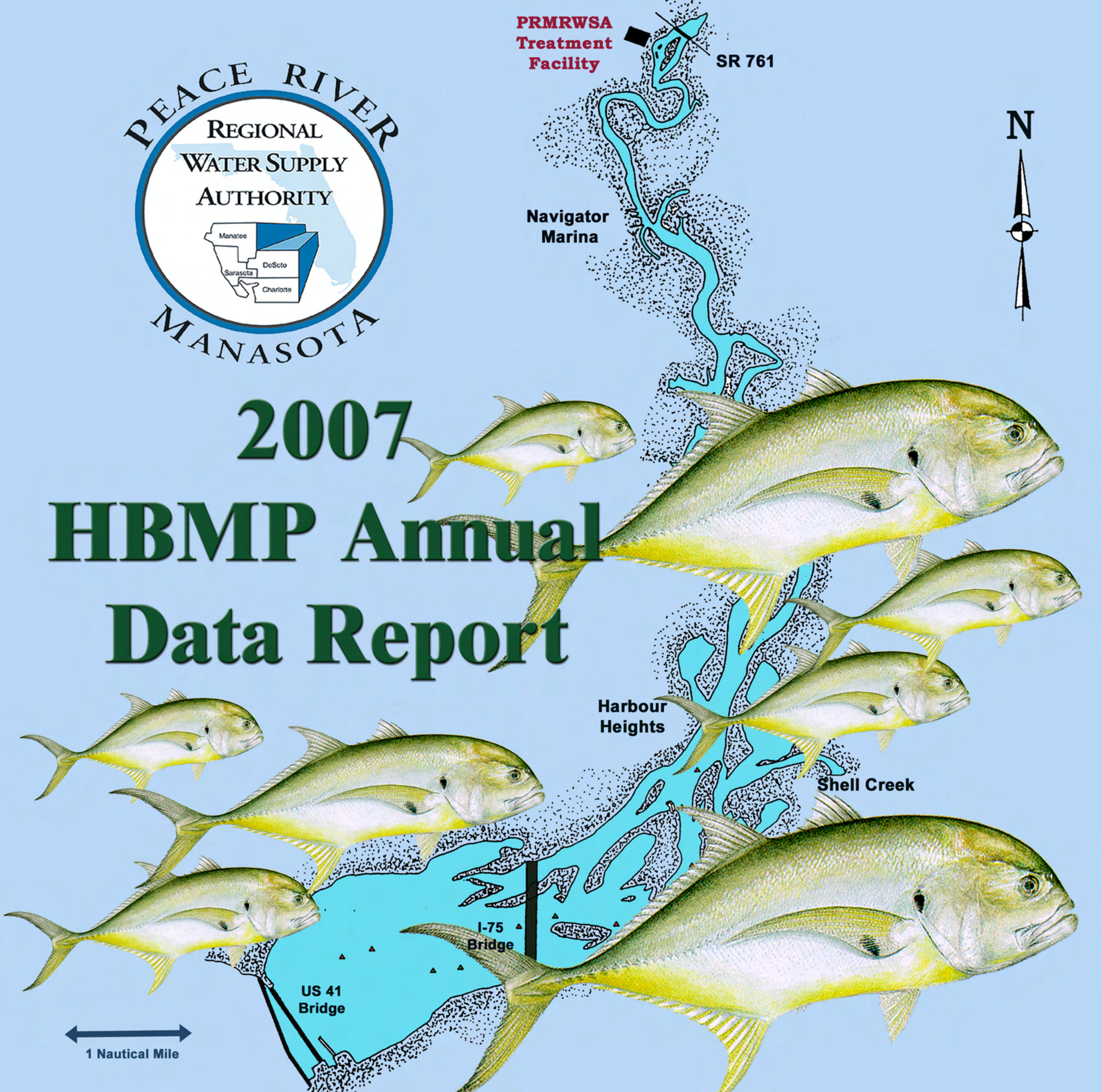
PEACE RIVER MANASOTA
REGIONAL WATER SUPPLY AUTHORITY

2007
HBMP Annual Data Report



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Peace River Hydrobiological Monitoring Program
2007 HBMP Annual Data Report

Required by

Southwest Florida Water Management District
Water Use Permit 20010420.0004

Prepared for

Peace River Regional Water Supply Facility

Peace River Manasota Regional
Water Supply Authority

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May 2008

Acknowledgments

The raw data, as well as the methods sections, presented in this report for the calendar year 2007 were provided by each of the contractors responsible for conducting specific elements of the Hydrobiological Monitoring Program.

- **EarthBalance (Florida Environmental)** – was responsible for all *in situ* water column physical measurements and the collection of water chemistry samples for both the "fixed" and "moving" station elements of the HBMP.

- **U.S. Geological Survey (Tampa Office) –** was responsible for all data collected at the two tide gages located in the lower Peace River that continuously collect data at 15 minute intervals. Measurements at each gaging location included measurements of: 1) surface and bottom conductivity; 2) surface and bottom water temperature; 3) and tide stage (water depth).

  Lower Peace River Continuous Recorders

  1. The Harbour Heights gage is designated by USGS as site 02297460, and it is located at the end of a private dock at River Kilometer 15.5.

  2. The second site is designated by USGS as 02297350 and it is located on a dock near Peace River Heights. This upstream monitoring site is located at River Kilometer 26.7.

  Gaged Stream Flow

  USGS also collects daily stream flow data at a wide number of gaging locations throughout southwest Florida. Flow data from a number of these sites are used by the HBMP program. Data for the period-of-record were obtained from the USGS web site: **(http://fl.water.usgs.gov/Tampa/index.html)**

  1. Peace River at Bartow (02294650)
  2. Peace River at Fort Meade (02294898)
  3. Peace River at Zolfo Springs (02295637)
  4. Peace River at Arcadia (02296750)
  5. Joshua Creek at Nocatee (02297100)
  6. Horse Creek near Arcadia (02297310)
  7. Prairie Creek near Fort Ogden (02298123)
  8. Shell Creek near Punta Gorda (02298202)
  9. Myakka River near Sarasota (02298830)
  10. Big Slough near North Port (02299450)

- **PBS&J (Tampa Office) –** was responsible for all data collected at the three Authority HBMP recorders located in the lower Peace River that continuously collect data at 15-

minute intervals. Measurements at each of the three gaging locations include surface conductivity and water temperature.

Authority HBMP Lower Peace River Continuous Recorders

1. **MZ4** – Near surface conductivity and temperature at 15-minute intervals from the HBMP continuous recording gage attached to the Manatee Speed Zone Sign located on the Peace River near Liverpool side channel (River Kilometer 21.9).

2. **MZ3** – Near surface conductivity and temperature at 15-minute intervals from the HBMP continuous recording gage attached to the Manatee Speed Zone Sign located on the Peace at River Kilometer 23.4.

3. **MZ2** – Near surface conductivity and temperature at 15-minute intervals from the HBMP continuous recording gage attached to the Manatee Speed Zone Sign located on the Peace River just downstream of Navigator Marina (River Kilometer 24.5).

- **Peace River/Manasota Regional Water Supply Authority** – provided measurements of daily withdrawals by the facility.

- **Benchmark Laboratory –** conducted all HBMP water chemistry analyses conducted during 2007.

Executive Summary

Historical Overview

On December 10, 1975, the Consumptive Use Permit #7500016 for the Peace River Regional Water Supply Facility was signed between General Development Utilities, Inc. and the Southwest Florida Water Management District (District). In conjunction with this agreement, a comprehensive Hydrobiological Monitoring Program (HBMP) was set forth to assess the responses of various physical, chemical and biological characteristics of the Charlotte Harbor Estuary to changes in Peace River flow. The program was designed to evaluate the impacts and significance of natural salinity changes on the aquatic fauna and flora in upper Charlotte Harbor, and to determine if freshwater withdrawals by the Peace River Regional Water Supply Facility (Facility) could be shown to alter these patterns.

Between 1979 and 2008, an ongoing series of individual reports have previously been submitted to the District, documenting the results of the HBMP during the period from January 1976 through December 2006. These reports include summarizations (findings) of data collected during the first four years of baseline monitoring, prior to the start of freshwater withdrawals, as well as comparisons of these data to the results obtained from the HBMP during subsequent years of water treatment facility operation. The period covered within this *2007 Annual Data Report* follows directly upon that contained within the preceding *2006 Annual Data Report* submitted in June 2007, as well as both the draft *HBMP 2004 Mid-term Interpretive Report* submitted in November 2006 and the draft *2006 Comprehensive Summary Report* submitted in April 2008. This current data report includes unreported HBMP data collected over the period from January through December 2007, and represents the eighteenth year of data collection for the Peace River Manasota Regional Water Supply Authority (Authority), as owner/operator of the Peace River Regional Water Supply Facility.

Although the Peace River Facility has only been operated by the Authority since 1991, the initial system was constructed by General Development Utilities and has been withdrawing water from the Peace River since 1980. The Facility's initial storage capacity was 625 million gallons in the form of an 85 acre off-stream, surface reservoir. Additional storage capacity was added in 1985 with the development of a series of Aquifer Storage Recovery (ASR) wells. These initial ASR wells added a further 1,080 million gallons of storage capacity by 1988. An additional expansion of ASR wells in 1989 further increased the Facility's total combined storage capacity to 2,785 million gallons. The storage capacity was again increased in 1995 by further expansion of ASR wells, providing a total combined ASR system storage capacity of approximately 3,865 million gallons. The storage capacity was again expanded in 2002 by the further addition of 12 new wells providing a total ASR system storage capacity of approximately 7,500 million gallons.

The Facility presently has the capacity to treat up to 24 mgd (37.1 cfs). The Facility's existing raw water river diversion station is comprised of four pumps having a combined maximum capacity of 44 mgd (68.0 cfs). In comparison, the long-term average annual daily total gaged river freshwater flow upstream of the Peace River Facility since 1976 has been approximately

796 mgd (1233 cfs). During periods of high river flow, raw river water is stored in the off-stream surface reservoir and any excess treated water is stored in the system's ASR wells. Conversely, when water is unavailable from the Peace River due to the established low flow cutoff of 130 cfs, water can be pumped from the raw off-stream surface water reservoir to the Peace River Facility for treatment, and/or previously treated water can also be recovered from the ASR well system to meet the water supply demands of the Authority's service area.

In order to meet growing regional water demand, the Authority has started another expansion of the Facility. This expansion includes an increase to the river pumping capacity to 90 mgd, which is currently the upper limit of the 1996 permit, and will also double the Facility's treatment capacity to 48 mgd. A larger new regional 640 acre off-stream reservoir with a capacity of 6 billion gallons is also under construction, and the existing transmission piping networks will also be gradually expanded to optimize regional water delivery. Completion of the ongoing physical expansion of the Facility's capacity and the new reservoir are scheduled for 2009.

Summary of Previous Key HBMP Findings

The following briefly summarizes a number of the primary findings and conclusions presented in the recently submitted draft *2006 Comprehensive Summary Report* (named for the period through which HBMP data were analyzed).

Rainfall – Climate researchers have suggested that natural climate cycles or phases can persist over multiple decades. One of these cycles, the Atlantic Multidecadal Oscillation (AMO) refers to long term cool and warm phase differences of only about 1°F (0.6°C) in North Atlantic average sea surface temperatures. An analysis of Atlantic sea surface temperatures suggests that warm AMO phases occurred during 1869-1893, 1926-1969, and from 1995 to date, while cooler phases occurred during the 1894-1925 and 1970-1994 time periods. Climatological data indicate that differences between relatively warm and cool AMO periods affect both air temperature and rainfall patterns. Analyses presented as part of the *2002 Comprehensive Summary Report* indicated the following patterns.

- Total annual average Peace River watershed rainfall levels at the Bartow and Arcadia gages were found to be slightly higher prior to the 1960s when compared with the period from the late 1960s to the mid 1990s. The data indicate that between the mid 1990s and 2006 annual total rainfall levels have, on average, increased within these two interior Peace River watersheds.

- Annual average wet-season (June-September) rainfall in the Peace River watershed was generally higher during the 1930s through the mid-1960s when compared with the interval from the late 1960s through the early 1990s. Since approximately 1994 there has been a notable increase in wet-season rainfall.

- No similar long-term patterns were apparent with regard to dry-season (January-May and October-December) rainfall, although periodic high annual totals were observed corresponding to El Niño events.

- The plots of yearly annual deviations from the average rainfall further supported the conclusions that total annual rainfall during the 1940s and 1950s was above the long-term average of 52 inches per year, and generally below this average during much of the 1970s and 1980s.

- Similar analyses of annual deviations conducted after dividing yearly rainfall totals into wet-season (June through September) and dry-season (October through December and January through May) indicated slightly higher wet-season rainfall during the earlier time periods. In contrast, dry-season rainfall varied randomly around the long-term average over time.

Lower Peace River Estuarine Freshwater Inflows – The following summarizes the major findings of analyses presented in the Comprehensive Summary Report.

- The trend analyses indicate that there have been long-term statistically significant declines in flows in the upper reaches of the watershed at both Bartow (since 1940) and Zolfo Springs (since 1934).

- U.S. Geological Survey (USGS) gaged Peace River at Arcadia flows also show statistically significant declines in a number of flow metrics over the 75-year period-of-record.

- In the southern tributaries of the Peace River watershed, by comparison, flows have increased over their periods-of-record (which are of shorter duration than the northern gages). Shell Creek flow data indicate statistically significant increases in the lowest flow percentiles (base flows), while there have been increasing trends in Prairie Creek at all percentiles between the monthly minimum and median values, and all percentiles of flow at the Joshua Creek gage have increased over time.

- Even with such agriculturally augmented dry-season flows in many of the southern watershed basins, combined total gaged flows upstream of the Facility still show statistically significant declines over the 1951 to 2006 interval for all monthly percentiles below the median flow.

- There were no statistically significant trends in flows at any of the USGS gages along the main stem of the Peace River during the period of HBMP monitoring between 1976 and 2006.

- All of the analyzed flow metrics (percentiles) at the Joshua Creek gaging location showed statistically significant increases over the 1976-2006 time interval. The results indicate the relative magnitude of agricultural development that has occurred in the Joshua Creek basin during this time interval.

- In comparison, the trend test results show that only median and those flows below have been augmented by agricultural development in the Horse Creek and Prairie Creek basins.

- The observed differences in trends may indicate that not only have all three of these southern Peace River watershed basins seen augmented dry-season stream flows due to agricultural ground water pumping, but that the degree of land use and drainage changes that have occurred in the Joshua Creek watershed have also resulted in structural changes that have fundamentally altered hydrologic surface flows in the basin.

Peace River Treatment Facility Withdrawals – The following observations and conclusions were presented in the report with regard to the status, long-term patterns and trends in Facility freshwater withdrawals.

- Prior to 1988 when withdrawal quantities were not based on a percent of river flow, much larger percentages of low flows were initially taken under the District's original monthly based withdrawal schedule.

- Time-series plots plainly show the relatively steady increases in the amounts of freshwater withdrawals by the Facility since 1980 due to increasing potable water demands. Also clearly evident is the noticeable increase in maximum Facility withdrawals following completion of the Facility's 2002 expansion, which resulted in the Authority's increased ability to treat and store larger daily amounts of freshwater.

- Comparisons indicate that other than during the warm/dry months of April and May when the Facility is often not withdrawing water from the Peace River due to the 130 cfs cutoff, Facility withdrawals have been fairly uniform throughout most of the year, differing primarily between changes in the permits and differences in Facility capacities.

- The low flow cutoffs based on flows at the USGS Peace River at Arcadia gage have often resulted in periods each year when the Facility does not withdraw water from the river. During 2000 the Facility did not withdraw any water from the Peace River for a total of 248 days, and relied solely on stored reserves another 219 days during 2001.

- Facility withdrawals have periodically exceeded the ten percent criteria since it was established in 1988. The primary reason for these discrepancies stems from the way that stage/flow data are gathered. The Authority uses "provisional" preceding day flow data from the water level recorder at the USGS gaging station on the Peace River at Arcadia. Currently, these data are taken directly from the USGS Tampa office's website. However, after the fact, the USGS checks and evaluates the data from the stage recorder and validates the river cross section a number of times each year. Thus, the daily values used by the Authority are only "provisional" and are occasionally changed by the USGS weeks or months after the fact. It is not uncommon for subsequent determinations of percent withdrawals, based on revised USGS calculations of daily flows, to conclude that daily Facility withdrawals, based on provisional flow information, in fact exceeded the established ten percent criteria. Such differences also result in instances when the Authority actual takes less than the permitted ten percent. The Authority and the USGS Tampa office staff have continued to work to reduce such instances to the greatest possible extent.

Status and Trends in "Fixed" HBMP Station Water Quality Parameters – The HBMP water quality monitoring design has included the monthly collection of *in situ* physical measurements and chemical water characteristics at a number of fixed station locations (Figure 1.5) along the lower Peace River and in upper Charlotte Harbor. These data were used to describe the present status, and statistically test for long-term changes in the water quality characteristics at these specific selected locations along the lower Peace River HBMP monitoring transect. The following summarizes the results and findings of these analyses for a number of key water quality parameters.

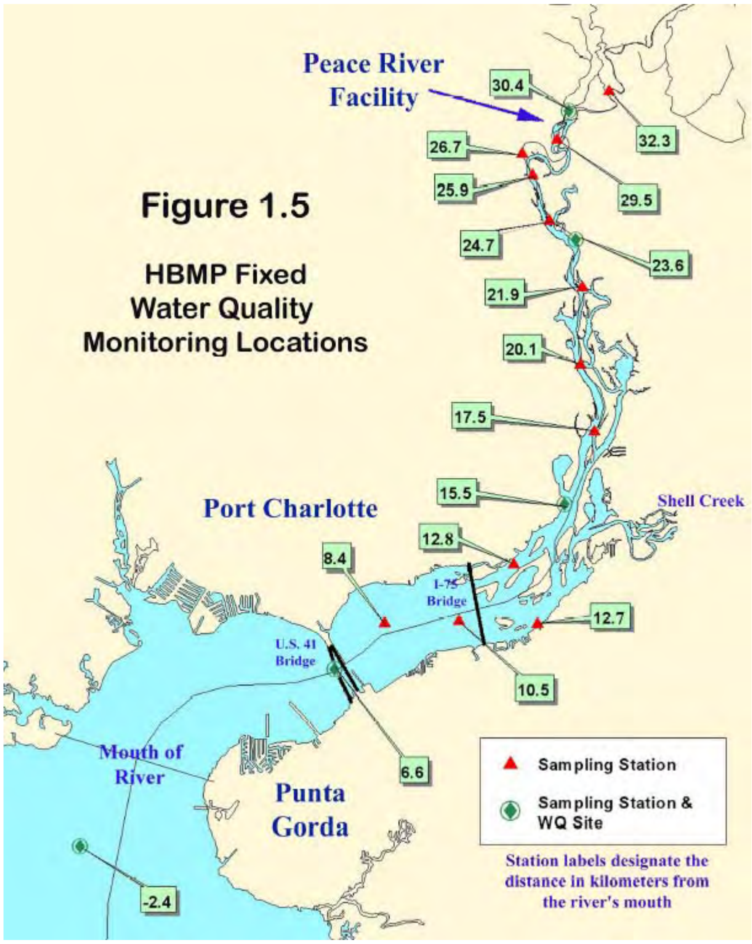
Figure 1.5

HBMP Fixed Water Quality Monitoring Locations

- **Salinity –** There is a strong, distinct spatial salinity gradient along the lower Peace River monitoring transect. The greatest inter-annual variability in salinity generally occurs in the surface waters near the mouth of the river in the upper harbor where seasonal differences may reach 35 parts per thousand (or practical salinity units) between extended periods of low and high freshwater inflow. The influences of the recent high freshwater inflows during the 1997/1998 El Niño event and the extended 1999-2001 drought are evident in the time-series plots.

- **Dissolved Oxygen –** Near-bottom dissolved oxygen concentrations show clear seasonal cycles in response to higher freshwater flows during the summer wet-season. The duration and magnitude of periods of very low dissolved oxygen concentrations increase toward the river mouth as higher bottom salinities establish greater vertical stratification in the water column during high flows. Other studies have noted apparent declines in dissolved oxygen concentrations in the lower river over time, but have been unable to clearly identify any cause. The current analyses, based on a somewhat longer data set than these previous analyses, generally finds similar surface and bottom annual average dissolved oxygen concentrations along the HBMP monitoring transect when comparing the 1976-1989 and 1996-2006 time periods.

- **Water Color –** Humic compounds derived from the breakdown and subsequent leaching of vegetation into surface waters are the source of the high water color that characterizes the blackwater river systems of southwest Florida. Color levels in the estuary temporally increase quickly in response to increased freshwater inflow, with very high color levels extending well into the harbor during extended periods of high freshwater flows such as occurred during the 1997/1998 El Niño or recently during the extremely high flows that occurred during 2001, 2003, 2004 and 2005. Statistical analyses indicated significant differences between the average annual surface color levels at the two most downstream monitoring locations (River Kilometer (RK) -2.3 and 6.6) between the 1976-1989 and 1996-200 sampling periods. These differences reflect the higher recent inflows of dark colored water farther down the river and into the upper harbor during the recent period of high flows.

- **Nitrite+Nitrate Nitrogen –** Concentration levels and seasonal patterns of dissolved inorganic nitrite+nitrate nitrogen differ along the lower river/upper harbor HBMP monitoring transect. The time-series plots indicate that inorganic nitrite+nitrate nitrogen levels at the most downstream fixed sampling station (located near the arbitrarily defined river mouth) are typically near or at method detection limits. Salinities are typically high in this region of the estuary and, except during periods of very high river flow, phytoplankton primary production is limited by the availability of inorganic nitrogen. Conversely, during extended periods of high freshwater river flows, surface salinities decline, bringing increased nutrient loading and higher levels of water color that limit the penetration of light into the water column and subsequently reduces phytoplankton growth and nitrogen uptake. By comparison, inorganic nitrogen levels progressively increase moving upstream along the HBMP sampling transect, as dilution by low nutrient/high salinity harbor water declines and higher water color increasingly limits phytoplankton nitrogen uptake. Only during periods of extended low freshwater flow, such as during the spring dry-season, are ambient inorganic nitrogen levels low at the upstream river sampling sites. The observed statistically significant increase in inorganic nitrogen concentrations in the upper harbor (RK -2.4) matches with the corresponding increase in water color and supports the previous observations that these increases reflect higher inflows of darker (nitrogen rich) freshwater farther downstream into the upper harbor during the recent period of characteristically higher river flows.

- **Total Kjeldahl Nitrogen –** While this gross measurement of combined inorganic ammonia and organic water column nitrogen shows distinct seasonal patterns, spatially levels at all the monitoring locations were observed to be relatively similar. Statistical tests found no significant differences when comparing the 1976-1989 and 1996-2006 time periods.

- **Ortho-Phosphorus –** Probably the most dramatic long-term change in water quality in the lower Peace River has been the marked, observed statistically significant long-term decline in dissolved inorganic (and total) phosphorus concentrations. Phosphorus concentrations generally reflect both the spatial and temporal variation in Peace River freshwater inputs. The highest phosphorus concentrations are typically associated with seasonal low river flow, when the influences of ground water are more pronounced. Long-term temporal patterns indicate rapid declines in both the magnitude and variability in phosphorus levels when compared with the first six years of HBMP monitoring. Comparisons of the average annual mean phosphorus concentrations between the 1976-1989 and 1996-2006 time periods indicate a continued decline at the HBMP river stations, even though the largest changes occurred prior to 1984. Of particular note however are more recent observations, which show phosphorus levels throughout the lower Peace River/upper Charlotte Harbor Estuary have dramatically increased following Hurricanes Charley, Francis and Jeanne in August and September of 2004. It is apparent that the historically high flows that occurred in the upper Peace River watershed following this unusual series of events has at least temporarily increased phosphorus concentrations throughout the system to levels not seen for over 20 years.

- **Silica –** Both the long-term time-series plots and the statistical comparisons of mean annual average reactive silica concentrations indicate that silica levels have recently dramatically increased along the entire length of the lower Peace River monitoring transect. During the most recent eleven years of HBMP monitoring, silica concentrations at all five fixed sampling sites have increased and the range of variability has increased when compared with similar data from the 1976-1989 period. It may be that the observed increases in ambient reactive silica levels in the Peace River estuarine system reflect the cumulative influences of increased ground water use and the expansion of water intense agriculture in the Peace River watershed, or it may be associated with other land use changes occurring upstream in the watershed. The Authority is currently collecting additional dry- and wet-season data at a number of locations throughout the upper watershed in order to be able to better identify potential sources of both apparent increasing silica and phosphorus concentrations.

- **Chlorophyll *a* –** Previous studies observed marked declines in the periodic very high chlorophyll *a* concentrations or phytoplankton “blooms” that commonly occurred in the surface waters throughout the lower Peace River/upper Charlotte Harbor estuarine system during the late 1970s and early 1980s. However, the current examination of the data, which extends similar analyses through 2006 indicates that since 2004 chlorophyll *a* levels in the lower river and upper harbor have uniformly shown increases to annual average levels not seen in over 20 years. Following Hurricanes Charley, Francis and Jeanne in August and September of 2004, as previously discussed, water quality data from the lower river showed marked increases in ortho-phosphorus levels that correspond with the observed increases in chlorophyll *a*. Since phosphorus levels in the lower Peace River/upper Charlotte Harbor Estuary are naturally high, and nutrient additions have shown local estuarine phytoplankton populations are seasonally nitrogen and not phosphorus limited, it is doubtful that the observed increases in phosphorus levels are directly the ultimate cause of the observed increases in chlorophyll *a* concentrations. More likely is that other water quality constituents not monitored by the HBMP, but having the same source as the observed phosphorus increases, are responsible for the observed increases in phytoplankton levels. Overall, the result of the observed historic declines, combined with the recent observed increases, is that there are no statistically significant differences in average annual seasonally weighted mean chlorophyll *a* concentrations between the 1976-1989 and 1996-2006 time intervals at any of the fixed HBMP monitoring locations. This result demonstrates the inherent difficulty in using most commonly applied statistical trend procedures when evaluating long-term changes in water quality parameters having multiple non-seasonal increasing and decreasing patterns.

Current Hydrobiological Monitoring Program

The initial monitoring elements of the HBMP were designed in 1976 to provide answers to specific questions raised by District staff during the Facility's original permitting process. These questions raised concerns regarding the potential for negative impacts that might be associated with possible salinity changes in Charlotte Harbor resulting from freshwater withdrawals. The HBMP was from its conception envisioned as a dynamic program. Modifications have been made to the program's monitoring elements throughout its history, with study elements having been added and deleted in order to enhance the overall knowledge base of the lower Peace River/upper Charlotte Harbor estuarine system. Historically, those major monitoring elements aimed at assessing direct relationships with variations in freshwater inflow have had the longest histories (vegetation and water quality). Other HBMP elements, primarily those focused on assessing indirect biological indicators, have extended over a number of years and then ended once a sufficient baseline basis of information had been accumulated.

Based on the results of the 1993 and 1995 Summary HBMP Reports and additional analyses requested by District staff during the 1996 permit renewal process, an expanded HBMP was approved by the District in March 1996 as a part of Water Use Permit (WUP) #2010420 for implementation in 1996 and subsequent years. The Peace River Facility's 20-year Water Use Permit continues to require the submission of Annual Data Reports, as well as Mid-term and Comprehensive Summary Documents respectively after data collection for the 3rd and 5th years of each five-year period. Specific conditions within the 1996 permit renewal included major expansions of both the physical and biological elements of the Hydrobiological Monitoring Program.

USGS Continuous Recorders –The primary goal of this HBMP study element has been to develop an extensive database of short-term changes in surface and near-bottom salinity in the lower Peace River. In 1996 the USGS installed an automated 15-minute interval water level conductivity and stage recorder approximately 15.5 kilometers upstream of the river's mouth at Harbour Heights. In November 1997 a similar Peace River Heights recorder was installed at approximately RK 26.7 just downstream of the Peace River Treatment Facility (Figure 5.1). As indicated in previous HBMP annual reports, both surface and bottom conductivities at the downstream Harbour Heights site (River Kilometer 15.5) are very strongly influenced by tide (water stage) during periods when river flows are relatively low. During May, in the dry-season, it was not uncommon for surface and bottom conductivities to vary 7000 to 15000 uS/cm (roughly from 4 to 9 psu) over a tidal cycle. During the wet-season, this lower reach of the Peace River is characteristically far fresher and daily variations in both surface and near bottom conductivities resulting from tidal influences are greatly reduced, typically varying over a range of less than 0.2 psu. However, during September 2007, wet-season freshwater inflows were historically low, and conductivities in this lower reach of the river remained relatively high throughout the year.

At the more upstream continuous USGS gage at Peace River Heights RK 26.7), the conductivity data collected in 2007 showed surface and bottom conductivities varying 5000 to 15000 uS/cm (roughly from 3 to 9.0 psu) over a tidal cycle during the May spring dry-season. This is again in direct contrast to recent wetter years such as 2005, when the data indicate only small, infrequent differences in conductivity (usually less than 100 uS/cm) resulting from tidal variations during the May 2005 dry-season. During September 2007, conductivities were low, but still showed small variations due to normal daily tidal cycles in water levels due to the historically low wet-season flows.

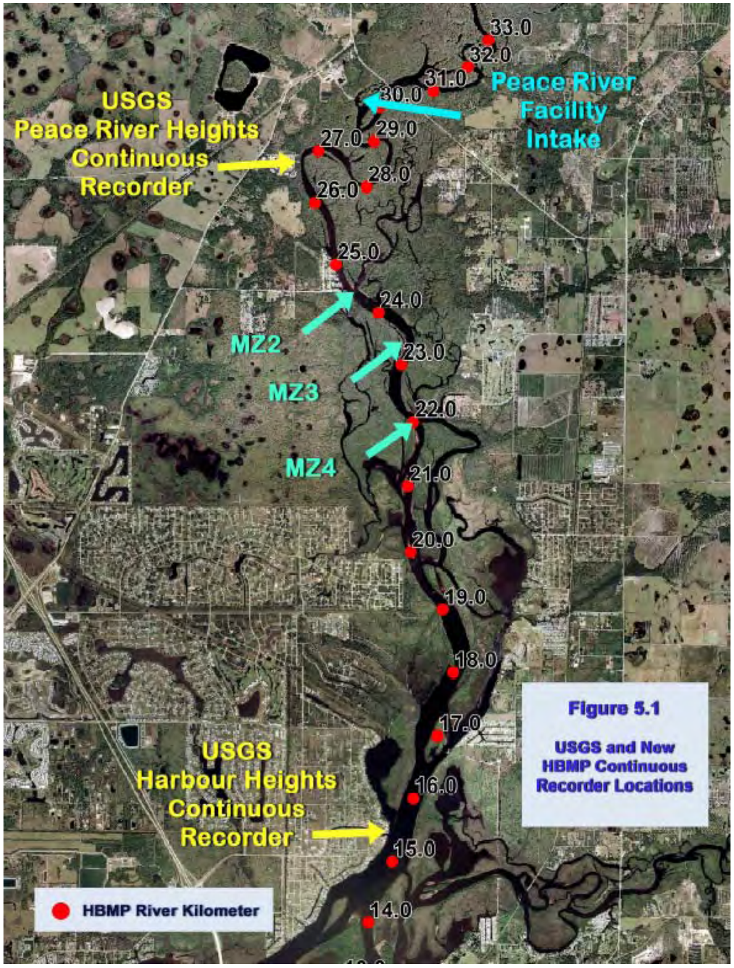

Figure 5.1

USGS and New HBMP Continuous Recorder Locations

Conductivities at the more upstream Peace River Heights recording gage indicated the extent and duration of the upstream movement of higher conductivity harbor waters during 2007. High conductivity water (5,000–20,000 uS/cm) extended upstream into this characteristically freshwater reach of the lower river during January, from mid-March through the first part of July, and then again during November and December. This is in direct contrast to the preceding much wetter years (2003-2005) when conductivities at the Peace River Heights gage exceeded 1000 uS/cm for only just a few days over the entire year.

Additional Authority Continuous Recorders – The three new HBMP recorders (MZ2 through MZ4) installed by the Authority showed analogous patterns to those observed at the two USGS continuous gages located downstream and upstream along the HBMP monitoring transect (Figure 5.1). As previously discussed with respect to corresponding data from the two USGS continuous gages located downstream and upstream of these HBMP recorder locations, surface conductivities in the reach of the lower Peace River characterized by the three HBMP recorders typically show a great degree of daily tidal variability during periods of low flow and usually only very small or limited tidal salinity changes during higher flows. However, due to the historically low wet-season flows that occurred during the summer of 2007, the region of the lower river characterized by the three HBMP recorders experienced daily tidal increases in salinities throughout almost the entire year.

Water Chemistry and Water Column Physical Profiles – The primary focus of the HBMP program extends along the monitoring transect centerline from south below the mouth of the river (which follows an imaginary line between Punta Gorda Point and Hog Island) to just north of the 761 Bridge, which is located upstream of the Peace River Facility. Two separate HBMP study elements incorporate both *in situ* water column profile physical measurements combined with the collection of chemical water quality sampling along the monitoring transect. Several goals are associated with both the individual and combined findings of these water quality

HBMP study elements. A principal goal of both monitoring efforts is to assess the overall "health of the estuary" by collecting sufficient long-term data to statistically describe spatial and seasonal variability of the water quality characteristics of the lower Peace River/upper Charlotte Harbor Estuary, and test for significant changes over time (trends). A further goal of these HBMP elements is to determine whether significant relationships exist between freshwater inflows and the seasonal/spatial variability of key selected water quality parameters. If such relationships can be shown, then the ultimate goal becomes to determine the potential magnitude of change that might result from both existing permitted withdrawals and projected future increases, and compare such predicted changes due to withdrawals with the normal ranges of observed natural seasonal and annual variability.

Similar and comparable physical and chemical water quality parameter measurements along the upper Charlotte Harbor/lower Peace River estuarine monitoring transect are collected under these two different HBMP study elements.

1. During the first week of each month, water quality measurements (physical and chemical) are conducted at four "moving" salinity-based isohaline locations (0, 6, 12 and 20 psu) along a river kilometer centerline running from the imaginary "mouth" of the Peace River upstream to above its junction with Horse Creek, and downstream to Boca Grande Pass. The relative monthly location of each sampling is based on the first occurrence of these specific isohalines (± 0.5 ppt), with freshwater being defined as the first occurrence of conductivities less than 500 ms. Historically, this isohaline sampling effort was undertaken in conjunction with other long-term phytoplankton elements of the HBMP (see Phytoplankton Studies described below.)

2. Approximately two weeks after the collection of the "moving" isohalines, water column physical profiles are conducted, near high tide, at sixteen "fixed" locations along a transect running from just below the river's mouth upstream to a point just above the Peace River Facility (see Figure 1.5 above). In addition, chemical water quality samples are taken at five of these locations.

Both of these water quality study HBMP elements include physical *in situ* water column profile measurements of characteristic parameters (temperature, dissolved oxygen, pH, conductivity and salinity) at 0.5 meter intervals from the surface to the bottom. In addition both efforts measure the penetration of photosynthetically active radiation (PAR) to determine ambient extinction coefficients at specific sampling locations. Both studies also include the analyses of an extensive list of chemical water quality parameters. The only difference is that at the "fixed" sampling stations both sub-surface and near-bottom samples are collected at each of the five sites, while only sub-surface water chemistry samples are taken as part of the "moving" isohaline based HBMP study element.

Summary of 2007 HBMP Study Results

The following compares data collected during 2007 with similar average values for key parameters previously compiled during various elements of the ongoing long-term monitoring programs. This summary of 2007 data includes the following key HBMP study elements.

1. Peace River freshwater inflows and facility withdrawals.

2. Physical measurements such as water temperature, color and extinction coefficients.

3. Water quality characteristics such as nitrate/nitrite, ortho-phosphorus, nitrogen to phosphorus ratios, and reactive silica.

4. Biological measurements of phytoplankton biomass (chlorophyll *a*.)

In making comparisons of the 2007 data with averages of similar data collected over the preceding 24-year period (1983-2006), it should be noted that the very wet winter/spring El Niño of 1997/1998 was followed by very dry La Niña conditions that influenced southwest Florida and the entire Peace River watershed between 1999 and early 2002. A weaker El Niño occurred at the end of 2002, and freshwater flows during 2003, 2004 and 2005 were generally above average. Rainfall in the Peace River watershed during both 2006 and 2007 by comparison was well below average, especially during the usually wetter summer months. The summer 2007 wet-season, like the 2006 wet-season, was often characterized by afternoon summer thunderstorms building along the coast rather than inland, and unlike recent preceding years, the Peace River watershed was unaffected by any tropical storm events.

- **Flows** – Average mean daily Peace River flow at the Arcadia gage during 2007 was only 173 cfs, which was less than half the preceding annual average flow of 376 cfs that occurred under the very dry conditions of 2006. The combined average flow over these last two very dry years has been only approximately 15 percent of the average daily mean flow that occurred over the preceding two unusually wet years (1747 cfs during 2004 and 1859 in 2005). The average mean daily flow of 173 cfs during 2006 was the 2nd lowest mean daily average flow over the past 32 years, and only slightly higher than the average daily flow of only 139 cfs that occurred in 2000 during the past extended 1999-2001 drought. The extremely low average mean flow during 2000 was the lowest that has occurred during the years of HBMP monitoring. Overall, gaged Peace River at Arcadia freshwater mean flows during 2007 were just 18 percent of the average daily flow for the preceding long-term period 1976-2006. In comparison, the sum of average daily flows from the Peace River at Arcadia, Horse Creek, Joshua Creek, and Shell Creek during 2007 was roughly 22 percent of the average daily flows over the longer term 1976-2006 HBMP monitoring period.

- **Withdrawals** – Throughout 2007, the Peace River Facility operated under a series of District modifications to the Water User Permit and Executive Orders that temporarily altered the low flow cutoff and/or temporarily increased the percent of flow that could be withdrawn from the river. The Facility's mean average daily withdrawal during 2007 was 17.3 cfs. Overall withdrawals comprised 10.1 percent of the annual Arcadia gaged flow, and 4.9 percent of the combined lower Peace River gaged flow (Peace River at Arcadia, Horse Creek, Joshua Creek and Shell Creek). Combined total freshwater withdrawals by the Peace River and the City of Punta Gorda facilities accounted for approximately 7.1 percent of total freshwater flows to the estuary. There were a number of days during 2007 when Peace River Facility withdrawals exceeded the designated maximum percent allowed by the District. Such exceedances of the permitted percent withdrawals primarily result from subsequent revisions by USGS of the provisional daily flow information available to the Authority at the time of actual withdrawals. Often there are extended periods each year when the Peace River Facility does not withdraw any water from the river due to either the low flow threshold and/or Facility operations. During 2007, the facility did not withdraw any water from the river approximately 33 percent of the time. Since the later half of 2002, maximum Facility withdrawals have increased due to the completed facility expansion, which has resulted in an increase in the Authority's ability to divert, treat and store larger daily amounts of freshwater when river flows are high.

- **Salinity Spatial Distribution** – The influences of the much drier than usual conditions that characterized 2007 were reflected in the seasonal and average spatial distributions of each of the four sampled, moving isohalines along the HBMP monitoring transect. Overall, the relative spatial distributions of each of the isohalines during 2007 reflected upstream movements of 7-11 kilometers when compared with their previous long-term 1983-2006 averages.

The following provides comparisons between 2007 and long-term averages for the following selected physical, chemical and biological water quality characteristics.

- **Temperature –** Mean water temperatures during 2007 at each of the salinity isohalines were similar to one another, as well as to corresponding values measured over the preceding 24-year period (1983-2006). It should, however, be noted that the water temperatures measured during both January and December 2007 were, as during the previous four years (2003-2006), much warmer than usual in comparison to values measured over the longer term period-of-record.

- **Water Color** – The average color levels throughout the estuary during the three relatively wet years between 2003 and 2005 were markedly higher when compared to those observed during the extended 1999-2002 drought. Color levels in 2007 were below their long-term averages within all but the highest salinity isohaline as a result of the extremely low average seasonal freshwater inflows over most of the year. Somewhat surprisingly, mean and median color levels within the most downstream 20 psu isohaline were very similar during 2007 to the statistical long-term annual averages.

- **Extinction Coefficient** – The rates of measured light attenuation at each of the four HBMP isohalines reflect the interactions of both ambient color and phytoplankton biomass (chlorophyll *a*). Comparisons of mean extinction values among the four isohalines in 2007 and with corresponding long-term averages indicate very similar patterns as those described for water color. Relatively low levels of color and chlorophyll *a* during 2007 within each of the four isohalines resulted in light extinction coefficients being well below their long-term 1983-2006 historical annual averages.

- **Nitrite/Nitrate Nitrogen** - During 2007, the average concentrations of this major inorganic form of nitrogen were much lower in each of the four sampled estuarine isohaline zones when compared with the long-term (1983-2006), historical annual averages. Typically monthly comparisons among the isohalines indicate nitrite/nitrate inorganic nitrogen concentrations in the lower Peace River/upper Charlotte Harbor estuarine system are characterized by a distinct spatial gradient that shows strong responses to seasonal patterns of freshwater inflows. Concentrations typically decrease rapidly with increasing salinity, with inorganic nitrogen levels within the 20 psu isohaline often being near or at method detection limits over much of the year. Normally, estuarine inorganic nitrogen concentrations decline to their lowest levels during the relatively drier spring as phytoplankton populations respond to increasing water temperatures and light, and increased primary production removes available inorganic nitrogen.

- **Ortho-phosphorus** - Estuarine inorganic phosphorus concentrations in the lower Peace River and upper Charlotte Harbor are heavily influenced by the characteristically “very” high natural levels found in the Peace River watershed. As a result, the observed difference in concentrations among the four isohalines simply reflects conservative dilution by Gulf waters. Unlike inorganic nitrogen, seasonal observed changes in phosphorus concentrations in the estuary are for the most part unaffected by biological uptake. Inorganic phosphorus concentrations entering the estuary system from the Peace River watershed are typically lower during wetter periods, when a higher proportion of flow results from surface flow (rather than coming from groundwater, which is naturally richer in phosphorus). Historically, since the late 1970s, there had been marked declines in inorganic phosphorus levels in the lower Peace River/upper Charlotte Harbor estuarine system due to declines in the combined influences of phosphate mining and processing in the upper reaches of the basin. However, following Hurricane Charlie and the subsequent influences of Hurricanes Francis and Jeanne during the late summer of 2004, inorganic phosphorus concentrations have dramatically increased throughout the lower Peace River/upper Charlotte Harbor estuarine system. Ortho-phosphorus concentrations during both 2006 and 2007 were well above both historic and recent levels. Currently, the direct cause for these increased levels remains unclear.

- **Nitrogen to Phosphorus Atomic Ratios** – Calculated atomic inorganic nitrogen to phosphorus ratios for ambient measured concentrations in 2007, as indicated by the long-term averages, show nitrogen to always be the limiting macronutrient at each of the four isohalines.

- **Silica** – Seasonally, silica levels in the lower Peace River/upper Charlotte Harbor estuarine system typically peak following periods of high freshwater inflows. Although silica levels also seem to be positively correlated with higher water temperatures (possibly reflecting recycling from riverine/estuarine sediments), historically lower silica concentrations in higher salinity zones of the estuary have often occurred during corresponding periods of combined low spring freshwater inflow and spring increases in phytoplankton diatom numbers. Between 1983 and the late 1990s these seasonal patterns of increasing and decreasing reactive silica concentrations remained relatively stable with no indications of any consistent systematic changes over time. However, as discussed in previous HBMP reports, silica levels started showing increasing concentrations during the late 1990s. Then, as flows declined during the extended 1999-2002 drought, silica levels also declined. However, following the return of higher than average flows during 2003-2005 measured silica levels in the estuary again began rapidly increasing. Even though flows during both 2006 and 2007 were below normal, silica levels throughout the lower river/upper harbor estuary reached historically high levels during the past two summer wet-seasons. The immediate cause of these fairly recent increases is unknown. However, studies in other areas have found that increases in dissolved silica concentrations have been associated with land use changes and clearing of natural vegetation. In many of these systems, changes in silica concentrations have also been found to be associated with changes in both calcium and magnesium levels.

- **Chlorophyll *a*** – The seasonal patterns of freshwater inflows to the estuary during 2007 were characterized by extremely dry conditions, when compared to the long-term average conditions. Seasonally, there was an unusual peak in flow during February, and then conditions were unusually dry until the summer wet-season, when flows were again well below normal. Typically, seasonal periods of increased flows produce both higher than average inputs of limiting inorganic nutrients (nitrogen), as well as higher than average levels of water color (resulting in greater light attenuation). The early increase in flows in February was followed in March by increases in chlorophyll *a* levels within each of the four estuarine salinity zones. The higher flows in July and August were followed by sharp increases in phytoplankton biomass in September in both the 12 and 20 psu zones. Overall, phytoplankton production (chlorophyll *a*) levels within the three upstream Peace River/upper Charlotte Harbor estuarine salinity zones were below the long-term (1983-2006) corresponding averages. As in previous years, phytoplankton levels were generally higher within the intermediate (6 and 12 psu) isohalines, reflecting a balance between stimulation due to increased nitrogen inputs, and light inhibition resulting from higher water color. During previous years, taxonomic counts indicated that such “bloom” events within these intermediate salinity zones were predominantly characterized by high numbers of dinoflagellates (Dinophyceae) or diatoms (Bacillariophycae).

Conclusions

This document represents the twelfth Annual Data Report submitted under the expanded Hydrobiological Monitoring Program (HBMP) initiated in 1996 in compliance with Water Use Permit 20010420.0004. The graphical and summary analyses presented in this document do not indicate any substantial changes, or atypical events in either the physical or biological data collected during 2007, other than those previously noted. These include:

- Freshwater inflows during 2007 were characterized by much drier than normal flows, especially during the normal summer wet-season (Figure 2.3 below).

- There has been a continuation of the previously noted long-term increase in reactive silica concentrations in the lower Peace River (Figure 3.18 below).

- There are strong indications that inorganic phosphorus concentrations in the freshwater entering the estuary have increased in recent years, following decades of major declines that began in the late 1970s (Figure 3.20 below).

The "limited" analyses presented in the Annual Data Report do not suggest that there have been any long-term changes resulting from either current or historic water withdrawals by the Peace River Regional Water Supply Facility.

Permanent Historic and Current HBMP Data

This Executive Summary provides a brief over view of the HBMP project and the recent findings from the 2007 annual report. The entire report, including summary graphics and tables, and all historic project water quality data are available in electronic format on a CD titled *2007 HBMP Annual Data Report*. This CD is available upon request by contacting the Southwest Florida Water Management District or the Peace River Manasota Regional Water Supply Authority. All historic water quality and *in situ* data collected during the fixed, moving station, and continuous recorder elements of the HBMP are provided on the *2007 HBMP Annual Data Report* CD in a separate directory labeled 2007 Data Sets, as files in ASCII, Excel and/or SAS formats.

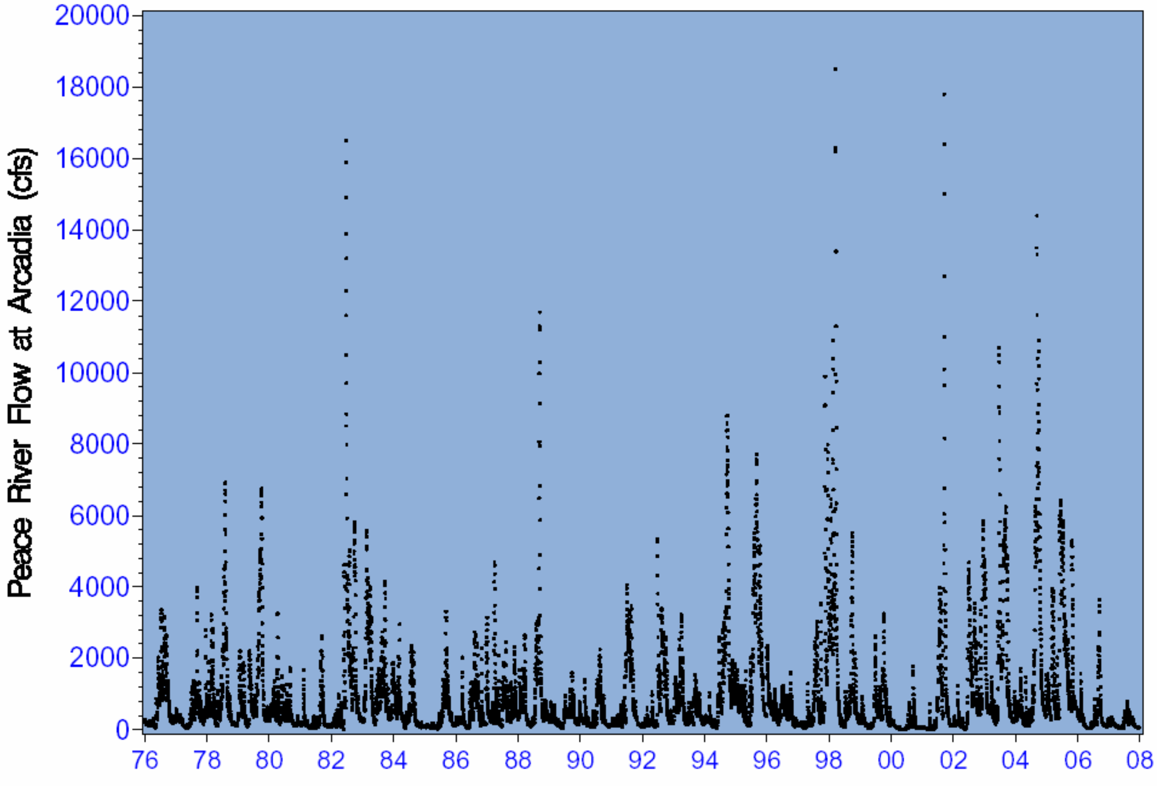

Figure 2.3 Daily Peace River flow at Arcadia (1976-2007)

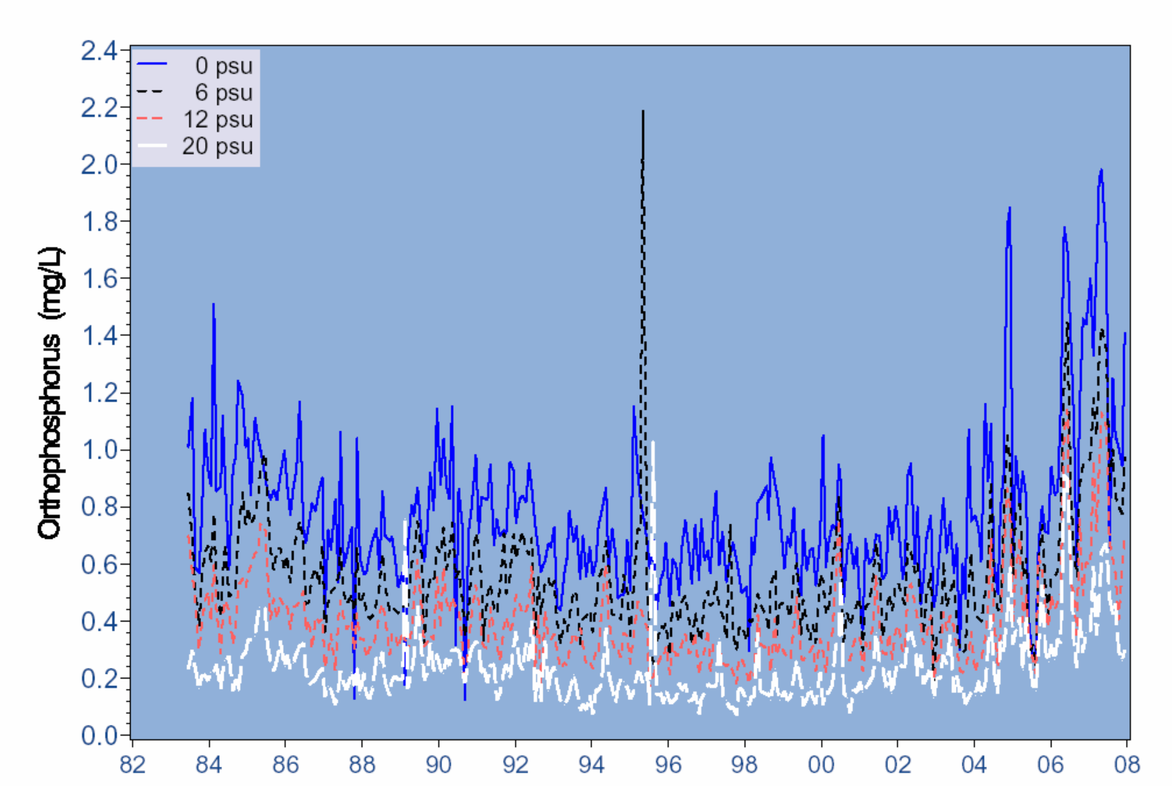

Figure 3.18 Monthly orthophosphorus at each isohaline based sampling zone (1983-2007)

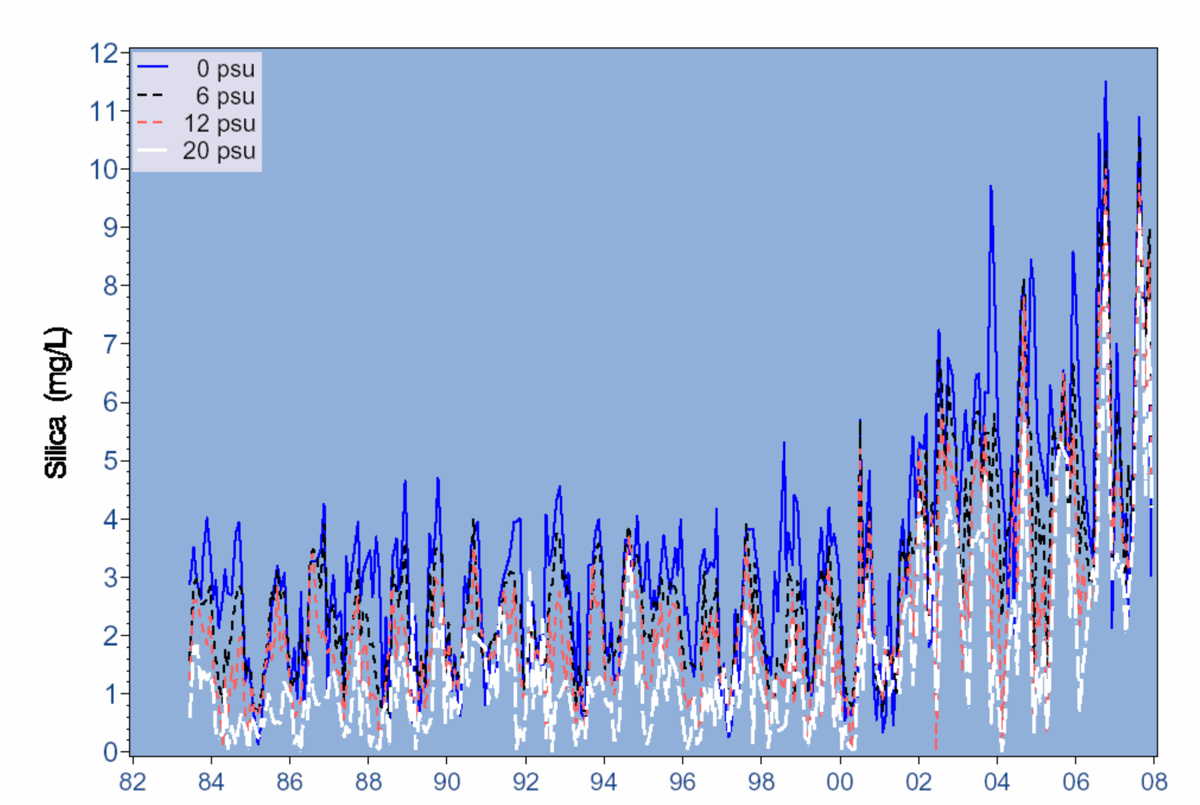

Figure 3.20 Monthly silica at each isohaline based sampling zone (1983-2007)

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1.0 Introduction/Summary

1.1 Report Objectives

The primary purpose of this introductory section the of *2007 HBMP Annual Data Report* is to summarize and provide brief overviews of the historic background and current status of the Peace River Manasota Regional Water Supply Authority's (Authority) Hydrobiological Monitoring Program (HBMP). The following summarizes the major topics included in this section.

- A review of the Authority's Peace River Facility Water Use Permit (WUP), and the overall goals and objectives of the associated HBMP.
- An overview of major previous and current HBMP monitoring elements, as well as special HBMP studies.
- A brief summary of some of the key findings of previous HBMP reports and studies.
- An outline of current HBMP monitoring elements.
- Summary results presented in Sections 2 through 7 of this *2007 HBMP Annual Data Report*.
- An overview of the current and historic data sets used in the analyses of 2007 HBMP data.
- A general summary of any problems encountered during 2007 monitoring that resulted in either missing or unusable data.

The following outlines the organization and primary objectives of each of the other sections of the *2007 HBMP Annual Data Report*.

- **Section 2.0 (Peace River Gaged Flows and Peace River Facility Withdrawals) –** The purpose of this section is to provide analysis and summaries of 2007 gaged river freshwater inflows to the lower Peace River estuary, and provide comparisons with freshwater withdrawals by Peace River Regional Water Supply Facility (Facility). This section also presents comparisons of the 2007 flow record and facility withdrawal levels with similar long-term information over the historic 1976-2007 period, which corresponds with the interval of HBMP monitoring.
- **Section 3.0 (Physical and Chemical Water Quality Characteristics at "Moving" Isohaline Based Locations) –** The intention of this section is to provide a brief overview of the initial objectives of the "moving" isohaline based monitoring program, describe the current sampling plan, and present both the results of data collected in 2007 as well as

summary graphical and tabular comparisons of the 2007 results with previous similar salinity based sampling HBMP data collected between 1983-2006.

- **Section 4.0 (Physical and Chemical Water Quality Characteristics at "Fixed" Lower River/Upper Harbor Monitoring Transect Locations) –** This section summarizes the objectives of the long-term "fixed" station monitoring program, describing both the historic and current sampling designs, and presents both the results of data collected in 2007 as well as summary graphical and tabular comparisons of selected 2007 water quality monitoring results with previous similar HBMP data collected between 1975-2006.

- **Section 5.0 (USGS and HBMP Continuous Recorders) –** This report section summarizes the initial principle objectives envisioned in establishing 15-minute U.S Geological Survey (USGS) continuous recorders (tide stage, and surface and bottom temperature and conductivity) at Harbour Heights (River Kilometer 15.5) and Peace River Heights (River Kilometer 26.7). Also described and summarized are the design criteria that were used in establishing three additional HBMP 15-minute continuous recorders (subsurface temperature and conductivity) in December 2005 at River Kilometers 22.0, 23.4 and 24.5. The results of data collected in 2007 at these five locations are presented, and graphical and tabular results are compared with the previous data collected at these locations.

- **Section 6.0 (Significant Environmental Change) –** The objective of the report's final section discusses the Southwest Florida Water Management District's (District) concept of an "Adverse Impact" and compares and contrasts the HBMP working definition of "Significant Environmental Change" relative to impacts potentially associated with Facility withdrawals from the lower Peace River.

1.2 Peace River Facility Water Use Permit and Related HBMP

The Authority's Peace River Treatment Facility is located adjacent to a side-branch of the Peace River in southwest DeSoto County. Although the system has only been operated by the Authority since 1991, the Facility has been operating and withdrawing water from the Peace River since 1980. The Facility presently has the capacity to treat up to 24 million gallons per day (mgd), which is equivalent to withdrawals from the river of 37.2 cubic feet per second (cfs). The existing raw water river diversion station has four pumps having a combined maximum capacity of 44 mgd (68.0 cfs). During periods of high river flow (or periods where permitted withdrawal exceeds demand), raw river water is stored in an off-stream surface reservoir and any excess treated water is stored in the system's 21 aquifer storage/recovery (ASR) wells. Conversely, when water is unavailable from the Peace River due to the established low flow 130 cfs cutoff (or when demand exceeds permitted withdrawals), water can be pumped from the raw water reservoir to the Peace River Facility for treatment, and/or previously treated water can also be recovered from the ASR well system to meet the water supply demands of the Authority's service area.

As part of the Authority's future plan to meet projected increasing water demands due to regional growth in the member counties, the Authority is currently implementing plans to further expand the Peace River Facility. Current plans are to increase the river Facility pumping capacity of the river pump station to 90 mgd, which is the current permit limit. These plans also include the current ongoing construction that will let the Facility treat 48 mgd, which is twice the current capacity. In addition, a new regional off-stream reservoir with a capacity of approximately 6 billion gallons is under construction, and pipe networks will be expanded to optimize water delivery. Completion of this next expansion under the current Water Use Permit is expected during 2009.

On December 10, 1975, the Consumptive Use Permit #7500016 for the Peace River Regional Water Supply Facility was signed between General Development Utilities, Inc. and the Southwest Florida Water Management District. In conjunction with this agreement, a comprehensive Hydrobiological Monitoring Program was set forth to assess the responses of various physical, chemical and biological characteristics of the Charlotte Harbor Estuary to changes in Peace River flow. The program was designed to evaluate the influences and significance of natural salinity changes on the aquatic fauna and flora in upper Charlotte Harbor, and to determine if freshwater withdrawals by the Peace River Regional Water Supply Facility could be shown to alter these patterns. The area of study is shown in **Figure 1.1**.

In 1976 the initial monitoring elements of the HBMP were designed in coordination with District staff to provide answers to specific questions raised during the original permitting process. These questions raised concerns regarding the potential for negative impacts potentially associated with salinity changes in the lower Peace River/upper Charlotte Harbor estuarine system resulting from freshwater withdrawals. Analysis of data from pre- and post-water treatment plant operation, presented in the August 1982 Summary Report, indicated the need to revise the monitoring program to better evaluate changes in the Charlotte Harbor system due to both natural seasonal and longer-term variations in freshwater inflows, and relative magnitude and timing of changes due to Facility withdrawals. Further modifications and refinements to the HBMP were made in 1985 and again in conjunction with the renewal of the Water Use Permit in November 1988.

The current Water Use Permit (No. 20010420.0004) was issued by the District to the Authority in March 1996. The permit contained specific conditions for the continuation and enhancement of the Hydrobiological Monitoring Program for the lower Peace River/upper Charlotte Harbor Estuary. The HBMP study elements specified in the 1996 permit were designed to build upon and add to the HBMP monitoring activities that have been ongoing since 1975, and predate the 1980 completion and initial consumptive Facility withdrawals. The initial background and HBMP monitoring conducted prior to operations provided a basis for pre-withdrawal conditions against which later comparisons were made.

Between 1979 and 2008, an ongoing series of individual reports have been submitted to the District, documenting the results of the HBMP during the period from January 1976 through December 2006. These reports include summarizations (findings) of data collected during the first four years of baseline monitoring, prior to the start of freshwater withdrawals, as well as comparisons of these data to the results obtained from the HBMP during subsequent years of water treatment plant operation. Under the 1988 permit, data reports were required to be submitted annually, and two expanded Comprehensive Summary Reports were submitted that included a range of comparative analyses of the data reported over the preceding periods. The first Comprehensive Summary Report was finalized in December 1993 and included analyses of long-term data collected between 1983 and 1991. The next Comprehensive Summary Report was filed in draft form in 1994 (finalized in April 1995), and statistically summarized and evaluated the results of the HBMP study elements conducted between 1976 and 1993.

The 1996 Water Use Permit specifies reporting requirements with respect to data collected and interpreted under the HBMP. In addition to Annual Data Reports, the permit requires limited Mid-term Reports and much more extensive Comprehensive Summary Reports to be submitted to the District approximately after the third and fifth years of each five-year interval of the duration of the 20-year permit. Due to increased public concerns regarding long-term hydrologic alterations of freshwater flows in the Peace River watershed, the Authority has expanded the level of data analysis in all of the HBMP Reports beyond that originally envisioned during the 1996 permit renewal. The primary focus of these additional increased statistical analyses and evaluations have been specifically directed toward further assessing both the magnitude and distribution of potential impacts resulting from current and projected future Facility withdrawals under the 1996 permit. The HBMP Scientific Review Panel (Panel)also recommended a number of significant modifications and additions to the HBMP over recent years. In addition to these program modifications, the Panel has provided suggestions and asked questions about the HBMP data which have been included in recent HBMP reports.

The *2002 Peace River HBMP Comprehensive Summary Report* (named for the period through which HBMP data were analyzed) both extended previous selected analyses of study elements undertaken in conjunction with the preceding summary reports of long-term HBMP data, as well as presented new analyses of a number of program elements. The draft *HBMP 2004 Mid-term Interpretive Report* submitted in November 2006 focused primarily on analyses of long-term changes in seasonal patterns and flows in the Peace River watershed, and provided updated summaries of both existing and future expansions, as well as future projected increases in demands. The recently submitted draft *2006 HBMP Comprehensive Summary Report* (submitted in April 2008) combined, updated and extended many of the analyses of long-term HBMP data presented in previous HBMP summary reports, as well as provided new enhanced statistical modeling relative to the potential spatial and temporal magnitudes of predicted short- and long-term salinity increases due to permitted Facility freshwater withdrawals from the lower Peace River.

The period covered within this *2007 HBMP Annual Data Report* follows directly upon that contained within the preceding *HBMP 2006 Annual Data Report* submitted in June 2007. This current report includes unreported HBMP data collected over the period from January through December 2007, and represents the 18th year of data collection for the Authority, as owner/operator of the Peace River Regional Water Supply Facility.

As defined by the District 1996 Water Use Permit conditions, the primary focus and overall objective of the HBMP is to assess the following key issues.

- Monitor river withdrawals from the Peace River by the Facility and evaluate gaged tributary flows from Joshua, Horse and Shell Creeks, as well as the primary Peace River flows measured at Arcadia and direct rainfall to the lower Peace River.

- Evaluate relationships between the ecology of the lower Peace River/upper Charlotte Harbor estuary and freshwater inflows.

- Monitor selected water quality and biological variables in order to determine whether the ecological characteristics of the estuary related to freshwater inflows are changing over time.

- Determine the relative degree and magnitude of effects of Peace River withdrawals by the Facility on ecological changes that may be observed in the lower Peace River/upper Charlotte Harbor estuarine system.

- Evaluate whether consumptive freshwater withdrawals significantly contribute to any adverse ecological impacts to the estuary resulting from extended periods of low freshwater inflows.

- Evaluate whether the withdrawals have had any significant effects on the ecology of the estuary, based on related information such as nutrient loadings, fish abundance, or seagrass distributions data collected by other studies conducted by the District or other parties.

The overall primary goal of both the historic and current HBMP study elements has been to provide the District with sufficient information to determine whether the biological communities of the lower Peace River/upper Charlotte Harbor estuarine system have been, are being, or may be adversely impacted by permitted freshwater withdrawals by the Authority’s water treatment Facility. The expanding base of ecological information regarding the lower Peace River and upper Charlotte Harbor estuary resulting from the ongoing HBMP also provides a further basis to be periodically used to evaluate the effectiveness of the withdrawal schedule with regard to preventing significant environmental changes.

1.3 Previous HBMP Study Elements and Studies

The HBMP was not conceived to be a rigid monitoring program but rather a flexible study design that could be periodically restructured based on updated findings and identified research needs. When the first discussion began with District staff in 1975 about what might be included within such a monitoring effort, very little was known about either salinity/flow relationships, or the spatial/temporal distributions of other physical/chemical water quality parameters in the lower Peace River/upper Charlotte Harbor estuary. Even less was known about the biological communities that studies in other estuarine systems had indicated could potentially be negatively affected by freshwater diversions. As a result, much of the effort under the initial HBMP study design was directed toward developing sufficient data to statistically describe the spatial distribution and seasonal variability of physical and chemical indicators within this estuarine system, and to determine potential relationships with naturally occurring variation in freshwater inflows. The initial HBMP investigations included the collection of monthly *in situ* water column profile characteristics, and surface and near-bottom water chemistry at a wide variety of sites located from upstream of the Facility to near Boca Grande Pass.

In addition, initial attempts were begun to determine if key indicator species or biological communities could be identified to assess responses to natural variations in freshwater inflows. Determining the presence of such long-term relationships was thought to be especially important because, with only a small percentage of total flow being initially diverted, the direct effects of withdrawals were projected to be extremely small in comparison to natural variation. These original HBMP elements included: 1) the initial long-term study of the seasonal pattern of juvenile fishes in the upper harbor; 2) studies of benthic indicator species; 3) the investigation of the seasonal distribution of sea stars in the harbor and lower river; and 4) the vegetation study of first and last occurrence of selected plant taxa along the lower Peace River.

In the 1980s, studies of zooplankton and phytoplankton community structure and primary production were added to the HBMP. These studies were again not intended to directly evaluate the influences of withdrawals, but rather were designed to address issues related to the "health of the estuary" and the influences of naturally occurring extended periods of drought and flood conditions on key initial components of the estuarine food-chain. The short-term benthic invertebrate study and the fish nursery investigation conducted in the late 1990s were again not designed to measure the influences of withdrawal directly, but rather were intended to investigate the response of biological communities to natural variations in freshwater inflows.

An explicit element in the District's 1996 renewal of the Water Use Permit was the development of standardized station descriptors to be applied across all HBMP program elements. A morphometric study of the lower river/upper harbor for the HBMP using the "mouth" of the Peace River as defined by the previous USGS standardized protocol as using an imaginary line extending from Punta Gorda Point to Hog Island. Since the morphometric study, all new and previous on-going study elements monitoring locations have been cross-referenced to this "River Kilometer" identification system.

Modifications have been made to the HBMP elements throughout its history. While the overall effort (inflation adjusted) of the monitoring program has remained relatively constant, study elements have been added and deleted in order to enhance the overall knowledge base of the lower Peace River/upper Charlotte Harbor estuarine system. Historically, those major monitoring elements aimed at assessing direct relationships with variations in freshwater inflow have had the longest histories. Other program elements, primarily those focused on assessing indirect biological indicators, have extended over a number of years and then ended once a sufficient baseline level of information had been accumulated.

The outside HBMP Scientific Review Panel implemented in conjunction with the 1996 Water Use Permit renewal has also recommended a number of changes to the monitoring program study elements. Overall the Panel has recommended that the HBMP should focus monitoring primarily on assessing long-term trends in key physical, chemical and biological characteristics directly related to the Facility's potential influences and less on elements more directly related to the overall "health of the estuary" potentially influenced by other anthropogenic impacts.

1.4 Overview of Previous HBMP Summary Results

Expanded analyses of recent and longer-term HBMP monitoring data over the entire period–of-record (since 1976) have been conducted at three and five-year intervals as required under the 1996 Water Use Permit as part of the *2000 Mid-term Interpretive Report*, the *2002 Peace River HBMP Comprehensive Summary Report*, the draft *HBMP 2004 Mid-term Interpretive Report*, and the recently submitted draft *2006 HBMP Comprehensive Summary Report*. The results of the analyses presented in this extensive series of reports further support previous monitoring program findings regarding the potential magnitude of the changes that are potentially directly attributable to facility withdrawals. These earlier findings are presented in previous Summary HBMP Reports submitted in the 1980s, 1993, 1995, and as part of the supplementary analyses requested by District staff during the 1996 permit renewal process. Combined, the primary purpose of these summary documents has been to provide the District with a sufficient history of analyses to meet the following goals and objectives.

- Assess the presence or absence of long-term trends for important HBMP variables and freshwater inflows.

- Determine key relationships between ecological characteristics and freshwater inflows, and determine whether the biological health and productivity of the estuary are showing signs of stress related to natural periods of low freshwater inflow or potential negative influences of facility withdrawals.

- Assess the presence or absence of adverse ecological impacts and determine the relative magnitude of influence Facility withdrawals may have contributed.

- Evaluate the environmental considerations that may be associated with projected additional future increased withdrawals from the river and the feasibility of increased water supplies.

- Assess and evaluate the effectiveness of the withdrawal schedule for preventing adverse environmental impacts. Evaluate the overall HBMP design and make recommendations regarding implementing modifications.

The overall findings of the summary HBMP reports submitted to the District in conjunction with the 1996 permit requirements have supported the following conclusions.

- There have been statistically significant declines in high, median and low flows over the long-term period-of-record at the USGS Peace River at Bartow and Peace River at Zolfo Springs gaging sites in the northern Peace River watershed.

- Similar trend analyses of seasonal long-term Peace River at Arcadia flows, by comparison, indicate that there have been statistically significant declines of only the lower flow percentiles.

- Low and base flows in the upper Peace River watershed have been impacted by phosphate mining, agriculture and urban anthropogenic land use changes, while observed differences in mean and median flows have primarily resulted from natural multidecadal variability in rainfall.

- Historical watershed flow data indicate higher average flows over the summer months (June-September) during both the historic warmer “wetter” Atlantic Multidecadal Oscillation (AMO) phase that occurred prior to 1969 and the more recent period since 1995, when compared with the cooler “drier” phase that persisted between 1969-1994.

- In the southern portion of the Peace River watershed, base flows have increased over periods-of-record in the Joshua, Horse and Shell Creek tributaries as a result of seasonal augmentation due to agricultural ground water irrigation.

- In response to increasing potable water demands, Peace River Facility withdrawals have steadily and progressively increased since being initiated in 1980. However, the magnitude of withdrawals has remained extremely small when compared to the natural seasonal variability of rates of freshwater inflow to the estuary. Over the past 28 years, annual total Peace River Facility withdrawals have averaged approximately one percent of total freshwater flow at the river’s mouth.

- Since its inception in 1976, the HBMP has incorporated numerous physical, chemical, and biological study elements directed toward assessing both the overall “health of the estuary” as well as direct and indirect adverse impacts potentially associated with facility withdrawals. To date, none of these monitoring efforts have detected any significant adverse changes associated with facility withdrawals.

- Long-term comparisons of upstream and downstream occurrences of selected indicator plant species along the lower Peace River spanning nearly 30 years have indicated that the distributions of the selected indicator species have not indicated any signs of systematic progressive changes over time. Since seasonal river flows over this extended period have exhibited a great degree of natural variation including both extended dry and wet intervals, it is apparent that the observed relatively stable spatial distribution of the riparian vegetation communities along the lower Peace River are maintained by the combined influences of both seasonal variability of exposure to differing salinity regimes due to changing flows and localized physical floodplain characteristics. Thus monitoring differences in the spatial distribution of riparian vegetation along the lower river have not been found to be sensitive enough to access potential changes due to Facility freshwater withdrawals.

- Summary results of developed statistical salinity models have indicated that, on average, the influences of facility withdrawals on the salinity structure of the Lower Peace River between the U.S. 41 Bridge and the Peace River Facility have historically resulted in maximum daily changes of < 0.3 psu (practical salinity units).

- These statistical models were also used to predict what the potential magnitude of salinity changes might be expected to occur under the maximum permitted daily withdrawals under the 1996 Water Use Permit. Modeled results predict a maximum daily salinity change of < 0.1 - 0.5 psu occurring between River Kilometers 14 and 18 when USGS gaged Peace River flow at Arcadia ranged between 400 and 1000 cfs (cubic feet per second). The modeled results predict that similar changes in salinity (< 0.1 - 0.5 psu) would occur further upstream, as flows decline to near 200 cfs, and that potential salinity changes further decline under lower flows approaching the low flow withdrawal threshold of 130 cfs.

- Further findings based on results of the 2006/2007 series of Facility "Pump Tests" and similar statistical models developed using data from the two USGS and three HBMP continuous recorders concluded that the maximum expected increases in salinity due to facility withdrawals would be difficult to actually measure (other than by using continuous recorders) given the normal daily range of tidal salinity variations during the periods when the facility is potentially having its greatest influence.

As long as salinity changes attributable to facility withdrawals remain a fraction of the normal typical range of daily (and seasonal) salinity variations along the lower Peace River/upper Charlotte Harbor HBMP study monitoring transect, no significant measurable environmental changes in the estuarine system would be expected. To date, none of the conducted HBMP data analyses have shown that facility withdrawals have had, or are expected to cause, measurable negative physical or biological adverse impacts within the lower Peace River estuarine system.

1.5 Ongoing HBMP Program Study Elements

An explicit element of the updated HBMP was the development of standardized station descriptors to be applied across all program elements (**Figure 1.2**). As part of the required morphometric study, the "mouth" of the Peace River was defined using USGS standardized protocols as an imaginary line extending from Punta Gorda Point to Hog Island. **Figure 1.3** and **Table 1.1** provide a summary of the locations of all ongoing long-term fixed study elements and a cross-reference to previous station identifications. The following briefly outlines each of the current HBMP study elements.

1.5.1 Water Chemistry and Water Column Physical Profiles

The primary focus of the HBMP program extends along the monitoring transect centerline from River Kilometer (RK) -2.4 south of the river's mouth upstream to RK 30.4 located just above the 761 Bridge, north of the Peace River Facility (see **Figure 1.2**). Two separate HBMP study elements incorporate both *in situ* water column profile physical measurements combined with the collection of chemical water quality sampling along the monitoring transect. Several goals are associated with both the individual and combined findings of these water quality HBMP study elements. A principal goal of both monitoring efforts is to assess the overall "health of the estuary" by collecting sufficient long-term data to statistically describe spatial and seasonal variability of the water quality characteristics of the lower Peace River/upper Charlotte Harbor Estuary, and test for significant changes over time (trends). A further goal of these HBMP elements is to determine whether significant relationships exist between freshwater inflows and the seasonal/spatial variability of key selected water quality parameters. If such relationships can be shown, then the ultimate goal becomes to determine the potential magnitude of change that might result from both existing permitted withdrawals and projected future increases, and compare such predicted changes due to withdrawals with the normal ranges of observed natural seasonal and annual variability.

Similar and comparable physical and chemical water quality parameter measurements along the upper Charlotte Harbor/lower Peace River estuarine monitoring transect are collected under these two different HBMP study elements.

1. During the first week of each month, water quality measurements (physical and chemical) are conducted at four "moving" salinity-based isohaline locations (0, 6, 12 and 20 psu) along a river kilometer centerline running from the imaginary "mouth" of the Peace River upstream to above its junction with Horse Creek, and downstream to Boca Grande Pass. The relative monthly location of each sampling is based on the first occurrence of these specific isohalines (± 0.5 psu), with freshwater being defined as the first occurrence of conductivities less than 500 ms. Historically, this isohaline sampling effort was undertaken in conjunction with other long-term phytoplankton elements of the HBMP.

2. Approximately two weeks after the collection of the "moving" isohalines, water column physical profiles are conducted, near high tide, at sixteen "fixed" locations along a transect running from just below the river's mouth upstream to a point just above the Peace River Facility (see **Figure 1.3** and **Table 1.1**). In addition, chemical water quality samples are taken at five of these locations.

Both of these water quality study HBMP elements include physical *in situ* water column profile measurements of characteristic parameters (temperature, dissolved oxygen, pH, conductivity and salinity) at 0.5 meter intervals from the surface to the bottom. In addition both efforts measure the penetration of photosynthetically active radiation (PAR) to determine ambient extinction coefficients at specific sampling locations. Both studies also include the analyses of an extensive list of chemical water quality parameters (**Table 1.2**). The only difference is that at the "fixed" sampling stations both sub-surface and near-bottom samples are collected at each of the five sites, while only sub-surface water chemistry samples are taken as part of the "moving" isohaline based HBMP study element.

During 2007, EarthBalance, Inc. (formerly Florida Environmental) conducted all fieldwork (physical water column profile measurements and water chemistry parameter sampling) associated with both the "moving" and "fixed" station HBMP monitoring elements. Benchmark EnviroAnalytical, Inc. was responsible for conducting all 2007 water chemistry analyses.

In response to the recommendations contained within the *2000 HBMP Mid-term Interpretive Report*, the number of water chemistry parameters associated with both the "moving and "fixed" HBMP study elements was decreased from those originally specified in the 1996 monitoring conditions. These changes were made only after extensive consultation with both the HBMP

Scientific Review Panel and District staff. As a result of this consultation, a revised/ reduced long-term water quality sampling list of 12 parameters was implemented in March 2003 (**Table 1.2**).

Further descriptions, as well as complete summaries of the 2007 monitoring results and historical comparisons of the "isohaline" and "fixed" location based HBMP monitoring study elements are presented respectively in Section 4 and Section 5 of this report.

1.5.2 USGS Continuous Recorders

The primary goal of this element of the HBMP was to develop an extensive database of short-term (daily or more frequent) changes in surface and near-bottom salinity in the lower Peace River. These data, combined with corresponding gage height, freshwater flows and withdrawals, would then be used to develop detailed spatial and temporal relationships. A secondary, longer-term goal was to potentially assess any systematic changes in river salinity that might be observed due to predicted decadal increases in sea level.

In 1996 the USGS installed automated 15-minute interval water level recorders at the following two locations.

1. On a dock near Boca Grande, which is the estuary's largest opening to the Gulf of Mexico.

2. At approximately 15.5 kilometers upstream of the river's mouth at the end of a dock in Harbour Heights. The gaging station at Harbour Heights also measures surface and bottom conductivity/temperature at 15-minute intervals.

In November 1997 a third gage was installed on a private dock at RK 26.7, approximately three kilometers downstream of the Peace River Facility. This gage also measures water level as well as surface and bottom conductivity/temperature at 15-minute intervals.

Based on consultation with USGS staff, the water level recorder information from the gage at Boca Grande was discontinued at the end of 2004. The original purpose of this gage was to assess potential increase in salinity that might be naturally occurring due to projected gradual increases in sea level expected to occur over time. However, USGS staff felt that any conclusions regarding sea level rises at this site would be compromised due to the gages location near the mouth of the pass. After consultation with the Scientific Review Panel and District, Authority staff decided to delete future collection of gage height information at the Boca Grande site from the HBMP monitoring program. The relative locations of each of these USGS gages are depicted in **Figure 5.1**.

Summary results of 2007 information for the continuous USGS recorders located at Harbour Heights (RK 15.5) and Peace River Heights (RK 26.7) are further presented in Section 5 of this document.

1.5.3 Additional HBMP Continuous Recorders

During 2005, the Authority evaluated a number of possible alternative sites and methodologies to be utilized in the deployment of additional continuous conductivity monitoring devices downstream of the Facility. The objective was to deploy additional continuous conductivity recorders at other monitoring sites to be used as part of an expanded HBMP study element directed specifically toward measuring Facility withdrawal impacts under lower flow conditions. Analyses of conductivity data from these new monitoring locations were recently used as part of both the recent draft HBMP *Pump Test Study* and the draft *2006 HBMP Comprehensive Summary Report* to extend previous graphical and statistical results with regard to directly measuring salinity changes due to withdrawals.

The first step to deploying additional continuous recorders was to determine the potential spatial distribution of arraying such new continuous recorders downstream of the Facility in order to maximize their ability to detect salinity changes (impacts) that could be directly attributed to Facility freshwater withdrawals. Existing statistical models and graphical analyses of salinity/flow relationships were reviewed from the long-term HBMP fixed stations and USGS continuous recorders in this reach of the lower Peace River. These results were then evaluated in relationship to potential existing physical structures (docks, pilings, etc.) to which additional continuous recorders might be attached (**Table 5.2**). A series of potential new monitoring sites located between the two existing USGS continuous recorders were selected for evaluation

One option considered was to locate a third land based gage similar in design to the two existing USGS continuous recorders on one of the single family docks located just upstream (between River Kilometers 24.5 and 25.0) of the entrance to Navigator Marina. However, a series of other potential sites exist further downstream, due to the recent placement of Manatee Speed Zone markers along the river. The Authority was able to receive permission from US Fish and Wildlife to establish continuous recorders using these markers. Three of these Manatee Speed Zone markers were chosen for the initial deployment of the new HBMP continuous recorders, the locations of which are indicated by the light-green arrows in **Figure 5.1**. The methodologies used for deployment of the three new continuous recorders are depicted in **Figure 5.6** and **Photographs 5.1** through **5.4.**

1.6 Summary of 2007 Results

The following text and tables compare data collected during 2007 with similar average values for key parameters previously compiled during various elements of the ongoing long-term monitoring programs. The following key HBMP project elements are include in this summary.

1. Peace River freshwater inflows and facility withdrawals.

2. Physical measurements such as water temperature, color and extinction coefficients.

3. Water quality characteristics such as nitrate/nitrite, ortho-phosphorus, nitrogen to phosphorus ratios, and reactive silica.

4. Biological measurements of phytoplankton biomass (chlorophyll *a*.)

In making comparisons of the 2007 data with averages of similar data collected over the preceding 24-year period (1983-2006), it should be noted that the very wet winter/spring El Niño of 1997/1998 was followed by very dry La Niña conditions that influenced southwest Florida and the entire Peace River watershed between 1999 and early 2002 (see **Figures 2.3** and **2.4**). A weaker El Niño occurred at the end of 2002, and freshwater flows during 2003, 2004 and 2005 were generally above average. Rainfall in the Peace River watershed during both 2006 and 2007 by comparison was well below average, especially during the usually wetter summer months. The summer 2007 wet-season, like the 2006 wet-season, was often characterized by afternoon summer thunderstorms building along the coast rather than inland, and unlike recent preceding years, the Peace River watershed was unaffected by any tropical storm events.

- **Flows –** Average mean daily Peace River flow at the Arcadia gage during 2007 was only 173 cfs, which was less than half the preceding annual average flow of 376 cfs that occurred under the very dry conditions of 2006. The combined average flow over these last two very dry years has been only approximately 15 percent of the average daily mean flow that occurred over the preceding two unusually wet years (1747 cfs during 2004 and 1859 in 2005). The average mean daily flow of 173 cfs during 2006 was the 2nd lowest mean daily average flow over the past 32 years, and only slightly higher than the average daily flow of only 139 cfs that occurred in 2000 during the past extended 1999-2001 drought. The extremely low average mean flow during 2000 was the lowest that has occurred during the years of HBMP monitoring. Overall, gaged Peace River at Arcadia freshwater mean flows during 2007 were just 18 percent of the average daily flow for the preceding long-term period 1976-2006 (see **Table 2.8**). In comparison, the sum of average daily flows from the Peace River at Arcadia, Horse Creek, Joshua Creek, and Shell Creek during 2007 was roughly 22 percent of the average daily flows over the longer term 1976-2006 HBMP monitoring period.

- **Withdrawals –** Throughout 2007, the Peace River Facility operated under a series of District modifications to the Water User Permit and Executive Orders that temporarily altered the low flow cutoff and/or temporarily increased the percent of flow that could be withdrawn from the river. The Facility's mean average daily withdrawal during 2007 was 17.3 cfs. Overall withdrawals comprised 10.1 percent of the annual Arcadia gaged flow, and 4.9 percent of the combined lower Peace River gaged flow (Peace River at Arcadia, Horse Creek, Joshua Creek and Shell Creek). Combined total freshwater withdrawals by the Peace River and the City of Punta Gorda facilities accounted for approximately 7.1 percent of total freshwater flows to the estuary. There were a number of days during 2007 when Peace River Facility withdrawals exceeded the designated maximum percent allowed by the District. Such exceedances of the permitted percent withdrawals primarily result from subsequent revisions by USGS of the provisional daily flow information available to the Authority at the time of actual withdrawals. Often there are extended periods each year when the Peace River Facility does not withdraw any water from the river due to either the low flow threshold and/or Facility operations. During 2007, the facility did not withdraw any water from the river approximately 33 percent of the time. Since the later half of 2002, maximum Facility withdrawals have increased due to the completed facility expansion, which has resulted in an increase in the Authority's ability to divert, treat and store larger daily amounts of freshwater when river flows are high.

- **Salinity Spatial Distribution** – The influences of the much drier than usual conditions that characterized 2007 were reflected in the seasonal and average spatial distributions of each of the four sampled, moving isohalines along the HBMP monitoring transect (**Figure 3.5**). Overall, the relative spatial distributions of each of the isohalines during 2007 reflected upstream movements of 7-11 kilometers when compared with their previous long-term 1983-2006 averages.

Comparisons of means between 2007 and long-term averages for the following selected physical, chemical and biological water quality characteristics measured in conjunction with the "moving" and "fixed" HBMP study elements are presented in **Tables 3.8** and **4.5**.

- **Temperature** – Mean water temperatures during 2007 at each of the salinity isohalines were similar to one another, as well as to corresponding values measured over the preceding 24-year period (1983-2006). It should, however, be noted that the water temperatures measured during both January and December 2007 were, as during the previous four years (2003-2006), much warmer than usual in comparison to values measured over the longer term period-of-record.

- **Water Color** – The average color levels throughout the estuary during the three relatively wet years between 2003 and 2005 were markedly higher when compared to those observed during the extended 1999-2002 drought. Color levels in 2007 were below their long-term averages within all but the highest salinity isohaline as a result of the extremely low average seasonal freshwater inflows over most of the year. Somewhat surprisingly, mean and median color levels within the most downstream 20 psu isohaline were very similar during 2007 to the statistical long-term annual averages.

- **Extinction Coefficient** – The rates of measured light attenuation at each of the four HBMP isohalines reflect the interactions of both ambient color and phytoplankton biomass (chlorophyll *a*). Comparisons of mean extinction values among the four isohalines in 2007 and with corresponding long-term averages indicate very similar patterns as those described for water color. Relatively low levels of color and chlorophyll *a* during 2007 within each of the four isohalines resulted in light extinction coefficients being well below their long-term 1983-2006 historical annual averages.

- **Nitrite/Nitrate Nitrogen** - During 2007, the average concentrations of this major inorganic form of nitrogen were much lower in each of the four sampled estuarine isohaline zones when compared with the long-term (1983-2006), historical annual averages. Typically monthly comparisons among the isohalines indicate nitrite/nitrate inorganic nitrogen concentrations in the lower Peace River/upper Charlotte Harbor estuarine system are characterized by a distinct spatial gradient that shows strong responses to seasonal patterns of freshwater inflows. Concentrations typically decrease rapidly with increasing salinity, with inorganic nitrogen levels within the 20 psu isohaline often being near or at method detection limits over much of the year. Normally, estuarine inorganic nitrogen concentrations decline to their lowest levels during the relatively drier spring as phytoplankton populations respond to increasing water temperatures and light, and increased primary production removes available inorganic nitrogen.

- **Ortho-phosphorus** - Estuarine inorganic phosphorus concentrations in the lower Peace River and upper Charlotte Harbor are heavily influenced by the characteristically "very" high natural levels found in the Peace River watershed. As a result, the observed difference in concentrations among the four isohalines simply reflects conservative dilution by Gulf waters. Unlike inorganic nitrogen, seasonal observed changes in phosphorus concentrations in the estuary are for the most part unaffected by biological uptake. Inorganic phosphorus concentrations entering the estuary system from the Peace River watershed are typically lower during wetter periods, when a higher proportion of flow results from surface flow (rather than coming from groundwater, which is naturally richer in phosphorus). Historically, since the late 1970s, there had been marked declines in inorganic phosphorus levels in the lower Peace River/upper Charlotte Harbor estuarine system due to declines in the combined influences of phosphate mining and processing in the upper reaches of the basin. However, following Hurricane Charlie and the subsequent influences of Hurricanes Francis and Jeanne during the late summer of 2004, inorganic phosphorus concentrations have dramatically increased throughout the lower Peace River/upper Charlotte Harbor estuarine system. Ortho-phosphorus concentrations during both 2006 and 2007 were well above both historic and recent levels. Currently, the direct cause for these increased levels remains unclear.

- **Nitrogen to Phosphorus Atomic Ratios** – Calculated atomic inorganic nitrogen to phosphorus ratios for ambient measured concentrations in 2007, as indicated by the long-term averages, show nitrogen to always be the limiting macronutrient at each of the four isohalines.

- **Silica** – Seasonally, silica levels in the lower Peace River/upper Charlotte Harbor estuarine system typically peak following periods of high freshwater inflows. Although silica levels also seem to be positively correlated with higher water temperatures (possibly reflecting recycling from riverine/estuarine sediments), historically lower silica concentrations in higher salinity zones of the estuary have often occurred during corresponding periods of combined low spring freshwater inflow and spring increases in phytoplankton diatom numbers. Between 1983 and the late 1990s these seasonal patterns of increasing and decreasing reactive silica concentrations remained relatively stable with no indications of any consistent systematic changes over time. However, as discussed in previous HBMP reports, silica levels started showing increasing concentrations during the late 1990s. Then, as flows declined during the extended 1999-2002 drought, silica levels also declined. However, following the return of higher than average flows during 2003-2005 measured silica levels in the estuary again began rapidly increasing. Even though flows during both 2006 and 2007 were below normal, silica levels throughout the lower river/upper harbor estuary reached historically high levels during the past two summer wet-seasons. The immediate cause of these fairly recent increases is unknown. However, studies in other areas have found that increases in dissolved silica concentrations have been associated with land use changes and clearing of natural vegetation. In many of these systems, changes in silica concentrations have also been found to be associated with changes in both calcium and magnesium levels.

- **Chlorophyll *a*** – The seasonal patterns of freshwater inflows to the estuary during 2007 were characterized by extremely dry conditions, when compared to the long-term average conditions. Seasonally, there was an unusual peak in flow during February, and then conditions were unusually dry until the summer wet-season, when flows were again well below normal. Typically, seasonal periods of increased flows produce both higher than average inputs of limiting inorganic nutrients (nitrogen), as well as higher than average levels of water color (resulting in greater light attenuation). The early increase in flows in February was followed in March by increases in chlorophyll *a* levels within each of the four estuarine salinity zones. The higher flows in July and August were followed by sharp increases in phytoplankton biomass in September in both the 12 and 20 psu zones. Overall, phytoplankton production (chlorophyll *a*) levels within the three upstream Peace River/upper Charlotte Harbor estuarine salinity zones were below the long-term (1983-2006) corresponding averages. As in previous years, phytoplankton levels were generally higher within the intermediate (6 and 12 psu) isohalines, reflecting a balance between stimulation due to increased nitrogen inputs, and light inhibition resulting from higher water color. During previous years, taxonomic counts indicated that such “bloom” events within these intermediate salinity zones were predominantly characterized by high numbers of dinoflagellates (Dinophyceae) or diatoms (Bacillariophycae).

1.7 Conclusions

This document represents the twelfth Annual Data Report submitted under the expanded Hydrobiological Monitoring Program (HBMP) initiated in 1996 in compliance with Water Use Permit 20010420.0004. The graphical and summary analyses presented in this document do not indicate any substantial changes, or atypical events in either the physical or biological data collected during 2007, other than those previously noted. These include:

- Freshwater inflows during 2007 were characterized by a much drier than normal flows, especially during the normal summer wet-season.
- There has been a continuation of the previously noted long-term increase in reactive silica concentrations in the lower Peace River.
- There are strong indications that inorganic phosphorus concentrations in the freshwater entering the estuary has increased in recent years, following decades of major declines that began in the late 1970s

The “limited” analyses presented in the *2007 HBMP Annual Data Report* do not suggest that there have been any long-term changes resulting from either current or historic water withdrawals by the Peace River Regional Water Supply Facility.

1.8 Permanent Data

All historic water quality and *in situ* data collected during the fixed and moving station elements of the HBMP used in the preparation of this document are provided on the *2007 HBMP Annual Data Report* CD in the directory labeled 2007 Data Sets, as files in ASCII, Excel and/or SAS formats. Table 1.3 provides a summary and links to descriptions of the variables within each of the SAS data sets.

Table 1.3
Long-term Historical HBMP Data Sets

Data Set Name	Time Period	Brief Description
HBMP SAS Data Sets		
Flwd07.sd2	1931-2007	Historic daily flow data for: Peace at Bartow, Fort Meade, Zolfo Springs and Arcadia. Daily tributary flows for: Horse Creek near Arcadia; Joshua Creek near Nocatee; Prairie Creek near Ft. Ogden; and Shell Creek near Punta Gorda. Daily flows for the Myakka River near Sarasota and Big Slough near North Port. Historic daily Peace River and Shell Creek Water Treatment Facility withdrawals. All values in cfs.
Cmov8307.sd2	1983-2007	Water quality, and phytoplankton biomass and carbon uptake measurements (1983-1999) from monthly surface samples collected at each of the four moving isohalines. Relative locations reflect distances from the river mouth in kilometers.
Hymov07.sd2	1983-2007	Monthly hydrolab *in situ* water quality measurements taken at 0.5 meter intervals at each of the four moving isohalines. Relative locations reflect distances from the river mouth in kilometers.
Hyfix07.sd2	1996-2007	Monthly *in situ* hydrolab water column profile data taken at 0.5 meter intervals from fixed sample locations from near the river's mouth to just upstream of the Treatment Facility.
Cfix9607.sd2	1996-2007	Monthly surface and bottom chemical water quality samples taken at five intervals from fixed sample locations from near the river's mouth to just upstream of the Treatment Facility.
Efix9607.sd2	1996-2007	Water column extinction coefficients collected at the fixed sampling locations.
Boca04.sd2	1996-2004	Water level at 15-minute intervals from the continuous recording gage near Boca Grande.
HH07.sd2	1996-2007	Water level and surface and bottom conductivity and temperature at 15-minute intervals from the continuous recording gage on the Peace River near Harbour Heights (River Kilometer 15.5).
PRH07.sd2	1997-2007	Water level and surface and bottom conductivity and temperature at 15-minute intervals from the continuous recording gage on the Peace River near Peace River Heights (River Kilometer 26.7).
MZ4_07.sd2	2006-2007	Near surface conductivity and temperature at 15-minute intervals from the HBMP continuous recording gage attached to the Manatee Speed Zone Sign located on the Peace River near Liverpool side channel (River Kilometer 21.9).
MZ3_07.sd2	2006-2007	Near surface conductivity and temperature at 15-minute intervals from the HBMP continuous recording gage attached to the Manatee Speed Zone Sign located on the Peace at River Kilometer 23.4.
MZ2_07.sd2	2006-2007	Near surface conductivity and temperature at 15-minute intervals from the HBMP continuous recording gage attached to the Manatee Speed Zone Sign located on the Peace River just downstream of Navigator Marina (River Kilometer 24.5).

Table 1.3
Long-term Historical HBMP Data Sets

Data Set Name	Time Period	Brief Description
Environmental Quality Laboratory Background Data Sets		
SAS Version 6.0.8 Data Sets		
Chall_2.sd2	1976-1990	EQL fixed station Charlotte Harbor background water chemistry data.
Hydroall.sd2	1976-1990	EQL fixed station Charlotte Harbor hydrolab water column profile data.
SAS Version 6.1.3 Data Sets		
Chem_v12.sd2	1976-1990	EQL fixed station Charlotte Harbor background water chemistry data.
Hall_v12.sd2	1976-1990	EQL fixed station Charlotte Harbor hydrolab water column profile data.

❖ **Note:** Click on the data set name to review a comprehensive listing of the data set contents.

1.9 Problems Encountered During 2007

The following outlines the limited number of problems and errors encountered during data collection for various elements of the 2007 HBMP monitoring program. Overall, very few data collection problems and/or other data issues were encountered during 2007.

- **USGS Continuous Recorders** – Due to short-term instrument failures, a limited number of records for gage height, temperature and/or conductivity are unavailable for the Harbour Heights (RK 15.5) and Peace River Heights (RK 26.7) gaging sites during 2007.

- **HBMP Continuous Recorders** – Due to similar instrument issues, primarily resulting from low water levels at the recorder sites, a very limited number of 15-minute temperature and conductivity values were also not collected at some of the three additional HBMP continuous recorder locations (River Kilometers 21.9, 23.4 and 24.5) during 2007. Accurate and complete information from these monitoring sites was determined to have been especially critical when the Authority conducted a series of low flow "pump tests" in conjunction with the District's temporary reduction in the withdrawal threshold from 130 to 90 cfs due to the extreme drought conditions. During the period between January and May 2007, second stilling wells were installed and paired data sondes were deployed at each of the three continuous HBMP recorder locations.

2.0 Peace River Gaged Flows and Regional Water Supply Facility Withdrawals

The purpose of this section is to provide an overview of 2007 gaged river freshwater inflows to the lower Peace River/upper Charlotte Harbor Estuary, and provide comparisons with the relative magnitude and timing of freshwater withdrawals. This section also presents comparisons of the 2007 flow record and river withdrawal levels with similar longer-term information over the 1976-2007 time interval, corresponding with the historic period of HBMP monitoring.

Previously presented **Figures 1.1** and **1.2** depict the location of the Peace River Regional Water Supply Facility (Facility) in relation to both the lower Peace River watershed and the lower Peace River/upper Charlotte Harbor Estuary. As indicated, the Peace River Facility intake withdrawal structure is located on a side channel, in the tidal portion of the lower river estuarine system. This reach of the lower tidal river is often characterized by brackish conditions during seasonal periods of low freshwater inflow (< 90 cfs – Peace River at Arcadia). The relationships between gaged Peace River at Arcadia flows and conductivities measured approximately two kilometers downstream of the Facility's river intake at the USGS continuous recorder located at River Kilometer (RK) 26.7 are shown in **Figures 5.4** and **5.5**.

Table 2.1 summarizes the series of USGS monitoring gages used by the HBMP to assess both long-term yearly and seasonal patterns of freshwater inflows to the lower Peace River/upper Charlotte Harbor estuarine system. Both historic and recent (real time) flow data collected by USGS are obtained from the USGS Tampa Web Site (http://fl.water.usgs.gov/Tampa/index.html) and used to update the long-term HBMP database on a yearly basis. Since flow data are retrieved for the annual HBMP data reports early during the calendar year, all flows for at least the preceding report year and the last three months of the previous calendar year should be considered "provisional." These current data may be subject to subsequent revision by USGS before being finalized annually for the past "water year" (October through September).

Table 2.1
Primary USGS Gages Used in HBMP Hydrology Analyses

USGS Gage Name	Gage Reference Number	Upstream Basin Area (Square Miles)	Period-Of-Record (Complete Years)
Peace River at Bartow	02294650	390	1940-2007
Peace River at Fort Meade	02294898	480	1975-2007
Peace River at Zolfo Springs	02295637	826	1934-2007
Peace River at Arcadia	02296750	1367	1932-2007
Joshua Creek at Nocatee	02297100	132	1951-2007
Horse Creek near Arcadia	02297310	218	1951-2007
Prairie Creek near Fort Ogden	02298123	233	1964-2007
Shell Creek near Punta Gorda	02298202	373	1966-2007
Myakka River near Sarasota	02298830	229	1937-2007

Table 2.1
Primary USGS Gages Used in HBMP Hydrology Analyses

USGS Gage Name	Gage Reference Number	Upstream Basin Area (Square Miles)	Period-Of-Record (Complete Years)
Big Slough near North Port	02299450	81	2002-2006

2.1 2007 Gaged Flows to the Lower Peace River

Daily Peace River discharges (in cubic feet per second) at the USGS gaging station at Arcadia, Florida during the January through December 2007 reporting period are depicted in **Figure 2.1**. Freshwater inflows during 2007 were characterized by much drier than normal conditions throughout the year, extending the drought conditions that began in 2006. While the overall seasonal pattern of gaged flow was typical of that normally observed, the actual rates were far below normal (**Figure 2.2**).

Much of the decline in summer flows observed during both 2006 and 2007 can be directly attributed to the predominant atypical patterns of wet-season afternoon thunderstorm activity that took place throughout much of the summer (**Map 2.1**). Summer thunderstorms in southwest Florida normally build up in the early afternoon in the interior of the state and move toward the coast later in the afternoon. However, during both 2006 and 2007 the thunderstorm activity predominately seemed to build along the coast and remain there. The result was that while many of the coastal USGS stream flow gages with smaller watersheds actual experienced higher flows throughout much of the summer than the gaged flows in the larger watersheds in the interior of the Peace River watershed.

The influence of tropical storms on summer wet-season rainfall patterns was far less during 2006 than during the previous two years, while during 2007 the only named tropical storm that influenced rainfall in the Peace River watershed was Olga that passed north of the area in December (**Map 2.14**).

Table 2.2
Maps Showing the Tracts of Tropical Storms/Hurricanes since the Beginning of the Recent Warm (Wet) Atlantic Multidecadal Oscillation Phase

1995	**1996**	**1997**	**1998**	**1999**	**2000**
2001	**2002**	**2003**	**2004**	**2005**	**2006**
2007					

The seasonal patterns of freshwater inflows during 2007 are further graphically summarized in relation to the preceding long-term historical averages (1976-2006) in **Figure 2.2**. Statistical analyses were used to determine long-term average daily "exceedances" of the 10th, 25th, 50th (median), 75th and 90th percentiles for Peace River flow using the daily Arcadia gage record. Thus, the line presented in **Figure 2.2** for Q90 represents a level of freshwater inflow that, over the long-term 1976-2006 average, is only exceeded ten percent of the time on that particular day.

This graphic clearly shows that gaged Peace River at Arcadia flows during 2007 were below the corresponding median (Q50) levels almost continually throughout the year (with the exceptions of brief interval in February). Over extended periods, and especially during the summer months, Peace River at Arcadia gaged flows were near or below the corresponding daily Q10 values, indicating the extent of the extremely dry conditions that characterized Peace River watershed rainfall patterns during most of 2007. Plots of gaged and total upstream flows for both 2007 and the long-term period of HBMP monitoring (1976-2007) are presented in Table 2.3 for selected locations, as well as for the entire upper harbor.

Table 2.3
Freshwater Inflows During 2007 and the Period 1976-2006

Figure	Description
Figure 2.1	Daily Peace River flow at Arcadia (2007)
Figure 2.2	Daily 2007 River flow at Arcadia in relation to long-term daily statistical averages
Figure 2.3	Daily Peace River flow at Arcadia (1976-2007)
Figure 2.4	Monthly mean Peace River flow at Arcadia (1976-2007)
Figure 2.5	3-month moving average Peace River flow at Arcadia (1976-2007)
Figure 2.6	Total daily flow - Peace River + (Horse + Joshua) Creeks (2007)
Figure 2.7	Total daily flow - Peace River + (Horse + Joshua) Creeks (1976-2007)
Figure 2.8	Mean monthly flow - Peace River + (Horse + Joshua) Creeks (1976-2007)
Figure 2.9	3-month moving average flow - Peace River + (Horse + Joshua) Creeks (1976-2007)
Figure 2.10	Total daily flow - Peace River + (Horse + Joshua + Shell) Creeks (2007)
Figure 2.11	Total daily flow - Peace River + (Horse + Joshua + Shell) Creeks (1976-2007)
Figure 2.12	Mean monthly flow - Peace River + (Horse + Joshua + Shell) Creeks (1976-2007)
Figure 2.13	3-month moving average flow - Peace River + (Horse + Joshua + Shell) Creeks (1976-2007)
Figure 2.14	Total daily gaged flow – (Peace + Myakka) Rivers + (Horse + Joshua + Shell) Creeks (2007)
Figure 2.15	Total daily gaged flow - (Peace + Myakka) Rivers + (Horse + Joshua + Shell) Creeks (1976-2007)
Figure 2.16	Mean monthly gaged flow - (Peace + Myakka) Rivers + (Horse + Joshua + Shell) Creeks (1976-2007)
Figure 2.17	3-month moving average gaged flow - (Peace + Myakka) Rivers + (Horse + Joshua + Shell) Creeks (1976-2007)

Daily Peace River at Arcadia gage flows between 1976, the beginning of the HBMP and the most recent year (2007) are shown in **Figure 2.3**. This figure clearly shows the magnitude of the extended drought that occurred between 1999 and 2002, the higher than average flows that immediately followed during 2003, 2004 and 2005, the very dry conditions in 2006, and the continuing extremely dry situation in 2007. This figure clearly shows that the magnitude of the 2007 drought and the lack of wet-season flows was beyond anything observed since the beginning of HBMP monitoring in 1976. Arcadia gaged flows over the same long-term period are further depicted as mean monthly values in **Figure 2.4** and again based on 3-month moving averages in **Figure 2.5**. Analogous graphical plots for 2007 and 1976-2007 interval are presented for total gaged flow upstream of the Peace River Treatment Facility (Peace River at Arcadia + Horse and Joshua Creeks) are shown in **Figures 2.6** through **2.9**. Similar plots are also shown in **Figures 2.10** through **2.13** for the total gaged lower Peace River flow at the U.S. 41 Bridge (Peace River at Arcadia + Horse, Joshua and Shell Creeks). **Figures 2.14** through **2.17** show comparative plots of daily, mean monthly, and 3-month moving average total gaged freshwater inflows to upper Charlotte Harbor by including Myakka River flows. (However, it should be noted that the USGS Myakka River near Sarasota gaging location does not include runoff from a substantial portion of the lower Myakka River watershed.) Combined, these graphics again clearly indicate the historically dry conditions that characterized much of 2007.

Comparison of the data displayed in **Figures 2.2** and **2.3** shows that Peace River average daily flow at Arcadia during 2007 was only approximately 18.5 percent of that calculated over the preceding longer 1976-2006 period. The data displayed in **Figures 2.6** and **2.7** for the sum of average daily flows upstream of the Peace River Facility indicate that they were roughly 19.3 percent of the average over the longer preceding time period of HBMP monitoring (1976-2006). In comparison, **Figures 2.10** and **2.11** show that the addition of Shell Creek flows were sufficient to raise the deficit enough that total freshwater inflows to the lower Peace River estuary during 2007 were approximately 22.1 percent of the longer 1976-2006 term average.

Table 2.4 provides comparisons of the relative contributions of each of the downstream USGS gages on the major tributaries to the lower Peace River over both the recent historic period (1976-2006) and the reporting year (2007). Relative percentages are provided both upstream of the Peace River Facility and at the U.S. 41 Bridge (downstream of the river's confluence with Shell Creek). These summary results clearly show the influences of the previously discussed spatial differences in 2007 summer rainfall patterns, with more normal summer afternoon thunderstorm activity occurring along the western coastline and often little afternoon rainfall occurring throughout much of the main inland areas of the Peace River watershed.

Table 2.4
Comparisons of Relative Contributions of Gaged Flows Over Recent Historic (1976-2006) and the Current Period (2007)

Time Period	Percent of Total Gaged Flow at Facility			Percent of Total Gaged Flow at U.S. 41 Bridge			
	Peace at Arcadia	Horse Creek	Joshua Creek	Peace at Arcadia	Horse Creek	Joshua Creek	Shell Creek
1976-2006	75.6	15.4	9.0	58.4	11.9	7.0	22.7
2007	72.8	9.6	17.6	49.0	6.5	11.8	32.7

2.2 Peace River Facility Withdrawals

Due to extended drought conditions during 2006 and concern about the upcoming 2007 dry season, the Authority asked and received permission from the District in December 2006 to reduce the low flow Peace River at Arcadia withdrawal threshold from 130 cfs to 90 cfs until the end of the drought using the 1996 permit's 10 percent criteria. However, due to the unexpected historic low Peace River flows during the summer of 2007, the District issued an additional series of Executive Orders that temporarily modified the Authority's Peace River Facility withdrawals schedule (Table 2.5). The series of District Executive Orders modified the withdrawal schedule to include withdrawals based on the total gaged flows upstream of the Facility (Peace River at Arcadia, plus Horse Creek near Arcadia and Joshua Creek near Nocatee), modifications of the low flow threshold, and increases in the allowable percent withdrawals.

Table 2.5
2007 Modifications to the Normal 1996 Permitted Withdrawal Schedule

Event	Effective Dates	Low Flow Threshold	Gages Used	Percent Withdrawal
Temporary WUP	1/1/07 to 8/12/07	90 cfs	Peace River at Arcadia	10
Executive Order	8/13/07 to 8/29/07	130 cfs	Three gages upstream of the Facility	12
Executive Order	8/30/07 – 10/31/07	90 cfs	Three gages upstream of the Facility	12
Executive Order	11/1/07 – 4/19/08	90 cfs	Three gages upstream of the Facility	14 or 21 *

* Variable percent withdrawal based on District proposed MFL criteria

The most recent Executive Order was based on the draft criteria presented in the District's proposed Minimum Flow and Level (MFL) for the lower Peace River. The MFL recommended that during seasonal Block 2 (October 27 to April 19) the maximum permitted withdrawals should be 14 percent of all flows between 90 and 330 cfs based on the combined gaged flows upstream of the Facility. Maximum withdrawals could then increase to 21 percent of the combined gaged flows above the long-term historic median flow of 330 cfs during the Block 2 time interval.

The current modifications to the Facility's 1996 Water Use Permit are a temporary response to the severity of the 2006/2007 drought and do not constitute a permanent change to the Authority's 1996 permitted 10 percent withdrawal based solely on Peace River at Arcadia gaged flows.

Daily freshwater withdrawals (in cubic feet per second) by the Peace River Facility during 2007 are shown in **Figure 2.18**. Several items of note are depicted in this figure. The first being that, even with the temporary modifications of withdrawal schedule (Table 2.5), there were extended periods when the Peace River Facility was unable to withdraw water from the river. During 2007, the Facility was unable to withdraw water from the river (except for a few days) from mid-April through the first part of July and again during December due to the low flow threshold criteria. Even with the District's temporary withdrawal schedule modifications, the Peace River Facility was unable to withdraw water from the river 32.6 percent of the time during 2007, and annual average withdrawals were only approximately 68 percent of that withdrawn during the much wetter 2002-2005 four year interval.

Daily withdrawals since Facility startup are shown from 1980-2006 in **Figure 2.19**. This figure clearly indicates the increases in maximum withdrawals beginning in the later half of 2002 following the Facility's most recently completed expansion, which increased the Peace River Treatment Facility's ability to divert, treat and store larger daily amounts of freshwater.

Additional figures depicting Peace River Facility withdrawals in relation to different combinations of total gaged flows are presented in Table 2.6.

Table 2.6

Peace River Water Treatment Facility Withdrawals and Freshwater Inflows During 2007 and the Period 1980-2007

Figure	Description
Figure 2.18	Daily water treatment facility withdrawals (2007)
Figure 2.19	Daily water treatment facility withdrawals (1980-2007)
Figure 2.20	Monthly mean water treatment facility withdrawals (1980-2007)
Figure 2.21	3-month moving average water treatment facility withdrawals (1980-2007
Figure 2.22	Daily Peace River flows at Arcadia and water treatment facility withdrawals (2007)
Figure 2.23	Daily total gaged flow at the Facility (Peace River at Arcadia + Horse + Joshua Creeks) and water treatment facility withdrawals (2007)
Figure 2.24	Daily total gaged flow at river's mouth (Peace River at Arcadia + Horse + Joshua + Shell Creek) and water treatment facility withdrawals (2007)
Figure 2.25	Peace River flows at Arcadia vs. water treatment facility withdrawals (2007)
Figure 2.26a	2007 water treatment facility withdrawals as percent of Peace River at Arcadia flows
Figure 2.26b	Jan 1st to Aug 12th Facility withdrawals as percent of Peace River at Arcadia flows
Figure 2.26c	Aug 3 rd to Oct 31st Facility withdrawals as percent of combine upstream gaged flows
Figure 2.26d	Nov 1st to Dec 31st Facility withdrawals as percent of combine upstream gaged flows

Plots of the monthly means and 3-month moving averages of withdrawals over the 1980-2007 period are depicted in **Figures 2.20** and **2.21.** The effects of the 1999-2001 long-term drought on Facility water withdrawals, the higher than average flows in 2003-2005, the very dry conditions in both 2006 and 2007, as well as the Facility's increased treatment capacity following the 2002 expansion are clearly evident in these two figures**.** Seasonal relationships between 2007 Peace River total gaged inflows (at Arcadia, the Facility and U.S. 41 Bridge) and Peace River Facility withdrawals are further depicted in **Figures 2.22** through **2.24**.

Figure 2.26a shows Facility withdrawals from the river during 2007 relative to the percent of preceding daily gaged Peace River at Arcadia flow. Due to the extreme drought conditions during 2007 the District issued a number of Executive Orders (Table 2.5) that both altered the percent of flow available for withdrawal and changed the amount to also include gaged daily inflows from both Horse and Joshua Creeks. The black, blue and rose colored dots shown in **Figure 2.26a** provide comparisons relative to Peace River at Arcadia flows among the various withdrawal criteria used in 2007. **Figure 2.26b** shows the relationships between Facility withdrawals and Peace River at Arcadia flows during the first part of the year when the standard ten percent at Arcadia criteria were in effect. Percent withdrawals based on combined Peace River inflows including the two Horse and Joshua Creek tributaries upstream of the Facility are shown in **Figures 2.26c** and **2.26d**, when the temporary 12 and 14 percent Executive Order criteria were employed.

Figures 2.26b, 2.26c and **2.26d** all show that Facility withdrawals at times exceed the established percent withdrawal criteria. Historically, the reason for these discrepancies stems from the way that stage/flow data are gathered. The Facility uses "provisional" preceding day flow data from the water level recorders at the USGS gaging station at each of the locations. Such "provisional" real-time data are obtained directly from the USGS Tampa office's Web Site a number of times each day by the Authority. This is accomplished in order to determine an accurate working estimate of the preceding daily Arcadia flow on which to establish the Facility's current day's withdrawal schedule. However, after the fact, the USGS checks and evaluates the data from both the gage stage recorders and periodic river cross section measurements collected a number of times each year. Based on such quality assurance checks the USGS may make revisions to the real-time information before establishing finalized daily flow estimates for the preceding water year. Thus, the daily values used by the Facility are only "provisional" and can and are often changed as a result of ongoing USGS data quality assurance procedures weeks or even months later. It is therefore not uncommon for subsequent determinations of percent withdrawals, based on the finalized, revised USGS calculations of the initial "provisional" daily flows, to sometimes indicate that daily withdrawals, based on initial real-time flow information, exceeded the District's permitted maximum ten percent. Under low flow conditions, such as occurred throughout much of 2007, even small adjustments between USGS provisional and finalized flow estimates can result in fairly large changes in the relative percent of flow.

2.3 Comparisons of Peace River Facility and Shell Creek Facility Withdrawals

There are two public suppliers that withdraw potable water from the lower Peace River system. As previously described, the Authority's Peace River Treatment Facility withdraws water from the intake withdrawal structure located on a side channel, in the tidal portion of the lower river estuarine system. Water is stored untreated in the Facility's off-stream reservoir, or treated water is stored in a series of Aquifer Storage Recovery (ASR) wells. Under normal conditions, the Facility's existing 1996 permit has a 130 cfs threshold flow for withdrawals based on the upstream USGS Arcadia gage. Withdrawals above the 130 cfs threshold are limited to 10 of the preceding days flow, with a 90 mgd maximum daily cap.

The older City of Punta Gorda Facility utilizes an in-stream reservoir constructed in the tidal portion of Shell Creek, just below the confluences of Shell and Prairie Creeks. Unlike the Peace River Facility's flow based permit structure, the current 20-year Shell Creek permit issued in September 2007 allows an annual average of 8.008 mgd, with a maximum monthly cap of 11.728 mgd.

Figures 2.27 and **2.28** provide comparisons of both the 2007 and recent historic withdrawal patterns of the two facilities. **Figure 2.29** provides an indication of both the magnitude and timing of the total withdrawals by the two facilities that occurred in the lower Peace River estuarine system during 2007 in relation to total gaged flows for the major tributaries.

Table 2.7

Comparisons of Peace River Water Treatment Facility and Shell Creek Facility Withdrawals with Freshwater Inflows during 2007 and the Period 1980-2006

Figure	Description
Figure 2.27	Daily Peace River and Shell Creek water treatment facility withdrawals (2007)
Figure 2.28	Daily Peace River and Shell Creek water treatment facility withdrawals (1980-2007)
Figure 2.29	Daily total gaged flow at river's mouth (Peace River at Arcadia + Horse + Joshua + Shell Creek) and total water treatment facility withdrawals (2007)

2.4 Summary

Annual mean Peace River flows based on: 1) the Peace River at Arcadia gage; 2) total gaged flow upstream of the Peace River Facility; and 3) total gaged flow upstream of the U.S. 41 Bridge, are summarized since 1976 (the start of the HBMP) in **Table 2.8**. The table also includes mean annual Facility lower Peace River withdrawals (since 1980) and City of Punta Gorda Shell Creek withdrawals. The annual percentages that Peace River Facility withdrawals have comprised of gaged Peace River flows measured at Arcadia, the Facility and the U.S. 41 Bridge are also included. Finally the table indicates the percent of annual total flow to the upper harbor utilized by both the Peace River and City of Punta Gorda facilities.

Total Peace River Facility withdrawal during 2007 was approximately 10.2 percent of the total gaged freshwater flow measured at the USGS Arcadia gage, 7.3 percent of the upstream gaged flow at the Facility, and 4.9 percent of the combined average daily inflows upstream of the U.S. 41 Bridge. During the entire period of Facility withdrawals 1980-2007, total combined withdrawals have been approximately 1.30 percent of the corresponding gaged Peace River at Arcadia flows and 0.75 percent of the corresponding combined daily flows of the Peace River, and Horse, Joshua, and Shell Creeks.

3.0 *In Situ* Physical Measurements, Water Chemistry and Phytoplankton Biomass at "Moving" Isohaline Locations

3.1 Introduction

An early objective of the Peace River HBMP was the development of a comprehensive understanding of phytoplankton production and related community structure within the Charlotte Harbor estuarine system. Development of a conceptual understanding of the temporal and spatial relationships between freshwater inflows and phytoplankton production was established as a fundamental goal towards developing an overall understanding of other key interrelated biological communities and physical processes within the estuary, including secondary production and nutrient cycling. Components of the long-term HBMP "isohaline" salinity based monitoring study element were designed in part to develop a greater understanding of the interactions of seasonal freshwater inflows and the temporal and spatial responses of phytoplankton production in the lower Peace River/upper Harbor estuarine system. Specific goals of these studies included determining both the immediate and long-term phytoplankton responses to freshwater inputs, including both nutrient loadings (nitrogen) and increased water color (light availability). The HBMP's historic, long-term phytoplankton investigations in the lower Peace River/upper Charlotte Harbor estuarine system provided:

- Measurements of populations and community structure acting as barometers of changes over both short (daily to weekly) and longer (seasonal) temporal scales.

- Insight into basic spatial/temporal processes affected by water quality and having secondary widespread interrelations and effects upon other estuarine food-web components.

Phytoplankton production generally represents an immediately available food resource, unlike other estuarine production such as that associated with seagrass, mangrove and saltmarsh habitats, where much of the resource becomes available through secondary processes. Of the various inputs into the Charlotte Harbor estuarine system, phytoplankton production represents both the largest single component of primary production and a food source directly accessible to many filter and detrital feeding organisms. Phytoplankton production and community composition, due to the short generation times involved, have also been shown to be effective in demonstrating ephemeral, seasonal and long-term changes in water quality. Phytoplankton production represents a highly integrated estuarine component and can be used to provide information on both direct and predictive secondary impacts of external influences.

3.2 Historical Long-Term Phytoplankton Study Elements

Since its inception in the early 1980s, the HBMP has incorporated a number of long-term monitoring studies designed to answer specific question with regard to spatial and temporal patterns in phytoplankton production, community structure and biomass. The objectives of these HBMP studies have been to develop sufficient information to evaluate trends and establish a long-term understanding of differences in the response in the lower Peace River/upper Charlotte

Harbor estuarine system to periods of both extended drought as well as unusually high freshwater inflows.

Phytoplankton Primary Production – Statistically comparable levels of phytoplankton ^{14}C fixation rates were measured monthly at each of the four salinity-based isohaline locations between June 1983 and December 1999. In addition to overall estimates of phytoplankton production, carbon uptake rates were determined for three separate size fractions: 1) greater than 20 microns; 2) 5 to 20 microns; and 3) less than 5 microns. The results of this long-term HBMP study clearly showed the quick response of phytoplankton production to brief pulses of relatively nitrogen rich freshwater into the estuary during the early spring. These results further supported the extreme importance to other components of the estuarine food-web of early spring/summer flows to the estuary during the start of the typical summer wet-season.

Phytoplankton Taxonomic Identification – A second element of the HBMP phytoplankton study, conducted monthly between 1989 and 2004, sought to quantify the specific responses of major phytoplankton taxonomic groups to variations in the periodicity of freshwater inflow. The developed monthly phytoplankton taxonomic information included: 1) raw counts of the relative taxonomic structure; 2) percent composition of key major taxonomic groups; and 3) summary species diversity and evenness index estimates. The results of these microscopic phytoplankton surveys generally indicated the relative dominance of the following groups.

- Among samples collected at intermediate and higher salinities, the smallest phytoplankton size fraction (<5 microns) was often observed to be dominated by Cryptophyceae species (*Chroomanas* spp. and *Cryptomonas* spp.). Small Bacillariphyceae (*Thalossiosira* spp., *Nitzschia* spp., *Navicula* spp.) were also often observed to comprise significant portions of the nano-plankton components at these salinities.

- At the very highest salinities, influenced by Gulf waters, chain-forming and larger diatoms frequently dominated the net-plankton size fraction. Seasonally important diatoms at these locations were *Skeletonema costatum*, *Asterionella glacialis*, *Odentella sinensis*, *Corethron criophilum*, *Coscinodiscus centralis*, and *Coscinodiscus eccentricus*, as well as species of Chaetoceros and Rizosolenia. Dinophyceae (*Ceratium* spp. and *Peridinium* spp.) were often seasonally common during the summer months.

- At intermediate salinities, blooms of *Skeletonema costatum* were commonly associated with relative increases in carbon uptake and chlorophyll *a* within the largest size fraction. However, seasonally, dinoflagellates (*Prorocentrum micans*, *P. minimum*, *Gymnodinium* spp. and *Gyrodinium* spp.) were also major components of the largest phytoplankton size fraction. Specifically, at 6 and 12 o/oo salinity at the mouth of the Peace River, during the typical spring phytoplankton increase the larger size fractions were seasonally dominated by blooms of *Gyrodinium splendens*.

- The picoplankton size fraction (< 5 microns) at the lower salinity stations often contained significant numbers of non-flagellated, smooth, circular to ovoid, green cells. Taxonomically, such cells included Cyanophyceae (*Synechoccus* spp., *Chroococcus* spp., *Anacystis* spp.) as well as Chlorophyceae (*Nannochloris* spp., *Chlorella* spp.). Small phytoflagellates (*Chlamydomonas* spp., *Carteria* spp., *Chroomonas* spp., *Cryptomonas* spp.) were also common components of the picoplankton within the lower salinity areas. The larger size fractions in the riverine portions of the estuary were found to be generally characterized by mixtures of Chlorophyceae (*Ankistrodesmus* spp., *Coelastrum* spp., *Crucigenia* spp., *Pediastrum* spp., *Scenedesmus* spp., *Tetraedron* spp.), Bacillariophyceae (*Cyclotella* spp., *Nitschia* spp., *Navicula* spp., *Fragillaria* spp.), and Cyanophyceae (*Anabaena* spp., *Anacystis* spp.).

Phytoplankton Biomass Estimates – Although direct *in situ* measurements of carbon uptake rates and enumerations of phytoplankton taxonomic structure are no longer conducted, the HBMP isohaline based monitoring study element continues to collect monthly information of phytoplankton biomass (chlorophyll *a*), in relation to seasonal and flow related variations in physical parameters, water column light profiles, and the major chemical constituents associated with phytoplankton growth. This report presents data collected during the twenty-fifth year (2007) of this unique long-term study of the relationships between phytoplankton productivity and Peace River flow into upper Charlotte Harbor.

3.3 Overview of "Isohaline" Based Monitoring Methods

The following briefly outlines and summarizes the methodologies used to measure and evaluate the physical, chemical, and biological parameters. Environmental Quality Laboratory, Inc. (EQL) was responsible for all aspects of the HBMP "moving" isohaline based station monitoring between 1983 and July 2000, after which time EarthBalance, Inc. (formerly Florida Environmental) was contracted to conduct the physical water column measurements and collection of water chemistry samples for both the "moving" isohaline and "fixed" HBMP station elements. A number of EarthBalance staff previously worked on the HBMP while with EQL and all previously used field collection procedures have been maintained.

Since the initial inception of the HBMP monitoring program in 1976, all water chemistry analyses had been conducted by EQL, which was purchased in 2000 by ASCI, Inc. ASCI continued to conduct all HBMP chemical analyses through January 2002. However, due to issues regarding QA/QC and the long-term stability of ASCI, in February 2002 the Peace River Manasota Water Supply Authority (Authority) changed the chemistry contract to Benchmark EnviroAnalytical, Inc. located in Palmetto, Florida. All laboratory methods previously used by EQL/ASCI have been continued by Benchmark, who conducted all HBMP chemistry analyses during 2007.

The four isohaline based monthly sampling locations in this HBMP study element represent non-fixed surface salinity zones, such that the monthly location of each isohaline is dependent upon both tide stage and the preceding amount of freshwater inflow from the Peace River. Table 3.1 summarizes the historical statistical distribution of these isohaline locations. The four salinity sampling zones are:

- Station 101 = 0 psu (practical salinity units)
- Station 102 = 5-7 psu

- Station 103 = 11-13 psu
- Station 104 = 20-22 psu

Table 3.1
Summary Statistics of the Four Isohaline Locations (Kilometers) from the Peace River's Mouth for the Period 1983-2007

Isohaline	Minimum (Downstream)	Maximum (Upstream)	Mean	Median
0 psu	0.6	37.6	21.9	21.1
6 psu	-16.3	28.3	12.6	12.6
12 psu	-30.1	25.0	7.6	9.0
20 psu	-36.3	21.0	0.3	3.3

Note: HBMP reports previous to 2006 used the units "o/oo". However, since 2006 equivalent practical salinity units (psu) have been used, which distinguishes salinity determined by *in situ* conductivity rather than wet chemistry.

The Peace River Water Treatment Facility is located at approximately river kilometer 29.8. To date, the most upstream occurrence of the 0 psu isohaline sampling location has been just over a quarter mile upstream of the point were Horse Creek joins the Peace River (during June 2000). The most downstream occurrence of the 20 psu isohaline sampling location has been in the Gulf of Mexico just off Boca Grande (September 1988) (see **Figure 3.1**).

The relative location of each of these four isohalines during 2007 is shown in **Figure 3.2**, while long-term patterns for the period 1983-2007 are presented in **Figures 3.3** and **3.4**. The affects of the extended drought conditions that influenced freshwater flows in the Peace River watershed between 2000 and 2002 are noticeable in the atypical upstream movements and near historic maximum extents of all four isohalines during this extended, unusually dry period following the 1997/1988 El Niño climatic event. Following the end of this extended drought, the seasonal variability of the relative locations of each of these four measured isohalines returned to cyclical patterns similar to those previously observed during more normal annual hydrologic conditions. However, in response to the very dry conditions that characterized much of 2006 and all of 2007, the relative spatial distribution of the four moving isohalines returned to patterns similar to those observed during the previous extended drought.

The box and whisker plots presented in **Figure 3.5** summarize and compare the relative locations of each of the four "moving" isohaline sampling zones during both 2007 and over the preceding 1983-2006 monitoring period. As shown in **Diagram 3.1**, the box indicates the median line (50th percentile) as well as the 25th and 75th percentiles respectively at the bottom and top. Whisker lines then extend from the 25th percentile to the 10th percentile and from the 75th percentile to the 90th percentile. Extreme values (outside the 10th-90th percentiles) are represented by dots at the end of the whiskers. The statistical mean is indicated by a colored dot within the box. In **Figure 3.5**, the zero reference line denotes the imaginary mouth of the Peace River as defined in the previous morphometric study (see **Figure 1.2**). The influence of the much lower than average freshwater inflows during 2007 is evident in the seasonal pattern of the locations of all four of the HBMP isohalines during 2007, when compare to the longer-term 1983-2006 historic preceding period of HBMP isohaline based monitoring.

Table 3.2
Isohaline Locations During 2007 and the Period 1983-2006

Figure	Description
Figure 3.1	Study area with most upstream and downstream locations of 0 & 20 isohaline sampling locations
Figure 3.2	Relative distance (km) from the mouth of the river (2007)
Figure 3.3	Relative distance from the mouth of the river of 0 and 6 psu salinity sampling zones (1983-2007)
Figure 3.4	Relative distance from the mouth of the river of 12 and 20 psu salinity sampling zones (1983-2007)
Figure 3.5	Box & whisker plots of relative distance (km) from the mouth of the river

3.3.1 *In Situ* Measurements of Physical Parameters

Depth, temperature, dissolved oxygen, conductivity, and pH were measured *in situ* with Hydrolab Surveyor systems. Profiles were made from the surface to the bottom in 0.5m increments at each sampling station location. Depth measurements were determined on the basis of pre-measured marks on the unit's cable and/or the unit's depth sensor.

Pre-sampling instrument calibrations were conducted within four hours prior to use. Temperature was measured with a linear resistance thermistor, factory calibrated and accurate to within ±0.2 ^{o}C. Dissolved oxygen (DO) was measured with a temperature-compensated, passive, polarographic cell, which measures the partial pressure of oxygen as parts per million (ppm or mg/l) of oxygen, ±0.2 ppm. The probe was calibrated using the oxygen tension of water-saturated air (temperature corrected) as a standard.

The conductivity probe was calibrated against a KCl solution of known conductivity. Probe response was then tested with a solution of known low and high conductivity to ensure that the reading was within ±1.0 percent of the range selected. The probes are automatically temperature compensated to provide conductivity at 25 ^{o}C.

The Hydrolab pH probes are glass, KCl filled with silver/silver chloride reference electrodes and refillable junctions. They are automatically temperature compensated. Two buffer solutions of 7.0 and 10.0 pH (± 0.1 units) were used to calibrate the accuracy of the probe.

3.3.2 Light Profile

Light intensity profiles were utilized to gather sufficient data to calculate the water column extinction coefficient at each isohaline sampling location. A LI-COR quantum/radiometer/photometer equipped with an underwater quantum sensor was used to measure photosynthetically active radiation (400-700 nanometers). Light intensities (microeinsteins/m^2/sec) were measured in the air just above the water surface, again just below the surface, and at six selected depths (20, 40, 60, 80, and 100 cm).

3.3.3 Water Chemistry

Surface water samples were collected for analysis at each salinity-based station in pre-labeled, polyethylene containers. The containers were rinsed with sample water, filled, preserved and immediately placed in the dark on ice until transferred to Benchmark EnviroAnalytical, Inc. following standard chain of custody and Florida Department of Environmental Protection (FDEP) quality assurance procedures. Specific methods of analyses used by the laboratory are listed in **Table 3.3**.

In response to the recommendations contained within the *1998 HBMP Mid-term Interpretive Report* and the *2002 Peace River Comprehensive Summary Report* the number of water chemistry parameters associated with both the “moving” and “fixed” HBMP study elements were decreased from those originally specified (17 parameters) in the 1996 monitoring conditions. These changes were made only after extensive consultation with both the HBMP Scientific Review Panel and District staff. As a result of this coordination, all monitoring during 2007 was conducted using the revised/reduced long-term water quality sampling parameter list (12 parameters) implemented starting in March 2003 (**Table 1.2**).

3.4 Physical and Water Chemistry Data Collected in the “Moving” Isohaline Locations

Water quality data collected at the four “moving” isohaline locations in conjunction with the isohaline, salinity based HBMP study element are presented and summarized in the following Tables and Figures. **Tables 3.4** and **3.5** summarize the determinations of key physical, chemical and biological measurements. Seasonal representations of selected parameters are further graphically presented in **Figures 3.6** through **3.13** (see Table 3.6).

Relationships of the 2007 data to those data collected during the preceding 24 years of study (1983-2006) are shown for selected physical, chemical and biological measurements in **Figures 3.14** through **3.21** (see Table 3.7). Further comparisons of these parameters are presented as box and whisker plots by salinity for both 2007 and long-term data collected between 1983-2006 in **Figures 3.22** through **3.29**. The box and whisker plots display a detailed distribution of the data as depicted in **Diagram 3.1**, showing the median (50th percentile) at the center of the box and the 25th and 75th percentiles at the bottom and top of the box, respectively. The statistical means are shown as dots within each box. The whiskers are lines that extend from the 25th percentile to the 10th percentile and 75th percentile to the 90th percentile. Extreme values (outside the 10th-90th percentiles) are represented by dots at the ends of the whiskers.

Table 3.6
Summary Tables and Graphics of Key Physical and Chemical Measurements for Data Collected in 2007 at the Four Isohaline Locations

Tables	Description
Table 3.4	Physical and chemical water quality parameters
Table 3.5	Physical and chemical water quality parameters - nutrients
Figure 3.6	Monthly temperature at salinity sampling zones - 2007
Figure 3.7	Monthly color at salinity sampling zones - 2007
Figure 3.8	Monthly extinction coefficient at salinity sampling zones - 2007
Figure 3.9	Monthly nitrite/nitrate at salinity sampling zones - 2007
Figure 3.10	Monthly ortho-phosphorus at salinity sampling zones - 2007
Figure 3.11	Monthly atomic N/P ratio at salinity sampling zones - 2007
Figure 3.12	Monthly silica at salinity sampling zones - 2007
Figure 3.13	Monthly chlorophyll *a* at salinity sampling zones - 2007

Table 3.7
Summary Graphics of Key Physical and Chemical Measurements for Data Collected During the Period 1983-2007 at the Four Isohaline Locations

Figure	Description
Figure 3.14	Monthly temperature at salinity sampling zones1983-2007
Figure 3.15	Monthly color at salinity sampling zones1983-2007
Figure 3.16	Monthly extinction coefficient at salinity sampling zones1983-2007
Figure 3.17	Monthly nitrite/nitrate at salinity sampling zones1983-2007
Figure 3.18	Monthly ortho-phosphorus at salinity sampling zones1983-2007
Figure 3.19	Monthly atomic nitrogen/phosphorus ratio at salinity sampling zones1983-2007
Figure 3.20	Monthly silica at salinity sampling zones1983-2007
Figure 3.21	Monthly chlorophyll *a* at salinity sampling zones1983-2007
Figure 3.22	Box and whisker plots of temperature at salinity sampling zones (2007) & (1983-2006)
Figure 3.23	Box and whisker plots of color at salinity sampling zones (2007) & (1983-2006)
Figure 3.24	Box and whisker plots of extinction coefficient at salinity sampling zones (2007) & (1983-2006)
Figure 3.25	Box and whisker plots of nitrite/nitrate at salinity sampling zones (2007) & (1983-2006)
Figure 3.26	Box and whisker plots of ortho-phosphorus at salinity sampling zones (2007) & (1983-2006)
Figure 3.27	Box and whisker plots of atomic N/P ratio at salinity sampling zones (2007) & (1983-2006)
Figure 3.28	Box and whisker plots of silica at salinity sampling zones (2007) & (1983-2006)
Figure 3.29	Box and whisker plots of chlorophyll *a* at salinity sampling zones (2007) & (1983-2006)

3.5 Summary

Statistical comparisons between mean 2007 values and long-term 1983-2006 averages for selected measurements and parameters are summarized in **Table 3.8.** The following summarizes comparisons of the findings from the 2007 data with those previously collected as part of the long-term isohaline based HBMP water quality monitoring program element.

- **Salinity Spatial Distribution** – The influences of the much drier than usual conditions that characterized 2007 (see **Section 2**) were reflected in the seasonal and average spatial distributions of each of the four sampled, moving isohalines along the HBMP monitoring transect. Overall, the relative spatial distributions of each of the isohalines during 2007 reflected upstream movements of 7-11 kilometers when compared with their previous long-term 1983-2006 averages.

- **Temperature** – Mean annual water temperatures during 2007 at the two lower salinity isohalines (0 and 6 psu) were slightly above corresponding values measured over the preceding 24-year period (1983-2006). Overall, water temperatures measured at all four of the four salinities during both January and December 2007 were, as during the previous four years (2003-2006), much warmer than usual when compared to similar seasonal values measured over the longer term period-of-record.

- **Water Color** – The average color levels throughout the estuary during the three relatively wet years between 2003 and 2005 were markedly higher when compared to those observed during the extended 1999-2002 drought. Color levels in 2007 were below their long-term averages within all but the highest salinity isohaline as a result of the extremely low average seasonal freshwater inflows over most of the year. Somewhat surprisingly, mean and median color levels within the most downstream 20 psu isohaline were very similar during 2007 to the statistical long-term annual averages.

- **Extinction Coefficient** – The rates of measured light attenuation at each of the four HBMP isohalines reflect the interactions of both ambient color and phytoplankton biomass (chlorophyll *a*). Comparisons of mean extinction values among the four isohalines in 2007 and with corresponding long-term averages indicate very similar patterns as those described for water color. Relatively low levels of color and chlorophyll *a* during 2007 within each of the four isohalines resulted in light extinction coefficients being well below their long-term 1983-2006 historical annual averages.

- **Nitrite/Nitrate Nitrogen** - During 2007, the average concentrations of this major inorganic form of nitrogen were much lower in each of the four sampled estuarine isohaline zones when compared with the long-term (1983-2006), historical annual averages. Typically monthly comparisons among the isohalines indicate nitrite/nitrate inorganic nitrogen concentrations in the lower Peace River/upper Charlotte Harbor estuarine system are characterized by a distinct spatial gradient that shows strong responses to seasonal patterns of freshwater inflows. Concentrations typically decrease rapidly with increasing salinity, with inorganic nitrogen levels within the 20 psu isohaline often being near or at method detection limits over much of the year. Normally, estuarine inorganic nitrogen concentrations decline to their lowest levels during the relatively drier, spring as phytoplankton populations respond to increasing water temperatures and light, and increased primary production removes available inorganic nitrogen.

- **Ortho-phosphorus** - Estuarine inorganic phosphorus concentrations in the lower Peace River and upper Charlotte Harbor are heavily influenced by the characteristically "very" high natural levels found in the Peace River watershed. As a result, the observed difference in concentrations among the four isohalines simply reflects conservative dilution by Gulf waters. Unlike inorganic nitrogen, seasonal observed changes in phosphorus concentrations in the estuary are for the most part unaffected by biological uptake. Inorganic phosphorus concentrations entering the estuary system from the Peace River watershed are typically lower during wetter periods, when a higher proportion of flow results from surface flow (rather than coming from groundwater, which is naturally richer in phosphorus). Historically, since the late 1970s, there had been marked declines in inorganic phosphorus levels in the lower Peace River/upper Charlotte Harbor estuarine system due to declines in the combined influences of phosphate mining and processing in the upper reaches of the basin. However, following Hurricane Charlie and the subsequent influences of Hurricanes Francis and Jeanne during the late summer of 2004, inorganic phosphorus concentrations have dramatically increased throughout the lower Peace River/upper Charlotte Harbor estuarine system. Ortho-phosphorus concentrations during both 2006 and 2007 were well above both historic and recent levels. Currently, the direct cause for these increased levels remains unclear.

- **Nitrogen to Phosphorus Atomic Ratios** – Calculated atomic inorganic nitrogen to phosphorus ratios for ambient measured concentrations in 2007, as indicated by the long-term averages, show nitrogen to always be the limiting macronutrient at each of the four isohalines.

- **Silica** – Seasonally, silica levels in the lower Peace River/upper Charlotte Harbor estuarine system typically peak following periods of high freshwater inflows. Although silica levels also seem to be positively correlated with higher water temperatures (possibly reflecting recycling from riverine/estuarine sediments), historically lower silica concentrations in higher salinity zones of the estuary have often occurred during corresponding periods of combined low spring freshwater inflow and spring increases in phytoplankton diatom numbers. Between 1983 and the late 1990s these seasonal patterns of increasing and decreasing reactive silica concentrations remained relatively stable with no indications of any consistent systematic changes over time. However, as discussed in previous HBMP reports, silica levels started showing increasing concentrations during the late 1990s. Then, as flows declined during the extended 1999-2002 drought, silica levels also declined. However, following the return of higher than average flows during 2003-2005 measured silica levels in the estuary again began rapidly increasing. Even though flows during both 2006 and 2007 were below normal, silica levels throughout the lower river/upper harbor estuary reached historically high levels during the past two summer wet-seasons. The immediate cause of these fairly recent increases is unknown. However, studies in other areas have found that increases in dissolved silica concentrations have been associated with land use changes and clearing of natural vegetation. In many of these systems, changes in silica concentrations have also been found to be associated with changes in both calcium and magnesium levels.

- **Chlorophyll *a*** – The seasonal patterns of freshwater inflows to the estuary during 2007 were characterized by extremely dry conditions, when compared to the long-term average conditions. Seasonally, there was an unusual peak in flow during February, and then conditions were unusually dry until the summer wet-season, when flows were again well below normal. Typically, seasonal periods of increased flows produce both higher than average inputs of limiting inorganic nutrients (nitrogen), as well as higher than average levels of water color (resulting in greater light attenuation). The early increase in flows in February was followed in March by increases in chlorophyll *a* levels within each of the four estuarine salinity zones. The higher flows in July and August were followed by sharp increases in phytoplankton biomass in September in the both the 12 and 20 psu zones. Overall, phytoplankton production (chlorophyll *a*) levels within the three upstream Peace River/upper Charlotte Harbor estuarine salinity zones were below the long-term (1983-2006) corresponding averages. As in previous years, phytoplankton levels were generally higher within the intermediate (6 and 12 psu) isohalines, reflecting a balance between stimulation due to increased nitrogen inputs, and light inhibition resulting from higher water color. During previous years, taxonomic counts indicated that such “bloom” events within these intermediate salinity zones were predominantly characterized by high numbers of dinoflagellates (Dinophyceae) or diatoms (Bacillariophycae).

4.0 Water Chemistry Data Collected at "Fixed" Station Locations

4.1 Introduction

A number of the HBMP study elements prior to 1996 had included the collection of water quality data. The majority of these data, however, were limited to *in situ* physical measurements of water column characteristics. The following studies include the collection of such *in situ* water column profile data.

1. The monthly HBMP night trawl fish study conducted between 1976-1986.
2. The sea star and benthic invertebrate studies carried out between 1976 and 1984.
3. The long-term, monthly fixed station HBMP study of water column characteristics that was undertaken between 1976 and 1986 at a number of fixed sampling sites in the lower Peace River and upper Charlotte Harbor.

Prior to 1996, the only HBMP study that included chemical water quality monitoring was, as discussed in **Section 3.0**, the collection since 1983 at the four "moving" isohaline locations of monthly water column profiles and surface water chemistry samples taken in conjunction with the HBMP study elements of phytoplankton estuarine production.

Under the 1996 Water Use Permit (WUP) renewal, the HBMP monitoring program was expanded to include the collection of monthly water chemistry data at an additional five "fixed" sampling sites spatially distributed along the HBMP monitoring transect from downstream near the mouth of the river to upstream of the Peace River Water Treatment Facility (Facility). In addition, the sampling of *in situ* physical water column profile data only was initiated at ten additional "fixed" sampling locations beyond the five "fixed" water chemistry sampling locations. These new HBMP water sampling and *in situ* water column investigations were initiated using sampling sites formerly utilized (1975-1990) by General Development Corporation's Environmental Quality Laboratory (EQL) for similar long-term lower Peace River/upper Charlotte Harbor background monitoring. An additional fixed monthly sampling site was added in 1998 to correspond to the location of the third USGS recorder installed in 1997 at River Kilometer (RK) 26.7. The relative locations of these "fixed" sampling locations are shown in **Figure 4.1**, while **Table 4.1** provides both currently used HBMP river kilometers, as well as previously used EQL station numbers and USGS river mile designations.

Long-term water chemistry data were collected by EQL between the inception of the HBMP monitoring program in 1976 and 1990 at each of the five current HBMP water quality monitoring locations in conjunction with General Development Corporation's background monitoring program of the lower Peace River and Charlotte Harbor. Between 1990 and 1996, the District collected some monthly data at two of these locations (River Kilometers -2.4 and 6.6) as part of its Charlotte Harbor SWIM monitoring program, and Charlotte County also collected monthly data at these same two sites as background for the South Gulf Cove and Manchester Waterway Permit monitoring programs. As part of the 1996 expanded HBMP monitoring program, the Authority contracted the USGS to collect both the *in situ* hydrolab profile and water chemistry information at the "fixed" HBMP monitoring locations. In July 2000, EarthBalance, Inc. (formerly Florida Environmental) became responsible for all of the water chemistry and biological HBMP fieldwork. This has included the taking of physical water column measurements and the collection of water chemistry samples for both the "moving" isohaline (**Section 3**) and "fixed" HBMP station elements. ASCI conducted both the "fixed" and "moving" HBMP chemical analyses between the sale of EQL in 1998 and January 2002. However, due to concerns regarding QA/QC issues and the long-term stability of ASCI, in February 2002 the Authority changed all HBMP water chemistry analyses to Benchmark EnviroAnalytical, Inc. located in Palmetto, Florida. Benchmark conducted all the chemistry samples collected during 2007, and all laboratory methods previously used by EQL/ASCI have been continued by Benchmark.

4.2 Description of "Fixed Station" Data Collection

The following description provides an overview and summary of the procedures and methods used during the "fixed" station elements of the HBMP.

The "fixed" station water quality monitoring project consists of two categories of data collection (**Figure 4.1**).

1. Monthly physical water column *in situ* water quality measurements at 16 "fixed" sampling sites. *In situ* field measurements made at all sixteen physical water column profile sites include depth, pH, temperature, dissolved oxygen, specific conductance, and light characteristics. Field measurements are made at 0.5 m intervals, beginning at the surface and ending near the bottom. Depths are determined based on pre-labeled marks on the units cable combined with direct sonde pressure based readings.

2. Monthly sub-surface and near-bottom chemical water quality samples are collected at five locations, spaced between the river's mouth and just upstream of the facility along the established river kilometer centerline transect.

Near-surface and near-bottom samples collected at the five monthly water quality monitoring sites were analyzed between 1996 and 2003 for color, turbidity, alkalinity, total nutrients (ammonia nitrogen, ammonia plus organic nitrogen, nitrate plus nitrite nitrogen, nitrite nitrogen, ortho-phosphorus, phosphorus), total organic carbon, total inorganic carbon, dissolved organic carbon, dissolved silica, dissolved chloride, total suspended solids, volatile suspended solids, salinity (estimated from specific conductance), and chlorophyll *a* (**Table 1.2**).

In response to the recommendations contained within both the *1998 HBMP Mid-term Interpretive Report* and the *2002 Peace River Comprehensive Summary Report* the number of water chemistry parameters associated with both the "moving" and "fixed" HBMP study elements were decreased from those originally specified in the 1996 monitoring conditions. These changes were made only after extensive consultation with both the HBMP Scientific Review Panel and District staff. Based on the result of this coordination, the revised/reduced long-term water quality sampling parameter list was implemented starting in March 2003 (**Table 1.2**).

In situ field measurements made in conjunction with sampling at these five “fixed” water quality sites continue to include depth, pH, temperature, dissolved oxygen, specific conductance, and light characteristics.

4.3 Data Collection and Analyses

A detailed compilation of all procedures and protocols used during all elements of the HBMP has been compiled in the “Project and Quality Control Plan” submitted to the District in August 2002. All *in situ* physical water quality procedures and methods used in the “fixed” station HBMP monitoring during 2007 were analogous to previously described methods in **Section 3.0** for the “moving” isohaline study elements, with the added use of a Kemmerer to collect near-bottom water samples at each of the five water quality sampling locations.

4.4 Results and Conclusions

The following summarizes some of the key seasonal and historical patterns observed from the “fixed” station monitoring data both recently during 2007 and over the long-term 1976-2007 interval.

4.4.1 Physical Water Column Characteristics (2007)

The results for the period January through December 2007 of the *in situ* hydrolab water column profiles at the sixteen fixed stations are contained in the appropriate summary data sets summarized in **Table 1.3** (see **Section 1**). These monthly data are presented graphically in **Figure 4.2** through **Figure 4.6** (Table 4.2).

Table 4.2
Summary Graphics of Mean Monthly Physical Water Column *In Situ* Water Quality Measurements at the Fixed Sampling Locations During 2007

Figure	Description
Figure 4.2a	2007 Mean monthly temperature at river kilometers –2.4, 6.6, 8.4 and 10.5
Figure 4.2b	2007 Mean monthly temperature at river kilometers 12.7, 12.8, 15.5 and 17.5
Figure 4.2c	2007 Mean monthly temperature at river kilometers 20.1, 21.9, 23.6 and 24.7
Figure 4.2d	2007 Mean monthly temperature at river kilometers 25.9, 29.5, 30.4 and 32.3
Figure 4.3a	2007 Mean monthly dissolved oxygen at river kilometers –2.4, 6.6, 8.4 and 10.5
Figure 4.3b	2007 Mean monthly dissolved oxygen at river kilometers 12.7, 12.8, 15.5 and 17.5
Figure 4.3c	2007 Mean monthly dissolved oxygen at river kilometers 20.1, 21.9, 23.6 and 24.7
Figure 4.3d	2007 Mean monthly dissolved oxygen at river kilometers 25.9, 29.5, 30.4 and 32.3
Figure 4.4a	2007 Mean monthly pH at river kilometers –2.4, 6.6, 8.4 and 10.5
Figure 4.4b	2007 Mean monthly pH at river kilometers 12.7, 12.8, 15.5 and 17.5
Figure 4.4c	2007 Mean monthly pH at river kilometers 20.1, 21.9, 23.6 and 24.7

Table 4.2
Summary Graphics of Mean Monthly Physical Water Column *In Situ* Water Quality Measurements at the Fixed Sampling Locations During 2007

Figure	Description
Figure 4.4d	2007 Mean monthly pH at river kilometers 25.9, 29.5, 30.4 and 32.3
Figure 4.5a	2007 Monthly 1% Light depth at river kilometers –2.4, 6.6, 8.4 and 10.5
Figure 4.5b	2007 Monthly 1% Light depth at river kilometers 12.7, 12.8, 15.5 and 17.5
Figure 4.5c	2007 Monthly 1% Light depth at river kilometers 20.1, 21.9, 23.6 and 24.7
Figure 4.5d	2007 Monthly 1% Light depth at river kilometers 25.9, 29.5, 30.4 and 32.3
Figure 4.6a	2007 Mean monthly specific conductance at river kilometers –2.4, 6.6, 8.4 and 10.5
Figure 4.6b	2007 Mean monthly specific conductance at river kilometers 12.7, 12.8, 15.5 and 17.5
Figure 4.6c	2007 Mean monthly specific conductance at river kilometers 20.1, 21.9, 23.6 and 24.7
Figure 4.6d	2007 Mean monthly specific conductance at river kilometers 25.9, 29.5, 30.4 and 32.3

The following patterns and observations with regards to seasonal differences among the sixteen “fixed” sampling sites are shown and supported by these figures.

- **Dissolved Oxygen** – Previous results have indicated that within the downstream reaches of the river between River Kilometers -2.4 and 10.5, there is typically a wet-season depression of average water column dissolved oxygen levels in response to increased wet-season flows. This seasonal pattern typifies the widely documented hypoxic/anoxic conditions that typically result in upper Charlotte Harbor as a result of the extreme water column stratification that commonly occurs near the mouth of the river and upper regions of the harbor during the summer. This typical observed seasonal depression of average water column dissolved oxygen concentrations in this reach of the lower river is generally more intense and of greater duration than that observed at the more upstream monitoring sites. However, during 2007 average water column dissolved oxygen levels generally declined as water temperatures increased, reaching their lowest levels during August/September throughout both the lower river and upper harbor as water temperatures and flows increased. However, of particular note is the observation that during 2007 the water column profile data did not show any indication of the hypoxic/anoxic bottom dissolved oxygen levels that typically develop in the upper harbor during the summer. This strongly suggests that the historically low flows that occurred during the summer of 2007 were insufficient to induce the level of water column stratification necessary to cause the development of extremely low near bottom dissolved oxygen levels in upper Charlotte Harbor. Neither the 2006 nor 2007 HBMP water column profile data additionally indicated any lingering influences from the historically massive, wide spread depression of dissolved oxygen levels that occurred throughout the entire water column in the Charlotte Harbor Estuary following Hurricane Charlie in August 2004.

- **Light Extinction –** The 2007 HBMP data indicate that both the timing and magnitude of the ability of light to penetrate into the water column (1 percent depth) exhibit both strong temporal (seasonal) and spatial differences among the "fixed" monitoring sites along the HBMP lower Peace River/upper Charlotte Harbor sampling transect. In many other estuarine systems, the extinction of light is often highly influenced by ambient chlorophyll *a* concentrations (phytoplankton biomass). However, due to the "black water" characteristics of freshwater flows from the Peace River watershed into the harbor, light extinction in the lower Peace River/upper Charlotte Harbor estuarine system is primarily mediated by water color. **Figures 4.5a** through **4.5d** indicate that water clarity during 2007 was the greatest throughout the lower river and especially in the upper harbor during both the typical spring dry-season and other periods of lower flows (see **Figure 2.1**). The influences of the relatively low levels of highly colored freshwater flows throughout most of 2007 are clearly evident in the comparatively high one percent light depths observed in the most downstream upper harbor monitoring locations throughout the year.

- **Conductivity/Salinity** – **Figures 4.6a** through **4.6d** clearly show the influences of the drier than average conditions and the resulting much lower than average river flows during 2007 on the temporal and spatial patterns of conductivity (salinity) throughout the lower Peace River/upper Charlotte Harbor estuarine system. Comparisons of seasonal and spatial patterns during 2007 are particularly dramatic when contrasted with those over the recent wetter than average three-year period between 2003-2005. During this previous relatively wet three-year interval, higher conductivity harbor waters were not observed much upstream of approximately RK 26.0 throughout the entire year. However, during the spring dry-season and late fall of 2007, brackish conditions in the lower river extended upstream even beyond the Peace River Facility. Due to the extremely low relative freshwater inflows throughout 2007, seasonally low conductivity levels seasonally extended only downstream to approximately RK 23.6 during the 2007 summer wet-season. Such relatively high salinity conditions in the lower river have seasonally occurred both in 2006 and 2007, as well as during the extended drought that affected southwest Florida and the Peace River basin during much of the 1999-2002 period. During these years, very high conductivities have been observed even at the most upstream sampling locations during extended periods of low freshwater inflows.

4.4.2 Chemical Water Quality Characteristics (2007)

The 2007 water chemistry data for the five "fixed" water quality stations are contained in the appropriate summary data sets and summarized in **Table 1.3** (see **Section 1**). Comparisons of surface and bottom samples for selected parameters are graphically summarized in **Figure 4.7** through **Figure 4.15** (Table 4.3).

Table 4.3
Summary Graphics of Chemical Water Quality Measurements for Monthly Data Collected During 2007 at the Fixed Sampling Locations
(River Kilometers –2.4, 6.6, 15.5, 23.6 and 30.4)

Figure	Description
Figure 4.7a	Monthly surface color at fixed sampling stations (2007)
Figure 4.7b	Monthly bottom color at fixed sampling stations (2007)
Figure 4.8a	Monthly surface total suspended solids at fixed sampling stations (2007)
Figure 4.8b	Monthly bottom total suspended solids at fixed sampling stations (2007)
Figure 4.9a	Monthly surface nitrite/nitrate at fixed sampling stations (2007)
Figure 4.9b	Monthly bottom nitrite/nitrate at fixed sampling stations (2007)
Figure 4.10a	Monthly surface total Kjeldahl Nitrogen at fixed sampling stations (2007)
Figure 4.10b	Near bottom total Kjeldahl Nitrogen at fixed sampling stations (2007)
Figure 4.11a	Monthly surface ortho-phosphorus at fixed sampling stations (2007)
Figure 4.11b	Monthly bottom ortho-phosphorus at fixed sampling stations (2007)
Figure 4.12a	Monthly surface silica at fixed sampling stations (2007)
Figure 4.12b	Monthly bottom silica at fixed sampling stations (2007)
Figure 4.13a	Monthly surface chlorophyll *a* at fixed sampling stations (2007)
Figure 4.13b	Monthly bottom chlorophyll *a* at fixed sampling stations (2007)

These graphics indicate that, for a number of water quality constituents, there were strong spatial and temporal seasonal differences within the areas of the lower Peace River/upper Charlotte Harbor Estuary represented by the five “fixed” water quality monitoring locations. In addition, further differences are also apparent both within and among sampling locations between sub-surface and near-bottom samples. Water color, for example, is clearly seasonally higher further upstream, while late summer water color levels near the river’s mouth are often higher at the surface than near the bottom.

A number of other measured water quality parameters indicated strong seasonal relationships related to annual patterns of increasing and decreasing flow, while other seasonal patterns and spatial relationships for these water quality characteristics reflect far more complex relationships.

- **Total Suspended Solids** – The highest levels of total suspended solids near the surface of the water column often occurred during the spring and fall near the mouth of the river. These seasonal patterns probably reflect both temporal and spatial plankton production patterns in the upper estuary. Correspondingly, lowest levels often occur in the lower river and upper harbor during the summer wet-season, while the very highest measured levels are typically observed near the bottom of the water column. During 2007, the seasonal patterns in total suspended solids deviated from the more normal patterns due both to unusual higher flows during February and the very low summer wet-season inflows.

- **Inorganic Nitrite+Nitrate Nitrogen** – In the Charlotte Harbor estuarine system inorganic nitrite+nitrate nitrogen concentrations are typically the lowest during the peak of the spring dry-season, when high light and water temperatures result in increased phytoplankton production and freshwater inflows are low. Concentrations rapidly increase in the lower salinity reaches of the estuary with higher flows as nitrogen is carried from the watershed and increasing color reduces light penetration of the water column and phytoplankton growth. The data indicated that there is often a distinct spatial gradient in inorganic nitrogen with higher levels progressively occurring upstream. During 2007 inorganic nitrogen concentrations downstream in upper Charlotte Harbor were low or at near detection limits throughout the entire year due to the low volume of freshwater inflows.

- **Total Kjeldahl Nitrogen –** Typically, total Kjeldahl nitrogen concentrations in the lower Peace River/upper Charlotte Harbor estuarine system are generally the highest during the summer wet-season, reflecting the influences of increased freshwater inflows. During both 2006 and 2007 overall total Kjeldahl nitrogen levels were notably lower in comparison to the preceding much wetter 2003-2005 time interval.

- **Ortho-Phosphorus** – As previously discussed (see **Section 3**), inorganic phosphorus concentrations in the Peace River estuary follow patterns typical of conservative water quality constituents. Estuarine phosphorus concentrations are primarily influenced by dilution of high ambient levels in Peace River freshwater by saline Gulf water moving up the harbor. Thus the HBMP monitoring data typically indicate distinct spatial patterns in inorganic phosphorus concentrations among the sampling sites, with concentrations being markedly higher upstream than downstream. Following Hurricane Charlie in August 2004 (and the subsequent Hurricanes Frances and Jeanne storms in September), the data indicated that there were atypical marked increases in inorganic phosphorus levels associated with high levels of hurricane related flows from the Peace River watershed. During the wetter than average conditions during 2005, inorganic phosphorus patterns in the lower river/upper harbor estuarine system returned to more typical seasonal patterns. However, during the dry conditions that characterized both 2006 and 2007, phosphorous concentrations in the lower river/upper harbor estuarine system have returned to higher levels not seen in over two decades. As previously, discussed in **Section 3** the exact cause for the observed increases since 2004 currently remains unknown.

- **Silica –** Annual reactive silica concentrations in the Peace River estuary characteristically indicate a number of differing temporal and spatial patterns. Typically, during the spring dry-season silica levels are annually the lowest throughout the lower Peace River/upper Charlotte Harbor estuarine system corresponding to depressed flow inputs and periods of increased chlorophyll *a* biomass (potentially reflecting uptake by diatoms in the phytoplankton). Then usually during May and June, as water temperatures increase and the start of the summer wet-season begins, concentrations often rapidly increased throughout the estuary. However, reactive silica concentrations during 2007 also continued to reflect the recently observed pattern of increasing levels noted in previous HBMP reports. Peak silica levels were generally near or at seasonally historically high levels during 2007. The specific cause(s) for the observed recent increases in silica concentrations remain unknown, although as suggested in **Section 3** changes in concentrations may possibly be associated with unidentified recent alterations of land use patterns in the watershed.

- **Chlorophyll *a*** –Phytoplankton biomass (chlorophyll *a*) patterns in the lower Peace River/upper Charlotte Harbor Estuary are normally characterized by several seasonal peaks throughout the year that differed both seasonally and spatially among the HBMP "fixed" sampling locations. Typically chlorophyll *a* phytoplankton biomass in the lower Peace River/upper Charlotte Harbor Estuary showed distinct increases both during the spring with increasing light and water temperatures and during the late fall after wet-season flows have increased nitrogen levels and associated high color levels begin to decline. The common occurrences of such spring and fall phytoplankton increases have often been noted in conjunction with the HBMP isohaline-based monitoring program (**Section 3.0**). However, the seasonally high flows during February combined with the extremely low freshwater inflows during the 2007 summer wet-season resulted in some atypical shifts in the temporal patterns of phytoplankton increases (blooms) within the estuary. Chlorophyll *a* levels at a number of the HBMP sampling sites were seasonally unusually high during February and March showing responses to the atypical February flows. Additional spikes in chlorophyll *a* levels were observed in the lower Peace River at RK 23.6 in July and RK 15.5 in August. These phytoplankton "blooms" were probably stimulated by nitrogen inputs during relatively inconsistent brief periods of higher flows during the early summer followed by intervals of lower flows and reduced water color. Chlorophyll *a* levels at the most downstream HBMP "fixed" station upper harbor monitoring site generally remained relatively low throughout the year due to the very low summer wet-season inflows.

4.4.3 Long-Term Physical and Chemical Water Quality Characteristics (1976-2007)

EQL conducted an extensive, long-term water quality monitoring program between 1976 and 1990 both within the lower Peace River and the Charlotte Harbor estuarine system, independent of the requirements of the HBMP, as part of an overall regional background water quality assessment for the General Development Corporation. These data included chemical water quality analyses of monthly surface and bottom samples, at the same locations, for many of the same parameters that were added to the HBMP permit requirements during 1996. **Figures 4.14** through **4.29** (Table 4.4) graphically compare the historical EQL estuarine data, for a selected number of surface and bottom measurements, gathered during the 1976-1990 period with those subsequently measured as part of the current HBMP effort during the more recent 1996-2007 time interval.

Table 4.4
Selected Long-Term Physical and Chemical Water Quality Data Collected Monthly During the Periods 1976-1990 and 1996-2007 at the Fixed Sampling Locations (River Kilometers –2.4, 6.6, 15.5, 23.6 and 30.4)

Figure	Description
Figure 4.14a	Monthly long-term surface salinity River Kilometer –2.4
Figure 4.14b	Monthly long-term surface salinity River Kilometer 6.6
Figure 4.14c	Monthly long-term surface salinity River Kilometer 15.5
Figure 4.14d	Monthly long-term surface salinity River Kilometer 23.6
Figure 4.14e	Monthly long-term surface salinity River Kilometer 30.4
Figure 4.15a	Monthly long-term bottom salinity River Kilometer –2.4
Figure 4.15b	Monthly long-term bottom salinity River Kilometer 6.6
Figure 4.15c	Monthly long-term bottom salinity River Kilometer 15.5
Figure 4.15d	Monthly long-term bottom salinity River Kilometer 23.6
Figure 4.15e	Monthly long-term bottom salinity River Kilometer 30.4
Figure 4.16a	Monthly long-term surface dissolved oxygen levels River Kilometer –2.4
Figure 4.16b	Monthly long-term surface dissolved oxygen levels River Kilometer 6.6
Figure 4.16c	Monthly long-term surface dissolved oxygen levels River Kilometer 15.5
Figure 4.16d	Monthly long-term surface dissolved oxygen levels River Kilometer 23.6
Figure 4.16e	Monthly long-term surface dissolved oxygen levels River Kilometer 30.4
Figure 4.17a	Monthly long-term bottom dissolved oxygen levels River Kilometer –2.4
Figure 4.17b	Monthly long-term bottom dissolved oxygen levels River Kilometer 6.6
Figure 4.17c	Monthly long-term bottom dissolved oxygen levels River Kilometer 15.5
Figure 4.17d	Monthly long-term bottom dissolved oxygen levels River Kilometer 23.6
Figure 4.17e	Monthly long-term bottom dissolved oxygen levels River Kilometer 30.4
Figure 4.18a	Monthly long-term surface water color River Kilometer –2.4
Figure 4.18b	Monthly long-term surface water color River Kilometer 6.6
Figure 4.18c	Monthly long-term surface water color River Kilometer 15.5
Figure 4.18d	Monthly long-term surface water color River Kilometer 23.6
Figure 4.18e	Monthly long-term surface water color River Kilometer 30.4
Figure 4.19a	Monthly long-term bottom water color River Kilometer –2.4
Figure 4.19b	Monthly long-term bottom water color River Kilometer 6.6
Figure 4.19c	Monthly long-term bottom water color River Kilometer 15.5
Figure 4.19d	Monthly long-term bottom water color River Kilometer 23.6
Figure 4.19e	Monthly long-term bottom water color River Kilometer 30.4

Table 4.4
Selected Long-Term Physical and Chemical Water Quality Data Collected Monthly During the Periods 1976-1990 and 1996-2007 at the Fixed Sampling Locations (River Kilometers –2.4, 6.6, 15.5, 23.6 and 30.4)

Figure	Description
Figure 4.20a	Monthly long-term surface nitrite/nitrate nitrogen River Kilometer –2.4
Figure 4.20b	Monthly long-term surface nitrite/nitrate nitrogen River Kilometer 6.6
Figure 4.20c	Monthly long-term surface nitrite/nitrate nitrogen River Kilometer 15.5
Figure 4.20d	Monthly long-term surface nitrite/nitrate nitrogen River Kilometer 23.6
Figure 4.20e	Monthly long-term surface nitrite/nitrate nitrogen River Kilometer 30.4
Figure 4.21a	Monthly long-term bottom nitrite/nitrate nitrogen River Kilometer –2.4
Figure 4.21b	Monthly long-term bottom nitrite/nitrate nitrogen River Kilometer 6.6
Figure 4.21c	Monthly long-term bottom nitrite/nitrate nitrogen River Kilometer 15.5
Figure 4.21d	Monthly long-term bottom nitrite/nitrate nitrogen River Kilometer 23.6
Figure 4.21e	Monthly long-term bottom nitrite/nitrate nitrogen River Kilometer 30.4
Figure 4.22a	Monthly long-term surface total Kjeldahl nitrogen River Kilometer –2.4
Figure 4.22b	Monthly long-term surface total Kjeldahl nitrogen River Kilometer 6.6
Figure 4.22c	Monthly long-term surface total Kjeldahl nitrogen River Kilometer 15.5
Figure 4.22d	Monthly long-term surface total Kjeldahl nitrogen River Kilometer 23.6
Figure 4.22e	Monthly long-term surface total Kjeldahl nitrogen River Kilometer 30.4
Figure 4.23a	Monthly long-term bottom total Kjeldahl nitrogen River Kilometer –2.4
Figure 4.23b	Monthly long-term bottom total Kjeldahl nitrogen River Kilometer 6.6
Figure 4.23c	Monthly long-term bottom total Kjeldahl nitrogen River Kilometer 15.5
Figure 4.23d	Monthly long-term bottom total Kjeldahl nitrogen River Kilometer 23.6
Figure 4.23e	Monthly long-term bottom total Kjeldahl nitrogen River Kilometer 30.4
Figure 4.24a	Monthly long-term surface ortho-phosphorus River Kilometer –2.4
Figure 4.24b	Monthly long-term surface ortho-phosphorus River Kilometer 6.6
Figure 4.24c	Monthly long-term surface ortho-phosphorus River Kilometer 15.5
Figure 4.24d	Monthly long-term surface ortho-phosphorus River Kilometer 23.6
Figure 4.24e	Monthly long-term surface ortho-phosphorus River Kilometer 30.4
Figure 4.25a	Monthly long-term bottom ortho-phosphorus River Kilometer –2.4
Figure 4.25b	Monthly long-term bottom ortho-phosphorus River Kilometer 6.6
Figure 4.25c	Monthly long-term bottom ortho-phosphorus River Kilometer 15.5
Figure 4.25d	Monthly long-term bottom ortho-phosphorus River Kilometer 23.6
Figure 4.25e	Monthly long-term bottom ortho-phosphorus River Kilometer 30.4

Table 4.4
Selected Long-Term Physical and Chemical Water Quality Data Collected Monthly During the Periods 1976-1990 and 1996-2007 at the Fixed Sampling Locations (River Kilometers –2.4, 6.6, 15.5, 23.6 and 30.4)

Figure	Description
Figure 4.26a	Monthly long-term surface silica River Kilometer –2.4
Figure 4.26b	Monthly long-term surface silica River Kilometer 6.6
Figure 4.26c	Monthly long-term surface silica River Kilometer 15.5
Figure 4.26d	Monthly long-term surface silica River Kilometer 23.6
Figure 4.26e	Monthly long-term surface silica River Kilometer 30.4
Figure 4.27a	Monthly long-term bottom silica River Kilometer –2.4
Figure 4.27b	Monthly long-term bottom silica River Kilometer 6.6
Figure 4.27c	Monthly long-term bottom silica River Kilometer 15.5
Figure 4.27d	Monthly long-term bottom silica River Kilometer 23.6
Figure 4.27e	Monthly long-term bottom silica River Kilometer 30.4
Figure 4.28a	Monthly long-term surface chlorophyll *a* River Kilometer –2.4
Figure 4.28b	Monthly long-term surface chlorophyll *a* River Kilometer 6.6
Figure 4.28c	Monthly long-term surface chlorophyll *a* River Kilometer 15.5
Figure 4.28d	Monthly long-term surface chlorophyll *a* River Kilometer 23.6
Figure 4.28e	Monthly long-term surface chlorophyll *a* River Kilometer 30.4
Figure 4.29a	Monthly long-term bottom chlorophyll *a* River Kilometer -2.4 **
Figure 4.29b	Monthly long-term bottom chlorophyll *a* River Kilometer 6.6 **
Figure 4.29c	Monthly long-term bottom chlorophyll *a* River Kilometer 15.5 **
Figure 4.29d	Monthly long-term bottom chlorophyll *a* River Kilometer 23.6 **
Figure 4.29e	Monthly long-term bottom chlorophyll *a* River Kilometer 30.4 **

- ❖ Note: EQL samples not analyzed for chlorophyll *a* are indicated as “Zero”
- ❖ Plot scales may not include unusually high “outlier” data points

These presented graphical analyses indicate the occurrence of a number of interesting patterns relative to long-term temporal and spatial water quality patterns within the lower Peace River/upper Charlotte Harbor estuarine system. The following summarizes several of the key observations that can be made from the presented plots of these long-term estuarine water quality data.

- Record high surface and bottom salinities occurred at each of the five HBMP “fixed” water quality monitoring locations during the extended drought that began in 1999 and extended through the first half of 2002. Then during the relatively high flow summer wet-seasons that occurred between 2003 and 2005, near record low salinity levels were observed both near the surface and bottom of the water column, at the more downstream sampling sites. Both 2006 and 2007 were again characterized by much drier than usual conditions in the Peace River watershed, which again resulted in much higher than usual seasonal salinities both in the lower Peace River and upper Charlotte Harbor.

- Salinities throughout the estuary were generally higher during both the 1999-2002 and 2006-2007 droughts than during the similar extended drought following the 1983 El Niño.

- Near-bottom dissolved oxygen concentrations show clear seasonal cycles in response to summer wet-season freshwater inflows. Both the duration and magnitude of these periods of depressed dissolved oxygen concentrations increase towards the river's mouth. The highly unusual period of widespread hypoxic/anoxic conditions that immediately followed Hurricane Charlie in August 2004 are evident from both the subsurface and near bottom measurements taken throughout the lower river and upper harbor. Dissolved oxygen levels recovered relatively quickly following this rare event, with little indication of any lingering influences.

- Temporally, water color levels increase very quickly in response to changes in freshwater inflows. As expected, color levels are spatially much higher upstream than near the mouth of the river, although very high color can reach well into the harbor during periods of high freshwater inflow.

- Both inorganic nitrite+nitrate nitrogen and total Kjeldahl nitrogen concentrations have indicated very similar seasonal patterns and levels of annual variation over the entire 32-year monitoring period. Spatially inorganic nitrogen concentrations markedly increase moving upstream. Peaks in total Kjeldahl nitrogen levels at the upstream sampling locations were clearly evident following Hurricane Charlie in August 2004.

- Most of the previously reported apparent marked declines in inorganic phosphorus concentrations that have occurred in the lower Peace River/upper Charlotte Harbor Estuary took place prior to 1985. Since that time inorganic phosphorus concentrations have shown fairly consistent seasonal patterns over a comparably narrow range of variation (excluding a few periodic data points). However, since the end of the 1999-2002 drought the data indicate that phosphorus levels at the upper freshwater HBMP "fixed" monitoring station locations have increased to levels not seen for over 20 years, with the sharpest rise following Hurricane Charlie.

- Plots of the long-term data clearly show that reactive silica concentrations have both increased and exhibit a much wider range of variation during the recent 1996-2007 HBMP monitoring period when compared to older EQL background monitoring data collected during the 1976-1990 period. Silica levels are much higher at the upstream sampling sites, and show a strong seasonal pattern of increases with increasing flows.

- The long-term data show that high chlorophyll *a* concentrations or "blooms" commonly occurred during the late 1970s and early 1980s throughout the lower Peace River/upper Charlotte Harbor estuarine system. During the drier period of the later 1980s and early

> 1990s the frequency of such events declined. However, as flows have generally increased again over the past decade (even with the recent droughts) so have the occurrences of periodic spikes in phytoplankton biomass (chlorophyll *a*).

Table 4.5 presents statistical summaries of mean near-surface values at each of the five “fixed” sampling locations during 2007, and provides a comparison with the combined previous data gathered during the periods between 1976-1990 and 1996-2006.

5.0 USGS and HBMP Continuous Recorders

5.1 Introduction and Overview

The USGS began a cooperative water quality data collection program with the Authority in August 1996. An initial USGS continuous recorder (15-minute intervals) was installed later that month in the lower Peace River (**Figure 5.1**) at the end of an exiting private dock at Harbour Heights (RK 15.5). This USGS gaging site (02297460) monitors water level, surface and bottom specific conductance, and temperature.

The following month (September 1996) USGS installed an additional 15-minute recorder, which measured only water level at a site adjacent to Boca Grande. This site was located approximately near River Kilometer –31.8, and designated by USGS as 02293332. Tide stage data were collected at this location between 1996 and 2004. The original purpose of this gage was to assess potential gradual increases in sea level expected to occur over time in order to account for natural increases in salinity that might be occurring in the lower Peace River estuary. However, USGS staff felt that any conclusions regarding sea level rises at this site would be compromised due to the gage's location near the mouth of the Boca Grande Pass. The Authority (after consultation with the Scientific Review Panel and District staff) therefore decided to delete the continued collection of water level information at this site at the end of 2004.

The USGS added a second continuous recorder in the lower Peace River at the request of the Authority in November 1997 further upstream (RK 26.7) on a private dock near Peace River Heights (**Figure 5.1**). This USGS site (02297350) also measures water level, surface and bottom specific conductance, and corresponding temperatures at 15-minute intervals.

Water level measurements at these two USGS recording sites are made utilizing a float sensor in a PVC stilling well. USGS combination temperature and specific conductance probes are used to measure near-surface and near-bottom specific conductance and temperature. The near-surface sensors are suspended one-foot below the surface using a float, while the near-bottom sensors are suspended about one-foot from the bottom in the same stilling well. Readings are electronically averaged over two-minute intervals and recorded at 15-minute intervals using a Campbell Scientific CR-10 electronic data logger. Data are retrieved and the sensors are recalibrated at approximately monthly intervals.

The particular locations of the USGS recorders on existing docks were established in part due to the USGS need to be able to have land based access for the ease of routine maintenance and the downloading of data. The influences of tide, wind and antecedent flow conditions can individually and combined result in an extremely wide range of observed variation in daily averaged conductivity measurements at the Harbour Heights gage located at RK 15.5 when compared to corresponding flows at the Peace River at Arcadia gage (**Figures 5.2** and **5.3**). The influences of these confounding affects by comparison are noticeably less at the more upstream USGS Peace River Heights gaging site located at RK 26.7 (**Figures 5.4** and **5.5**).

Table 5.1
Average Daily Conductivity at the two USGS Continuous Recorders Versus Peace River at Arcadia Flow

USGS Gage / River Kilometer	Subsurface Conductivity	Near Bottom Conductivity
Harbour Heights (RK 15.5)	**Figure 5.2**	**Figure 5.3**
Peace River Heights (RK 26.7)	**Figure 5.4**	**Figure 5.5**

The 1996 renewal of the Facility's Water Use Permit set a threshold of 130 cfs at the USGS Peace River at Arcadia gage for the start of freshwater withdrawals. (**Section 2.2** and **Table 2.5** summarize the temporary withdrawal changes made during 2007 due to the severity of the 2006-2007 drought). However, as shown in Table 5.1, salinity levels are often extremely low in the reach of the river (River Kilometer (RK) 26.7) at the Peace River Heights USGS recorder (**Figure 5.1**), which is often characterized by freshwater conditions when Peace River at Arcadia flows are 130 cfs or greater. While the physical location of this upstream continuous recorder is appropriate to detect potential long-term systematic shifts in the freshwater/saltwater interface during low levels of freshwater inflow, it is extremely doubtful if the direct influences of the Facility withdrawals can typically be measured at this upstream location when flows are near or above 130 cfs.

Therefore, the *2002 HBMP Comprehensive Report* (finalized in September 2004) recommended that an additional series of continuous conductivity gages be established by the Authority downstream of the USGS Peace River Heights recorder location. The primary objective of installing an additional series of HBMP continuous conductivity recorders, when combined with the two existing long-term USGS sites, was to obtain greater resolution of the direct relationships among freshwater flow, stage height, and conductivity downstream of the Facility during periods of withdrawals. The addition of these gages was specifically designed to determine potential salinity changes during Facility withdrawals within the reach of the river characterized by the movement of the freshwater/saltwater interface at flows immediately above (or below) the 130 cfs threshold. The primary objective of selected locations of these additional gages was, therefore, to assure and enhance the monitoring program's ability to directly measure salinity changes due to Facility withdrawals under lower flow conditions.

A number of possible alternative sites and deployment methodologies were evaluated by the Authority to assure that these monitoring objectives were met by the additional HBMP continuous conductivity recorders. The first step in deploying these instruments was to determine the potential spatial distribution of arraying the recorders downstream of the Facility. Again, the primary objective was to spatially maximize the new recorders' ability to detect salinity changes (impacts) that could be directly attributed to Facility freshwater withdrawals. Existing statistical models and graphical analyses of salinity/flow relationships were reviewed from the long-term HBMP fixed stations and USGS continuous recorders along the lower Peace River HBMP monitoring transect. These results were next evaluated in relationship to potential existing physical structures (docks, pilings, etc.) to which additional continuous recorders might be attached (**Table 5.2**). A series of potential new monitoring sites located between the two existing USGS continuous recorders were selected and evaluated. The recent placement of a large number of Manatee Speed Zone markers along the lower river provided a series of spatially distributed potential sites downstream of the Facility. The Authority received permission from U.S. Fish and Wildlife to establish continuous recorder locations using these Manatee markers.

Three of these Manatee Speed Zone markers were chosen for the initial deployment of the new HBMP continuous recorders, and the locations of these are indicated by the light-green arrows in **Figure 5.1**.

- **MZ4** –The Manatee Speed Zone Marker located on the Peace River near the Liverpool side channel (RK 21.9).
- **MZ3** – The Manatee Speed Zone Marker located on the Peace River at RK 23.4.
- **MZ2** – The Manatee Speed Zone Marker located on the Peace River just downstream of the Navigator Marina (RK 24.5).

The methodologies used for deployment of the three new continuous recorders are depicted in **Figure 5.6** and **Photographs 5.1** through **5.4**.

- **Figure 5.6** – This diagram shows the method used to attach the PVC stilling well to the deep side of the selected Manatee Speed Zone Markers, using a series of stainless steel clamps.
- **Photo 5.1** – The photograph shows actually strapping the PVC stilling well to the inside of one of the Manatee Speed Zone Markers.
- **Photo 5.2** – The method used to attach the YSI conductivity/temperature sonde to the bullet floats is shown in this photograph. The size of the bullet floats was selected based on the weight of the sonde, and the diameter of the stilling well. Unlike the USGS continuous recorders, these YSI units have been deployed to measure conductivity and temperature only just below the surface. The Manatee Speed Zone Markers are located in relatively shallow depths along the sides of the main river channel. These locations are therefore not well suited for measuring differences between surface and bottom values.
- **Photo 5.3** – This photograph shows the YSI conductivity/temperature sonde attached to two bullet floats being readied for placement in the stilling well.
- **Photo 5.4** – This last photograph shows the stilling well (with the locking cap) as seen from the river.

Data from these recorders are retrieved at approximately monthly intervals (or more often as needed). A complete cleaned, calibrated and checked set of sondes are typically deployed each month. However, if this is not possible, then the data are retrieved, the stability of the specific conductance and temperature sensors are checked, and the conductivity probes are cleaned and recalibrated. The factory calibrated temperature is checked against a second instrument, while specific conductance is calibrated against standards with values that bracket the range of expected values in the Peace River. The sensors are considered calibrated if the temperature is within 0.2 °C and specific conductance is within five percent of the standard values.

5.2 Results from USGS Continuous Recorders (2007)

All current (2007) and historical data gathered at the USGS continuous recording conductivity gages at the two USGS lower Peace River continuous gages located at Harbour Heights (0229746) and Peace River Heights (02297350), as well as historical information for stage level gage near Boca Grande (2293332) are contained in the appropriate summary data sets summarized in **Table 1.3** (see **Section 1**).

Gage height, as well as surface and bottom conductivity and temperature readings collected in 2007 at 15-minute intervals at Harbour Heights on the Peace River (USGS Station 02297460, RK 15.5) are presented in **Figures 5.7** through **5.11**. Similar plots are shown in **Figures 5.12** through **5.16** for the continuous gage at Peace River Heights on the Peace River (USGS Station 02297350, River Kilometer 26.7). These graphics are summarized in Table 5.3.

The duration and magnitude of the extremely low freshwater inflows from the Peace River watershed are clearly evident by the surface and bottom conductivities observed at both the Harbour Heights (RK 15.5) and Peace River Heights (RK 26.7) gages throughout most of 2007. Conductivities at the more upstream Peace River Heights recording gage indicated the extent and duration of the upstream movement of higher conductivity harbor waters during 2007. High conductivity water (5,000 – 20,000 uS/cm) extended upstream into this characteristically freshwater reach of the lower river during January, from mid-March through the first part of July, and then again during November and December. This is in direct contrast to the preceding much wetter years (2003-2005) when conductivities at the Peace River Heights gage exceeded 1000 uS/cm for only just a few days over the entire year.

Table 5.3
Summary Graphics of 2007 Data from USGS Continuous Recorders

Figure	Description
Figure 5.7	Gage height (15-minute intervals) for Peace River fixed station at Harbour Heights – USGS Gage 02297460 (River Kilometer 15.5)
Figure 5.8	Surface conductivity (15-minute intervals) for Peace River fixed station at Harbour Heights – USGS Gage 02297460 (River Kilometer 15.5)
Figure 5.9	Bottom conductivity (15-minute intervals) for Peace River fixed station at Harbour Heights – USGS Gage 02297460 (River Kilometer 15.5)
Figure 5.10	Surface temperature (15-minute intervals) for Peace River fixed station at Harbour Heights – USGS Gage 02297460 (River Kilometer 15.5)
Figure 5.11	Bottom temperature (15-minute intervals) for Peace River fixed station at Harbour Heights – USGS Gage 02297460 (River Kilometer 15.5)
Figure 5.12	Gage height (15-minute intervals) for Peace River fixed station at Peace River Heights – USGS Gage 02297350 (River Kilometer 26.7)
Figure 5.13	Surface conductivity (15-minute intervals) for Peace River fixed station at Peace River Heights – USGS Gage 02297350 (River Kilometer 26.7)
Figure 5.14	Bottom conductivity (15-minute intervals) for Peace River fixed station at Peace River Heights – USGS Gage 02297350 (River Kilometer 26.7)
Figure 5.15	Surface temperature (15-minute intervals) for Peace River fixed station at Peace River Heights – USGS Gage 02297350 (River Kilometer 26.7)

Table 5.3
Summary Graphics of 2007 Data from USGS Continuous Recorders

Figure	Description
Figure 5.16	Bottom temperature (15-minute intervals) for Peace River fixed station at Peace River Heights – USGS Gage 02297350 (River Kilometer 26.7)

Comparisons of gage heights and both surface and bottom conductivity measurements at the two Peace River gage locations, Harbour Heights (RK 15.5) and Peace River Heights (RK 26.7), are presented in **Figures 5.17** through **5.28** for the last two weeks in May 2007 (dry-season) and first two weeks of September 2007 (wet-season). These intervals were selected as representative of some of the lowest and highest flows observed during 2007. An overview of these graphics is presented in Table 5.4.

Table 5.4
Summary Graphics of Comparisons of Stage Height and Surface and Bottom Conductivity During May and September 2007 at the USGS Continuous Recorders

Figure	Description
Figure 5.17	Surface conductivity and stage height in May - station 02297460 (River Kilometer 15.5)
Figure 5.18	Bottom conductivity and stage height in May – station 02297460 (River Kilometer 15.5)
Figure 5.19	Surface and bottom conductivity in May - station 02297460 (River Kilometer 15.5)
Figure 5.20	Surface conductivity and stage height in September -station 02297460 (River Kilometer 15.5)
Figure 5.21	Bottom conductivity and stage height in September – station 02297460 (River Kilometer 15.5)
Figure 5.22	Surface and bottom conductivity in September – station 02297460 (River Kilometer 15.5)
Figure 5.23	Surface conductivity and stage height in May - station 02297350 (River Kilometer 26.7)
Figure 5.24	Bottom conductivity and stage height in May - station 02297350 (River Kilometer 26.7)
Figure 5.25	Surface and bottom conductivity in May – station 02297350 (River Kilometer 26.7).
Figure 5.26	Surface conductivity and stage height in September - station 02297350 (River Kilometer 26.7)
Figure 5.27	Bottom conductivity and stage height in September - station 02297350 (River Kilometer 26.7)
Figure 5.28	Surface and bottom conductivity in September - station 02297350 (River Kilometer 26.7)

As indicated in previous HBMP annual reports, **Figures 5.17** and **5.18** show that both surface and bottom conductivities at the downstream Harbour Heights site (RK 15.5) are very strongly influenced by tide (water stage) during periods when river flows are relatively low. During May, in the dry-season, it was not uncommon for surface and bottom conductivities to vary 7000 to 15000 uS/cm (roughly from 4 to 9.0 psu) over a tidal cycle. During September, in the wet-season, this lower reach of the Peace River is characteristically far fresher and daily variations in both surface and near bottom conductivities resulting from tidal influences are greatly reduced, often varying over a range of less than 0.2 psu. However, during September 2007, wet-season freshwater inflows were still historically low, and conductivities in this lower reach of the river were still very high.

At the more upstream continuous USGS gage at Peace River Heights (RK 26.7), the conductivity data collected in 2007 showed surface and bottom conductivities varying 5000 to 15000 uS/cm (roughly from 3 to 9.0 psu) over a tidal cycle during the May spring dry-season. This is again in direct contrast to recent wetter years such as 2005, when the data indicate only small, infrequent differences in conductivity (usually less than 100 uS/cm) resulting from tidal variations during the May 2005 dry-season. During September 2007, conductivities were low, but still showed small variations (**Figures 5.26** and **5.27)** due to normal daily tidal cycles in water levels due to the historically low wet-season flows.

5.3 Results from HBMP Continuous Recorders (2007)

All 2007 data for the three HBMP continuous (15-minute interval) conductivity gages attached to Manatee Seed Zone at River Kilometers 21.9, 23.4 and 24.5 (**Figure 5.1**) are contained in the appropriate summary data sets summarized in **Table 1.3** (see **Section 1**).

- **MZ4 –** Near surface conductivity and temperature at 15-minute intervals from the HBMP continuous recording gage attached to the Manatee Speed Zone Sign located on the Peace River near Liverpool side channel (River Kilometer 21.9).

- **MZ3 –** Near surface conductivity and temperature at 15-minute intervals from the HBMP continuous recording gage attached to the Manatee Speed Zone Sign located on the Peace River at River Kilometer 23.4.

- **MZ2 –** Near surface conductivity and temperature at 15-minute intervals from the HBMP continuous recording gage attached to the Manatee Speed Zone Sign located on the Peace River just downstream of Navigator Marina (River Kilometer 24.5).

Surface conductivity readings collected in 2007 at 15-minute intervals at the three HBMP continuous recorder sites are presented in **Figures 5.29** through **5.31**. More detailed graphics of this 15-minute data are also presented over two week intervals during both periods of spring dry-season low flow at the end of May (**Figures 5.32** through **5.34**) and summer wet-season high flow over the first two weeks of September (**Figures 5.35** through **5.37**). Single graphics directly comparing spatial differences among the three sites are further presented for these same two seasonally dry and wet time periods as both 15-minute interval data and as daily averages in **Figures 5.38** through **5.41**. These graphics are summarized in Table 5.5.

As previously discussed with respect to corresponding data from the two USGS continuous gages located downstream and upstream of these HBMP recorder locations, surface conductivities typically show a great degree of daily tidal variability during periods of low flow and usually only very small or limited tidal salinity changes during higher flows. However, due to the historically low wet-season flows that occurred during the summer of 2007, the region of the lower river characterized by the three HBMP recorders experienced daily tidal increases in salinities throughout almost the entire year.

Table 5.5
2007 HBMP Continuous Recorder Results

Location	Jan-Dec 2007	May 2007	September 2007	Comparison of Three Sites May 2007		Comparison of Three Sites September 2007	
				15-Minute	Daily Average	15-Minute	Daily Average
MZ4 (RK 21.9)	Figure 5.29	Figure5.32	Figure 5.35	Figure 5.38	Figure 5.39	Figure 5.40	Figure 5.41
MZ3 (RK 23.4)	Figure 5.30	Figure 5.33	Figure 5.36				
MZ2 (RK 24.5)	Figure 5.31	Figure 5.34	Figure 5.37				

5.4 Summary Comparisons among USGS and HBMP Continuous Recorders

The seasonal and daily ranges of variation in salinity at the three HBMP continuous recorders are statistically summarized and compared with similar data from the two USGS recorders over the past two years in Tables 5.6 (2006) and 5.7 (2007).

Table 5.6
Seasonal and Daily Ranges of Salinity at the Two USGS and Three HBMP Continuous Recorders during 2006

Location	Annual Salinity Statistics				Daily Change (Δ) in Salinity			
	Mean Salinity (psu)	Median Salinity (psu)	Minimum Salinity (psu)	Maximum Salinity (psu)	Mean Salinity Change (psu)	Median Salinity Change (psu)	Minimum Salinity Change (psu)	Maximum Salinity Change (psu)
Harbour Heights (RK 15.5)	8.1	7.6	0.1	24.7	6.0	6.0	0	14.3
MZ4 (RK 21.9)	2.7	0.9	0.1	18.6	3.4	3.1	0	13.7
MZ3 (RK 23.4)	2.0	0.5	0.1	18.3	3.1	2.3	0	14.1
MZ2 (RK 24.5)	1.6	0.4	0.1	16.5	2.8	1.9	0	13.3
Peace River Heights (RK 26.7)	1.1	0.3	0.1	14.1	1.6	1.0	0	10.4

Table 5.7
Seasonal and Daily Ranges of Salinity at the Two USGS and Three HBMP Continuous Recorders during 2007

Location	Annual Salinity Statistics				Daily Change (Δ) in Salinity			
	Mean Salinity (psu)	Mean Salinity Change (psu)	Mean Salinity Change (psu)	Mean Salinity Change (psu)	Mean Salinity Change (psu)	Median Salinity Change (psu)	Minimum Salinity Change (psu)	Maximum Salinity Change (psu)
Harbour Heights (RK 15.5)	13.1	13.6	0.5	30.6	13.0	8.0	2.3	15.8
MZ4 (RK 21.9)	5.1	4.0	0.2	23.3	5.8	5.0	0.1	17.7
MZ3 (RK 23.4)	3.9	2.6	0.2	25.1	5.0	3.7	0.0	21.5
MZ2 (RK 24.5)	3.1	1.5	0.2	23.8	4.5	3.0	0.0	20.8
Peace River Heights (RK 26.7)	1.7	0.5	0.2	22.2	2.8	1.5	0.0	20.5

Peace River watershed flows during 2006 were unusually low, except for a brief period from the end of August through mid September following tropical storm Ernesto (which passed from south to north across Florida east of the Peace River watershed). This is especially apparent, when making comparisons with the extended high seasonal flows that characterized much of the preceding three-year period between 2003 and 2005 (**Figure 2.7**). Thus, comparisons of the annual and daily statistical summary salinity values presented in these two tables further emphasize just how extremely dry conditions were in 2007. Not only were mean and median salinities measurably higher at each of the five continuous recorder locations during 2007 than in 2006, but there were large differences in both the maximum recorded levels and observed ranges of daily tidal variability. **Figures 5.42** and **5.43** further graphically depict the spatial and temporal salinity differences between the past two years along the lower Peace River.

As these summary statistics indicate, salinities (conductivity) naturally vary over fairly broad ranges under low flow conditions in the reach of the river downstream of the Peace River Facility. Historical and recent statistical models presented in the *2007 Draft "Pump Test" Findings* and the draft *2006 HBMP Comprehensive Summary Report* have indicated that potential daily average salinity changes in the reach of the lower river characterized by the continuous recorders due to Facility freshwater withdrawals are estimated (modeled) to be in the range of 0.1-0.5 psu. As long as the withdrawal schedule limits potential modeled daily average changes to this range, salinity changes due to Facility withdrawals are expected to be small and difficult to directly measure.

6.0 Significant Environmental Change

Since its inception, the Hydrobiological Monitoring Program (HBMP) has incorporated numerous study elements directed toward assessing both the overall “health of the estuary” as well as impacts potentially associated with Facility withdrawals. None of the extensive HBMP analyses done to date have indicated any significant long-term physical, chemical or biological changes in the lower Peace River/upper Charlotte Harbor estuarine system, resulting from either current or historic water withdrawals by the Facility.

An approach for determining whether permitted surface withdrawals have or are causing adverse environmental changes in the estuary utilizing HBMP data was proposed in the *2002 HBMP Comprehensive Summary Report* and is summarized in this section. Additionally, this section recounts the hierarchy of management actions proposed to be implemented in response to detected changes that could forewarn of potential future changes that would constitute an adverse change.

6.1 Regulatory Basis of Review

The Southwest Florida Water Management District’s (District) *Basis of Review* has established a specific series of performance standards for water use permits associated with withdrawals from natural surface waterbodies, such as the Peace River.

- *Flow rates shall not deviate from the normal rate and range of fluctuation to the extent that water quality, vegetation, and animal populations are adversely impacted in streams and estuaries.*
- *Flow rates shall not be reduced from the existing level of flow to the extent that salinity distributions in tidal streams and estuaries are significantly altered as a result of withdrawals.*
- *Flow rates shall not deviate from the normal rate and range of fluctuation to the extent that recreational use or aesthetic qualities of the water resource are adversely impacted.*

From a technical standpoint, adverse environmental impact can be defined using a wide range of metrics that quantify deviations from the pre-withdrawal salinity patterns, water quality conditions, and the distribution and abundance of biological communities. The Peace River HBMP Scientific Review Panel (Panel) has been established primarily to assist District and Peace River Manasota Regional Water Supply Authority (Authority) staff in assessing the continued technical efficacy and ability of the HBMP to detect potential adverse impacts caused by the Facility, and secondarily to assist in the interpretation of analysis of HBMP data.

6.2 Resource Management Goals and Relevant Hydrobiological Indicators

In issuing the Peace River Facility’s Water Use Permit, the District has identified the primary resources of interest, as well as resource management and protection goals for the lower Peace River and upper Charlotte Harbor estuarine system.

1. Protect the extent, distribution, and diversity of physical and biological habitats in the lower Peace River and upper Charlotte Harbor.

2. Protect the abundance of fish and invertebrate species of sport and commercial importance in the lower Peace River and upper Charlotte Harbor.

3. Protect the estuarine fish nursery function in the lower Peace River and upper Charlotte Harbor.

4. Protect the spatial and temporal distributions of organisms that are important food sources for fish in the lower Peace River.

5. Protect seasonal patterns of nutrient delivery to the estuary so that trophic interactions are maintained in the lower Peace River and Goals 1 through 4 are met.

6. Protect seasonal patterns of organic matter delivery to the estuary so that trophic interactions are maintained in the lower Peace River and Goals 1 through 4 are met.

7. Protect the temporal and spatial characteristics of salinity distributions in the estuary so that Goals 1 through 4 are met.

8. Protect dissolved oxygen concentrations in the estuary so that Goals 1 through 4 are met.

9. Protect the abundance of any rare, threatened or endangered species that use the lower Peace River or upper Charlotte Harbor.

10. Protect suitable habitats and water quality for fish and wildlife that are not of sport or commercial importance.

6.3 Rationale for Defining Significant Environmental Change

Inherent in the District rules is the recognition that surface water withdrawals are linked to potential changes in salinity, associated water quality constituents and biological communities. Freshwater withdrawals have a direct and instantaneous physical affect on salinity, while the effects of freshwater withdrawals on other water quality constituents, and biological communities in particular, are typically indirect and more complex (**Figure 6.1**). Such indirect impacts are mediated by physical and chemical processes, and are typically manifested on slower time scales (i.e. weeks, months, or seasons).

District staff, with assistance from the HBMP Scientific Review Panel (Panel), is responsible for the interpretation of data collected from the HBMP and other sources to determine if the permitted Facility surface water withdrawals have caused harm to the lower Peace River/upper Charlotte Harbor estuarine systems. The term *adverse impact*, which is included in the Authority's water use permit, has a distinct legal meaning in the context of water use permitting. The HBMP Scientific Review Panel expressed a concern that delaying action until this regulatory threshold had been crossed limited the ability to avoid perceived potential impacts. Therefore, based on consultation with the HBMP Panel and District staff, the *2002 Peace River Comprehensive Summary Report* proposed that the less restrictive term *significant environmental* *change* be used by the Authority as a lower threshold criterion for assessing the findings of the HBMP

The following definition of *significant environmental change* has been revised slightly from that originally proposed to include not only differences from the pre-withdrawal condition (before 1980), but also to incorporate comparisons between more recent periods and conditions under differing permitted withdrawals.

Significant Environmental Change

> ***A detected change, supported by statistical inference or a preponderance of evidence, in the normal or previous abundance, distribution, species composition, or species richness of biological communities of interest in the lower Peace River and upper Charlotte Harbor that is directly attributable to reductions in freshwater inflows caused by permitted surface water withdrawals.***

Conditions meeting the working definition of *significant environmental change* stated above could be measured and described in many different ways. Some simple examples are described below.

1. **Significant environmental changes in lower river/upper harbor habitats** - this would include measurable spatial and temporal changes in the natural variability of the salinity structure of characteristic fixed and/or dynamic estuarine components of sufficient magnitude to alter effected biological communities.

2. **Change in species richness or community balance** - numerous measures and indices exist to describe species richness, community balance, and biodiversity (e.g. Shannon-Weaver index) for various biotic indicators.

3. **Dislocation of an indicator species' distribution -** the "center of abundance" statistic and observed first and last occurrences have been used in the HBMP with respect to the distribution of larval and juvenile fish, benthos, and vegetation.

4. **Elimination or reduced abundance of a "desirable" indicator species -** the elimination, or a significant reduction in the abundance, of a desirable (e.g. economically or ecologically important) indicator species would likely be considered a significant environmental change.

5. **Introduction or increased abundance of an "undesirable" indicator species** - the converse of the above described scenario, the introduction, or a significant increase in the abundance, of an "undesirable" (e.g. non-native or nuisance) indicator species within a reporting unit would also likely be considered a significant environmental change.

Using this framework for identifying whether a significant environmental change has occurred, a series of hierarchy of management responses can be developed and structured according to various potential criteria and outcome objectives.

6.4 Authority's Management Response Plan (MRP) to a Potential Observed Significant Environmental Change

Waiting until an adverse environmental impact has occurred to initiate appropriate management actions or remedial measures reduces the opportunity to adequately protect resources that may be at risk. Therefore, the Authority has adopted a MRP that is a proactive approach to protecting the resources of concern in the lower Peace River estuarine system.

The plan recommends that salinity deviations be used as the primary indicator of significant environmental change that could lead to potential adverse environmental impact. In addition, salinity deviations will be used as the triggering mechanism for a range of management responses aimed at reversing or minimizing the change to prevent potential adverse environmental impact. Salinity deviations from the target distribution (**Figure 6.2**) will be evaluated in terms of magnitude, spatial extent, and/or temporal duration to develop a decision tree that is linked to various management actions (**Figure 6.3**). Using this approach, the intensity and urgency of the management response would be appropriately linked to the degree of the observed salinity deviations.

Initial management actions will focus on determining if the observed deviation is in fact real and not a measurement error or an artifact of the sampling design. If the change is determined to be real, the next series of management actions will focus on better understanding and describing the change, and determining potential cause and affect relationships. Finally, the most intense management actions may involve regulatory enforcement actions as well as remediation and mitigation. A hierarchy of management actions, contained in the Authority's MRP is listed sequentially in order of increasing intensity and urgency below.

1. **Data QA/QC Audit** - This action would involve the performance of an intense QA/QC audit to determine if the detected change was the result of laboratory problems, data entry errors, violation of sampling protocols, etc.

2. **Data Comparison (Correlates)** - This action would involve a review of data correlates (e.g., specific conductance is a correlate to salinity) to determine if there is more than one line of evidence reflecting the detected change.

3. **Scientific Review Panel Meeting** - If Steps 1 and 2 indicate that the detected change is not due to quality control problems, and is reflected in multiple lines of evidence, the next step would be to convene a special meeting of the Panel. The purpose of the meeting would be to review the findings of Steps 1 and 2, and to determine a possible modified course of action to refine the understanding of the magnitude and extent of the detected change. If deemed appropriate, the Panel could recommend additional data analyses, or a redirected and focused sampling effort to better elucidate the detected change. Recommendations of the Panel would be subject to further review and approval by District staff.

4. **Redirected Sampling Effort** - This action would involve conducting more focused supplemental sampling in the affected river segments with the objective of gaining a better understanding of the detected change. The additional data collected from this effort could then be subjected to Steps 1 and 2 above if deemed appropriate. This action would

determine if detection of the change is repeatable under a more focused sampling program. Although this step could be valuable, it may not be necessary for a redirected sampling effort to be conducted for all hydrobiological changes detected by the HBMP. For some hydrobiological changes, District staff could recommend proceeding directly to Step 5 without conducting any redirected or additional sampling.

5. **Determination of Significant Environmental Change** - Based on the findings of Steps 1 through 4, the next step would be to reconvene the Panel with the objective of evaluating whether the detected change is substantial enough to potentially constitute an adverse environmental change. This step would involve a detailed assessment of the data analyses conducted in Steps 1 through 4 to ascertain whether conditions consistent with the working definition of significant environmental change presented above have been met. A formal determination of significant environmental change would be made via a consensus of professional opinion by District staff and the Panel members in consideration of technical and scientific factors only. Following this determination, the Peace River/Manasota Regional Water Supply Authority Board would be briefed on the findings and recommendations of District staff and the Panel.

6. **Regulatory Summit Meeting** – If, after the completion of Step 5, District staff and the Panel conclude that a significant environmental change has occurred, the next step would be to convene a meeting with all applicable regulatory agencies and affected parties to determine the appropriate regulatory course of action. At a minimum, the regulatory agencies represented would include the District and FDEP, however, depending on the environmental changes involved other state and federal agencies may be involved (e.g., Florida Fish and Wildlife Conservation Commission; U.S. Fish and Wildlife Service). Actions by the group in attendance would include revisiting Steps 1, 2 and 4 above. If after reviewing the presented evidence the group (via a consensus of professional opinion) formally determines that significant environmental change has occurred, then the group must decide on the urgency or type of regulatory actions required. Further actions could include deferral to the Water Management District Governing Board, or immediate enforcement of regulatory actions such as temporary modification of the withdrawal schedule. If more substantial regulatory actions such as permanent modifications to the withdrawal schedule and/or mitigation were determined to be appropriate, preparations would be made for presenting recommendations to the District Governing Board for formal action.

7. **District Governing Board Hearing** - This step would involve the presentation of data and other evidence indicating the occurrence of significant environmental change to the District Governing Board. The formal determination of adverse impact from a regulatory and legal standpoint would be made by the District Governing Board. If it is determined that the detected change constitutes an adverse environmental impact, then the Governing Board could require appropriate remediation and or mitigation.

8. **Remediation** - The requirement of appropriate remedial measures by the District Governing Board could include such actions as permanent modifications to the permitted withdrawal schedule. Modifications to the withdrawal schedule could include provisional

> or temporary reductions in withdrawal rates, or modifications to the schedules such that greater withdrawals would occur during high flows, but lesser withdrawals would occur during low flows. In the event that the permitted withdrawals resulted in irreversible significant harm to resources of concern, mitigation could be required.

In the implementation of the sequence of management responses described above, the primary objective is the prevention of any adverse impacts. However, the intensity of the management response should not be the only criteria considered. The detection of any hydrobiological change must always be framed within the degree of certainty that the detected change is real, and not solely due to chance. Therefore, the intensity of the management response should be tied not only to the magnitude or severity of the hydrobiological change, but also to the degree of certainty that the detected change is real, and whether it is caused by Authority withdrawals. Table 6.1 below presents a conceptual matrix approach that integrates the magnitude of the detected change and the probability that the change is due to chance alone (e.g. alpha).

Table 6.1
Conceptual Decision Matrix For Determining An Appropriate Management Response To Detected Hydrobiological Change

Probability of Making a Type I Error	**Magnitude of Detected Hydrobiological Change**		
Alpha	**Small**	**Moderate**	**Large**
0.20	Data Comparison	Scientific Review Panel Meeting	Redirected Sampling
0.10	Scientific Review Panel Meeting	Redirected Sampling	Determination of Significant Change
0.05	Redirected Sampling	Determination of Significant Change	Regulatory Summit Meeting

As shown in Table 6.1, the intensity of the selected management response is a function of both factors. If the detected change is relatively large, but the degree of certainty is low (e.g. high alpha) then a less intense management response would be appropriate. If, on the other hand, the detected change is considered to be moderate, but the degree of certainty is high (e.g. low alpha), then a more intense management response would be indicated. The application of this approach would obviously vary with the specific hydrobiological changes and statistical measures of certainty involved. The approach of the selected management response would also depend on whether the observed change was found to be attributable directly to Facility withdrawals or potentially to anthropogenic upstream activities.

6.5 Assessment of Permitted Withdrawals

Since its inception in 1976 the HBMP has incorporated numerous physical, chemical, and biological study elements directed toward assessing both the overall "health of the estuary" as well as direct and indirect adverse impacts potentially associated with Facility withdrawals. To date none of the extensive analyses that have been conducted in conjunction with these long-term monitoring program elements, and reported in numerous previous HBMP documents submitted to the District, have found or suggest any significant long-term physical, chemical or biological changes in the lower Peace River/upper Charlotte Harbor estuarine system resulting from either current or historic water withdrawals by the Facility. The data and analyses presented in this 2007 HBMP Annual Data Report continue to support this overall conclusion. Lower than average flows during 2007 resulted in upstream shifts in a number of water quality characteristics when compared to the longer, historic HBMP information. In other instances, constituents such as silica and ortho-phosphorus have shown progressive, systematic changes over time (trends). However, these trends have been shown to be associated with other changes in the watershed and not related to Facility withdrawals.

The analyses and evaluations of the 2007 HBMP data presented in Sections 2 through 5 neither indicated any potential “Significant Environmental Changes,” nor were any changes observed that required administrative action as per the Authority’s Management Response Plan

7.0 References

American Public Health Association, 1992, Standard methods for the examination of water and wastewater (18th edition): American Public Health Association, Washington, D.C.

Ardaman & Associates. 2002. Effects of Phosphate mining and other Land Uses on Peace River Flows. Florida Phosphate Council.

Barr, G. L., 1996, Hydrogeology of the Surficial and Intermediate Aquifer Systems in Sarasota and adjacent counties, Florida; U.S. Geological Survey Water Resources Investigations Report 96-4063, 81 p.

Basso, R. 2002. Surface water/ground water relationship in the Upper Peace River Basin. Hydrologic Evaluation Section, Southwest Florida Water Management District. Brooksville, FL. 47 pp.

Basso, R. 2003. Predicted Change in Hydrologic Conditions along the Upper Peace River due to a Reduction in Ground-Water Withdrawals. Hydrologic Evaluation Section. Southwest Florida Water Management District. 51 pp.

Basso, R.J., 2004. An Evaluation of Stream Flow Loss during Low Flow Conditions in the Upper Peace River (draft). Southwest Florida Water Management District.

Basso, R. and R. Schultz. 2003. Long-term variation in rainfall and its effect on Peace River flow in West-Central Florida. Hydrologic Evaluation Section. Southwest Florida Water Management District. 33 pp.

Beach, M. 2003. Technical Memorandum SWUCA: Estimation of Historical Ground-Water Withdrawals. Southwest Florida Water Management District.

Beach, M., Chan, D., Kelly, G.M. 2003. Southern District Ground-Water Flow Model, Version 1.0, SWFWMD Technical Report, Brooksville, Florida.

Boman, B.J., and Stover, E.W. 2002. Outline for Managing Irrigation of Florida Citrus with High Salinity Water. Publication. Institute of Food and Agricultural Sciences, University of Florida. Publication No. ABE 332.

Boynton, W.R., W.M. Kemp, and C.W. Keefe. 1982. A comparative analysis of nutrients and other factors influencing estuarine phytoplankton production. In V.S. Kennedy (Eds.), Estuarine Comparisons. Academic Press, New York, pp. 69-90.

Britton, L.J., and Greeson, P.E., eds., 1989, Methods for collection and analysis of aquatic biological and microbiological samples: U.S. Geological Survey Techniques of Water_Resources Investigations, Book 5, Chapter A4, 363 p.

Browder, J.A., and D. Moore. 1981. A new approach to determining the quantitative relationship between fishery production and the flow of fresh water to estuaries. *In* Proc. Nat. Symp. Of Freshwater Flow to Estuaries. Vol. 1. FWS/OBS-81/04, R. Cross, and D. Williams (Eds.), U.S. Fish & Wild. Serv., Wash. D.C.

Brown, M.T., and Tighe, R.E. 1991. Techniques and Guidelines for Reclamation of Phosphate Mined Lands, FIPR Publication #03-044-095

Coley, D.M, and P.R. Waylen. 2006. Forecasting dry season streamflow on the Peace River at Arcadia, Florida USA. Journal of American Water Resources Association. pp 851-862.

Cressie, N.A.C. 1993. *Statistics for Spatial Data*, Wiley & Sons, New York (p. 316-319).

Day, J.W., Jr., C.A.S. Hall, W. M. Kemp, and A. Yanez-Arancibia. 1986. Estuarine Science. John Wiley & Sons, New York.

Duinker, J.C. 1980. The estuary: its definition and geodynamic cycle. *In* E. Olausson and I. Cato (Eds.), Chemistry and Biochemistry of Estuaries. Wiley & Sons. New York. Pp. 1-35.

Enfield, D.B., A.M. Mestas-Nunez, and P.J. Trimble, 2001, The Atlantic Multidecadal oscillation and its relation to Rainfall and River Flows in the Continental U.S., Geophysical Research Letters, Volume 28, No. 10, pp. 2077-2080.

Environmental Quality Laboratory, Inc. 1979. Hydrobiological Monitoring. January 1976 through October 1978. Lower Peace River and Charlotte Harbor. Volumes I & II. Prepared for General Development Utilities.

Environmental Quality Laboratory, Inc. 1981. Hydrobiological Monitoring. February 1980 through February 1981. Lower Peace River and Charlotte Harbor. Prepared for General Development Utilities.

Environmental Quality Laboratory, Inc. 1983. Hydrobiological Monitoring Program. Data Report for the Period from March 1982 through February 1983. Covering the Lower Peace River and Charlotte Harbor. Prepared for General Development Utilities.

Environmental Quality Laboratory, Inc. 1984. Hydrobiological Monitoring Program. Report for the Period from March 1983 through February 1984. Covering the Lower Peace River and Charlotte Harbor. Prepared for General Development Utilities.

Environmental Quality Laboratory, Inc. 1992. Hydrobiological monitoring program summary report for the lower Peace River and Charlotte Harbor: Phytoplankton-Production and structure 1983-1991; Taxonomy 1.989-1991: Zooplankton -Structure and Taxonomy 1989-1991. Report prepared for the Peace River Manasota Regional Water Supply Authority.

Environmental Quality Laboratory, Inc. 1995. Hydrobiological Monitoring Program Summary Report for the Lower Peace River and Charlotte Harbor. Report prepared for the Peace River Manasota Regional Water Supply Authority.

Enfield, D.B, and L. Cid-Serrano. 2005. Projecting the Risk of Future Climate Shifts. Unpublished draft.

Estevez, E and Culter, J. 2001. Peace River Benthic Macroinvertebrate and Mollusk Indicators. Mote Marine Laboratory report prepared for the Peace River Manasota Regional Water Supply Authority.

Fairbridge, R.W. 1980. The estuary: its definition and geodynamic cycle. *In* E. Olausson and I. Cato (Eds.), Chemistry and Biochemistry of Estuaries. Wiley & Sons. New York. Pp. 1-35.

Filardo, M.J. and W.M. Dunstan. 1985. Hydrodynamic control of phytoplankton on low salinity waters of the James River estuary, Virginia. Est. Coastal and Shelf Sci., 21:653-667.

Fishman, M.J., and Friedman, L.C., eds., 1989, Methods for determination of inorganic substances in water and fluvial sediments: U.S. Geological Survey Techniques of Water_Resources Investigations, Book 5, Chap. A1, 545 p.

Flannery, M. and M. Barcelo. 1998. Spatial and temporal patterns of streamflow trends in the upper Charlotte Harbor watershed. In Proceedings of the Charlotte Harbor Public Conference and Technical Symposium. Charlotte Harbor National Estuary Program. Technical Report. No. 98-02.

Flannery, M.S., E.B. Peebles, and R.T. Montgomery. 2002. A percentage-of-flow approach for managing reductions of freshwater inflows from unimpounded rivers to southwest Florida estuaries. Estuaries 25:1318-1342.

Florida Marine Research Institute. 1998. Development of GIS-Based Maps to Determine the Status and Trends of Oligohaline Vegetation in the Tidal Peace and Myakka Rivers.

Friedman, L.C., and Erdmann, D.E., 1982, Quality assurance practices for the chemical and biological analyses of water and fluvial sediments: U.S. Geological Survey Techniques of Water_Resources Investigations, Book 5, Chap. A6, 181 p.

Geurink, Jeffrey S.; Mahmood Nachabe, Mark Ross, and Patrick Tara. 2000. Development of Interfacial Boundary Conditions for the Southern District Ground Water Model of the Southwest Florida Water Management District (Draft Final Report). Southwest Florida Water Management District. Brooksville, Florida.

Golder Associates. 2002. Ona Mine Project, IMC Phosphates Company, Hardee County, Florida. Draft Environmental Impact Statement.

Gore, J.A., C. Dahm, and C. Klimas. 2002. A review of “Upper Peace River: An Analysis of Minimum Flows and Levels August 25, 2002 Draft.” Prepared for the Southwest Florida Water Management District.

Gray, W.M., J.D. Sheaffer, and C.W. Landsea, 1997, Climate Trends associated with Multidecadal Variability of Atlantic Hurricane Activity “Hurricanes :Climate and Socioeconomic Impacts” H.F. Diaz and R.S. Pulwarty, Eds., Springer–Verlag, New York, 15-53.

Hammett, K. M., 1988. Land Use, Water Use, Streamflow, and Water-Quality Characteristics of the Charlotte Harbor Inflow Area, Florida. Open-File Report 87-472.

Hammett, K. M., 1990, Land Use, Water Use, Streamflow Characteristics, and Water Quality Characteristics of the Charlotte Harbor Inflow Area, Florida, U.S. Geological Survey Water-Supply Paper 2359-A, 64 p.

Hammett, K. M., 1992. Physical Processes, Salinity Characteristics, and Potential Salinity Changes due to Freshwater Withdrawals in the Tidal Myakka River, Florida. Water-Resources Investigations Report 90-4054.

Hickey, J., 1998, Analysis of Stream Flow and Rainfall at selected Sites in West-Central Florida, SDI Environmental Services, Inc., SDI Project No. WCF-840, 53 p.

Horowitz, A.J., Demas, C.R., Fitzgerald, K.K., Miller, T.L., and Rickert, D.A., 1994, U.S. Geological Survey protocol for the collection and processing of surface water samples for the subsequent determination of inorganic constituents in filtered water: U.S. Geological Survey Open_File Report 94_539, 57 p.

Janicki Environmental, Inc. 2002. Regression analysis of salinity-stream flow relationships in the lower Peace River/upper Charlotte Harbor estuary. Final report to the Southwest Florida Water Management District.

Janicki Environmental, Inc. 2003. Water quality data analysis and report for the Charlotte Harbor National Estuary Program. Final report.

Jitts, H.R. 1959. The adsorption of phosphate by estuarine bottom deposits. Aust. J. Mar. Freshwater Res., 10:7-21.

Kelly, M, 2004. Florida River Flow Patterns and the Atlantic Multidecadal Oscillation. Ecological Evaluation Section. Southwest Florida Water Management District. 79 pp & Appendices.

Kelly, M., A. Munson, J. Morales, and D. Leeper. 2005. Minimum Flows and Levels for the Middle Segment of the Peace River, from Zolfo Springs to Arcadia. Southwest Florida Water Management District.

Kemp, W.M. and Boynton, 1984. Spatial and temporal coupling of nutrient inputs to estuarine primary production: the role of particulate transport and decomposition. Bull. Mar. Sci., 35(3): 522-535.

Landsea,C.W., R.A. Pielke, Jr., A.M. Mestas-Nunez, and J.A. Knaff, 1999, Atlantic Basin Hurricanes: Indices of Climatic Changes, Climatic Change, 42, 89-129.

Lewelling, B. R, 1997. Hydrologic and Water-Quality Conditions in the Horse Creek Basin, West-Central Florida, October 1992-February 1995. Water-Resources Investigations Report 97-4077.

Lewelling, B. R., and Wylie, R. W., 1993. Hydrology and Water Quality of Unmined and Reclaimed Basins in Phosphate-Mining Areas, West-Central Florida. Water-Resources Investigations Report 93-4002.

Lewelling B. R., A. B. Tihansky, and J. L. Kindinger, 1998, Assessment of the Hydraulic Connection between Ground Water and the Peace River, West-Central, Florida, U.S. Geological Survey Water Resources Investigations Report 97-4211, 96 p

Longley, W.L. (Ed.). 1994. Freshwater inflows to Texas bays and estuaries: ecological relationships and methods for determination of needs. Texas Water Development Board and Texas Parks and Wildlife Department, Austin, TX. 386 pp.

McPherson, B. F., R. L. Miller, and Y.E. Stoker. 1997. Physical, Chemical, and Biological characteristics of the Charlotte Harbor Basin and Estuarine System, *in* Southwestern Florida – A Summary of the 1982-89 U.S. Geological Survey Charlotte Harbor Assessment and Other Studies, U.S. Geological Survey Water-Supply Paper 2486.

Michel, J.F., R.C. Work, F.W. Rose, and R.G. Rehrer. 1975. A Study of the Effect of Fresh Water Withdrawals on the Lower Peace River, DeSoto County, Florida. University of Miami Rosenstiel School of Marine and Atmospheric Science. UM-RSMAS#75002.

Patrick, T., Trout, K., Ross, M., Vomacka, J., and Stewart, M., 2003. Hydrologic Investigation of the Phosphate-Mined Upper Saddle Creek Watershed, West-Central Florida. University of South Florida. FIPR Publication: #03-118-203. Florida Institute of Phosphate Research, Bartow, Florida.

Peebles, E. 2002. An Assessment of the Effects of Freshwater Inflow on Fish and Invertebrate Habitat Use in the Peace River and Shell Creek Estuary. University of South Florida report to the Southwest Florida Water Management District.

Peek, H. M., 1951, Cessation of Flow of Kissengen Spring in Polk County, Florida, *in* Water resource Studies, Florida Geological Survey Report of Investigations No. 7, p. 73-82.

PBS&J and W. Dexter Bender. 1999. Syntheses of Technical Information. Volume 1. Charlotte Harbor National Estuary Program Technical Report No. 99-02.

PBS&J, Inc. 1999. Summary of Historical Information Relevant to the Hydrobiological Monitoring of the Lower Peace River and Upper Charlotte Harbor Estuarine System. Final report prepared for the Peace River Manasota Regional Water Supply Authority.

PBS&J, Inc. 2000. Morphometric Habitat Analysis of the Lower Peace River. Final report prepared for the Peace River Manasota Regional Water Supply Authority.

PBS&J, Inc. 2002. HBMP Midterm Interpretive Report. Final report prepared for the Peace River Manasota Regional Water Supply Authority.

PBS&J, Inc. 2002. Supplemental Analyses to the HBMP Midterm Interpretive Report. Report prepared for the Southwest Florida Water Management District.

PBS&J, Inc. 2003. 2002 HBMP Annual Data Report. Final report prepared for the Peace River Manasota Regional Water Supply Authority.

PBS&J, Inc. 2004. 2003 HBMP Annual Data Report. Final report prepared for the Peace River Manasota Regional Water Supply Authority.

PBS&J, Inc. 2004. 2002 Peace River HBMP Comprehensive Summary Report. Final report prepared for the Peace River Manasota Regional Water Supply Authority.

PBS&J, Inc. 2005. 2004 HBMP Annual Data Report. Final report prepared for the Peace River Manasota Regional Water Supply Authority.

PBS&J, Inc. 2006. Assessment of Potential Shell Creek Impacts Resulting from Changes in City of Punta Gorda Facility Withdrawals. Final report submitted to the Peace River/Manasota Regional Water Supply Authority & City of Punta Gorda Utilities Department.

PBS&J, Inc. 2006. 2005 HBMP Annual Data Report. Final report prepared for the Peace River Manasota Regional Water Supply Authority.

PBS&J, Inc. 2006. HBMP 2004 Mid-term Interpretive Report. Draft report prepared for the Peace River Manasota Regional Water Supply Authority.

PBS&J, Inc. 2007. 2006 HBMP Annual Data Report. Final report prepared for the Peace River/Manasota Regional Water Supply Authority.

PBS&J, Inc. 2007. Peace River Cumulative Impact Study. Final report prepared for the Florida Department of Environmental Protection.

PBS&J, Inc. 2008. 2006 HBMP Comprehensive Summary Report. Draft report prepared for the Peace River/Manasota Regional Water Supply Authority.

Pritchard, D.W. 1956. The dynamic structure of a coastal plain estuary. J. Mar. Res., 15:33-42.
Rantz and others, 1982a, Measurement and computation of streamflow: Volume 1. Measurement of stage and discharge: U.S. Geological Survey Water_Supply Paper 2175, p. 1_284.

Rantz and others, 1982b, Measurement and computation of streamflow: Volume 2. Computation of discharge: U.S. Geological Survey Water_Supply Paper 2175, p. 285_631.

Rieker, L; V. Korhnak, and M.T. Brown. 1991. The Hydrology of Reclaimed Phosphate-Mined Wetlands. In Techniques and Guidelines for Reclaiming of Phosphate Mine Lands. FIPR Pub. no. 03-044-095, Florida Institute of Phosphate Research. Bartow, Florida. pp 7-1 - 7-42.

Ross, M.A., J. S. Geurink, M. N. Nachabe, and P. Tara, 2001, Development of Interfacial Boundary Conditions for the Southern District Ground Water Model of the Southwest Florida Water Management District, Water Resources Report No. CMHAS.SWFWMD.00.03, 31 p.

SDI, Inc. 2003. Cumulative risk of decreasing streamflows in the Peace River watershed. Prepared for Peace River/Manasota Regional Water Supply Authority.

SDI Environmental Services, Inc. 2004. Development of Hydrologic Model to Assess Phosphate Mining on the Ona Fort Green Extension.

Schreuder, P.J., J.K. Earls, J.M. Duemeyer. 2006. Impact of Phosphate Mining on Streamflow. FIPR Publication No. 03-145-220.

Stanley, D.L., 1995, Standard procedures and quality_control practices for the U.S. Geological Survey National Field Quality Assurance program from 1982 through 1993: U.S. Geological Survey Open_File Report 95_317, 75 p.

Stanley, D.L., Shampine, W.J., and Schroder, L.J., 1992, Summary of the U.S. Geological Survey National Field Quality Assurance program from 1979 through 1989: U.S. Geological Survey Open_File Report 92_163, 14p.

Sholkovitch, E. 1976. Flocculation of dissolved organic and inorganic matter during mixing of river water and sea water. Geochim. Cosmochim. Acta., 40:831-845.

Stewart, H. G., 1966, Ground-Water Resources of Polk County, Florida Geological Survey Report of Investigations No. 44, 170 p.

Southwest Florida Water Management District. 2002. Upper Peace River: An analysis of minimum flows and levels, Draft. Ecologic Evaluation Section. Resource Conservation and Development Department. Brooksville, FL.

Southwest Florida Water Management District. 2002. An Analysis of Vegetation-Salinity Relationships in Tidal Rivers on the Coast of West Central Florida.

Southwest Florida Water Management District. 2004. Shell Creek and Prairie Creek Watersheds Management Plan – Reasonable Assurance Documentation. Shell, Prairie, and Joshua Creeks Watershed Management Plan Stakeholders Group.

Tyler, M.A. 1986. Flow induced variation in transport and deposition pathways in the Chesapeake Bay: the effect on phytoplankton dominance and anoxia. *In* Estuarine Variability – Proceedings of the Eighth Biennial International Estuarine Research Conference. Douglas A. Wolfe, editor. Academic Press, Inc.

URS, 2005. Hydrologic Condition Analysis. Charlotte Harbor National Estuary Program.

Ward, J.R., and Harr, C.A., eds., 1990, Methods for collection and processing of surface_water and bed_material samples for physical and chemical analyses: U.S. Geological Survey Open_File Report 90_140, 71 p.

Wershaw, R.L., Fishman, M.J., Grabbe, R.R., and Lowe, L.E., 1987, Methods for the determination of organic substances in water and fluvial sediments: U.S. Geological Survey Techniques of Water_Resources Investigations, Book 5, Chapter A3, 80 p.

White, W.A., 1970, The geomorphology of the Florida Peninsula: Florida Bureau of Geology Bulletin 51, 164 p.

2007 HBMP Tables

This section contains tables not included directly in the text for each section

- **Section 1 – Introduction / Summary**
- **Section 2 – Peace River Gaged Flows and Regional Water Supply Facility Withdrawals**
- **Section 3 – *In Situ* Physical Measurements, Water Chemistry and Phytoplankton Biomass at “Moving Isohaline Locations**
- **Section 4 – Water Chemistry Data Collected At “Fixed” Station Locations**
- **Section 5 – USGS and HBMP Continuous Recorders**

Table 1.1

HBMP Fixed Sampling Locations

USGS River Mile	USGS Location Number	Previous EQL Station Number	Additional Sampling	New River Kilometer designation based on Morphometric Study
Current *In Situ* Water Column Profile Sampling Locations				
CH6	265355082075500	9	Water Quality	**-2.4**
RM3.95	265640082033500	10	Water Quality	**6.6**
RM4.88	265724082024400	21		**8.4**
RM6.25	265727082012800	11		**10.5**
RM8.61	265711081595500	Shell Creek 9 (92)		**12.7**
RM8.6B	265819082003200	22		**12.8**
RM10.2	2297460	12	Water Quality/Tide Gage/Conductivity	**15.5**
RM11.2	270022081591000	23		**17.5**
RM 12.55	270124081592500	13		**20.1**
RM13.95	270235081592400	24		**21.9**
RM14.82	270318081593100	14	Water Quality	**23.6**
RM15.45	270337081595800	25		**24.7**
RM16.29	270418082001600	15		**25.9**
N/A	2297350	N/A	Tide Gage/ Conductivity	**26.7**
RM18.25	270451081595100	17		**29.5**
RM18.95	2297330	18	Water Quality	**30.4**
RM19.5	270537081585800	19		**32.3**
Previous Vegetation Transect Locations				
N/A	N/A	I		**15.6**
N/A	N/A	II		**22.3**
N/A	N/A	III		**20.4**
Previous EQL Water Column and Chemistry Sampling Sites				
N/A	N/A	16		**27.1**
N/A	N/A	20		**34.1**

Table 1.2
HBMP Chemical Water Quality Parameters

Ongoing Long-term Analytes	Analytes Deleted Starting March 2003
Salinity	Alkalinity
Chloride	Turbidity
Color	Total Phosphorus
Silica	Inorganic Carbon
Ortho-Phosphorus	Total Organic Carbon
Nitrate + Nitrite Nitrogen	Dissolved Organic Carbon
Ammonia/Ammonium Nitrogen	
Total Kjeldahl Nitrogen	
Total Nitrogen	
Suspended Solids	
Volatile Solids	
Chlorophyll *a*	

Table 2.8
Long-Term Yearly Mean Measurements of Peace River Flows and Facility Withdrawals during HBMP Monitoring Period

Year	Peace River Total Gaged Flow (cfs) at:			Withdrawals (cfs)		Peace River Facility Withdrawals as Percentages of Total Gaged Flows at:			Total of Authority and City of Punta Gorda Withdrawals as Percent of Total Gaged Flow as US 41 Bridge
	Arcadia	Peace River Facility	US 41 Bridge	Peace River Facility	City of Punta Gorda from Shell Creek	Arcadia	Facility	US 41 Bridge	
1976	704.5	784.2	960.8	No Withdrawals	2.5	No Withdrawals			0.3
1977	478.7	588.0	732.0		3.0				0.4
1978	997.3	1254.6	1525.8		3.0				0.2
1979	1171.5	1532.7	2080.5		3.2				0.2
1980	495.2	578.2	726.3	3.9	3.4	0.7	0.6	0.5	0.9
1981	288.4	442.3	629.7	5.1	3.7	1.8	1.2	0.8	1.4
1982	1610.5	2141.9	2746.9	5.9	3.9	0.4	0.3	0.2	0.4
1983	1371.4	1778.7	2319.9	5.1	3.8	0.4	0.3	0.2	0.4
1984	567.0	742.9	1102.7	4.1	4.2	0.7	0.6	0.4	0.8
1985	369.0	510.6	680.8	7.2	3.9	2.0	1.4	1.1	1.6
1986	549.0	781.3	1013.7	7.5	3.8	1.4	1.0	0.7	1.1
1987	802.8	1095.5	1357.8	7.6	3.8	1.0	0.7	0.6	0.8
1988	1054.1	1425.2	1738.4	9.5	5.0	0.9	0.7	0.6	0.8
1989	373.6	481.9	699.0	9.6	5.2	2.6	2.0	1.4	2.1
1990	402.4	544.5	741.4	8.7	5.3	2.2	1.6	1.2	1.9
1991	771.2	1063.7	1567.6	10.4	4.7	1.4	1.0	0.7	1.0
1992	784.6	1143.0	1543.7	9.4	5.0	1.2	0.8	0.6	0.9
1993	698.5	903.1	1249.3	12.0	4.9	1.7	1.3	1.0	1.4
1994	1365.9	1788.6	2259.0	11.7	5.0	0.9	0.7	0.5	0.7
1995	1708.1	2250.4	3071.6	12.2	4.9	0.7	0.5	0.4	0.6
1996	598.2	725.6	928.8	12.5	5.2	2.1	1.7	1.3	1.9
1997	1059.9	1439.0	1777.6	12.1	5.0	1.1	0.8	0.7	1.0
1998	1916.0	2459.9	2921.3	15.4	5.1	0.8	0.6	0.5	0.7
1999	565.9	782.7	1144.5	12.8	5.5	2.3	1.7	1.2	1.7
2000	138.7	220.8	335.3	5.7	6.1	4.1	2.6	1.7	3.5

Table 2.8
Long-Term Yearly Mean Measurements of Peace River Flows and Facility Withdrawals during HBMP Monitoring Period

Year	Peace River Total Gaged Flow (cfs) at:			Withdrawals (cfs)		Peace River Facility Withdrawals as Percentages of Total Gaged Flows at:			Total of Authority and City of Punta Gorda Withdrawals as Percent of Total Gaged Flow as US 41 Bridge
	Arcadia	Peace River Facility	US 41 Bridge	Peace River Facility	City of Punta Gorda from Shell Creek	Arcadia	Facility	US 41 Bridge	
2001	1038.4	1442.0	1936.9	7.9	6.1	0.8	0.6	0.4	0.7
2002	1180.7	1615.7	2191.2	22.8	6.5	1.9	1.4	1.0	1.3
2003	1856.3	2454.3	2921.9	26.1	6.8	1.4	1.1	0.9	1.1
2004	1746.5	2363.3	2788.1	24.2	6.9	1.4	1.0	0.9	1.1
2005	1859.9	2338.7	2954.7	29.1	6.9	1.6	1.2	1.0	1.2
2006	376.0	538.2	820.1	18.4	7.5	4.9	3.4	2.2	3.2
2007	173.1	237.6	353.2	17.3	7.3	10.2	7.3	4.9	7.1

Table 3.3

Water Chemistry Methods used during Isohaline Based “Moving” Station HBMP Monitoring Study Element

Parameter	Method	Detection Limit
Color	EPA 110.2	2.0 Co_Pt Units
Chloride	EPA 325.2	0.4 mg/l
Total Suspended Solids	EPA 160.2	0.6 mg/L
Volatile Suspended Solids	EPA 160.4	1.4 mg/L
NO2+NO3 Nitrogen	EPA 353.2	0.004 mg/l
NH3+NH4 Nitrogen	EPA 350.1	0.005 mg/l
Total Kjeldahl	EPA 351.2	0.05 mg/l
Ortho-Phosphorus	EPA 365.2	0.002 mg/l
Silica	EPA 370.1	0.04 mg/l
Iron	EPA 236.1	0.03 mg/l
Chlorophyll *a*	Flurometeric SM 10200H.3 Spectrophotometric SM10200H.2	0.25 ug/l 3.4 ug/l

Table 3.4
2007 Physical and Chemical Water Quality Parameters

Month	Sample Location	Temperature (C)	Color (CPU)	Light Extinction Coefficient (K)	Iron (mg/l)	Silica (mg/l)
Jan	0 psu	23.0	70	1.3	0.20	7.00
Jan	6 psu	22.2	70	1.9	0.14	5.87
Jan	12 psu	22.1	60	3.4	0.13	4.86
Jan	20 psu	21.5	50	1.5	0.20	3.40
Feb	0 psu	20.6	90	1.2	0.21	5.28
Feb	6 psu	20.3	80	2.5	0.16	5.52
Feb	12 psu	19.9	60	1.1	0.14	4.52
Feb	20 psu	19.5	30	1.1	0.14	3.00
Mar	0 psu	24.3	50	1.2	0.11	3.95
Mar	6 psu	23.2	70	0.5	0.13	3.80
Mar	12 psu	22.5	50	1.2	0.12	3.52
Mar	20 psu	22.0	50	1.1	0.10	3.23
Apr	0 psu	22.7	40	2.8	0.11	4.09
Apr	6 psu	23.7	45	0.7	0.09	2.88
Apr	12 psu	23.1	45	1.0	0.14	3.57
Apr	20 psu	21.9	30	1.1	0.12	2.04
May	0 psu	27.5	40	1.1	0.08	2.33
May	6 psu	27.5	45	1.6	0.13	4.91
May	12 psu	27.2	50	1.5	0.11	3.12
May	20 psu	26.6	40	1.3	0.08	2.69

Table 3.4
2007 Physical and Chemical Water Quality Parameters

Month	Sample Location	Temperature (C)	Color (CPU)	Light Extinction Coefficient (K)	Iron (mg/l)	Silica (mg/l)
Jun	0 psu	29.3	40	2.9	0.12	4.80
Jun	6 psu	29.2	45	3.3	0.10	3.84
Jun	12 psu	28.9	45	3.2	0.10	3.55
Jun	20 psu	28.5	35	1.4	0.07	3.57
Jul	0 psu	30.6	100	1.7	0.67	7.97
Jul	6 psu	31.2	70	1.9	0.20	7.41
Jul	12 psu	30.6	50	1.3	0.18	7.08
Jul	20 psu	30.6	40	1.3	0.14	6.07
Aug	0 psu	31.0	150	2.8	0.51	10.90
Aug	6 psu	31.0	140	2.1	0.37	10.60
Aug	12 psu	30.9	100	1.7	0.30	9.76
Aug	20 psu	30.5	70	1.4	0.17	9.23
Sep	0 psu	28.8	150	2.7	0.54	8.24
Sep	6 psu	29.6	150	2.2	0.37	8.11
Sep	12 psu	29.1	100	2.2	0.26	8.59
Sep	20 psu	28.9	100	1.8	0.16	8.22
Oct	0 psu	29.2	180	2.3	0.27	7.49
Oct	6 psu	28.8	140	1.9	0.26	7.14
Oct	12 psu	27.7	100	1.9	0.29	5.91
Oct	20 psu	28.0	90	1.3	0.25	4.40

Table 3.4
2007 Physical and Chemical Water Quality Parameters

Month	Sample Location	Temperature (C)	Color (CPU)	Light Extinction Coefficient (K)	Iron (mg/l)	Silica (mg/l)
Nov	0 psu	21.7	160	1.6	0.28	7.03
Nov	6 psu	22.2	100	2.0	0.17	8.97
Nov	12 psu	21.8	90	2.3	0.14	8.44
Nov	20 psu	21.6	70	2.0	0.30	7.72
Dec	0 psu	21.2	70	1.2	0.12	3.03
Dec	6 psu	22.7	80	1.7	0.13	4.22
Dec	12 psu	22.2	80	1.4	0.13	4.38
Dec	20 psu	21.7	60	1.3	0.14	4.19

Table 3.5
2007 Physical and Chemical Water Quality Parameters - Nutrients

Month	Sample Location	Ammonia / Ammonium (mg/l)	Nitrite + Nitrate Nitrogen	Total Kjeldahl Nitrogen (mg/l)	Ortho-phosphorus	Available N/P Atomic Ratio
Jan	0 psu	0.073	0.004	0.74	1.6	0.1
Jan	6 psu	0.114	0.004	0.92	1.0	0.3
Jan	12 psu	0.090	0.004	0.91	0.6	0.4
Jan	20 psu	0.115	0.004	0.58	0.4	0.7
Feb	0 psu	0.057	0.509	1.14	1.3	1.0
Feb	6 psu	0.058	0.542	1.07	1.2	1.2
Feb	12 psu	0.070	0.283	1.09	1.0	0.8
Feb	20 psu	0.067	0.256	0.77	0.6	1.2
Mar	0 psu	0.075	0.249	0.68	1.7	0.4
Mar	6 psu	0.294	0.149	0.92	1.1	1.0
Mar	12 psu	0.435	0.089	0.62	0.7	1.7
Mar	20 psu	0.308	0.020	0.56	0.4	2.1
Apr	0 psu	0.052	0.121	0.67	2.0	0.2
Apr	6 psu	0.051	0.023	0.74	1.3	0.1
Apr	12 psu	0.067	0.004	0.79	0.9	0.2
Apr	20 psu	0.065	0.004	0.48	0.5	0.3
May	0 psu	0.087	0.013	0.69	2.0	0.1
May	6 psu	0.074	0.045	0.66	1.4	0.2
May	12 psu	0.111	0.033	0.72	1.1	0.3
May	20 psu	0.099	0.004	0.47	0.6	0.4

Table 3.5
2007 Physical and Chemical Water Quality Parameters - Nutrients

Month	Sample Location	Ammonia / Ammonium (mg/l)	Nitrite + Nitrate Nitrogen	Total Kjeldahl Nitrogen (mg/l)	Ortho-phosphorus	Available N/P Atomic Ratio
Jun	0 psu	0.074	0.037	0.80	1.7	0.1
Jun	6 psu	0.067	0.004	0.78	1.4	0.1
Jun	12 psu	0.051	0.014	0.77	1.1	0.1
Jun	20 psu	0.185	0.006	0.67	0.7	0.6
Jul	0 psu	0.060	0.333	0.85	0.7	1.4
Jul	6 psu	0.039	0.037	0.92	0.9	0.2
Jul	12 psu	0.075	0.006	1.03	0.7	0.3
Jul	20 psu	0.064	0.007	0.63	0.5	0.3
Aug	0 psu	0.131	0.345	1.21	1.3	0.9
Aug	6 psu	0.097	0.190	0.94	1.0	0.7
Aug	12 psu	0.090	0.104	0.89	0.6	0.7
Aug	20 psu	0.239	0.028	0.64	0.4	1.4
Sep	0 psu	0.110	0.190	1.13	1.1	0.7
Sep	6 psu	0.079	0.137	0.84	0.8	0.6
Sep	12 psu	0.143	0.030	1.25	0.6	0.7
Sep	20 psu	0.144	0.004	0.52	0.5	0.7
Oct	0 psu	0.101	0.222	0.79	1.0	0.7
Oct	6 psu	0.058	0.109	0.73	0.8	0.5
Oct	12 psu	0.158	0.064	0.71	0.4	1.3
Oct	20 psu	0.155	0.004	0.56	0.3	1.2

Table 3.5
2007 Physical and Chemical Water Quality Parameters - Nutrients

Month	Sample Location	Ammonia / Ammonium (mg/l)	Nitrite + Nitrate Nitrogen	Total Kjeldahl Nitrogen (mg/l)	Ortho-phosphorus	Available N/P Atomic Ratio
Nov	0 psu	0.080	0.090	0.77	0.9	0.4
Nov	6 psu	0.058	0.005	0.74	0.8	0.2
Nov	12 psu	0.047	0.004	0.70	0.6	0.2
Nov	20 psu	0.079	0.004	0.45	0.3	0.7
Dec	0 psu	0.092	0.053	0.39	1.4	0.2
Dec	6 psu	0.078	0.064	0.48	1.0	0.3
Dec	12 psu	0.069	0.062	0.33	0.7	0.4
Dec	20 psu	0.089	0.044	0.41	0.3	1.0

Table 3.8
Mean Near Surface Values for Key Physical, Chemical and Biological Measurements by Isohaline

Isohaline	River Kilometer	Temperature (^{0}C)	COLOR (Co_Pt units)	Nitrite + Nitrate Nitrogen (mg/l)	Ortho – Phosphorus (mg/l)	Atomic Nitrogen to Phosphorus Ratio	Silica (mg/l)	Extinction Coefficient (K)	Chlorophyll *a* (ug/l)
Summary of data from current year – 2007									
0 (psu) Salinity	32.5	25.8	95	0.181	1.379	0.2	6.0	1.9	7.7
6 (psu) Salinity	19.7	26.0	86	0.109	1.050	0.2	6.1	1.9	14.9
12 (psu) Salinity	15.4	25.1	68	0.075	0.764	0.3	5.5	1.8	20.6
20 (psu) Salinity	11.2	24.9	53	0.030	0.446	0.4	4.6	1.4	14.4
Summary of data from preceding period 1983-2006									
0 (psu) Salinity	21.5	24.9	144	0.480	0.750	0.8	3.2	2.9	10.1
6 (psu) Salinity	12.3	25.3	119	0.212	0.537	0.5	2.8	2.6	23.5
12 (psu) Salinity	7.4	25.1	91	0.099	0.383	0.4	2.2	2.1	27.5
20 (psu) Salinity	0.3	24.8	54	0.037	0.229	0.4	1.4	1.5	13.7

Table 4.1
HBMP Fixed Sampling Locations

USGS River Mile	USGS Location Number	Previous EQL Station Number	Additional Sampling	New River Kilometer designation based on Morphometric Study
Current *In Situ* Water Column Profile Sampling Locations				
CH6	265355082075500	9	Water Quality	**-2.4**
RM3.95	265640082033500	10	Water Quality	**6.6**
RM4.88	265724082024400	21		**8.4**
RM6.25	265727082012800	11		**10.5**
RM8.61	265711081595500	Shell Creek 9 (92)		**12.7**
RM8.6B	265819082003200	22		**12.8**
RM10.2	2297460	12	Water Quality/Tide Gage/Conductivity	**15.5**
RM11.2	270022081591000	23		**17.5**
RM 12.55	270124081592500	13		**20.1**
RM13.95	270235081592400	24		**21.9**
RM14.82	270318081593100	14	Water Quality	**23.6**
RM15.45	270337081595800	25		**24.7**
RM16.29	270418082001600	15		**25.9**
N/A	2297350	N/A	Tide Gage/ Conductivity	**26.7**
RM18.25	270451081595100	17		**29.5**
RM18.95	2297330	18	Water Quality	**30.4**
RM19.5	270537081585800	19		**32.3**
Previous EQL Water Column and Chemistry Sampling Sites				
N/A	N/A	16		**27.1**
N/A	N/A	20		**34.1**

Table 4.5
Mean Near Surface Values for Key Physical, Chemical and Biological Measurements at Fixed Sampling Sites

River Kilometer	Color (Co_Pt Units)	Iron (mg/L)	Nitrite+Nitrate Nitrogen (mg/L)	Total Kjeldahl Nitrogen (mg/L)	Ortho-phosphorus (mg/L)	Silica (mg/L)	Chlorophyll *a* (ug/L)
Summary of data from current year – 2007							
-2.4	14	0.07	0.004	0.27	0.10	3.4	5.3
6.6	35	0.12	0.024	0.41	0.25	3.9	8.6
15.5	77	0.18	0.083	0.69	0.65	5.4	15.0
23.6	96	0.19	0.160	0.86	1.18	6.1	13.6
30.4	90	0.18	0.213	0.79	1.41	5.9	9.3
Summary of data from preceding period 1976-2006							
-2.4	59	0.29	0.041	0.69	0.21	2.0	16.7
6.6	94	0.31	0.093	0.82	0.33	2.9	14.3
15.5	142	0.36	0.236	1.12	0.57	4.5	27.7
23.6	149	0.38	0.421	1.03	0.72	5.2	16.0
30.4	149	0.37	0.493	1.06	0.77	5.2	13.4

Table 5.2
Evaluation of Potential Locations for Additional Authority Continuous Recorder Deployments

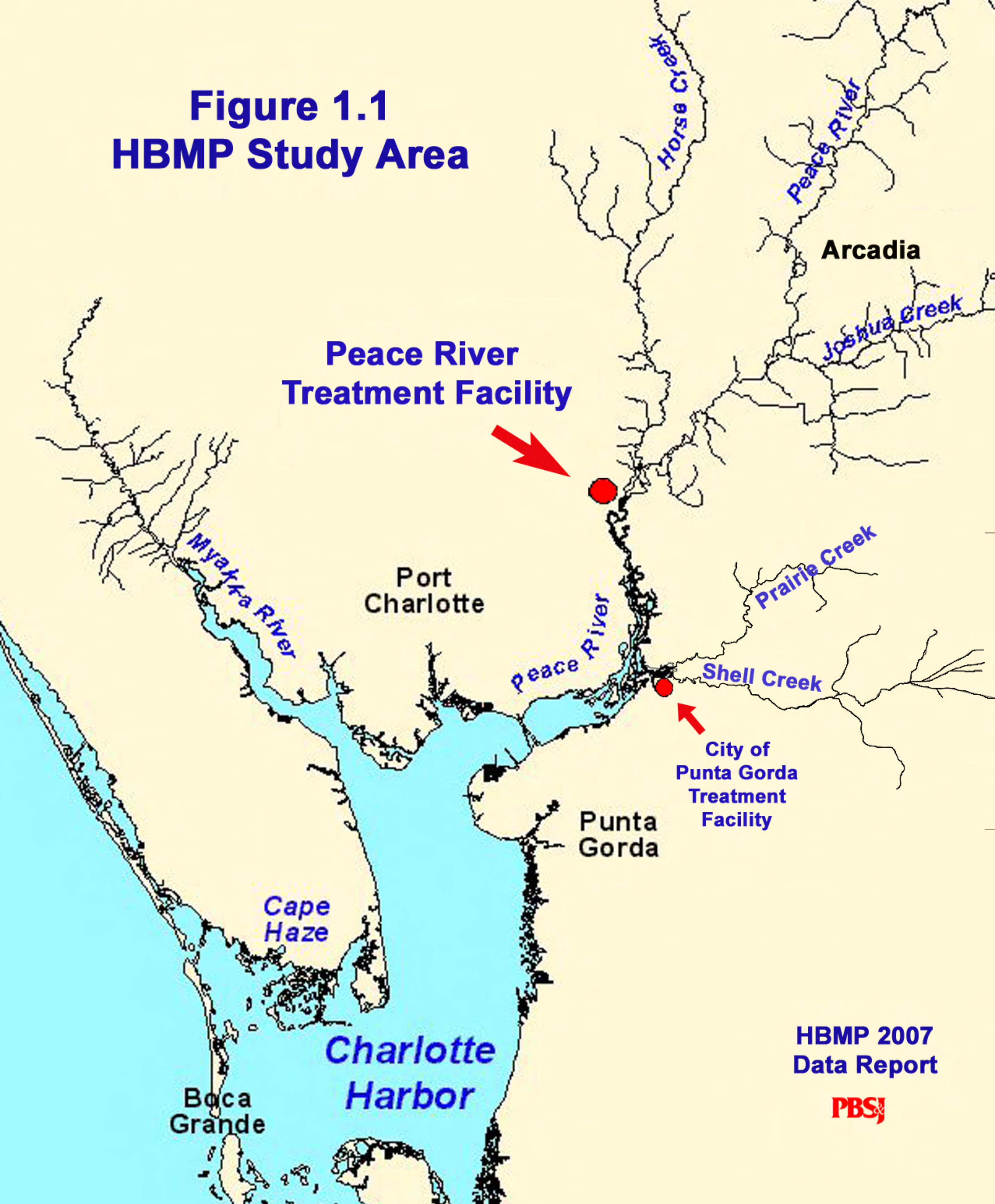
ID	Name	Location	# pilings	Depth 1 (feet)	Depth 2 (feet)	Channel Depth (feet)	Latitude		Longitude		Channel Position
USGS1	USGS Peace River Heights Recording Gage	Campground (Dock)					27	4.629	82	0.432	
MZ-1	MZ above Navigator	Between Navigator & campground	2	3.0	3.2		27	4.204	82	0.203	side
Dock 1	Dock (Alderon)	Upstream of Navigator	multiple	9.6			27	3.781	82	0.098	side
Dock 2	Dock (south of Alderon)	Upstream of Navigator	multiple	10.5			27	3.78	82	0.095	side
MZ-2	MZ across from Navigator	Across from Navigator	2	2.4	2.4		27	3.65	81	59.96	side
MZ-3	MZ below Navigator across from Cattail marsh	Downstream of Navigator	2	3.0	3.0	11.0	27	3.247	81	59.48	side
MZ-4	MZ North tip Liverpool I.	Tip upstream of Liverpool channel	2	3.4	3.4	8.0	27	2.58	81	59.36	side
MZ-5	MZ mid Liverpool, middle channel	Mid Liverpool mid channel	2	4.3	4.4	4.4	27	2.069	81	59.49	side
R/G-A	Red/Green Marker A	South tip Island 33	1	8.2		16	27	1.975	81	59.52	side
R-14	Red Marker 14	South tip Liverpool	1	4.0		12.4	27	1.896	81	59.47	side
MZ-6	MZ South tip Liverpool	South tip Liverpool	2	3.2	3.2	12.4	27	1.884	81	59.44	side
R-12	Red Marker 12	South tip Liverpool	1	8.1		11.6	27	1.815	81	59.45	side
G-11	Green Marker 11		1	7.6		8.0	27	1.443	81	59.41	side
Dock 3	Dock just below Marker 11	West bank below Marker 11	multiple	6.0		8.0	27	1.36	81	59.44	center
R-10	Red Marker 10	Immediately above upper power lines	1	8.2		10.0	27	1.09	81	59.12	side
G-9	Green Marker 9	Below upper power lines	1	5.2		19.0	27	0.58	81	59.03	side
G-7	Green Marker 7		1	6.7		8.0	27	0.371	81	59.21	side
G-5	Green Marker 5		1	8.3		8.3	27	0.216	81	59.3	mid
R-4	Red Marker 4	Immediately above lower power lines	1	6.4		7.0	27	0.036	81	59.32	side
R-2	Red Marker 2	Immediately below lower power lines	1	10.3		14.0	26	59.8	81	59.35	side
MZ7	MZ adjacent to Red Marker 2	Immediately below lower power lines	2	9.4	9.4	14.0	26	59.8	81	59.34	side
USGS2	USGS Harbor Heights Recording Gage	At end of dock					26	59.25	81	59.58	

*** Note**: MZ denotes Manatee zone US Fish & Wildlife markers; R denotes “red” channel navigational markers that are identified by their number; G denotes “green” channel navigational markers that are identified by their number. The two existing USGS continuous recorder sites and the three new HBMP sites are highlighted in red.

2007 HBMP Figures

- **Section 1 – Introduction / Summary**
- **Section 2 – Peace River Gaged Flows and Regional Water Supply Facility Withdrawals**
- **Section 3 – *In Situ* Physical Measurements, Water Chemistry and Phytoplankton Biomass at "Moving Isohaline Locations**
- **Section 4 – Water Chemistry Data Collected At "Fixed" Station Locations**
- **Section 5 – USGS and HBMP Continuous Recorders**
- **Section 6 – Significant Environmental Change**

Figure 1.1
HBMP Study Area



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Data Report

PBSJ

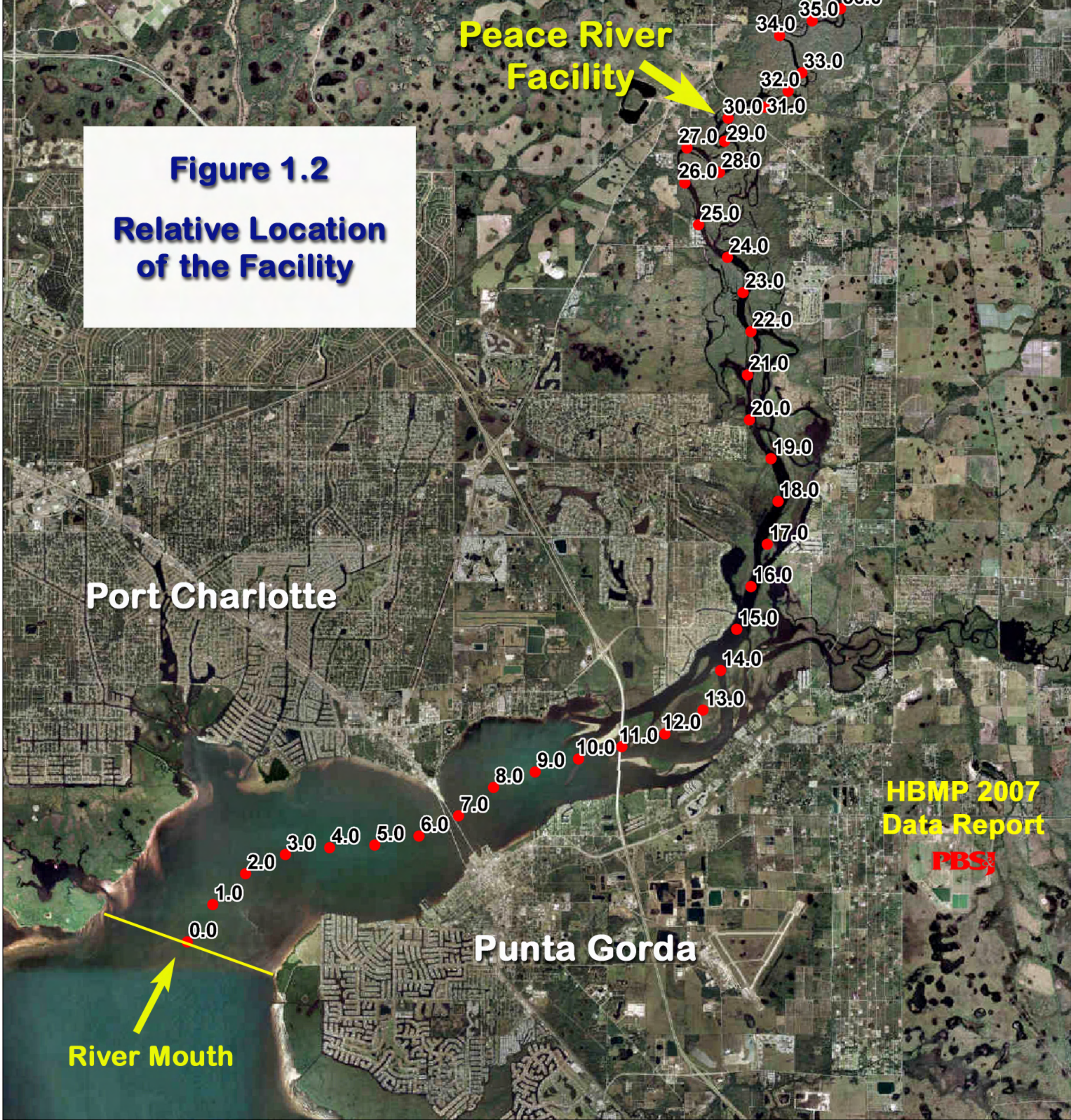

Figure 1.2

Relative Location of the Facility

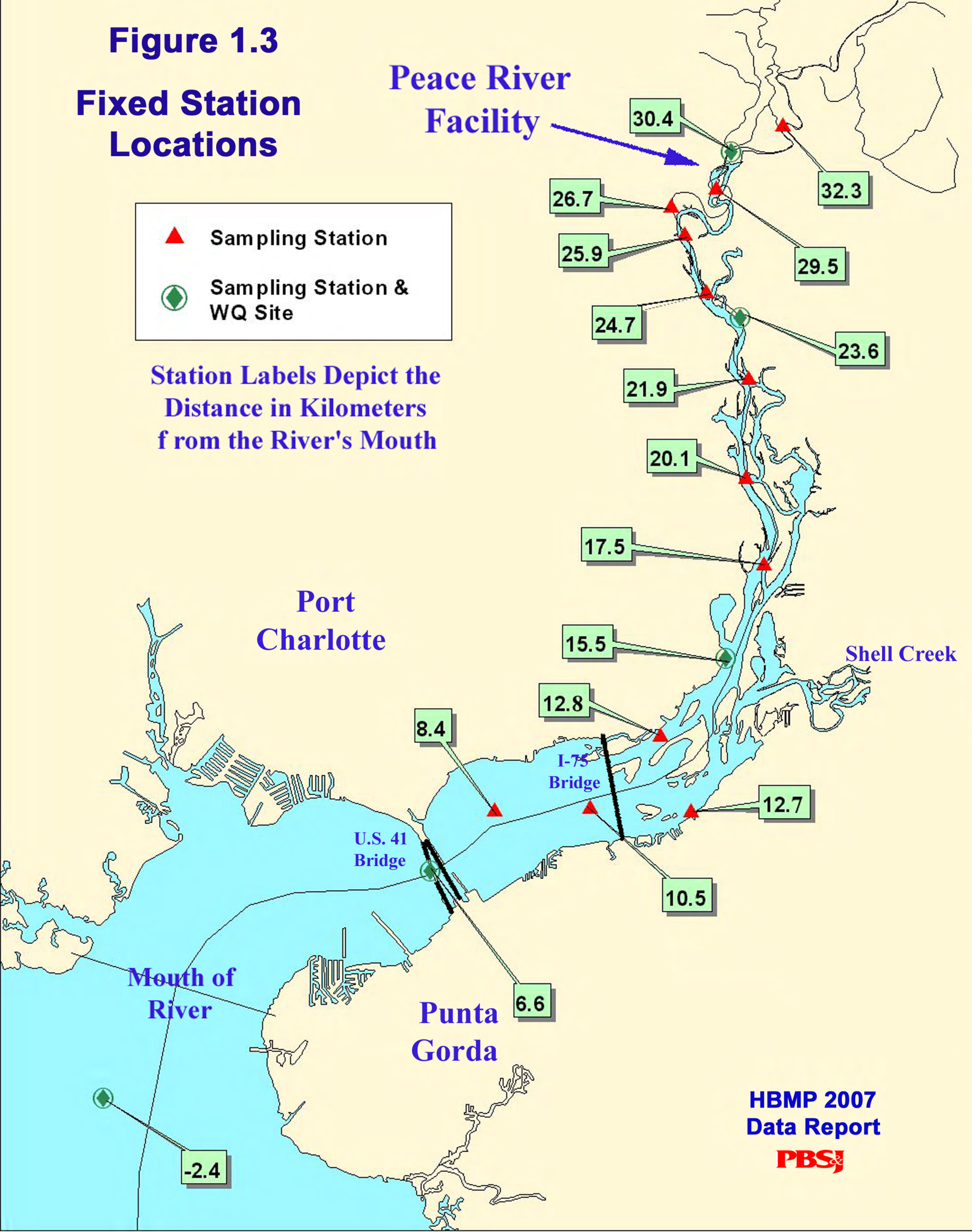

Figure 1.3

Fixed Station Locations

Station Labels Depict the Distance in Kilometers from the River's Mouth

HBMP 2007 Data Report

PBSJ

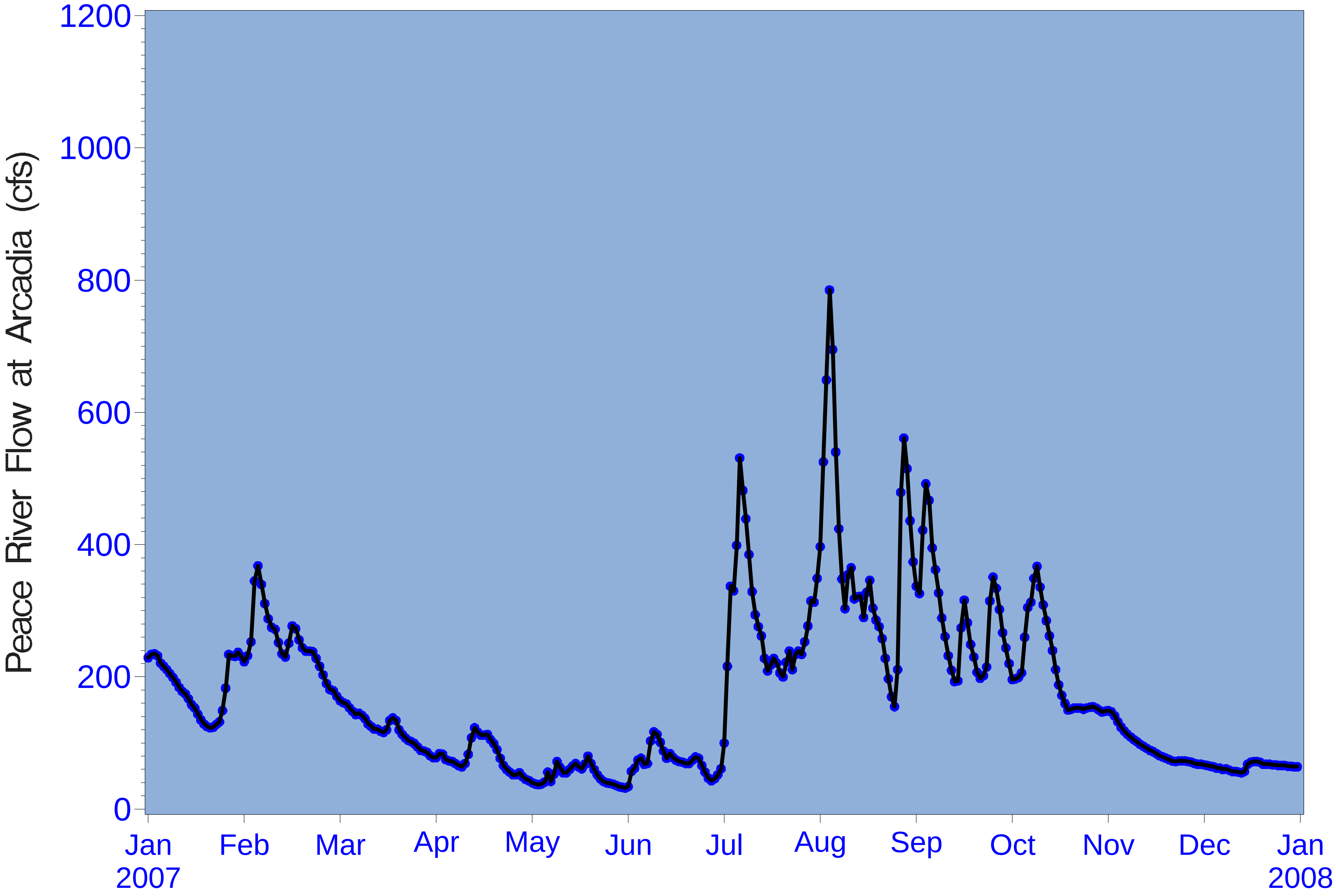

Figure 2.1 Daily Peace River flow at Arcadia (2007)

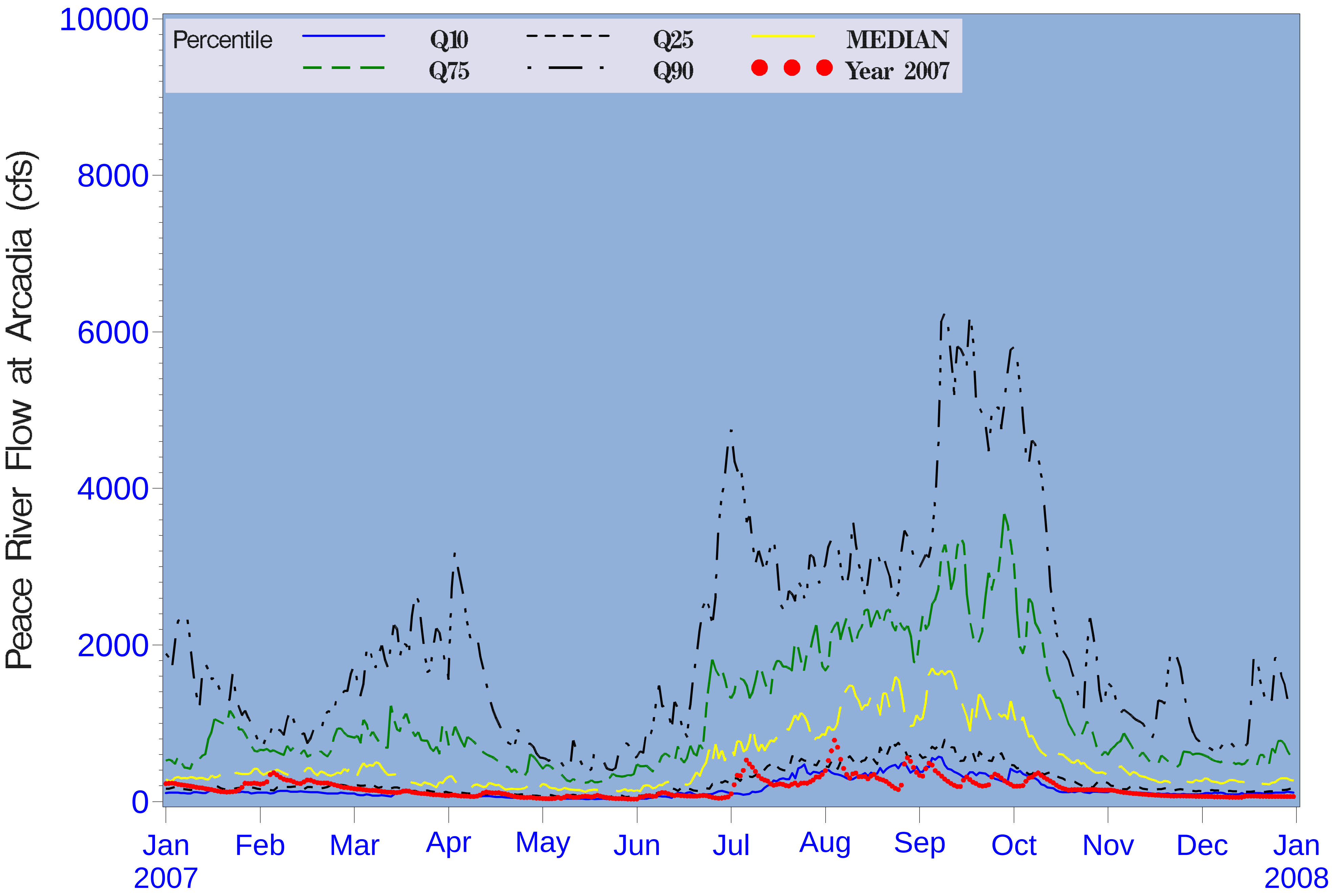

Figure 2.2 Daily 2007 Peace River flow at Arcadia in relation to long-term statistical averages

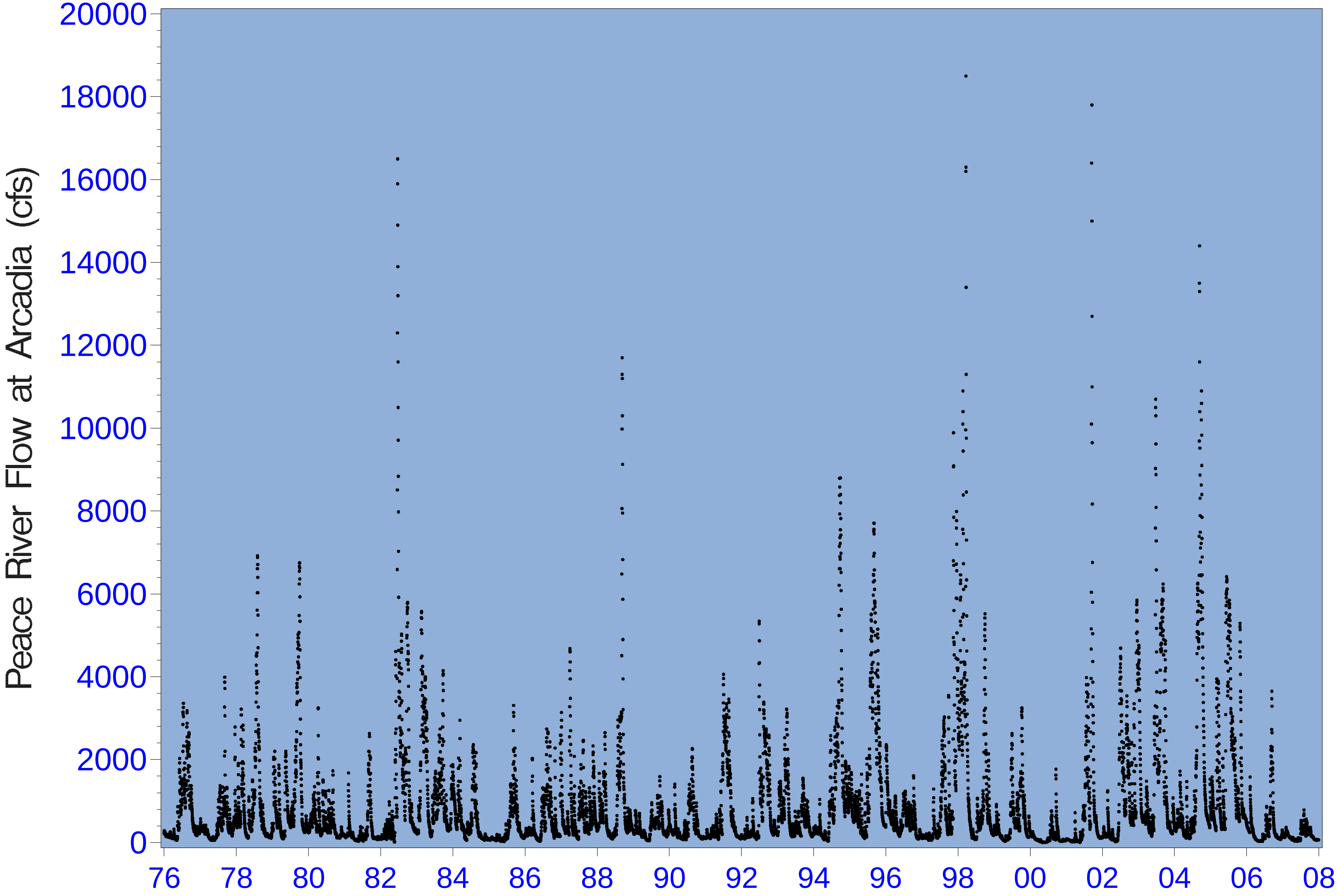

Figure 2.3 Daily Peace River flow at Arcadia (1976-2007)

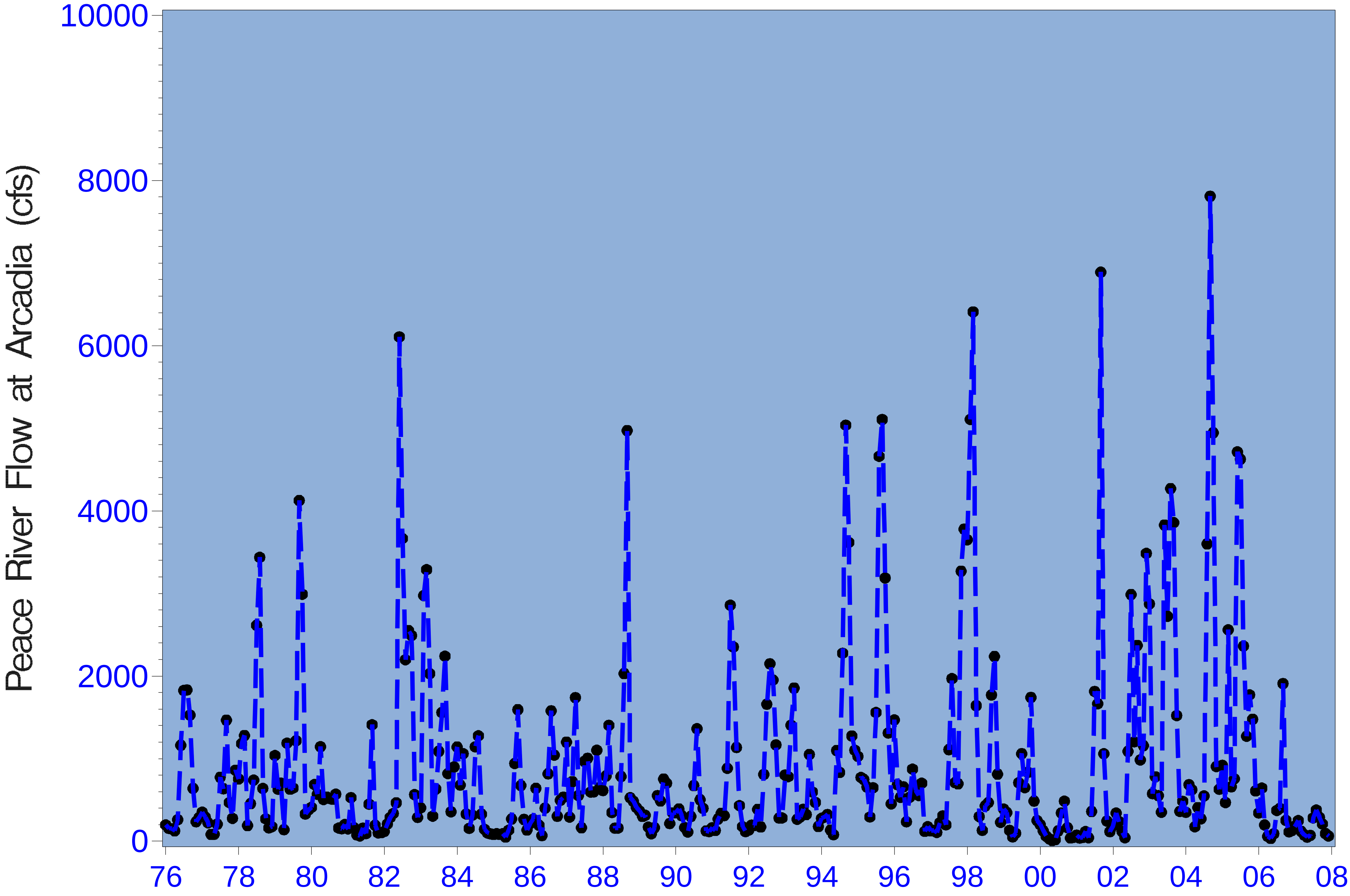

Figure 2.4 Monthly mean Peace River flow at Arcadia (1976-2007)

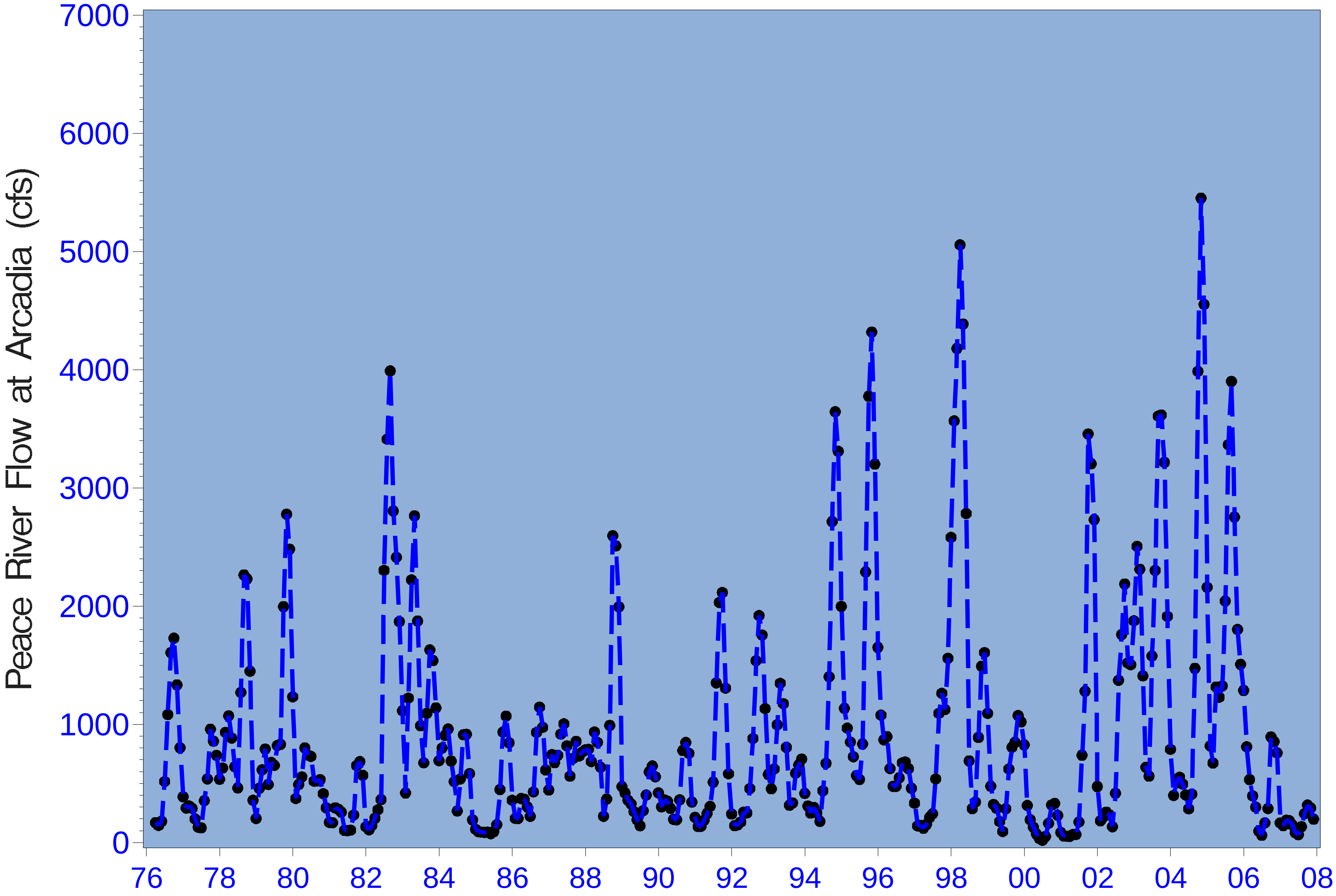

Figure 2.5 3-Month moving average Peace River flow at Arcadia (1976-2007)

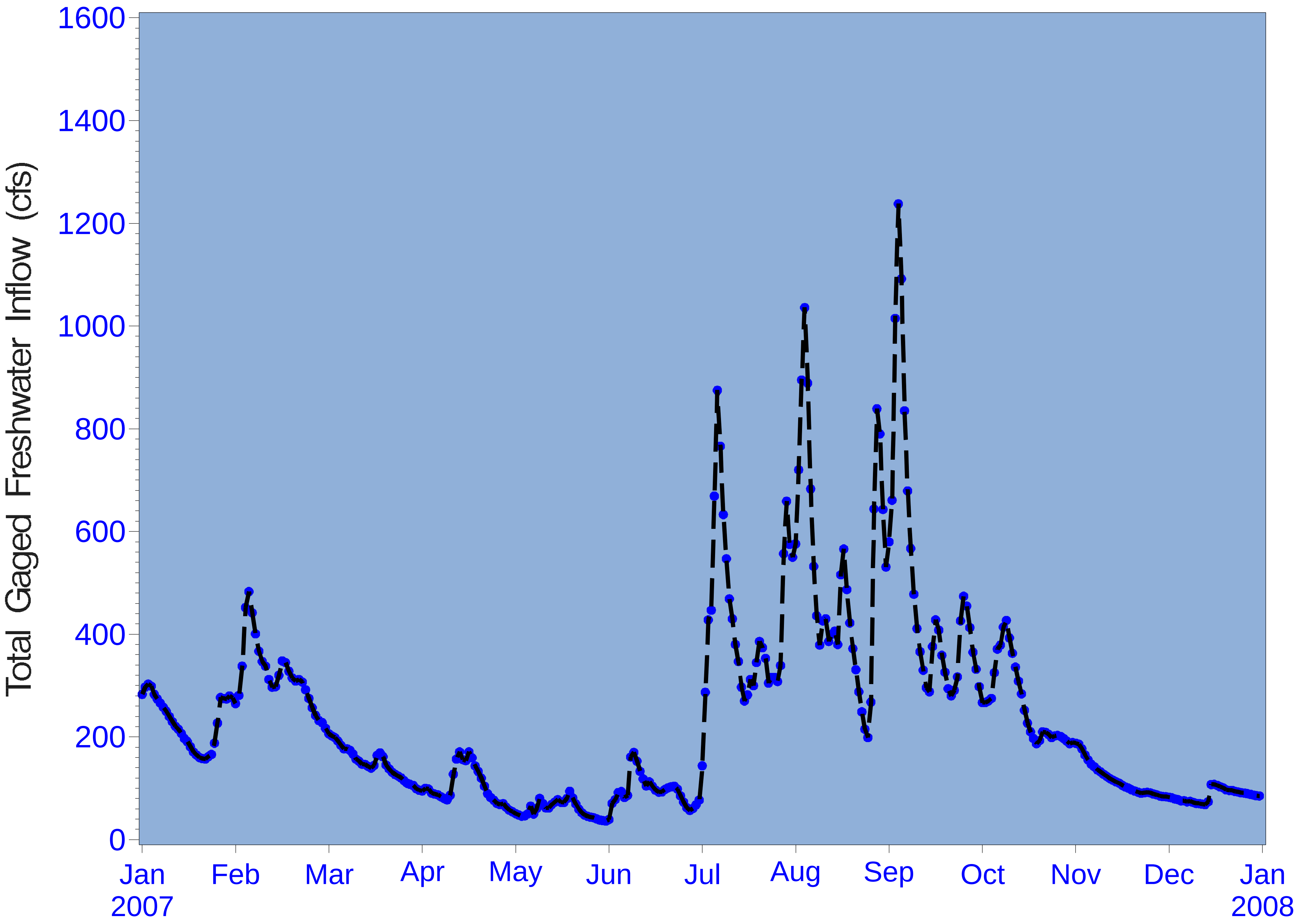

Figure 2.6 Total daily gaged flow - Peace River at Arcadia + Horse and Joshua Creeks (2007)

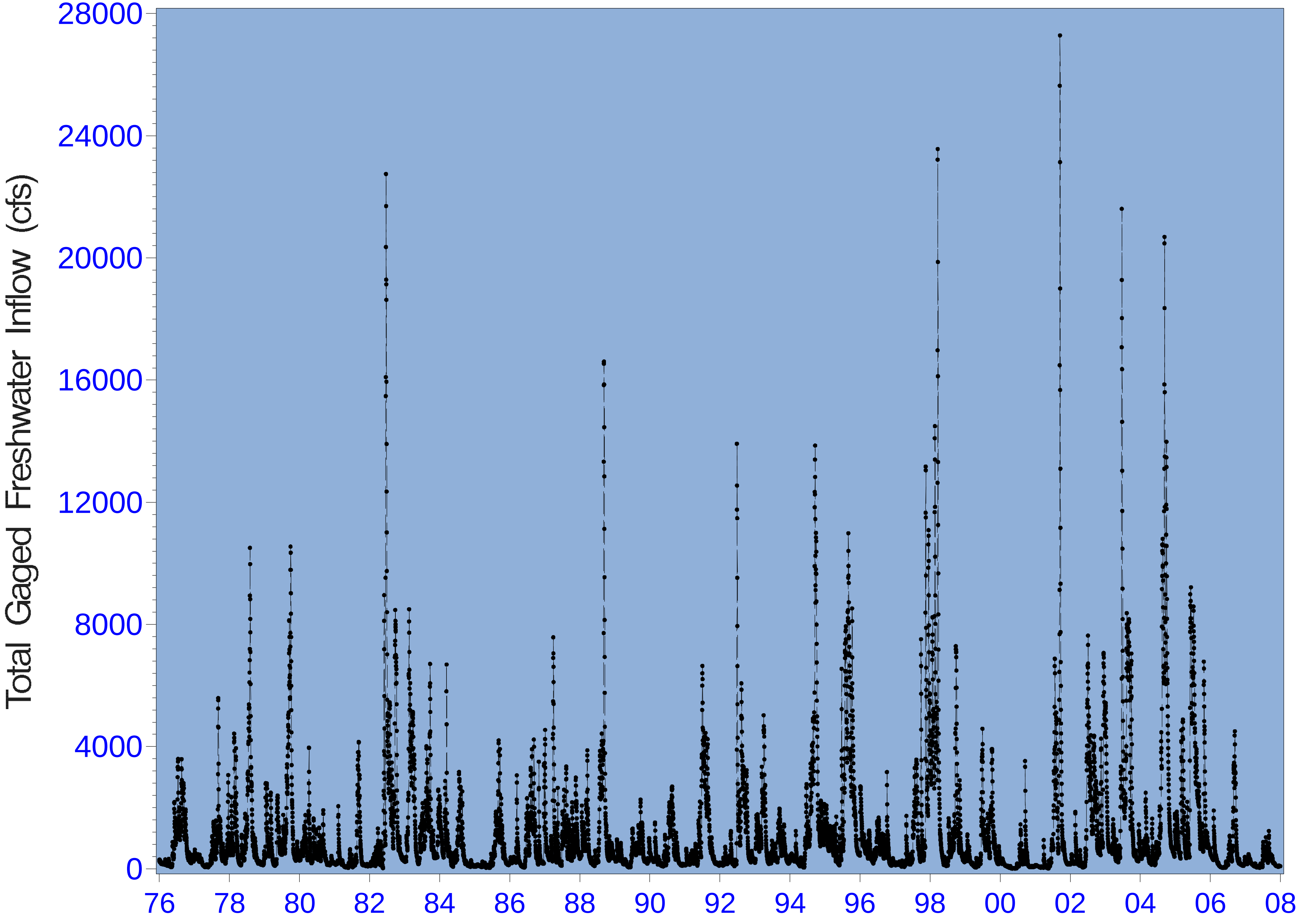

Figure 2.7 Total daily gaged flow - Peace River at Arcadia + Horse and Joshua Creeks (1976-2007)

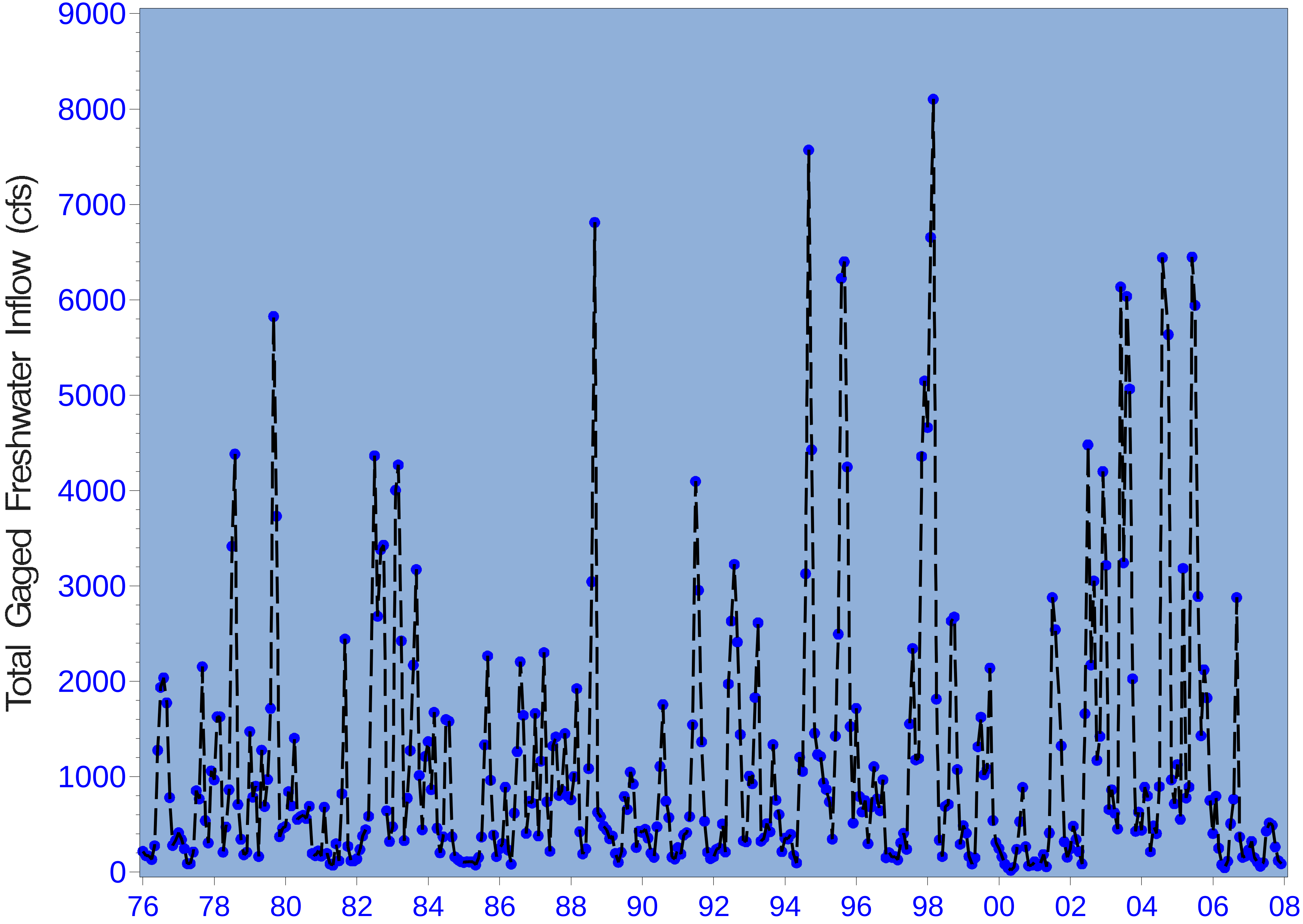

Figure 2.8 Mean monthly flow - Peace River at Arcadia + Horse and Joshua Creeks (1976-2007)

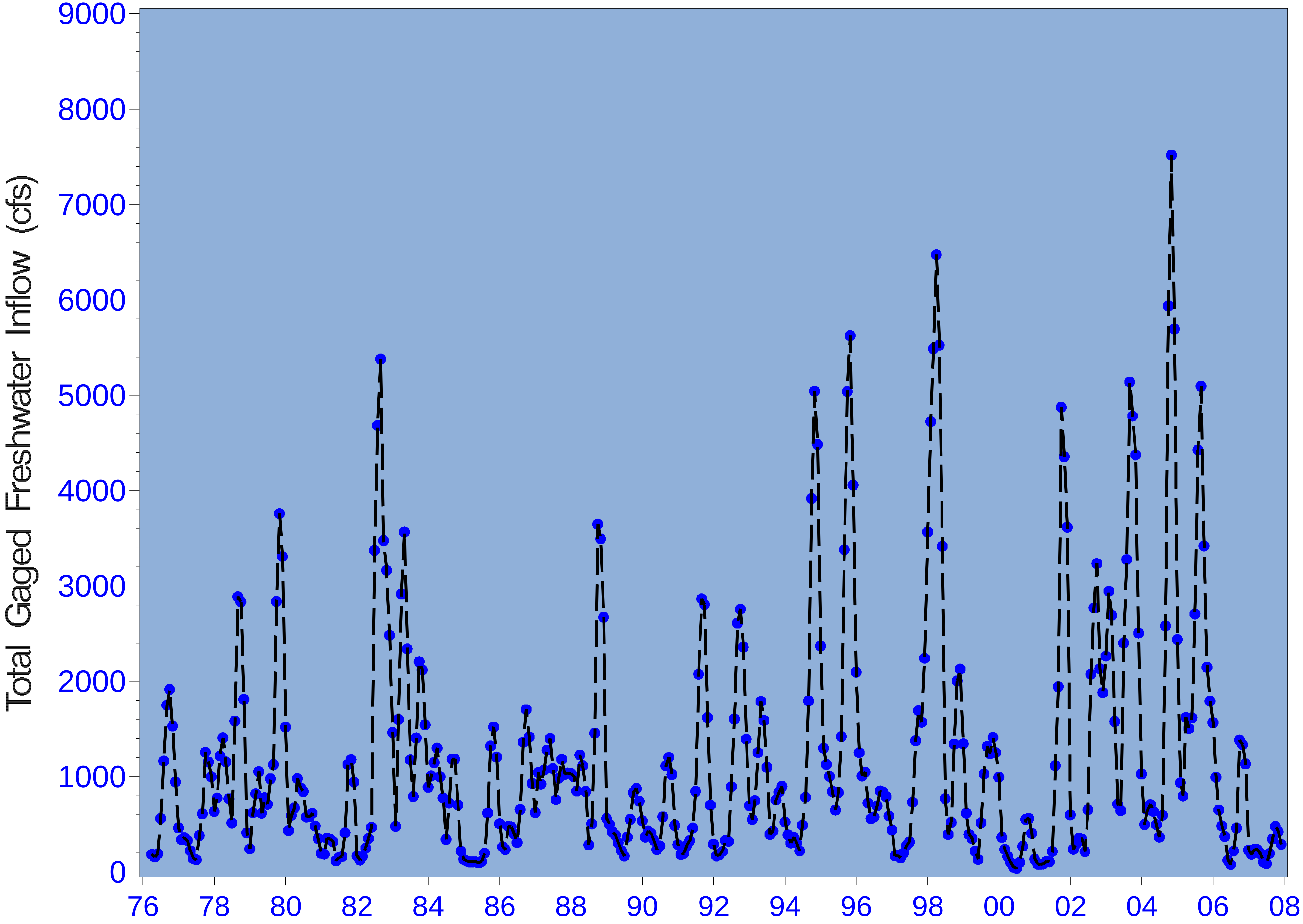

Figure 2.9 3-Month moving average flow - Peace River + Horse and Joshua Creeks (1976-2007)

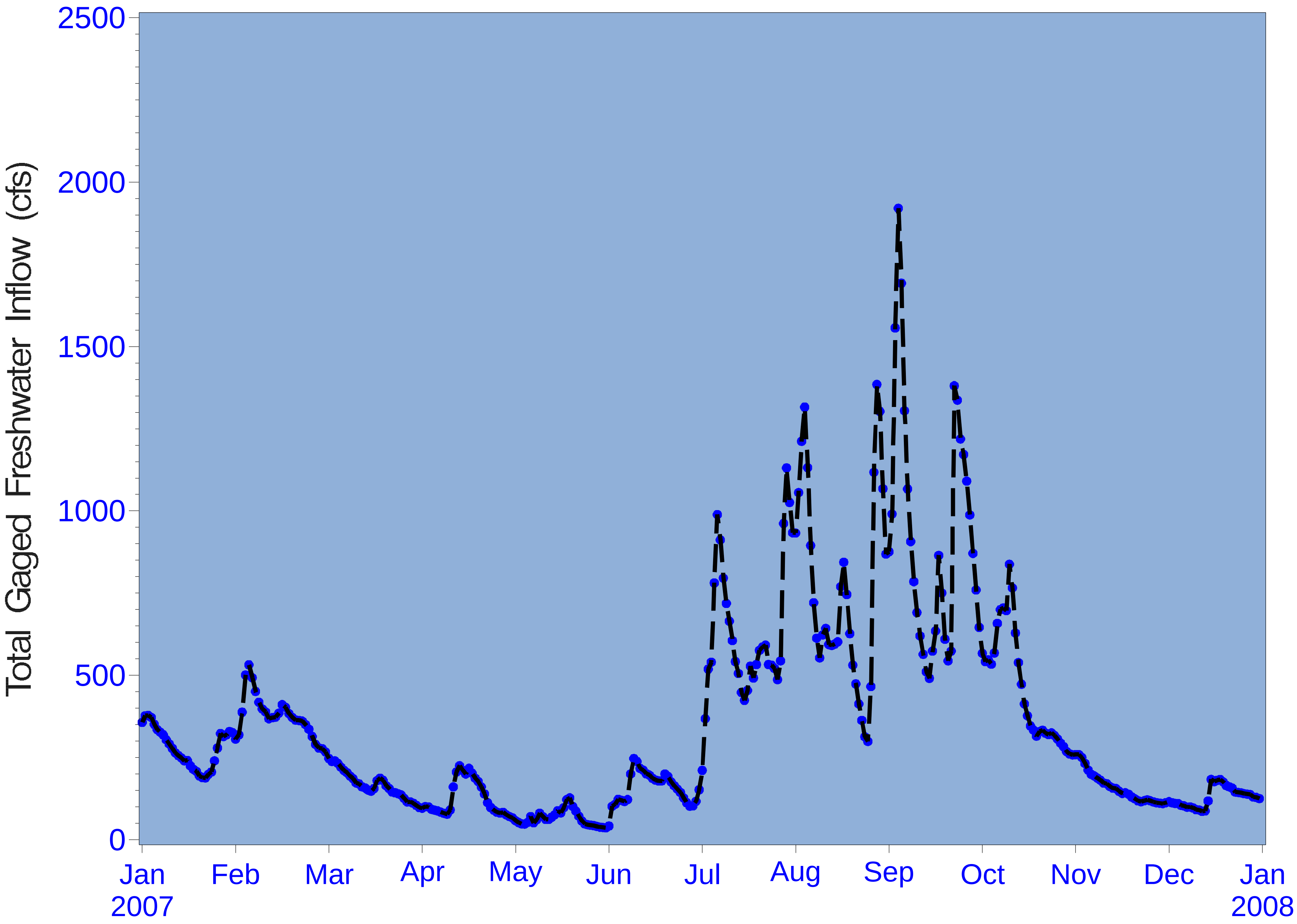

Figure 2.10 Total daily gaged flow - Peace River at Arcadia + Horse, Joshua and Shell Creeks (2007)

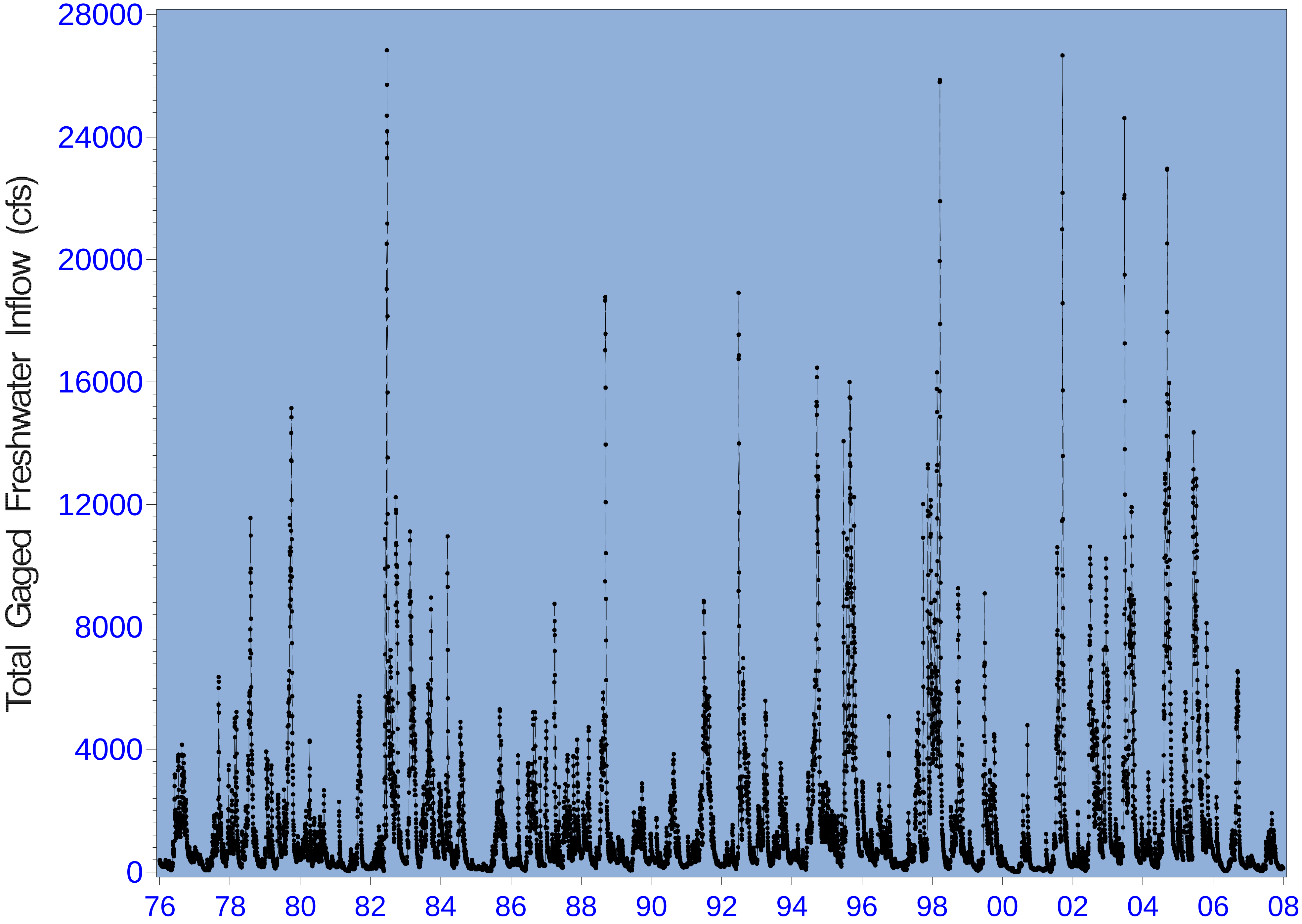

Figure 2.11 Total daily gaged flow - Peace River at Arcadia + Horse, Joshua and Shell Creeks (1976-2007)

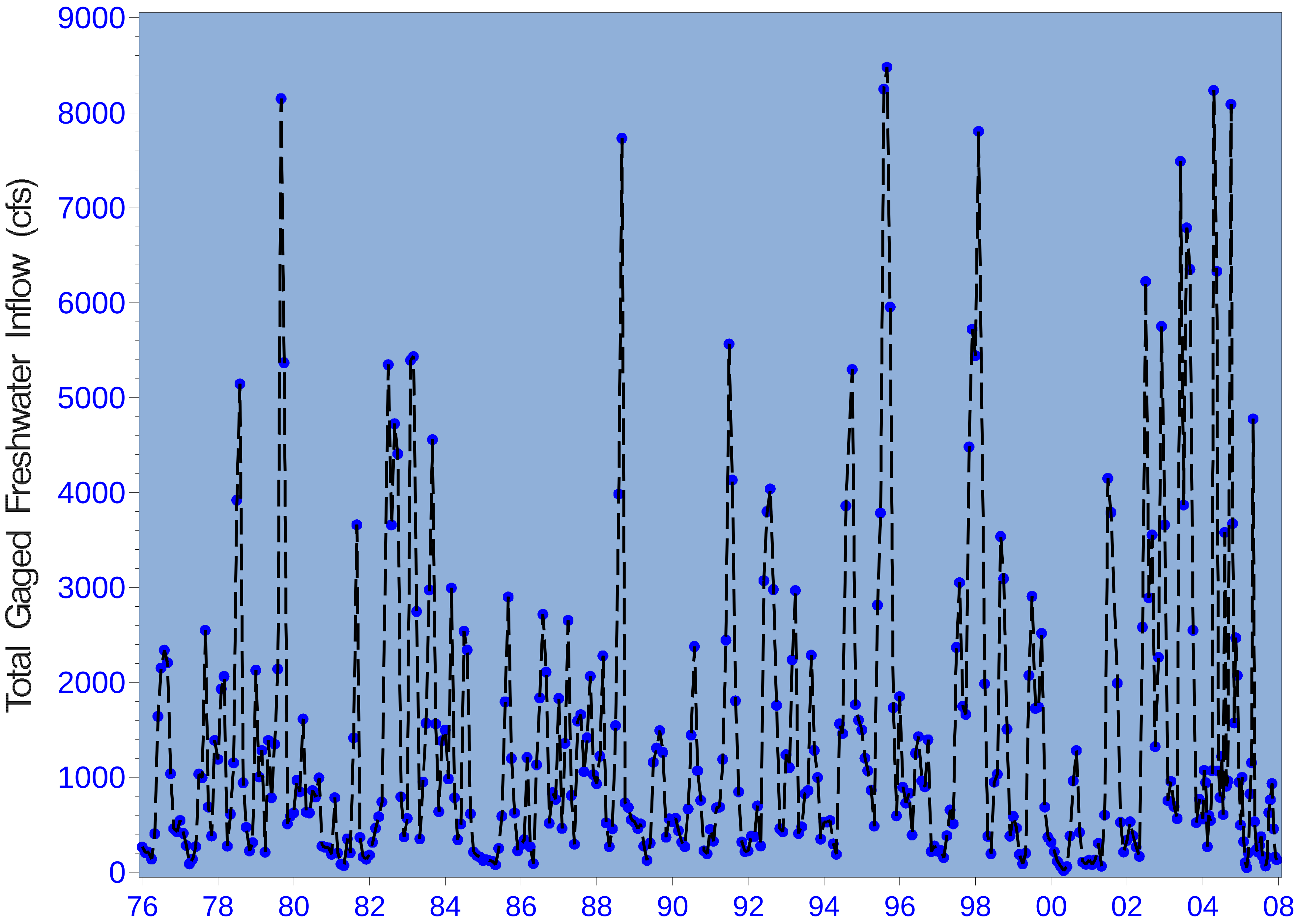

Figure 2.12 Mean monthly flow - Peace River at Arcadia + Horse, Joshua and Shell Creeks (1976-2007)

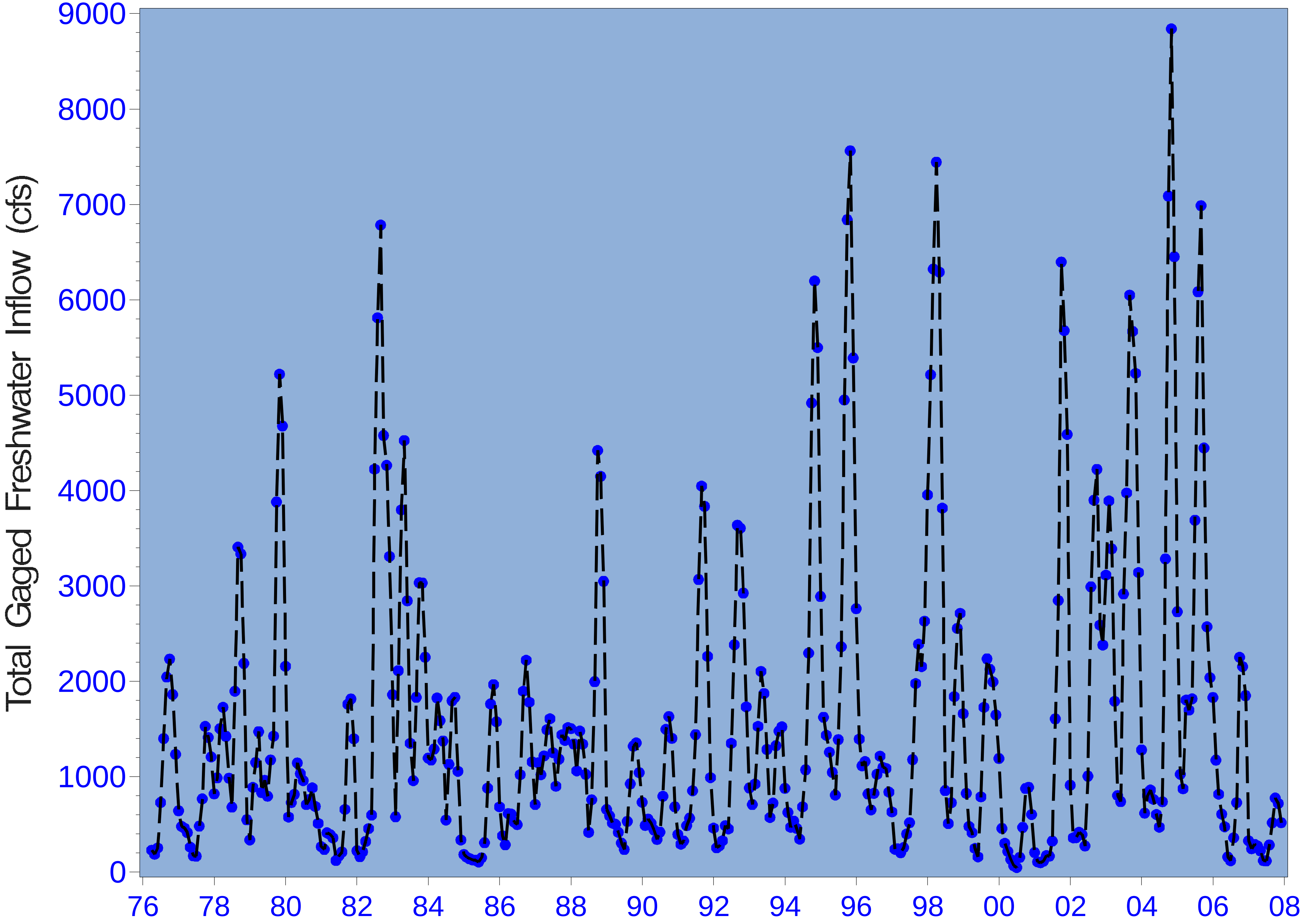

Figure 2.13 3-Month moving average flow - Peace River + Horse, Joshua and Shell Creeks (1976-2007)

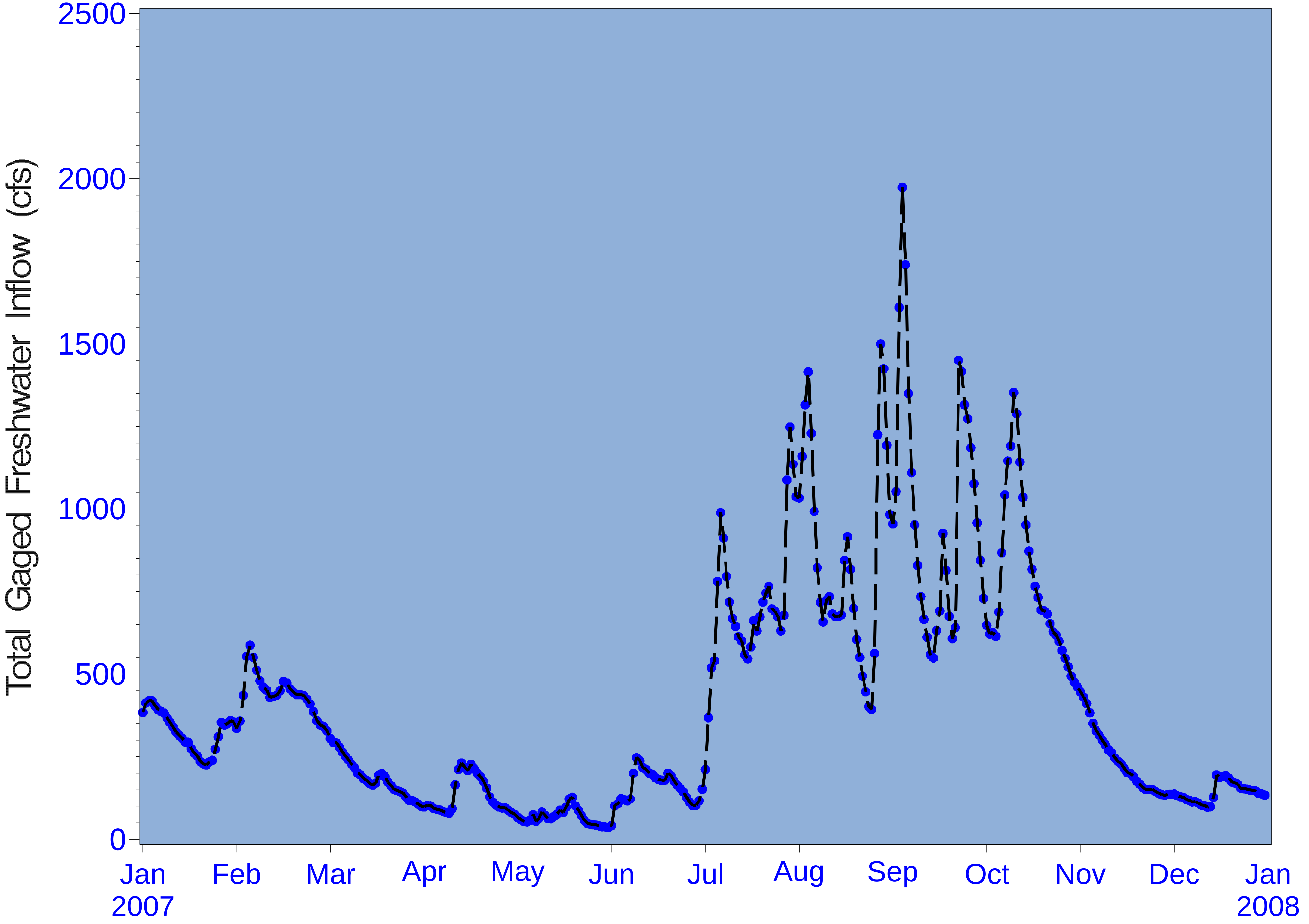

Figure 2.14 Total daily gage flow -Peace & Myakka Rivers + Horse, Joshua and Shell Creeks (2007)

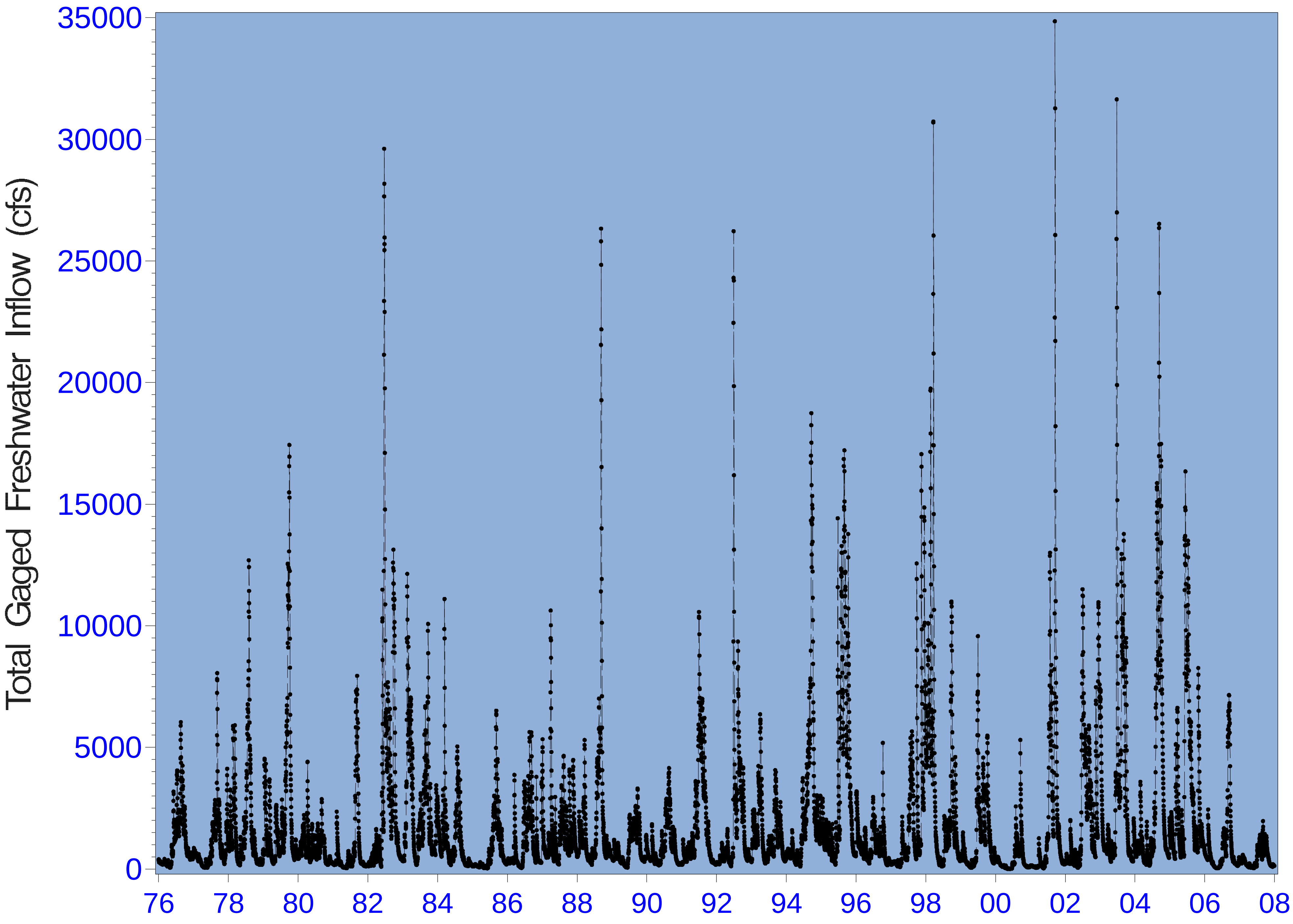

Figure 2.15 Total daily gaged flow - Peace & Mykka Rivers + Horse, Joshua and Shell Creeks (1976-2007)

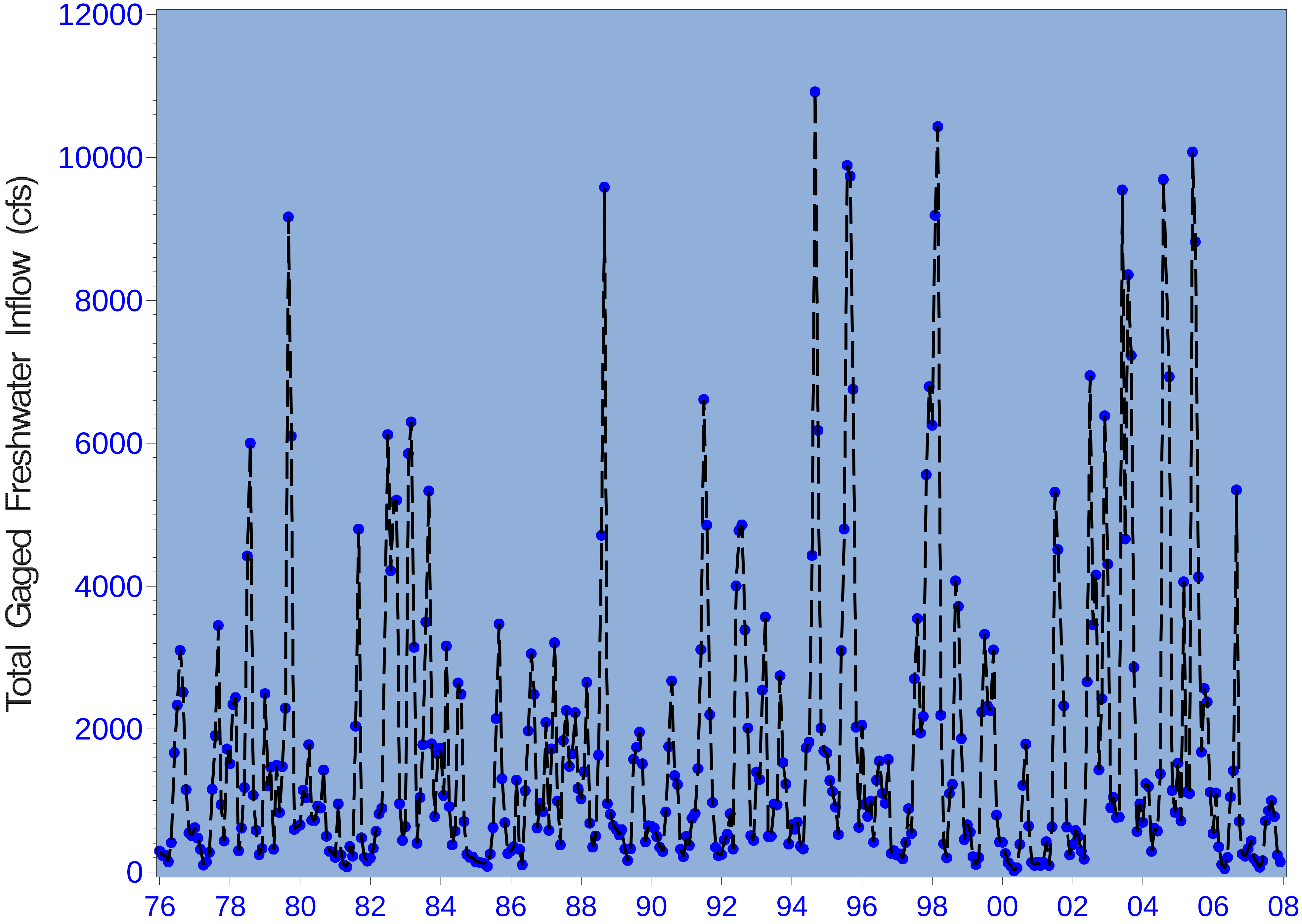

Figure 2.16 Mean monthly flow - Peace & Myakka Rivers + Horse, Joshua and Shell Creeks (1976-2007)

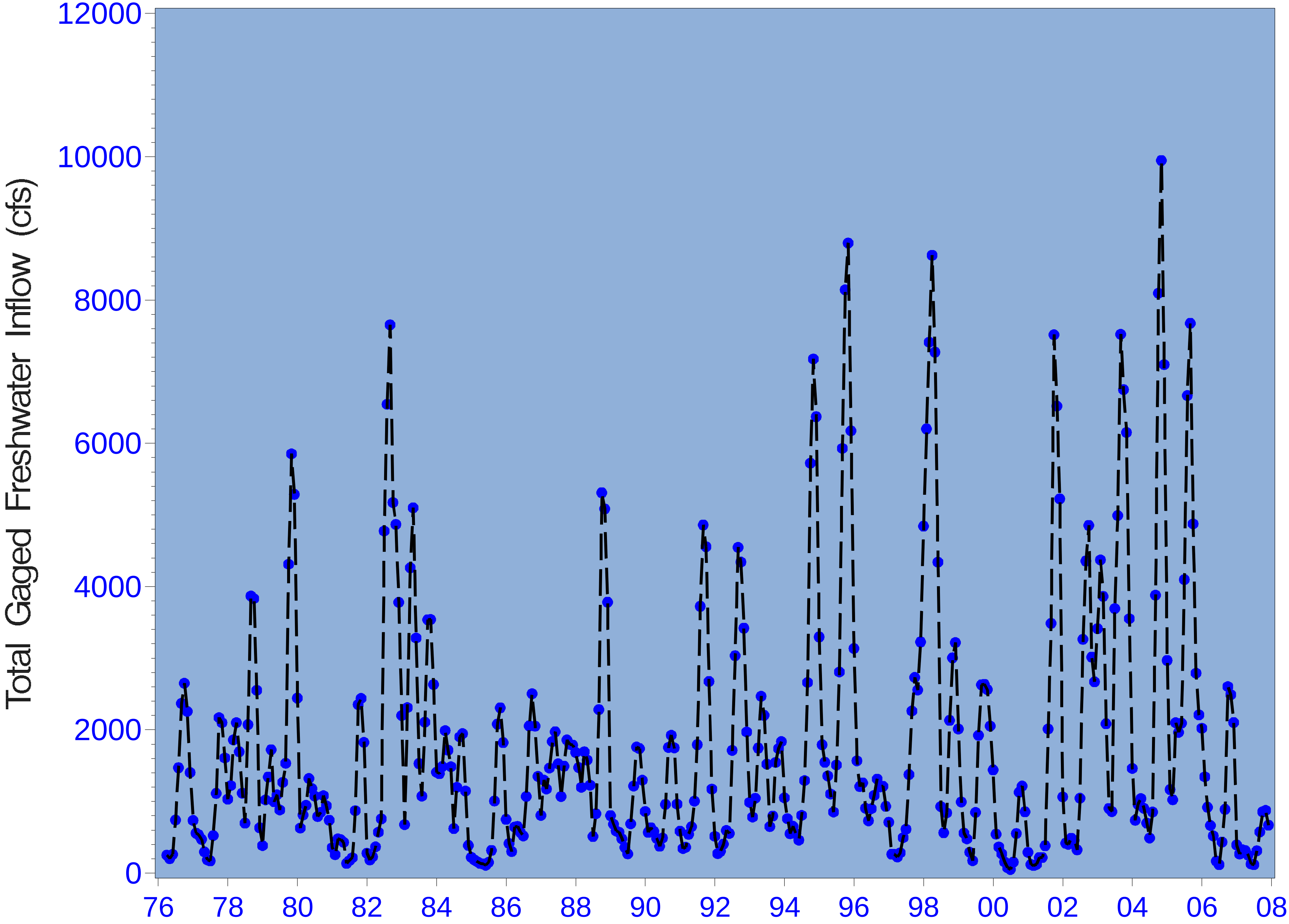

Figure 2.17 3-Month moving average flow - Peace & Myakka Rivers + Horse, Joshua and Shell Creeks (1976-2007)

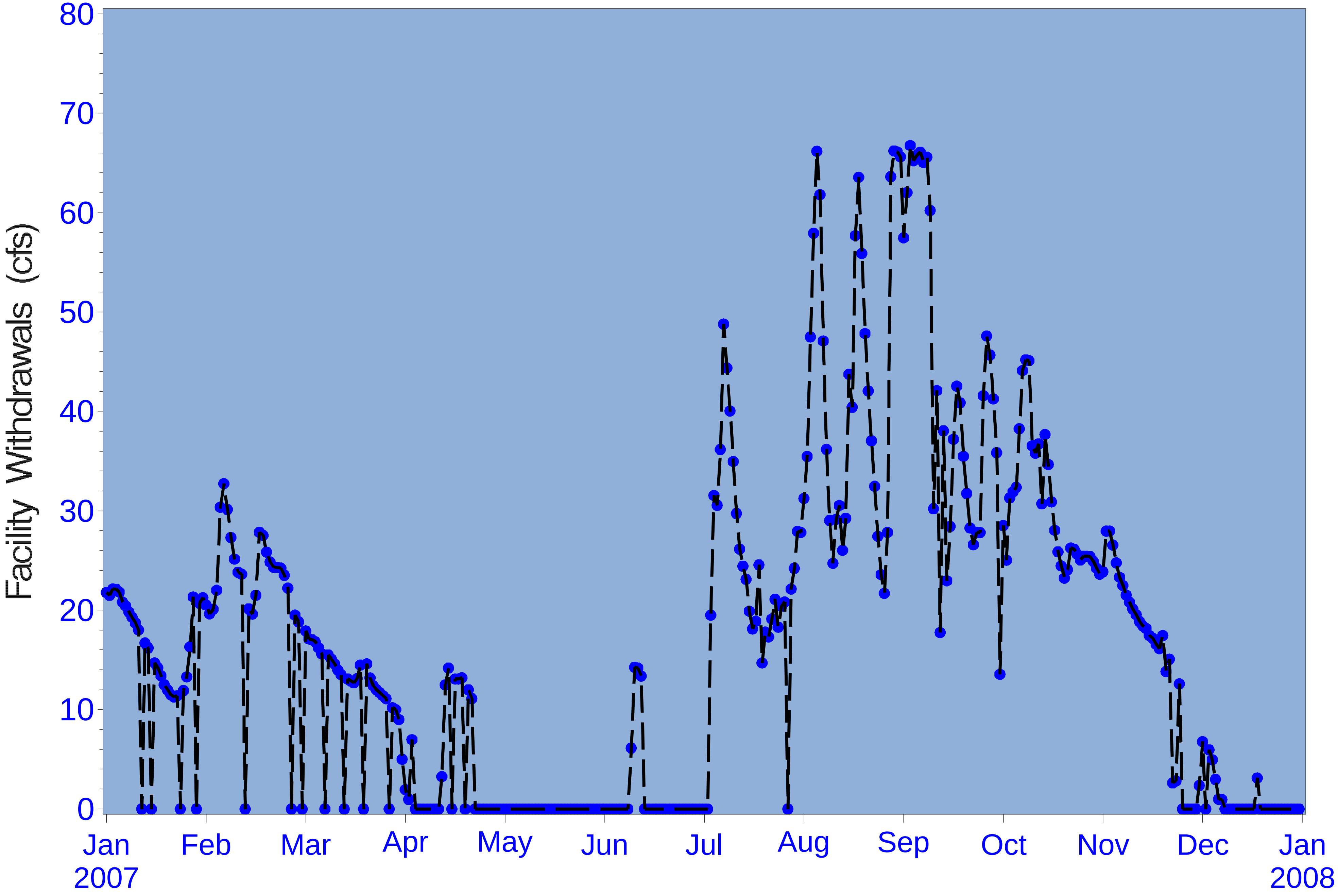

Figure 2.18 Daily water treatment facility withdrawals (2007)

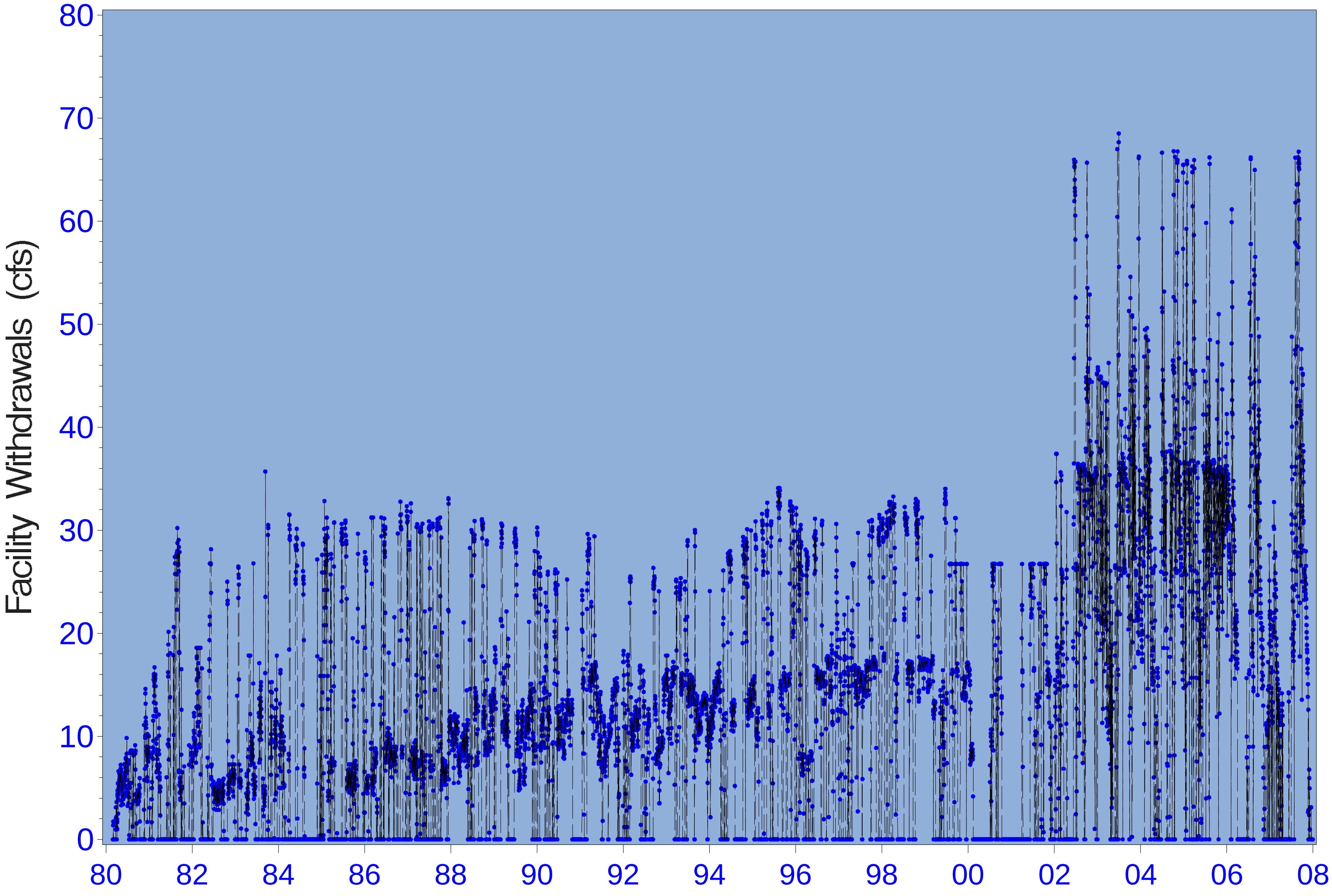

Figure 2.19 Daily water treatment facility withdrawals (1980-2007)

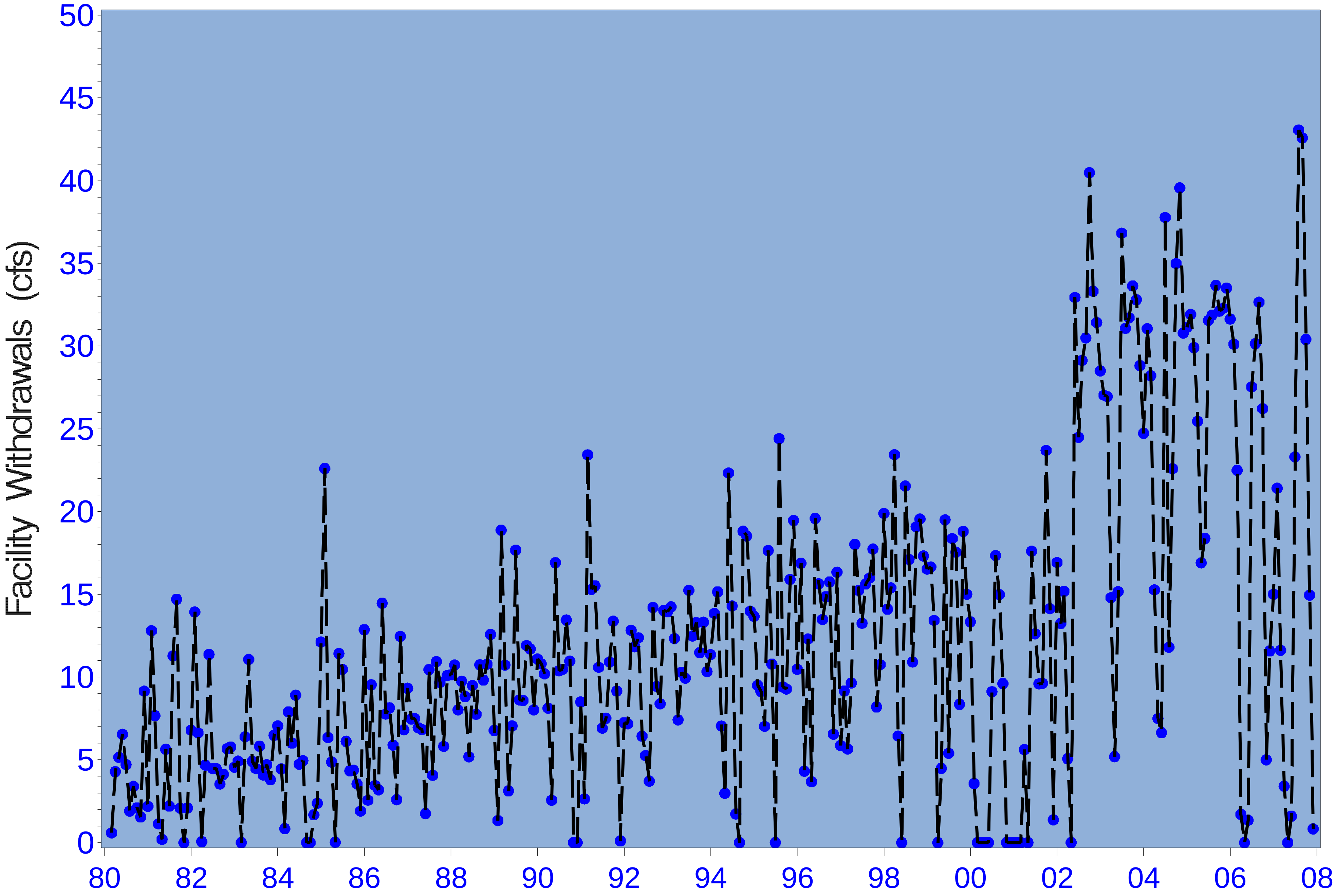

Figure 2.20 Monthly mean water treatment facility withdrawals (1980-2007)

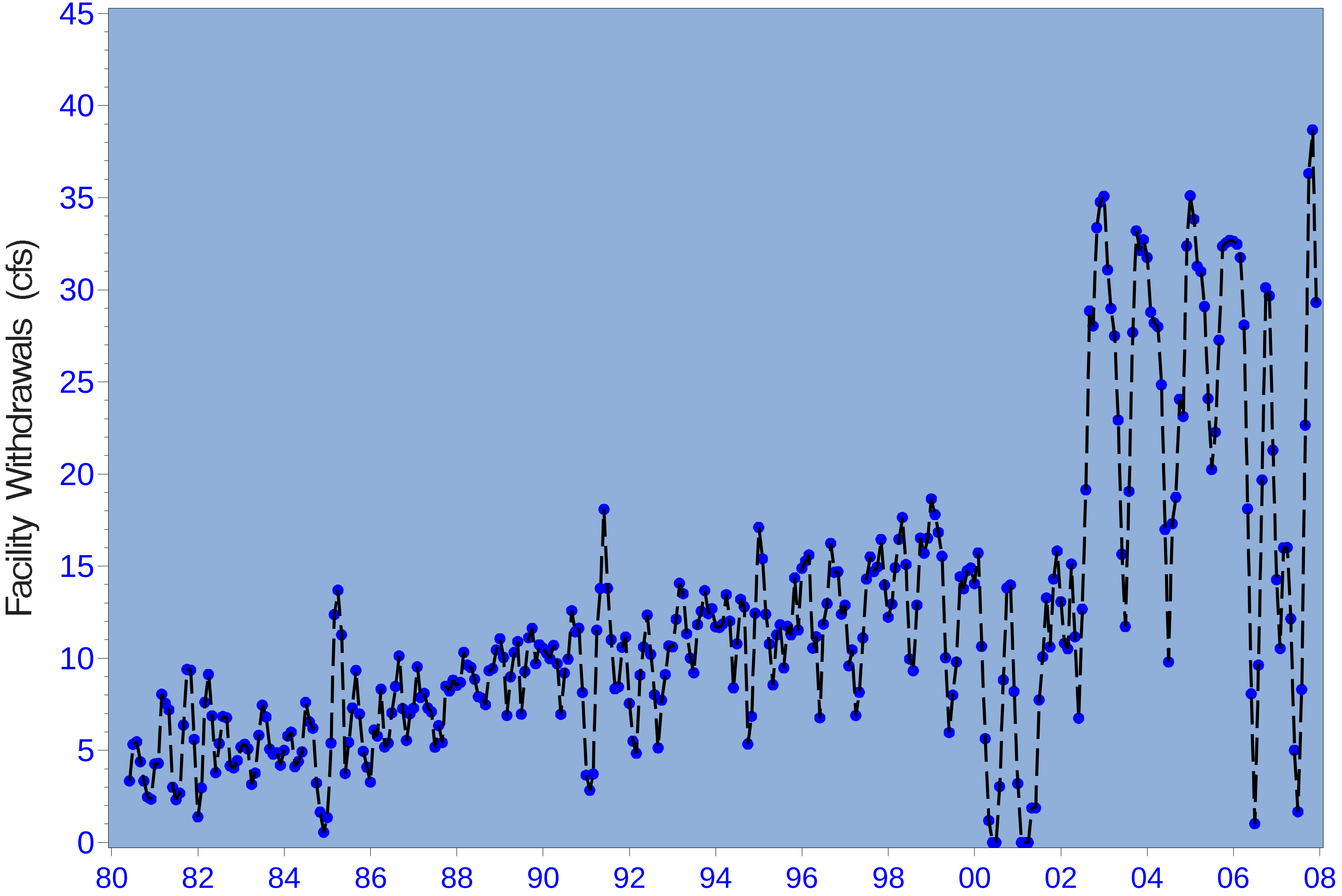

Figure 2.21 3-Month moving average water treatment facility withdrawals (1980-2007)

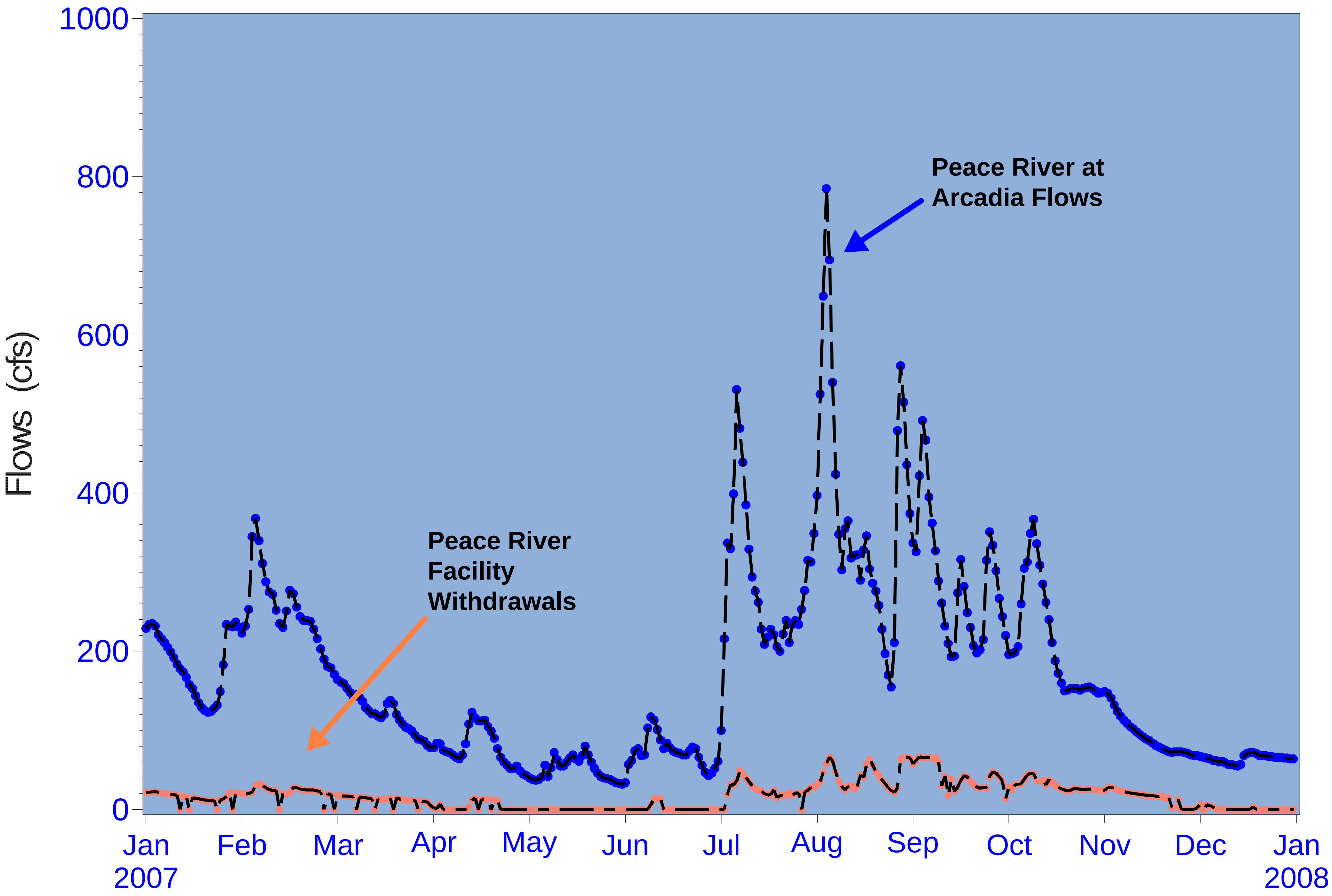

Figure 2.22 Daily Peace River flows at Arcadia and water treatment facility withdrawals (2007)

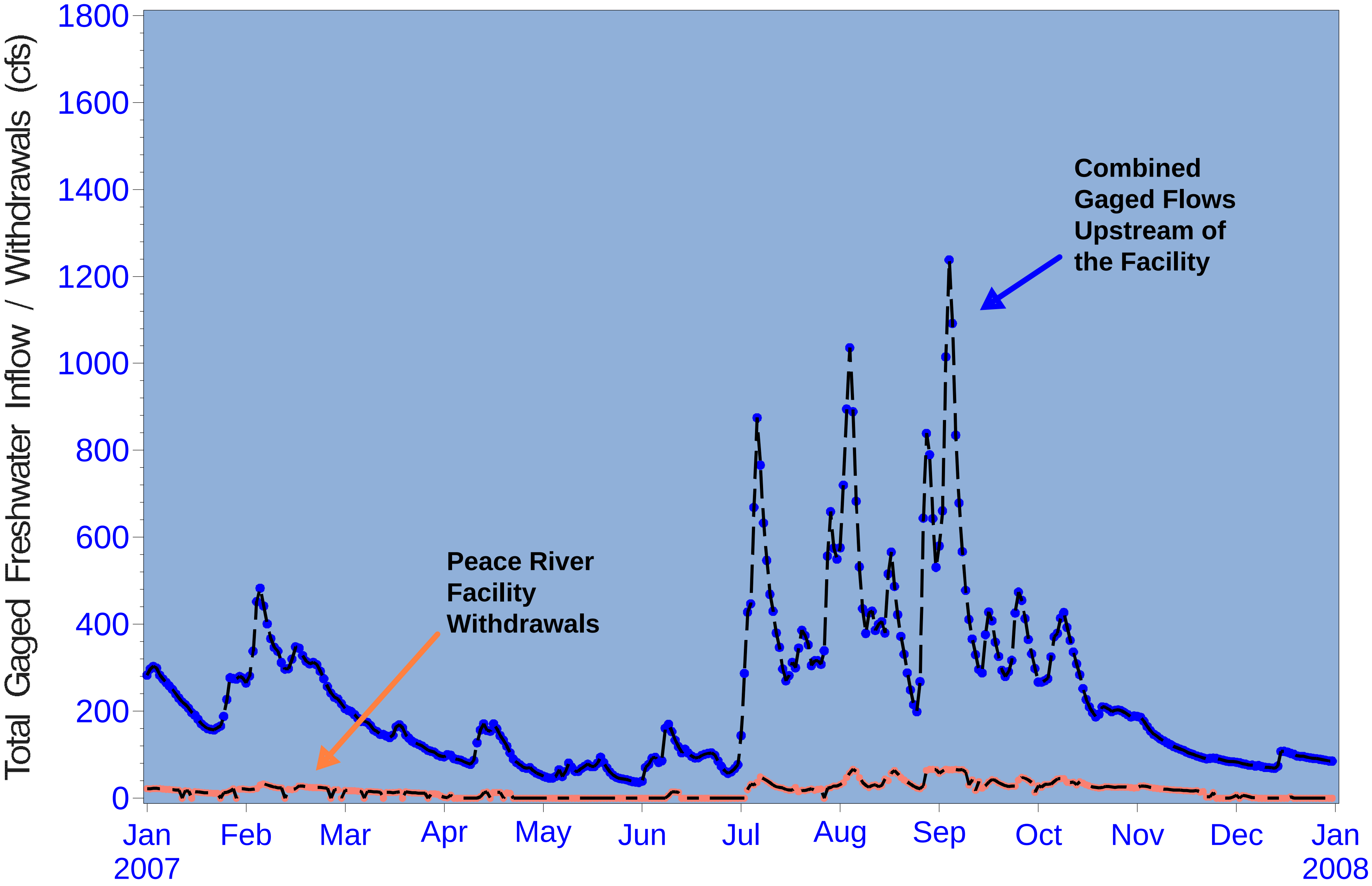

Figure 2.23 Daily total gage flow at the Facility (Peace River at Arcadia + Horse + Joshua Creeks) and water treatment facility withdrawal (2007)

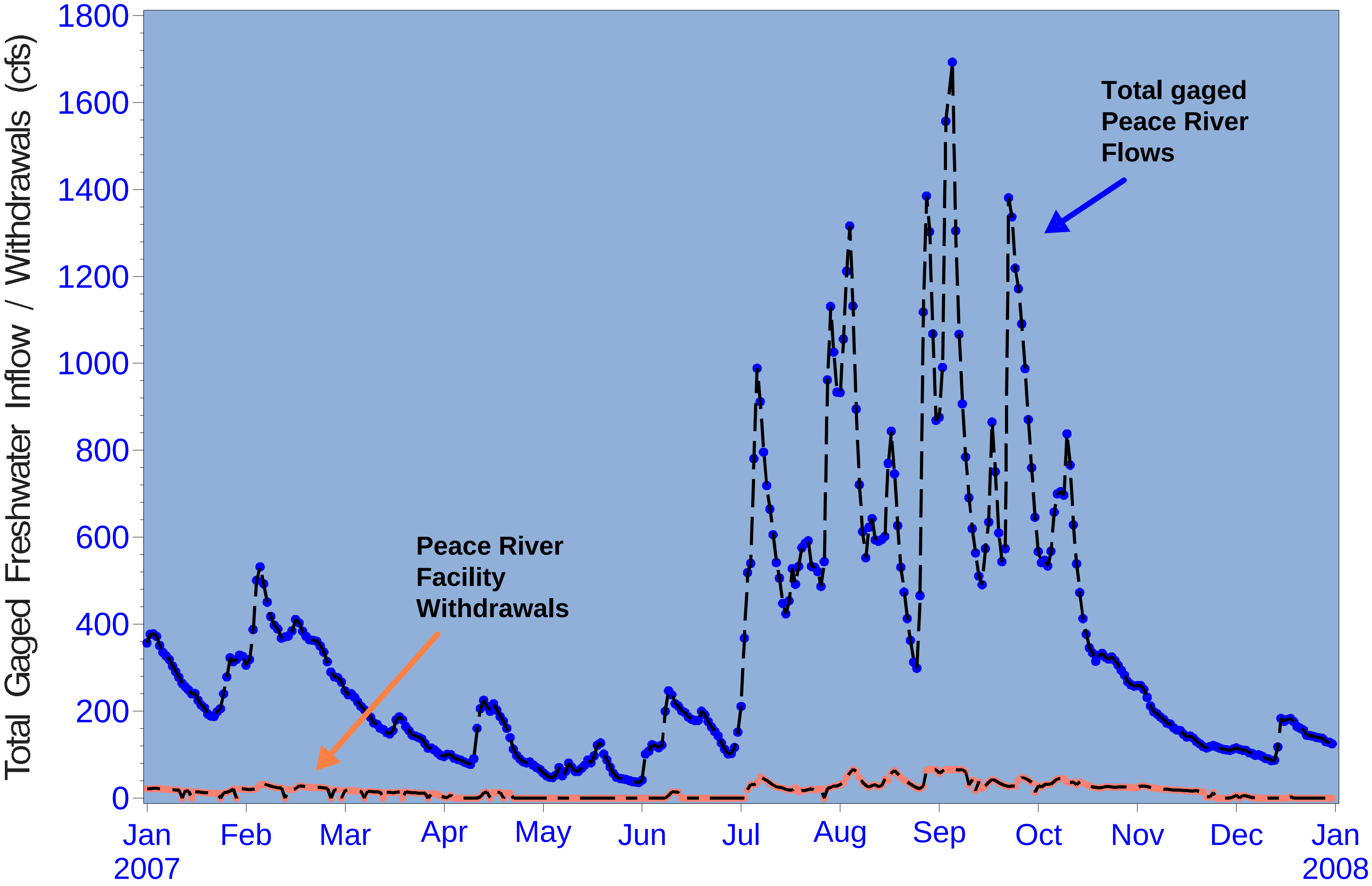

Figure 2.24 Daily total gaged flow at the river's mouth (Peace River at Arcadia + Horse + Joshua + Shell Creeks) and water treatment facility withdrawals (2007)

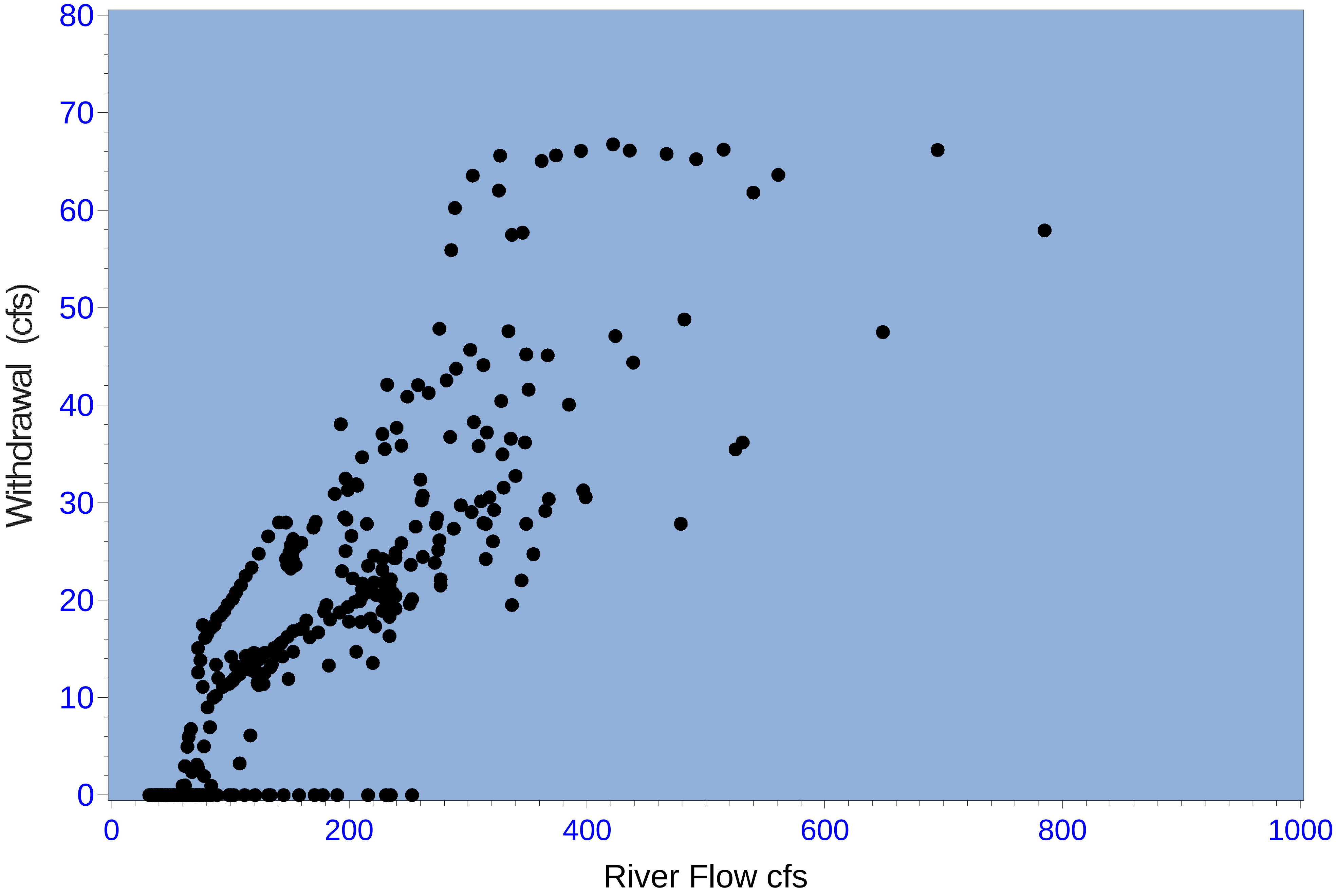

Figure 2.25 Peace River flows at Arcadia vs. water treatment facility withdrawals (2007)

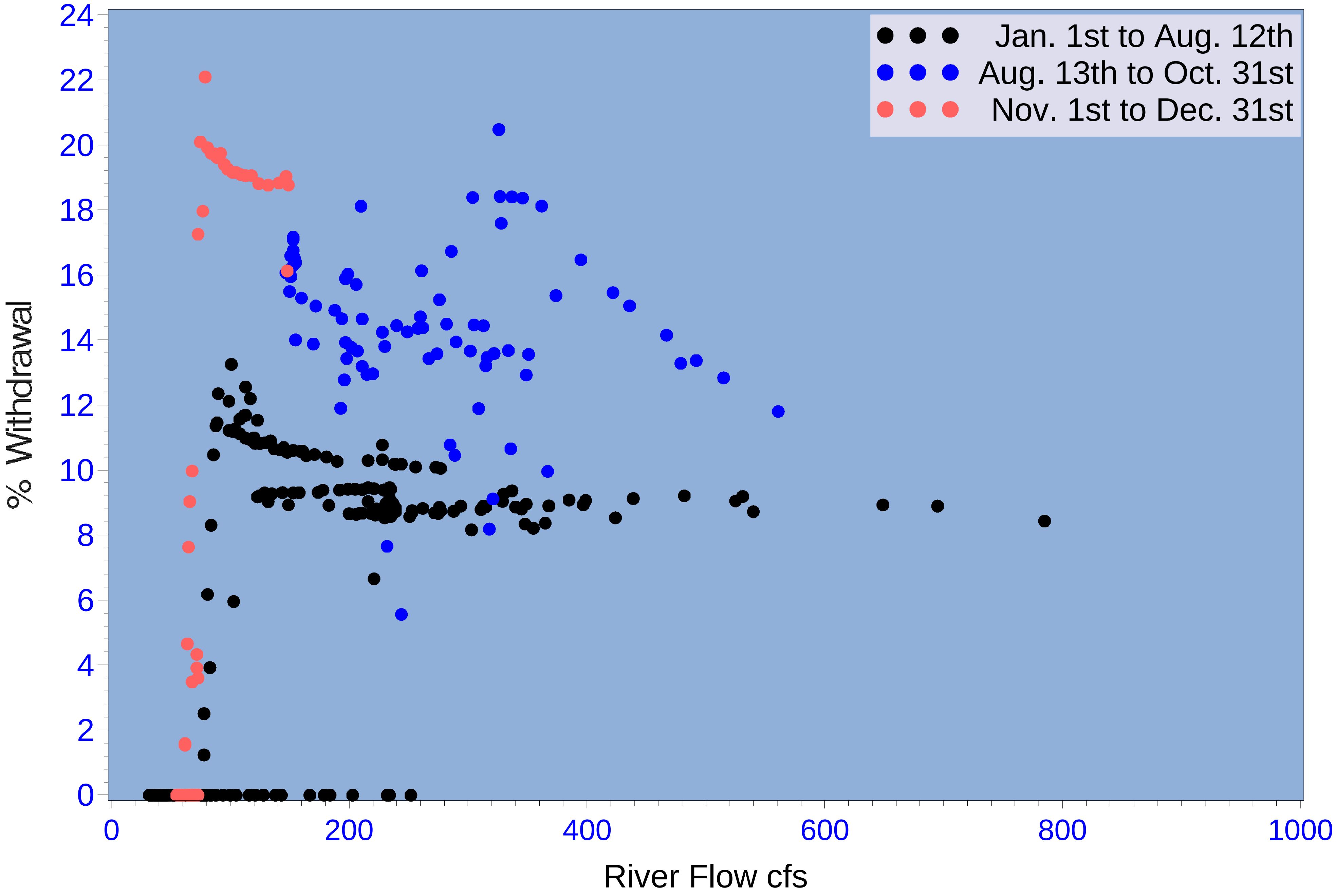

Figure 2.26a 2007 water treatment facility withdrawals as percent of Peace River at Arcadia flows

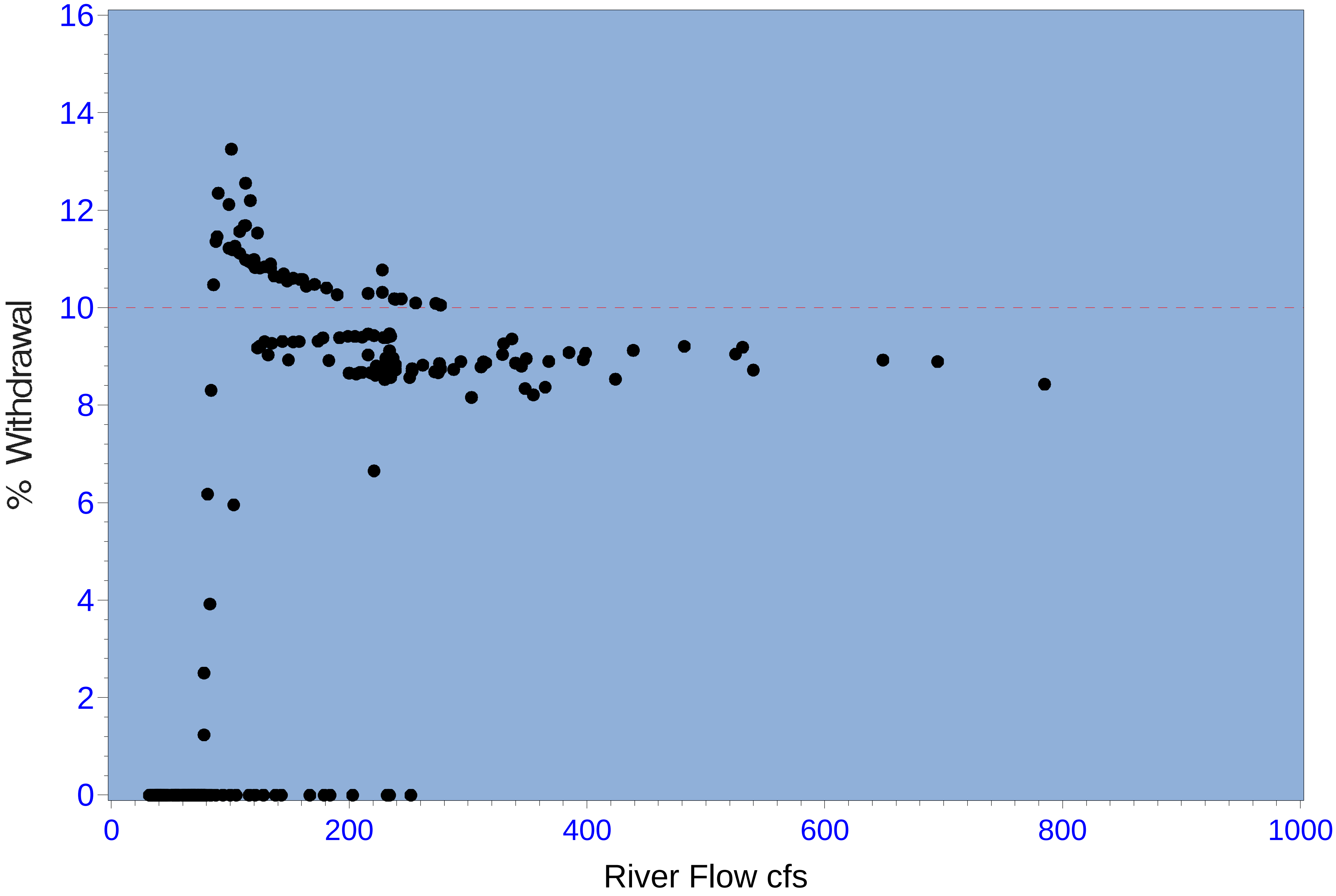

Figure 2.26b Jan 1st to Aug 12th Facility withdrawals as percent of Peace River at Arcadia flows

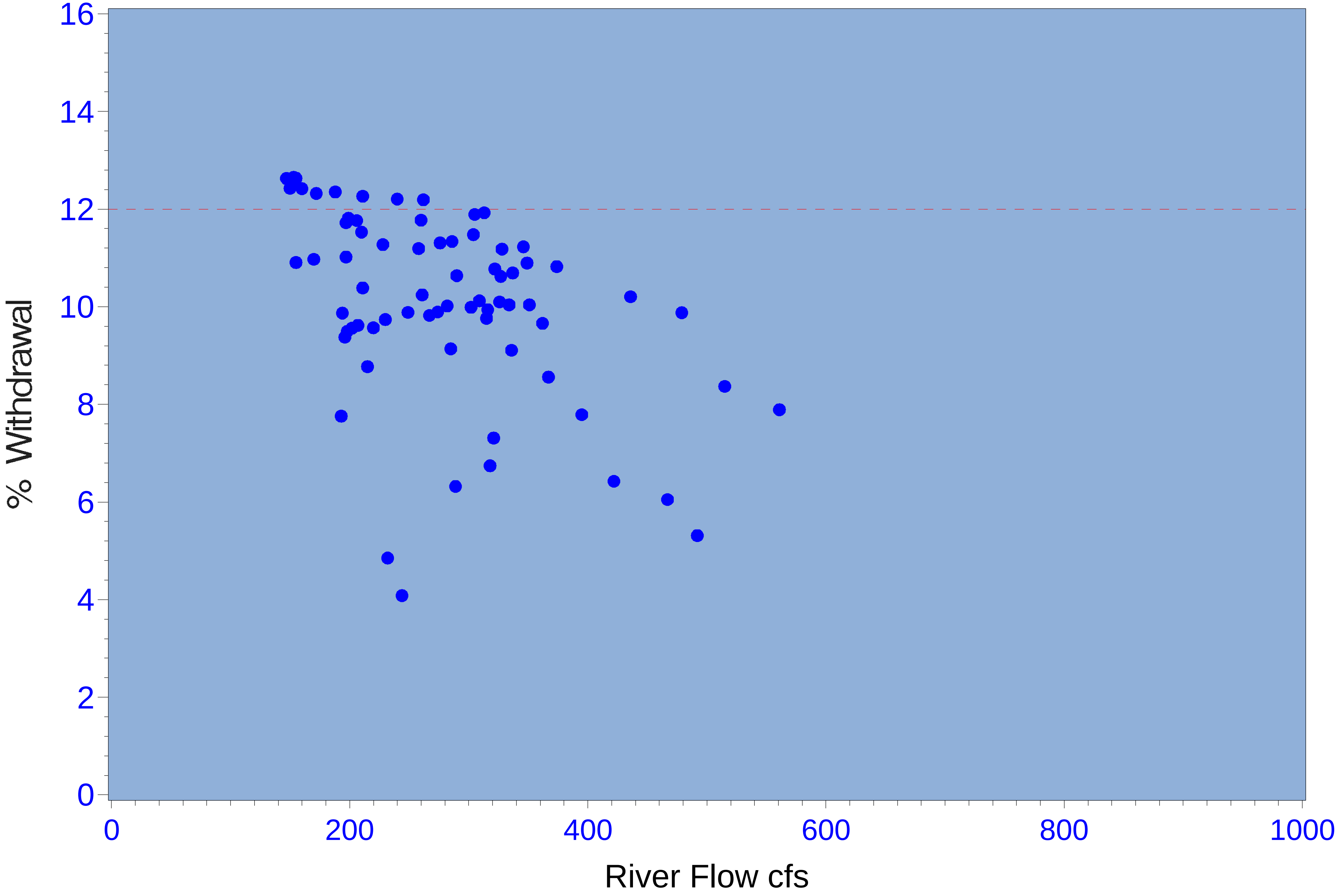

Figure 2.26c Aug 13th to Oct 31st Facility withdrawals as percent of combine upstream gaged flows

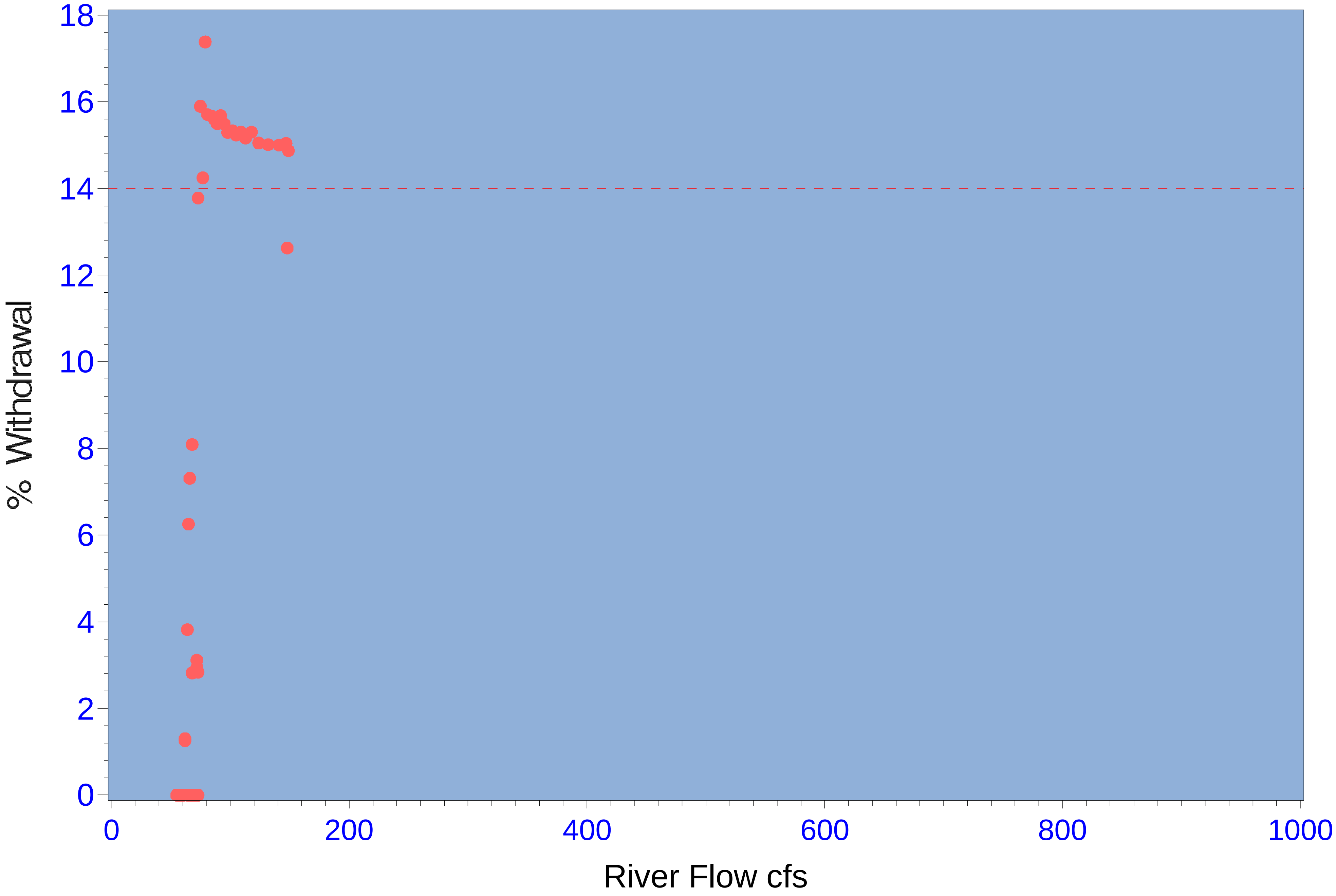

Figure 2.26d Nov 1st to Dec 31st Facility withdrawals as percent of combine upstream gaged flows

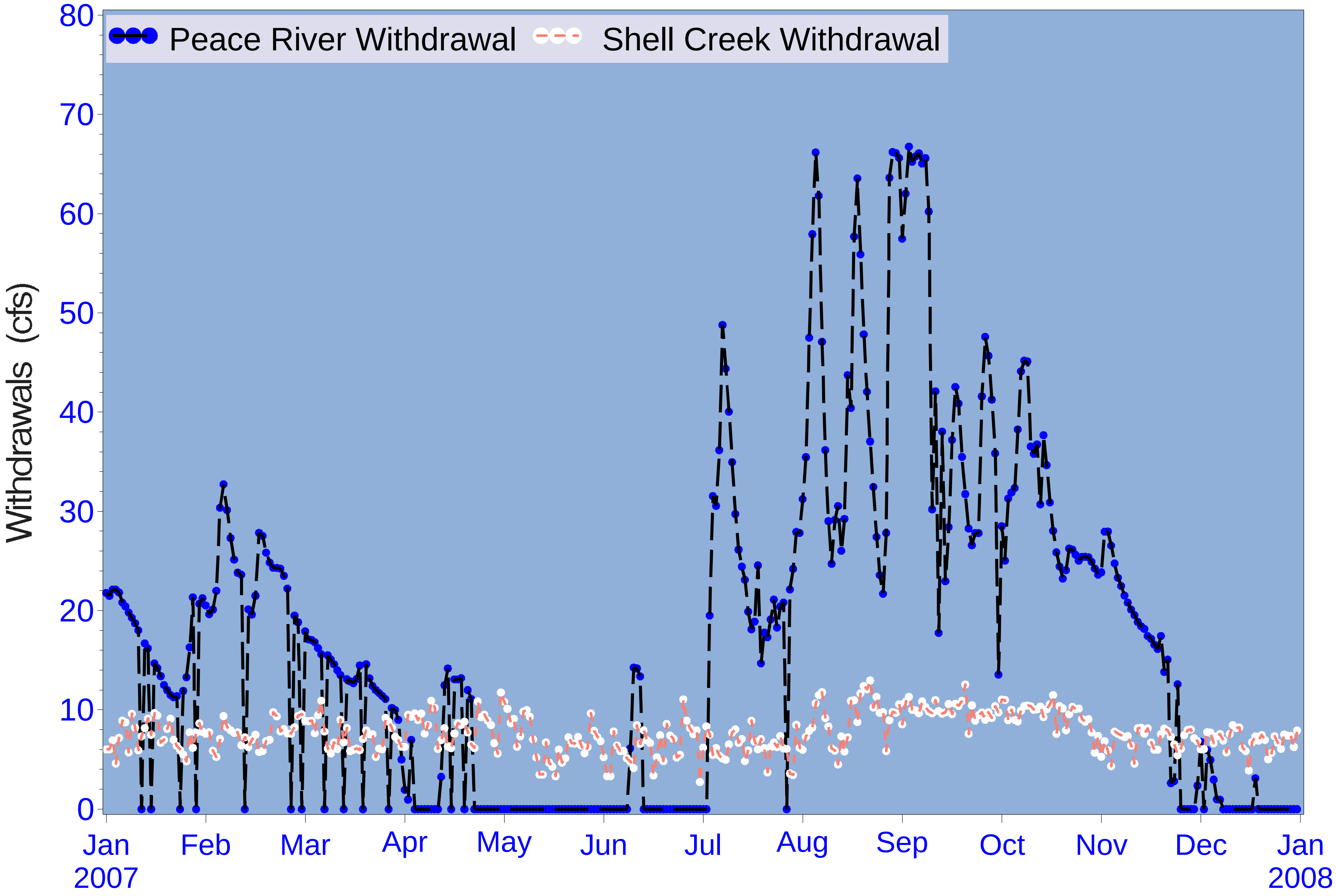

Figure 2.27 Daily Peace River and Shell Creek water treatment facility withdrawals (2007)

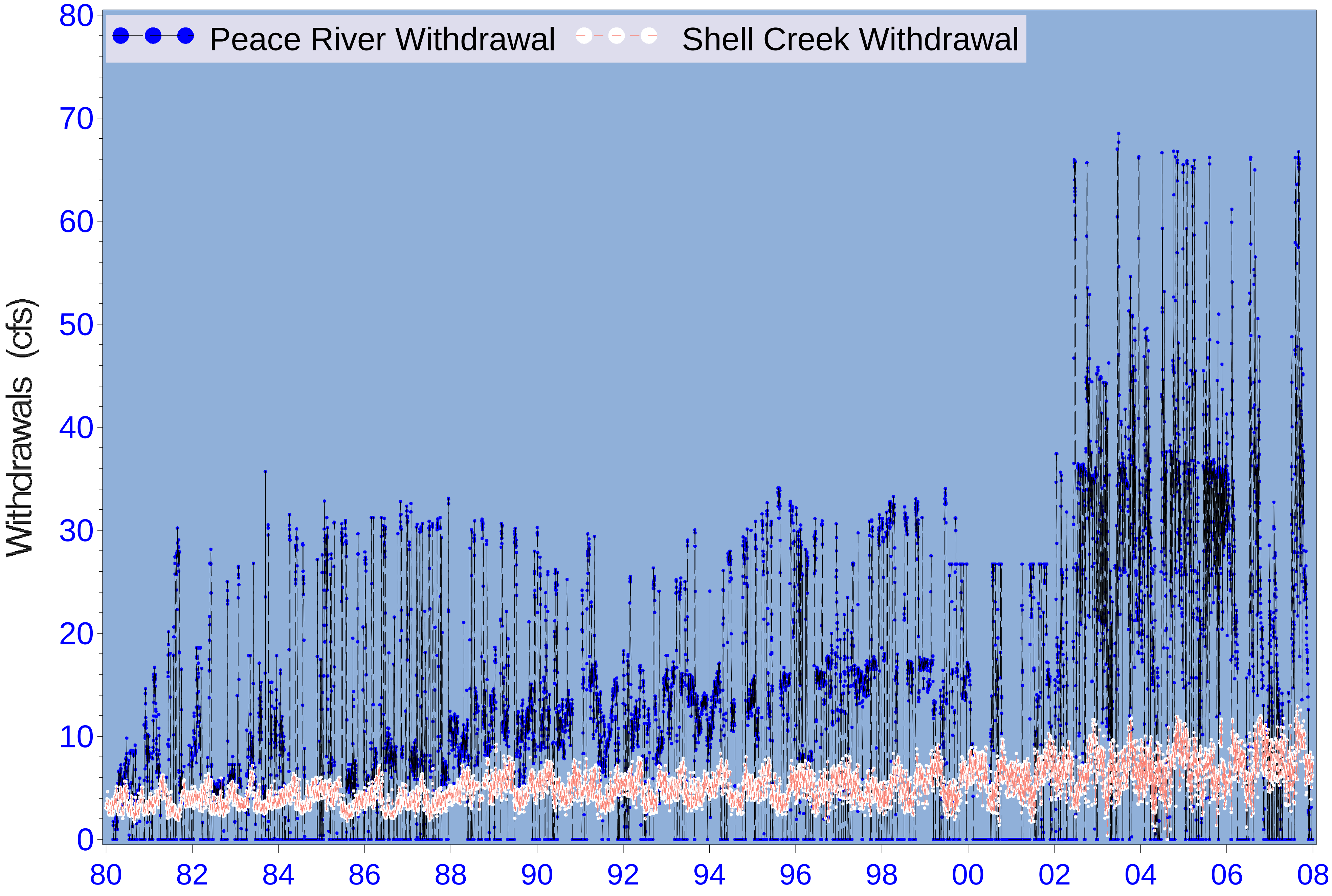

Figure 2.28 Daily Peace River and Shell Creek water treatment facility withdrawals (1980-2007)

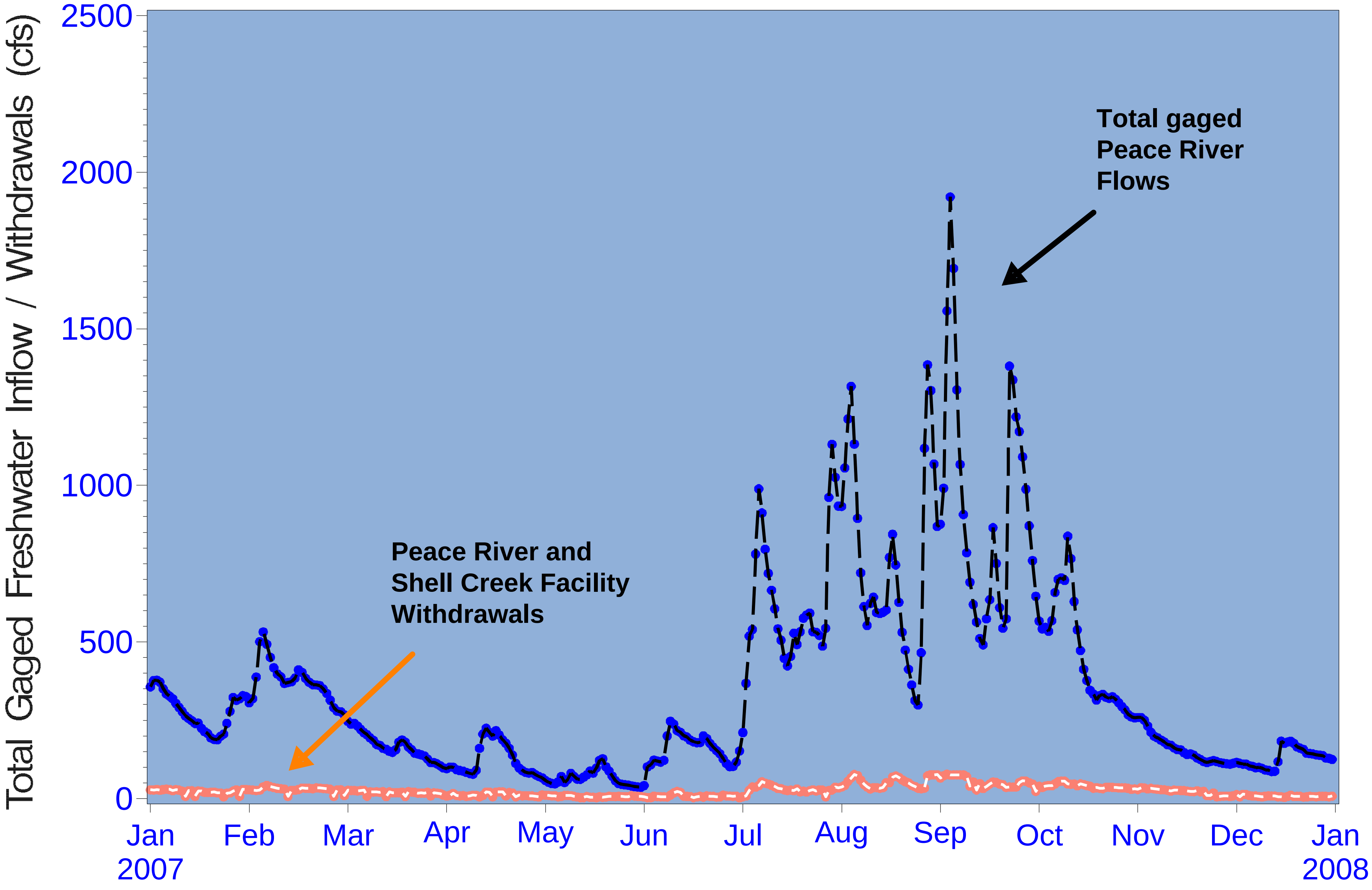

Figure 2.29 Daily total gaged flow at the river's mouth (Peace River at Arcadia + Horse + Joshua + Shell Creeks) and total water treatment facility withdrawals (2007)

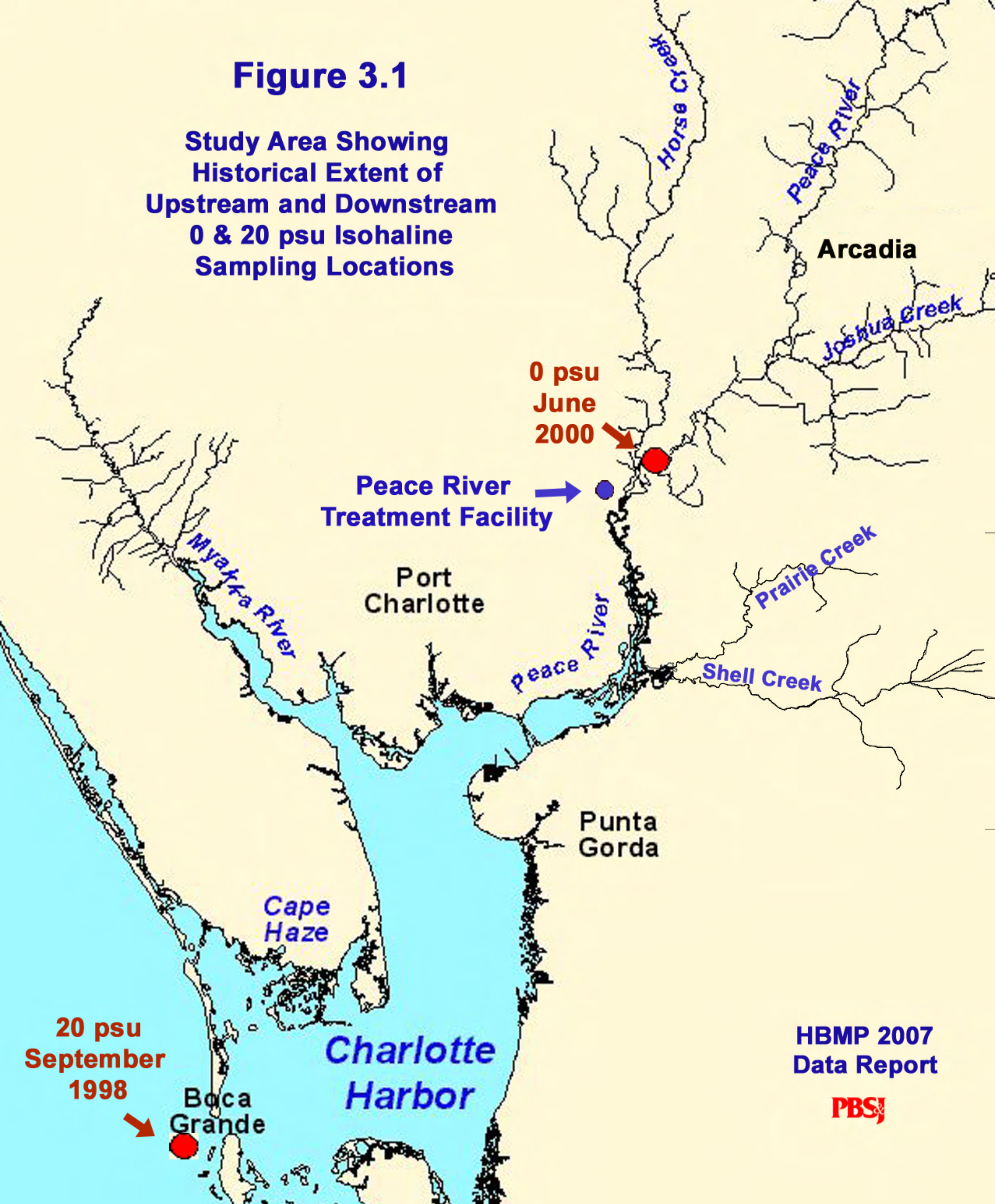

Figure 3.1

Study Area Showing Historical Extent of Upstream and Downstream 0 & 20 psu Isohaline Sampling Locations

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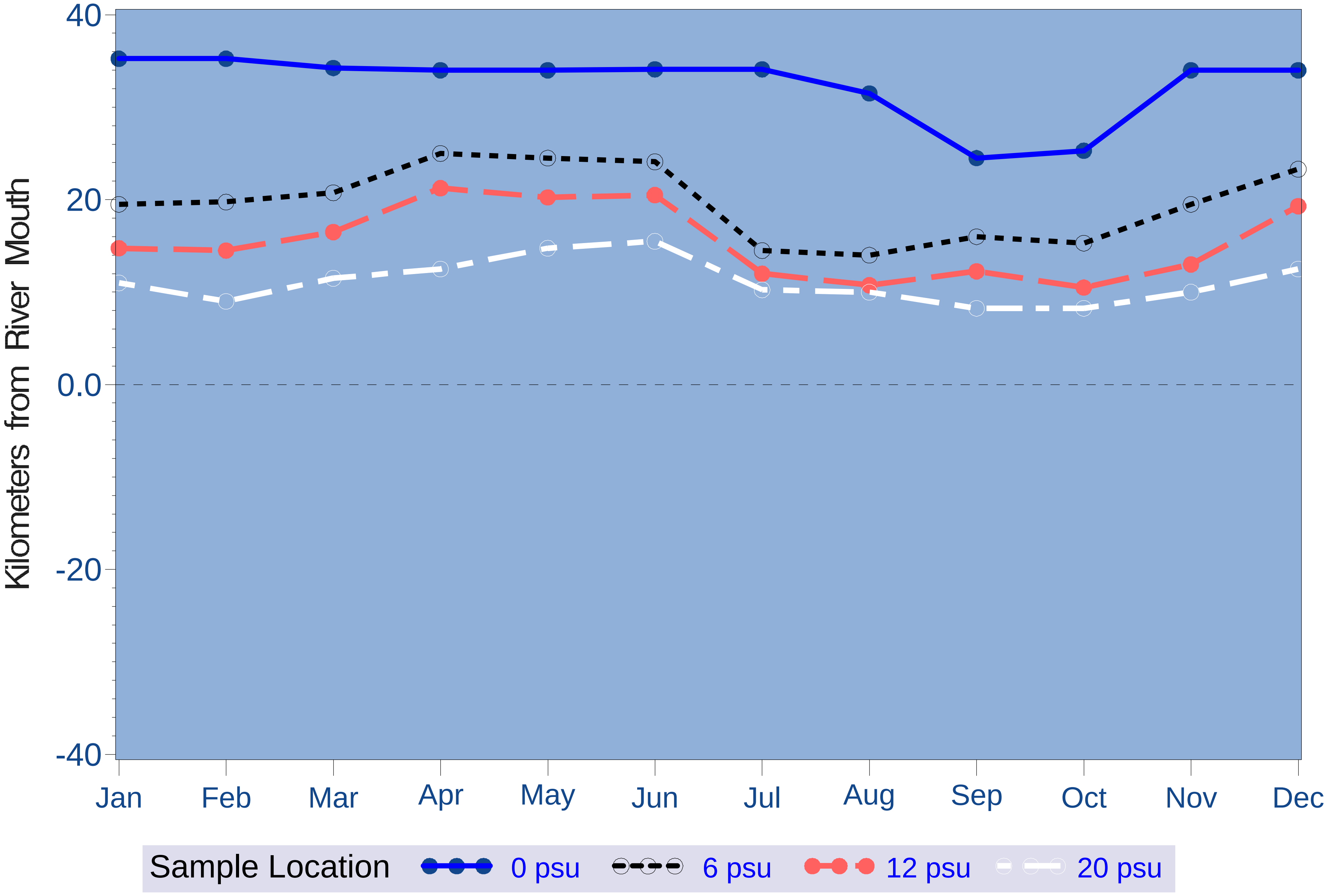


Figure 3.2 Relative distance (km) from the mouth of the river (2007)

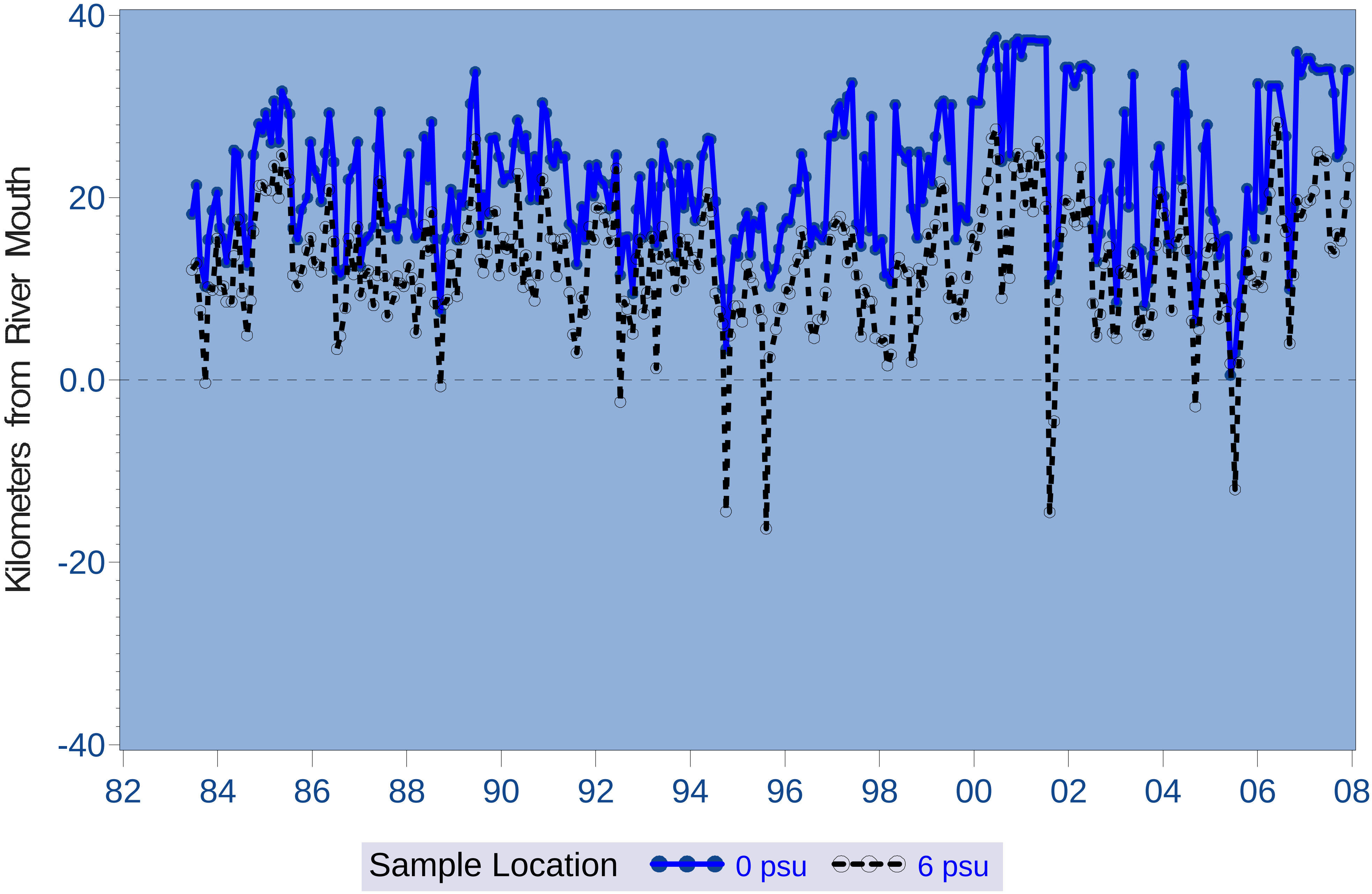


Figure 3.3 Relative distance (km) from the mouth of the river of 0 and 6 psu salinity sampling zones (1983-2007)

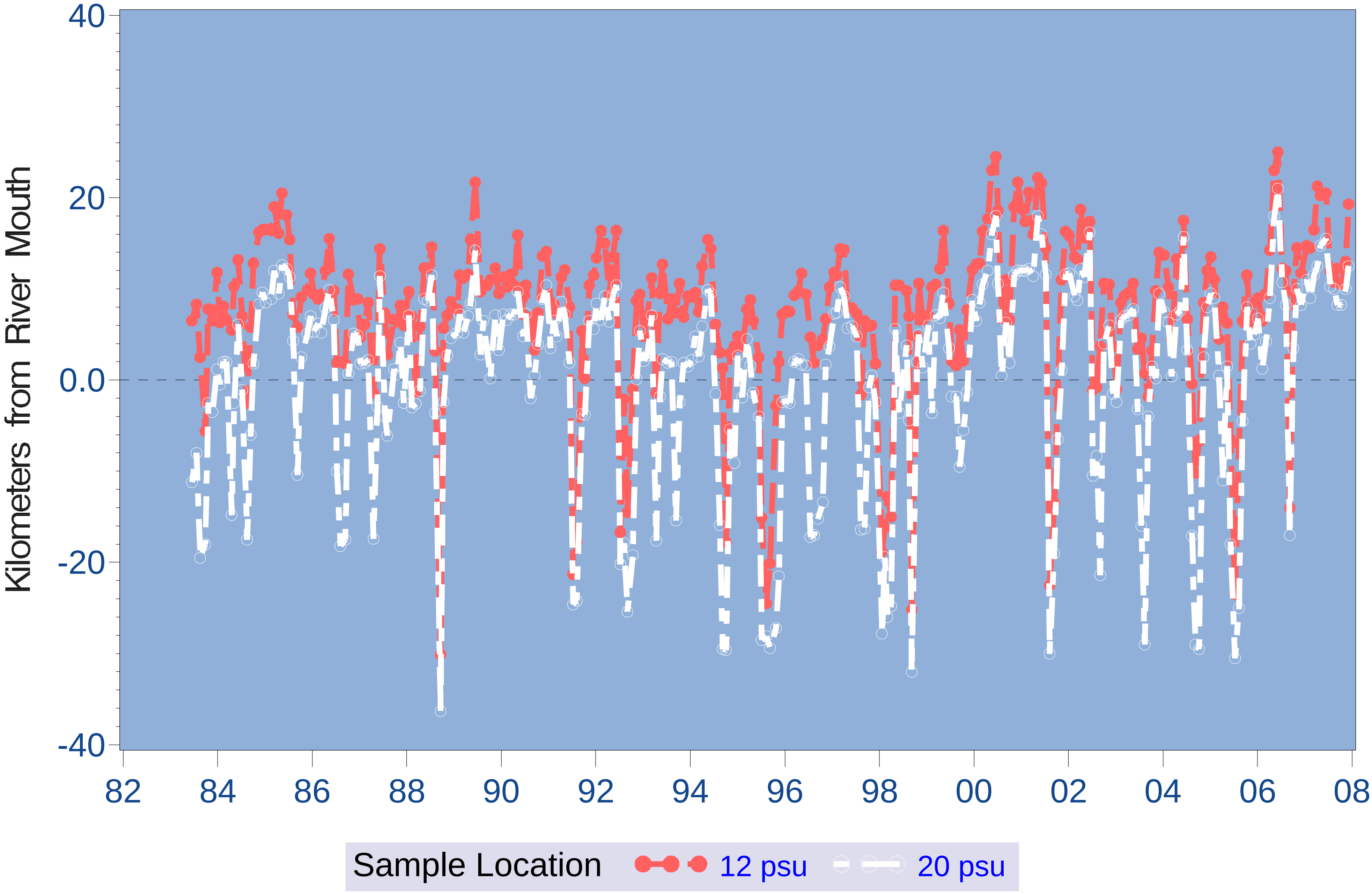


Figure 3.4 Relative distance (km) from the mouth of the river of 12 and 20 psu salinity sampling zones (1983-2007)

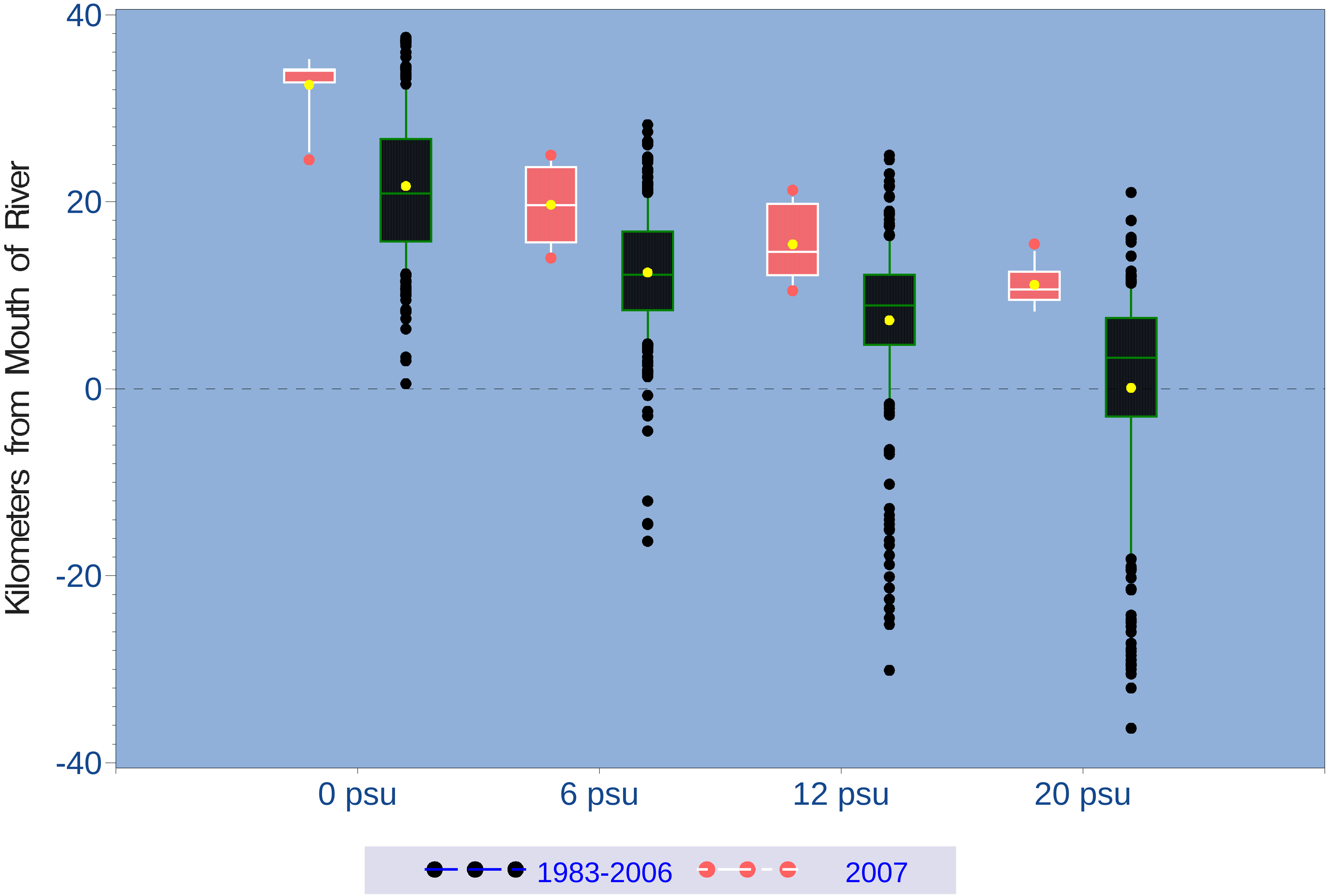


Figure 3.5 Box & whiskers of distance (km) of salinity zones from the mouth of the river

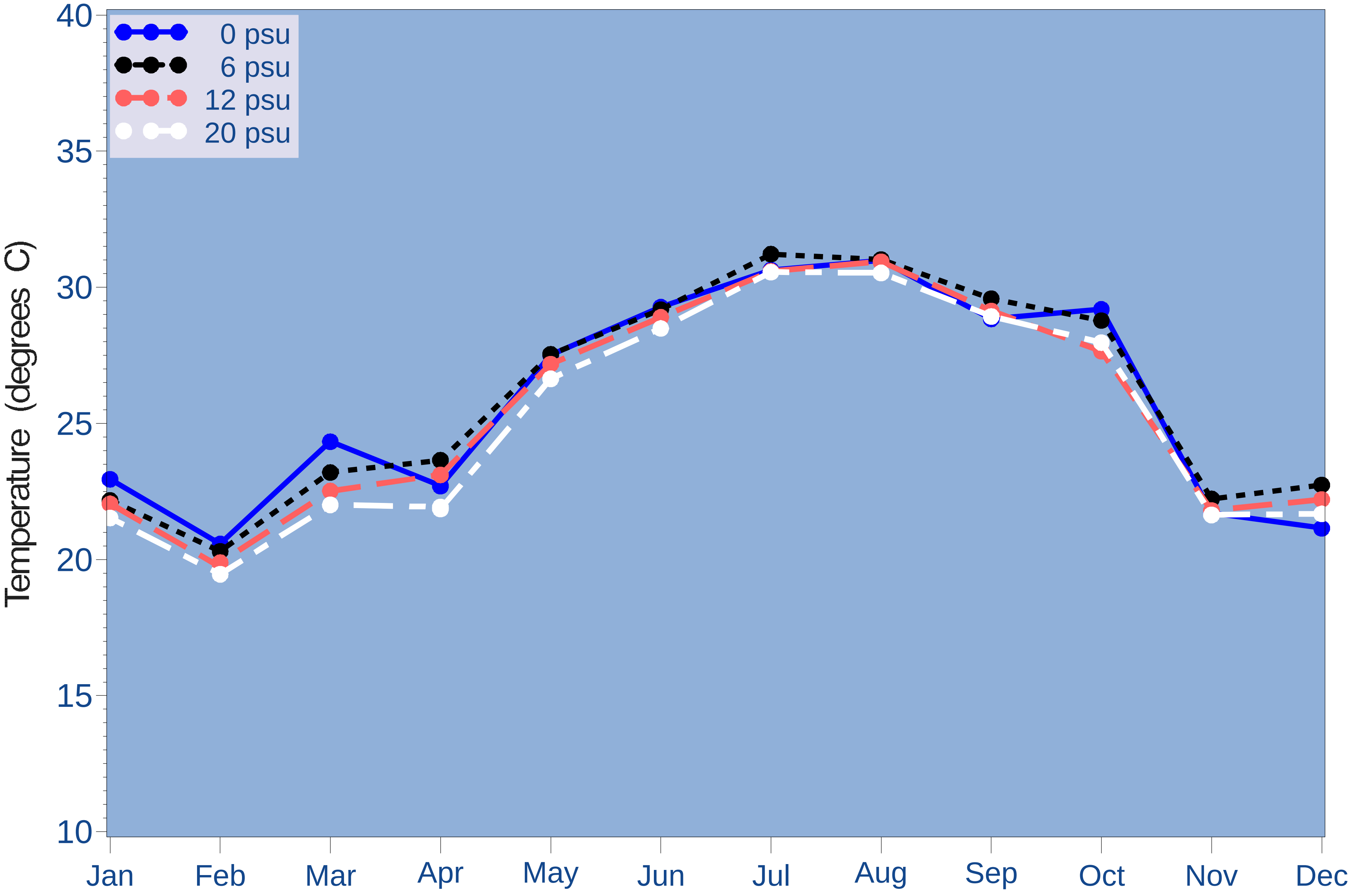


Figure 3.6 Monthly temperature at each of the four salinity based sampling zones (2007)

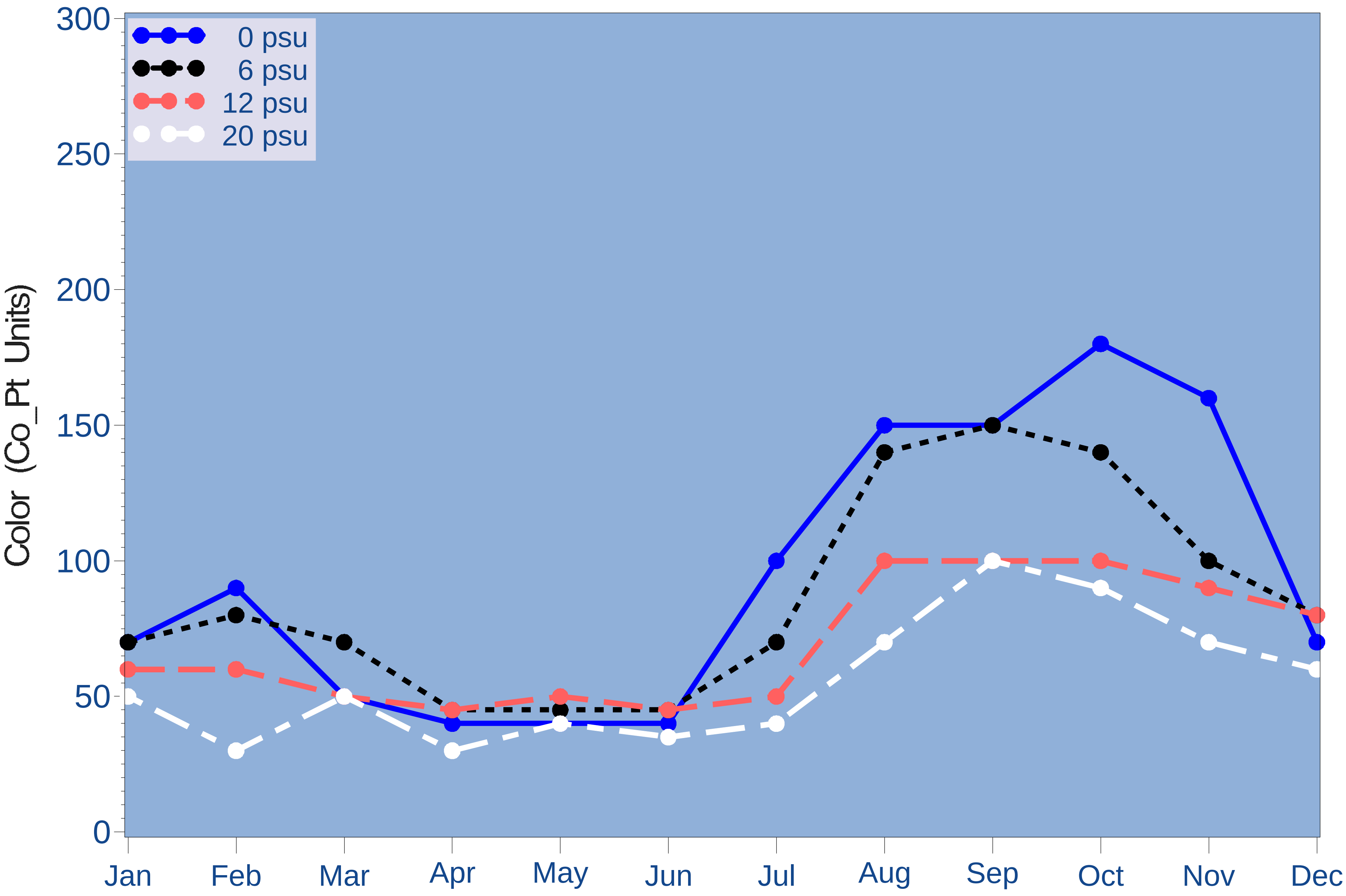


Figure 3.7 Monthly color at each of the four salinity based sampling zones (2007)

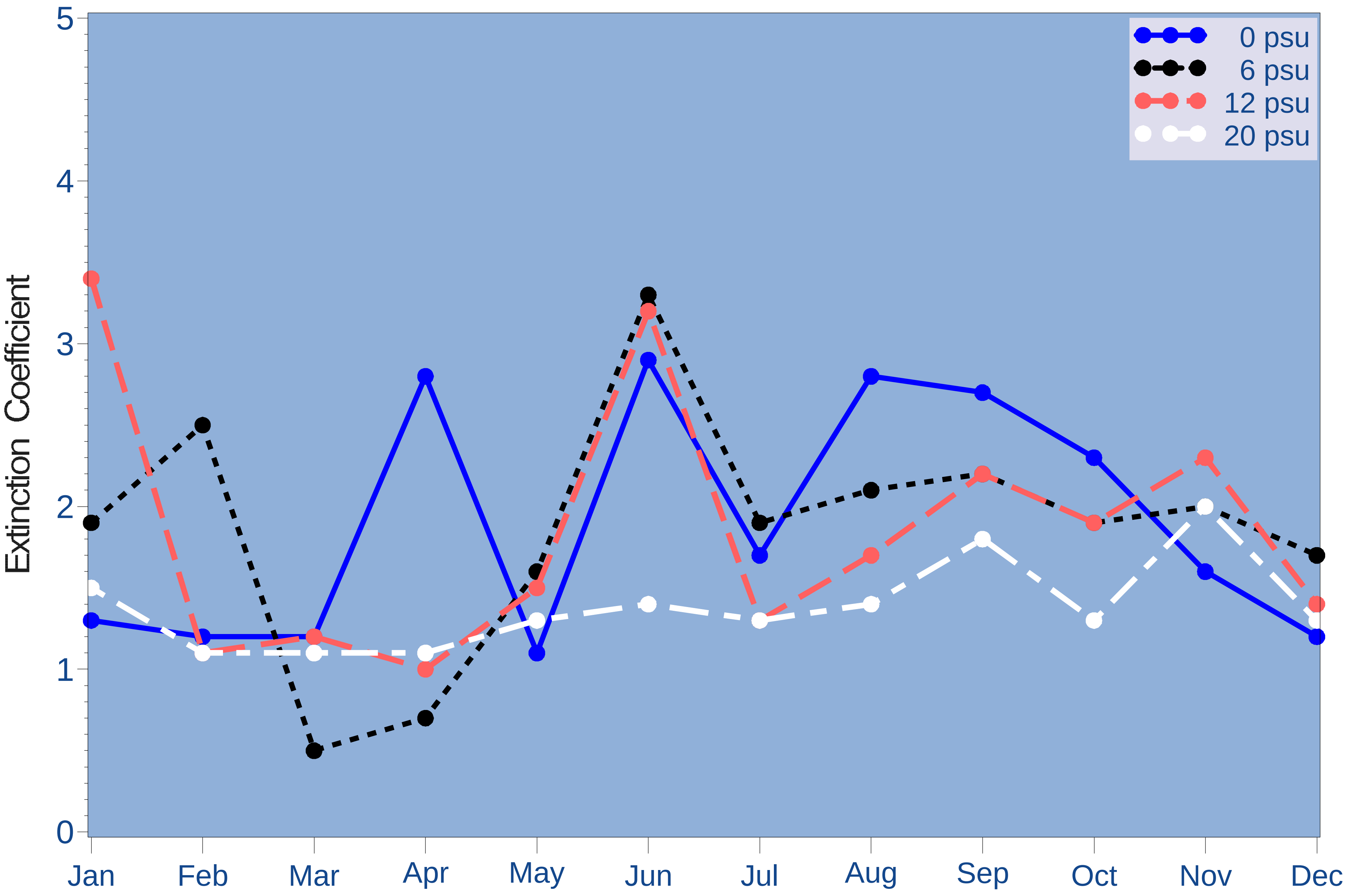


Figure 3.8 Monthly extinction coefficient at each of the salinity based sampling zones (2007)

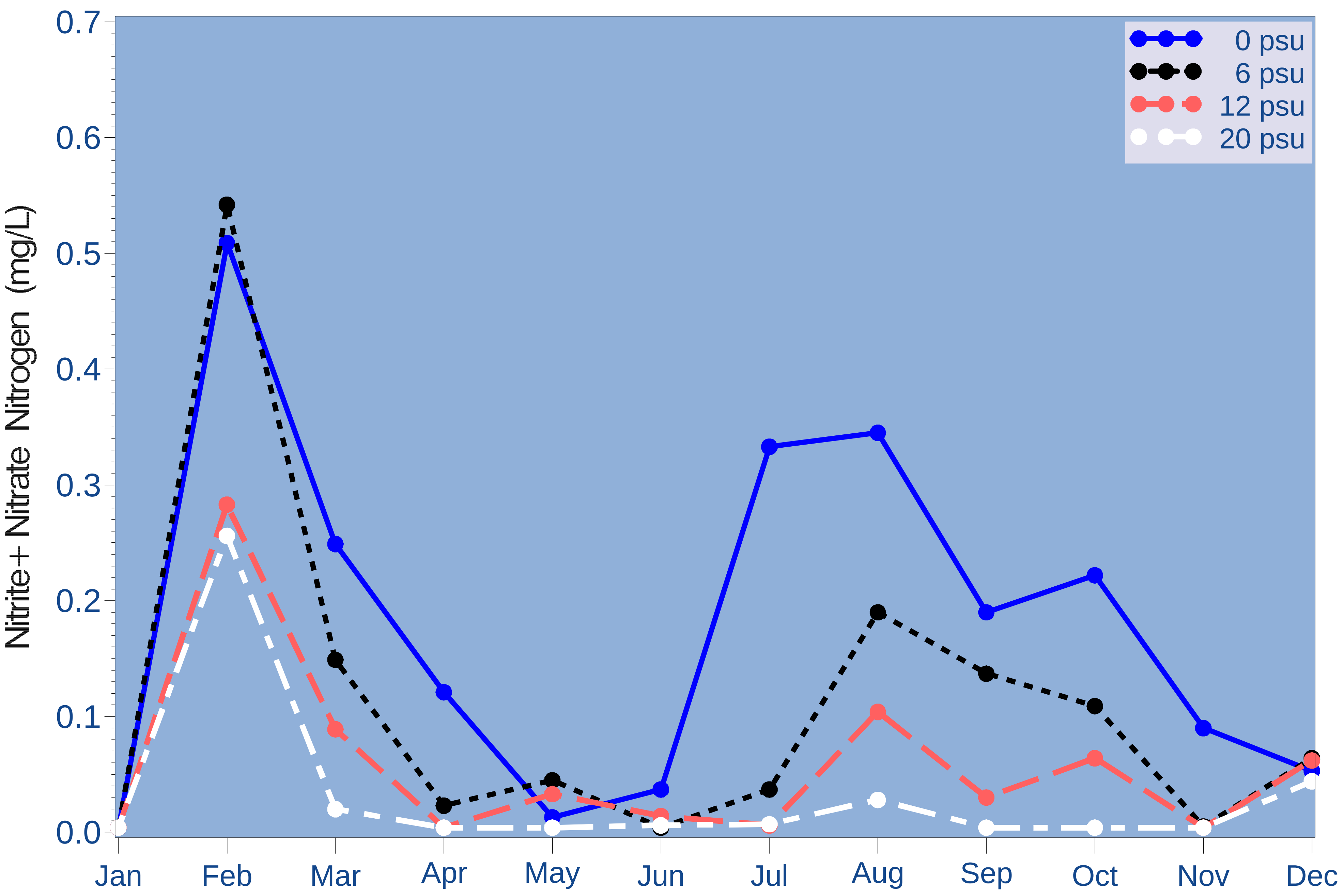


Figure 3.9 Monthly nitrite+nitrate nitrogen at each of the four salinity based sampling zones (2007)

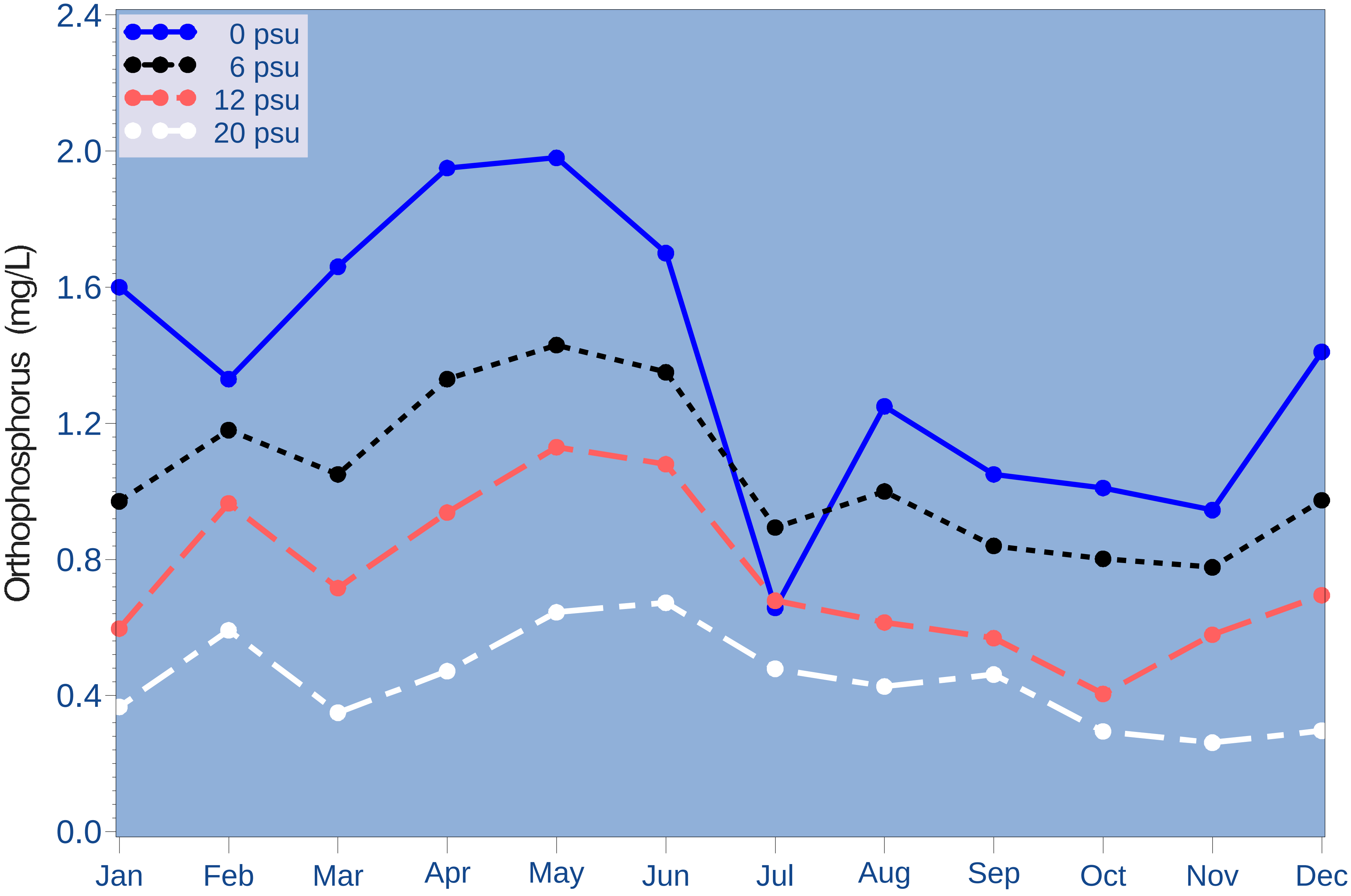


Figure 3.10 Monthly orthophosphorus at each of the four salinity based sampling zones (2007)

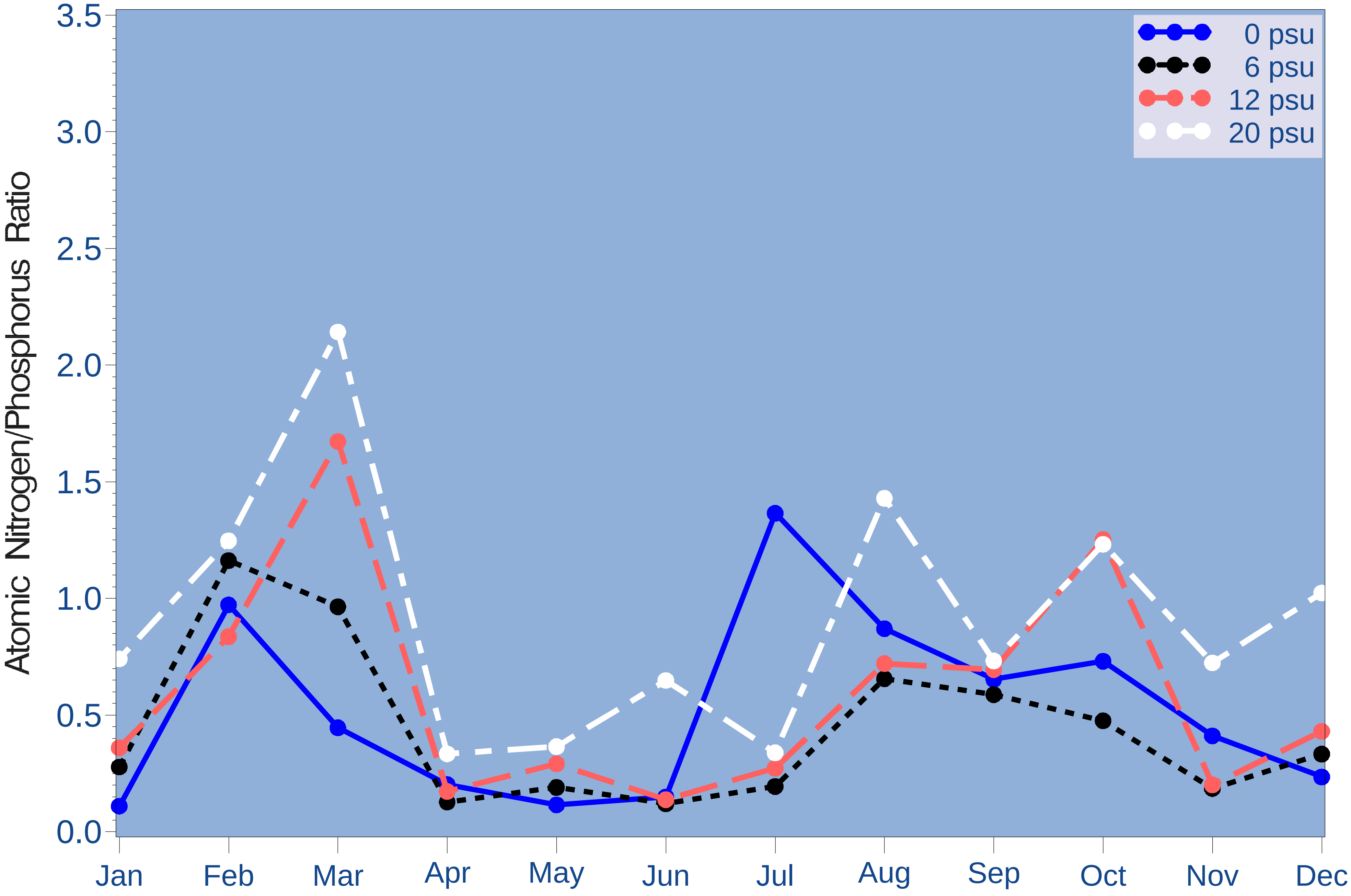


Figure 3.11 Monthly Atomic N/P ratio at each of the four salinity based sampling zones (2007)

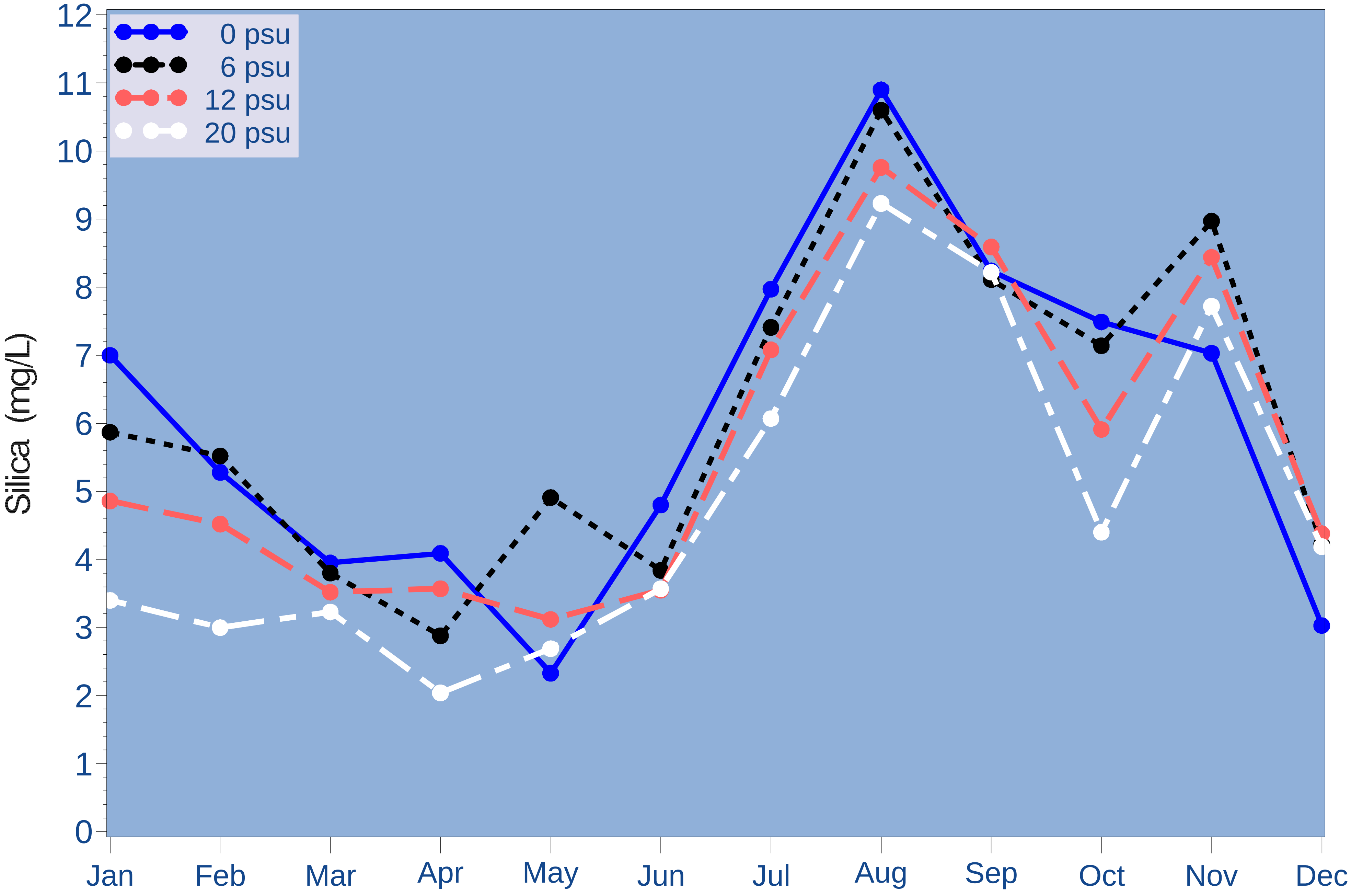


Figure 3.12 Monthly silica at each of the four salinity based sampling zones (2007)

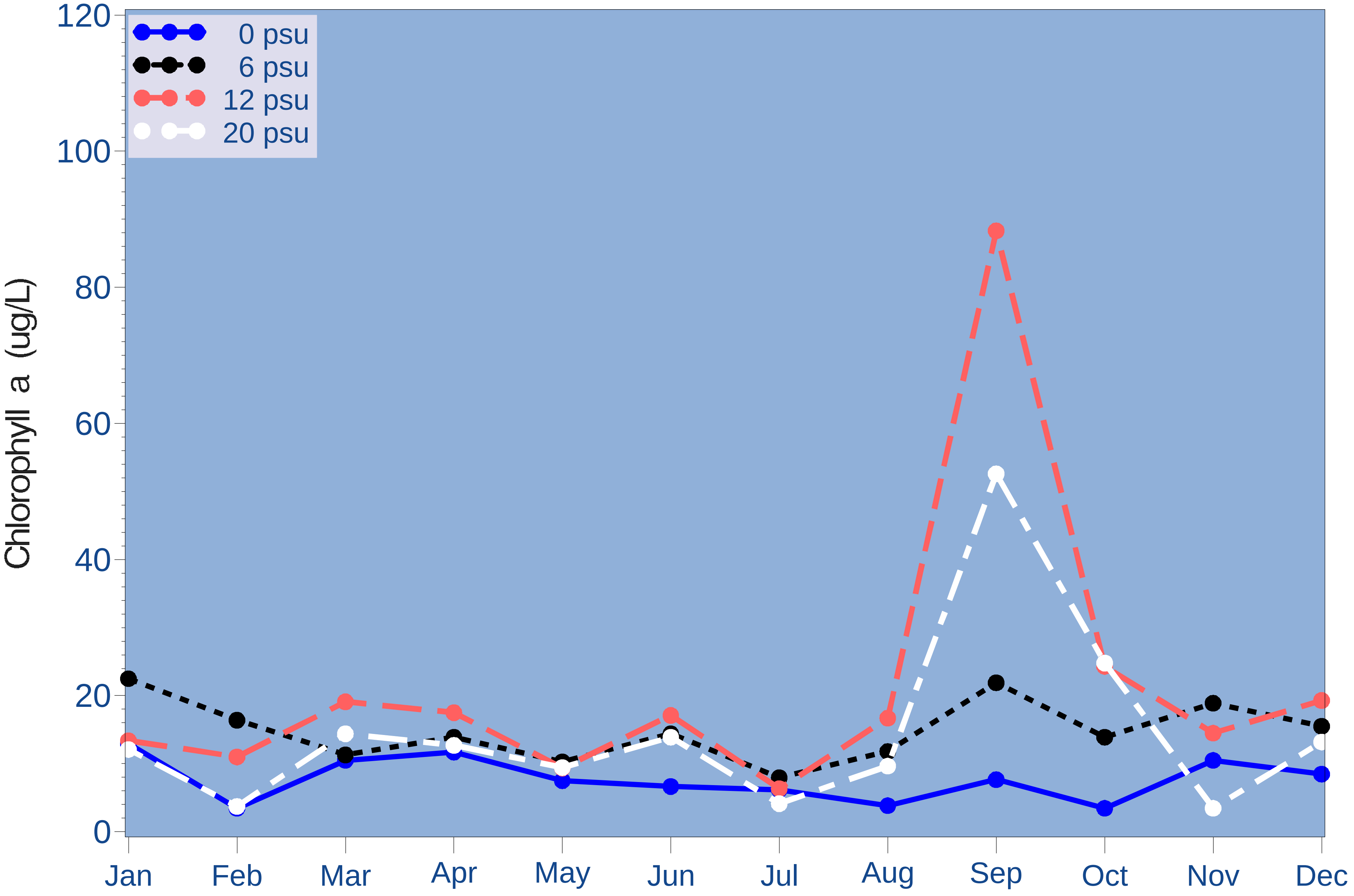


Figure 3.13 Monthly chlorophyll a at each of the four salinity based sampling zones (2007)

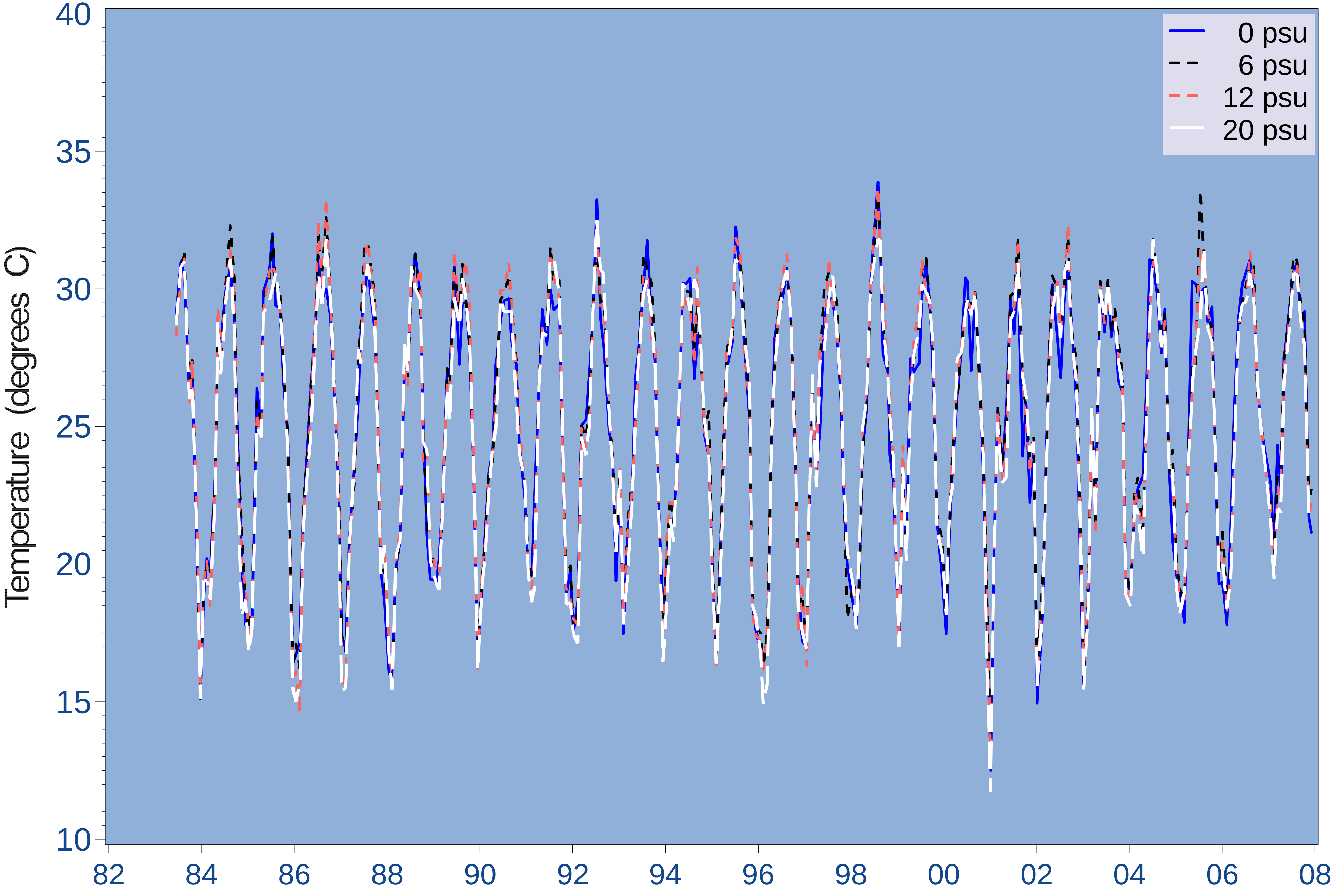


Figure 3.14 Monthly temperature at each isohaline based sampling zone (1983-2007)

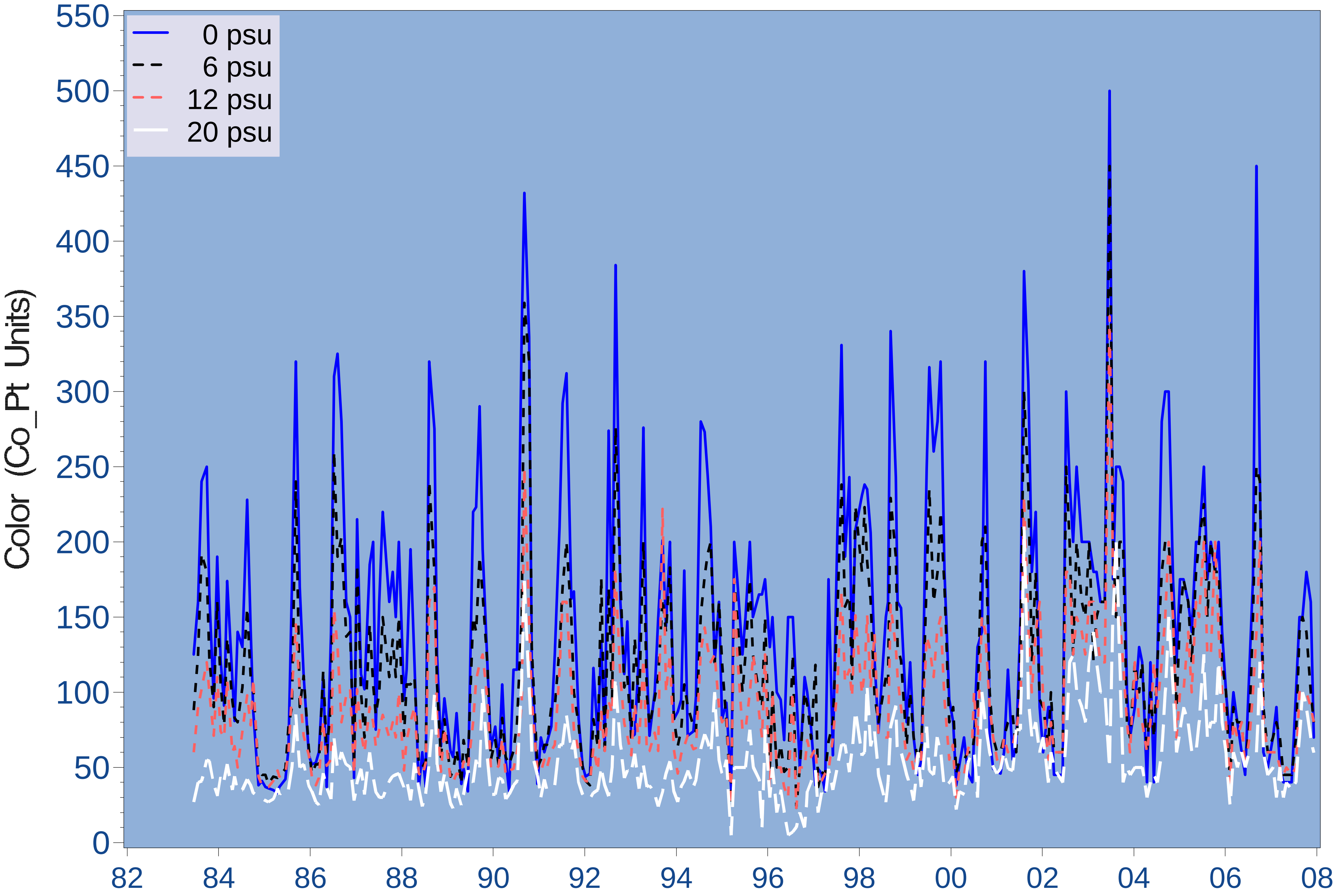


Figure 3.15 Monthly color at each isohaline based sampling zone (1983-2007)

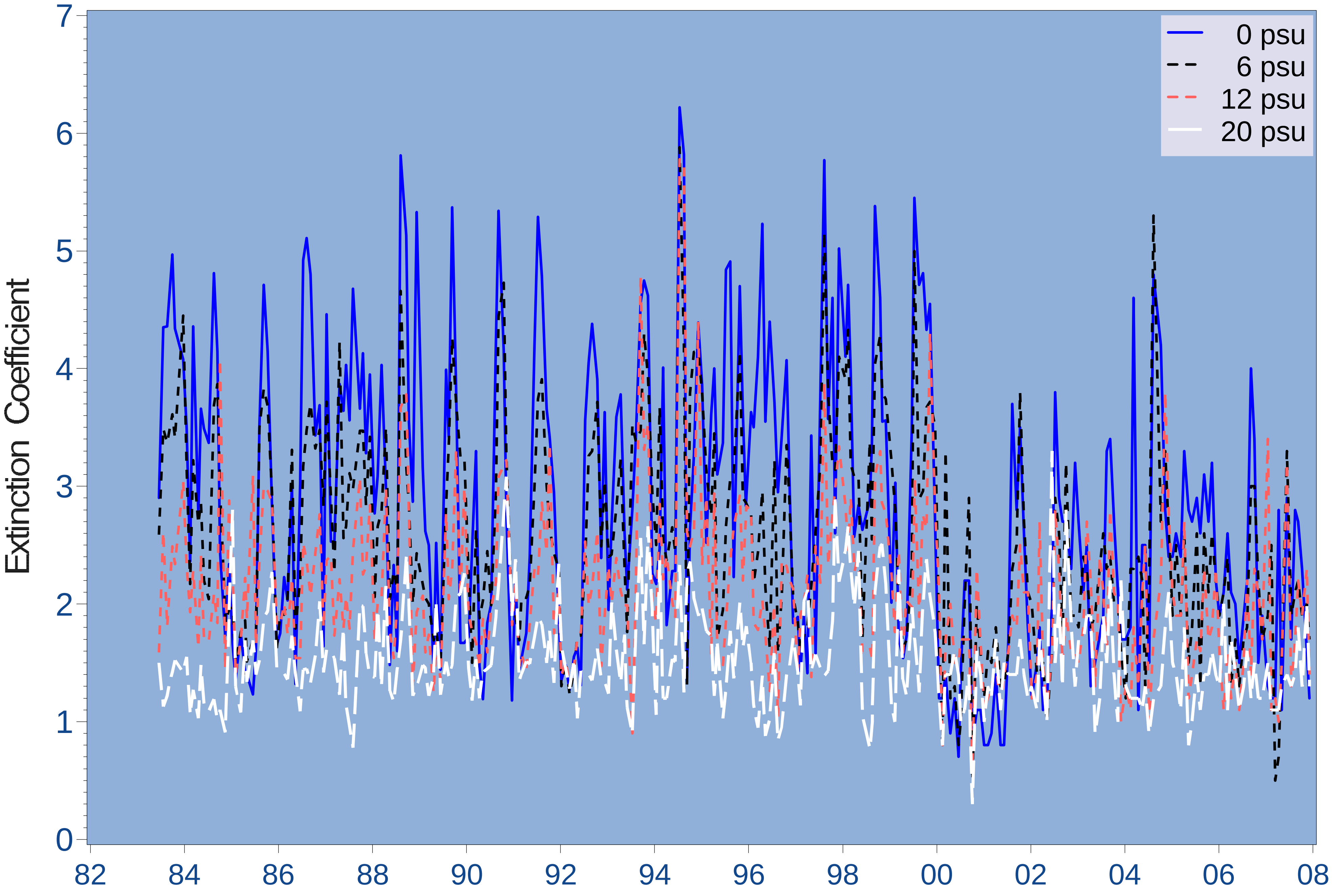


Figure 3.16 Monthly extinction coefficient at each isohaline based sampling zone (1983-2007)

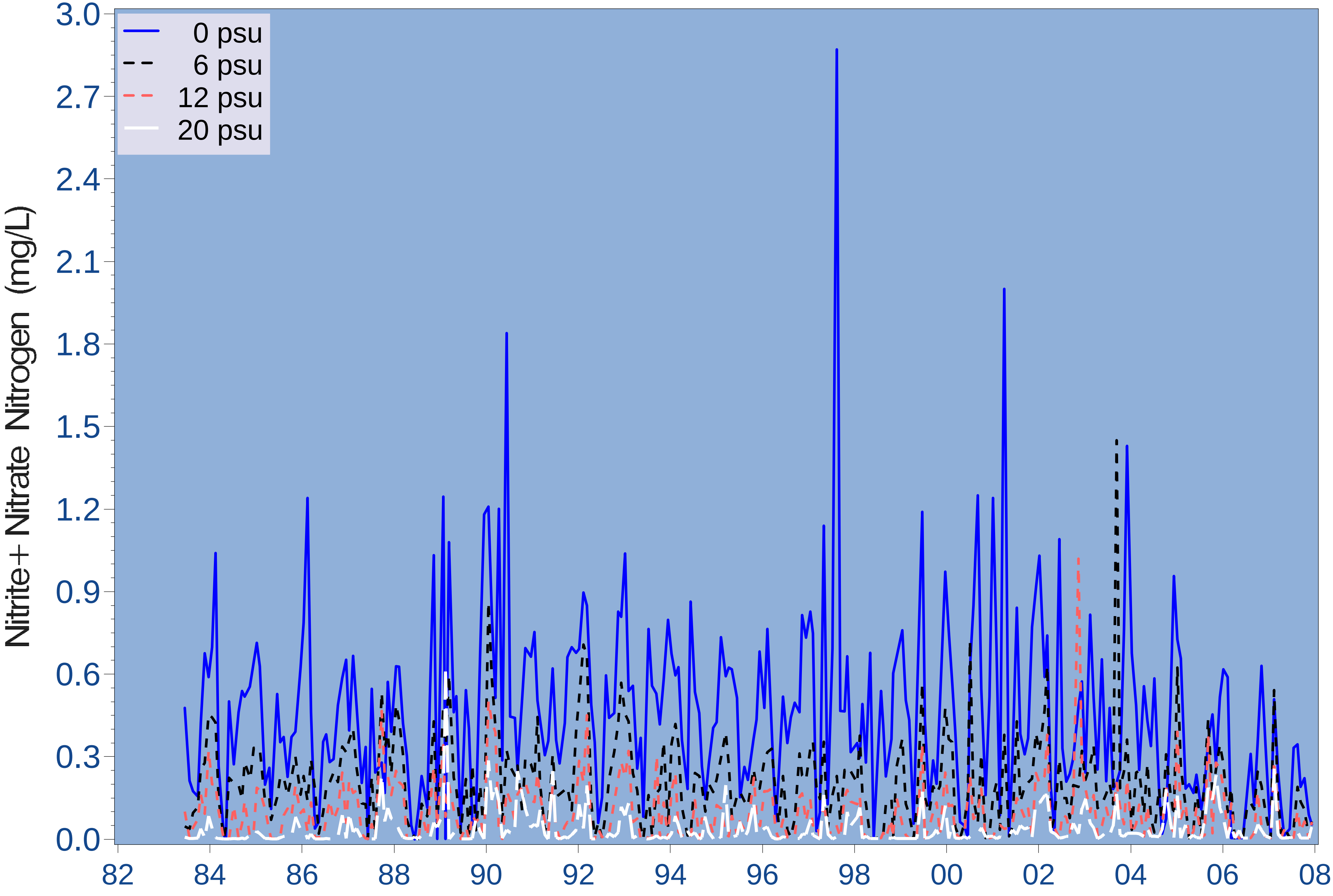


Figure 3.17 Monthly nitrite/nitrate at each isohaline based sampling zone (1983-2007)

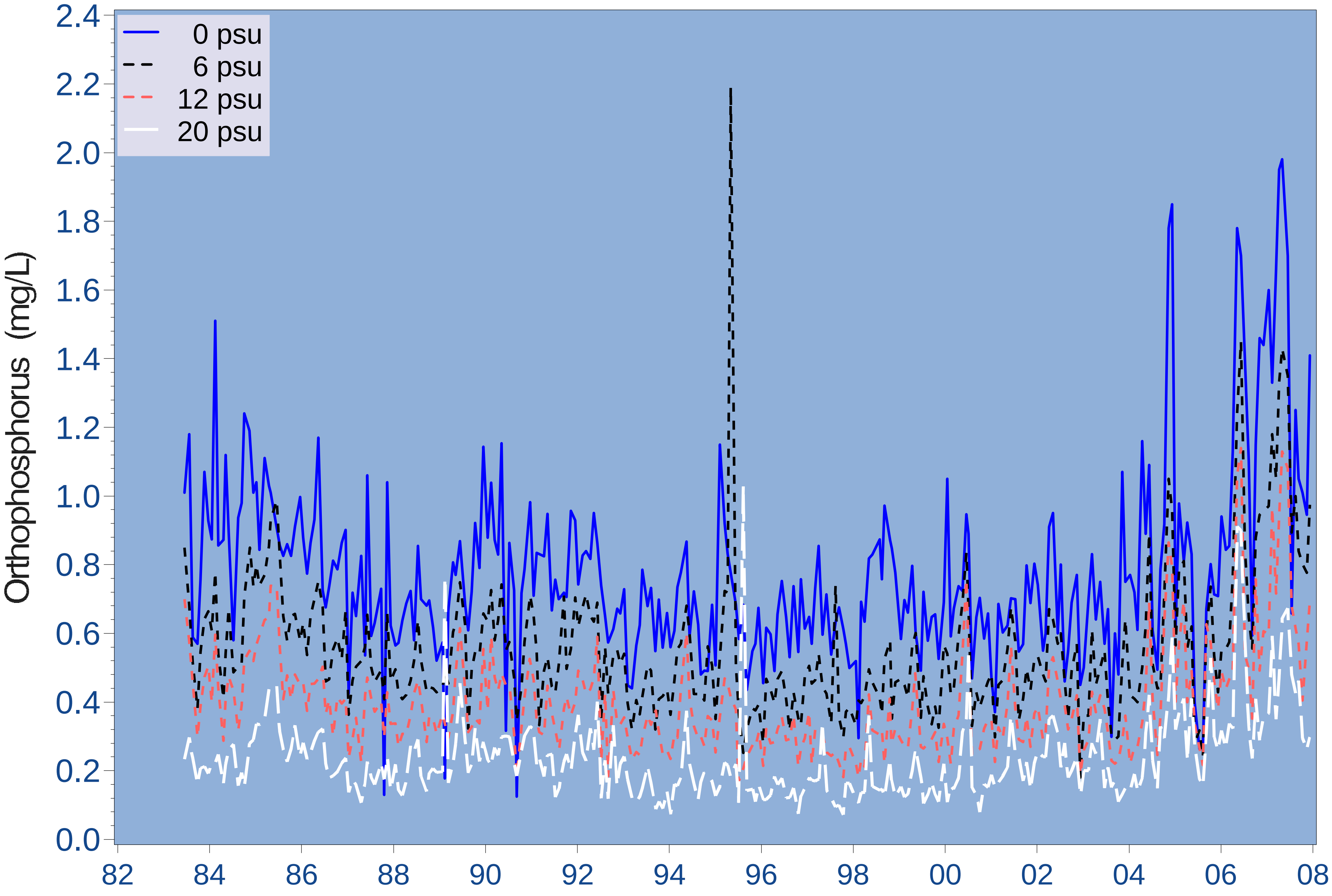


Figure 3.18 Monthly orthophosphorus at each isohaline based sampling zone (1983-2007)

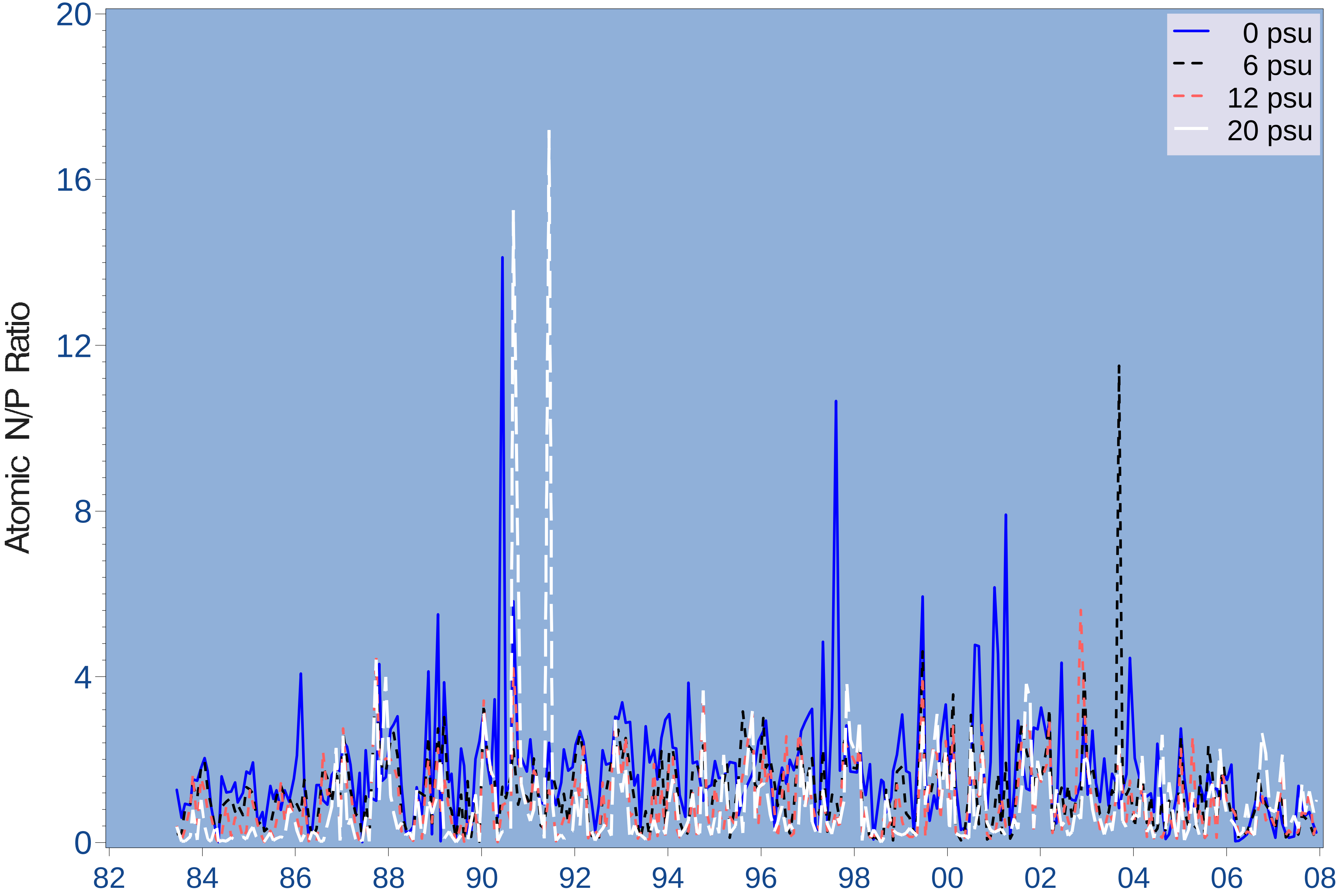


Figure 3.19 Monthly atomic nitrogen/phosphorus ratio at each isohaline based sampling zone (1983-2007)

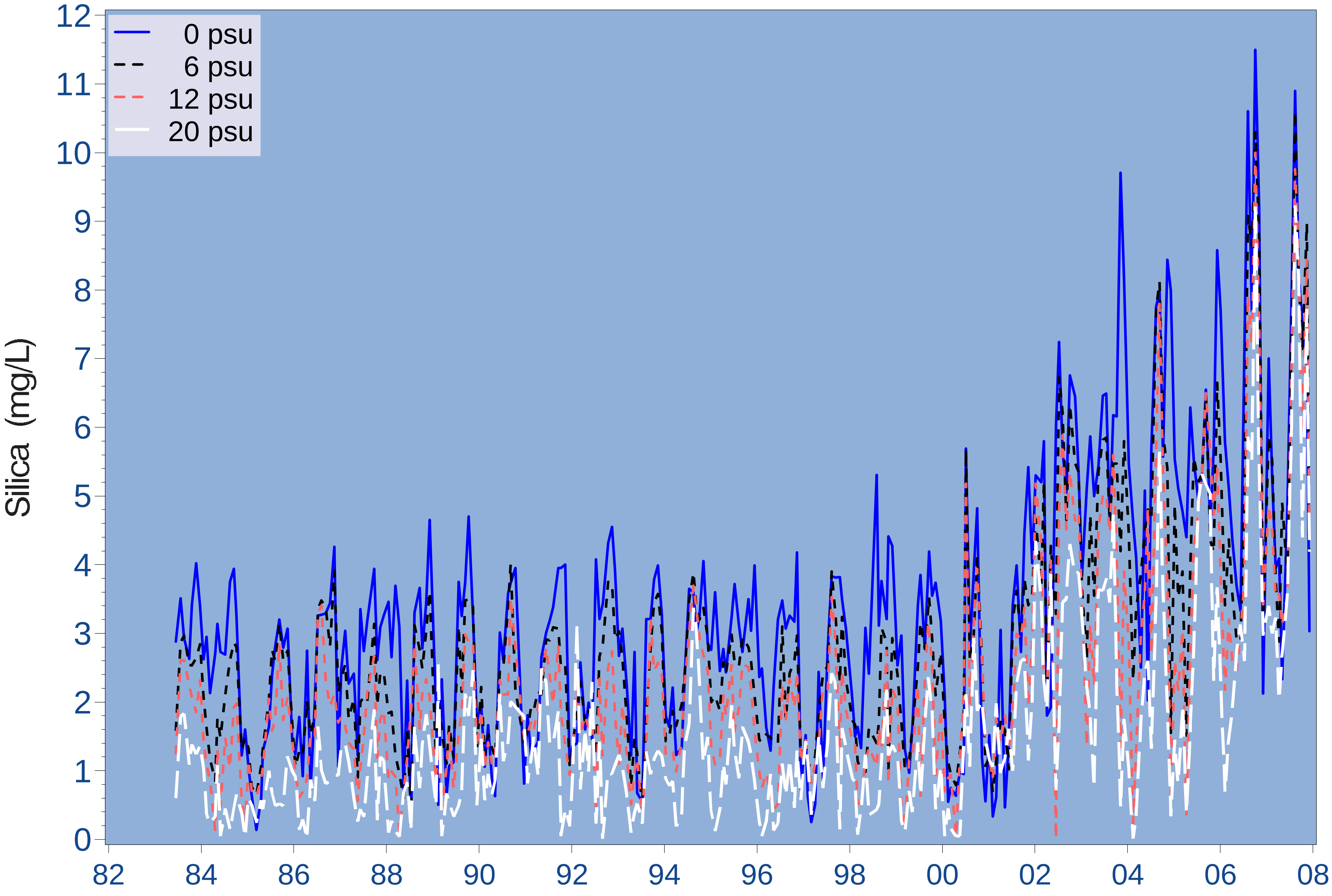


Figure 3.20 Monthly silica at each isohaline based sampling zone (1983-2007)

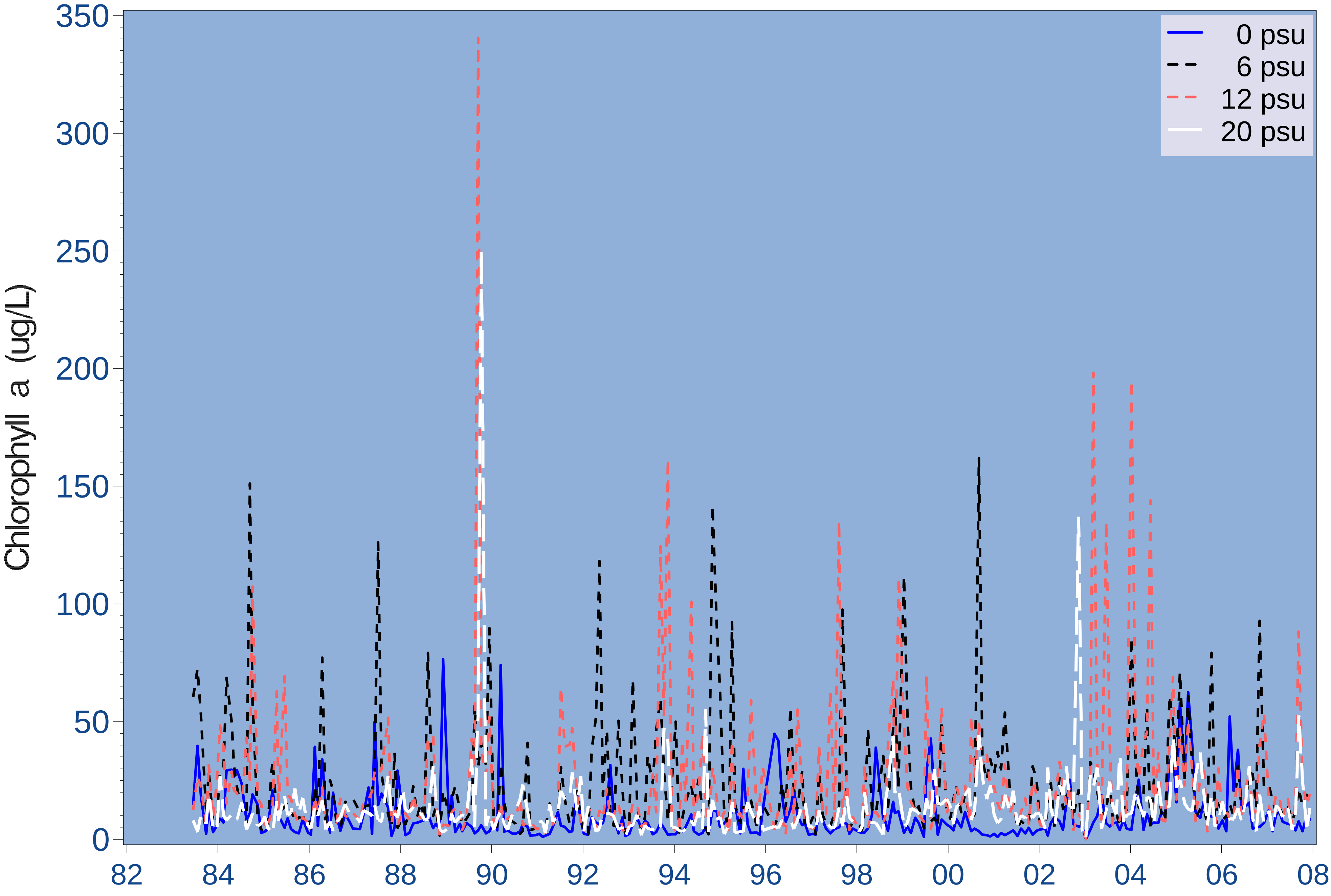


Figure 3.21a Monthly chlorophyll a (ug/L) at each isohaline based sampling zone (1983-2007)

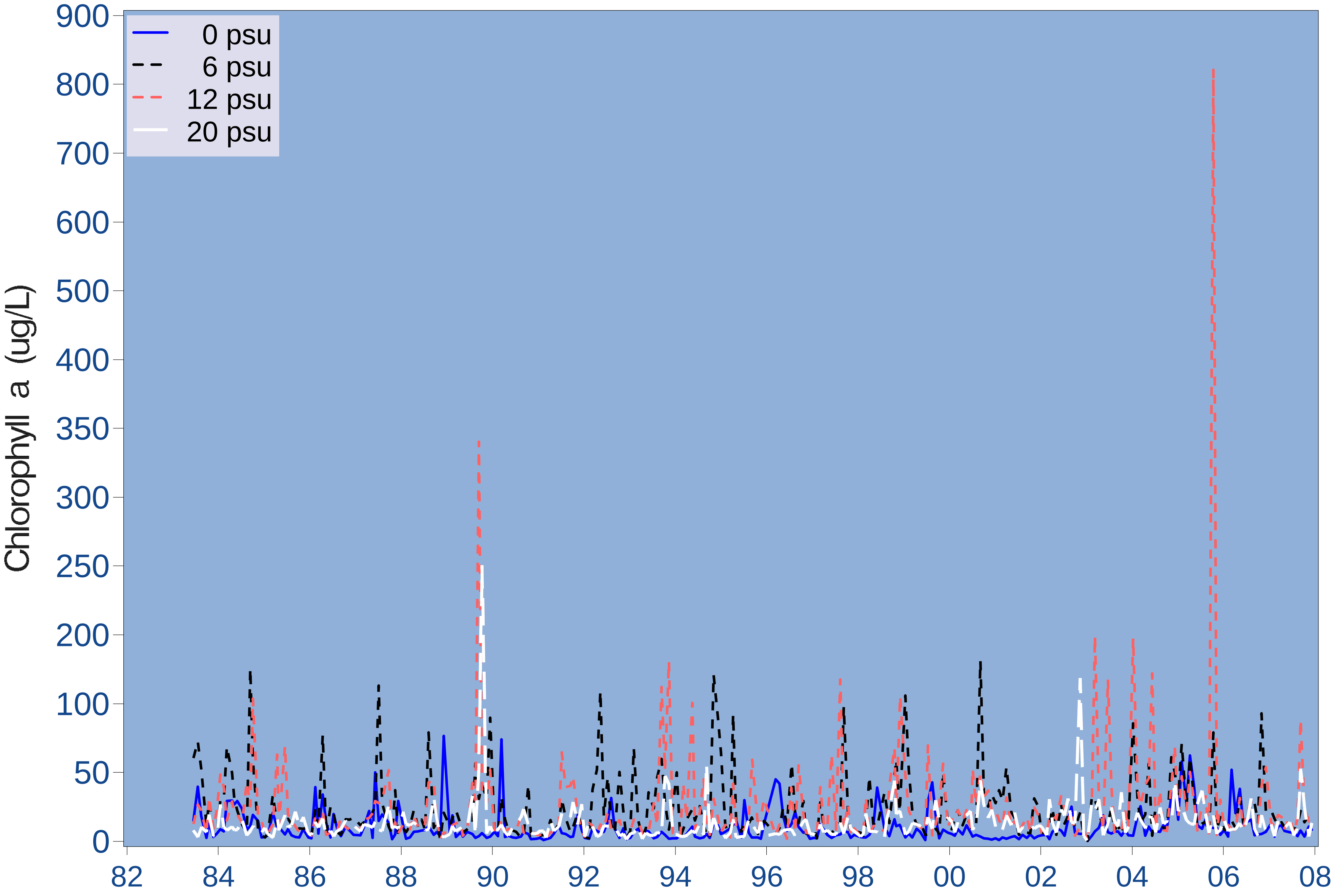


Figure 3.21b Monthly chlorophyll a (ug/L) at each isohaline based sampling zone (1983-2007)

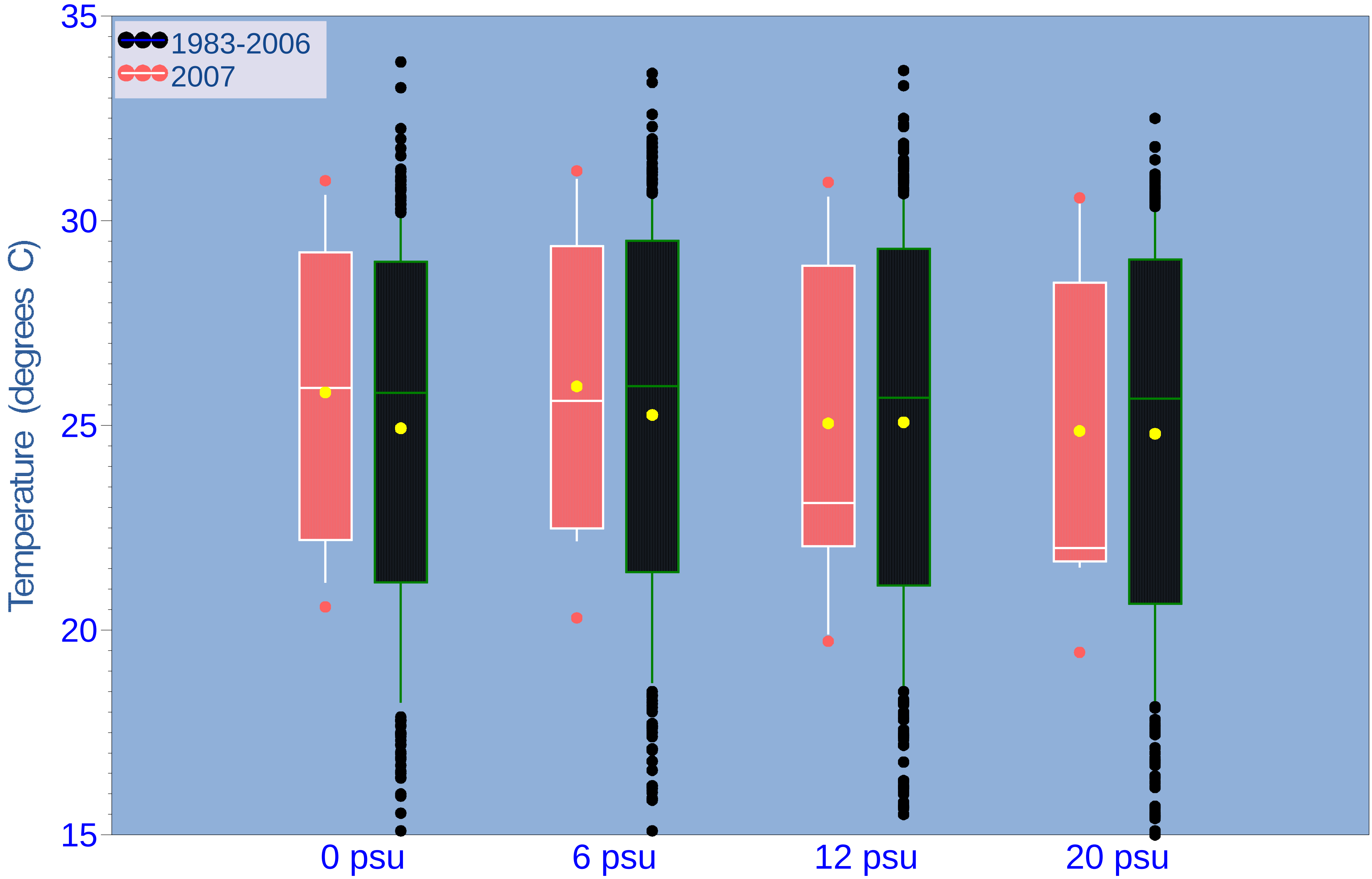


Figure 3.22 Box and whisker plots of temperature at salinity sampling zones

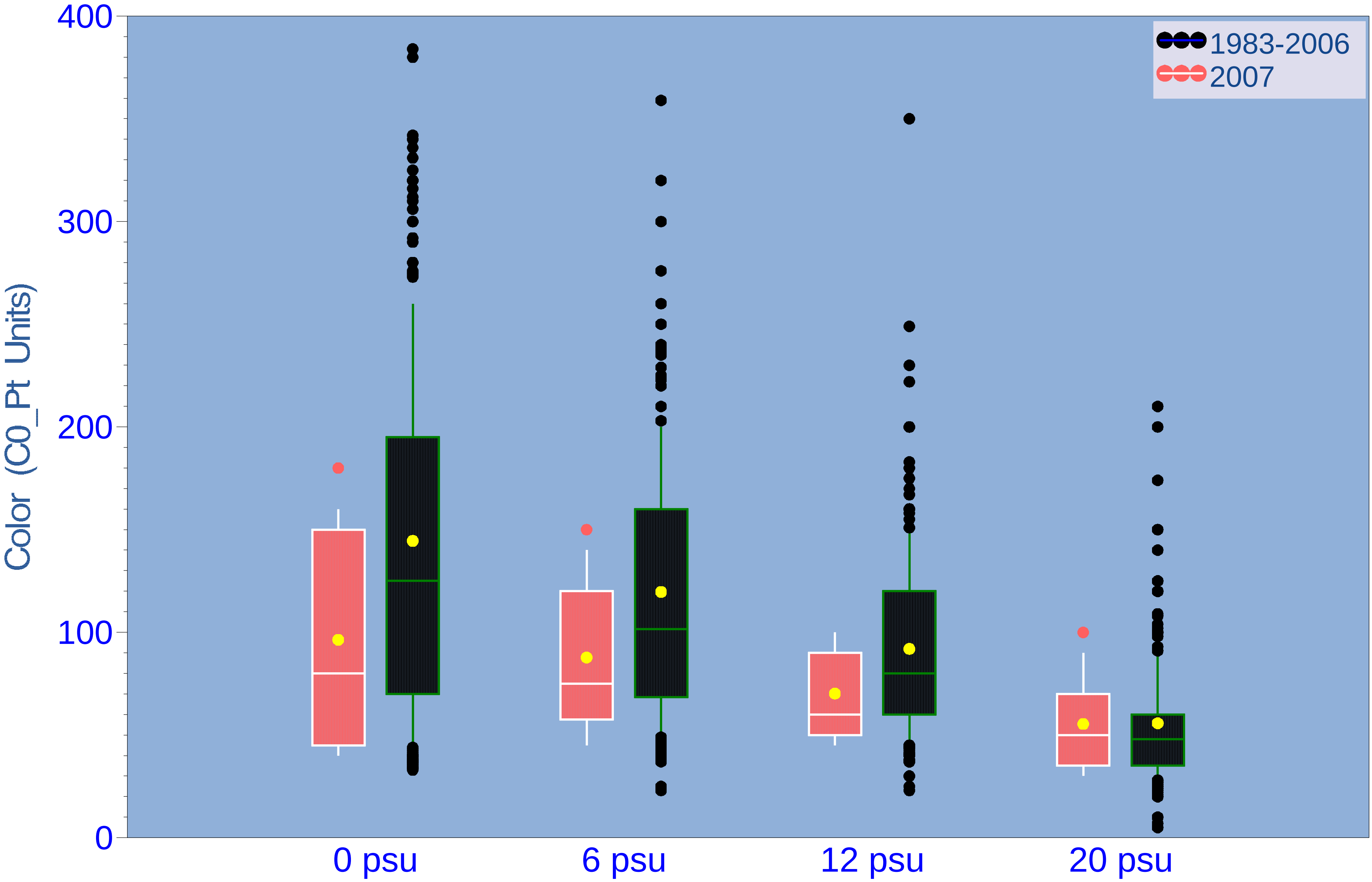


Figure 3.23 Box and whisker plots of Color at salinity sampling zones

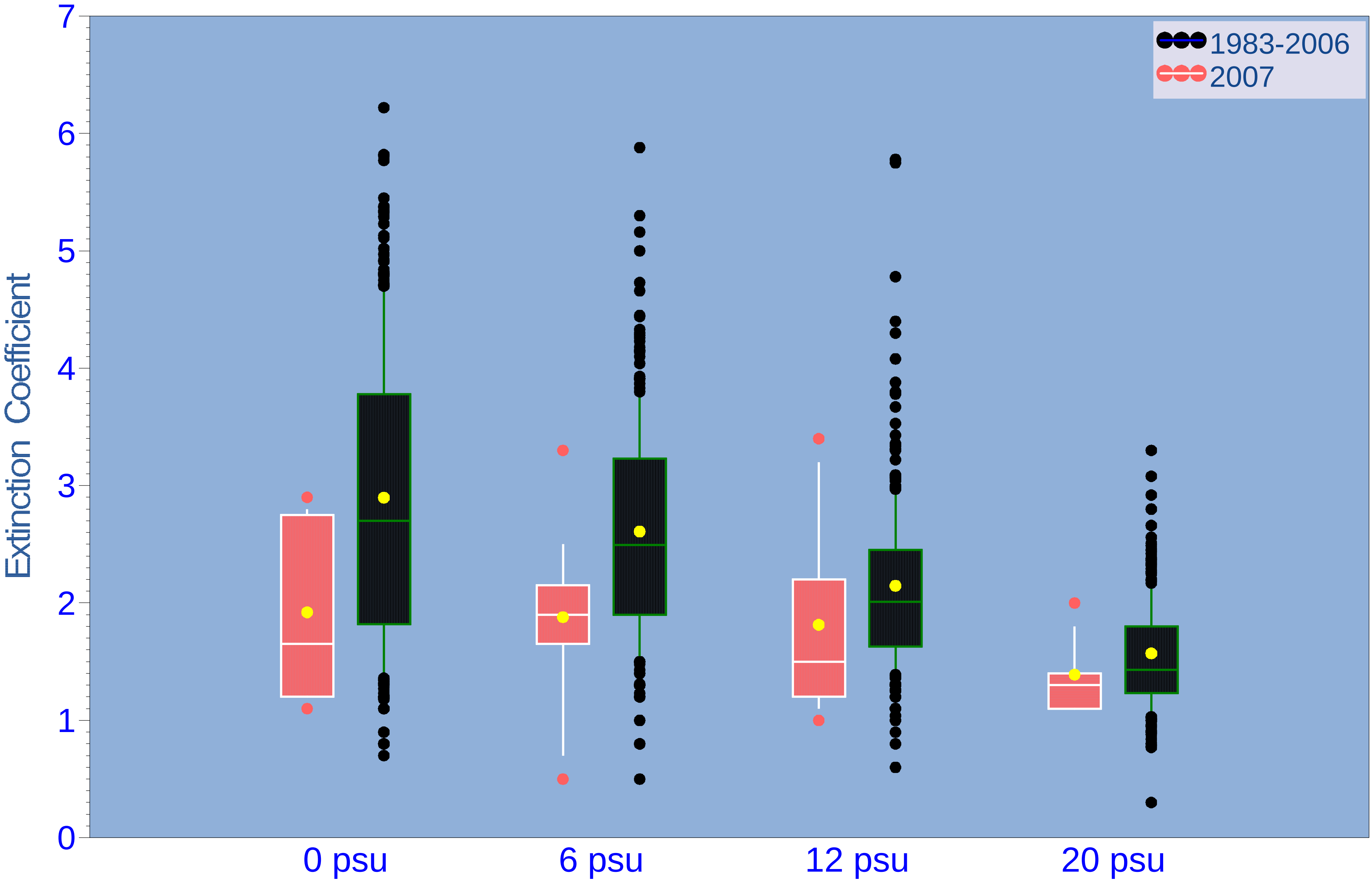


Figure 3.24 Box and whisker plots of extinction coefficient at salinity sampling zones

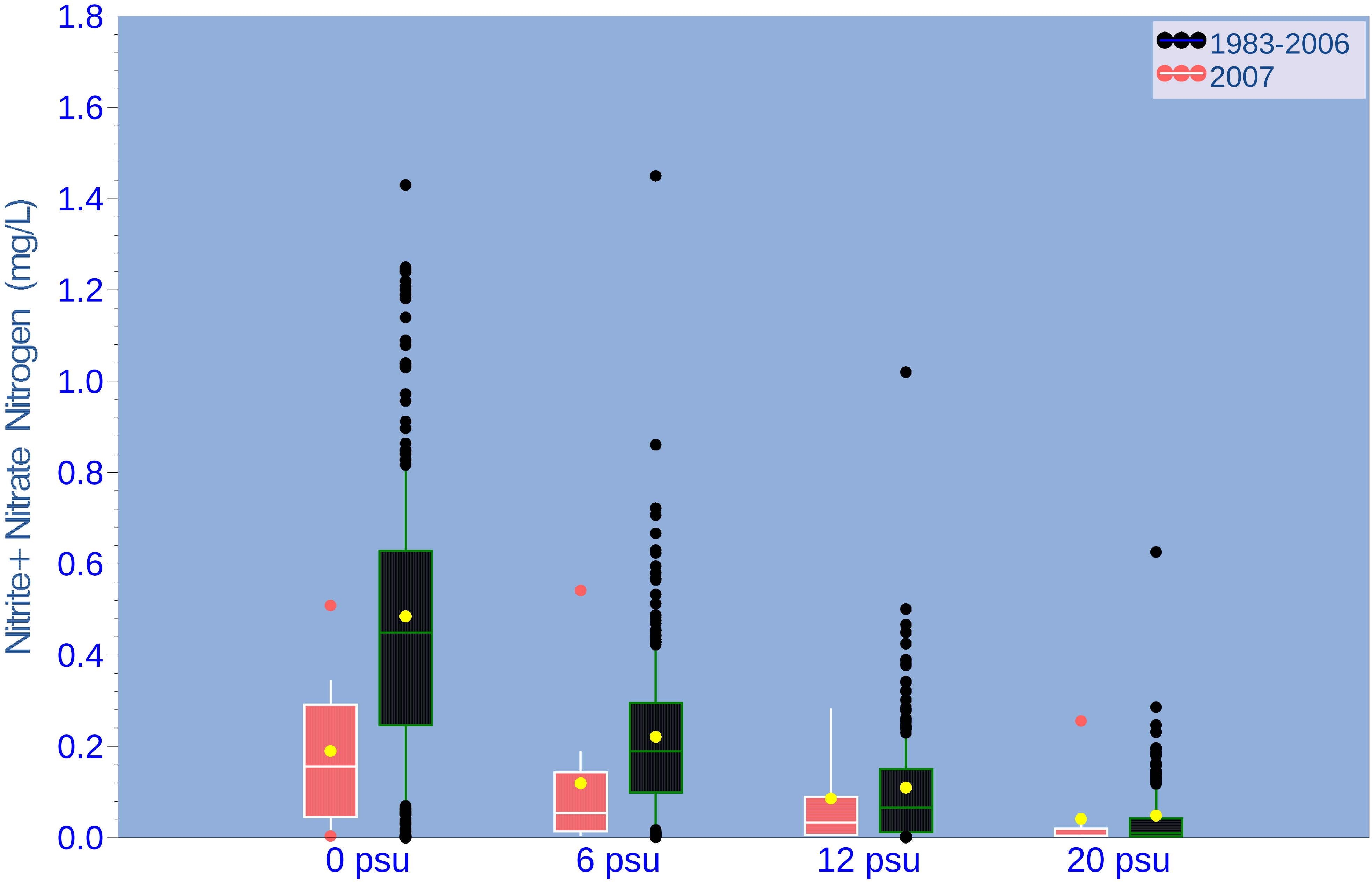


Figure 3.25 Box and whisker plots of nitrite/nitrate at salinity sampling zones

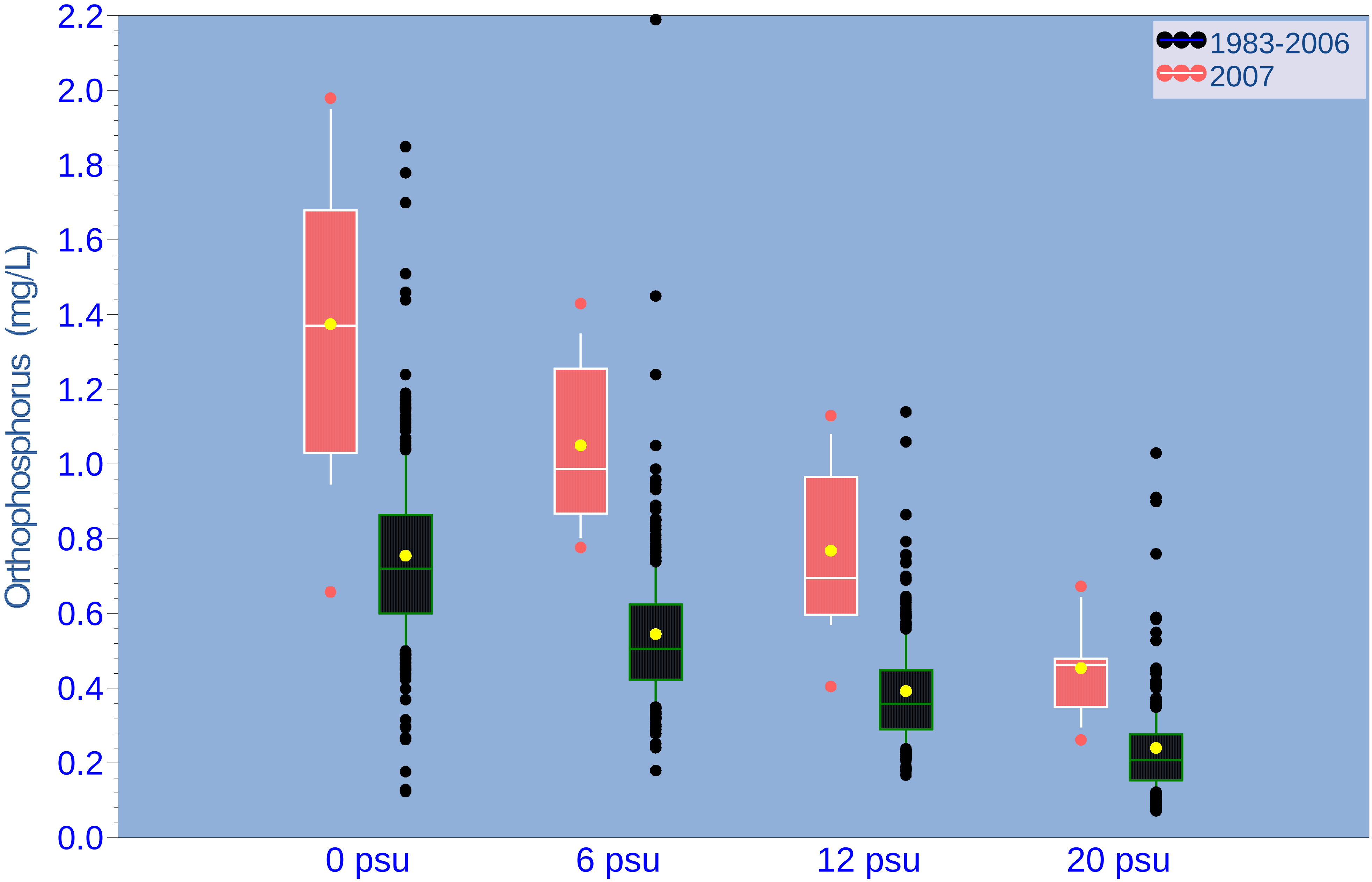


Figure 3.26 Box and whisker plots of ortho-phosphorus at salinity sampling zones

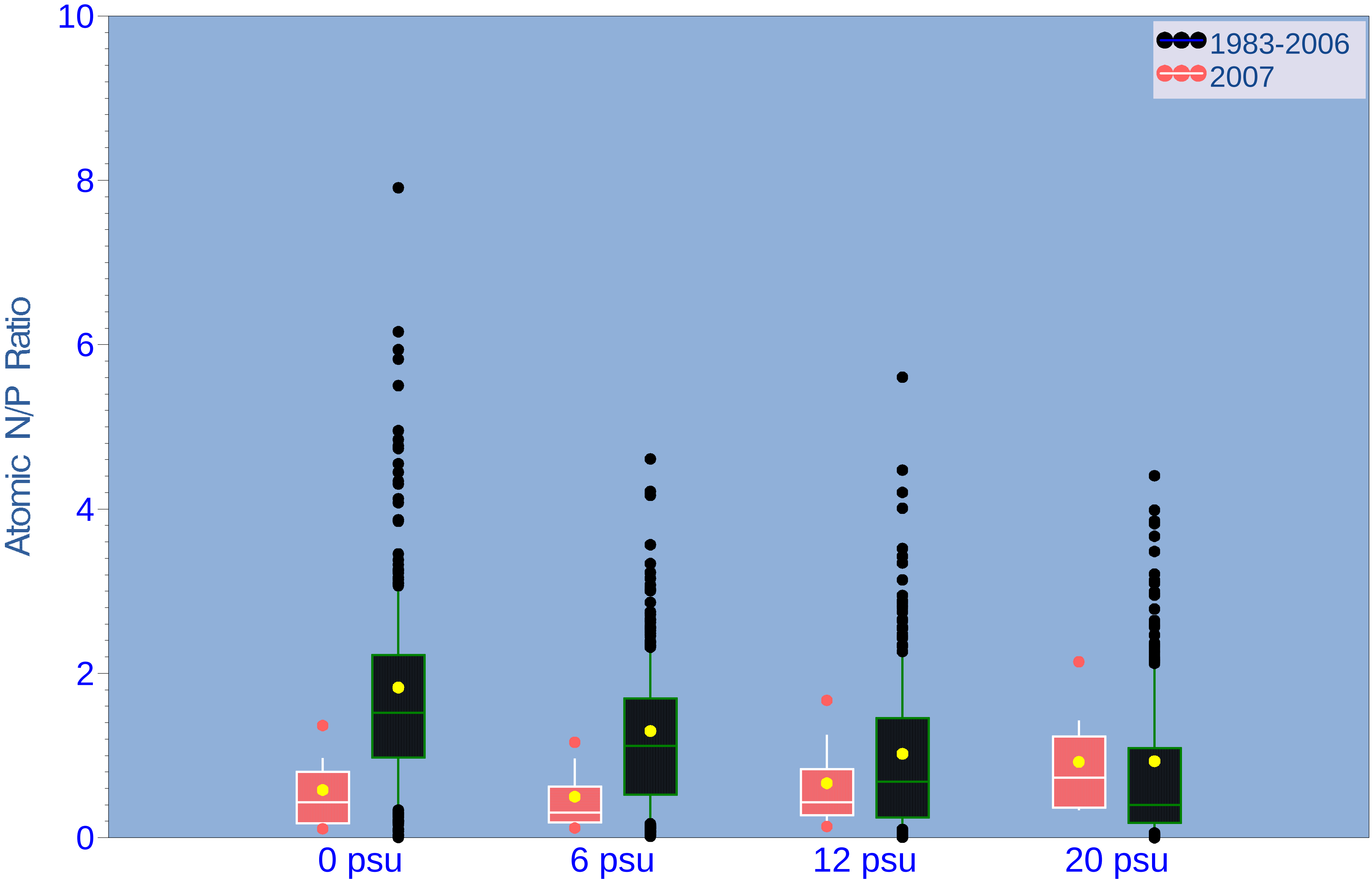


Figure 3.27 Box and whisker plots of atomic N/P ratio at salinity sampling zones

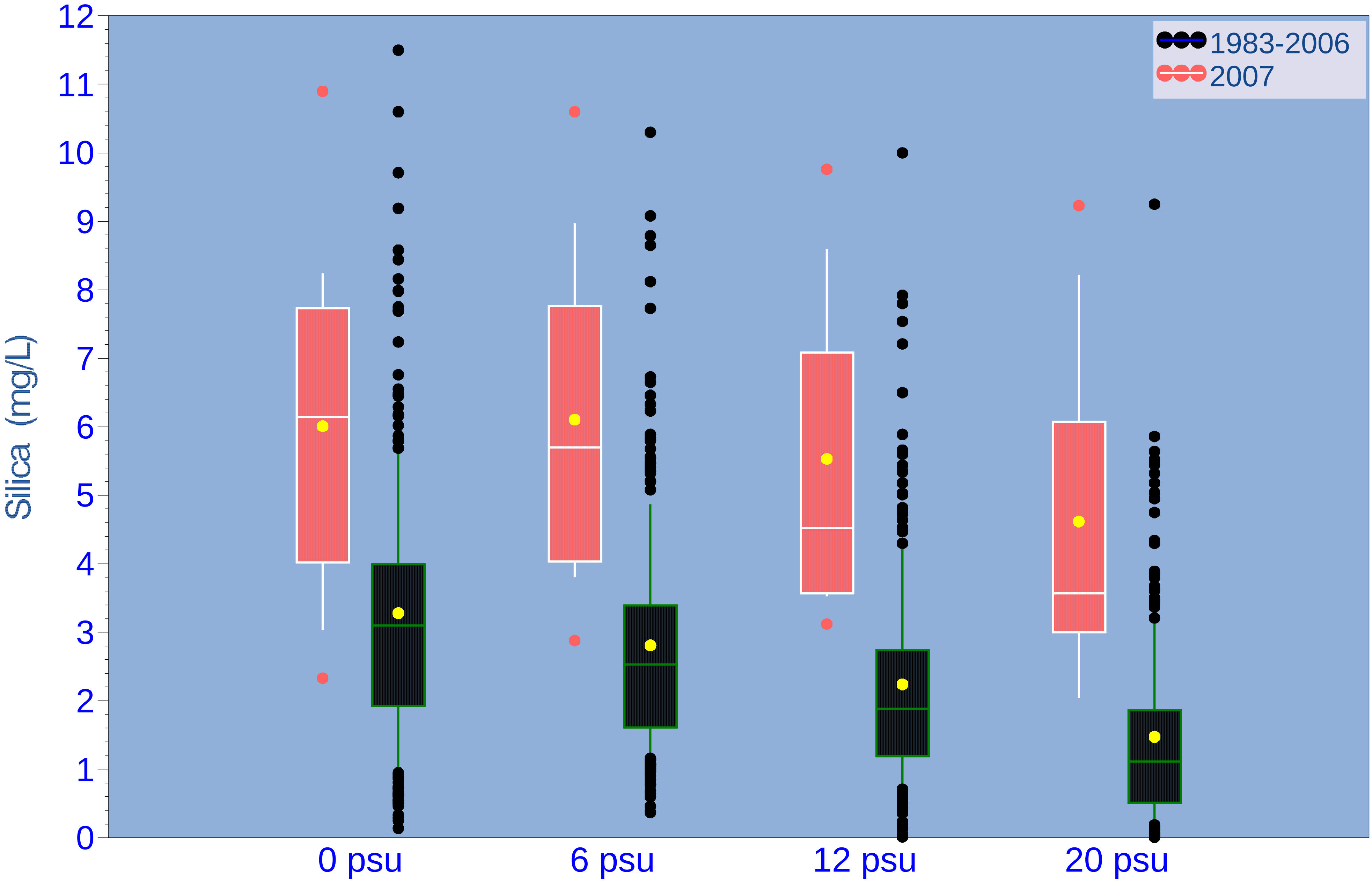


Figure 3.28 Box and whisker plots of silica at salinity sampling zones

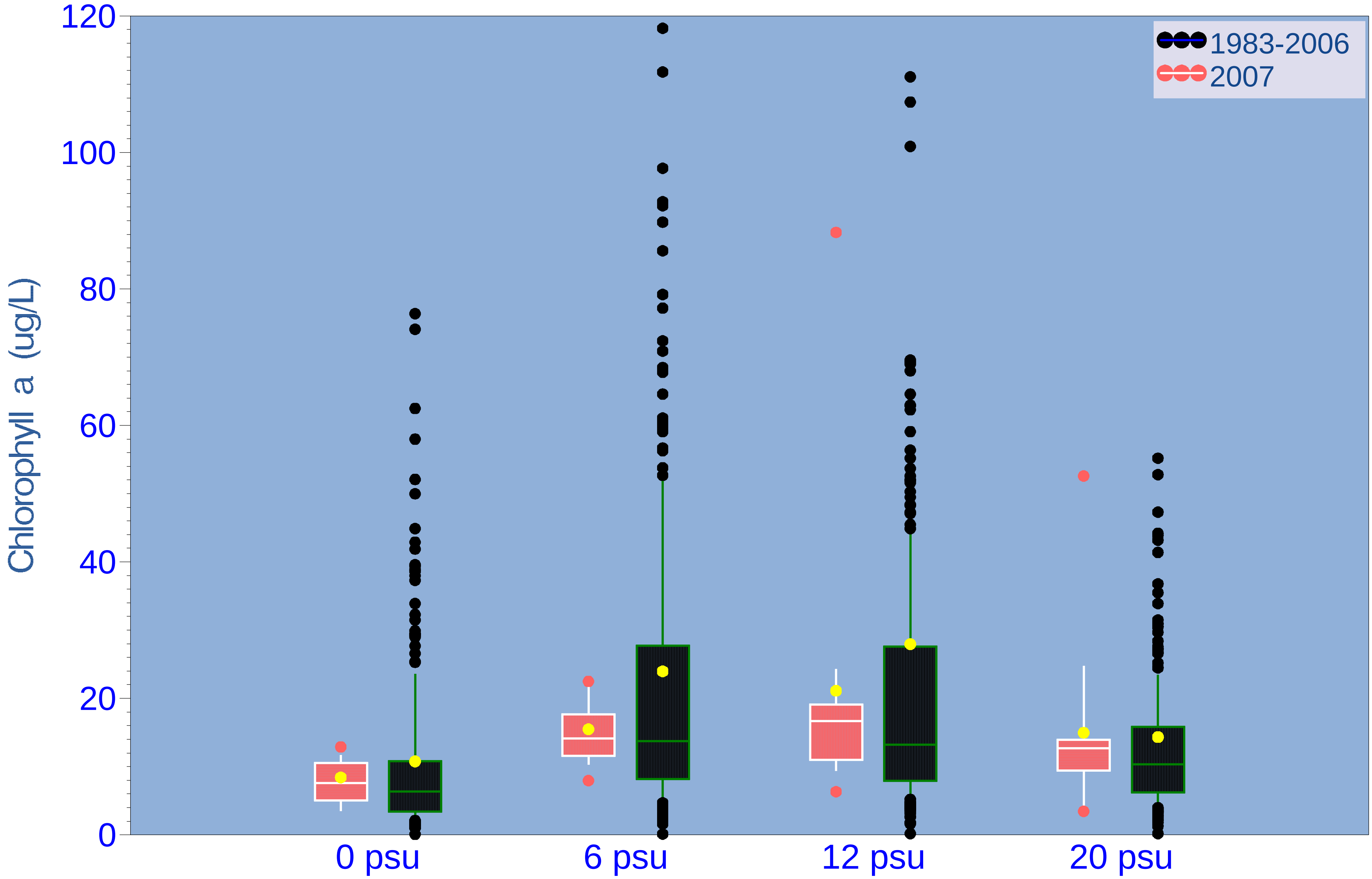


Figure 3.29 Box and whisker plots of chlorophyll a (ug/L) at salinity sampling zones

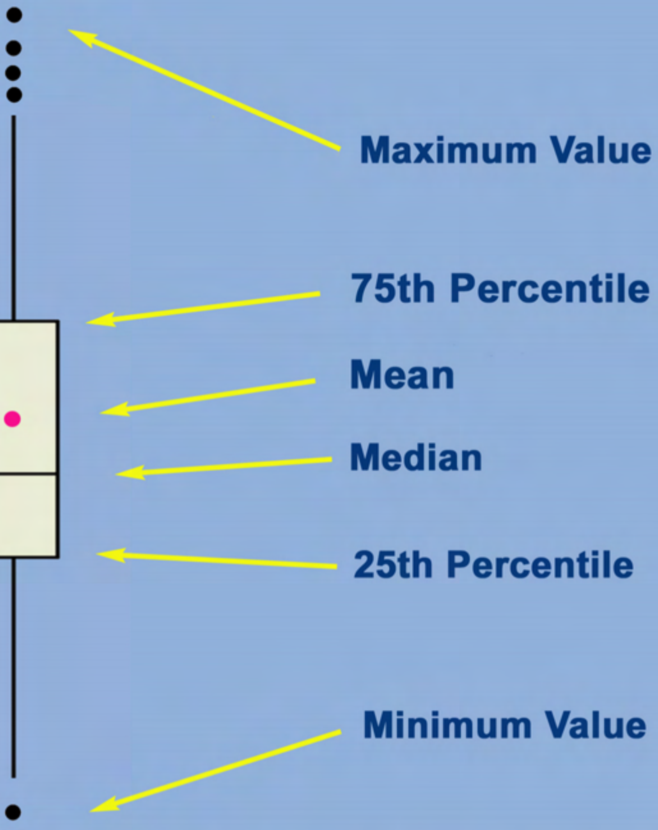
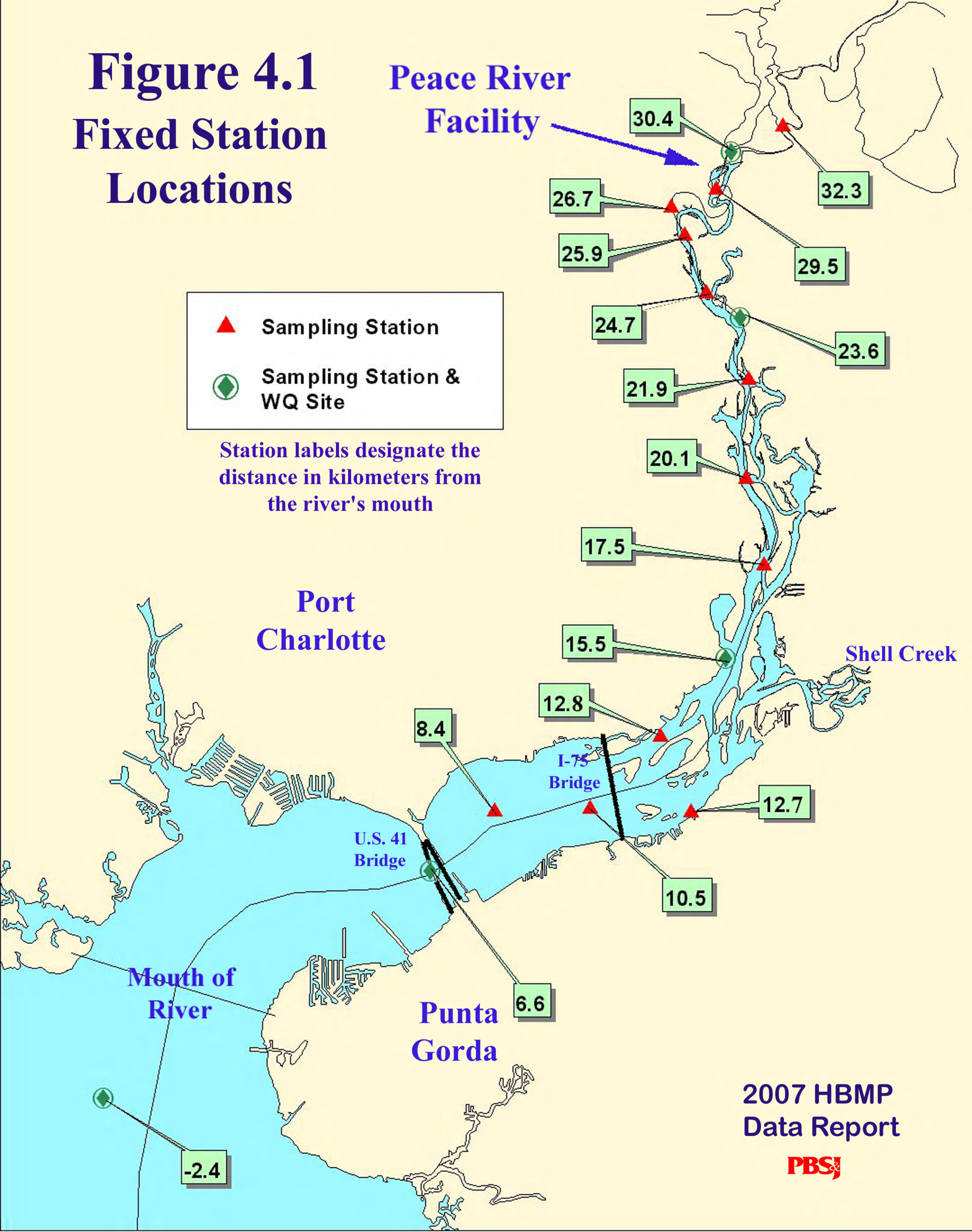


Diagram 3.1 Diagram of box and whisker plot format

Figure 4.1 Fixed Station Locations



Station labels designate the distance in kilometers from the river's mouth

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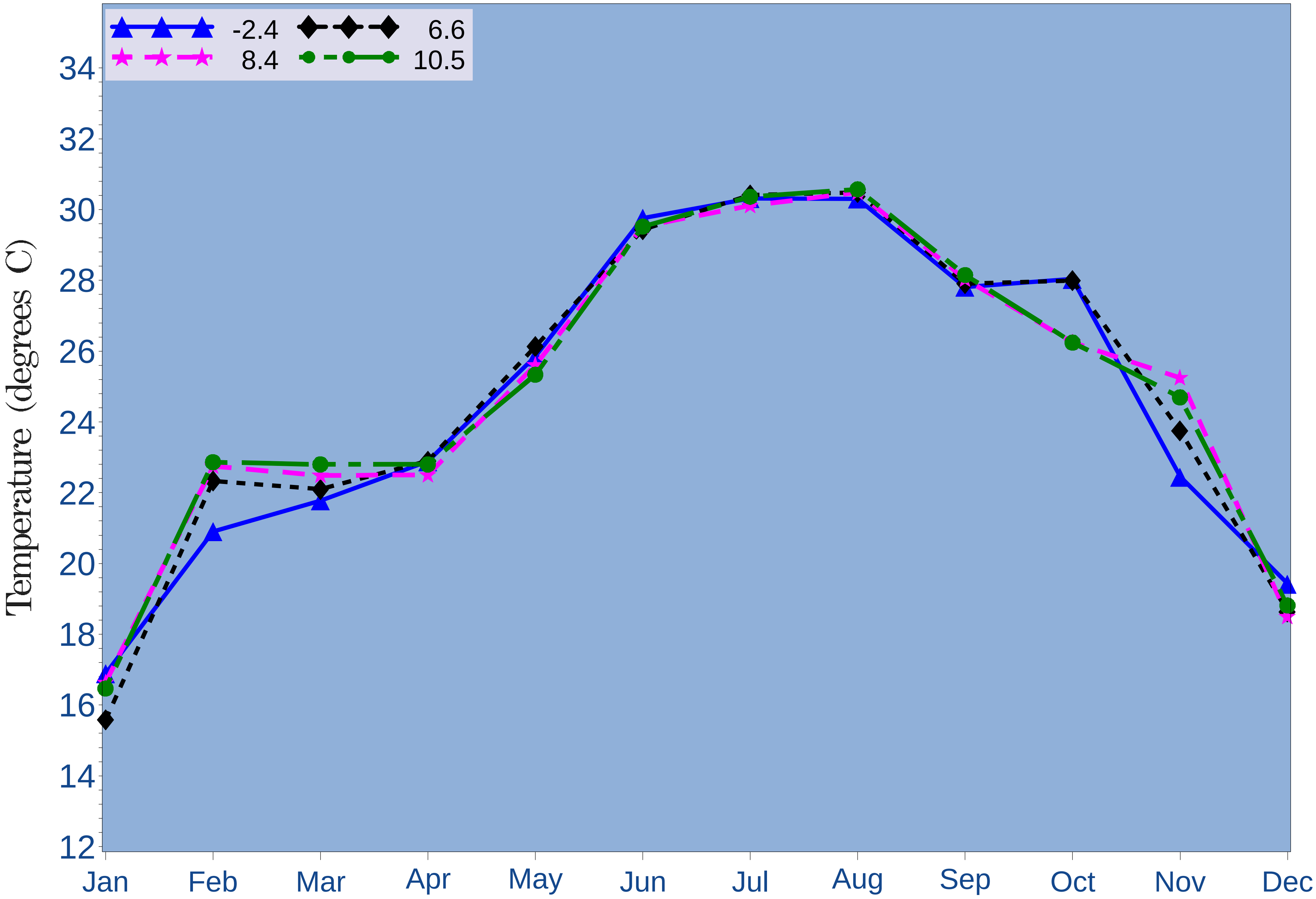

Figure 4.2a 2007 Mean monthly Mean monthly temperature at river kilometers -2.4, 6.6, 8.4 and 10.5

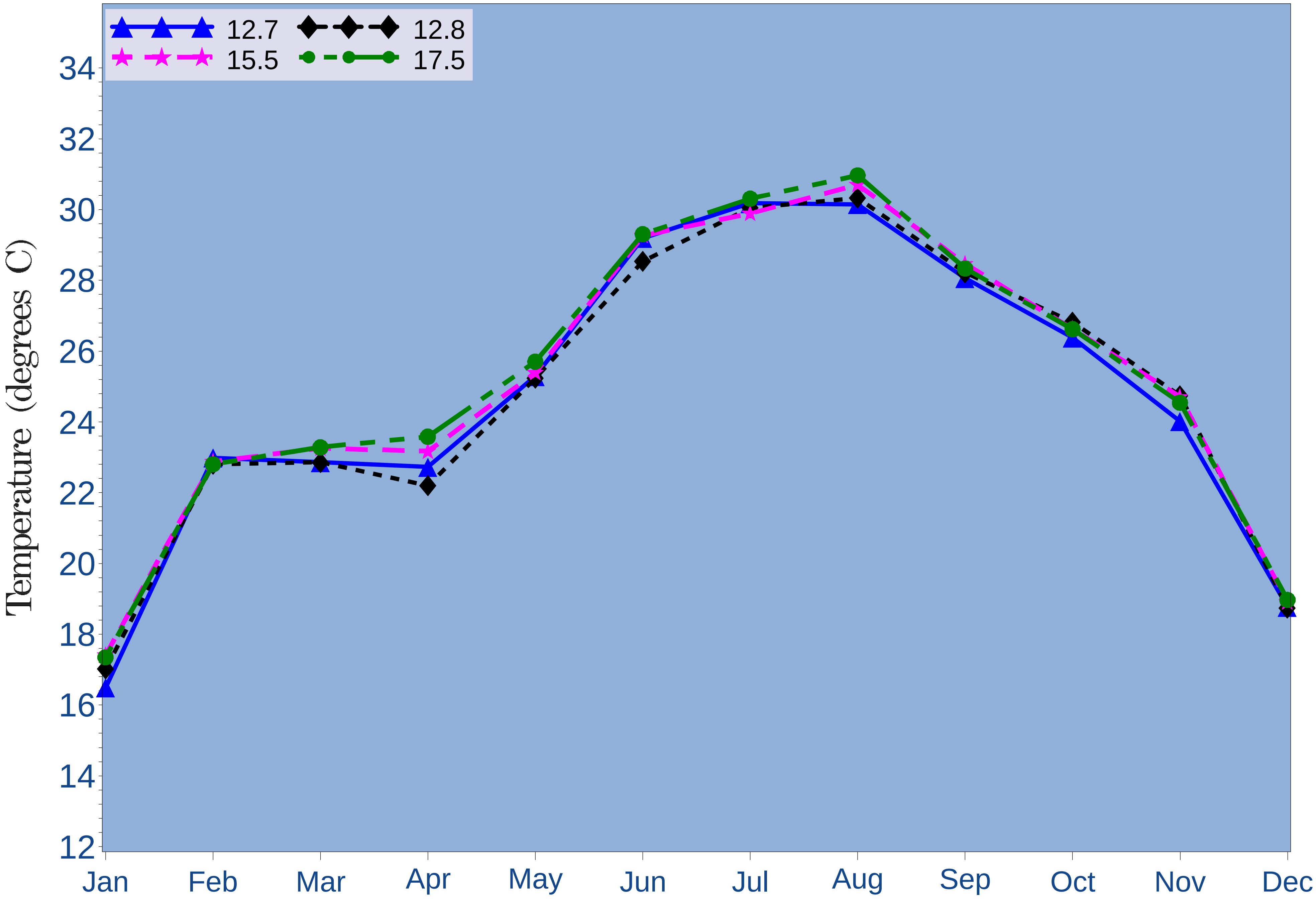

Figure 4.2b 2007 Mean monthly temperature at river kilometers 12.7, 12.8, 15.5 and 17.5

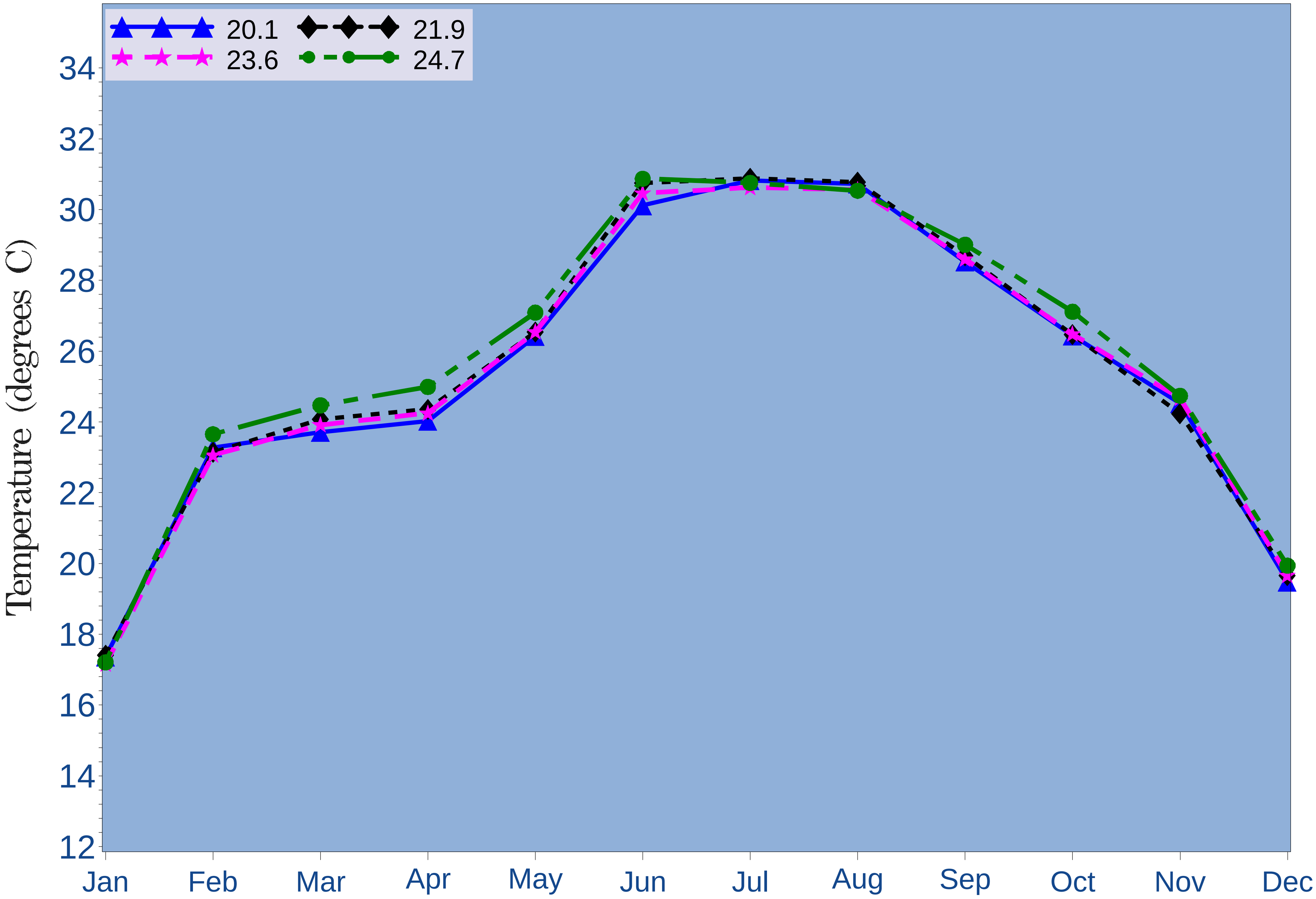

Figure 4.2c 2007 Mean monthly temperature at river kilometers 20.1, 21.9, 23.6 and 24.7

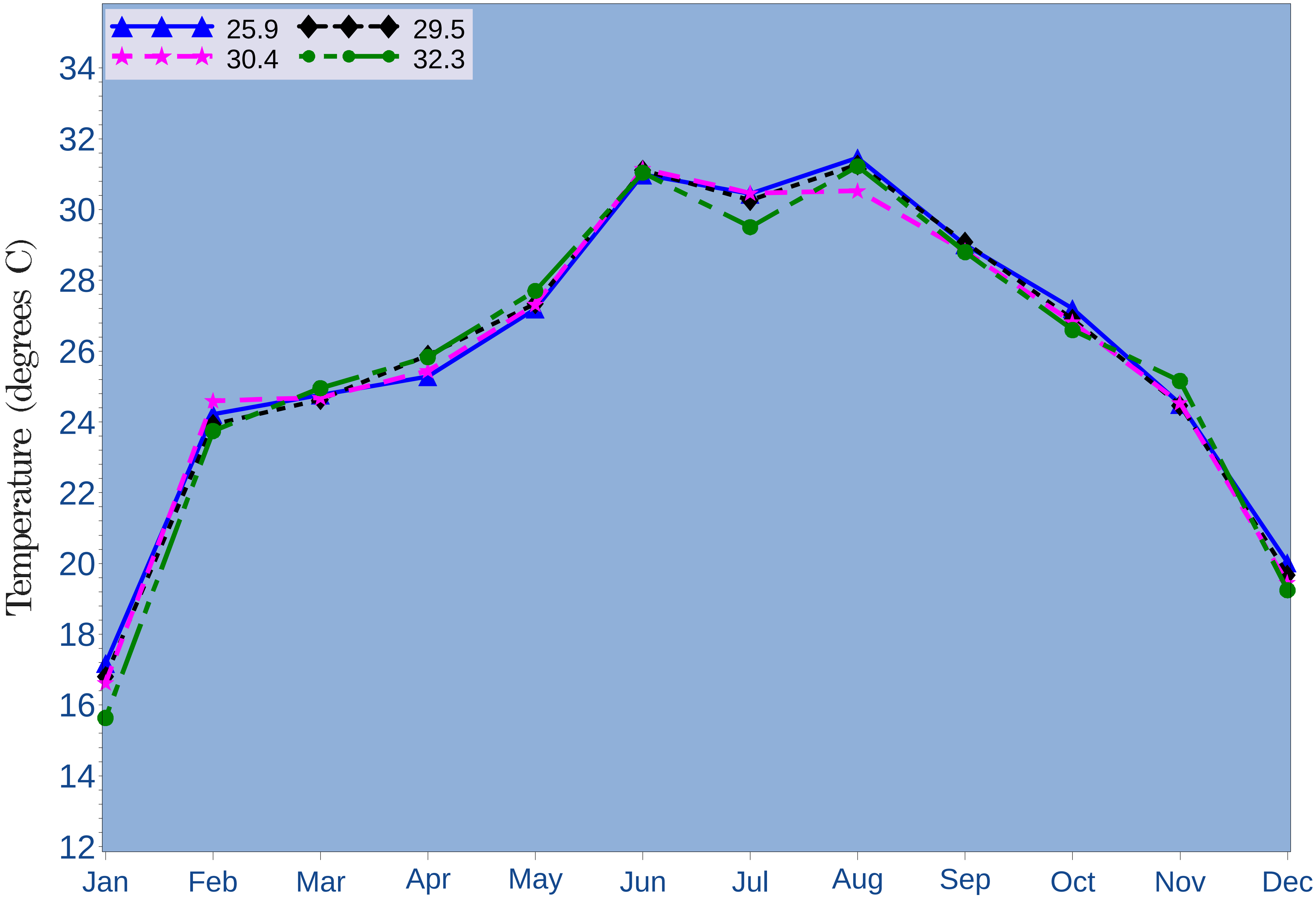

Figure 4.2d 2007 Mean monthly temperature at river kilometers 25.9, 29.5, 30.4 and 32.3

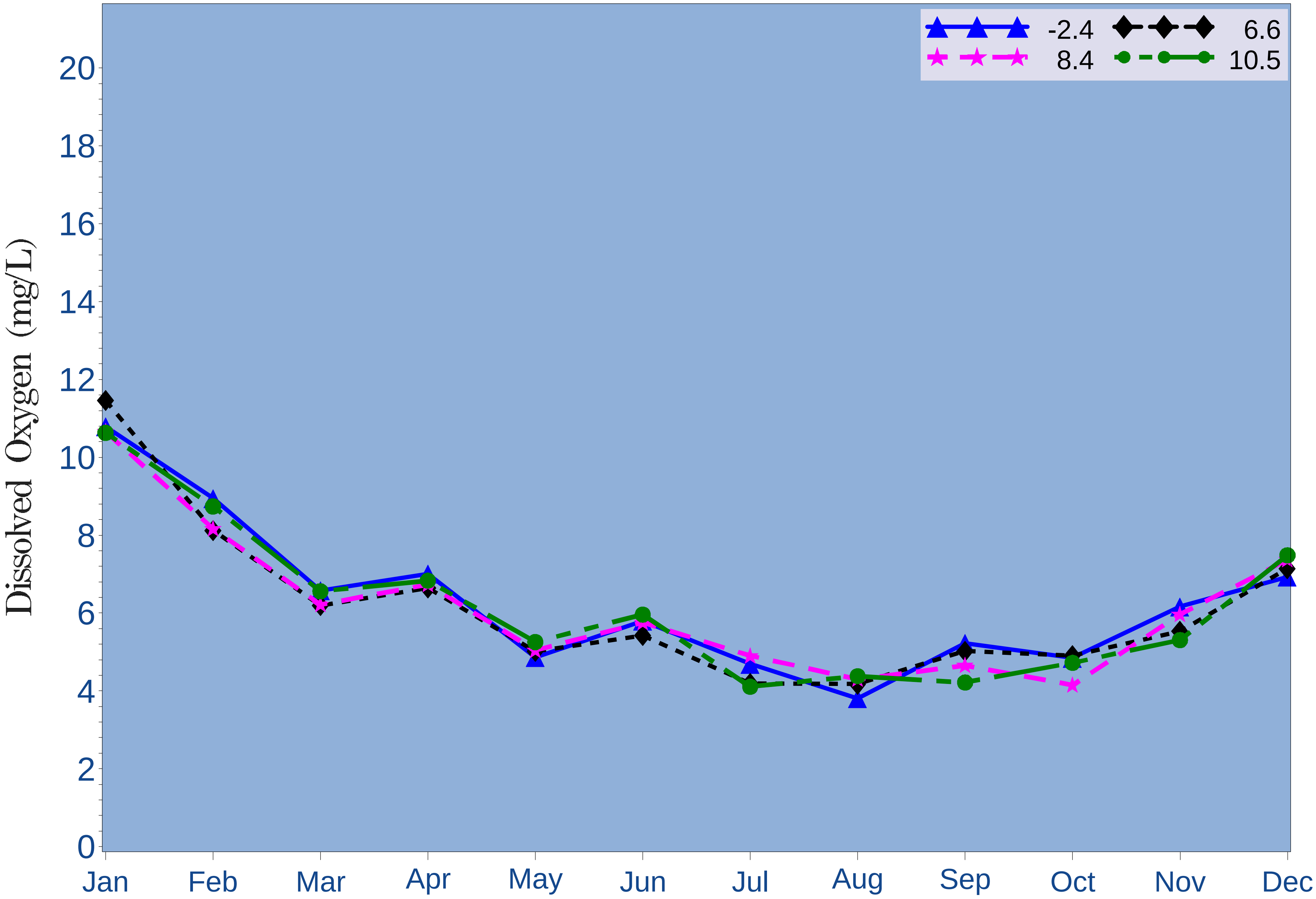

Figure 4.3a 2007 Mean monthly dissolved oxygen at river kilometers -2.4, 6.6, 8.4 and 10.5

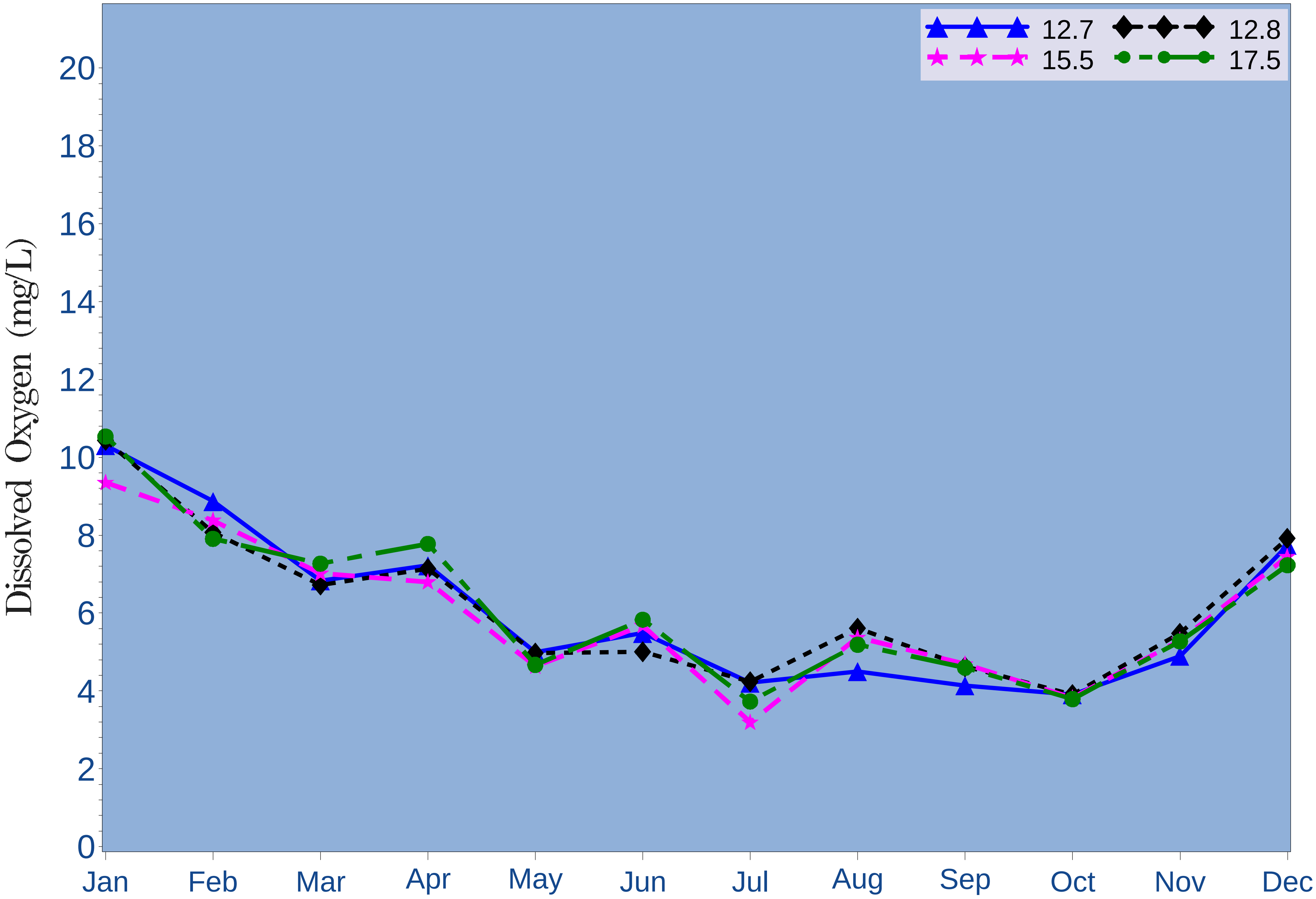

Figure 4.3b 2007 Mean monthly dissolved oxygen at river kilometers 12.7, 12.8, 15.5 and 17.5

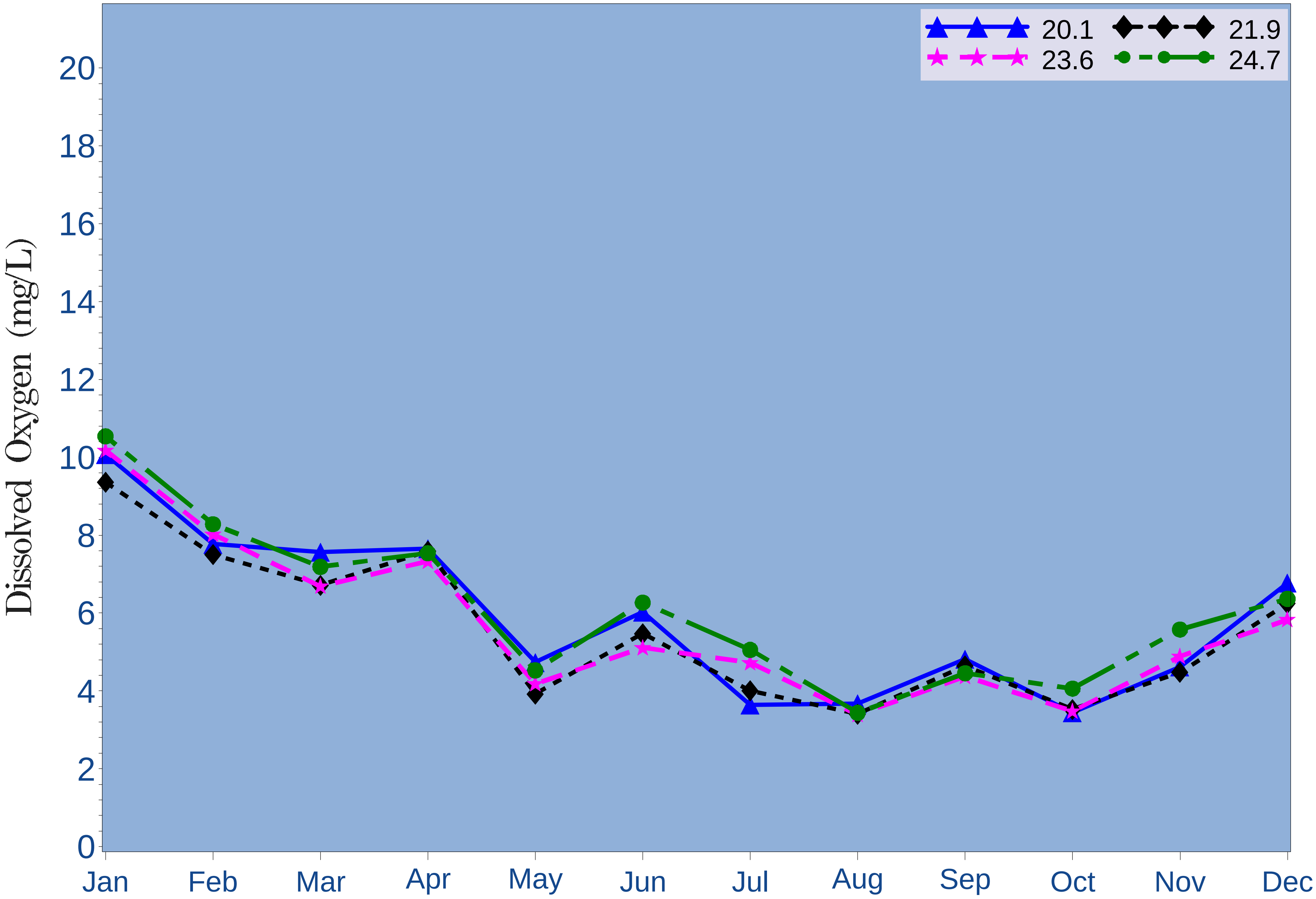

Figure 4.3c 2007 Mean monthly dissolved oxygen at river kilometers 20.1, 21.9, 23.6 and 24.7

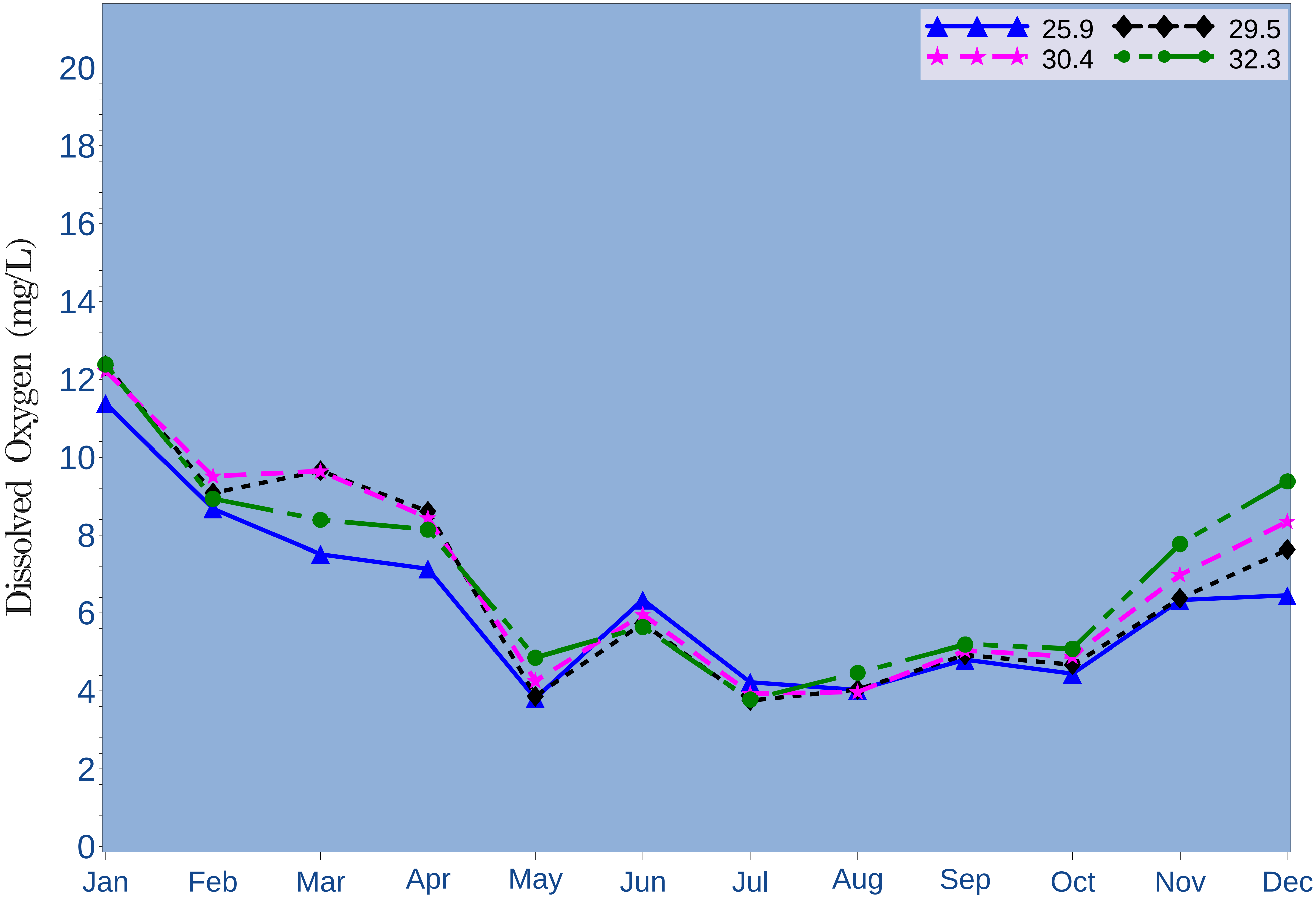

Figure 4.3d 2007 Mean monthly dissolved oxygen at river kilometers 25.9, 29.5, 30.4 and 32.3

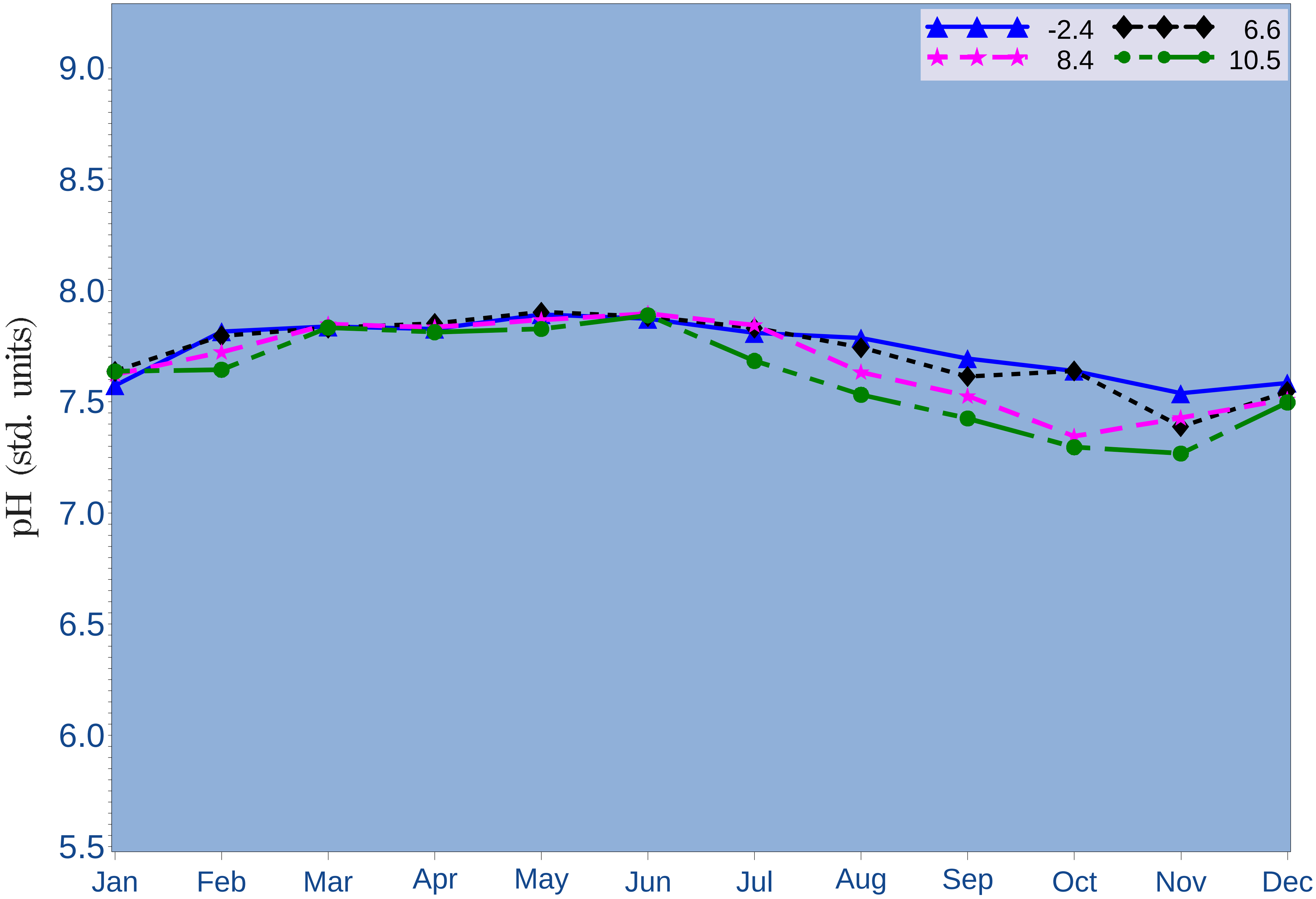

Figure 4.4a 2007 Mean monthly pH at river kilometers -2.4, 6.6, 8.4 and 10.5

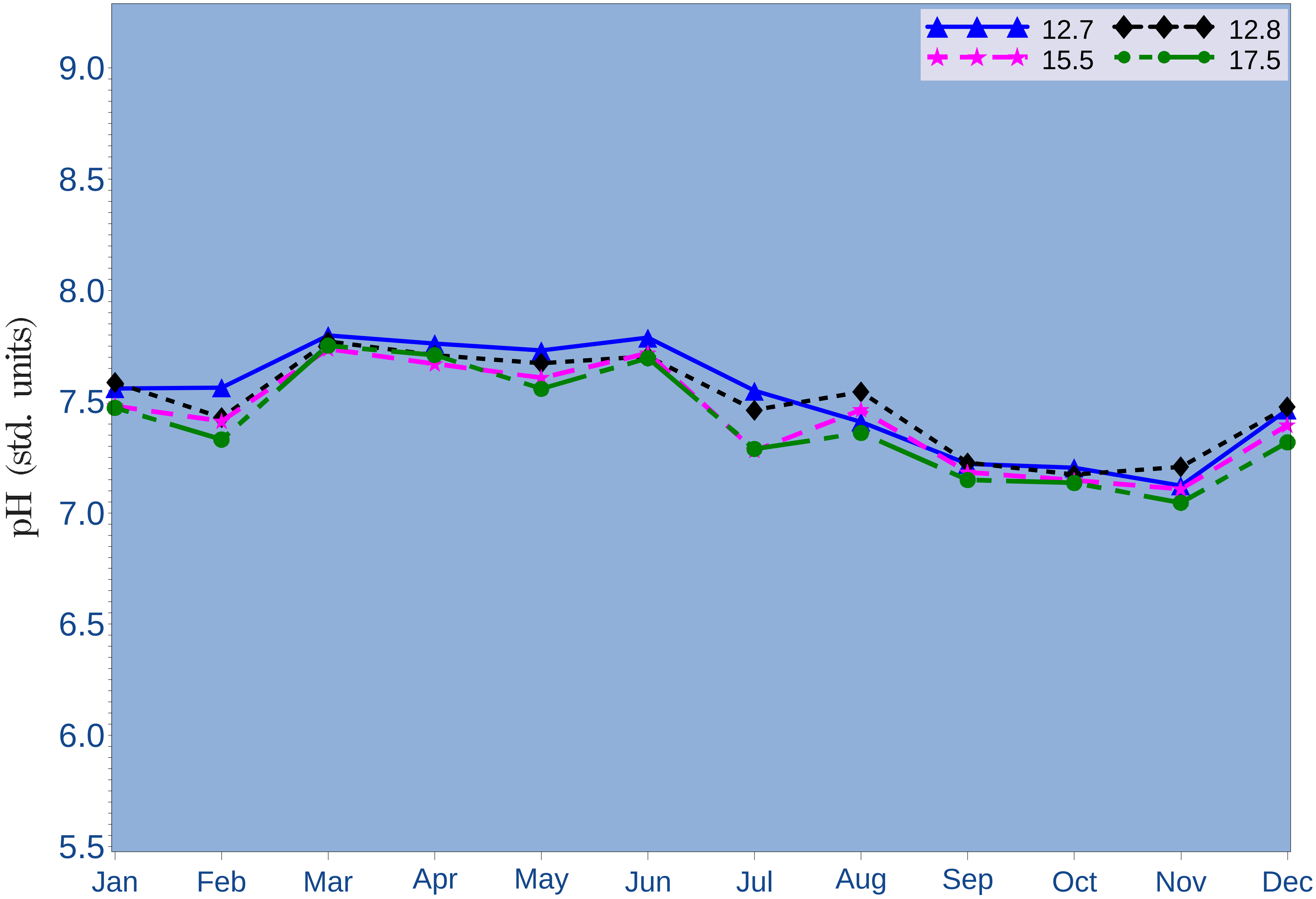

Figure 4.4b 2007 Mean monthly pH at river kilometers 12.7, 12.8, 15.5 and 17.5

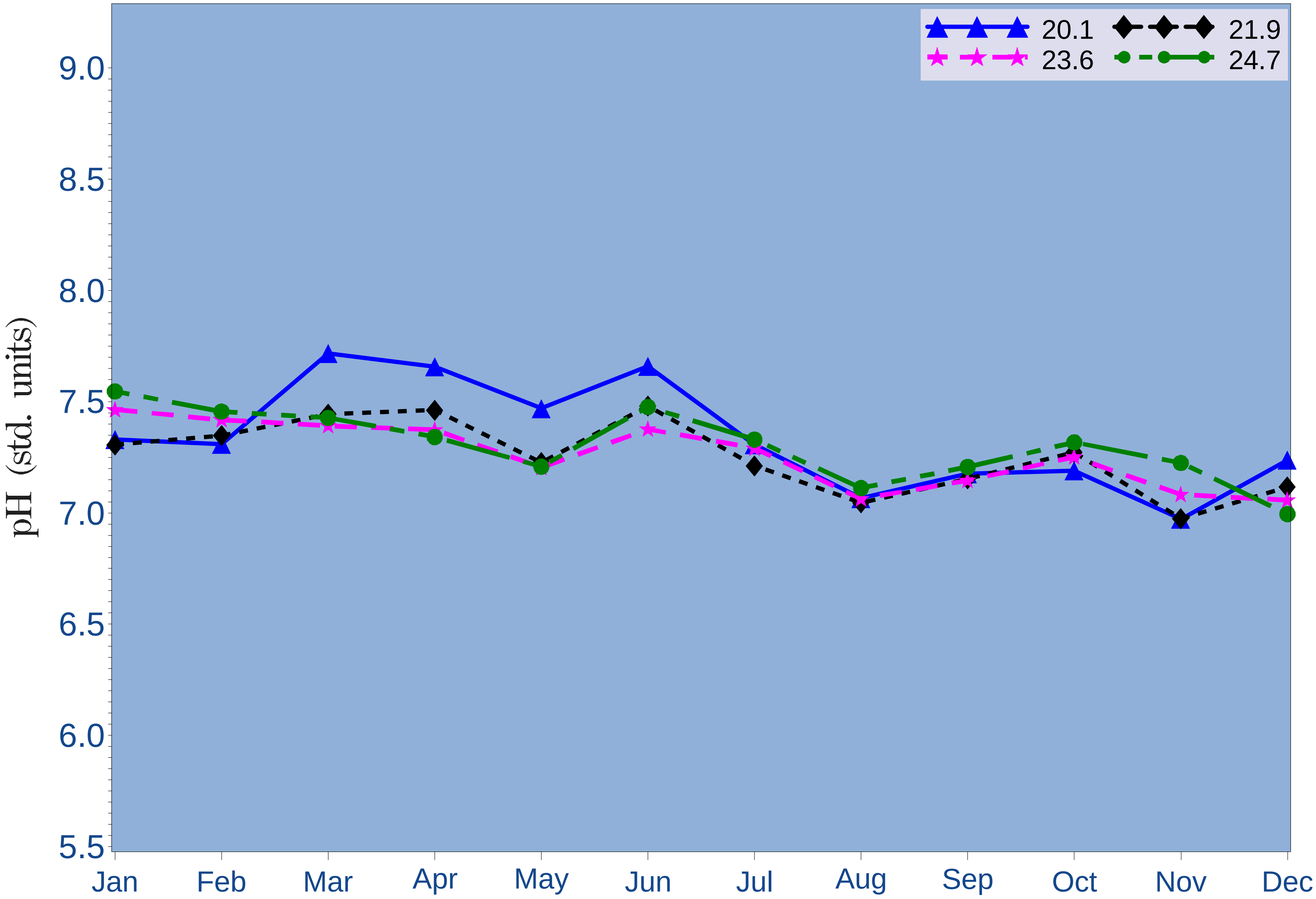

Figure 4.4c 2007 Mean monthly pH at river kilometers 20.1, 21.9, 23.6 and 24.7

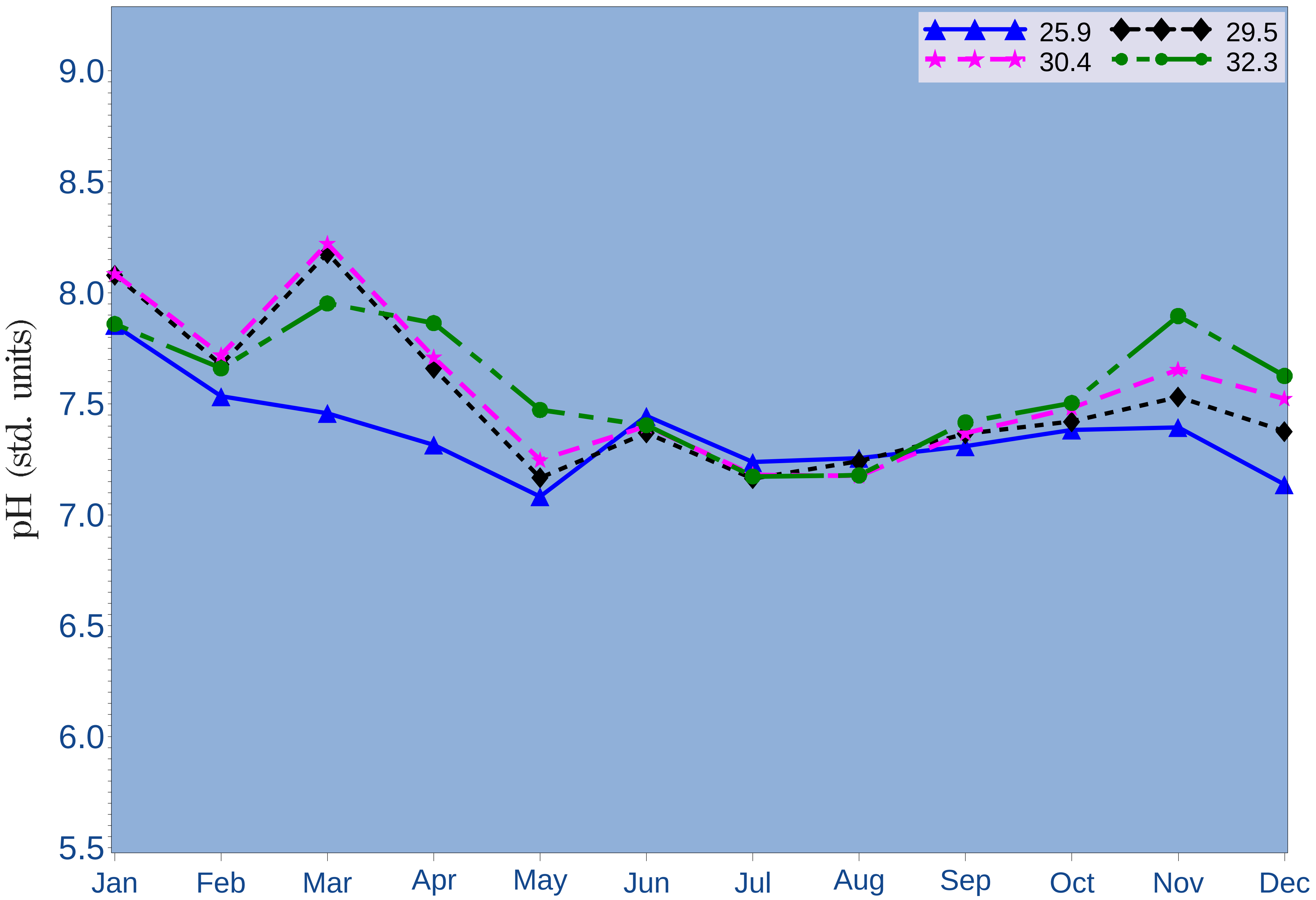

Figure 4.4d 2007 Mean monthly pH at river kilometers 25.9, 29.5, 30.4 and 32.3

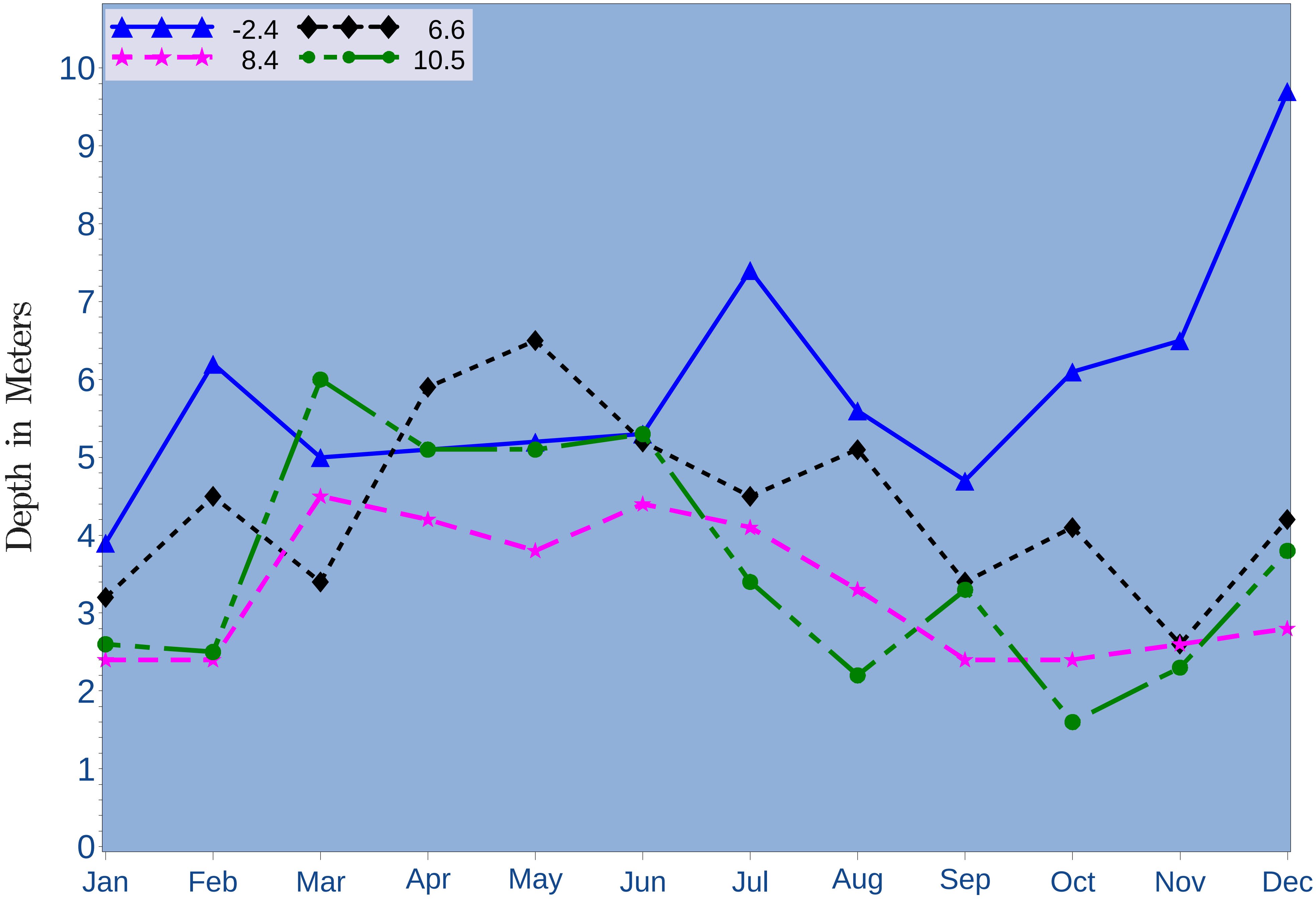

Figure 4.5a 2007 Monthly 1% light depth at river kilometers -2.4, 6.6, 8.4 and 10.5

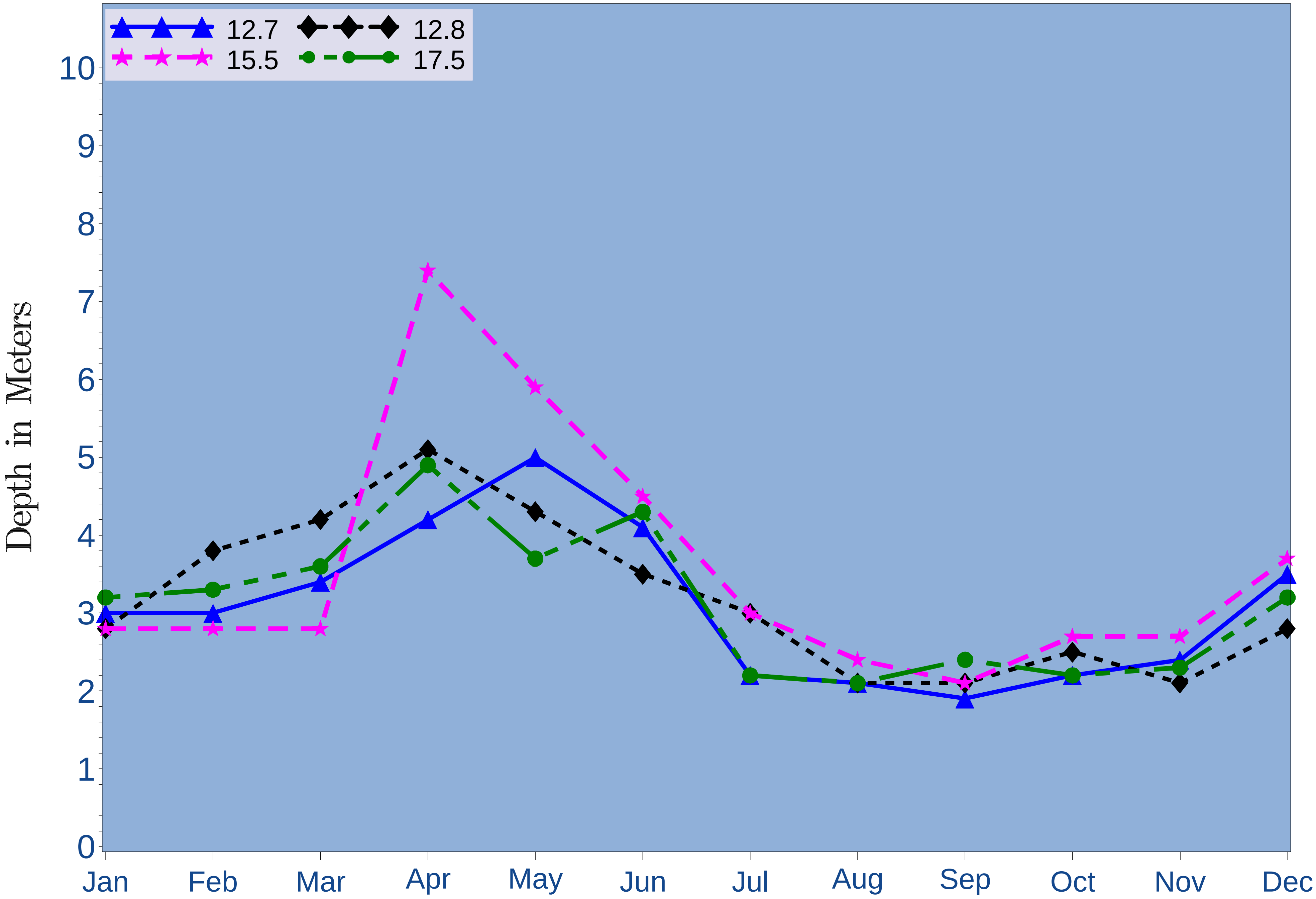

Figure 4.5b 2007 Monthly 1% light depth at river kilometers 12.7, 12.8, 15.5 and 17.5

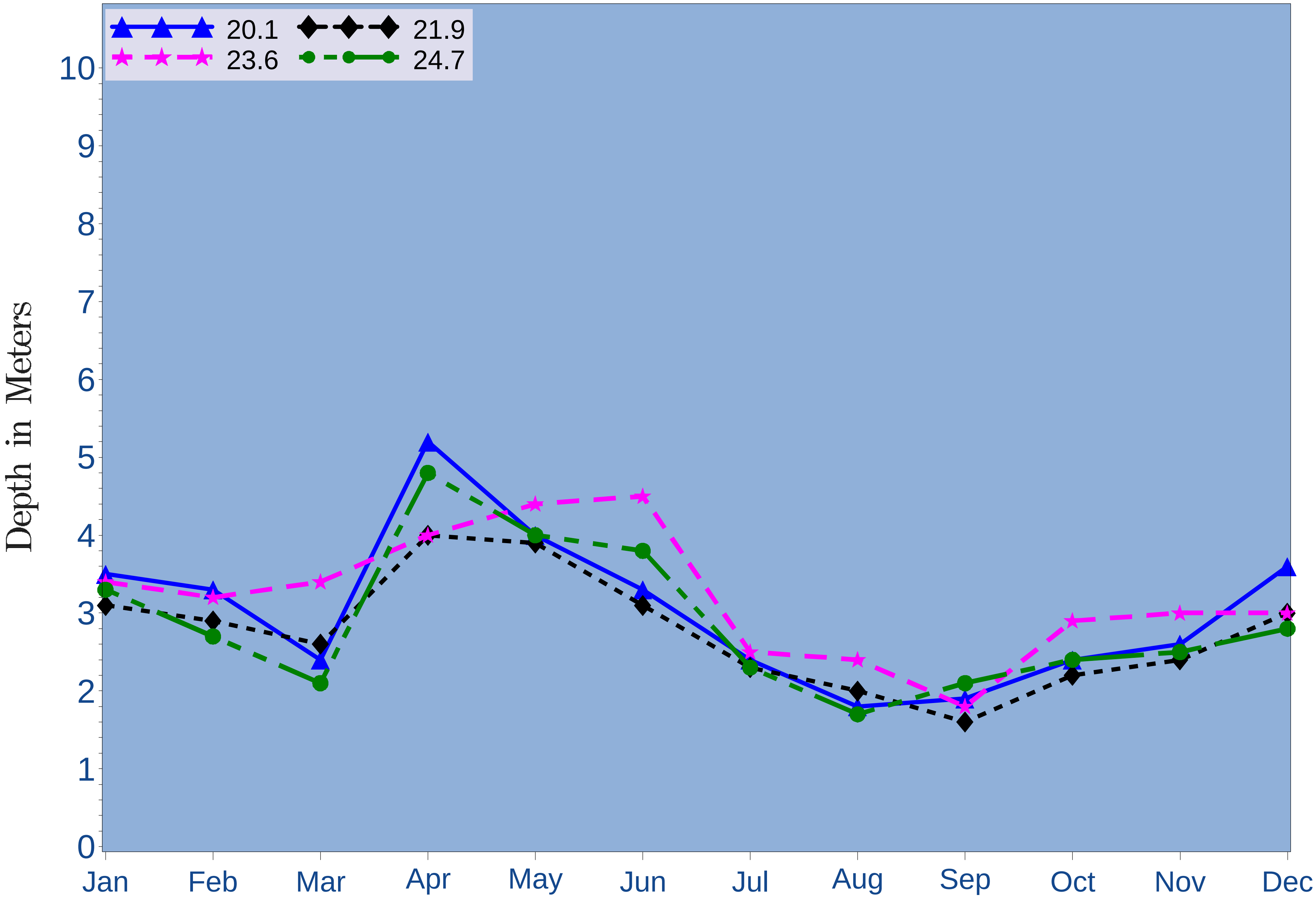

Figure 4.5c 2007 Monthly 1% light depth at river kilometers 20.1, 21.9, 23.6 and 24.7

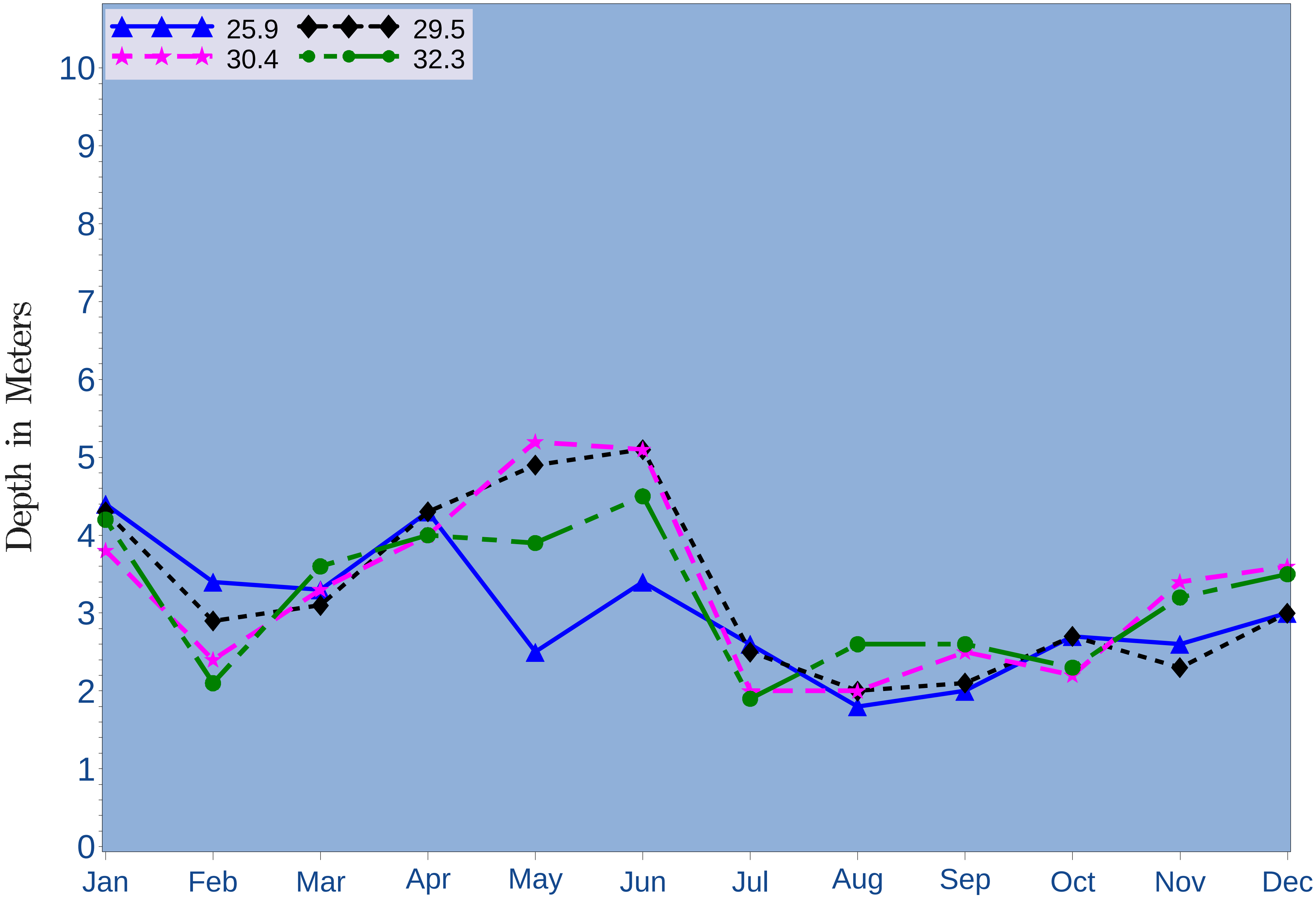

Figure 4.5d 2007 Monthly 1% light depth at river kilometers 25.9, 29.5, 30.4 and 32.3

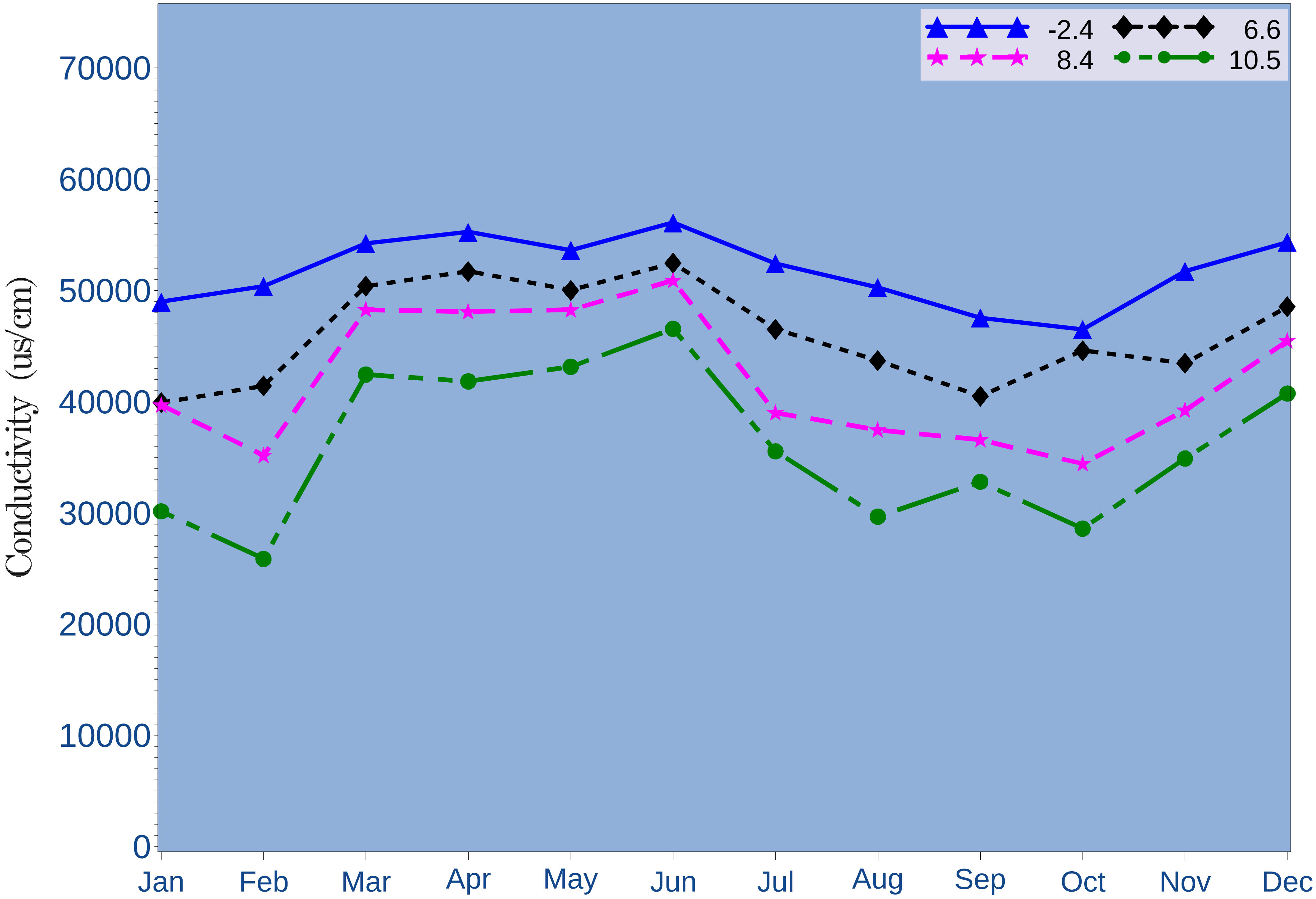

Figure 4.6a 2007 Mean monthly specific conductance at river kilometers -2.4, 6.6, 8.4 and 10.5

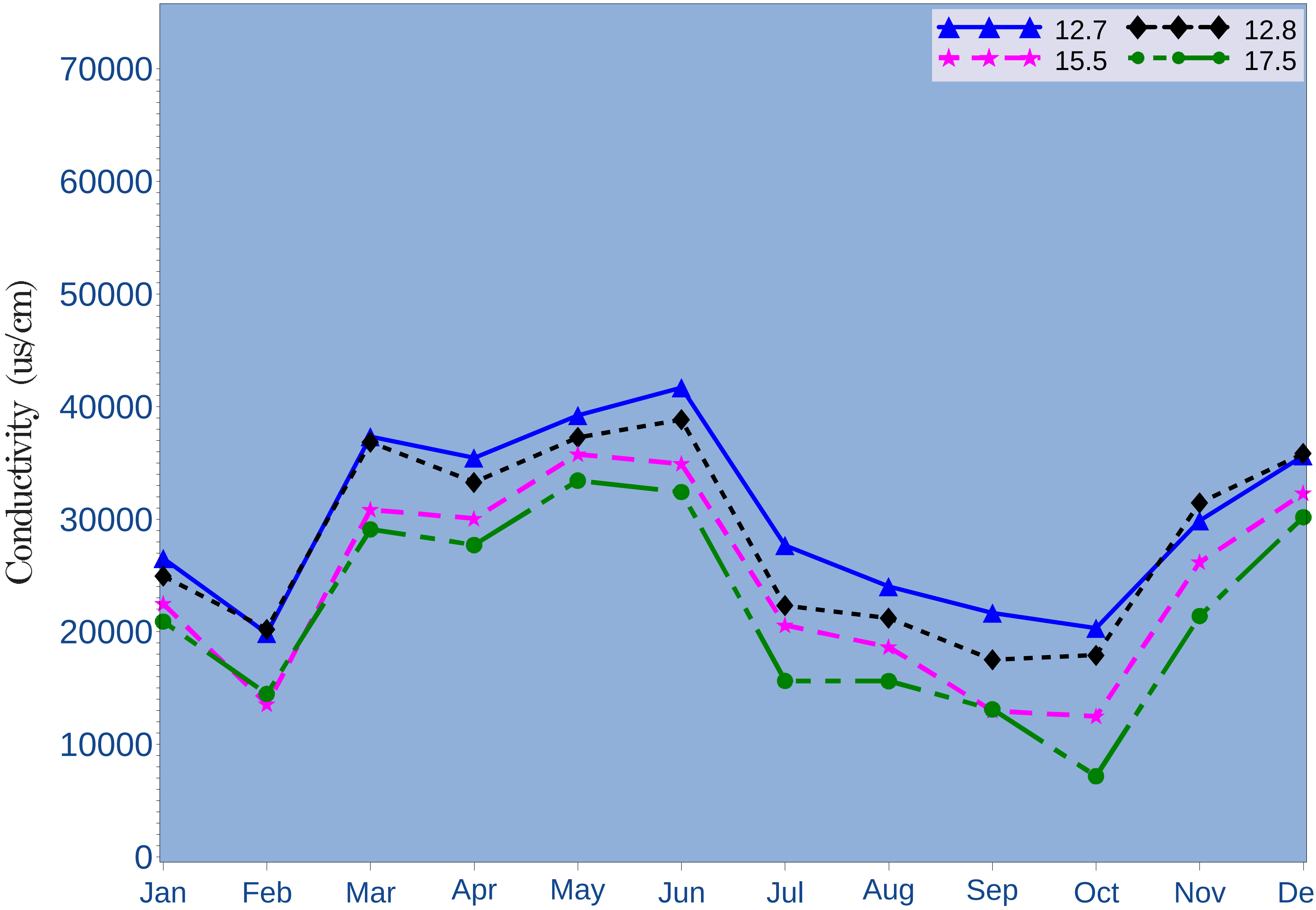

Figure 4.6b 2007 Mean monthly specific conductance at river kilometers 12.7, 12.8, 15.5 and 17.5

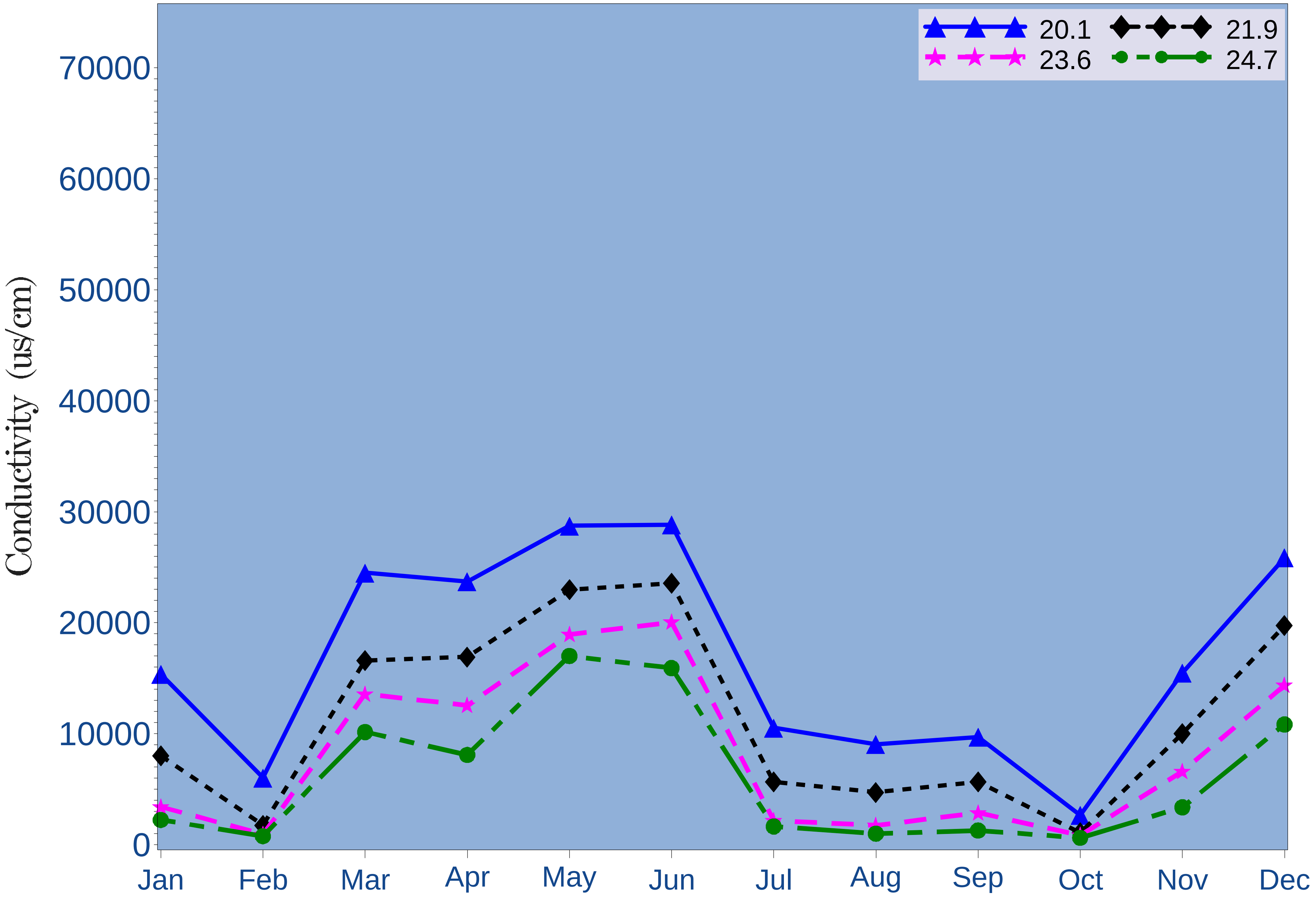

Figure 4.6c 2007 Mean monthly specific conductance at river kilometers 20.1, 21.9, 23.6 and 24.7

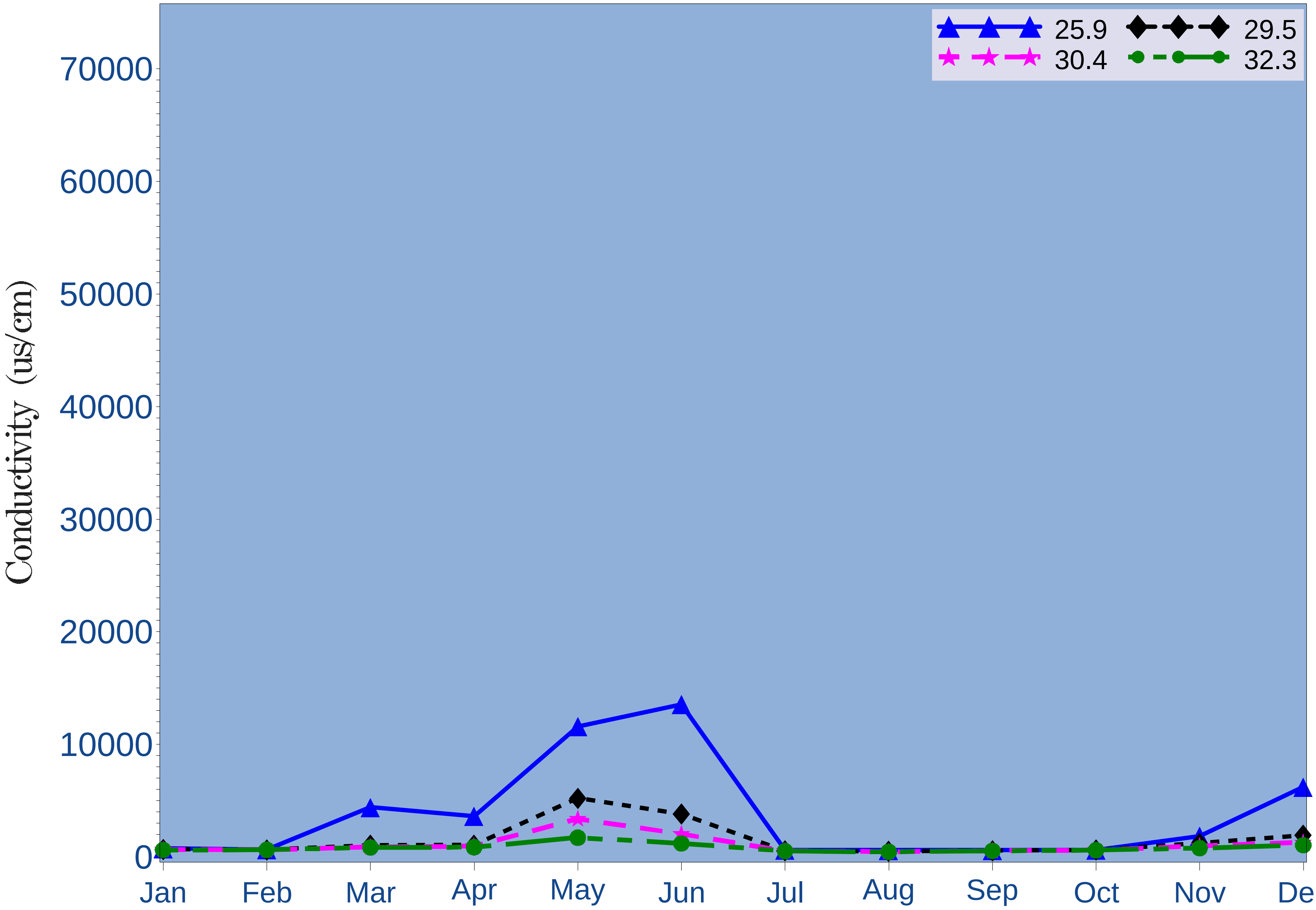

Figure 4.6d 2007 Mean monthly specific conductance at river kilometers 25.9, 29.5, 30.4 and 32.3

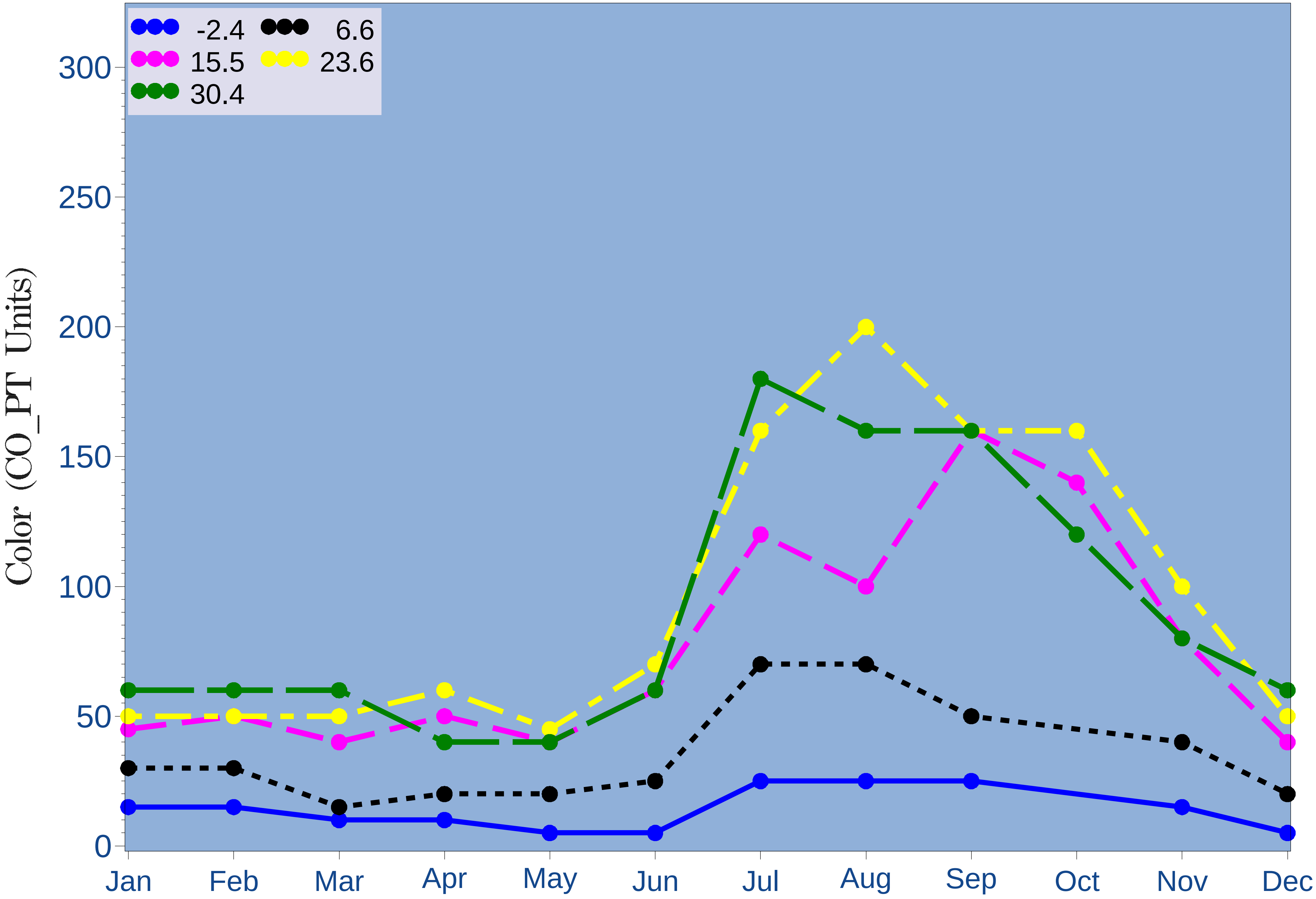

Figure 4.7a Surface color at fixed sampling stations (2007)

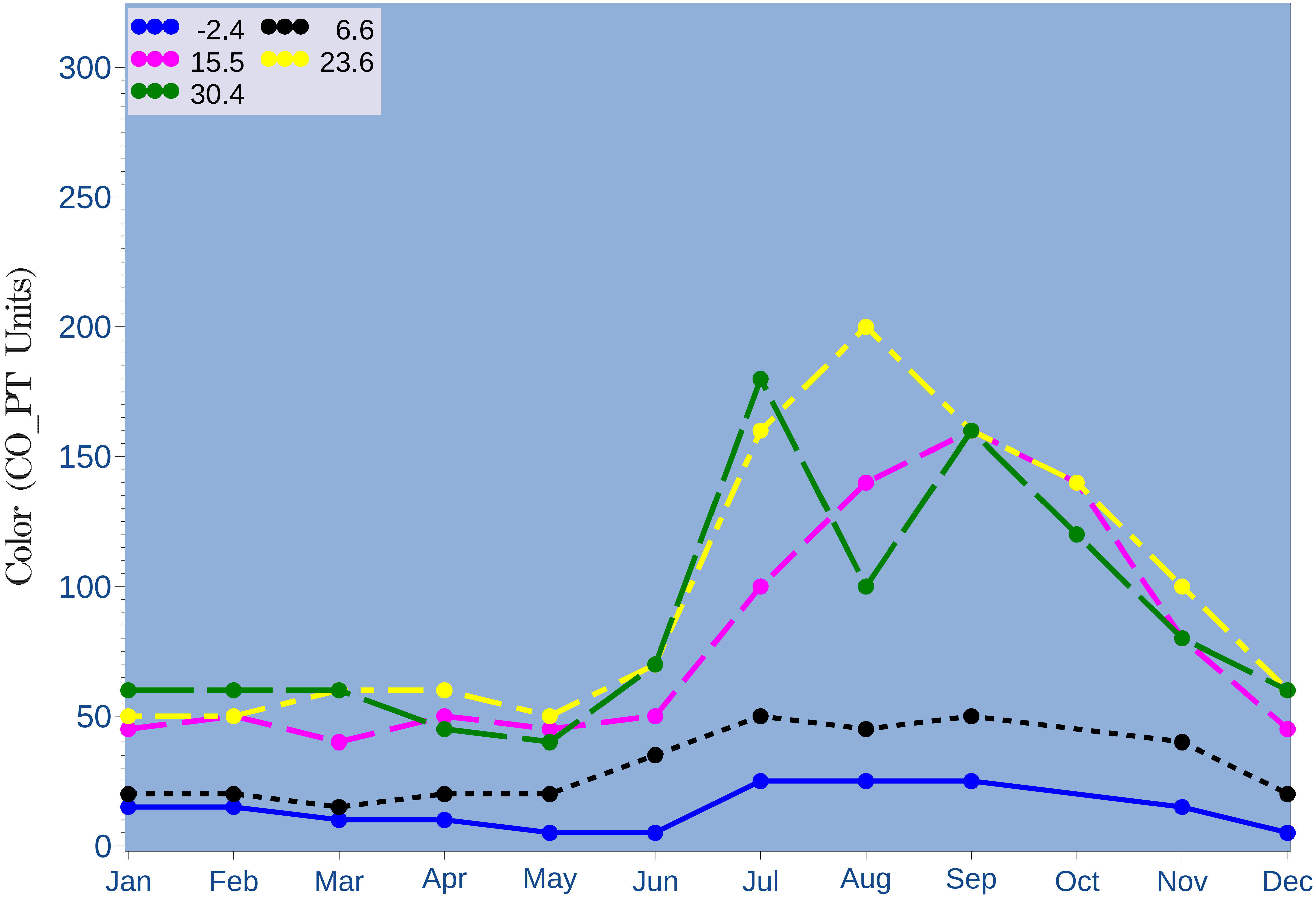

Figure 4.7b Bottom color at fixed sampling stations (2007)

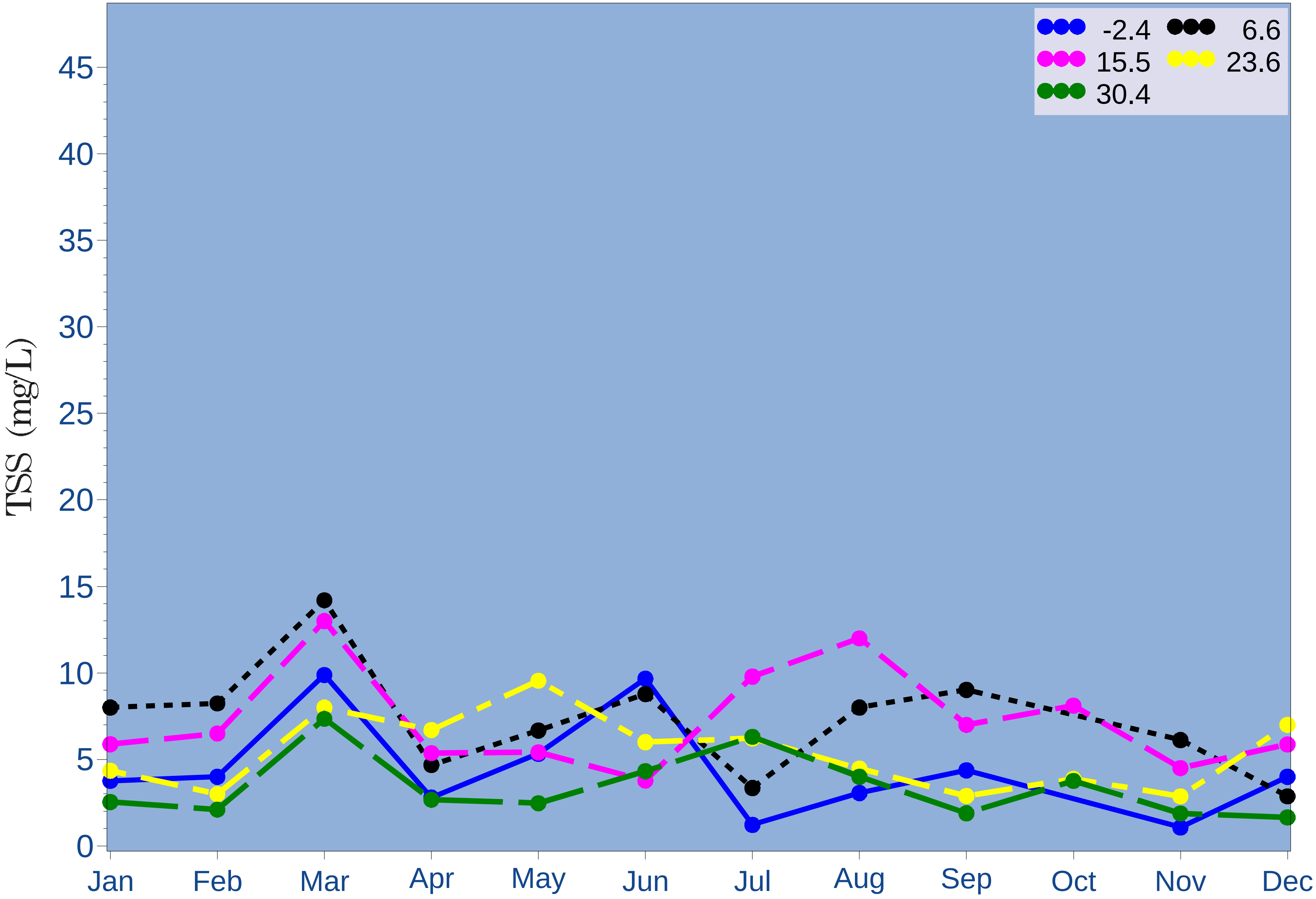

Figure 4.8a Surface total suspended solids at fixed sampling stations (2007)

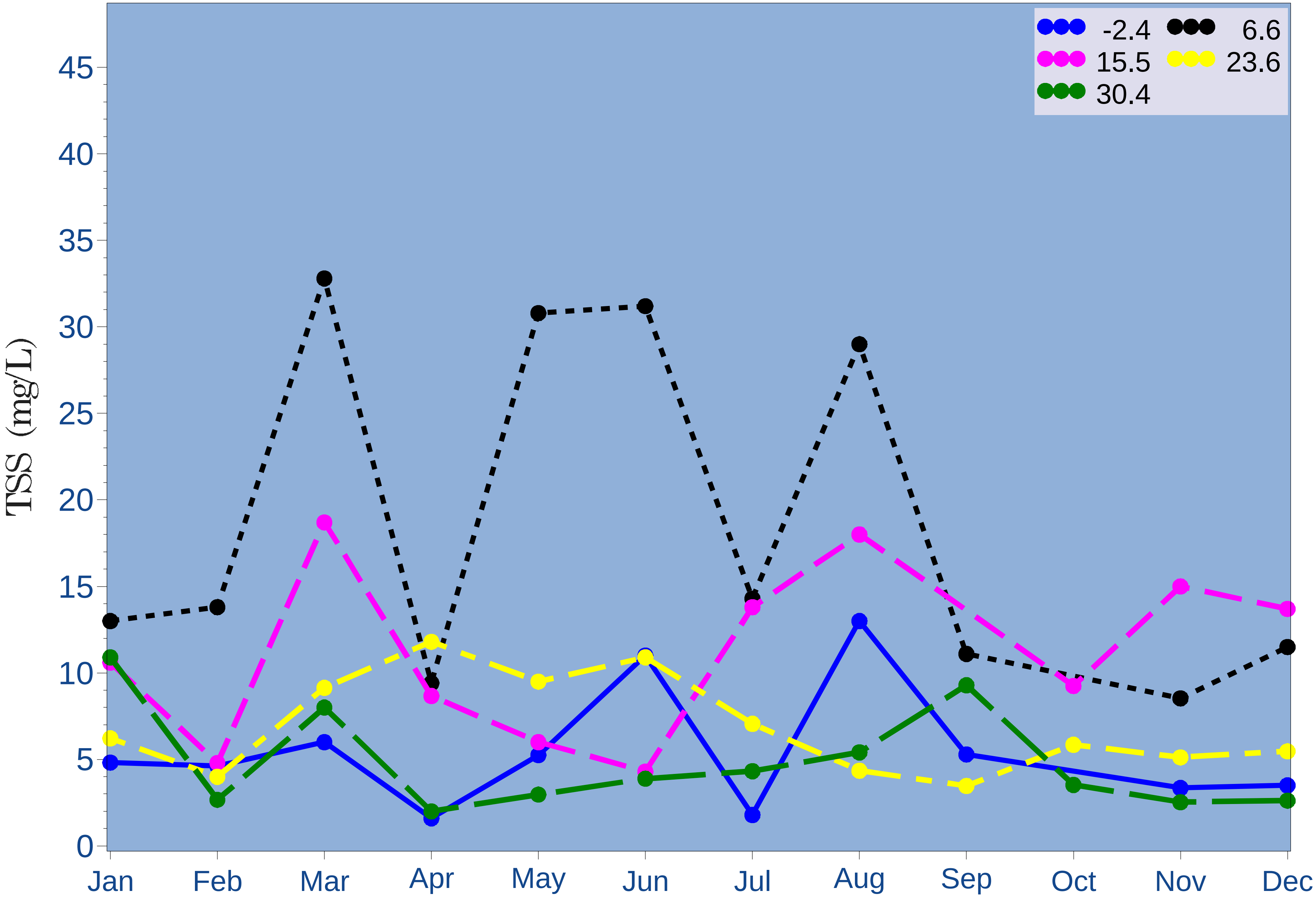

Figure 4.8b Monthly bottom total suspended solids at fixed sampling stations (2007)

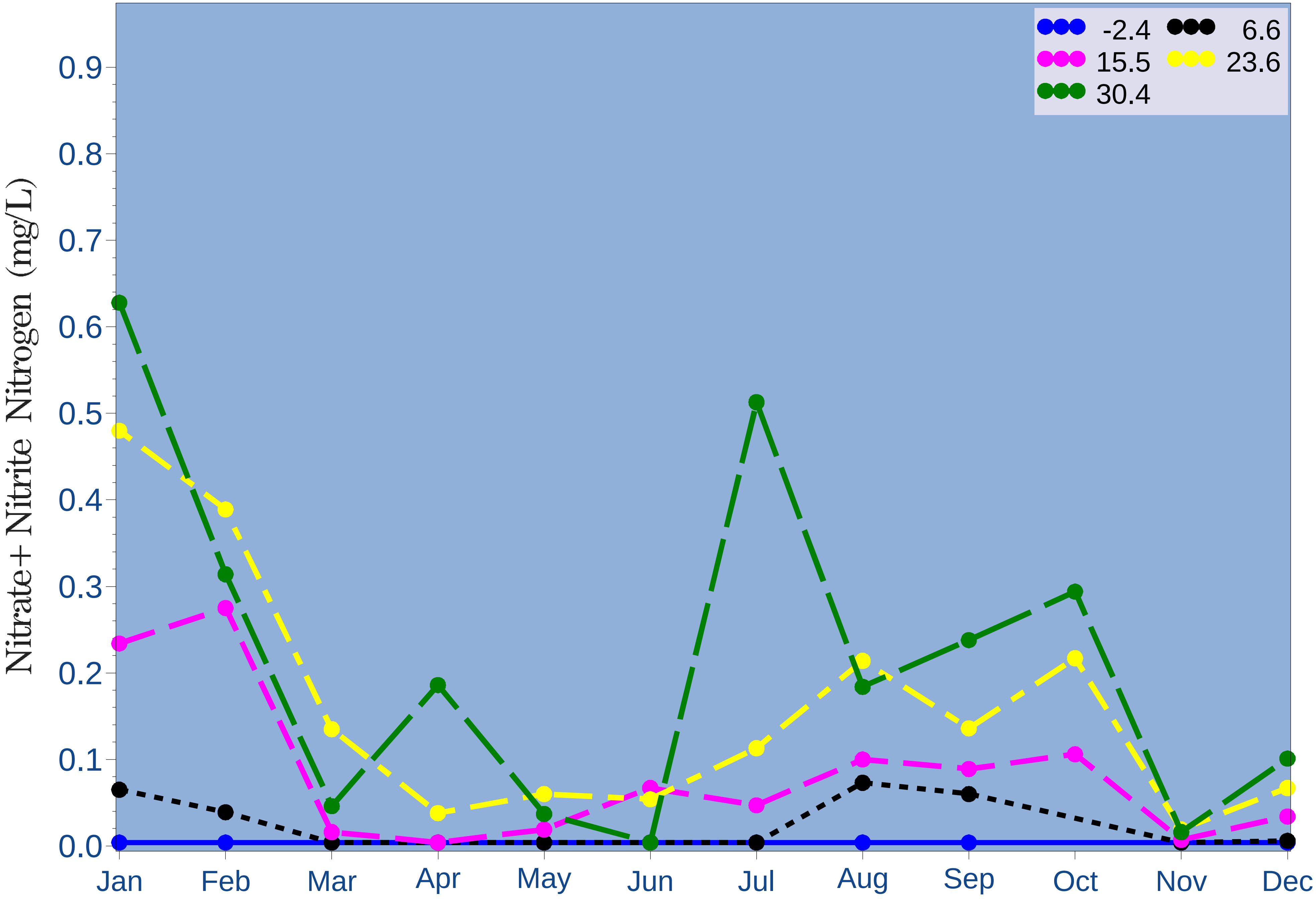

Figure 4.9a Monthly surface nitrate/nitrite nitrogen at fixed sampling stations (2007)

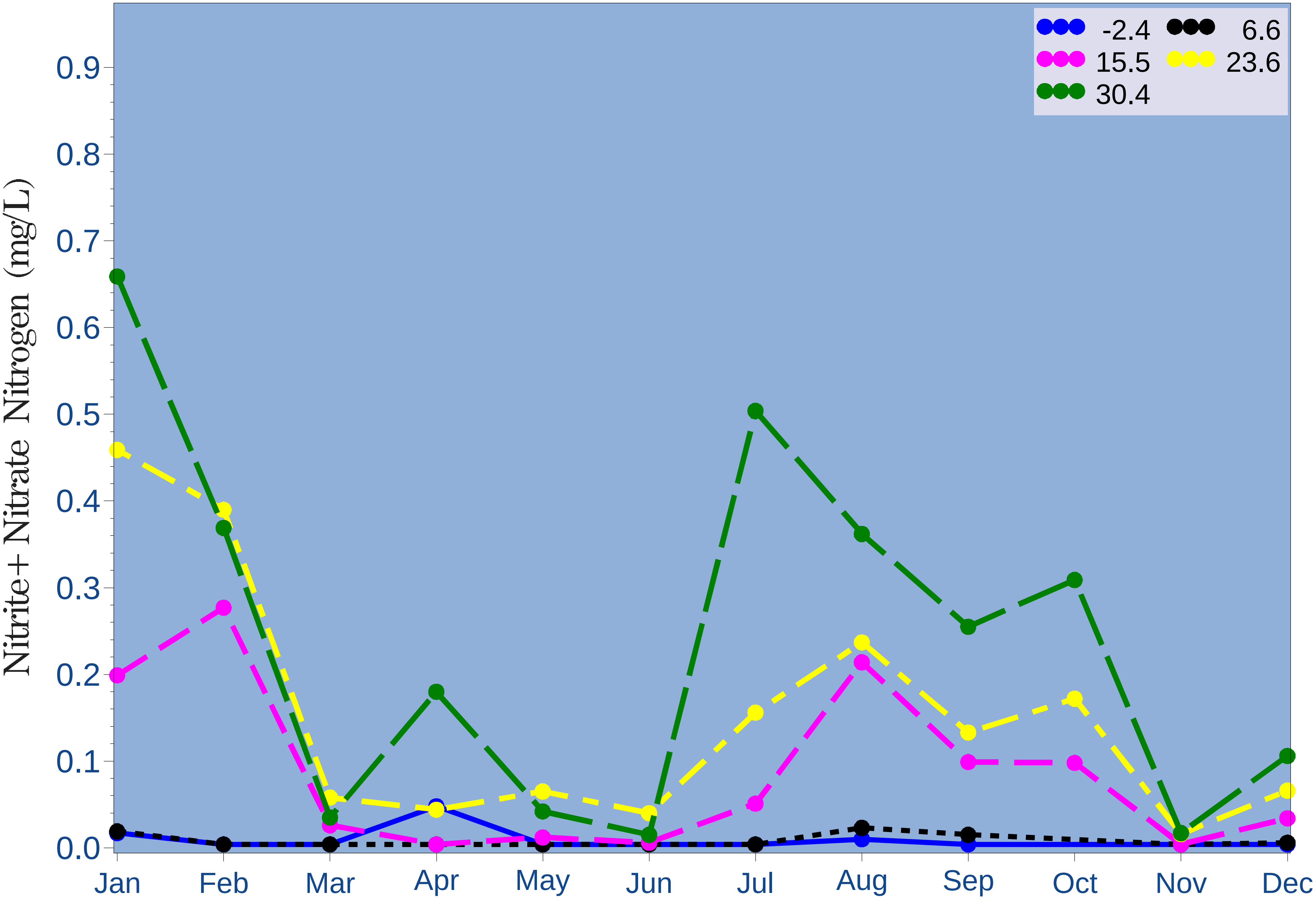

Figure 4.9b Monthly bottom nitrite/nitrate nitrogen at fixed sampling stations (2007)

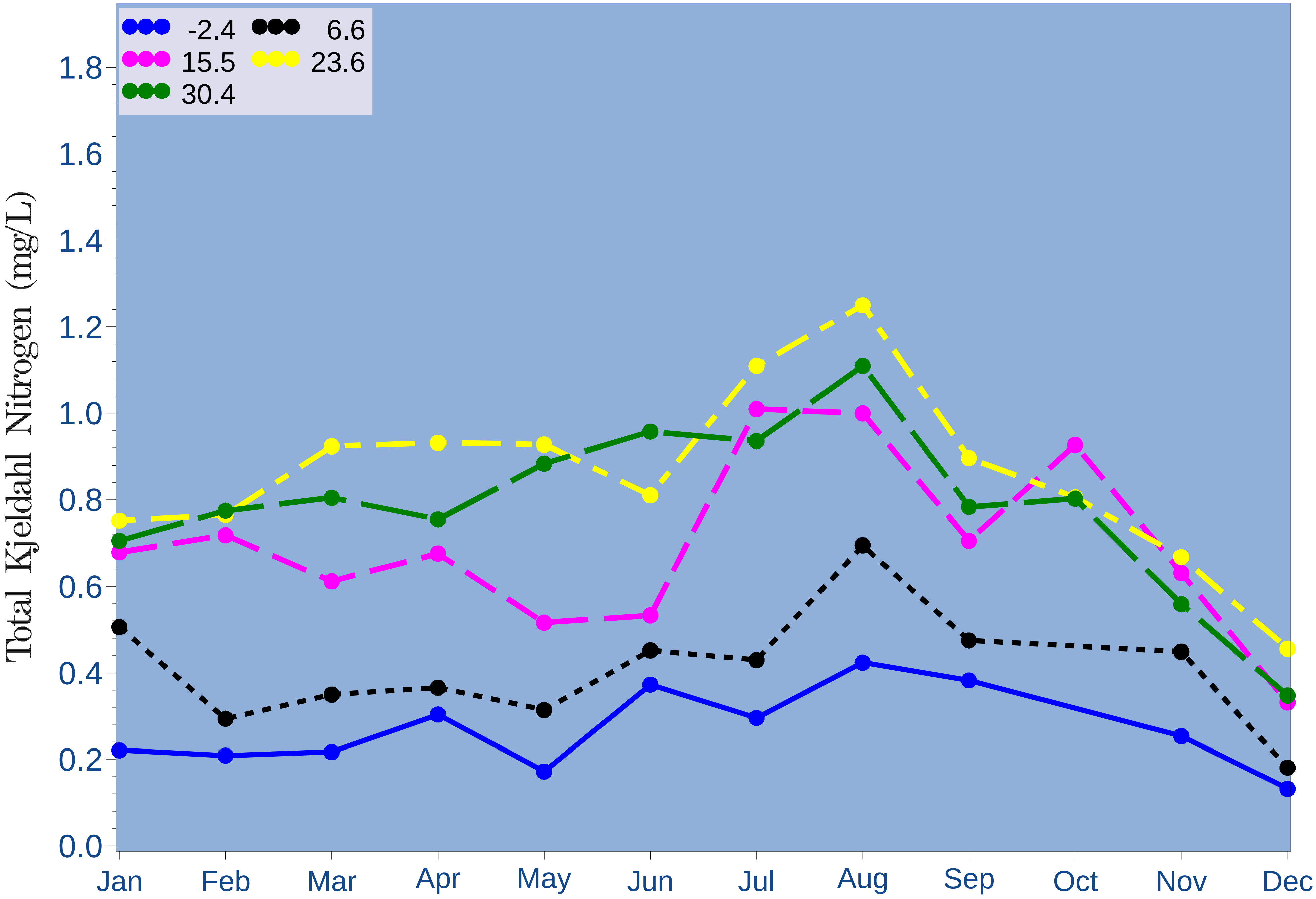

Figure 4.10a Monthly surface total Kjeldahl nitrogen at fixed sampling stations (2007)

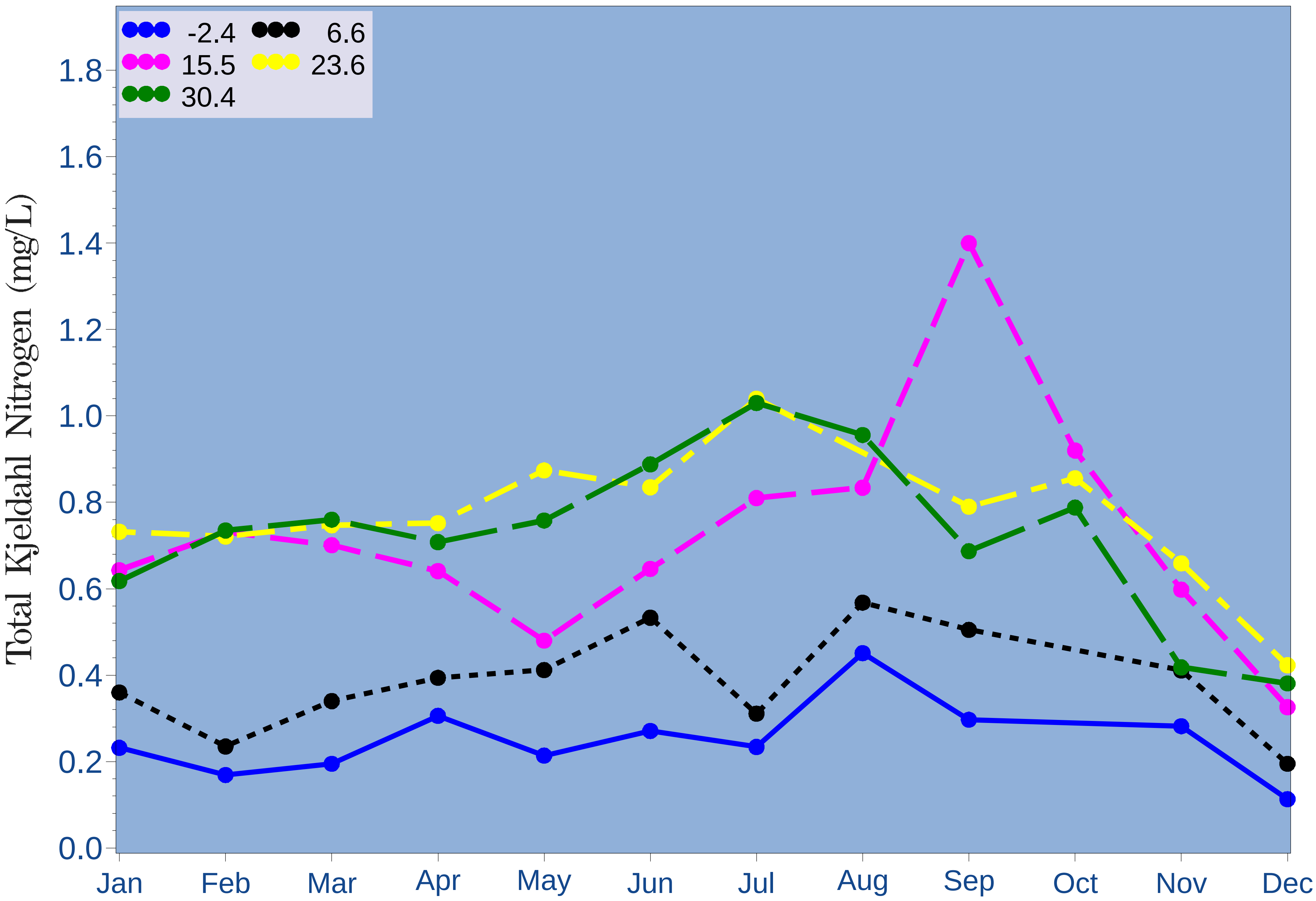

Figure 4.10b Monthly bottom total Kjeldahl nitrogen at fixed sampling stations (2007)

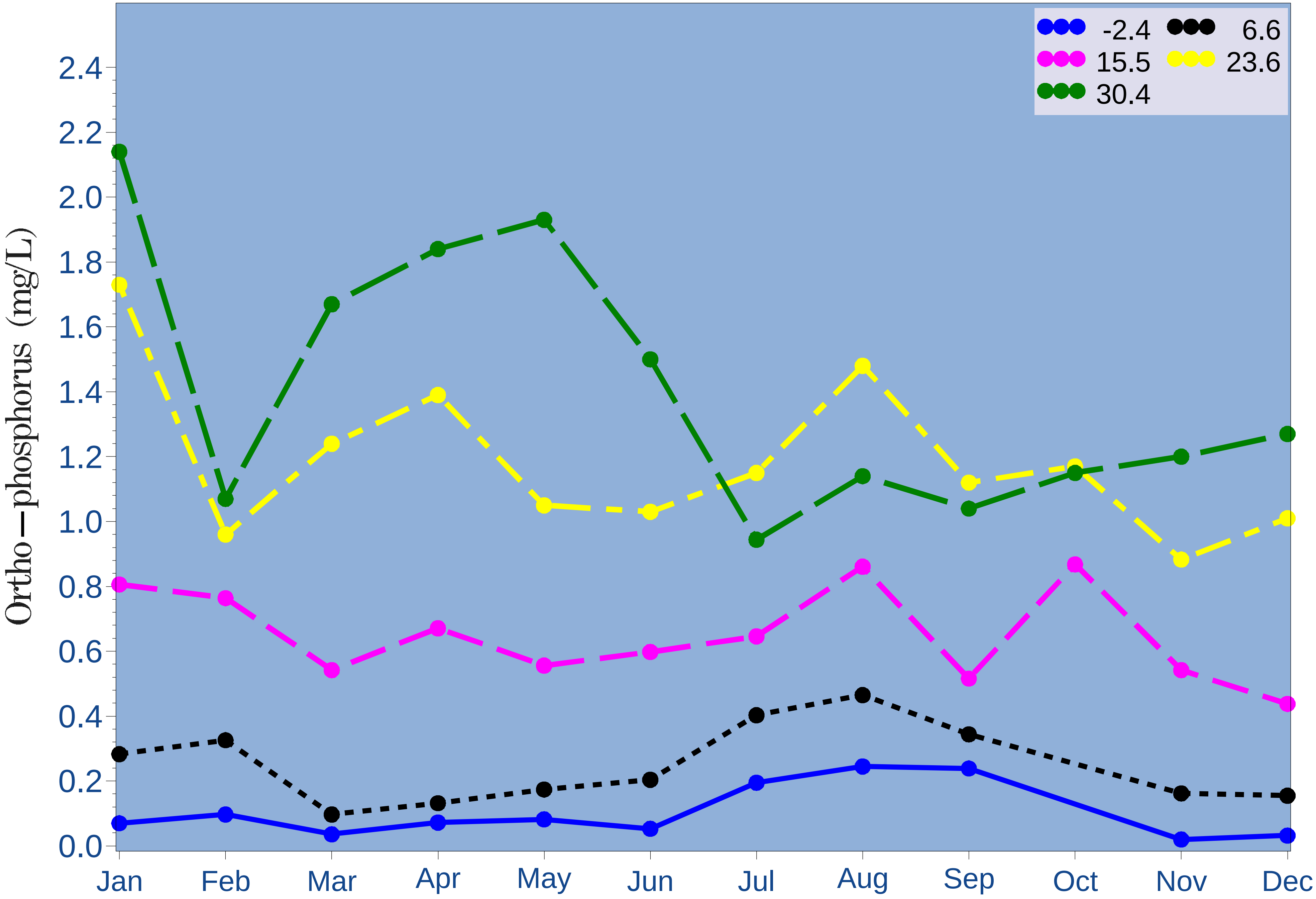

Figure 4.11a Monthly surface ortho-phosphorus at fixed sampling stations (2007)

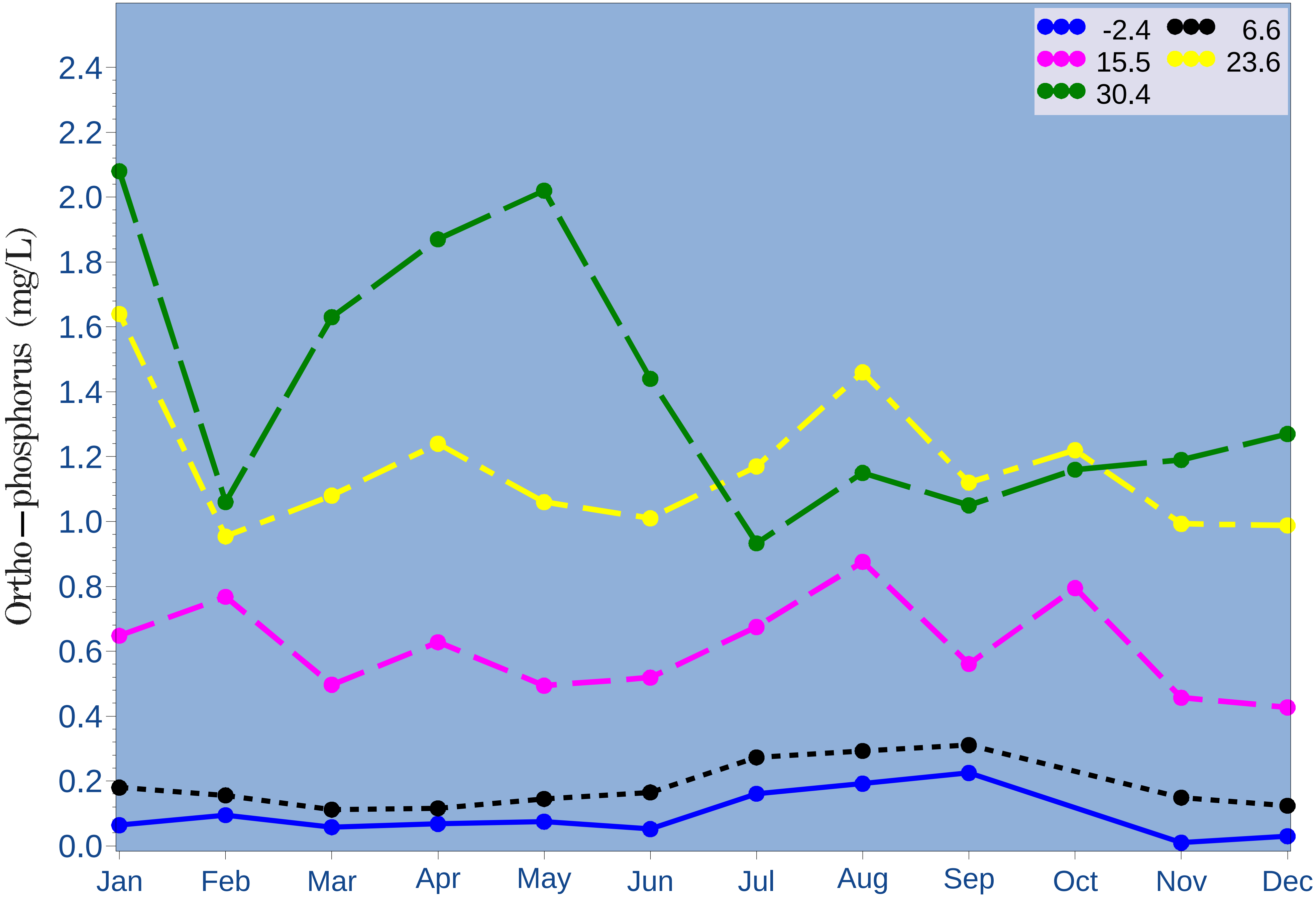

Figure 4.11b Monthly bottom ortho-phosphorus at fixed sampling stations (2007)

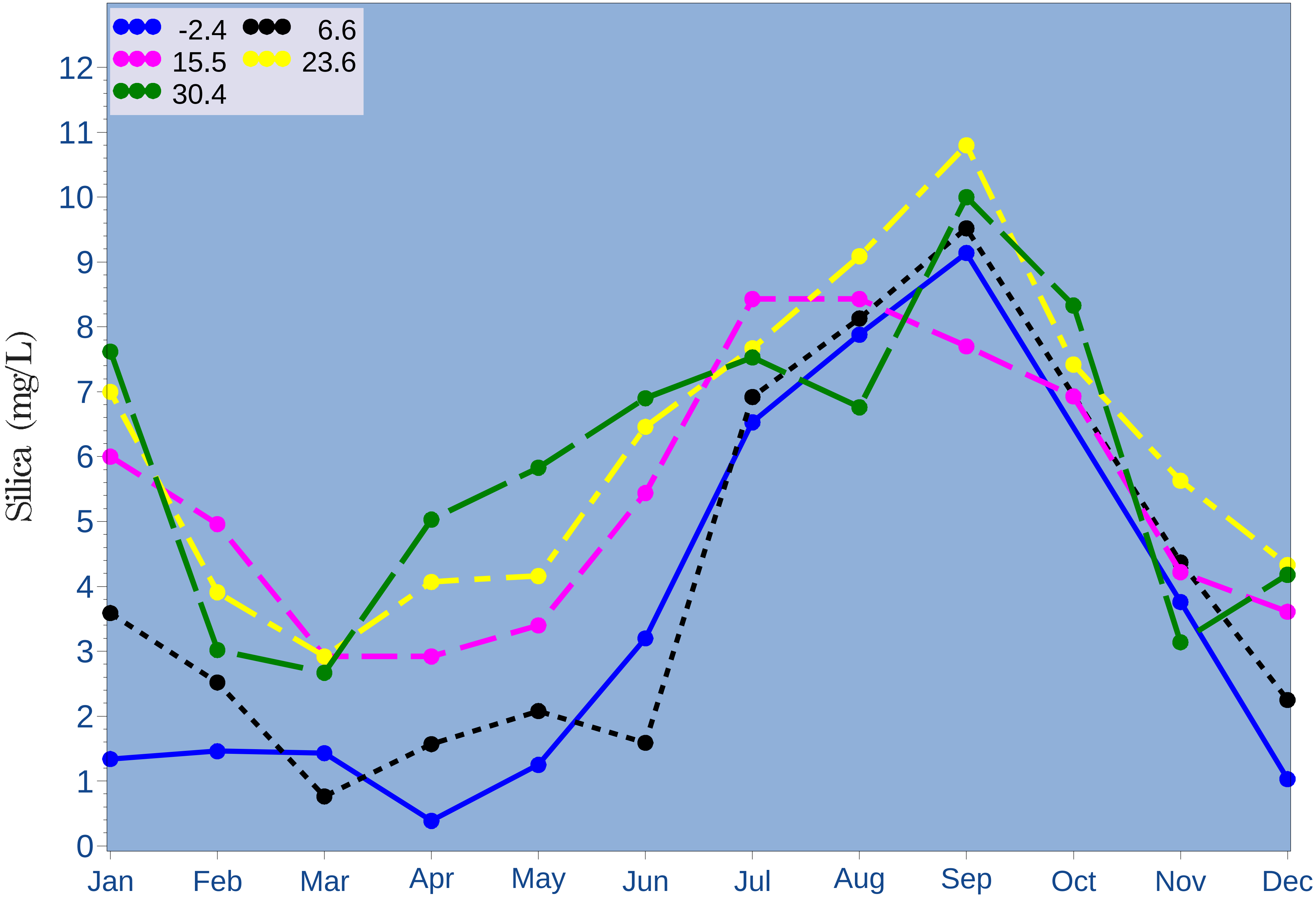

Figure 4.12a Monthly surface silica at fixed sampling stations (2007)

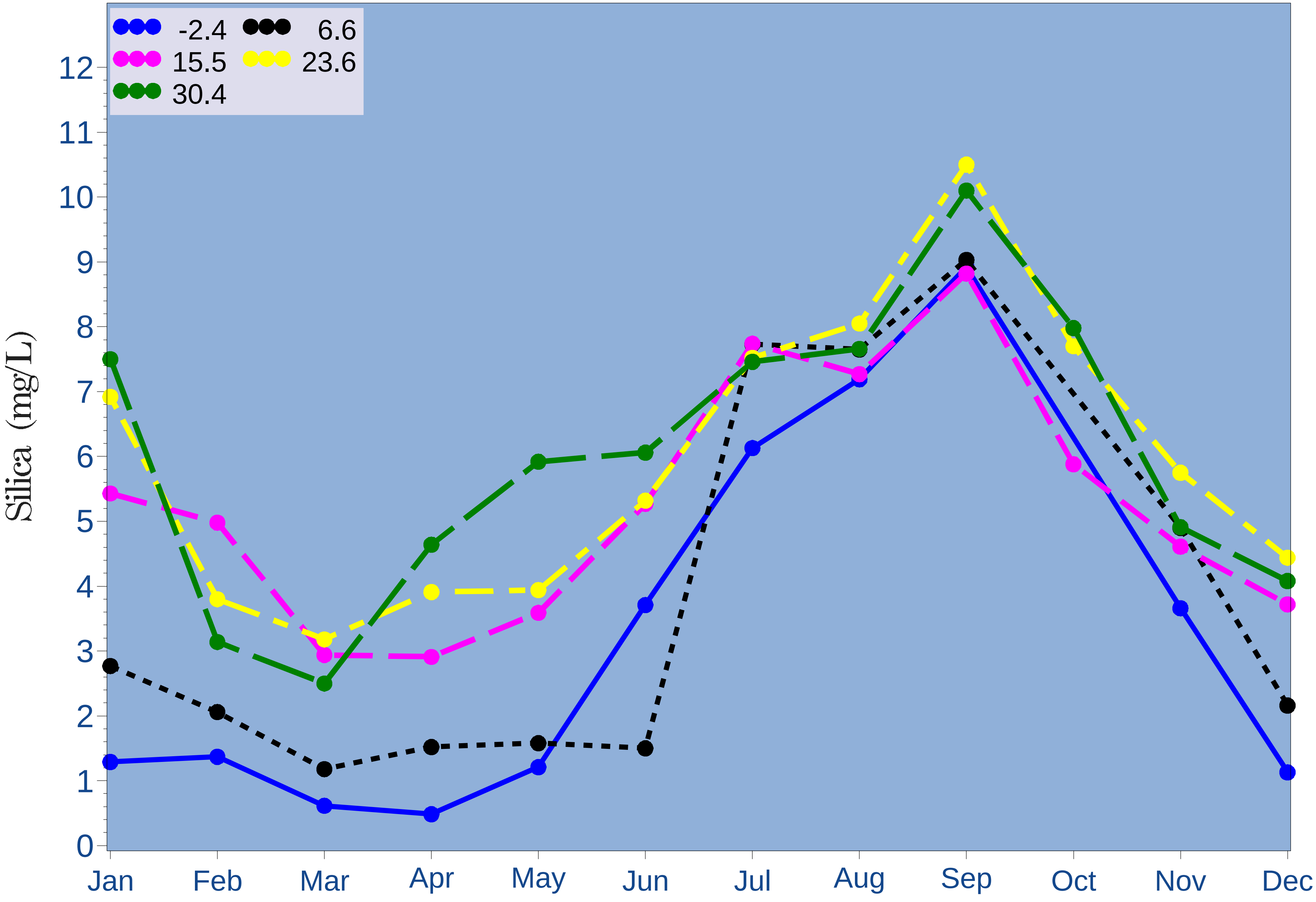

Figure 4.12b Monthly bottom silica at fixed sampling stations (2007)

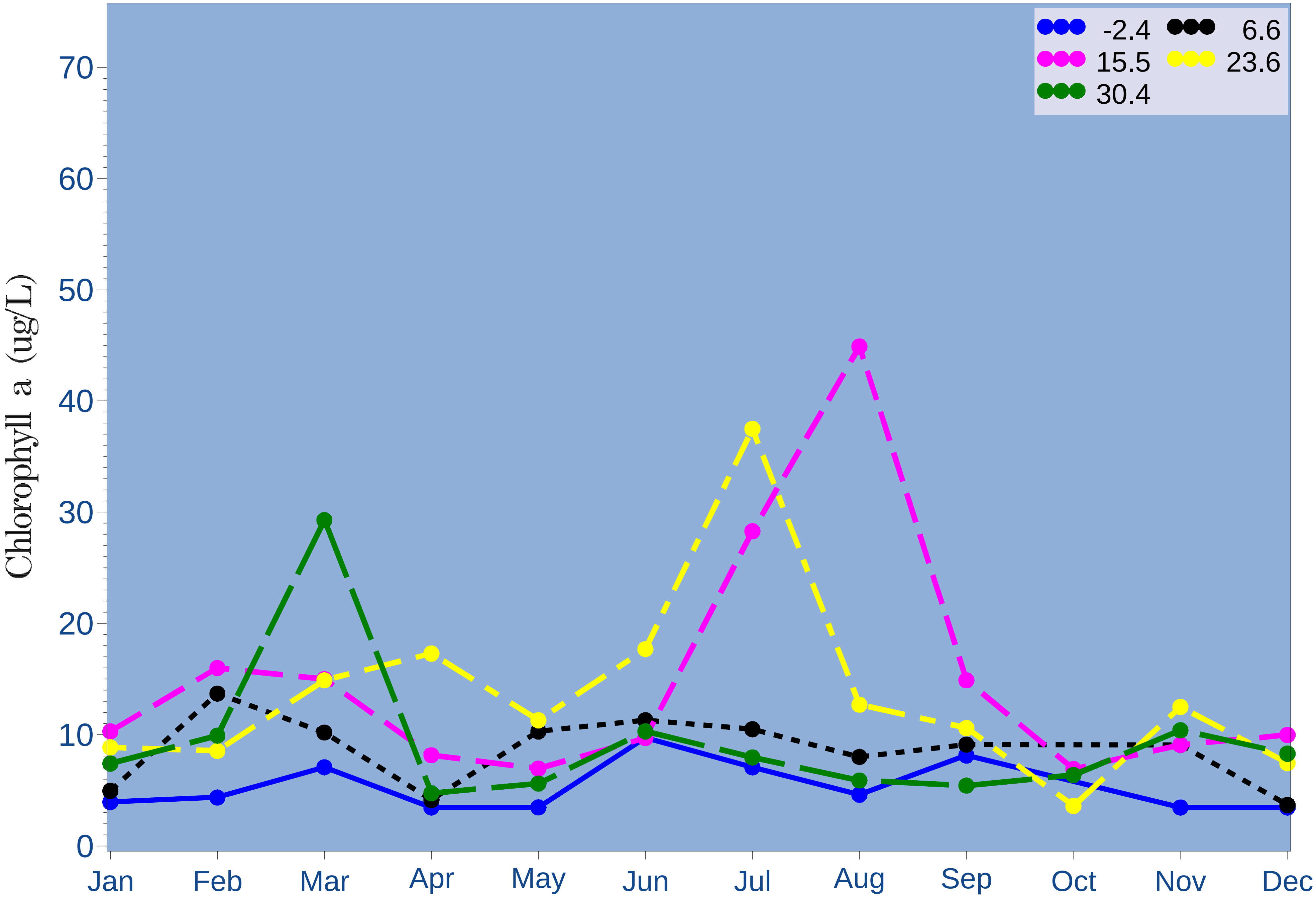

Figure 4.13a Monthly surface chlorophyll a (mg/m3) at fixed stations (2007)

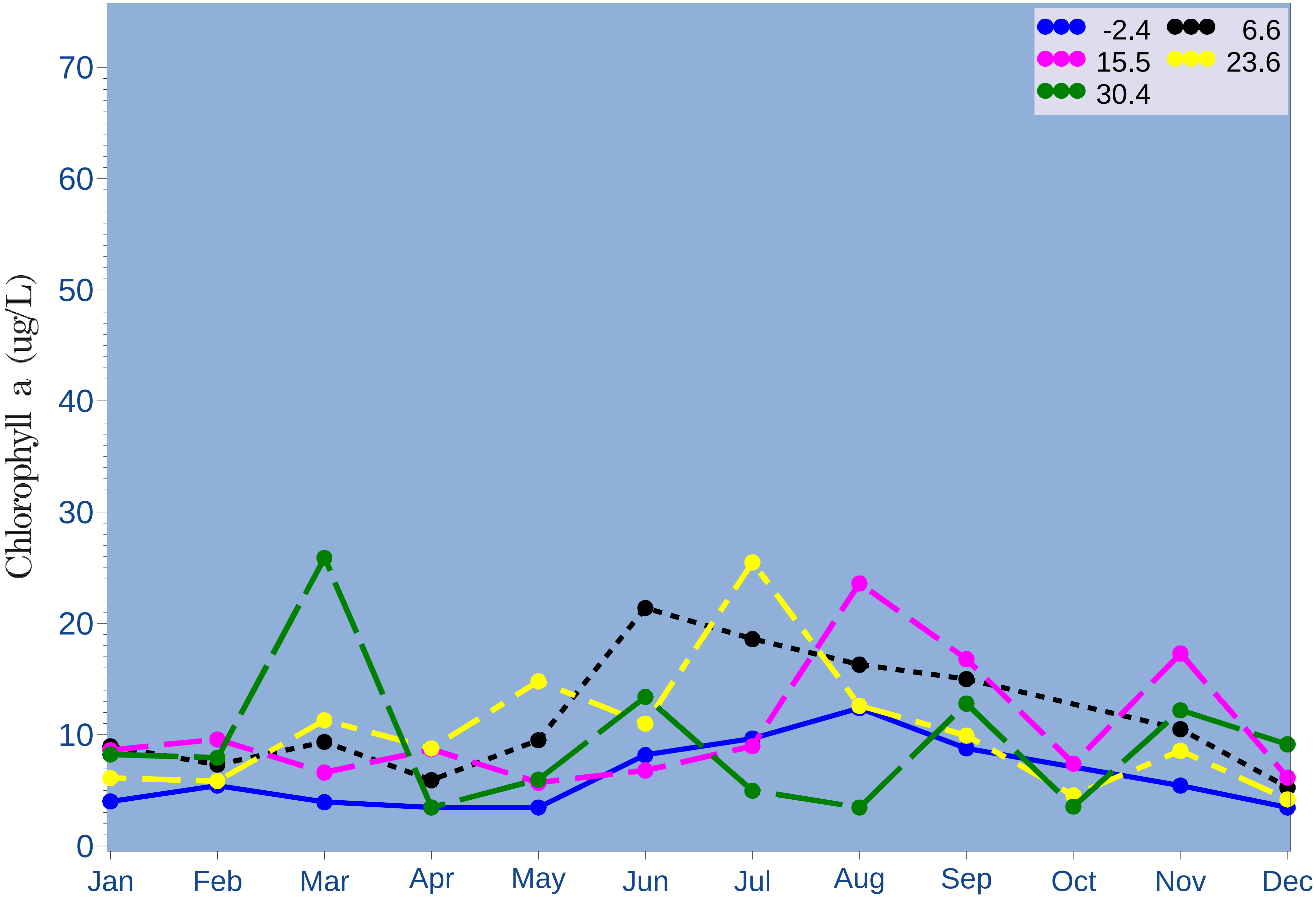

Figure 4.13b Monthly bottom chlorophyll a (mg/m3) at fixed stations (2007)

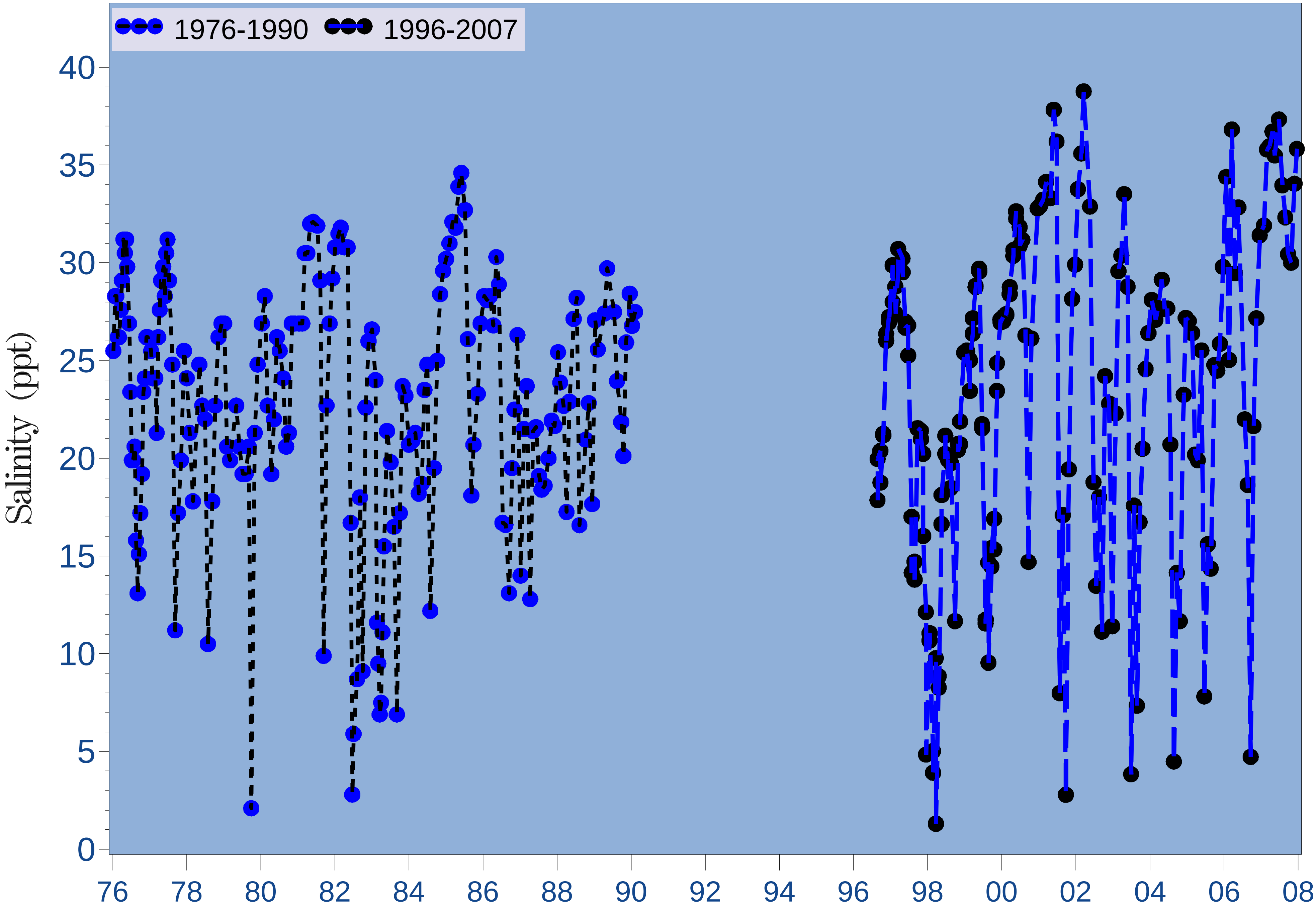

Figure 4.14a Monthly long-term surface salinity at river kilometer -2.4

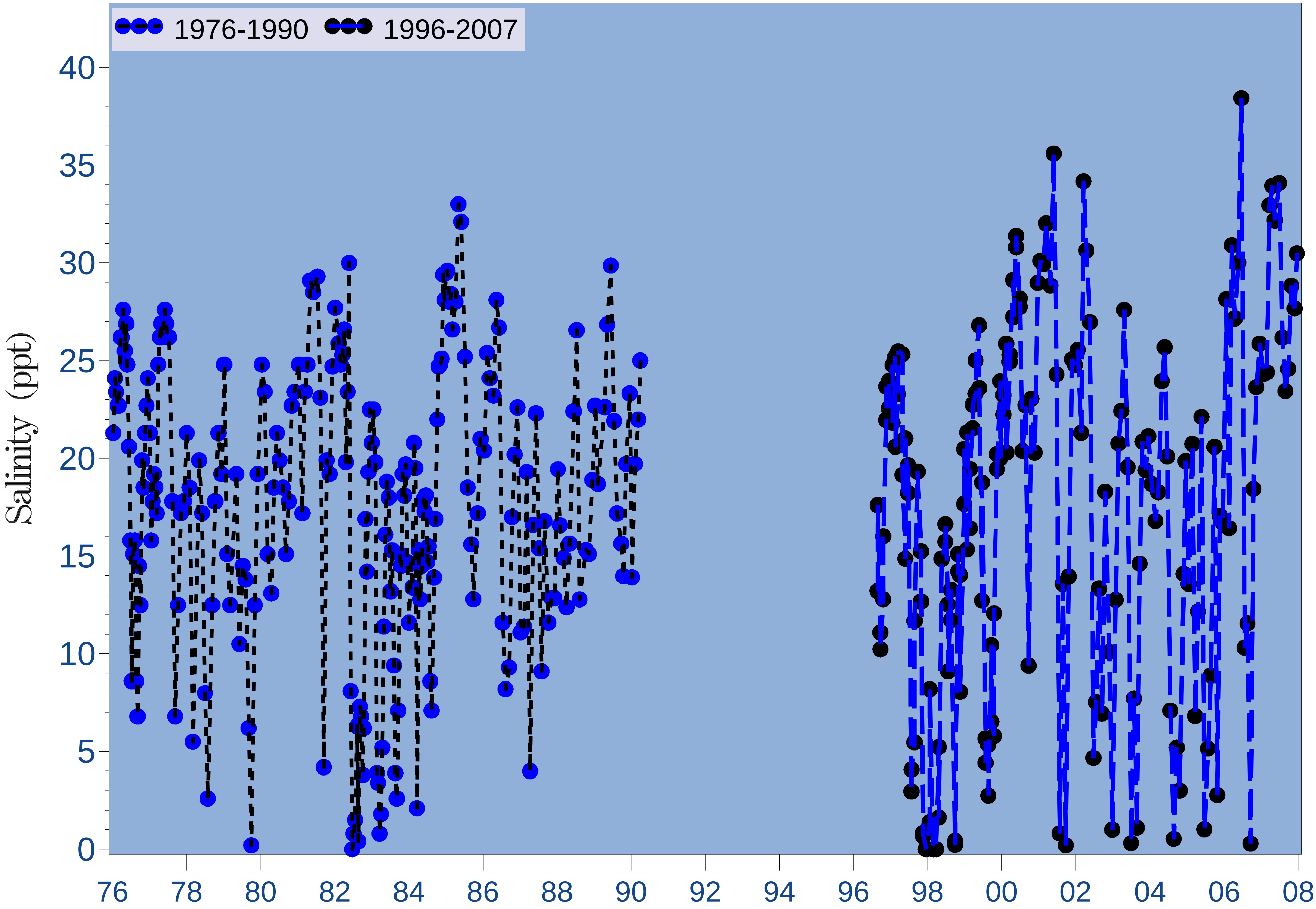

Figure 4.14b Monthly long-term surface salinity at river kilometer 6.6

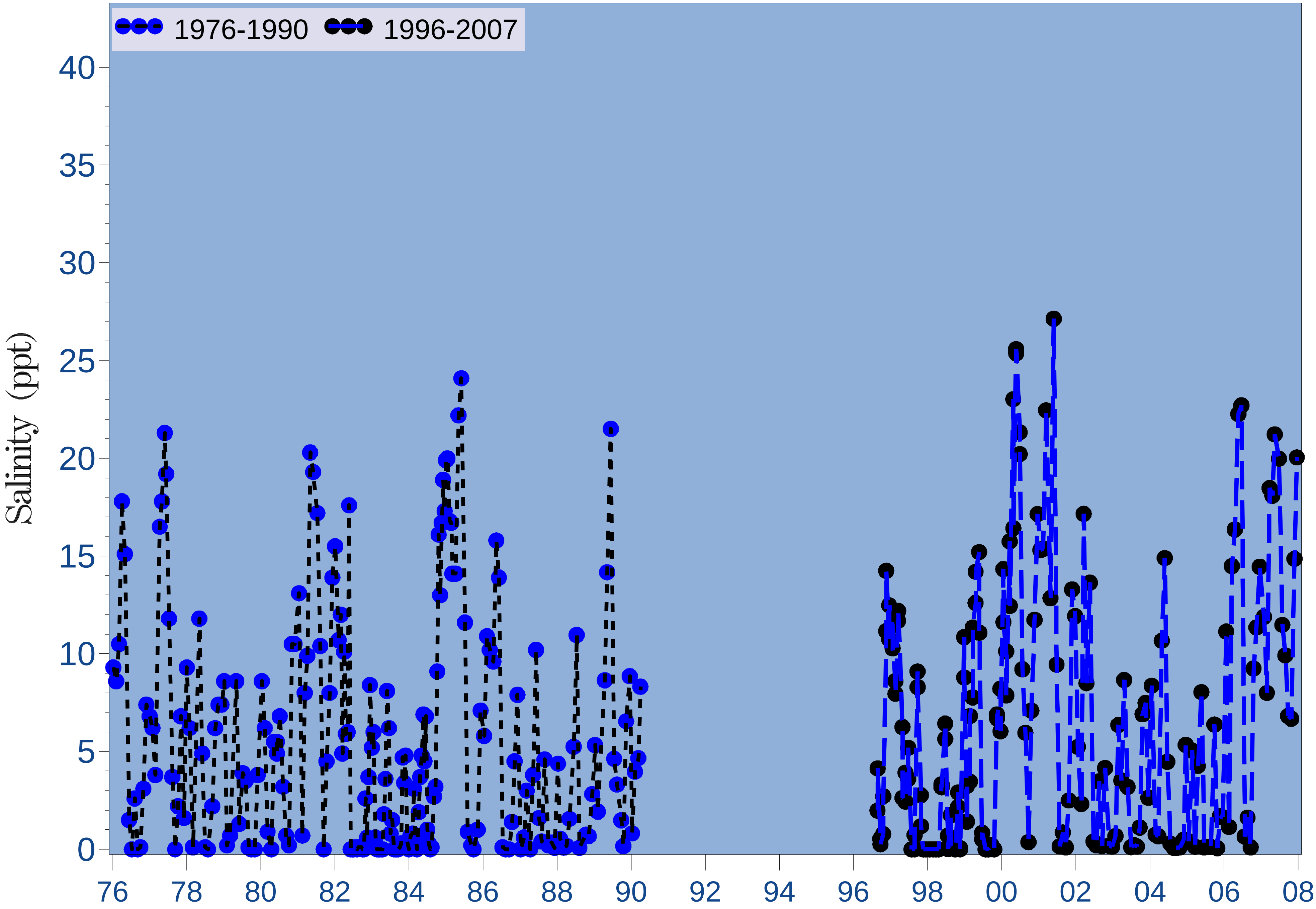

Figure 4.14c Monthly long-term surface salinity at river kilometer 15.5

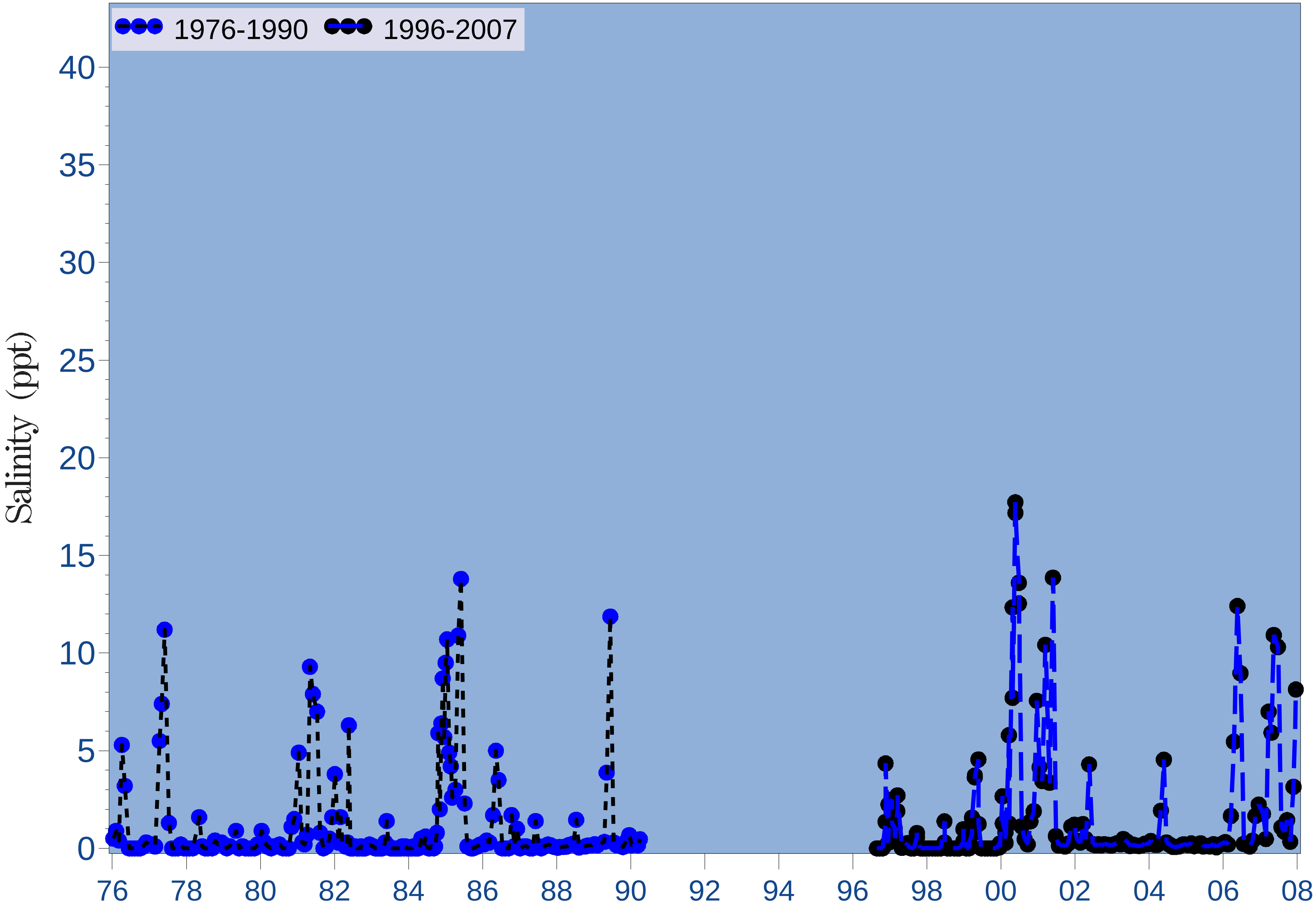

Figure 4.14d Monthly long-term surface salinity at river kilometer 23.6

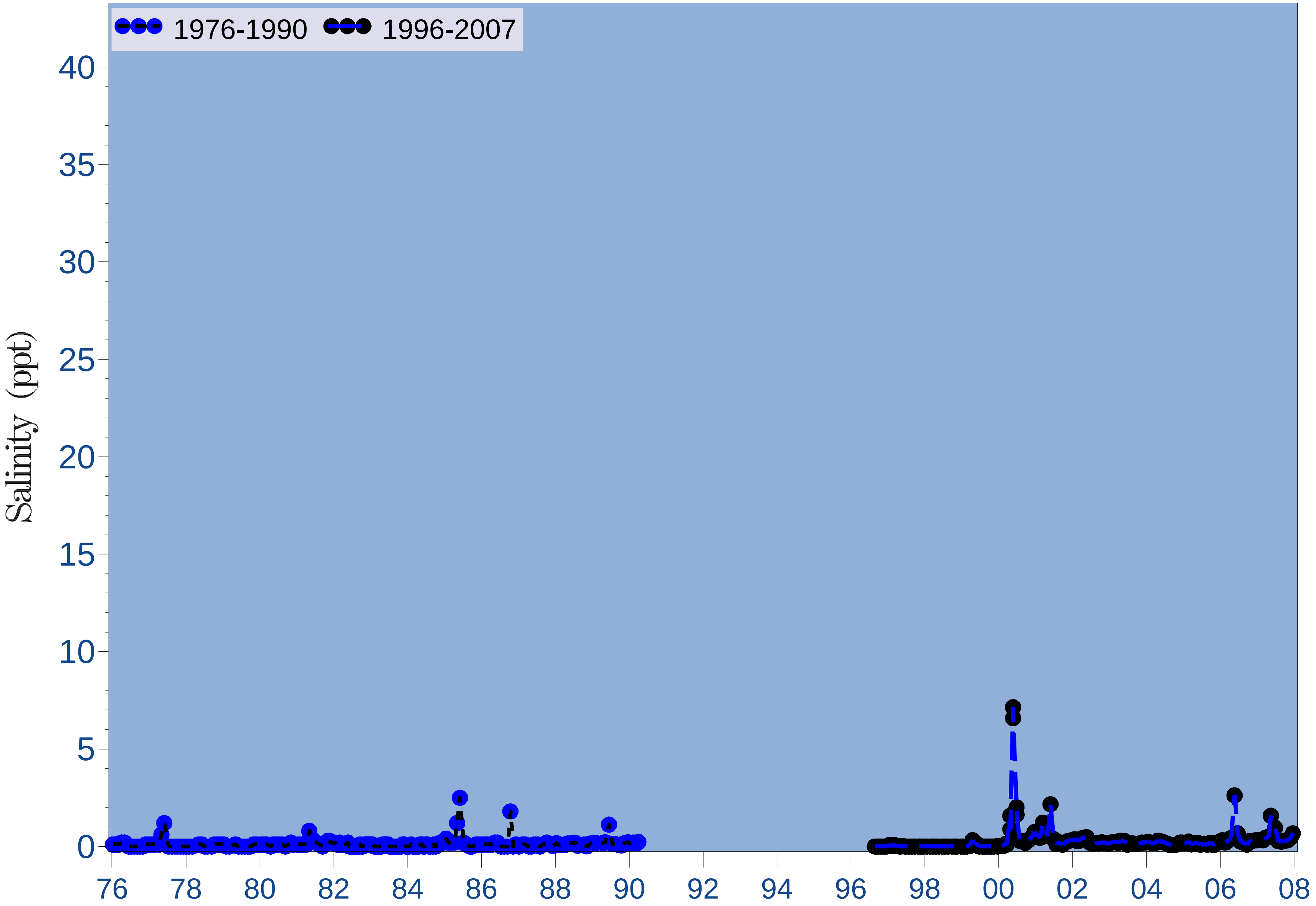

Figure 4.14e Monthly long-term surface salinity at river kilometer 30.4

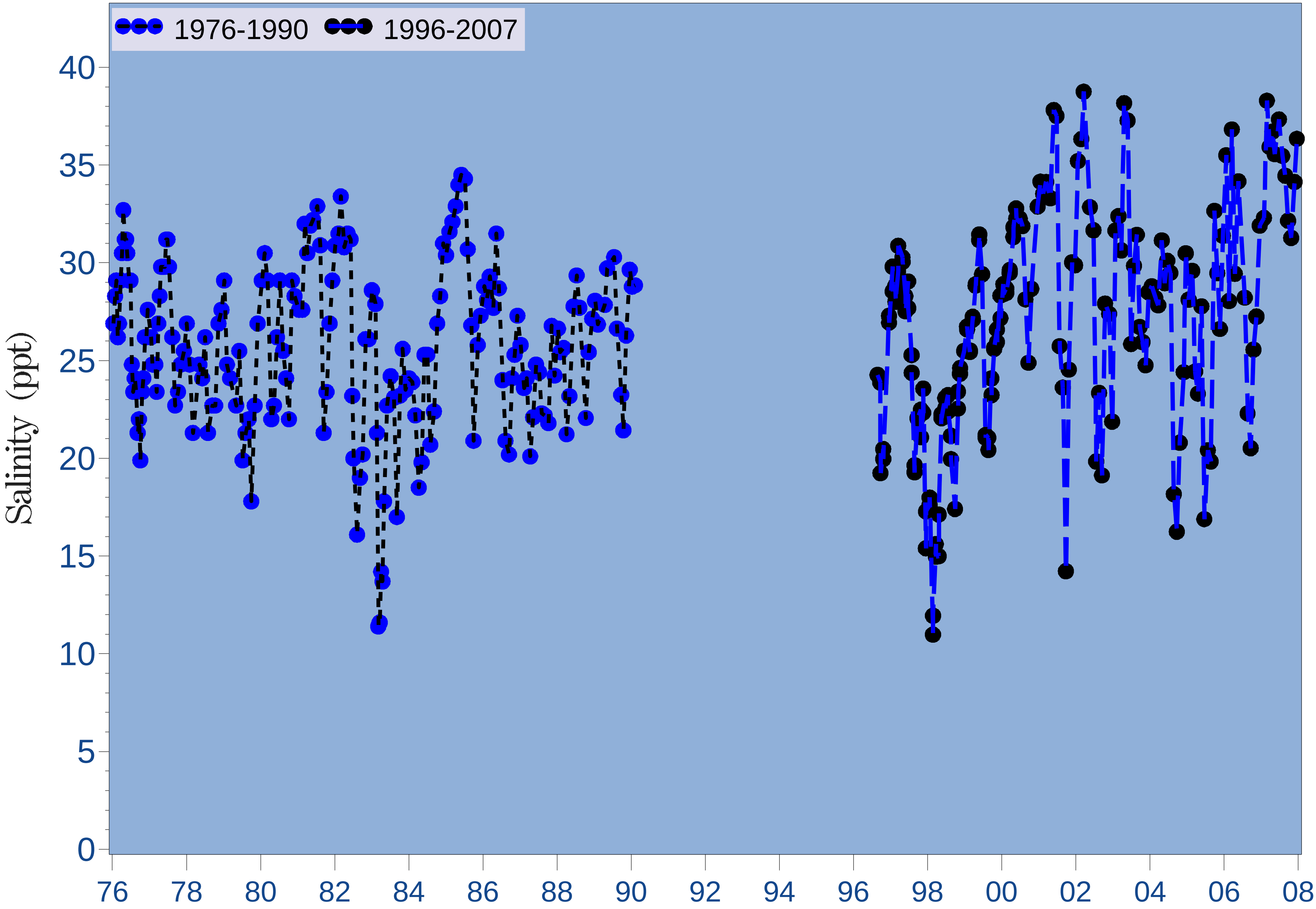

Figure 4.15a Monthly long-term bottom salinity at river kilometer -2.4

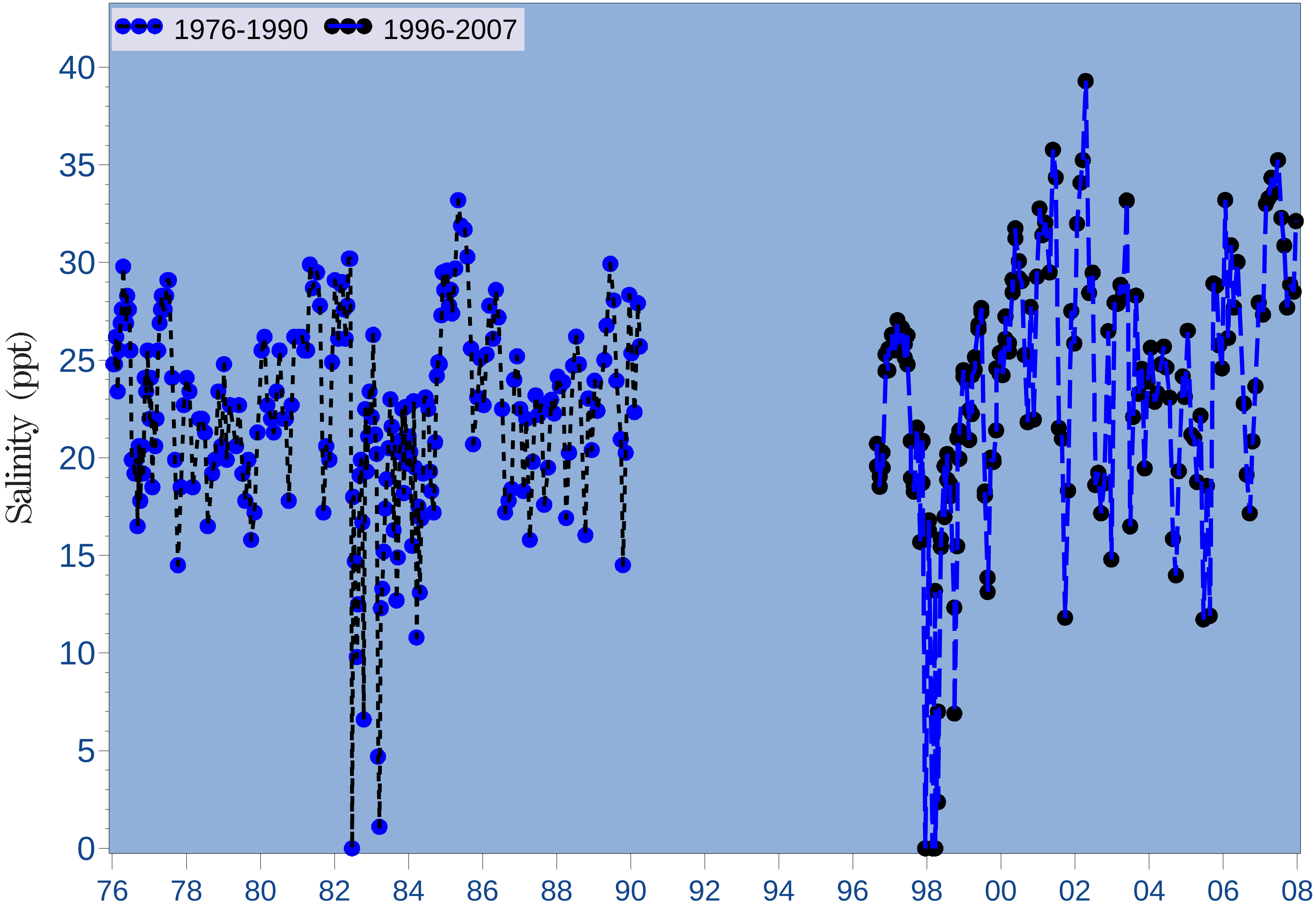

Figure 4.15b Monthly long-term bottom salinity at river kilometer 6.6

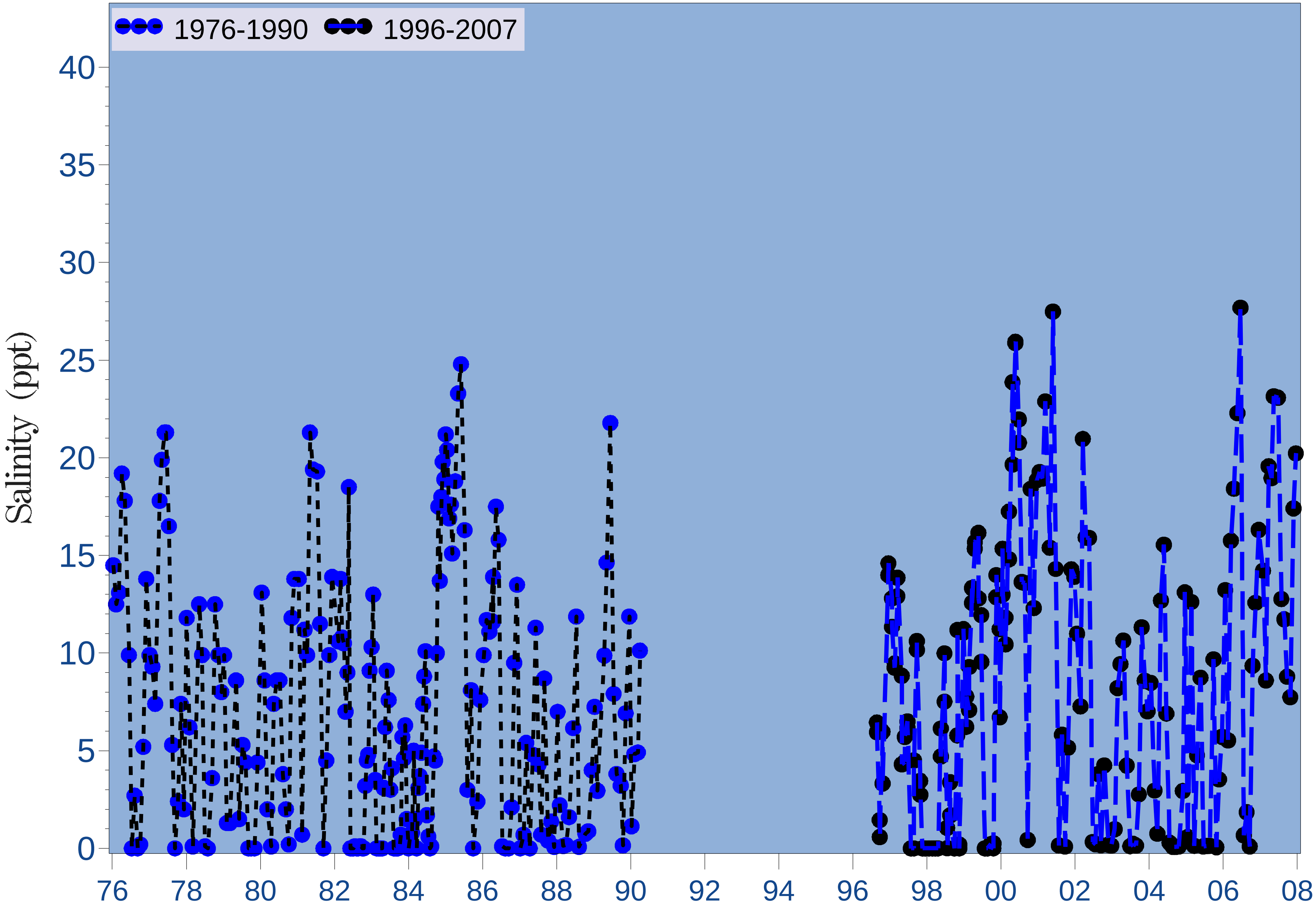

Figure 4.15c Monthly long-term bottom salinity at river kilometer 15.5

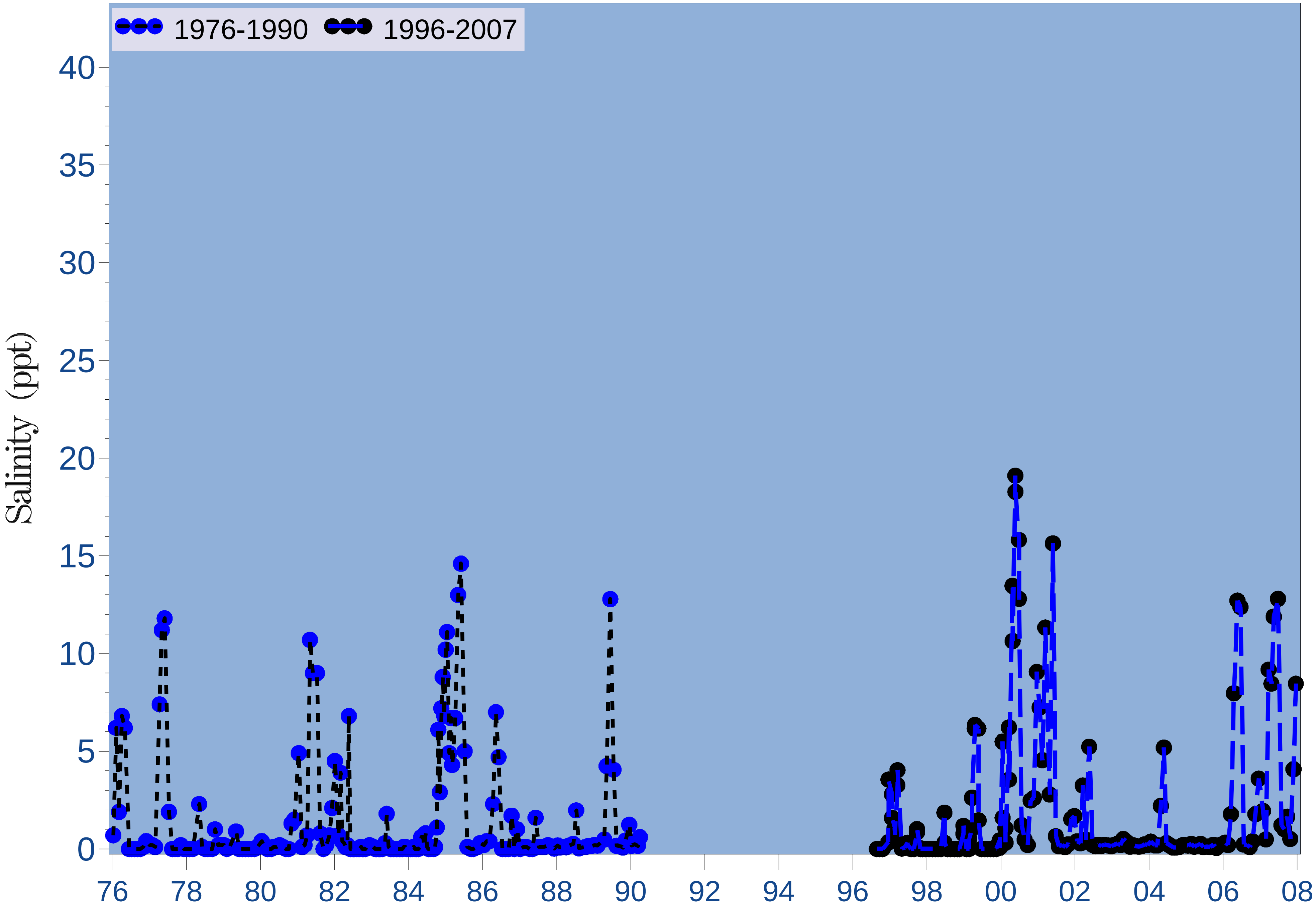

Figure 4.15d Monthly long-term bottom salinity at river kilometer 23.6

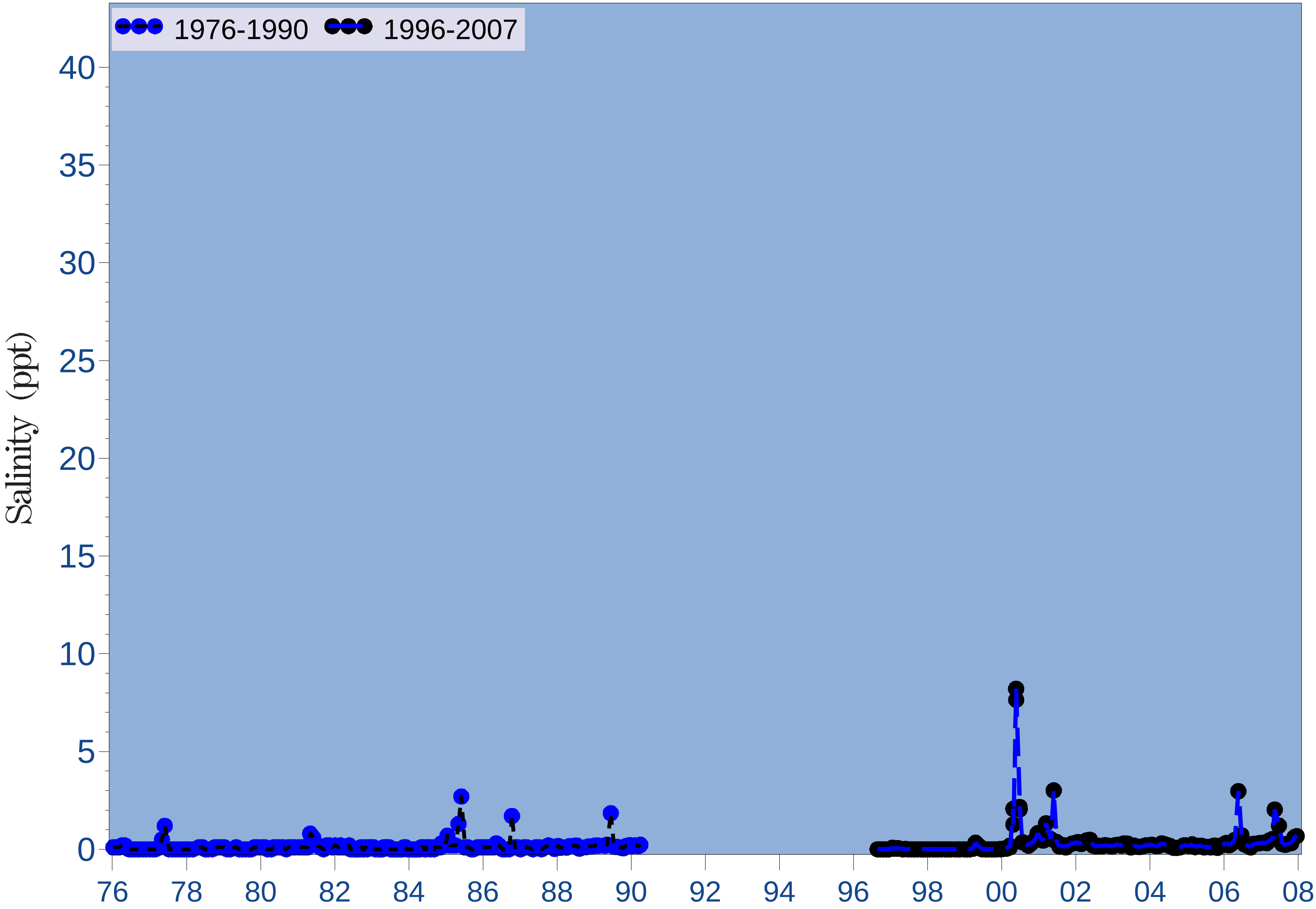

Figure 4.15e Monthly long-term bottom salinity at river kilometer 30.4

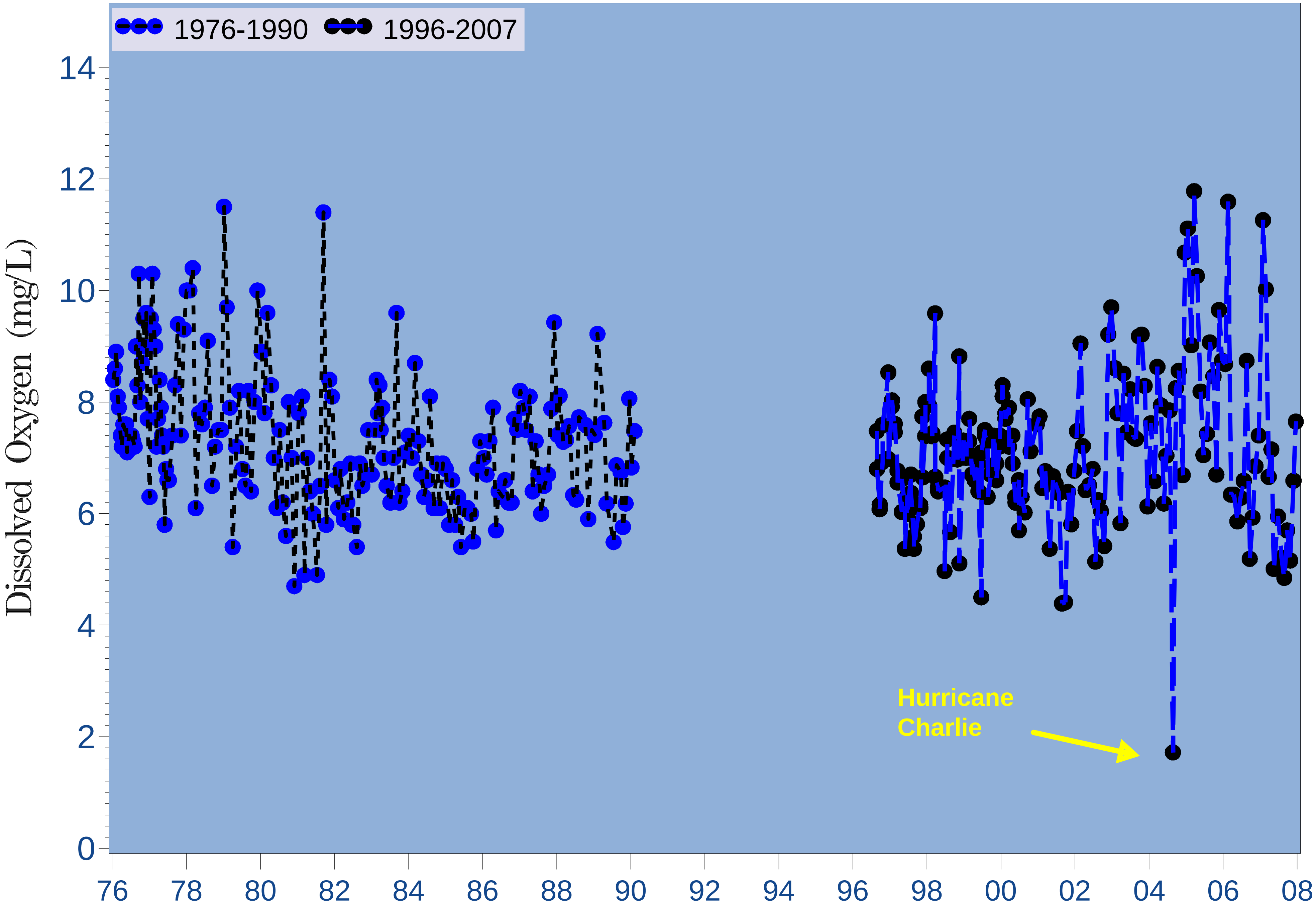

Figure 4.16a Monthly long-term surface dissolved oxygen at river kilometer -2.4

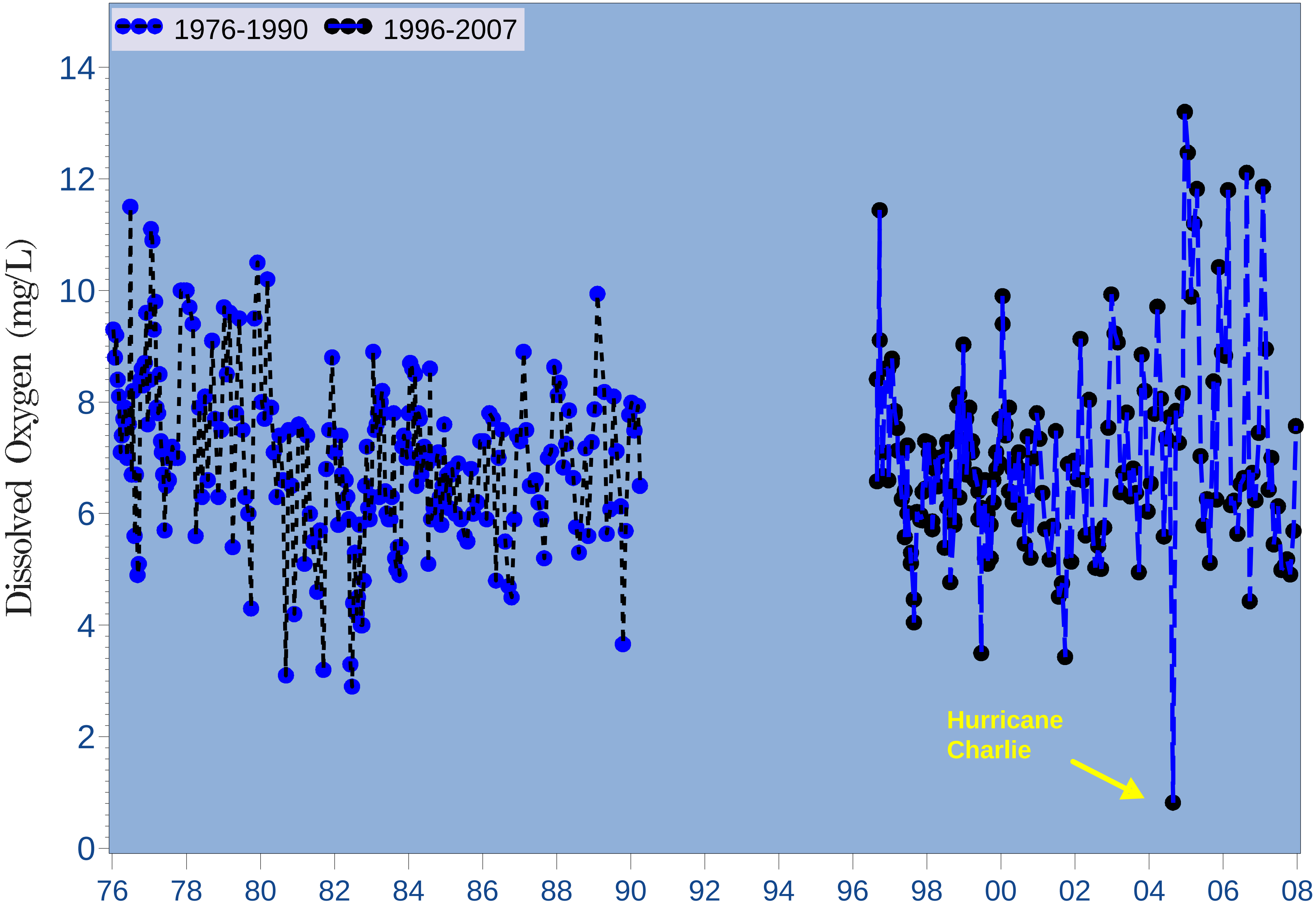

Figure 4.16b Monthly long-term surface dissolved oxygen at river kilometer 6.6

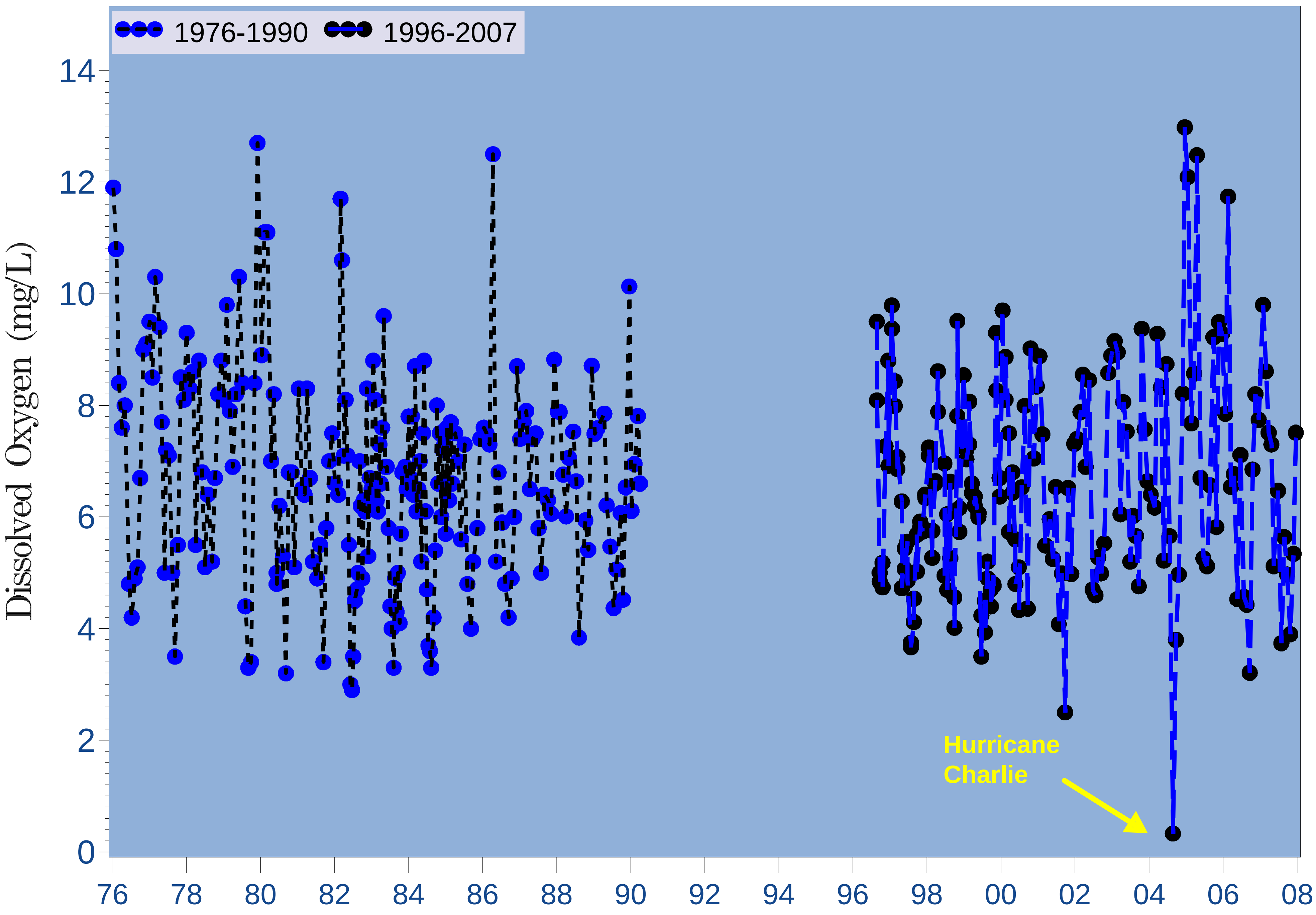

Figure 4.16c Monthly long-term surface dissolved oxygen at river kilometer 15.5

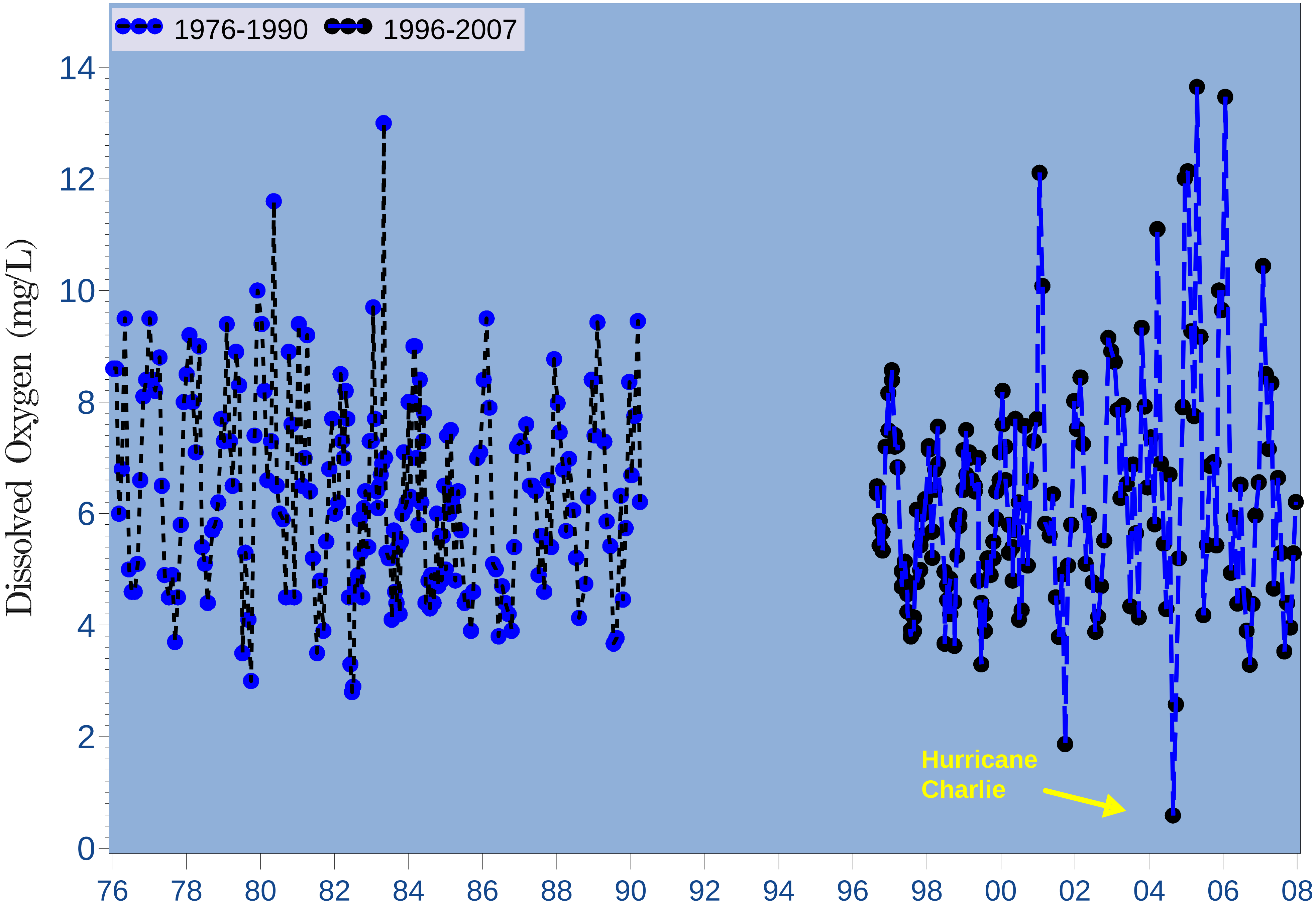

Figure 4.16d Monthly long-term surface dissolved oxygen at river kilometer 23.6

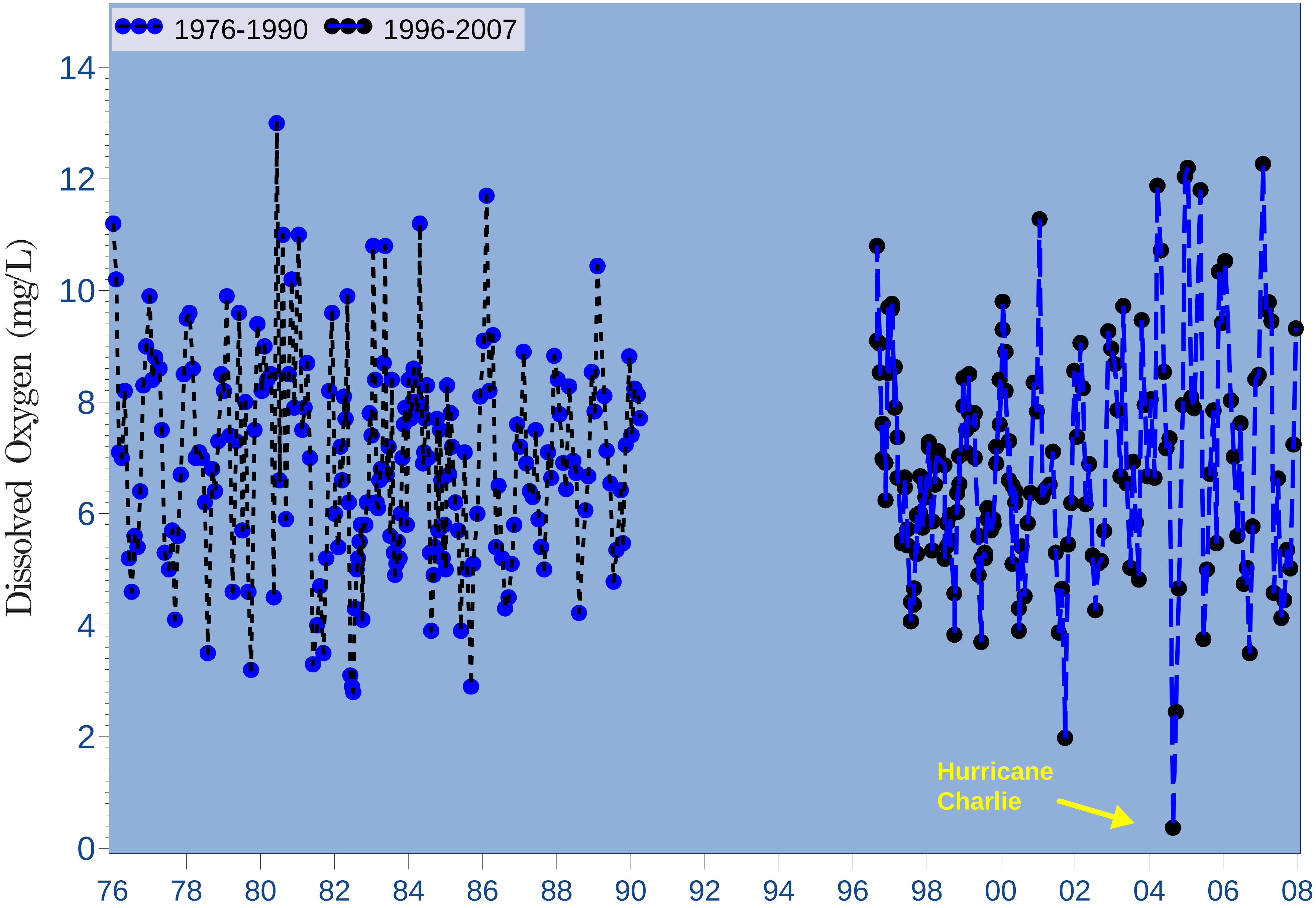

Figure 4.16e Monthly long-term surface dissolved oxygen at river kilometer 30.4

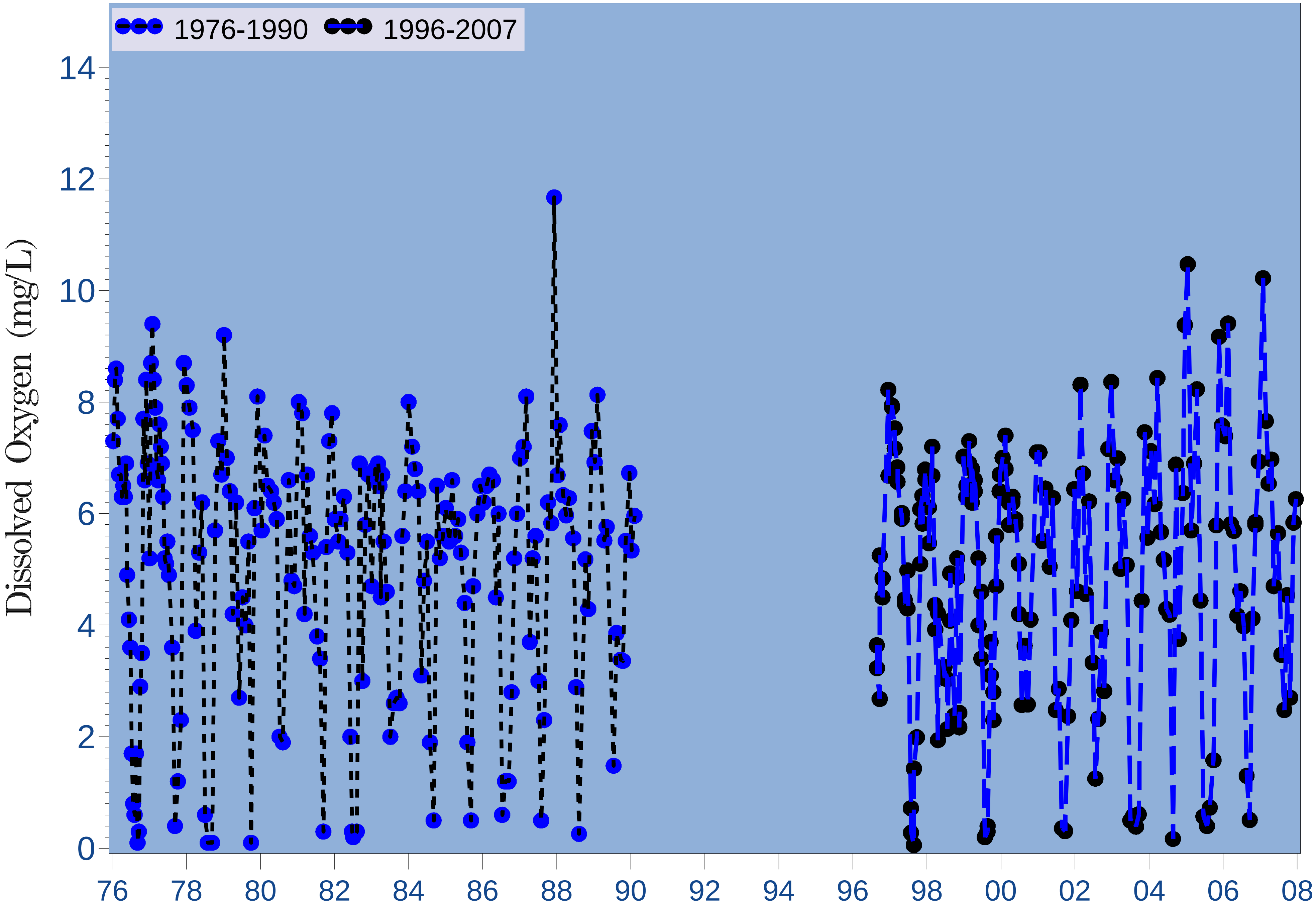

Figure 4.17a Monthly long-term bottom dissolved oxygen at river kilometer -2.4

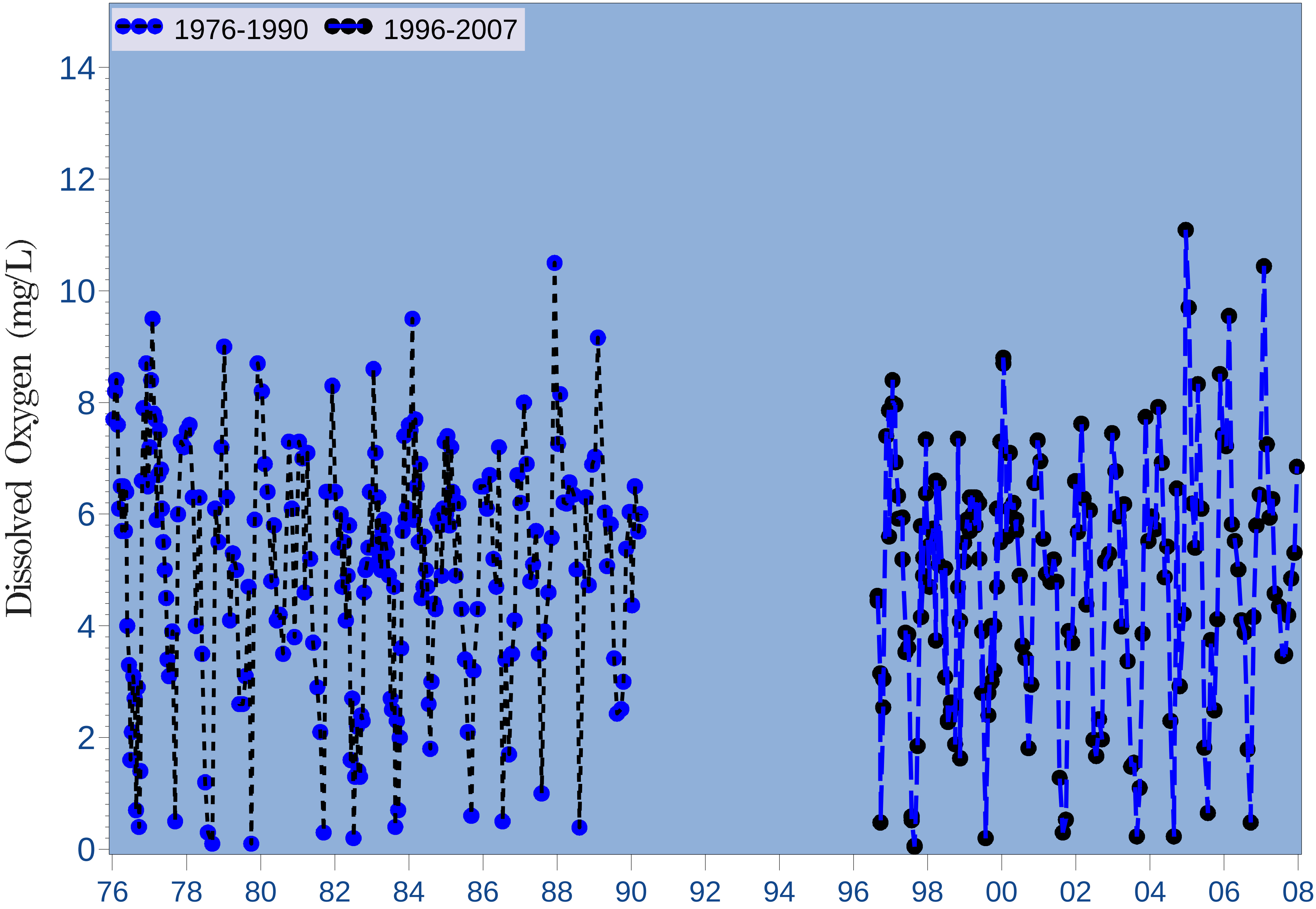

Figure 4.17b Monthly long-term bottom dissolved oxygen at river kilometer 6.6

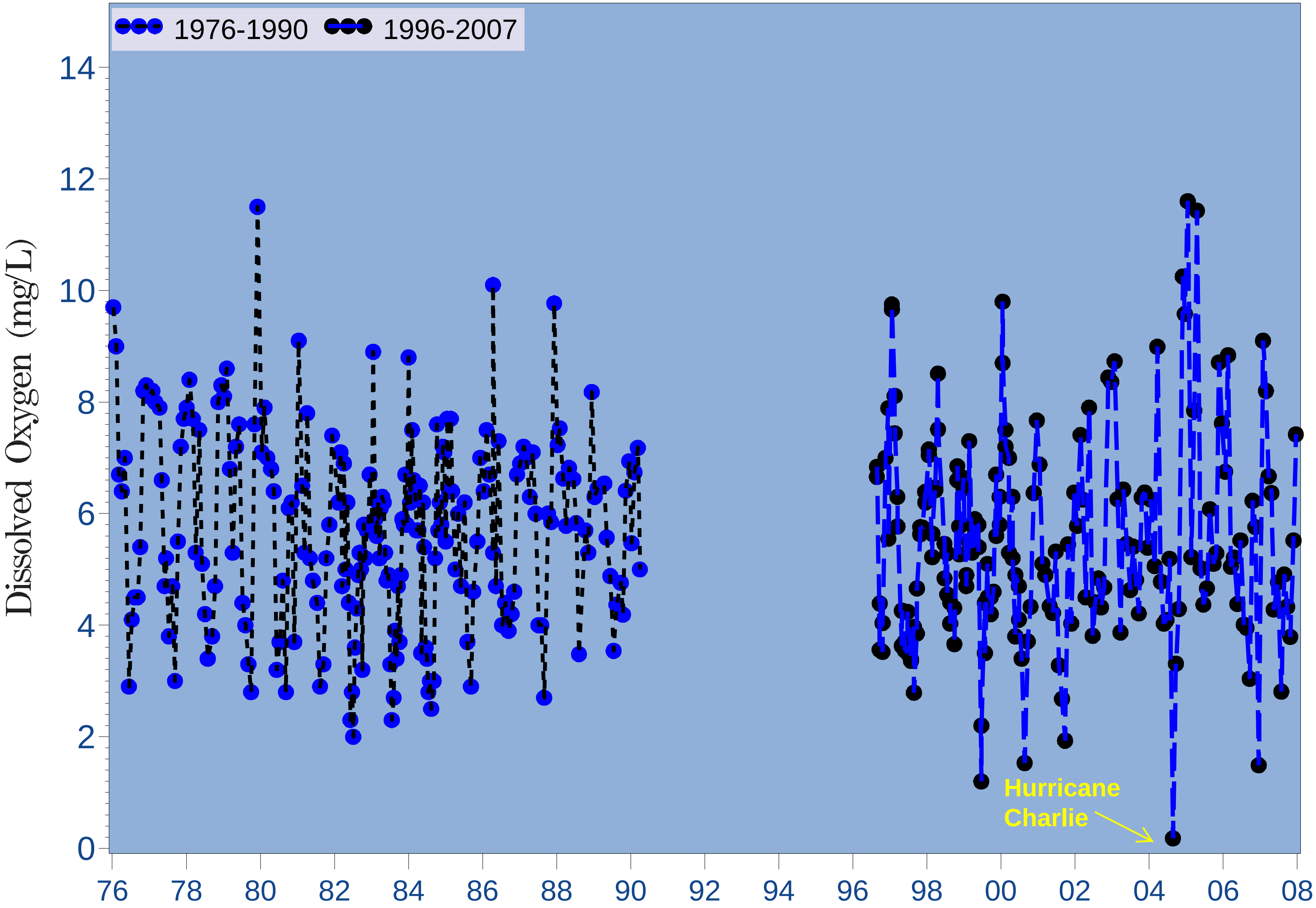

Figure 4.17c Monthly long-term bottom dissolved oxygen at river kilometer 15.5

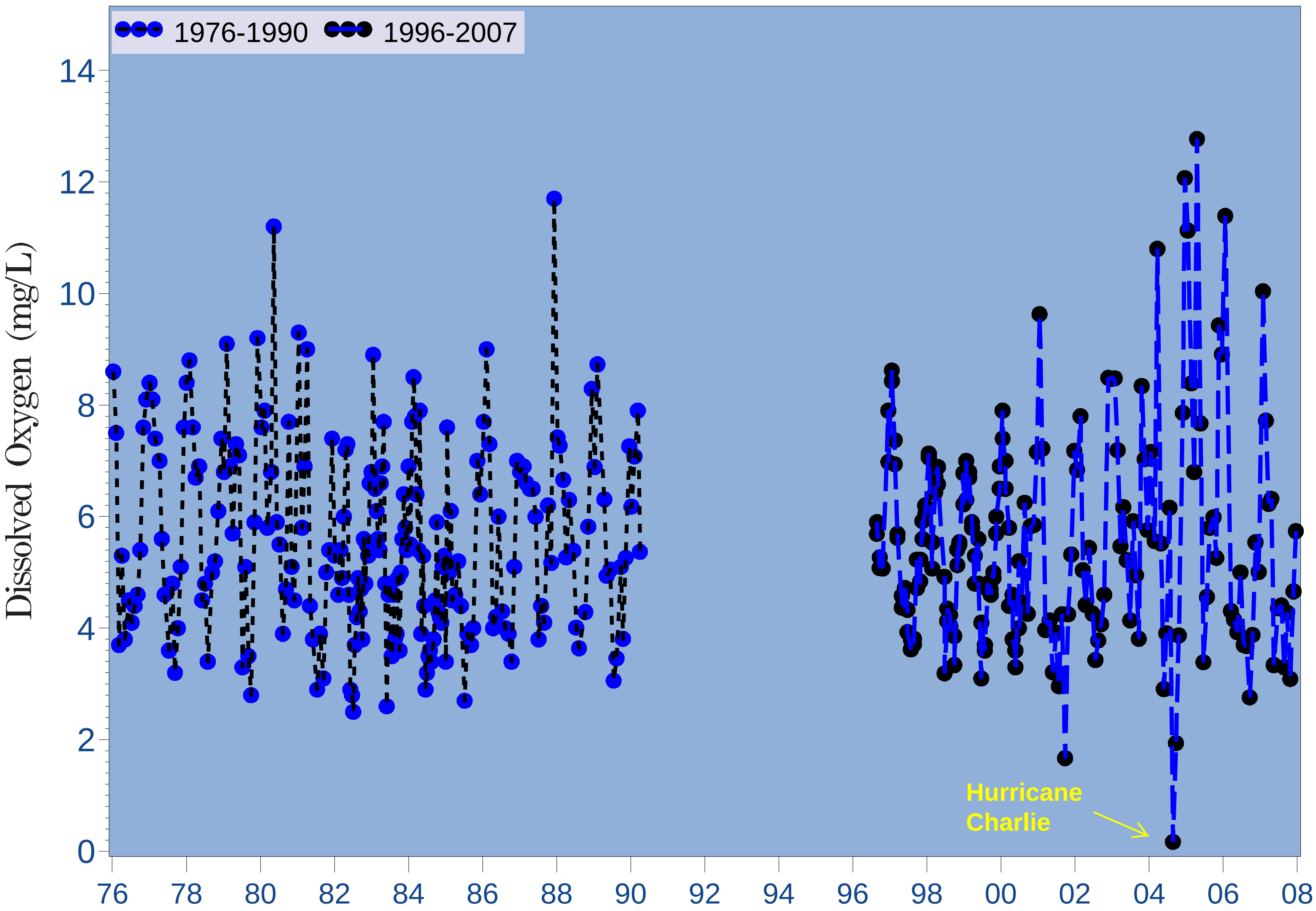

Figure 4.17d Monthly long-term bottom dissolved oxygen at river kilometer 23.6

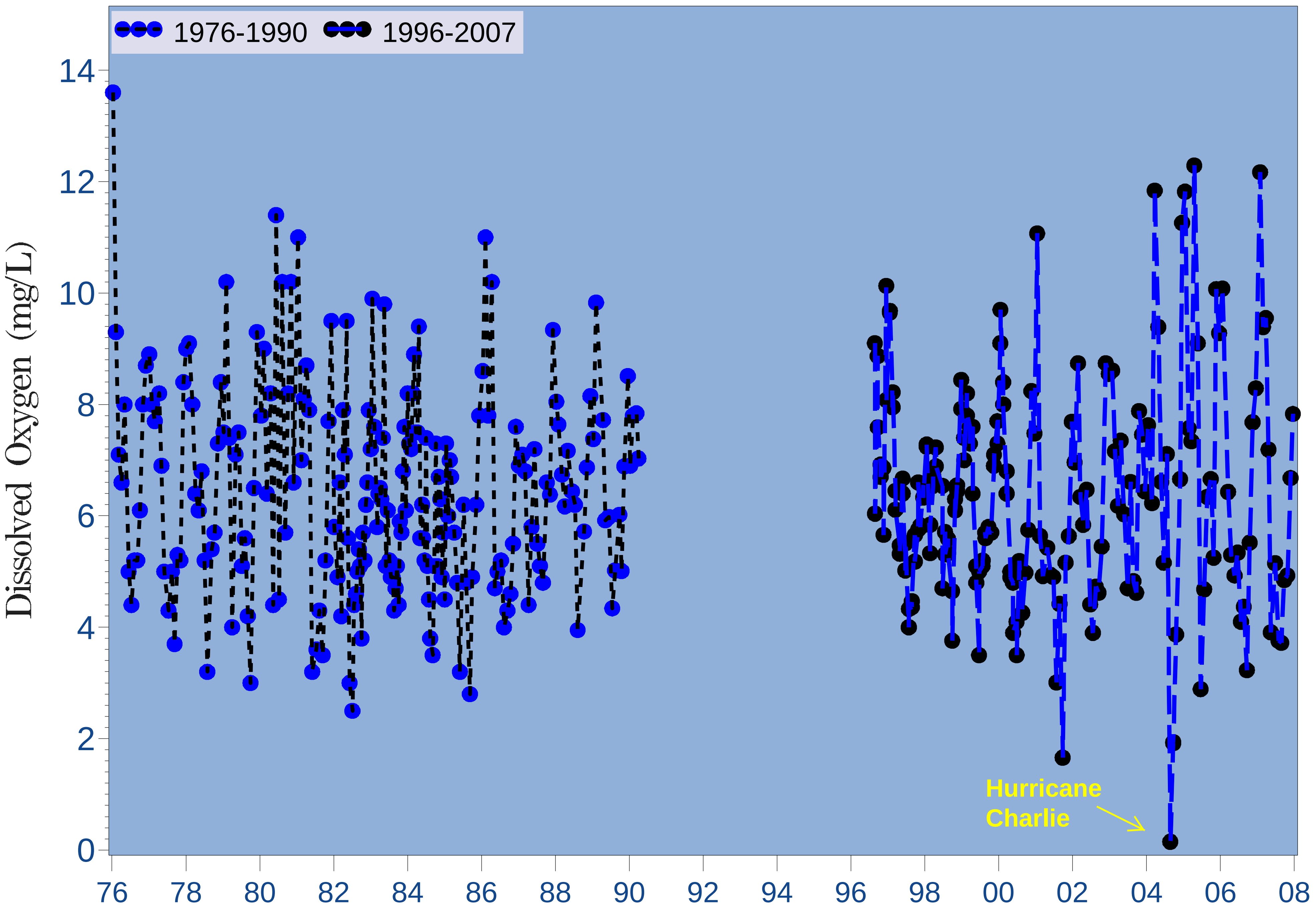

Figure 4.17e Monthly long-term bottom dissolved oxygen at river kilometer 30.4

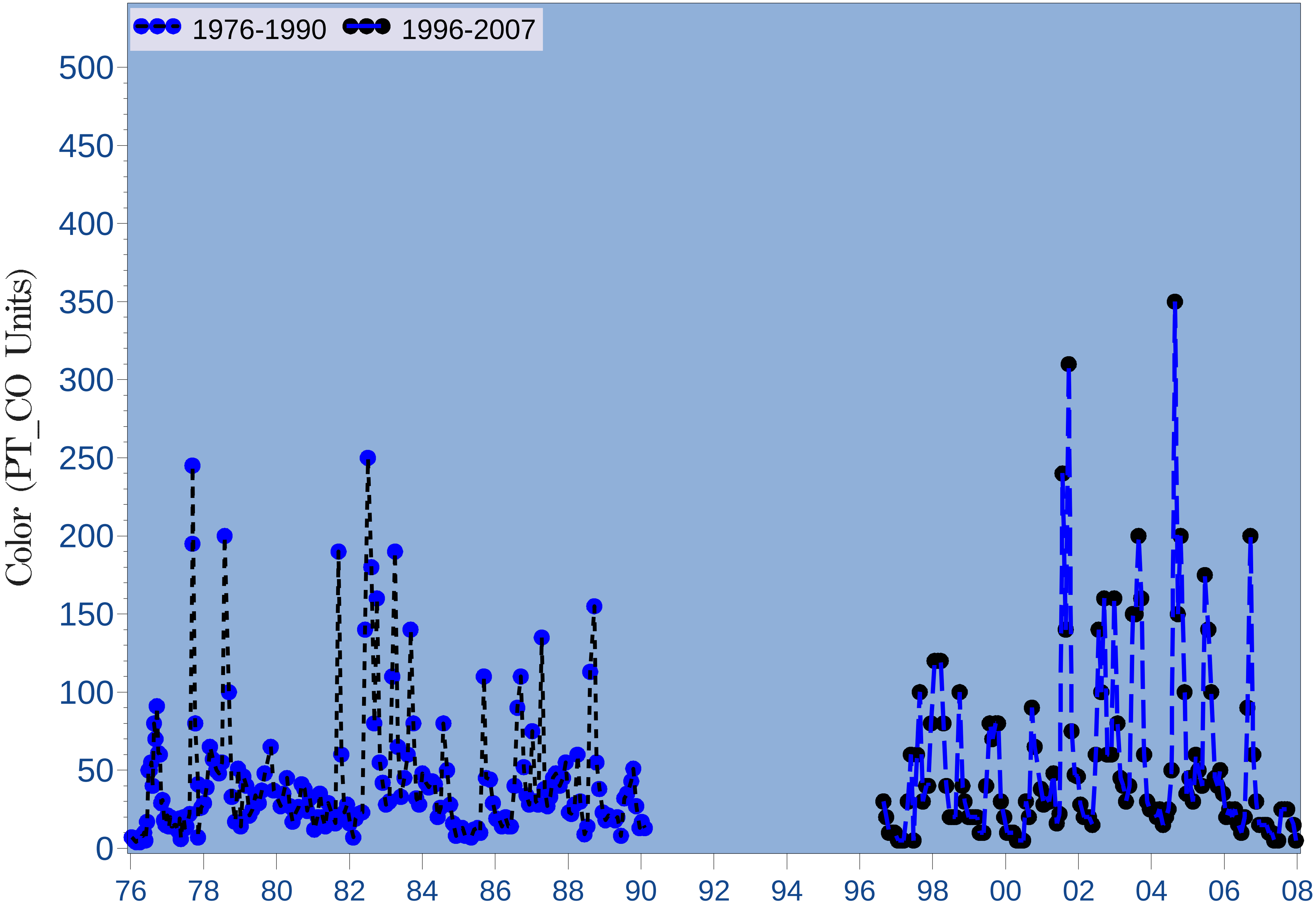

Figure 4.18a Monthly long-term surface color at river kilometer -2.4

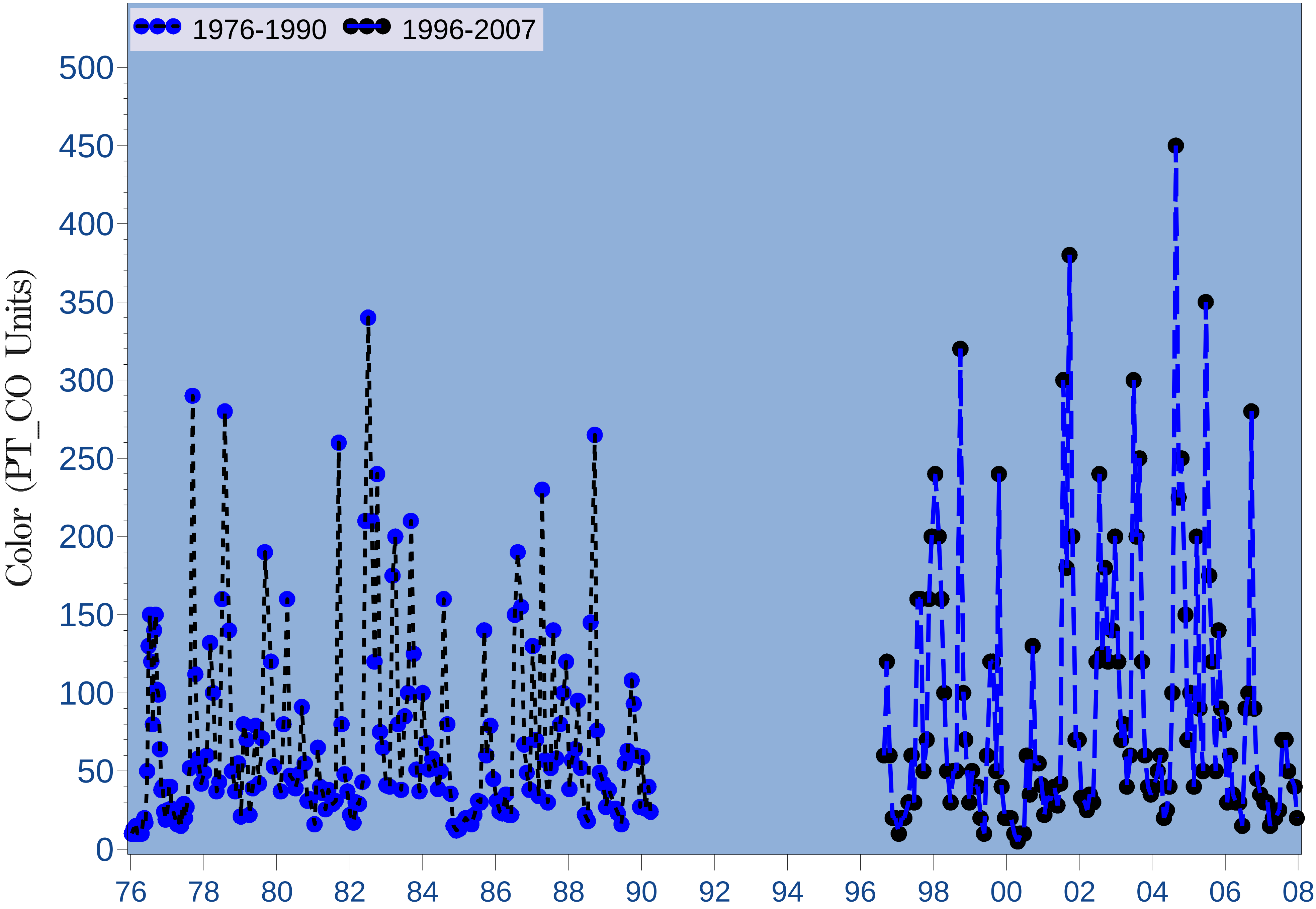

Figure 4.18b Monthly long-term surface color at river kilometer 6.6

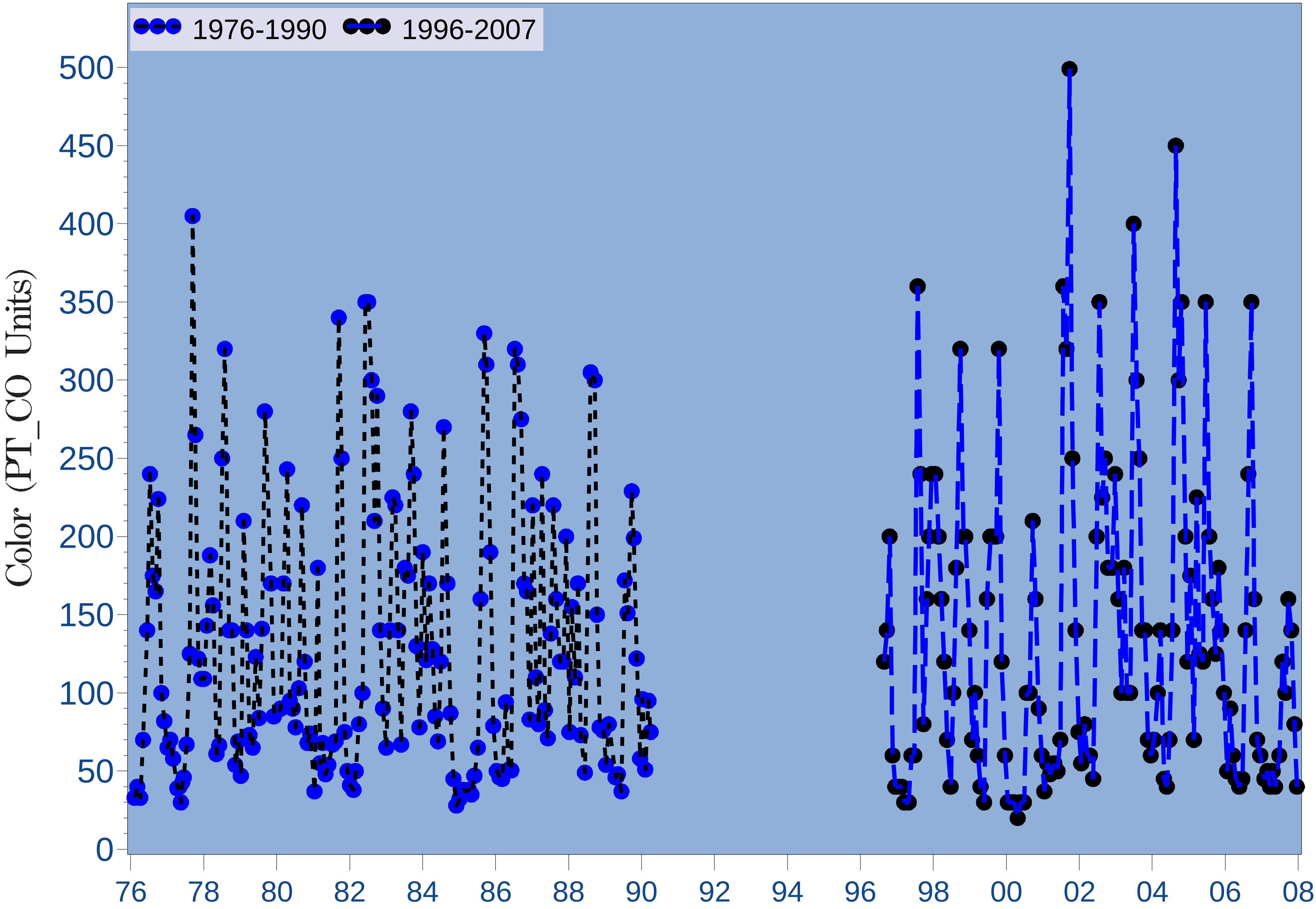

Figure 4.18c Monthly long-term surface color at river kilometer 15.5

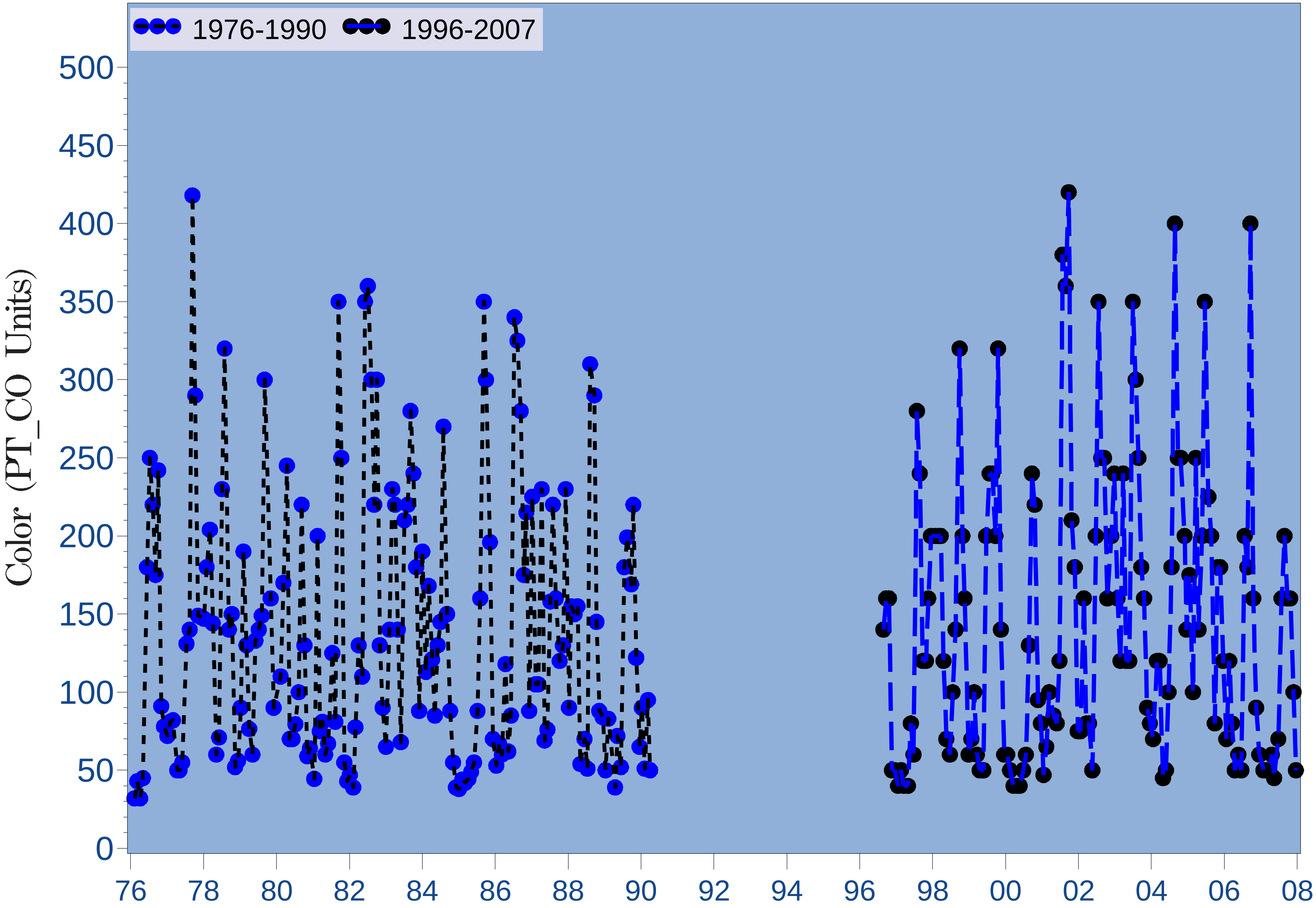

Figure 4.18d Monthly long-term surface color at river kilometer 23.6

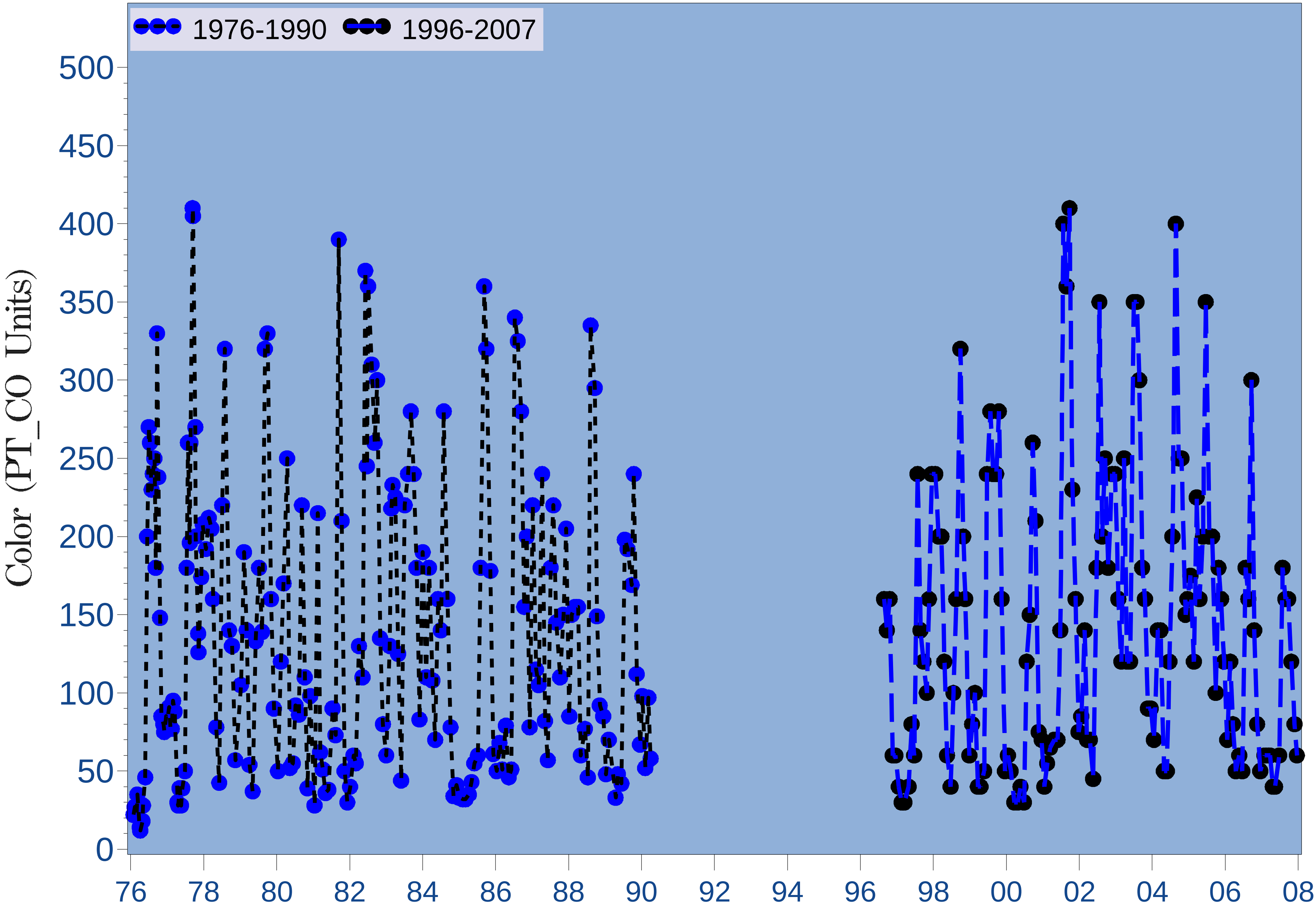

Figure 4.18e Monthly long-term surface color at river kilometer 30.4

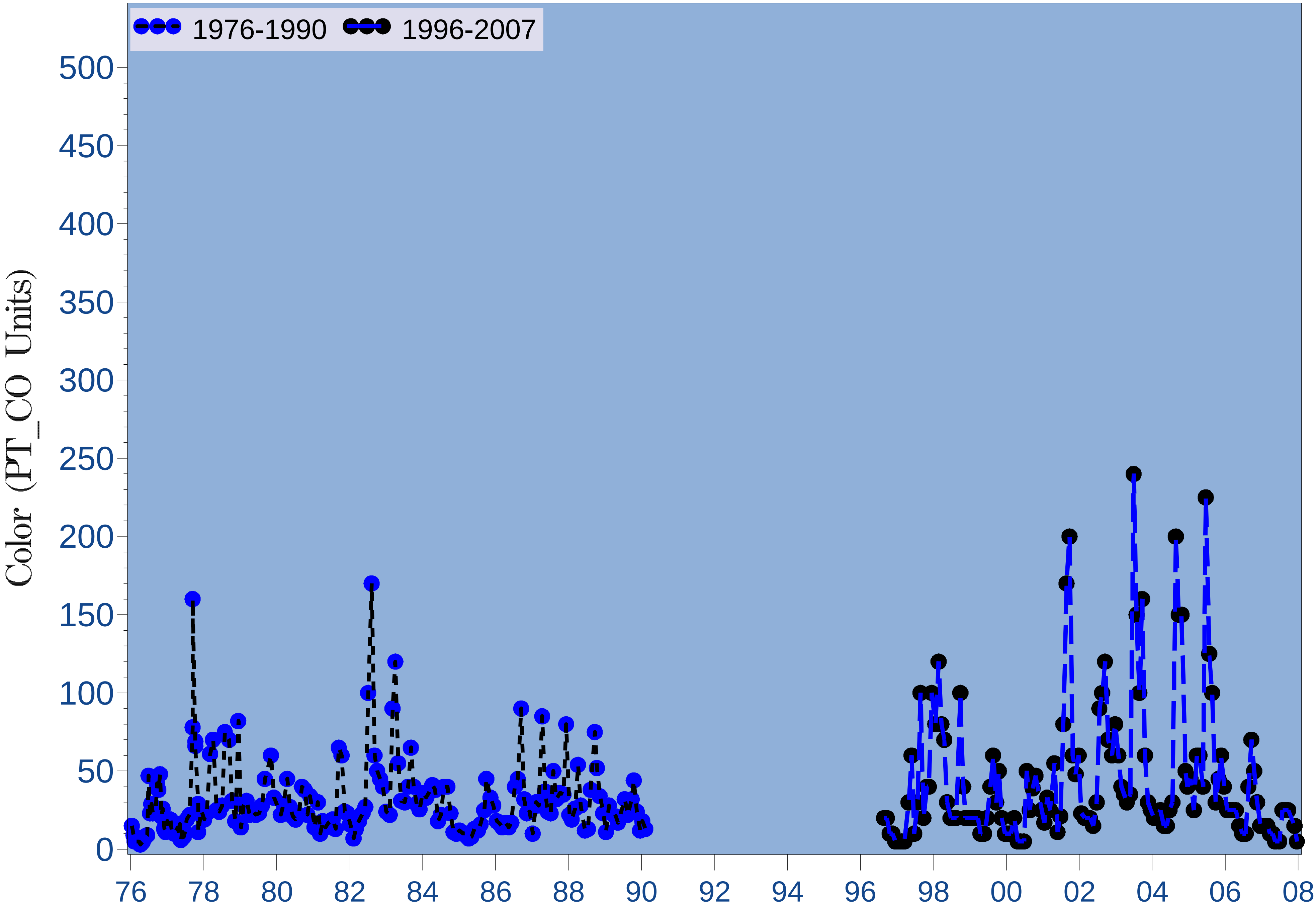

Figure 4.19a Monthly long-term bottom color at river kilometer -2.4

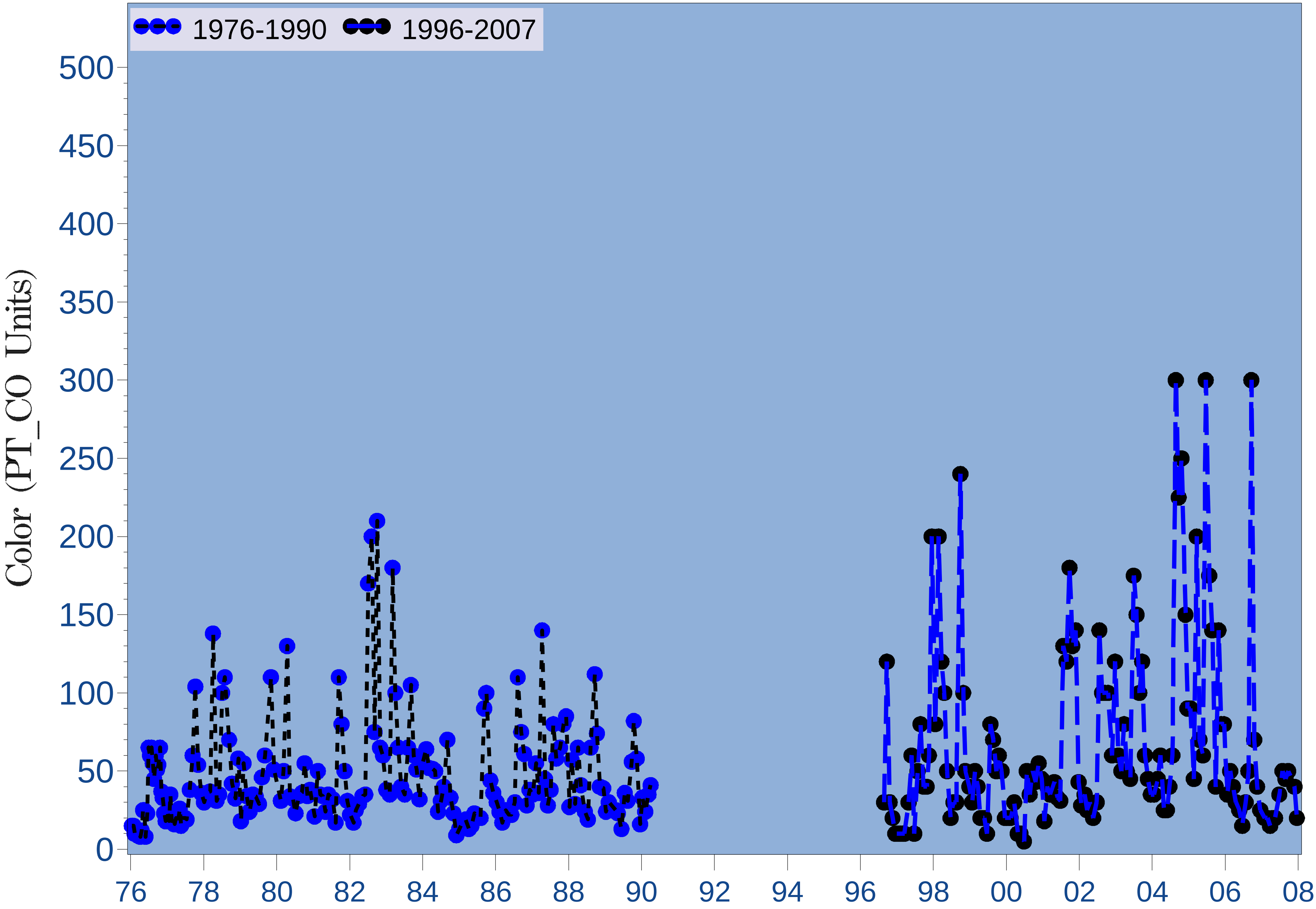

Figure 4.19b Monthly long-term bottom color at river kilometer 6.6

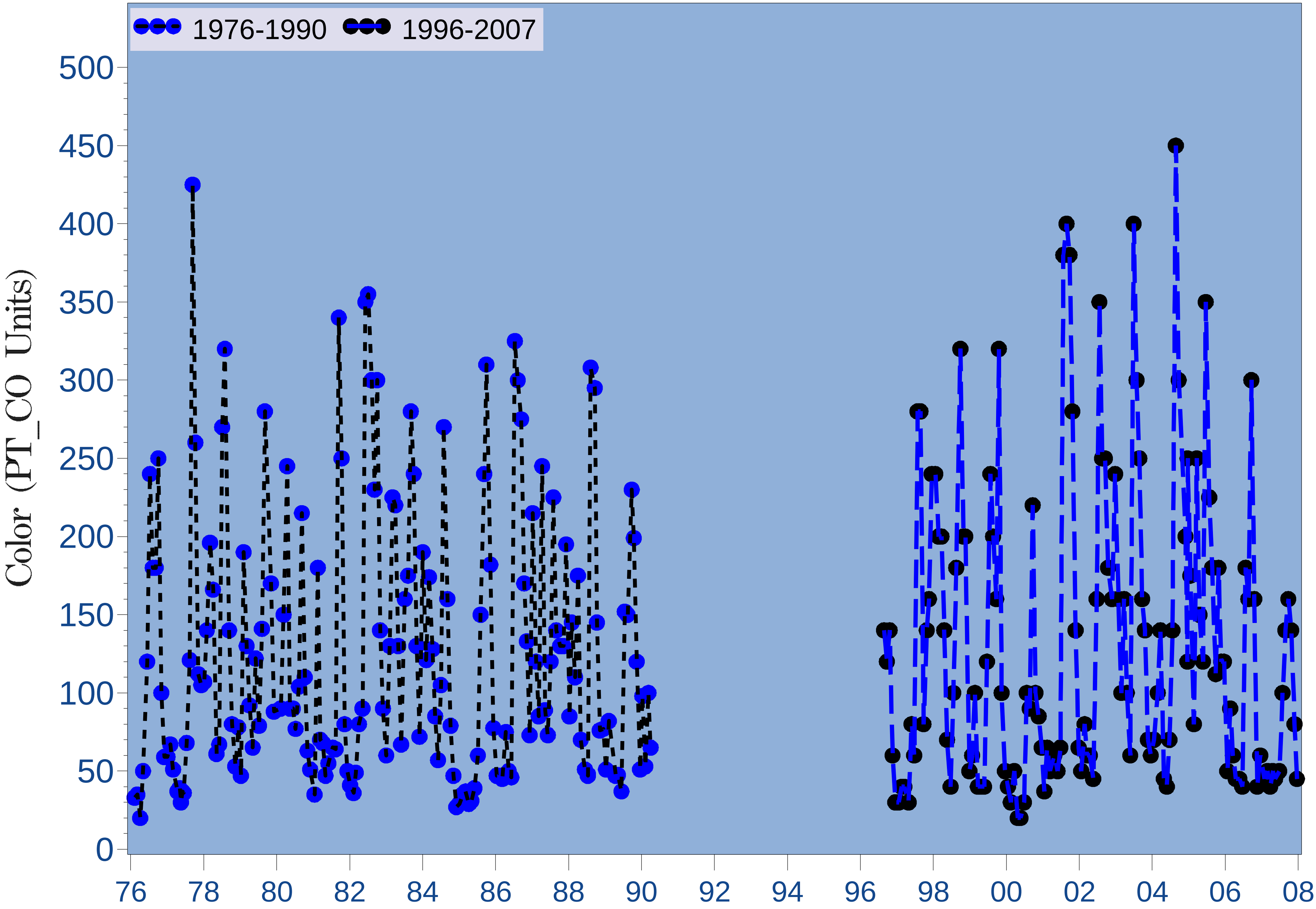

Figure 4.19c Monthly long-term bottom color at river kilometer 15.5

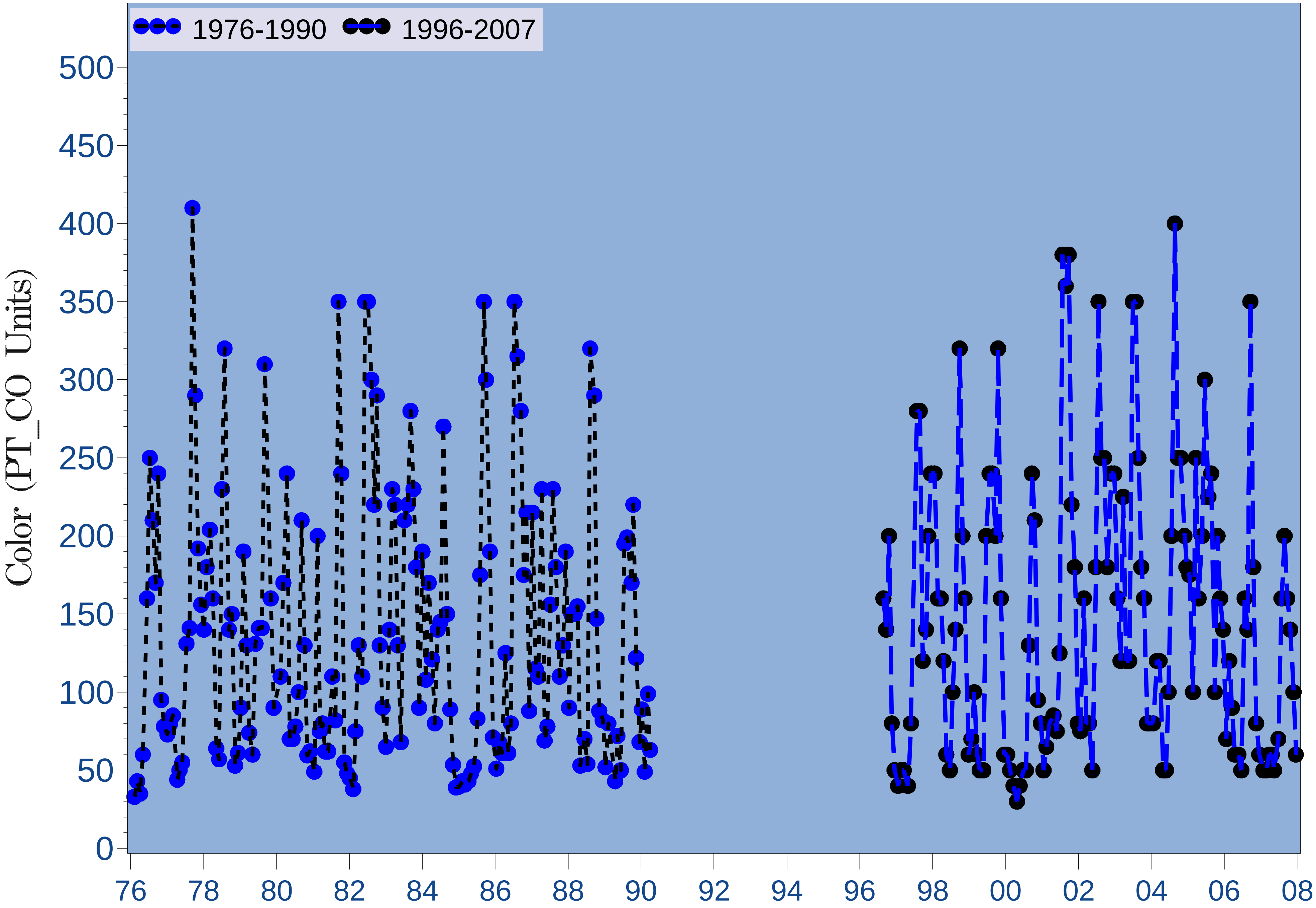

Figure 4.19d Monthly long-term bottom color at river kilometer 23.6

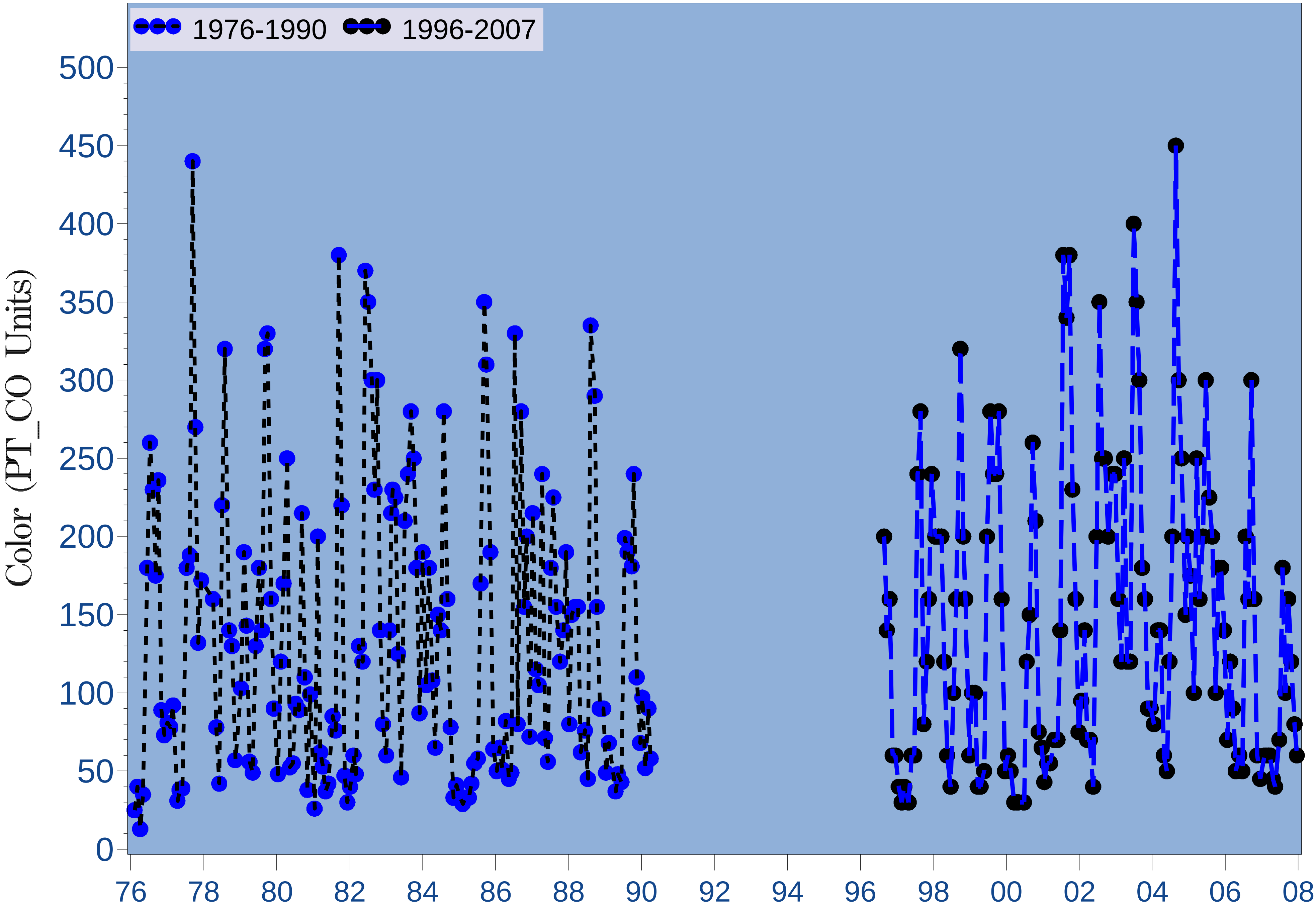

Figure 4.19e Monthly long-term bottom color at river kilometer 30.4

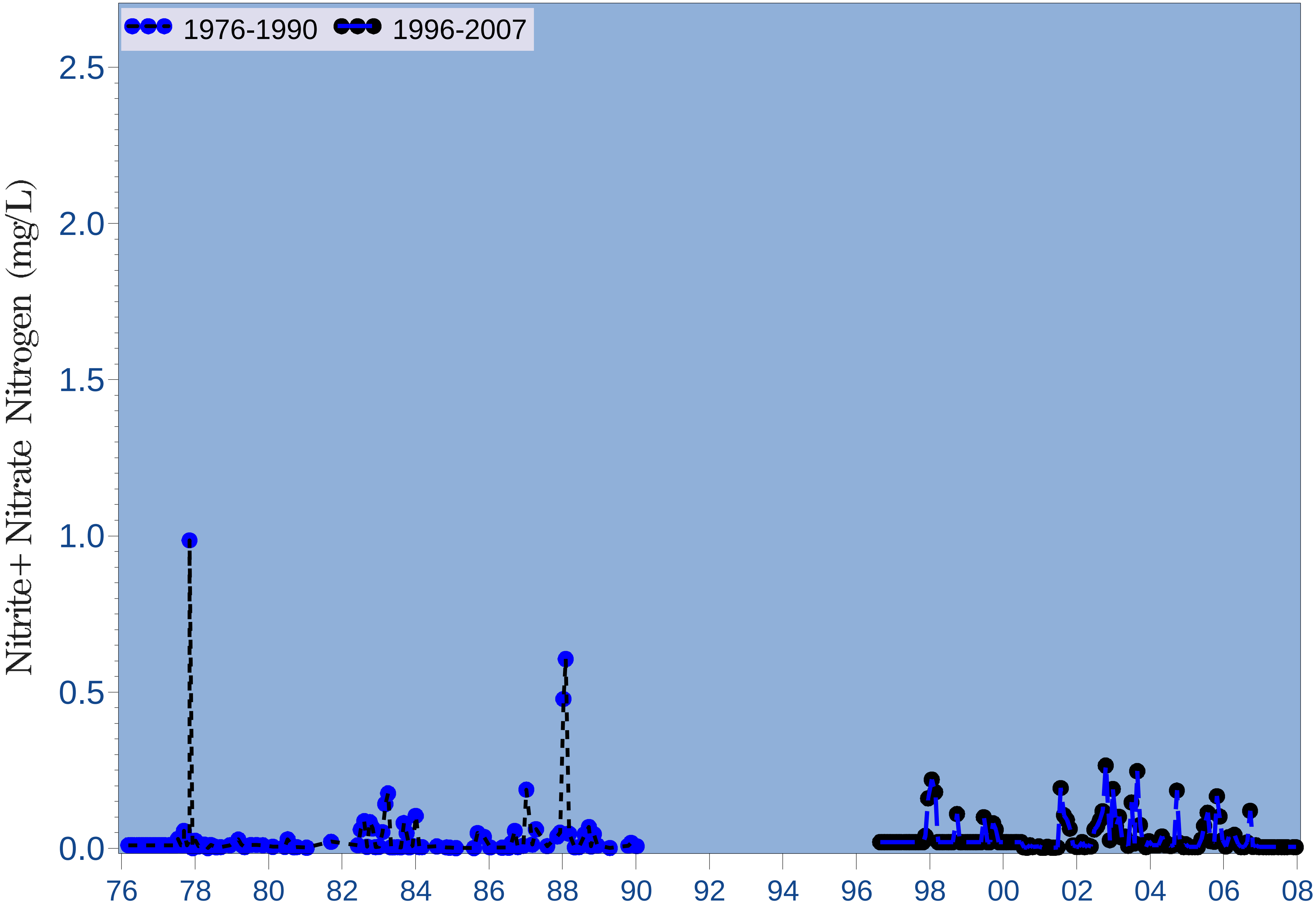

Figure 4.20a Monthly long-term surface nitrite/nitrate nitrogen at river kilometer -2.4

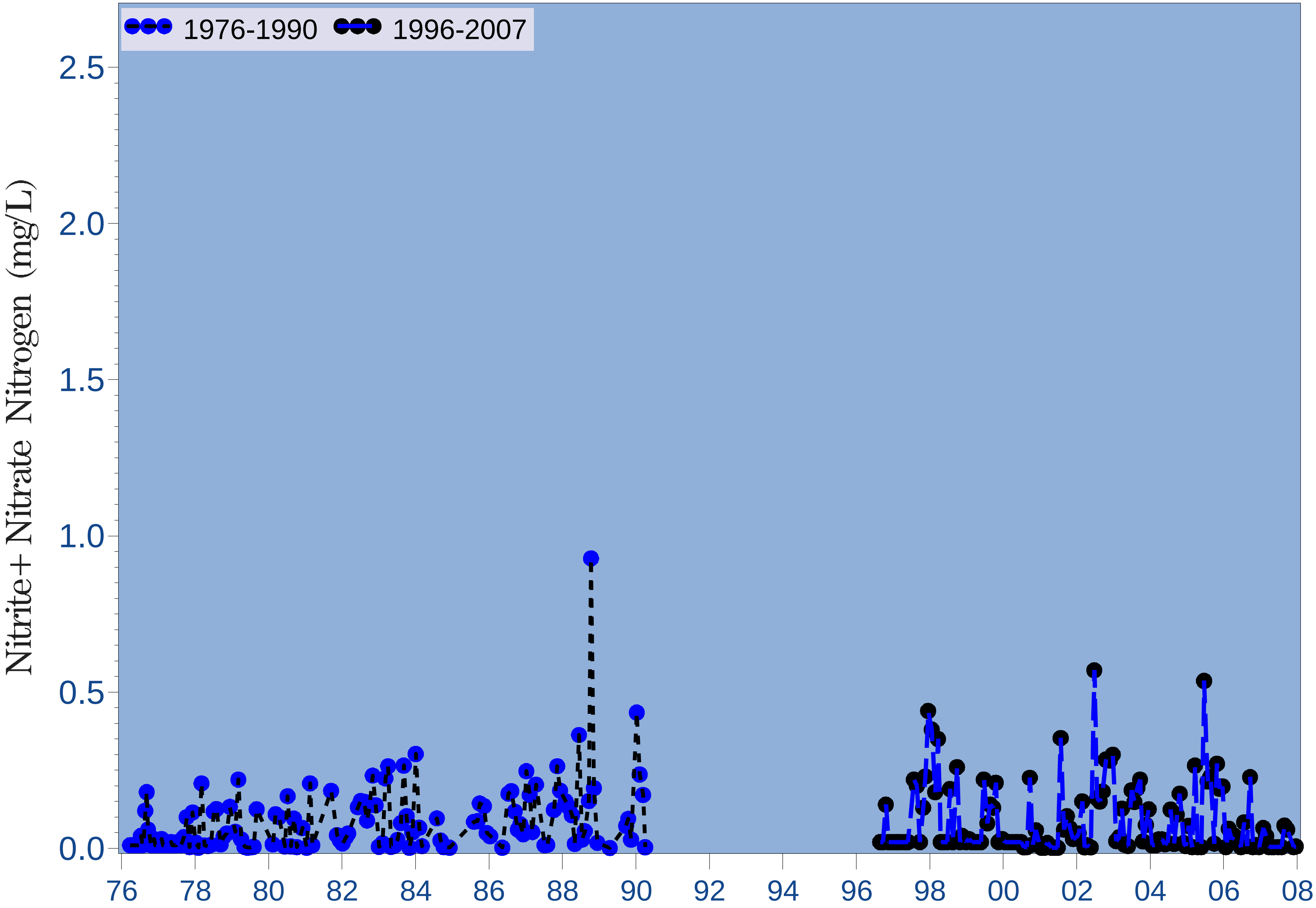

Figure 4.20b Monthly long-term surface nitrite/nitrate nitrogen at river kilometer 6.6

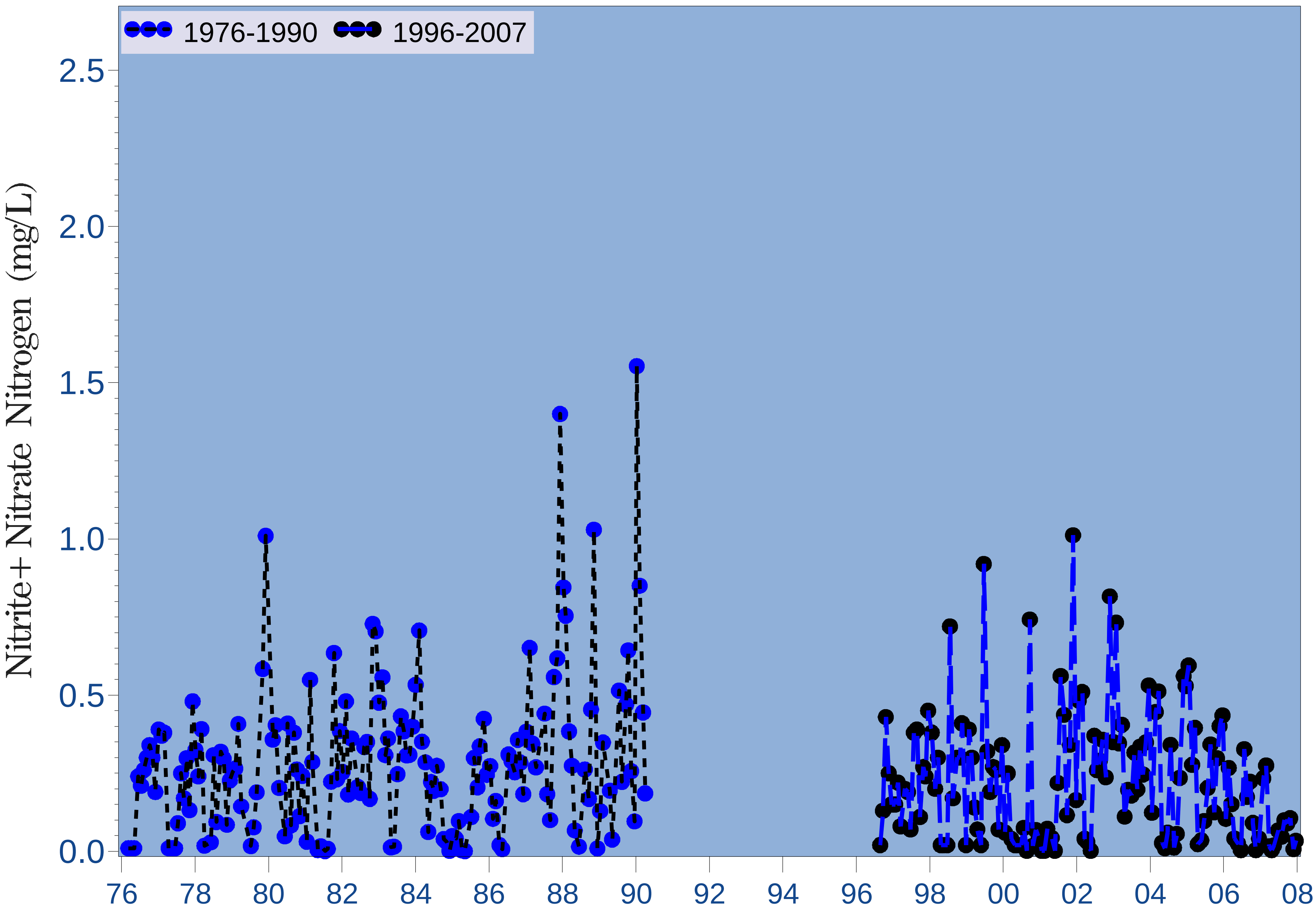

Figure 4.20c Monthly long-term surface nitrite/nitrate nitrogen at river kilometer 15.5

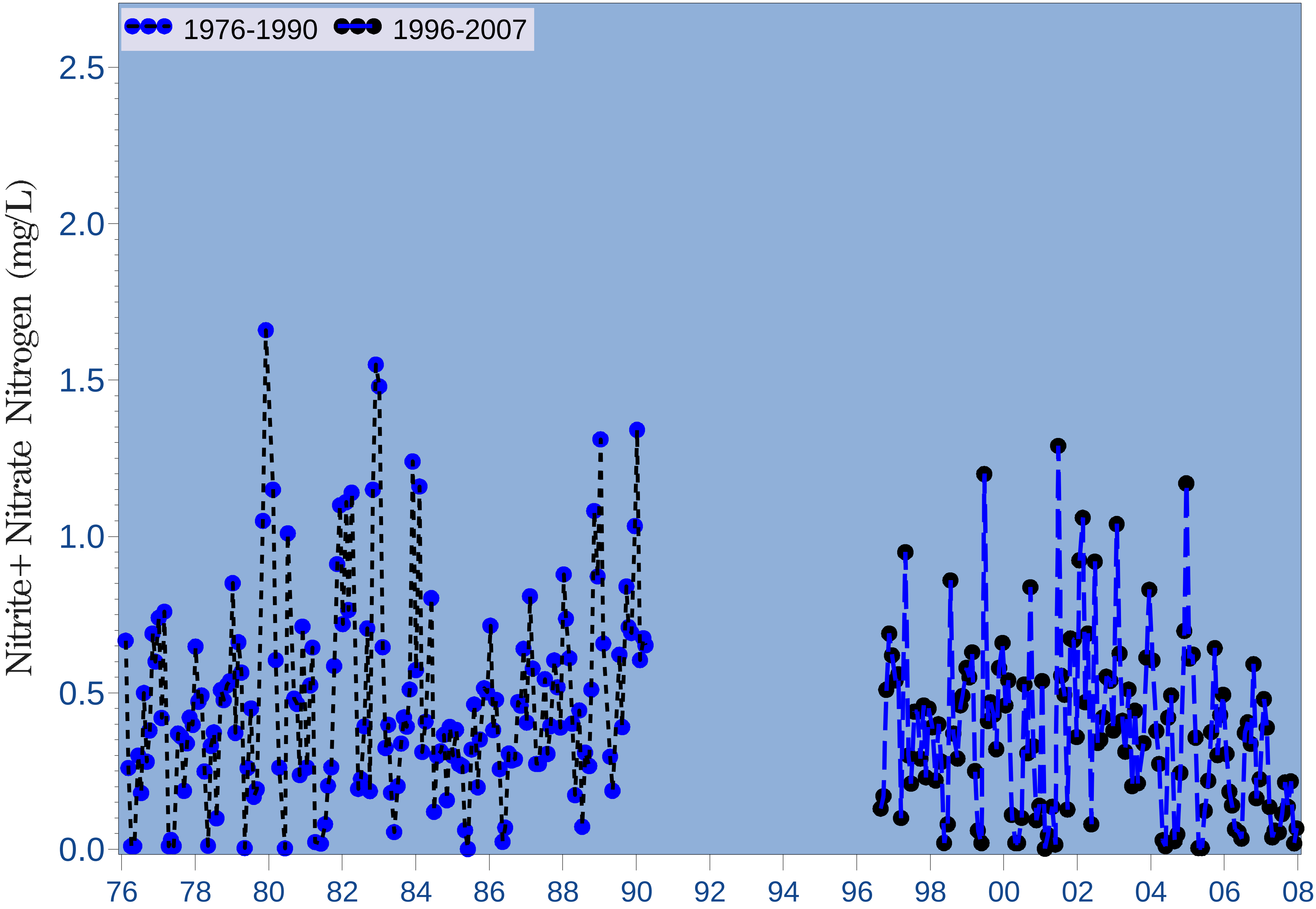

Figure 4.20d Monthly long-term surface nitrite/nitrate nitrogen at river kilometer 23.6

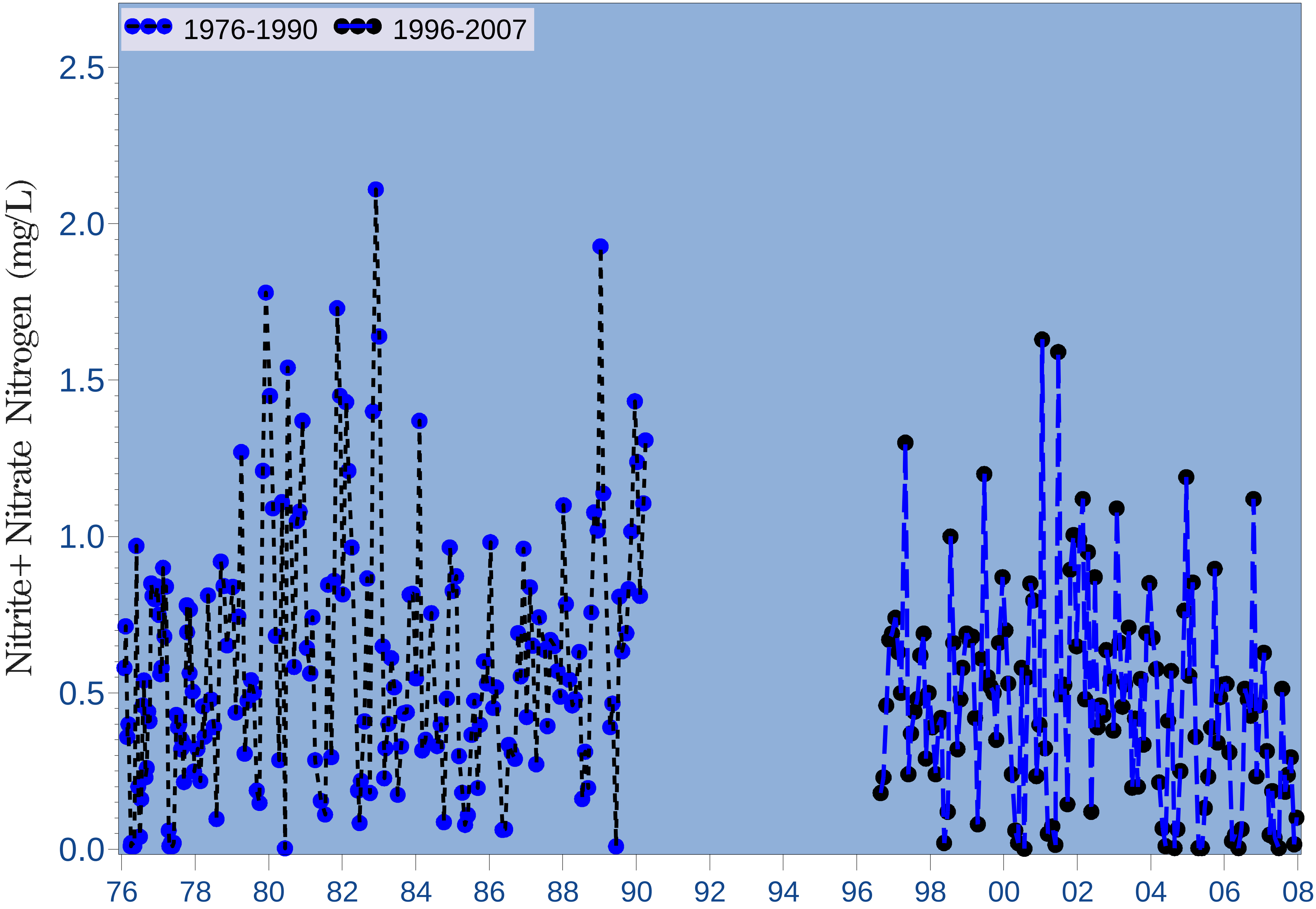

Figure 4.20e Monthly long-term surface nitrite/nitrate nitrogen at river kilometer 30.4

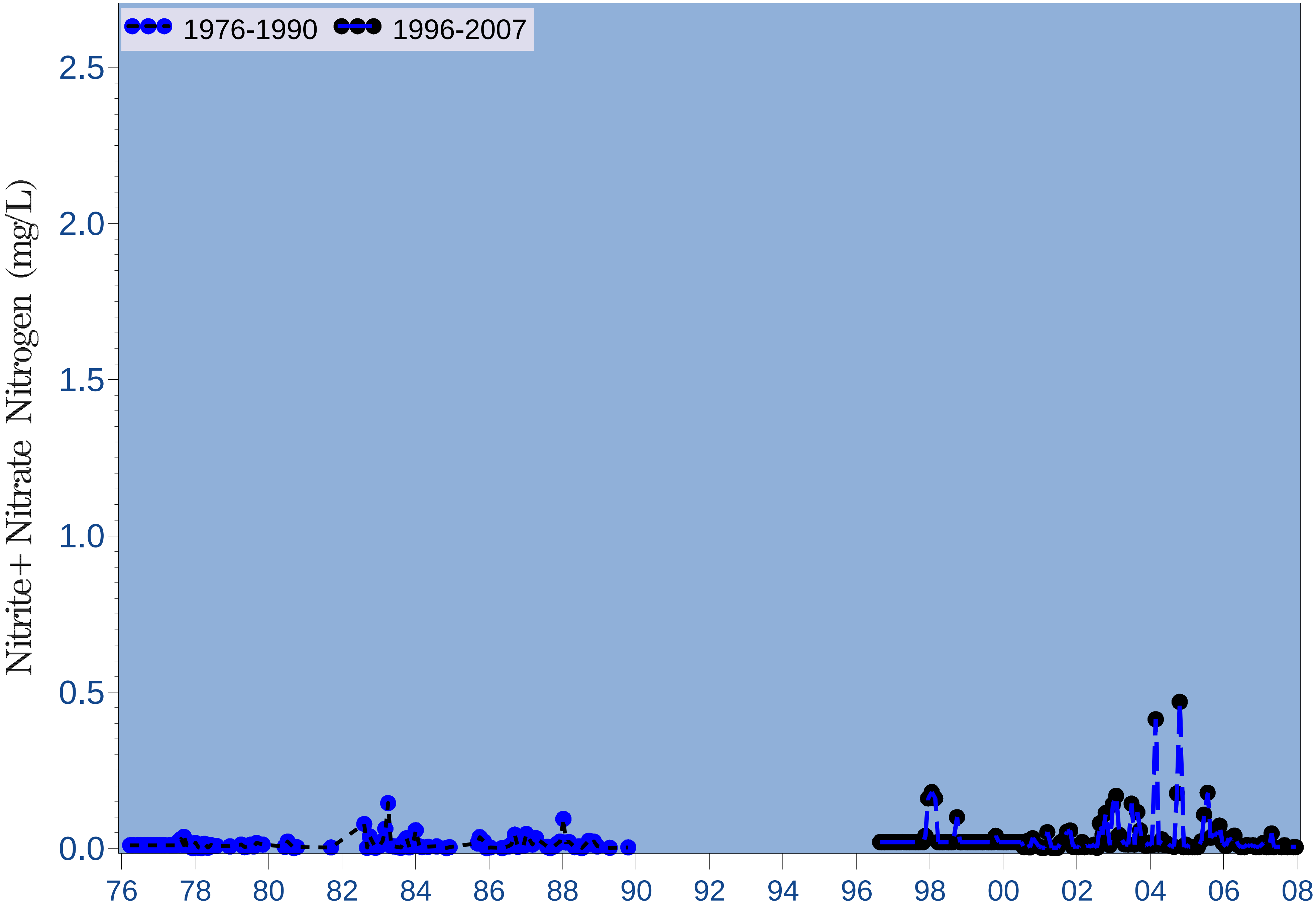

Figure 4.21a Monthly long-term bottom nitrate/nitrite nitrogen at river kilometer -2.4

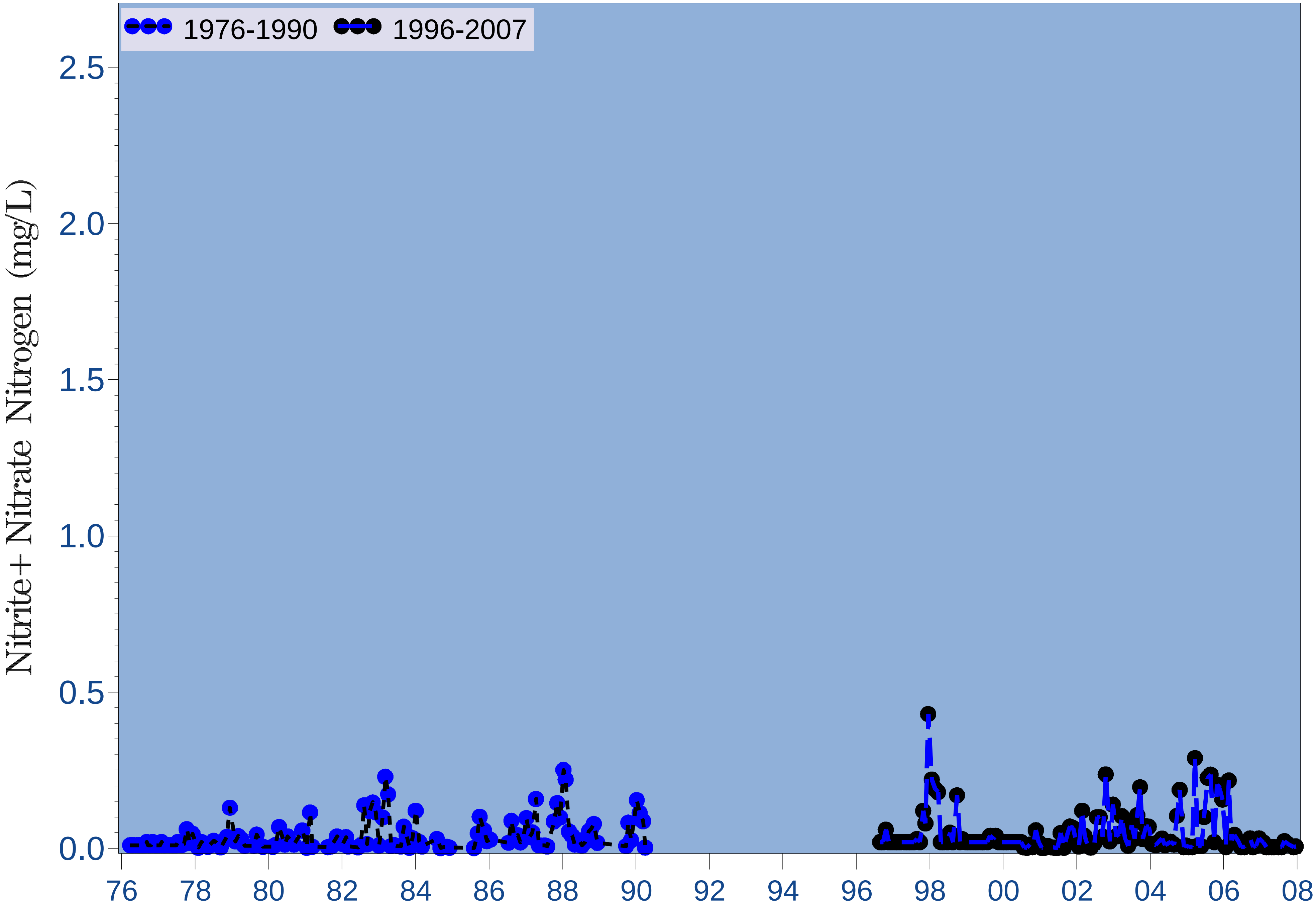

Figure 4.21b Monthly long-term bottom nitrate/nitrite nitrogen at river kilometer 6.6

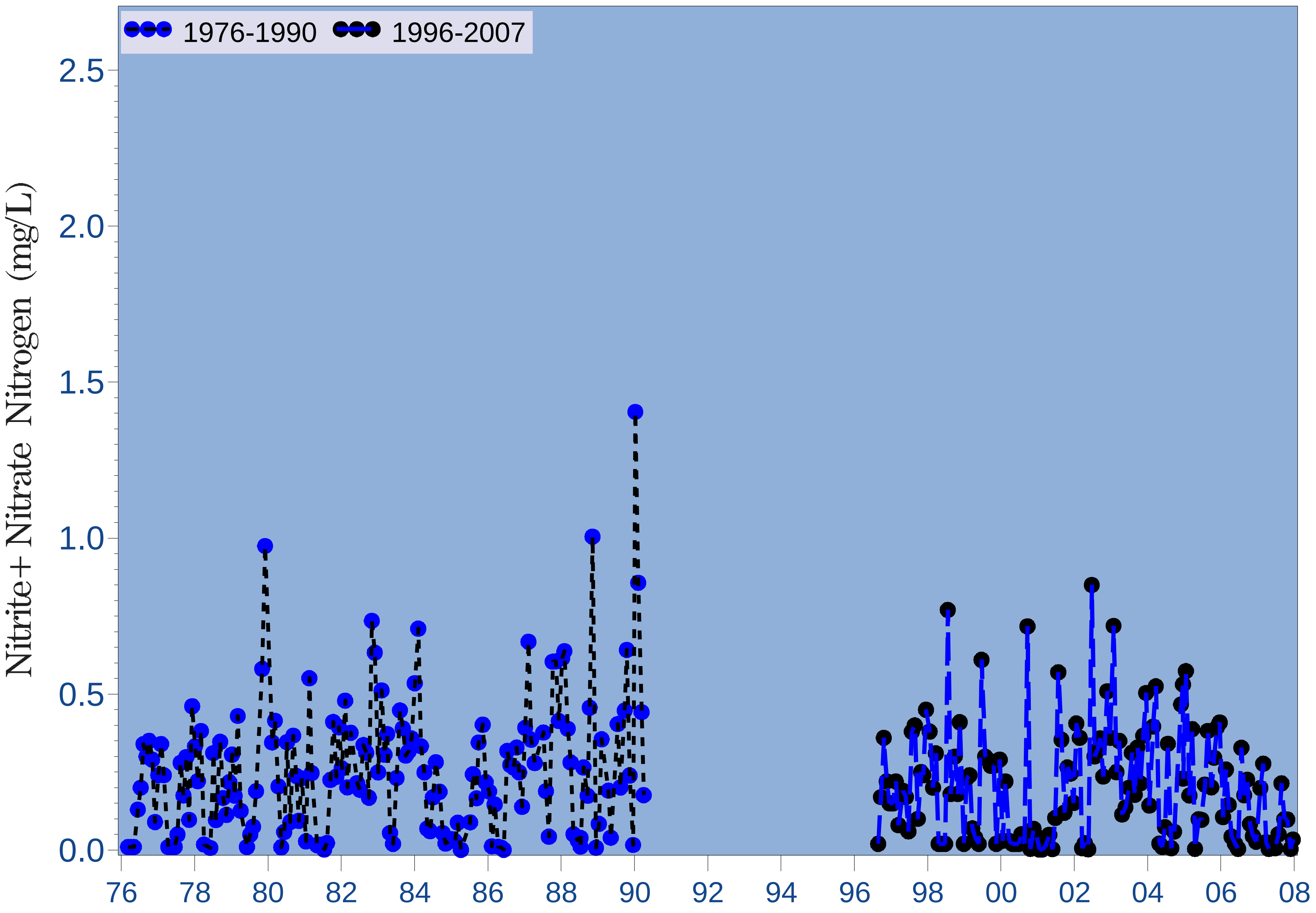

Figure 4.21c Monthly long-term bottom nitrate/nitrite nitrogen at river kilometer 15.5

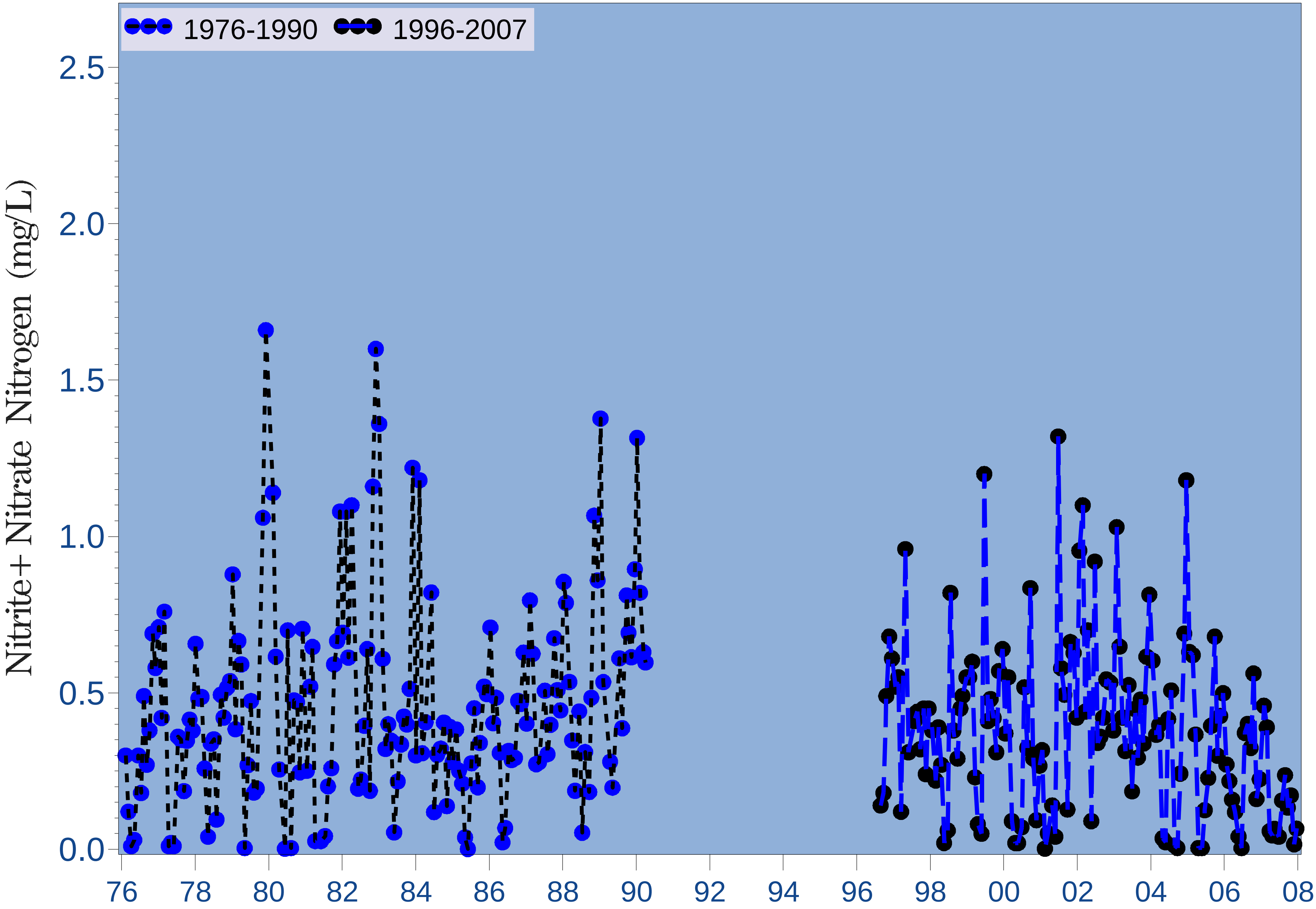

Figure 4.21d Monthly long-term bottom nitrate/nitrite nitrogen at river kilometer 23.6

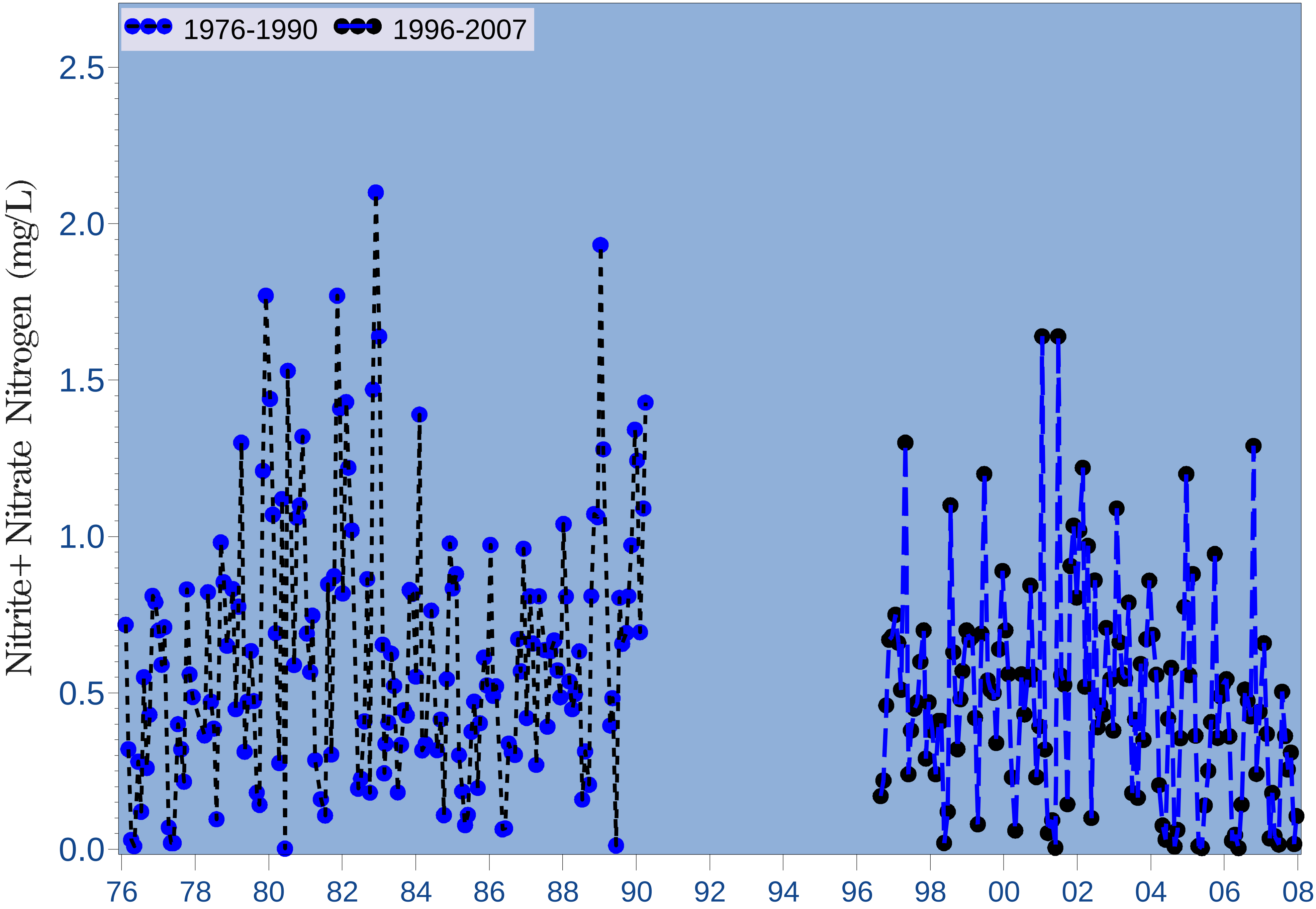

Figure 4.21e Monthly long-term bottom nitrate/nitrite nitrogen at river kilometer 30.4

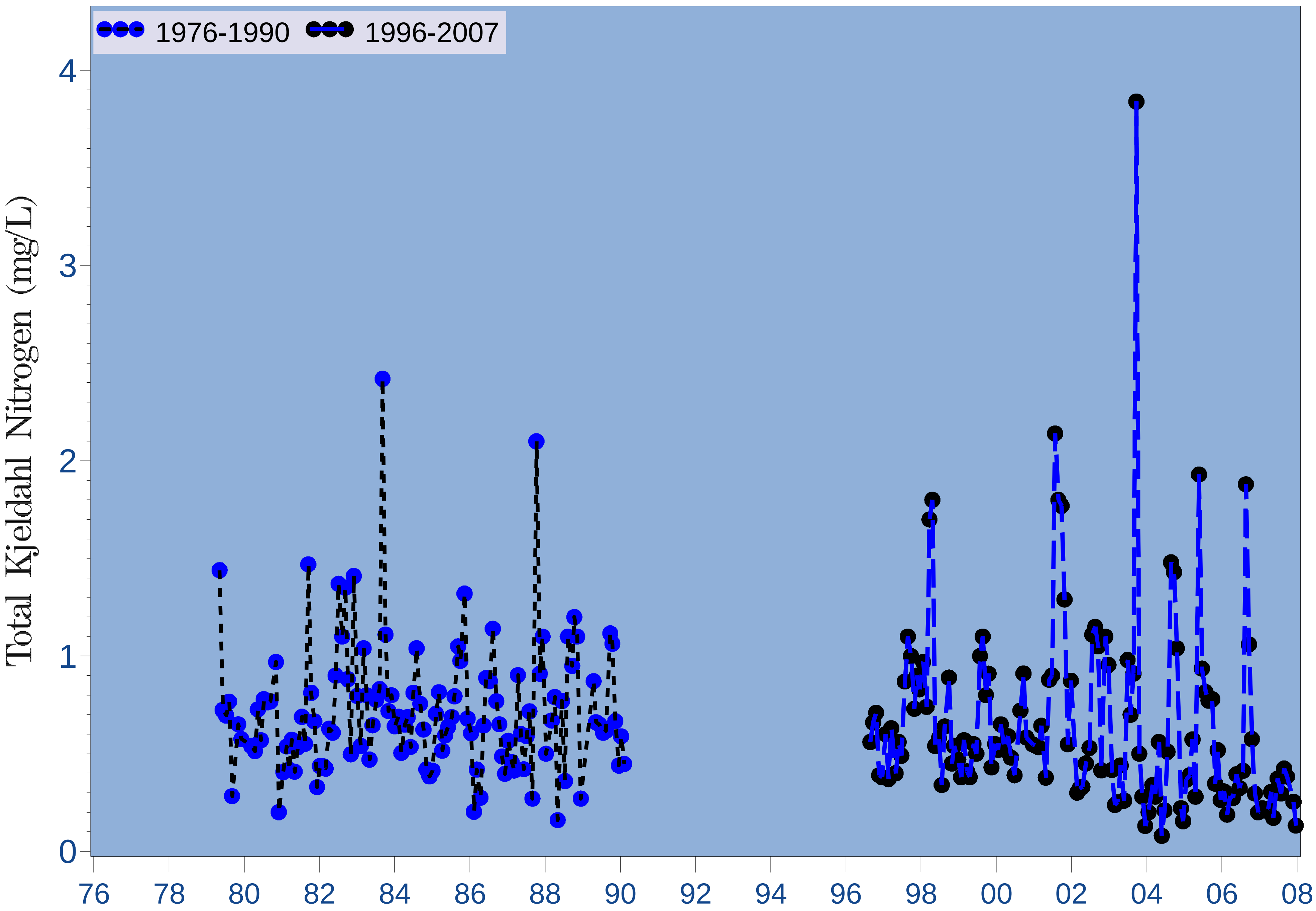

Figure 4.22a Monthly long-term surface total Kjeldahl nitrogen at river kilometer -2.4

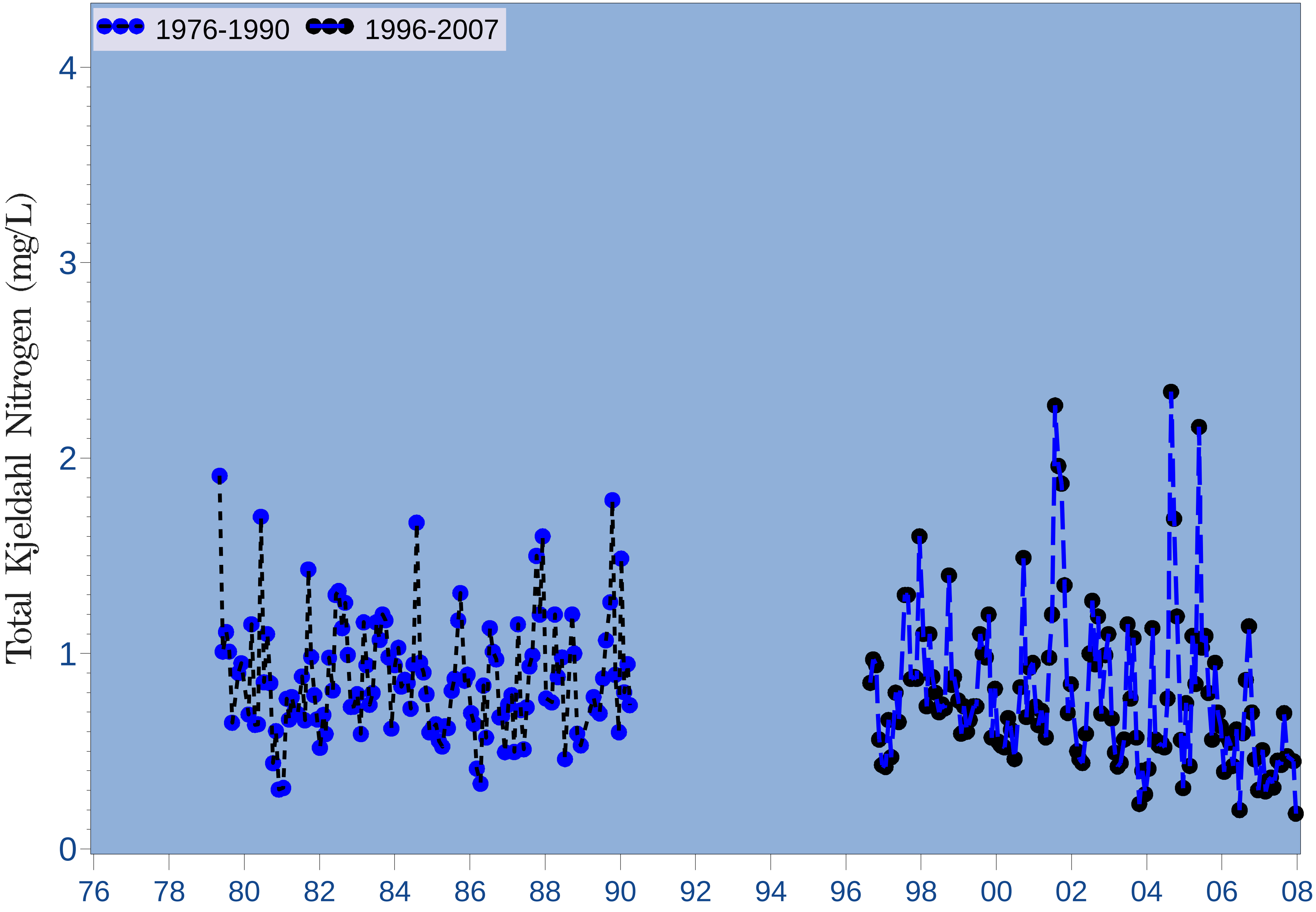

Figure 4.22b Monthly long-term surface total Kjeldahl nitrogen at river kilometer 6.6

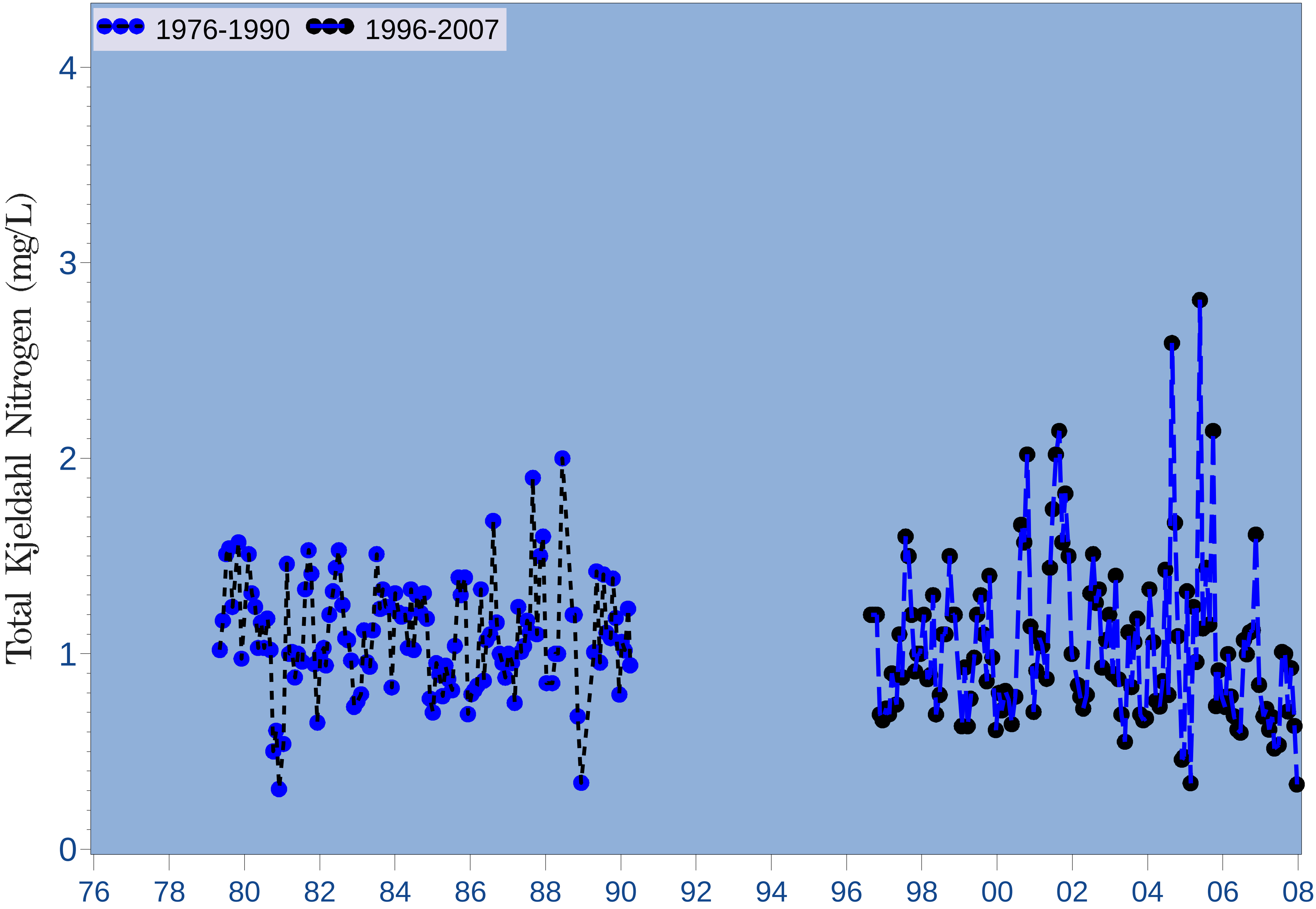

Figure 4.22c Monthly long-term surface total Kjeldahl nitrogen at river kilometer 15.5

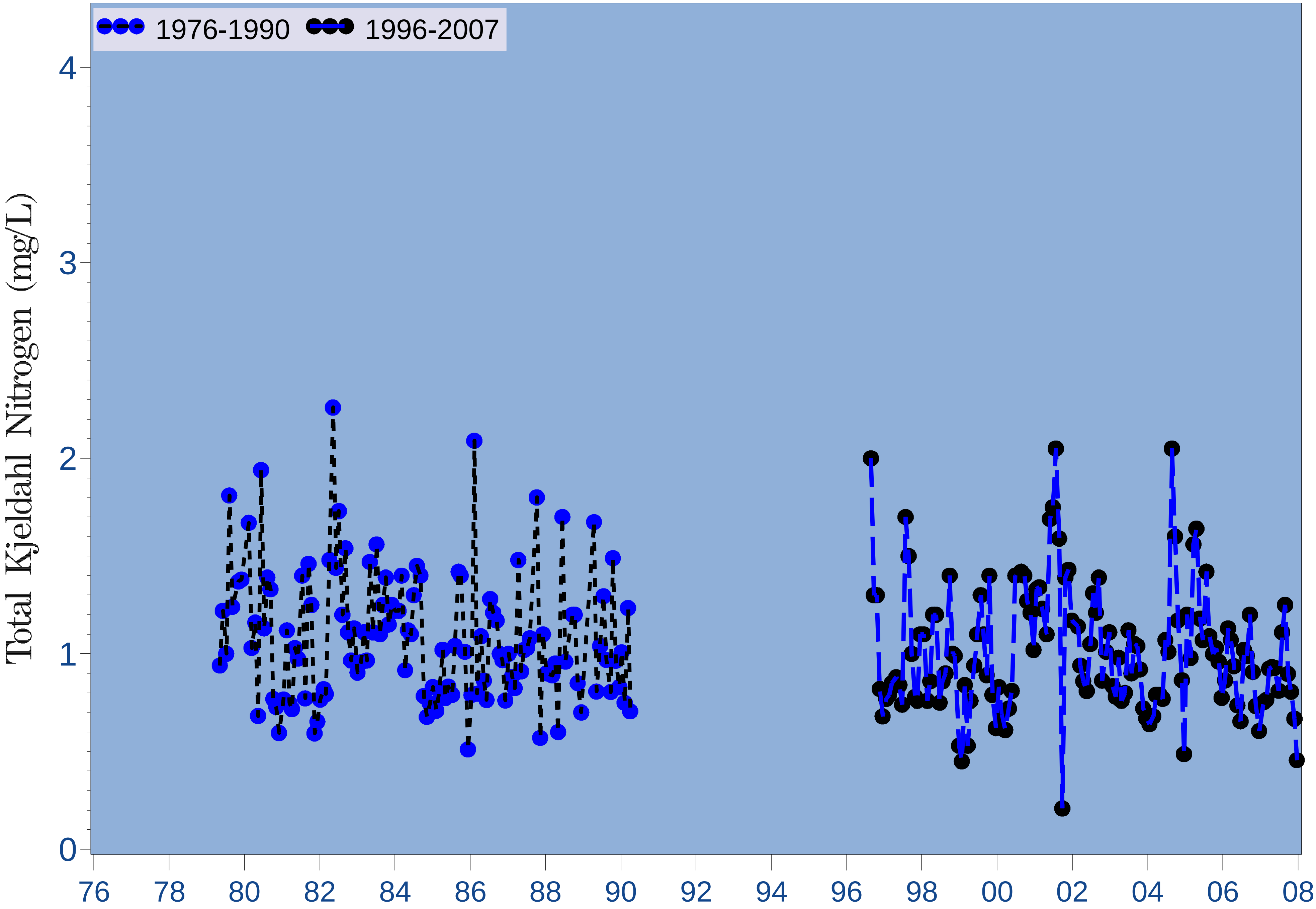

Figure 4.22d Monthly long-term surface total Kjeldahl nitrogen at river kilometer 23.6

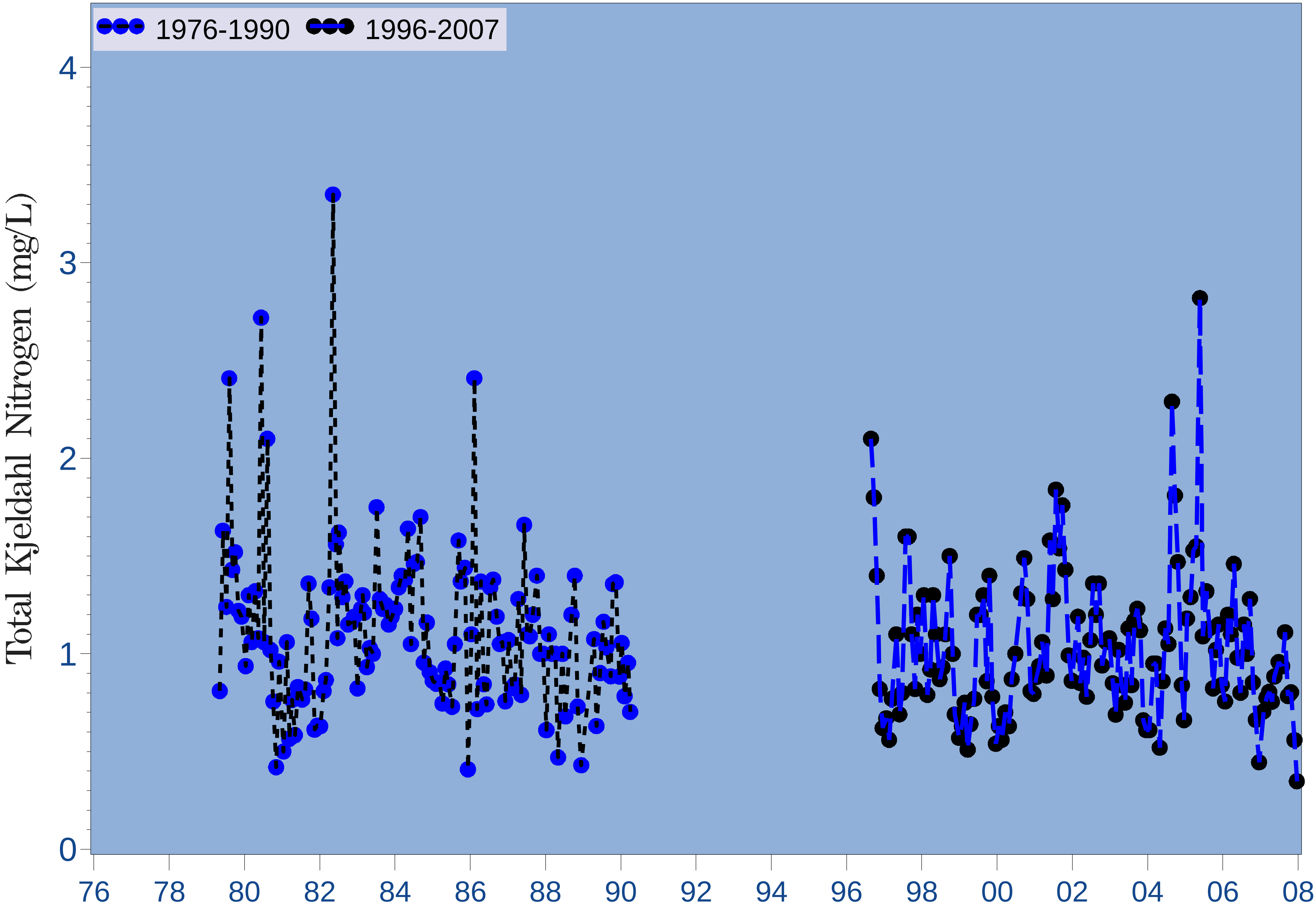

Figure 4.22e Monthly long-term surface total Kjeldahl nitrogen at river kilometer 30.4

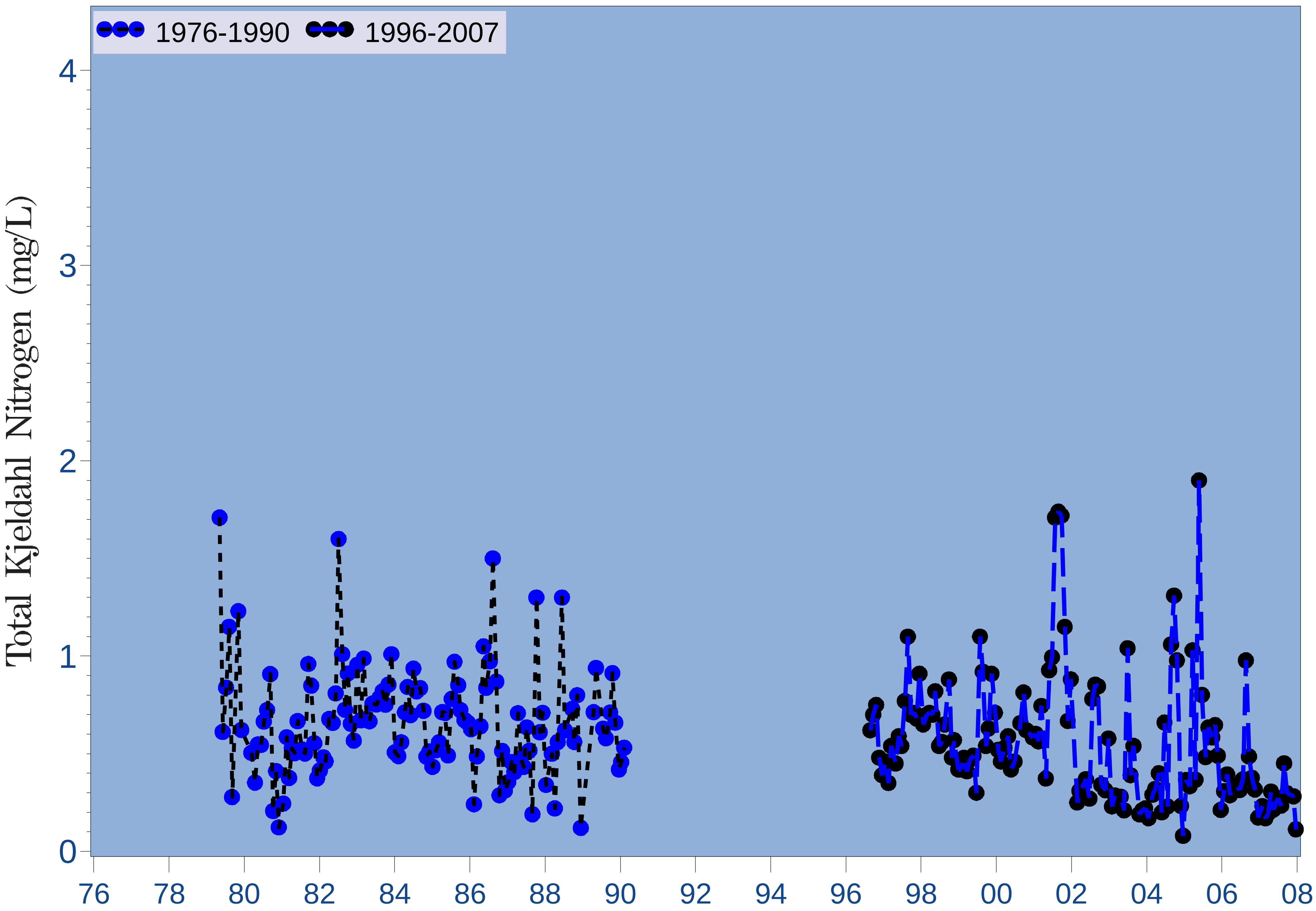

Figure 4.23a Monthly long-term bottom total Kjeldhal nitrogen at river kilometer -2.4

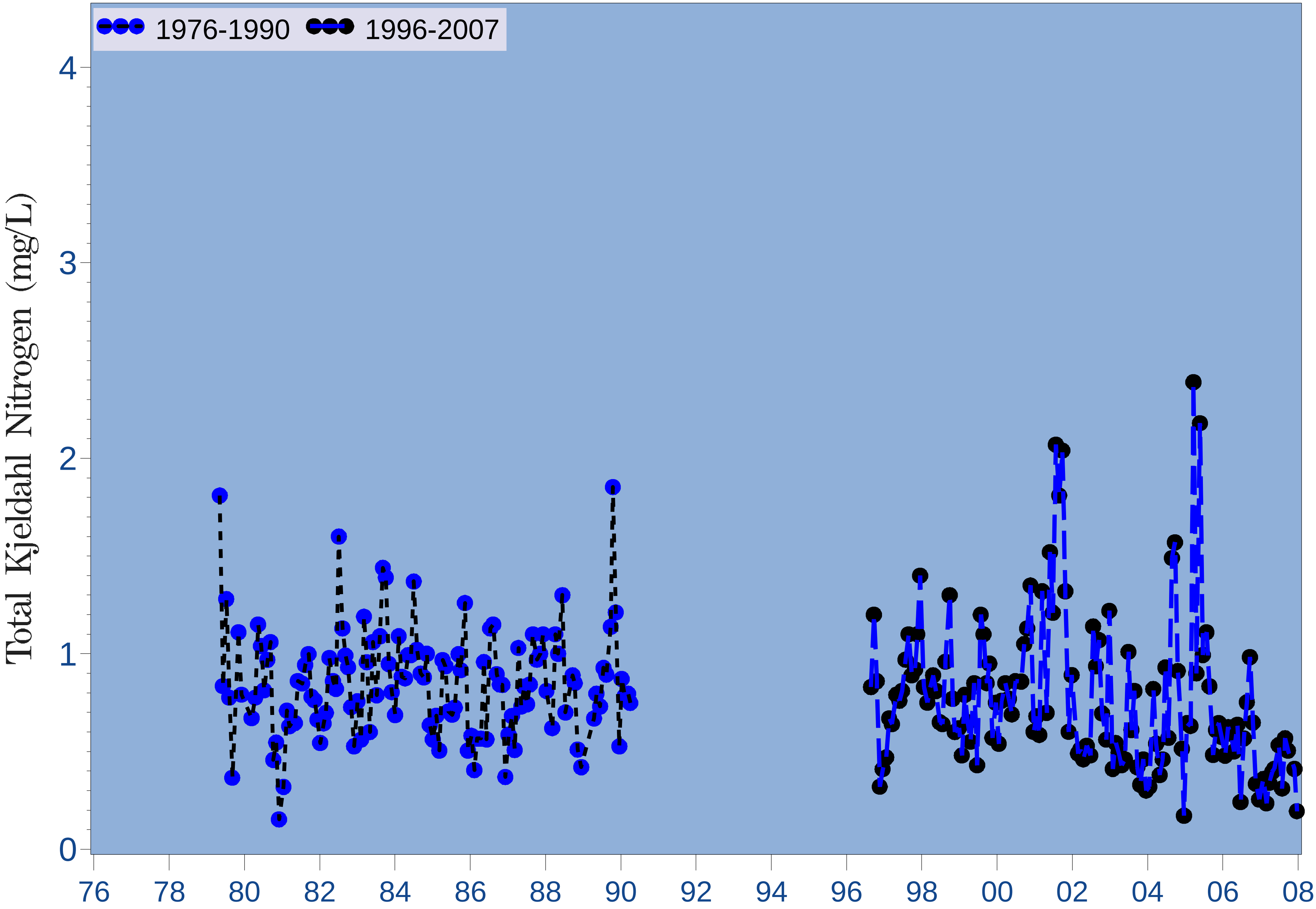

Figure 4.23b Monthly long-term bottom total Kjeldhal nitrogen at river kilometer 6.6

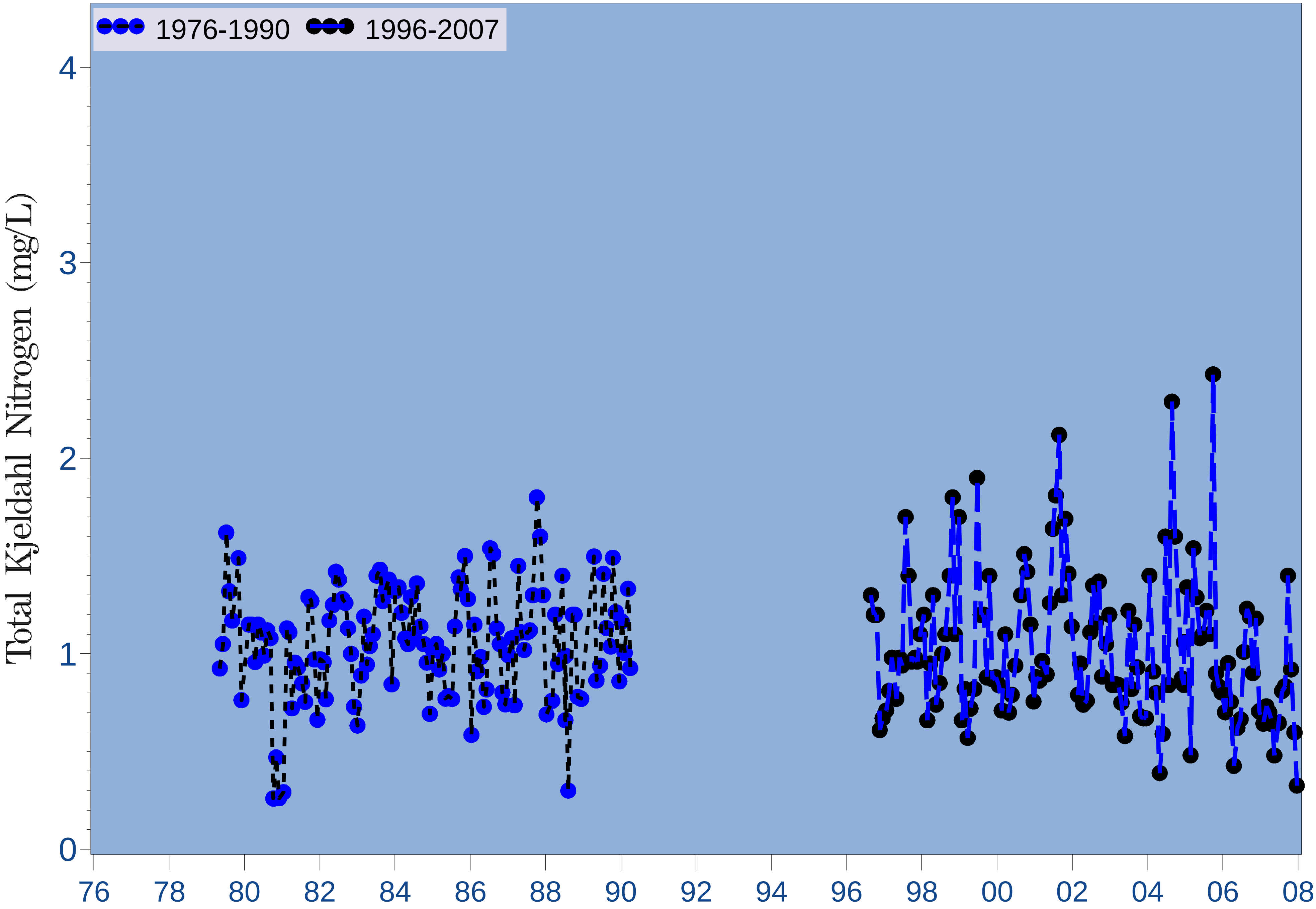

Figure 4.23c Monthly long-term bottom total Kjeldhal nitrogen at river kilometer 15.5

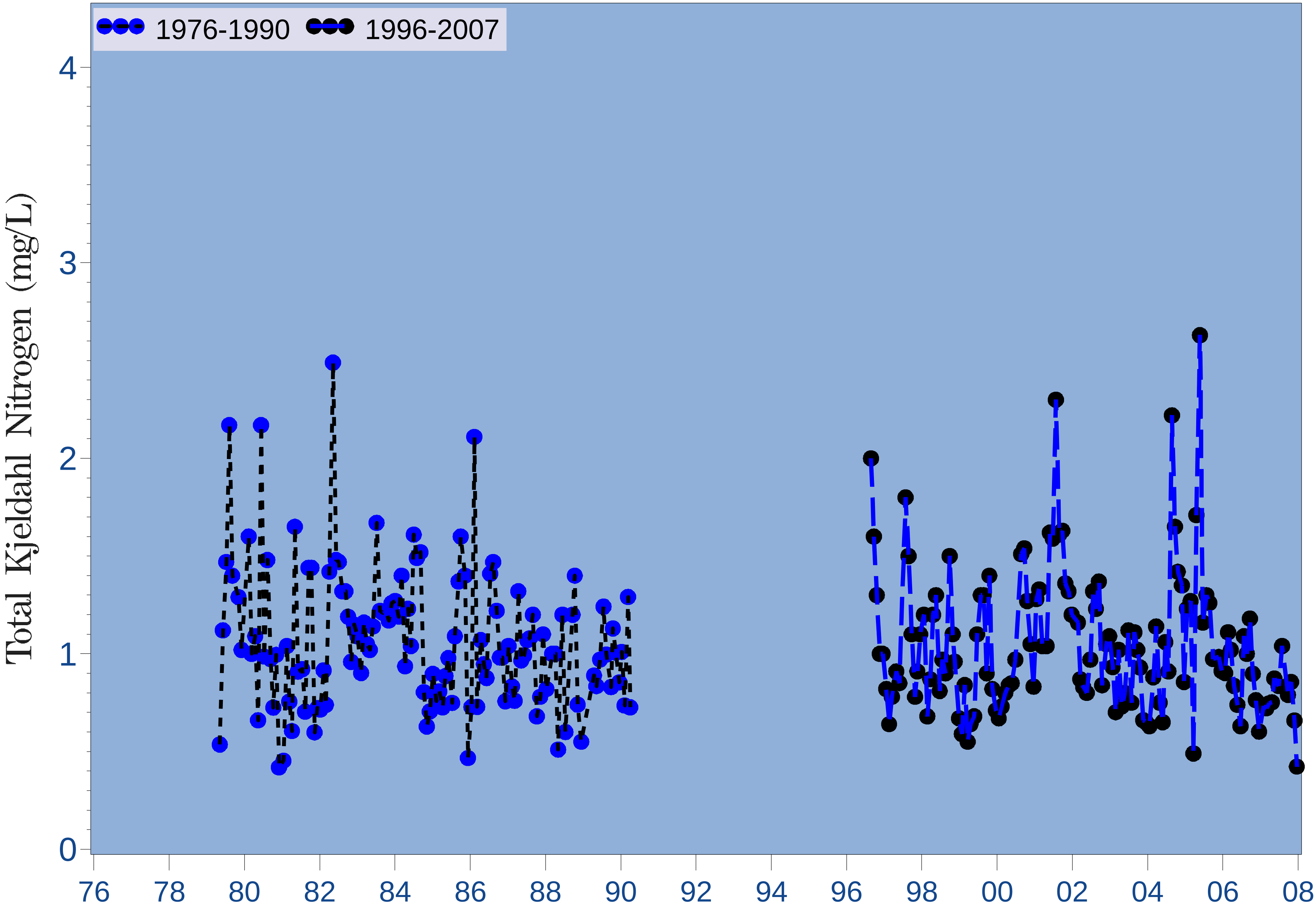

Figure 4.23d Monthly long-term bottom total Kjeldhal nitrogen at river kilometer 23.6

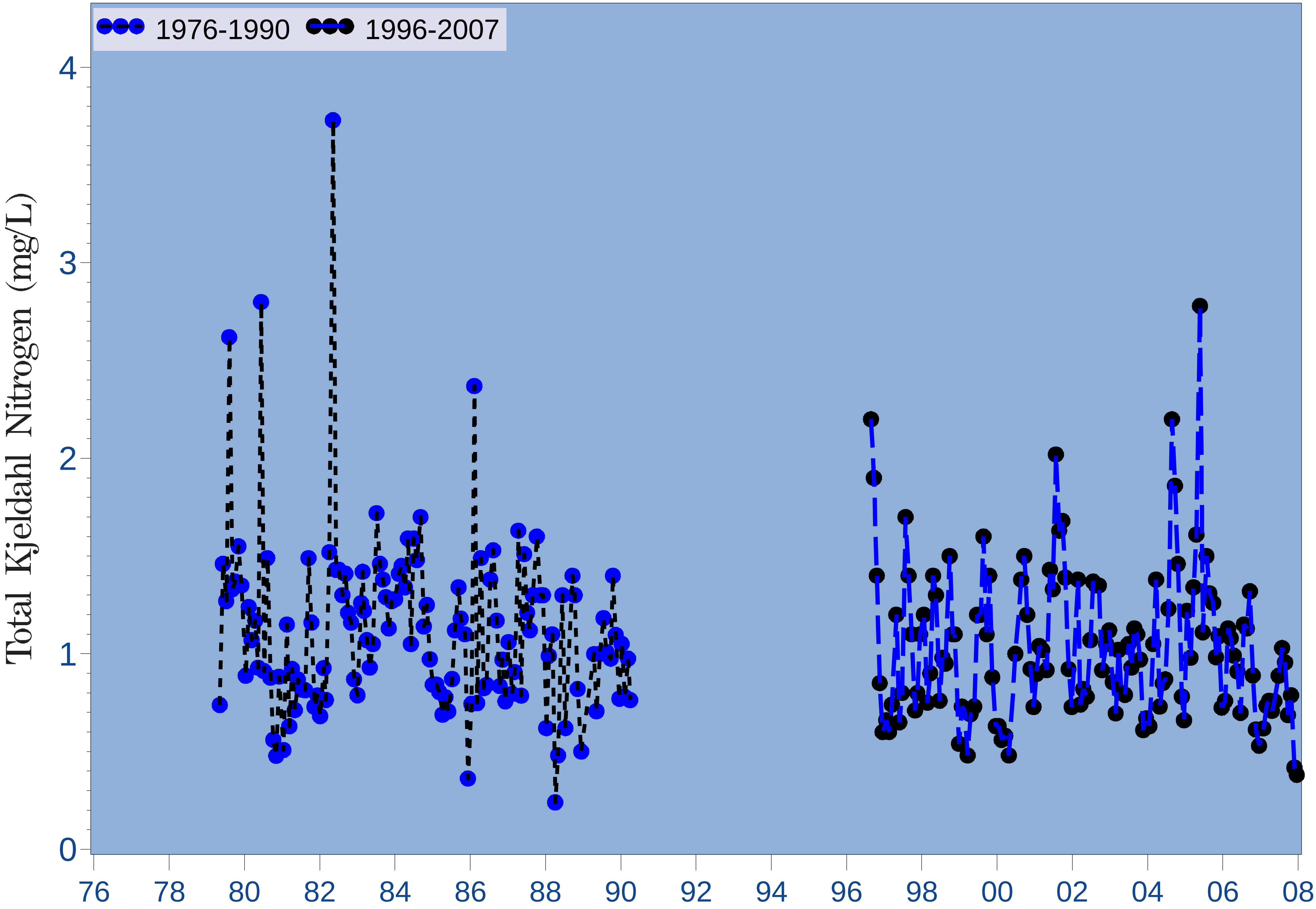

Figure 4.23e Monthly long-term bottom total Kjeldhal nitrogen at river kilometer 30.4

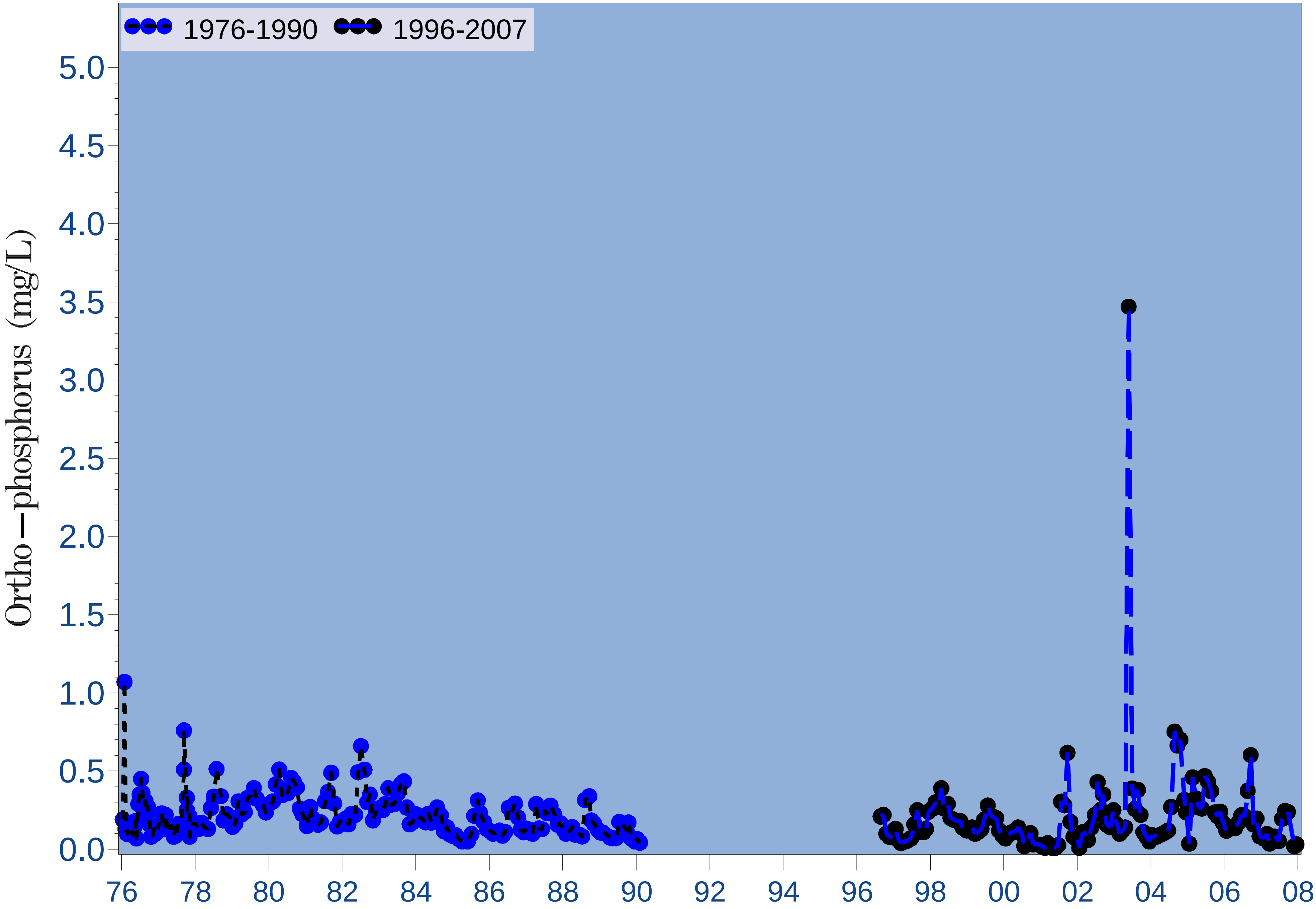

Figure 4.24a Monthly long-term surface ortho-phosphorus at river kilometer -2.4

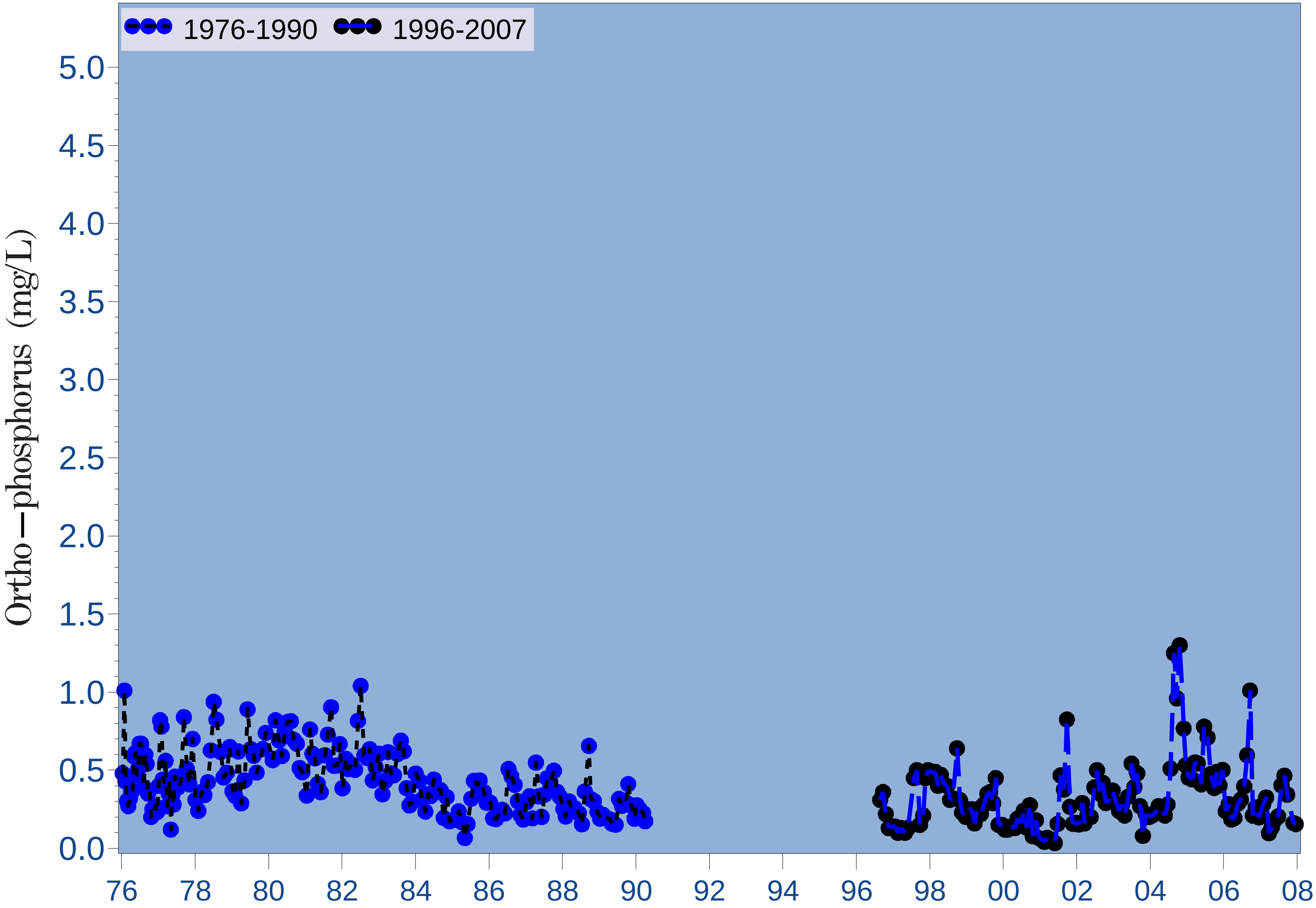

Figure 4.24b Monthly long-term surface ortho-phosphorus at river kilometer 6.6

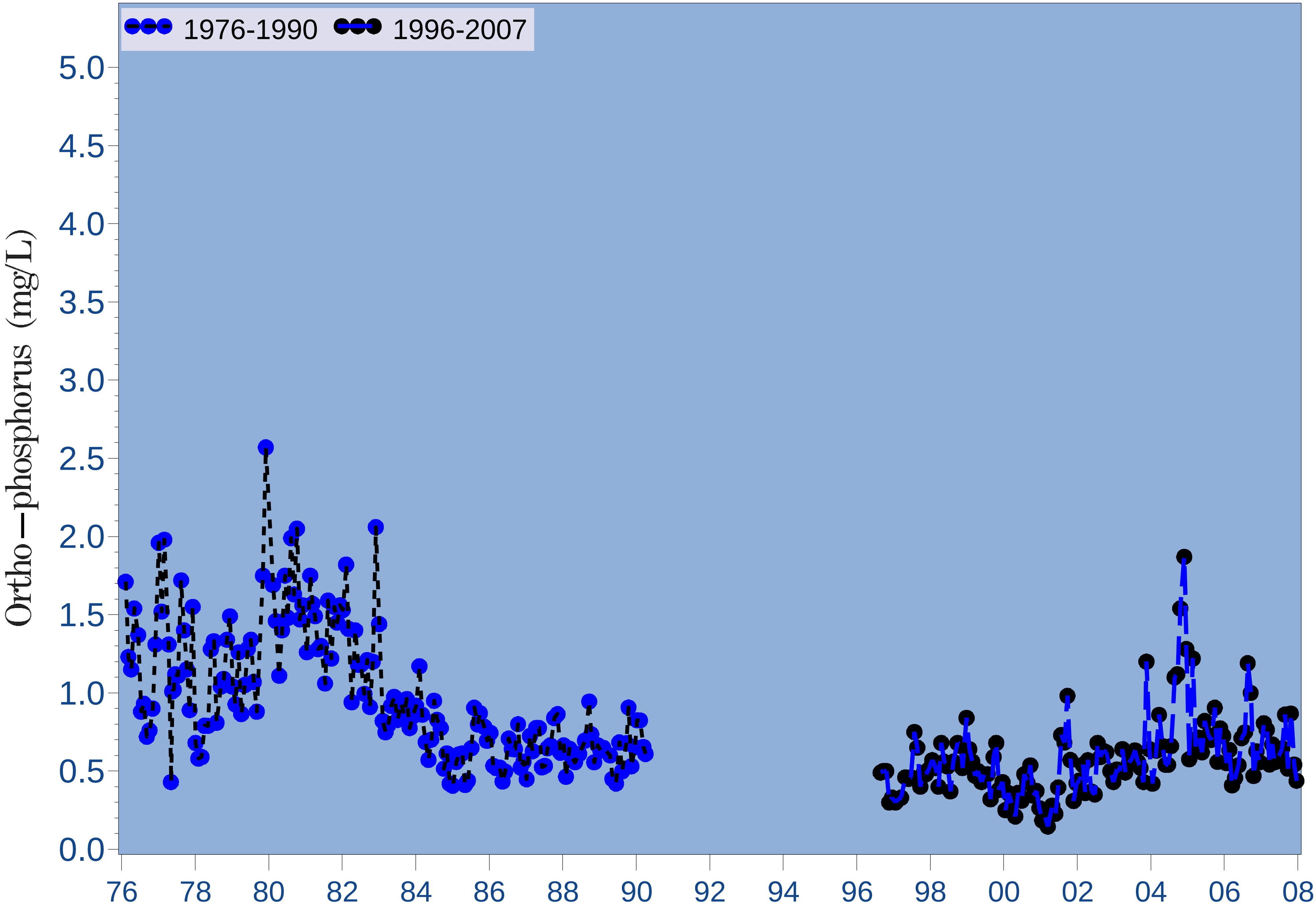

Figure 4.24c Monthly long-term surface ortho-phosphorus at river kilometer 15.5

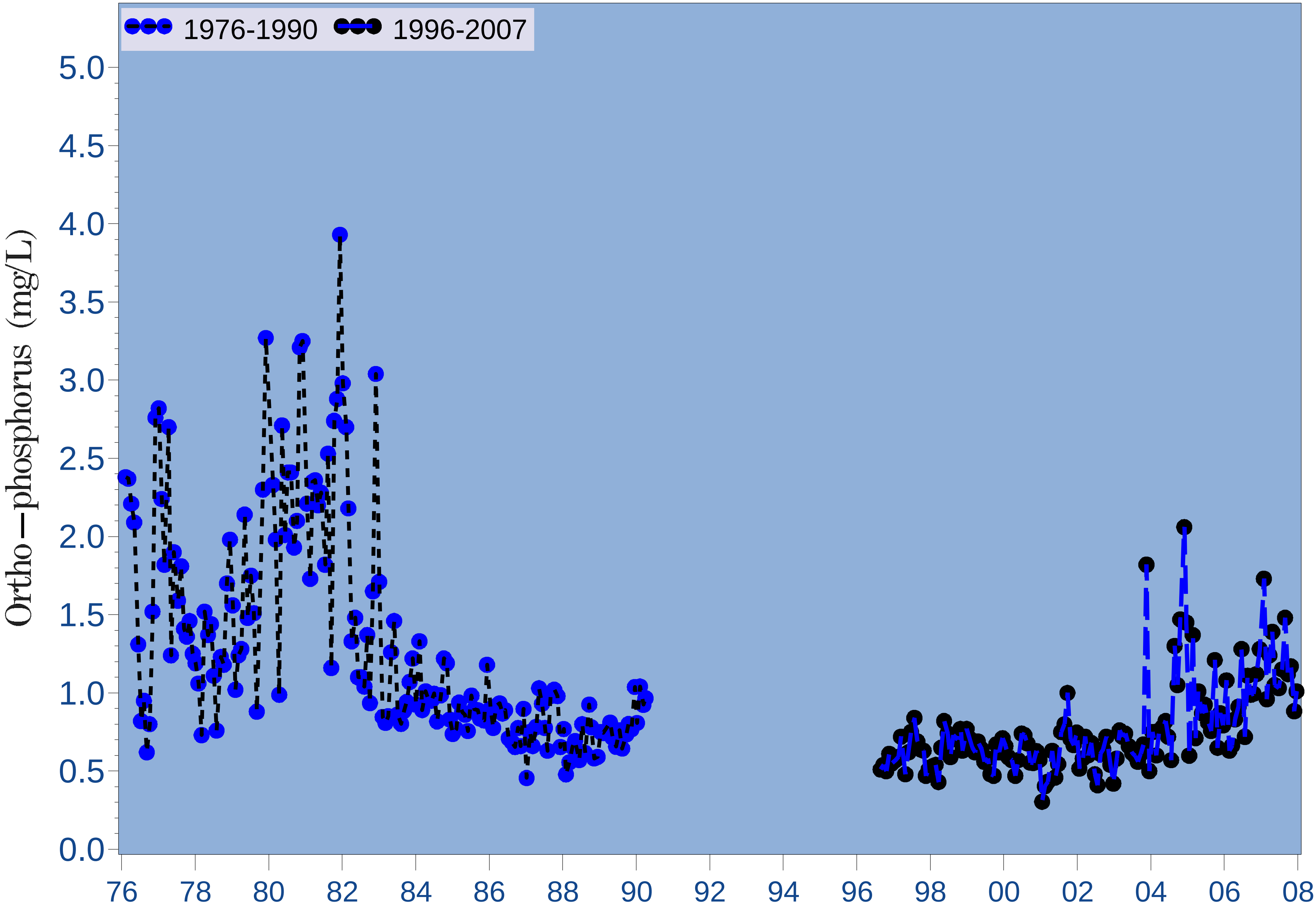

Figure 4.24d Monthly long-term surface ortho-phosphorus at river kilometer 23.6

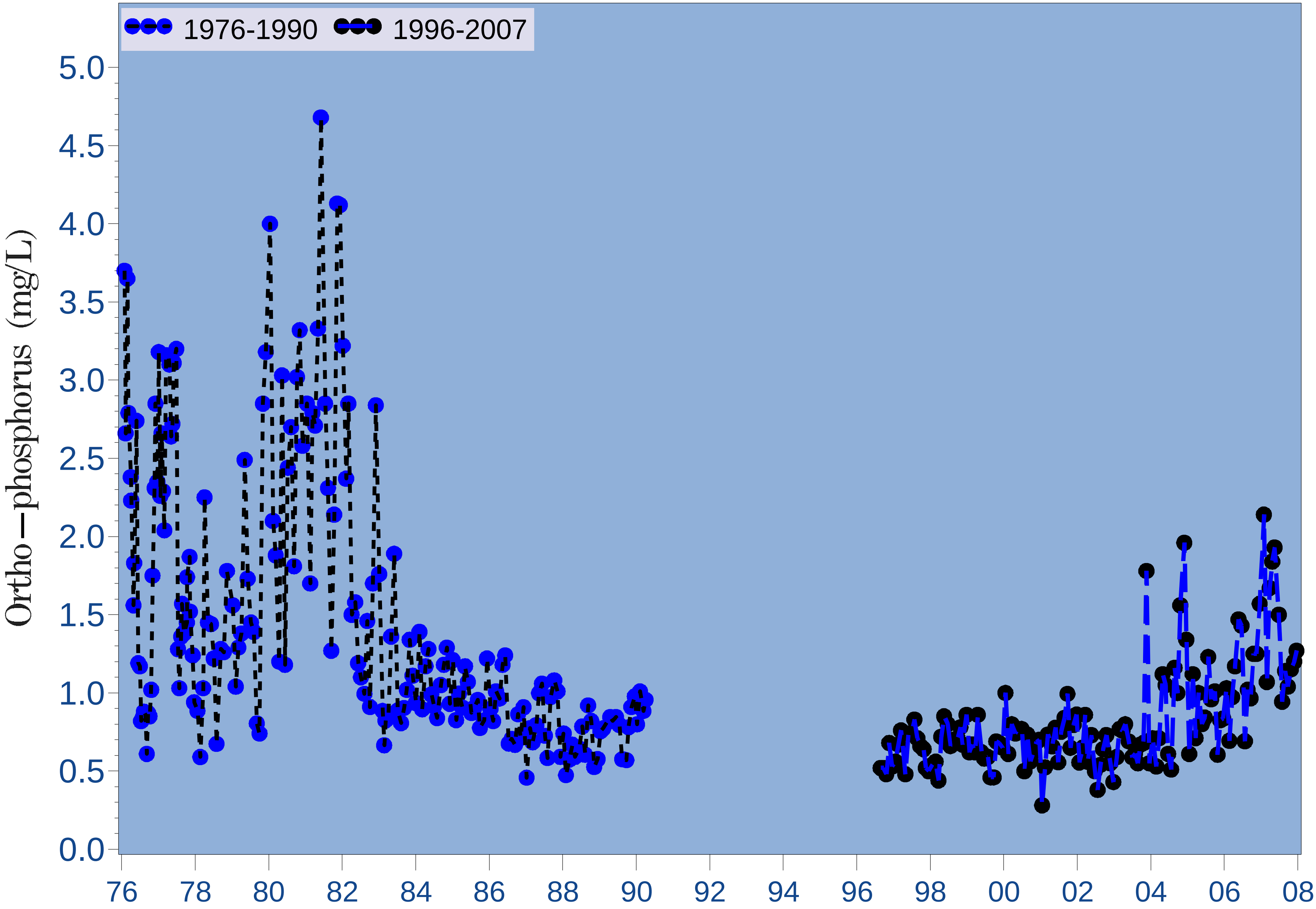

Figure 4.24e Monthly long-term surface ortho-phosphorus at river kilometer 30.4

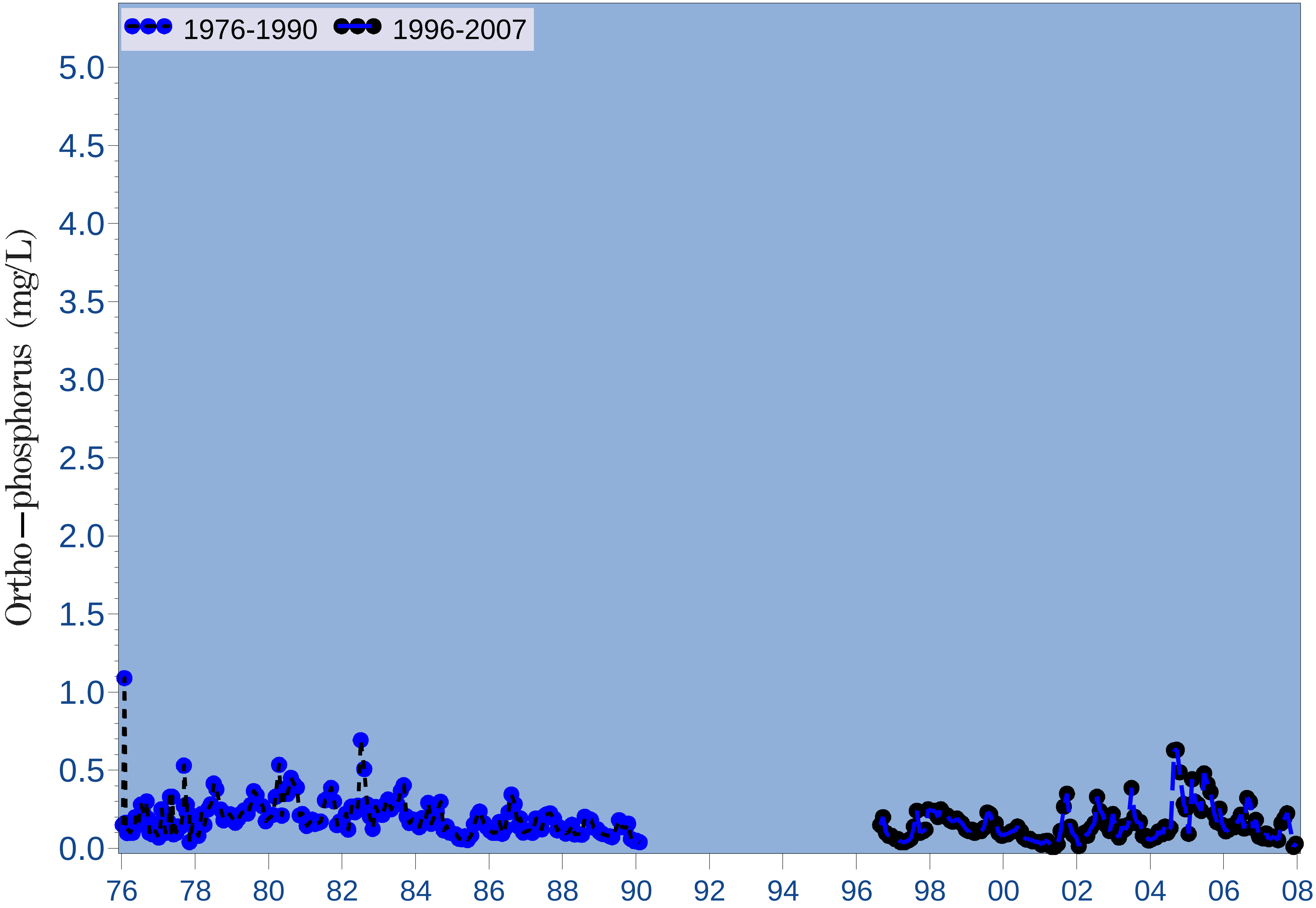

Figure 4.25a Monthly long-term bottom ortho-phosphorus at river kilometer -2.4

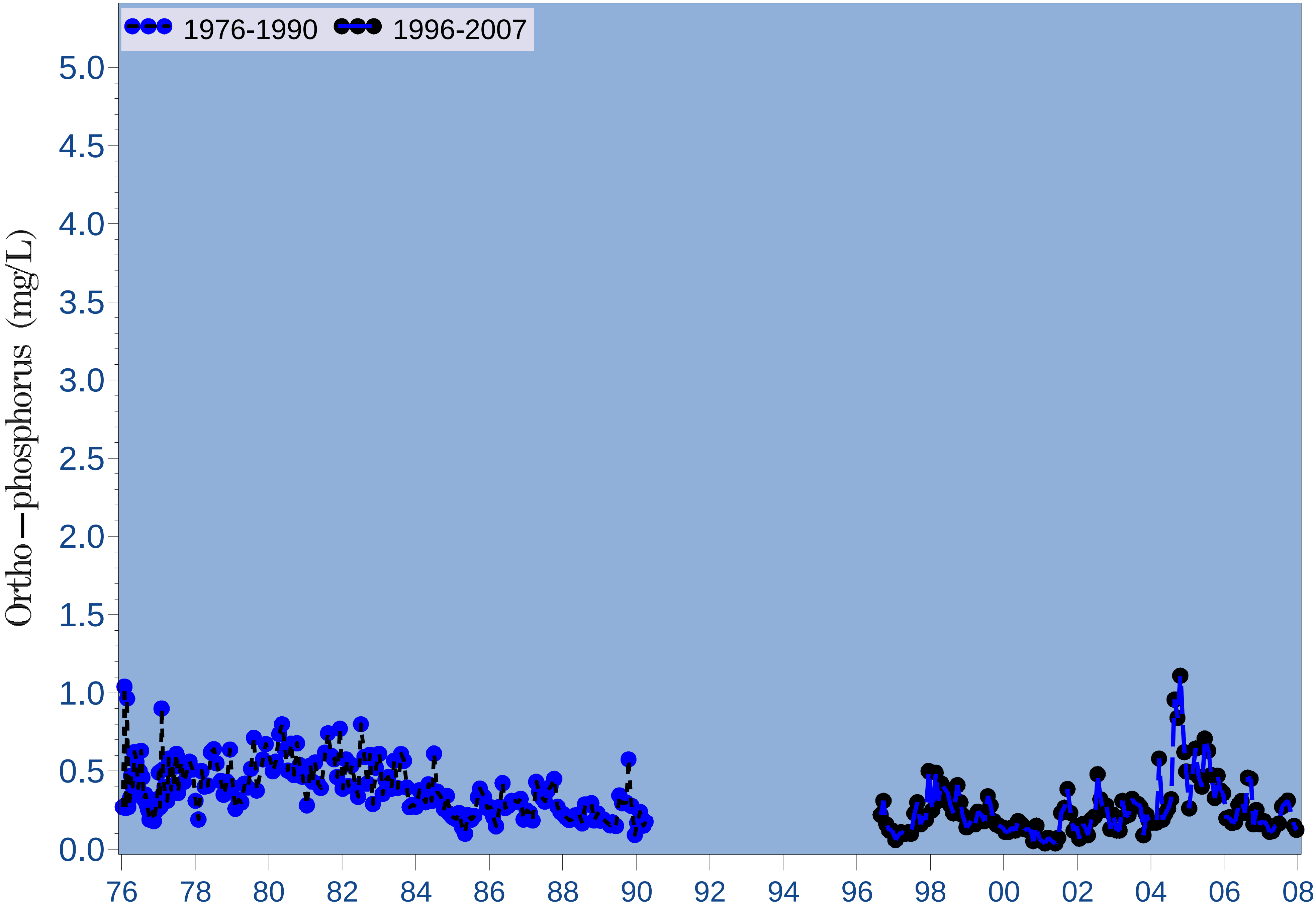

Figure 4.25b Monthly long-term bottom ortho-phosphorus at river kilometer 6.6

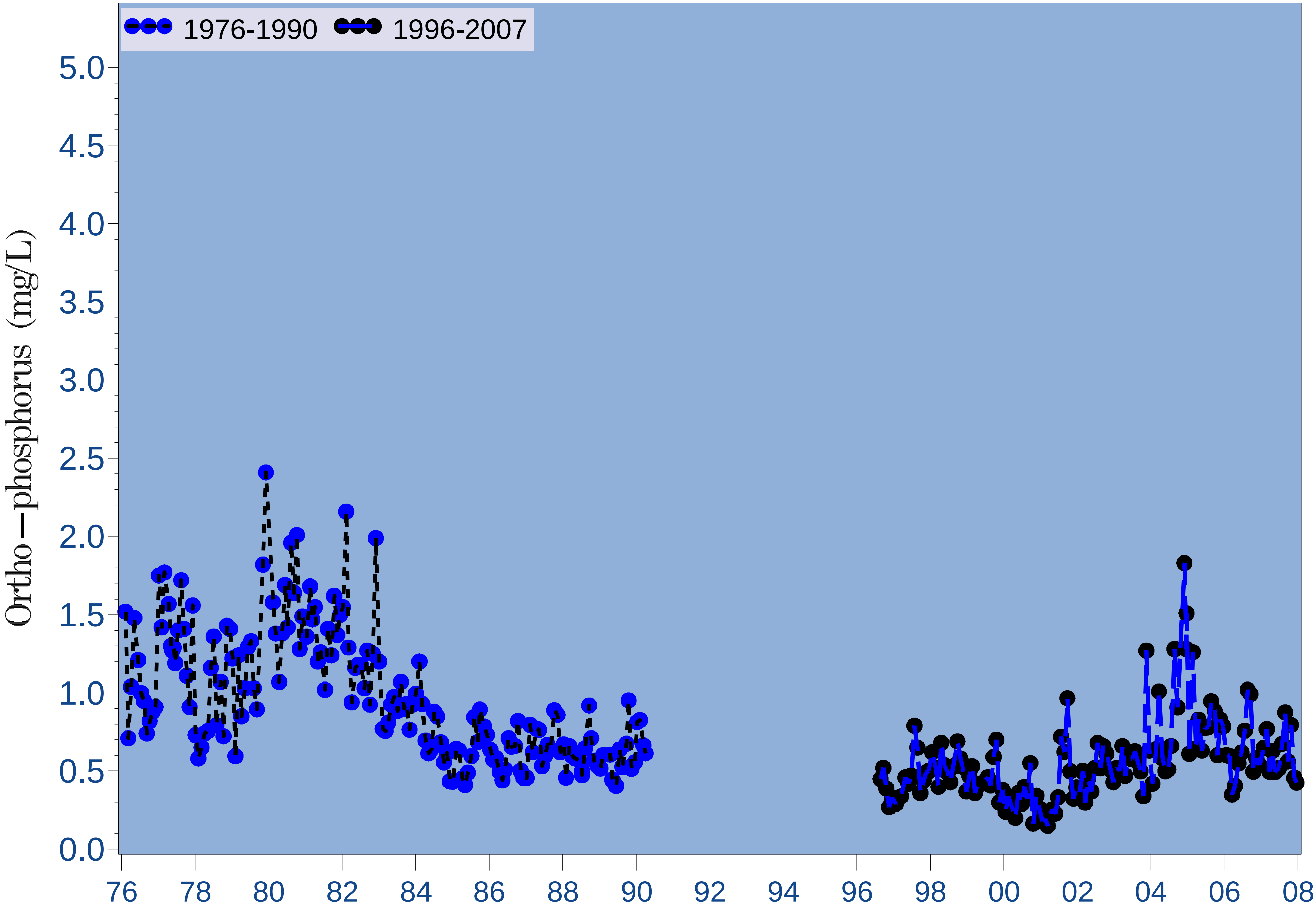

Figure 4.25c Monthly long-term bottom ortho-phosphorus at river kilometer 15.5

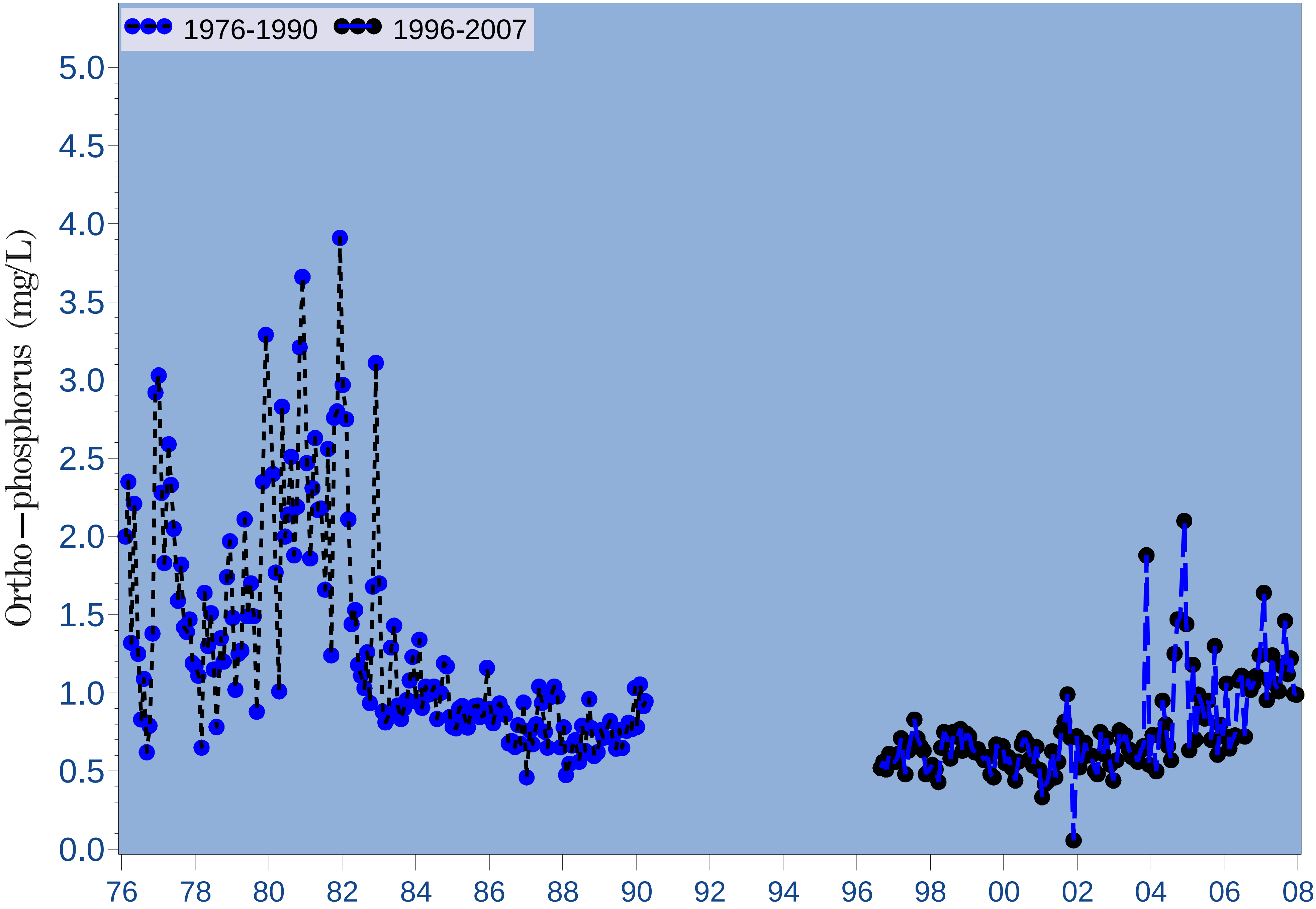

Figure 4.25d Monthly long-term bottom ortho-phosphorus at river kilometer 23.6

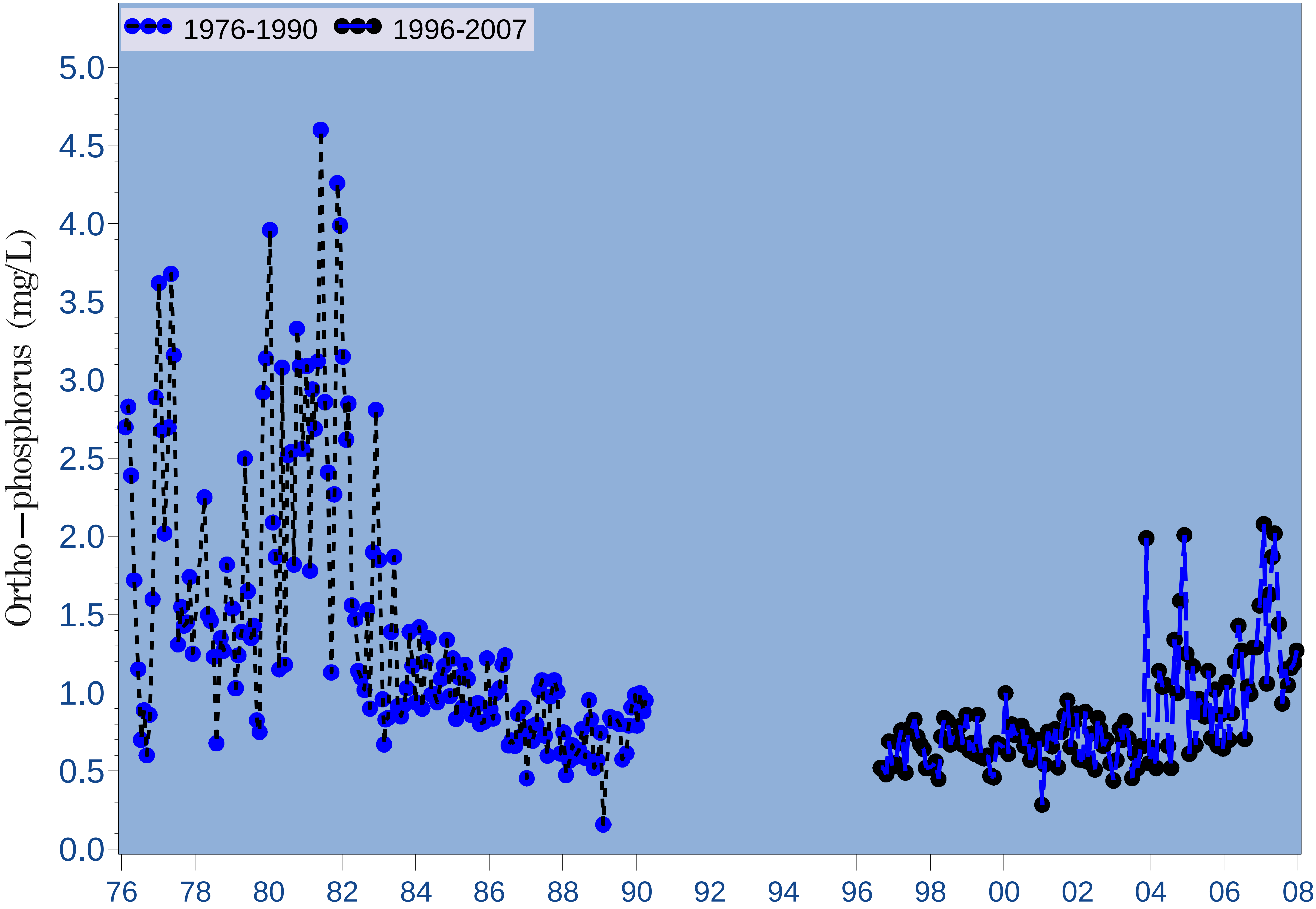

Figure 4.25e Monthly long-term bottom ortho-phosphorus at river kilometer 30.4

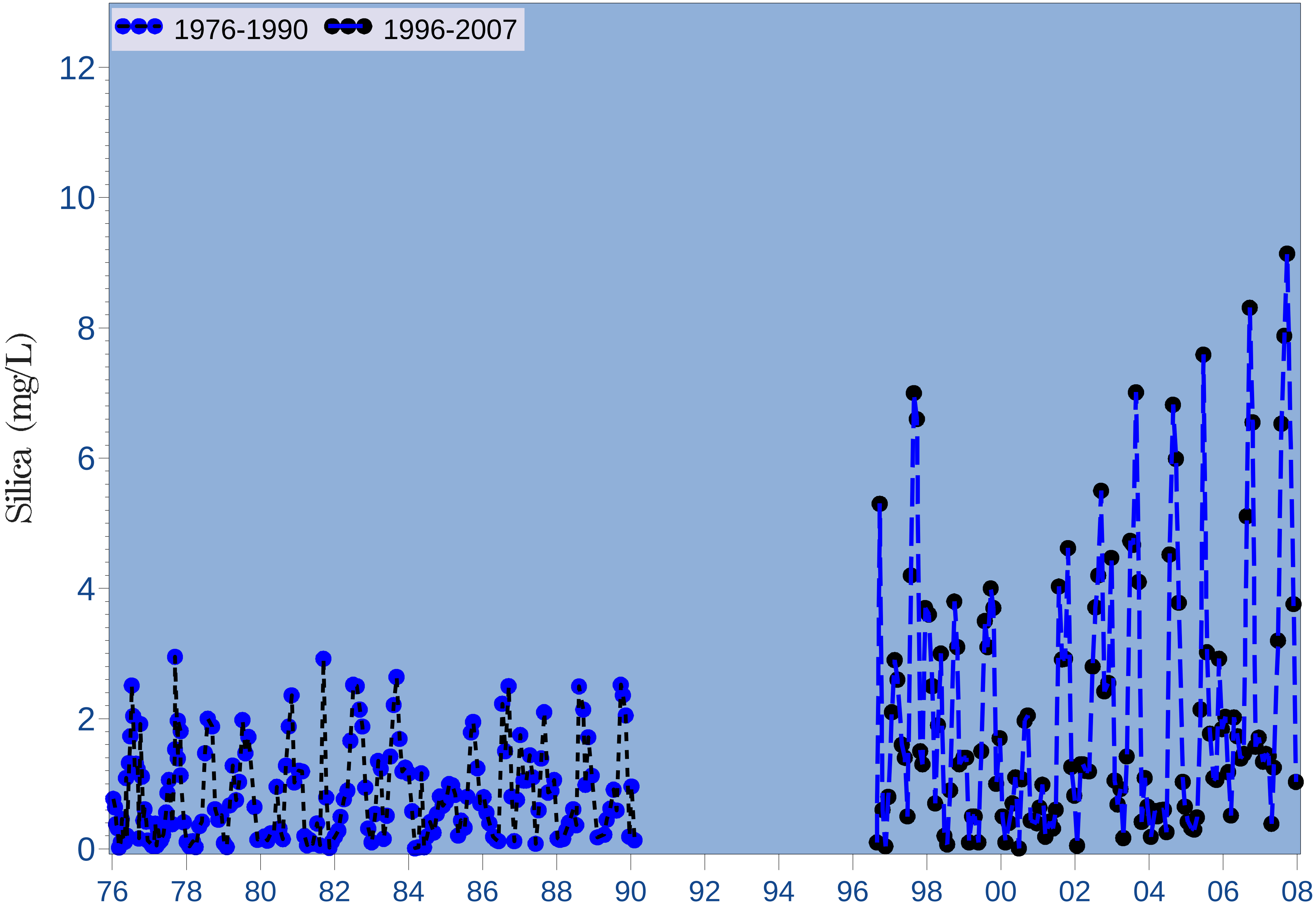

Figure 4.26a Monthly long-term surface silica at river kilometer -2.4

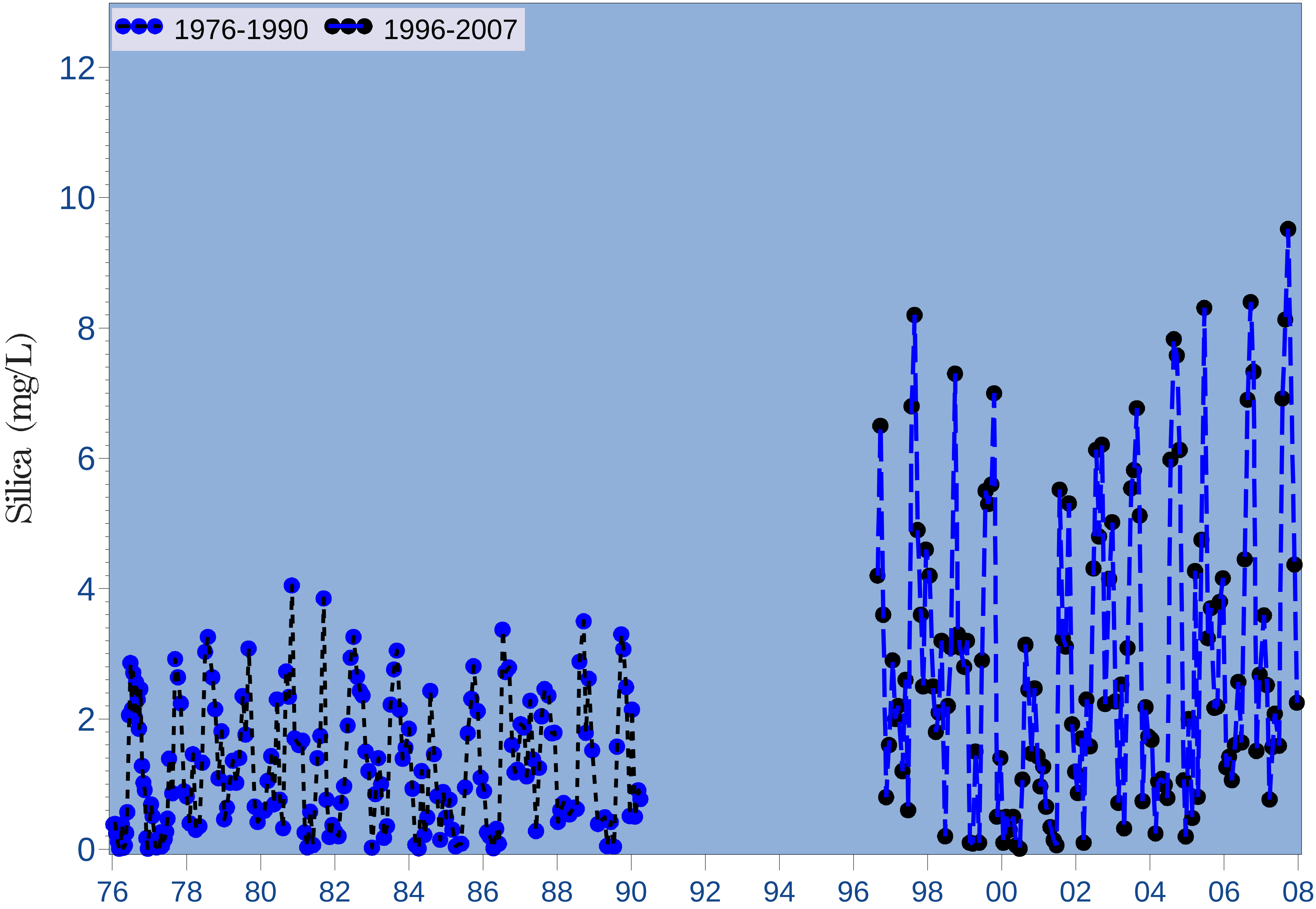

Figure 4.26b Monthly long-term surface silica at river kilometer 6.6

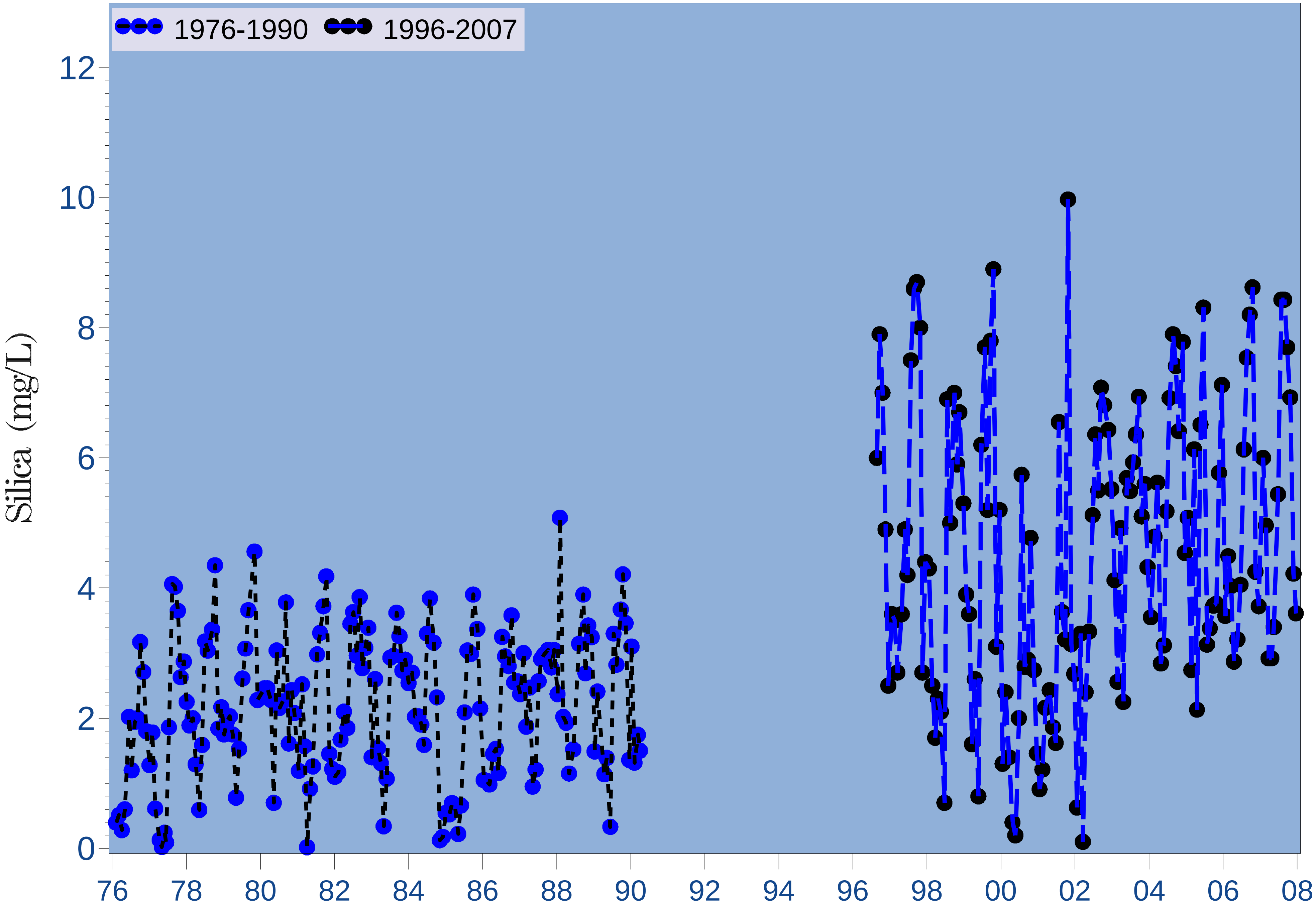

Figure 4.26c Monthly long-term surface silica at river kilometer 15.5

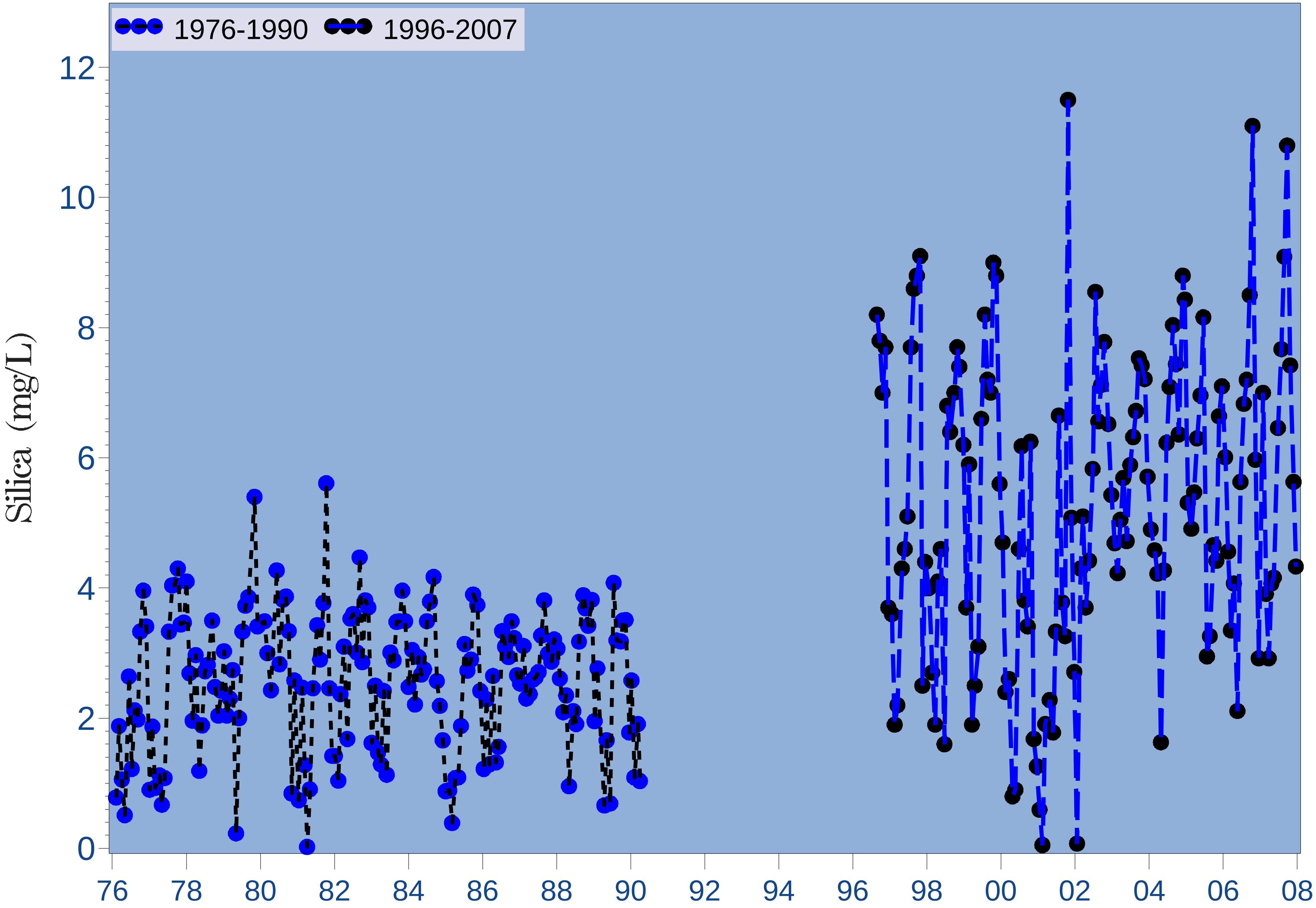

Figure 4.26d Monthly long-term surface silica at river kilometer 23.6

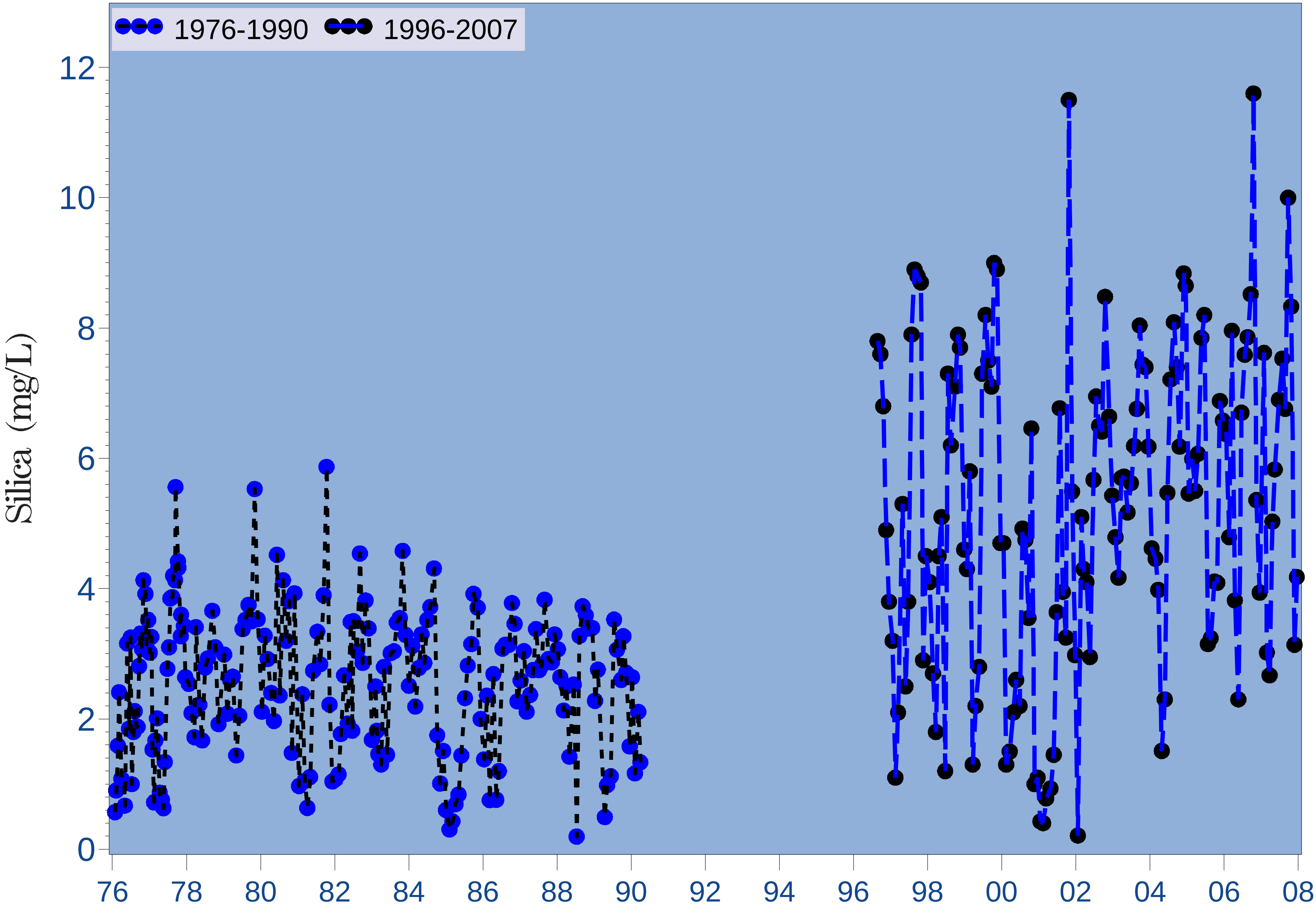

Figure 4.26e Monthly long-term surface silica at river kilometer 30.4

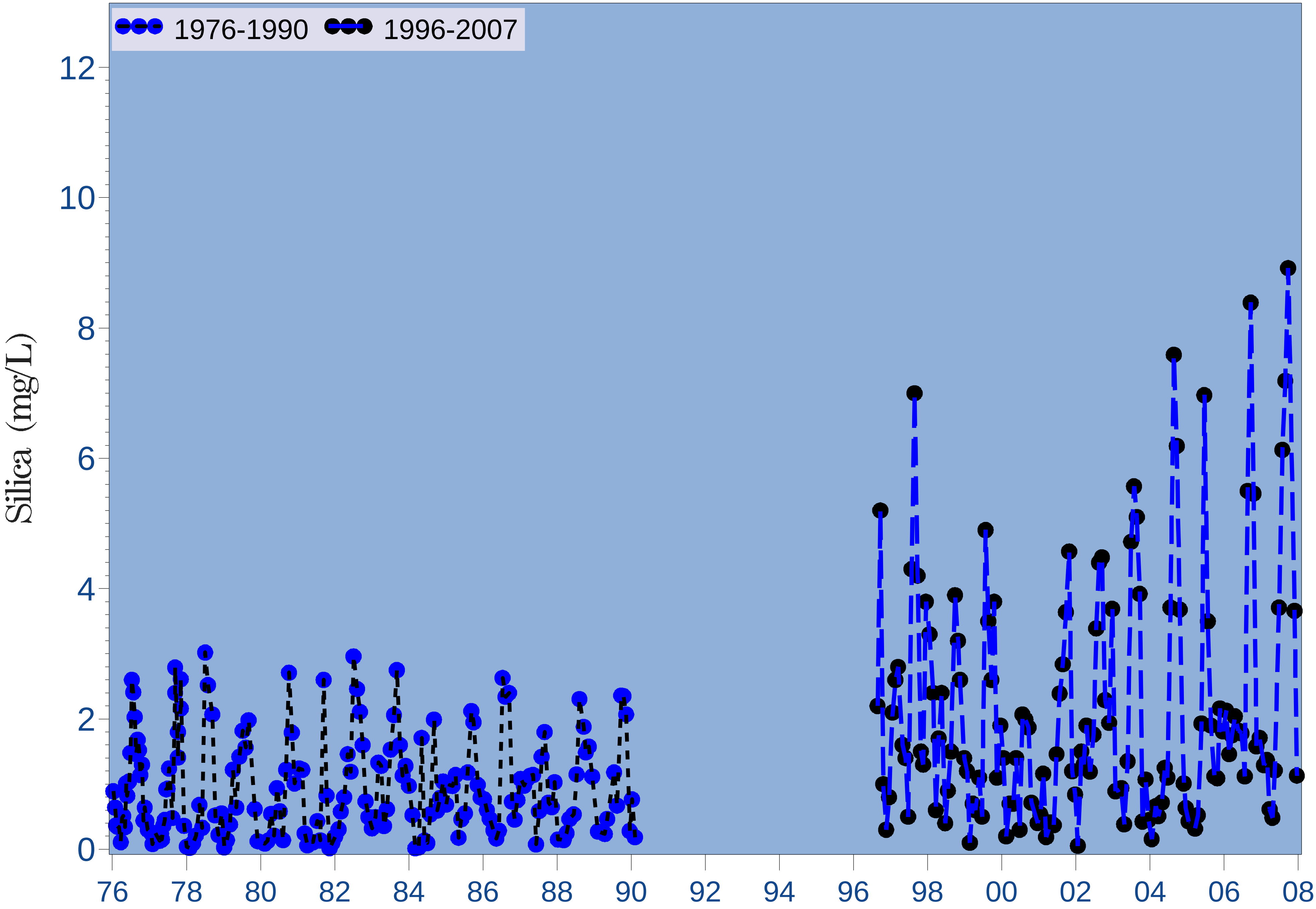

Figure 4.27a Monthly long-term bottom silica at river kilometer -2.4

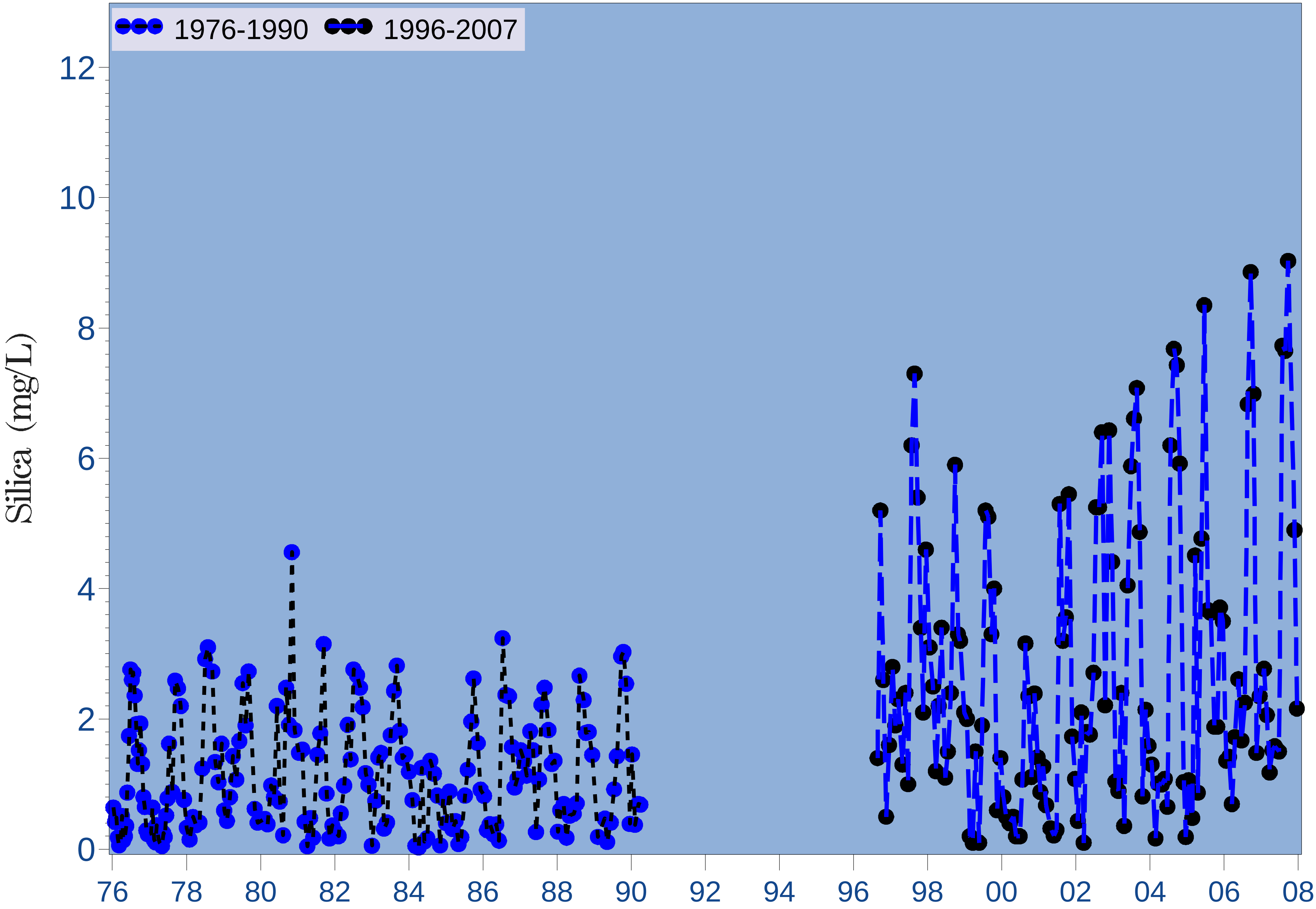

Figure 4.27b Monthly long-term bottom silica at river kilometer 6.6

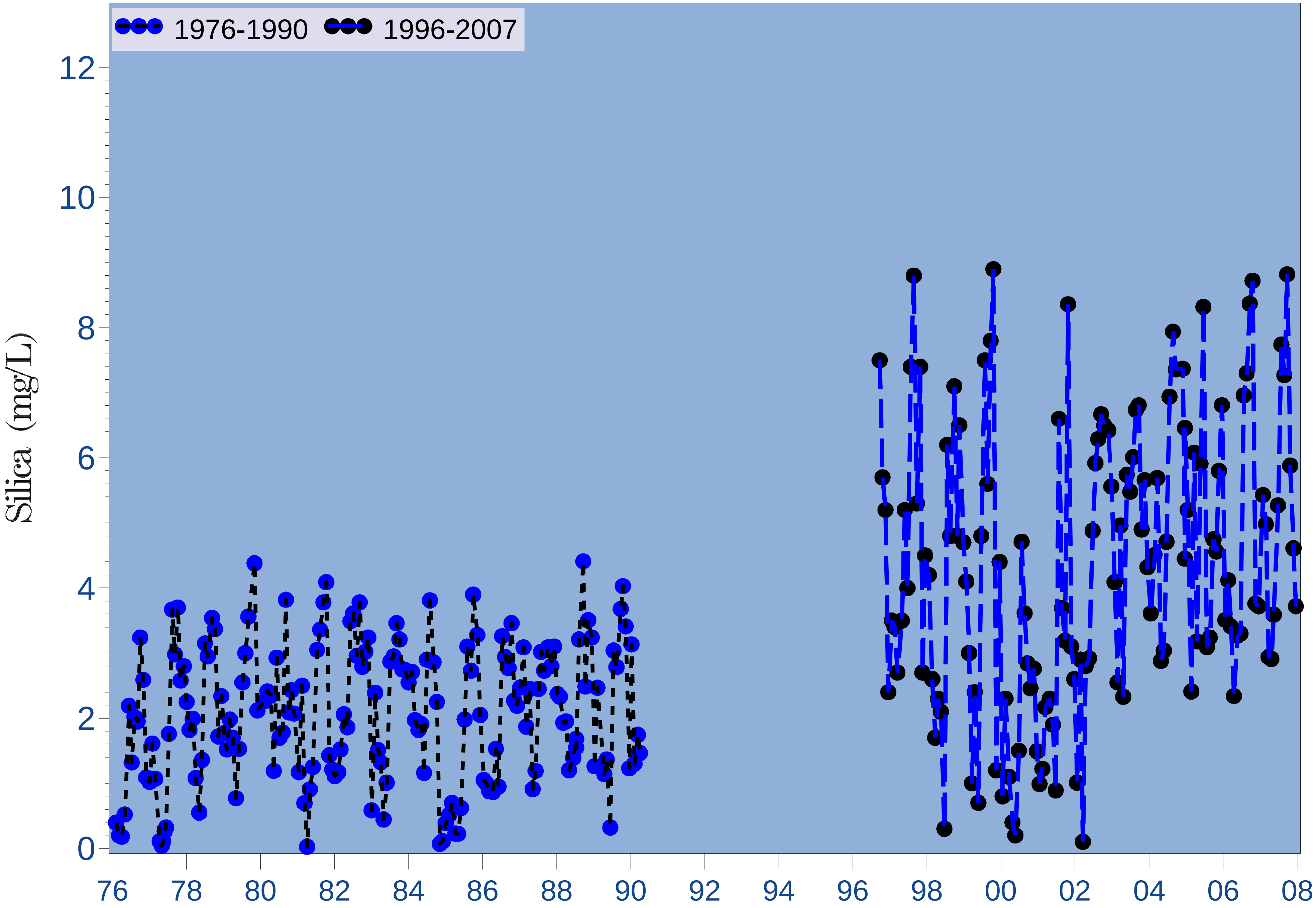

Figure 4.27c Monthly long-term bottom silica at river kilometer 15.5

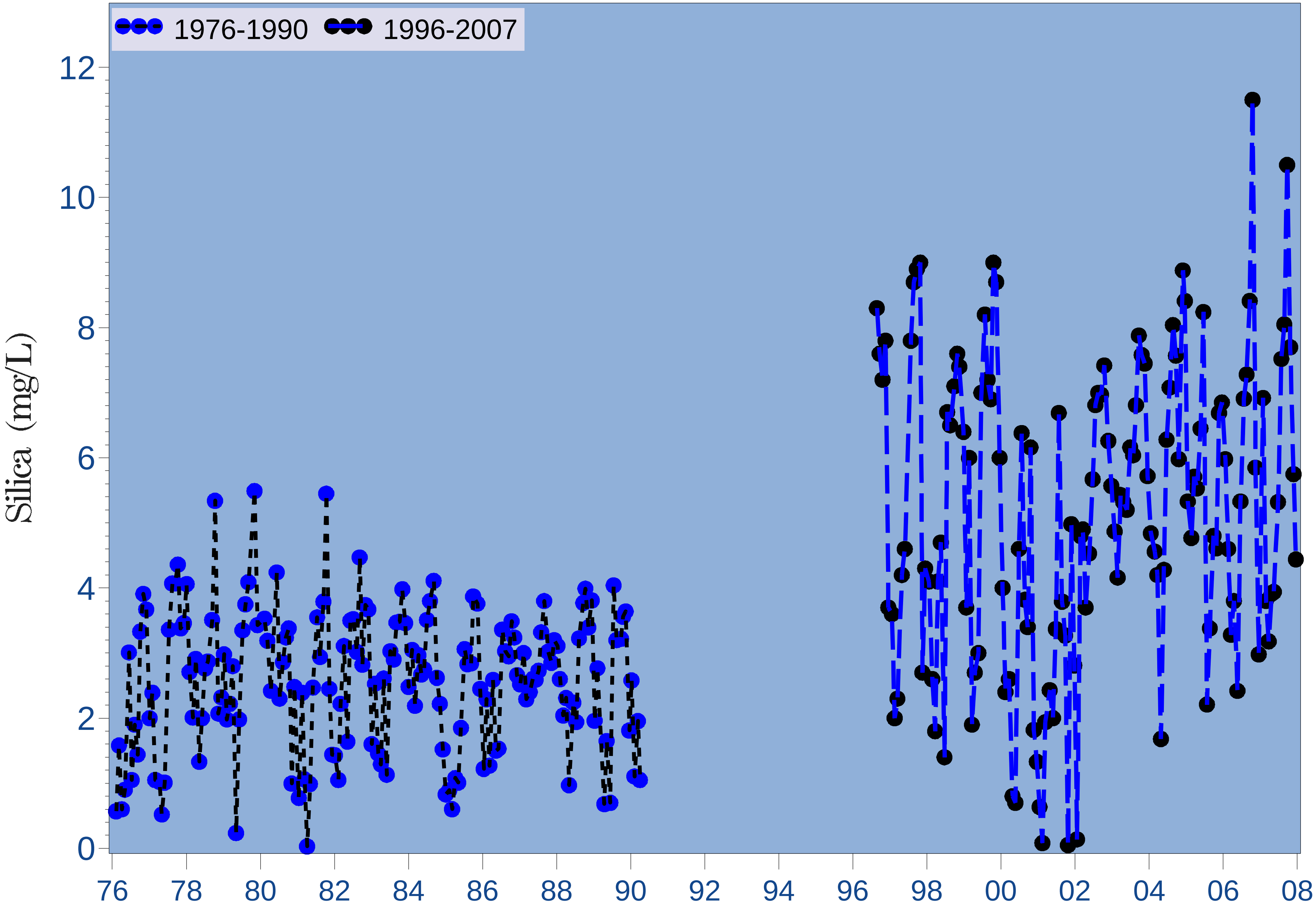

Figure 4.27d Monthly long-term bottom silica at river kilometer 23.6

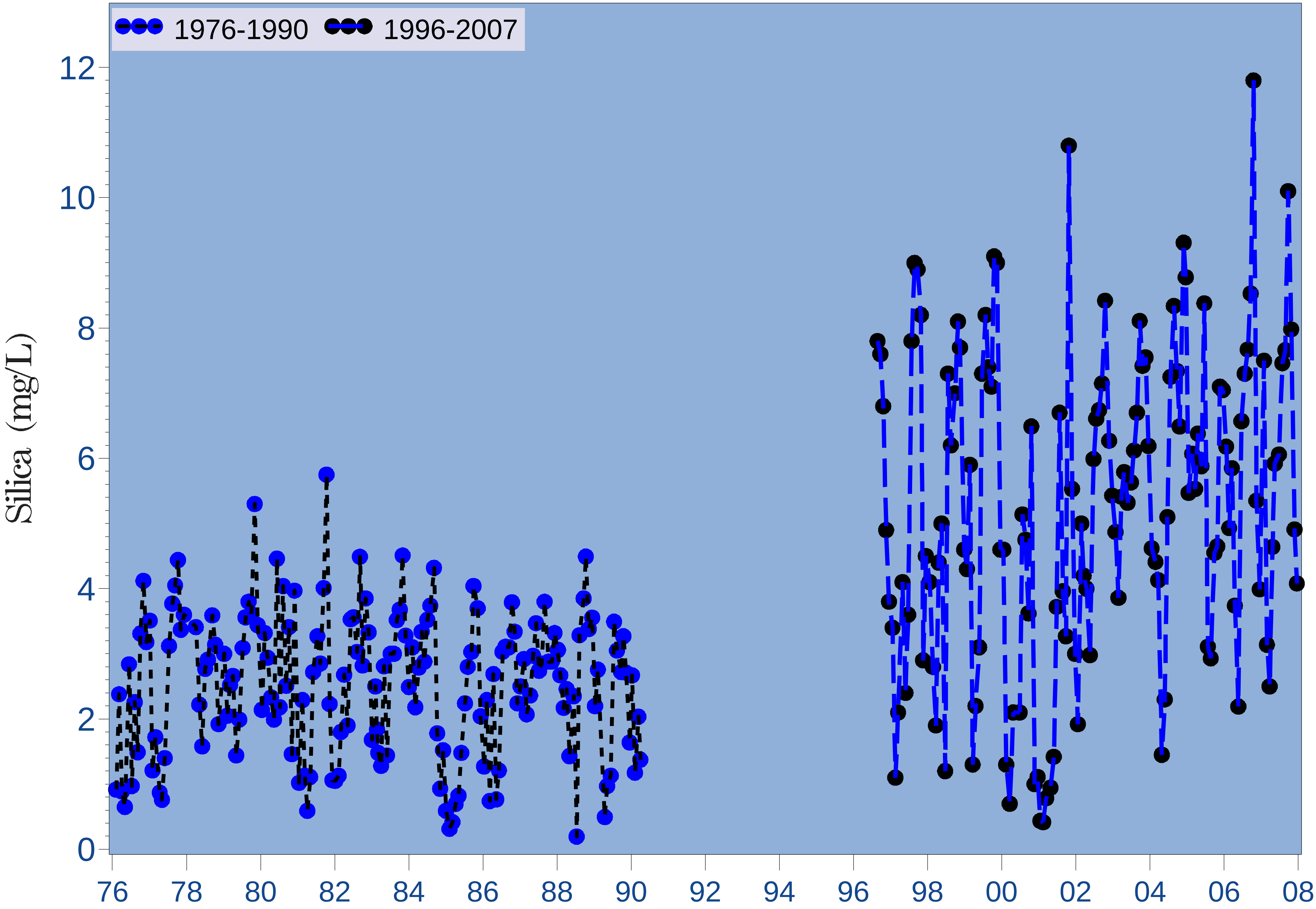

Figure 4.27e Monthly long-term bottom silica at river kilometer 30.4

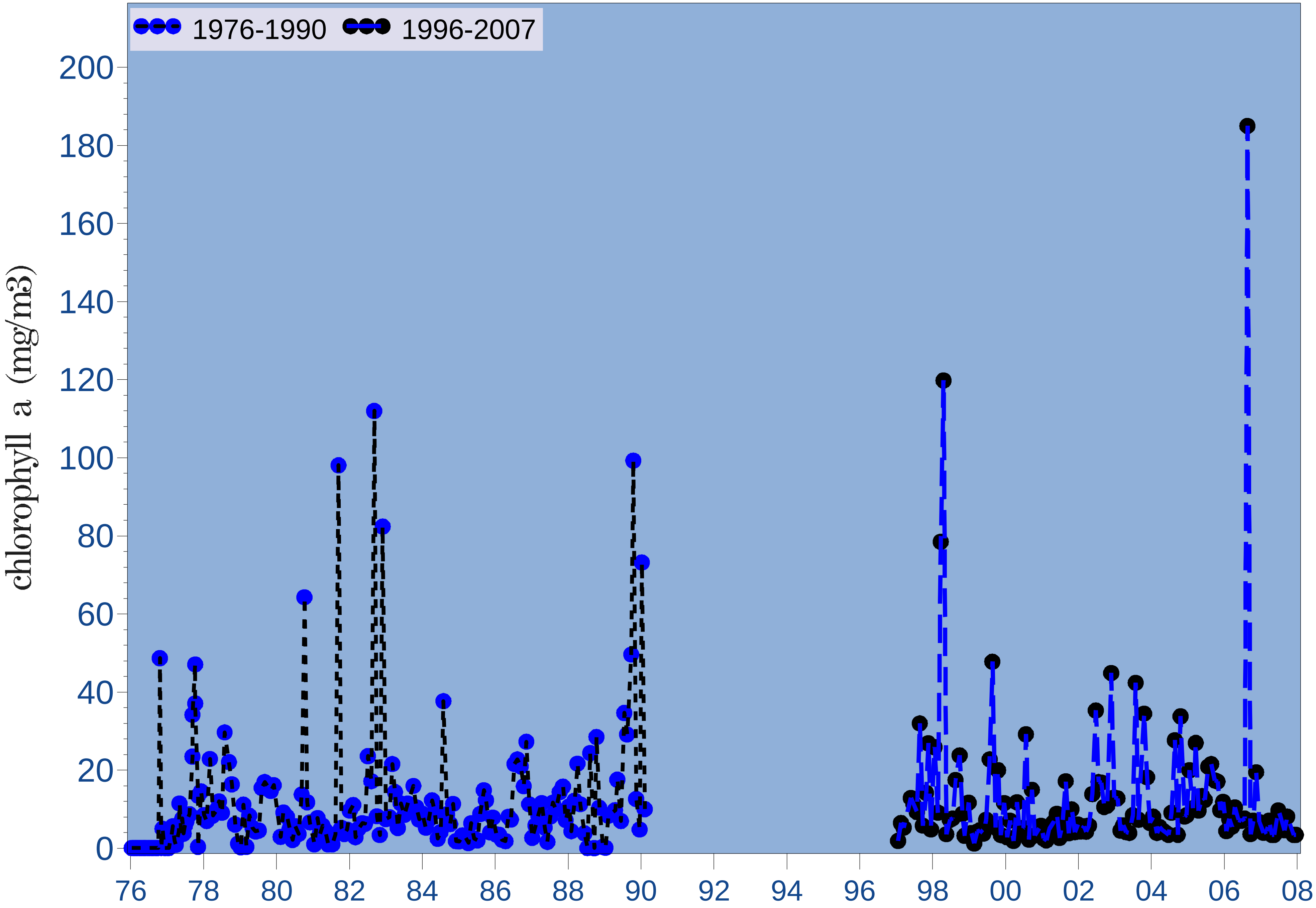

Figure 4.28a Monthly long-term surface chlorophyll a at river kilometer -2.4

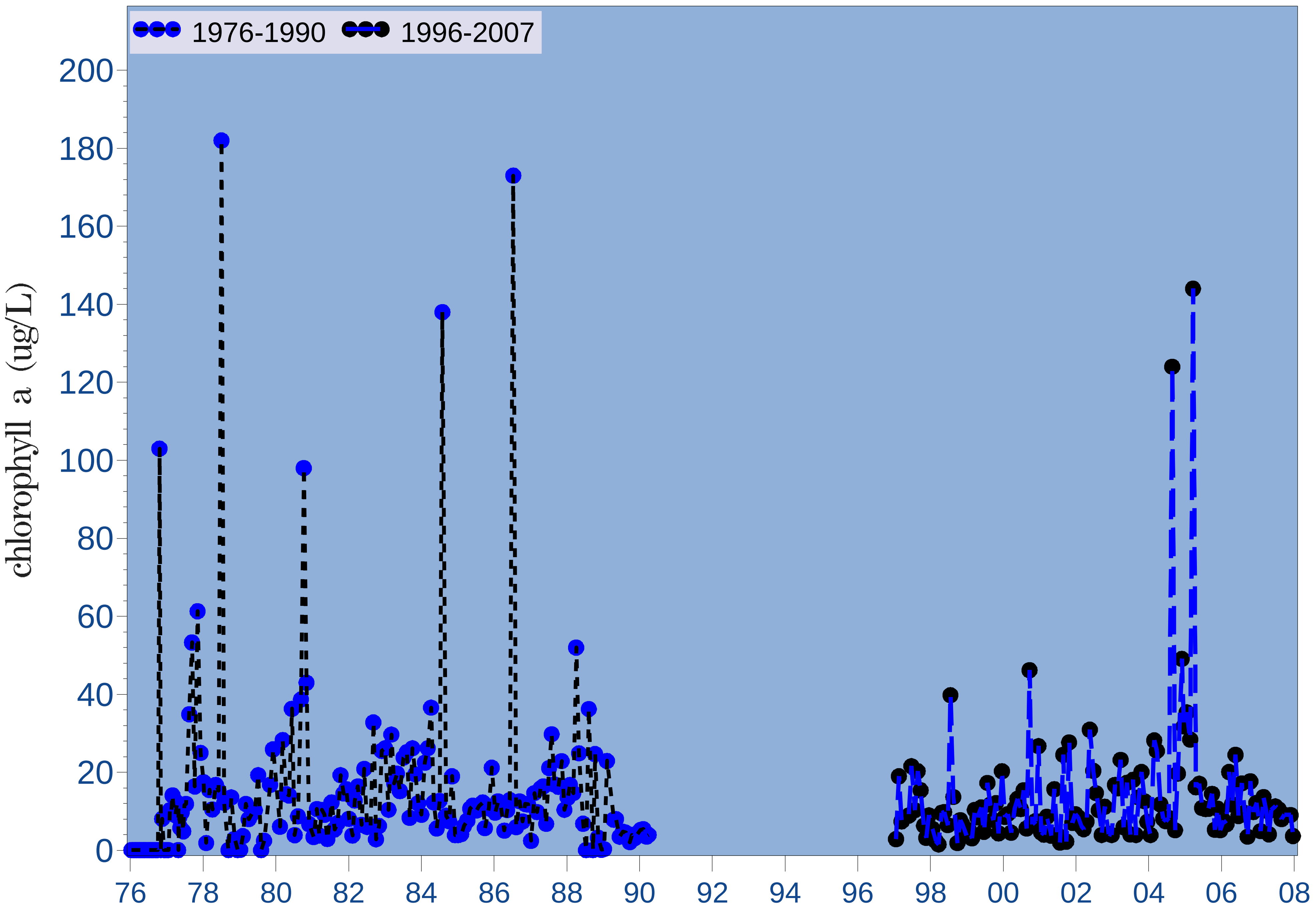

Figure 4.28b Monthly long-term surface chlorophyll a at river kilometer 6.6

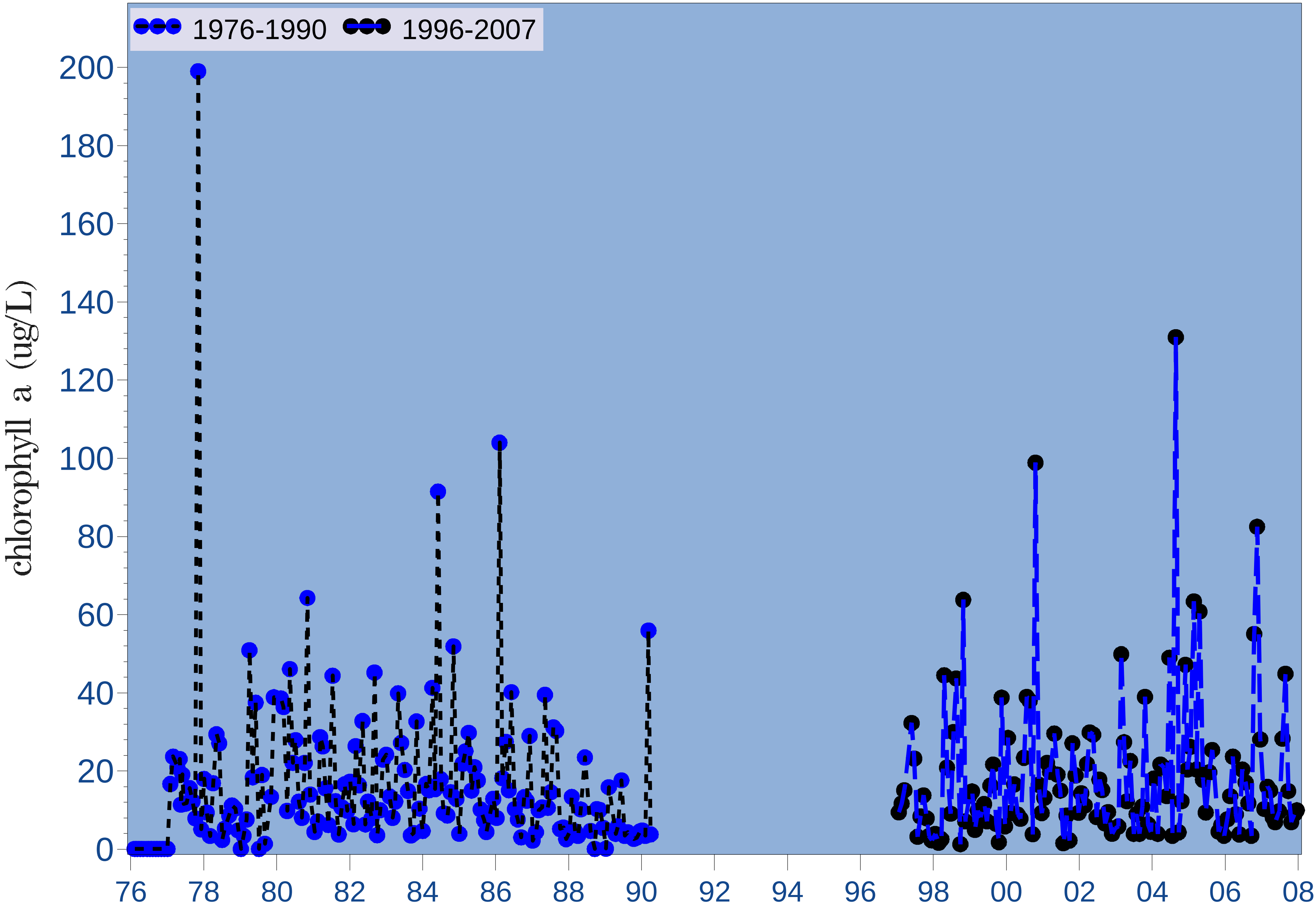

Figure 4.28c Monthly long-term surface chlorophyll a at river kilometer 15.5

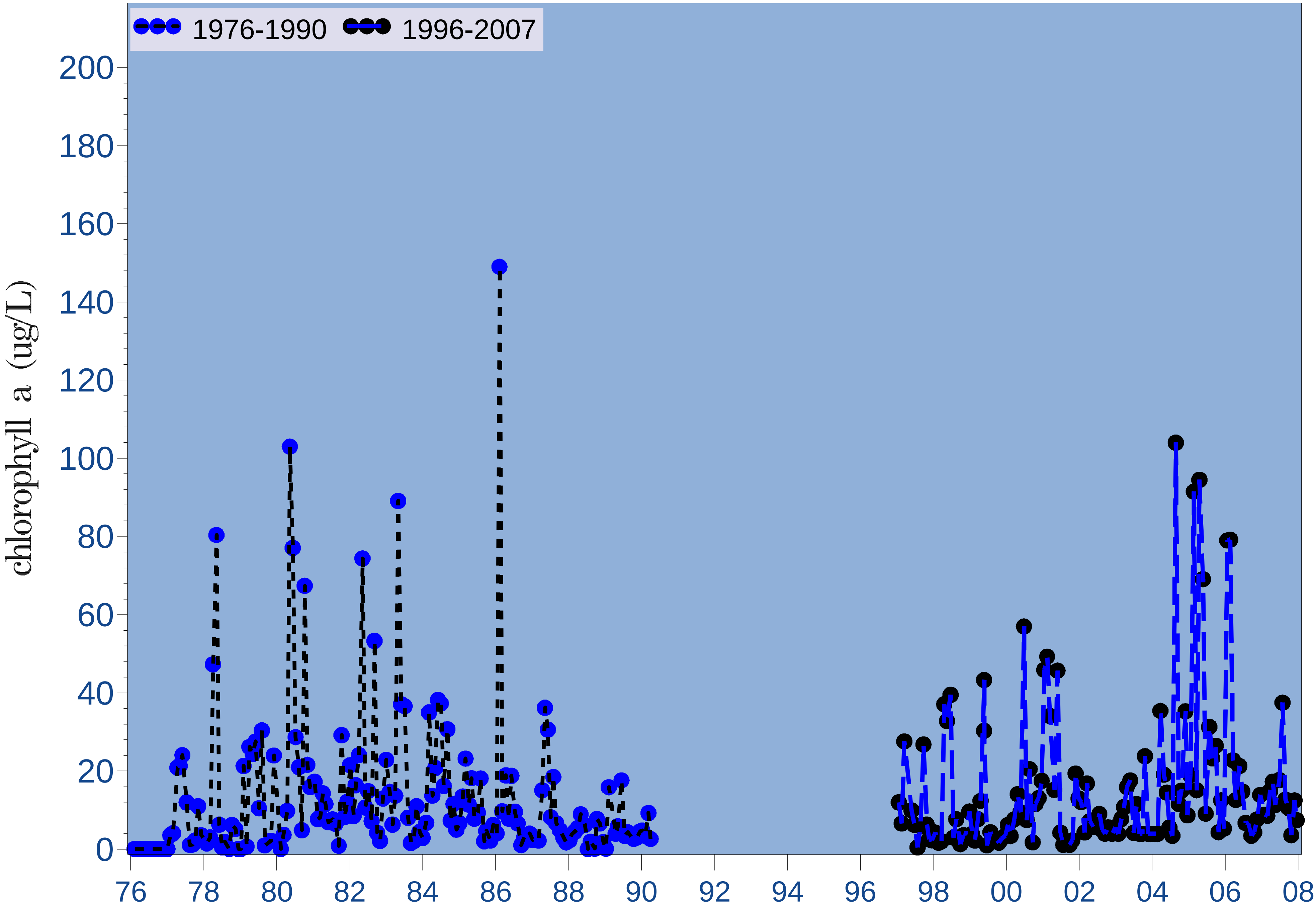

Figure 4.28d Monthly long-term surface chlorophyll a at river kilometer 23.6

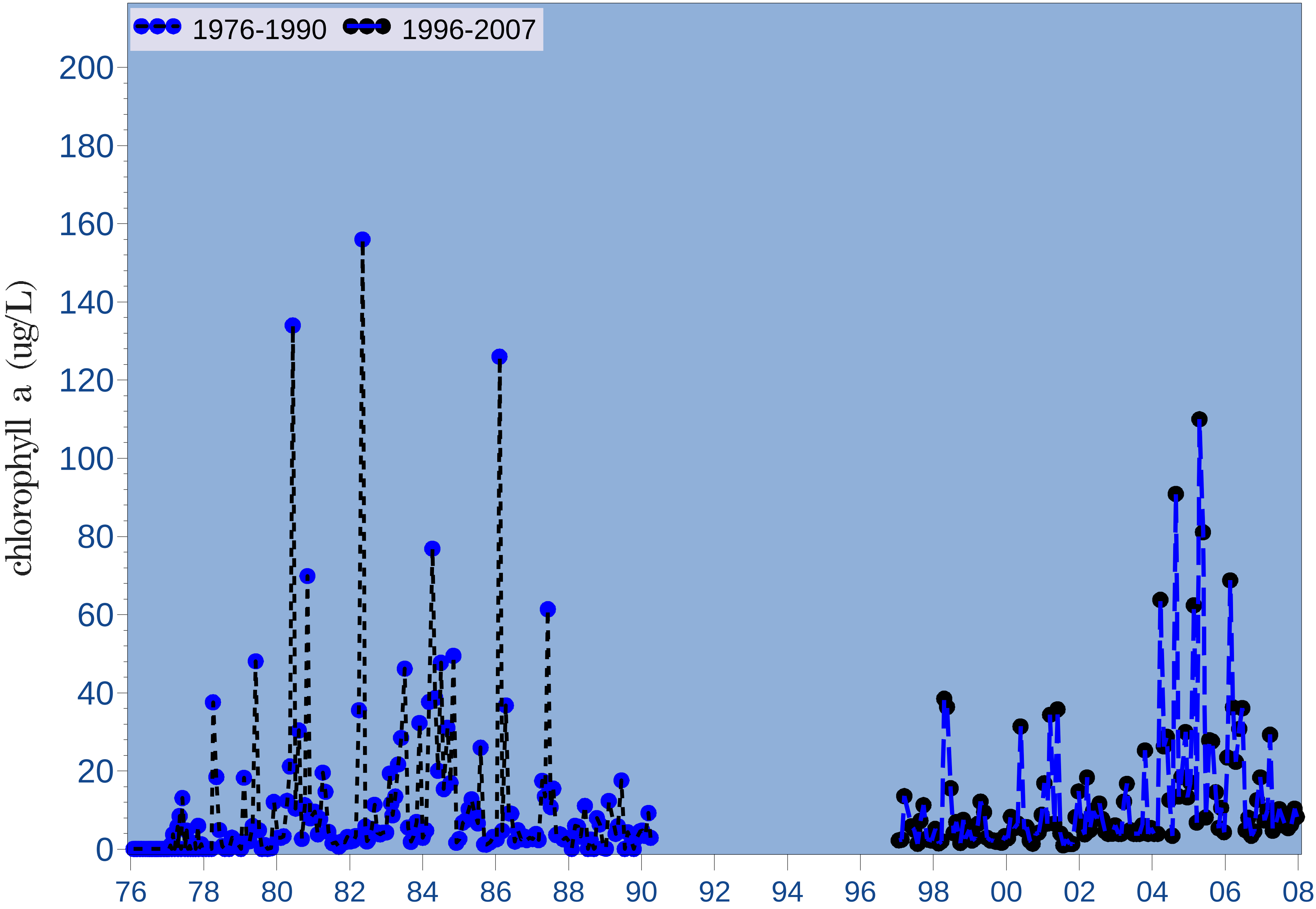

Figure 4.28e Monthly long-term surface chlorophyll a at river kilometer 30.4

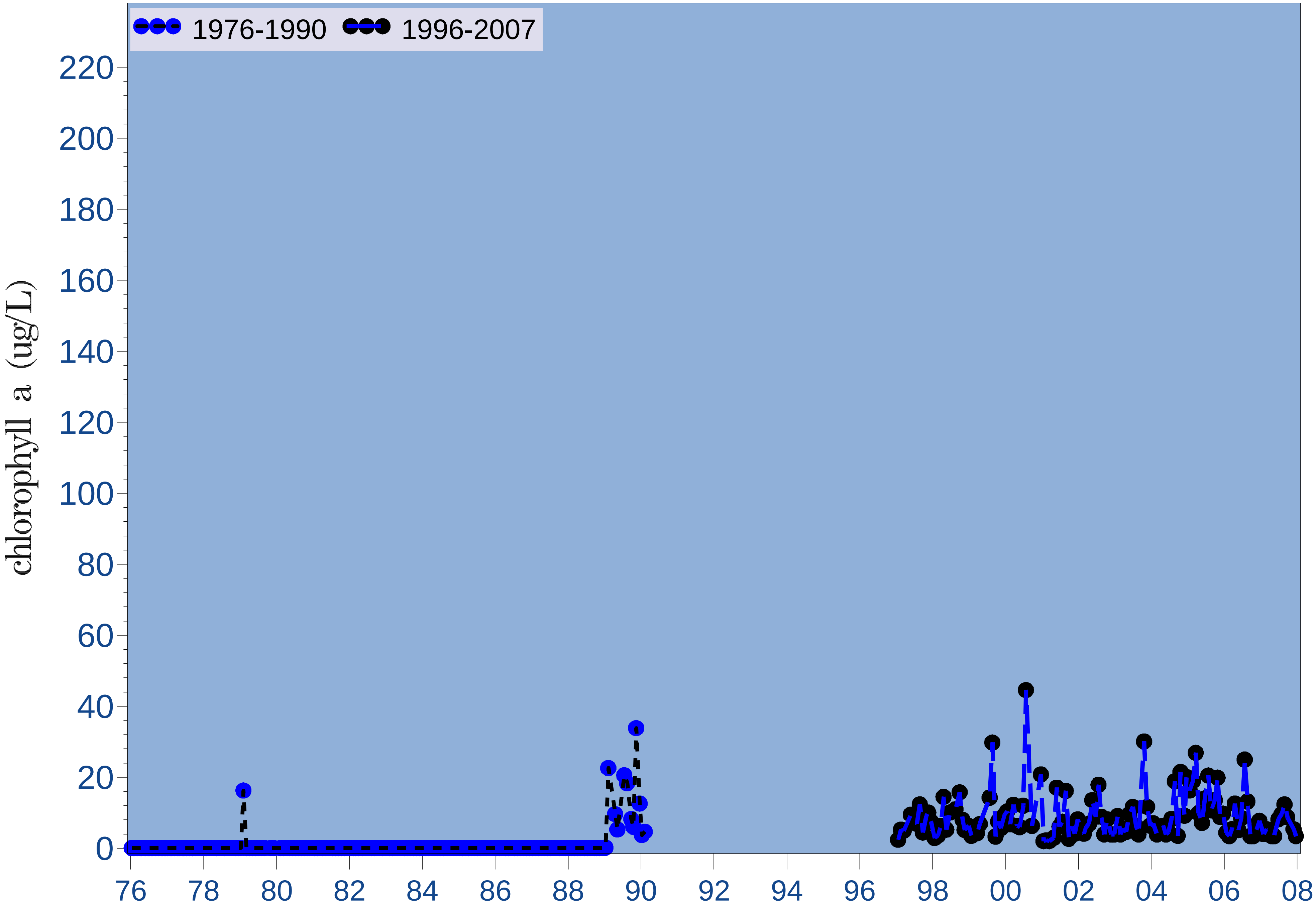

Figure 4.29a Monthly long-term bottom chlorophyll a at river kilometer -2.4

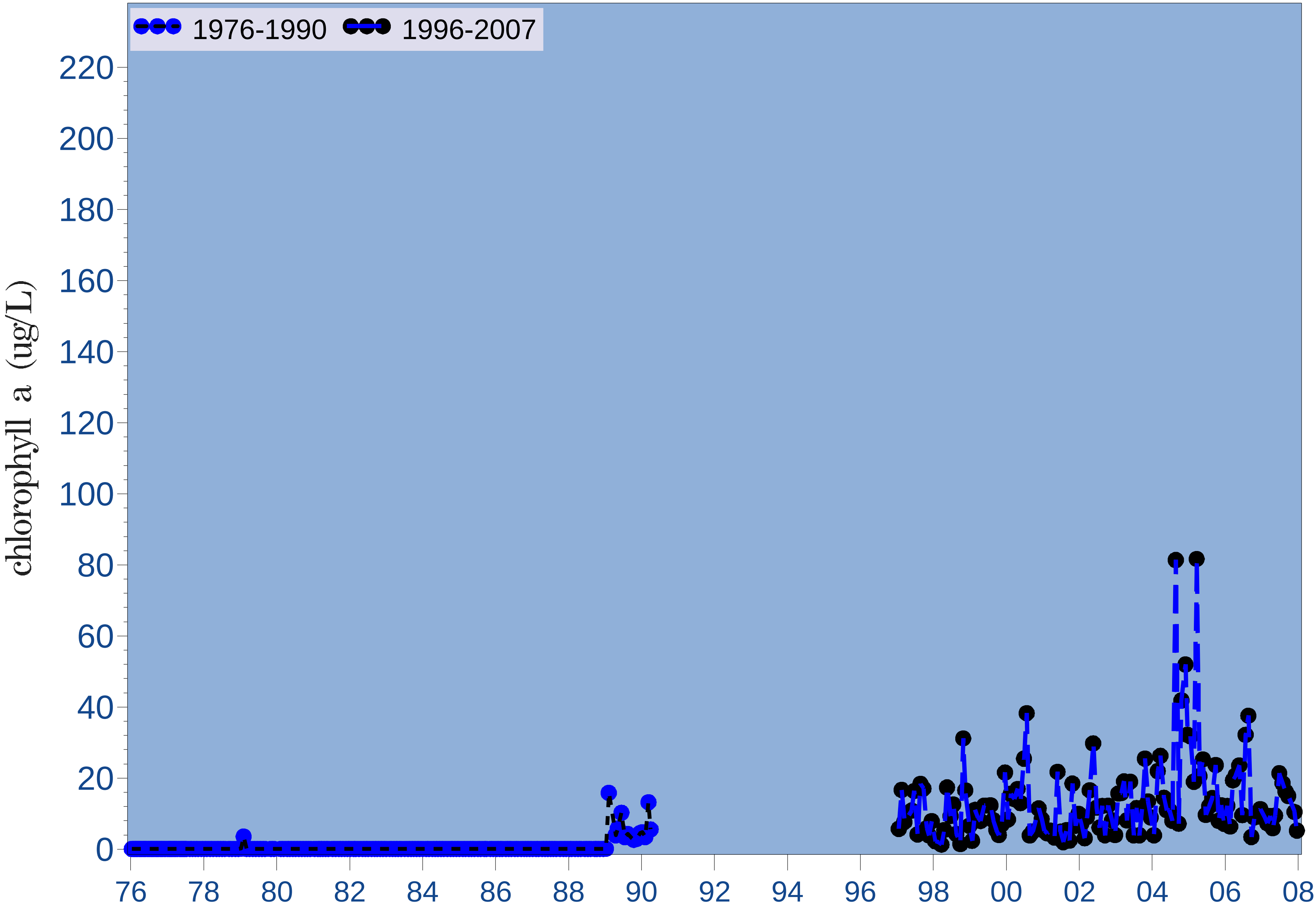

Figure 4.29b Monthly long-term bottom chlorophyll a at river kilometer 6.6

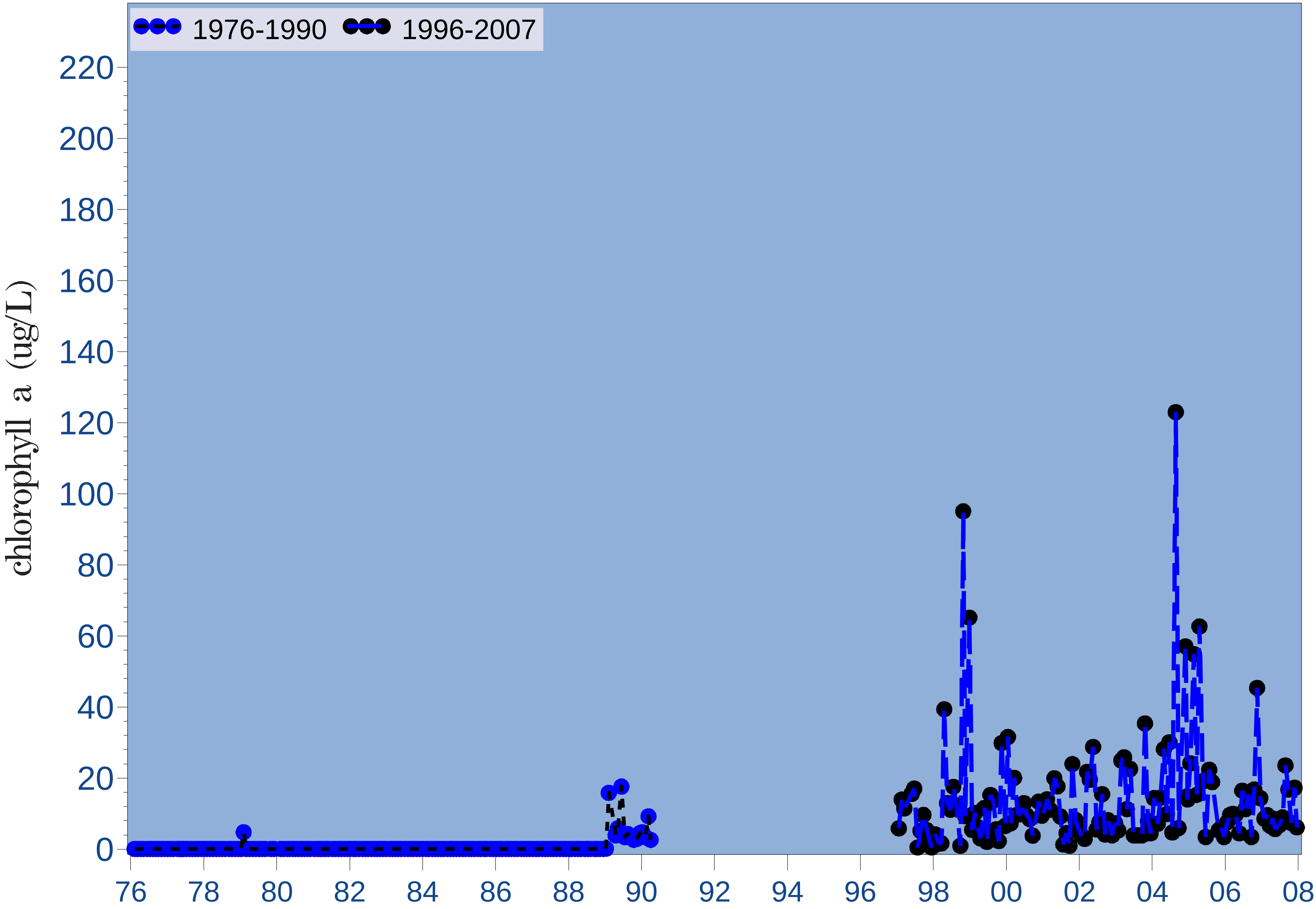

Figure 4.29c Monthly long-term bottom chlorophyll a at river kilometer 15.5

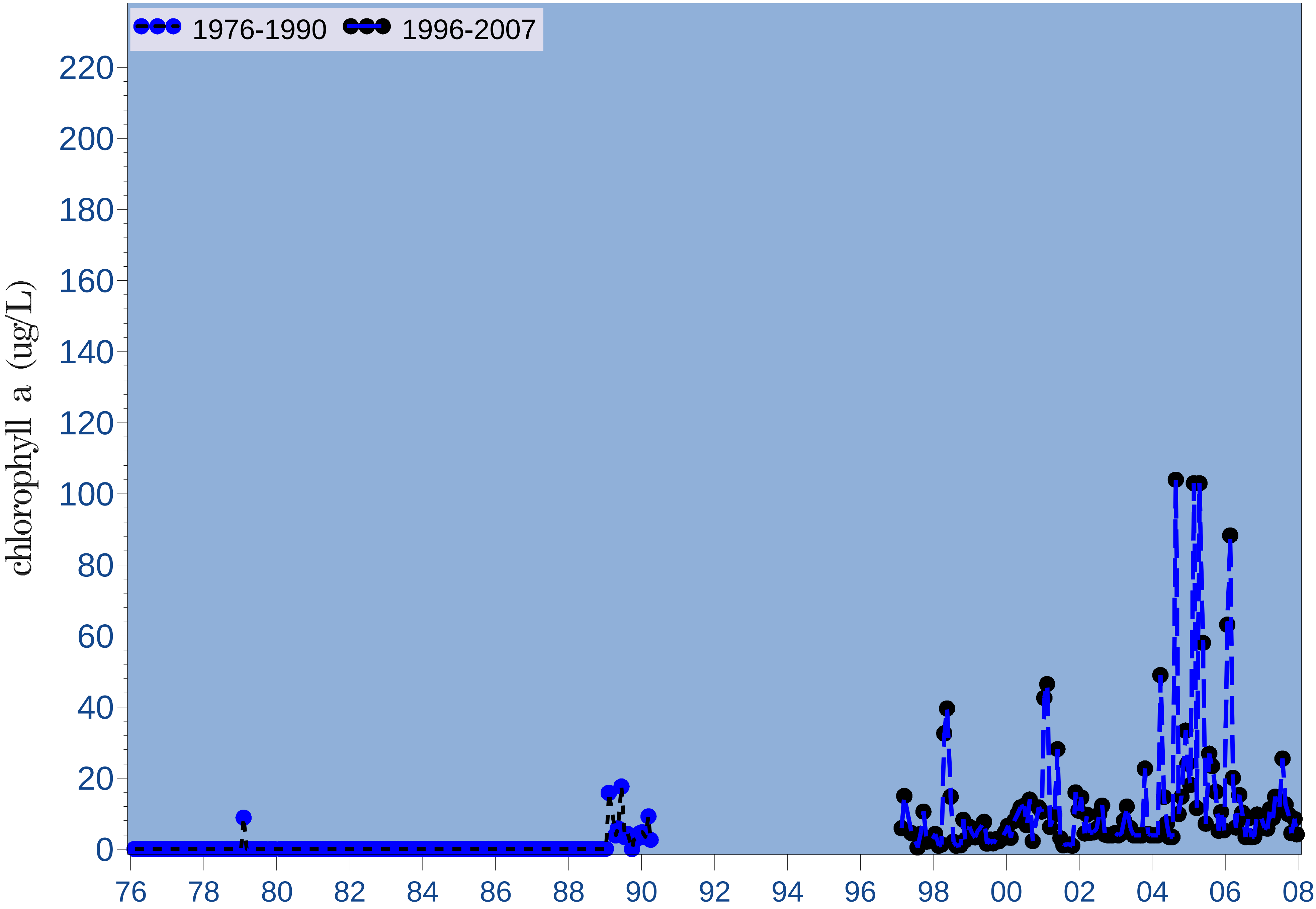

Figure 4.29d Monthly long-term bottom chlorophyll a at river kilometer 23.6

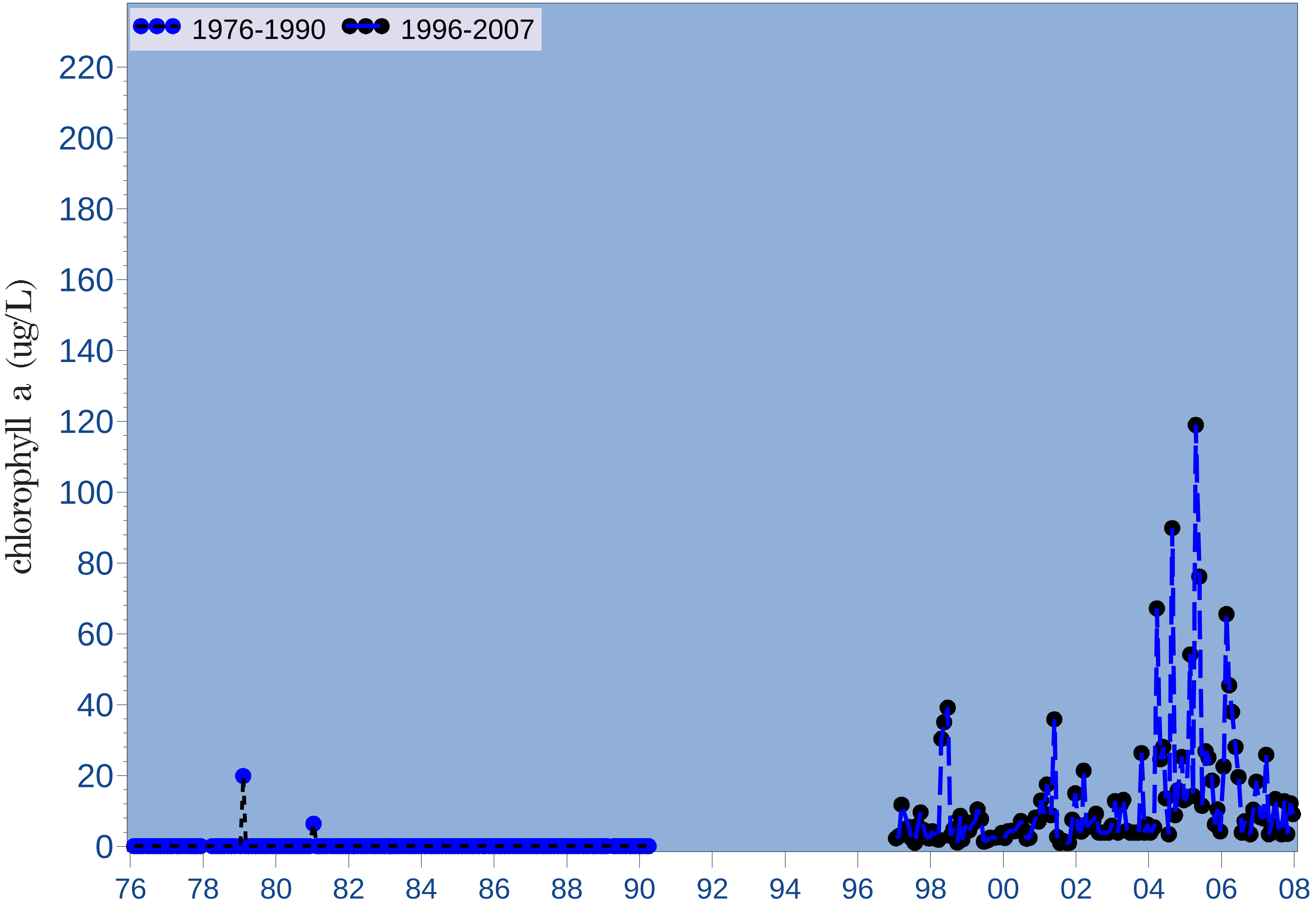

Figure 4.29e Monthly long-term bottom chlorophyll a at river kilometer 30.4