Clam Bay Water Quality Analysis – Technical Memorandum

2021 Water Quality Analysis for Evaluation of Compliance with Numeric Nutrient Criteria

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Executive Summary

Water quality monitoring data from samples collected monthly from Clam Bay between January 2021 and December 2021 were analyzed and evaluated to determine whether the different regions of Clam Bay are currently in compliance with previously established Numeric Nutrient Criteria (NNC) and established criteria for copper. Water quality data results for 2021 were compared to data available in previous memos dating back to March 2015. Previous reports have suggested that impacts from Hurricane Irma, which occurred in September 2017, may have had longer term impacts than originally expected, particularly related to tidal channel restoration activities conducted in 2018 as a result of the storm. It is unknown whether high levels of nutrients can still be attributed to Hurricane Irma four years after the storm event, particularly considering that additional storm events have occurred in the intervening years.

Data presented here are compared to data analyzed by others as presented in reports submitted for previous years dating back to 2015. Overall, the 2021 results are similar to those observed in previous years since Hurricane Irma. Sample results indicate that Clam Bay is in compliance with Total Nitrogen (TN), and for copper concentrations found in saltwater sites. Percent Dissolved Oxygen (DO) was below established criteria for saltwater sites 15 percent of the time in 2021, which slightly exceeds the standard allowance of 10 percent of samples below 42 percent saturation.

Observations made in 2020 indicated a reduction in Total Phosphorus (TP) exceedances of NNC compared to 2018 and 2019, although observations made in January through June 2021 showed an increase in exceedances compared to the previous six months, potentially related to Tropical Storm Eta, which impacted southwest Florida in October/November 2020. Tropical Storm Eta caused a storm surge of 2.86 feet into Naples and winds gusting at over 50 miles per hour[1]. These conditions would have disturbed sediments and possibly damaged vegetation, resulting in additional nutrients in the water column.

Observations made in July through December 2021 showed a decrease in exceedances compared to the previous six months. Thirty-three of 108 TP values (31 percent) exceeded established criteria in Clam Bay during 2021. Twenty-seven of the 33 TP exceedances occurred between January and June of 2021. This 31 percent exceedance rate is higher than the 10 percent allowable annual exceedance rate for a water to be considered not impaired with respect to TP, and therefore Clam Bay would be considered impaired with respect to TP. There were no TN exceedances of 108 samples during 2021 and therefore Clam Bay is not considered impaired for TN for calendar year 2021.

Dissolved oxygen saturation percentages, calculated using temperature and DO concentrations, were analyzed as related to minimum criteria for saturation. As used in previous reports (**Appendix A**), a standard of 42 percent saturation is used to determine whether the samples are meeting criteria for Class II waters. Overall, 7 percent of samples fell slightly below the 42 percent saturation criteria during the first half of 2021 but an average of 15 percent of samples fell below the 42 percent saturation threshold for all of 2021 and therefore DO saturation is slightly out of compliance with state water quality standards.

The water quality standard for copper in marine waters is 3.7 μg/L, although the impaired waters rule allows for a certain number of exceedances before a waterbody is considered to be out of compliance with this standard. Based on information presented in Table 3 of Chapter 62-303 and the number of samples collected,

at least 16 samples would need to exceed the water quality criteria for the waterbody to be listed as verified impaired for the January to December 2021 sample period. Because only 5 samples exceeded the 3.7 μg/L threshold (all between March and May of 2021), Clam Bay would not be considered impaired with respect to copper based on results of samples collected during the twelve months of 2021.

While Tropical Storm Eta made landfall on Florida's west coast in October/November 2020 and significant impacts were experienced in Naples just to the south of Clam Bay. Since July-December water quality data were improved over January-June water quality data in Clam Bay, the bay does not appear to have suffered any persistent impacts as a result of this storm for the parameters considered here, though long-term impacts may be seen in future samples if damage to mangrove communities occurred but has not yet manifested itself.

Water quality data, including TN, TP, percent DO saturation, and copper, were also measured throughout 2021 at six berm outfall sites on the east side of Clam Bay. Overall, the berm water quality data are highly variable as is expected of stormwater samples. Copper exceeded established Downstream Protection Values (DPVs) in 7 of 13 samples collected between January and March 2021 for which samples could be properly evaluated. Results are unknown for the remainder of the year because hardness measurements, needed to correct copper data for comparison to the assigned DPV, were not collected.

While TP and TN discharging from berm outfall sites exceed the 50th percentile DPV values at approximately the same rate for both nutrients, TP exceedances at the 90th percentile level occur more often than for TN, as reflected by the high number of TP exceedances in the bay itself compared to no TN exceedances indicated in Clam Bay between January and December 2021. Relatively few TN exceedances were indicated in prior years compared to frequent exceedances of TP concentration in the bay since 2015; 2020 data are consistent with previous years' observations.

The most probable cause of high levels of TN (when they do occur which is not often), TP and copper are historic uses of fertilizers and algicides in the watershed upstream of the bay. Nutrients and metals can become bound in upstream soils and sediments, and can be re-released when sediments are disturbed, such as after a storm event. Resuspension of sediments can cause new releases of contaminants for many years after contaminant inputs cease. Unlike TP and copper, TN can be released to the atmosphere from sediments as a gas over time and therefore may become less problematic as years pass without additional excessive TN inputs.

Finally, it as determined during the course of analyzing data that the equations for determining the TN and TP exceedance levels appear to be in error in the Rule (62-302.532, F.A.C.). Through correspondence with developers of the equation included in the rule (Dave Tomasko and Emily Keenan, **Appendix C**), it appears that 'specific conductivity' was shortened to 'conductivity' over time. Calculating TN and TP exceedance levels using 'conductivity' instead of 'specific conductivity' results in approximately 20 percent higher exceedance rates. When possible, the Rule should be updated to refer to 'specific conductivity.'

[1] https://yaleclimateconnections.org/2020/11/tropical-storm-eta-heads-toward-landfall-north-of-tampa/

Recommendations include:

- Re-establish measurement and calculation of hardness for berm samples so that copper data collected from berm discharges can be appropriately evaluated for exceedances of DPVs.

- Continue monitoring, and possibly increase the sample collection depth, within the bay to the extent practicable. The collection depth of samples appears to be relatively shallow, which can affect the results. Generally, samples should be collected from the middle of the water column for greatest accuracy.
- Verify that previous calculations for nutrient criteria exceedances in prior years used specific conductivity rather than specific conductance in calculations of TN and TP exceedance values in Clam Bay.
- Request that the Florida Department of Environmental Protection (FDEP) update Rule 62-302.532, F.A.C., to read 'specific conductivity' in place of 'conductivity'.

Upstream management recommendations include:

- Preventing grass clippings and other yard waste from entering the stormwater system.
- Educating residents regarding Collier County's Fertilizer and Urban Landscaping Ordinance[2].
- Reducing and/or eliminating the use of copper-containing chemicals on lawns and in stormwater ponds.
- Expanding overall community education regarding how resident actions can affect Clam Bay. Based on experience of the author of this report, many residents believe that what enters a storm drain is transported to a wastewater treatment plant and they are unaware that chemicals, fertilizers, RV waste and other material disposed in storm drains can flow directly to and directly affect natural waters downstream.

[2] Collier County's Fertilizer and Urban Landscaping Ordinance – PelicanBay.org

Background

The overall purpose of this report is to summarize the status of water quality with respect to set criteria for Clam Bay as measured for Total Nitrogen (TN), Total Phosphorus (TP), percent dissolved oxygen (DO) saturation, and copper (Cu) concentrations. Water quality samples for these parameters (and other parameters not discussed here) were measured monthly between January 2021 and December 2021 at nine locations throughout Clam Bay. Similar water quality parameters were measured monthly for six locations in a canal behind a berm that discharges to Clam Bay. This report summarizes water quality exceedances for sites located in Clam Bay as well as levels of TN, TP and copper at berm discharge sites that may contribute to the degradation of water quality in Clam Bay.

One of the reasons for the creation of the Pelican Bay Services Division (PBSD) Municipal Services Taxing & Benefit Unit (MSTBU) is to maintain the conservation preserve areas; the PBSD is responsible for advising Collier County (County) on dredging and maintaining Clam Pass to enhance the health of the affected mangrove forest. Mangroves in the region were severely adversely impacted by Hurricane Irma in September 2017 and restoration activities to clear waterways and conduct other restoration activities were undertaken in 2018.

These activities appear to have affected water quality in subsequent years based on previous reports submitted by others, although it is does not seem likely that impacts and activities associated with Hurricane Irma are still affecting water quality over four years later. Tropical Storm Sally and Tropical Storm Eta passed through the region in September and October/November 2020, respectively, and may have had an influence on water quality in the wake of these more recent storms.

As described in detail in the ESA 2020 Annual Report, dated March 24, 2021 (**Appendix A)**, the U.S. Environmental Protection Agency (EPA) adopted nutrient concentration criteria for Clam Bay in 2011, which were also reviewed and approved by the FDEP. Clam Bay has been assigned Numeric Nutrient Criteria (NNC) that are termed Site-Specific Alternative Criteria (SSAC), as listed in Chapter 62-302.501 of the Florida Administrative Code (F.A.C). The criteria developed for TN and TP depend upon salinity/specific conductivity conditions, since nutrient concentrations in saltwater systems, including estuaries and tidal rivers (such as Clam Bay) vary with rainfall, runoff and tidal influence.

The SSAC relates to findings at reference sites with little or no human influence where nutrient concentrations decrease as salinity increases, reflecting the combination of terrestrial nutrient runoff sources from adjacent lands with relatively low nutrient concentrations in offshore waters. As a result, nutrient concentrations even in pristine locations may pass or fail nutrient criteria targets depending on rainfall, tidal stage, location, and possibly prevailing winds (depending on the depth of the water column).

In addition to considering salinity/specific conductivity of waters when evaluating whether specific nutrients meet NNC, the evaluation process also considers the frequency with which nutrient concentrations exceed NNC values and the amount of time over which exceedances have occurred in order to determine management responses. Small exceedances over short periods of time would result in a different response than larger exceedances, and/or exceedances that occur over longer periods of time.

A high-level process of management responses previously used to evaluate nutrient results, and to plan for management responses related to the degree and length of exceedances between 2015-2020, is discussed in more detail and is graphically depicted in the ESA 2020 Annual Report (**Appendix A)**. Management recommendations to address TP and copper in particular are discussed below.

Clam Bay Nutrient Status

Data Analyses – Nutrient Status and Development of Site-Specific Alternative Criteria (SSAC)

The analyses conducted below were used to assess the water-quality status of Clam Bay, with respect to nutrients from the months of January through December 2021. Samples were collected monthly at each of the nine sampling stations within Clam Bay. Additional water quality samples collected at the berm outfall are discussed separately below. Maps of all 2021 sampling sites showing water quality observations in Clam Bay are presented in **Figure 1** and **Appendix B** and maps of all Clam Bay and berm sample locations are presented in **Figure 1** below**.**

Clam Bay Nutrient Status

A total of 108 water-quality samples were collected within Clam Bay for the analytical period covered in this report. Water-quality monitoring results from Clam Bay and its watershed were either provided by County staff or downloaded from the Watershed Information Network (WIN) database for Clam Bay and berm sample locations. Water quality samples were collected by County staff per FDEP protocols.

FDEP adopted Site Specific Alternative Criteria (SSAC) for Clam Bay, as listed in 62-302.532, F.A.C. Prior research conducted in Clam Bay had determined that both TN and TP need to be considered in evaluating nutrient conditions in bay waters and for predicting the amount of phytoplankton that may result from higher nutrient levels. Chapter 62-302.531, F.A.C. states that waterbody nutrient status shall be determined on an annual basis, preferably for a calendar year. This report summarizes findings for calendar year 2021.

The SSAC for Clam Bay is written as follows:

No more than 10 percent of the individual Total Phosphorus (TP) or Total Nitrogen (TN) measurements shall exceed the respective TP Upper Limit or TN Upper Limit.

The equations below are used to determine the upper limits of TP and TN concentrations noted above for Clam Bay, as shown in Equations 1 and 2, respectively[3]:

Equation 1: TP Upper Limit (mg/L) = $e^{(-1.06256-0.0000328465*Conductivity(\mu S))}$

*Equation 2: TN Upper Limit (mg/L) = 2.3601 – 0.0000268325*Conductivity (µS)*

TN and TP concentrations were compared to the calculated upper limit thresholds to determine if TP or TN concentrations exceeded the designated upper limits, as determined from the equations above, for samples collected January through December 2021. The values of TN and TP collected throughout an entire year are compared to the Upper Limits (formally known as the "90th Percentile Protection Limit"), calculated as in the equations above using salinity/specific conductivity data from the sample location. These upper limits are numbers that FDEP has set as the upper limits of concentrations that cannot be exceeded in order to protect the biological integrity of Clam Bay.

[3]Based on correspondence with Dave Tomasko and Emily Keenan, who were involved in the development of the equations below, it was determined that 'conductivity' should read 'specific conductivity'. Results presented below were calculated using specific conductivity (Appendix C).

Clam Bay Nutrient Status

Figure 1: Water quality Sample locations for Clam Bay and Berm Water Quality Monitoring

Results – Nutrient Status

Throughout the analysis period discussed in this report (January through December 2021), none of the 108 samples exceeded the calculated TN upper limit. Comparatively, 33 of 108 samples (31 percent of total samples) exceeded the calculated TP upper limit criteria for calendar year 2021, and 21 of the 108 samples exceeded the criteria by more than 5 percent. It should be noted that 27 of the 35 TP exceedances occurred during the first half of the year between January and June 2021. Water quality with regard to TP appears to have improved during more recent months, with only 8 exceedances between July and December 2021.

These results indicate that TN did not exceed SSAC thresholds for Clam Bay in 2021 and therefore Clam Bay is not impaired with respect to TN. However, TP values collected for the 12 months of 2021 do exceed SSAC thresholds (33 of 108 samples, or 31%), well in excess of the allowable 10 percent exceedance rate and therefore Clam Bay would be determined to be impaired for TP based upon these data, which represent an entire year of data as specified by 62-302.531, F.A.C. Given that the TP exceedance rate was lower in 2020 than in previous years and is lower comparable to 2021 (27 of 104 samples or a 26 percent TP exceedance rate in 2020), it seems unlikely that the cause still reflects residual effects of impacts and restoration efforts from Hurricane Irma, as was often cited in the ESA 2020 Annual Report (**Appendix A**). However, Tropical Storm Eta, which made landfall near Naples in late 2020, may have resulted in sediment disturbances, which may have led to increases in TP in the water column in early 2021.

Tables 1 and 2 below are replicated from the ESA 2020 Annual Report and provide a visual summary of NNC exceedances for TP and TN, respectively, from March 2015 through December 2020, with data from the January through December 2021 samples added to the end of each table; data from November 2017 through December 2020 was updated based on a current analysis of data downloaded from the Watershed Information Network (WIN). It should be noted that data collected prior to November 2017 were analyzed by previous authors and have not been re-analyzed for this report. There were slight differences for unknown reasons between previous report exceedance data and the current re-analysis of data from November 2017 through December 2020.

Clam Bay Nutrient Status

Table 1. Representation of frequency of impairment for TP for different site and date combinations. Green represents samples in compliance with criteria. Red cells indicate exceedance of criteria. Red cells with an "X" represent values that are within 5% of criteria concentrations, suggesting lack of compliance should be interpreted with caution, due to analytical precision. Gray cells represent a lack of data. (Note: Data from November 2017 through December 2021 were calculated based on Watershed Information Network data available in March 2022, prior exceedances were determined by others.)

Date (month/year)	Station								
	1	2	3	4	5	6	7	8	9
Mar-15			X						
Mar-15									
Apr-15									
May-15		X							
Jun-15									
Jul-15									
Aug-15									
Sep-15									
Oct-15									
Nov-15		X							
Dec-15									
Jan-16									
Feb-16		X							
Mar-16									
Apr-16									
May-16									
Jun-16									
Jul-16									
Aug-16									
Sep-16				X					
Oct-16									
Nov-16									
Dec-16									
Jan-17									
Feb-17									
Mar-17			X						
Apr-17									
May-17									X
Jun-17									
Jul-17									
Aug-17									
Sep-17									
Oct-17									

Clam Bay Nutrient Status

Date (month/year)	Station								
	1	2	3	4	5	6	7	8	9
Nov-17									
Dec-17									
Jan-18									
Feb-18									
Mar-18					X	X			
Apr-18									X
May-18							X		
Jun-18									
Jul-18									
Aug-18									
Sep-18									
Oct-18									
Nov-18									
Dec-18									
Jan-19									
Feb-19									
Mar-19			X						
Apr-19									
May-19									
Jun-19									
Jul-19									
Aug-19									
Sep-19		X							
Oct-19									
Nov-19									
Dec-19									
Jan-20						X			
Feb-20									
Mar-20							X		
Apr-20									X
May-20									
Jun-20								X	X
Jul-20								X	X
Aug-20		X							
Sep-20									
Oct-20									
Nov-20									
Dec-20									
Jan-21								X	X

Clam Bay Nutrient Status

Date (month/year)	Station								
	1	2	3	4	5	6	7	8	9
Feb-21									
Mar-21	X	X	X				X		
Apr-21									
May-21									
Jun-21	X	X	X	X	X			X	
Jul-21									
Aug-21									
Sep-21									
Oct-21									
Nov-21									
Dec-21									

Table 2. Representation of frequency of impairment for TN for different site and date combinations. Green represents samples in compliance with criteria. Red cells indicate exceedance of criteria. Red cells with an "X" represent values that are within 5% of criteria concentrations, suggesting lack of compliance should be interpreted with caution, due to analytical precision. Gray cells represent a lack of data. (Note: Data from November 2017 through December 2021 were calculated based on Watershed Information Network data available in March 2022, prior exceedances were determined by others.)

Date (month/year)	Station								
	1	2	3	4	5	6	7	8	9
Mar-15									
Mar-15									
Apr-15									
May-15									
Jun-15									
Jul-15									
Aug-15									
Sep-15									
Oct-15									
Nov-15									
Dec-15									
Jan-16									
Feb-16									
Mar-16									
Apr-16									
May-16									
Jun-16									

Clam Bay Nutrient Status

Date (month/year)	Station								
	1	2	3	4	5	6	7	8	9
Jul-16									
Aug-16									
Sep-16									
Oct-16									
Nov-16									
Dec-16									
Jan-17									
Feb-17									
Mar-17									
Apr-17									
May-17									
Jun-17									
Jul-17									
Aug-17									
Sep-17									
Oct-17									
Nov-17									
Dec-17									
Jan-18									
Feb-18									
Mar-18									
Apr-18	X				X				
May-18			X						
Jun-18							X		
Jul-18						X			
Aug-18	X							X	
Sep-18									
Oct-18		X		X					
Nov-18									
Dec-18									
Jan-19	X		X						
Feb-19									
Mar-19									
Apr-19									
May-19									
Jun-19	X							X	
Jul-19									
Aug-19									
Sep-19									

Clam Bay Nutrient Status

Date (month/year)	Station								
	1	2	3	4	5	6	7	8	9
Oct-19						X			
Nov-19						X		X	
Dec-19		X							
Jan-20									
Feb-20									
Mar-20									
Apr-20				X					X
May-20									
Jun-20									
Jul-20									
Aug-20									
Sep-20									
Oct-20									
Nov-20									
Dec-20									
Jan-21									
Feb-21									
Mar-21									
Apr-21									
May-21									
Jun-21									
Jul-21									
Aug-21									
Sep-21									
Oct-21									
Nov-21									
Dec-21									

Clam Bay Results – Dissolved Oxygen

Dissolved oxygen (DO) saturation percentages as related to minimum criteria are presented below, calculated using temperature and DO concentrations. As cited in previous reports (**Appendix A**), a standard of 42 percent saturation is used to determine whether the samples are meeting criteria for Class II waters. Overall, 7 percent of samples fell slightly below the 42 percent saturation criteria during the first half of 2021, but an average of 15 percent of samples fell below the 42 percent saturation threshold for all of 2021 (**Table 3**). Results for July-December 2021 indicate that DO saturation generally declined compared to January through July 2021 samples, as often occurs with warmer water temperatures. Results where DO was 90-95% or higher suggest that algal blooms may have been occurring at certain sample locations on some dates.

Table 3 – Dissolved oxygen saturation values (%) at sites Clam Bay 1 to 9. Highlighted values fall below the established standard criteria for Class II waters (42% saturation) as cited in previous reports analyzing these data.

Date (month/year)	Station/Dissolved Oxygen Saturation (%)								
	1	2	3	4	5	6	7	8	9
Jan-21	60.4	61	57.8	58.2	80.1	86.9	98.4	90.9	50.3
Jan-21	84.8	61.4	80.4	76.8	83.7	84	82.6	84.9	76.9
Feb-21	83.2	60.9	76.2	79.3	87	89.1	91.9	80	81.5
Mar-21	45.9	40.1	51.8	74	81.1	83.1	77.9	71.4	70.8
Apr-21	65	40	32.8	63.1	76.3	90.3	96.7	93.7	67.9
May-21	60.1	43.9	62.5	83.1	94.5	84.2	91.1	81.4	67.1
June-21	81.3	33.7	66.7	53.6	74.6	85.8	77.9	92.9	72.9
July-21	9.8	10	21.6	42.6	63.2	75	69.3	72.4	39.5
Aug-21	24.7	6.3	26.6	27.2	78.9	88.7	74.5	71.9	94.7
Sep-21	61.5	29.6	40.3	44.5	61.1	78.2	78.8	53.8	39.6
Oct-21	19.3	26	52.2	57.2	75.1	91.9	88.3	73.6	65.1
Nov-21	60.6	51.2	55.4	62.7	105.4	98.8	108.3	97.3	97.6
Dec-21	58.2	44.2	56.8	61.6	71.7	85	85.2	78.3	63.5

Clam Bay Results – Comparison of Nutrients to Dissolved Oxygen Saturation and Chlorophyll-a Concentrations

The following is a summary of Pearson correlation data analyzed to determine whether relationships exist between nutrients, DO percent saturation, and chlorophyll-a concentrations in Clam Bay.

- There appears to be a correlation between TN and DO ($p < 0.05$), with a negative correlation relationship, indicating that high TN is associated with lower DO saturation.
- There appears to be a correlation between TP and DO ($p < 0.05$) with a negative correlation relationship, indicating that high TP is associated with lower DO saturation.
- There appears to be a correlation between TN and chlorophyll-a ($p < 0.10$). Knowing the depth of sample collection as compared to water depth at the site would assist in further interpreting these results, as chlorophyll-a may be stratified near the upper portion of the water column to collect the most sunlight. With a positive correlation relationship, this indicates that higher TN is associated with higher chlorophyll-a concentrations.
- There appears to be a correlation between TP and chlorophyll-a ($p < 0.01$) with a positive correlation relationship, indicating that higher TP is associated with higher chlorophyll-a concentrations.

Clam Bay Results – Copper

The water quality standard for copper in marine waters is 3.7 µg/L, although the impaired waters rule allows for a certain number of exceedances before a waterbody is considered to be out of compliance with this standard. **Table 4** below reports the copper data collected for the Clam Bay sites for 2021. Based on information presented in Table 3 of Chapter 62-303 and the number of samples collected, at least 16 samples would need to exceed the water quality criteria for the waterbody to be listed as verified impaired for the January to December 2021 sample period. Because only 5 samples exceeded the 3.7 µg/L threshold (all between March and May of 2021), Clam Bay would not be considered impaired based on results of samples collected during the twelve months of 2021.

Table 4 – Copper values at sites Clam Bay 1 to 9 (µg/L). Values highlighted in yellow exceed the 3.7 µg Cu / L copper criteria for Class II waters.

Date (month/year)	Station/Copper concentrations (µg/L)								
	1	2	3	4	5	6	7	8	9
Jan-21	2.9	2.89	2.35	1.95	1.2	1.2	1.2	1.51	1.23
Feb-21	3.5	2.13	3.05	1.82	1.2	1.2	1.2	1.32	1.2
Mar-21	2.43	6.38	2.24	1.2	1.2	1.2	1.2	1.2	1.2
Apr-21	3.89	3.85	3.02	2.12	1.53	1.81	2.11	3.1	2.03
May-21	6.58	5.3	3.69	1.2	1.2	2.05	2.57	2.54	1.34
June-21	3.04	2.79	2.18	1.75	1.67	1.47	2.03	1.65	1.73
July-21	2.05	2.35	1.65	1.54	1.13	1.2	1.94	1.05	1.2
Aug-21	2.5	1.89	1.4	1.35	1.18	1.05	1.17	1.05	1.05
Sep-21	2.38	1.41	1.27	0.98	1.05	1.05	1.05	1.05	1.05
Oct-21	1.17	1.05	1.05	1.05	1.2	1.35	1.2	1.2	1.05
Nov-21	1.59	2.1	1.43	1.45	1.05	1.05	1.16	1.1	1.1
Dec-21	1.37	2.27	2.16	1.44	1.2	1.2	2.5	1.2	1.2
Median	2.47	2.31	2.17	1.45	1.2	1.2	1.2	1.2	1.2
N	12	12	12	12	12	12	12	12	12
# > 3.7	2	3	0	0	0	0	0	0	0
% > 3.7	17	25	0	0	0	0	0	0	0

Clam Bay Berm Water Quality Data

Nutrient Results – Berm Data

As described in detail in the ESA 2020 Annual Report (**Appendix A)**, while upstream sources of inflow water (such as the area behind the berm) may not be assigned their own upper limits for nutrients and other pollutants, these features may be assigned Downstream Protection Values (DPVs). To briefly summarize, the outfall nutrient and copper concentrations are generally expected to be higher than found in the bay itself; however, there is an upper limit to how much higher these concentrations can be before they are expected to have an adverse impact on water quality in the bay. DPVs have been set for berm outfall sites.

There are two DPV values for each parameter (TN and TP), one of which would be expected to be exceeded 50 percent of the time (50th percentile) and one of which would be expected to be exceeded only 10 percent of the time (90th percentile). Therefore, while water quality upstream of the bay (i.e., behind the berm) cannot be evaluated based on SSAC set for the bay itself, these DPV numbers can indicate whether the water discharging from the berm outfalls may be expected to have an adverse impact on the bay. DPVs for berm outfall sites for TP have been proposed at 0.10 mg/L and 0.25 mg/L for the 50th and 90th percentiles, respectively. DPVs for TN have been proposed at 1.31 mg/L for the 50th percentile and 1.80 mg/L for the 90th percentile, respectively.

Table 5 below indicates the percentage of total samples collected from the berm discharge outfall sites that exceed the 50th/median or 90th percentile DPV values during the January to December 2021 sampling period, while **Tables 6 and 7** represent TP and TN 50th percentile exceedances, respectively, by site and date from 2015 through December 2021. While TP and TN discharging from berm outfall sites exceed the 50th percentile DPV values at approximately the same rate for TN and TP, the TP exceedances at the 90th percentile occur more often for TP than for TN, as reflected by the high number of TP exceedances in the bay itself compared tono TN exceedances indicated in Clam Bay between January and December 2021. Relatively few TN exceedances were indicated in prior years compared to frequent exceedances of TP concentration in the bay since 2015 (**Tables 2 and 3**); 2021 data is consistent with previous years' observations.

Table 5. Percentage of TN or TP concentrations from Berm outfall stations which exceeded the median or 90th percentile DPV values between January and December 2021.

	Total Nitrogen		Total Phosphorus	
	Median	90th Percentile	Median	90th Percentile
Exceedance Rate (%)	60%	9%	63%	35%

Table 6. Representation of frequency of impairment for median TP DPV (0.10 mg/L) for different berm outfall site and date combinations. Green represents samples in below the median DPV value. Red cells indicate exceedance of the median DPV value. Gray cells represent a lack of data.

Date	Glenview	N-41 Pipe	N-Berm	N-Boardwalk	P-11	PB-13	St. Lucia
March-15							
April-15							
May-15							
June-15							
July-15							
August-15							
September-15							
October-15							
November-15							
December-15							
January-16							
February-16							
March-16							

Clam Bay Berm Water Quality Data

Date	Glenview	N-41 Pipe	N-Berm	N-Boardwalk	P-11	PB-13	St. Lucia
April-16							
May-16							
June-16							
July-16							
August-16							
September-16							
October-16							
November-16							
December-16							
January-17							
February-17							
March-17							
April-17							
May-17							
June-17							
July-17							
August-17							
September-17							
October-17							
November-17							
December-17							
January-18							
February-18							
March-18							
April-18							
May-18							
June-18							
July-18							
August-18							
September-18							
October-18							
November-18							
December-18							
January-19							
February-19							
March-19							
April-19							
May-19							
June-19							
July-19							
August-19							

Clam Bay Berm Water Quality Data

Date	Glenview	N-41 Pipe	N-Berm	N-Boardwalk	P-11	PB-13	St. Lucia
September-19							
October-19							
November-19							
December-19							
January-20							
February-20							
March-20							
April-20							
May-20							
June-20							
July-20							
August-20							
September-20							
October-20							
November-20							
December-20							
January-21							
February-21							
March-21							
April-21							
May-21							
June-21							
July-21							
August-21							
September-21							
October-21							
November-21							
December-21							

Note: In an event that multiple outfall samples were taken within a given month at a specific location, cell color reflects the highest value for the site that month.

Clam Bay Berm Water Quality Data

Table 7. Representation of frequency of impairment for median TN DPV (1.31 mg/L) for different berm outfall site and date combinations. Green represents samples in below the median DPV value. Red cells indicate exceedance of the median DPV value. Gray cells represent a lack of data.

Month/Year	Outfall Stations						
	Glenview	N-41 Pipe	N-Berm	N-Boardwalk	P-11	PB-13	St. Lucia
March-15							
April-15							
May-15							
June-15							
July-15							
August-15							
September-15							
October-15							
November-15							
December-15							
January-16							
February-16							
March-16							
April-16							
May-16							
June-16							
July-16							
August-16							
September-16							
October-16							
November-16							
December-16							
January-17							
February-17							
March-17							
April-17							
May-17							
June-17							
July-17							
August-17							
September-17							
October-17							
November-17							
December-17							
January-18							
February-18							

Clam Bay Berm Water Quality Data

Month/Year	Outfall Stations						
	Glenview	N-41 Pipe	N-Berm	N-Boardwalk	P-11	PB-13	St. Lucia
March-18							
April-18							
May-18							
June-18							
July-18							
August-18							
September-18							
October-18							
November-18							
December-18							
January-19							
February-19							
March-19							
April-19							
May-19							
June-19							
July-19							
August-19							
September-19							
October-19							
November-19							
December-19							
January-20							
February-20							
March-20							
April-20							
May-20							
June-20							
July-20							
August-20							
September-20							
October-20							
November-20							
December-20							
January 2021							
February 2021							
March 2021							
April 2021							
May 2021							

Clam Bay Berm Water Quality Data

Month/Year	Outfall Stations						
	Glenview	N-41 Pipe	N-Berm	N-Boardwalk	P-11	PB-13	St. Lucia
June 2021							
July 2021							
August 2021							
September 2021							
October 2021							
November 2021							
December 2021							

Note: In an event that multiple outfall samples were taken within a given month at a specific location, cell color reflects the highest value for the site that month.

Dissolved Oxygen Results – Berm Data

Dissolved oxygen (DO) saturation data collected for berm outfall stations are presented here to provide an overview of where DO levels might be low. However, there are no specific water quality standards for DO in waters behind the berm. Given the overall high levels of DO in Clam Bay, as presented in **Table 3** above, it does not appear that low DO percent saturation levels at the outfall stations (shown in **Table 8**) are affecting Clam Bay. Generally speaking, the DO percent saturations reported below are low at the Glenview and St. Lucia stations throughout the year, and there does not appear to be any particular pattern at the other stations. Given that the berm sampling stations are essentially treated stormwater runoff, variability is expected throughout the year depending on temperature and rainfall, among other variables.

Table 8. Percent DO saturation results for berm outfall stations from January through May 2021. Grey cells indicate no data provided*

Date	Glenview	PB-11	St_Lucia	PB-13	N Boardwalk	N_Berm
January-21	27.5	63.9	52.5		53.7	81.4
February-21	12.4		22.6		22.6	57.2
March-21	19.4	81.7			77.4	50.3
April-21	9.7	56.6	38.3	56.6	24.4	50.7
May-21	9.7	81.1	26.0	7.7	12.9	35.4
June-21	18.5	39.5	18.3	47.0	27.4	52.4
July-21	8.5	61.3	22.8	56.8	16.3	58.8
August-21	11	52.4	18.1	73.6	22.2	47.1
September-21	9.9	40.44	17.2	9.8	18.1	39.3
October-21	12.3	18.1	13	44.1	20.6	44.8
November-21	15.3	27.4	26.5	65.5	25.9	63.7
December-21	15.9	47.7			32.1	54.7

*If two results were provided in a given month the average of the two results was used.

Clam Bay Berm Water Quality Data

Copper Results – Berm Data

Freshwater surface waters, such as those behind the berm, do not have assigned water quality criteria as they are not natural waterbodies. However, knowledge of copper levels in the upstream surface waters can inform the potential for each area to contribute to copper levels in Clam Bay downstream.

Water-quality standards for copper concentrations in freshwater require knowledge of the water hardness, The equation to determine the hardness-normalized copper standard is as follows:

Copper Standard (μg/L) = $e^{(0.8545[\ln H]-1.702)}$

H = hardness in units of $CaCO_3$/L; e = the base of the natural logarithm (approximately 2.718281)

With regard to the Clam Bay berm outfall stations data, copper concentrations and water hardness are only available for January, February and March of 2021 and are presented in **Table 9** below. Hardness data were not collected for April through December 2021, and therefore copper data for these months are not included here because the copper concentrations cannot be corrected for hardness. Overall, 53 percent of the samples exceeded calculated freshwater water quality standards for copper at the berm outfall stations discharging into Clam Bay from January through March 2021.

Table 9. Copper concentrations in berm outfall stations from January to March 2021. Copper levels exceeding freshwater copper water quality standards (as calculated per the equation in Section 3.4 above) are highlighted in yellow.

Location	Date	Cu (μg/L)
Glenview	1/13/2021	13
PB-11	1/13/2021	32.1
St_Lucia	1/13/2021	11.6
N_BERM	1/13/2021	20.2
N_BOARDWALK	1/13/2021	26.9
GLENVIEW	2/23/2021	9.61
ST_LUCIA	2/23/2021	5.85
N_BERM	2/23/2021	21.9
N_BOARDWALK	2/23/2021	10.3
Glenview	3/25/2021	16
PB-11	3/25/2021	23.5
N_BERM	3/25/2021	21.7
N_BOARDWALK	3/25/2021	60.2

*While copper was collected for April through December 2021, hardness data was not collected during these months and copper results could therefore not be normalized for hardness for correct calculation; as a result, additional copper concentrations for the remainder of 2021 are not presented here.

Conclusions and Recommendations

Water quality data collected from Clam Bay throughout calendar year 2021 were analyzed to determine whether the different regions of Clam Bay are currently in compliance with previously established NNC and SSAC and established criteria for copper. Results indicate that 33 of 108 TP values exceeded established criteria in Clam Bay during 2021, no TN concentration exceedances occurred during this time period. The 2021 data presented here are compared to data analyzed by others as presented in reports dating back to 2015. The 2021 results are similar to those observed in previous years. The 2021 samples also indicate that Clam Bay is currently in compliance with TN, as well as for copper concentrations found in saltwater sites. Clam Bay is slightly out of compliance for percent DO saturation, with an actual exceedance rate of 15 percent compared to the allowed 10 percent exceedance rate.

A comparison of nutrient concentrations to percent DO saturation and to chlorophyll-*a* in Clam Bay indicate that there is a statistically significant relationship between the parameters, indicating that higher DO saturation is associated with higher chlorophyll-*a* levels. There is a negative relationship between TN and TP in Clam Bay and DO saturation in Clam Bay, meaning that higher levels of nutrients result in a lower level of DO saturation.

Water quality data, including TN, TP, percent DO saturation, and copper, were also measured through 2021 at six berm outfall sites on the east side of Clam Bay. Overall, these berm water quality data are highly variable, as is expected of stormwater samples. Copper exceeded established Downstream Protection Values (DPVs) in 7 of 13 samples collected between January and March 2021 for which samples could be properly evaluated. Results are unknown for the remainder of the year because water hardness measurements were not collected as needed to correct copper data for comparison to the assigned DPV.

While the TP and TN concentrations discharging from berm outfall sites exceeded the 50th percentile DPV values at approximately the same rate for TN and TP, TP exceedances at the 90th percentile level occur more often for TP than for TN, as reflected by the high number of TP exceedances in the bay itself compared to only two TN exceedances indicated in Clam Bay between January and December 2021. Relatively few TN exceedances were indicated in prior years compared to frequent exceedances of TP concentration in the bay since 2015; this is consistent with previous years' observations.

The most probable cause of high levels of TN, TP and Copper are historic uses of fertilizers and algicides. Nutrients and metals can become bound in the upstream soils and sediments can be re-released when soils and sediments are disturbed, such as erosion and/or sediment transport after a storm event. Resuspension of sediments and erosion of soils can cause new releases of contaminants for many years after contaminant inputs cease.

Finally, it as determined during the course of analyzing data that the equations for determining the TN and TP exceedance levels appear to be in error in the Rule (62-302.532, F.A.C.). Through correspondence with developers of the equation included in the rule (Dave Tomasko and Emily Keenan, **Appendix C**), it appears that 'specific conductivity' was shortened to 'conductivity' over time. Calculating TN and TP exceedance levels using 'conductivity' instead of 'specific conductivity' results in approximately 20 percent higher exceedance rates. When possible, the Rule should be updated to refer to 'specific conductivity.'

Conclusions and Recommendations

Recommendations include:

- Re-establish the measurement and calculation of hardness for berm samples so that copper data collected from berm discharges can be appropriately evaluated.
- Continue monitoring, and possibly increase the sample collection depth within Clam Bay to the extent practicable. The collection depth of samples appears to be relatively shallow, which can affect the results. Generally, samples should be collected from the middle of the water column for greatest accuracy.
- Verify that previous calculations for nutrient criteria exceedances in 2020 used specific conductivity rather than specific conductance in calculations of TN and TP exceedance values in Clam Bay.
- Request that the Florida Department of Environmental Protection (FDEP) update Rule 62-302.532, F.A.C., to read 'specific conductivity' in place of 'conductivity'.

Upstream management recommendations include:

- Preventing grass clippings and other yard waste from entering the stormwater system.
- Educating residents regarding Collier County's Fertilizer and Urban Landscaping Ordinance.
- Reducing and/or eliminating the use of copper-containing chemicals on lawns and in stormwater ponds.
- Expanding overall community education regarding how resident actions can affect Clam Bay. Based on experience of the author of this report, many residents believe that what enters a storm drain is transported to a wastewater treatment plant and they are unaware that chemicals, fertilizers, RV waste and other material disposed in storm drains can flow directly to and directly affect natural waters downstream.

Appendix A

ESA 2021 ANNUAL REPORT (2020) ON CLAM BAY NUMERIC NUTRIENT CRITERIA

Appendix A

ESA

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esassoc.com

Technical Memorandum

date	March 24, 2021
to	Tim Hall Turrell, Hall and Associates, Inc.
cc	
from	Emily Keenan, M.S. Bob Woithe, PhD.
subject	Annual Report (2020) on Clam Bay Numeric Nutrient Concentration (NNC) Criteria

Executive Summary

Water quality data collected from Clam Bay between January 2020 and December 2020 were analyzed to determine the degree to which the waters of Upper, Inner and Outer Clam Bay are in compliance with relevant criteria. For nutrients, it was found that levels of phosphorous were out of compliance with existing site-specific criteria for Clam Bay both in the current year (2020) as well as previous years. Levels of nitrogen were not out of compliance. Due to elevated phosphorus concentrations in consecutive years, an analysis of the potential impact on water clarity within the system was performed to identify potential management actions.

The results from these past 12 months were then compared against water quality data going back to March 2015. In general, phosphorus concentrations have increased over recent years in a pattern that suggests that the impacts from Hurricane Irma may have had longer-term consequences than was originally anticipated. A timeline of impacts, activities and water quality suggests that the rainy season of 2018 might have brought more phosphorus into the Clam Bay system than even the hurricane- impacted prior year. This may have been associated with activities that were conducted in 2018 to reestablish tidal channels in the mangrove forests adjacent to Clam Bay. These channels were reestablished in large part due to damage to the forests that occurred in response to the passage of Hurricane Irma in September 2017. In the most recent monitoring period (January 2020 to December 2020), a notable reduction in phosphorus exceedances was observed throughout the Clam Bay system further supporting the likelihood that the previous period of wide-spread elevated phosphorus concentrations was due to extreme weather events.

Based on data from throughout the Clam Bay system, there is a positive correlation between phosphorous concentrations and the amount of algae in the water column, and an inverse correlation between phosphorous and levels of dissolved oxygen (DO). These results suggest that phosphorous concentrations are at potentially problematic levels in Clam Bay, and they should be carefully monitored, to ensure that conditions do not deteriorate, and that the recent impairments do not become a long-term condition. Should phosphorous continue to exceed established criteria; the County might wish to consider developing a site-specific phosphorus loading model, to develop appropriate management responses.

Similar trends were found for nitrogen, but phosphorus tended to explain more of the variability in levels of chlorophyll-a and DO than was found for nitrogen. These data suggest that both nitrogen and phosphorus are important for the management of water quality in Clam Bay, but phosphorus might have more of an influence on ecosystem health than nitrogen.

Unfortunately, the trend over the past six years has been of an increase in both nitrogen and phosphorus, at least in Outer Clam Bay. Upper and Inner Clam Bay do not show the same trend of increased nitrogen and phosphorus that was seen in Outer Clam Bay. However, despite the trends of increased nutrient concentrations, the majority of stations did not exhibit a concurrent increase in the amount of algae in the water column, as quantified by concentrations of chlorophyll-a.

The waters of Clam Bay would be considered to be out of compliance with existing DO criteria used by the state of Florida. This conclusion is consistent with the results of the previous annual report which identified sufficient depressed DO concentrations to be considered out of compliance over the 12- month period. However, a formal determination of impairment for DO by FDEP would require the review of data over a 7.5-year period, rather than an individual year. Nonetheless, it would be helpful to better characterize the benthic habitats in Upper and Inner Clam Bay, as it is not that unusual for mangrove-lined creeks to have healthy ecology, even if they "fail" state-designated water quality criteria.

While the amount of copper in the various treatment ponds sampled along the eastern border of Clam Bay exceeded criteria for freshwater water bodies, the open waters of Clam Bay would not be considered to be impaired for copper. That finding seems to represent an improvement in water quality in the bay, most likely associated with reductions in the amount of copper-containing herbicides used in the Pelican Bay stormwater treatment system.

Background

In 2012, the United States Environmental Protection Agency formally adopted nutrient concentration criteria for Clam Bay (which had been produced for Collier County) that had also been reviewed and approved by FDEP. The Numeric Nutrient Concentration (NNC) criteria produced for Clam Bay are termed Site Specific Alternative Criteria (SSAC) and they are listed in Florida Administrative Code (FAC) 62-302.531. The SSAC for Clam Bay were based upon a relationship between salinity and nutrients that was initially established at one of FDEP's "reference sites" in Estero Bay. The need to take into account salinity was based upon the finding that nutrient concentrations in estuaries and tidal rivers vary as a function of rainfall and runoff, as well as tidal influence. Even FDEP's reference sites, which were chosen to represent waterbodies with little to no human impacts, have nutrient concentrations that are inversely correlated with salinity. This reflects land-based nutrient sources combining with lower nutrient concentrations in offshore waters. Therefore, a single nutrient concentration criterion does not make much sense, as water quality data from even pristine locations could potentially pass or fail proposed criteria simply as a function of location, tidal stage or antecedent rainfall.

The SSAC for Clam Bay incorporates nutrient concentrations, while also taking into account the salinity, such that a finding of elevated nutrients in combination with higher salinities is considered more problematic than elevated nutrients in combination with lower salinities. Additionally, the frequency with which values exceed NNC criteria is taken into account when determining the appropriate management response as is the amount of time over which an exceedance has occurred. For example, if nutrient concentrations were to exceed NNC criteria by a relatively small percentage, and if such an exceedance was to only last a short period of time, the appropriate management

response would be different than if water quality was to exceed criteria by a greater margin, and if the condition of exceedance lasts for a greater period of time. In this manner, the management response associated with any impairment determination is proportional, and based upon both the magnitude and duration of any exceedances.

Based on prior work conducted in Clam Bay, it was found that the amount of floating microscopic algae (i.e., phytoplankton) in the bay was likely stimulated by both Total Nitrogen (TN) and Total Phosphorous (TP). Accordingly, the amount of both TN and TP in Clam Bay is used to determine the degree of nutrient enrichment of Clam Bay's waters. The language in FAC 62-302.531 states that the water quality status of waterbodies is to be determined on an annual basis, preferably within a calendar year.

As outlined in FAC 62-302.532, for each year, the value of each individual TN and TP sample collected within Clam Bay is compared to an "upper boundary" of the expected relationship between those two variables and salinity. This boundary was originally informed by the water quality data from an FDEP-designated reference water body. The formal name of the upper boundary condition is the "90th percentile prediction limit" which was originally derived for the relationship between nutrient concentrations and salinity in Clam Bay, and which is based on the determination by FDEP that Clam Bay's water (in 2012) was sufficient to protect its biological integrity. In other words, a TN or TP concentration higher than the 90th percentile prediction limit is a nutrient concentration higher than at least 90 percent of the values that would be expected, after taking into account the salinity value at the time that the water quality sample was collected.

The number of occasions when a nutrient concentration is higher than the 90th percentile prediction limit is quantified for each year, and an annual percent exceedance is then calculated. To attempt to be consistent with previous methods used by FDEP, if more than 13 percent of TN or TP concentrations exceed the 90th percentile prediction limit (for a given year) then the year as a whole is classified as one where water quality is out of compliance with the existing criteria. If fewer than 13 percent of the values exceed the 90th percentile prediction limit, then water quality is not considered to be out of compliance.

If more than 15 percent of TN or TP values exceed the 90th percentile prediction limit, then the degree of impairment is determined (as per FDEP guidance) to be more problematic than if only 13 percent of values exceeded the established criteria. The screening of water quality data against the adopted NNC criteria is performed as outlined in Figure 1, where different outcomes are given different scores, depending on the frequency of impairment, as well as the duration that the impairment has lasted. The possible outcomes displayed in Figure 1 are then compared for both TN and TP, and the combined outcomes are converted into designations of "green", "yellow" and "red" which correspond to an increasing need for concern (Figure 2).

As a final step, the appropriate management response to water quality within a given year is then identified based on the results from Figure 2. For example, if water quality data suggest that TN and TP concentrations are elevated, then it is important to determine if the ecological health of Clam Bay appears to be adversely impacted by those nutrient concentrations. As a test of the impact of potential nutrient enrichment, water quality data would then be tested to determine if phytoplankton levels are perhaps higher, or dissolved oxygen levels lower, based on nutrient concentrations (Figure 3).

In this manner, management responses are proportional to the frequency and duration of exceedance conditions, as well as the determination of whether or not nutrient supply appears to be causing adverse water quality conditions. With this information as background, the rest of this report will focus on the analysis of water quality data collected

during the period of January 2020 to December 2020, at nine open water locations shown in Figure 4. In addition to the open water sample sites, a number of sampling locations were located in the stormwater treatment ponds and swales east of the mangrove fringe and stormwater berm on the east side of Outer, Inner and Upper Clam Bays (Figure 4).

Figure 1. Flow chart for determining water quality compliance in Clam Bay.

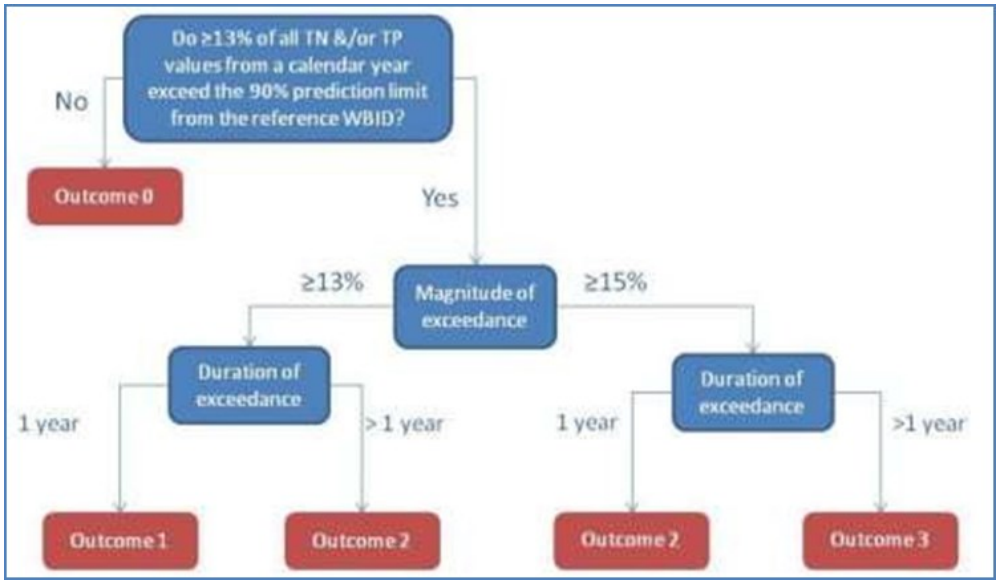


Figure 2. Management response matrix using outcomes for TN and TP.

	Total Phosphorus			
Total Nitrogen	**Outcome 0**	**Outcome 1**	**Outcome 2**	**Outcome 3**
Outcome 0				
Outcome 1				
Outcome 2				
Outcome 3				

Figure 3. Management response actions in response to various outcomes in Clam Bay.

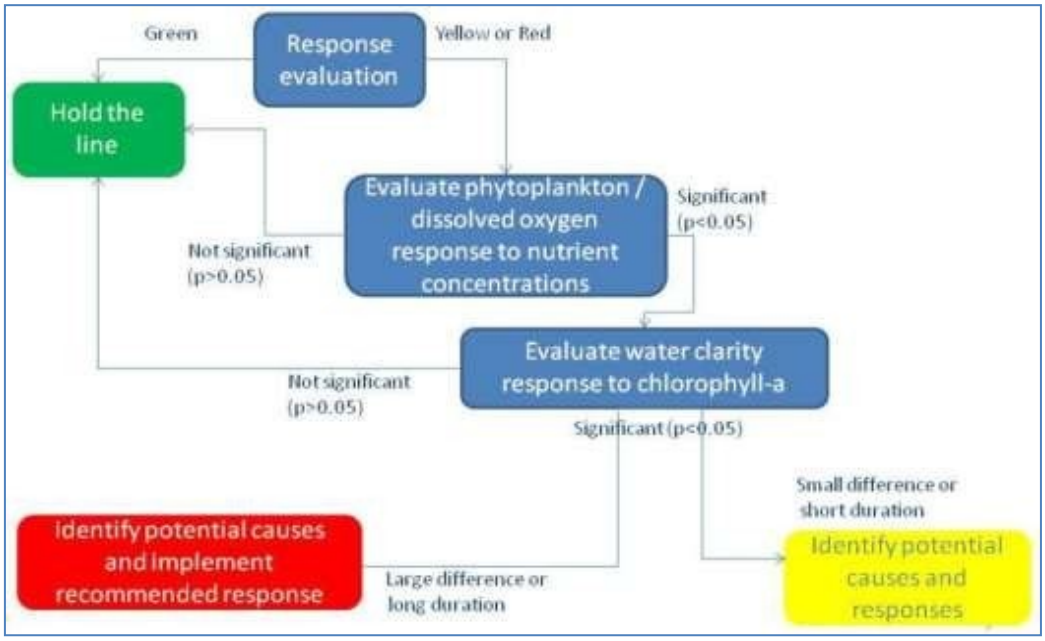
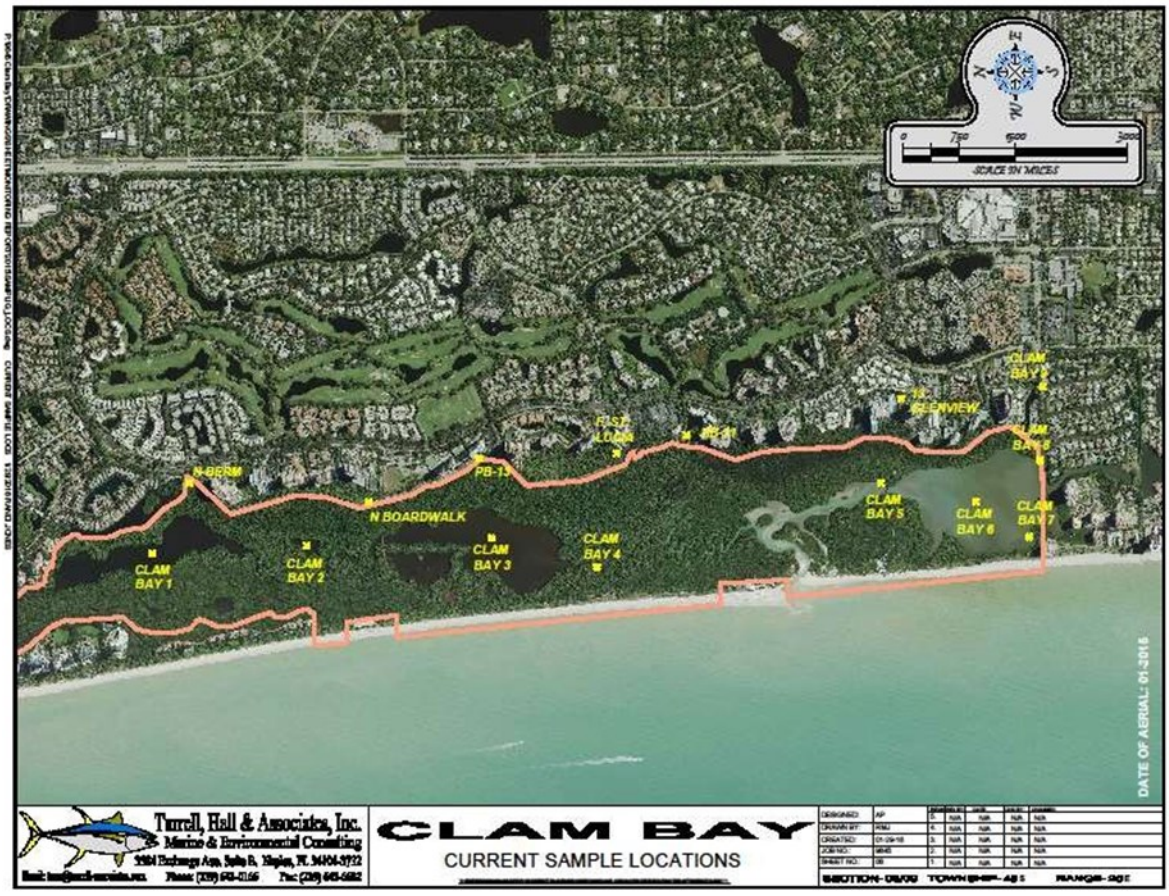


Figure 4. Locations of monthly monitoring stations sampled for Clam Bay and its directly adjacent watershed.



Data Analysis – Nutrient Status

The analysis conducted below was used to assess the water quality status of Clam Bay during the months of January 2020 to December 2020. Samples were collected monthly at each of the nine sampling stations; therefore, a total of 108 water quality samples were reported within Clam Bay for the analysis period. Water quality data from Clam Bay and its watershed were provided by Turrell, Hall and Associates, Inc.

For comparison with the FDEP adopted SSAC for Clam Bay, as listed within FAC. 62-302-532, the water quality data set provided by Turrell, Hall and Associates was analyzed based on the following criteria:

> *No more than 10 percent of the individual Total Phosphorus (TP) or Total Nitrogen (TN) measurements shall exceed the respective TP Upper Limit or TN Upper Limit*

The Upper Limits for TP and TN concentrations noted above are derived based on Equations 1 and 2, respectively:

$$\underline{\text{Equation 1:}}\ TP\ Upper\ Limit\ (mg/L) = e^{(-1.06256-0.0000328465*Conductivity(\mu s))}$$

$$\underline{\text{Equation 2:}}\ TN\ Upper\ Limit\ (mg/L) = 2.3601 - 0.0000268325*Conductivity(\mu S)$$

The nutrient dataset examined was supplemented with in situ water quality data (e.g., temperature, dissolved oxygen, pH, conductivity, and salinity) retrieved from the chain of surface water grab sample custody forms for each sampling event. TN and TP concentrations were compared to the derived upper limit thresholds to quantify the presence or absence of elevated concentrations of TP and/or TN, with results listed in (Appendix A).

Over the period analyzed (January 2020 to December 2020), no (0) ambient water quality values for TN exceeded the respective TN Upper Limit. In comparison, 26 of the 108 TP measurements (approximately 24 percent) exceeded their respective TP Upper Limit. Based on these results, the frequency of exceedance would be high enough for the waters of Clam Bay to be determined to be impaired for TP.

This report is intended to present results over the most recent annual reporting period. However, in order to more extensively investigate the nutrient exceedances observed in Clam Bay, all data collected as part of the existing ambient monitoring program implemented by Turrell Hall and Associates were evaluated to identify potential trends (March 2015 to December 2020). For this effort, TN and TP event exceedances were displayed in a manner intended to allow a quick visualization or results by month and by station (Tables 1 and 2). Sampling locations and months are color coded according to results. Green represents “passing” values while red represents time and month combinations where TN or TP values exceeded NNC criteria. Additionally, red cells denoted with an “x” represent date and location combinations where criteria were exceeded, but where the TN or TP concentrations were within 5 percent of the relevant threshold concentration. On those occasions, the TN or TP concentrations are close enough to “non-impaired” levels that impairment could be related to issues such as rounding errors or laboratory precision.

Table 1. Representation of frequency of impairment for TP for different site and date combinations. Green represents samples in compliance with criteria. Red cells indicate exceedance of criteria. Red cells with an "X" represent values that are within 5% of criteria concentrations, suggesting lack of compliance should be interpreted with caution, due to analytical precision. Clear cells represent a lack of data.

Sampling Event	Station								
	1	2	3	4	5	6	7	8	9
15-Mar			X						
15-Mar									
15-Apr									
15-May		X							
15-Jun									
15-Jul									
15-Aug									
15-Sep									
15-Oct									
15-Nov		X							
15-Dec									
16-Jan									
16-Feb		X							
16-Mar									
16-Apr									
16-May									
16-Jun									
16-Jul									
16-Aug									
16-Sep				X					
16-Oct									
16-Nov									
16-Dec									
17-Jan									
17-Feb									
17-Mar			X						
17-Apr									
17-May									X
17-Jun									
17-Jul									
17-Aug									
17-Oct									
17-Nov									
17-Dec									

Table 1. Continued.

Sampling Event	Station								
	1	2	3	4	5	6	7	8	9
18-Jan									
18-Feb									
18-Mar					X	X			
18-Apr									X
18-May							X		
18-Jun									
18-Jul									
18-Aug									
18-Sep									
18-Oct									
18-Nov									
18-Dec									
19-Jan									
19-Feb									
Mar-19			X		X				
19-Apr									
19-May									
19-Jun									
19-Jul							X		
19-Aug									
19-Sep		X							
19-Oct									
19-Nov									
19-Dec									
20-Jan						X			
20-Feb									
20-Mar									
20-Apr									
20-May									
20-Jun								X	X
20-Jul								X	X
20-Aug		X							
20-Sep									
20-Oct									X
20-Nov									
20-Dec									

Table 2. Representation of frequency of impairment for TN for different site and date combinations. Green represents samples in compliance with criteria. Red cells indicate exceedance of criteria. Red cells with an "X" represent values that are within 5% of criteria concentrations, suggesting lack of compliance should be interpreted with caution, due to analytical precision. Clear cells represent a lack of data.

Sampling Event	Station								
	1	2	3	4	5	6	7	8	9
15-Mar									
15-Mar									
15-Apr									
15-May									
15-Jun									
15-Jul									
15-Aug									
15-Sep									
15-Oct									
15-Nov									
15-Dec									
16-Jan									
16-Feb									
16-Mar									
16-Apr									
16-May									
16-Jun									
16-Jul									
16-Aug									
16-Sep									
16-Oct									
16-Nov									
16-Dec									
17-Jan									
17-Feb									
17-Mar									
17-Apr									
17-May									
17-Jun									
17-Jul									
17-Aug									
17-Oct									
17-Nov									
17-Dec									

Table 2. Continued.

Sampling Event	Station								
	1	2	3	4	5	6	7	8	9
18-Jan									
18-Feb									
18-Mar									
18-Apr									
18-May									
18-Jun									
18-Jul			X						
18-Aug									
18-Sep									
18-Oct									
18-Nov			X						
18-Dec									X
19-Jan									
19-Feb									
Mar-19									
19-Apr									
19-May								X	
19-Jun									
19-Jul									
19-Aug									
19-Sep									
19-Oct									
19-Nov									
19-Dec									
20-Jan									
20-Feb									
20-Mar									
20-Apr									
20-May									
20-Jun									
20-Jul									
20-Aug									
20-Sep									
20-Oct									
20-Nov									
20-Dec									

Since TP exceedances have occurred in all reporting periods, the process shown in the Figure 1 flowchart yields a score of "3" for TP compared to a score of "0" for TN (Figure 2). Using three years' worth of data, the combination of outcome "3" for TP and outcome "0" for TN would result in a "yellow" management response as illustrated in Figure 3. Since the TP exceedance rate was greater than 15 percent, has persisted for more than one year, and coincides with a TN exceedance rate less than 13 percent, the "yellow" management response would be the outcome for the 2020 annual data collection effort. This is an improvement compared to previous annual evaluations (2018 and 2019) when the management response was "red". Consequently, the following additional data investigations were conducted:

- Determining the relationship, if any, between nutrients and chlorophyll-a
- Determining the relationship, if any, between nutrients and dissolved oxygen
- Determining the relationship, if any, between chlorophyll-a and water clarity

Depending upon the findings of the analyses listed above, management implications would be developed, which could include the need to determine the basis for a potential adverse impact on water quality.

A review of the monitoring program's complete record of 51 months of data of data (October 2016 to December 2020) indicated a direct relationship between nutrients and chlorophyll-concentrations (Figures 5 and 6). However, chlorophyll concentrations appear to more strongly influenced by TP than TN based upon the respective R^2 for each regression (TP r^2=0.4157; TN r^2=0.1269)). Additionally, an inverse relationship between nutrients and DO was observed (Figure 7 and 8). The collection of Secchi depth readings as a surrogate for water clarity began in November 2017. Therefore, the analysis relating algal production to water clarity was restricted to the period of November 2017 to December 2020. A significant inverse relationship between Chl-a and water clarity was observed. This suggests that increased algal production was responsible for reduction in water clarity (p=0.0011, r^2=0.0318); however, the strength of the interaction was weak suggesting that other factors such as color and suspended solids also impact water clarity.

Figure 5. Relationship between total nitrogen and chlorophyll-a over the period of October 2016 to December 2020 in Clam Bay (p<0.0001, r2=0.1269).

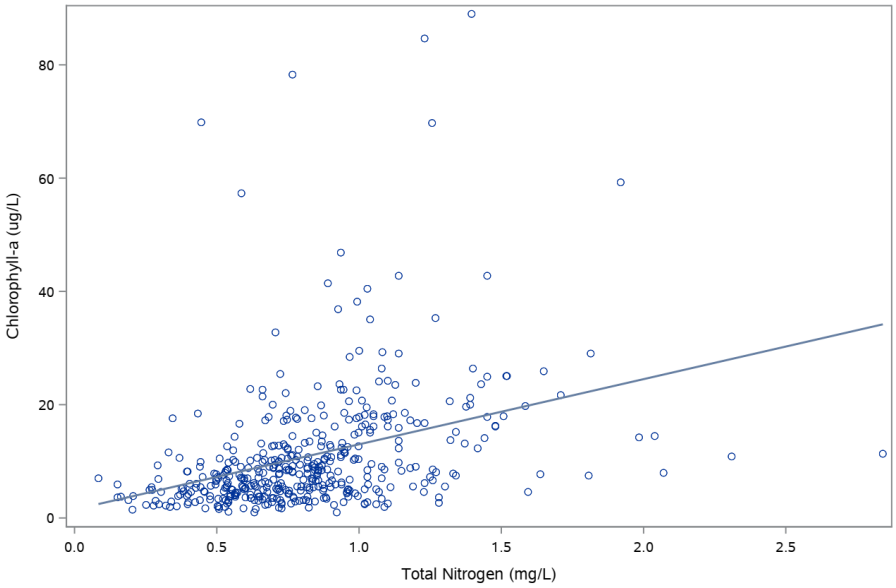


Figure 6. Relationship between total phosphorus and chlorophyll-a over the period of October 2016 to December 2020 in Clam Bay (p<0.0001, r2=0.4157).

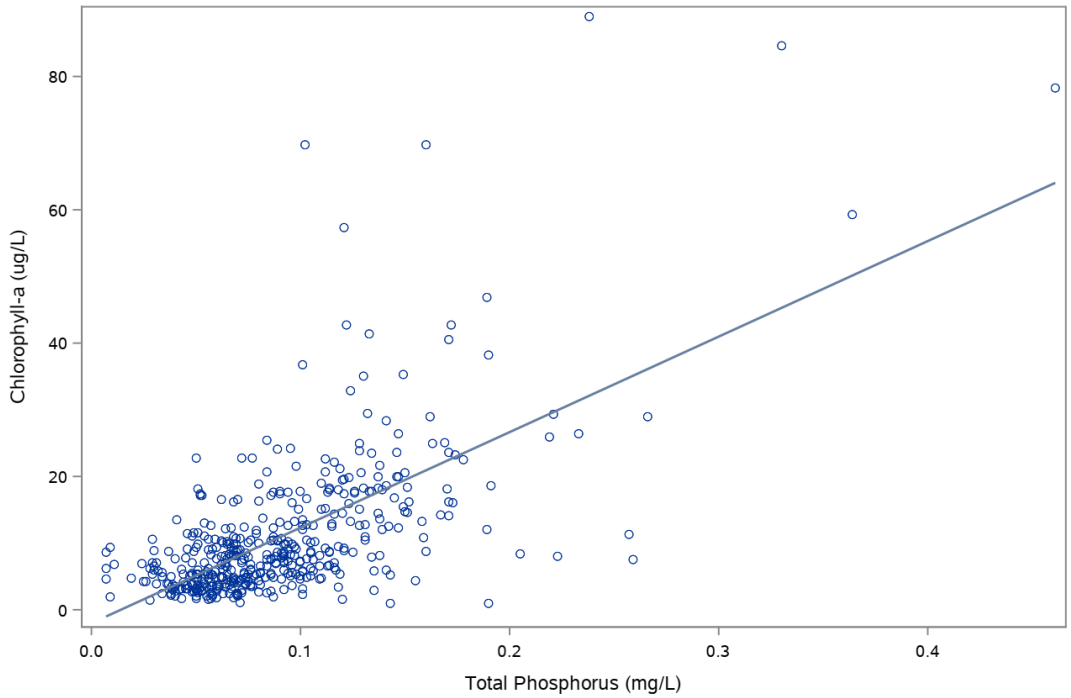


Figure 7. Relationship between total nitrogen and dissolved oxygen over the period of October 2016 to December 2020 in Clam Bay (p<0.001, r2=0.1456).

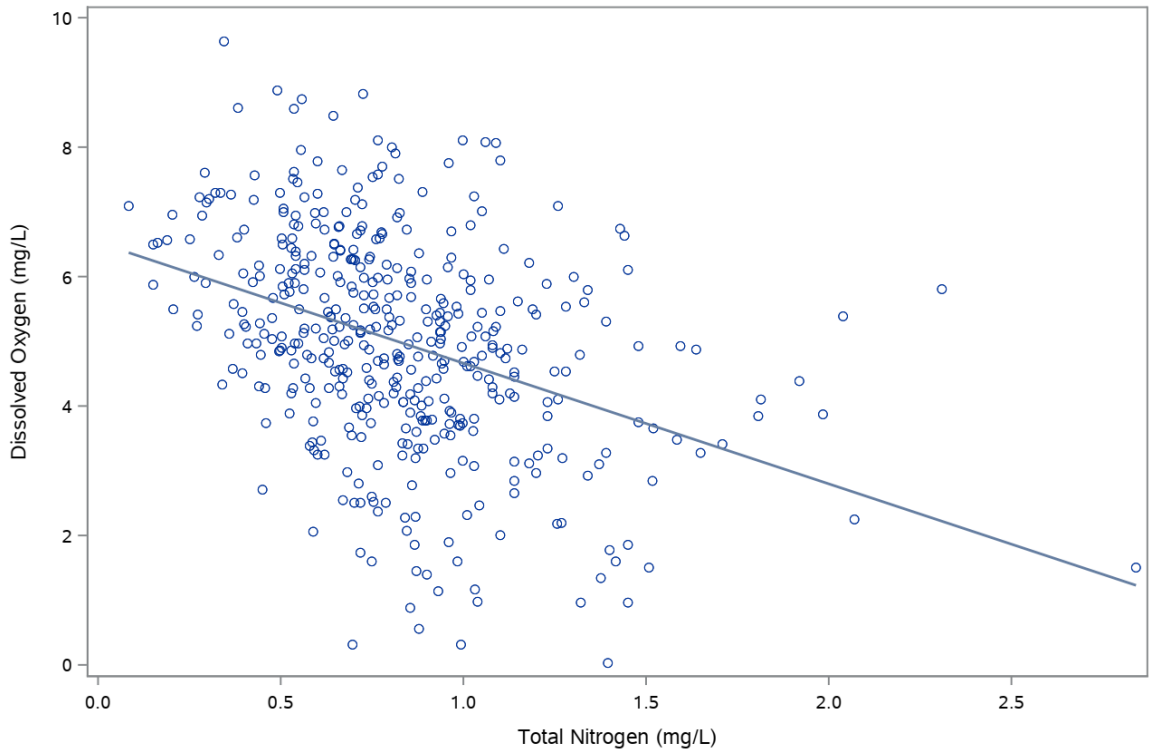
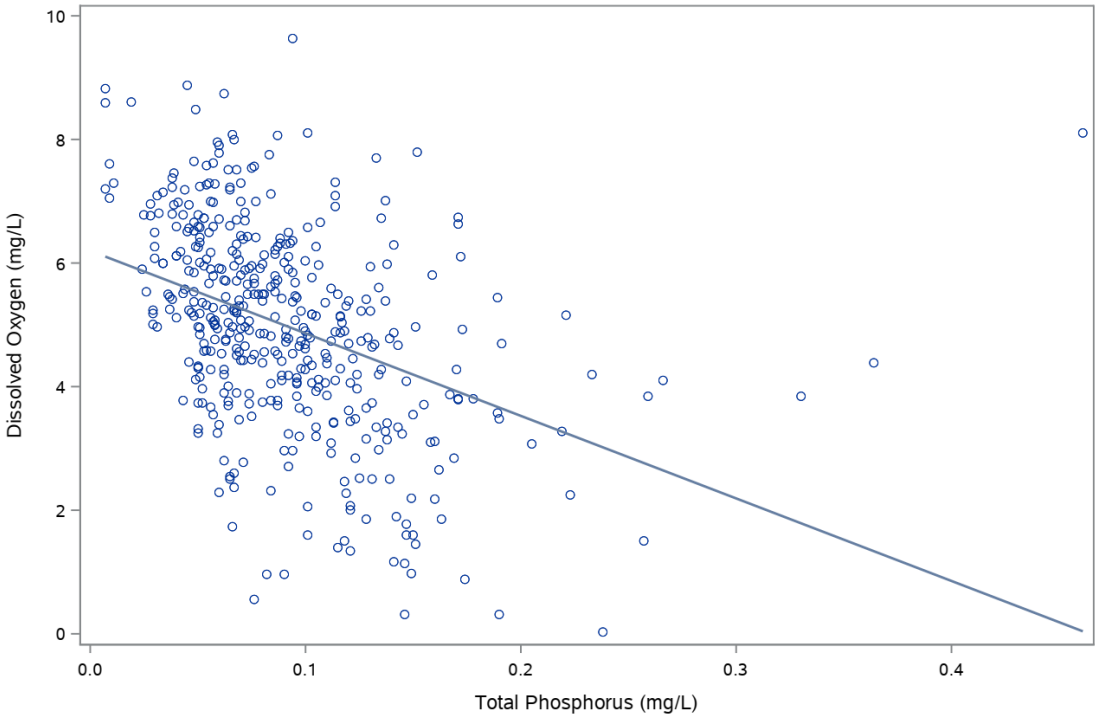


Figure 8. Relationship between total phosphorus and dissolved oxygen over the period of October 2016 to December 2020 in Clam Bay ($p<0.001$, $r^2=0.1592$).



In addition to the data assessments described above, data from Clam Bay outfall monitoring stations were compared to the proposed Downstream Protective Values (DPV) derived for Clam Bay (PBS&J 2011). Due to concerns and restrictions related to the Coronavirus pandemic, no samples were collected in April 2020 at the outfall monitoring stations. Outfall TN and TP concentrations were compared to the median and 90th percentile DPV values to determine if elevated concentrations were found at those locations (Appendices B and C).

The median DPV quantity represents a value that would be expected to be exceeded approximately 50 percent of the time, while the 90th percentile value represents a concentration sufficiently high that only 10 percent of values would be expected to be higher. Using this approach, the amount of TN or TP in the water column at stations sampled in the Clam Bay watershed can be compared to criteria that are meant to be protective of the open waters of Clam Bay proper. The TN and TP concentrations in DPV estimates are expected to be higher than concentrations in the open waters of Clam Bay. The influence of the more saline and lower nutrient content waters of the Gulf of Mexico would not yet have diluted the higher nutrient concentrations found in freshwater inflows from the watershed. The median and 90th percentile DPVs for TN were 1.31 and 1.8 mg/L respectively. The median and 90th percentile DPVs for TP were 0.10 and .25 mg/L respectively

For data collected at the outfall monitoring sites, 63 percent and 27 percent of the TN concentrations exceeded the median and 90th percentile DPV values for TN respectively (Table 3). For those same outfall monitoring sites, 64 percent and 22 percent of the TP concentrations exceeded the median and 90th percentile DPV values respectively (Table 3). It should be noted that DPV values would be expected to be exceeded approximately 50 percent and 10 percent of the time for "median" and "90th percentile" thresholds. The results in Table 3 suggest that the concentrations of TN and TP were elevated above levels that would be expected in stormwater runoff during both typical (i.e., median) and non-typical (i.e., 90th percentile) conditions, compared to the data set used to develop NNC criteria for Clam Bay.

Table 3. Percentage of TN or TP concentrations from outfall stations which exceeded the median or 90th percentile DPV values.

	Total Nitrogen		*Total Phosphorus*	
	Median	**90th Percentile**	**Median**	**90th Percentile**
Exceedance rate (%)	63	27	64	22

Daily cumulative rainfall data reported by the South Florida Water Management District meteorological station located at the Cocohatchee Canal at Palm River Road (COCO1_R) were retrieved over the period of January 1, 1997 - December 31, 2020. The long-term average annual rainfall was calculated as 48.6 inches over the twenty four-year period (Figure 9). In the most recent eight-year period (since 2013), seven of the eight years exceeded the long-term average with four of the years (2013, 2015, 2017 and 2019) reporting at least 10 inches more rain per year than the long-term average. Overall, it appears that this region has experienced greater than average rainfall than during the previous 16 years. A review of the cumulative departure of Cocohatchee River monthly rainfall from the long-term geometric mean monthly rainfall (1997-2020) shows an apparent transition in rainfall starting in 2008 (Figure 10). Rainfall prior to 2008 presents drier months compared to the long-term geometric mean combined with limited heavy monthly rainfall events. In contrast, the period after 2008 depicts an increased frequency of months with both much higher and much lower than average rainfall. It appears that the region is experiencing more frequent very high and very low rainfall months in both the "wet" and the "dry" seasons. It is possible that this deviation from the previously observed rainfall pattern has contributed to the observed change in water quality within the Clam Bay system. However, it is unlikely that stormwater impacts alone are responsible for the prolonged TP exceedances observed in Clam Bay starting in 2017.

Figure 9. Annual Cumulative Rainfall at long-term SFWMD meteorological monitoring station (COCO1_R) over period of 1997-2020. Red dashed line indicates long-term average annual rainfall (48.6 inches).

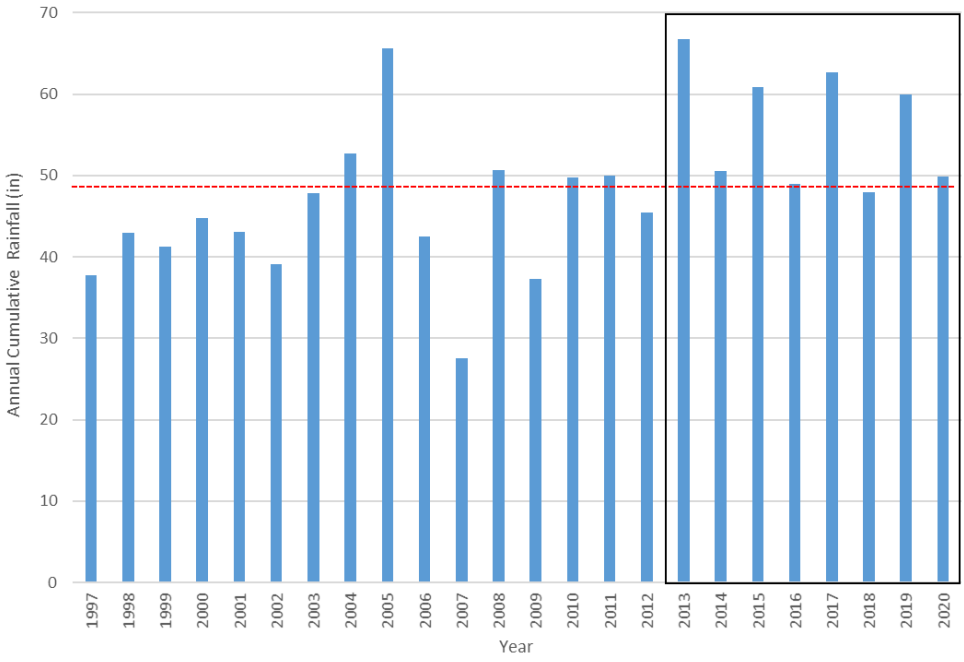
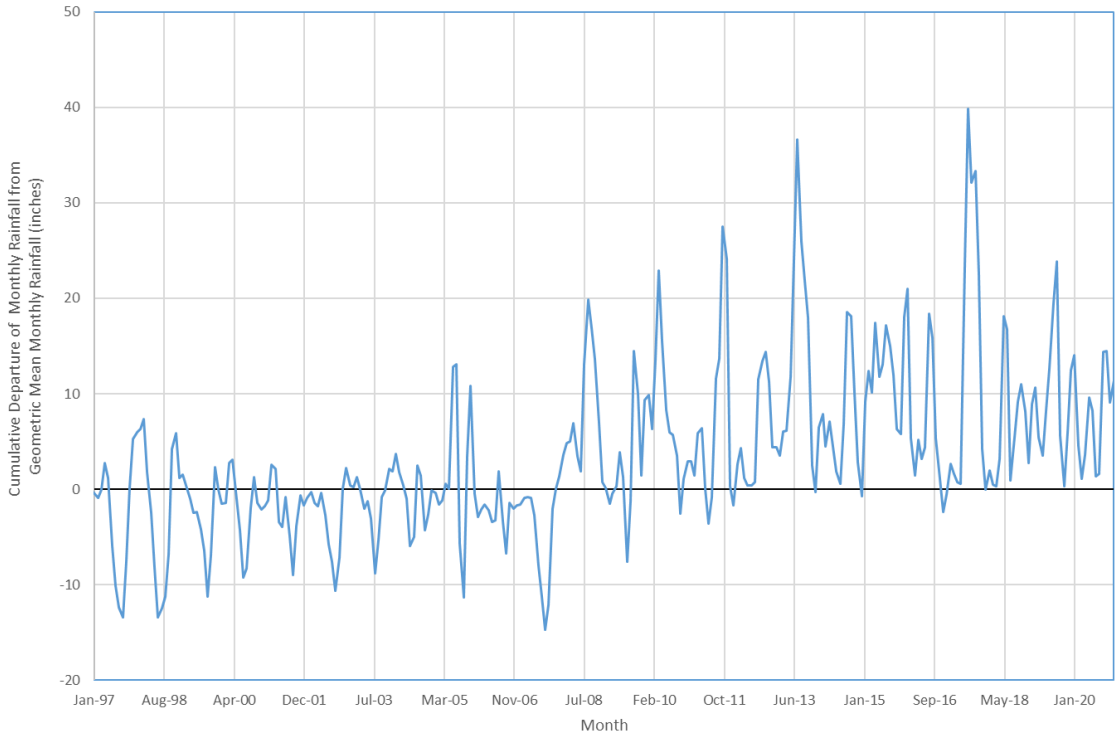


Figure 10. Cumulative Departure of long-term SFWMD meteorological monitoring station (COCO1_R) Monthly Rainfall from Geometric Mean Monthly Rainfall (1997-2020).



Results – Nutrient Status

Table 1 shows that exceedances of TP criteria have decreased in the most recent annual monitoring period. From March 2015 to April 2016, there were never more than 4 stations (out of the 9 sampled) that had TP concentrations higher than guidance criteria. From May 2016 to February 2017, there was only one month with more stations exceeding criteria than stations with TP concentrations below criteria. From March 2017 to June 2018, six of the fifteen months had results where the majority of stations exceeded criteria. From July 2018 to December of 2019, twelve of the eighteen months had every station exceeded the NNC criteria for TP. System-wide exceedances were reporting in January and April of 2020 followed by several exceedances limited to the southern portions of Clam Bay. Overall in 2020, there has been a substantial reduction in TP concentrations compared to previous year.

For most months, up until July 2018, stations 1, 2 and 3 were much more likely to have exceeded NNC criteria for TP than stations 4 to 9. Stations 1, 2 and 3 represent locations in Upper Clam Bay, the channel between Upper and Inner Clam Bay, and Inner Clam Bay, respectively. A trend test was performed for each station using the Mann's one-sided, upper-tail test for trend consistent with approach used by FDEP for planning list consideration (FAC 62-303.351) to evaluate for notable changes in concentrations over time that may indicate a change within the system. The annual geometric mean for TN, TP and chlorophyll-a were evaluated over the period of 2015 to 2020 (Table 4).

Table 4. Results of trend analysis for Total Nitrogen (TN), Total Phosphorus (TP) and Chlorophyll-a for the period of 2015 to 2020. Statistical significance is set at p < 0.05. However, "potential significance" is indicated for relationships where the p value was between 0.10 and 0.05.

Location	TN	TP	Chl-a	Location
CB 1	No	No	No	Upper Clam Bay
CB 2	No	No	Potential decrease (p<0.10)	Channel Between Inner & Upper Clam Bay
CB 3	No	No	Potential decrease (p<0.10)	Inner Clam Bay
CB 4	Potential increase (p<0.10)	No	No	Channel Between Inner and Outer Clam
CB 5	Potential increase (p<0.10)	Potential increase (p<0.10)	No	Outer Clam Bay
CB 6	Potential increase (p<0.10)	Potential increase (p<0.10)	No	Outer Clam Bay
CB 7	Increase (p<0.05)	Potential increase (p<0.10)	No	Outer Clam Bay
CB 8	Increase (p<0.05)	Potential increase (p<0.10)	No	Outer Clam Bay
CB 9	No	No	No	Canal to Outer Clam Bay

The results of the trend analysis show evidence of a fairly widespread increase in the abundance of both nitrogen and phosphorus at those stations outside of Upper and Inner Clam Bay. These results suggest that Upper and Inner Clam Bay may not be degrading, in terms of nutrient supply, but nutrients do seem to be increasing in most of the stations located throughout Outer Clam Bay (CB4 to CB8).

While nutrients are increasing in most of the stations in Outer Clam Bay, there does not yet appear to be evidence of a similar system-wide increase in algal populations, at least for those species of algae (i.e., phytoplankton) suspended in the water column. It is important to note that an increase in chlorophyll-a concentrations were not identified within Clam Bay. However, a potential reduction in the abundance of phytoplankton was observed in Inner Clam Bay and interconnecting channels (Clam Bay 2 and 3). Continued evaluation of the linkage between nutrients (TN and TP) on phytoplankton production and ultimately, water clarity is necessary to determine potential water quality impacts in Clam Bay due to nutrient loading.

As shown in Table 2, TN values only rarely exceeded NNC guidance criteria prior to May 2018. The first month where more stations failed TN criteria than passed was in May 2018. The majority of stations failed NNC criteria for TN only in the months of May and October of 2018. In contrast to TP, prior to 2020 stations in Upper and Inner Clam Bay do not appear to exceed criteria for TN any more often than stations in the better flushed waters of Outer Clam Bay. In the most recent monitoring year (2020), there were disproportionately more TP exceedances in Outer Clam Bay compared to the other areas of the system.

Based on these results, the following sequence of events is expanded upon from those provided in the 2019 reporting effort to assist in documenting the pattern of TN and TP impairments illustrated in Tables 1 and 2:

- In the spring of 2017, heavy rainfall may have resulted in some of the impairments noted for TP
- The passage of Hurricane Irma in September 2017 (no samples were taken that month) likely adversely impacted water quality through rainfall and runoff
    - Hurricane Irma also defoliated many of the mangroves along the shoreline, and resulted in clogging of tidal channels with debris from limbs and trees being blown over
- During the spring of 2018, the reestablishment of tidal channels in the mangrove forests adjacent to Upper, Inner and Outer Clam Bay may have resulted in discharges of water that were enriched with nutrients from mangrove leaves and Irma-induced damage
    - May 2018, which coincided with channel reestablishment, was the only month (out of 43) where the majority of stations exceeded TN criteria
- After the start of the wet season of 2018, runoff from nutrient-enriched mangrove forests (with newly established tidal channels and much mangrove debris) resulted in the sustained impairments for TN noted from July to October 2018
- However, elevated levels of TP have extended until April 2020, which suggests an impact not directly related to nutrient inflow from either Hurricane Irma or the initial efforts to reestablish tidal drainage patterns in the mangrove fringe
- A reduction in TP exceedances have been observed in the Clam Bay system starting in May 2020, with observed exceedances occurring predominantly in the Outer Clam Bay portion of the system.

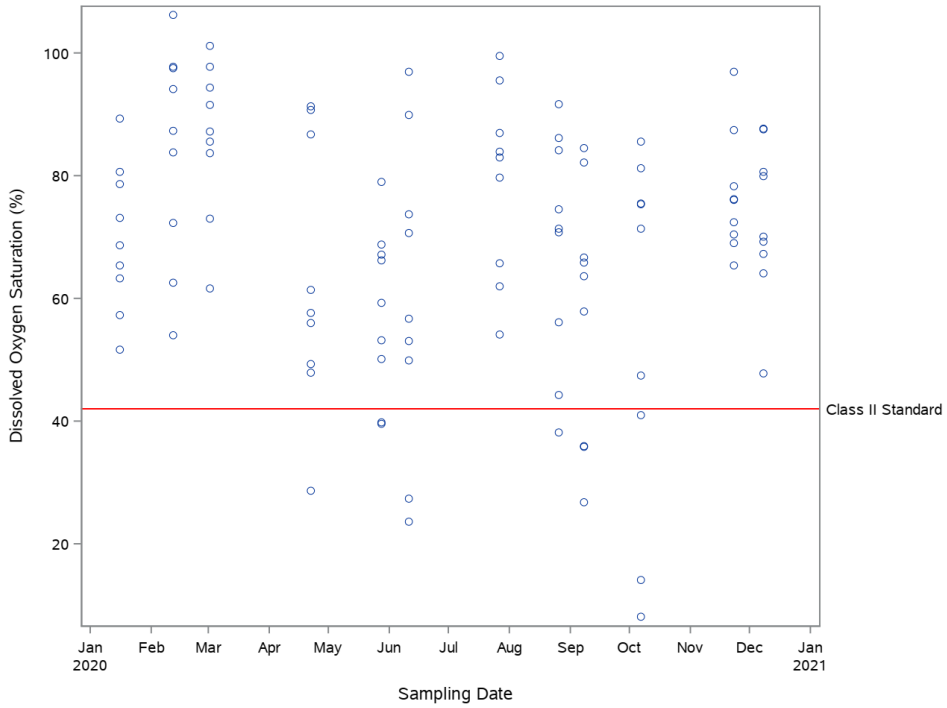
Although the time series of impairments for TP suggests an initial impact from Hurricane Irma, those initial impacts were either sustained for more than 2 years after the landfall of the hurricane (up to April 2020) or the Clam Bay system has fundamentally changed over time, in terms of nutrient supply. Possible scenarios for sustained effects from Hurricane Irma include a combination of: 1.) ongoing nutrient inflow from hurricane derived mangrove forest detritus; 2.) continuing sediment erosion or reworking from tidal channel reestablishment; and/or resuspension or recycling of nutrients initially introduced by Hurricane Irma that have not yet left the Clam Bay system.

Results – Dissolved Oxygen

For levels of DO the applicable regulatory criterion, as outlined in FAC 62-302.533, is that minimum DO levels (for Class II waters like Clam Bay) shall not be lower than 42 percent saturation more than 10 percent of the time (for average daily values) or that 7-day average values shall not be below 51 percent saturation more than once in any 12-week period, or that the 30-day average DO percent saturation shall not be below 56 percent more than once per year.

The less-restrictive 7-day and 30-day criteria require DO measurements to be made over a 24-hour period, which is not applicable for comparison with water quality data collected at a single time of day, once a month. As such, the more restrictive criterion was used for Clam Bay, and DO values (in units of percent saturation) were compared against the 42 percent saturation value. Results are shown in Figure 11.

Figure 11. Dissolved oxygen values (percent of 100 percent saturation) for nine stations in Clam Bay, over the period of January 2020 to December 2020.



DO values were collected at nine stations over twelve months (n = 108). As such, it would take eleven values below 42 percent saturation for Clam Bay to be considered to be out of compliance with the DO criteria listed in FAC 62-302.533. Twelve values show DO at lower than 42 percent saturation, the majority of which occurred at Clam Bay stations 1 and 2 (five sampling events each). All but two of the depressed values were from either Upper Clam Bay (Clam Bay 1) or the narrow channel between Upper Clam Bay and Inner Clam Bay (Clam Bay 2). The remaining depressed values were identified in Inner Clam Bay (Clam Bay 3) and northern portion of the channel between Inner Clam Bay and Outer Clam Bay (Clam Bay 4), as shown in Table 5. Based on these results, the waters of Clam Bay would be considered to be out of compliance with existing DO criteria. This conclusion is consistent with the results of the previous annual report which identified sufficient depressed concentrations to be considered out of compliance over the 12-month period. An impairment designation as presented by FDEP would encompass the review of data over a 7.5-year period, as such, a more comprehensive review of the data would be necessary to incorporate the annual fluctuations in dissolved oxygen concentrations.

Table 5. Dissolved Oxygen Saturation values at sites Clam Bay 1 to 9, in units of %. Values highlighted in yellow are below the criteria for Class II waters (42%). Grey cells indicate no data collected.

Station	1	2	3	4	5	6	7	8	9
1/16/2020	68.7	51.6	63.3	65.4	78.6	89.3	80.6	73.1	57.3
2/12/2020	97.7	62.5	54.0	72.3	87.3	94.1	97.5	106.2	83.8
3/2/2020	73.0	61.6	83.7	85.6	87.2	97.7	101.1	91.5	94.3
4/22/2020	47.9	28.7	49.3	56.0	57.6	86.7	90.7	91.3	61.4
5/28/2020	39.8	39.6	53.2	50.1	67.1	79.0	66.2	68.8	59.3
6/11/2020	27.4	23.6	49.9	53.1	73.7	89.9	96.9	70.7	56.7
7/27/2020	62.0	54.1	65.7	79.7	83.9	86.9	83.0	95.5	99.5
8/26/2020	38.2	44.2	56.1	74.5	86.1	91.6	84.1	70.8	71.4
9/8/2020	35.9	26.8	35.8	57.9	65.8	82.2	84.5	66.7	63.6
10/7/2020	14.1	8.1	47.4	41.0	75.5	81.2	75.3	71.3	85.5
11/23/2020	69.0	65.4	72.4	70.4	78.3	96.9	87.4	76.2	76.0

Results - Copper

For levels of copper, there are different criteria used for marine waters versus freshwater systems such as stormwater ponds. For marine waters, the standard, as listed in FAC 62-302.530, is that concentrations are not to exceed 3.7 µg / liter. However, the State of Florida's Impaired Waters Rule (FAC 62-303) allows for a certain amount of "exceedances" to occur, before water quality is considered to be out of compliance. Table 6 summarizes the data collected from all stations, from January of 2020 to December of 2020, for Stations Clam Bay 1 to Clam Bay 9, all of which are located in the open waters of Upper, Inner or Outer Clam Bay.

Of the 108 samples collected for copper, only eight of them exceeded the established criteria of 3.7 µg / liter. Based on guidance in Table 3 of FAC 62-303, Clam Bay is not out of compliance for copper for the sampling period evaluated. The determination of copper exceedances in freshwater sampling sites in the watershed requires the simultaneous collection of data on "hardness". Over this analysis period, all samples from freshwater locations included results on hardness, and those data are analyzed below.

The copper standard for freshwater is more complicated than the marine standard as it requires the concurrent recording of a value for "hardness" in units of mg CaCO3 / liter. The toxicity of copper is mostly restricted to the abundance of the copper ion, and the greater the abundance of other dissolved compounds, the lower the probability that free copper ions will be available to bind with cell membranes, etc. and cause direct and indirect biological impacts. Briefly stated, the higher the hardness level of a water sample, the lower the probability that a given level of copper will be toxic.

Table 6. Copper values at sites Clam Bay 1 to 9, in units of µg / liter. Values highlighted in yellow exceed copper criteria for Class II waters (3.7 µg Cu / liter).

Station	1	2	3	4	5	6	7	8	9
1/16/2020	5.1	2.7	2.0	1.7	1.6	1.6	1.6	1.6	1.6
2/12/2020	2.4	3.6	4.3	2.2	1.6	1.6	2.7	1.6	1.6
3/2/2020	3.2	4.3	2.1	1.6	1.6	1.6	2.9	1.6	0.2
4/22/2020	3.0	2.1	1.7	2.0	1.2	1.2	1.5	1.2	1.2
5/28/2020	2.5	1.9	1.4	1.6	1.2	1.2	1.2	1.2	1.2
6/11/2020	2.6	2.6	2.1	2.4	1.1	1.1	1.1	1.1	1.1
7/27/2020	3.2	2.3	1.4	1.2	1.2	1.2	1.2	1.2	1.2
8/26/2020	1.4	1.8	1.2	1.2	1.2	1.2	1.3	1.2	1.2
9/8/2020	2.0	2.1	1.9	1.6	1.2	2.0	1.3	1.2	1.5
10/7/2020	2.1	1.7	1.2	1.3	1.1	1.1	1.1	1.1	1.1
11/23/2020	1.5	1.5	1.5	1.2	1.2	1.1	1.1	1.1	1.2
12/8/2020	3.7	5.8	6.3	4.9	3.1	4.0	4.4	2.9	3.6
mean	2.7	2.7	2.3	1.9	1.4	1.6	1.8	1.4	1.4
median	2.6	2.2	1.8	1.6	1.2	1.2	1.3	1.2	1.2
N	12	12	12	12	12	12	12	12	12
#> 3.7	1	1	2	1	0	1	1	0	0
% > 3.7	8	8	17	8	0	8	8	0	0

Once the level of hardness is determined, the copper criterion for a sample collected from freshwater is derived as:

$$Copper\ standard\ (mg\ /\ liter) = e^{(0.8545[lnH]-1.702)}$$

Where:

e = the base of the natural logarithm (ca. 2.718281), and

lnH = natural log of hardness (in units of mg CaCO3 / liter)

Thus, the determination of whether a sample meets or exceeds the water quality standards for copper only requires determination of the concentration of copper for marine samples; a concurrent value for hardness is required to determine compliance with freshwater criteria. In the data set examined it appears that there were 68 date and location combinations where freshwater stations were sampled (Table 7).

Table 7. Copper values at Stormwater Pond Sites, in units of µg / liter. Values highlighted in yellow exceed copper criteria for Class IIIF waters. Grey cells indicate no data available.

Date	Glenview	PB-11	St Lucia	PB-13	N-Berm	N-Boardwalk
1/16/2020	22.5	22.3			38.7	5.8
2/12/2020	23.6	19.4	19.9	23.4	23.8	13.3
3/9/2020	18.3				35.4	21.3
4/x/2020	No Samples Collected due to Coronavirus Concerns					
5/26/2020	16.3	36.6	40.9	20.6	16.7	9.7
6/11/2020	13.4	23.3	12.2	19.8	15.5	
7/27/2020	16.1	15.5	11.2	10.4	13.5	5.7
8/24/2020	26.2	54.8	84.5	13.1	8.6	5.7
9/15/2020	25.6	18.0	8.6	15.0	9.9	11.6
10/13/2020	24.5	11.6	27.7	11.2	21.9	13.5
11/3/2020	6.0	17.6	11.9	8.0	19.5	12.4
12/1/2020	13.7	12.7	16.4		25.1	29.4

Copper concentrations at all sites exceeded the hardness-normalized copper criteria for Class III freshwater systems during at least one monitoring period. The levels of copper were often many times higher than impairment thresholds. The N-Boardwalk locations had lower exceedance rates than the other sampled locations. The pond monitoring stations are located within the series of open water features on the west side of the Pelican Bay development, just east of the mangrove fringe that separates Clam Bay from its developed watershed.

Recommendations

For the waters of Upper, Inner and Outer Clam Bay, water quality monitoring should continue at the same nine stations locations sampled in the reviewed data set. For determining compliance with nutrient criteria, chlorophyll-a data should be collected (and be corrected for phaeophytin) along with both Total Nitrogen and Total Phosphorous data. To ensure results can be compared to NNC criteria established specifically for Clam Bay, specific conductance data also need to continue to be collected in association with the chlorophyll-a, Total Nitrogen, and Total Phosphorous samples.

The finding of increased concentrations of nitrogen and phosphorus in Outer Clam Bay should be considered to be indicative of a problem that cannot be dismissed as being solely related to hurricanes, changes in rainfall, and/or local efforts to increase tidal exchange in the mangrove forests that bound the Clam Bay system. In addition to the potential effect of the recreation of tidal channels in the adjacent mangrove fringe, the use of reclaimed water for irrigation should be investigated. Reclaimed water might not by itself add more nutrients to landscapes than the landscapes can effectively assimilate. However, if homeowners or property managers are adding fertilizers on top of the nutrients supplied by reclaimed water, the combination of reclaimed water irrigation with fertilizer application could be a potential mechanism though which excessive nitrogen and phosphorus loads are brought into the Clam Bay system.

As of now, the increased nutrient supply does not seem to have brought about a subsequent decline in ecosystem health, as concentrations of chlorophyll-a (an indicator of algal abundance in the water column) are not similarly

increasing in most stations. While levels of dissolved oxygen do not meet state criteria for the Clam Bay system as a whole, most of the locations where values are out of compliance are in Upper and Inner Clam Bay, areas where reduced tidal flushing and an extensive mangrove fringe likely would produce non-compliant values even in the absence of human activities.

For copper, values recorded in 2020 show that while the stormwater treatment system often fails copper standards for freshwater water bodies, there were substantial fewer exceedances (N=8) observed in the open waters of Upper, Inner and Outer Clam Bay. While there was an observed increased compared to 2019, when only one exceedance was reported, these results suggest that reductions in the use of copper-containing herbicides have had a positive impact on the abundance of copper in the bay itself.

APPENDIX C. COLOR CODE EXCEEDANCE TABLES FOR CLAM BAY OUTFALLS.

Table A1. Representation of frequency of impairment for *median TP DPV* (0.10 mg/L) for different outfall site and date combinations. Green represents samples in below with median DPV value. Red cells indicate exceedance of median DPV value. Gray cells represent a lack of data.

Month/Year	Outfall Stations						
	Glenview	N-41 Pipe	N-Berm	N-Boardwalk	P-11	PB-13	St. Lucia
March-15							
April-15							
May-15							
June-15							
July-15							
August-15							
September-15							
October-15							
November-15							
December-15							
January-16							
February-16							
March-16							
April-16							
May-16							
June-16							
July-16							
August-16							
September-16							
October-16							
November-16							
December-16							
January-17							
February-17							
March-17							
April-17							
May-17							
June-17							
July-17							
August-17							
September-17							
October-17							

Month/Year	Outfall Stations						
	Glenview	N-41 Pipe	N-Berm	N-Boardwalk	P-11	PB-13	St. Lucia
November-17							
December-17							
January-18							
February-18							
March-18							
April-18							
May-18							
June-18							
July-18							
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May-20							
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October-20							
November-20							
December-20							

Note: In an event that multiple outfall samples were taken within a given month at a specify location, cell color indicates worse findings.

Table A2. Representation of frequency of impairment for *90th TP DPV* (0.25 mg/L) for different outfall site and date combinations. Green represents samples in below with 90th DPV value. Red cells indicate exceedance of 90th DPV value. Gray cells represent a lack of data.

Month/Year	Outfall Stations						
	Glenview	N-41 Pipe	N-Berm	N-Boardwalk	P-11	PB-13	St. Lucia
March-15							
April-15							
May-15							
June-15							
July-15							
August-15							
September-15							
October-15							
November-15							
December-15							
January-16							
February-16							
March-16							
April-16							
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May-17							
June-17							
July-17							
August-17							
September-17							
October-17							
November-17							
December-17							
January-18							
February-18							

Month/Year	Outfall Stations						
	Glenview	N-41 Pipe	N-Berm	N-Boardwalk	P-11	PB-13	St. Lucia
March-18							
April-18							
May-18							
June-18							
July-18							
August-18							
September-18							
October-18							
November-18							
December-18							
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November-20							
December-20							

Note: In an event that multiple outfall samples were taken within a given month at a specify location, cell color indicates worse findings.

Table A3. Representation of frequency of impairment for *median TN DPV* (1.31 mg/L) for different outfall site and date combinations. Green represents samples in below with median DPV value. Red cells indicate exceedance of median DPV value. Gray cells represent a lack of data.

Month/Year	Outfall Stations						
	Glenview	N-41 Pipe	N-Berm	N-Boardwalk	P-11	PB-13	St. Lucia
March-15							
April-15							
May-15							
June-15							
July-15							
August-15							
September-15							
October-15							
November-15							
December-15							
January-16							
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October-17							
November-17							
December-17							
January-18							

Month/Year	Outfall Stations						
	Glenview	N-41 Pipe	N-Berm	N-Boardwalk	P-11	PB-13	St. Lucia
February-18							
March-18							
April-18							
May-18							
June-18							
July-18							
August-18							
September-18							
October-18							
November-18							
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November-20							
December-20							

Note: In an event that multiple outfall samples were taken within a given month at a specify location, cell color indicates worse findings.

Table A4. Representation of frequency of impairment for *90th TN DPV* (1.8 mg/L) for different outfall site and date combinations. Green represents samples in below with 90th DPV value. Red cells indicate exceedance of 90th DPV value. Gray cells represent a lack of data.

Month/Year	Outfall Stations						
	Glenview	N-41 Pipe	N-Berm	N-Boardwalk	P-11	PB-13	St. Lucia
March-15							
April-15							
May-15							
June-15							
July-15							
August-15							
September-15							
October-15							
November-15							
December-15							
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December-17							
January-18							
February-18							

Month/Year	Outfall Stations						
	Glenview	N-41 Pipe	N-Berm	N-Boardwalk	P-11	PB-13	St. Lucia
March-18							
April-18							
May-18							
June-18							
July-18							
August-18							
September-18							
October-18							
November-18							
December-18							
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May-20							
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July-20							
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November-20							
December-20							

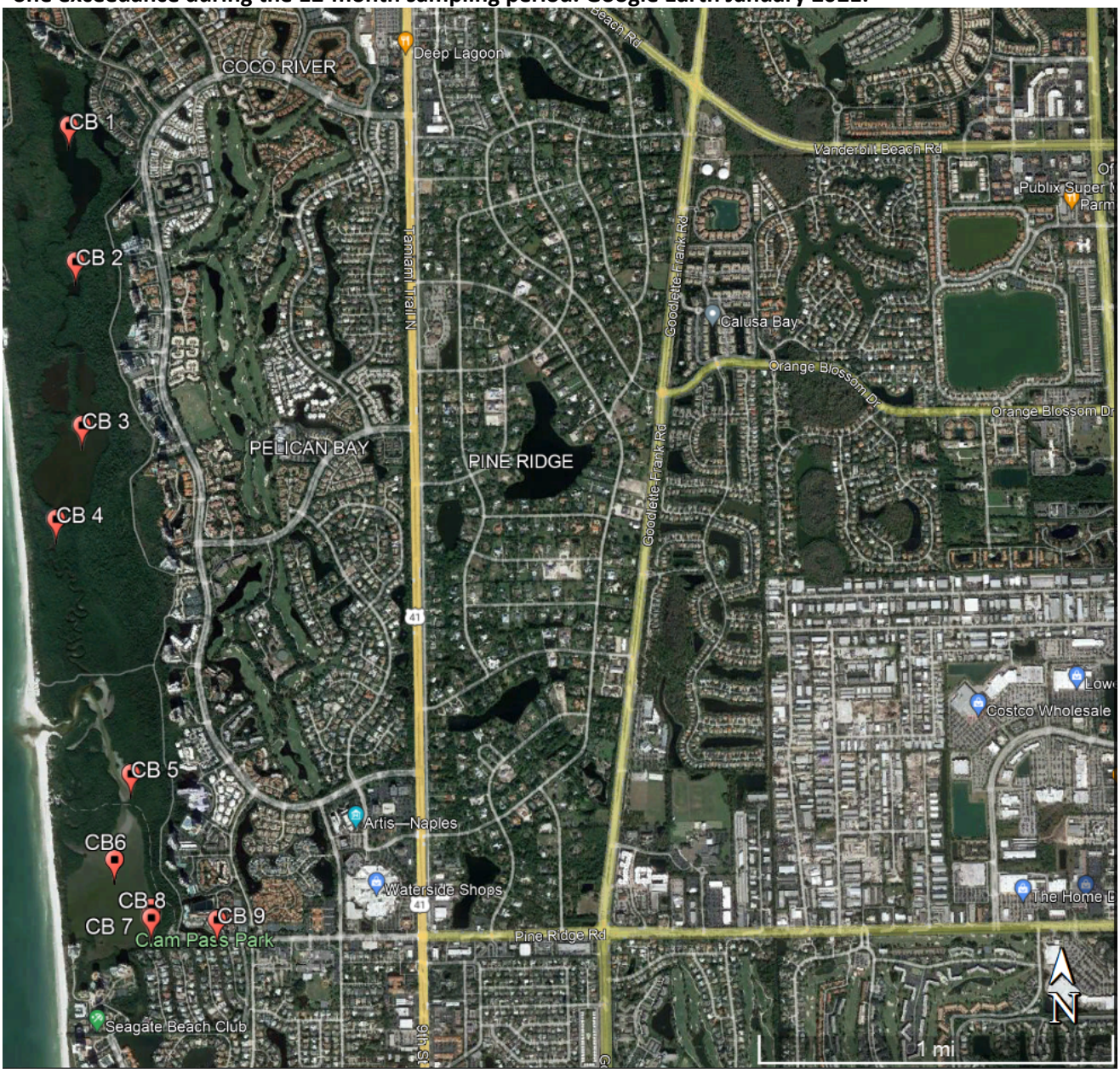
Note: In an event that multiple outfall samples were taken within a given month at a specify location, cell color indicates worse findings.

Appendix B

WATER QUALITY RESULTS IN CLAM BAY

MAPS

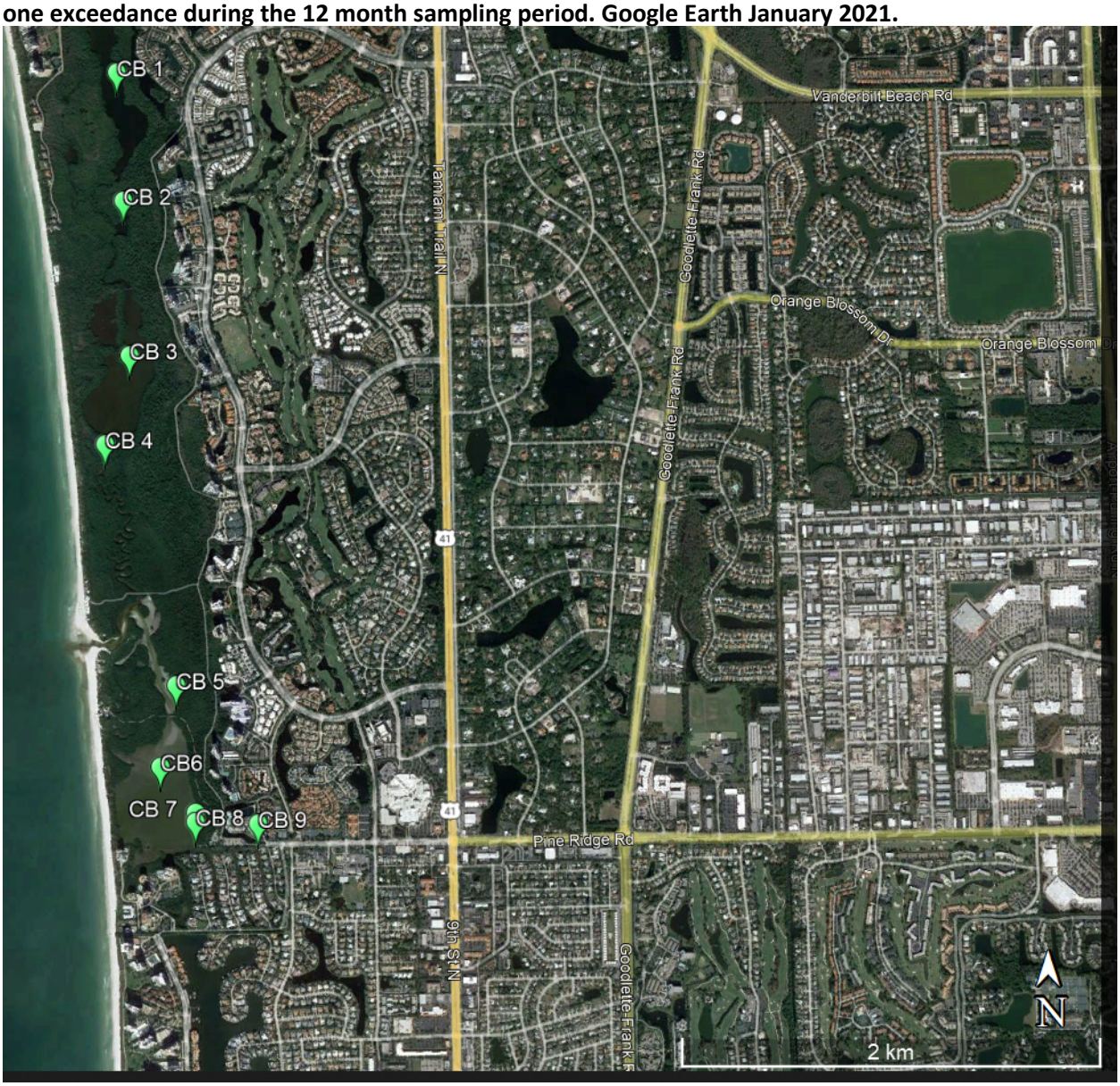
Clam Bay Total Phosphorus water quality results January-December 2021. Green pins indicate no exceedances for a site for all 12 months for which samples were collected, red pins indicate at least one exceedance during the 12-month sampling period. Google Earth January 2021.



Source: Google Earth Imagery, January 2021

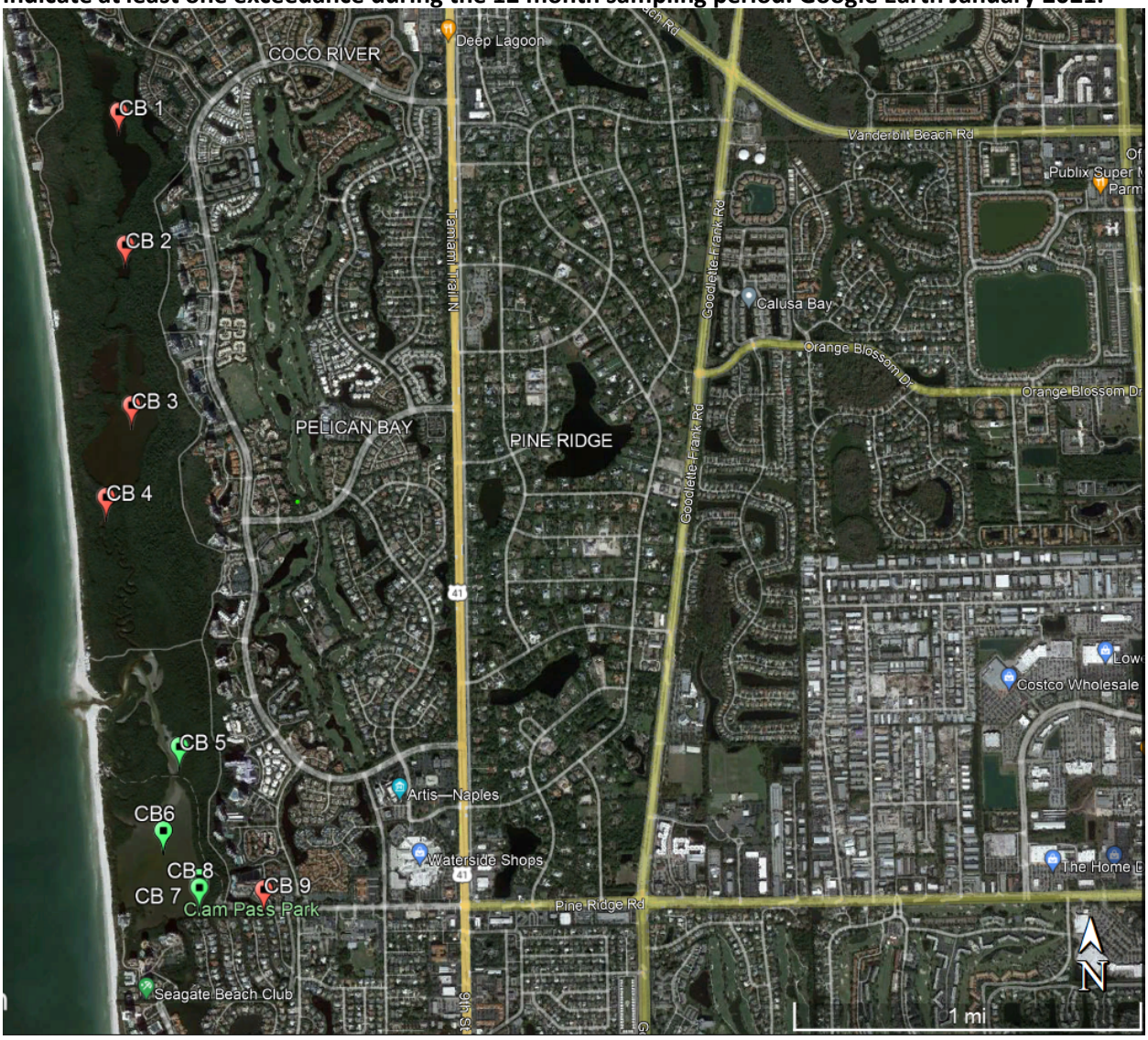
Clam Bay Total Nitrogen water quality results January-December 2021. Green pins indicate no

exceedances for a site for all 12 months for which samples were collected, red pins indicate at least one exceedance during the 12 month sampling period. Google Earth January 2021.



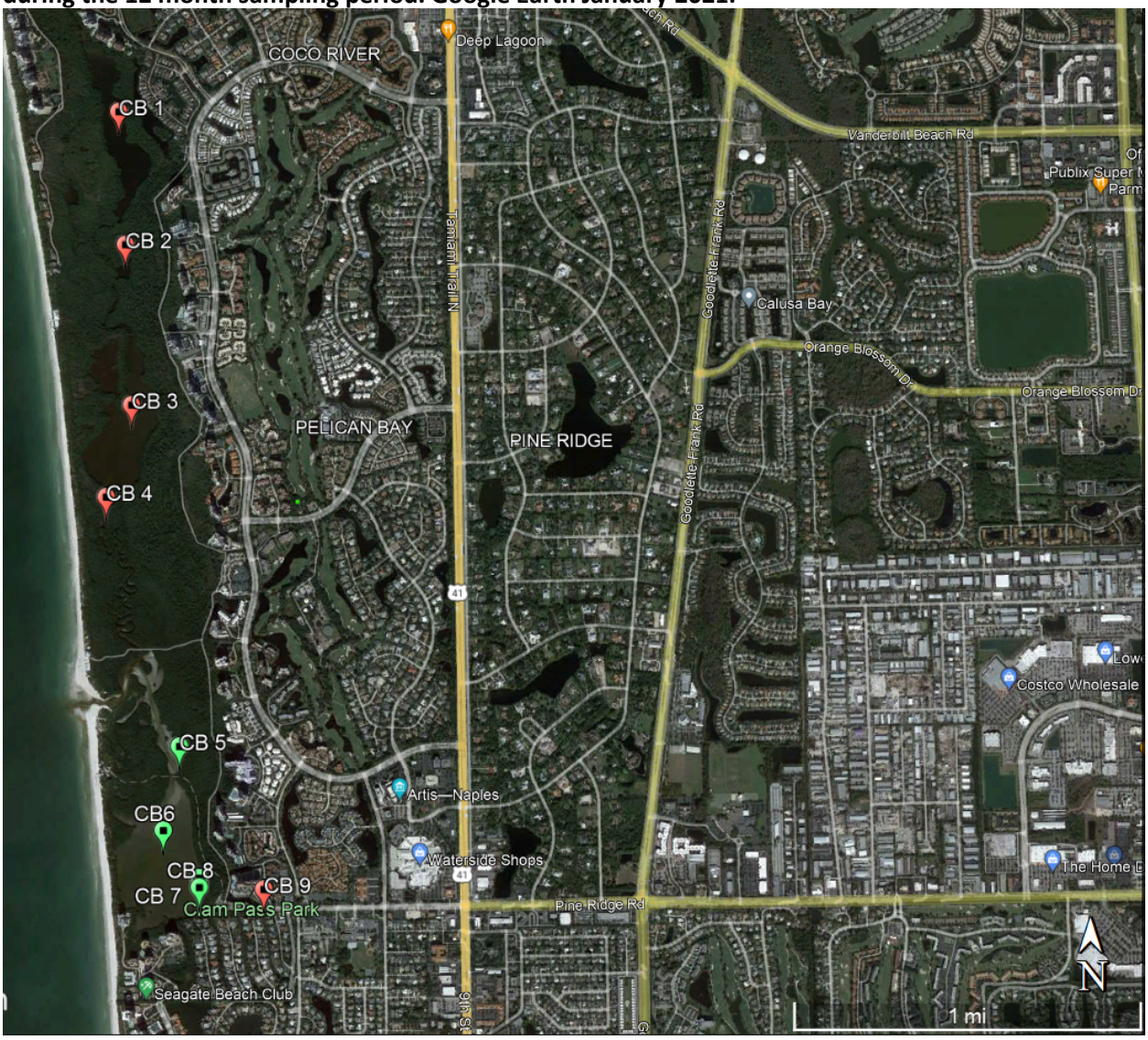
Source: Google Earth Imagery, January 2021

Clam Bay Dissolved Oxygen Saturation (percent) water quality results January-December 2021. Green pins indicate no exceedances for a site for all 12 months for which samples were collected, red pins indicate at least one exceedance during the 12 month sampling period. Google Earth January 2021.



Source: Google Earth Imagery, June 2021

Clam Bay Copper water quality results January-December 2021. Green pins indicate no exceedances for a site for all 12 months for which samples were collected, red pins indicate at least one exceedance during the 12 month sampling period. Google Earth January 2021.



Source: Google Earth Imagery, June 2021

Appendix C

CORRESPONDENCE REGARDING CONDUCTIVITY VS. SPECIFIC CONDUCTIVITY

From:	Ewe, Sharon
To:	Emily Keenan
Cc:	Brunty, Jennifer; Elliott, Steven
Subject:	RE: Clam Bay Numeric Nutrient Criteria
Date:	Friday, April 8, 2022 9:14:25 AM
Attachments:	image001.png image002.png

Thank you for the clarification, Emily. I really appreciate it.

We will move on as appropriate, and note that the equations used Specific Conductance instead of Conductivity.

Thank you.

-Sharon

From: Emily Keenan <EKeenan@esassoc.com>
Sent: Friday, April 8, 2022 8:56 AM
To: Ewe, Sharon <Sharon.Ewe@stantec.com>
Cc: Brunty, Jennifer <Jennifer.Brunty@stantec.com>; Elliott, Steven <Steven.Elliott@stantec.com>
Subject: RE: Clam Bay Numeric Nutrient Criteria

Hi Sharon:
While I wasn't able to find my project files, I did verify that Salinity and Specific Conductance are the only variables available for Estero Bay (via WIN). Specific conductance is the default parameter used in the majority of monitoring programs, including those Dave and I were responsible for implementing. I suspect that Dave and I used the term conductivity as a shorthand, which was never addressed as it moved through rule review and eventual adoption.

Please let me know if you need any further information,
Emily

Emily Keenan *(she/her)*
Environmental Scientist

ESA | Environmental Science Associates
mobile: 727.433.1200

From: Ewe, Sharon <Sharon.Ewe@stantec.com>
Sent: Thursday, April 7, 2022 12:27 PM
To: Emily Keenan <EKeenan@esassoc.com>
Cc: Brunty, Jennifer <Jennifer.Brunty@stantec.com>; Elliott, Steven <Steven.Elliott@stantec.com>
Subject: Clam Bay Numeric Nutrient Criteria

Hi Emily,
I was looking through the 2011 Clam Bay report (https://www.colliercountyfl.gov/home/showdocument?id=40064) where you and Dave Tomasko had conducted the sampling and generated the equations for the TN and TP exceedances. We have a question about the Clam Bay Numeric Nutrient Criteria equations below.

Equation 1: Total nitrogen (mg/L) = 1.30908 – 0.0000166414* (Conductivity (µM))

Equation 2: Total Phosphorus (mg/L)= exp(-2.3091 – 0.0000129727*conductivity(µS))

I spoke with Dave this morning about whether it was Specific Conductivity (mS/cm) or Conductivity (mS) that was used in deriving the equations and Dave seemed to remember that it was Specific Conductivity that was used although the units shown above are for Conductivity (i.e. mS only). However, he asked that I confirm with you. The question came about as using Conductivity per the equations result in a different number of exceedances compared to using Specific Conductivity and I am trying to verify what was used.

Do you concur with Dave's assessment that it was Specific Conductivity that was used to derive the equations? Any guidance of units used then would be greatly appreciated.

Please feel free to give me a call if you have any questions.

Cheers,
Sharon

Sharon Ewe, Ph.D.,
Principal Scientist.
Pronouns: she/her/hers

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