



PRMRWSA
Treatment
Facility

SR 761

Navigator
Marina



2017

HBMP Annual Data Report

Harbour
Heights

Shell Creek

I-75
Bridge

US 41
Bridge



**Peace River Hydrobiological
Monitoring Program
2017 HBMP Annual Data Report**

Required by

**Southwest Florida Water Management District
Water Use Permit 20010420.009**

Prepared for

Peace River Regional Water Supply Facility

**Peace River Manasota Regional
Water Supply Authority**



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Acknowledgments

The raw data, as well as the methods descriptions, presented in this report for the calendar year 2017 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 (Ft Myers Office)** – was responsible for all data collected at the three 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.
3. More recently the USGS installed a third recorder site designated as Peace River at Platt (02297345) located at the Facility’s intake structure (RK 29.8).

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://waterdata.usgs.gov/fl/nwis/sw/>)

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)

- **VHB/ESA** – was responsible during 2017 for conducting the special study chlorophyll transects and for monitoring eight Authority HBMP recorders located in the lower Peace River that continuously collect data at 15-minute intervals. Measurements at each of these eight surface recorder locations include surface conductivity and water temperature. Subsurface dissolved oxygen is further monitored at 15-minute intervals at RK 12.7 in conjunction with the measurements of conductivity and temperature.

Eight 2017 Ongoing Authority HBMP Lower Peace River Continuous Recorders

1. **RK 9.2** – Near surface conductivity and temperature are measured at 15-minute intervals from the HBMP continuous recording gage attached to a navigation marker located between the I-75 and U.S.41 Bridges. Data collection began in June 2011 and is continuing.
2. **RK 12.7 (surface)** – Near surface conductivity, temperature and dissolved oxygen are recorded at 15-minute intervals from the HBMP continuous recorder attached to a Manatee Speed Zone Sign located on the lower Peace River downstream of Shell Creek (River Kilometer 12.9). Data collection began in June 2011 and continues.
3. **RK 18.5** – Near surface conductivity and temperature are recorded at 15-minute intervals from the HBMP continuous recorder attached to a navigational aid located near the power line crossing. Data collection began in June 2011 and continues.
4. **RK 18.7 (Hunter Creek)** – Near surface conductivity and temperature are recorded at 15-minute intervals from the HBMP continuous recorder attached to a Manatee Speed Zone Sign located near the power line crossing near Jim Long Lake. Data collection began in June 2011 and continues.
5. **RK 20.8** – Near surface conductivity and temperature are recorded at 15-minute intervals from the HBMP continuous recorder attached to a navigational aid located just downstream on an island. Data collection began in June 2011 and continues.
6. **RK 21.9** – Near surface conductivity and temperature are measured 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). Data have been collected at this site since 2006.
7. **RK 24.5** – 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). Data have been collected at this site since 2006.
8. **RK 31.7** - Near surface conductivity and temperature are measured at 15-minute intervals from the HBMP continuous recording gage attached to the old railroad

trestle located on the Peace River upstream of the Facility (River Kilometer 31.7). Data collection also began in May 2008 and continues.

Three Previous Authority HBMP Lower Peace River Continuous Recorders

1. **RK 23.4** – 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. Data were collected from 2006 until May 2008, after which monitoring at this site was suspended.
 2. **RK 12.7 (bottom)** – Near bottom conductivity, temperature and dissolved oxygen were recorded at 15-minute intervals from the HBMP continuous recorder attached to a Manatee Speed Zone Sign located on the lower Peace River downstream of Shell Creek (River Kilometer 12.9). Data collection began in May 2008 and continued until June 2011 when the instruments were moved to record near surface measurements.
 3. **RK 30.6** - Near surface conductivity and temperature were measured 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 the Hwy 761 bridge (bridge River Kilometer 30.7). Data collection began in May 2008 and was discontinued in June 2011.
- **Peace River/Manasota Regional Water Supply Authority** – provided measurements of daily withdrawals by the facility, as well as data collected as part of an ongoing upstream watershed background monitoring effort.
 - **City of Punta Gorda** – provided measurements of daily withdrawals and data from the Shell Creek HBMP, as well as all historical data collected as part of their HBMP.
 - **Benchmark Laboratory** – conducted all HBMP water chemistry analyses conducted during 2017.

Sam Stone of the Peace River Manasota Water Supply Authority provided helpful comments of this report.

Lastly, a special acknowledgement is extended to Ralph Montgomery who, in his many years of work for the Authority, led the efforts of many in the pursuit of the understanding of the Peace River and its complexities.

Executive Summary

Historical Overview

On December 10, 1975, Consumptive Use Permit #27500016 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 whether freshwater withdrawals by the Peace River Regional Water Supply Facility (Facility) could be shown to alter these patterns.

Between 1979 and 2017, an ongoing series of reports have been submitted to the District, documenting the results of the HBMP during the period from January 1976 through December 2017. These reports include summarizations (findings) of data collected during the first four years of baseline monitoring, prior to the start of Facility freshwater withdrawals, as well as comparisons of historic data to the results obtained from the HBMP during subsequent years of water treatment facility operation. The period covered within this *2017 HBMP Annual Data Report* follows directly upon that contained within the preceding *2016 HBMP Annual Data Report* finalized in June 2017, as well as the *2016 HBMP Comprehensive Summary Report* finalized in October 2017. This current data report includes HBMP data collected over the period from January through December 2017, and represents the 27th year of data collection for the Peace River Manasota Regional Water Supply Authority (Authority), as owner/operator of the Facility.

The Facility has been operated by the Authority since 1991. However, the initial system was constructed by General Development Utilities and has been withdrawing water from the Peace River since 1980. The Facility's initial river water storage capacity was 625 million gallons in the form of an 85-acre off-stream surface reservoir. Additional storage capacity was added incrementally from 1985 through 2002 providing approximately 6.3 million gallons of treated water storage in 21 Aquifer Storage and Recovery (ASR) wells.

A major expansion in 2002 included increasing the Facility's treatment capacity from 12 mgd to 24 mgd (37.1 cfs), with raw river water diversion from the Peace River accomplished using four pumps having a combined maximum capacity of 44 mgd (68.0 cfs). Combined, the 2002 Facility expansions enhanced the Authority's ability to withdraw raw river water during periods of higher river flows for storage in the off-stream surface reservoir. Any excess treated potable water could also be stored in the system's underground ASR well system. Conversely, when water was unavailable from the Peace River as seasonal lower flows dropped below the established "low flow" cutoff of 130 cfs, water could be pumped from the raw off-stream surface water reservoir to the Peace River Facility for treatment, and/or alternatively previously treated water could be recovered from the ASR well system to meet regional service area water supply demands.

In 2009, the Authority completed its most recent major Facility expansion, which was undertaken in order to meet projected future regional water demands. This included increasing the river pumping capacity to 90 mgd (the upper limit of the 1996 permit), and doubling the Facility's treatment capacity to 48 mgd. An additional much larger regional 640-acre off-stream reservoir (with a capacity of 6 billion gallons) was also completed in 2009. Subsequently, the pumping capacity of diversions from the river was re-rated to 120 mgd. Further improvements as of late 2015 increased the Facility's treatment capacity and the Facility is now permitted to treat 51 mgd. Current planning includes additions and expansions to the system transmission pipe networks to expand and optimize water delivery throughout the four county service region.

A revised withdrawal schedule (**Table 1**) based on the District's adopted MFL was issued by the District to the Authority on April 26, 2011. This permit modification maintained the original 32.7 mgd yearly average, with a maximum monthly allowed average of 38.1 mgd. The permitted maximum daily diversions from the river were increased under the District Water Use Permit from 90 mgd to 120 mgd, in order to allow the Authority greater flexibility in utilizing the upgraded withdrawal structure on the river and further provide greater overall system reliability. Previous to implementation of the April 2011 revised withdrawal schedule, daily Facility's river withdrawals were based on the preceding daily average flow measured at the USGS Arcadia gage. The District's revised permitted withdrawal schedule utilizes the previous day's combined flow based on the readings from three USGS gages upstream of the Facility located on the Peace River at Arcadia, Horse Creek near Arcadia, and Joshua Creek at Nocatee. The low flow cutoff for Facility withdrawals however remained the same as previously permitted at 130 cfs, but was also changed to reflect the combined flow of the three upstream gages.

Table 1
April 2011 Revised Authority Lower Peace River Withdrawal Schedule
(based on combined USGS gaged flow at three upstream gages)

Block	Allowable Percent Reduction in Flow	
Block 1 (April 20 th – June 25 th)	16% if flow is above 130 cfs	
Block 2 (October 27 th – April 19 th)	16% if flow is > 130 cfs	28% if flow > 625 cfs
Block 3 (June 26 th – October 26 th)	16% if flow is > 130 cfs	28% if flow > 625 cfs

Two additional modifications were made to the Facility's water use permit in 2011. The first occurred in October 2011 and made small adjustments in the allowable annual average withdrawal increasing it from 32.7 mgd to 32.855 mgd. This permit modification also increased the allowable monthly maximum from 38.1 mgd to 38.3 mgd. Both modifications increased system reliability. The final permit modification occurred in November 2011 and didn't change any of the permit conditions other than changing the expiration date of the 1996 Water Use Permit from 2016 to 2037, in order to conform to the length of the Facility's existing bonds and to conform to new District rules allowing longer-term permits.

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 lower Peace River/upper Charlotte Harbor estuary resulting from Facility 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 estuarine system. Historically, water quality is the monitoring element that has had the longest history and is aimed at assessing direct relationships with temporal variations in freshwater inflow. 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 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 the Water Use Permit (WUP) #20010420 for implementation in 1996 and subsequent years. The Peace River Facility's 1996 Water Use Permit initially required 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 further included major expansions of both the physical and biological elements of the Hydrobiological Monitoring Program. (Note: One of the recommendations of the *2006 HBMP Comprehensive Summary Report* was the replacement of the Mid-term HBMP Reports with more focused, topic-specific reports. These focused reports would be designed to address specific issues and analyses suggested by the HBMP Scientific Review Panel, which supported this recommendation to the District).

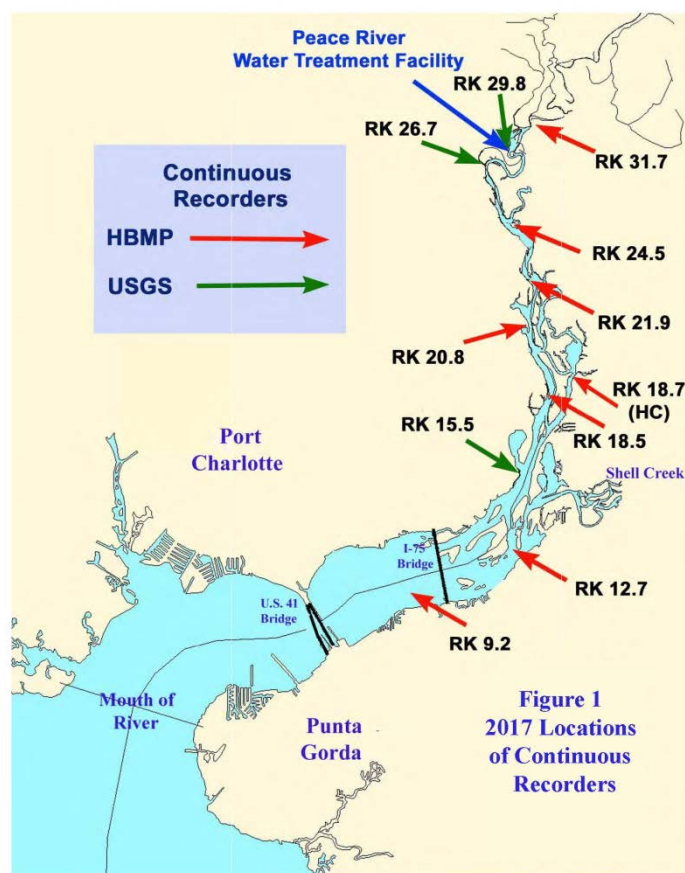
USGS Continuous Recorders – The primary goal of this HBMP study element has been to develop an extensive database of short-term changes in surface and near-bottom salinity in the lower Peace River. In 1996, the USGS installed an automated 15-minute interval water level conductivity and stage recorder 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 River Kilometer (RK) 26.7 just downstream of the Facility (**Figure 1**), and in December 2009, a third recorder was installed by USGS at the Facility's intake (RK 29.8).

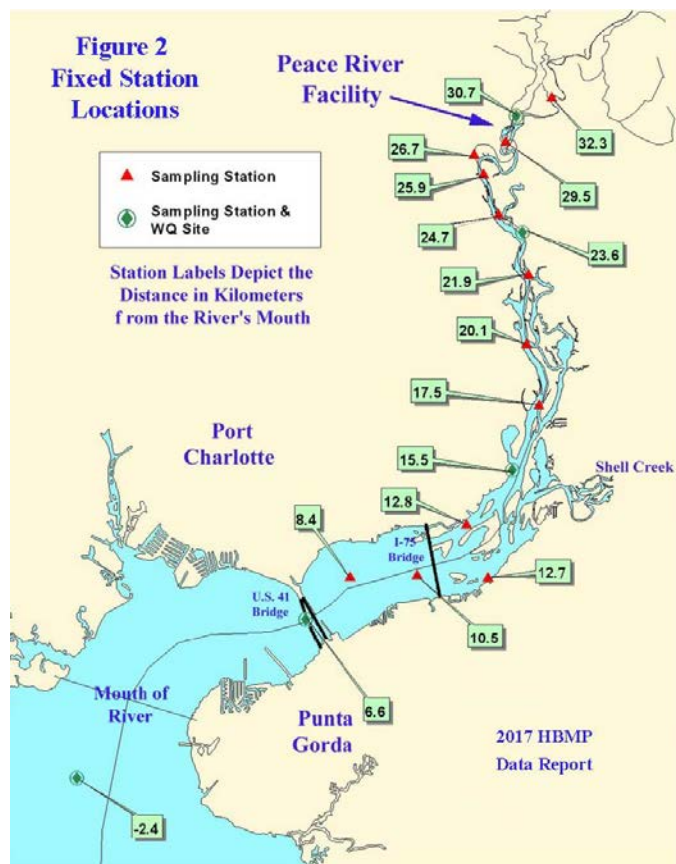
As indicated in previous HBMP annual reports, both surface and bottom conductivities at the downstream Harbour Heights site (RK 15.5) are very strongly influenced by tide (water stage) during periods when river flows are relatively low. During the wet season, this lower reach of the Peace River is characteristically 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.

At the more upstream continuous USGS gage at Peace River Heights (RK 26.7), the data collected in 2017 showed lower surface and bottom conductivities than those observed further downstream, but still more variable during the drier month of May than during the wetter month of July. The May 2017 results at the Peace River Heights gage were less than those observed during many previous drier spring periods. This contrasts to less frequent wetter May conditions (such as occurred during 2005), when corresponding May data indicated only small, infrequent differences in conductivity (usually less than 100 uS/cm) resulting from daily tidal variations. During the wet season in July 2017, conductivities at this upstream USGS gaging site were low, and did not noticeably respond to daily tidal variations.

At the most upstream Platt USGS recorder located at the Facility intake (RK 29.8), data collected in May 2017 showed little daily variation in conductivity in response to tides. This is in direct contrast to May 2012 when much drier conditions resulted in tidal conductivity changes in the range of 4,000 to 8,000 uS/cm (approximately 2.0 to 4.5 psu). As expected, under the higher wet season flows (July), there was no indication of tidal influences on measured conductivities.

Additional Authority Continuous Recorders – The HBMP recorders located along the HBMP monitoring transect (Figure 1) and installed during 2005, 2008, and 2011 by the Authority spatially showed similar patterns during 2017 to those described for the recorders at the three USGS continuous monitoring sites. Spatially, daily and longer term temporal changes in surface conductivities (salinity) at the HBMP recorder locations typically showed a far greater degree of daily tidal variability during periods of low flow, in comparison to usually much smaller (and spatially limited) tidal changes observed during intervals of higher freshwater upstream inflows.





Water Chemistry and Water Column Physical Profiles – This HBMP program element is primarily spatially focused along the HBMP monitoring transect centerline (**Figure 2**), which extends from below the mouth of the river (an imaginary line between Punta Gorda Point and Hog Island) to upstream of the Facility to where Horse Creek enters the lower Peace River. Two separate HBMP study elements incorporate sampling both *in situ* water column profile physical measurements combined with the determination of chemical water quality characteristics along the HBMP monitoring transect. Several objectives are associated with both the individual and combined findings of these water quality monitoring 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. Where such relationships exist, a further objective then becomes to determine the potential magnitude/timing of change that might result from both existing and projected future permitted Facility withdrawals. The potential for impacts can then be accessed through comparing predicted changes due to withdrawals with the normal ranges of observed natural seasonal and annual variability.

Standardized, 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 μmS . Historically, this isohaline sampling effort was undertaken in conjunction with other long-term phytoplankton elements of the

HBMP. In addition, a surface water sample is also collected at RK 30.7 (historic Station 18).

2. Approximately two weeks after the collection of the “moving” isohalines, water column physical profiles are conducted, near high tide, at 16 “fixed” locations along a transect running from just below the river’s mouth upstream to a point just above the Peace River Facility (Figure 2). In addition, chemical water quality samples are taken at five of these locations (including RK 30.7).

Both of these water quality HBMP study 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 each sampling location. 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 2017 HBMP Study Results

The following compares data collected during 2017 with similar average values for key parameters previously compiled in conjunction with elements of the ongoing long-term monitoring programs. This summary includes comparisons of:

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 2017 data with similar data collected over the preceding 40-year period (1976-2016), it should be noted that rainfall/flow have annually varied considerably during the recent historic period.

- 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 (with the later two years characterized by a number of tropical depressions/hurricanes during the summer wet season).

- Rainfall in the Peace River watershed during the recent 2006-2009 interval by comparison was well below the historic long-term average.
- More recent seasonal rainfall patterns during both 2010 and 2013 were near or above normal, while the drier seasons of 2011 and 2012 were well below normal.
- Conditions in 2015 and 2016 were characterized by average to above average flows with higher than normal flows occurring in months from both the typically wet (August-September) and dry (February) seasons.
- Conditions in 2017 were characterized by normal to below normal dry season flows, but well above normal wet season flows.

Flows – Total daily gaged flows for the three combined gages upstream of the Facility over the HBMP period are shown in **Figure 3**. Average mean daily Peace River flow during 2017 was 1,948 cfs, which is above the 1,202 cfs average over the HBMP monitoring period (1976-2017). Overall, annual mean flow upstream of the Facility during 2017 was 164.2 percent of the average daily flow over the long-term 1976-2017 period.

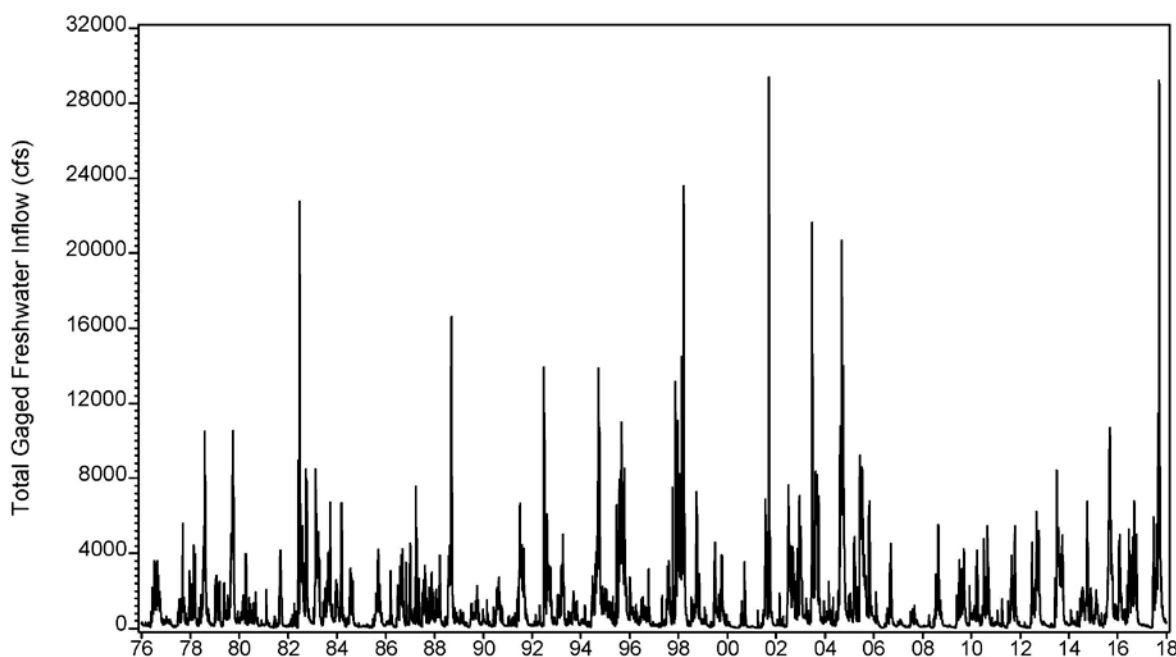


Figure 3. Total daily gaged flow at Facility – Peace River at Arcadia + Horse and Joshua Creeks (1976-2017)

Withdrawals – Total Peace River Facility withdrawals during 2017 were approximately 3.1 percent of the total gaged freshwater flow measured at the USGS Arcadia gage, 2.4 percent of the upstream gaged flow at the Facility, and 1.7 percent of the combined average daily inflows upstream of the U.S. 41 Bridge. During the entire period of Peace River Facility withdrawals (1980-2017), total combined withdrawals have been approximately 2.1 percent of the corresponding gaged Peace River at Arcadia flows, 1.6 percent of total gaged flow upstream of

the Facility, and only 1.2 percent of the combined daily freshwater flows of the Peace River, and Horse, Joshua, and Shell Creeks.

Occasionally, Peace River Facility withdrawals exceeded the seasonally designated maximum percent allowed by the April 2011 revised permit withdrawal schedule. Such exceedances of the permitted percent withdrawals primarily result from subsequent USGS revisions 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 2017, the facility did not withdraw any water from the river on 152 days or approximately 42 percent of the time. Maximum daily Facility withdrawals increased both in 2002 and 2009 due to the completed Facility expansions, which resulted in increases in the Authority's ability to divert, treat, and store larger daily amounts of freshwater when river flows meet the District's threshold criteria. The 2011 revised withdrawals schedule further increased the amounts of water the Facility was able to take from the river, especially under periods of higher flows.

Water Temperature – Surface and bottom water temperatures in 2017 followed the strong seasonal pattern typically observed in south Florida. Water temperatures reach their highest levels during the wet season, and were relatively similar across months of the wet season (June-September), and along the spatial transect. Dry season temperatures, spanning January-May and October-December) displayed greater variability between months. Historically, the annual peak in water temperatures in the estuary varies between June and August depending on annual variations in cloud cover and differences in seasonal rainfall patterns. The 2017 data show relatively normal cold conditions during the start of the year with typical winter cold fronts.

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 (DO) levels in response to increased wet-season flows. This seasonal pattern typifies the widely documented hypoxic/anoxic conditions that typically occur 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 high summer wet season. 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. During 2017 (as typically observed in previous years), dissolved oxygen levels generally declined as water temperatures increased, resulting in DO levels reaching their lowest levels during summer wet season throughout both the lower river and upper harbor as both water temperatures and flows increased. The 2017 wet season column profile data (as has occurred since 2010) indicated the return of normal hypoxic/anoxic dissolved oxygen levels in the upper harbor. Such normal summer/high flow low DO levels did not occur (or were far less in magnitude/duration) during the extended 2006-2009 drought. This indicates that the flows that occurred during the summer of 2017 were again of sufficient duration and intensity to induce the level of water column stratification necessary to cause the development of widespread extremely low near-bottom dissolved oxygen levels in upper Charlotte Harbor.

Light Extinction – The 2017 HBMP data indicate that both the timing and magnitude of the ability of light to penetrate into the water column (1 percent depth) exhibits 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, light extinction in the lower Peace River/upper Charlotte Harbor estuarine system is often primarily mediated by existing water color due to the “black water” characteristics of freshwater inflows from the Peace River watershed. Water clarity during 2017 (as in previous years) was the greatest in the lower river, and especially in the upper harbor, during the typical spring dry season and other periods of lower flows. The influences of the summer wet-season rainfall conditions are clearly evident in comparing the one percent light depths observed between the more downstream lower river/upper harbor monitoring locations with the upstream characteristically freshwater reaches of the lower river.

Conductivity/Salinity – Seasonal changes in flow influenced the temporal and spatial patterns of 2017 conductivity (salinity) throughout the lower Peace River/upper Charlotte Harbor estuarine system. Seasonally spatial conductivity patterns in the tidal lower Peace River were reflective of the normal to below normal dry-season flows and above normal wet-season flow in 2017. Late fall conditions with low river flow occurred over much of the previous decade, allowing brackish conditions in the lower river to often extend upstream even beyond the Peace River Facility intake structure. Such relatively high salinity conditions in the lower river were especially noticeable during the extended droughts that affected southwest Florida and the Peace River watershed during much of the 1999-2001 and 2006-2009 periods. During these years, very high conductivities were observed even at the most upstream sampling locations during the extended periods of low freshwater 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 limits phytoplankton growth. The data typically indicate a distinct spatial gradient within the lower river/upper harbor estuarine system with higher levels of inorganic nitrogen progressively occurring upstream. Nitrite+nitrate nitrogen levels in 2017 were similar to the longer-term averages at each of the five fixed-station locations.

Total Kjeldahl Nitrogen – Typically, total Kjeldahl nitrogen concentrations in the lower Peace River/upper Charlotte Harbor estuarine system are the highest during the summer wet season, reflecting the influences of increased freshwater inflows, and this is reflected in 2017 measurements. Overall, during 2017, the annual average Kjeldahl concentrations were slightly lower than the historic long-term averages.

Ortho-Phosphorus – Inorganic phosphorus concentrations in the Peace River Estuary follow patterns typical of conservative water quality constituents (reflecting dilution rather than biological uptake). 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 Charley in August 2004 (and the subsequent Hurricanes Frances and Jeanne storms in September 2004), 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. However, the periods following Tropical Storm Emily and Hurricane Irma in 2017 were not marked with the increases seen in 2004. The direct cause for the increased levels seems to have been related to the discharges of water during the closure of the Ft. Meade phosphogypsum stack system and general phosphate mining operations in the upstream Whidden Creek subbasin. Phosphorus concentrations began to decline during 2009 and have continued to decline to previous observed lower levels. Inorganic ortho-phosphorus levels in 2017 at the five fixed monitoring sites were similar to the mean long-term values.

Silica – Historically, annual reactive silica concentrations in the Peace River estuary characteristically have indicated a number of differing temporal and spatial patterns. During the spring dry season, silica levels were normally at their annual lowest concentrations 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 increased and the start of the summer wet-season began, concentrations characteristically rapidly increased throughout the estuary. Reactive silica concentrations during 2017 continued to reflect the recently observed pattern of increased levels noted in previous HBMP reports, with 2017 average silica levels greater than the long-term averages. The increasing silica levels seem to have been associated with the closing of the Ft. Meade phosphogypsum stack system and general phosphate mining operations in the upstream Whidden Creek subbasin. However, unlike phosphorus concentrations, silica levels have continued to be near historic high seasonal levels through much of the estuary.

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 differ both seasonally and spatially among the HBMP “fixed” sampling locations. Typically, chlorophyll *a* phytoplankton biomass in the lower Peace River/upper Charlotte Harbor Estuary shows 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. However, the occurrences of spring phytoplankton increases are often muted during drought conditions such as those that characterized the 2006-2009 time interval. The common occurrences of such spring and fall phytoplankton increases have often been noted in conjunction with the HBMP isohaline-based monitoring program. The spatial distribution of measured chlorophyll *a* phytoplankton biomass along the HBMP sampling transect during 2017 exhibited one or two relatively high spikes (blooms) in phytoplankton biomass. The mean values for the five fixed-station monitoring locations in 2017 were similar to the long-term averages.

Long-term Changes in Upstream Water Quality

Analyses of long-term water quality data from both the fixed and isohaline monitoring program study elements presented in this and previous HBMP reports have identified several important recent and longer term changes in water quality that have occurred upstream of the Facility that

may influence both aspects of operations and/or the biological communities of the estuarine system.

- There have been long-term, progressive increases in the conductance of the water coming downstream to the Facility during the drier months of the year. This trend has been accompanied by increasing volumes of water (base flow) during the normally seasonal drier time intervals. These changes over recent decades have been primarily associated with increasing land conversions from less to more intense forms of agriculture that increasingly rely on irrigation using high conductivity water pumped from the upper Floridan aquifer. Such changes are particularly apparent in the Joshua and Horse Creek basins in the southern portions of the Peace River watershed. The upstream changes in water quality (conductance, chlorides, and TDS levels) originating from agricultural discharges during the dry season have yet to be a serious hindrance to water supply operations. However, such changes may become a problem in the future if the current trends in the contributing upstream basins continue.
- Silica levels in the lower Peace River/upper Charlotte Harbor estuary have increased over the past decade. More recently, phosphorus levels in the lower Peace River that had historically shown dramatic declines during the late 1970s and 1980s had returned to levels not observed in decades, before more recently again declining to previous lower levels. These observed changes in long-term HBMP data, combined with the Authority's watershed monitoring and the District's watershed ambient surface water quality monitoring, indicate that these recent changes coincide well with the previous closure of phosphogypsum stacks and general phosphate mining operations and associated discharges in the Whidden Creek subbasin.

Conclusions

This document represents the 22nd Annual Data Report submitted under the expanded Hydrobiological Monitoring Program (HBMP) initiated in 1996 in compliance with Water Use Permit 20010420. 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 2017, other than those previously noted. These include:

- Freshwater inflows during 2017 were influenced by lower than average rainfall during the dry season and higher than average rainfall conditions during the typical summer wet season.
- The previously noted long-term increase in reactive silica concentrations noted at the lower Peace River/upper Charlotte Harbor monitoring locations continued.
- Inorganic phosphorus concentrations in the freshwater entering the estuary had increased in recent years, following decades of major declines that began in the late 1970s. However, observations since 2009 have shown that levels have substantially declined again to levels near where they were prior to the observed recent increase.

- The observed recent increases in silica and phosphorus seem to have been linked to the previous closure of phosphogypsum stack systems and general phosphate mining operations in the Whidden Creek basin, located in the upper Peace River watershed.

The “limited” analyses presented in the *2017 HBMP Annual Data Report* do not suggest that there have been any long-term, systematic 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 overview of the HBMP project and the recent findings from the 2017 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 *2017 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 *2017 HBMP Annual Data Report* CD in a separate directory labeled 2017 Data Sets, as files in SAS format.

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1 Introduction/Summary

1.1 Report Objectives

This introductory section of the 2017 *HBMP Annual Data Report* summarizes and provides a brief overview of the historic background and current status of the Peace River Manasota Regional Water Supply Authority's (Authority) Hydrobiological Monitoring Program (HBMP). The following provides an overview of the major topics included in this section.

- A historical 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 recent previous HBMP reports and studies.
- An outline of current HBMP monitoring elements.
- Summary results of the information presented in Sections 2 through 7 of this *2017 HBMP Annual Data Report*.
- An overview of the current and historic data sets used in the analyses of 2017 HBMP data.
- A general summary of specific problems encountered by study elements during the 2017 HBMP monitoring that resulted in either missing or unusable data.

The following outlines the organization and primary objectives of each of the sections of the *2017 HBMP Annual Data Report* following this introduction and generalized summary.

- **Section 2.0 (Peace River Gaged Flows and Regional Water Supply Facility Withdrawals)** – The purpose of this section is to provide an analysis and summary of 2017 gaged river freshwater inflows to the lower Peace River estuary, and compare estuarine inflows with freshwater river withdrawals by the Peace River Regional Water Supply Facility (Facility). This section also compares 2017 flows and Facility withdrawals with analogous long-term metrics over the historic 1976-2016 time interval, which corresponds with the prior period 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 established in 1983, and to describe the current elements of the isohaline based sampling plan. Graphical and tabular results are presented comparing and contrasting the data collected

during 2017 with previous salinity (isohaline) based HBMP sampling program data historically collected between 1983 and 2016.

- **Section 4.0 (Physical and Chemical Water Quality Characteristics at “Fixed” Station Locations)** – This section summarizes the objectives of the original HBMP long-term “fixed” station monitoring program initially established in 1976. This section describes both the historic and current sampling designs of the HBMP fixed station monitoring. Information is also presented relative to the results of the “fixed” station data collected during 2017. In addition, the section also presents summary graphical and tabular comparisons of selected 2017 water quality monitoring results with previous similar HBMP data collected over the preceding 1976-2016 time interval.
- **Section 5.0 (USGS and HBMP Continuous Recorders)** – This section of the *2017 HBMP Data Report* summarizes the initial principal objectives envisioned in establishing 15-minute U.S Geological Survey (USGS) continuous recorders (tide stage, and surface and bottom temperature and conductivity) at two locations along the lower Peace River (Harbour Heights and Peace River Heights) in the late 1990s. Also described and summarized are the design criteria that were later used, based on recommendations of the HBMP Scientific Review Panel, in initially establishing three additional Authority 15-minute continuous recorders (subsurface temperature and conductivity) along the HBMP monitoring transect in December 2005. Two similar Authority recorders were further added in May 2008, and more recently three additional Authority recorders were deployed at the end of June 2011. In December 2009, USGS installed its third pair of near surface and near bottom continuous recorders immediately adjacent to the Facility’s river intake structure. The results of data collected in 2017 by the current array of USGS and Authority HBMP continuous recorders along the lower river are presented in this section. Included are graphical and tabular results that provide comparisons of surface salinity range measured along the lower Peace River HBMP monitoring transect.
- **Section 6.0 (HBMP *In Situ* Chlorophyll Transect Monitoring)** – Based on the recommendation of the HBMP Scientific Review Panel, and following consultation with District staff, the Authority implemented a new HBMP special study element beginning in April 2013. This special study employs an *in situ* fluorometer chlorophyll *a* methodology in order to provide the type of enhanced spatial intense information needed to accurately define on a monthly basis both the magnitude and spatial extent of variations in chlorophyll *a* patterns within the lower Peace River/upper Charlotte Harbor estuary.
- **Section 7.0 (Assessment of Upstream Changes in Water Quality)** – This section briefly summarizes key findings from previous analyses of observed changes in water quality characteristics in the Peace River watershed upstream of the Facility. A comprehensive analysis of Peace River watershed data was presented in the *2011* and *2016 HBMP Comprehensive Summary Reports* submitted to the District. As part of the Authority’s ongoing Water Supply Study, the long-term water quality information for the upstream Peace River watershed, outside of the HBMP study area, was updated through the end of 2017. The updated graphical results for previously identified key upstream

subbasins are presented in this section. Additionally, this section provides statistical summaries of HBMP data collected at River Kilometer 30.7 (above the Water Treatment Facility). The evaluation of these data is intended to provide early identification of upstream water quality changes that might potentially influence Facility operations and assessment of possible upstream sources of change.

1.2 Overview of the History of Peace River Facility and Facility Water Use Permit

The Authority's Peace River Regional Water Supply Facility is located adjacent to a side-branch of the Peace River in southwest DeSoto County. Originally permitted, constructed, and operated by General Development Utilities, and later owned and operated by the Authority (since 1991), the Facility has been operating and withdrawing water from the Peace River since 1980. **Table 1.1** summarizes changes in the Facility's withdrawal schedules associated with each of the historic modifications of the Facility's Water Use Permit's (WUP) specific conditions prior to the most recent 2011 modifications (**Table 1.2**). The following briefly summarizes the historical major changes in the Facility's permitted water withdrawal schedules.

- The Facility's 1982 modification of the WUP changed the previous limited annual average withdrawals from 5.0 mgd to 8.2 mgd (12.7 cfs), with the maximum daily withdrawal from 18 mgd to 22 mgd, which was limited by the Facility's physical ability to withdraw water from the river (which was 22 mgd or 34.0 cfs). Monthly individual low flow Peace River at Arcadia cutoffs were determined based on the previous 20 years of USGS average flow data. As a result, the individual monthly low flow cutoffs changed from a previous range of 91 to 664 cfs to a new range with a low of 100 cfs in April and May to a high of 664 cfs in September.
- In October 1988, the Water Use Permit renewal limited withdrawals to ten percent of the previous day flow as measured at the USGS Peace River at Arcadia gage, up to the limit of 34.0 cfs (22 mgd) per day (which matched the pumping capacity of the river intake facility at the time). The low flow cutoffs during the period from 1989 to 1995 were 130 cfs during the months of June through February, and then 100 cfs during the March through May spring dry season.
- The 20-year 1996 Water Use Permit renewal increased the low flow cutoff to 130 cfs year round, while concurrently raising the maximum withdrawal capacity to 90 mgd (139 cfs). The 1996 permit renewal retained the ten percent withdrawal limit established under the previous October 1988 permit. The Authority's permitted increase with the maximum river withdrawal and the completion of the Peace River Option expansion in 2001 both contributed to the intent to increase the Facility's treatment capacity, meet increased public demand and allow the capture of a greater portion of the full permitted ten percent withdrawal under higher flow conditions, and increased the Facility's reliability with the ability to withdraw and store excess amounts of water above actual daily demands.
- In April 2011, the Authority's withdrawal schedule was revised, following the District's adoption of Minimum Flow and Level (MFL) criteria for the lower Peace River. This

permit revision also included a change where the daily river flows were combined to include flows from PR @ Arcadia, Joshua Creek and Horse Creek. This change provides approximately the same annual total quantities of water with a higher rate of reliability, by greater utilization of higher summer wet-season flows through making use of the Facility's 2009 major expansions of both river intake and off-stream storage capacities.

Table 1.1**Historic Summary of Facility Permits**

Year	December 1975	March 1979	May 1982	October 1988	March 1996
Water Use Permit Number	27500016	27602923	202923	2010420	2010420.02
Average Permitted River Withdrawal (mgd)	5.0	5.0	8.2	10.7	32.7
Maximum Permitted River Withdrawal (mgd)	12 & 18	12 & 18	22	22	90
Diversion Schedule Low Flow Cutoff (cfs)	91 – 664 *	91 – 664 *	100 – 664 *	100 & 130 **	130 **
Maximum Percent Withdrawal of River Flow (%)	5	5	n/a	10	10

* Withdrawals based on historic monthly averages

** Withdrawals are based on percent of actual daily flow from the preceding daily flow at the USGS at Arcadia gage

Table 1.2

**April 2011 Revised Authority Lower Peace River Withdrawal Schedule
(based on combined flow of the Peace River at Arcadia,
and the Horse and Joshua Creek USGS Gages)**

Block	Allowable Percent Reduction in Flow	
Block 1 (April 20 th – June 25 th)	16% above 130 cfs	
Block 2 (October 27 th – April 19 th)	16% if flow > 130 cfs and < 625 cfs	28% if flow > 625 cfs
Block 3 (June 26 th – October 26 th)	16% if flow > 130 cfs and < 625 cfs	28% if flow > 625 cfs

Prior to 2009 and with the Peace River Option expansion (2001), the Peace River Facility had the capacity to treat up to 24 mgd and relied on four river pumps with a combined maximum capacity of 44 mgd (68.0 cfs) for raw river water diversions. During periods of high river flow (or periods when permitted withdrawal exceeded demands), raw river water was stored in the Facility's 0.6 billion gallon off-stream surface reservoir and any excess treated water was stored in the system's 21 aquifer storage/recovery (ASR) wells. Conversely, when water was unavailable from the Peace River due to the established low flow 130 cfs cutoff (or when demand exceeds permitted withdrawals), water was pumped from the raw water reservoir to the Peace River Facility for treatment, and/or previously treated water was recovered from the ASR well system to meet the water supply demands of the Authority's service area.

During 2009, the Authority finished implementing a series of expansions to the Peace River Facility undertaken as part of its ongoing plans to meet projected future increasing water

demands resulting from expected future regional growth in the four member counties. These expansions included increasing the Facility's river pumping capacity from 44 to 90 mgd (the 1996 permit limit) and construction that increased the Facility's treatment capacity to 48 mgd (twice the previous capacity). In addition, construction of a new regional off-stream reservoir with a capacity of approximately 6 billion gallons was completed. The pumping capacity from the river was later re-rated to 120 mgd. Further improvements as of late 2015 increased the Facility's treatment capacity and the Facility is now permitted to treat 51 mgd. Current planning includes additions and expansions to the system transmission pipe networks to expand and optimize water delivery throughout the four county service region.

1.2.1 Facility Water Use Permit Related HBMP Program

On December 10, 1975, the Consumptive Use Permit #27500016 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 (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 influences and significance of natural seasonal and annual salinity changes on the aquatic fauna and flora in the lower river/upper harbor estuary, and to determine if freshwater withdrawals by the Peace River Regional Water Supply Facility could be shown to potentially significantly alter these natural 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 *HBMP Summary Report*, indicated the need to revise the monitoring program to better evaluate changes in the Charlotte Harbor system. Revisions to the HBMP monitoring elements were implemented to assess natural seasonal and longer-term variations in freshwater inflows, relative to the magnitude and timing of expected salinity changes due to Facility withdrawals. Further modifications and refinements to the HBMP study elements were made in 1985, 1988, and then again in 1996 in conjunction with the renewal of the Facility's Water Use Permit.

The current Water Use Permit (# 20010420) was issued by the District to the Authority in March 1996. The permit contained specific conditions for the continuation and enhancement of the lower Peace River/upper Charlotte Harbor estuary HBMP. The HBMP study elements specified in the 1996 permit renewal were designed to build upon and add to the HBMP monitoring activities initiated in 1975. The initial background HBMP monitoring conducted prior to construction completion and the Facility's initial river withdrawals was undertaken to provide a basis for pre-withdrawal conditions against which later comparisons could be made.

Between 1979 and 2016, an ongoing series of individual annual data reports have been submitted to the District, documenting the results of the HBMP during the period from January 1976

through December 2016. 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, which was filed in draft form in 1994 (finalized in April 1995), 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 required 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 20-year permit. As a result of 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 has 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 that 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. It is significant to add that the 2002 report as requested by the Scientific Review Panel, included major work in evaluating the past history of riparian vegetation data collected by the HBMP. The findings were that the past studies of riparian vegetation though interesting, found that riparian vegetation was not sensitive enough to reflect the possible impacts of Facility fresh water withdrawals. Based on these findings the Panel and District staff agreed to reduce the vegetation monitoring requirements in the HBMP. The *HBMP 2004 Mid-term Interpretive Report* 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 *2006 HBMP Comprehensive Summary Report* 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 *2011* and *2016 HBMP Comprehensive Summary Reports* again provided an extensive update and analyses of each of the ongoing HBMP study elements, refinement and expansion of statistically based salinity modeling, a comprehensive historical summary of upstream watershed water quality changes,

and analyses of the effectiveness of the Facility's withdrawal schedule in limiting the potential impacts of withdrawals on the downstream estuarine system.

The period covered within this *2017 HBMP Annual Data Report* follows directly upon that contained within the preceding *2016 HBMP Annual Data Report* submitted in June 2017. This current report includes unreported HBMP data collected over the period from January through December 2017, and represents the 28th year of data collection for the Authority, as owner/operator of the Peace River Regional Water Supply Facility.

As defined by the District's 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 distribution data collected as part of 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 periodically 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 regarding 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 in flow. Included in these original HBMP elements were the following investigations.

- An initial long-term study of the seasonal pattern of juvenile fishes in the upper harbor
- Studies of benthic indicator species
- An investigation of the seasonal distribution of star fish (sea star) *Luidia clathrata* in the harbor and lower river
- A series of long-term vegetation studies along the lower Peace River included the following studies:
 1. Periodic infrared aerials and the review of possible riparian vegetation changes
 2. The first and last occurrence of selected plant taxa
 3. Riparian vegetation along transects at fixed locations

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 components of the estuarine food-chain. A focused shorter-term benthic invertebrate study and a separate fish nursery investigation were both conducted in the late 1990s. Again, these investigations were 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 and enhancement of the HBMP was the development of standardized spatial location descriptors subsequently applied across all HBMP program elements. A morphometric study was undertaken 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 ongoing study element's 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.

An outside HBMP Scientific Review Panel was implemented in conjunction with the 1996 Water Use Permit renewal to review HBMP findings, and make recommendations relative to the ongoing study elements, methods of data analyses, and conclusions. The Panel recommended that the primary focus of HBMP monitoring should be on assessing long-term trends in key physical, chemical, and biological characteristics that can be directly linked to the Facility's potential influences, and apply less effort on elements more directly related to the overall "health of the estuary", which are potentially influenced to a much greater extent by other up stream anthropogenic impacts.

1.4 Overview of Results Presented in Previous Comprehensive Summary HBMP Reports

Expanded analyses of recent and longer-term HBMP monitoring data over the entire period-of-record (since 1976) have been conducted as required under the 1996 Water Use Permit as part of the following documents.

- *2000 Mid-term Interpretive Report*
- *2002 Peace River HBMP Comprehensive Summary Report*
- *HBMP 2004 Mid-term Interpretive Report*
- *2006 HBMP Comprehensive Summary Report*
- *2011 HBMP Comprehensive Summary Report*
- *2016 HBMP Comprehensive Summary Report*

The results of the analyses presented in this extensive series of reports further support previous monitoring program findings and conclusions regarding the relatively small magnitude of additional change to the much greater natural range of temporal and spatial estuarine variation that are potentially directly attributable to facility withdrawals. Similar earlier findings were presented in the 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 as required by the 1996 permit have supported the following general conclusions.

- There have been statistically significant declines in high, median, and low flows over the long-term period of record at the USGS 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 slightly higher average flows over the summer months (June-September) during 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 stream flow augmentation due to agricultural groundwater irrigation runoff.
- 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. Since the initiation of Facility withdrawals in 1980, annual total Peace River Facility withdrawals have ranged approximately from 0.2 to 5.0 percent (0.2 to 5.8 percent when the city of Punta Gorda withdrawals are also included; [Table 2.2](#)) of total freshwater flow at the river's mouth. The higher percentages reflect the combined influences of Facility expansions with periods of lower flow.
- 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.
- Long-term comparisons of the upstream and downstream occurrences of selected indicator plant species along the lower Peace River, spanning nearly 30 years, indicated that the distributions of the selected indicator species had not systematically or progressively changed over time. Seasonal river flows over this extended period exhibited a great degree of natural variation, including both extended dry and wet intervals. It was thus apparent that the observed relatively stable spatial distribution of the riparian vegetation communities along the lower Peace River is maintained by the combined influences of both seasonal variability of exposure to differing salinity regimes due to changing flows and localized physical floodplain characteristics. It was concluded that monitoring differences in the spatial distribution of riparian vegetation along the lower river was not sensitive enough to access potential changes due to Facility freshwater withdrawals.
- Previous statistical salinity models under the 1996 withdrawal schedule (and before) indicated that 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 had historically resulted in daily changes of 0.1-0.5 psu (practical salinity units) downstream of the Facility along the HBMP monitoring transect. Modeling presented in the *2011 HBMP Comprehensive Summary Report* indicated average (mean) changes in salinity downstream of the Facility were < 0.4 psu. The updated models indicated that the largest expected salinity changes will occur downstream in the normally higher brackish lower river reaches of the river. The *2016 HBMP Comprehensive Summary Report* updated models with data through 2016 and found that estimated annual average salinity changes due to actual Facility withdrawals ranged from approximately 0.1 psu upstream (approximately River Kilometer 24.5 and above) to around 1.1 psu downstream (approximately River Kilometer 15.5 and below). The modeled results indicate that salinity changes due to Facility withdrawals have increased since the most recent

expansion and change in the withdrawal schedule. These increases remain relatively small when compared to the range of naturally occurring daily, seasonal and longer term flow/tide related variation along the lower Peace River. The results further indicate that, by design, the largest increases in salinity resulting from the withdrawal schedule are focused into wetter periods, and occur in regions of the lower river that naturally experience relatively large salinity fluctuations. The components of the withdrawal schedule thus effectively reduce the relative potential influences of withdrawals which are more likely to occur during low river flows.

- The modeling results indicated that, much of the time, Facility withdrawals have limited (if any) influence on the salinities for several reasons. First, the Facility does not affect salinity during the period of time when combined gage flows at Peace River at Arcadia, Joshua Creek and Horse Creek are below the District's low flow cutoff threshold of 130 cfs. Upstream flows can be below the 130 cfs threshold over extended intervals (typically about 120 days) each year. Conversely, also when flows are high enough that a particular reach of the river is always characterized by freshwater conditions, Facility withdrawals cannot affect salinity in that portion of the lower river. A somewhat less intuitive finding of the series of "pump tests" was the observation that Facility withdrawals, even during low to moderate flows, primarily only resulted in higher observed salinities during incoming tides. Withdrawals therefore seem to have very little directly measurable influence on salinities during the outgoing and low phases of the daily tidal cycle. Since the presented summary statistics were based on hourly estimates (versus daily estimates), it is therefore not surprising that more than half the observations did not predict any differences in salinities with and without withdrawals.
- Similar statistical analyses of the relative movement of the monitored isohalines presented in the *2011 HBMP Comprehensive Summary Report* indicated that the expected / predicted maximum Facility impacted salinity location change due to withdrawals has increased from 0.1-0.5 kilometers location under the 1996 withdrawals schedule to 1.1-1.4 kilometers location in 2011 under the current revised, MFL based withdrawal schedule. The results of the *2016 HBMP Comprehensive Summary Report* analyses suggested that under the Facility's revised withdrawal schedule such salinity impacted location movement was estimated to be 0.7 to 1.3 kilometers. Smaller changes in isohaline location due to withdrawals are estimated for the peak summer wet season months when flows are naturally higher. During such periods, the isohalines naturally, rapidly move further downstream. Thus the withdrawal schedule again functions to time the maximum changes due to withdrawals with the periods of highest natural change, limiting the magnitude of potential impacts.

The results of statistical models presented in the 2011 and 2016 summary reports predict commensurate increases in salinity concentration changes and the movement of isohaline locations resulting from increased Facility withdrawals. While the annual averages (mean and median) of projected changes due to actual Facility withdrawals would still remain difficult to measure directly, the modeled estimated largest annual changes in these indicators have increased to detectable levels. However, these estimated maximum changes due to actual Facility withdrawals continue to remain small in comparison to the relative far greater magnitude

of typical naturally occurring daily, seasonal, and annual variations. The Facility's modified withdrawal schedule by design directs the largest volumes of diverted river water to occur during the summer wet season. During the summer wet season, salinities and isohaline locations are naturally experiencing a high natural degree of variation in response to increasing freshwater inflows when expected impacts to the downstream estuary from greater withdrawals would be minimal.

1.5 2017 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 1.3** 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 this element of the lower Peace River/upper Charlotte Harbor HBMP program extends along the monitoring transect centerline from River Kilometer (RK) -2.4 south of the river's mouth upstream to RK 30.7 located just above the SR 761 Bridge, north of the Peace River Facility (see **Figure 1.3**). 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 any future modifications, 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 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 event 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 μ S. 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 16 “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 1.3](#)). In addition, chemical water quality samples are taken at five of these locations.

Both of these water quality HBMP study 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 1.4](#)). 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 2017, EarthBalance Corporation (formerly Florida Environmental, Inc.) 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 2017 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 were decreased from those originally specified in the 1996 monitoring conditions. These changes were made 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 1.4](#)).

Further descriptions, as well as complete summaries of the 2017 monitoring results and historical comparisons of the “isohaline” and “fixed” location based HBMP monitoring study elements are presented respectively in [Section 3](#) and [Section 4](#) 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, could then be used to develop detailed spatial and temporal statistical 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, 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 gage was installed on a private dock near Peace River Heights at RK 26.7, approximately 3 kilometers downstream of the Peace River Facility, and in December 2009, USGS added another recorder at the Facility's intake (RK 29.8) near Platt. These gages also measure 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 the 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 summarized in [Table 1.5](#) and depicted in [Figure 5.1](#).

In 2010, the Authority became aware that USGS had modified the method used to collect near-surface data in January 2005 from "floating" to "fixed depth" probes while making repairs following Hurricane Charley (August 2004). The Authority conducted a series of analyses comparing and contrasting the near-surface conductivity measurements used by both methods and was unable to detect any statistically significant differences.

Summary results of 2017 information for the continuous USGS recorders located at Harbour Heights (RK 15.5), Peace River Heights (RK 26.7), and the Facility (RK 29.8) are further presented in [Section 5](#) of this document.

1.5.3 Additional HBMP Continuous Recorders

In 2005, based on recommendations by the Scientific Review Panel and approval by District staff, 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. An objective of the Panel and resulting recommendation was to deploy additional continuous conductivity recorders at other monitoring sites spatially along the lower river as part of an expanded HBMP study element. This expanded element would re-direct portions of the monitoring efforts from the "health of the harbor" type of monitoring to specifically measure salinity changes due to Facility withdrawals under lower flow conditions. Analyses of conductivity data from these new monitoring locations were used as part of the HBMP *Pump*

Test Study and the 2006, 2011, and 2016 HBMP Comprehensive Summary Reports to extend previous graphical and statistical results with regard to directly measuring and modeling salinity changes due to withdrawals.

The first step to deploying these additional continuous recorders was to determine the potential spatial distribution for 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 along 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. A series of potential new monitoring sites located between the two existing USGS continuous recorders were then selected for evaluation.

One option considered was to locate land-based gages similar in design to the existing USGS continuous recorders. However, a much broader series of other potential sites exist due to the recent placement of Manatee Speed Zone markers and the expansion of navigation markers along the lower river. The Authority was able to receive permission from U.S. Fish and Wildlife Service and U.S. Coast Guard to establish continuous recorders using these markers. Three Manatee Speed Zone markers were chosen by the Authority for the initial deployment in December 2005 of HBMP continuous recorders measuring near-surface conductivity.

Based on comments and recommendations made by members of the HBMP Scientific Review Panel at its meeting in December 2007, the Authority added two additional continuous recorders and relocated the recorder previously at RK 23.4 in May 2008. The intent of these new recorder locations was to extend upstream and downstream the area along the lower river covered by the continuous recorder array.

- A new recorder was installed downstream of the USGS Harbour Heights gage on a Peace River Manatee Zone Marker (RK 12.7) below the confluence with Shell Creek. Unlike the other HBMP recorders, this instrument was installed near the bottom of the water column (~ 1.7 meters) and measures conductivity, temperature, and dissolved oxygen levels continuously at 15-minute intervals.
- A new recorder was also installed above the USGS Peace River Heights gage on a Manatee Zone Marker (RK 30.6) just upstream of the Facility's intake near the SR 761 Bridge. This recorder measures subsurface conductivity and temperature at 15-minute intervals.
- The HBMP recorder previously located at RK 23.4 was relocated upstream to the old railroad trestle (RK 31.7) above the Facility. This recorder also measures subsurface conductivity and temperature at 15-minute intervals.

The Peace River Scientific Review Panel met again in December 2010 and recommended the deployment of an additional continuous recorder between the I-75 and U.S. 41 Bridges. The Panel further recommended that several new recorders be located between the USGS Harbour

Heights gage and the HBMP gage near the Liverpool area in order to better define the relationships between salinity and flow in that reach of the lower River and within the Hunter Creek side channel. The following changes and additions to the HBMP continuous recorder array were made in June 2011.

- The existing recorder (RK 30.6) located just downstream of the SR 761 Bridge was discontinued since USGS had installed the Platt gaging location just downstream at the Facility's intake structure (RK29.8).
- A new 15-minute interval subsurface conductivity and temperature recorder was located on a navigation marker at RK 9.2 between the I-75 and U.S. 41 Bridges.
- The recorder at RK 12.7 (which also measures dissolved oxygen) was moved from the bottom of the water column to the surface so that its values would be comparable with those at the other HBMP recorder sites.
- A recorder measuring subsurface conductivity and temperature at 15-minute intervals was attached to a channel marker at RK 18.5 near the Power Line Crossing.
- A subsurface conductivity and temperature recorder was located on the river's large Hunter Creek side channel near the connection to Jim Long Lake. Located on a Manatee Zone marker (approximately RK 18.7), the objective of this site was to both determine if higher salinity water was moving upstream on this side channel and the potential influences of ungaged freshwater inflows to this region of the lower river.
- A 15-minute subsurface conductivity and temperature recorder was located on the navigation channel marker at RK 20.8 just downstream of an island in the lower river.

The locations of the recorders during 2017 are summarized in [Table 1.5](#) and [Figure 5.1](#). The methodologies used for deployment of the continuous recorders are depicted in [Figure 5.5](#) and [Photographs 5.1](#) through [5.11](#).

1.5.4 Spatial *In Situ* Chlorophyll Monitoring along the HBMP Transect

Based on the recommendation of the HBMP Scientific Review Panel, and following consultation with District staff, the Authority implemented a new HBMP special study element beginning in April 2013. This special study employs *in situ* fluorometer chlorophyll *a* methodology in order to provide the type of enhanced spatial intense information needed to accurately define on a monthly basis both the magnitude and spatial extent of variations in chlorophyll *a* patterns within the lower Peace River/upper Charlotte Harbor estuary. Accurate spatial determinations of the relative intensity and location of monthly chlorophyll *a* maxima patterns are expected to provide additional information regarding the known seasonal interactions between changes in freshwater flow (relative to additions of both nutrients and color) in relation to the seasonal movement of important estuarine zones of primary (and secondary) production.

The results of this most recent HBMP element are expected to help determine the magnitude of both temporal and spatial variability of peak zones of high phytoplankton productivity in the lower river/upper harbor system. Ultimately, such determination of the seasonal influences of changes in river flow will be used to assess any potential impacts of Facility withdrawals on estuarine production under the existing established MFL criteria. An analysis of the utility of this HBMP special study element, and recommendations for its future continuance, are expected to be made following at least five years of data gathering, and then potentially at specific intervals as part of future major summary monitoring program reports.

1.6 Summary of 2017 Results

The following text and tables compare data collected during 2017 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 included 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 2017 data with averages of similar data collected over the preceding 40-year period (1976-2016), 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 [Figure 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 the 2006-2009 interval by comparison was well below average, while seasonal rainfall patterns since then have returned to more normal conditions. Freshwater inflows during 2017 were characterized by average to above average flows ([Figure 2.3b](#)) during the summer wet season, but below average flows during the dry season.

- **Flows** – Average mean daily Peace River flow of the three combined gages upstream of the Facility during 2017 was 1,948 cfs, which is above the 1,167 cfs average over the prior period of HBMP monitoring (1976-2016). Overall, annual mean flow upstream of the Facility during 2017 was 166.8 percent of the average daily flow over the prior long-term 1976-2016 period.
- **Withdrawals** – Total Peace River Facility withdrawals during 2017 were approximately 3.1 percent of the total gaged freshwater flow measured at the USGS Arcadia gage, 2.4 percent of the upstream gaged flow at the Facility, and 1.7 percent of the combined average daily inflows upstream of the U.S. 41 Bridge. During the prior period of Peace River Facility withdrawals (1980-2016), total combined withdrawals have been

approximately 2.1 percent of the corresponding gaged Peace River at Arcadia flows, 1.6 percent of total gaged flow upstream of the Facility, and only 1.2 percent of the combined daily freshwater flows of the Peace River, and Horse, Joshua, and Shell Creeks.

Occasionally, Peace River Facility withdrawals exceeded the seasonally designated maximum percent allowed by the April 2011 revised permit withdrawal schedule. Such exceedances of the permitted percent withdrawals primarily result from subsequent USGS revisions of the provisional daily flow information available to the Authority at the time of actual withdrawals. Often there are extended periods each year (typically 120 days) 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 2017, the facility did not withdraw any water from the river on 152 days or approximately 42 percent of the time. Maximum daily Facility withdrawals increased both in 2002 and 2009 due to the completed Facility expansions, which resulted in increases in the Authority's ability to divert, treat, and store larger daily amounts of freshwater when river flows meet the District's threshold criteria. The 2011 revised withdrawals schedule further increased the amounts of water the Facility was able to take from the river, especially under periods of higher flows.

- **Salinity Spatial Distribution** – Freshwater inflows to the lower Peace River during 2017 were above their recent historic long-term average (1976-2016) and much higher than during the recent severe 2006-2009 drought. The influences of wetter than normal conditions during the wet season, and below normal flows in the dry season that characterized 2017, are reflected in the 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 2017 reflected slight upstream movements when compared with their previous long-term 1983-2016 averages.

Comparisons of means between 2017 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 [Table 3.7](#) and [Table 4.4](#).

- **Temperature** – Mean annual water temperatures during 2017 at each of the four isohalines were, on average, about 1 degree (C) warmer than corresponding values measured over the preceeding HBMP period (1983-2016).
- **Water Color** – In comparison to averages over the preceding long-term historic period (1983-2016), water color levels during 2017 were at a slightly higher range than the long-term range at the upper two isohalines. This is in direct comparison with the generally lower levels observed during the 2006-2009 extended drought when color levels in the lower Peace River/upper Charlotte Harbor estuarine system were well below their long-term averages within all but the highest salinity isohaline. During 2017, flows upstream of the Facility were approximately 167 percent of that calculated over the longer 1976-2016 HBMP monitoring period. Including corresponding Shell Creek flows, which enter the lower Peace River further downstream nearer higher salinity harbor waters, the combined gaged flow was approximately 173 percent of the average over the HBMP

period. These differences in regional rainfall/flows are expressed in the observed spatial differences in seasonal water color among the isohalines.

- **Extinction Coefficient** – The rates of measured water column 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 during 2017 with corresponding long-term averages show similar levels at all four isohalines; median values were also very similar.
- **Nitrite/Nitrate Nitrogen** – During 2017, the annual average concentration of this major inorganic form of nitrogen was above the previously observed longer term (1983-2016) historical average at the three downstream isohalines (6, 12, and 20 psu), while being below normal at the most upstream isohaline (0 psu). While above average freshwater inflows during 2017 may have increased loadings of nitrite/nitrate, the increased volume may also have provided a greater degree of dilution leading to lower average concentrations. 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. Concentrations typically decrease 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 months as phytoplankton populations respond to increasing water temperatures and light, and increased primary production removes available inorganic nitrogen. As a result, inorganic nitrogen levels in the lower river and upper harbor are typically at their lowest levels in the late spring, just prior to increases in summer wet-season inflows (in 2017, levels at all isohalines declined from January to March and were at method detection limits during April and May).
- **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 primarily 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 rainfall runoff/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. Ortho-phosphorus concentrations remained well above recent historic levels throughout much of 2005-2009 and have recently begun rapidly declining again. However, following Hurricane Charley (and subsequent Hurricanes Frances and Jeanne) during the late summer of 2004, inorganic phosphorus concentrations dramatically increased throughout the lower Peace River/upper Charlotte Harbor estuarine system. The direct cause for the observed

increased levels seems to have been related to the impact of multiple hurricanes, and resulting excessive rainfall on the operation of phosphate mining operations and the recent closing of the Ft. Meade phosphogypsum stack system in the upstream Whidden Creek subbasin (see Section 5 of the *2011 Comprehensive Summary Report*). After Hurricane Irma in 2017, no such increased inorganic phosphorus concentration occurred even with sampling 9 days after the storms landfall. Annual average ortho-phosphorus concentrations at all four isohalines were similar in 2017 to the corresponding long-term averages.

- **Nitrogen to Phosphorus Atomic Ratios** – Calculated atomic inorganic nitrogen to phosphorus ratios for ambient measured concentrations in 2017, as well as longer term averages at each of the four isohalines, show nitrogen to almost always be the limiting macronutrient.
- **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 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 over the 2006-2009 interval were below normal, silica levels throughout the lower river/upper harbor estuary continued to reach historically high levels during the summer wet seasons. As with ortho-phosphorus, the proximate cause for these increasing levels seems to be related to increased mining operations and the ongoing closing of the Ft. Meade phosphogypsum stack system in the upstream Whidden Creek subbasin. However, while peak levels during 2009 and 2010 were somewhat lower than during the immediate preceding years, levels again increased in 2011. Annual average concentrations during 2017 were again well above their long-term averages at each of the four moving isohaline based monitoring locations.
- **Chlorophyll *a*** – The seasonal patterns of freshwater inflows to the estuary during 2017 were characterized by above average flows during much of the year when compared to the long-term average conditions. 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 2017 HBMP data indicate there were little to no increases in phytoplankton biomass at each of the four moving isohaline based monitoring locations throughout the year. Overall, chlorophyll *a* concentrations within the Peace River/upper Charlotte Harbor estuarine salinity zones during 2017 in the intermediate isohalines (6 and 12 psu) were generally

below their preceding long-term (1983-2016) averages, and similar to higher than the long-term averages in the freshest and most estuarine sampling zones (0 and 20 psu).

1.7 Conclusions

This document represents the 21st Annual Data Report submitted under the expanded Hydrobiological Monitoring Program (HBMP) initiated in 1996 in compliance with Water Use Permit 20010420. 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 2017, other than those previously noted. These include:

- Freshwater inflows during 2017 were influenced by seasonally wetter than normal conditions during the normal summer wet-season and drier than normal conditions during the normal dry-season.
- During 2017, the data indicated that increased reactive silica concentrations that have been noted at the lower Peace River/upper Charlotte Harbor HBMP monitoring locations were again greater than the long term averages. In part, some of the previously observed increase may have been related to discharges during routine mining operations and the closure of the Whidden Creek phosphogypsum stacks. However, levels have not declined as quickly as the corresponding decrease was observed in phosphorus levels following closure of the stacks.
- 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. However, observations since 2009 have shown that levels have substantially declined again to levels near where they were prior to the observed recent increases occurring over the 2004-2008 period.
- The observed recent increases in silica and phosphorus seem to have been linked to the routine mining operations and recent closure of phosphogypsum stack systems in the Whidden Creek basin in the upper Peace River watershed.

The “limited” analyses presented in the *2017 HBMP Annual Data Report* do not suggest that there have been any long-term, systematic changes resulting from either current or historic water withdrawals by the Peace River Manasota 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 *2017 HBMP Annual Data Report* CD in the directory labeled 2017 Data Sets, as files in ASCII, Excel, and/or SAS formats. **Table 1.6** provides a summary and links to descriptions of the variables within each of the SAS data sets.

Table 1.6
Long-term Historical HBMP Data Sets

Data Set Name	Time Period	Brief Description
HBMP SAS Data Sets		
Flow and Withdrawal Data for the Period-of-Record		
Flwd17_HBMP (sas7bdat)	1931-2017	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.
In Situ and Water Chemistry from “Moving” and “Fixed” HBMP Monitoring Elements		
Cmov8317 (sas7bdat)	1983-2017	Water quality and phytoplankton biomass measurements from monthly surface samples collected at each of the four moving isohalines. Relative locations reflect distances from the river mouth in kilometers.
Hymov8317 (sas7bdat)	1983-2017	Monthly hydrolab <i>in situ</i> 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.
Hyfix9617 (sas7bdat)	1996-2017	Monthly <i>in situ</i> 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.
Cfix9617 (sas7bdat)	1996-2017	Monthly surface and bottom chemical water quality samples taken at five different river kilometer intervals from fixed sample locations from near the river's mouth to just upstream of the Treatment Facility.
Efix9617 (sas7bdat)	1996-2017	Water column extinction coefficients collected at the fixed sampling locations.
USGS Continuous Recorder Data		
Boca04 (sas7bdat)	1996-2004	Water level at 15-minute intervals from the continuous recording gage near Boca Grande. Discontinued.
HH17 (sas7bdat)	1996-2017	Water level, and surface and bottom conductivity and temperature at 15-minute intervals from the continuous recording gage on the Peace River near Harbor Heights (River Kilometer 15.5).
PRH17 (sas7bdat)	1997-2017	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).
PLATT17 (sas7bdat)	2009-2017	Water level, and surface and bottom conductivity and temperature at 15-minute intervals from the continuous recording gage on the Peace River at the Facility intake (River Kilometer 29.8).
Ongoing HBMP Continuous Recorder Data		
RK09_17 (sas7bdat)	2011-2017	Near surface conductivity and temperature at 15-minute intervals from the HBMP continuous recording gage attached to a channel marker located on the Peace River between the I-75 and U.S. 41 Bridges (River Kilometer 9.2).
RK12_17 (sas7bdat)	2011-2017	Near surface conductivity, temperature, and dissolved oxygen at 15-minute intervals from the HBMP continuous recording gage attached to a Manatee marker located on the Peace River just downstream of Shell Creek (River Kilometer 12.7).

Table 1.6
Long-term Historical HBMP Data Sets

Data Set Name	Time Period	Brief Description
RK18_17 (sas7bdat)	2011-2017	Near-surface conductivity and temperature at 15-minute intervals from the HBMP continuous recording gage attached to channel marker near the power line crossing (River Kilometer 18.5).
RK18_HC_17 (sas7bdat)	2011-2017	Near-surface conductivity and temperature at 15-minute intervals from the HBMP continuous recording gage attached to the Manatee Speed Zone Sign located on Hunter Creek near Jim Long Lake (River Kilometer 18.7).
RK20_17 (sas7bdat)	2011-2017	Near-surface conductivity and temperature at 15-minute intervals from the HBMP continuous recording gage attached to the channel marker located on the Peace River located just downstream of the island (River Kilometer 20.8).
RK21_17 (sas7bdat)	2006-2017	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).
RK24_17 (sas7bdat)	2006-2017	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).
RK31_17 (sas7bdat)	2008-2017	Near-surface conductivity and temperature at 15-minute intervals from the HBMP continuous recording gage attached to the old railroad trestle located on the Peace River just upstream of the Facility (River Kilometer 31.7).
Previous HBMP Continuous Recorder Data		
RK23_08 (sas7bdat)	2006-2008	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. Discontinued.
RK12_bot_11 (sas7bdat)	2008-2011	Near-bottom conductivity, temperature and dissolved oxygen at 15-minute intervals from the HBMP continuous recording gage attached to Manatee marker located on the Peace River just downstream of Shell Creek (River Kilometer 12.7). Discontinued.
RK30_11 (sas7bdat)	2008-2011	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 upstream of the Facility (River Kilometer 30.6). Discontinued June 2011.
Environmental Quality Laboratory (EQL) Background Data Sets		
Chem_all (sas7bdat)	1976-1990	EQL fixed station Charlotte Harbor background water chemistry data.
Hydro_tb (sas7bdat)	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 2017

The following outlines the limited number of problems and errors encountered during data collection for various elements of the 2017 HBMP monitoring program. Overall, very few data collection problems and/or other data issues other than related to instrument failures were encountered during 2017 .

- **USGS Continuous Recorders** – In previous years, due to short-term instrument failures, some records for gage height, temperature, and/or conductivity were unavailable for the Harbour Heights (RK 15.5), Peace River Heights (RK 26.7), and Platt (RK 29.8) gaging sites. In 2017, there were very few (less than 1.1%) missing observations for the Harbor Heights and Peace River Heights sites. The bottom instrument at Platt was missing conductivity values for about 3.4% of the possible data points for 2017. The vast majority of these missing values at the Platt site occurred during January and October.
- **HBMP Continuous Recorders** – As a result of instrument issues, a very small amount of the data collected by the HBMP continuous recorders were flagged as questionable and were not used in the presented analyses. Such data issues are often caused by the sonde being “hung up” in the stilling well and potentially out of water, or by bio-fouling at characteristically higher salinity monitoring sites. In 2013, new copper screening to surround the probes became available from YSI, which has reduced the instances of missing data due to bio-fouling. All of the sondes were removed on September 5 2017 in preparation of the arrival of Hurricane Irma. The sondes were redeployed on September 27, resulting in a gap in data for most of the month of September. The sonde at River Kilometer 12.7 had an internal battery issue during November 2017 resulting in a 12-day data gap. The sonde again experience a battery issue in December 2017 resulting in a data gap beginning December 22, and lasting through the end of the year.

2.0 Peace River Gaged Flows and Regional Water Supply Facility Withdrawals

The purpose of this section is to present a general overview and summarize 2017 gaged river freshwater inflows to the lower Peace River/upper Charlotte Harbor estuary, as well as provide comparisons with the relative magnitudes of historic flows and the timing of the Authority's freshwater withdrawals at the Peace River Facility. This section compares freshwater inflows to the lower river and upper harbor and permitted freshwater withdrawals during 2017, with similar longer-term summary information from 1976-2016 (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 estuarine system. As indicated, the Peace River Facility intake withdrawal structure is located on a side channel, in the tidal portion of the lower river. This reach of the lower tidal river is often seasonally characterized by brackish conditions during periods of low freshwater inflow (approximately < 90 cfs as measured by the USGS Peace River at Arcadia gage). The long-term relationships between combined USGS gaged inflows upstream of the Facility (Peace River at Arcadia, Horse Creek near Arcadia, and Joshua Creek at Nocatee) and subsurface and near bottom conductivities measured over the 2010 to 2017 time interval by the USGS continuous recorder (Peace River at Platt - 02297345) at the Facility's river intake (RK 26.7) are shown in **Figure 5.3**.

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 (<http://waterdata.usgs.gov/nwis>) and recent/real time (<http://waterdata.usgs.gov/fl/nwis/current/?type=flow>) flow data collected by USGS were obtained from the USGS streamflow web sites and used to update the long-term HBMP watershed streamflow database. USGS flow data are retrieved for the annual HBMP data reports during the first part of each calendar year. USGS reports daily "provisional" flows on their web sites based on actual gage readings. However, these "provisional" flows are further updated to "accepted" flows based on actual periodic field measurements and cross-section adjustments (see **Figure 2.1**). USGS operates around "water years" running from October through September. Thus, flows for the last three months of each previous calendar year often represent "provisional" rather than "accepted" USGS data. In the instance of the *2017 HBMP Data Report*, some of the flow data in December 2017 for the gages listed in Table 2.1 had not been finalized by USGS to "accepted" prior to being downloaded for this report.

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	1940-2017
Peace River at Fort Meade	02294898	480	1975-2017
Peace River at Zolfo Springs	02295637	826	1934-2017
Peace River at Arcadia	02296750	1367	1932-2017
Joshua Creek at Nocatee	02297100	132	1951-2017
Horse Creek near Arcadia	02297310	218	1951-2017
Prairie Creek near Fort Ogden	02298123	233	1964-2017
Shell Creek near Punta Gorda	02298202	373	1966-2017
Myakka River near Sarasota	02298830	229	1937-2017
Big Slough near North Port	02299450	81	2002-2017

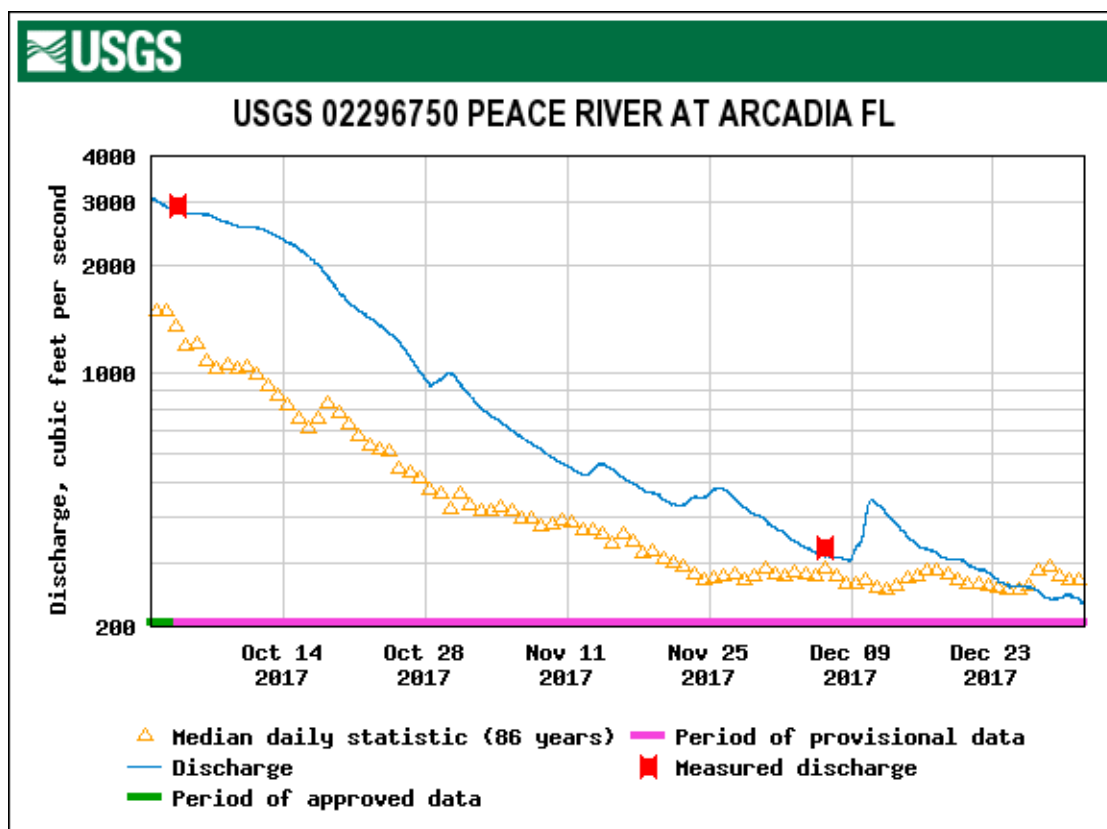


Figure 2.1 Example of USGS periodic measurements of actual discharge used to calibrate and convert daily measured “provisional” to “accepted flows” (copied from USGS Web Site for the Peace River at Arcadia gage).

2.1 2017 Gaged Flows to the Lower Peace River

Daily combined Peace River discharges (in cubic feet per second) for the USGS gaging stations upstream of the Facility during the January through December 2017 reporting period are depicted in [Figure 2.2](#). Freshwater inflows during 2017 were characterized by average to below average flows ([Figure 2.3b](#)) during the dry season. Higher than normal flows occurred during much of the typical wet season, as well as higher flows due to Tropical Storm Emily (7/31/17) and Hurricane Irma (9/10/17) which made landfall in South Florida ([Figure 2.3a](#)). Overall, flows in 2017 were higher than those observed in the prior 10-12 years ([Figure 2.4](#)). The annual mean combined gaged flow upstream of the Facility in 2017 of 1,948 cfs was well above the historical long-term (1976-2016) average of 1,168 cfs ([Table 2.2](#)).

Some of the decline in summer flows observed during an extended period of drought beginning in 2006 can be directly attributed to the occurrence of atypical patterns of wet season afternoon thunderstorm activity throughout portions of the summer during those years. Summer thunderstorms in southwest Florida normally build up along the eastern coastline and in the interior region of the state in the early afternoon and move toward the west coast later in the afternoon. However, during the referenced dry period, the typical afternoon thunderstorm activity often tended to build and remain along the western coastline. The result was that many of the coastal USGS stream flow gages within smaller coastal watersheds actually experienced higher flows throughout much of the drought years when compared to the much larger sub-basins in the interior of the Peace River watershed.

Tropical storms can have a dramatic influence on rainfall/flow patterns in the Peace River watershed. The reduced influence of tropical storms had reduced summer wet-season rainfall during the drought conditions that began in 2006 ([Figure 2.5](#)). This drier than average period, characterized by reduced tropical storm activity, is in direct contrast with the preceding 2004-2005 interval of unusual tropical storm activity. Tropical storms Ernesto (2006), Olga (2007), and Fay (2008) briefly influenced rainfall in the Peace River watershed. Increased tropical activity occurred during 2017. Tropical Storm Emily moved ashore along central Florida's Gulf Coast on July 31, 2017, producing soaking rains in parts of central and southern Florida. Following rapid intensification, and a path across the Atlantic Ocean and Caribbean Sea, Hurricane Irma made landfall as a major hurricane on September 10, 2017 as a major hurricane near Marco Island and moved quickly northward through the state of Florida. On October 28th 2017, Tropical Storm Philippe travelled across the Florida Keys and the southern tip of Florida after first making landfall in Cuba. Tropical Storm Philippe had little effect on the hydrology in the Peace River watershed, contributing only 0.91 inches of rain at the Arcadia rain gage (USC00080228). [Figure 2.6](#) displays the tropical storms occurring in the Atlantic during 2017. Maps for 1975-2016 can be found in the *2015 and 2016 HBMP Annual Data Reports*.

The seasonal patterns of freshwater inflows during 2017 are graphically summarized in relation to the preceding long-term historical averages (1976-2016) in [Figures 2.3a](#) and [2.3b](#). These flow duration graphics display the 7-day average combined flow upstream of the Facility during 2017 in relation to the long-term (1976-2016) daily statistical distributions of the average 7-day combined flow of the Peace River at Arcadia, Horse Creek near Arcadia, and Joshua Creek at Nocatee USGS gages. Statistical analyses were used to determine long-term, averages of the

10th, 25th, 75th and 90th percentiles for the combined gaged Peace River flow upstream of the Facility. Thus, the pink shaded area in [Figure 2.3b](#) represents the long-term (1976-2017) difference between the lowest (Q100) and 10th percentile (Q90) of flow calculated for each particular day of the year.

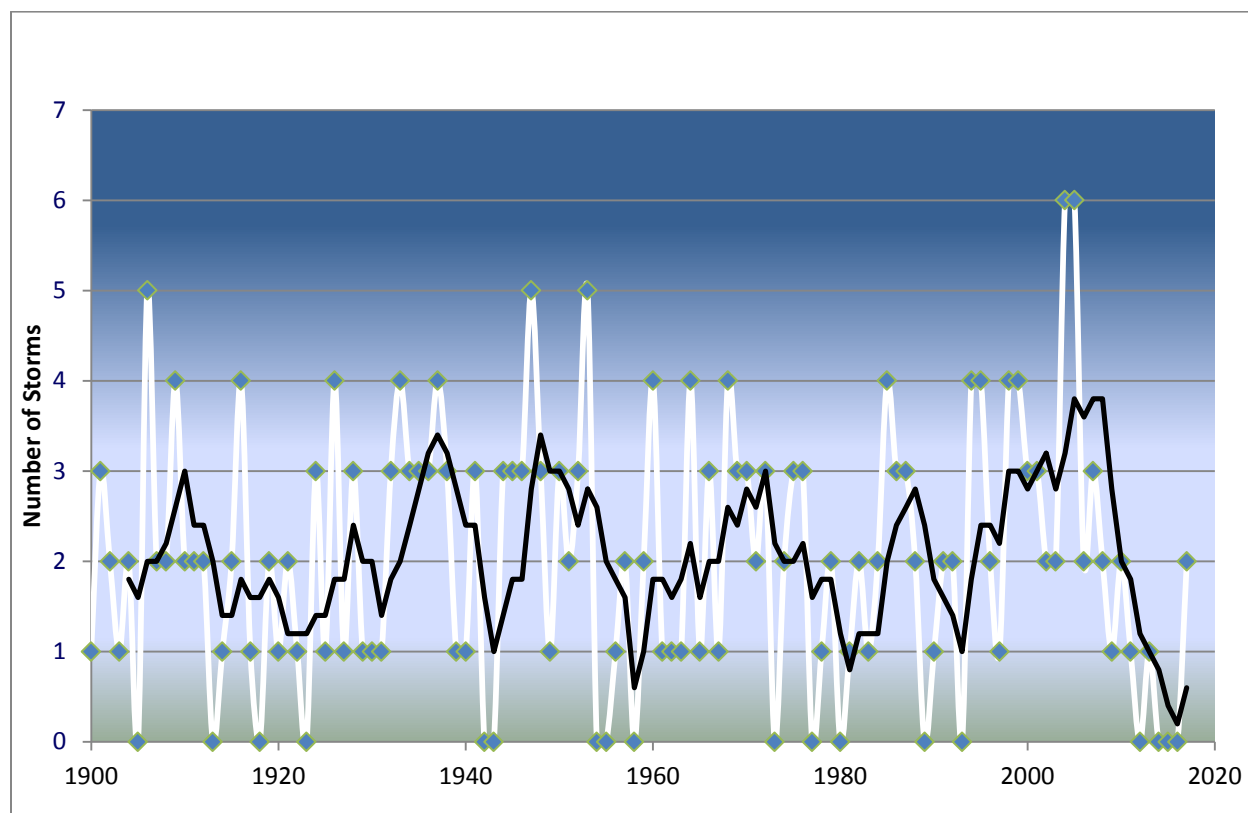


Figure 2.5 Long-term number and moving average (black line) of the number of tropical storms influencing southwest Florida.

[Figures 2.3a](#) and [2.3b](#) show that 2017 gaged Peace River flows during the typically drier months between January and May ranged from near normal to below normal, particularly in the month of May. Gaged Peace River flows were well above normal during June and September of 2017. Plots of USGS gaged flows during 2017 and over the prior period of HBMP monitoring (1976-2016), both for the Peace River at Arcadia and the combined gaged flows upstream of the Facility, are listed in [Table 2.3](#). Also included are figures showing 2017 and long-term USGS gaged flows for the lower Peace River (adding the flow for Shell Creek near Punta Gorda), as well as for the entire upper harbor (further including the addition of Myakka River and Big Slough USGS gaged flows).

Daily combined gaged flows upstream of the Facility over the 1976-2017 HBMP monitoring interval are shown in [Figure 2.4](#). 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, as well as the very dry conditions that extended from

2006 through the first half of 2009. The figure illustrates the magnitude of the drought during 2007, which was characterized by a lack of wet-season flows beyond anything observed since the beginning (1976) of HBMP monitoring.

Table 2.3
Freshwater Inflows during 2017 and the HBMP Period (1976-2017)

Figure	Description
Figure 2.2	Total daily gaged flow at the Facility: Arcadia + Horse and Joshua Creeks (2017)
Figure 2.3a	Comparisons of 7-day average 2017 flow upstream of the Facility to long-term (1976-2017) percentiles
Figure 2.3b	Log scale comparisons of 7-day average 2017 flow upstream of the Facility to 1976-2017 percentiles
Figure 2.4	Total daily gaged flow at the Facility: Arcadia + Horse and Joshua Creeks (1976-2017)
Figure 2.7	Mean monthly flow at the Facility: Arcadia + Horse and Joshua Creeks (1976-2017)
Figure 2.8	Total daily gaged flow of Lower Peace River: Arcadia + Horse, Joshua and Shell Creeks (2017)
Figure 2.9	Total daily gaged flow of Lower Peace River: Arcadia + Horse, Joshua and Shell Creeks (1976-2017)
Figure 2.10	Mean monthly flow of Lower Peace River: Arcadia + Horse, Joshua and Shell Creeks (1976-2017)
Figure 2.11	Total daily gaged flow to Upper Harbor: Lower Peace and Myakka Rivers + Big Slough (2017)
Figure 2.12	Total daily gaged flow to Upper Harbor: Lower Peace and Myakka Rivers (1976-2017)
Figure 2.13	Mean monthly gaged flow to Upper Harbor: Lower Peace and Myakka Rivers (1976-2017)

Combined gaged flows upstream of the Facility (Peace River at Arcadia + Horse and Joshua Creeks) over the same long-term period are further depicted as mean monthly values in **Figure 2.7**. Analogous graphical plots for both 2017 and the 1976-2017 HBMP period are presented in **Figures 2.8 through 2.10** for the total gaged lower Peace River flow at the U.S. 41 Bridge (Peace River at Arcadia + Horse, Joshua, and Shell Creeks). **Figures 2.11 through 2.13** 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. USGS gaged flows for Big Slough date back only to June of 2001 and were included in the 2017 figure, but not in the plots of long-term flows.)

The combined gaged flow upstream of the Facility during 2017 was approximately 166.8 percent of that calculated over the prior 1976-2016 HBMP monitoring period. The 2017 sum of average daily flows upstream of the Peace River Facility plus that of Shell Creek was roughly 173.2 percent of the average over the longer history of the prior HBMP monitoring period (1976-2016).

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 prior long-term HBMP period (1976-2016) and the current reporting year (2017). 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 show that, during 2017, the relative

percent contribution of freshwater flows from the Peace at Arcadia and Horse Creek flow was below average and the relative contribution from the Joshua Creek was above average. The contribution of the Peace at Arcadia and Horse Creek flows to freshwater inputs to upper Charlotte Harbor at the U.S. 41 Bridge was slightly lower as well when compared to the long-term average. In comparison, the relative percent contribution of Joshua and Shell Creeks was slightly higher than their longer term averages. This indicates that during intervals of 2017, the interior Peace River watershed received relatively less rainfall than the more coastal subbasins. This difference between interior and coastal rainfall patterns is not unusual.

Table 2.4
Comparisons of Relative Contributions of Gaged Flows Over Recent Historic (1976-2016) and the Current Period (2017)

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
1976-2016	75.6	15.1	9.4	57.9	11.5	7.2	23.4
2017	74.6	13.9	11.3	55.1	10.2	8.3	26.1

2.2 Peace River Facility Withdrawals

As a result of the extended drought conditions during 2006 and concern about the upcoming 2007 dry season ([Figure 2.4](#)), the Authority asked and received permission from the Southwest Florida Water Management District (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, while still 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 withdrawal schedule. The series of District Executive Orders issued by the District in response to the severity of the extended drought 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). These executive orders also modified the low flow threshold, and increased the allowable percent withdrawals all based on the District's initial draft proposed Lower Peace River Minimum Flow and Level (MFL). The contributions (since 1976) of the USGS gaged freshwater sources to the lower Peace River, both upstream of the Facility and at the U.S. 41 Bridge (which further includes flows from Shell Creek) are presented in [Table 2.2](#).

The series of District Executive Orders were initially based on the draft criteria presented in the District's proposed MFL for the lower Peace River ([Table 2.5](#)). The District's initial draft MFL for the lower Peace River proposed that during seasonal Block 2 (October 27 to April 19) the maximum permitted Facility 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.

Table 2.5
Drought Modifications to the Normal 1996 Permitted Withdrawal Schedule

Event	Effective Dates	Low Flow Threshold	Gages Used	Percent Withdrawal
Temporary WUP*	12/1/06 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% to 330 cfs 21% above 330 cfs
Executive Order	4/20/08 – 6/25/08	90 cfs	Three gages upstream of the Facility	10% to 221 cfs 26% above 221 cfs
Executive Order	6/26/08 – 10/26/08	90 cfs	Three gages upstream of the Facility	12% to 1370 cfs 15% above 1370 cfs
Executive Order**	10/23/08 -7/15/09	90 cfs	Three gages upstream of the Facility	4/20-6/25 10% to 221 cfs 26% above 221 cfs 6/26-10/26 12% to 1370 cfs 15% above1370 cfs 10/27-4/19 14% to 330 cfs 15% above 330 cfs
Executive Order	7/16/09 – March 2010	Same as above but increases maximum withdrawal from 90 to 120 mgd		
4/30/10 – Executive Orders ended and withdrawals returned to the original permit conditions				
Revised Permit Withdrawal Schedule Based on Adopted MFL	4/27/11 - Present	130 cfs	Three gages upstream of the Facility	Block I Apr 20 th Jun 25 th - 16% Block II Oct 27 th – Apr 19 th 16% if flow < 625 cfs 28% if flow > 625 cfs Block III Jun 26 th – Oct 26th 16% if flow < 625 cfs 28% if flow > 625 cfs

* Note 1: The temp WUP was extended each month by the governing board until the first Executive Order was approved

** Note 2: Variable percent withdrawal based on District proposed MFL criteria

In April 2010, after evaluating comments received on the initial draft report covering both the lower Peace River and Shell Creek MFLs, the District revised its initial draft proposed MFLs ([Table 2.6](#)) by modifying the maximum withdrawals allowable. The District's revised MFL for the lower Peace River eliminated the criteria of adjusting withdrawals based on whether flows were above or below the calculated seasonal mean. The District's revised MFLs instead added a 625 cfs upper threshold prior to changing the allowable percent withdrawal to both Blocks II and III, and delayed determination of a final Shell Creek MFL. In August 2010, the District approved and implemented the final MFL for the lower Peace River ([Table 2.7](#)).

Table 2.6
Initial Draft District Proposed Lower Peace River MFL Schedule
(based on combined USGS gaged flow at three upstream gages)

Block	Mean Flow	Allowable Percent Reduction if Flow:	
		Below the Median	Above the Median
Block I (April 20 th – June 25 th)	221	10	26
Block II (October 27 th – April 19 th)	330	14	21
Block III (June 26 th – October 26 th)	1370	12	15

Table 2.7
Final Adopted District Lower Peace River MFL Schedule
(based on combined USGS gaged flow at three upstream gages)

Block	Allowable Percent Reduction in Flow	
Block I (April 20 th – June 25 th)	16%	
Block II (October 27 th – April 19 th)	16% if flow < 625 cfs	29% if flow > 625 cfs
Block III (June 26 th – October 26 th)	16% if flow < 625 cfs	38% if flow > 625 cfs

The temporary modifications to the Facility's 1996 Water Use Permit presented in [Table 2.5](#) were in direct response to the severity of the 2006/2009 drought. These modifications were not permanent changes to the Authority's 1996 permitted 10 percent withdrawal of river flow based solely on Peace River at Arcadia gaged flows. In 2009, the Authority completed construction of the new 6 billion gallon reservoir, and expansion of maximum pumping capacity of the intake structure on the Peace River. Following the District's 2010 adoption of a final MFL for the lower Peace River, based on the combined flows of the three gaged flows upstream of the Facility ([Table 2.7](#)), the Authority subsequently requested a revised withdrawal schedule based on the District's adopted MFL. The Authority's goal in making this application was to provide for increased utilization of its recently increased off-stream storage system during higher river flows, in order to improve system reliability for the same 32.7 mgd average day delivery of water permitted in the Facility's 1996 District permit conditions.

A revised withdrawal schedule ([Table 2.8](#)) based on the District's adopted MFL was issued by the District to the Authority on April 26, 2011, and was implemented the following day. This permit modification maintained the original 32.7 mgd yearly average delivery of potable water to

the public and the maximum monthly allowed delivery of potable water average of 38.1 mgd. The maximum daily diversions from the river were increased from 90 mgd to 120 mgd, in order to allow greater flexibility with the Authority's recent Facility upgrades and improve system reliability. While the District's adopted MFL allows seasonal maximum withdrawals of 16%, (Block 1), 29% (Block 2), and 38% (Block 3), the Authority requested and received maximum withdrawals of 16% (Block 1) and 28% (Blocks 2 and 3) in the permitted diversion schedule. Daily Facility withdrawals had previously been based on the preceding daily average flow measured at only the USGS Arcadia gage. The new District permitted withdrawal schedule (following the final established MFL) instead utilizes the previous day's combined flow based on the readings from three gages upstream of the Facility located on the Peace River at Arcadia (USGS 02297310), Horse Creek (USGS 02297310), and Joshua Creek (USGS 02297100). The low flow cutoff for Facility withdrawals remained the same as previously permitted at 130 cfs, but was also changed to reflect the combined flow of the three upstream gages.

Table 2.8
April 2011 Revised Authority Lower Peace River Withdrawal Schedule
(based on combined USGS gaged flow at three upstream gages)

Block	Allowable Percent Reduction in Flow	
Block 1 (April 20 th – June 25 th)	16% if flow is above 130 cfs	
Block 2 (October 27 th – April 19 th)	16% if flow is > 130 cfs	28% if flow > 625 cfs
Block 3 (June 26 th – October 26 th)	16% if flow is > 130 cfs	28% if flow > 625 cfs

Two additional modifications were made to the Facility's water use permit in 2011. The first occurred in October 2011 and made a small adjustment in the allowable annual average delivery of potable water increasing it from 32.7 mgd to 32.855 mgd. This permit modification also increased the allowable monthly maximum delivery of potable water from 38.1 mgd to 38.3 mgd. The next permit modification occurred in November 2011 and didn't change any of the permit conditions other than to change the expiration date of the current water use permit from 2016 to 2037, in order to conform to the length of the Facility's existing bonds and to conform to new District rules allowing longer term water use permits.

Even with the District's revision of the withdrawal schedule based on the established MFL for the lower river, there continues to be a large number of days each year when the Peace River Facility does not withdraw water from the river. During 2017, the Facility didn't withdraw water from the river 42 percent (152 days) of the time. Reasons for the Facility not withdrawing water on a given day or time interval can be due to:

- The total USGS gaged stream flows upstream of the Facility being below the designated low flow threshold of 130 cfs for freshwater withdrawals
- Poor water quality from either upstream or downstream (conductivity, taste/odor)
- Facility maintenance

- Insufficient storage capacity (full existing storage system) even with the 2009 completion of the new 6 billion gallon reservoir

Daily river withdrawals since Facility startup are shown from 1980-2017 in [Figure 2.15](#). This figure clearly indicates the increase in maximum withdrawals beginning in the latter half of 2002 following expansion by the Facility, which increased the Peace River Treatment Facility's physical ability to divert, treat, and store larger daily amounts of freshwater. During 2009, the Authority completed a series of expansions to the Peace River Facility, which were undertaken as part of ongoing plans to meet projected future increasing water demands expected due to projected future regional growth in the member counties. These 2009 expansions included increasing the Facility's pumping capacity from the river from 44 mgd to 120 mgd, construction that increased the Facility's treatment capacity to 48 mgd (twice the previous capacity), and construction of a new regional off-stream reservoir with a capacity of approximately 6 billion gallons.

Additional figures depicting Peace River Facility withdrawals in relation to different combinations of total gaged flows are presented in [Table 2.9](#).

Table 2.9
Peace River Water Treatment Facility Withdrawals and Freshwater Inflows
During 2017 and the Period 1980-2017

Figure	Description
Figure 2.14	Daily water treatment facility withdrawals (2017)
Figure 2.15	Daily water treatment facility withdrawals (1980-2017)
Figure 2.16	Monthly mean water treatment facility withdrawals (1980-2017)
Figure 2.17	Daily total gaged flow at the Facility (Peace River at Arcadia + Horse + Joshua Creeks) and water treatment facility withdrawals (2017)
Figure 2.18	Daily total gaged flow at river's mouth (Peace River at Arcadia + Horse + Joshua + Shell Creek) and water treatment facility withdrawals (2017)
Figure 2.19	Peace River flows at Facility vs. water treatment facility withdrawals (2017)
Figure 2.20	2017 water treatment facility withdrawals as percent of combined USGS upstream gaged flows

A plot of the monthly mean withdrawal over 1980-2017 is provided in [Figure 2.16](#). 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 beginning in 2006, as well as the Facility's increased treatment capacity following the 2002 and 2009 expansions are evident in this figure. Seasonal relationships between 2017 Peace River total gaged inflows (at the Facility and U.S. 41 Bridge) and Peace River Facility withdrawals are further depicted in [Figures 2.17](#) and [2.18](#).

[Figure 2.19](#) shows the relationship between combined freshwater inflow at the three USGS gages upstream of the Facility and the actual amounts of water withdrawn, while [Figure 2.20](#) shows Facility withdrawals during 2017 relative to the percent of preceding daily combined

Peace River upstream gaged flow. Both of these graphics utilize different colors to depict potential differences among the withdrawal schedule's seasonal blocks (see [Table 2.8](#) above).

Horizontal lines in [Figure 2.20](#) indicate the 16 and 28 percent withdrawal thresholds, while the vertical line represents the 625 cfs flow required where the maximum percent of flow allowed to be withdrawn changes under the withdrawal schedule. Occasionally, Facility withdrawals exceed the percent withdrawal criteria set forth in the 2011 revised permit schedule. Historically, discrepancies have often stemmed from the way that stage/flow data are reported. The Facility uses "provisional" preceding day flow data for gaged flow based on the water level recorders at the USGS gaging station at each of the three upstream locations. Such "provisional" real-time data are obtained directly from the USGS Web Site a number of times each day by the Authority. This is accomplished in order to determine an accurate working estimate of the current daily stream flow on which to establish the Facility's subsequent day's withdrawal schedule. However, after the fact, the USGS checks and evaluates the data from both the gage 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. Experience has shown that adjustments of provisional gaged data frequently occur, especially during extended periods of low flow. 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 amounts under the permit withdrawal schedule.

2.3 Comparisons of Peace River Facility and Shell Creek Facility Withdrawals

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 ([Table 2.10](#)).

Table 2.10
Comparisons of Peace River Water Treatment Facility and Shell Creek Facility Withdrawals with Freshwater Inflows during 2017 and the Period of Record (1980-2017)

Figure	Description
Figure 2.21	Daily Peace River and Shell Creek water treatment facility withdrawals (2017)
Figure 2.22	Daily Peace River and Shell Creek water treatment facility withdrawals (1980-2017)
Figure 2.23	Daily total gaged flow at river's mouth (Peace River at Arcadia + Horse + Joshua + Shell Creek) and total water treatment facility withdrawals (2017)
Figure 2.24	Number of days annually without water treatment facility (PRF) withdrawals (1980-2017)

Figures 2.21 and **2.22** provide comparisons of both the 2017 and recent historic withdrawal patterns of the two facilities. **Figure 2.23** 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 2017 in relation to total gaged flows for the major tributaries.

Figure 2.24 depicts the number of days annually between 1980 and 2017 that the Peace River Facility hasn't withdrawn water from the river. As previously stated, the most common reason for no withdrawals being taken from the river is that the total USGS gaged stream flows upstream of the Facility is below the permitted flow threshold for freshwater withdrawal. During periods of lower freshwater flow, periods of poorer river water quality (conductivity or chlorophyll blooms) also cause the Facility to limit freshwater withdrawals and rely on previous storage. **Figure 2.25a** indicates the percent of days each year since 1951 that flows upstream of the Facility have been less than 200 cfs. As this figure indicates, the frequency of such events had increased since 2000, but frequency declined over the period 2014-2016 as flows were generally average to above average. The frequency again increased in 2017 as dry-season flows were below average. An alternative analysis of the same information is presented in **Figure 2.25b**. This figure depicts periods (intervals) since 1951 when the combined upstream flow above the Facility has historically been less than 200 cfs. The blue bars depict periods when the combined upstream flow above the Facility has historically been less than 200 cfs. Conversely, intervals characterized by lack of bars indicate wetter time intervals. This graphic indicates that not only has the frequency of low flow events increased but generally the duration of such events has also increased.

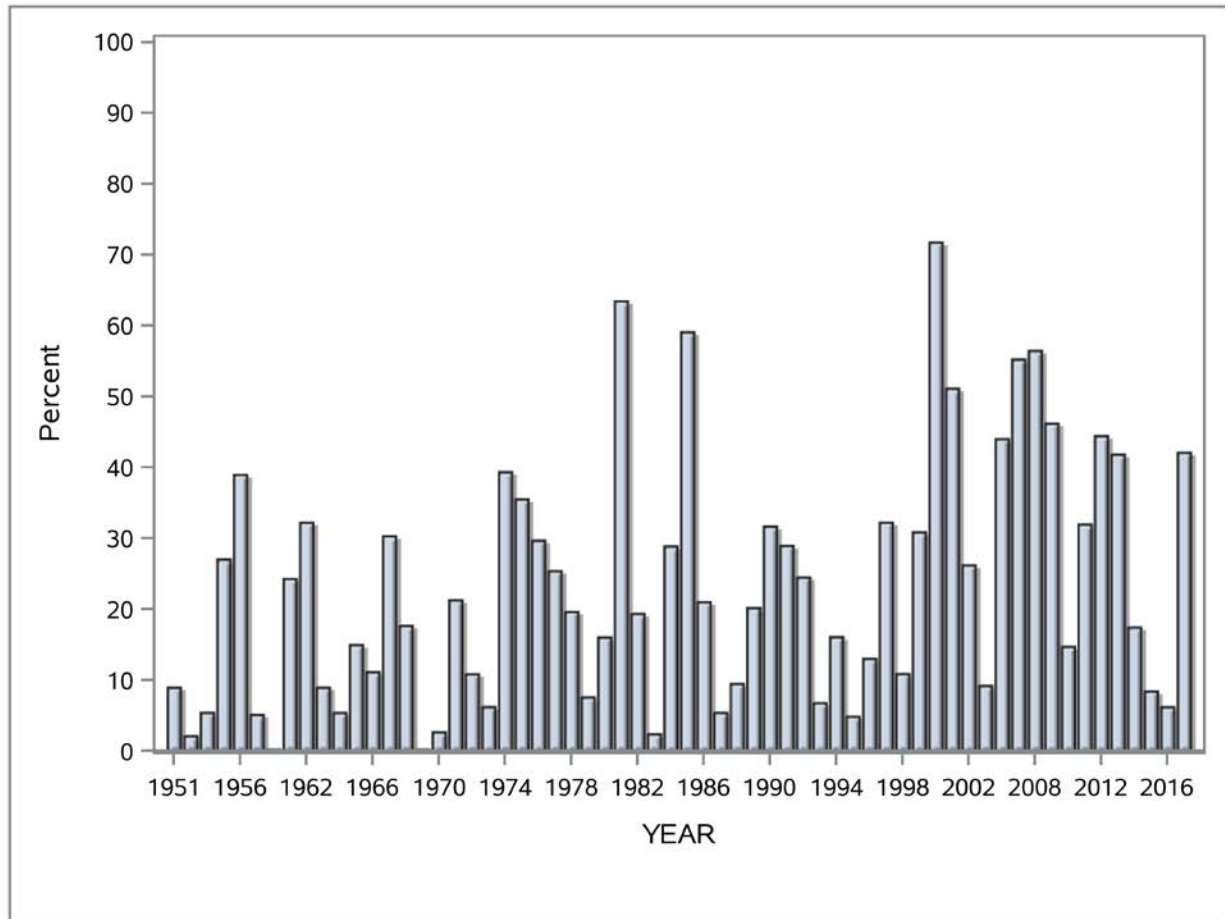


Figure 2.25a Indicates the percent of days each year since 1951 that flows upstream of the Facility have been less than 200 cfs. (The year 1951 represents the first year of complete flow records for all three of the USGS gages upstream of the Facility.)

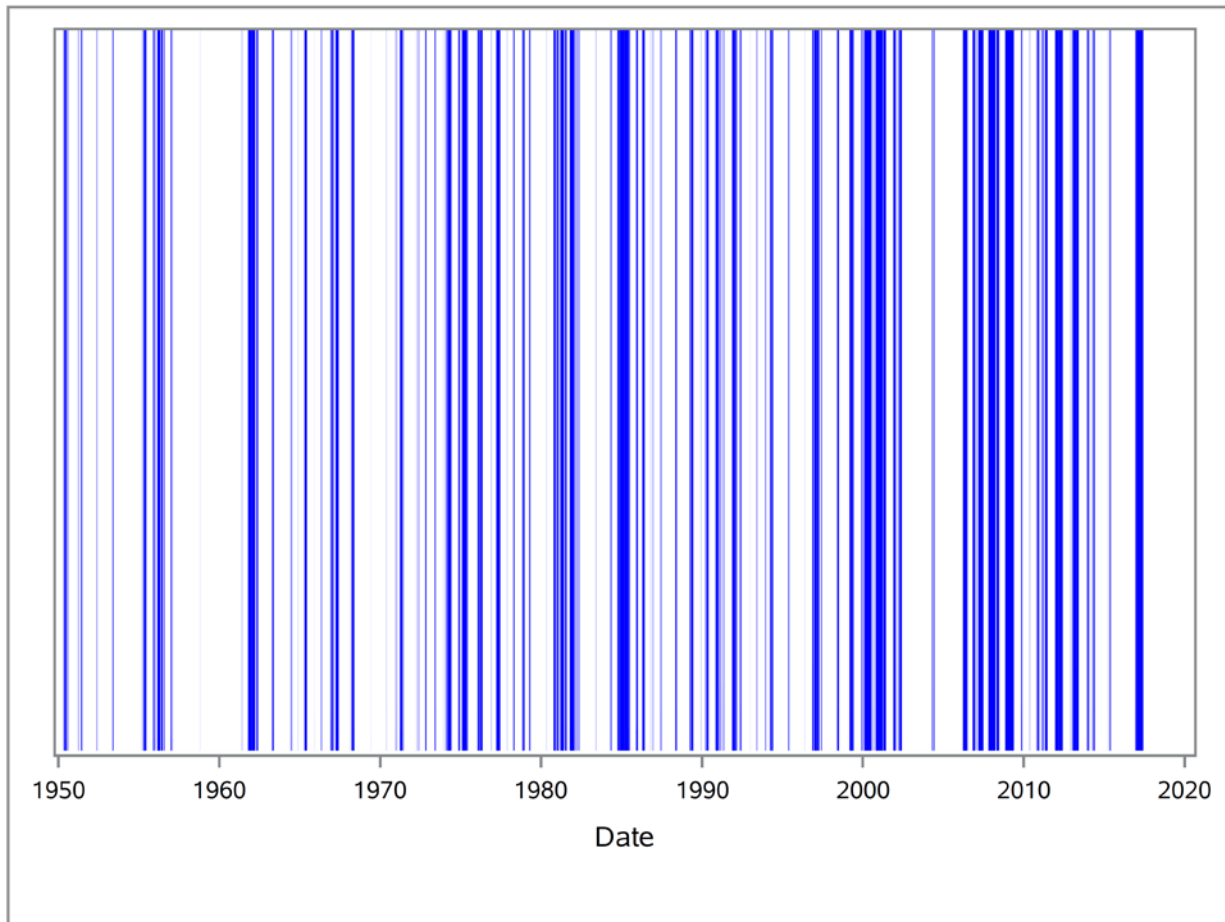


Figure 2.25b Blue bars depict periods when the combined upstream flow above the Facility has historically been less than 200 cfs. Conversely, intervals characterized by lack of bars indicate wetter time intervals.

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 since 1976 (the start of the HBMP) are summarized in [Table 2.2](#). 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 Authority's Peace River Facility and City of Punta Gorda Facility.

Total Peace River Facility withdrawals during 2017 were approximately 3.1 percent of the total gaged freshwater flow measured at the USGS Arcadia gage, 2.4 percent of the upstream gaged flow at the Facility, and 1.7 percent of the combined average daily inflows upstream of the U.S. 41 Bridge. During the entire period of Peace River Facility withdrawals (1980-2017), total combined average withdrawals have been approximately 2.1 percent of the corresponding gaged Peace River at Arcadia flows, 1.6 percent of total gaged flow upstream of the Facility, and only

1.2 percent of the combined daily freshwater flows of the Peace River and Horse, Joshua, and Shell Creeks.

The following from the USGS web site describes the level of error inherent in the USGS gage data used in assessing the potential impacts of the Facility's freshwater withdrawals from the lower Peace River.

Individual discharge measurements seldom are better than 2 percent. Stage discharge relations commonly have slopes of about 3 on logarithmic plots in which discharge is plotted as a function of effective stage (gage height minus offset, where offset commonly is approximately equal to gage height of zero flow). This implies that a 1 percent error in the effective stage input to the rating would translate into a 3 percent error in the computed discharge.

Figures 2.19 and 2.20, and Table 2.11 show how the Authority's Peace River Facility utilizing a withdrawal schedule based on a percent of the proceeding day's freshwater inflow, combined with sufficient off-stream storage (reservoirs and ASR wells), has allowed the Authority to withdraw sufficient water to meet regional demands while minimizing potential environmental impacts. This treatment and storage system allows the safe withdrawal of river water by following and accounting for the natural high seasonal variability of rainfall and flow patterns in the Peace River watershed.

Table 2.11
Statistical Comparisons of Peace River Water Treatment Facility Withdrawals
and Combined Upstream Gaged Inflows (cfs) during 2017
and the Period 1980-2016

Year / Measurement	Mean	Standard Deviation	Minimum	Maximum
2017				
Upstream gaged flow (cfs)	1,948.2	4,012.3	21.4	29,190
Facility withdrawal (cfs)	45.7	56.6	0.0	184
1980-2016				
Upstream gaged flow (cfs)	1181.9	1944.9	12.5	29,380
Facility withdrawal (cfs)	18.6	26.8	0	169.8

3.0 Physical and Chemical Water Quality Characteristics at “Moving” Isohaline Based 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. A specific goal of the HBMP isohaline based monitoring element has included determining immediate and long-term phytoplankton responses to freshwater inputs, including both nutrient loadings (nitrogen) and increased water color (which influences light availability). The HBMP’s historic, long-term phytoplankton investigations in the lower Peace River/upper Charlotte Harbor estuarine system have provided the following:

- Measurements of populations/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 that have secondary widespread interrelations and effects upon other estuarine food-web components.

Phytoplankton production generally represents an immediately available food resource. This is in contrast with some other sources of estuarine production such as that associated with seagrass, mangrove, and saltmarsh habitats, where much of the resource becomes available through extended secondary processes and nutrient recycling. 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, this element of the HBMP has incorporated a number of long-term monitoring studies designed to answer specific questions 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 Bacillariophyceae (*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*, *Odontella 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 increase in phytoplankton population, 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., *Nitzschia* 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 2017 as part 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 of this study element. 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 Corporation (formerly Florida Environmental, Inc.) has continued to be contracted to conduct the physical water column measurements and collection of water chemistry samples for both the “moving” isohaline and “fixed” HBMP station elements. Initially, a number of EarthBalance® staff had previously worked on the HBMP while with EQL, thus helping to maintain previously used field collection procedures.

Since the inception of the HBMP monitoring program in 1976, all water chemistry analyses were initially conducted by EQL, which was subsequently purchased in 2000 by ASCI, Inc. ASCI continued to conduct all HBMP chemical analyses through January 2002. However, in February 2002, due to issues regarding the long-term stability of ASCI, the chemistry work was changed to Benchmark EnviroAnalytical, Inc. located in Palmetto, Florida. All laboratory methods previously used by EQL/ASCI were continued by Benchmark, who conducted all HBMP chemistry analyses during 2017.

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 1983-2017

Isohaline	Furthest River Kilometer Downstream	Furthest River Kilometer Upstream	Mean	Median
0 psu	0.6	37.6	23.3	23.3
6 psu	-16.3	30.2	13.4	13.2
12 psu	-30.1	26.3	8.4	9.5
20 psu	-36.3	22.4	1.7	5.0

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 field *in situ* conductivity rather than laboratory 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 where Horse Creek joins the Peace River (during June 2000). (This upstream location also represents the practical upper end of the HBMP monitoring transect, since during low flows a number of existing limestone outcroppings effectively prevents further upstream monitoring by boat.) 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](#)).

[Table 3.2](#) lists the figures showing the isohaline locations during 2017 and the period 1983-2016. Isohaline station locations are based on the first location where the sampling boat reaches the 0, 6, 12, and 20 psu salinity.

Table 3.2
Isohaline Locations During 2017 and the Period 1983-2016

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) of isohaline sampling locations from the mouth of the river (2017)
Figure 3.3	Box & whisker plots of relative distance (km) from the mouth of the river (2017 and 1983-2016)

The relative location of each of these four isohalines during 2017 is shown in [Figure 3.2](#). Seasonal effects are apparent, particularly with downstream movement of the 12 and 20 psu station locations during the peak of the wet season (September).

The box and whisker plots presented in [Figure 3.3](#) summarize and compare the relative locations of each of the four “moving” isohaline sampling zones during both 2017 and over the preceding 1983-2016 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 3.3](#), the zero reference line denotes the imaginary mouth of the Peace River as defined in the previous morphometric study (see [Figure 1.2](#)). For several of the isohalines, mean and median river kilometers for 2017 were slightly upstream of the long-term values, but overall distributions of river kilometer were similar in 2017 to the long-term period.

3.3.1 *In Situ* Measurements of Physical Parameters

Depth, temperature, dissolved oxygen, conductivity, and pH were measured *in situ* with Hydrolab Surveyor (or YSI) 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 °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 °C.

The pH probes are typically 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-CORTM quantum/radiometer/photometer equipped with an underwater quantum sensor was used to measure photo-synthetically active radiation (400-700 nanometers). Light intensities (microeinsteins/m²/sec)

were measured in the air just above the water surface, again just below the surface, and at six selected depths (0, 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 was decreased from those originally specified (17 parameters) in the 1996 WUP 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 2017 was conducted using the revised/reduced long-term water quality sampling parameter list (12 parameters) implemented starting in March 2003 ([Table 1.4](#)).

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

Water quality data collected during 2017 at the four “moving” isohaline, salinity-based locations are presented and summarized in a series of 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 3.4](#) through [3.11](#) (see [Table 3.6](#)).

Comparisons of these parameters with earlier data are presented as box and whisker plots by salinity for both 2017 and preceding longer term data (collected between 1983 and 2016) in [Figures 3.12](#) through [3.19](#). As previously discussed, the box and whisker plots display a detailed distribution of the data as depicted in [Diagram 3.1](#), showing the median (50th percentile) line 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 2017, and During the Period 1983-2016, at the Four Isohaline Locations

Tables	Description
Table 3.4	2017 Physical and chemical water quality parameters
Table 3.5	2017 Physical and chemical water quality parameters - nutrients
Figure 3.4	Monthly temperature at salinity sampling zones – 2017
Figure 3.5	Monthly color at salinity sampling zones – 2017
Figure 3.6	Monthly extinction coefficient at salinity sampling zones – 2017
Figure 3.7	Monthly nitrite/nitrate at salinity sampling zones – 2017
Figure 3.8	Monthly ortho-phosphorus at salinity sampling zones – 2017
Figure 3.9	Monthly atomic N/P ratio at salinity sampling zones – 2017
Figure 3.10	Monthly silica at salinity sampling zones – 2017
Figure 3.11	Monthly chlorophyll <i>a</i> at salinity sampling zones – 2017
Figure 3.12	Box and whisker plots of temperature at salinity sampling zones (2017) & (1983-2016)
Figure 3.13	Box and whisker plots of color at salinity sampling zones (2017) & (1983-2016)
Figure 3.14	Box and whisker plots of extinction coefficient at salinity sampling zones (2017) & (1983-2016)
Figure 3.15	Box and whisker plots of nitrite/nitrate at salinity sampling zones (2017) & (1983-2016)
Figure 3.16	Box and whisker plots of ortho-phosphorus at salinity sampling zones (2017) & (1983-2016)
Figure 3.17	Box and whisker plots of atomic N/P ratio at salinity sampling zones (2017) & (1983-2016)
Figure 3.18	Box and whisker plots of silica at salinity sampling zones (2017) & (1983-2016)
Figure 3.19	Box and whisker plots of chlorophyll <i>a</i> at salinity sampling zones (2017) & (1983-2016)

3.5 Summary

Statistical comparisons between mean 2017 values and long-term 1983-2016 averages for selected *in situ* measurements and water quality parameters are summarized in [Table 3.7](#). The following summarizes comparisons of the findings from the 2017 data with those previously collected as part of the long-term isohaline-based HBMP water quality monitoring program element.

- Salinity Spatial Distribution** – During the dry-season of 2017, the combined gaged flows upstream of the Facility were less than characteristic longer term seasonal averages, while wet-season flows were at or above their characteristic longer term seasonal averages ([Figure 2.3b](#)). The influences of these deviations that characterized 2017 are reflected in the seasonal and average spatial distributions of each of the four sampled moving isohalines ([Figures 3.2](#) and [Figure 3.3](#) and [Table 3.7](#)) along the HBMP monitoring transect. The relative spatial distributions of each of the isohalines during 2017 reflected slight upstream movements, with the exception of the 20 psu isohaline, when compared with their previous long-term 1983-2016 averages.

- **Temperature** – Mean annual water temperatures during 2017 at each of the four isohalines were, on average, around 1 degree (C) warmer than corresponding values measured over the preceding 33-year period (1983-2016). The unusually colder than normal seasonal winter water temperatures observed early in 2010, 2011, and 2012 did not occur in 2017.
- **Water Color** – In comparison to averages over the preceding long-term historic period (1983-2016), water color levels during 2017 were at a slightly higher range than the long-term range at the upper two isohalines ([Figure 3.13](#)). This is in direct comparison with the generally lower levels observed during the 2006-2009 extended drought when color levels in the lower Peace River/upper Charlotte Harbor estuarine system were well below their long-term averages within all but the highest salinity isohaline. During 2017, flows upstream of the Facility were approximately 164 percent of that calculated over the longer 1976-2017 HBMP monitoring period. Including corresponding Shell Creek flows, which enter the lower Peace River further downstream nearer higher salinity harbor waters, the combined gaged flow was approximately 170 percent of the average over the HBMP period. These differences in regional rainfall/flows are expressed in the observed spatial differences in seasonal water color among the isohalines.
- **Extinction Coefficient** – Comparisons of mean extinction values among the four isohalines during 2017 with corresponding long-term averages ([Figure 3.14](#) and [Table 3.7](#)) show similar levels at all four isohalines; median values were also very similar. The rates of measured water column light attenuation at each of the four HBMP isohalines reflect the interactions of both ambient color and phytoplankton biomass (chlorophyll *a*).
- **Nitrite/Nitrate Nitrogen** – During 2017, the annual average concentration of this major inorganic form of nitrogen was above the previously observed longer term (1983-2016) historical average ([Figure 3.15](#) and [Table 3.7](#)) at the three downstream isohalines (6, 12, and 20 psu), while being below normal at the most upstream isohaline (0 psu). While above average freshwater inflows during 2017 may have increased loadings of nitrite/nitrate, the increased volume may also have provided a greater degree of dilution leading to lower average concentrations. 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 ([Figure 3.7](#)). Concentrations typically decrease 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 months as phytoplankton populations respond to increasing water temperatures and light, and increased primary production removes available inorganic nitrogen. As a result, inorganic nitrogen levels in the lower river and upper harbor are typically at their lowest levels in the late spring, just prior to increases in summer wet-season inflows (in 2017, levels at all isohalines declined from January to March and were at method detection limits during April and May).
- **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 primarily 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 rainfall runoff/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. Ortho-phosphorus concentrations remained well above recent historic levels throughout much of 2005-2009 and have recently begun rapidly declining again. However, following Hurricane Charley (and subsequent Hurricanes Frances and Jeanne) during the late summer of 2004, inorganic phosphorus concentrations dramatically increased throughout the lower Peace River/upper Charlotte Harbor estuarine system. The direct cause for the observed increased levels seems to have been related to the recent closing of the Ft. Meade phosphogypsum stack system in the upstream Whidden Creek subbasin (see Section 5 of the *2011 Comprehensive Summary Report*). After Hurricane Irma in 2017, no such increased concentration occurred even with sampling 9 days after the storms landfall. Annual average ortho-phosphorus concentrations at all four isohalines were similar in 2017 to the corresponding long-term averages (1983-2016; [Figure 3.16](#) and [Table 3.7](#)).

- **Nitrogen to Phosphorus Atomic Ratios** – Calculated atomic inorganic nitrogen to phosphorus ratios for ambient measured concentrations in 2017, as well as longer term averages at each of the four isohalines, show nitrogen to almost always be the limiting macronutrient ([Figure 3.17](#) and [Table 3.7](#)).
- **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 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 over the 2006-2009 interval were below normal, silica levels throughout the lower river/upper harbor estuary continued to reach historically high levels during the summer wet -seasons. As with ortho-phosphorus, the proximate cause for these increasing levels seems to be related to the on-going closing of the Ft. Meade phosphogypsum stack system in the upstream Whidden Creek subbasin. However, while

peak levels during 2009 and 2010 were somewhat lower than during the immediate preceding years, levels again increased in 2011. Annual average concentrations during 2017 were again well above their long-term averages at each of the four moving isohaline based monitoring locations ([Figure 3.18](#) and [Table 3.7](#)).

- **Chlorophyll *a*** – The seasonal patterns of freshwater inflows to the estuary during 2017 were characterized by above average flows during much of the year when compared to the long-term average conditions (see [Section 2](#)). 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 2017 HBMP data indicate there were little to no increases in phytoplankton biomass at each of the four moving isohaline based monitoring locations throughout the year ([Figure 3.11](#)). Overall, chlorophyll *a* concentrations within the Peace River/upper Charlotte Harbor estuarine salinity zones during 2017 in the intermediate isohalines (6 and 12 psu) were generally below their preceding long-term (1983-2016) averages ([Table 3.7](#)), and similar to the long-term averages in the freshest and most estuarine sampling zones (0 and 20 psu).

4.0 Physical and Chemical Water Quality Characteristics at “Fixed” Station Locations

4.1 Introduction

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

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

Prior to 1996, the only HBMP study element that included chemical water quality monitoring was the monthly “moving” isohaline monitoring at four locations along the HBMP monitoring transect. This ongoing study, initially began in 1983 to assess estuarine phytoplankton production (see [Section 3](#)), includes monthly *in situ* physical water column profile measurements and surface water chemistry samples taken in conjunction with the “moving” isohaline HBMP study element.

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 Regional Water Supply Facility (Facility). In addition to these five water chemistry locations, the sampling of *in situ* physical water column profile data was also initiated at ten additional “fixed” sampling locations. These new HBMP water chemistry 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 USGS recorder installed in 1997 at River Kilometer (RK) 29.8. 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 at each of the five current HBMP water quality monitoring locations by EQL, in conjunction with General Development Corporation’s background monitoring program of the lower Peace River and Charlotte Harbor, beginning at the

inception of the HBMP monitoring program in 1976, temporarily ending in 1990, as part of the HBMP. During the interval from 1990 to 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 Surface Water Improvement and Management (SWIM) monitoring program. Charlotte County also collected monthly data at these same two sites as background information for Florida DEP/U.S. Army Corps mandated 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 new “fixed” HBMP monitoring locations. Since July 2000, EarthBalance Corporation (formerly Florida Environmental, Inc.) has been responsible for both the “fixed” and “moving” ([Section 3](#)) field monitoring, including physical water column measurements and water chemistry samples. ASCI, Inc. analyzed both the “fixed” and “moving” HBMP chemical samples between the sale of EQL in 1998 and change from ASCI in January 2002. However, due to concerns regarding the long-term stability of ASCI, all HBMP water chemistry analyses were changed to Benchmark EnviroAnalytical, Inc. located in Palmetto, Florida in February 2002. Benchmark has continued to conduct all the chemistry analyses of samples collected through 2017, 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 ([Figures 4.1a and 4.1b](#)).

1. The first consists of monthly physical water column *in situ* water quality measurements at 16 “fixed” sampling sites. *In situ* field measurements made at all 16 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 of the water column. Depths are determined based on pre-labeled marks on the unit’s cable and/or combined with direct sonde pressure based readings.
2. The second type of data collection consists of monthly sub-surface and near-bottom chemical water quality samples collected at five locations, spaced between the river’s mouth and just upstream of the facility along the established River Kilometer centerline transect ([Figure 4.1b](#)).

Between 1996 and 2003, near-surface and near-bottom samples collected at the five monthly water quality monitoring sites were analyzed 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* (see [Table 1.4](#))

In response to 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 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 1.4](#)). *In situ* field measurements made in conjunction with sampling at these 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 was 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 locations during 2017 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 during 2017 and over the long-term 1976-2016 interval.

4.4.1 Physical Water Column Characteristics (2017)

The results for the *in situ* hydrolab water column profiles for the period January through December 2017 at the 16 fixed stations are contained in the appropriate 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 2017

Figure	Description
Figure 4.2	Wet and dry season surface (upper panel) and bottom (lower panel) temperature versus distance for fixed station locations (2017)
Figure 4.3	Wet and dry season surface (upper panel) and bottom (lower panel) dissolved oxygen versus distance for fixed station locations (2017)
Figure 4.4	Wet and dry season surface (upper panel) and bottom (lower panel) pH versus distance for fixed station locations (2017)
Figure 4.5	Wet and dry season 1% light versus distance for fixed station locations (2017)
Figure 4.6	Wet and dry season surface (upper panel) and bottom (lower panel) specific conductance versus distance for fixed station locations (2017)

The following patterns and observations with regards to seasonal differences among the 16 “fixed” sampling sites are shown and supported by these figures.

- **Water Temperature** – Surface and bottom water temperatures in 2017 ([Figure 4.2](#)) followed the strong seasonal pattern typically observed in south Florida. Water temperatures were at or near their peak, and were relatively similar across months, during the wet season (June-September), and along the spatial transect. Dry season temperatures, spanning January-May and October-December displayed greater variability between months. Historically, the annual peak in water temperatures in the estuary varies between June and August depending on annual variations in cloud cover and differences in seasonal rainfall patterns. The 2017 data further show relatively normal cold conditions during the start of the year with typical winter cold fronts.
- **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 (DO) levels in response to increased wet-season flows. This seasonal pattern typifies the widely documented hypoxic/anoxic conditions that typically occur 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 high flow summer wet season. 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. During 2017 (as typically observed in previous years), dissolved oxygen levels generally declined as water temperatures increased ([Figure 4.3](#)), resulting in DO levels reaching their lowest levels during summer wet season throughout both the lower river and upper harbor as both water temperatures and flows increased. The 2017 wet season column profile data (as has occurred since 2010) indicated the return of normal hypoxic/anoxic dissolved oxygen levels in the upper harbor. Such normal summer high flow low DO levels did not occur (or were far less in magnitude/duration) during the extended 2006-2009 drought. This indicates that the flows that occurred during the summer of 2017 were again of sufficient duration and intensity to induce the level of water column stratification necessary to cause the development of widespread extremely low near-bottom dissolved oxygen levels in upper Charlotte Harbor.
- **pH** – During 2017 as in previous years, pH values periodically show marked declines during periods of increased, lower pH summer freshwater inflows ([Figure 4.4](#)). Lower pH values indicate increased surface flows relative to groundwater influences. Surface flows from heavily vegetated upland/wetland areas are responsible for the characteristic “black water” wet-season inflows, which are high in humic acids. These surface water flow influences will decline and pH levels will increase as water flow moves downstream toward the mediating effects of higher pH, high salinity harbor waters.
- **Light Extinction** – The 2017 HBMP data indicate that both the timing and magnitude of the ability of light to penetrate into the water column (1 percent depth) exhibits 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, light extinction in the lower Peace River/upper Charlotte Harbor estuarine system is often primarily mediated by existing water color due to the “black water” characteristics of freshwater inflows from the Peace River watershed. **Figure 4.5** indicates that water clarity during 2017 (as in previous years) was the greatest in the lower river, and especially in the upper harbor, during the typical spring dry season and other periods of lower flows. The influences of the summer wet-season rainfall conditions are clearly evident in comparing the one percent light depths observed between the more downstream lower river/upper harbor monitoring locations with the upstream characteristically freshwater reaches of the lower river.

- **Conductivity/Salinity** – **Figure 4.6** clearly show the influences of both the wetter and drier intervals during 2017 on the temporal and spatial patterns of conductivity (salinity) throughout the lower Peace River/upper Charlotte Harbor estuarine system. Seasonally spatial conductivity patterns in the tidal lower Peace River were reflective of the normal to above normal flow in 2017 (**Figure 2.3b**). Late fall conditions with low river flow occurred over much of the previous decade, allowing brackish conditions in the lower river to often extend upstream even beyond the Peace River Facility intake. Such relatively high salinity conditions in the lower river were especially noticeable during the extended droughts that affected southwest Florida and the Peace River basin during much of the 1999-2001 and 2006-2009 periods (see **Table 2.6**). During these years, very high conductivities were observed even at the most upstream sampling locations during the extended periods of low freshwater inflows.

4.4.2 Chemical Water Quality Characteristics (2017)

The 2017 water chemistry data for the five “fixed” water quality stations are contained in the appropriate 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 4.13** (listed in **Table 4.3**).

These graphics indicate that, for a number of water quality constituents, there are strong spatial and temporal seasonal differences within the reaches of the lower Peace River/upper Charlotte Harbor estuary represented by the five “fixed” water quality monitoring locations. Further spatial and temporal differences are also apparent both within and among sampling locations between sub-surface and near-bottom samples. Water color, for example, clearly indicates a distinct seasonal pattern (**Figure 4.7**), with levels increasing first upstream and then progressively downstream at the beginning of the typical summer wet season. Water color levels downstream, nearer the river’s mouth, are at times higher at the surface than near the bottom indicating distinct stratification between more colored, lower density surface freshwater inflows and higher salinity bottom waters.

Table 4.3
Summary Graphics of Chemical Water Quality Measurements for Monthly
Data Collected During 2017 at the Fixed Sampling Locations
(River Kilometers –2.4, 6.6, 15.5, 23.6, and 30.7)

Figure	Description
Figure 4.7	Wet and dry season surface (upper panel) and bottom (lower panel) color versus distance for fixed station locations (2017)
Figure 4.8	Wet and dry season surface (upper panel) and bottom (lower panel) total suspended solids versus distance for fixed station locations (2017)
Figure 4.9	Wet and dry season surface (upper panel) and bottom (lower panel) nitrate/nitrite versus distance for fixed station locations (2017)
Figure 4.10	Wet and dry season surface (upper panel) and bottom (lower panel) Kjeldahl nitrogen versus distance for fixed station locations (2017)
Figure 4.11	Wet and dry season surface (upper panel) and bottom (lower panel) ortho-phosphorus versus distance for fixed station locations (2017)
Figure 4.12	Wet and dry season surface (upper panel) and bottom (lower panel) silica versus distance for fixed station locations (2017)
Figure 4.13	Wet and dry season surface (upper panel) and bottom (lower panel) chlorophyll <i>a</i> versus distance for fixed station locations (2017)

A number of other measured water quality parameters also show distinct seasonal relationships relative to the typical annual patterns of seasonal increasing and decreasing freshwater inflows. However, in other instances, the seasonal patterns and spatial relationships of some water quality characteristics reflect far more complex relationships.

- **Total Suspended Solids** –As expected, the very highest measured levels are typically observed near the bottom of the water column (**Figure 4.8**). Total suspended solids levels measured near the bottom of the water column also had greater peaks in the lower reaches of the reporting stations than the more upstream two fixed stations.
- **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 limits phytoplankton growth. The data typically indicate a distinct spatial gradient within the lower river/upper harbor estuarine system with higher levels of inorganic nitrogen progressively occurring upstream (**Figure 4.9**). Nitrite+nitrate nitrogen levels in 2017 were similar to the longer-term averages at each of the five fixed-station locations (**Table 4.4**).
- **Total Kjeldahl Nitrogen** – Typically, total Kjeldahl nitrogen concentrations in the lower Peace River/upper Charlotte Harbor estuarine system are the highest during the summer

wet season, reflecting the influences of increased freshwater inflows, and this is reflected in 2017 measurements (**Figure 4.10**). Overall, during 2017, the annual average Kjeldahl concentrations were slightly lower than the historic long-term averages (**Table 4.4**).

- **Ortho-Phosphorus** – As previously discussed (see **Section 3**), inorganic phosphorus concentrations in the Peace River estuary follow patterns typical of conservative water quality constituents (reflecting dilution rather than biological uptake). 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 (**Figure 4.11**). Following Hurricane Charley in August 2004 (and the subsequent Hurricanes Frances and Jeanne storms in September 2004), 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. However, the periods following Tropical Storm Emily and Hurricane Irma in 2017 were not marked with the increases seen in 2004. Phosphorus concentrations began to decline during 2009 and have continued to decline to previous observed lower levels. Inorganic ortho-phosphorus levels in 2017 at the five fixed monitoring sites were similar to the mean long-term values (**Table 4.4**). As previously discussed in **Section 3**, the direct cause for the increased levels seems to have been related to the discharges of water during the closure of the Ft. Meade phosphogypsum stack system and general phosphate mining activities in the upstream Whidden Creek subbasin.
- **Silica** – Historically, annual reactive silica concentrations in the Peace River estuary characteristically have indicated a number of differing temporal and spatial patterns. During the spring dry season, silica levels were normally at their annual lowest concentrations 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 of silica by diatoms in the phytoplankton). Then usually during May and June, as water temperatures increased and the start of the summer wet-season began, concentrations characteristically rapidly increased throughout the estuary (**Figure 4.12**). Reactive silica concentrations during 2017 continued to reflect the recently observed pattern of increased levels noted in previous HBMP reports, with 2017 average silica levels greater than the long term averages (**Table 4.4**). Again, the increasing silica levels seem to have been associated with the closing of the Ft. Meade phosphogypsum stack system and general phosphate mining activities in the upstream Whidden Creek subbasin. However, unlike phosphorus concentrations, silica levels have continued to be near historic high seasonal levels through much of the estuary.
- **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 shows 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. However, the occurrences of spring phytoplankton increases are often muted during drought conditions such as those that characterized the 2006-2009 time interval. 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). Chlorophyll *a* during 2017 (Figure 4.13) were seasonally similar spatially and temporally over the long-term average.

4.4.3 Statistical Comparisons of Physical and Chemical Water Quality Characteristics during 2017 with Comparable Longer-Term Data (1996-2016)

Comparative statistical relationships between the most recent 2017 surface water quality data collected at the five “fixed” monitoring sites along the HBMP monitoring transect (Figure 4.1) and analogous information collected during the preceding 20 years of study (1996-2016) are shown for selected physical, chemical and biological measurements in Figures 4.14 through 4.24 (see Table 4.5). Comparisons are presented as box and whisker plots and as previously discussed, the box and whisker plots display statistical distributions of the data (Diagram 3.1) showing the means, medians (50th percentile), and the 25th and 75th percentiles, with whisker lines extending to the 10th and 90th percentiles. Extreme values (outside the 10th-90th percentiles) are represented by dots at the ends of the whiskers.

Table 4.5
Summary Box and Whisker Graphics of Physical/Chemical Water Quality
Parameters Comparing Data Collected in 2017 with that over
the 1996-2016 Time Interval at the Fixed Sampling Locations
(River Kilometers –2.4, 6.6, 15.5, 23.6, and 30.7)

Figure	Description
Figure 4.14	Box and whisker plots of surface temperature at fixed sampling sites
Figure 4.15	Box and whisker plots of surface salinity at fixed sampling sites
Figure 4.16	Box and whisker plots of surface pH at fixed sampling sites
Figure 4.17	Box and whisker plots of dissolved oxygen at fixed sampling sites
Figure 4.18	Box and whisker plots of extinction coefficient at fixed sampling sites
Figure 4.19	Box and whisker plots of surface color at fixed sampling sites
Figure 4.20	Box and whisker plots of surface nitrite/nitrate at fixed sampling sites
Figure 4.21	Box and whisker plots of surface total Kjeldahl nitrogen at fixed sampling sites
Figure 4.22	Box and whisker plots of surface ortho-phosphorus at fixed sampling sites
Figure 4.23	Box and whisker plots of surface silica at fixed sampling sites
Figure 4.24a	Box and whisker plots of surface chlorophyll <i>a</i> (ug/L) at fixed sampling sites
Figure 4.24b	Box and whisker plots of surface chlorophyll <i>a</i> (ug/L) at fixed sampling sites (reduced range)

The following briefly describes both observed temporal and spatial patterns apparent in this series of figures.

- **Temperature** – Mean surface water temperatures at each of the five “fixed” monitoring sites 2017 were similar to averages for the preceding 20 years. The figure also indicates that long-term values for water temperatures at the two sites in the harbor downstream of the U.S. 41 Bridge are generally slightly lower than at the three more riverine sampling locations. These spatial differences probably result from the combined greater exposure of the estuarine waters to cold fronts during winter months, and the greater heating of highly colored upstream river water during the summer months.
- **Salinity** – The figure clearly shows the strong gradient in salinities along the HBMP monitoring transect, as well as the larger range of salinities during 2017. This was caused by the above normal flows during the wet season of 2017 and lower than normal flows during the dry season ([Section 2](#)).
- **pH** – Mean measured levels during 2017 at two upstream monitoring locations along the HBMP monitoring transect were increased in comparison to the statistical distributions of values over the longer-term 1996-2016 interval. Median values for 2017 were higher than long-term values for all stations. This result probably reflects the influences of salinities during 2017, since more marine waters characteristically have somewhat higher pH levels than freshwater inputs to the estuary.
- **Dissolved Oxygen** – Mean and median annual measured dissolved oxygen levels among the five sampling sites were generally similar to statistical metrics over the preceding 20 year interval. The previous occurrences of both very high and very low values apparent in longer-term data were not observed during 2017.
- **Light Extinction Coefficient** – As previously described, measured water column extinction coefficients primarily reflect the combined influences of water color, chlorophyll *a* (phytoplankton), and turbidity (also often heavily influenced by plankton). The presented figure indicates higher than average extinction coefficients (less clear water) during 2017 reflecting the higher than normal freshwater flows that characterized the wet season.
- **Water Color** – Since water color is often the primary factor influencing the extinction of light in the water column within the lower Peace River/upper Charlotte Harbor estuarine system, the spatial and temporal patterns depicted for water color closely follow those described for measured extinction coefficients.
- **Nitrite+Nitrate Nitrogen** – This major nutrient is often the limiting factor to phytoplankton growth in the lower river/upper harbor estuarine system, and shows both strong seasonal variability as well as spatial patterns among the HBMP sampling sites. Measured levels are often near or at detection limits at the more downstream monitoring locations during the spring dry season, prior to the beginning of the characteristic summer wet season, when freshwater inflows delivers inputs of nutrients (and color) from the

watershed. The spatial pattern of measured concentrations during 2017 along the HBMP was typical of those measured over the previous 1996-2016 time interval.

- **Total Kjeldahl Nitrogen (TKN)** – The spatial pattern of TKN among the five monitoring sites along the HBMP transect in 2017 were higher than the long-term averages. Spatially TKN levels progressively decrease from the watershed into the upper harbor.
- **Ortho-phosphorus** – Measured concentrations along the HBMP monitoring transect during 2017 were similar to the longer-term averages, which were heavily influenced by the recently observed high levels associated with the previously discussed closure of the Ft. Meade Whidden Creek phosphogypsum stack and general phosphate mining activities in the upstream Whidden Creek sub basin. The spatial distribution from the most upstream site to the most downstream monitoring location in the upper harbor reflects simple dilution by saline water.
- **Silica** – As previously discussed, silica levels over recent years in the lower Peace River have been much higher than historically observed. While concentrations of ortho-phosphorus, have declined over the past several years, silica levels have remained relatively high. The annual average silica levels in 2017 were appreciably higher, particularly in the five monitoring sites, than those observed in the earlier period.
- **Chlorophyll *a*** – The spatial distribution of measured chlorophyll *a* phytoplankton biomass along the HBMP sampling transect during 2017 exhibited one or two relatively high spikes (blooms) in phytoplankton biomass. Such events have often been observed to occur in the region between Harbour Heights and near the U.S. 41 Bridge. This region of the lower river is commonly characterized by intermediate salinities, where freshwater with higher nutrients from the watershed mix with nutrient poor (lower nitrogen) higher salinity harbor water, naturally stimulating “blooms” of phytoplankton production at the base of the estuarine food-chain. The fact that the statistical means at each of the five monitoring locations is greater than the calculated medians reflects the influences of periodic unusually higher than average measured chlorophyll values have on the statistical distributions of the data. The mean values for the five monitoring stations in 2017 were similar to the long-term averages.

5.0 USGS and HBMP Continuous Recorders

5.1 Introduction and Overview

During the 1996 permit renewal, a need was identified to begin collecting salinity data at fixed points along the HBMP monitoring transect at a much greater frequency than that being obtained by the ongoing monthly “fixed” and “moving” isohaline based monitoring study elements. The availability of such temporally intense data collected over an extended period, encompassing a wide variety of flows under differing tidal conditions was expected to provide the needed information for the development of more accurate statistical and/or mechanistic models. The development of such models would allow increased accuracy in assessing the relative magnitudes of short and longer-term salinity changes due to permitted Facility withdrawals. Both the magnitude and spatial duration of salinity changes along the HBMP monitoring transect resulting from Facility freshwater withdrawals are expected to be influenced by the interactions, and combined influences, of seasonally varying natural variations in flows and tides. In 1996, a 15-minute recorder location was established by USGS at Harbor Heights under an ongoing contract with the Authority. In 1997, USGS added another recorder location at Peace River Heights. Responding to comments and recommendations from the HBMP Scientific Review Panel, the Authority itself subsequently deployed three additional continuous salinity recorders in December 2005. This was followed by two additional recorders added in May 2008, and most recently three more recorders were added at the end of June 2011. In December 2009, USGS installed a pair of near-surface/near-bottom continuous recorders immediately adjacent to the Facility’s river intake structure. This USGS recorder provides the Authority the ability to assess river conductance both downstream and at the Facility in real time. The relative locations of the recorders along the lower Peace River HBMP monitoring transect are depicted in [Figure 5.1](#) and further summarized in [Table 5.1](#) and [Table 5.2](#).

Table 5.1
Summary of Historic and Current HBMP Continuous Recorders
along the Lower Peace River

Gage ID, Location, and Period of Monitoring	River Kilometer
RK09 (Authority) - Navigation Marker south of I75 Bridge – Jun 2011 to present	RK 09.2
RK12 (Authority) - Manatee Zone Marker near Shell Creek (near bottom) – May 2008 to Jun 2011	RK 12.7
RK12 (Authority) - Manatee Zone Marker near Shell Creek (surface) – Jun 2011 to present	RK 12.7
HH (USGS - 02297460) - Dock at Harbour Heights – Sep1996 to present	RK 15.5
RK18 (Authority) - Channel Marker in Area of Power Lines – June 2011 to present	RK 18.5
RK18_HC (Authority) - Manatee Zone Marker on Hunter Creek – Jun 2011 to present	RK 18.7
RK20 (Authority) - Channel Marker downstream of Island – June 2011 to present	RK 20.8
RK21 (Authority) - Manatee Zone Marker near Liverpool area – Dec 2005 to present	RK 21.9
RK23 (Authority) - Manatee Zone Marker downstream of Navigator Marina – Dec 2005 to May 2008	RK 23.4

Table 5.1
Summary of Historic and Current HBMP Continuous Recorders
along the Lower Peace River

Gage ID, Location, and Period of Monitoring	River Kilometer
RK24 (Authority) - Manatee Zone Marker gage near Navigator Marina – Dec 2005 to present	RK 24.5
PRH (USGS - 02297350) - Dock at Peace River Heights gage – Nov 1997 to present	RK 26.7
PRP (USGS – 02297345) - Peace River at Platt (Facility) – December 2009 to present	RK 29.8
RK30 (Authority) - Manatee Zone Marker near SR 761 Bridge – May 2008 to June 2011	RK 30.6
RK31 (Authority) - Old Railroad Bridge upstream of Facility – May 2008 to present	RK 31.7

Table 5.2
Maps of Continuous Recorder Locations along the Lower Peace River

Figure	Description
Figure 5.1(a)	2005 Locations of continuous recorders
Figure 5.1(b)	2006 Locations of continuous recorders
Figure 5.1(c)	2008 Locations of continuous recorders
Figure 5.1(d)	2010 Locations of continuous recorders
Figure 5.1(e)	2011-2017 Locations of continuous recorders

5.1.1 USGS Recorders

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(a)**) at the end of an existing private dock at Harbour Heights (RK 15.5). This USGS gaging site (02297460) monitors water level and both surface and bottom specific conductance, as well as water temperatures.

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 by USGS for the Authority at this location between 1996 and 2004. The original purpose of this gage was to assess potential gradual increases in sea level. Such a rise in sea level was expected to occur over time and monitoring was established in order to account for natural increases in salinity that might be occurring in the lower Peace River estuary. However, USGS staff at a later date 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 continuous conductivity 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(a)**). This USGS site (02297350) also measures water level, surface and bottom specific conductance, and corresponding temperatures at 15-minute intervals. More recently, in December 2009, USGS installed near-surface and near-bottom recorders (02297345) at the Facility's intake structure (RK 29.8; **Figure 5.1(d)**).

Water level measurements at the two original USGS river recording sites were initially made utilizing a floating sensor in a PVC stilling well and a fixed sensor near the bottom of the water column. USGS combination temperature and specific conductance probes measure near-surface and near-bottom specific conductance and temperature. Readings are electronically averaged over two-minute intervals and recorded at 15-minute intervals using an electronic data logger. Data are retrieved and the sensors recalibrated at approximately monthly intervals.

The near-surface sensors at the two original river gaging sites were initially suspended one foot below the surface using a float, while the near-bottom sensors were suspended about one foot from the bottom in the same stilling well. However, following damage caused by Hurricane Charley (August 2004), the Harbour Heights gage (02297460) was rebuilt on January 11, 2005. The upper sensor was set at a fixed depth (0.40 foot below NGVD 1929) below the water surface to measure the near-surface specific conductance and temperature and the lower sensor was fixed (3.5 feet below NGVD 1929) near the bottom. The sensors were subsequently lowered to a new elevation on Nov 21, 2006. The upper sensor was set at a fixed depth (1.40 feet below NGVD 1929) and the lower sensor was set at (4.4 feet below NGVD 1929) near the bottom. The Peace River Heights gage was also rebuilt at this time (January 6-7, 2005). The top sensor was set to a fixed elevation approximately 1.3 feet below NGVD 1929 and the bottom sensor at approximately 3.8 feet below NGVD 1929.

In 2009, using both the extensive data collected before and after these changes, as well as corresponding field measurements made during the monthly "fixed" station monitoring, the Authority completed a series of statistical comparisons to determine if these changes in depth resulted in meaningful systematic differences in the measured data. The results of these analyses concluded that no such changes could be detected.

The USGS continuous recorders located at the Facility's river intake structure were installed in December 2009. The bottom water quality sensor is located inside a pipe attached to the stilling well to record near bottom. The top water quality sensor is located in a 2-foot section of 3-inch diameter PVC pipe attached to a float. This floating sonde system is attached to two guide cables that are fastened to both a bracket at the top of a 16-inch aluminum stilling well and to two eyebolts in the bottom. The float keeps the water quality sensor approximately 1.5 feet from the water surface at all gage heights.

The particular locations of the USGS recorders on existing docks and structures were established in part due to the USGS's 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 in combination, result in extremely wide ranges of observed variation in daily averaged conductivity measurements. **Figure 5.2** indicates the high degree of variability in conductivity that occurs at the Harbour Heights gage located at RK 15.5 relative to corresponding total upstream USGS gaged flows (Peace River at Arcadia, plus Horse Creek near

Arcadia and Joshua Creek at Nocatee). The influences of these confounding effects of wind and tide, by comparison, are noticeably less at the more upstream USGS Peace River Heights gaging site located at RK 26.7 ([Figure 5.3](#)) and the Platt gaging site located at RK 29.8 ([Figure 5.4](#)).

The 1996 renewal of the Facility's Water Use Permit set a threshold of 130 cfs (for all 12 months) at the USGS Peace River at Arcadia gage for the start of freshwater withdrawals. [Section 2.2](#) and [Table 2.7](#) summarize the temporary changes made to the withdrawal schedule due to the severity of the 2006-2009 extended drought. However, as shown in the figures listed in [Table 5.3](#), conductivity (salinity) levels are often extremely low in the upstream reach of the river monitored by the Peace River Heights (RK 26.7) and Platt USGS (RK 29.8) recorders ([Figure 5.1\(e\)](#)). Often the reach of the river at and immediately downstream of the Facility monitored by these two gages is characterized by freshwater conditions when Peace River at Arcadia flows are 130 cfs or greater. Thus, while the physical location of these upstream continuous recorders is appropriate to detect potential long-term systematic shifts in the freshwater/saltwater interface during low levels of freshwater inflow, it is extremely doubtful whether the direct influences of the Facility withdrawals can typically be measured at these upstream locations when flows are near or above 130 cfs withdrawal threshold. However, the installation of the USGS recorder at the intake structure (RK 29.8) has provided the Authority with a far clearer view of seasonal tidal influences combined with the upstream movement of higher salinity waters under low flow conditions ([Figure 5.4](#)).

Table 5.3
Average Daily Conductivity at the Three USGS Continuous Recorders Versus
Combined Upstream Gaged Peace River Flow
(Peace River at Arcadia + Horse and Joshua Creeks)

USGS Gage / River Kilometer	Subsurface and Near-Bottom Conductivity
Harbour Heights (RK 15.5)	Figure 5.2
Peace River Heights (RK 26.7)	Figure 5.3
Peace River at Platt (RK 29.8)	Figure 5.4*

* Period of record is shorter for this gage than the others listed.

5.1.2 Authority HBMP Recorders

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 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 overall goal of the selected locations for 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 relation to potential existing physical structures (docks, pilings, etc.) to which additional continuous recorders might be attached. In addition to the existing navigational (red and green) markers along the lower Peace River, the U.S. Fish and Wildlife Service (USFWS) has placed a large number of Manatee Speed Zone markers along the lower river. Combined, these structures provide a series of spatially distributed potential sites for the placement of recorders downstream of the Facility. The Authority has received permission from both USFWS and U.S. Coast Guard to establish continuous recorders using these markers. Three of these Manatee Speed Zone markers were chosen by the Authority for the initial deployment in December 2005 of HBMP continuous recorders measuring near-surface conductivity ([Figure 5.1\(b\)](#)).

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

Based on comments and recommendations made by members of the HBMP Scientific Review Panel at its December 2007 meeting, the Authority added three additional continuous recorder locations in May 2008 by relocating the recorder previously at RK 23.4 to RK 31.7 and adding new recorders at RK 12.7 and RK 30.6 to extend upstream and downstream the area along the lower river covered by the continuous recorder array.

- **RK 12.7** – A recorder was installed downstream of the USGS Harbour Heights gage on a Peace River Manatee Zone Marker (RK 12.7) below the confluence with Shell Creek. Unlike the other HBMP recorders, this instrument was installed near the bottom of the water column (~1.7 meters) and measured conductivity, temperature, and dissolved oxygen levels continuously at 15-minute intervals.
- **RK 30.6** – A recorder was also installed above the USGS Peace River Heights gage on a Manatee Zone Marker (RK 30.6) just upstream of the Facility's intake structure near the SR 761 Bridge. This recorder measures subsurface conductivity and temperature at 15-minute intervals.

- **RK 31.7** – The HBMP recorder previously located at RK 23.4 was relocated upstream to the old railroad trestle (RK 31.7) above the Facility. This recorder also measures subsurface conductivity and temperature at 15-minute intervals.

The Peace River Scientific Review Panel met again in December 2010 and recommended the addition of an additional continuous recorder downstream of the I-75 Bridge, and that several new recorders be located between USGS Harbour Heights gage and the HBMP gage near the Liverpool area in order to better define the relationships between salinity and flow between the main channel and side channel in that reach of the lower River. The following changes and additions to the HBMP continuous recorder array were made in June 2011.

- **RK 30.6** – This recorder located just downstream of the SR 761 Bridge was discontinued since USGS had installed a third gaging location at the Facility intake structure (RK 29.8) immediately downstream.
- **RK 09.2** – A new recorder was located on a navigation marker between the I-75 and U.S. 41 Bridges. This recorder also measures subsurface conductivity and temperature at 15-minute intervals.
- **RK 12.7** – This recorder (which also measures dissolved oxygen) was moved from the bottom of the water column to the surface so that its values would be comparable with those at the other HBMP recorder sites.
- **RK 18.5** – A recorder measuring subsurface conductivity and temperature at 15-minute intervals was attached to a channel marker near the Power Line Crossing.
- **RK 18.7 HC** – A new subsurface conductivity and temperature recorder was located on the river's large Hunter Creek side channel near the connection to Jim Long Lake. Located on a Manatee Zone marker, the objective of this side channel site was to both determine if higher salinity water was moving upstream and potential influences of ungaged freshwater inflows to this region of the lower river.
- **RK 20.8** – This recorder was located on the navigation channel marker just downstream of Island Thirty-Three (odd name) in the lower river. The recorder measures subsurface conductivity and temperature at 15-minute intervals.

The following series of graphics indicate the changes in the spatial distribution of USGS and HBMP recorders over time.

- **Figure 5.1(a)** – Through 2005, the recorder array consisted of just the two USGS recorders, the first installed in 1996 and the second in 1997.
- **Figure 5.1(b)** – The number/location of sites following the addition of the three new HBMP continuous recorders in December 2005 are shown.

- **Figure 5.1(c)** – This graphic indicates the changes/expansion made to the HBMP records in May 2008.
- **Figure 5.1(d)** – A third USGS recorder was added in December 2009.
- **Figure 5.1(e)** – This graphic depicts the most recent series of changes made to the HBMP recorder locations.

The locations of the recorders during 2017 are summarized in **Table 5.1** and **Table 5.2** above and are shown in **Figure 5.1(e)**.

The methodologies used for deployment of the continuous recorders are depicted in **Figure 5.5** and **Photographs 5.1** through **5.11**.

- **Figure 5.5** – 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 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** – the YSI conductivity/temperature sonde is shown attached to two bullet floats being readied for placement in the stilling well.
- **Photo 5.4** – shows the stilling well (with the locking cap) as seen from the river.
- **Photo 5.5** – indicates how the YSI meter was previously deployed near the bottom of the water column at RK 12.7 to measure conductivity, temperature, and dissolved oxygen.
- **Photo 5.6** – shows the stilling well (with the locking cap) attached to the Manatee Speed Zone marker at RK 30.6 just upstream of the Facility and immediately downstream of the SR 761.
- **Photo 5.7** – the most upstream continuous recorder stilling well (with the locking cap) is shown attached to the old railroad trestle at RK 31.7.
- **Photo 5.8** – shows installation of the stilling well on the channel marker for the continuous recorder just downstream of Island Thirty-Three at RK 20.8.

- **Photo 5.9** – shows installing new stilling well for the continuous recorder at RK 18.7 on Hunter Creek near Jim Long Lake.
- **Photo 5.10** – deployment of the sonde on channel marker located at RK 18.5 is shown.
- **Photo 5.11** – this last photograph shows the amount of fouling that can occur on a sonde deployed for a month.

Data from these recorders are retrieved at approximately monthly intervals (or more often as needed during very dry periods when fouling becomes an issue at the more downstream sampling sites). A complete cleaned, calibrated, and checked replacement set of sondes is typically deployed each month. However, if this is not possible, then the data are retrieved, the stabilities 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 (2017)

All current (2017) and historical data gathered at the three USGS continuous recording conductivity gages located at Harbour Heights (02297460), Peace River Heights (02297350), and the Peace River at Platt (02297345), as well as historical information for the stage level gage near Boca Grande (2293332), are contained in the appropriate data sets summarized in **Table 1.6** (see **Section 1**).

Gage height, as well as surface and bottom conductivity readings collected in 2017 at 15-minute intervals, and displayed as daily averages, at Harbour Heights on the Peace River (USGS Station 02297460, RK 15.5) are presented in **Figure 5.6**. Similar plots are shown in **Figures 5.7** and **5.8**, respectively, for the continuous gage at Peace River Heights on the Peace River (USGS Station 02297350, River Kilometer 26.7), and for the gage at the Facility intake structure (USGS Station 02297345, River Kilometer 29.8). These graphics are summarized in **Table 5.4**.

The magnitude and duration of influence by low freshwater inflows from the Peace River watershed on the upstream movement of higher salinity harbor waters are clearly evident by the surface and bottom conductivities observed at the Harbour Heights (RK 15.5), Peace River Heights (RK 26.7), and Platt (RK 29.8) USGS gages. During the 2017 the Harbour Heights USGS gage went offline 3 times from April 8th to June 6th, July 2nd to August 9th, and October 10th to December 22nd. Conductivities at the more upstream Peace River Heights recording gage indicate the extent and duration of the upstream movement of higher conductivity harbor waters during 2017. Higher conductivity harbor water (1,000–2,000 uS/cm) extended upstream into the characteristically freshwater reach of the lower river at Peace River Heights during January and May of 2017 (**Figure 5.8**).

Table 5.4
Summary Graphics of 2017 Data from USGS Continuous Recorders

Figure	Description
Figure 5.6	2017 Daily average stage (upper panel) and conductivity (lower panel) for Peace River fixed station at Harbour Heights – USGS gage 02297460 (River Kilometer =15.5)
Figure 5.7	2017 Daily average stage (upper panel) and conductivity (lower panel) for Peace River fixed station at Peace River Heights – USGS gage 02297350 (River Kilometer = 26.7)
Figure 5.8	2017 Daily average stage (upper panel) and conductivity (lower panel) for Peace River fixed station at Peace River at Platt (Facility) – USGS gage 02297345 (River Kilometer = 29.8)

Comparisons of gage heights and both surface and bottom conductivity measurements at the three Peace River USGS gage locations, Harbour Heights (RK 15.5), Peace River Heights (RK 26.7) and the Facility intake structure (RK 29.8), are presented in **Figures 5.9** and **5.10** for May 2017 (dry season) and July 2017 (wet season). These intervals were selected as representative of some of the more typical dry-season and wet-season flows during 2017.

As indicated in previous HBMP annual reports, 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 July, 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, even during relatively wet periods, strong, sustained southerly winds can have an influence on salinity in this reach of the lower Peace River.

At the more upstream continuous USGS gage at Peace River Heights (RK 26.7), the conductivity data collected in 2017 (**Figure 5.9**) showed lower surface and bottom conductivities than those observed at RK 15.5, but still more variable during the drier May month than during the wet month of July. The May 2017 results at the Peace River Heights gage were less than those observed during many previous drier spring periods, when measured tidal variations in conductivity at this location were observed ranging 9,000 to 25,000 uS/cm. Again, this contrasts to wetter years such as 2005, when corresponding May data indicate only small, infrequent differences in conductivity (usually less than 100 uS/cm) resulting from tidal variations. During the wet season in July 2017, conductivities at this upstream USGS gaging site were low, and did not show any noticeable response to daily tidal variations (**Figure 5.9**).

At the most upstream Platt USGS recorder (02297345) located at the Facility intake structure (RK 29.8), data collected in May 2017 showed little daily variations in conductivity (**Figure 5.9**) in response to tides. As expected, under the higher summer wet-season flows in July, there was no indication of tidal influences on measured conductivities (**Figure 5.9**).

5.3 Results from HBMP Continuous Recorders (2017)

All data to date for the HBMP continuous (15-minute interval) conductivity/temperature gages at each of the following sites and corresponding intervals are contained in the appropriate data sets summarized in **Table 1.6** (see **Section 1**). Since July 2011, the HBMP continuous recorder array (**Figure 5.1(e)**) has included a total of eight ongoing monitoring locations:

1. RK 9.2 – June 2011 to present
2. RK 12.7 (subsurface) including dissolved oxygen – Jun 2011 to present
3. RK 18.5 – June 2011 to present
4. RK 18.7 (Hunter Creek) – Jun 2011 to present
5. RK 20.8 – June 2011 to present
6. RK 21.9 – Dec 2005 to present
7. RK 24.5 – Dec 2005 to present
8. RK 31.7– May 2008 to present

Conductivity readings (and dissolved oxygen at RK 12.7) collected in 2017 at 15-minute intervals, and displayed as daily averages, at the current eight ongoing HBMP continuous recorder sites are presented in **Figures 5.11** through **5.18**. More detailed graphics of this 15-minute data are also presented over monthly intervals during both periods of spring dry season low flow in May and during summer wet season high flow over the month of July (**Figure 5.19**). The daily average conductivities provide direct comparisons of the spatial differences among reaches of the lower river characterized by each of the recorder locations during both the May dry season and the July wet season (**Figure 5.19**). The various graphics presented summarizing and contrasting the 2017 results for the Authority's HBMP continuous recorders are shown in **Table 5.5**.

Table 5.5
2017 Authority's HBMP Continuous Recorder Results

Location	Daily Average Jan-Dec 2017	Conductivity Comparison among Sites May and July 2017	Monthly Comparison of Dissolved Oxygen 2017
RK 9.2	Figure 5.11	Figure 5.19	NA
RK 12.7 (surface)	Figure 5.12		Figure 5.20
RK 18.5	Figure 5.13		NA
RK 18.7 (Hunter Creek)	Figure 5.14		NA
RK 20.8	Figure 5.15		NA
RK 21.9	Figure 5.16		NA
RK 24.5	Figure 5.17		NA
RK 31.7	Figure 5.18		NA

As previously discussed with respect to corresponding data from the 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, in comparison to usually much smaller (and spatially limited) tidal salinity changes during intervals of higher freshwater inflows.

5.4 Summary Comparisons among USGS and HBMP Continuous Recorders

The seasonal and daily ranges of variation in near surface salinities (only sites with a complete year of data were included) at the HBMP and USGS continuous recorders are statistically summarized, compared, and contrasted for 2017 in [Table 5.6](#). The 2017 data are also graphically represented in [Figure 5.21](#). Data from 2007-2016 were summarized and plotted in the *2015* and *2016 Annual Data Reports*. It should be noted that the actual observed daily and seasonal changes in salinity are of a far greater magnitude than those accountable to Facility withdrawals alone as predicted by the HBMP statistical models developed in the *2008*, *2011*, and *2016 HBMP Comprehensive Summary Reports*.

Historically, estimated salinity changes due to Facility withdrawals have been such that they would have been difficult to physically measure given the far greater magnitudes of daily, seasonal, and annual naturally occurring variation. The Facility however has undergone major recent expansions (in 2002 and 2009), which have substantially increased its ability to withdraw, store, and treat water from the river while increasing overall reliability. In 2010, the District completed a review and adopted a final MFL for the lower Peace River, and the Authority's withdrawal schedule was subsequently modified in 2011. This modification seasonally increased the maximum allowed withdrawal percentages. The results of statistical models presented in the *2011* and the *2016 HBMP Comprehensive Summary Report* predicted commensurate increases in salinity changes and the movement of isohaline locations resulting from recent increased Facility withdrawals. Annual averages (mean and median) of projected salinity changes due to Facility withdrawals would however still remain difficult to be measured directly, and remain small in comparison to the relative far greater magnitudes of typical naturally occurring seasonal and annual variations shown in [Figure 5.21](#) for 2017 and in earlier Annual Data reports for the preceding 9 years.

6.0 HBMP *In Situ* Chlorophyll Transect Monitoring

6.1 Assessment of Chlorophyll (Phytoplankton Biomass) Maxima along the HBMP Monitoring Transect – Introduction and Overview

The current monthly “fixed” and “moving” HBMP water quality study elements (described in [Sections 3](#) and [4](#)) include sampling of chlorophyll *a* levels along the HBMP monitoring transect at widely spaced discrete sampling locations. As a common photosynthetic pigment among major primary producers, chlorophyll *a* levels are often used as a relative estimate of phytoplankton biomass in both freshwater and estuarine systems. Spatial and temporal variability of phytoplankton chlorophyll *a* concentrations are widely applied in estuarine ecology as a relative indicator of overall integrated levels of primary production. As a measure of phytoplankton biomass, chlorophyll *a* has a number of distinct advantages.

- Measured values can often be qualitatively coupled to important physical and chemical water quality characteristics.
- Measurements integrate phytoplankton cell types, sizes, and growth stages, and to some degree the relative overall cell health/viability.
- Applied methods of measurement are relatively simple, direct, and far less costly when compared to alternatives such as the microscopic identification of individual phytoplankton taxa and/or direct measures of carbon fixation.

The development of a comprehensive understanding of phytoplankton production (biomass) is a fundamental component in developing an integrated conceptual understanding of the interrelated physical/chemical systems and biological processes within the lower Peace River estuarine system as shown in conceptual [Figure 6.1](#) (developed by Dr. Ernst Peebles).

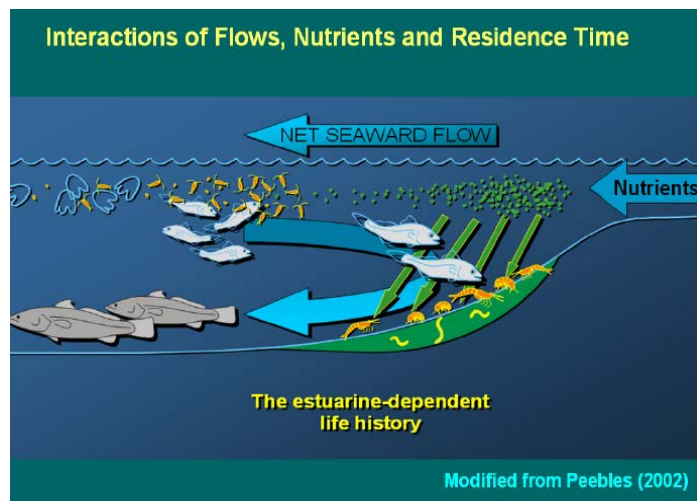


Figure 6.1 Importance of the Location of Estuarine Chlorophyll Maxima.

Phytoplankton production represents a large, immediately available food resource directly accessible to many estuarine grazing, filter/detrital feeding organisms. Phytoplankton production represents a basic, integrated estuarine food-web component that can be directly influenced by variations in freshwater inflows. As a result of the very short generation times involved (hours/days), when compared with many other potential biological indicators, phytoplankton production has the potential to be more directly quantitatively linked to changes in estuarine freshwater inflows. The observed numbers and spatial distributions

of other potential biological estuarine indicators are often subject to the confounding additional

influences associated with longer generation times, more intricate life-cycles, and the increasing complexity of predatory/prey interactions with each additional trophic level.

It should be noted that even though widely used as a standard relative measure, chlorophyll *a* concentration can still inherently be an imperfect absolute measure of phytoplankton biomass, since cellular pigment contents are influenced both by relative phytoplankton community structure and a wide array of commonly variable ambient physical (water color, shading, temperature) and chemical (nutrients) environmental conditions.

Advances in fluorescence technology have resulted in the recent capability of semi-quantitatively measuring *in situ* phytoplankton chlorophyll *a* and other accessory pigment estimates, without having to employ extensive filtering and expensive laboratory chemical extraction and analyses. *In situ* fluorometer chlorophyll *a* measurement procedures also present the potential utility of near-real-time data acquisition in synoptically identifying spatial phytoplankton biomass patterns along the lower river/upper harbor salinity gradient. The accuracy of such *in situ* measurements can be greatly enhanced through employing pre- and post-sampling fluorometer calibrations and comparisons to field measurements with “reference” values obtained utilizing standard laboratory (extraction) procedures.

Both the “fixed” and “moving” HBMP study elements have previously indicated the existence of seasonally-variable chlorophyll *a* maxima along the lower Peace River/upper Charlotte Harbor monitoring transect. Based on the recommendation of the HBMP Scientific Review Panel, and following consultation with District staff, the Authority volunteered to implement a new HBMP study element beginning in April 2013. This new HBMP study element employs *in situ* fluorometer chlorophyll *a* methodology in order to provide the type of enhanced spatial intense information needed to accurately define on a monthly basis both the magnitude and spatial extent of variations in chlorophyll *a* patterns within the lower Peace River/upper Charlotte Harbor Estuary. Accurate spatial determinations of the relative intensity and location of monthly chlorophyll *a* maxima patterns are expected to provide additional information regarding the known seasonal interactions between changes in freshwater flow (relative to additions of both nutrients and color) in relation to the seasonal movement of important estuarine zones of primary (and secondary) production.

The results of this HBMP element are expected to help determine the magnitude of both temporal and spatial variability of peak zones of high productivity in the lower river/upper harbor system. Ultimately, such determination of the seasonal influences of changes in river flow may be used to assess any potential influences of Facility withdrawals on estuarine production under the existing established MFL criteria. The information may further be applied to assess (and potentially refine) the existing and future spatial locations of the HBMP continuous recorder array (see [Section 5](#)). An analysis of the utility of this new HBMP study element, and recommendations for its future continuance, are expected to be made following several years of data gathering, and then potentially at specific intervals as part of future major summary monitoring program reports.

6.2 Sampling Methodology

The following briefly summarizes the basic approach that is currently being applied during the monthly collection of spatially intense *in situ* information on chlorophyll (and other parameters) along the HBMP monitoring transect. Prior to February 2017, data were collected using a YSI 6600 and a YSI 6920 sonde and associated sensors, peristaltic pump, and large flow-through chamber. Beginning in February 2017, a new YSI EXO3 sonde and associated sensors were deployed which allowed the use of a single sonde and a much smaller flow through cell. A detailed description of the methodology employed prior to February 2017 can be found in the *2016 HBMP Annual Data Report*.

- Using maps, landmarks, and GPS coordinates, the sampling boat travels along a predefined course (**Figure 6.2**) from the mouth of the river (RK 0) to above (~ RK 32) the uppermost HBMP continuous HBMP conductivity recorder located on the river at the old railroad crossing. A sampling speed of approximately 7-8 kilometers/hour is maintained using GPS tracking.

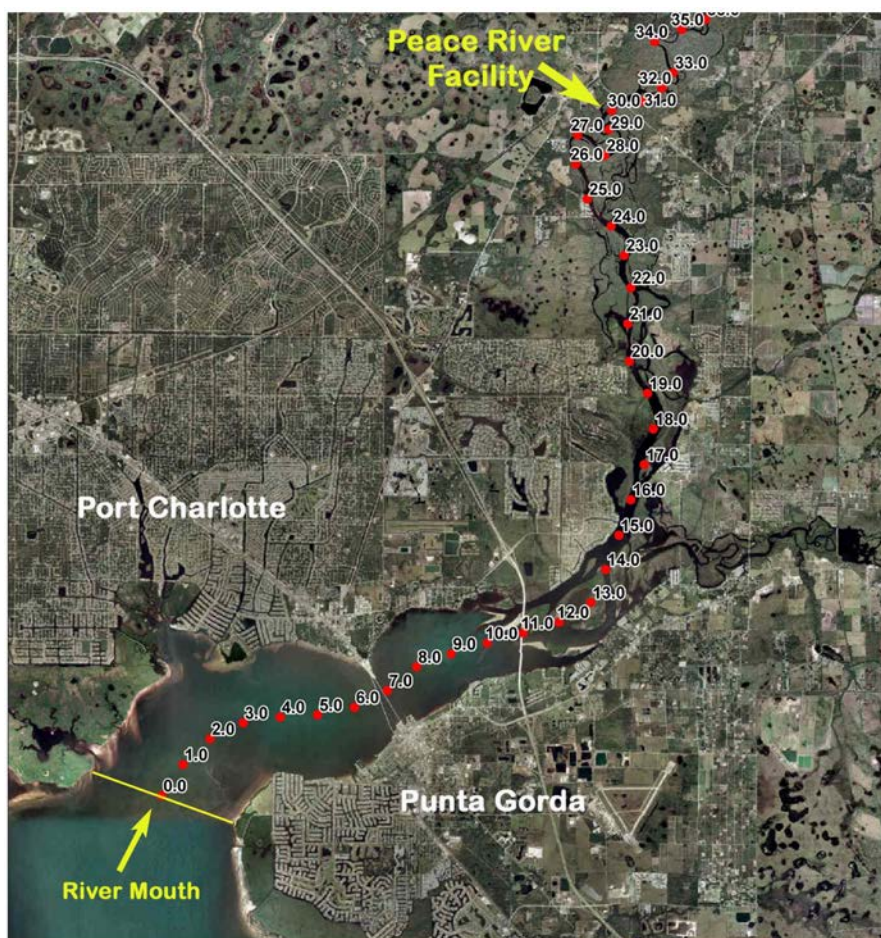


Figure 6.2 HBMP monitoring transect.

- A diaphragm pump intake tube is mounted on a bracket over the front/side of the boat to allow continuous uniform collection of subsurface water (0.2-0.5 meters).
- Water is pumped into an EXO2 flow-through chamber with an inflow and outflow that has a rapid turnover rate (<7 seconds). In practice, particulate matter may not be flushed out as quickly because the inflow is in the bottom of the chamber. However, particulate matter at the surface of the water column is rare.
- The EXO2 sonde is equipped with probes for chlorophyll-a, phycocyanin, phycoerythrin, turbidity, fDOM, temperature, and specific conductance/salinity. The optical sensors are detailed in [Table 6.1](#).
- A handheld data logger is used to integrate GPS data with sonde measurements, which are automatically combined with GPS coordinates and are recorded at 10 second intervals. The boat moves at 7 to 8 kilometers/hour, so this is about 1 sample per 20 meters.
- To the greatest extent possible, data collections are standardized within a defined temporal period relative to mid-daylight in order to normalize known daily variations in apparent chlorophyll *a* levels.
- Water grab samples (10-20 per transect sample run) are collected and analyzed by the lab for water color and chlorophyll. These samples are collected spatially along the transect as needed emphasizing both observed changes in optical readings and observed changes in collected physical water quality information. The objective is to provide laboratory estimates for comparison over as great a range of variability as possible. When there are no notable changes in measured parameters, grab samples are collected at a minimum of one sample per 30 minutes.
- Grab sample data are combined with corresponding sonde and location data for analysis.
- The statistical relationships (multivariate regression) are conducted following each sampling run comparing collected fluorometric measurements with laboratory color/chlorophyll results from the periodic field sampling. Chlorophyll concentrations along the entire transect length are then estimated based on the resulting statistical analyses of *in situ* fluorometric measurements against corresponding field grab samples.
- Every attempt is made to coordinate the *in situ* transect chlorophyll sampling with the monthly “fixed” station sampling being conducted by EarthBalance® (see [Figure 4.1b](#)). It is ultimately expected that the monthly corresponding “fixed” station monitoring data will be combined and statistically compared with the optical *in-situ* data for future analyses.

Table 6.1 Optical Sensors Used in Chlorophyll Transect Data Collection, Beginning February 2017.

Description	Units	Excitation (Reflectance) Band	Sensor Emission Band
Phycocyanin	Relative Fluorescence Units	590±15 nm	685±20 nm
Phycocyanin	Estimated concentration	590±15 nm	685±20 nm
Phycoerythrin	Relative Fluorescence Units	525±15 nm	685±20 nm
Phycoerythrin	Estimated concentration	525±15 nm	685±20 nm
Chlorophyll (on PC probe)	Relative Fluorescence Units	470±15 nm	685±20 nm
Chlorophyll (on PE probe)	Relative Fluorescence Units	470±15 nm	685±20 nm
Chlorophyll (on PC probe)	Estimated concentration	470±15 nm	685±20 nm
Chlorophyll (on PE probe)	Estimated concentration	470±15 nm	685±20 nm
Fluorescent Dissolved Organic Matter	Relative Fluorescence Units		480±40 nm
Fluorescent Dissolved Organic Matter	quinine sulfate units		480±40 nm

6.3 2017 Sampling Results

The initial monthly transect study results from data collected during 2017 are graphically presented in **Table 6.2**. Transect results are presented showing the spatial distribution of salinity, water color, and chlorophyll *a* along the approximate 32- kilometer length of the HBMP monitoring transect, starting near the mouth of the river (RK 0) and moving upstream to the old railroad bridge crossing (RK 31.7) upstream of the Authority's Treatment Facility.

The data for each month for these three parameters are presented using scaling based on the historic calculated ranges of data that have been seasonally observed for each of these water quality characteristics within the lower river/upper harbor estuary during long-term HBMP monitoring.

Table 6.2 2017 Sampling Results from *In Situ* HBMP Chlorophyll Transects

Month	Salinity	Chlorophyll <i>a</i>	Water Color
January	Figure 6.4	Figure 6.16	Figure 6.28
February	Figure 6.5	Figure 6.17	Figure 6.29
March	Figure 6.6	Figure 6.18	Figure 6.30
April	Figure 6.7	Figure 6.19	Figure 6.31
May	Figure 6.8	Figure 6.20	Figure 6.32
June	Figure 6.9	Figure 6.21	Figure 6.33
July	Figure 6.10	Figure 6.22	Figure 6.34
August	Figure 6.11	Figure 6.23	Figure 6.35
September	Figure 6.12	Figure 6.24	Figure 6.36
October	Figure 6.13	Figure 6.25	Figure 6.37
November	Figure 6.14	Figure 6.26	Figure 6.38
December	Figure 6.15	Figure 6.27	Figure 6.39

These presented fine-scale graphical results indicate the highly seasonal nature, and degree of small scale variation, that seasonally characterizes the spatial distributions of these estuarine water quality characteristics, which respond to natural variations in magnitude/duration of upstream freshwater inflows. Ultimately, this information is expected to be utilized towards the modeling of chlorophyll levels (and the location of maxima) relative to seasonal/annual variability in watershed inflows, and other water quality parameters measured as part of the other HBMP study elements.

7.0 Assessment of Upstream Changes in Water Quality

Since its inception, the Hydrobiological Monitoring Program (HBMP) has incorporated numerous study elements directed toward assessing the magnitude of changes resulting from permitted freshwater withdrawals on both the physical/chemical characteristic, as well as biological communities within the downstream estuarine environment of the lower Peace River/upper Charlotte Harbor. The HBMP has sought to determine seasonal and longer term changes in flows and other parameters, such as water quality, relative to ongoing land use changes in the upstream watershed and the overall “health” of the downstream estuary. Analyses of long-term water quality data from both the fixed and isohaline monitoring program study elements presented in this and previous HBMP reports have identified several important recent and longer term changes in water quality that have occurred upstream of the Facility that may influence both aspects of Facility operations and/or the biological communities of the estuarine system. These distinct observed patterns in water quality include the following changes.

- There have been long-term, progressive increases in the water quality conductance of the water coming downstream to the Facility during the drier months of the year. This trend has further been associated with increasing volumes of water (base flow) during the normally seasonal drier time intervals at a number of USGS subbasin Peace River watershed gaging sites at southern tributaries of the Peace River (particularly for Joshua Creek, but also historically at Prairie and Shell Creeks). Both of these changes have been linked (PBS&J 2007, Atkins 2013) to increased agricultural irrigation discharges of higher conductivity groundwater during typically seasonally drier periods.
- Seasonally, silica levels in the lower Peace River/upper Charlotte Harbor estuary progressively increased at a rapid rate over the past decade, but have shown some decline of late. More recently, phosphorus levels in the lower Peace River that had historically shown dramatic declines during the late 1970s and 1980s had returned to levels not observed in decades, before declining again to more typical previous levels over the past four years.

The following briefly summarizes several key findings from analyses of observed changes in water quality characteristics in the Peace River watershed. A comprehensive series of analyses of Peace River watershed specific conductance information was updated as part of the Year-Five *2016 HBMP Comprehensive Summary Report* finalized in 2017. The results of that analysis are included here, with data for 2017 added to the analyses. Additionally, water quality information for the Peace River Watershed long-term monitoring sites (USGS/SWFWMD/FDEP/Authority) has been updated through 2017 as part of the Authority’s ongoing Water Supply Study. The graphics presented in [Table 7.1](#) summarize the historic patterns of changes in key water quality characteristics that have historically occurred upstream of the Facility.

Table 7.1 - Time-Series Plots of Major Water Quality Characteristics in the Upstream Peace River Watershed

Parameter	Whidden Creek near Fort Meade	Peace River at Arcadia	Joshua Creek at Nocatee	Horse Creek near Arcadia
Conductivity	Figure 7.1	Figure 7.19	Figure 7.38	Figure 7.56
Color	Figure 7.2	Figure 7.20	Figure 7.39	Figure 7.57
Total Alkalinity	Figure 7.3	Figure 7.21	Figure 7.40	Figure 7.58
Total Dissolved Solids	Figure 7.4	Figure 7.22	Figure 7.41	Figure 7.59
Nitrite+Nitrate Nitrogen	Figure 7.5	Figure 7.23	Figure 7.42	Figure 7.60
Total Kjeldahl Nitrogen	Figure 7.6	Figure 7.24	Figure 7.43	Figure 7.61
Total Nitrogen	Figure 7.7	Figure 7.25	Figure 7.44	Figure 7.62
Total Phosphorus	Figure 7.8	Figure 7.26	Figure 7.45	Figure 7.63
Ortho-phosphate	Figure 7.9	Figure 7.27	Figure 7.46	Figure 7.64
Chlorophyll a	Figure 7.10	Figure 7.28	Figure 7.47	Figure 7.65
Calcium	Figure 7.11	Figure 7.29	Figure 7.48	Figure 7.66
Magnesium	Figure 7.12	Figure 7.30	Figure 7.49	Figure 7.67
Sodium	Figure 7.13	Figure 7.31	Figure 7.50	Figure 7.68
Potassium	Figure 7.14	Figure 7.32	Figure 7.51	Figure 7.69
Chloride	Figure 7.15	Figure 7.33	Figure 7.52	Figure 7.70
Sulfate	Figure 7.16	Figure 7.34	Figure 7.53	Figure 7.71
Fluoride	Figure 7.17	Figure 7.35	Figure 7.54	Figure 7.72
Iron	Figure 7.18	Figure 7.36	NA	Figure 7.73
Strontium	NA	Figure 7.37	Figure 7.55	Figure 7.74

7.1 Increasing Conductance in the Lower Peace River

The *Peace River Cumulative Impact Study* (PBS&J 2007) and *2011 HBMP Comprehensive Summary Report* (Atkins 2013) have identified anthropogenically related trends of increasing specific conductance within a number of the major upstream watershed tributaries to the lower Peace River. The observed changes in the lower portions of the Peace River watershed over recent decades have been primarily associated with increasing land conversions from less to more intense forms of agriculture, which increasingly relies on irrigation using higher conductivity ground water pumped from the upper Floridan aquifer. The *2016 HBMP Comprehensive Summary Report* continued the investigation of increased conductivity, and updated the analyses with more recent data. The *2016 HBMP Comprehensive Summary Report* evaluated patterns and historical trends in specific conductance and associated water quality characteristics measured at the Peace River at Arcadia gage, within both the upstream Joshua and Horse Creek tributaries, and at the fixed HBMP long-term monitoring site located at River Kilometer (RK) 30.7 located immediately upstream of the Peace River Facility's intake.

7.1.1 Peace River at Arcadia

The Peace River at Arcadia USGS gage (2296750) has the longest historic flow record (1931–present) of any of the gages in the Peace River watershed. It is also the most downstream gage located along the main stem of the river and includes flows not only from the immediate basin, but also from the upstream Bartow and Zolfo Springs watershed basins, as well as the Payne, Whidden and Charlie Creek tributary basins. Historic loss of flows from springs and seeps has been one of the factors that have affected base flow to the upper portion of the Peace River. Base flows in both the upper and middle Peace River have also been affected by changes in discharges and drainage alterations associated with urbanization, phosphate mining, and more intense forms of agriculture. Specific conductance values historically measured by USGS and more recently by the District at the Peace River at Arcadia gage site have ranged from low levels measured in the 1960s to a high of nearly 1,400 uS/cm in 2011. Seasonally, the highest mean and median specific conductance values typically occur in May toward the end of the normal spring dry season, while the lowest mean and median levels are often observed toward the end the summer wet season. The analyses of long-term data presented in the *2016 HBMP Comprehensive Summary Report*, and updated with 2017 data for this report, clearly indicate that both specific conductance (see [Figure 7.19](#)) and chloride ([Figure 7.33](#)) concentrations have increased over time during periods of lower flows. The observed patterns of water quality changes at the Arcadia gage clearly indicate seasonal contributions of higher conductivity groundwater into the middle portions of the Peace River. The largest increases in conductance occurred during the recent years of drought following the unusually high 2004-2005 flows. These unusually high levels can be traced back to the closure of the phosphogypsum stacks in the Whidden Creek subbasin (see *2015 HBMP Annual Data Report* for more information).

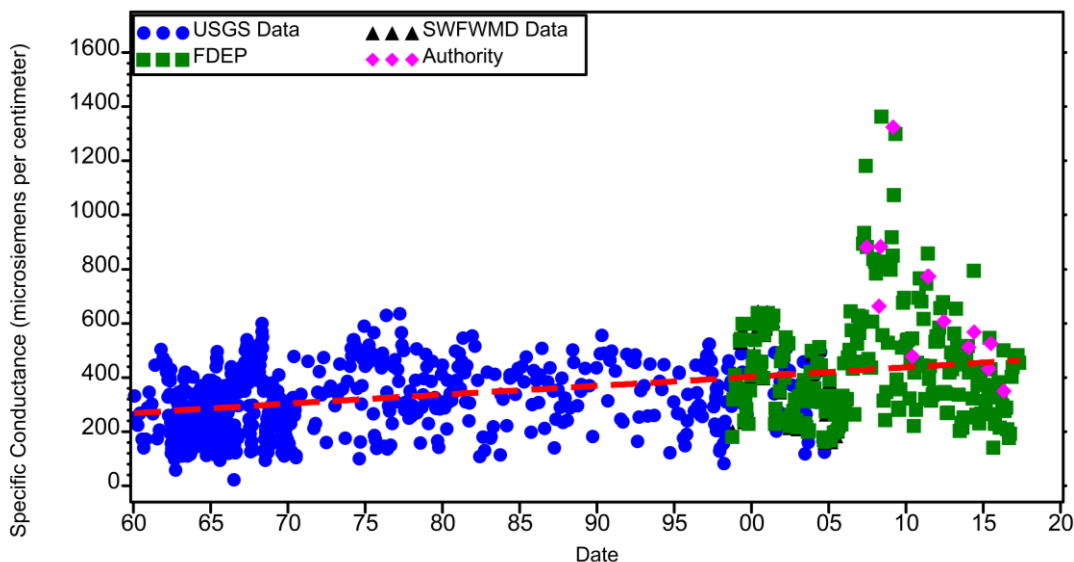


Figure 7.19 Specific conductance at USGS site 02296750 / FDEP site 3556 – Peace River at Arcadia – Peace River at Arcadia basin.

7.1.2 Joshua Creek at Nocatee

Joshua Creek begins in northeastern DeSoto County and flows southwest to where it joins the Peace River downstream of the Peace River at Arcadia gage at a point slightly upstream from Nocatee in central DeSoto County. Land use in this basin has historically changed from predominantly native habitats and unimproved pasture in the 1940s to extensive areas of improved pasture and more intense forms of agriculture such as citrus and row crops by the late 1990s. Approximately three quarters of the land use in the Joshua Creek basin by 1999 was in agricultural uses, with 29 percent of the basin being utilized for citrus production (PBS&J 2007). These alterations to more intense forms of agriculture are reflected in the historic changes in the water chemistry of Joshua Creek, which over recent decades has seen large increases in concentrations of both specific conductance (Figure 7.38) and total dissolved solids (Figure 7.59). These changes have been associated with increasing surface drainage of agricultural irrigation discharges of high conductivity groundwater pumped from the upper Floridan aquifer for irrigation, much of which ultimately flows into Joshua Creek. The augmentation of base flow resulting from agricultural discharges is particularly apparent during naturally occurring seasonal low flow periods, when irrigation is vital to agriculture. The available data indicate that water quality in Joshua Creek has undergone substantial chemical changes over time. These changes in conductivity and related water quality parameters stem from agricultural irrigation practices throughout the basin and have recently been particularly prevalent during drought conditions.

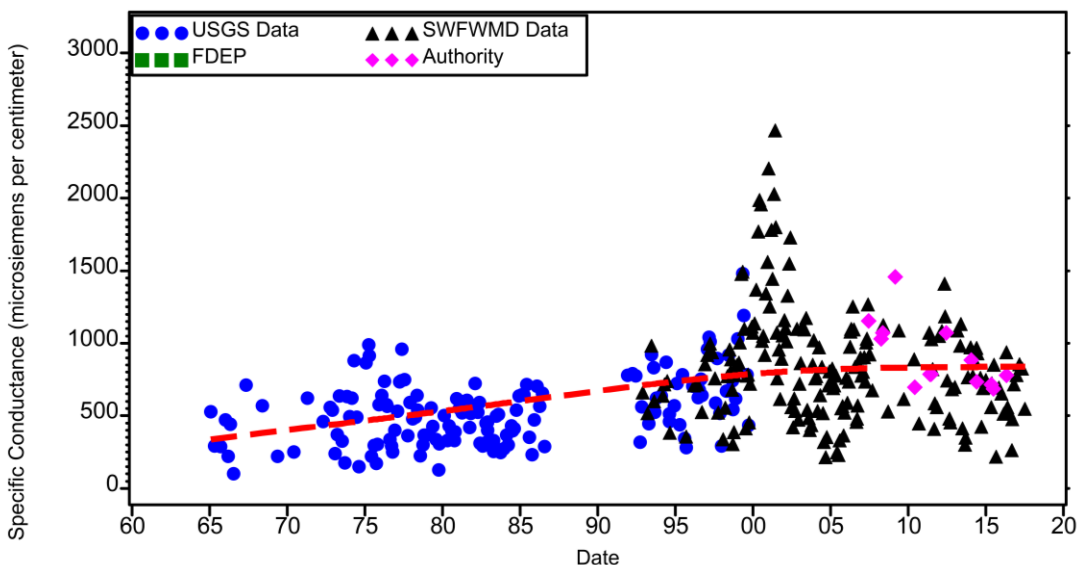


Figure 7.38 Specific conductance at USGS site 02297100 / District site 24431 – Joshua Creek at Nocatee – Joshua Creek basin.

The *Shell Creek and Prairie Creek Watersheds Management Plan* (SWFWMD 2004) addressed such water quality changes in Joshua Creek, acknowledging that the pumping of highly mineralized water from the upper Floridan aquifer for agricultural irrigation had been the primary contributing factor to the observed water quality degradation in Joshua Creek. The District’s watershed management plan proposed that basin conductivity target levels

(corresponding with the State standards for Class I waters) should not to be exceeded at any time by 2014. Recently, FDEP extended the time-line to meet management plan goals by another five years. **Figure 7.38** suggests that specific conductance values at Joshua Creek at Nocatee have declined in the most recent two to three years.

7.1.3 Horse Creek near Arcadia

Over portions of the southern Horse Creek basin, the head of the intermediate aquifer is often higher than that of the surficial aquifer, resulting in intermediate aquifer groundwater moving upward into the surficial aquifer and then discharging into the creek (PBS&J 2007). In other portions of the basin, ground water use has historically reduced the potentiometric surface of the lower aquifers and much of Horse Creek base flow is seasonally, predominantly influenced by agricultural irrigation ground water discharges. There have been a number of land use changes in the Horse Creek basin that have influenced basin flows. Phosphate mining has moved farther south from the Payne Creek basin and continues to expand into the adjoining northern areas of the Horse Creek basin. Agriculture and urban development have both at the same time expanded in the more southern portions of the basin. Agriculture in 1999 accounted for just under half of the Horse Creek basin's land use, with ten percent being in intense forms of agriculture (citrus and row crops).

Specific conductance levels are generally the highest in the southern part of the basin during the seasonal dry spring and other periods of low flow, such as during extended periods of drought (1999-2001 and 2006-2009). Again, the data (**Figure 7.56**) indicate that specific conductance and chloride (**Figure 7.70**) levels in southern Horse Creek have been increasing. This is primarily due to augmented base flow by surface discharges of highly mineralized deep aquifer ground water from agriculture irrigation. Specific conductance concentrations during dry periods exceed the protective levels set forth by the District in the *Shell Creek and Prairie Creek Watersheds Management Plan*.

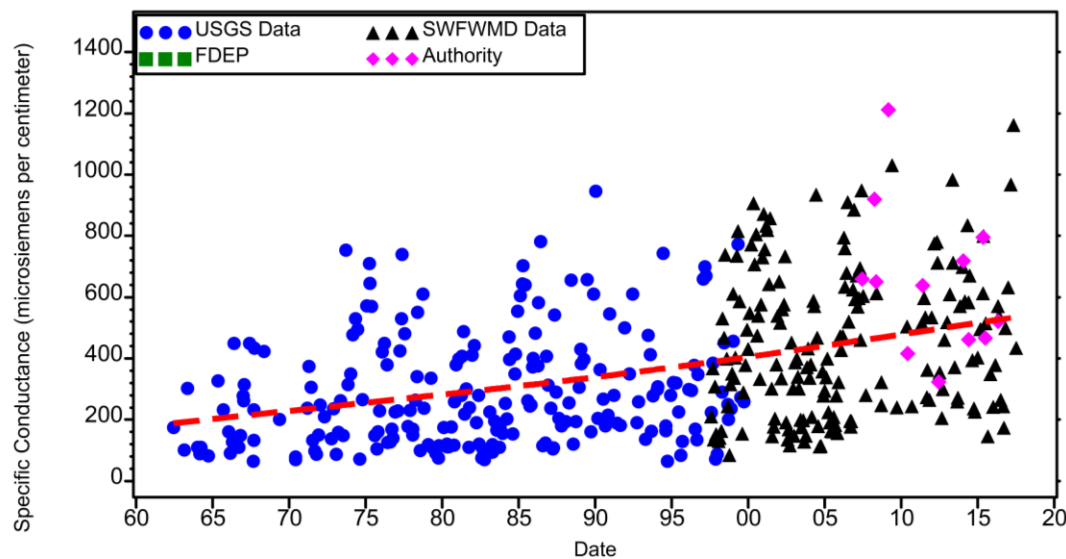


Figure 7.56 Specific conductance at USGS site 02297310 / District site 24049 – Horse Creek near Arcadia – Horse Creek basin.

Assessment of Upstream Changes in Water Quality

7.1.4 Peace River Kilometer 30.7

Monthly samples have, and continue to be, taken as part of the fixed station HBMP water quality monitoring program just upstream of the Peace River Facility at RK 30.7. Monthly sampling at this “fixed” sampling site began in 1976, ceased in 1990, and then resumed in 1996 as part of both the HBMP “fixed” and “moving” station water quality monitoring in conjunction with the renewal of the Facility’s 1996 water use permit. The data from this location have been of special interest due to its near upstream proximity to the Facility and thus the sampling frequency was increased in 1996 to twice monthly (by adding sample collection at RK 30.7 to the monthly “moving” HBMP sampling.) **Table 7.2** provides statistical summaries of data collection during the period 1976-1990 in comparison to similar data from the more recent 1996-2017 time interval. In order to eliminate potential upstream influences of higher salinity estuarine waters, only samples collected when the preceding 7-day average flow exceeded 130 cfs were used in **Table 7.2**. The second half of the table provides links to long-term plots for each parameter over time. The presented graphics include both monthly measured values as well as a fitted, smoothed line, which was calculated using the Statistical Analysis Software (SAS) cubic spline method.

Table 7.2 Statistical Summaries for Sampling Upstream of the Facility (RK 30.7) for Historic 1976-1990 and more Recent 1996-2017 Time Intervals

Parameter	Mean	Median	Minimum	Maximum	# Samples
Statistical Summary 1976-1990					
Temperature (°C)	24.6	25.8	12.0	32.0	181
Dissolved Oxygen (mg/l)	7.0	7.1	2.8	13.0	181
pH	7.3	7.3	5.9	9.4	181
Salinity (psu)	0.1	0.1	0	1.8	179
Conductivity (µS/cm)	375	400	100	3500	179
Total Dissolved Solids (mg/l)	264	242	99	3390	159
Chloride (mg/l)	23.3	22.2	3.5	126.0	167
Alkalinity-CaCO ₃ (mg/l)	51.7	51.6	14.4	88.8	161
Hardness-CaCO ₃ (mg/l)	126.0	126.0	25.5	215.0	152
Color (CPU)	153	138	22	410	173
Turbidity (NTU)	4.55	3.25	0.85	37.00	172
Ammonia/Ammonium (mg/l)	0.060	0.050	0.001	0.376	130
Nitrite/Nitrate (mg/l)	0.639	0.562	0.001	2.110	173
Total Kjeldahl Nitrogen (mg/l)	1.20	1.10	0.40	3.35	116
Total Nitrogen (mg/l)	1.880	1.778	0.861	3.421	116
Ortho-phosphorus (mg/l)	1.392	1.035	0.458	4.130	172
Total Phosphorus (mg/l)	1.586	1.215	0.476	4.680	172
Silica (mg/l)	2.75	2.82	0.20	5.87	173
Total Organic Carbon (mg/l)	29.69	29.95	4.21	59.90	160
Chlorophyll a (ug/l)	10.0	3.0	0.1	156.0	174
Iron (mg/l)	0.27	0.26	0	0.75	68
Sulfate (mg/l)	66	62	8	156	168
Fluoride (mg/l)	0.90	0.86	0.15	2.56	171

Assessment of Upstream Changes in Water Quality

**Table 7.2 Statistical Summaries for Sampling Upstream of the Facility (RK 30.7)
for Historic 1976-1990 and more Recent 1996-2017 Time Intervals**

Parameter	Mean	Median	Minimum	Maximum	# Samples	Figure
Statistical Summary 1996-2017						
Temperature (°C)	25.1	26.4	9.4	34.3	420	Figure 7.75
Dissolved Oxygen (mg/l)	6.6	6.4	0.4	16.9	418	Figure 7.76
pH	7.4	7.4	6.0	9.0	415	Figure 7.77
Salinity (psu)	0.2	0.2	0.0	1.1	413	Figure 7.78
Conductivity (µS/cm)	473	436	86	4,298	420	Figure 7.79
Total Dissolved Solids (mg/l)	293	276	0	1,024	143	Figure 7.80
Chloride (mg/l)	33.9	29.4	0.4	407.0	385	Figure 7.81
Alkalinity-CaCO ₃ (mg/l)	61.5	59.2	0.6	120.0	226	Figure 7.82
Hardness-CaCO ₃ (mg/l)	NA	NA	NA	NA	0	Figure 7.83
Color (CPU)	175	160	3	600	380	Figure 7.84
Turbidity (NTU)	3.37	2.80	0.51	18.00	85	Figure 7.85
Ammonia/Ammonium (mg/l)	0.06	0.03	0.01	0.61	380	Figure 7.86
Nitrite/Nitrate (mg/l)	0.47	0.43	0.00	3.25	383	Figure 7.87
Total Kjeldahl Nitrogen (mg/l)	1.11	1.09	0.51	2.82	380	Figure 7.88
Total Nitrogen (mg/l)	1.58	1.55	0.59	4.21	379	Figure 7.89
Ortho-phosphorus (mg/l)	0.74	0.69	0.00	2.14	387	Figure 7.90
Total Phosphorus (mg/l)	0.77	0.75	0.42	1.47	231	Figure 7.91
Silica (mg/l)	6.89	6.78	0.21	14.90	387	Figure 7.92
Total Organic Carbon (mg/l)	19.76	17.80	1.00	45.50	91	Figure 7.93
Chlorophyll a (ug/l)	10.6	6.0	0.1	110.0	374	Figure 7.94
Iron (mg/l)	0.41	0.38	0.03	1.49	340	Figure 7.95
Sulfate (mg/l)	78	75	3	278	144	Figure 7.96
Fluoride (mg/l)	0.54	0.50	0.03	1.30	144	Figure 7.97

When the Peace River flows are low over an extended period of time, the reach of the lower Peace River near the Facility is tidally subject to intrusions of brackish waters from the harbor (see discussion in [Section 5](#)). However, beyond periods of such low flow occurrences, the primary seasonal influences on specific conductance (and other associated water quality parameters) measured immediately upstream of the Facility are constituents contained in combined flows moving downstream from the Peace River at Arcadia, Joshua Creek at Nocatee, and Horse Creek near Arcadia stations (see [Table 7.1](#) above).

Dry-season conductance ([Figure 7.79](#)), as well as total dissolved solid, chloride, alkalinity, and sulfate concentrations at RK 30.7 clearly show ([Table 7.2](#)) that measured levels immediately upstream of the Facility have been increasing over time (after having excluded the upstream movement of higher saline harbor waters). At the same time, the relative annual contributions of the upstream gages to flows at the Facility indicate that over time the proportion from the Peace River at Arcadia station has been decreasing, while the relative contributions from Horse and Joshua Creeks have been increasing. The increasing relative proportion of flows during dry periods has resulted from a decoupling of rainfall and basin flow due to agricultural augmentation of flow.

Assessment of Upstream Changes in Water Quality

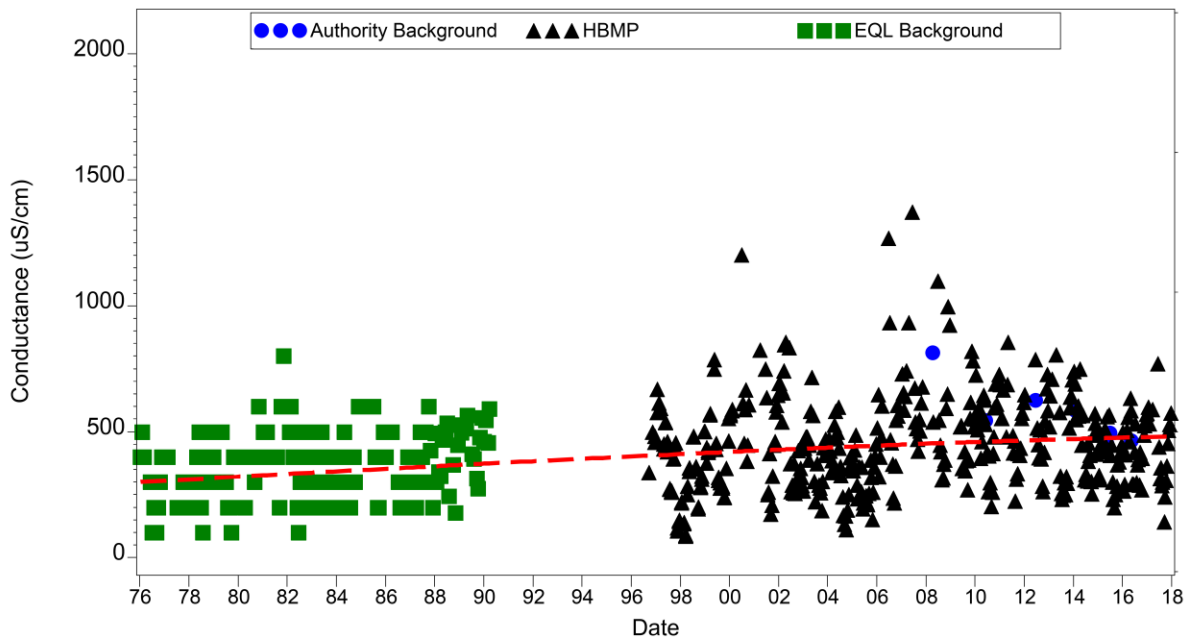


Figure 7.79 Monthly long-term conductivity at river kilometer 30.7 (S.R. 761).

The upstream changes in water quality (conductance, chlorides, and TDS levels) originating from agricultural discharges during the dry-season have yet to be a serious hindrance to water supply. However, this is not to say that such changes may not become a problem in the future if the current trends in the contributing upstream basins continue. Reducing agricultural groundwater pumping in these upstream basins would effectively decrease the potential for such impact to Facility operations. It would, however, also substantially reduce the total dry-season flows upstream of the Facility. To a great extent, the historic declines in base flow due to the anthropogenic losses of spring flows in the upper Peace River watershed have subsequently been replaced by agricultural discharges in the southern watershed basins. Future reductions of these artificially augmented flows without corresponding restoration of upper watershed base flows, when combined with projected future sea level rise, may have the unintended consequence of shifting the salt wedge further upriver and increasing the frequency of time during which the Facility is unable to withdraw river water during the dry season and put a higher premium on storing water during the wet season.

7.2 Changes in Nutrient Concentrations in the Lower Peace River

In addition to conductance, and related parameters, there have been some noted changes over time in regards to nutrients in the Lower Peace River. This section explores temporal patterns in nutrients at the fixed station HBMP water quality monitoring program just upstream of the Peace River Facility at RK 30.7. Additionally, existing water quality impairments in the Peace River watershed are discussed.

7.2.1 Nutrients at Peace River Kilometer 30.7

Figures 7.86 to 7.88 illustrate long-term time series plots for various forms of nitrogen at the HBMP fixed monitoring station at RK 30.7. These figures illustrate a nearly consistent level of ammonia/ammonium and total Kjeldahl nitrogen over the long-term period, with occasional relatively high spikes for each nutrient. In contrast nitrite/nitrate concentrations appear to have slowly declined over the long-term period. During 2017, the average concentrations of nitrite/nitrate for both isohaline and fixed station samples were similar to the previously observed longer term (1983-2016) historical annual averages (Sections 3 and 4, Figures 3.15 and 4.20, Tables 3.7 and 4.4).

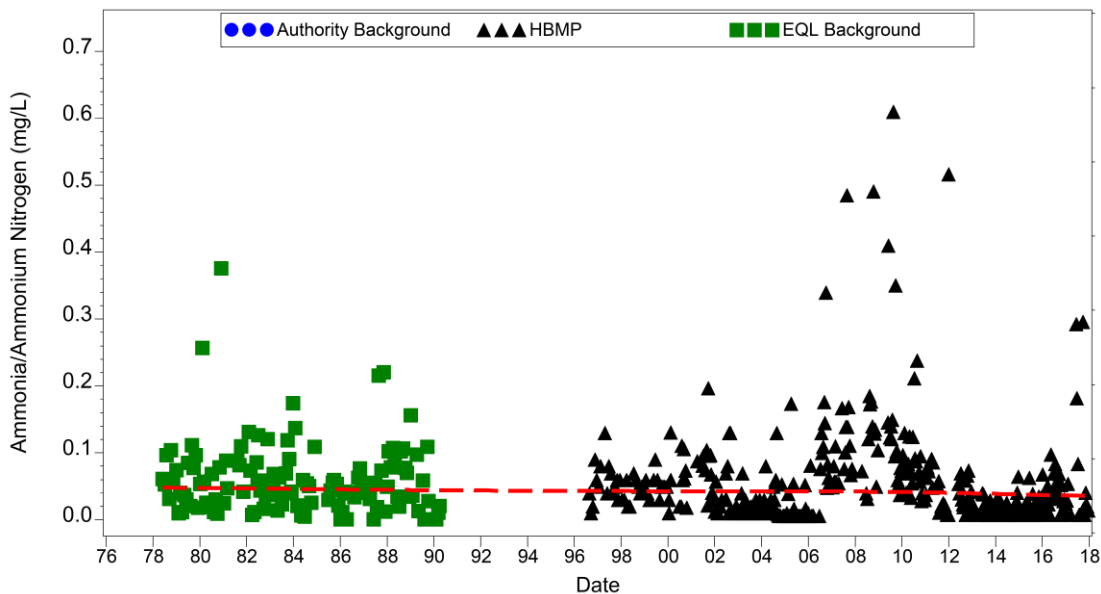


Figure 7.86 Monthly long-term surface ammonia/ammonium nitrogen at river kilometer 30.7 (S.R. 761).

Assessment of Upstream Changes in Water Quality

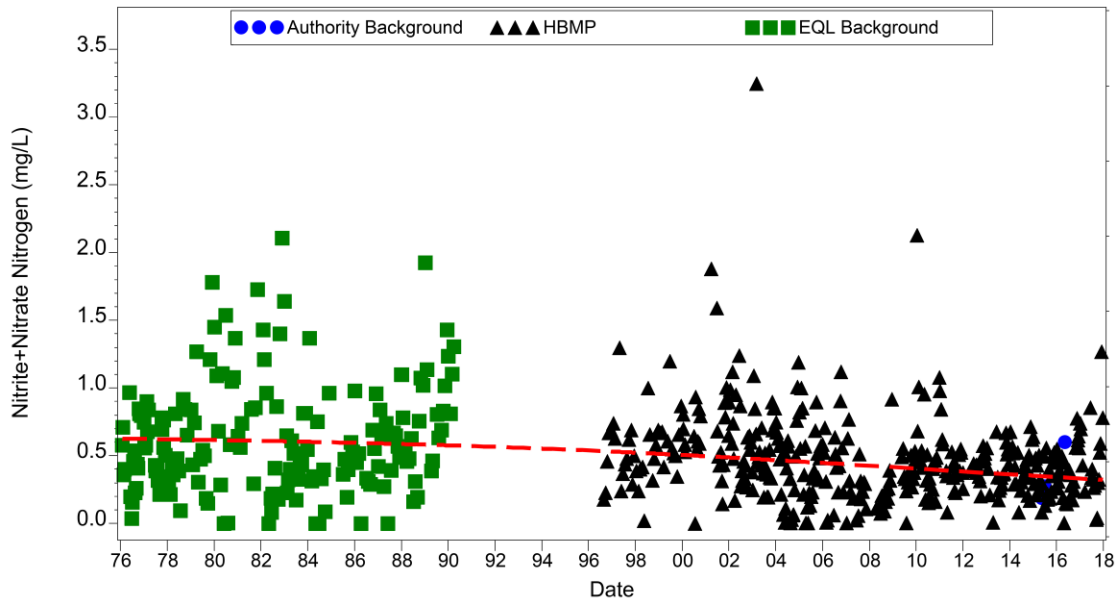


Figure 7.87 Monthly long-term surface nitrite/nitrate nitrogen at river kilometer 30.7 (S.R. 761).

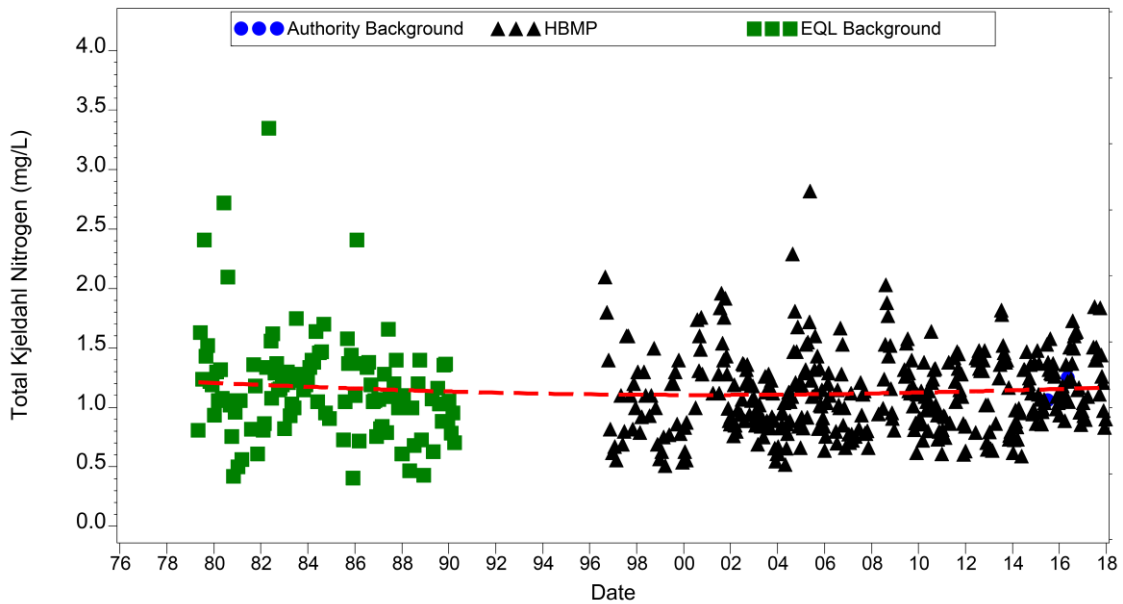


Figure 7.88 Monthly long-term surface total Kjeldahl nitrogen at river kilometer 30.7 (S.R. 761).

Assessment of Upstream Changes in Water Quality

Phosphorus levels in the lower Peace River had historically shown dramatic declines during the late 1970s and 1980s, but in the mid-2000s had returned to elevated levels not observed in decades, before declining again (Figure 7.90). Ortho-phosphorus levels reported from both the HBMP isohaline and fixed station sampling at station RK 30.7 were similar in 2017 to the long-term historical record (see discussion in Sections 3 and 4, Figure 3.16 and Figure 4.22). In contrast, seasonal silica levels in the lower Peace River and upper Charlotte Harbor have progressively increased over the past decade (Figure 7.92). Silica levels reported from both the HBMP isohaline and fixed station sampling at RK 30.7 were elevated compared to the long-term record (see discussion in Sections 3 and 4, Figure 3.18 and Figure 4.23). The notable changes in these two characteristic water quality parameters have been highlighted in HBMP reports going back over a number of years. The direct cause for the observed increased levels in both ortho-phosphorus and silica seems to have been related to the recent closing of the Ft. Meade phosphogypsum stack system in the upstream Whidden Creek subbasin (see Section 5 of the recent 2016 Comprehensive Summary Report).

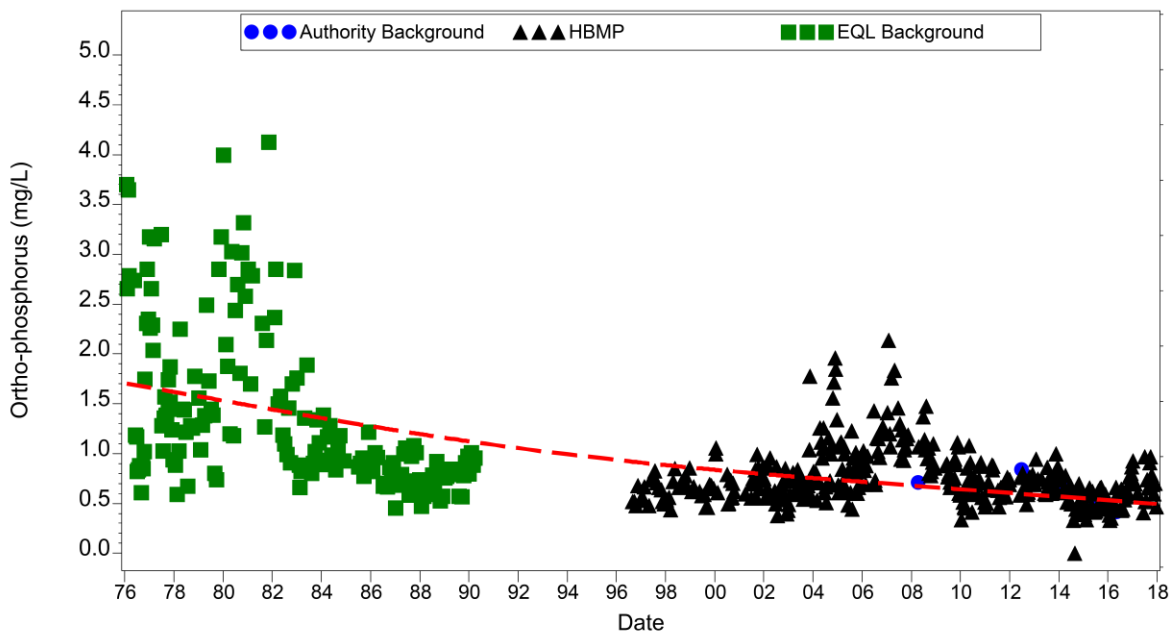


Figure 7.90 Monthly long-term surface ortho-phosphorus at river kilometer 30.7 (S.R. 761).

Assessment of Upstream Changes in Water Quality

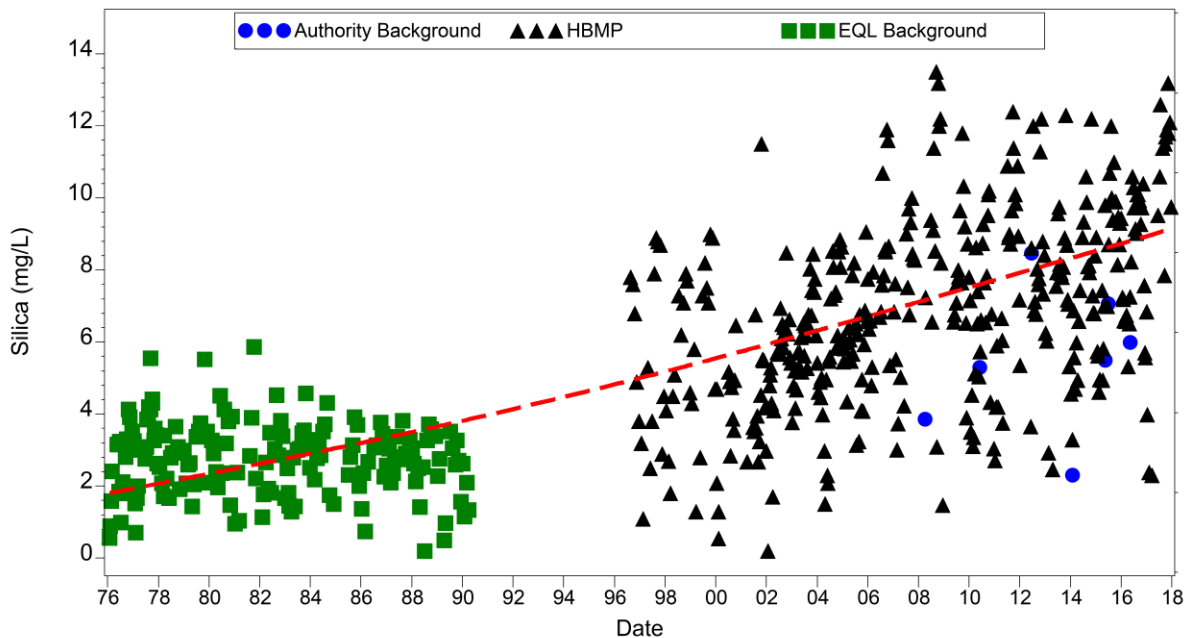


Figure 7.92 Monthly long-term surface silica at river kilometer 30.7 (S.R. 761).

7.2.2 Peace River Watershed Water Quality Impairments

The FDEP assess waterbodies as units designated as waterbody IDs (WBIDs). The WBID containing the river withdrawal point, the water treatment facility and reservoirs is WBID 1623A. This WBID was recently delisted (10/21/2016) for exceeding the historical chlorophyll *a* threshold. This historical chlorophyll *a* threshold is no longer valid as a numeric nutrient criteria has been approved. The WBID was placed on the planning list for total phosphorus (TP) meaning the FDEP will be collecting additional information prior to the next assessment to determine its status regarding TP.

Several WBIDs upstream of the facility have been listed as impaired for the presence of the indicator bacteria fecal coliform. Being listed as impaired is the first step in the restoration process that includes the development of Total Maximum Daily Loads (TMDLs) implemented through Basin Management Action Plans (BMAPs). Fecal coliform bacteria act as an indicator of the potential presence of pathogens associated with wastewater. Unfortunately, these bacteria are also naturally found within all warm-blooded creatures, i.e. mammal and birds, causing many false positive results. Many waterways flow through areas that can range from “natural” to rural to suburban/urban, making it difficult to identify the source of the bacteria except through expensive DNA analyses. These sources range from wildlife to cattle and horses to pets and humans across the range of land uses. This standard is meant to indicate the risk of the presence of pathogens and thus contact should be limited. It does not exclude these waters from being utilized as a potable water supply as they are removed through the treatment process. The US Environmental Protection Agency and FDEP have recognized the disadvantages of using fecal coliform and have recently moved to *E. coli* in freshwaters and *Enterococci* in marine waters as the indicators of choice.

Assessment of Upstream Changes in Water Quality

At this time, there are no verified impairments (exceedances of applicable water quality standards and designated uses based on the Impaired Waters Rule Chapters 62-303 and 62-302, Florida Administrative Code (F.A.C.)) that would hinder the operations of the Authority.

7.3 Summary

- There have been long-term, progressive increases in parameters such as conductance, chlorides, total dissolved solids, alkalinity, and sulfates in the water coming downstream to the Facility during the drier months of the year. This trend has further been associated with increasing volumes of water (base flow) during the normally seasonal drier time intervals. These changes over recent decades have been primarily associated with increasing land conversions from less to more intense forms of agriculture, which increasingly rely on irrigation using high conductivity water pumped from the upper Floridan aquifer. Such changes are particularly apparent in the Joshua and Horse Creek basins in the southern portions of the Peace River watershed. The upstream changes in water quality is due to changing water quality characteristics originating from agricultural discharges during the dry-season and have yet to be a serious hindrance to Peace River Facility water supply operations. However, this is not to say that such changes may not become a problem in the future if the current trends in these contributing upstream basins continue.
- Silica levels in the lower Peace River/upper Charlotte Harbor estuary have increased over the past decade. Additionally, phosphorus levels in the lower Peace River that had historically shown dramatic declines during the late 1970s and 1980s and recently returned to levels not observed in decades before showing declines again. These observed changes in long-term HBMP data, combined with the Authority's watershed monitoring and the District's watershed ambient surface water quality monitoring, indicate that these recent changes coincide well with the closure of phosphogypsum stacks and associated discharges in the Whidden Creek subbasin. It is therefore reasonable to assume that increases in these same parameters that predate the US Agri-Chemicals Fort Meade closure operations, may also have been related to changes in phosphate mining activities in the upper Peace River watershed.

8.0 References

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