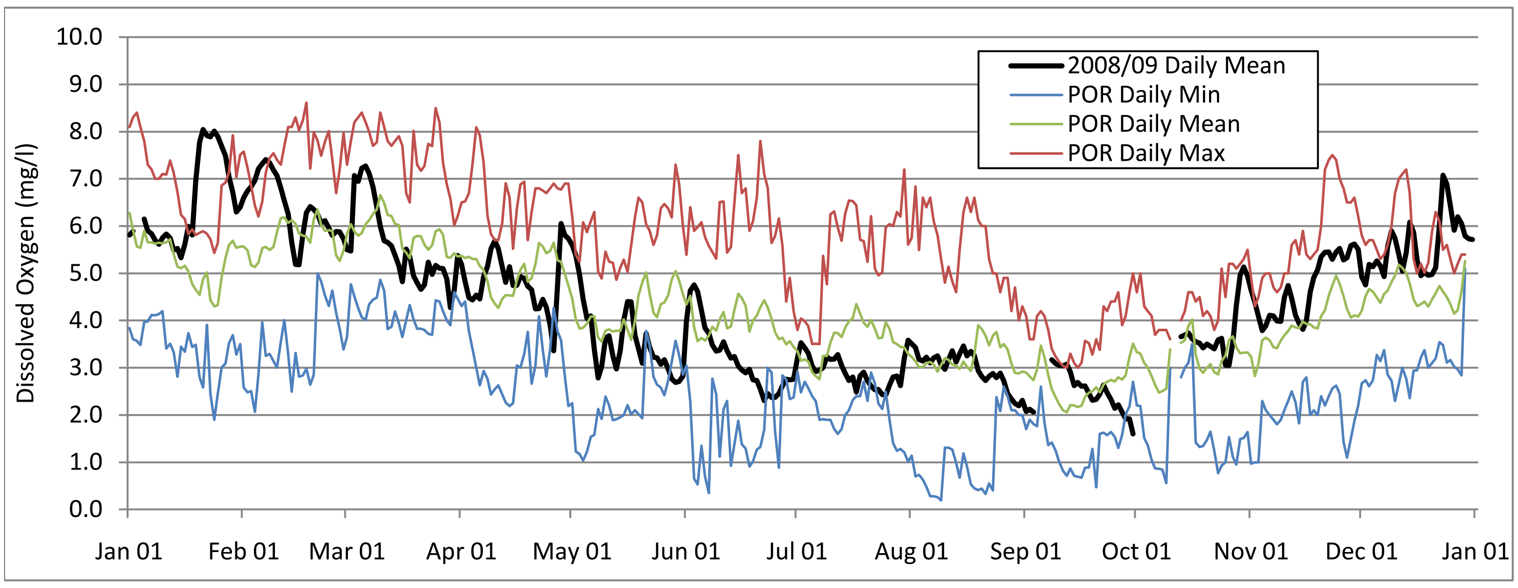



**A5. Kitching Creek Top (KCT)**

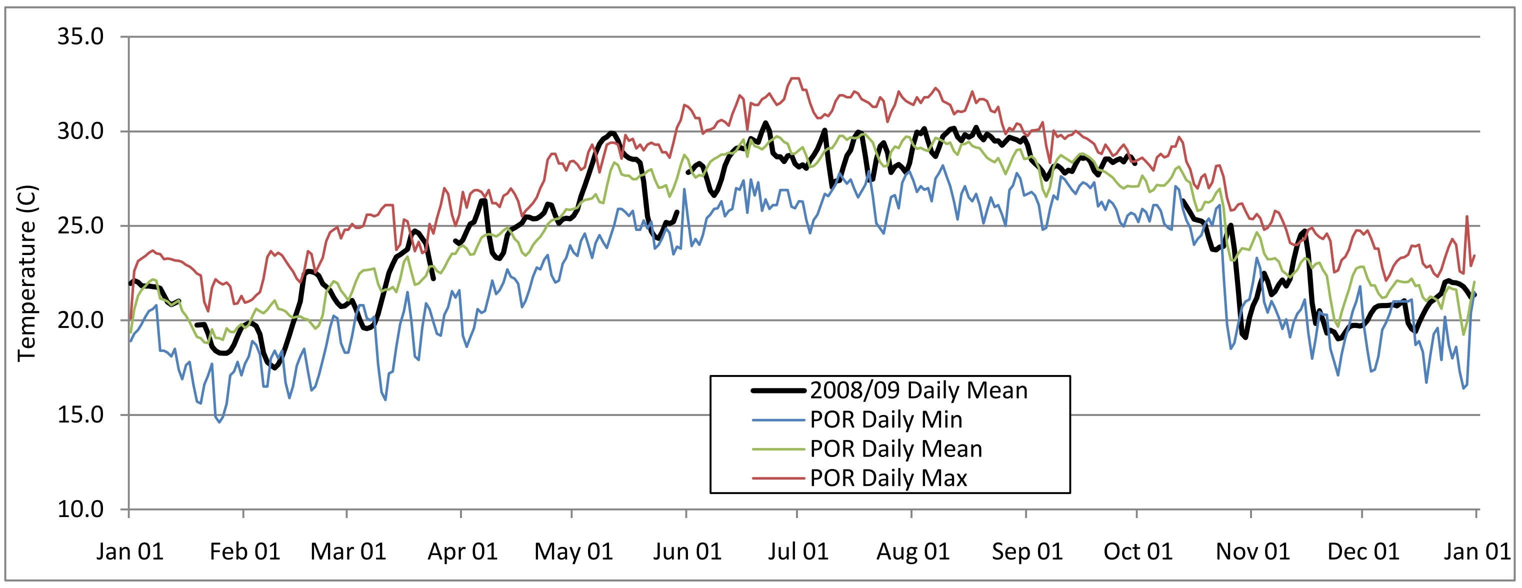


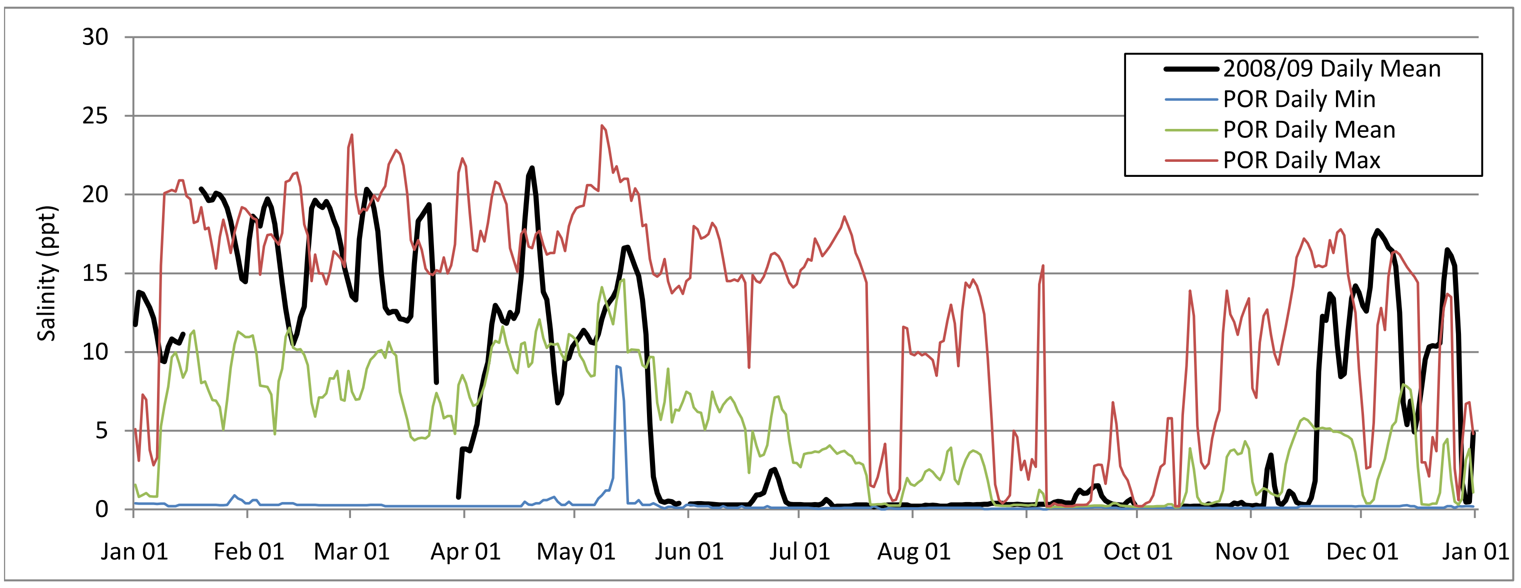



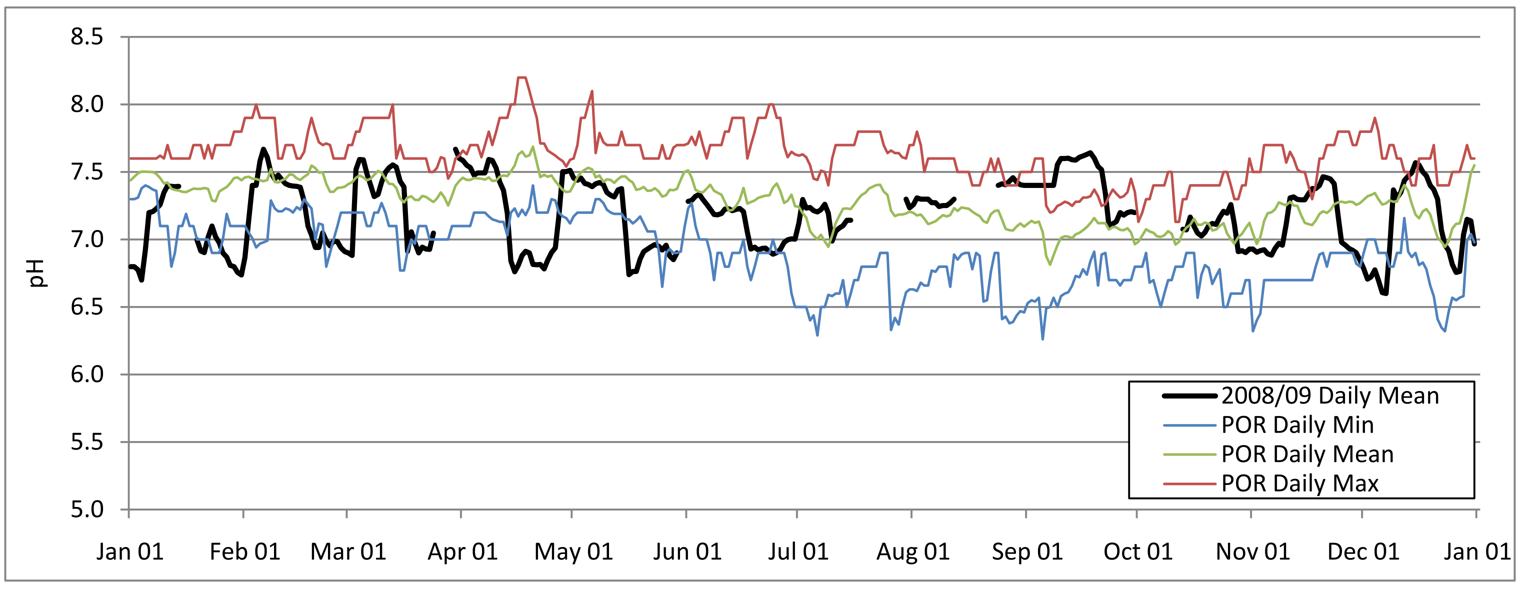



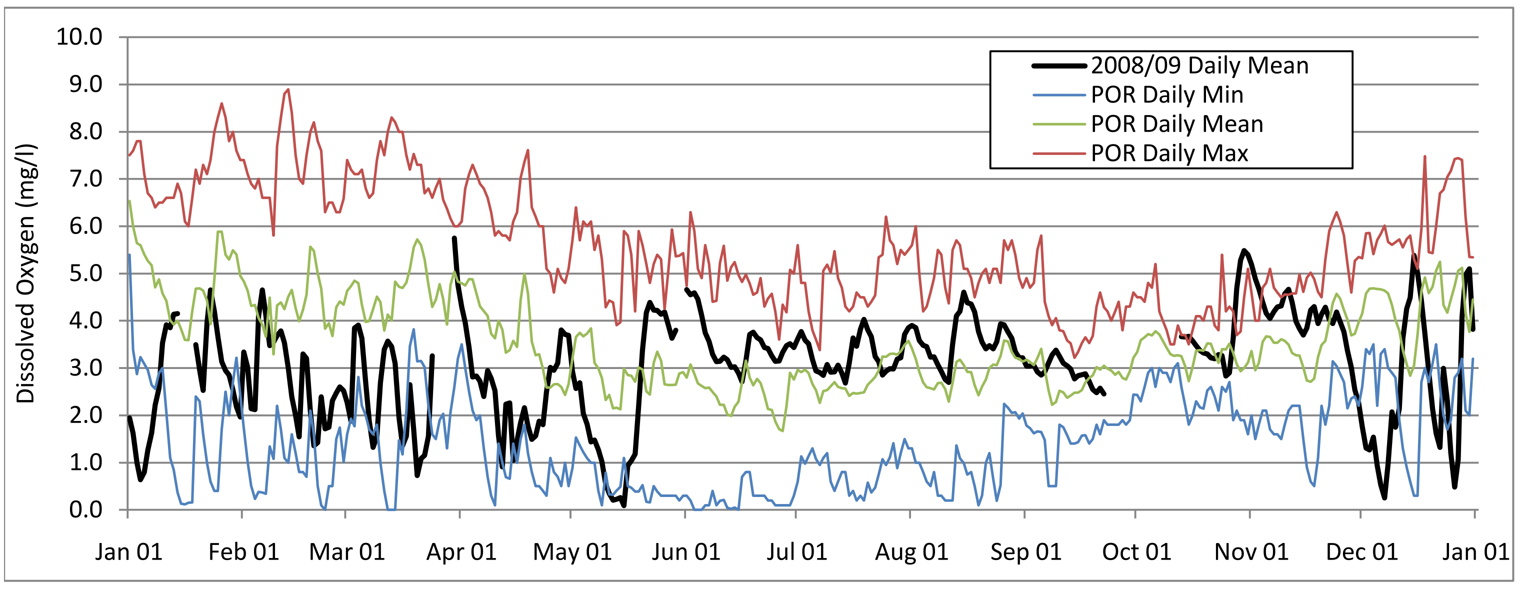



**A6. Kitching Creek Bottom (KCB)**



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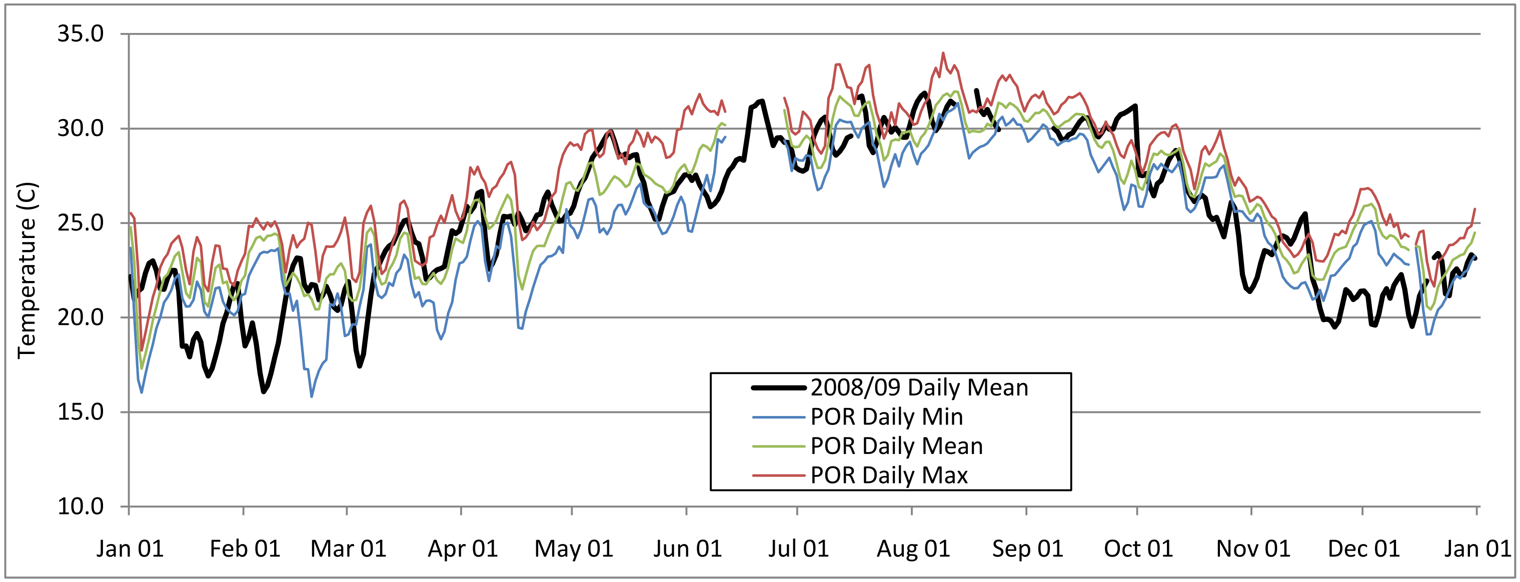
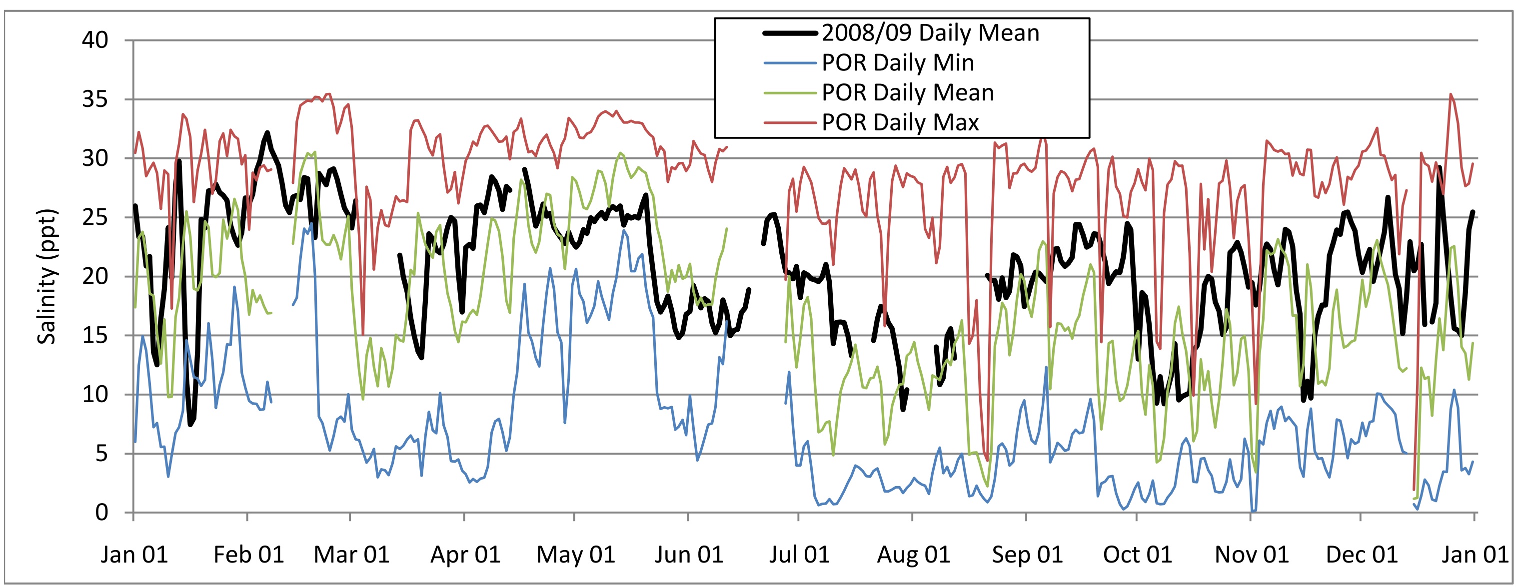
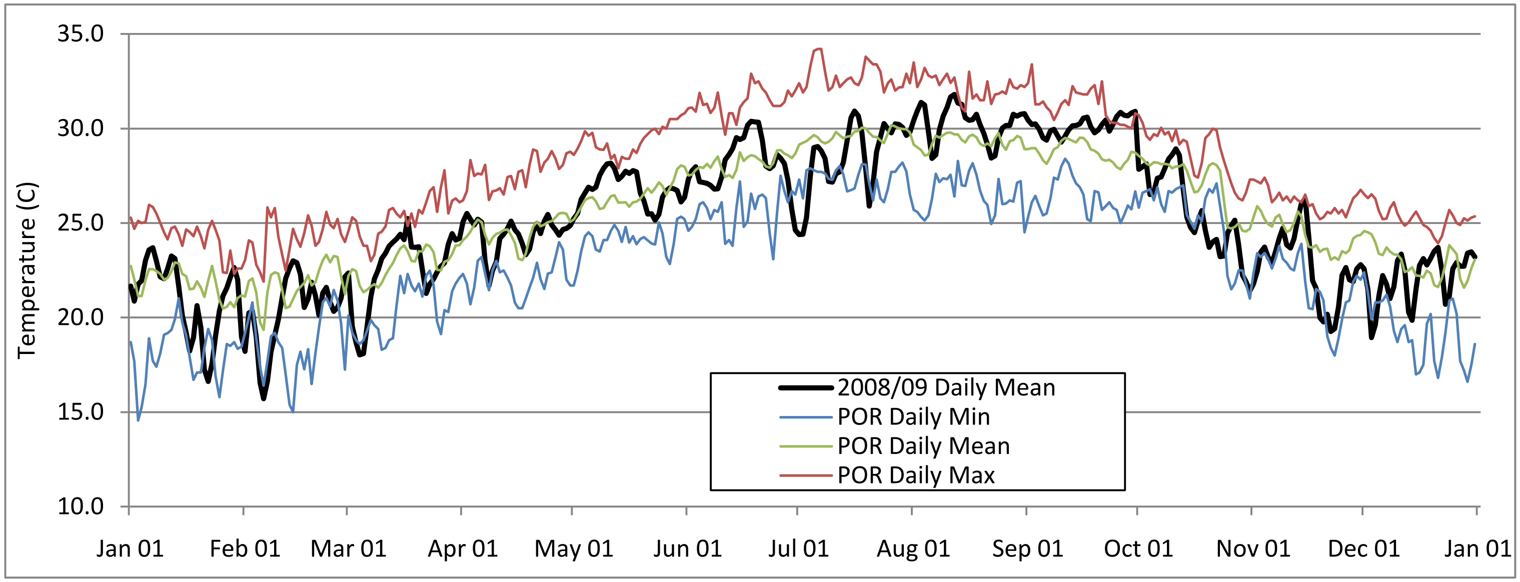


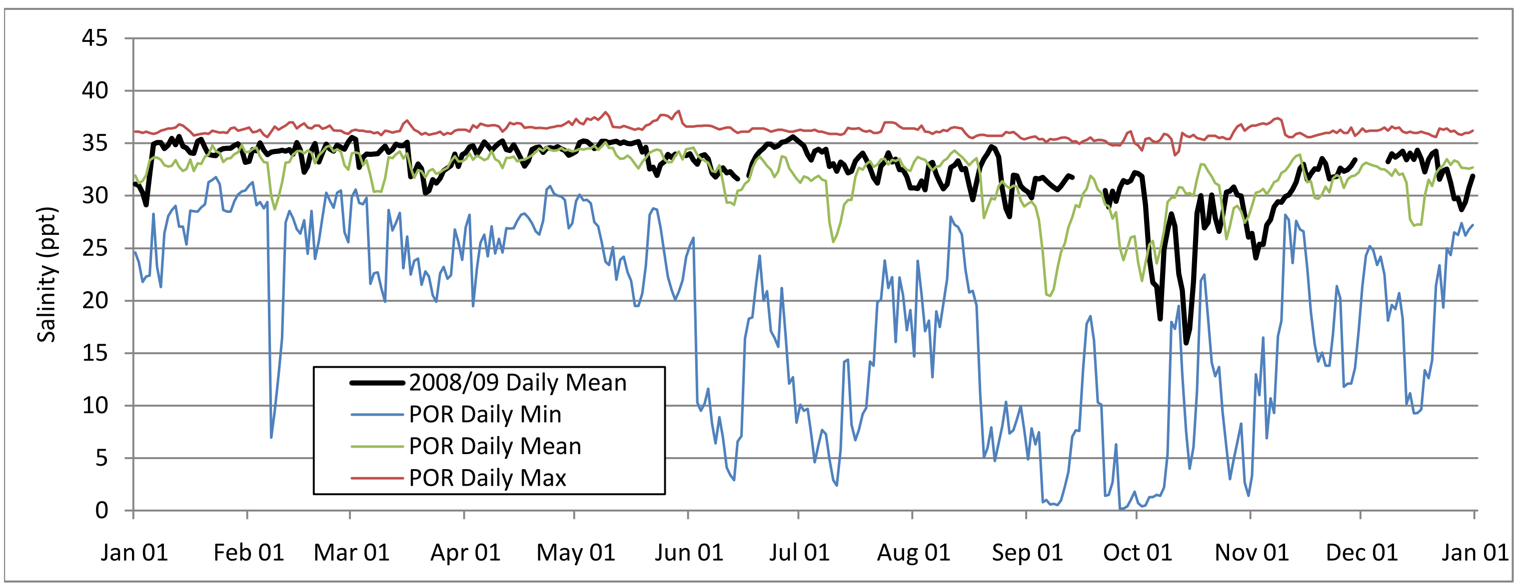
35.0
30.0
25.0
20.0
15.0
10.0
Temperature (C)
2008/09 Daily Mean
POR Daily Min
POR Daily Mean
POR Daily Max
Jan 01
Feb 01
Mar 01
Apr 01
May 01
Jun 01
Jul 01
Aug 01
Sep 01
Oct 01
Nov 01
Dec 01
Jan 01

40
35
30
25
20
15
10
5
0
Salinity (ppt)
2008/09 Daily Mean
POR Daily Min
POR Daily Mean
POR Daily Max
Jan 01
Feb 01
Mar 01
Apr 01
May 01
Jun 01
Jul 01
Aug 01
Sep 01
Oct 01
Nov 01
Dec 01
Jan 01

## A8. Pennock Point (PP)



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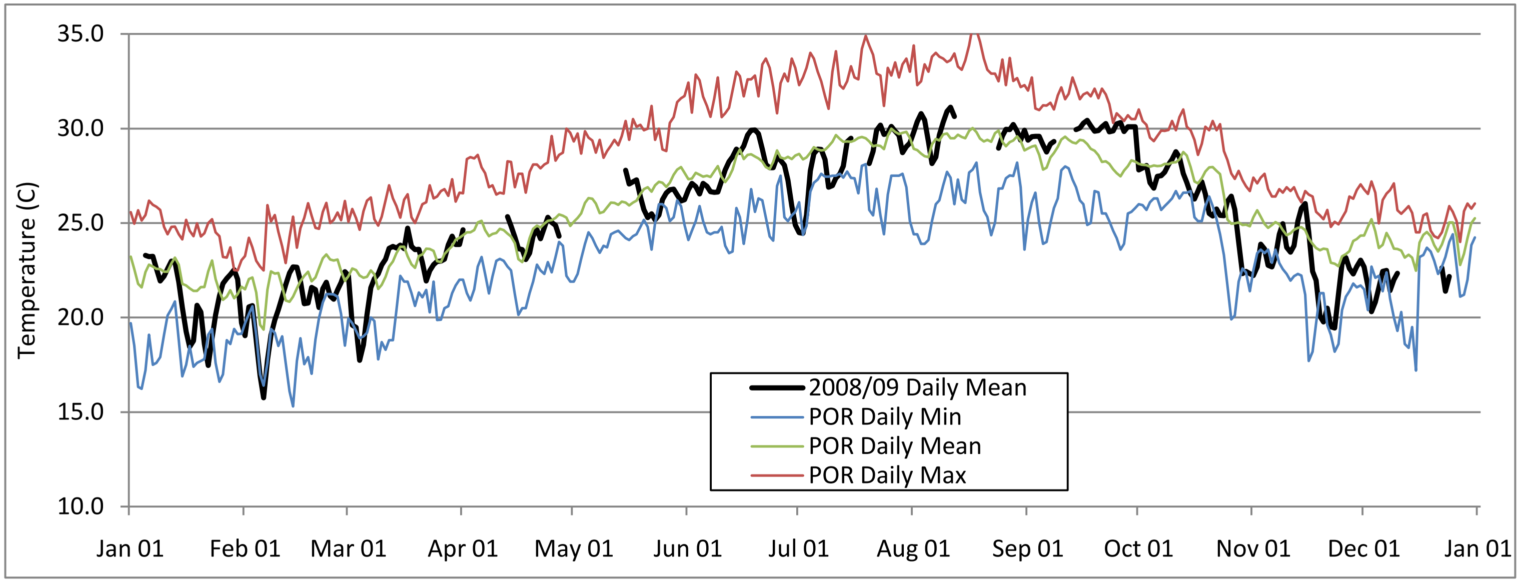
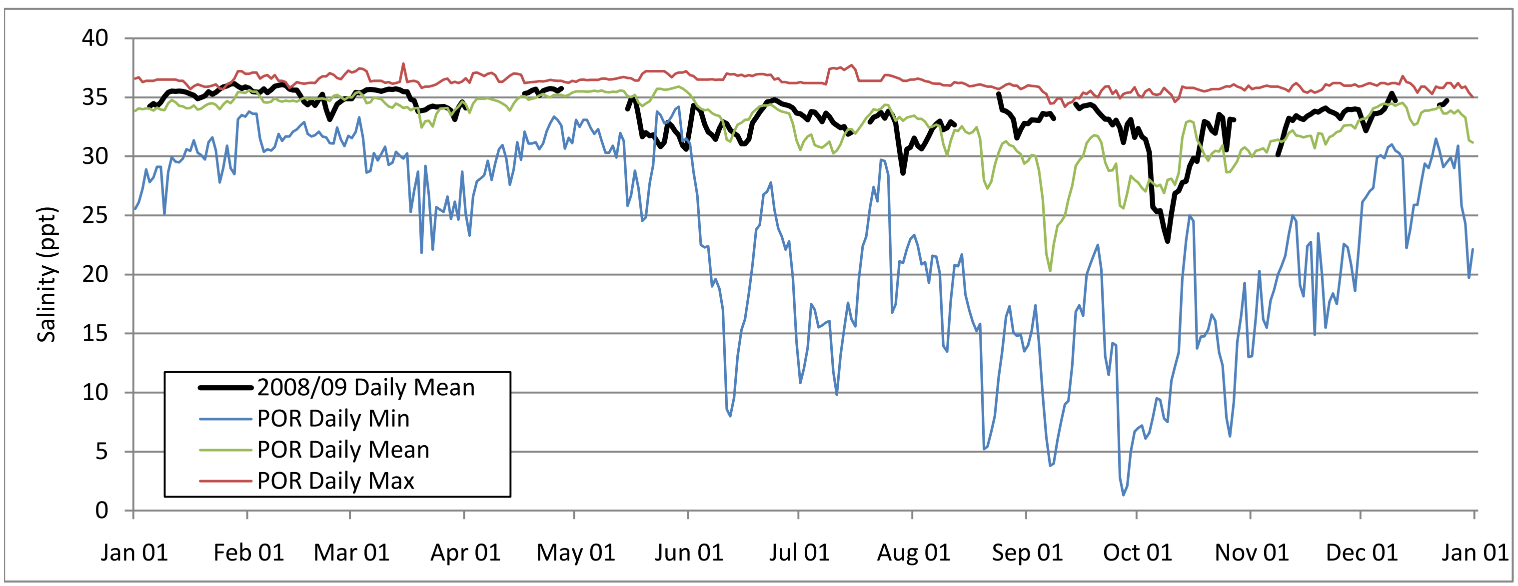
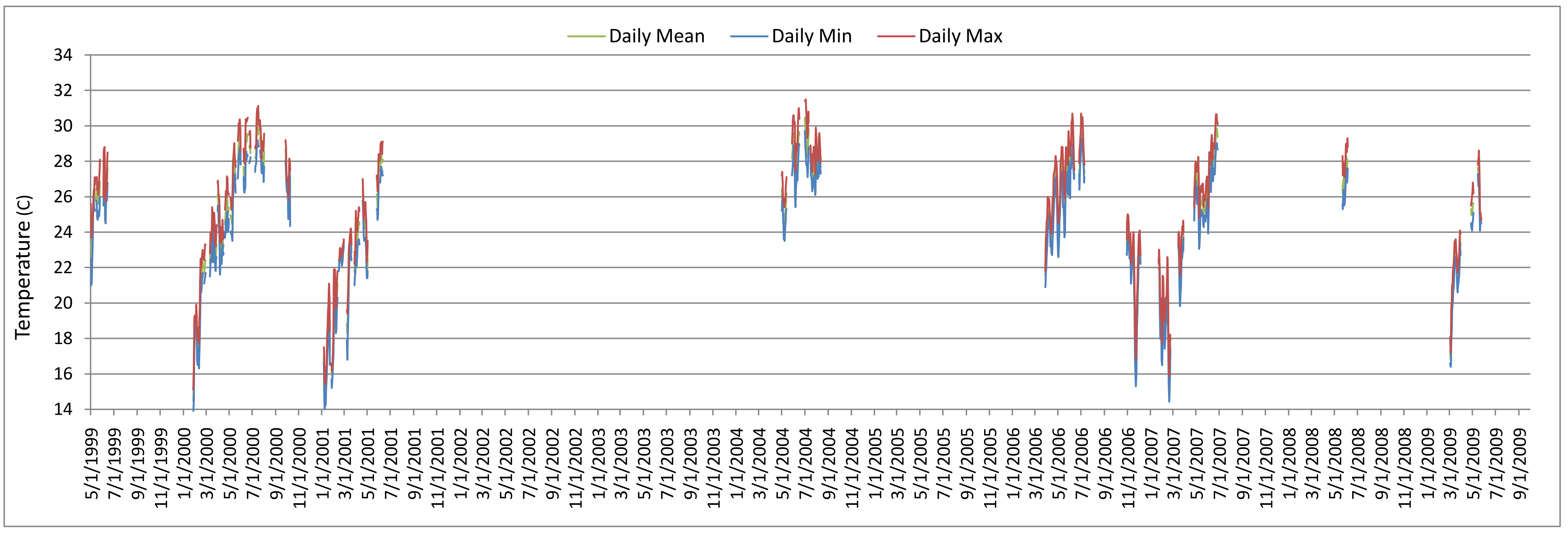


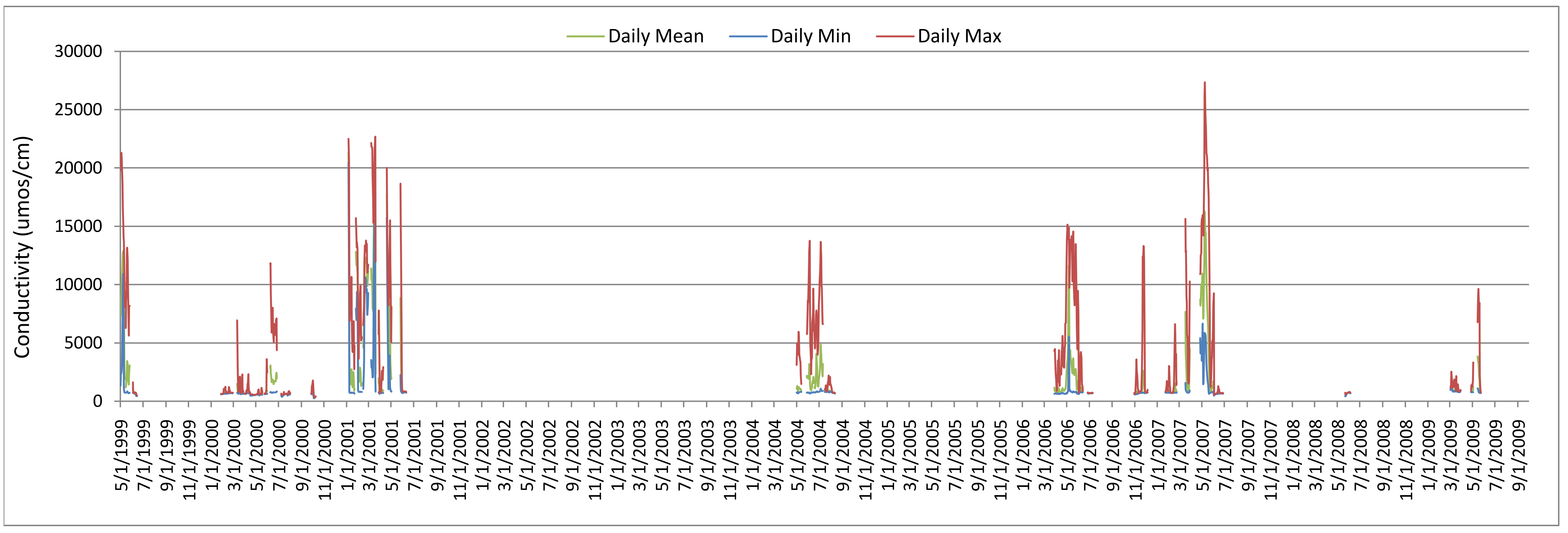



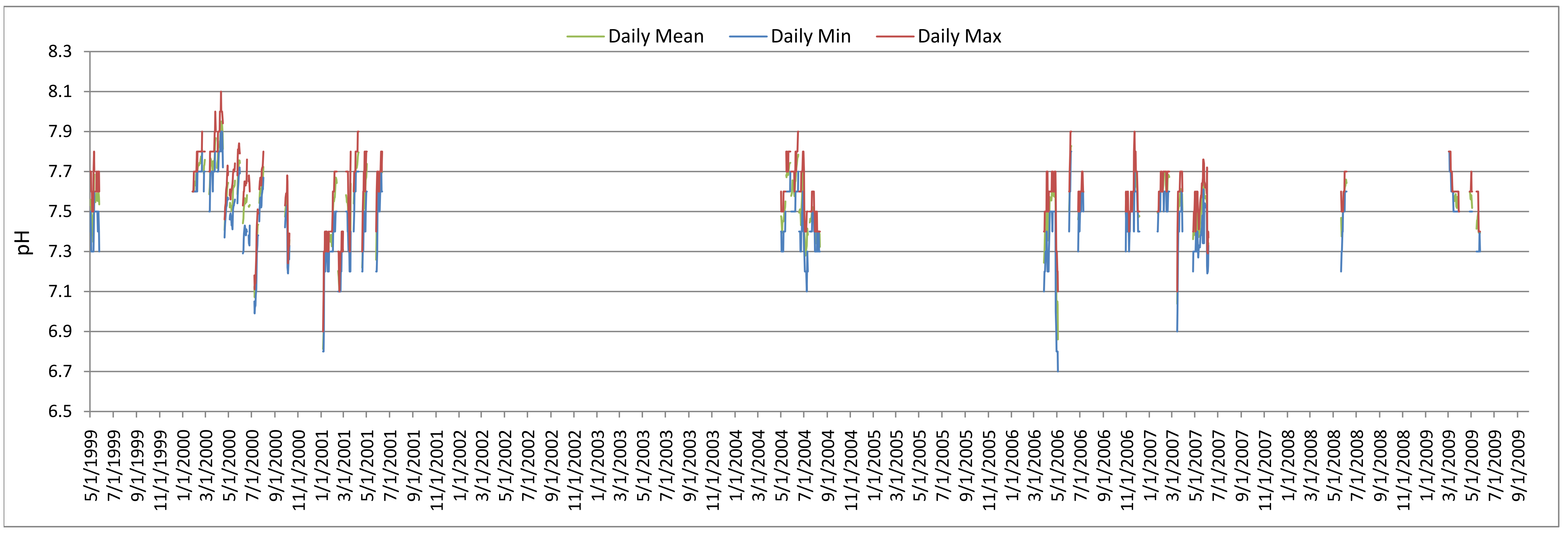
Appendix B

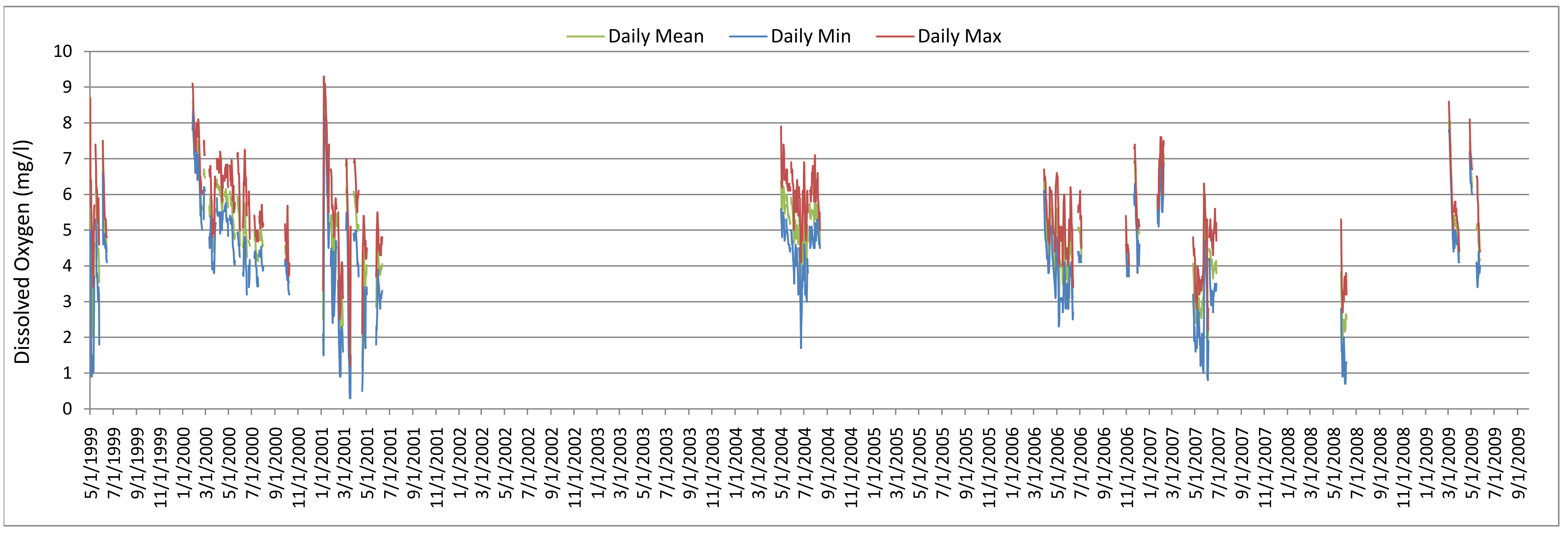
Plots of Daily Mean, Minimum and Maximum Water Quality Parameters for the Full Period of Record

**B1. Station 66**



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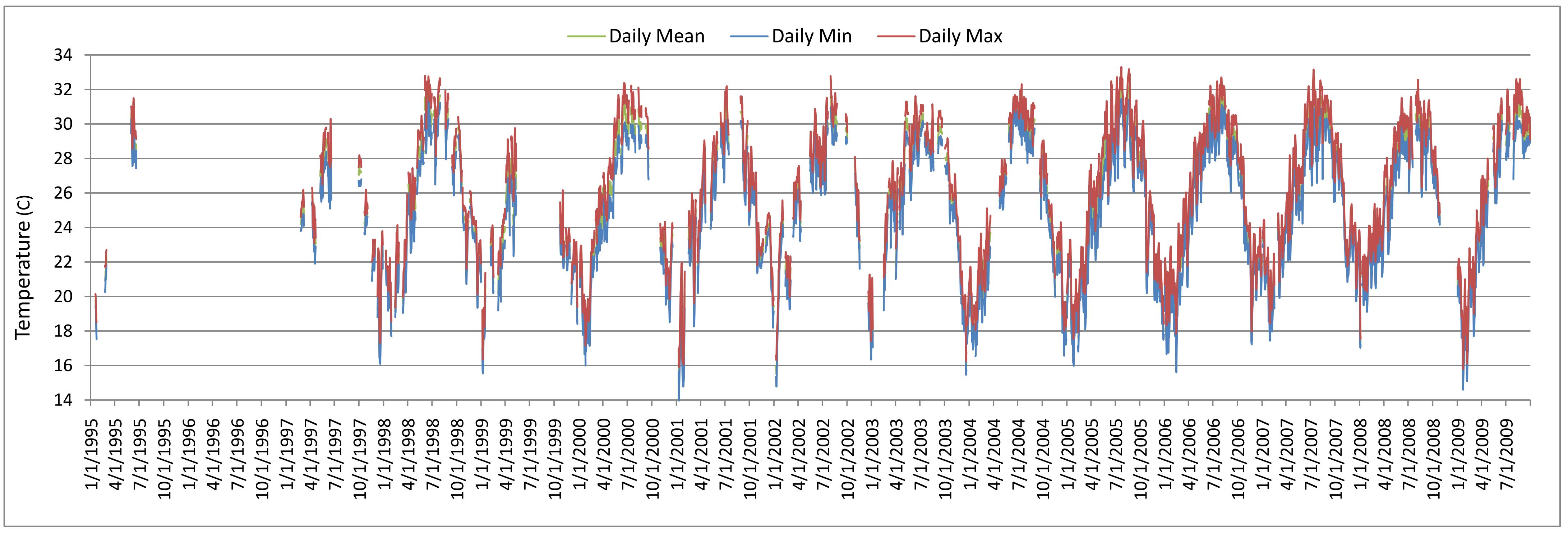


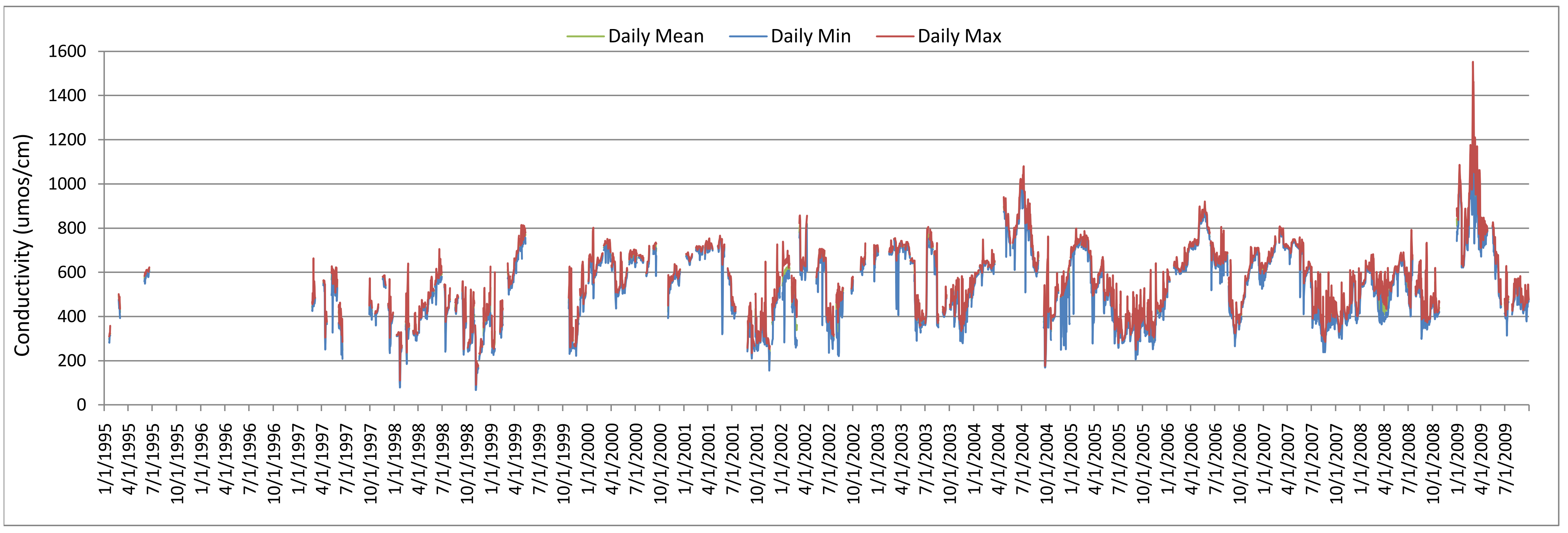


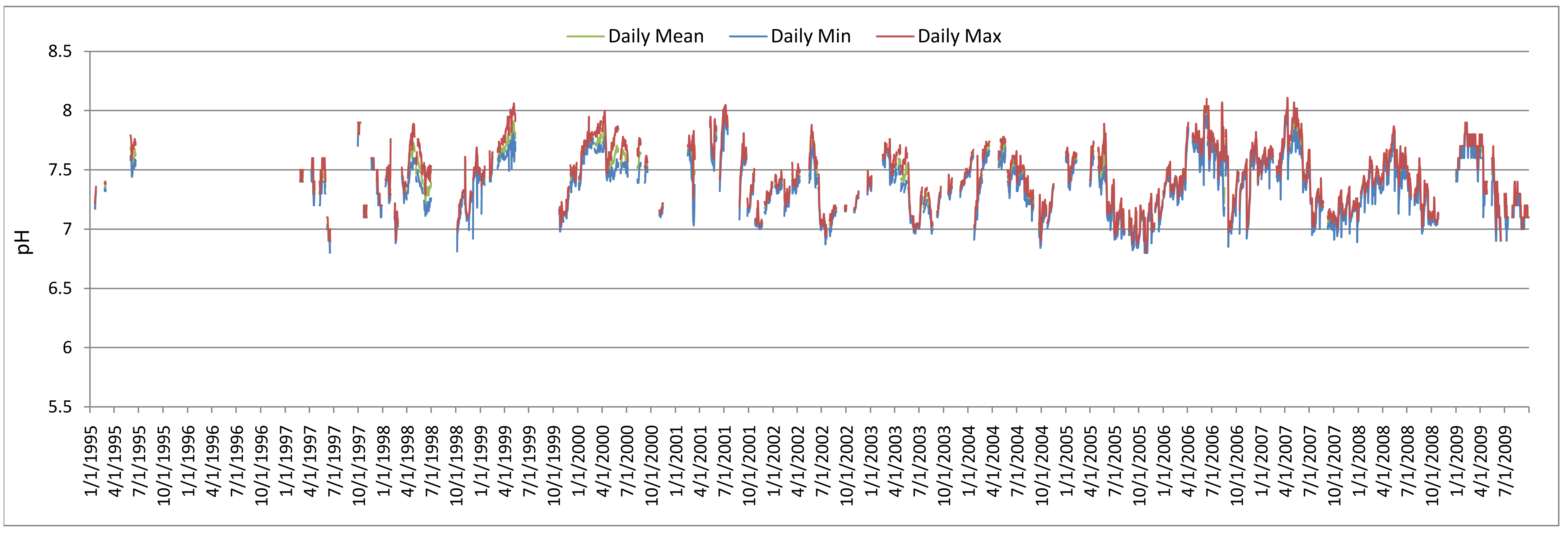


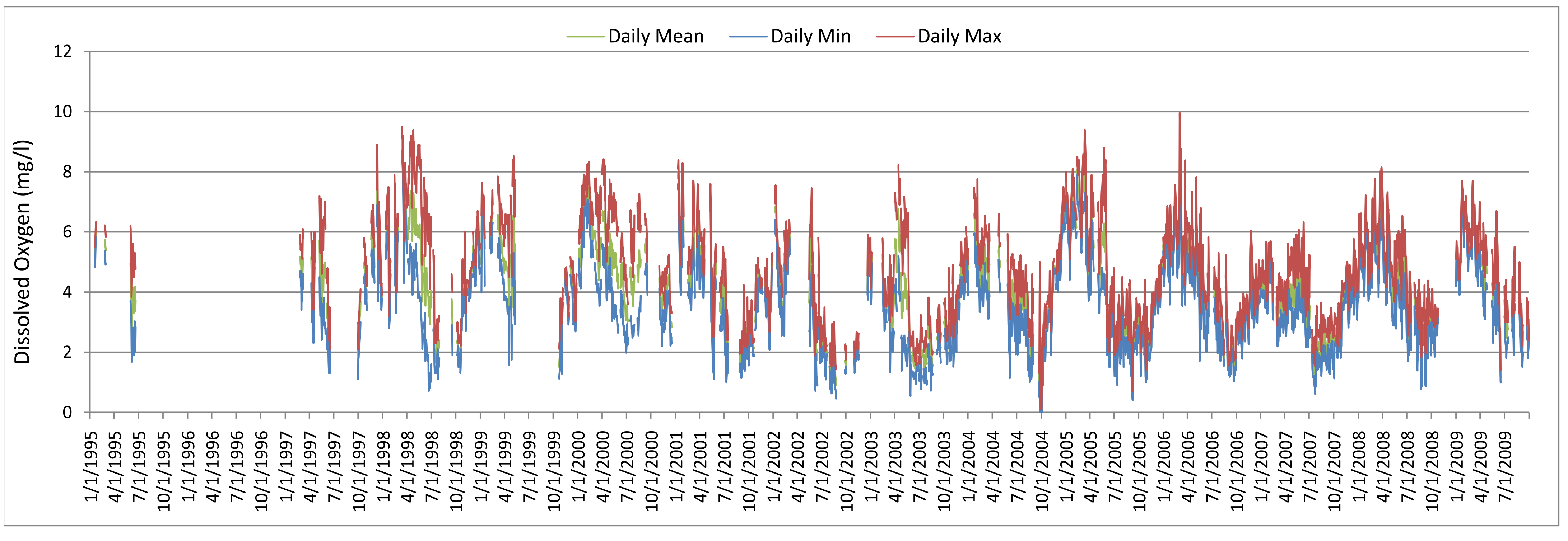

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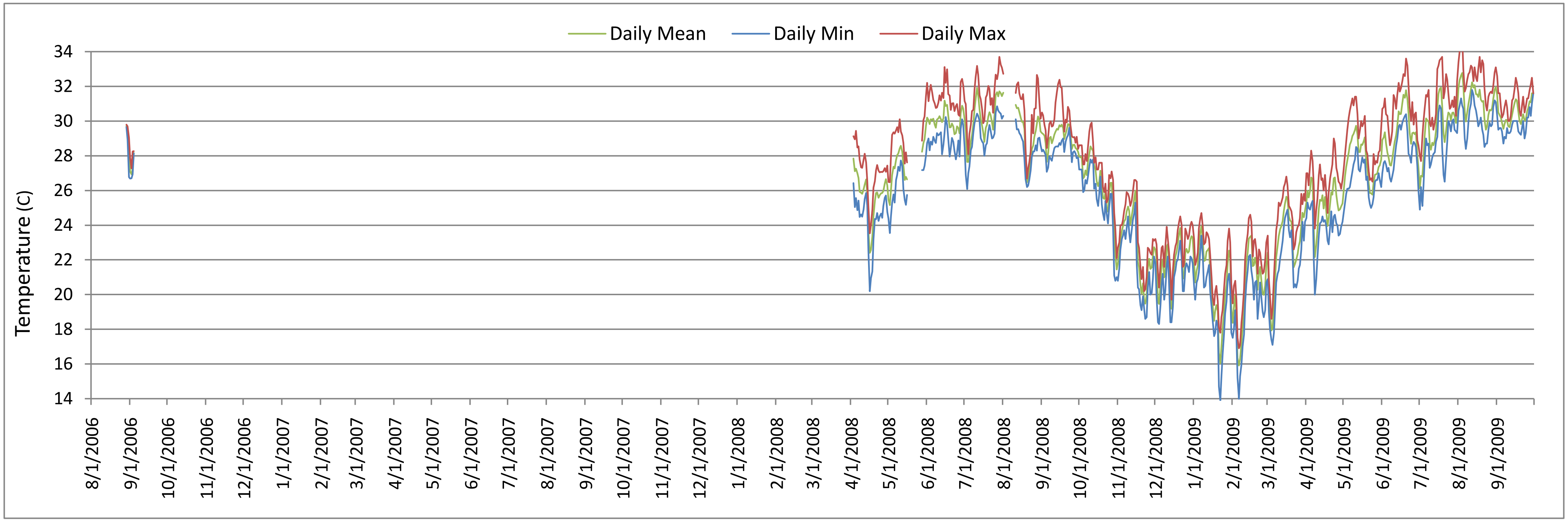


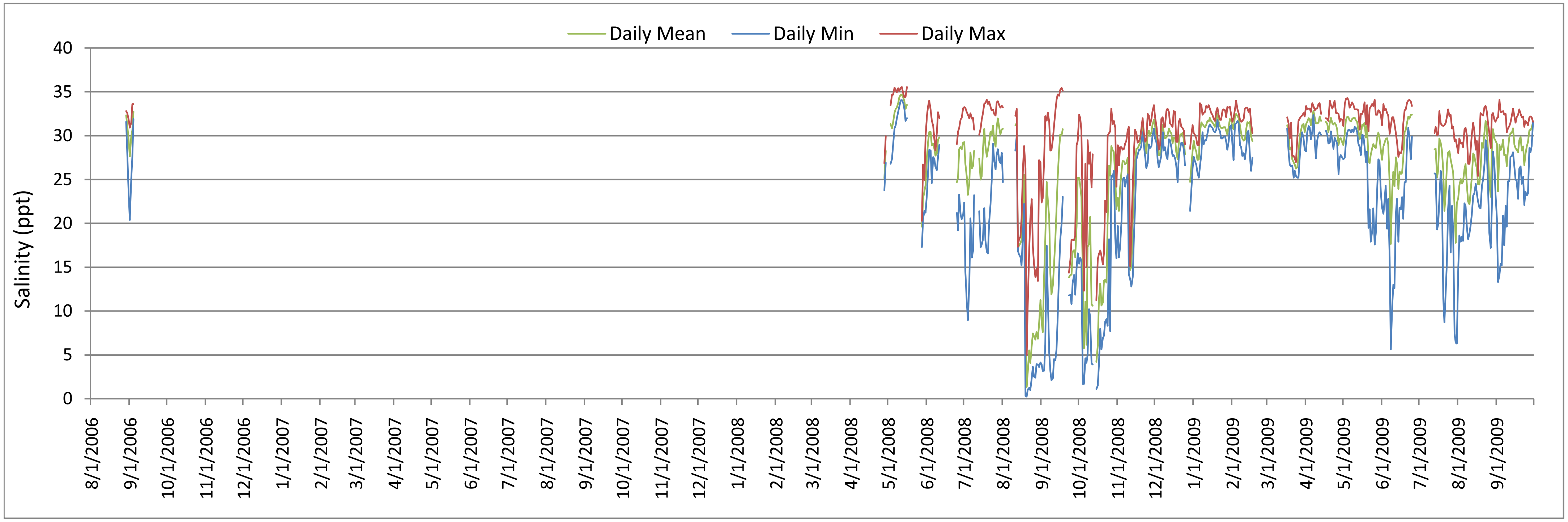

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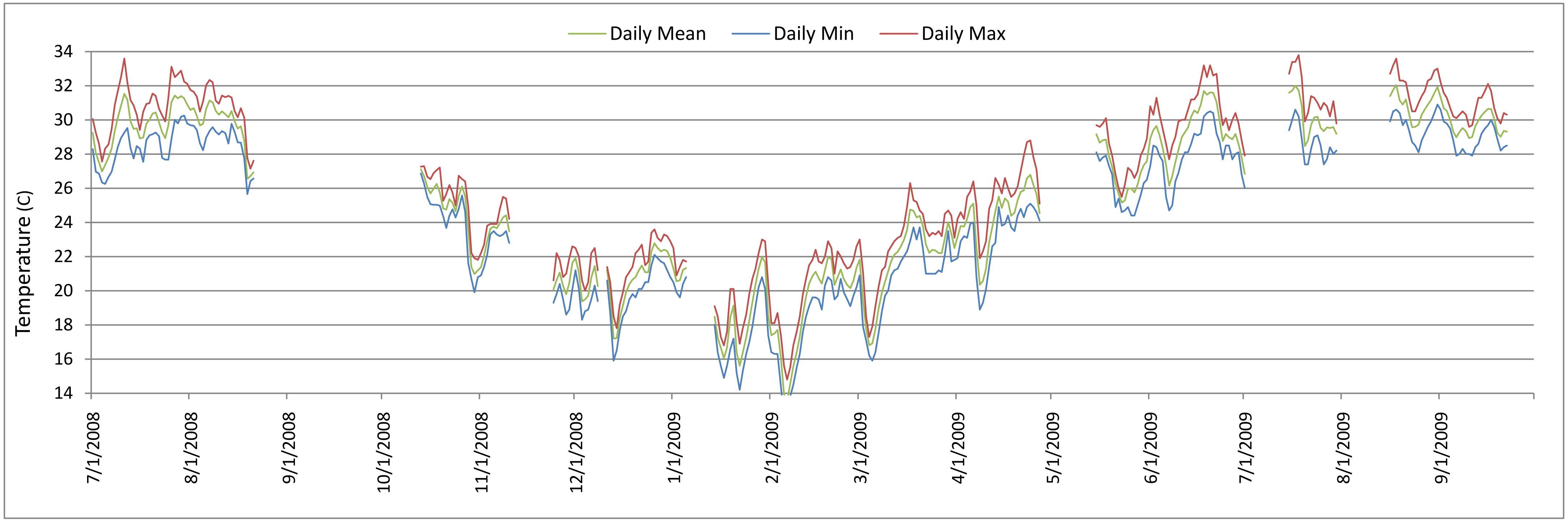


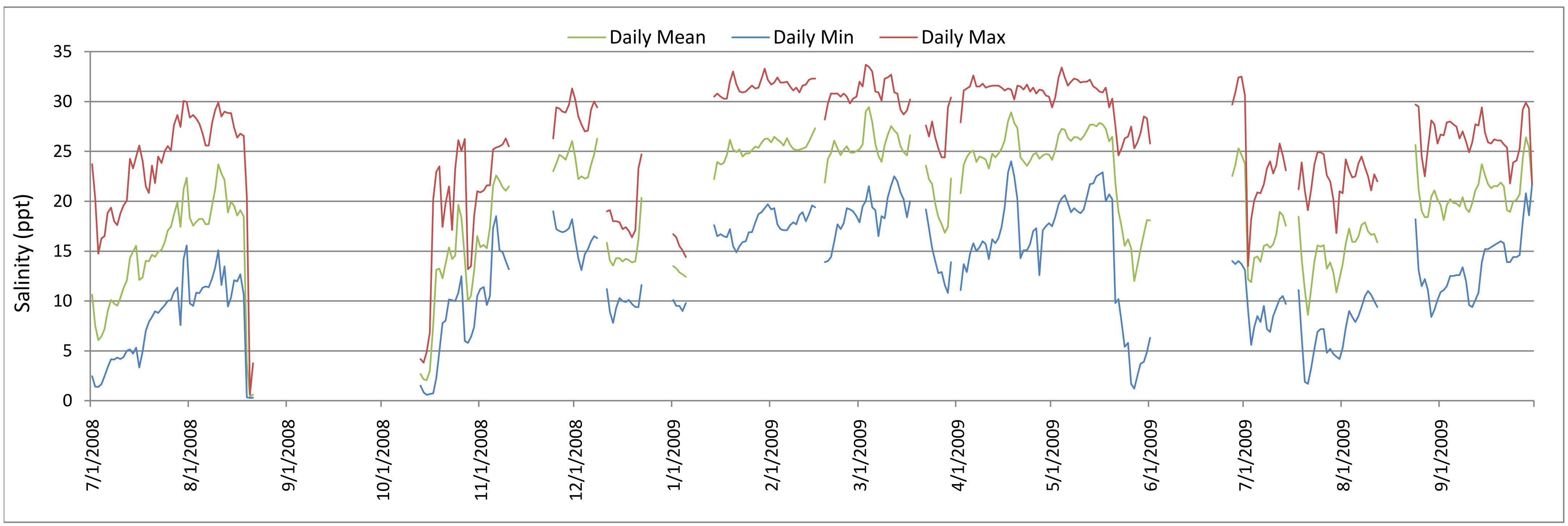

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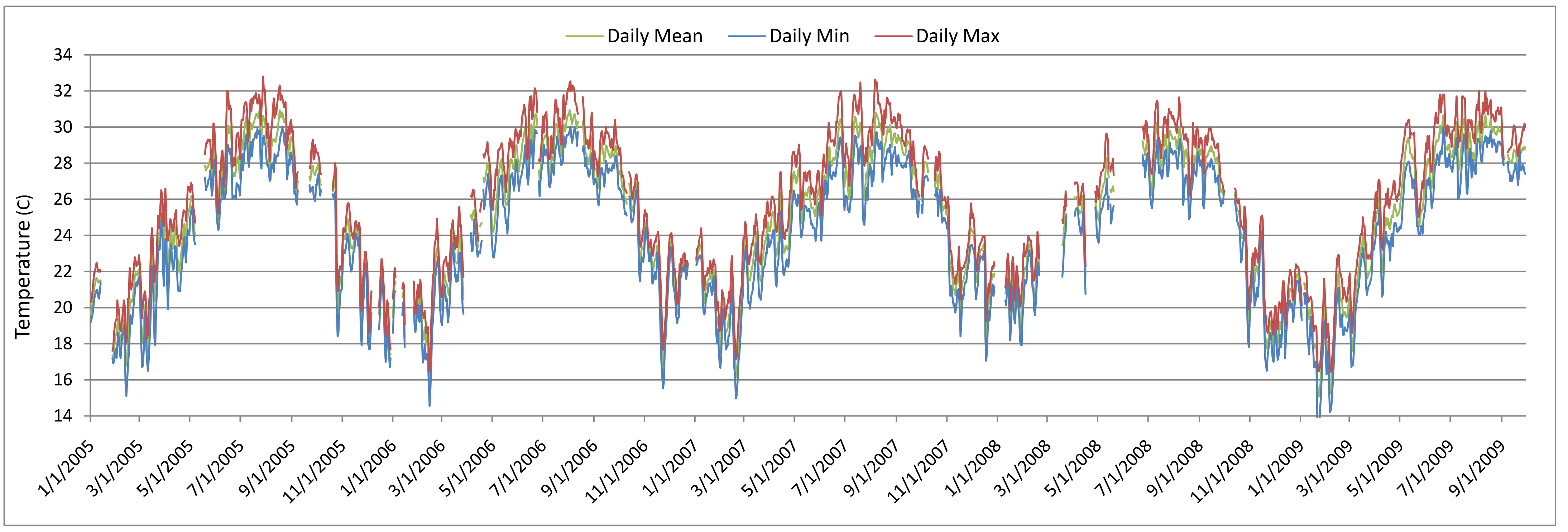


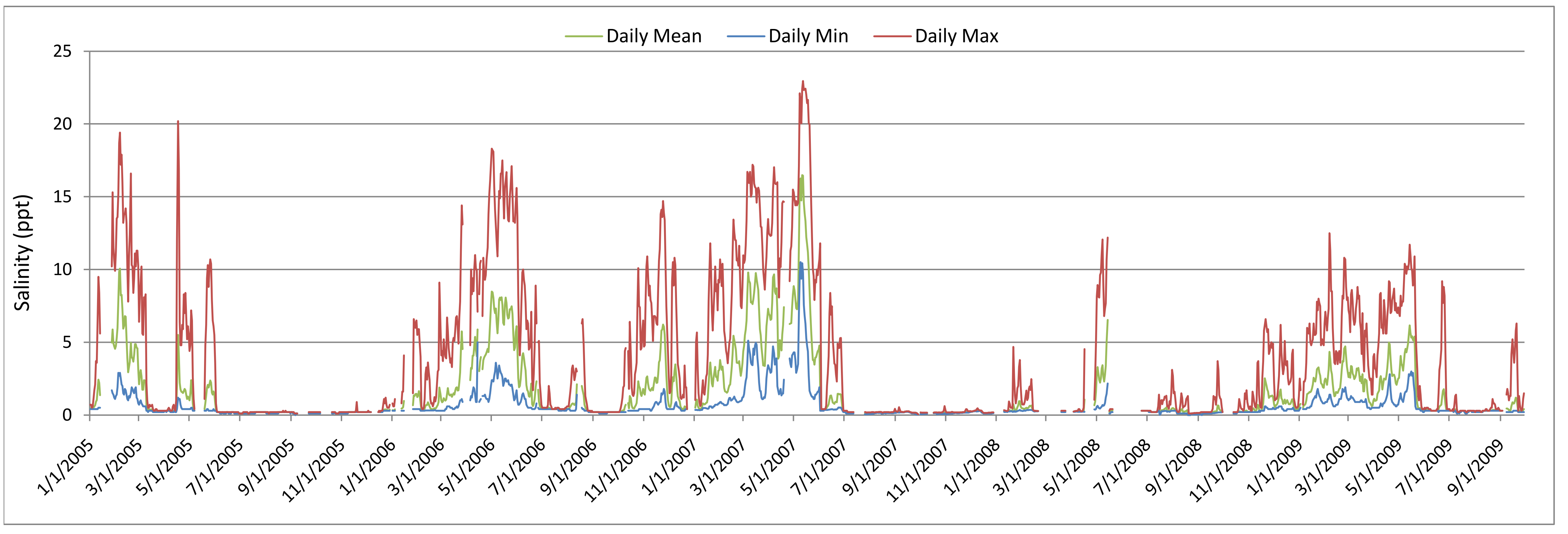


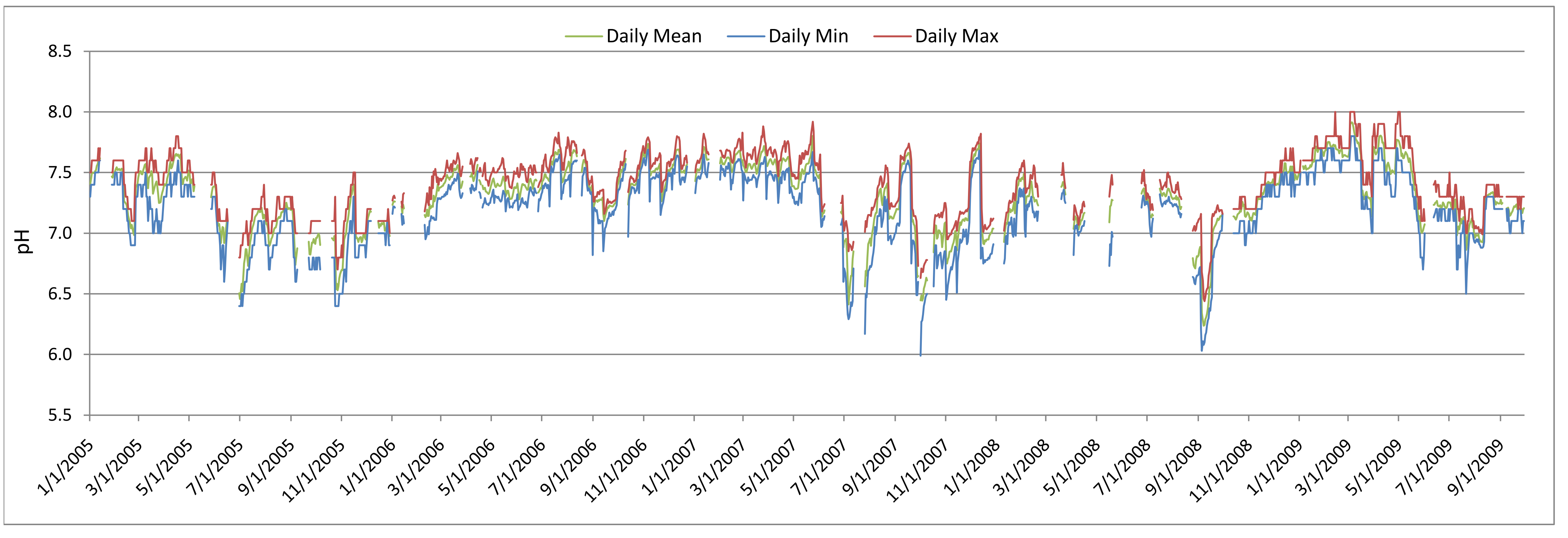


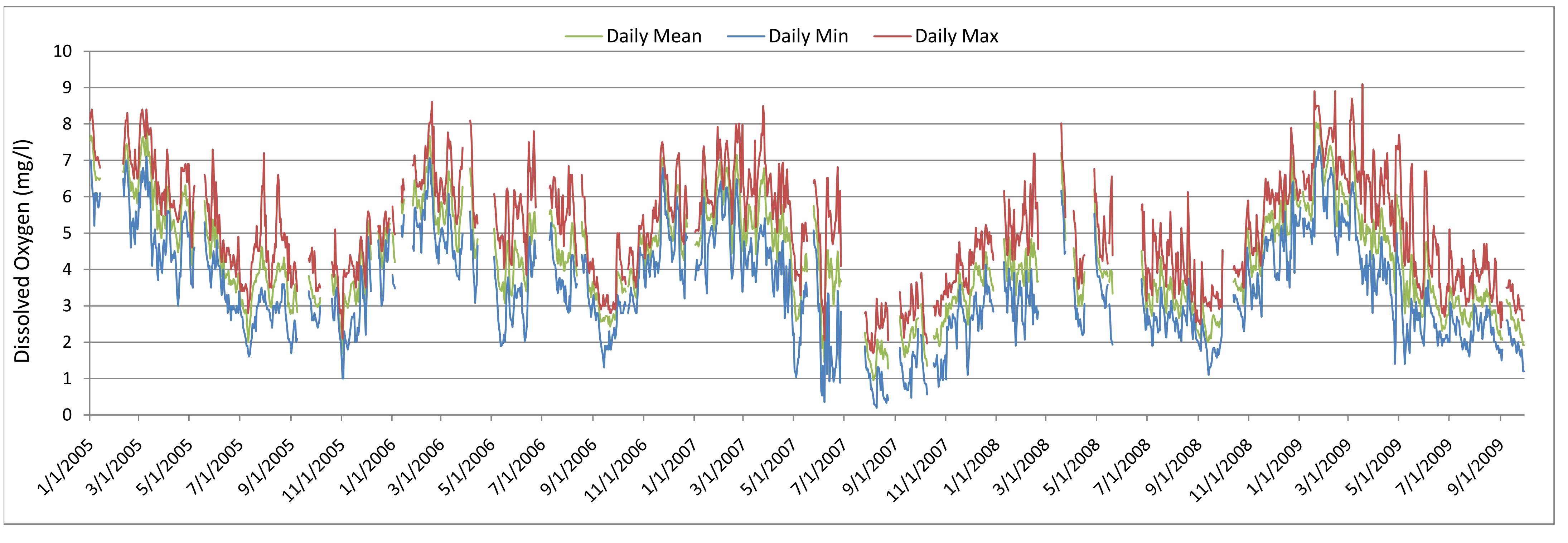

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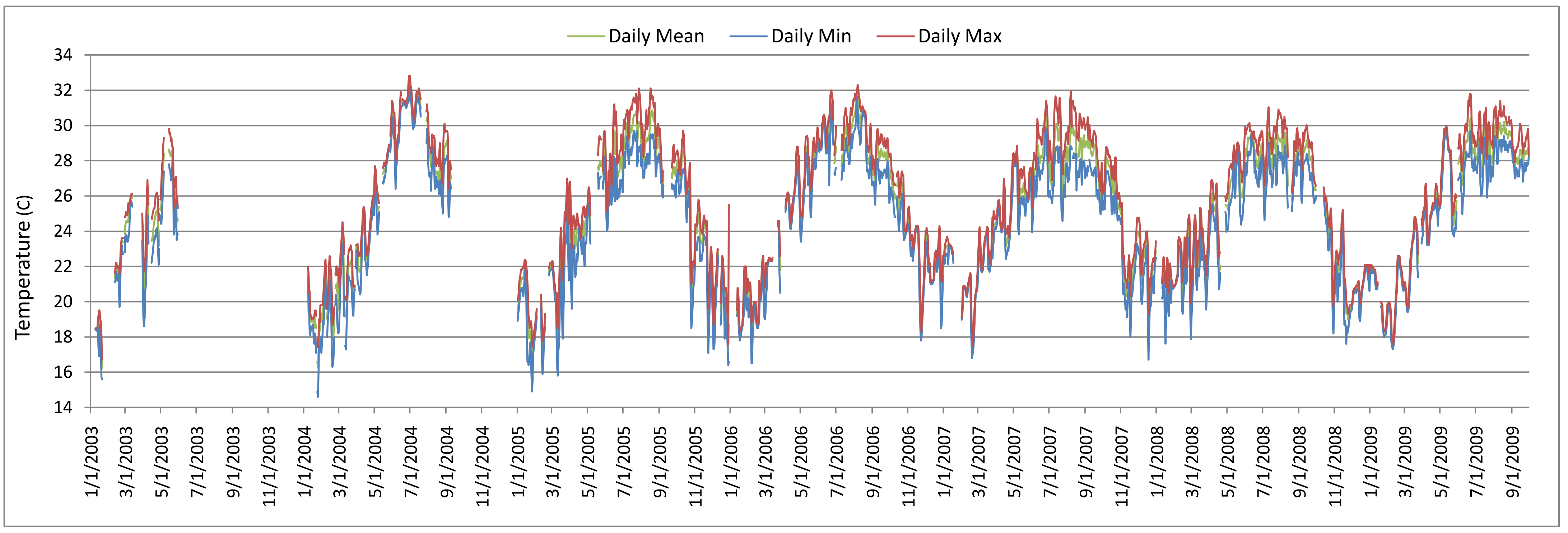


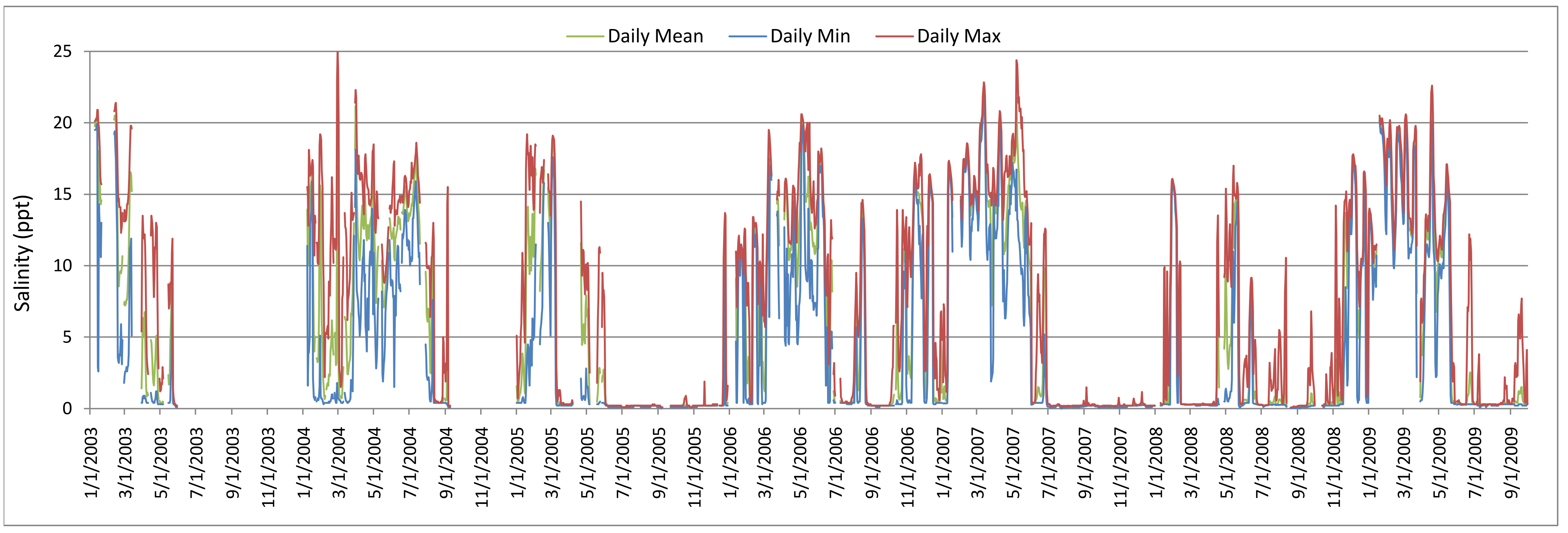


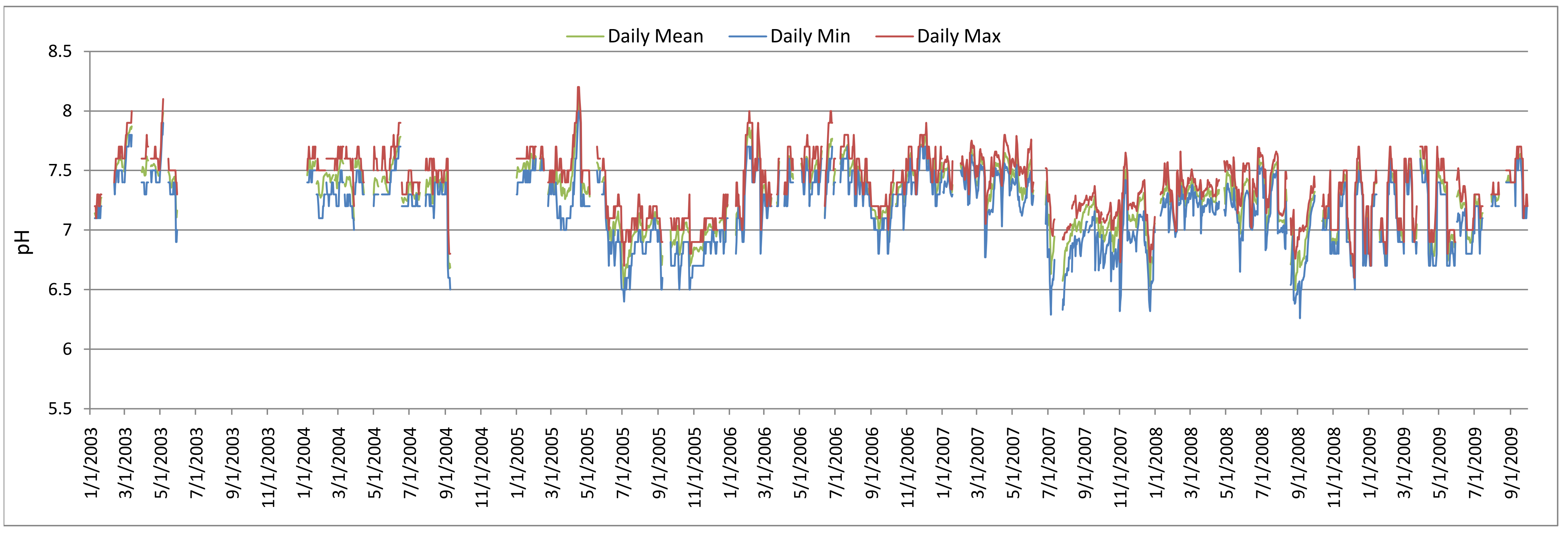


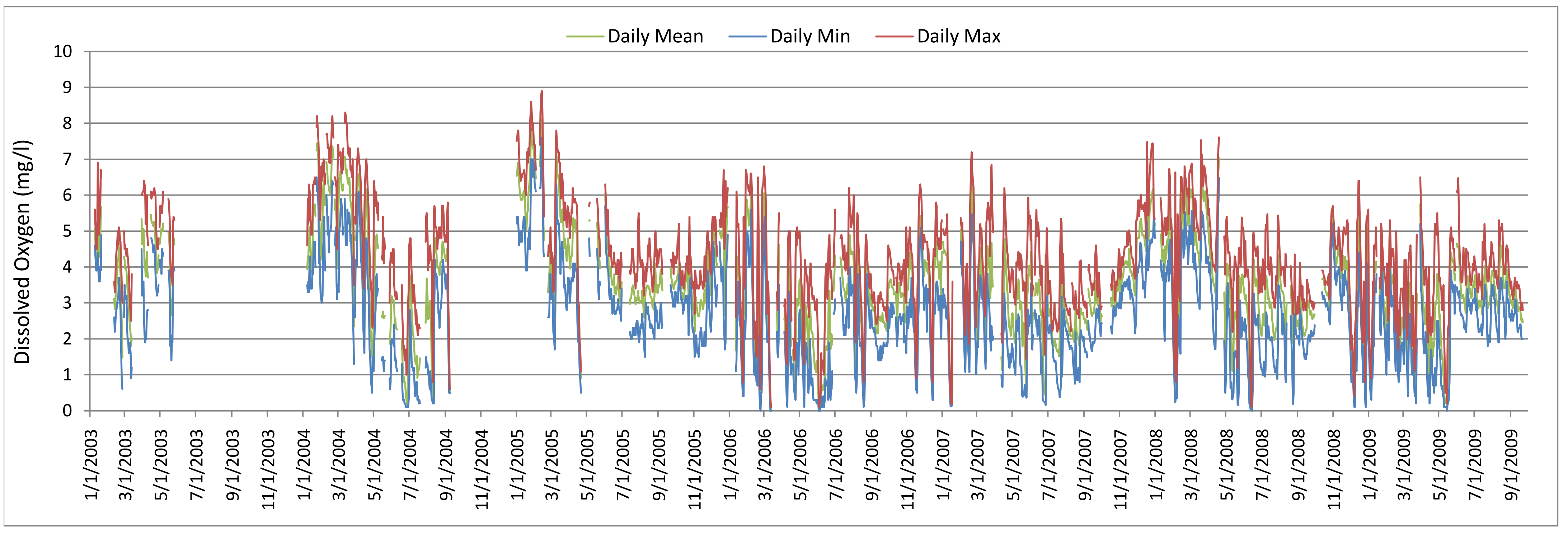

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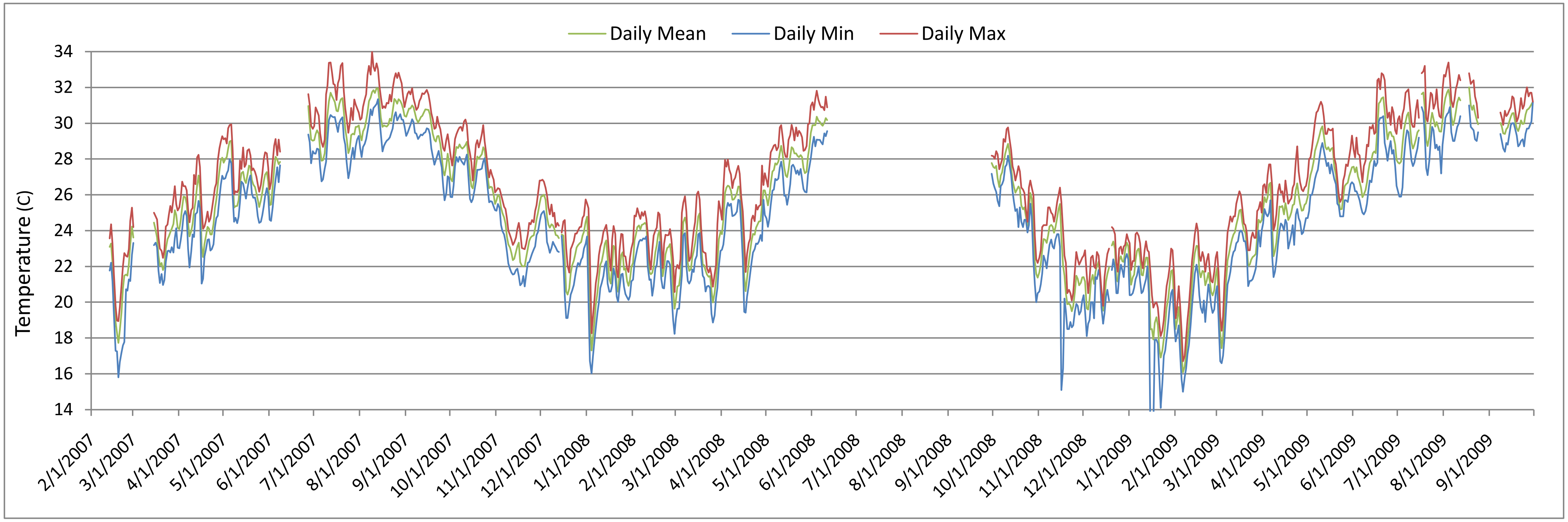

Daily Mean
Daily Min
Daily Max
Temperature (C)
34
32
30
28
26
24
22
20
18
16
14
2/1/2007
3/1/2007
4/1/2007
5/1/2007
6/1/2007
7/1/2007
8/1/2007
9/1/2007
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11/1/2007
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12/1/2008
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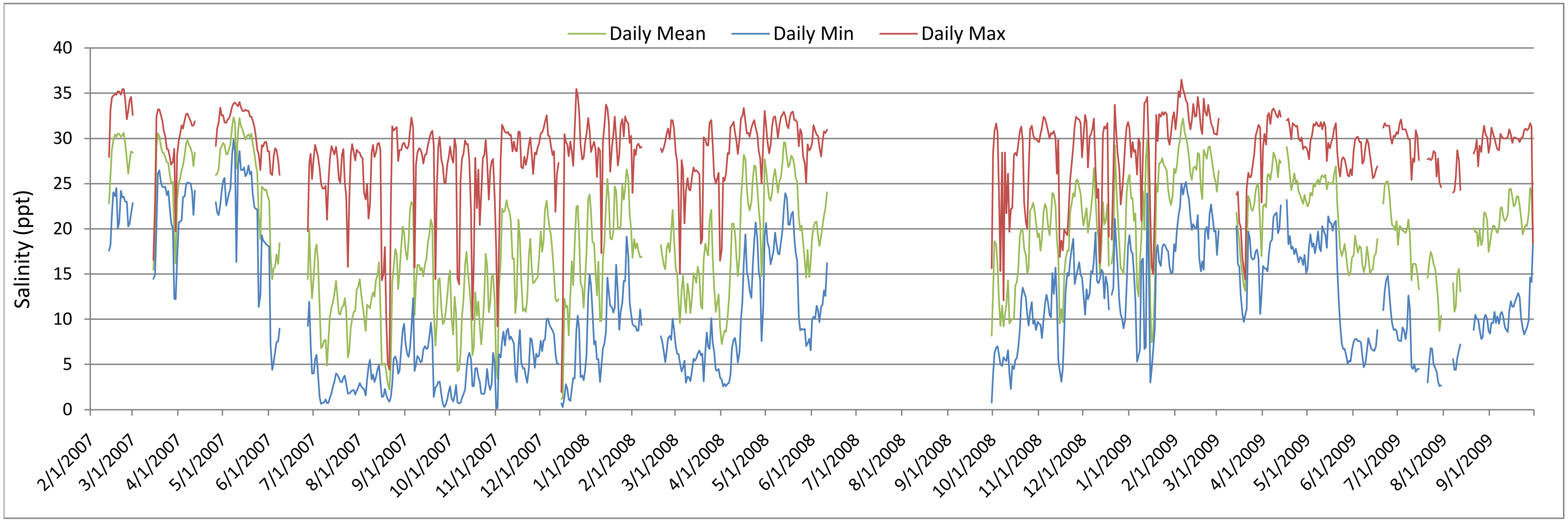
9/1/2009

Daily Mean
Daily Min
Daily Max
Salinity (ppt)
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30
25
20
15
10
5
0
2/1/2007
3/1/2007
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1/1/2009
2/1/2009
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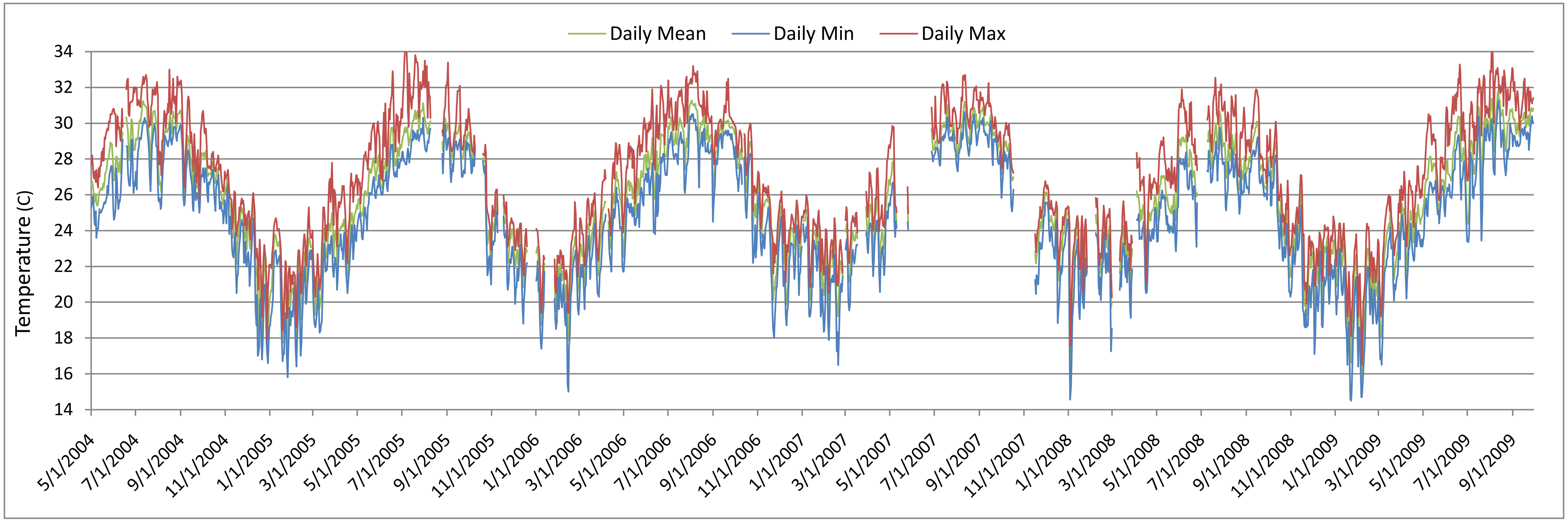
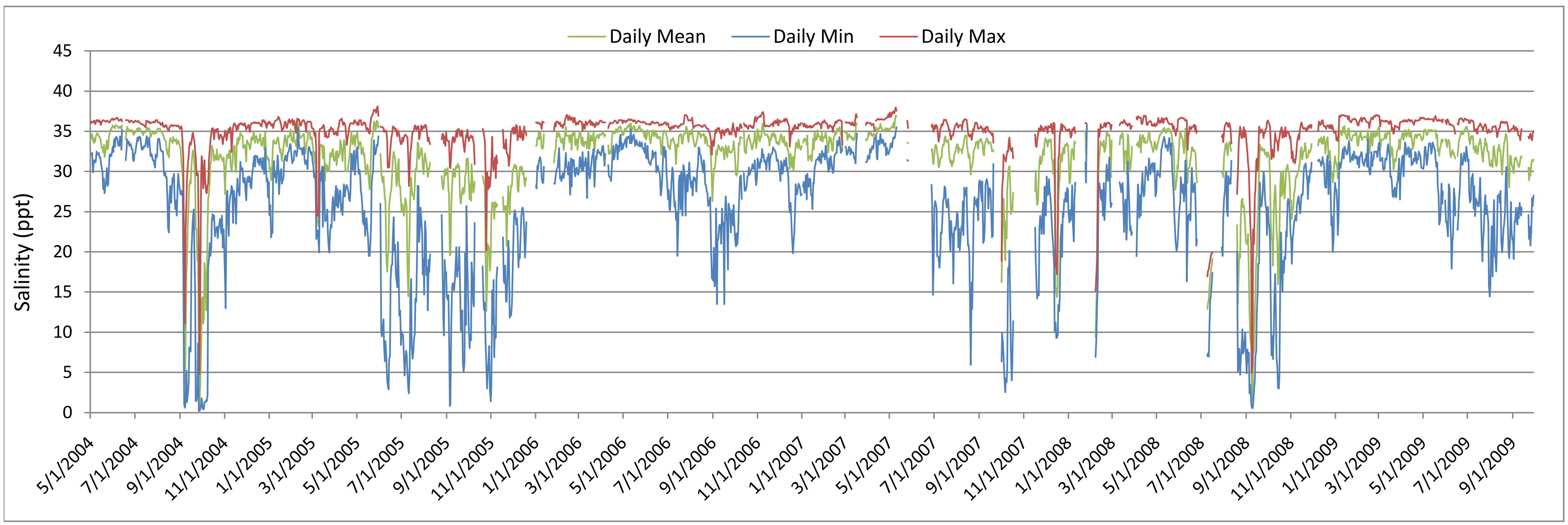
8/1/2009
9/1/2009

**B8. Pennock Point (PP)**



**B9. North Bay (NB)**