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. Sample results also 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, 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 in October/November 2020, which 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-five of 108 TP values (32 percent) exceeded established criteria in Clam Bay during 2021. Twenty-seven of the 35 TP exceedances occurred between January and June of 2021. This 32 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 only two TN exceedances of 108 samples (2 percent) during the same period 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, Clam Bay did not experience a direct hit from this storm and impacts of Tropical Storm Eta are unknown, though 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 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 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.

[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.

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 Florida Department of Environmental Protection (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/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/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**.**

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.

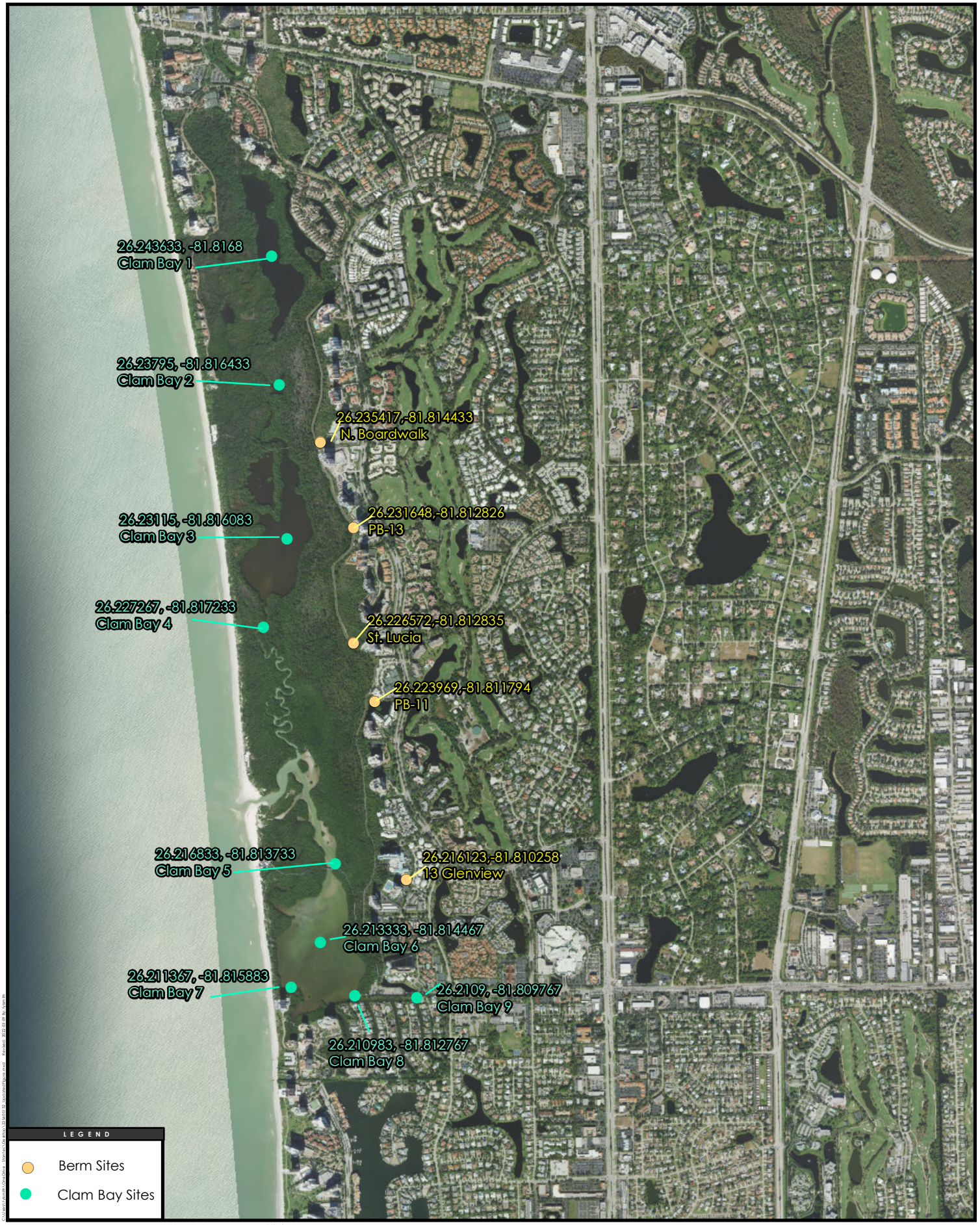
The equations below are used to determine the upper limits of TP and TN concentrations noted above for Clam Bay, as shown in Equations 1 and 2, respectively:

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 between January and 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/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.

Figure 1: Clam Bay and Berm Water Quality Monitoring Sites



Stantec

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Notes:
1. Coordinate System: NAD 1983 StatePlane Florida West FIPS 0902 Feet
2. Source data: Stantec Survey
3. Imagery: ESRI Aerial Imagery, 2020

Clam Bay
SITES AND LOCATIONS
March 2022

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0 1,000 2,000 Feet

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Independent Review by: X.X.X MM/DD/YY

Results – Nutrient Status

Throughout the analysis period discussed in this report (January through December 2021), only two of 108 samples exceeded the calculated TN upper limit, both by more than 5 percent. Comparatively, 35 of 108 samples (32 percent of total samples) exceeded the calculated TP upper limit criteria for calendar year 2021, and 15 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 only exceeded SSAC thresholds for Clam Bay twice (2 percent of samples) 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 (35 of 108 samples, or 32%), 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 (26 of 104 samples or 25 percent 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.

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. It should be noted that data collected prior to January 2021 were analyzed by previous authors and have not been re-analyzed for this report. However, based on a review of data from June 2020, it appears that some of the previous data may have been calculated using specific conductance rather than conductivity and may be in error compared to the SSAC calculation.

Note: January-June 2021 data have been updated since the fall 2021 report to use conductivity rather than specific conductance to calculate upper limit values, resulting in minor changes to values previously reported for January through June of 2021. It is unknown whether calculations for previous years used specific conductance or conductivity to determine the Upper Limit values for TN and TP.

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.

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									
Oct-17									
Nov-17									
Dec-17									

Clam Bay Nutrient Status

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

Clam Bay Nutrient Status

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

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.

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									
Jul-16									
Aug-16									
Sep-16									

Clam Bay Nutrient Status

Date (month/year)	Station								
	1	2	3	4	5	6	7	8	9
Oct-16									
Nov-16									
Dec-16									
Jan-17									
Feb-17									
Mar-17									
Apr-17									
May-17									
Jun-17									
Jul-17									
Aug-17									
Oct-17									
Nov-17									
Dec-17									
Jan-18									
Feb-18									
Mar-18									
Apr-18									
May-18									
Jun-18									
Jul-18			X						
Aug-18									
Sep-18									
Oct-18									
Nov-18			X						
Dec-18									X
Jan-19									
Feb-19									
Mar-19									
Apr-19									
May-19								X	
Jun-19									
Jul-19									
Aug-19									
Sep-19									
Oct-19									
Nov-19									
Dec-19									
Jan-20									

Clam Bay Nutrient Status

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

***Note: January-June 2021 data have been updated since the October semi-annual 2021 report to use conductivity rather than specific conductance to calculate upper limit values.**

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 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 (**Tables 2 and 3**); this is consistent with previous years' observations.

Table 5. Percentage of TN or TP	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							

Clam Bay Berm Water Quality Data

Date	Glenview	N-41 Pipe	N-Berm	N-Boardwalk	P-11	PB-13	St. Lucia
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							
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							

Clam Bay Berm Water Quality Data

Date	Glenview	N-41 Pipe	N-Berm	N-Boardwalk	P-11	PB-13	St. Lucia
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-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							

Clam Bay Berm Water Quality Data

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							
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							

Clam Bay Berm Water Quality Data

Month/Year	Outfall Stations						
	Glenview	N-41 Pipe	N-Berm	N-Boardwalk	P-11	PB-13	St. Lucia
May 2021							
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.

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 35 of 108 TP values exceeded established criteria in Clam Bay during 2021, and only two 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.

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.

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.